

Palestine Polytechnic University



College of Engineering & Technology
Electrical & Computer Engineering Department

Graduation Project Introduction

Environmental monitoring using wireless sensor network

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دائرة الهندسة الكهربائية و الحاسوب

اسم المشروع:

Environmental monitoring using wireless sensor network

أسماء الطلبة:

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بناء على نظام كلية الهندسة و التكنولوجيا و إشراف و متابعة المشرف المباشر على المشروع و موافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندسة الكهربائية و الحاسوب و ذلك للوفاء بمتطلبات درجة البكالوريوس في الهندسة تخصص هندسة أنظمة الحاسوب.

توقيع المشرف

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توقيع اللجنة الممتحنة

.....

.....

.....

توقيع رئيس الدائرة

.....

DEDICATION

To our families for their patience

To our brothers and sisters

To our teachers

ACKNOWLEDGMENT

Our appreciation to:

Palestine Polytechnic University

College of Engineering & Technology

Electrical & Computer Engineering Department

Our supervisor: Dr. Mohammed Al- Dasht for his great help and supports

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ABSTRACT

This project propose a system which consists of mobile circuits (remote station) that could be deployed in the area of interest to collect environmental data from surround. Also the system has a base station that is directly connected to a server. Base station is responsible for collecting data , transferring user commands to the remote stations, storing and visualizing data to the users using a web application. User can monitor and manage the remote stations through a suitable interface.

يهدف هذا المشروع الى بناء شبكة من المحطات اللاسلكية تقوم بقراءة المتغيرات البيئية مثل الحرارة والرطوبة وغيرها.

في هذا المشروع تم تصميم نظام يتكون من دائرة متنقلة يتم وضعها في المحيط المراد قياس العوامل البيئية المختلفة فيه . يحتوي النظام على محطة رئيسية تجمع القراءات المختلفة من المحطات المتنقلة و تقوم بنقلها الى السيرفر الرئيسي الذي يقوم بدوره بتخزين البيانات وترحيلها الى شبكة الانترنت، حيث يتيح للمستخدم استعراض هذه البيانات بعدة تمثيلات بيانية، كما يعطي النظام للمسؤول عن النظام امكانية التحكم في كل من المحطات المختلفة كل واحدة على حدة بناء على قيم الجهد في كل واحدة.

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CHAPTER ONE

1

Introduction

1.1 Overview

1.2 Project Objectives

1.3 Literature Review

1.4 Time Plan

1.5 Finance Study

1.6 Project Requirements

1.7 Risk Management

1.8 Report Contents

1.1 Overview:

“The emergence of a wireless sensor network (WSN) is essentially the latest trend of Moore’s law toward the minimization of ubiquity of computing devices” [1].

The convergence of the Internet, communications and information technologies, coupled with recent engineering advances, is paving the way for a new generation of inexpensive mobile devices, sensors and actuators. It is the distributed deployment of these network devices and sensors that bears promises for a significant impact, not only on science and engineering, but equally importantly on a broad range of applications relating to critical infrastructure protection and security, health care, the environment, energy, food safety, production processing, quality of life, and the economy [2].

The system proposed for this project is composed of a remote station (RS) and a base station (BS). Where the remote node is dynamic-powered and wakes up once to collect and transfer data. The Remote node consists of four functional sections: the sensors, the PIC18F4550 microcontroller, the RF circuit, and the power supply. The Base Station is also built around the PIC18F4550 microcontroller. For this application, we used the inner oscillator to generate a real time clock and configured the USART for asynchronous communication with the host PC, a series of operation could be done monitor and manage Rs using a web application.

This project combines many features that will be applied such as: reading from sensors; using microcontroller, wireless transmission of data, using radio frequency and implementing a data link protocol between Rs and Bs.

This chapter contains projects overview, objectives, literature review for related work, time plan, financial study, functional and non-functional system’s, user’s requirements, and expected risks management.

1.2 Project objectives:

The main goal of this project is to design a wireless sensor network of various mobile and multifunction sensor circuits (RS) that can be employed in hazard locations; using this network the user will be able to monitor various environmental parameters through RS and manage these stations according to the received information.

To achieve this goal many sub objectives are to be done:

- Setup a multiple sensor nodes (RS).
- Read sensor data by sensor node and transmit it using RF technology.
- Receive data and interrupt it by base station.
- Achieve communication between base station and server via serial port(RS232).
- Implement data link protocol to achieve communication through several nodes.
- Implement sever program for monitoring and visualize information to the clients through web application.

1.3 Literature Review

Recently, WSN has investigated widely by many researches, in [3], project team (A Saheen. and L. Herbawy.) present a system consists of multiple nodes connected to network, each node contains a processor, memory and I/O device. In the different kinds of sensors, the system should find the connected nodes, read its data and visualize it. Not like our project this system collects data through general purpose network controller (IP μ 8930 micro web server) from different nodes, each node contains one sensor and components are connected by weird connections using 10BaseT cable. The project handles environmental parameters and visualizes it. With the capabilities of the IP μ 8930 such as the supporting of TCP/IP –read and write it will

be easier to implement the networking process, but with a higher cost than using PIC. So we will avoid using it and take care of the protocol implementation.

In [4], the authors discuss many aspects that should be studied carefully such as communication networks, wireless sensor networks and smart sensors, physical transduction principles, commercially available wireless sensor systems, self-organization, signal processing and decision-making. We will discuss these aspects as follows:

One critical issue in designing the WSN is to choose the network topology. Many topologies are available mesh, bus, ring, Tree and fully connected, in our project it seems to be suitable the use of star topology (logically), physically it will be implied as bus topology; all nodes of the star topology are connected to a single hub node. The hub requires greater message handling, routing, and decision-making capabilities than the other nodes. If a communication link is cut, it only affects one node. However, if the hub is incapacitated the network goes down. In the rest of this section we will discuss three important terms:

Communication protocol: When multiple nodes desire to transmit, protocols are needed to avoid collisions and lost data. In Frequency Division Multiple Access (FDMA), different nodes have different carrier frequencies. Since frequency resources are divided, this decreases the bandwidth available for each node. FDMA also requires additional hardware at each node. In Code Division Multiple Access (CDMA), a unique code is used by each node to encode its messages. This increases the complexity of the transmitter and the receiver. In Time Division Multiple Access (TDMA), the RF link is divided on a time axis, with each node being given a predetermined time slot it to for communication. This decreases the sweep rate, but a major advantage is that TDMA can be implemented in software. All nodes require accurate, synchronized clocks for TDMA. TDMA is the multiplexing technique used in the proposed system.

Power management: software power management techniques can greatly decrease the power consumed by RF sensor nodes. TDMA is especially useful for power conservation, since a node can power down or 'sleep' between its assigned time slots, waking up in time to receive

and transmit messages. The required transmission power increases as the square of the distance between source and destination. Therefore, multiple short message transmission hops require less power than one long hop. In fact, if the distance between source and destination is R , the power required for single-hop transmission is proportional to R^2 . If nodes between source and destination used to transmit n short hops instead, the power required by each node is proportional to R^2/n . This is a strong argument in favor of distributed networks with multiple nodes, like nets of the mesh topology.

WSN standards: in 1993 the Institute of Electrical and Electronics Engineer (IEEE) and the National Institute of Standards and Technology (NIST) began work on a standard for Smart Sensor Networks. IEEE 1451, the Standard for Smart Sensor Networks was the result. The objective of this standard is to make it easier for different manufacturers to develop smart sensors and to interface those devices to networks.

1.4 Time Plan:

The following time plan shows the time scheduling in the first semester.

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Tasks																
Data and information gathering																
Requirement analysis and specifications																
Study of hardware and technology alternative's for system components																
Developing of general structure and block diagram of the system																
Documentation																

Figure (1-1) first semester time plans

The following time plan shows the time scheduling in the second semester.

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Tasks																
PIC testing																
RF circuit setup																
Implement wireless connection between PIC & Sensors circuits																
Data Link protocol setup																
Software programming																
System implementation																
Testing																
Documentation																

Figure (1-2) Second semester time plans

1.5 Finance study

The following table shows the HW parts needed for the project and their cost.

Component	Required Quantity	Prices in NIS
Microcontroller PIC 18F4550	2	288 NIS
RF module 's	2	100 NIS
Interfacing IC's packages (Decoders, Encoders and op_amps)	2	160 NIS
Temperature sensors	2	48 NIS
Oxygen sensors	2	10 NIS
Pressure sensor	2	10 NIS
Resistors and capacitors	20	100 NIS
Wires, buttons and other accessories	-	3 NIS
Total cost		719 NIS

Table (1-1) Estimated HW cost

1.6 Project requirements:

We have two types of requirements; which are

1.6.1 User requirements

There are two types of user's admin user and ordinary user.

- **Functional requirements :**

- Administrator should locate the remote stations in different locations.
- Administrator can setup more than one sensor at the same circuit.
- Administrator can turn on/off any node in the network.
- End user can log to the system using web application.
- End user can get information visualization in different formats.

- **Non-Functional Requirements:** contain the following:

- **Mobility:** The circuit should be mobile circuit with appropriate size and easy to locate.
- **Correctness:** The sensor nodes should transmit the appropriate data that represent the actual event that done.

1.6.2 System Requirements: contain the following:

- **Functional Requirements**

- System needs to address the different sensors in the same node.
- System needs to read data from sensors.
- System needs a wireless transmitter/receiver for data transfer.

- System needs protocol to achieve communication between several nodes
- System needs mechanism to interpret data and generate appropriate information.
- System needs a program at the server to read data from serial port and visualize and store it.

- **Non Functional Requirements**

-Reliability: The system should be reliable, meaning that it must send the correct code.

-Speed: The system must have acceptable response time to the parameters changes.

-Low Power Consumption: Since this system is portable it will operate using a battery, so in order to make system work for a reasonable time, it must consume low power.

1.7 Risk Management

Risk management will be discussed in three different aspects which are: risk classes , avoidance and management :

1.7.1 Risk Classifications

There are some possible risks that may occur in the project in both hardware and software. In this section we will briefly describe those risks and show their management.

1. **Technology Risks:** Such risks may occur because of the software or hardware used in the system such as incompatibility.
2. **Hardware Risks:** The risks that may occur are:
 - Device failure: the PIC may crash because of power supply problem or other problems.

- The device operates differently from what its expected such as sending incorrect signals.
- The receiver circuit may suffer from noise.
- The response time for the system is long which makes inefficient visualization.

3. **Software Risks:** we have to programs:

- Program of the PIC (PIC doesn't response to its functionalities correctly).
- The software on the server side (server program cant initiate serial connection).

The PIC software has two main tasks:

1. It listens to the data coming from the server through the serial port and adjusts it in an appropriate format.
2. It sends data coming from the remote station out to the server.

The server software has two main tasks:

1. It listens for incoming data on the serial port, analyses it, and determines the representations of the data.
2. Process and visualize the incoming information.

Any error in the above tasks means that the system will not operate correctly.

4. **Group Risks:** The risks that may occur are:

- Withdrawing or absence of one or more group members.
- Group meeting difficulties

5. **Tools Risks:** Loose of any support software or hardware used to develop the system, like microcontroller programming tools and case tools in software is considered as a risk.
6. **Requirements Risks:** Risks may occur if new changes are required in the system requirements that need major changes in the system design.
7. **Estimation Risks:** Risks may occur from the wrong estimation in the system design, implementation, resources and management.

There are risks such as: read data by PIC from receiver at an inappropriate time will be generate incorrect information.

1.7.2 Risk Avoidance

The following strategies will be taken to avoid risks mentioned above:

- Taking care when using hardware components and using them according to their specifications.
- The team members will work seriously and be dedicated for this work.
- Good estimation and usage of the projects budget and resources.
- Good estimation of system requirements.

1.7.3 Risk Management: Risk management will be as follows:

- Software development environment risks will be handled by the backup of software.
- Having a spare hardware component, so when any problem occurs we can find an alternative one.

- People risks are handled by good task distribution on the students especially when a member can't perform some of his tasks it will be easy to handle.

1.8 Report Contents

This documentation is categorized into chapters. Below it's a brief description about each one:

- **Chapter One: Introduction**

This chapter demonstrates a general idea about the project, its importance, literature review, time plan, finance study, system requirements and risk management.

- **Chapter Two: Theoretical Background**

This chapter provides a theoretical background about parts and technologies we used in the project.

- **Chapter Three: Project Conceptual Design**

This chapter describes the system in its abstract formula. It describes the project objectives, design options, general block diagram, system modeling and how the system works.

- **Chapter Four: Detailed Technical Project Design**

This chapter discusses a detailed description about project phases, subsystem design, overall system design and user system interface.

- **Chapter Five: Software System Design**

This chapter handles the software related to our system, depicts flow charts about system operation and illustrates different algorithms and techniques considered in writing the system software.

- **Chapter Six: System Implementation and Testing**

This chapter manifests the implementation procedures to be acted so as to integrate the project. Then, a sequence of procedural testing will be listed. The testing comprises both software and hardware testing.

- **Chapter Seven: Problems, Conclusions and Future work**

This chapter lists the problems faced us in accomplishing the system and how they were solved. Conclusions and future work are also proposed.

CHAPTER TWO

2

Theoretical Background

2.1 Overview

2.2 Project Components

2.3 Theoretical Background

2.4 Summary

2.1 Overview

The aim of this project is to design a mobile circuit that can collect environmental data using its sensor, and transmit these data to other circuit (base station) which will collect the data from remote stations and forward it to server that will apply visualization to the users. We will talk briefly about the project's components and provide theoretical background about technologies that used in our project design which involves:

1. Multiplexing:

There are two main categories of multiplexing that can be used in this project:

- Time Division Multiplexing.
- Frequency Division Multiplexing.

2. Wireless communication technology:

Consequently we will talk about the following three technologies:

- Infrared Technology.
- Bluetooth Technology.
- RF Technology.

