DEVELOPMENT OF WIRELESS RTD TEMPERATURE MEASUREMENT USING DECADE BOX

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JUDUL: **DEVELOPMENT OF WIRELESS RTD TEMPERATURE CALIBRATION USING DECADE BOX**

SESI PENGAJIAN: **2010/2011**

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In the industrial, temperature is one of the most frequently measured parameters in process system. The electrical thermometer is used, to sense and control the process temperatures. Regular calibration of these thermometers is critical to ensure consistent quality of product manufactured, as well as providing regulatory compliance for some industries. Industrial process temperature measurements are more critical than ever. Attempts to improve the quality or efficiency of industrial processes has led to a rapid increase in the number of temperature sensors installed in these systems as well as increased requirements for temperature measurement. The project is generally based on using temperature sensor devices for collecting and monitoring data from the plant station and transferring the measured temperature parameters to the computer.

In this project, GUI (Graphical User Interface) application will be developed using visual basic. This software is developed and responsible for establishing and manages communications between PC and wireless system. The wireless system is used to interface between instrument and computer. From this project, Decade Box represents RTD (Resistance Temperature Detector) is use as a temperature sensor to detect temperature change. The input will convert into current signal between 4 – 20 mA.

1.2 PROBLEM STATEMENT

In the industrial, temperature measurement is one of the most frequently measured parameters in process system. Resistance Temperature detectors have become industry standards for simple and cost-effective temperature measurement. However, achieving such measurement in an accurate, reliable and cost-effective manner is a challenging problem. If station is far away from the workplace, it is difficult to collect and monitor temperature changes. It wastes time to take and check temperature reading at plant station. They also need to analysis and monitor the data everyday or weekly to make sure the instrument in good condition.

1.3 OBJECTIVE OF THE RESEARCH

The objectives of the project are:

1. To develop GUI (Graphical User Interface) application using visual basic.

   Visual Basic is use as a main programming language. Data will transfer to PC and data will display in GUI application.

2. To interface between instrument and software application using the wireless system.

   Zig-Bee Wireless system is use to interface between instrument and computer. This system will use PIC controller as a converter that is convert analog signal from temperature transmitter to digital signal before data is transmit.

3. To monitor the temperature measurement directly by software application.

   Temperature measurement is the way that can be used to measure temperature where data from measurement process can be directly use for other purpose, such as analysis and monitoring data.

1.4 SCOPE OF THE PROJECT

The scopes of this project are:

1. Develop GUI (Graphical User Interface) application using Visual Basic in software application.

   Easy to collect and monitor the data from temperature transmitter by developed GUI application and programming using Visual Basic 2008 Edition software.

2. Zig-bee wireless technology will use to interface between computer and temperature instrument such as temperature transmitter, HART communicator, etc.

   In industry plant, wireless technology can help user and ease for user to collect data and doing observation of temperature only in controller room. So, user do not need to go the plant station and take readings manually.

3. Decade Box represents the RTD (Resistance Temperature Detector) is use as input device to detect temperature changes.

   This device is suitable for precision measurement applications and the calibration of laboratory or workplace equipment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will explain about the literature review part that taking from journals or articles which related with the project.

2.2 Smart RTD Temperature sensor with a prototype IEEE 1451.8 Internet Interfere

This research was conducted by Darold Wobschall and Wai sing Poh from Department of Electrical Engineering, University at Buffalo, Amherst. The Resistance Temperature Detector (RTD) was a sensor which can benefit greatly by smart transducer techniques that was, digital signal processing and digital transmission of data. The RTD was a stable sensor capable of resolving temperature changes to at least 0.001 °C over a temperature range of -200 °C to 400 °C continuously and over 600 °C for shorter times.

Thus, the readout must been capable of about 2 pm resolution while most analog readouts, such as the 4-20 mA ament loop, are have errors in the range of 100 to 500 ppm A microcomputer with a built-in high-resolution analog-todigital converter *(ADC)* is used here to acquire the signal [1].

Research by three partners from delphi corporation, Resistive Temperature device (RTD) high temperature sensor was developed for exhaust gas temperature measurement. Extensive modeling and optimization was used to supplement testing in development. The sensor was developed to be capable of withstanding harsh environments (-40 to 1000 degrees Celcius), typical of engine applications, including poisons, while maintaining high accuracy (< 0.5% drift after 500 hrs of aging at 950 degree Celcius) [2].

Resistance Temperature Detector (RTD) is basically a temperature sensitive resistor. It is a positive temperature coefficient device, which means that the resistance increases with temperature. The resistance of the metal is increasing with temperature. The resistive property of the metal is called its resistivity. The resistive property defines length and cross sectional area required to fabricate an RTD of a given value. The resistance is proportional to length and inversely proportional to the cross sectional area that see in the Equation (2.1):

$$R = (r \times L)/A \qquad (2.1)$$

Where R = Resistance (ohms)

r = Resistivity (ohms)

L = Length

A = Cross sectional area

The devices criterion for selecting a material to make an RTD is that the material must be malleable so that it can be formed into small wires. It must have a repeatable and stable slope or curve. The material should also be a resistant to corrosion and low cost. It is preferred that the material have a linear resistance verses temperature slope.

Some of the common RTD materials are Platinum with a temperature coefficient of 0.00385 - 0.003923 Ω/Ω/°C and practical temperature range of -452 to +1100°F (-269 to +593°C). The platinum RTD has the best accuracy and stability among the common RTD materials. The resistance versus temperature curve is fairly linear and the temperature range is the widest of the common RTD materials. Platinum has a very high resistivity, which means that only a small quantity of platinum is required to fabricate a sensor and making platinum cost competitive with other RTD materials. Platinum is the only RTD commonly available with a thin film element style. As a Primary uses, Platinum is the primary choice for most industrial, commercial, laboratory and other critical RTD temperature measurements. Copper, nickel and nickel iron are also commonly used RTD materials. Platinum RTDs are manufactured with two distinct types or temperature coefficients (μ). The temperature coefficient (μ) is the slope of the platinum RTD between 0°C to 100°C [3].

This is calculated by the following formula in the Equation (2.2):

$$\mu = (R_{100} - R_0)/ (100 \text{ X } R_0) \tag{2.2}$$

Where μ= Temperature Coefficient (W/W/°C)

R_{100} = RTD resistance at 100°C

R_0 = RTD resistance at 0°C

2.2.1 Measurement Circuit

RTDs are three measurement techniques. RTDs were inherently 2-wire devices. A 2-wire measurement has the RTD as one leg of a resistance bridge circuit with a DC source supplying excitation current to the RTD. Voltage across the bridge is measured and resistance calculated using formula see in the Equation (2.3):

$$R = V/I \tag{2.3}$$

The calculated result includes the resistance of the test leads as well as the RTD resistance, which significantly reduces accuracy. Figure 2.1 shows the 2-wire RTD measurement is the least expensive. This has led to the development of more accurate 3-wire and 4-wire measurement techniques.

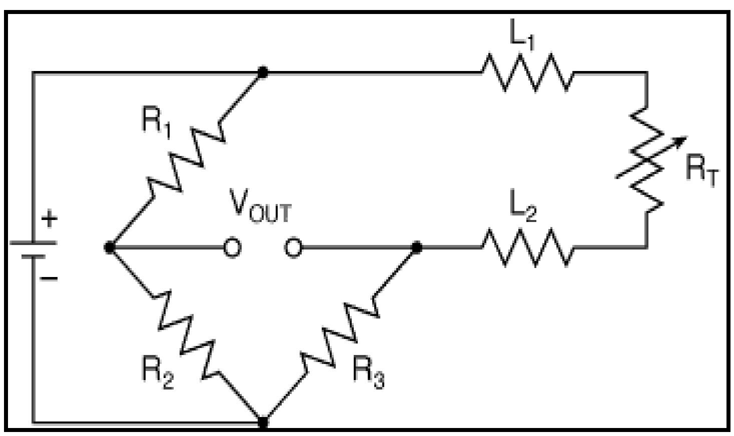

Figure 2.1: 2 - wire RTD [5]

The 3-wire technique was useful when there is significant distance between the sensor and the instrument. A bridge circuit was utilized with an instrument that has a high-impedance DC op-amp input circuit. The third wire was connected between one end of the RTD and the HI SENSE terminal of the instrument. These insures that little or no current flows through that lead, so its resistance is not much of a factor in the measurement. By using equal wire lengths and diameters for the other two leads, their voltage drops cancel out. Figure 2.2 shows the 3-wire circuit provides better accuracy, especially for long lead runs [3], [5].

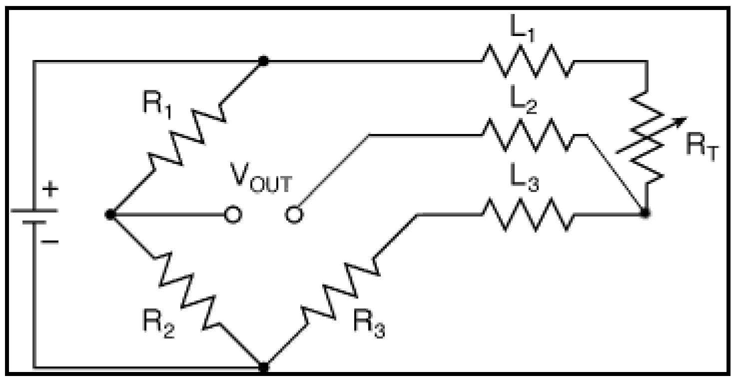

Figure 2.2: 3-wire RTD [5]

The 4-wire, or Kelvin, measurement uses one pair of leads to supply excitation current to the RTD and a second set of instrument leads to measure voltage directly across the RTD. The 4-wire measurements minimize lead voltage drop and provide the greatest accuracy is combined with an instrument having high input impedance. These is technique of choice in research labs and other sensitive applications. Figure 2.3 shows the 4-wire circuit has the best accuracy.

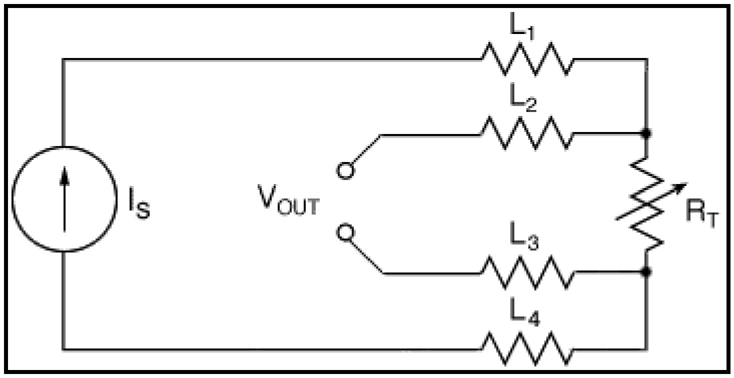

Figure 2.3: 4-wire RTD [5]

While not as accurate as the 4-wire method, the 3-wire technique provides acceptable accuracy in many industrial applications, and simplifies wiring since only three-wire cables are needed [3],[5].

2.3 Temperature Measurement

Temperature was a key role in many industrial and commercial processes. A temperature transmitter will use a measuring device to sense the temperature, and then regulate a 4-20 mA feedback loop to a control element that affects the temperature. The control element might consist of a valve that opens or closes to allow more steam into a heating process or more fuel to a burner. Thermocouple (TC) and Resistive temperature detector (RTD) were the two most types of temperature sensing devices. Fluke was provide a broad range of temperature calibration tools to help quickly and reliably calibrate the temperature instrumentation.

With the new integrated HART calibrator, hook-up was a much simpler. Simply connect the source and measure leads as for an analog transmitter. Then, using the provided HART cable, connect the serial port to instrument power input or the HART terminals. A simple connection between HART and transmitter is shown in the figure 2.4 [6].

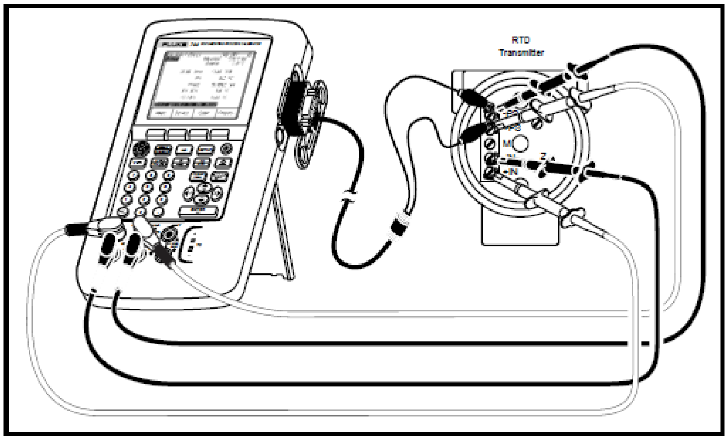

Figure 2.4: Simply connection between HART and Transmitter [6]

2.3.1 Maintenance and Calibration of HART Field Instrumentation

Maintenance and calibration technique are introduced by Richard Pirret; P.E. from Fluke Corporation, Everett, Washinton. HART was the most widely used digital communication protocol in the process industries, with over five million HART field instruments installed in over 100,000 plants worldwide. HART was supported by all of the major vendors of process field instruments and preserves present control strategies by allowing traditional 4-20 mA signals to co-exist with digital communication on existing two-wire loops. This device was compatible with traditional analog devices and provides important information for installation and maintenance, such as Tag-IDs, measured values, range and span data, product information and diagnostics.

Besides, HART can support cabling savings through use of multidrop networks. This device can reduces operation costs, through improved management and utilization of smart instrument networks. Calibration of an analog transmitter is fairly straightforward. Following an As-Found test, the zero and span adjustments may be used to set the correct relationship between the input signal and the 4 – 20 mA output which shown in the figure 2.5 [6].

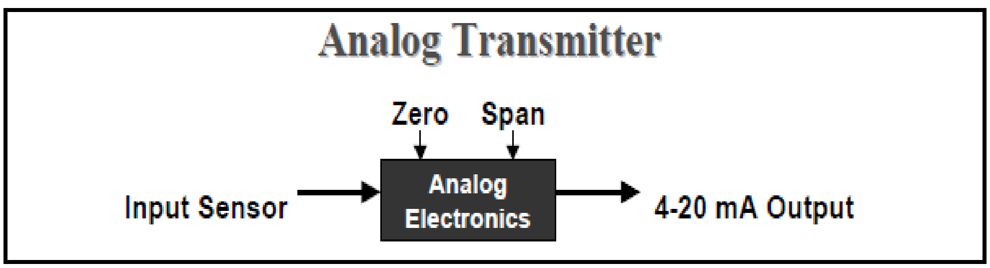

Figure 2.5: Analog Transmitter [6]

The calibration approach for a HART instrument will depend on how the transmitter outputs are used. If only the 4-20 mA analog signal is used, it may be treated much as an analog transmitter. Using the manual zero and span buttons on the transmitter, or by digitally setting the PV LRV and PV URV, the correct relationship between input sensor and 4-20 mA analog output are set, was shown in the figure 2.6. However, the Sensor Input stage has not been properly adjusted.

If one were to use a communicator to read the digital value PV, it will most likely be incorrect, even though the 4-20 mA output will be correct. If any of the digital signals will be used by the control system, then a more rigorous approach is required. If the PV will be used, then the input stage must be correctly set using Sensor Trim. Then the PV LRV and PV URV should be digitally assigned, and never changed using the manual zero and span buttons. Finally, the Output Trim is used to correctly set the relationship between the PVAO and the 4-20 mA analog output. Holladay 3 provides an excellent discussionon the proper calibration of HART devices [12].