Besides, the chapter provides theoretical background about microcontrollers, RF modules and sensors.

2.2 Project components

The hardware components used are:

Remote station: consists of Radio frequency modules: RR-433.9, RT4-433.9 microcontroller and the sensing devices.

Base station: contains microcontroller that accepts data through RF receiver which is connected to the digital inputs, microcontroller sends information to the server through serial port, and accepts commands from user then transmits it to the remote station via RF transmitter.

Sensing package: Temperature, humidity and voltage sensing.

The software components consist of two programs:

- A program on the Base station that receives data from sensors through the RF receiver (interrupts it and generates the appropriate packet).
- A program on the server side which receives packets from base station, performs visualization to the different users, also server packetize and transmits user commands to the RS.

More details about project components are introduced in chapter three.

2.3 Theoretical Background

In this section we will describe the main categories of multiplexing and the wireless communication technologies:

2.3.1 Multiplexing:

Many multiplexing techniques are available but the main techniques will be discussed

Time division Multiplexing (TDM)

It's a type of digital multiplexing in which two or more signals transfers as sub channels in one channel logically they appear in two different channels but physically they are in the same one, in this mechanism each bit stream will have its own time slot to be transferred in fixe length. One TDM frame consists of multiple time slot one for each user. [5] As shown in figure (2-1).

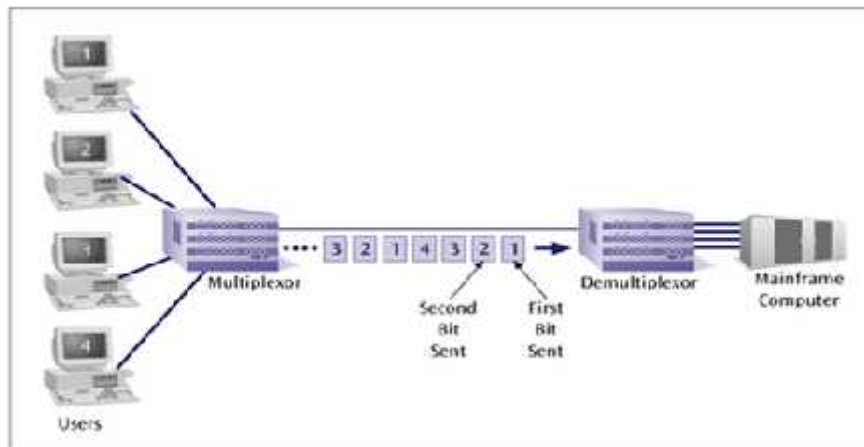


Figure (2-1) TDM Multiplexing

In the Frequency division multiplexing (FDM), the total bandwidth available to the system, divided into a series of non overlaying frequency sub-bands that are then assigned to each communicating source and user pair [6]. The following table compares TDM and FDM technologies:

FDM	TDM
Need External hard ware (band pass filters) which is complicate to construct and design.	Use relatively simple and less costly logic circuits.
The power amplifier in the transmitter has nonlinear characteristics which are more complex and it leads to out of band spectral components.	Linear amplifier characteristics.
Not sensitive to the propagation delay.	Sensitive to the delay on each time slot.
Not complex equalization techniques.	Channel equalization techniques is complex

Table (2-1) FDM Vs TDM

In general TDM technique has some of drawbacks as discussed before but it's still more efficient to use in our project since its simplicity relatively and doesn't need external hardware and can be implemented through programming so we will use it.

2.3.2 Wireless communications

Wireless is a term that refers to any type of electrical connection that is achieved without using hard wired connection. Wireless communication is the transfer of data or information between electrical or electronic components over a distance without using electrical wires. Distances can vary from very short distances (few meters like TV remote control) to very long

distances (thousands of kilometers for radio waves) [7]. Wireless communication is considered networks, satellite television, GPS units, wireless computer keyboard and mice, and many other applications. Wireless communication can take place via many technologies, such like Radio frequency, infrared, and Bluetooth. However, a brief description about Bluetooth and infrared technologies will be provided. Then detailed information about Radio frequency technology will be provided.

1. Infrared Technology

Visible light is energy at wavelengths between 380 and 780 nm. Ultraviolet (UV) has a wavelength shorter than visible light and Infrared (IR) wavelengths are longer than 780 nm Infrared technology introduced in many applications such like: target acquisition and tracking, remote control for radio and television, security systems, short range wireless communication, and many other applications.

2. Bluetooth technology

Bluetooth networking transmits data via low-power radio waves. It communicates on a frequency of 2.45 gigahertz (actually between 2.402 GHz and 2.480 GHz, to be exact). This frequency band has been set aside by international agreement for the use of industrial, scientific and medical devices (ISM).Bluetooth has high senses to the environmental changes, it suitable to us in the indoor applications [8].

3. Radio Frequency technology

Radio is the transmission of signals, by modulating electromagnetic waves with frequencies below those of visible light. Information is carried by modulating (changing) of some properties of waves (such as amplitude or frequency). When radio waves pass an electrical conductor, it produces a current which can be detected and can be transformed to other signals that carry information [9].

Each system contains a transmitter which consists of a source of electrical energy, producing alternating current of a desired frequency of oscillation. The transmitter contains a system some property of the energy produced to impress a signal on it. This modulation might be a simple as turning the energy on and off, or altering more subtle properties such as amplitude, frequency, phase, or combinations of these properties. The transmitter sends the modulated electrical energy to an antenna; this structure converts the rapidly-changing alternating current into an electromagnetic wave that can move through free space. Electromagnetic waves travel through space either directly, or have their path altered by reflection, refraction or diffraction. The intensity of the waves diminishes due to geometric dispersion some energy may also be absorbed by the intervening medium in some cases. Noise will generally alter the desired signal; this electromagnetic interference comes from natural sources, as well as from artificial sources such as other transmitters and accidental radiators. Noise is also produced at every step due to the inherent properties of the devices used. If the magnitude of the noise is large enough, the desired signal will no longer be discernable; this is the fundamental limit to the range of radio communications [10].

Frequencies specifications

Each frequency range has a band designator and each range of frequencies behaves differently and performs different functions. The frequency spectrum is shared by civil, government, and military users of all nations according to International Telecommunications Union (ITU) radio regulations. For communications purposes, the usable frequency spectrum

now extends from about 3Hz to about 300GHz. There are also some experiments at about 100THz where research on laser communications. The ranges from 3Hz to 300GHz have been split into regions, these regions become to be standards to describe in International Telecommunications Union radio regulations [11].

The following table (2-2) shows the frequency specification:

	Designation	Frequency	Wavelength
ELF	Extremely low frequency	3Hz-30HZ	100,000km-10,000km
SLF	Super low frequency	30HZ-300Hz	10,000km-1000km
ULF	Ultralow frequency	3000Hz-3000Hz	1000km-100km
VLF	Very low frequency	3kHz-30kHz	100km-10km
LF	Low frequency	30kHz-300kHz	10km-1km
MF	Medium frequency	300kHz-3000kHz	1km-100m
HF	High frequency	3MHz-30MHz	10m-10m
VHF	Very high frequency	30MHz-300MHz	10m-1m
UHF	Ultra high frequency	300MHz-3000MHz	1m-10cm
SHF	Super high frequency	3GHz-30GHz	10cm-1cm
EHF	Extremely high frequency	30GHz-300GHz	1cm-1mm

Table (2-2) Frequency specifications

AM Vs FM modulation:

Two types for frequency modulation can be used in this project and they will be discussed as follows:

Radio Frequency modules:

As implementation requirements for WSN system, the system should use wireless technique in order to transfer data from sensor node to the controlling unit in the system; this

project will use the RF technology to send and receive data [12]. The following figure(2-2) show general RF module Block diagram:

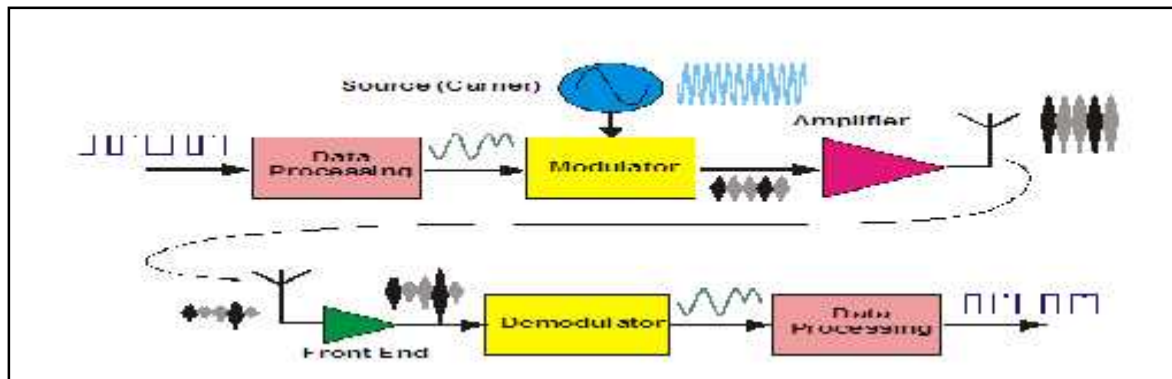


Figure (2-2) General RF module Block Diagram [13]

RF-transmitter: in order to make the signal pass through the air, it must be modulated on to a carrier signal which is sufficiently stable with temperature and other factors to allow detection by a tuned receiver in the presence of interference [14].

Modulation: the method of imposing the information signal onto the carrier signal is termed modulation which can be of different classifications; this project uses AM modulation of transferred signal. Amplitude Modulation (AM) is a method of impressing data onto an alternating current (AC) carrier wave-form. The highest frequency of modulating data is normally less than 10 percent of the carrier frequency. The AM must be accomplished cost effectively and accurately for maximum range and minimum interference.

RF-receiver: the antenna catches the transmitted signal and passes it to the receiver module, the main task of the receiver is to enhance weak wanted signal, often in the presences of strong unwanted signals which introduce minimal noise and distortion. In many cases, some selective faltering required to assist his task.

Demodulation: the process of removing the information signal from the carrier is termed demodulation, it should be done to have optimal signal in the presence of noise, interference in addition power efficient and cheap. **Data Processing:** Pre and post processing of the information

signal is often an afterthought for low power radio applications, usually implying some form of microprocessor or DSP engine with the presumed complexity, cost, power consumption and size penalties. The benefits of matched filtering, error detection and correction (coding), channel equalisation, etc, are however significant in terms of range, robust transmission, power conservation and data rate optimisation.

2.3.3 Microcontrollers

Microcontroller is a highly integrated single-chip microcomputer. Microcontrollers include a CPU to process information, program memory to store instructions, data memory to store information, system timing, and input/output sections to communicate with the outdoor world.

A microcontroller can do the work of many different types of logic circuits. Discrete logic circuits are permanently wired to perform the function they were designed to do. If the design requirements are changed slightly, an entire printed circuit board or many boards may have to be redesigned to accommodate the change. With a microcontroller performing the logic functions, most changes can be made simply by reprogramming the microcontroller. That is, the software (program) is changed rather than the hardware (logic circuits). This makes the microcontroller a very attractive building block in any digital system.

With a microcontroller-based design, the designer can simply add a feature set to the product with minimal software/hardware changes. Microcontrollers can also be used to replace analog circuitry. Special interface circuits can be used to enable a microcontroller to input and output analog signals.

Microcontroller architecture

Figure (2-3) shows the general block diagram of a microcontroller [15].

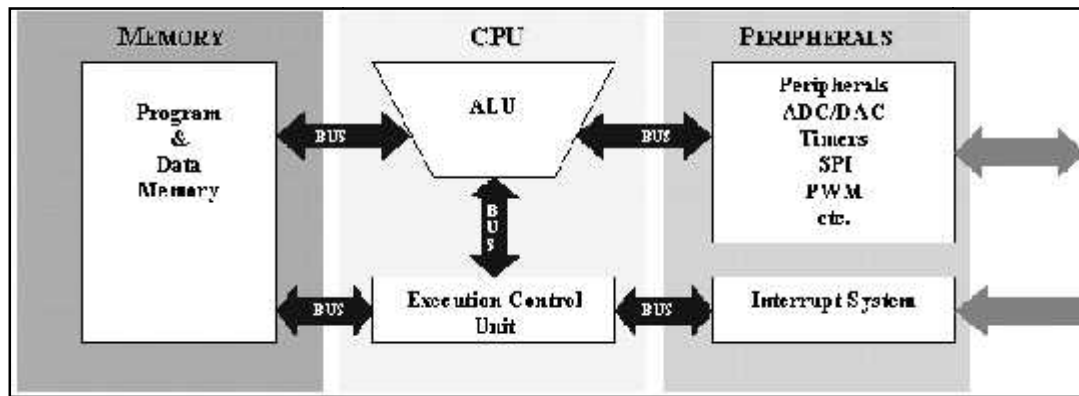


Figure (2-3): Microcontroller General Block Diagram

In general any microcontroller architecture contains the following main components:

Central Processing Unit CPU (CPU) is the heart of a microcontroller where all of the arithmetic and logical operations are performed. This is the calculator part of the microcontroller. The CPU gets program instructions from the program memory.

Program and Data Memory contains a set of CPU instructions organized into a particular sequence to do a particular task. Program Memory is referred to as Read Only Memory (ROM) or OTP/EPROM. OTP or “One-Time Programmable” can be programmed only once and the program is stored permanently, even when the microcontroller power is turned off. Program memory enables the microcontroller to immediately begin running its program as soon as it is turned on.

Inputs/Outputs and Peripherals Microcontrollers require interface sections to communicate with external circuitry. Input ports allow data and status conditions to be read into the microcontroller while the output ports allow the microcontroller to affect external logic systems.