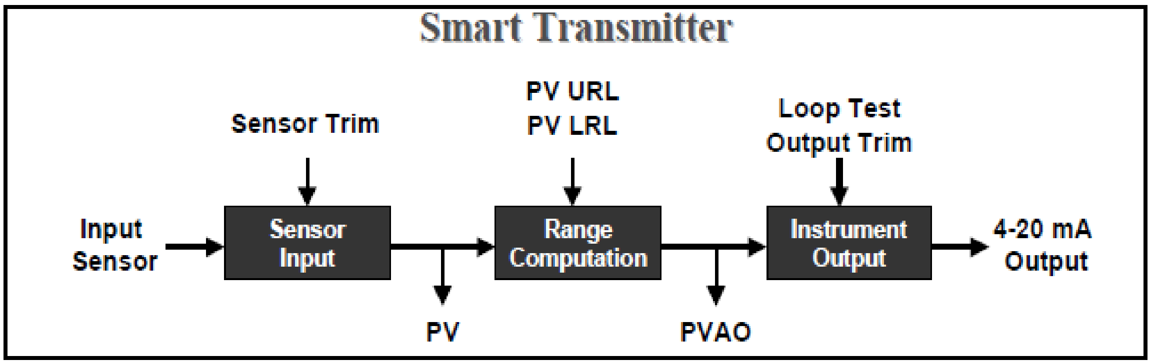

Figure 2.6: Smart Transmitter [6]

2.3.2 Application of Neural Fuzzy Network to Pyrometer Correction and Temperature Control in Rapid Thermal Processing

This research was analyzed by Jiun-Hong Lai and Chin-Teng Lin from *Member, IEEE.* In this research, Rapid thermal processing (RTP) technology inherently possesses these features and several advantages over traditional batch furnaces is provided. One advantage of RTP is that it eliminates the long ramp-up and ramp-down time associated with furnaces, enabling a significant reduction in the thermal budget. Another advantage of RTP is that it allows better control over the processing environment which is becoming critical in some applications. A neural fuzzy network is used to predict the emissivity changes for the compensation of measured temperature [8]. Figure 2.7 shows schematic of RTP system.

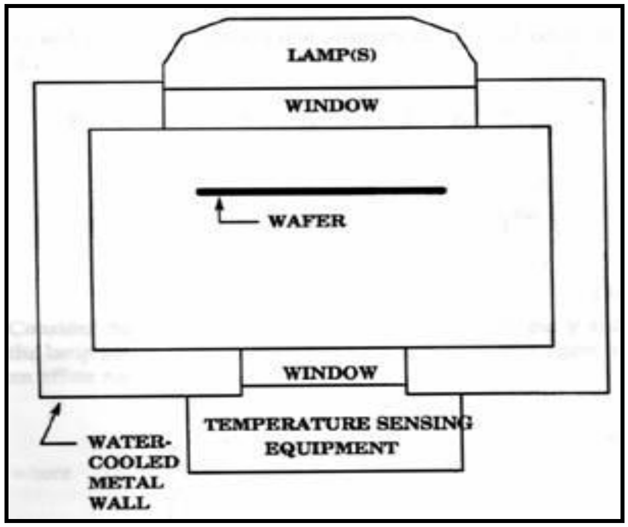

Figure 2.7: Schematic of the RTP system [8]

2.3.3 Data Acquisition and Resistance Measurements Using a Simple Program

This research was developed by H.Golnabi, P.Azimi and G.H.Poseh from sharif University of technology. This project was describe a simple method for the automated data acquisition and analysis of data taken by programmable instruments. Device controls and communication method are explained and some typical illustrative examples showing the potential applications of the method in real experiments are presented. This method offers a quick and fexible way to control many instruments by using a multi-device arrangement of a stacking method in a parallel operation.

In this project, the General-Purpose Interface Bus (GPIB) was used here for remote control of the devices. By using Excel and Visa interactive programs and using GPIB interface, easy communication and data transfer between instruments and a PC is accomplished. A special probe system was devised for the small resistant measuring experiments and the DC resistance measurements are performed by using the four-probe method. The related temperatures were measured by using a silicone diode as a resistance thermometer detector. Using these data acquisition method, short circuit voltage measurement, resistance measurements and the temperature dependence of resistance for a thin platinum wire are reported [7].

2.4 Introduction to Zigbee wireless technology

ZigBee is a new technology now being deployed for wireless sensor networks. A sensor network is an infrastructure comprised of sensing, computing and communications elements that allows the administrator to instrument, observe and react to events and phenomena in a specified environment. Typical applications include, but are not limited to, data collection, monitoring, surveillance and medical telemetry. The administrator typically is a civil, government, commercial or industrial entity. The mainly advantages of ZigBee technology are reliable and self configuration, supports large number of nodes, easy to deploy, very long battery life, secure, low cost, can be used globally.

XBee and XBee-PRO Modules were engineered to meet ZigBee/IEEE 802.15.4 standards and address the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of critical data between devices. The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other [10].

2.4.1 Application of ZigBee sensor network to data acquisition and monitoring

This research was developed by Mitsugu Terada from Department of Applied Physics, Faculty of Science, Fukuoka University, 8-19-1 Nanakuma, Jonan-ku, and Fukuoka City, Japan. In this research, A ZigBee sensor network for data acquisition and monitoring application. A ZigBee module is connected via a USB interface to a Microsoft Windows PC, which works as a base station in the sensor network. Data collected by remote devices are sent to the base station PC, which is set as a data sink. Each remote device is built of a commercially available ZigBee module product and a sensor.

The sensor is a thermocouple connected to a cold junction compensator amplifier. The signal from the amplifier is input to an A/D converter port on the ZigBee module. Temperature data are transmitted according to the ZigBee protocol from the remote device to the data sink PC. The data sampling rate is one sampling per second; the highest possible rate is four samplings per second. The data are recorded in the hexadecimal number format by device control software, and the data file is stored in text format on the data sink PC [9].

2.4.2 Design, Development and Implementation of temperature sensor using Zigbee Concept

This researcher is developed by T.C.Manjunath, *Ph.D.* (*IIT Bombay*) & Fellow IETE, Ashok Kusagur , Shruthi Sanjay, Saritha Sindushree, and C. Ardil from Electronics and Communication Engineering of New Horizon College of Engineering at Karnata, India. This researcher was develop to sense the temperature and to display the result on the

LCD using the zigbee technology. In development of temperature sensor, this experiment was worked by it senses the temperature and afterthat amplification is fed to the microcontroller and then is connected to the zigbee module, which transmits the data and at the other end the zigbee reads the data and displays on to the LCD.

This experiment was also describe that Zigbee is a consortium of software, hardware and services companies that have developed a common standard for wireless, networking of sensors and controllers. While other wireless standards are concerned with exchanging large amounts of data, Zigbee is for devices that have smaller throughout needs. The other driving factors are low cost, high reliability, high security, low battery usage, simplicity and interoperability with other Zigbee devices. For this experiment, the output of the amplifier is given to the PIC microcontroller as shown in the figure 2.8. The inbuilt ADC of PIC microcontroller converts this analog data to digital form. The parallel data received is converted to serial data by the inbuilt USART.

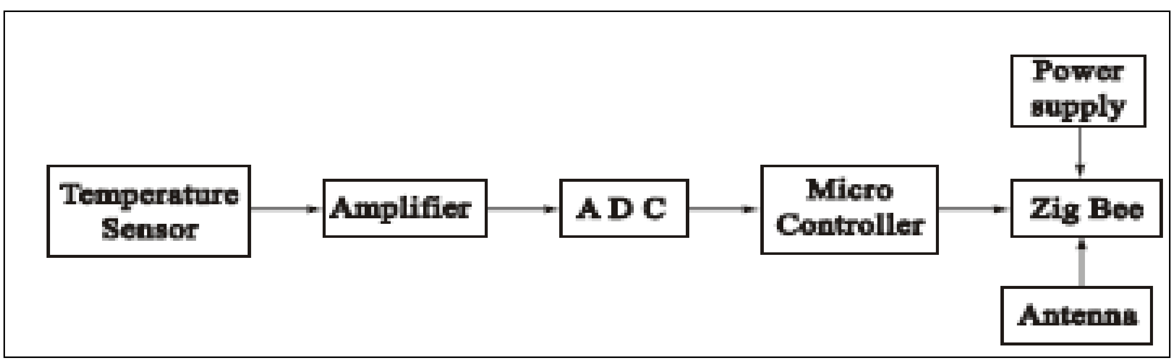

Figure 2.8: Block diagram of the transmitting section [11]

The similar power supply is designed for receiving Zigbee as in the transmitter as shown in the figure 2.9. This data was fed to the PIC microcontroller through pin 18. The serial data received is converted into parallel data by the inbuilt USART and is displayed on the four byte LCD. The buzzer is connected to pin 15 of PIC microcontroller. If the sensed temperature exceeds 40 degree C, the buzzer is on [11].

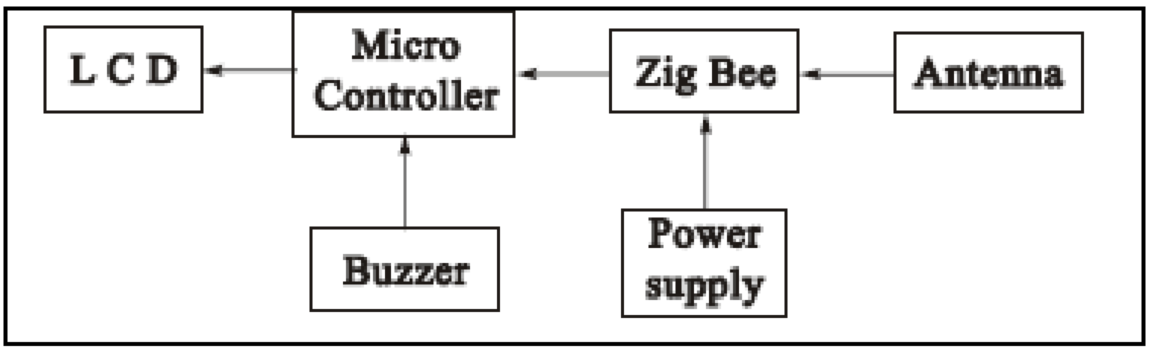

Figure 2.9: Block diagram of the receiving section [11]

2.4.3 Design of wireless temperature monitoring and control system based on ZigBee technology in communication room

This researher is developed by Hu Bing and Fan Wenyao from College of Electrical and Information Engineering Xihua University Chengdu, China. This research is about the normal operation of the equipment in communication room is directly influenced by the temperature. Many communications industries have been concerned greatly about the problem that how to provide an adapt circumstance for the communication room.

This system adopts the ZigBee technology, the cluster tree network topology structure, the 2.4G HZ RF wireless transceiver modules of the JN5121, SHT11 temperature sensors and solenoid valve in order to arrange the sensors flexibly, acquire real-time data, and cool down the high temperature of the communications equipment, etc. The system is designed to be simple, highly reliable and the cost is low. It provides a new way for the temperature monitoring system in the communication room [12].

The area of the communication room in this monitoring system project is 300 m^2 and according to the practical demands, the ZigBee wireless network is the tree topology structure. In combination with the features of the system network, the communication room is divided into two zones. In every zone, the high heat productive equipments such as the SPC switch equipment and the transmission facilities are installed with ten acquisition controller nodes and one router node. The composite structure of this wireless temperature monitoring system is as illustrated in figure 2.10.

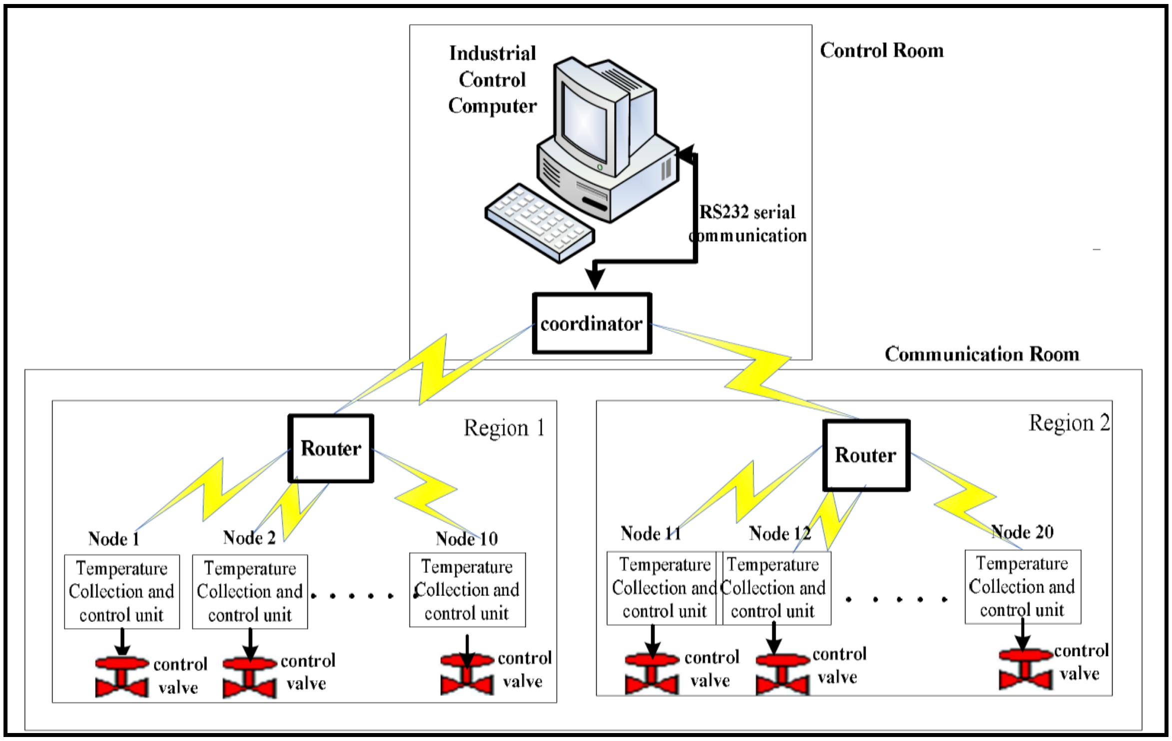

Figure 2.10: The Structure of the Communication Room Monitor and Control system [12]

In this figure, a basic ZigBee wireless network is formed by coordinator node, router nodes, and many acquisition controller nodes. In this way, the temperature of many types of equipment can be acquired at the same time. The temperature monitoring unit of every node can monitor the temperature of the equipment independently and control the on or off state of the control valves according to the alarming temperature set. When the temperature of the equipment is higher than the set alarming temperature, the control valves will be opened to lead the cool air from the air conditioning to the equipment. In contract, if the temperature of the equipment is lower than the set alarming temperature,the control valves will be closed.

2.4.4 Design of Wireless Sensor Network node on ZigBee for Temperature Monitoring

This researcher is developed by Sridevi Veerasingam, Saurabh Karodi, Sapna Shukla and Mehar Chaitanya Yeleti from Department of Instrumentation and Control Engineering National Institute of Technology, Tiruchirappalli India. This research was about portable wireless data logging system for temperature monitoring in real time process dynamics. Process variables (like temperature, pressure, flow, level) vary with time in certain applications and these variations should be recorded so that a control action can take place at a defined set point.