Analog to Digital and Digital to Analog Converters An analog-to-digital converter (abbreviated ADC, A/D or A to D) is an electronic circuit that converts continuous signals to discrete digital numbers. The reverse operation is performed by a digital to analog converter (DAC).

Universal Asynchronous Receiver/Transmitter (UART) A universal asynchronous receiver/transmitter is a type of "asynchronous receiver/transmitter", a computer hardware that translates data between parallel and serial forms. UARTs are commonly used in conjunction with other communication standards such as EIA RS-232.

Microcontroller Applications

Microcontroller's applications are more or less limited only by the user imagination. Microcontrollers now reside in our televisions, keyboards, modems, printers, telephones, cars, household appliances, and every other part of home and work life. The market for microcontrollers continues to expand rapidly, encompassing a wide range of consumer, industrial, automotive, and telecommunication applications. The emergence of new low cost microcontrollers offers a wealth of benefits for today's consumer applications and represents an entirely new profit source for manufacturers. In the past, the high cost of electronics limited the use of microcontrollers to "high tech" applications such as video recorders, stereo systems, and high-end durable goods such as washing machines. Today, the application base has broadened to include systems such as coffee machines, irons, shavers, and cleaners, where the introduction of electronics helps to provide product differentiation and allows the inclusion safety features.

PIC Microcontroller

PIC is a family of RISC microcontrollers made by Microchip Technology , regarded that PIC stands for Peripheral Interface Controller, the 8-bit PIC was developed in 1975 to improve performance of the overall system by offloading I/O tasks from the CPU. The PIC used simple

microcode stored in ROM to perform its tasks. PICs use a RISC instruction set, which varies in length from about 35 instructions for the low-end PICs to about 70 instructions for the high-end PIC [16].

2.3.4 Sensors:

Sensors are hardware devices that produce measurable response to a change in a physical condition like temperature and pressure, Sensors sense or measure physical data of the area to be monitored. The continual analog signal sensed by the sensors is digitized by an Analog-to-digital converter and sent to controllers for further processing. Characteristics and requirements of Sensor node should be small size, consume extremely low energy, operate in high volumetric densities, are autonomous and operate unattended, and be adaptive to the environment As wireless sensor nodes are microelectronic sensor device, can only be equipped with a limited power source of less than 0.5 Ah and 1.2 V [17]. Sensors are classified into three categories:

Passive, Omni Directional Sensors: Passive sensors sense the data without actually manipulating the environment by active probing. They are self powered i.e. energy is needed only to amplify their analog signal. There is no notion of “direction” involved in these measurements.

Passive, narrow-beam sensors: These sensors are passive but they have well-defined notion of direction of measurement. Typical example is ‘camera’.

Active Sensors: These groups of sensors actively probe the environment, for example, a sonar or radar sensor or some type of seismic sensor, which generate shock waves by small explosions. The overall theoretical work on WSN’s considers Passive, Omni directional sensors. Each sensor node has a certain area of coverage for which it can reliably and accurately report the particular quantity that it is observing. Several sources of power consumption in sensors are

a) Signal sampling and conversion of physical signals to electrical ones, b) signal conditioning, and c) analog-to-digital conversion.

We will talk about 3 types of sensors, which will be used in our projects as follows:

1. Temperature Sensors

A thermocouple is a junction formed from two dissimilar metals. Actually, it is a pair of junctions. One at a reference temperature (like 0 °C). and the other junction at the temperature to be measured. A temperature difference will cause a voltage to be developed that is temperature dependent. (That voltage is caused by something called the Seebeck effect.) Thermocouples are widely used for temperature measurement because they are inexpensive, rugged and reliable, and they can be used over a wide temperature range. In particular, other temperature sensors (like thermostats and LM35 sensors) are useful around room temperature [18].

2. Humidity sensor

Capacitive Relative Humidity sensors have proven themselves to be a practical sensor technology in a wide variety of industrial applications. In its simplest form, a capacitor is formed when two conductive plates are separated by an insulator (dielectric). The electrical capacitance is defined by the area of the plates, the distance between them and the dielectric coefficient of the medium separating the plates. In a Capacitive RH Sensor, the dielectric material is allowed to diffuse and absorb water vapor so that it equilibrates with the external environment. The 'dry' dielectric coefficient is significantly lower than that of water, and thus the electrical capacitance increases as the dielectric absorbs water reflecting the Relative Humidity of the surroundings. From an electrical standpoint, however, these Sensors exhibit a relatively small change in

capacitance over their measurement range. A capacitance change of 40 to 50pF over 0 to 100% RH with a 0% RH capacitance (C_{0RH}) of 100 to 200pF is not uncommon [19].

3. Voltage sensing

The system contains mobile circuit that dynamically powered, so its need to monitor the battery value, many technology's were developed for this purpose but this project will use simple design to monitor the RS voltage , this circuit will be discussed more clearly in chapter four .

2.4 Summary

In this chapter we have talked about theoretical information about technologies and components related to our project. We talked about wireless communication technologies such as: Radio frequency, Infra red, and Bluetooth. Also we have talked about microcontrollers' architecture. Finally we have talked about sensors.

Project Conceptual Design

3.1 Overview

3.2 Detailed Project Objectives

3.3 Design Options

3.4 Detailed Project Components

3.5 Project Design Block Diagram

3.6 System Modeling

3.7 How Does the System Work?

3.8 Summary

3.1 Overview

In this chapter we provide a detailed description for system objectives, system components, list of design options along with their strengths and weaknesses, graphical explanations such like: general block diagrams and system modeling diagrams, and finally a description of how the system works.

3.2 Detailed Project Objectives

The main objective of this project is to design a wireless network of sensors (RSs) that can be located at the hazard locations, monitored and managed through web application from safe place. Each Station in the network should be multi functional, which means that multiple sensors from the same package can locate in the same station.

The following objectives are also to be achieved:

- Read sensors' data in the remote station and transmits it to the base station.
- Apply RF technology to transfer data from RS to the server side.
- Accept data and interrupt it by the base station, generate and write the packets to the database on the server side.
- Build software (web service) at the server which accepts data from serial port and perform required visualization (Temperature degree, humidity percent and voltage value).

3.3 Design Options

In this system there are many design options, below are these options:

1. Processor Options

Option 1: Using a microprocessor such 8085, 8086, etc, with needed components such memory, A/D converters, etc...This option have the advantage of using only what is required of components but increase the complexity of connecting components and cause a larger size circuit at the base station side.

Option 2: Using a microcontroller that contain all needed components; memory, A/D converters, etc.

This option seems more appropriate, because:

- Using CMOS (Complementary Metal Oxide Semiconductor) fabrication technique which requires much less power than older fabrication techniques, which permits battery operation.
- Using advanced memory options such as EEPROM (Electrically Erasable Programmable ROM) which is economic option in case of holding small amount of parameters that need to be changed over time , Flash when a requirement for large amounts of non-volatile program memory (faster than EEPROM), and Battery backed-up static RAM which is useful when a large non-volatile program and DATA space is required and it is much faster than other types of non-volatile memory so it is well suited for high performance application.

- Power management and low voltage: microcontroller contains low voltage parts that require at most 5V to operate and that microcontroller's clock can be slowed up or even stopped putting the microcontroller in sleep mode which mean low power consumption.
- Having many components in a single chip (computer on a single chip) reduce the need for external components which mean lower cost components and less size. components such as CPU core, memory, I/O, UART, USART, ADC, Watchdog Timer.

2. Wireless technology options

There are many options of wireless technologies that we can use such:

Option 1: Infrared technology

Infrared technology has many advantages that make it suitable in many applications since it need low power requirements, simple circuitry which enables it to be incorporated into integrated circuit of a product, improve security because directionality of the beam helps ensure that data isn't leaked or spilled to nearby devices, noise immunity not to have interference from signals of other devices, portable and low cost.

Infrared is not suitable for our project since it considered to be line of sight which mean that it will decrease the flexibility of the system and can be blocked by common materials which make it less reliable.

Option 2: Bluetooth technology:

Bluetooth is a wireless LAN technology designed to connect devices of different functions such as telephones, notebooks, computers...and so on. A Bluetooth technology suitable for many inner applications such as companies, offices and home systems [20]. Bluetooth module has higher cost than IR and RF modules, more sensitive to the environmental changes and has some limitations in our country so it will be difficult to get so it seems inappropriate to our project.

Option 3: RF technology (it used in this project)

RF technology is useful for many reasons such as communication between two parties, it does not require a line of sight, not blocked by common materials; it can penetrate most solids and pass through walls, cover larger range than Bluetooth and IR, and not sensitive to weather/environmental conditions. On the other hand it has some drawbacks where it has higher cost than infrared, operates at lower speed since its data rate transmission is lower than wired and infrared transmission, and required Federal Communications Commission (FCC) license for some products. But it still the most suitable choice for our project.

3. RF Transmitter options

Option 1: using RTQ4-xxx Transmitter, It's a radio transmitter with crystal oscillator and external antenna that allows realizing a complete radio transmitter adding a coding circuit and shows stable electric characteristics. It has many features such as: high output power, Range 100+ meters, working frequency (433.92, 868.35, 9115 MHz) [21]. It seems an excellent choice for this project, but it's not available in Palestine and, so we were to look for alternative and suitable Transmitter.

Option 2: using RT4-xxx Transmitter, Fortunately RTQ4-xxx is a pin out compatible with RT4 Transmitter that is available with suitable price [22].

This transmitter has the following key features:

- Available as 315, 418, 433 MHz frequency.
- Range up to 70 meters.
- Available in DLL (Dual in line) package shape or SIL (serial in line) package shape.
- Wide operating voltage (5-12 volts).

It seems that the range is less than RTQ4 transmitter. But indeed, 70m is enough for this project, it will be better if it was RTQ4- but we have to deal what is available and we will try to expand the range by using the different features of networks topologies.

3.4 Detailed Project Components

1. PIC 18F4550

Microcontroller is needed in order to receive signals from RF receiver, process it and transmit it via USART (which is connected to the serial port) to the server to be stored and visualized. The microcontroller we used is PIC 18F4550, below we discuss some expect features that we will use in this project: (for more information about PIC18F4550 refer to the data sheet, Appendix A).

- **High-Performance RISC CPU.**
 - Only 75 single word instructions to learn.
 - All instructions are single cycle (1 μ s) except for program branches.
 - Operating speed: DC - 20MHz clock input.
 - 8 k Bytes Flash Program Memory.

- 368 Byte RAM Data Memory and 256 Byte EEPROM Data Memory.
- In-circuit serial programming.

- **Special Microcontroller Features.**

- C compiler optimized architecture with optional extended instruction set
- Self-programmable under software control
- Extended Watchdog Timer (WDT).
- Wide operating voltage range (2.0V to 5.5V).
- 34 I/O pins with individual direction control.
- 40-pin DIP.



Figure (3-1): PIC18F4550

2. RF Module specifications and interfacing:

RT4 and RR3 is AM transmitter/receiver module for wireless communication, it used in various applications security, automated home systems, sensor reporting.....etc.

AM-RT4 AM hybrid transmitter module provide complete RF transmitters which can be used to transmit data at up to 4 kHz from any standard CMOS/TTL source. The module is very simple to integrate into a design and offer low current consumption (typ. 4 mA). Data can be supplied directly to the data input of the module from a microprocessor or a data encoding device such as HT12E (Holtek).

RR3-XXX is a super regenerative data receiver Sensitivity typically exceeds -100dBm (2.2uVrms) when matched to 50 ohm. It shows high frequency stability also in presence of mechanical vibrations, manual handling and in a wide range of temperature[23].



Figure (3-2) RR3-433.9



Figure (3-3) AM-RT4

RR3-xxx characteristics	AM-RT4 characteristics
<ul style="list-style-type: none"> - RF supply voltage 4.5 up to 5.5 VDC - Supply current 2.5 typical, 5.5 Max mA - Working frequency 200 up to 450 MHz - Tuning Tolerance ± 0.2 typical , ± 0.5 Max MHz - 3dB Bandwidth ± 2 typical , ± 3 Max MHz - Max data rate 2 KHz - Operating Temperature min -25up +80 	<ul style="list-style-type: none"> - Supply Voltage 2 up to 14 Vdc - Supply Current ($V_{cc}=5V$ Data=1KHz) 4 mA, - Working Frequency 303.8, 433.92 MHz - RF Output Power into 50W ($V_{cc}=5V$) 0 dBm - Harmonic Spurious Emissions -30 dBc - Input Voltage High 2 Vcc V - Max Data Rate 4 KHz - Operating Temperature -25 +80 °C

Table (3-1) RF Module Characteristics

Module Interfaces Devices:

There were many options for these devices which have great functional properties such as the CTA88 encoder/decoder chip which have 8 bit data lines in the same package and one line to select decoding or encoding operation but unfortunately it has very critical limitations from the company that produce it (unavailable) from security and economical point of view.

So we choose the following available module to achieve communication between module parts R/T and other devices we use The 2^{12} decoders/encoders. They are a series

of CMOS LSIs for remote control system applications, paired with Holteks 2^{12} series of encoders (refer to the encoder/decoder cross reference table). For proper operation, a pair of encoder/decoder with the same number of addresses and data format should be chosen. The decoders receive serial addresses and data from a programmed 2^{12} series of encoders that are transmitted by a carrier using an RF or an IR transmission medium. They compare the serial input data three times continuously with their local addresses. If no error or unmatched codes are found, the input data codes are decoded and then transferred to the output pins. The VT pin also goes high to indicate a valid transmission [24]. The 2^{12} series of decoders are capable of decoding information's that consist of N bits of address and $12-N$ bits of data. Of this series, the HT12D is arranged to provide 8 address bits and 4 data bits.

3.5 Project Design Diagram

In this section we described the project components as follows:

1. Block Diagram

The following figure (Figure 3-4) shows the general block diagram of the system in which we can see that sensors readings are transmitted by a RF transmitter to a receiver that sends these readings to server through a PIC to be visualized for the clients.