This research proposed a 8-bit embedded platform for a temperature sensor node having a network interface using the 802.15.4 ZigBee protocol, that is a wireless technology developed as open global standard to address the low-cost, low-power wireless sensor networks. The wireless temperature sensor node senses and transmits the variations in the local temperature to the central computing unit placed within the range [13].

The development of Sensor networks requires technologies from different research areas in Sensing, Communication and Computing (including Hardware, Software and Algorithms). Thus combined and separate advancements in each of these areas have driven research in sensor networks.These inexpensive, Low-power communication devices can be deployed throughout a physical space, providing dense sensing close to physical phenomena, processing and communicating this information and coordinating actions with other nodes.

Temperature is sensed and converted to the digital form by means of Analog to Digital converter (ADC) and is given to the input port of the microcontroller. The microcontroller transmits the data serially through the ZigBee module. The schematic of the sensor node is given in figure 2.11.

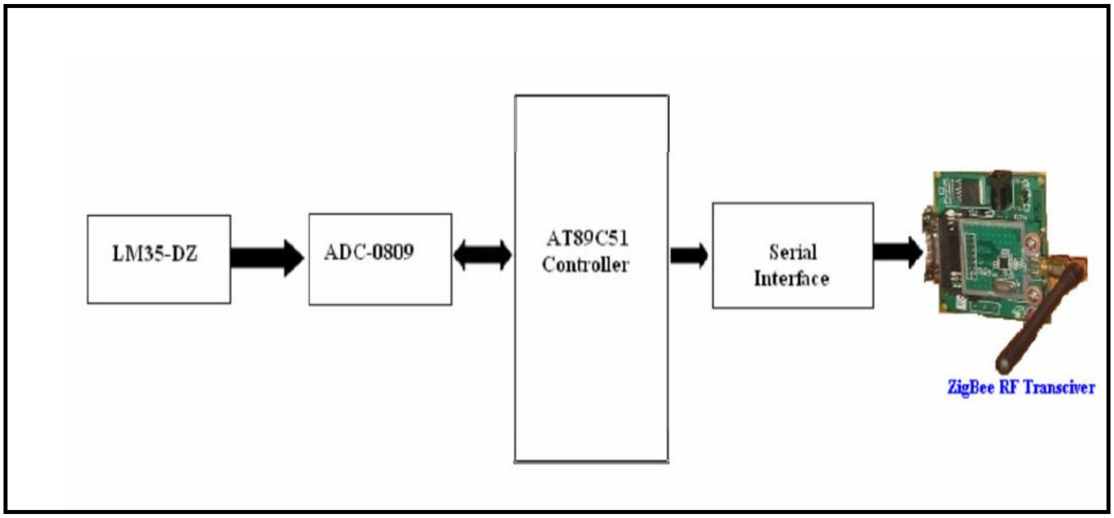

Figure 2.11: Block diagram of Wireless Sensor nodes [12]

2.5 Introduction to Visual Basic 2008 Edition

Visual Basic (VB) is the third-generation event-driven programming language and integrated development environment (IDE) from Microsoft for its COM programming model. VB is an easy to learn and use programming language, because of its graphical development features and BASIC heritage.

A programmer can put together an application using the components provided with Visual Basic itself. Programs written in Visual Basic can also use the Windows API, but doing so requires external function declarations.

The language not only allows programmers to create simple GUI applications, but can also develop complex applications. Programming in VB is a combination of visually arranging components or controls on a form, specifying attributes and actions of those components, and writing additional lines of code for more functionality. Since default attributes and actions are defined for the components, a simple program can be created without the programmer having to write many lines of code. Performance problems were experienced by earlier versions, but with faster computers and native code compilation this has become less of an issue. The latest version of Visual Basic is Microsoft Visual Basic 2008 Express Edition [4].

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will explain about the methodology part that consists of three main parts are instrument, software and hardware which, shown overview of main parts in the figure 3.1. Each these parts of instrument, hardware and software are important to make the project successful.

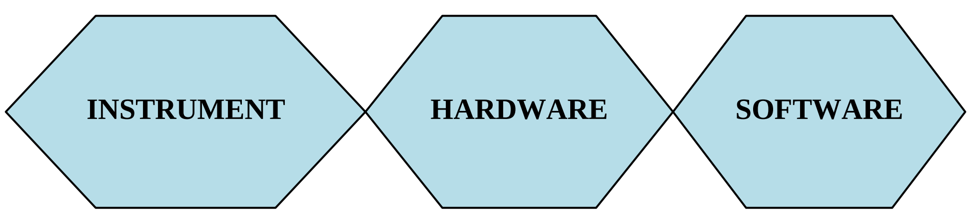

Figure 3.1: Overview of main parts

3.1.1 Overview

In this project, RTD represents Decade Box as a temperature sensor and temperature transmitter will be use together with HART communicator and decade box in doing the measurement. Figure 3.2 is show interfacing between instrument, hardware and software. Zigbee wireless system is use to interface between computer and temperature instrument. Simulation of the develop software is important to test the accuracy of measurement using Visual Basic. Communication between transmitter and receiver Zig-bee is shown in the figure 3.3.

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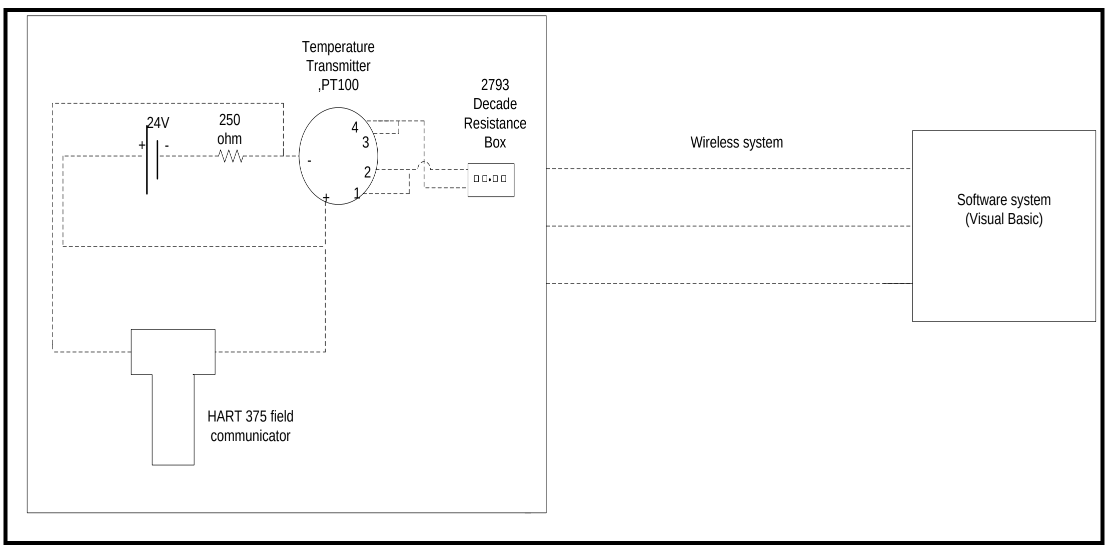

Figure 3.2: Instrument, hardware and software interfacing

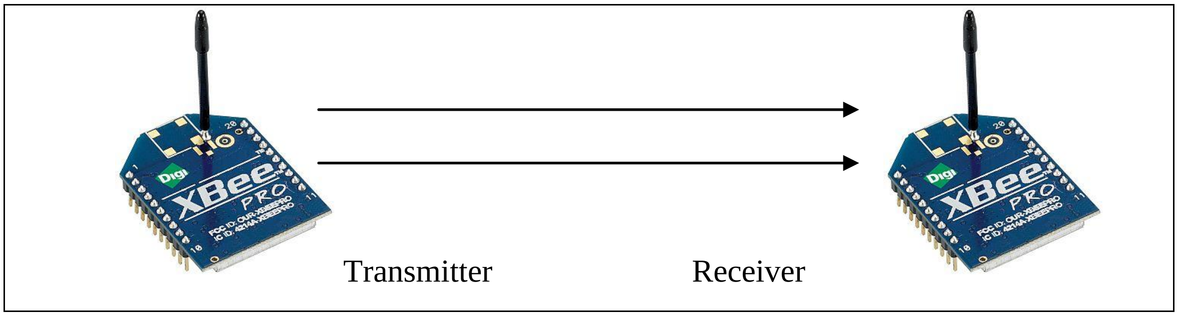

Figure 3.3: ZigBee wireless system [16]

3.2 INSTRUMENT

3.2.1 Basic Instrument Connection

Figure 3.4 is shown the basic instrument connection that used for interfacing with PC to measure the temperature measurement. The basic instrument circuit is used to produce the output signal and measure the temperature measurement. Basic instrument includes temperature transmitter, decade box, power supply and HART.

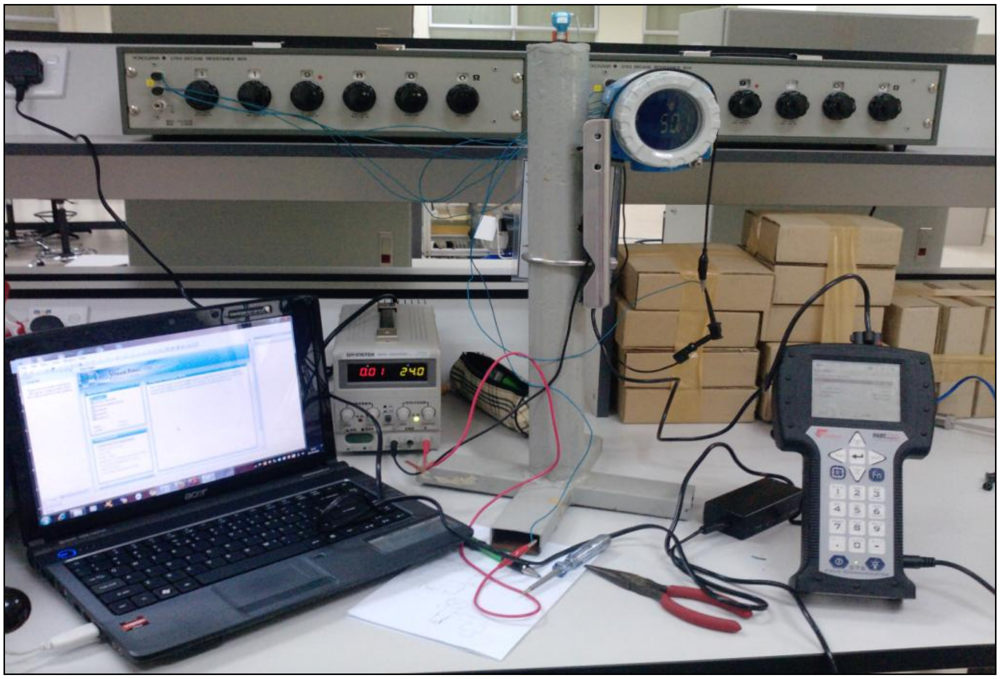

Figure 3.4: Instrument

3.2.2 YOKOGAWA Temperature Transmitter

A temperature transmitter is a device used to sense a temperature and transmit an output representative of the sensed temperature. Process control transmitters are used to measure process parameters in a process control system. Temperature transmitters are used in controlling industrial processes by sensing a temperature of the process and transmitting the information to a remote location. A process temperature transmitter provides an output related to a sensed process substance temperature. The temperature transmitter output can be communicated over the loop to a control room, or the output can be communicated to another process device such that the process can be monitored and controlled.

The transmitter injects a current into the temperature sensor and the resultant voltage drop across the temperature sensor is used to measure resistance. The voltage is converted into a digital format using an analog to digital converter and provided to a microcontroller. The microcontroller converts the measured voltage into a digital value representative of temperature. The temperature transmitter generally includes housing and a temperature probe which attaches to the housing.

In order to monitor a process temperature, the transmitter includes a sensor, such as a resistance temperature device (RTD) or a thermocouple. An RTD changes resistance in response to a change in temperature. By measuring the resistance of the RTD, temperature can be calculated. A thermocouple provides a voltage in response to a temperature change. Typically, the temperature transmitter is located in a remote location and coupled to a control room over a 4-20 mA current loop. A temperature sensor is placed in the process fluid and provides an output related to temperature of the process fluid. Temperature transmitter is shown in the figure 3.5.

Figure 3.5: YOKOGAWA Temperature Transmitter [15]

3.2.3 HART Communicator

The 375 Field Communicator is the new standard in handheld communicators. Built on over ten years of experience with the HART Communicator, user requirements drove the features of this next generation communicator. HART users worldwide told us bow to make a better communicator. Fieldbus users said that want a portable intrinsically safe communicator that supports all their fieldbus devices.

The 375 Field Communicator is designed to support all HART and FOUNDATION fieldbus devices. If we are familiar with the 275 HART Communicator, used in thousands of plants worldwide for more than ten years, we will appreciate universal HART support in a single intrinsically safe handheld communicator. The 375 field Communicator can also be used to configure all the FOUNDATION fieldbus devices in your plant. Use it to perform diagnostics for effective start-up and troubleshooting of FOUNDATION fieldbus segments. Create a quality segment by diagnosing the network DC voltage and average noise. Figure 3.5 shows HART 375 Field Communicator.

Figure 3.6: HART 375 Field Communicator [14]

3.2.4 Decade Box

Model 2793 is high-accuracy, stable DC variable resistor with 6 dials and is available in two styles: 279301 for medium resistance from 0.1 to 1,111.210 Ω in 1 mΩ steps (best suited for calibration of resistance thermometers or bridges); 279303 for high resistance from 0 to 111.1110 MΩ in 100 Ω steps (suitable for calibration of insulation resistance testers or bridges). Figure 3.7 shows the decade box that use to detect temperature changes.

Specifications of Decade box are:

- Up to 100 MΩ in 100 Ω step
- Low voltage coefficient Variation of the resistance value is less than ±0.1% at 1 MΩ and 10 MΩ steps against 100 V application, and less than ±0.04% at 100 Ω, 1 kΩ, 10 kΩ, and 100 kΩ steps against 10 V application.
- Shock-and vibration-proof construction
- Easy-to-read in-line indication
- Best suited for calibration of insulation resistance testers and bridges

Figure 3.7: Model 2793 Decade box [17]

3.3 HARDWARE

3.3.1 Introduction to ZIGBEE

Zigbee is a wireless network protocol specifically designed for low data rate sensors and control networks as shown in figure 3.8. Zigbee is a consortium of software, hardware and services companies that have developed a common standard for wireless, networking of sensors and controllers. While other wireless standards are concerned with exchanging large amounts of data, Zigbee is for devices that have smaller throughout needs. The other driving factors are low cost, high reliability, high security, low battery usage, simplicity and interoperability with other Zigbee devices.

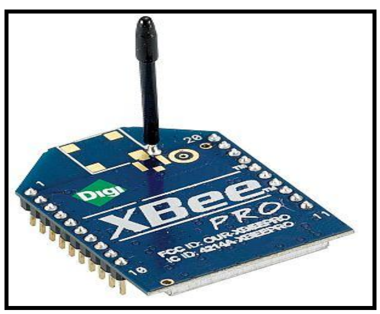

Figure 3.8: ZIGBEE Chip [16]

Compared to other wireless protocol that Zigbee wireless protocol offers low complexity. It also offers three frequency bands of operation along with a number of network configurations and optional security capability. In health care, Zigbee can be used for patient monitoring process control, assuring compliance with environmental standards and energy management. Used correctly, Zigbee enabled devices can give a warning before a breakdown occurs so that repairs can be made in the most cost effective manner. They will be used for controlling our home entertainment systems, lights, garage door openers, alarms, panic buttons and many other uses. Figure 3.9 indicates that Zigbee-PRO with USB Development Board.

Figure 3.9: ZigBee –PRO with USB Development Board

3.5.1 Features Overview

XBee and XBee-PRO Modules were engineered to meet ZigBee/IEEE 802.15.4 standards and address the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of critical data between devices. The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other. Table 3.1 show the features overview of ZIGBEE. Table 3.3 is show the USB signals pin.

Table 3.2: Specifications of the XBee and XBee-PRO OEM RF Modules

Specification	XBee	XBee-PRO
Performance		
Indoor/Urban Range	up to 100 ft. (30 m)	up to 300 ft. (100 m)
Outdoor RF line-of-sight Range	up to 300 ft. (100 m)	up to 4000 ft. (1200 m)
Transmit Power Output	1 mW (0 dBm)	60 mW (18 dBm), 100 mW EIRP
RF Data Rate	250,000 bps	250,000 bps
Receiver Sensitivity	-92 dBm (1% PER)	-100 dBm (1% PER)
Power Requirements		
Supply Voltage	2.8 – 3.4 V	2.8 – 3.4 V
Transmit Current (typical)	45 mA (@ 3.3 V)	270 mA (@ 3.3 V)
Receive Current (typical)	50 mA (@ 3.3 V)	55 mA (@ 3.3 V)
Power-down Current	< 10 µA	< 10 µA
General		
Operating Frequency	ISM 2.4 GHz	ISM 2.4 GHz
Dimensions	0.960" x 1.087" (2.438cm x 2.761cm)	0.960" x 1.297" (2.438cm x 3.294cm)
Operating Temperature	-40 to 85° C (industrial)	-40 to 85° C (industrial)
Antenna Options	U.FL Connector, Chip Antenna or Wire Antenna	U.FL Connector, Chip Antenna or Wire Antenna
Networking & Security		
Supported Network Topologies	Point-to-Point, Point-to-Multipoint, Peer-to-Peer and Mesh	Point-to-Point, Point-to-Multipoint, Peer-to-Peer and Mesh
Number of Channels	16 Direct Sequence Channels (software selectable)	16 Direct Sequence Channels (software selectable)
Network Layers	PAN ID and Source/Destination Addressing	PAN ID and Source/Destination Addressing
Agency Approvals		
FCC Part 15.247	pending	pending
Industry Canada (IC)	pending	pending
Europe	pending	pending

Table 3.3: USB signals and their implantations on the XBee/XBee-PRO RF Module

Pin	Name	Description	Implementation
1	VBUS	Power	Power the RF module
2	D-	Transmitted & Received Data	Transmit data to and from the RF module
3	D+	Transmitted & Received Data	Transmit data to and from the RF module
4	GND	Ground Signal	Ground

3.4 SOFTWARE

3.4.1 Visual basic Edition 2008

Microsoft Visual Studio Express is a set of freeware integrated development environments (IDE) developed by Microsoft that are lightweight versions of the Microsoft Visual Studio product line. Express Editions were conceived beginning with Visual Studio 2005. The idea of Express editions, according to Microsoft, is to provide streamlined, easy-to-use and easy-to-learn IDEs for users other than professional software developers, such as hobbyists and students. The first versions of Visual Studio 2005 Express were released on October 2005 and the Service Pack 1 versions were released on December 2006. Visual Studio 2005 Express Editions ran on Windows 2000 SP4 and above Windows NT-based platforms. In line with popular demand since their original release, these editions will always remain free-of-charge.

Visual Studio 2008 Express editions were released in November 2007 and their SP1 on August 11, 2008. Visual Studio 2008 and 2010 Express Editions require Windows XP or a later Windows version; Windows 2000 is no longer supported for development but can be a target platform if using 2008 Express. Microsoft may make previous versions of Visual Studio Express unavailable. Currently, Visual Studio 2005 Express editions are available for download from the Microsoft website.

From the Windows **Start** menu, choose Microsoft Visual Basic 2008 Express Edition where a place to create new project is shown in the figure 3.10.

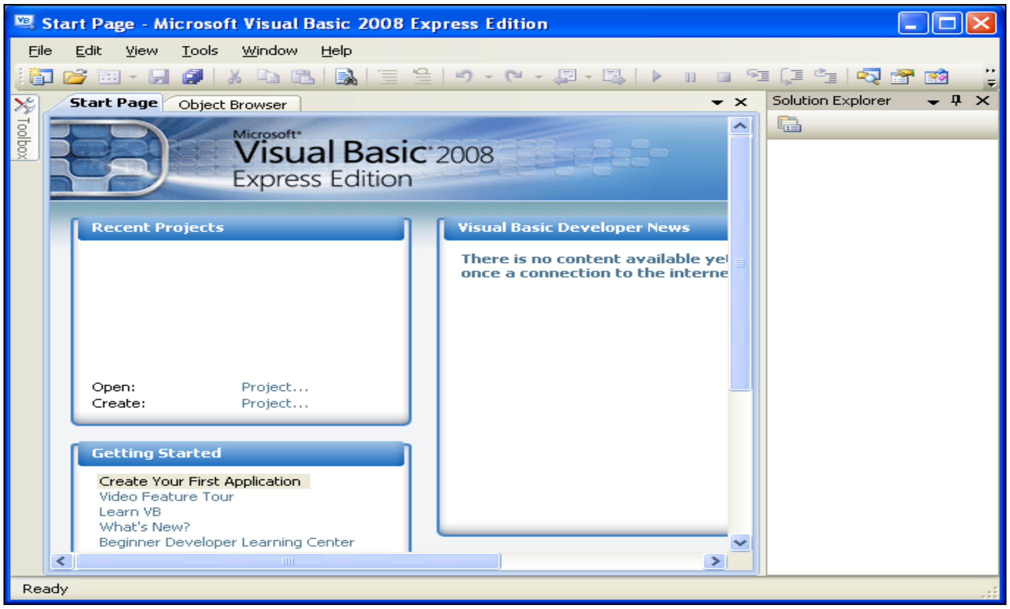

Figure 3.10: Create New Project

The **New Project** dialog box opens as shown in the Figure 3.11. Select **Windows Application** and Input project **Name**.

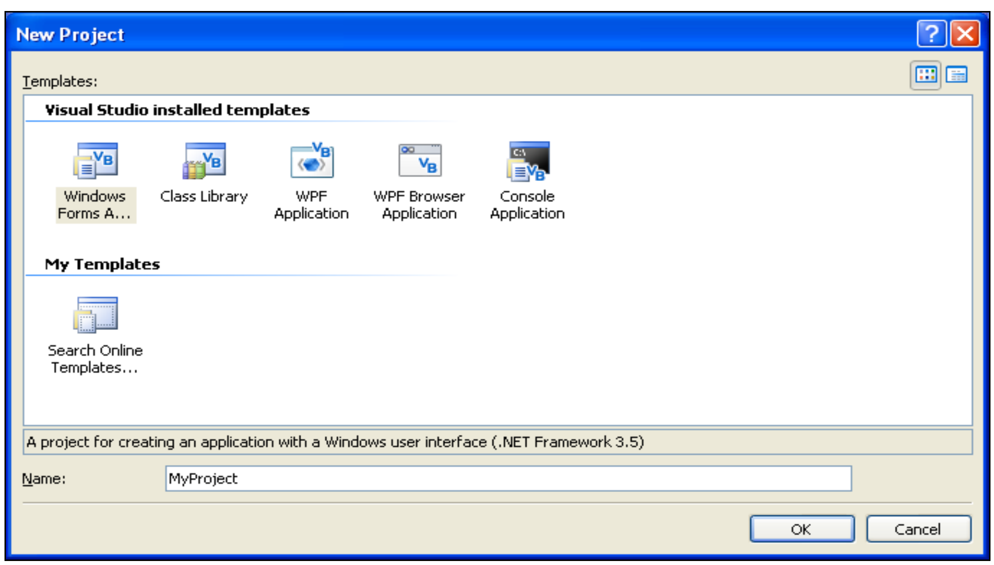

Figure 3.11: New Project dialog box

Then, Open **Toolbox** window as shown in the Figure 3.12. (The **Toolbox** is on the left side of Visual Basic 2008. You can keep it open by clicking the **Auto Hide** icon, which looks like a push pin.). Find **SerialPort** control on the **Components** of **Toolbox**. Drag **SerialPort** control into frame **Form1** to add **SerialPort1**.

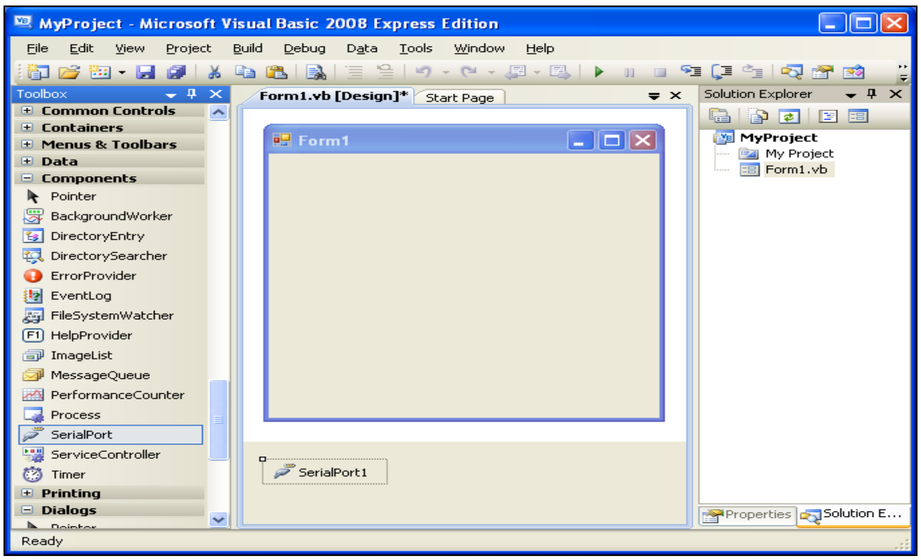

Figure 3.12: Toolbox Window

3.4.2 SQL Server Express

SQL Server Express is a freeware, light-weight, and redistributable edition of Microsoft SQL Server. It provides an integrated data storage solution for developers writing Windows applications and Web sites that have basic data storage needs. SQL Server Express replaces MSDE 2000 and significantly expands on its feature set. The SQL Server Management Studio Express can also be downloaded to provide a graphical user interface for administering SQL Server Express. Figure 3.13 shows the SQL Manager 2008 for SQL Server.

The SQL Server Express Edition has the following limitations:

i. Limited to one physical CPU
ii. Lack of enterprise features support
iii. 1 GB memory limit for the buffer pool
iv. Databases have a 4 GB maximum size (10 GB beginning with SQL Server Express 2008 R2)
v. No Data mirroring and/or clustering
vi. No profiler tool
vii. No workload throttle
viii. No UI to import/export data to table
ix. No Server Agent background process

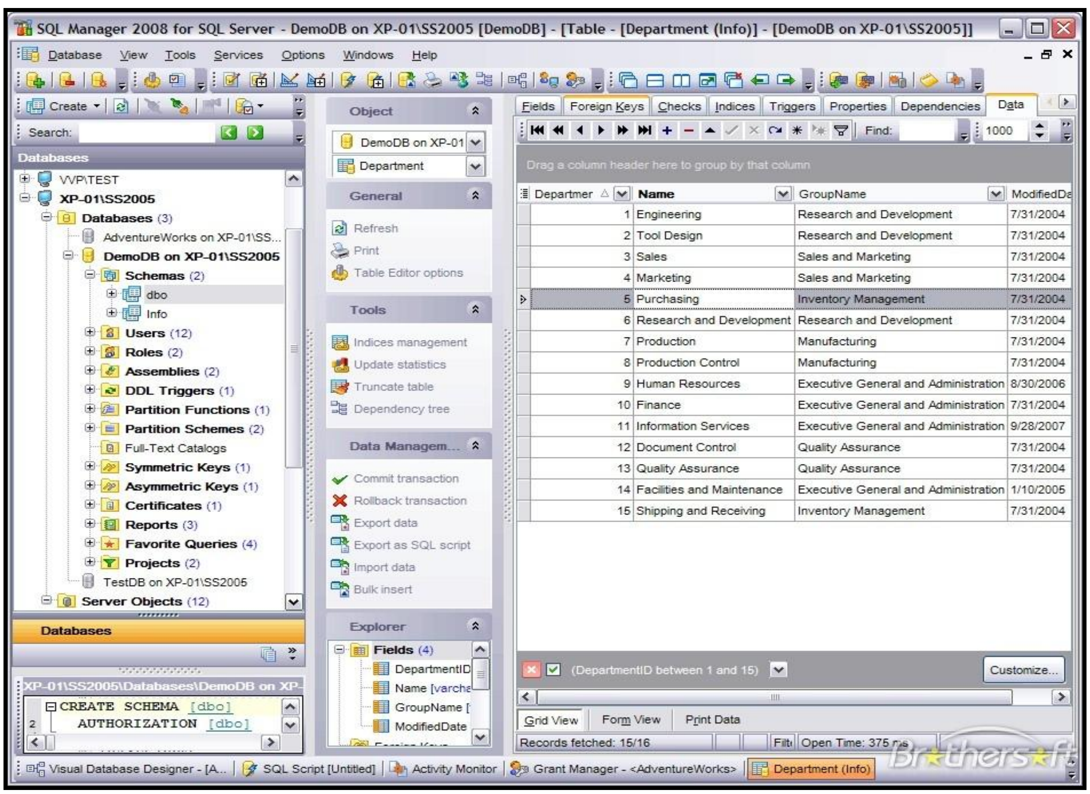

Figure 3.13: SQL Manager 2008 for SQL Server

3.4.3 X-CTU Configuration and Test Utility Software

X-CTU is a Windows-based application provided by Digi. This program was designed to interact with the firmware files found on Digi's RF products and to provide a simple-to-use graphical user interface to them. X-CTU is designed to function with all Windows-based computers running Microsoft Windows 98 SE and above. When launched, this will show four tabs across the top of the program where shows in figure 3.14. Each of these tabs has a different function. The four tabs are:

1. **PC Settings**: Allows a customer to select the desired COM port and configure that port to fit the radios settings.
2. **Range Test**: Allows a customer to perform a range test between two radios.
3. **Terminal**: Allows access to the computers COM port with a terminal emulation program. This tab also allows the ability to access the radios' firmware using AT commands.
4. **Modem Configuration**: Allows the ability to program the radios' firmware settings via a graphical user interface. This tab also allows customers the ability to change firmware versions.

3.4.3.1 PC Settings Tab

When the program is launched, the default tab selected is the "PC Settings" tab. The PC Settings tab is broken down into three basic areas are the COM port setup, the Host Setup, and the User Com ports that can see in figure 3.14.