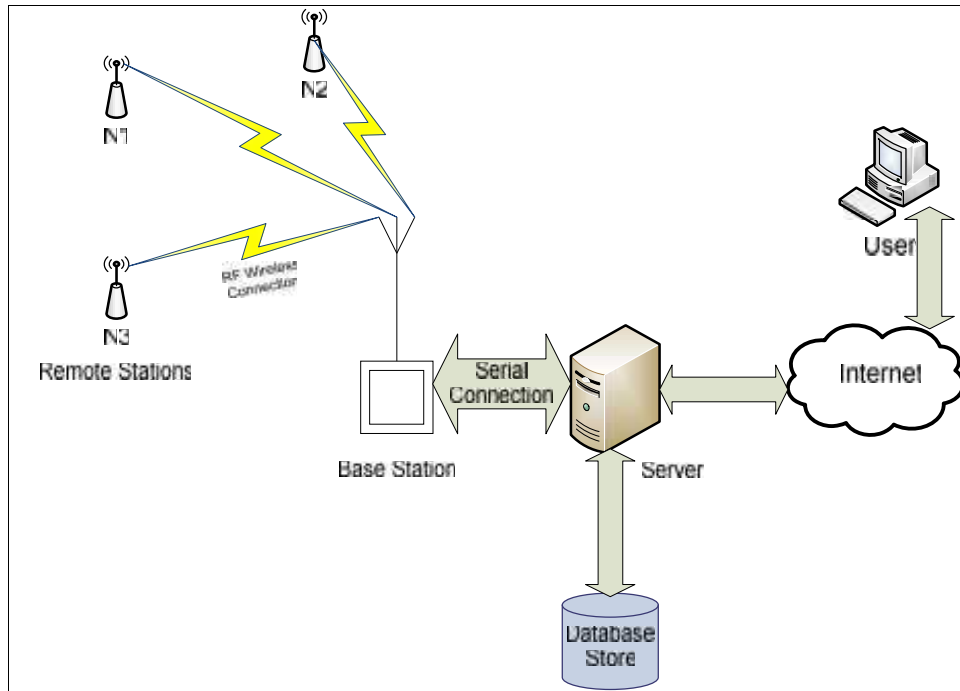


Figure (3-4): general block diagram

Base Station Block diagram:

Figure (3-4) shows the main component of the base station and its interfacing units.

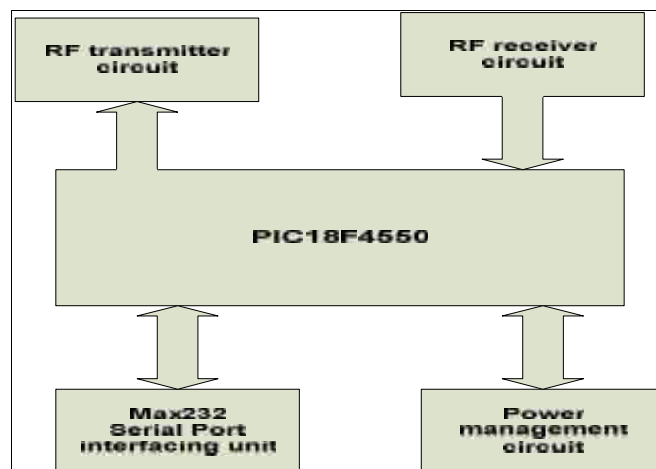


Figure (3-5) BS detailed Block Diagram

Remote station Block Diagram:

Figure (3-6) shows the RS components and its interfacing circuits.

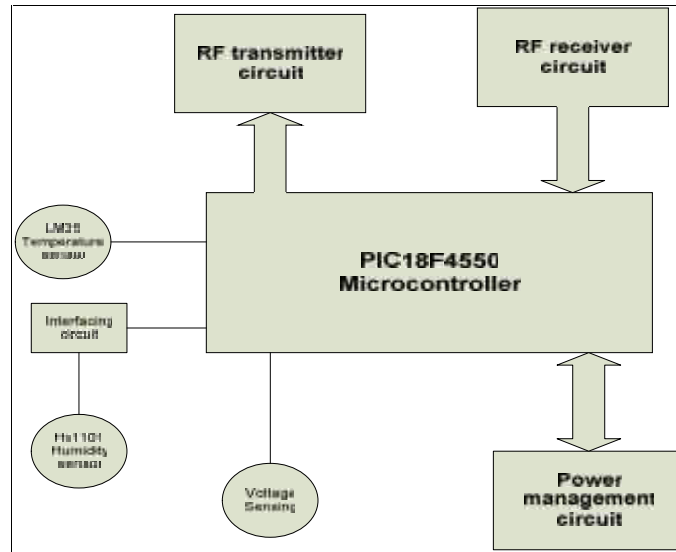


Figure (3-6) RS detailed block diagram

3.6 System Modeling

Different models can describe the operation of the proposed system; these can be described as follows:

1. Data Flow Diagrams

The figures (3-7) show the data flow model of the system. it shows how the sequence of data start with enter data from sensors that gather the data from surround environment, these data encoded through the interfacing circuit in order to transmit it to the base station, each sensor value will be put in its own packet to differentiate between sensor readings.

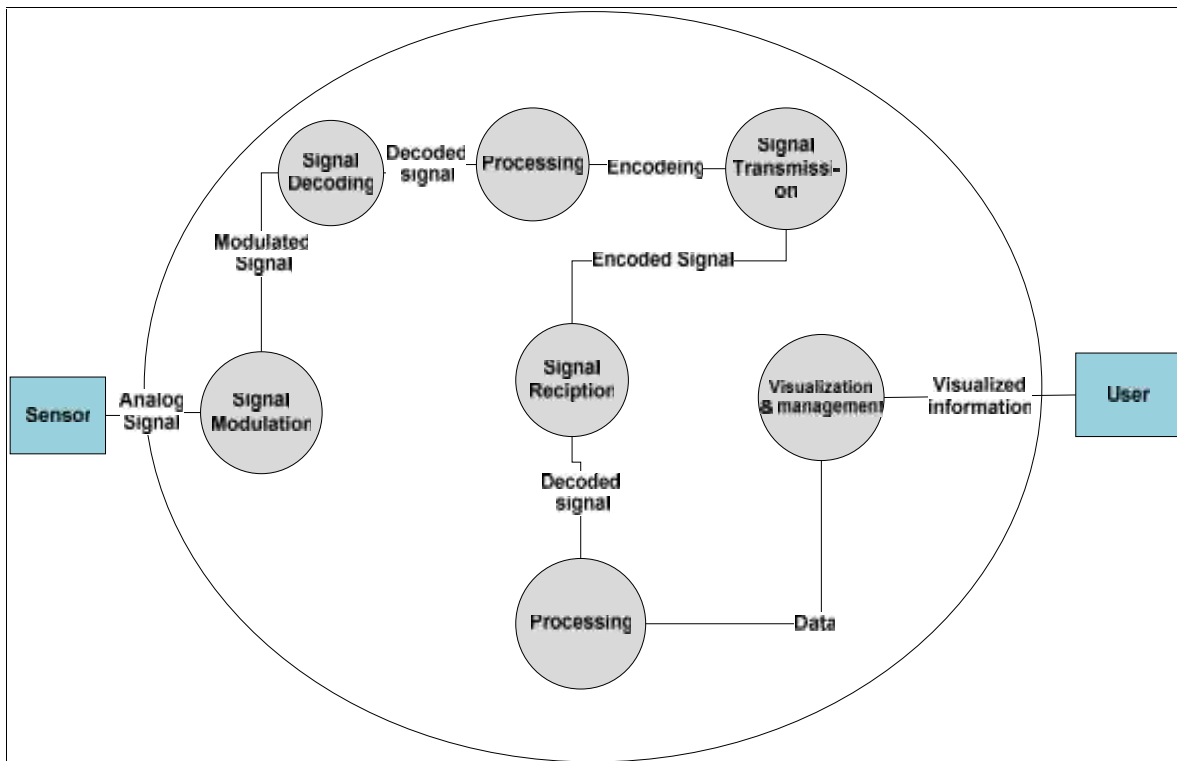


Figure (3-7): System data flow model

2. Sequence Model

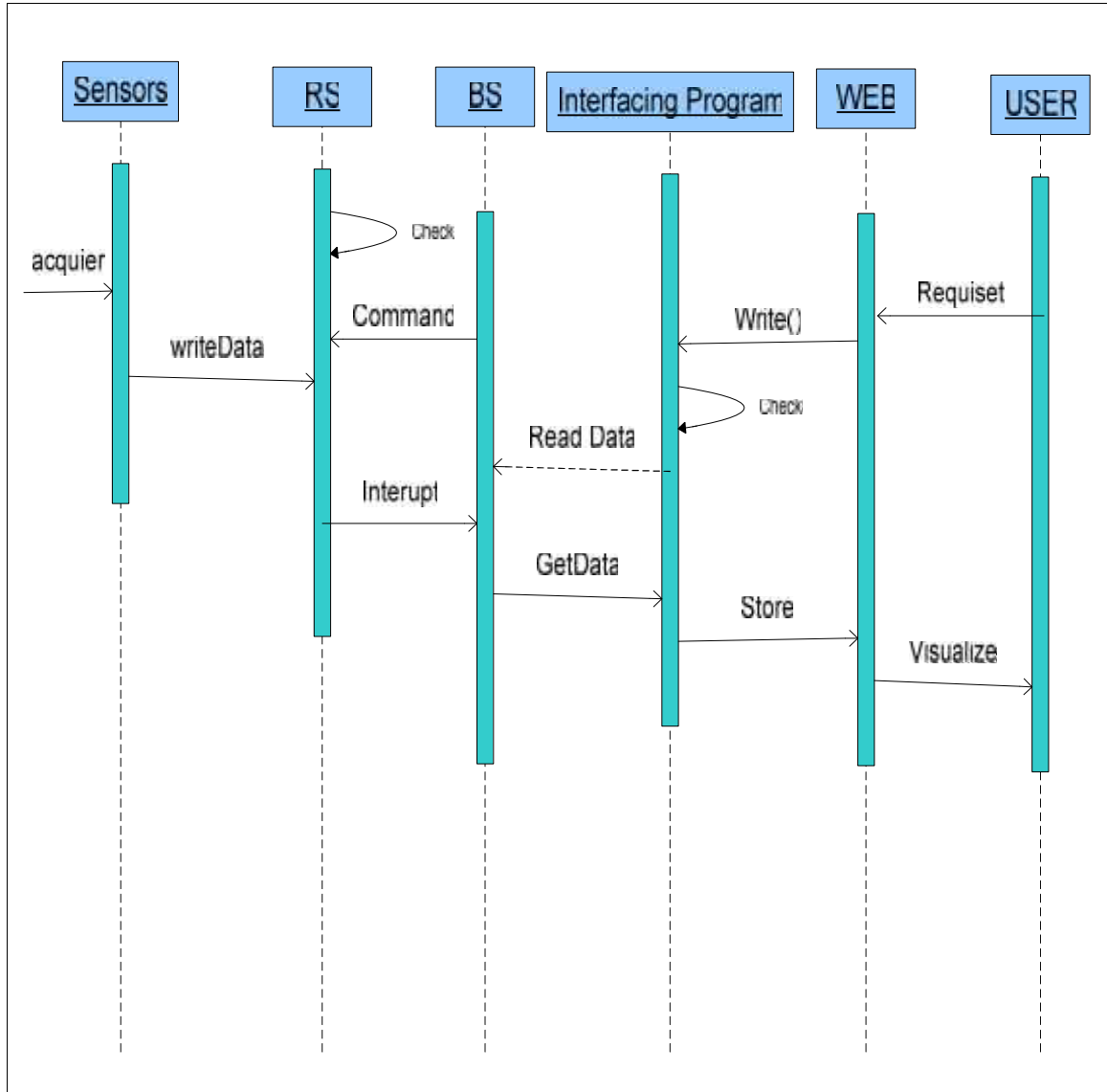


Figure (3-8): System Sequence Diagram

3.7 How Does the System Work?

First all remote stations will initialize to sleep mode by the base station, when user want to access the system, user should login to the web page and request the data visualization mode, data will transfer from the data base to the user, if admin user access the system from the web page then the intermediate program will transfer his commands to the base station which will move it directly to the desired remote station.

3.8 Summary

At the end of this chapter we have provided a detailed description for system objectives, system components, list of design options along with their strengths and weakness, graphical explanations such like: general block diagrams and system modeling diagrams, and finally a description of how the system works.

Detailed Technical Project Design

4.1 Overview

4.2 Detailed description of the project phases

4.3 Subsystem detailed design and overall system design

4.4 User-system interface

4.5 Summary

4.1 Overview

In this chapter we will provide a detailed description about project phases, subsystems schematics and design, and schematic design for the whole system. Then we will talk about user-system interface that is how the user can interact with the project.

4.2 Detailed description of the project phases

The system design in this project consists of three phase which are setup phase, programming phase and testing phase. Consequently we will provide a detail description of these phases.

4.2.1 Phase 1: setup phase

The following parts describe the project components:

1. Microcontroller (PIC18F4550)

First of all, we have studied how to program and use the microcontroller. A simple C program is written to read from a switch and set the corresponding LED. The aim of this part was to have a practice on using MPLAB program that used to assemble the C code to hexadecimal code and then using PICkit2 device to download the hexode to the program memory at the microcontroller.

2. Wireless Communication

This part tests the data transfer between the surrounded environment and using RF technology to transferring data.

RF-Transmitter:

In this project we used RT4-433.9 which is a hybrid circuit that realizes a complete radio transmitter; it has many features such as high reliability and DIL (Dual In Line) package shape. RT4-433.9 used in many applications such as security systems, car alarm and remote control. This circuit needs an encoding circuit to work in a right way without any distortion and to transmit the required data to the specific receiver in the receiving side; the used encoder is HT12-E. While the encoder enabled, HT12E gets the 4 bits data from the data source (PIC) which is connected to the sensor circuits, microcontroller encodes 4 bit data and adds the 8 bit address of the desired receiver, then forwards the signal to the transmitter .