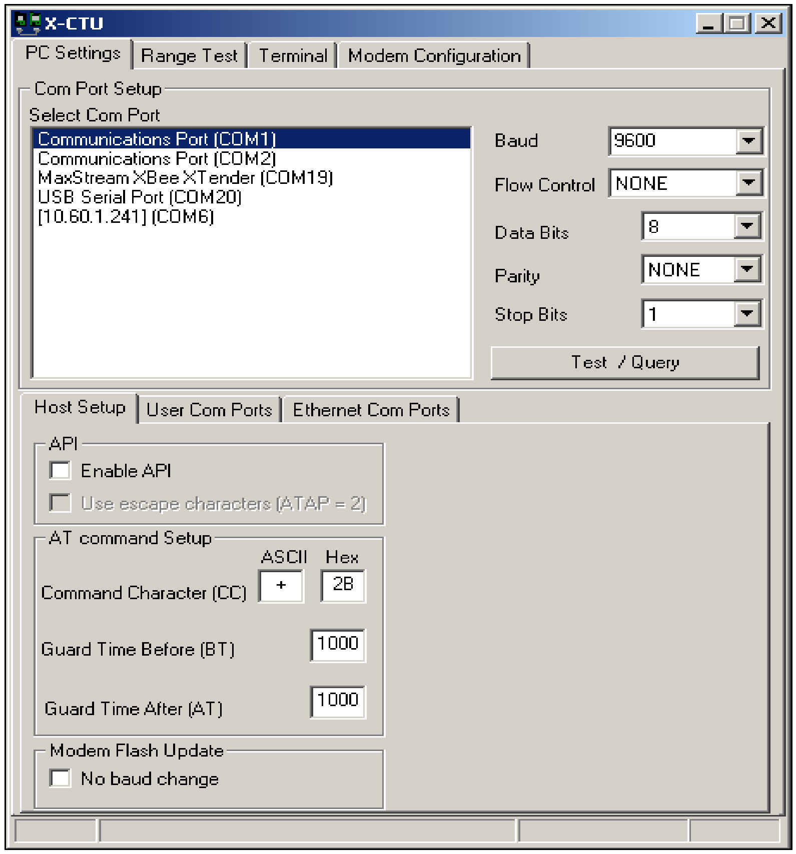

Figure 3.14: X-CTU window

The PC settings tab allows the user to select a COM port and configure the selected COM port settings when accessing the port. Some of these settings include:

i. Baud Rate: Both standard and non-standard
ii. Flow Control: Hardware, Software (Xon/Xoff), None
iii. Data bits: 4, 5, 6, 7, and 8 data bits
iv. Parity: None, Odd, Even, Mark and Space
v. Stop bit: 1, 1.5, and 2

To change any of the above settings, select the pull down menu on the left of the value and select the desired setting. To enter a non-standard baud rate, type the baud rate into the baud rate box to the left. The Test / Query button is used to test the selected

COM port and PC settings. If the settings and COM port are correct, you will receive a response similar to the one depicted in figure 3.15.

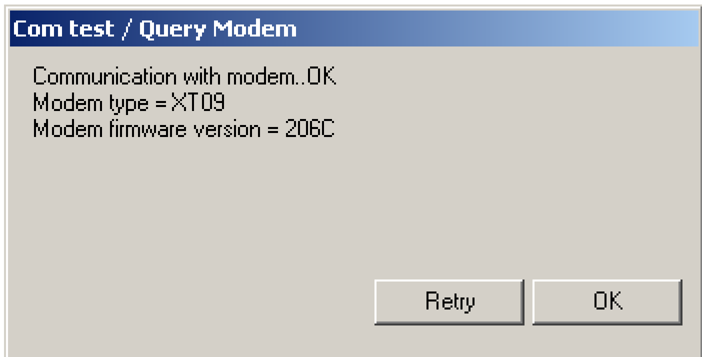

Figure 3.15: COM Test/Query Modem response

3.4.3.2 Range Test Tab

The range test tab is designed to verify the range of the radio link by sending a user-specified data packet and verifying the response packet is the same, within the time specified which shows in figure 3.16. For performing a standard range test, follow the steps found in most Quick Start or Getting Started Guides that ship with the product. By default, the size of the data packet sent is 32 bytes. This data packet specified can be adjusted in either size or the text sent.

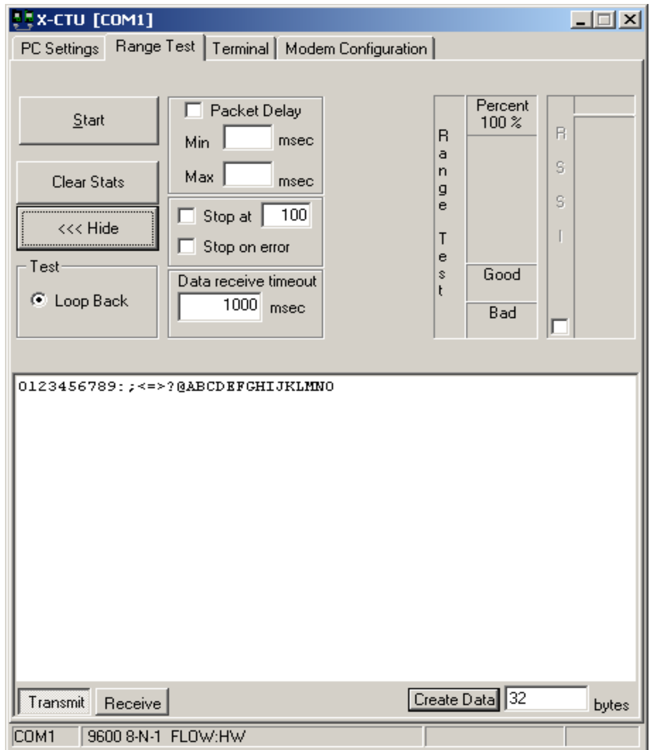

Figure 3.16: Range Test Tab

To modify the size of the packet sent, change the value next to the "Create Data" box and click on the "Create Data" button. If you want to change the data sent, delete the text in the transmit window and place in your desired text. By modifying the text, data packet size, packet delay and the data receive timeout; the user is able to simulate a wide range of scenarios.

3.4.3.3 The Terminal Tab

The Terminal tab has three basic functions are terminal emulator ability to send and receive predefined data pacts (Assemble packet). This tab is an ability to send and receive data in Hex and ASCII formats (Show/Hide hex). This is shown in figure 3.17. The main white portion of this tab is where most of the communications information will occur while using X-CTU as a terminal emulator. The text in blue is what has been typed in and directed out to the radio's serial port while the red text is the incoming data from the radio's serial port as show in figure 3.17.

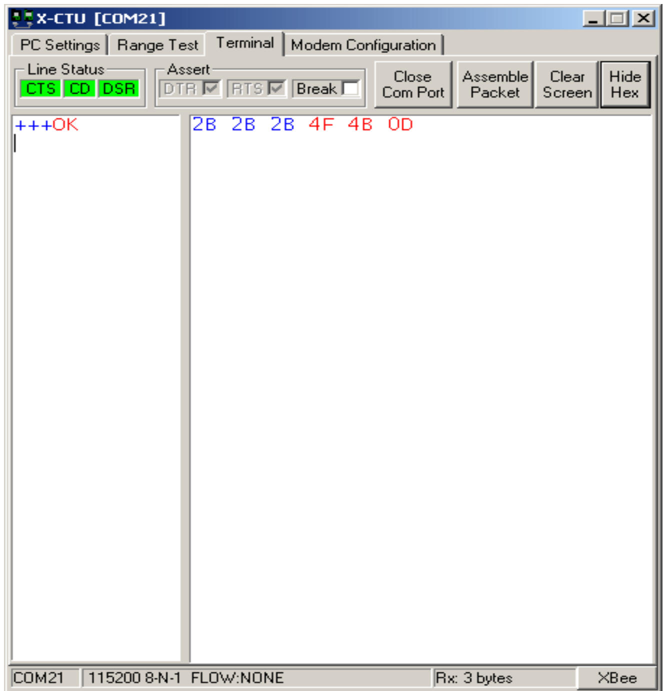

Figure 3.17: Terminal Tab

The Assemble Packet option on the Terminal tab is designed to allow the user to assemble a data packet in either ASCII or Hex characters. This is accomplished by selecting the Assemble packet window and choosing either ASCII (default) or Hex. Once selected, the data packet is assembled by typing in the desired characters as depicted in figure 3.18.

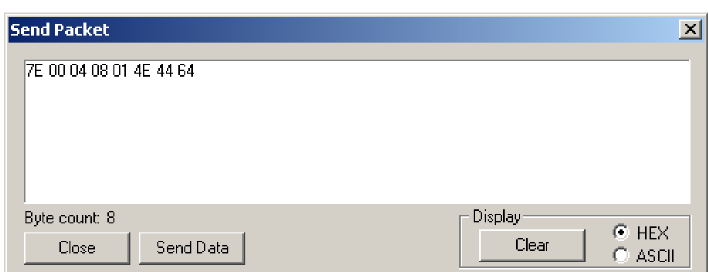

Figure 3.18: Assemble packet window

The Line Status indicators shows the status of the RS-232 hardware flow control lines. Green indicates the line is asserted while black indicates de-asserted. The Break option is for engaging the serial line break. This can be accomplished by checking or asserting the Break option. Asserting the Break will place the DI line high and prevent data from being sent to the radio.

3.4.3.4 Modem Configuration tab

The Modem configuration tab has four basic functions are provide a Graphical User Interface with a radio's firmware, and Read and Write firmware to the radio's microcontroller. These tab are also allow the user to download updated firmware files from either the web or from a compressed file and saving or loading a modem profile as shown in figure 3.19.

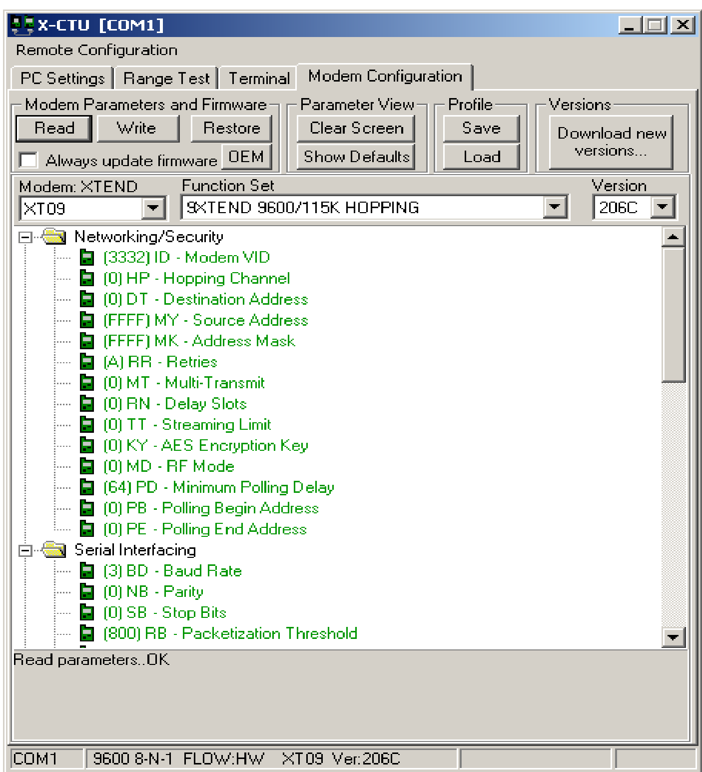

Figure 3.19: Modem configuration tab

3.5 Work of Flow Chart

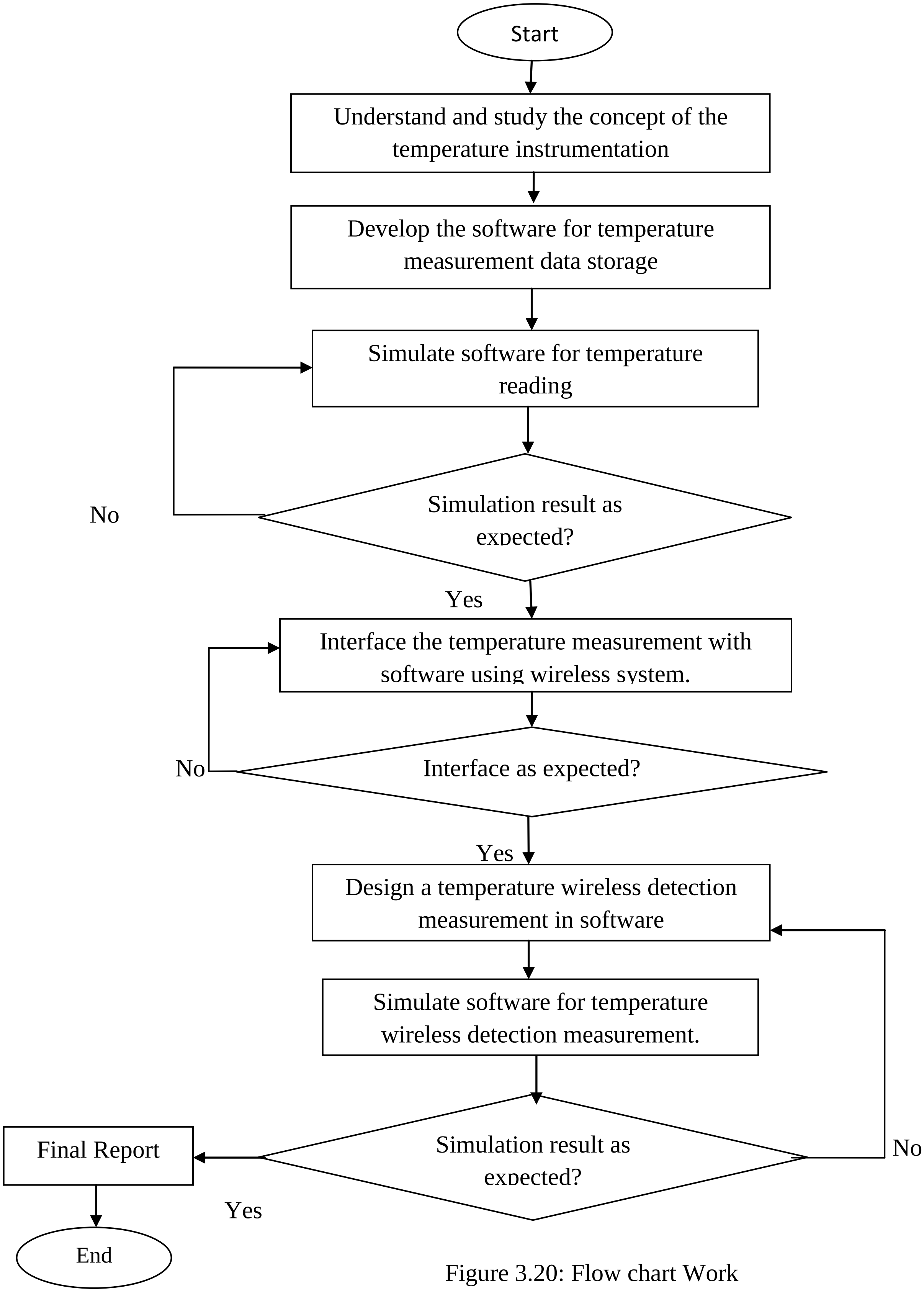

Figure 3.20: Flow chart Work

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter indicates the result and outcome from Visual Basic Express Edition 2008 using GUI application. It was explained and described as the result in graph and table form. This chapter indicates the GUI implementations that display the temperature and resistance changes.