Although every transmitter has a distinct address, but one transmitter must be enabled at a time, so software and hardware components used to control the transmitter enable, the hardware used to generate a free running frequenter is 555 chip with other components, this is done during the testing phase but after this we connect it to line of the microcontroller I/O lines and verify the enable / disable process through set or reset the connected pin. Figure (4-1) shows how the enable/disable processes apply to the HT12E to synchronize the transmission operation at RT4.

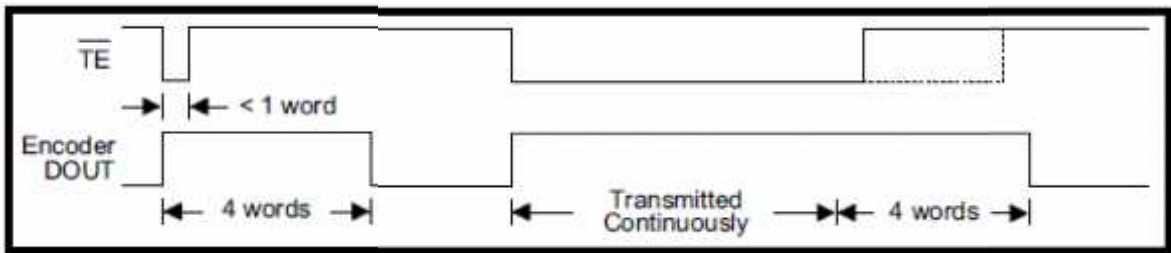


Figure (4-1) Transmission timing for HT12E [25]

RF-Receiver:

The RR3-433.9 is a super regenerative data receiver. This receiver sensitivity typically exceeds 10dB/m, and the frequency accuracy is very high. At the receiving side the RR3 should connect to HT12D decoding circuit to realize the incoming data, this decoder checks the serial input data three times with its local 8-bits address to ensure that it matches the transmitter address, when it matches, it passed the 4 bits data to the microcontroller input port it keep checking the VT pin to ensure there are valid and new data received. Figure (4-2) shows how the data reception and checking are synchronized.

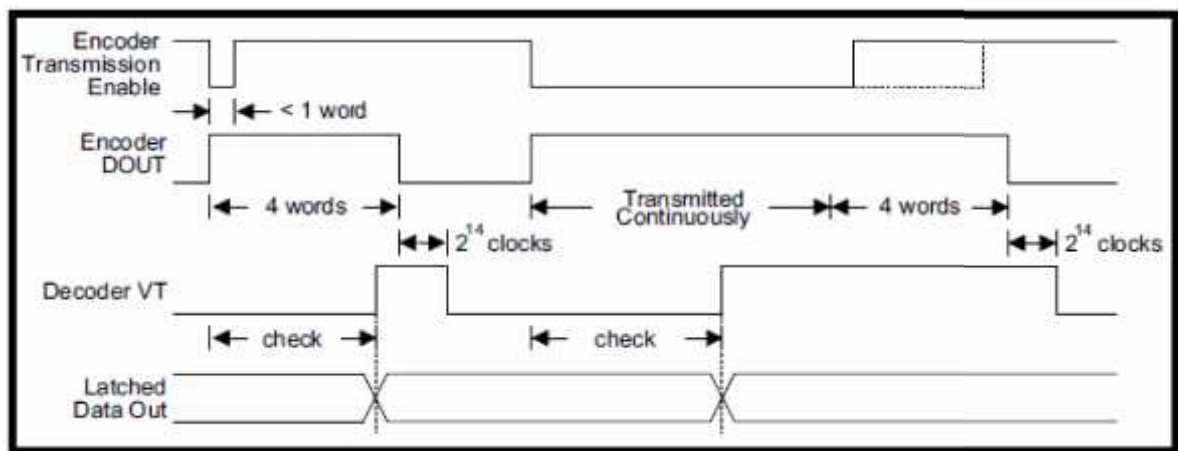


Figure (4-2) HT12D timing diagram [26]

Integrating RT4 with RR3:

As noticed from the previous discussion of the timing diagrams for HT12E and HT12D it's important to notice that the synchronization process between the two modules done during the encoding/decoding phase so to have the compatibility between them the oscillator frequency for both of them must have same ratio, which affect the data rate of the module. From the figure (4-3) we can see that the frequency is related to the power

and R_{osc} (resistor at encoder/decoder oscillator pins), the recommended oscillator frequency is $F_{OSCD}(\text{decoder}) = 50 F_{OSCE}(\text{HT12E encoder})$ so to work at the max voltage transmission the frequency of the encoder must be within the range of $3K_{Hz}$ to $4K_{Hz}$ this will be done if the R_{OSC} is $1M$. On the other hand the HT12D frequency chosen in the same way with respect to the power supply and the R_{osc} to get the compatibility with HT12E frequency.

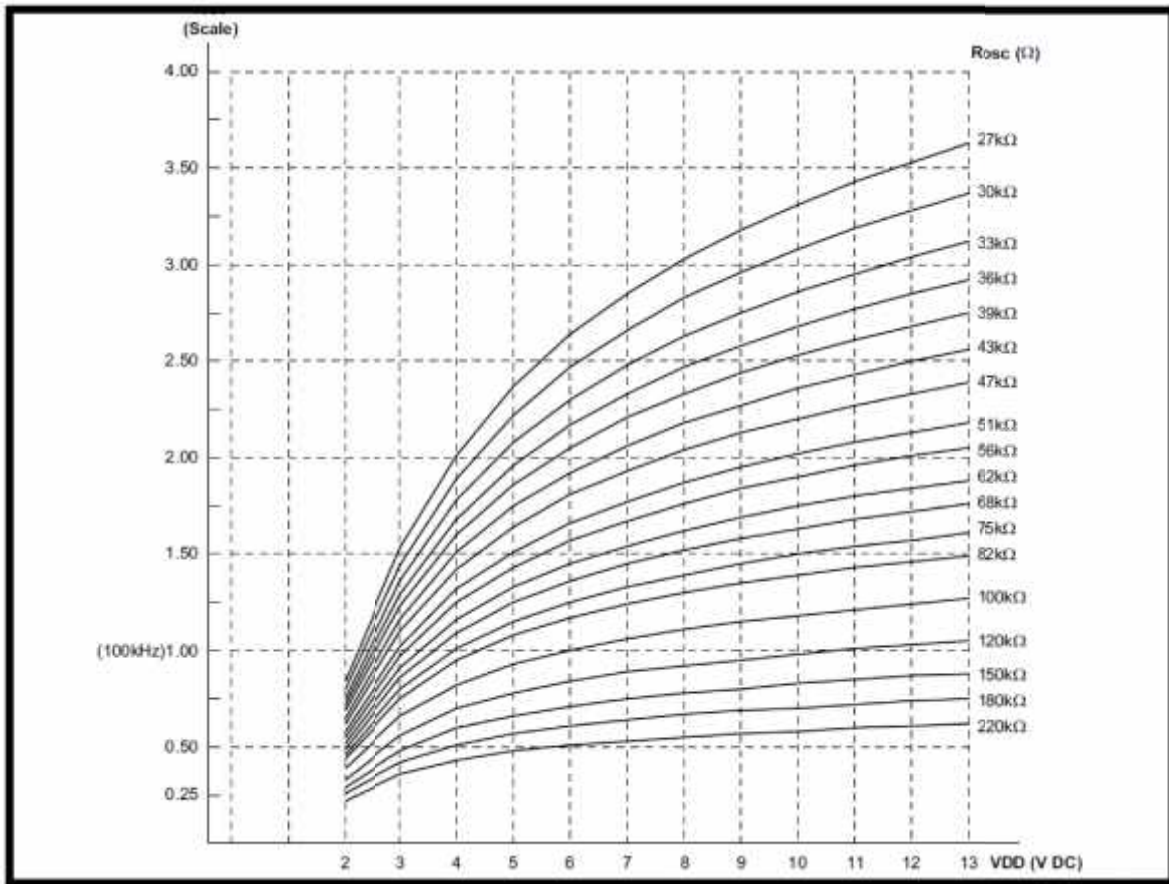


Figure (4-3) frequency, power and Rocs [27]

3. Remote station Vs Sensing Circuits

For humidity sensing, we opted for the Humirel HS1101 capacitive sensor. This device, when combined with a CMOS 555 timer operating as a stable multivibrator,

produces a signal with a humidity dependent frequency. To minimize temperature effects, it is important to use the Texas Instruments TLC555 device in this design. Refer to the HS1101 datasheet if another device is used. Also note that care must be taken at the node of the HS1101 and the 555. Stray capacitance values will lead to erroneous and unpredictable measurements. We chose to solder this node above the circuit card.

The relationship between the output frequency of the 555 and the relative humidity can be seen in Figure (4-4). A first order equation that relates relative humidity to frequency is:

$$\text{R.H.} = 565.1 - 0.0767 * f$$

A second order equation can be used for improved accuracy:-

$$\text{R.H.} = -6.4790\text{E-}06 * f^2 + 1.0047\text{E-}02 * f + 2.7567\text{E+}02$$

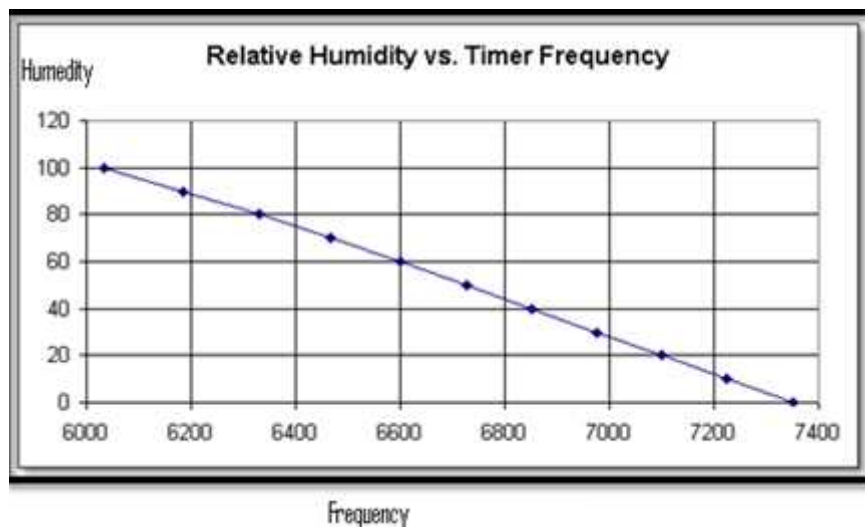


Figure (4-4) Relative Humidity Vs Timer Frequency [28]

Temperature sensing is very straight-forward with the LM335. This output of this device is equal to the absolute temperature in degrees Kelvin divided by 100 or:

$$V_{out} = \text{Temperature (K)}/100$$

To determine the temperature in degrees C, use the equation:

$$^{\circ}\text{C} = 100 * V_{\text{out}} - 273$$

To determine the temperature in degrees Fahrenheit, use the equation:

$$^{\circ}\text{F} = 1.8 * ^{\circ}\text{C} + 32.2$$

$$= 1.8 * (100 * V_{\text{out}} - 273) + 32.2$$

$$= 180 * V_{\text{out}} - 459.2$$
 At room temperature, this device outputs about 3volts.

For voltage monitor and control, the figure (4-5) showing simple power monitor circuit which is connected to the A/D lines in the microprocessor via 2 resistors in series the PIC microcontroller operate at +5v we apply the voltage divider rule between these resistors as the following:

The max value entered to the microcontroller will not exceed +4v when we use +12v power supply in the software side this will be considered when the power calculation is done.

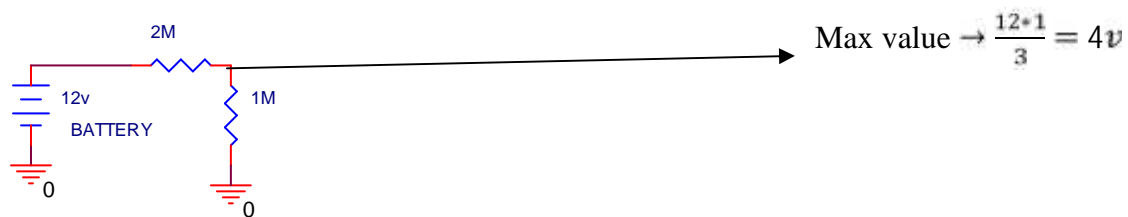


Figure (4-5) Voltage monitor circuit

Also RS needs to turn on/off its circuits according to the user commands that are received from the BS to achieve this special purpose transistors where used to perform digital on/off switches .As the following circuit shows in figure (4-6); if we apply logic 1 at the transistor base the voltage will flow to the connected device.

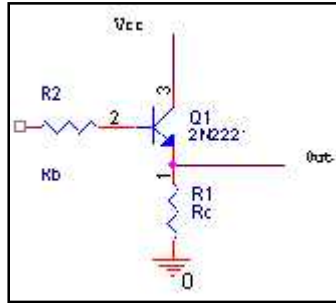


Figure (4-6) On - Off switch

4. Base station Vs PC serial connection

RS232 buffering and level translation is accomplished through the MAX232. A standard RS connector is used to connect to the PC. Power is provided via a 9VDC wall mount power supply driving a 78L05 regulator for +5 volts and an LT1121 for +3.3V. A single green LED is used to provide a power indicator. When the microprocessor detects the reception of a valid data packet, additional current is injected into the LED causing it to pulse.

4.2.2 Phase 2: programming phase

In this phase we wrote the basic functions that achieve communications between remote station and base station, also sub programs written to communicate with the server. More details about this phase will be described in chapter five.

4.2.3 Phase 3: testing phase

In this section we tested the overall system including circuits on base station, remote station and the software implementation in PC and PIC.

4.3 Subsystem detailed design

In this section we will describe the different units of the system as follows:

4.3.1 Remote station with sensing circuit

RS uses the RT4 and RR3 to communicate with the BS, microcontroller manages the operations between reception and transmission according to the received command from base station, which will set the station in one of two modes: Sleep mode or run mode, also an RS contains sensing circuit to acquire data from surround, like: humidity circuit, temperature and voltage monitor circuit figures (4-7), (4-8) & (4-9) show these circuits.

Temperature sensing circuit:-

As we mentioned before, the LM35 is directly connected to the microcontroller, directly, since our design aimed to reduce the circuit size we choose to connect it directly because it's suitable for this application, the following figure (4-7) shows the LM35 sensor:

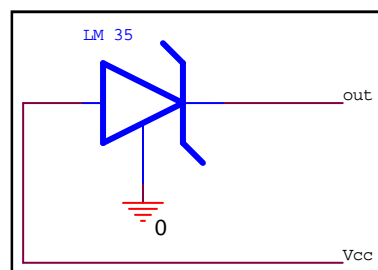


Figure (4-7)-LM35-temperature sensor

So as the PIC is concerned, finding a starting edge is the only approach since a time = 0 event must be established to find a lapse in time. Afterwards, an end point must be found. Since a periodic waveform has a defined endpoint, every second rising or falling edge will constitute a period. This is necessary because, in this case, frequency is the inverse of a periodic event in time. The following equation gives the equation for frequency (f).

$$f = \frac{1}{\text{time_period}}$$

Since the only reference to the waveform is edges, there is little else that can be done without introducing error. Because a frequency can be measured, a simple conversion can be implemented to calculate capacitance.

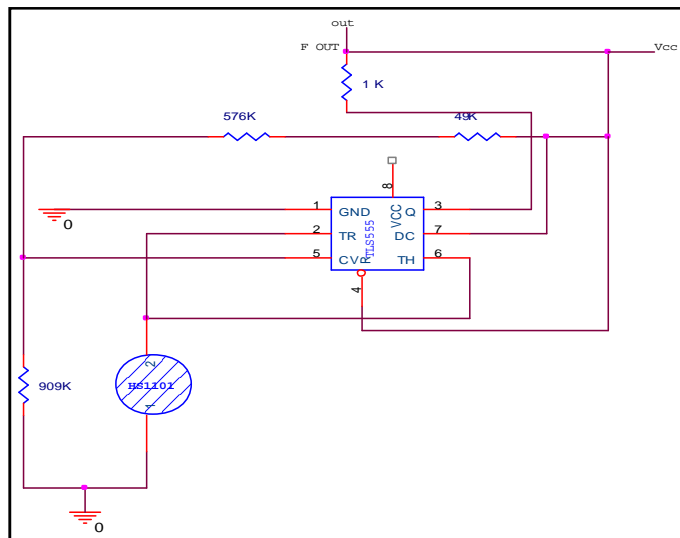


Figure (4-9) Humidity sensing circuit

4.3.2 Base station with serial interface circuit

In this section we describe the base station and how it's connect to the server using the serial port.

Serial interfacing circuit:

The circuit in figure (4-11) was designed to make serial communication with the server serially through serial port to perform all needed communications with the server to get user commands and transfer remote stations data.

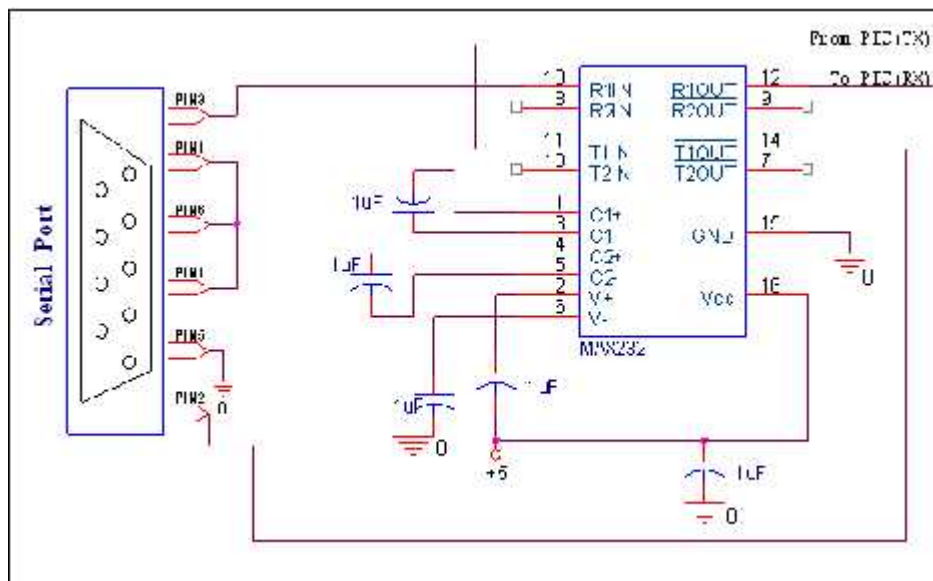


Figure (4-11): The Serial port to the PIC Interface Circuit

Since serial port at the server works at RS-232 signal voltage levels and that PIC microcontroller works at TTL levels, we need MAX232 to adapt the RS-232 signal voltage levels to TTL logic. And it just needs one voltage (+5V) and generates the necessary RS-232 voltage levels (-10V and +10V) internally. It requires only 5 capacitors as shown in the semantic above.

4.4 User-System Interface:

The user interact with the system using web application according to the user type, user can log to the system and get the different functionalities, so any operation will be done through the web browser, first user should login to the system through the login window in this step the system determine the user type according to the user name and password, according to the user type the following screens appear, The following figure (4-13) shows the admin page:

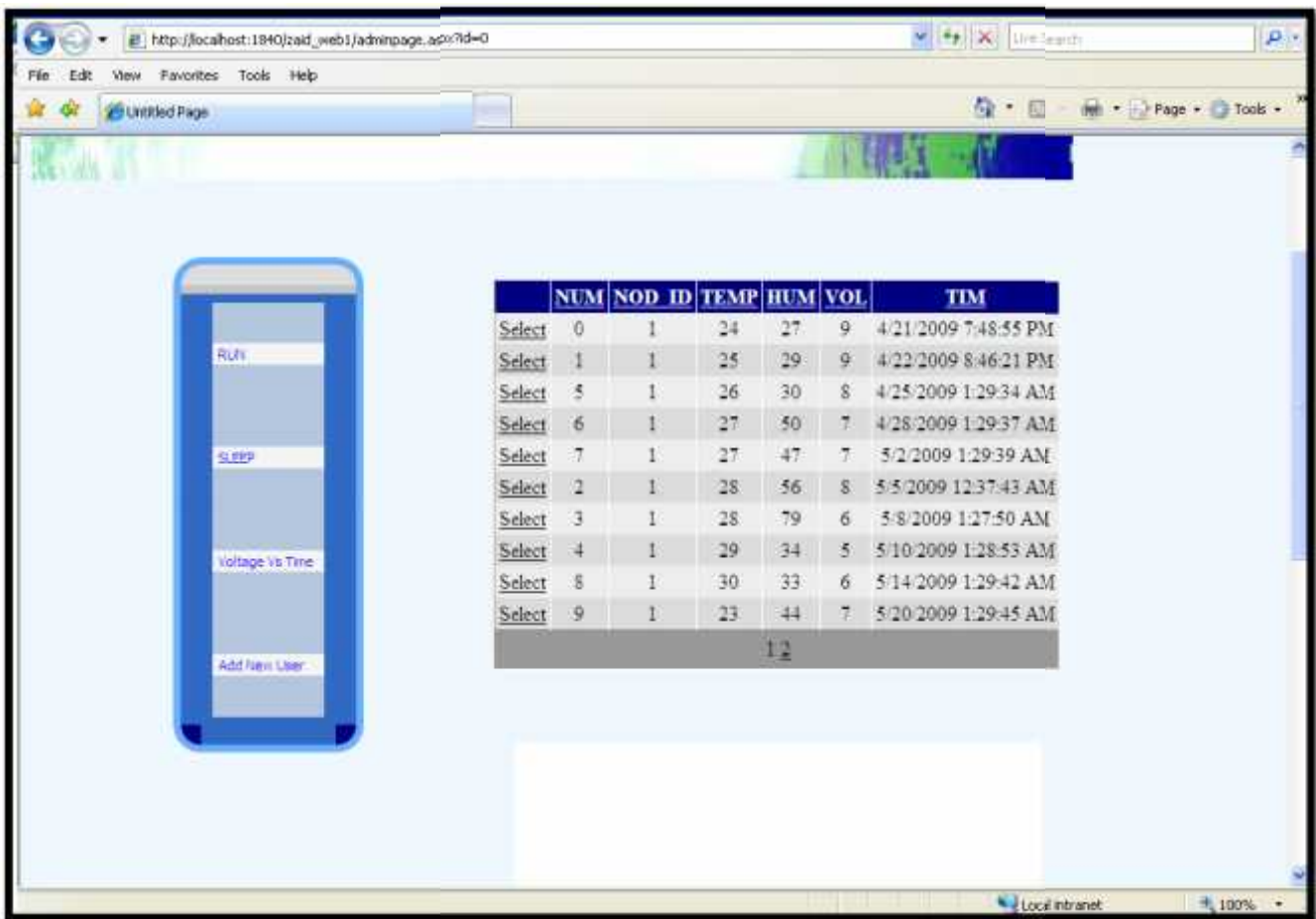


Figure (4-13) Admin page interface

If ordinary user login into a system the following screen will appear:

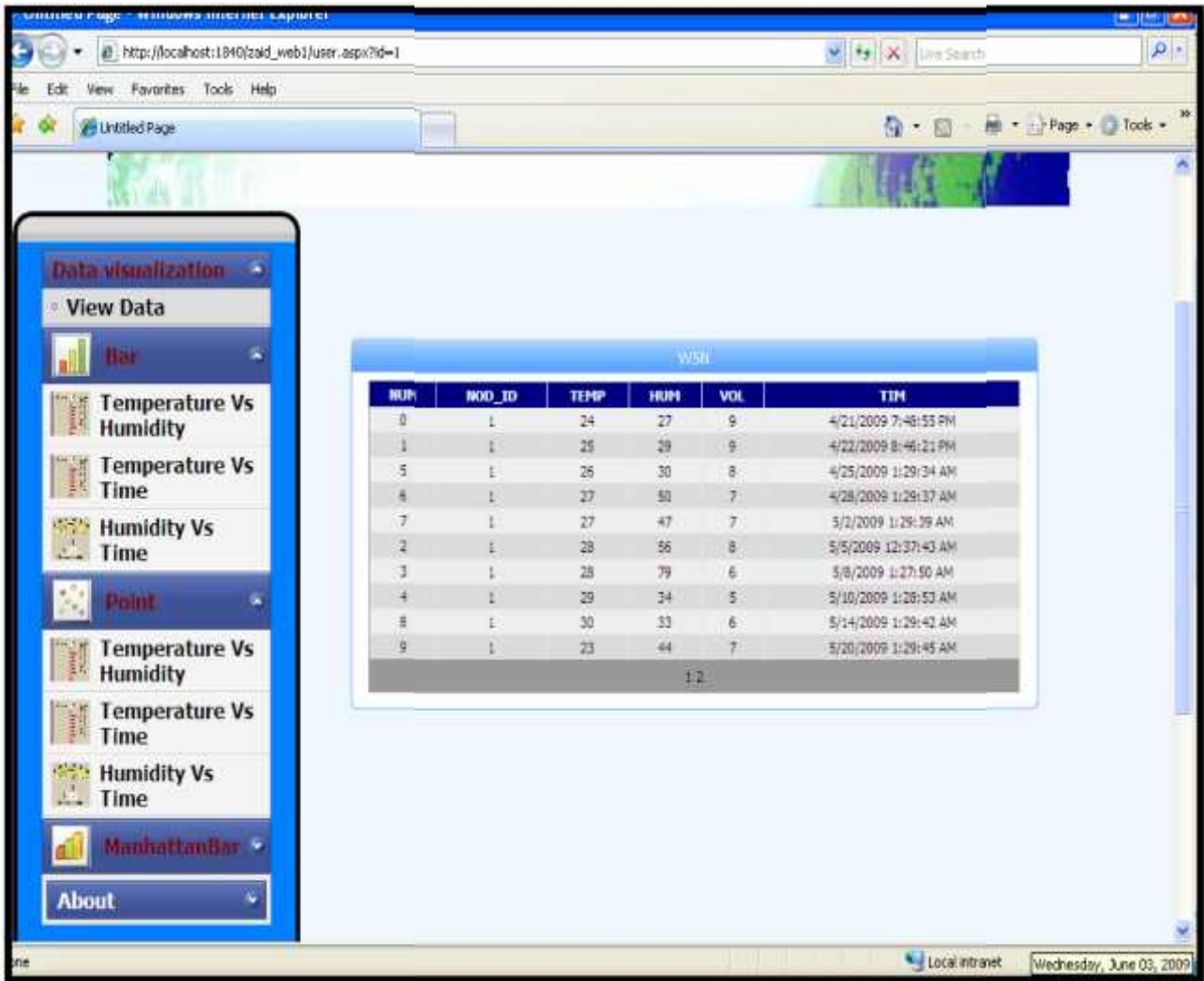


Figure (4-14) user screen

According to the selected function by the user the data will appear as the following figure:



Figure (4-15) user function screen

4.5 Summary

This chapter has provided a description about project phases which can be summarized by understanding the way microcontroller and RF works, implementing the connection between the microcontroller and PC first serially then wirelessly, and finalizing the project in case of both hardware and software components then provide information about hardware system design confirmed with schematics. Then we talked about User-System Interface that is, how different users can interact with the project.