4.2 Results and Discussion: Temperature Monitoring

The design for monitor and data record functions of GUI application as shown in the Figure 4.1 and 4.2. The monitor of GUI application contains four sections which date/time, current, temperature and resistance. The date/time section was display current date and time during monitor the temperature. Current section was for key in the current value ranges, 4-20 mA. Temperature section was display the temperature value. Resistance section was display the resistance value from convert temperature to resistance using equation 4.2. Besides, temperature can convert to resistance by using temperature table shown in the appendix A.

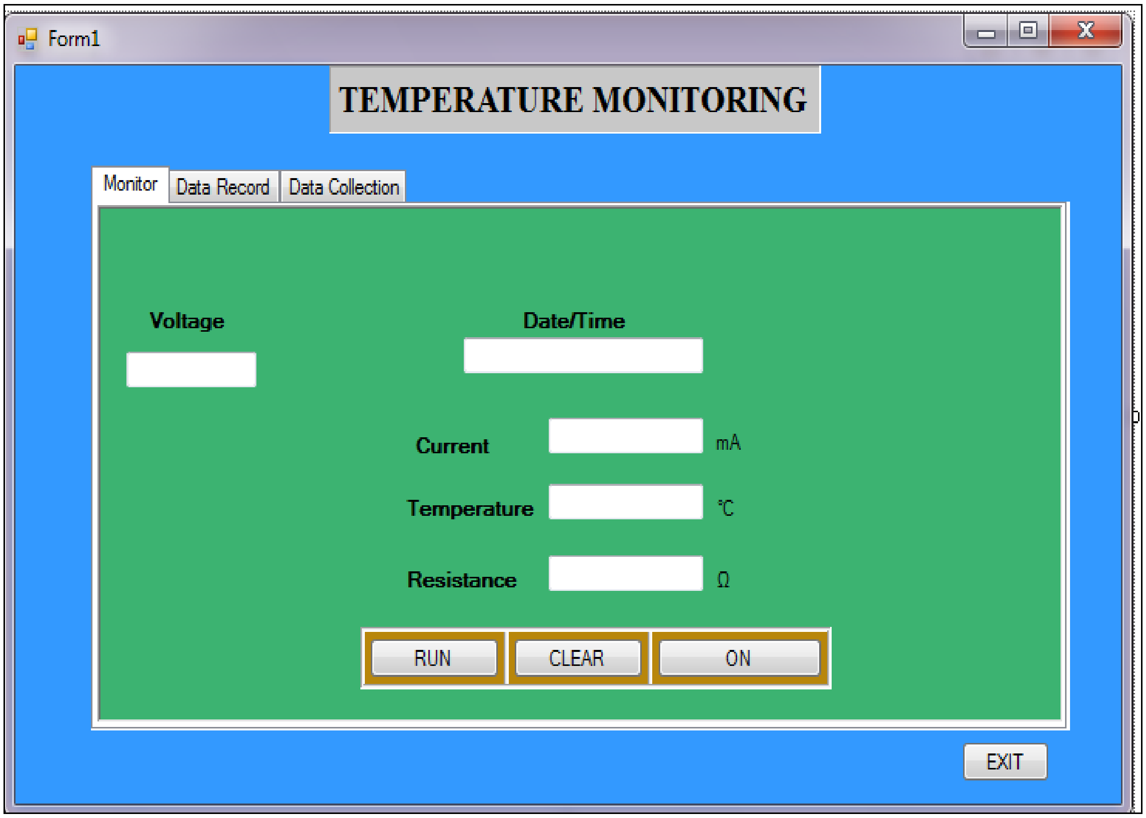

Figure 4.1: Design for Monitor function of GUI

Data from monitoring system will communicate with data record of GUI application shown in figure 4.2. The data record of GUI application contains three sections which are current, temperature and date/time. The current and temperature sections will record and save the data. Date/time section will record and save the date and time of data.

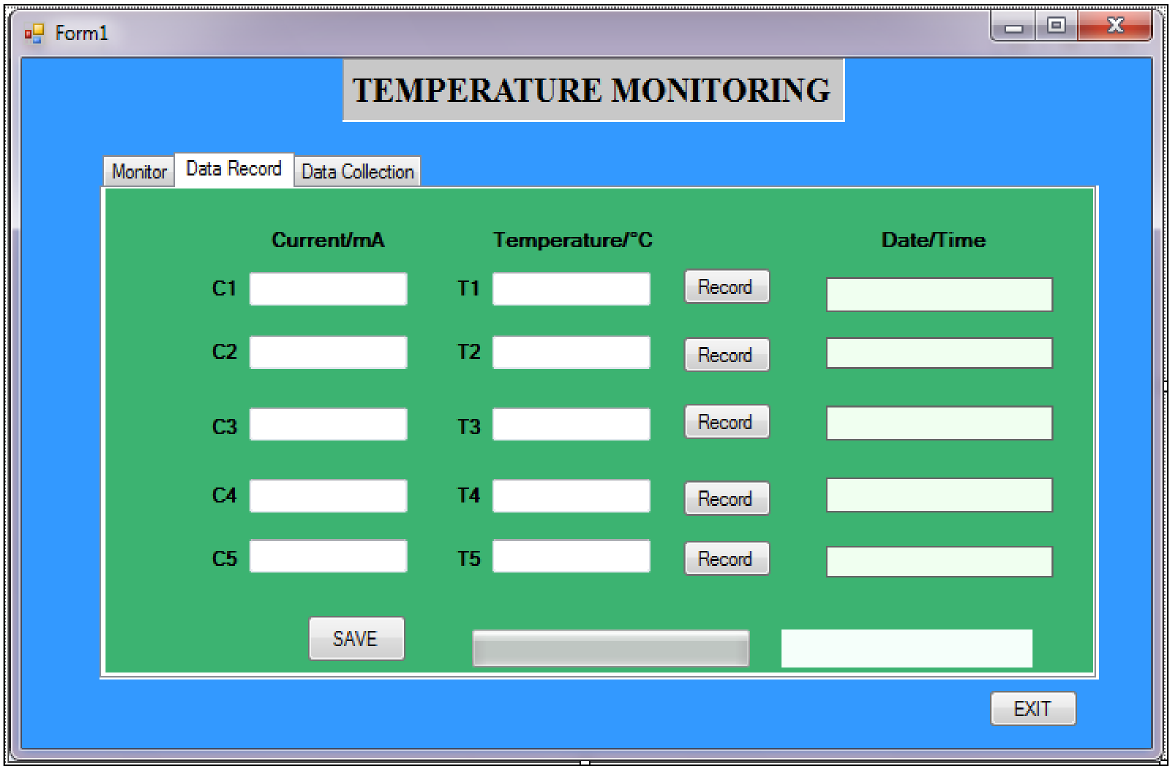

Figure 4.2: Design For Data Record Of GUI

The figure 4.3 And 4.4 tre show the output data of temperature monitoring system after rum the system. Every data from monitor system that shown in figure 4.3, will record and save in the data record system of GUI application that shown in figure 4.4. Date and time of temperature measurement are also recored.

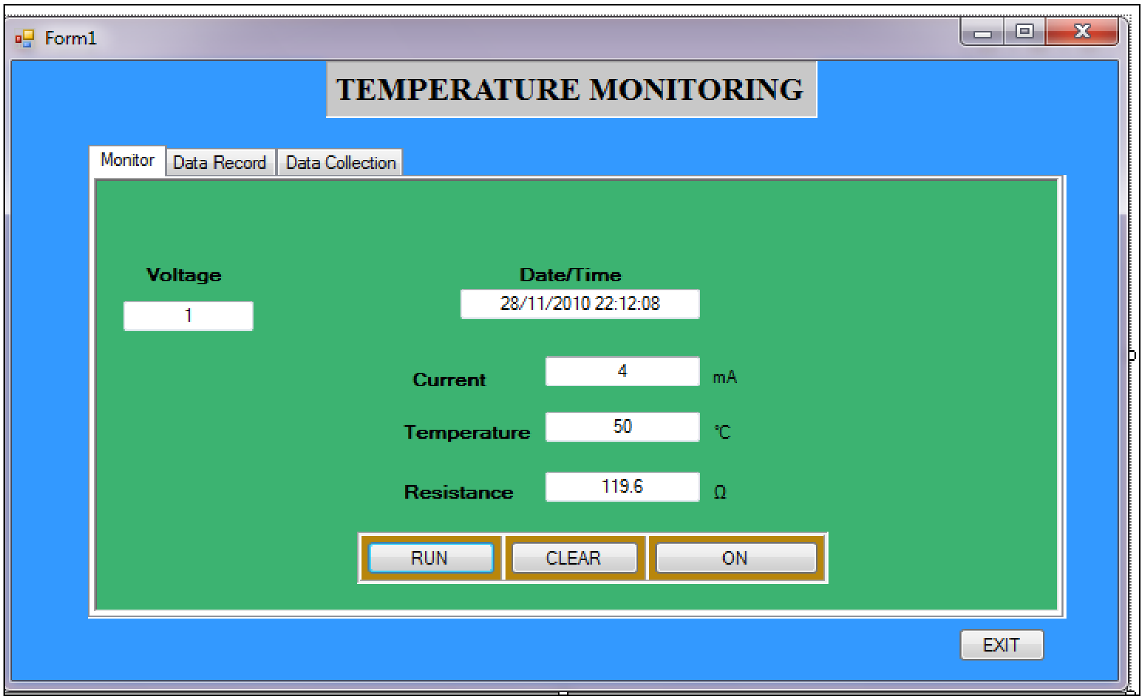

Figure 4.3: GUI displays the data after run the system

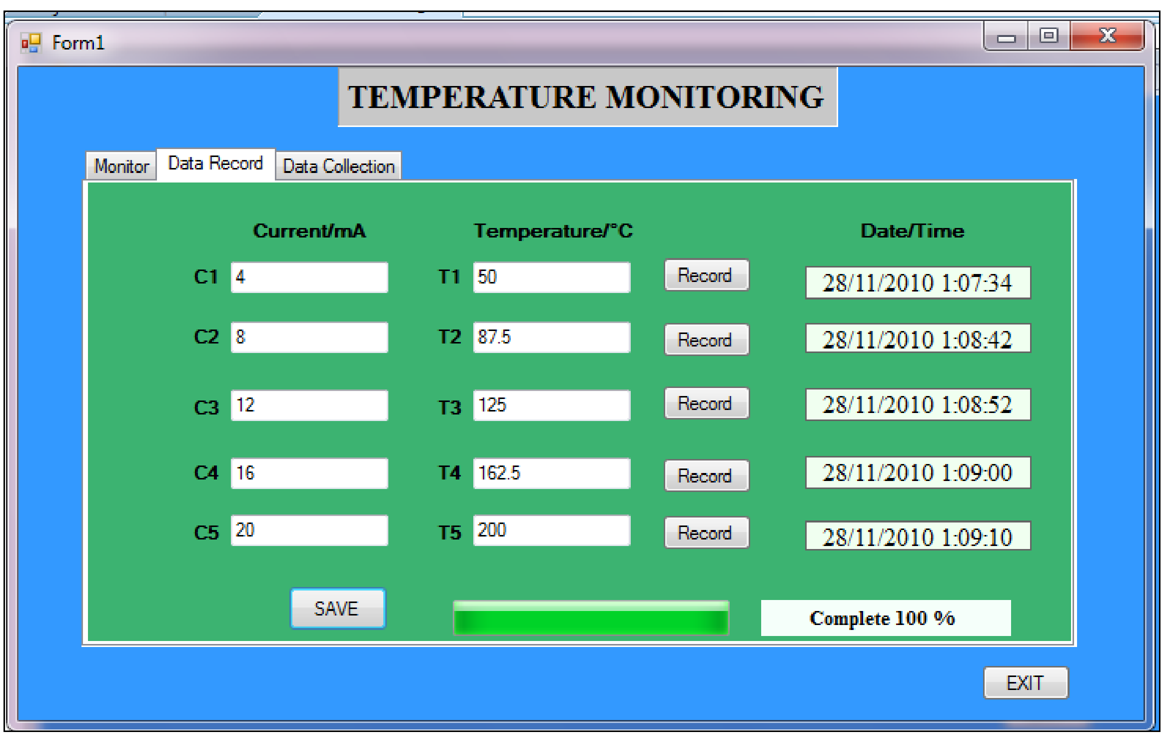

Figure 4.4: Data Record of GUI applicatio

After GUI application has implemented, all the data collection are key in at table as shown in table 4.1. From observation, temperature is proportional with resistance. If temperature is increase, resistance is increase too. If temperature is decrease, resistance is also decrease. From the graph in figure 4.5, the graph can conclude that relationship between temperature and resistance are directly proportional.

Table 4.1: Summary of data collection from GUI

Current (mA)	Temperature (°C)	Resistance (Ω)
4	50.0	119.6
8	87.5	134.3
12	125.0	149.0
16	162.5	163.7
20	200	178.4

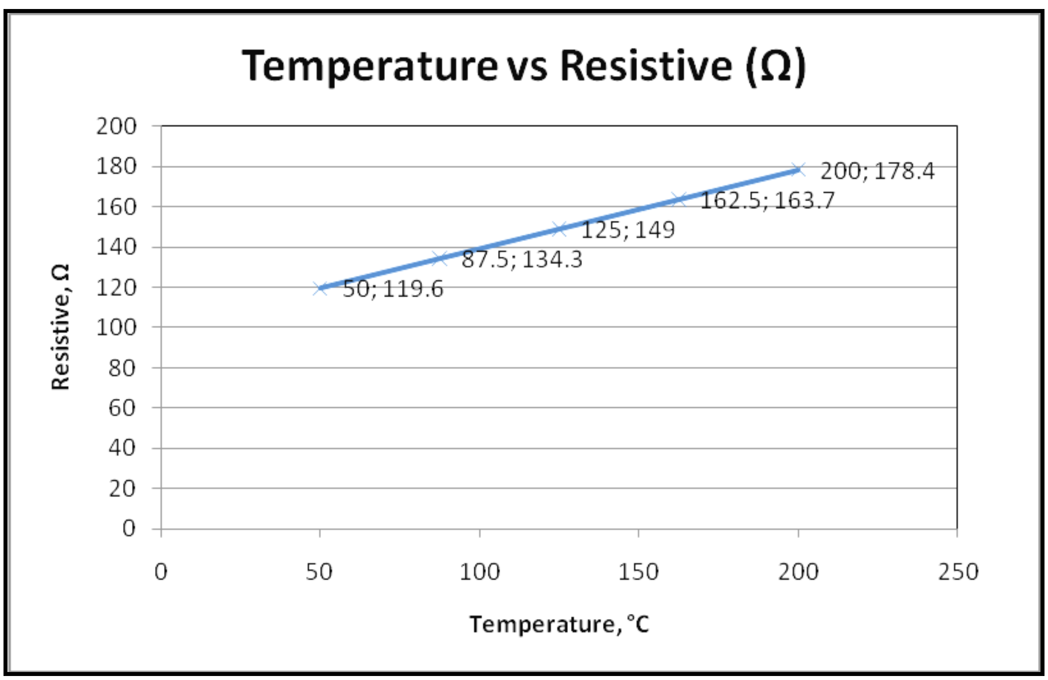

Figure 4.5: Graph of Relationship between Temperature and Resistance

Temperature is measured and Resistance is calculated by using the formula in the equation 4.1 and 4.2.