Software System Design

5.1 Overview

5.2 Software requirement specifications

5.3 Flow Charts

5.4 Software implementation

5.5 Summary

5.1 Overview

In this chapter we provide a description about the system software requirement specifications including a detailed description for the base and remote stations program and server programs. Also we will present many algorithms and flowcharts that describe our system.

5.2 Software requirement specifications

Since our project interacts with the server to visualize the received information from base station and transfer commands to the remote stations, it's needed to have two programs, one resides in PIC at BS and RS and the other in the server. In this section we will provide the software requirements needed to program PIC and server.

5.2.1 Microcontroller software

For the microcontroller software, there are needs; the following paragraphs describe these.

- **Operating system**

Windows OS is widely used, so we have decided to write The PIC microcontroller code in a text editor also we used an appropriate program to transfer the code to the PIC.

- **Compiler**

The PIC microcontroller programming deals with hexadecimal code, so it is suitable to use the C compiler or an assembler to convert the code from language code to machine code "hexadecimal".

The PIC codes were written in C programming language according to PIC programming specifications which can be found in MPLAB C18 C Compiler Libraries provided by *MICROCHIP*. The compiler we used is the MPLAB 7.13 version C compiler in which one can write the C code for a specific PIC, then after compiling a hex code file will be generated.

- **PICKit2 programmer**

PICKit2 is provided with the microcontroller, so we will use MP Lab program to load hex files from PC to a PIC specified by user; it required to be connected to PC through USB. When user connect PIC to the programmer it can load the hex file to the programmer then it can program PIC, after programming, then the hex code will be loaded completely to PIC.

5.2.2 Server's software

At the server side we need a program that receives packets from BS through the serial port, process it, and store data in the database according to these packets. Also server program accept commands from user and send it to the BS, this program work as a middleware between web application and hardware connection. The server program was written in java programming language using Net beans IDE.

Also we need a database to store the received data from serial port using java program and store it into the appropriate format in tables according to the arrival time of these data. Also the database should accept user command and store it in special table called command table as we will see later, the database is built using Oracle 10g express edition.

We need also a program (web application) that deals with the information in the database, this program will achieve the visualization upon the user request, manage users

accounts, authentication issues and user commands. This program is written in ASP.NET2 programming language using Visual studio 2005.

5.3 Software Implementation

Here we will describe the software parts of the project:

5.3.1 Web application

The user (admin user or ordinary user) interact with the system through the web application, the web application accept commands from admin user and move it to special table in the database store (COM_table) , also web application get data from WSN_table and visualize it in different formats (bar chart, point, line...) as the user request.

The users can interact with the system as follows:

- User should select any parameter to visualize it with respect to other parameters (temperature Vs time, temperature Vs humidity, humidity Vs time or the three parameters temperature, humidity and time).
- If the user selects bar chart the data will appear as bar representation.
- If the user requested point the data will appear in point representation.
- If the admin user request voltage representation then voltage Vs time chart will appear in the requested chart Point or bar chart.
- If the admin user wants to turn on specific node then he should select the nod from data view table, and then click on the run button.

-If the admin user wants to turn off specific node then he should select the node from data view table, and then click on the sleep button.

-Admin user can add new user and define its type from add new user menu.

5.3.2 Data base store

The database built using oracle 10g, it contains two tables one for accepting incoming data from serial port WSN table and other for accept incoming commands from the admin user COM table.

The table's schema looks like the following:

COM table: which stores Boolean value in R and S columns at the beginning the R initiated to 0 and S to 1 when run command is clicked then the value at the R column will be complemented and so the S column value with respect to the Nod_id column that represent the node number.

Table	Column	Data Type	Length	Precision	Scale	Primary Key	Nullable	Default	Comment
COM	NOD ID	Number	-	-	0	-	✓	-	-
	R	Number	-	-	0	-	✓	-	-
	S	Number	-	-	0	-	✓	-	-
									1-3

Figure (5-1) command table.

WSN table: incoming data from the serial port through java application will be stored in the order that it's entered Nod_id, Temperature value, Humidity value, voltage value and the arrival time.

Table	Column	Data Type	Length	Precision	Scale	Primary Key	Nullable	Default	Comment
<u>WSN</u>	<u>NUM</u>	Number	-	-	0	1	-	-	-
	<u>NOD_ID</u>	Number	-	-	0	-	✓	-	-
	<u>TEMP</u>	Number	-	-	0	-	✓	-	-
	<u>HUM</u>	Number	-	-	0	-	✓	-	-
	<u>VOL</u>	Number	-	-	0	-	✓	-	-
	<u>TIM</u>	Date	7	-	-	-	✓	-	-
									1-6

Figure (5-2) WSN table

5.3.3 Serial port interfacing program:

At the server side java application run and keep listening to the serial port, and also look at the database COM table to check R and S values. If the data on the serial port ready then the program accept it according to its header as the following:

N: node ID

T: temperature value

H: humidity value

V: voltage value

-The program inserts the data to the database WSN table with the arrival time of the data using SYSDATE function.

-If the value on the com table is changed R (run command) or S (sleep) then the program transfer this change to base station as command with respect to the selected node (Nod_id).

Figure (5-3) shows the packet format from server to base station:

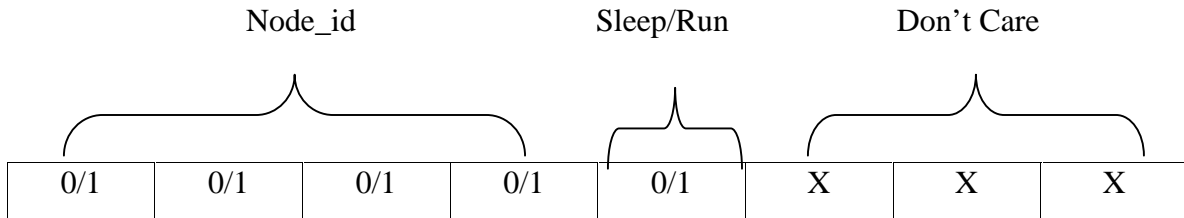


Figure (5-3) Server to Base Station Packet format

5.3.4 Base Station program

The base station at the begging initializes all the remote stations to sleep mode by sending sleep command to all nodes. Then BS will keep listening to the serial port to accept admin user commands Run which mean get the remote station data or Sleep that enter the remote station to sleep mode (Power consumption mode).

The packet format from base station to the remote station as the following:

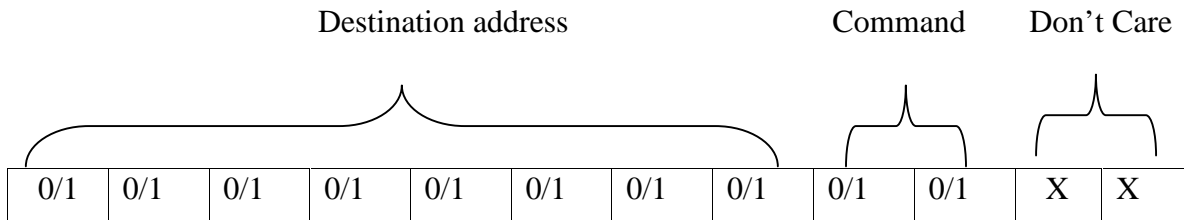


Figure (5-4) Base Station to Remote Station packet format

Modifying Packet											Case	
11	10	9	8	7	6	5	4	3	2	1		
0	0	0	0	0	0	0	0	0	0	X	X	Sleep node 1
0	0	0	0	0	0	0	0	1	1	X	X	Run node 1

Table (5-1) Modification packets

When the base station receives Run command, it will do the following:

- send the command to the desired remote station by setting the remote station address on the address lines of the base station.
- transmit its address with the desired command
- Wait for complete transmission
- starts collect data according to the incoming packets from remote station
- send the received packets to the server.

The packet format from base station to the server looks like the following figures:

Nod_id

0/1	0/1	0/1	0/1
-----	-----	-----	-----

Temperature header (T)

0	1	0	1	0	1	0	0
---	---	---	---	---	---	---	---

Temperature value

0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
-----	-----	-----	-----	-----	-----	-----	-----

Humidity header (H)

0	1	0	0	0	1	0	0
---	---	---	---	---	---	---	---

Humidity value

0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
-----	-----	-----	-----	-----	-----	-----	-----

Voltage header (V)

0	1	0	1	0	1	1	0
---	---	---	---	---	---	---	---

Voltage value

0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
-----	-----	-----	-----	-----	-----	-----	-----

Figure (5-5) packet formatting

5.3.5 Remote Station program:

At the beginning remote station initialized to the receive mode, then keeps listening to the incoming packet from base station, if the received command is sleep command then Rs enter the sleep mode by turning off the transmitter and the sensing circuits. But if the received command is Run command then the RS start collecting data from sensing circuits packetize it in the following format:

Tttt tttt: Hhhh hhhh: Vvvv

T: stands for temperature it's transmitted as two nibbles.

H: stands for humidity also transmitted in two nibble format.

V: stands for voltage as we can see it's transmitted as one nibble because the range of its values between (0 - 12 v) so one nibble will represent the desired value.

The RS will response to the Run command by sending these values to the BS with respect to their order. The packet format from the Remote Station to the base station looks like the following:

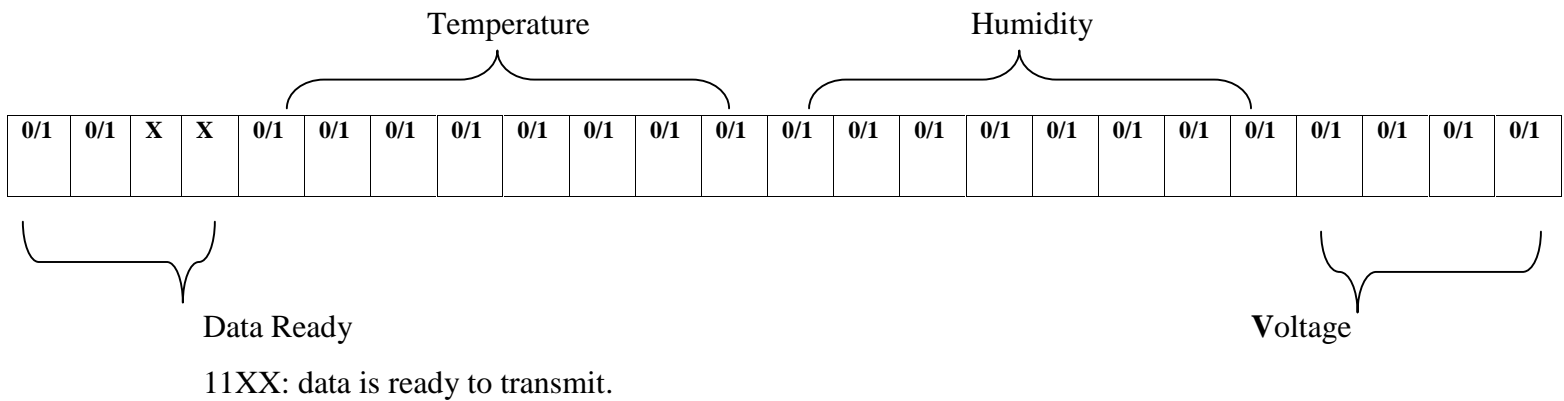


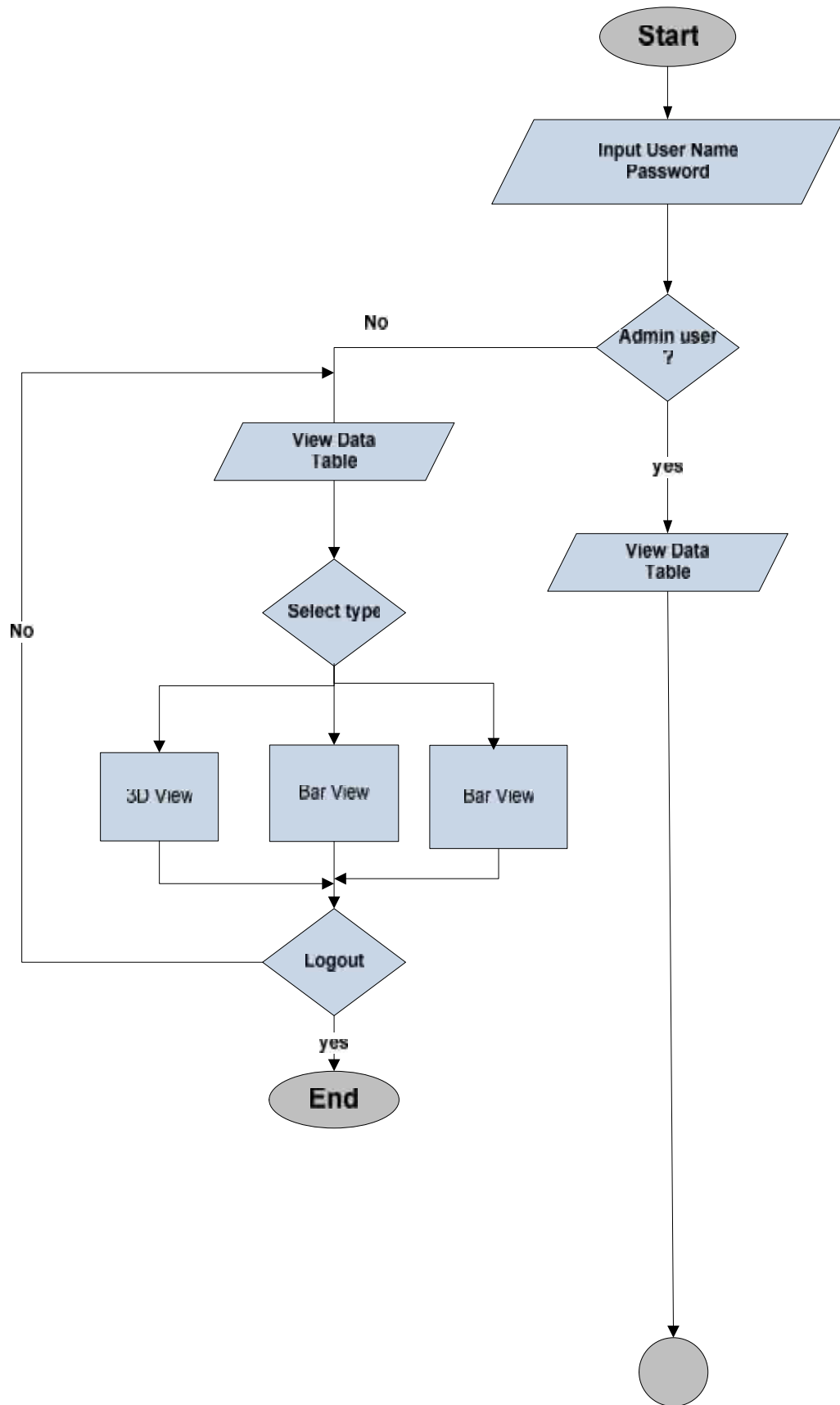
Figure (5-6) remote station to base station bracket format

To ensure completeness of collecting data from sensing circuits in the Rs and give the correct synchronization between Rs and the Bs pilot message sent from Rs to Bs till that data is ready to be transmitted.