Temperature Measured:

$$\text{Temperature} = [(15(0.1*\text{Current} - 0.4)/0.16] + 50 \quad (4.1)$$

Resistance measured:

$$\text{Resistance} = 100 - 0.392 * (0° - \text{Temperature}) \quad (4.2)$$

Temperature calculation using formula those show in equation 4.1 and 4.2. Table 4.2 is shown the calculation of Temperature.

Table 4.2: Calculation of Temperature

Current/mA	**Temperature/**°C
4	TEMPERATURE = [(15(0.1*4-0.4)/016] + 50 = 50°C
8	TEMPERATURE = [(15(0.1*8-0.4)/016] + 50 = 87.5°C
12	TEMPERATURE = [(15(0.1*12-0.4)/016] + 50 = 125°C
16	TEMPERATURE = [(15(0.1*16-0.4)/016] + 50 = 162.5°C
20	TEMPERATURE = [(15(0.1*20-0.4)/016] + 50 = 200°C

The results of this temperature measurement are shown in the table 4.3. Before temperature measurement, temperature value ranges, 50 °C-200 °C and current value ranges, 4-20 mA are setting in the HART communicator. Then, set the resistance value based on the temperature table as follow temperature value. After that, the operation of system is observed. Temperature and current value are measured and recorded the data in table as shown in table 4.3.

Table 4.3: Temperature and Current Measured

Resistance, Ω	Actual Current, mA	Actual Temperature, °C	Measured Current, mA	Measured Temperature, °C
119.75	4	50.0	4.125	50.16
134.17	8	87.5	8.099	87.62
148.82	12	125.0	12.096	125.12
163.29	16	162.5	16.095	162.59
177.23	20	200.0	20.103	200.02

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter is state that describes the conclusion based on objective research and problem statement. In this chapter, also summarize new observations and new insight from result of this project.

5.2 Summary of work

For this project, the objectives have been achieved and successful. The GUI application can develop and created by using visual basic 2008 software where use programming language. Temperature can monitor and measure manually using software application. Interfacing between instrument and computer was done and can communicate with each other by using ZigBee wireless systems.

In industrial, monitoring critical issues such as temperature, smoke, humidity, power and airflow can help minimize financial loss in the face of disaster and reduces the time required to restore operations. Zigbee wireless systems are potentially suitable for many other applications. It is works at low power consumption and it is usually small.

As conclusion, it is concluded that Visual basic is a good platform to develop use friendly software to monitor and measure the temperature measurement. Development of wireless RTD temperature measurement using decade box is new learning experience for student. The monitoring system can be used in the communication room flexibly. It can reduces the inconvenience of every of kind field wiring and save expense.

5.3 Future Recommendation

As future recommendation, there are some suggestion that seem can be implemented to improve this system. Here has some point or idea that should be added in future:

1. This software application is too complex. In order to reduce the CPU utilization, the code efficiency must be maximize and hardware trigger mode must be used if want to get maximum sampling frequency.
2. Upgrade the program for more function and limited for analysis the data only. Use the software as a controller to control an actuator such as heater. Various controllers can be implemented such as discontinuous controller or continues controller mode. For example, P, PD and PID controller, PLC programming and others controller can be used to control plant temperature.
3. Build fully automatic temperature monitoring using software application. By implementing this system, it can save a lot of time to monitor temperature from long distance and cost is reduced by using ZigBee wireless system.

4. Build two way communications for interfacing between instrument and PC. By implementing this communication, it makes easy to do maintenance the instrument from controller room such as temperature calibration. This system has been transmitted and received the signal in two way communication.

5.3.1 Costing and Commercialization

This software application is suitable for commercialization especially students and industrial applications. Most of software application has been build to replace manual calculation and monitoring system. Manual calculation and monitoring manually requires a lot of time, concentration and focus. Thus, user can minimize their time in doing temperature monitoring and analysis instead of using manual method which require more time. This software application can increase productivity of work and make job easier. In addition, ZigBee provides specifications for devices that have low data rates, consume very low power and thus, ther are characterized by long battery life.

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[17] Model 2793 DECADE RESISTANCE BOXES, Yokogawa Electric Corporation, Available at www.yokogawa.com.

APPENDICES

APPENDIX A

TEMPERATURE – RESISTANCE TABLE

Temperature vs. Resistance Tables for Resistance Temperature Detectors (RTD) [1]

This reference manual consists of reference tables that give temperature vs. resistance relationships for resistance temperature detectors for Platinum, Copper, Nickel, and Nickel-Iron sensors.

These tables give ohm values from one to three decimal places for each degree of temperature. Such tables are satisfactory for most industrial uses but may not be adequate for computer and similar applications. If greater precision is required, the reader should contact the manufacturer for equations which permit easy and unique generation of the temperature vs. resistance relationship.

[1] Temperature vs. resistance data in Tables 29 and 30 have been developed from ASTM E1137. All other temperature vs. resistance data in Tables 31 to 36 have been developed from wire manufacturers' data.

List of Tables

Following is a list of the resistance temperature detectors tables included in this reference manual.

Table 27 — Limits of Error for RTDs

Type	Initial Tolerance @ 0 °C ±0.01%	±0.03%	±0.06%	±0.1%	±0.12%	±0.2%	±0.5%
Pt	● 5	● 3	● A	● 1	● B		
Cu						●	
Ni							●
Ni-Fe							●

1, 3, 5, A, B see Table 28

Table 28 — Classification of Initial Tolerances[2]

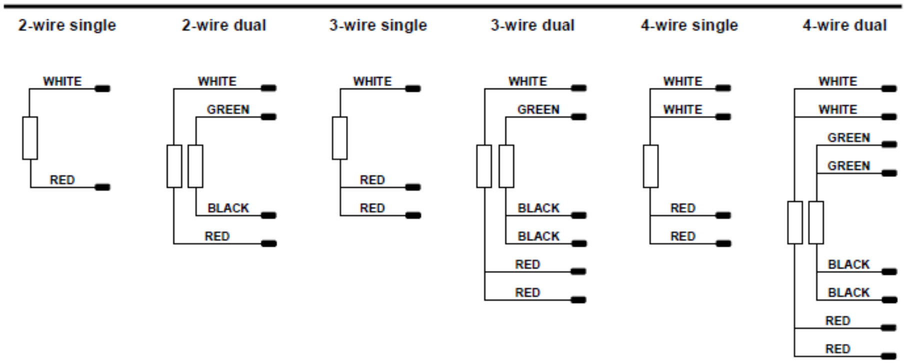
Use given equations to calculate tolerances at specified temperatures:

$$5 = \pm [\,0.03 + 0.0017\,|t|\,]\ ^\circ C$$
$$3 = \pm [\,0.08 + 0.0017\,|t|\,]\ ^\circ C$$
$$A = \pm [\,0.15 + 0.0020\,|t|\,]\ ^\circ C$$
$$1 = \pm [\,0.26 + 0.0042\,|t|\,]\ ^\circ C$$
$$B = \pm [\,0.30 + 0.0050\,|t|\,]\ ^\circ C$$

where:
$|t|$ = value of temperature without regard to sign, °C.

Note 2 — The equations represents values for 3 and 4-wire PRTs. Caution must be exercised with 2-wire PRTs due to lead resistance.

Figure 1 — Pyromation's Standard Element Connections



Pt°C

TABLE 31 100Ω *Platinum RTD* — *0.00392 coefficient*
temperature in °C

Resistance in Ohms

°C	0	1	2	3	4	5	6	7	8	9	10	°C
-200	17.08											-200
-190	21.46	21.02	20.58	20.15	19.71	19.27	18.83	18.40	17.96	17.52	17.08	-190
-180	25.80	25.37	24.94	24.50	24.07	23.63	23.20	22.76	22.33	21.89	21.46	-180
-170	30.11	29.68	29.25	28.82	28.39	27.96	27.53	27.10	26.67	26.23	25.80	-170
-160	34.39	33.97	33.54	33.11	32.69	32.26	31.83	31.40	30.97	30.54	30.11	-160
-150	38.65	38.22	37.80	37.37	36.95	36.52	36.10	35.67	35.25	34.82	34.39	-150
-140	42.87	42.45	42.03	41.61	41.19	40.76	40.34	39.92	39.49	39.07	38.65	-140
-130	47.07	46.66	46.24	45.82	45.40	44.98	44.56	44.14	43.72	43.29	42.87	-130
-120	51.25	50.84	50.42	50.00	49.58	49.17	48.75	48.33	47.91	47.49	47.07	-120
-110	55.41	54.99	54.58	54.16	53.75	53.33	52.92	52.50	52.09	51.67	51.25	-110
-100	59.54	59.13	58.72	58.30	57.89	57.48	57.06	56.65	56.24	55.82	55.41	-100
-90	63.66	63.25	62.84	62.43	62.01	61.60	61.19	60.78	60.37	59.96	59.54	-90
-80	67.76	67.35	66.94	66.53	66.12	65.71	65.30	64.89	64.48	64.07	63.66	-80
-70	71.84	71.43	71.02	70.61	70.21	69.80	69.39	68.98	68.57	68.17	67.76	-70
-60	75.90	75.50	75.09	74.68	74.28	73.87	73.47	73.06	72.65	72.24	71.84	-60
-50	79.95	79.55	79.14	78.74	78.33	77.93	77.52	77.12	76.71	76.31	75.90	-50
-40	83.99	83.58	83.18	82.78	82.38	81.97	81.57	81.16	80.76	80.36	79.95	-40
-30	88.01	87.61	87.21	86.80	86.40	86.00	85.60	85.20	84.79	84.39	83.99	-30
-20	92.02	91.62	91.22	90.82	90.42	90.02	89.61	89.21	88.81	88.41	88.01	-20
-10	96.02	95.62	95.22	94.82	94.42	94.02	93.62	93.22	92.82	92.42	92.02	-10
0	100.00	99.60	99.20	98.81	98.41	98.01	97.61	97.21	96.81	96.41	96.02	0
0	100.00	100.40	100.80	101.19	101.59	101.99	102.39	102.78	103.18	103.58	103.97	0
10	103.97	104.37	104.77	105.16	105.56	105.95	106.35	106.75	107.14	107.54	107.93	10
20	107.93	108.33	108.72	109.12	109.52	109.91	110.30	110.70	111.09	111.49	111.88	20
30	111.88	112.28	112.67	113.07	113.46	113.85	114.25	114.64	115.03	115.43	115.82	30
40	115.82	116.21	116.61	117.00	117.39	117.79	118.18	118.57	118.96	119.35	119.75	40
50	119.75	120.14	120.53	120.92	121.31	121.71	122.10	122.49	122.88	123.27	123.66	50
60	123.66	124.05	124.44	124.83	125.22	125.61	126.00	126.39	126.78	127.17	127.56	60
70	127.56	127.95	128.34	128.73	129.12	129.51	129.90	130.29	130.68	131.07	131.45	70
80	131.45	131.84	132.23	132.62	133.01	133.39	133.78	134.17	134.56	134.95	135.33	80
90	135.33	135.72	136.11	136.49	136.88	137.27	137.65	138.04	138.43	138.81	139.20	90
100	139.20	139.59	139.97	140.36	140.74	141.13	141.51	141.90	142.29	142.67	143.06	100
110	143.06	143.44	143.83	144.21	144.59	144.98	145.36	145.75	146.13	146.52	146.90	110
120	146.90	147.28	147.67	148.05	148.43	148.82	149.20	149.58	149.97	150.35	150.73	120
130	150.73	151.11	151.50	151.88	152.26	152.64	153.02	153.41	153.79	154.17	154.55	130
140	154.55	154.93	155.31	155.70	156.08	156.46	156.84	157.22	157.60	157.98	158.36	140
150	158.36	158.74	159.12	159.50	159.88	160.26	160.64	161.02	161.40	161.78	162.16	150
160	162.16	162.54	162.91	163.29	163.67	164.05	164.43	164.81	165.19	165.56	165.94	160
170	165.94	166.32	166.70	167.07	167.45	167.83	168.21	168.58	168.96	169.34	169.71	170
180	169.71	170.09	170.47	170.84	171.22	171.60	171.97	172.35	172.73	173.10	173.48	180
190	173.48	173.85	174.23	174.60	174.98	175.35	175.73	176.10	176.48	176.85	177.23	190
200	177.23	177.60	177.97	178.35	178.72	179.10	179.47	179.84	180.22	180.59	180.96	200
210	180.96	181.34	181.71	182.08	182.46	182.83	183.20	183.57	183.95	184.32	184.69	210
220	184.69	185.06	185.43	185.81	186.18	186.55	186.92	187.29	187.66	188.03	188.41	220
230	188.41	188.78	189.15	189.52	189.89	190.26	190.63	191.00	191.37	191.74	192.11	230
240	192.11	192.48	192.85	193.22	193.59	193.96	194.32	194.69	195.06	195.43	195.80	240
250	195.80	196.17	196.54	196.90	197.27	197.64	198.01	198.38	198.74	199.11	199.48	250
260	199.48	199.85	200.21	200.58	200.95	201.31	201.68	202.05	202.41	202.78	203.15	260
270	203.15	203.51	203.88	204.24	204.61	204.98	205.34	205.71	206.07	206.44	206.80	270
280	206.80	207.17	207.53	207.90	208.26	208.63	208.99	209.35	209.72	210.08	210.45	280
290	210.45	210.81	211.17	211.54	211.90	212.26	212.63	212.99	213.35	213.72	214.08	290
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Pt°C

TABLE 31 100 Ω *Platinum RTD* — *0.00392 coefficient*
temperature in °C

Resistance in Ohms

°C	0	1	2	3	4	5	6	7	8	9	10	°C
300	214.08	214.44	214.80	215.17	215.53	215.89	216.25	216.61	216.98	217.34	217.70	300
310	217.70	218.06	218.42	218.78	219.14	219.51	219.87	220.23	220.59	220.95	221.31	310
320	221.31	221.67	222.03	222.39	222.75	223.11	223.47	223.83	224.19	224.55	224.91	320
330	224.91	225.26	225.62	225.98	226.34	226.70	227.06	227.42	227.78	228.13	228.49	330
340	228.49	228.85	229.21	229.56	229.92	230.28	230.64	230.99	231.35	231.71	232.07	340
350	232.07	232.42	232.78	233.13	233.49	233.85	234.20	234.56	234.92	235.27	235.63	350
360	235.63	235.98	236.34	236.69	237.05	237.40	237.76	238.11	238.47	238.82	239.18	360
370	239.18	239.53	239.89	240.24	240.59	240.95	241.30	241.66	242.01	242.36	242.72	370
380	242.72	243.07	243.42	243.78	244.13	244.48	244.83	245.19	245.54	245.89	246.24	380
390	246.24	246.59	246.95	247.30	247.65	248.00	248.35	248.70	249.06	249.41	249.76	390
400	249.76	250.11	250.46	250.81	251.16	251.51	251.86	252.21	252.56	252.91	253.26	400
410	253.26	253.61	253.96	254.31	254.66	255.01	255.36	255.71	256.06	256.40	256.75	410
420	256.75	257.10	257.45	257.80	258.15	258.49	258.84	259.19	259.54	259.89	260.23	420
430	260.23	260.58	260.93	261.27	261.62	261.97	262.31	262.66	263.01	263.35	263.70	430
440	263.70	264.05	264.39	264.74	265.08	265.43	265.78	266.12	266.47	266.81	267.16	440
450	267.16	267.50	267.85	268.19	268.54	268.88	269.23	269.57	269.91	270.26	270.60	450
460	270.60	270.95	271.29	271.63	271.98	272.32	272.66	273.01	273.35	273.69	274.03	460
470	274.03	274.38	274.72	275.06	275.40	275.75	276.09	276.43	276.77	277.11	277.46	470
480	277.46	277.80	278.14	278.48	278.82	279.16	279.50	279.84	280.18	280.52	280.87	480
490	280.87	281.21	281.55	281.89	282.23	282.57	282.91	283.24	283.58	283.92	284.26	490
500	284.26	284.60	284.94	285.28	285.62	285.96	286.30	286.63	286.97	287.31	287.65	500
510	287.65	287.99	288.32	288.66	289.00	289.34	289.67	290.01	290.35	290.69	291.02	510
520	291.02	291.36	291.70	292.03	292.37	292.71	293.04	293.38	293.71	294.05	294.39	520
530	294.39	294.72	295.06	295.39	295.73	296.06	296.40	296.73	297.07	297.40	297.74	530
540	297.74	298.07	298.41	298.74	299.07	299.41	299.74	300.07	300.41	300.74	301.08	540
550	301.08	301.41	301.74	302.07	302.41	302.74	303.07	303.41	303.74	304.07	304.40	550
560	304.40	304.73	305.07	305.40	305.73	306.06	306.39	306.72	307.06	307.39	307.72	560
570	307.72	308.05	308.38	308.71	309.04	309.37	309.70	310.03	310.36	310.69	311.02	570
580	311.02	311.35	311.68	312.01	312.34	312.67	313.00	313.33	313.66	313.99	314.31	580
590	314.31	314.64	314.97	315.30	315.63	315.96	316.28	316.61	316.94	317.27	317.59	590
600	317.59	317.92	318.25	318.58	318.90	319.23	319.56	319.88	320.21	320.54	320.86	600
610	320.86	321.19	321.52	321.84	322.17	322.49	322.82	323.14	323.47	323.79	324.12	610
620	324.12	324.44	324.77	325.09	325.42	325.74	326.07	326.39	326.72	327.04	327.36	620
630	327.36	327.69	328.01	328.34	328.66	328.98	329.31	329.63	329.95	330.28	330.60	630
640	330.60	330.92	331.24	331.57	331.89	332.21	332.53	332.85	333.18	333.50	333.82	640
650	333.82	334.14	334.46	334.78	335.11	335.43	335.75	336.07	336.39	336.71	337.03	650
660	337.03											660

°C 0 1 2 3 4 5 6 7 8 9 10 °C

APPENDIX B

ZIGBEE SPECIFICATION

1. XBee & XBee-PRO OEM RF Modules

XBee and XBee-PRO Modules were engineered to meet ZigBee/IEEE 802.15.4 standards and address the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of critical data between devices.

The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other.

1.1. Features Overview

High Performance at a Low Cost

XBee

- Indoor/Urban: **up to 100'** (30 m)
- Outdoor line-of-sight: **up to 300'** (100 m)
- Transmit Power: 1 mW (0 dBm)
- Receiver Sensitivity: -92 dBm

XBee-PRO

- Indoor/Urban: **up to 300'** (100 m)
- Outdoor line-of-sight: **up to 4000'** (300 m)
- Transmit Power: 100 mW (20 dBm) EIRP
- Receiver Sensitivity: -100 dBm

RF Data Rate: 250,000 bps

Advanced Networking & Security

Retries and Acknowledgements

DSSS (Direct Sequence Spread Spectrum) for reliable long range delivery

16 direct sequence channels, each with over 65,000 unique network addresses available

128-bit Encryption (coming soon)

Self-routing/Self-healing mesh networking (coming soon)

Low Power

XBee

- TX Current: 45 mA (@3.3 V)
- RX Current: 50 mA (@3.3 V)
- Power-down Current: < 10 µA

XBee-PRO

- TX Current: 270 mA (@3.3 V)
- RX Current: 55 mA (@3.3 V)
- Power-down Current: < 10 µA

Easy-to-Use

XBee & XBee-PRO Modules are interchangeable & pin-for-pin compatible

Small Form Factor

No configuration necessary for out-of-box RF communications

Free Testing and Configuration Software included (X-CTU Software)

Software-selectable interface data rates

Free & Unlimited Technical Support

1.1.1. Worldwide Acceptance

FCC Approval Pending (USA) Refer to Appendix A [p22] for FCC Requirements. Devices that contain XBee Modules inherit MaxStream's FCC Certification

ISM (Industrial, Scientific & Medical) 2.4 GHz frequency band

Manufactured under ISO 9001:2000 registered standards

XBee & XBee-PRO OEM RF Modules are optimized for use in **US, Canada, Australia, Israel** and **Europe** (contact MaxStream for complete list of approvals).

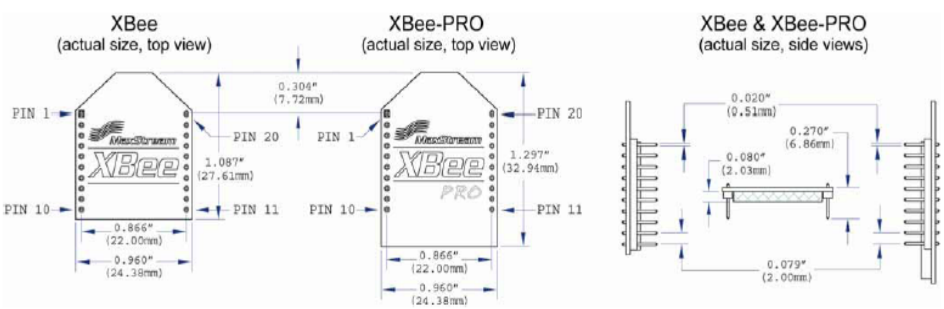
1.2. Specifications

Table 1-01. Specifications of the XBee and XBee-PRO OEM RF Modules

Specification	XBee	XBee-PRO
Performance		
Indoor/Urban Range	up to 100 ft. (30 m)	up to 300 ft. (100 m)
Outdoor RF line-of-sight Range	up to 300 ft. (100 m)	up to 4000 ft. (1200 m)
Transmit Power Output	1 mW (0 dBm)	60 mW (18 dBm), 100 mW EIRP
RF Data Rate	250,000 bps	250,000 bps
Receiver Sensitivity	-92 dBm (1% PER)	-100 dBm (1% PER)
Power Requirements		
Supply Voltage	2.8 – 3.4 V	2.8 – 3.4 V
Transmit Current (typical)	45 mA (@ 3.3 V)	270 mA (@ 3.3 V)
Receive Current (typical)	50 mA (@ 3.3 V)	55 mA (@ 3.3 V)
Power-down Current	< 10 µA	< 10 µA
General		
Operating Frequency	ISM 2.4 GHz	ISM 2.4 GHz
Dimensions	0.960" x 1.087" (2.438cm x 2.761cm)	0.960" x 1.297" (2.438cm x 3.294cm)
Operating Temperature	-40 to 85° C (industrial)	-40 to 85° C (industrial)
Antenna Options	U.FL Connector, Chip Antenna or Wire Antenna	U.FL Connector, Chip Antenna or Wire Antenna
Networking & Security		
Supported Network Topologies	Point-to-Point, Point-to-Multipoint, Peer-to-Peer and Mesh	Point-to-Point, Point-to-Multipoint, Peer-to-Peer and Mesh
Number of Channels	16 Direct Sequence Channels (software selectable)	16 Direct Sequence Channels (software selectable)
Network Layers	PAN ID and Source/Destination Addressing	PAN ID and Source/Destination Addressing
Agency Approvals		
FCC Part 15.247	pending	pending
Industry Canada (IC)	pending	pending
Europe	pending	pending

1.3. Mechanical Drawings

Figure 1-01. Mechanical drawings of the XBee and XBee-PRO Modules (antenna options not shown)
XBee and XBee-PRO Modules are pin-for-pin compatible



distributed by: gridconnect

1.4. Pin Signals

Figure 1-02. XBee & XBee-PRO Module Pin Numbers
(top sides shown - shield on bottom)

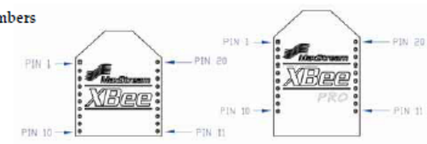


Table 1-01. Pin Assignments for the XBee and XBee-PRO Modules
Low-asserted signals are distinguished with a horizontal line above signal name.

Pin #	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART Data Out
3	DIN / $\overline{\text{CONFIG}}$	Input	UART Data In
4	CD / DOUT_EN / DO8	Output	Carrier Detect, TX_enable or Digital Output 8
5	$\overline{\text{RESET}}$	Input	Module Reset
6	PWM0 / RSSI	Output	PWM Output 0 or RX Signal Strength Indicator
7	[reserved]	-	Do not connect
8	[reserved]	-	Do not connect
9	DTR / SLEEP_RQ / DI8	Input	Pin Sleep Control Line or Digital Input 8
10	GND	-	Ground
11	AD4 / DIO4 / RF_TX	Either	Analog Input 4, Digital I/O 4 or Transmission Indicator
12	DIO7 / $\overline{\text{CTS}}$	Either	Digital I/O 7 or Clear-to-Send Flow Control
13	ON / $\overline{\text{SLEEP}}$	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	AD5 / DIO5 / Associate	Either	Analog Input 5, Digital I/O 5 or Associated Indicator
16	AD6 / DIO6 / $\overline{\text{RTS}}$	Either	Analog Input 6, Digital I/O 6 or Request-to-Send Flow Control
17	AD3 / DIO3 / COORD_SEL	Either	Analog Input 3, Digital I/O 3 or Coordinator Select
18	AD2 / DIO2	Either	Analog Input 2 or Digital I/O 2
19	AD1 / DIO1	Either	Analog Input 1 or Digital I/O 1
20	AD0 / DIO0	Either	Analog Input 0 or Digital I/O 0

- Minimum connections are: VCC, GND, DOUT and DIN.
- Signal Direction is specified with respect to the module
- Functions listed in descriptions are software selectable and may not all be available at time of release.
- Module includes a 50k pull-up resistor attached to $\overline{\text{RESET}}$.
- Unused inputs should be tied to GND / Unused outputs should be left disconnected.

1.5. Electrical Characteristics

Table 1-02. DC Characteristics of the XBee & XBee-PRO (V_{CC} = 2.8 – 3.4 VDC)

Symbol	Parameter	Condition	Min	Typical		Max	Units
V_{IL}	Input Low Voltage	All Digital Inputs	-	-		0.35 * V_{CC}	V
V_{IH}	Input High Voltage	All Digital Inputs	0.7 * V_{CC}	-		-	V
V_{OL}	Output Low Voltage	I_{OL} = 2 mA, V_{CC} >= 2.7 V	-	-		0.5	V
V_{OH}	Output High Voltage	I_{OH} = -2 mA, V_{CC} >= 2.7 V	V_{CC} - 0.5	-		-	V
II_{IN}	Input Leakage Current	V_{IN} = V_{CC} or GND, all inputs, per pin	-	0.025		1	uA
II_{OZ}	High Impedance Leakage Current	V_{IN} = V_{CC} or GND, all I/O High-Z, per pin	-	0.025		1	uA
TX	Transmit Current	V_{CC} = 3.3 V	-	45 (XBee)	270 (PRO)	-	mA
RX	Receive Current	V_{CC} = 3.3 V	-	50 (XBee)	55 (PRO)	-	mA
PWR-DWN	Power-down Current	SM parameter = 1	-	< 10		-	uA

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Electronics)"

Signature : ____

Name : NAJIDAH HAMBALI

Date : 29 NOVEMBER 2010

"All the trademark and copyrights use herein are property of their respective owner. References of information from other sources are quoted accordingly; otherwise the information presented in this report is solely work of the author."

Signature : ______________________________

Author : OLIVEA KAREN AK BUHAN

Date : 29 NOVEMBER 2010

To my beloved mother and father

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Miss Najidah Hambali, for her germinal ideas, invaluable guidance, continuous encouragement, motivation, advice and constant support in making this research possible.

Besides, I also would like to express very special thanks to my co-supervisor Mr. Zamri, Mr.shahrizal and other lectures for their suggestions and co-operation throughout the project.

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Finally, I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream amd sacrifice throughtout my life. Thanks for their encouragement and support.

Thank You.

ABSTRACT

The project proposed is to develop GUI (Graphical User Interface) application using visual basic. Wireless system is interfacing between camputer-based and instrument for temperature measurement to measure temperature where the data from measurement process can be directly use for other purpose, such as calculation and data monitoring. This project will involve designing the GUI application to monitor temperature changes using visual basic 2008. Manual method in temperature measurement are measure and calculate the data manually. The system is developed to facilitate for taking the data directly from the computer. This project will use the wireless RTD system as a sensor to interface between computer and temperature instrument such as temperature transmitter. Wireless RTD system that will use is called Zig-bee technology. Zig-bee technology are self configuring short range network and low cost. Decade box will use as a testing and calibration to create a resistance or capacitance with a specific value by using a combination of the rotary decade switches. For this project, the expected outcome is GUI application will monitor temperature changes through Zigbee wireless system. This project will make the wireless process instrumentation and wireless terminal technology for instrumentation directly leads to efficient process and equipment validation in current technology.

ABSTRAK

Projek yang dicadangkan adalah untuk membangunkan GUI *(Graphical User Interface)* aplikasi yang menggunakan *Visual Basis*. Sistem komunikasi tanpa wayar antara komputer dan instrumen bagi pengukuran suhu untuk mengukur suhu di mana data dari proses pengukuran dapat terus digunakan untuk tujuan lain, seperti pengiraan dan data pemantauan. Projek ini akan melibatkan merancang aplikasi GUI untuk memantau perubahan suhu menggunakan *Visual Basic 2008*. Kaedah manual dalam pengukuran suhu mengukur dan menghitung data secara manual. Sistem ini dibangunkan untuk memudahkan untuk mengambil data secara terus dari komputer. Projek ini akan menggunakan sistem tanpa wayar RTD sebagai pengesan untuk perhubungan komunikasi antara komputer dan alat pemancar suhu seperti suhu. Sistem tanpa wayar RTD yang akan menggunakan teknologi yang dikenali sebagai Zigbee. Teknologi Zigbee ini adalah untuk menyediakan rangkaian jarak pendek dan kos yang rendah. *Decade Box* akan digunakan sebagai ujian dan kalibrasi untuk mencipta rintangan atau kapasitor dengan nilai tertentu dengan menggunakan kombinasi dari suis dekad pemutaran. Untuk projek ini, hasil yang dijangkakan adalah aplikasi GUI akan memantau perubahan suhu melalui sistem tanpa wayar Zigbee. Projek ini akan memastikan instrumentasi proses tanpa wayar, dan teknologi terminal tanpa wayar untuk instrumentasi secara langsung ke arah proses yang cekap dan validasi peralatan teknologi yang terkini.

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ADC	Analog- Digital Converter
DC	Direct Current
GUI	Graphical User Interface
GPIB	General-Purpose Interface Bus
IDE	Integarted Developement Environment
LCD	Liquid Crystal Display
LRV	Lower Range Value
PWM	Pulse Width Modulate
RTD	Resistance Temperature Detector
URV	Upper Range Value
VB	Visual Basic

LIST OF APPENDIXES