5.4 Flowcharts

In this section we will provide flowchart schematics that describe the system operation; a general flow chart that describes the overall system will be provided, then detailed flow charts that describe both programs in PIC and server will be also presented.

The following flow chart represent the web application that run at the server, by which the user can interact with the system according to his type, the flow chart display the cases when admin user login to the system and ordinary user.



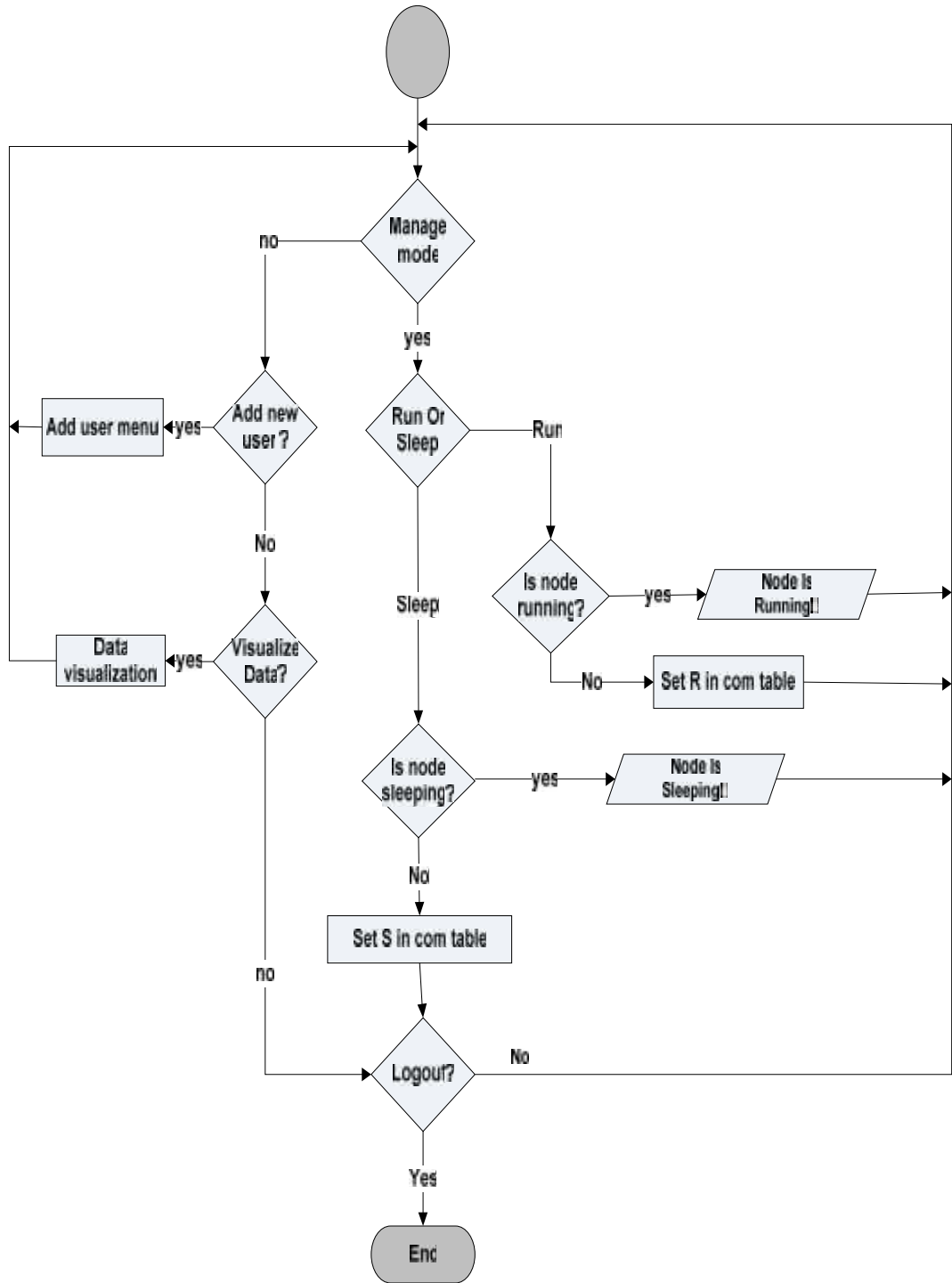


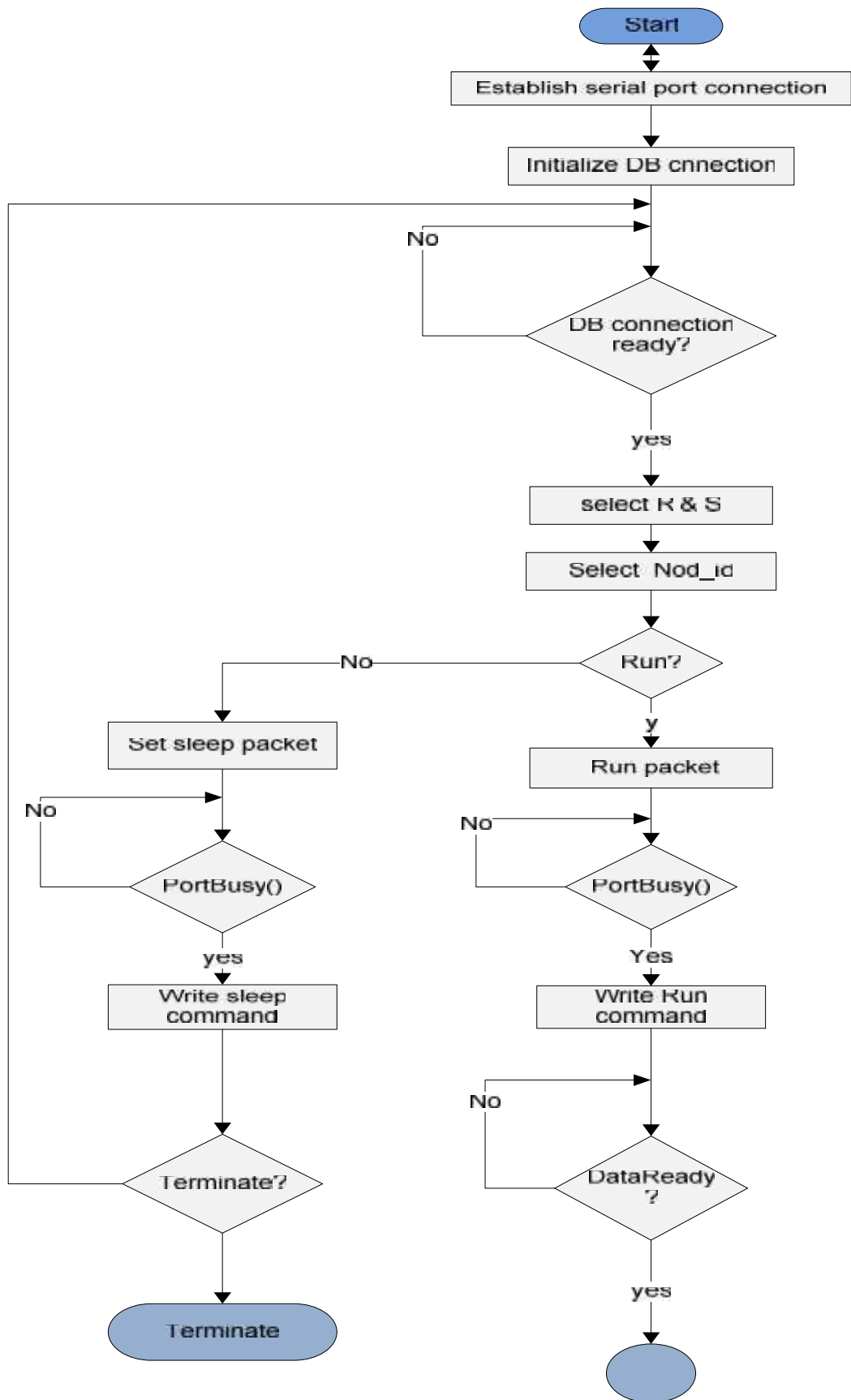
Figure (5-7) web application flow chart

The following flow chart shows the interaction between the base station and the server, this algorithm implemented in java programming language for reading the serial port, listening to the serial port and check the com table in the database to apply the admin user commands run or sleep.

If there were a valid data coming from base station then the program read it and store the data in the WSN table, also if the value in the com table R changed to 1 the program write run command in the corresponding format that represent the desired node and wait to get the data, but if S in com table changed to 1 then the program write sleep command on the serial port and close the connection, then keep listing to the data base.

The follow chart use the following functions:

- DbConnectionRedy() : this function return one if the connection with the oracle server is ready to use
- PortBusy() : return 1 if the serial port is busy according to hardware or software malfunctions.
- DataReady() : this function resides in the base station, this function announce that the BS received the data from RS and its ready to move to the server.



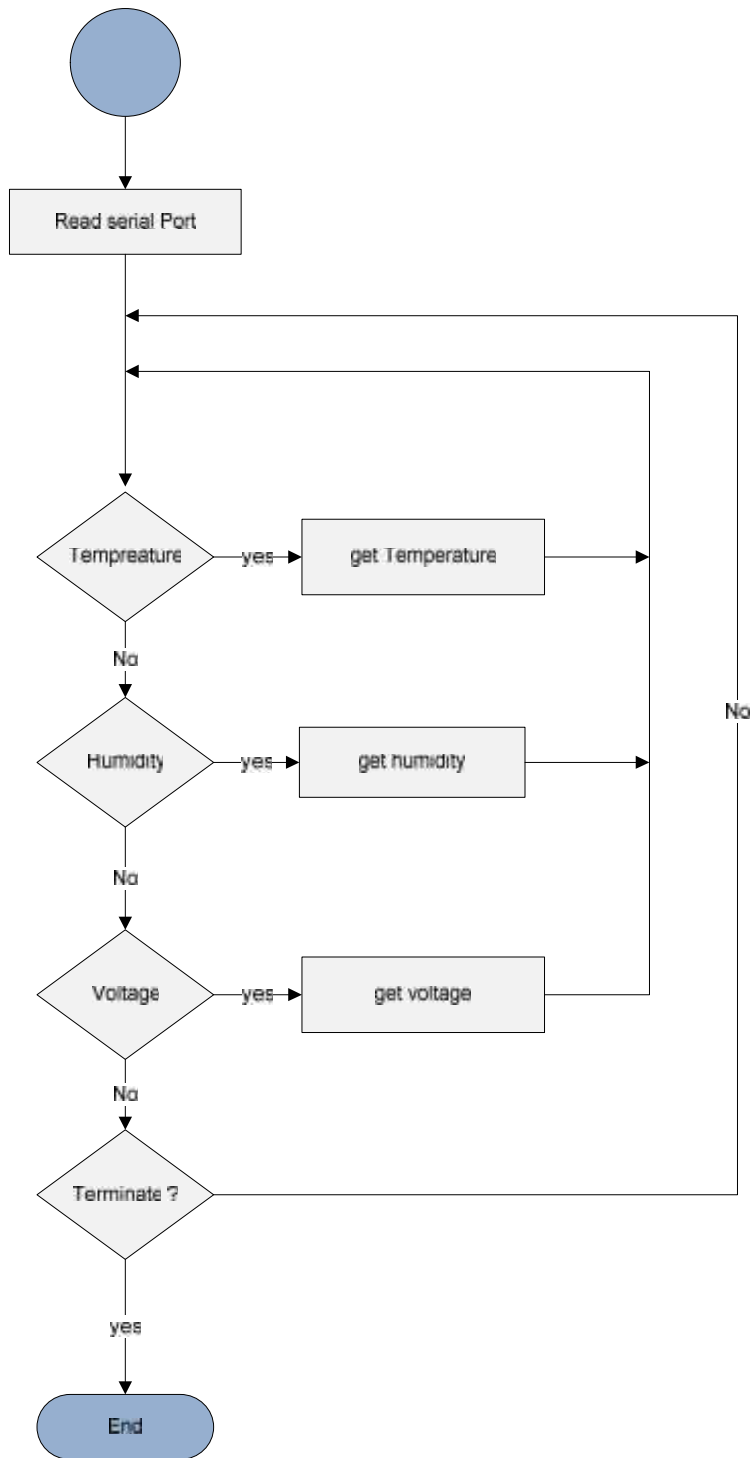
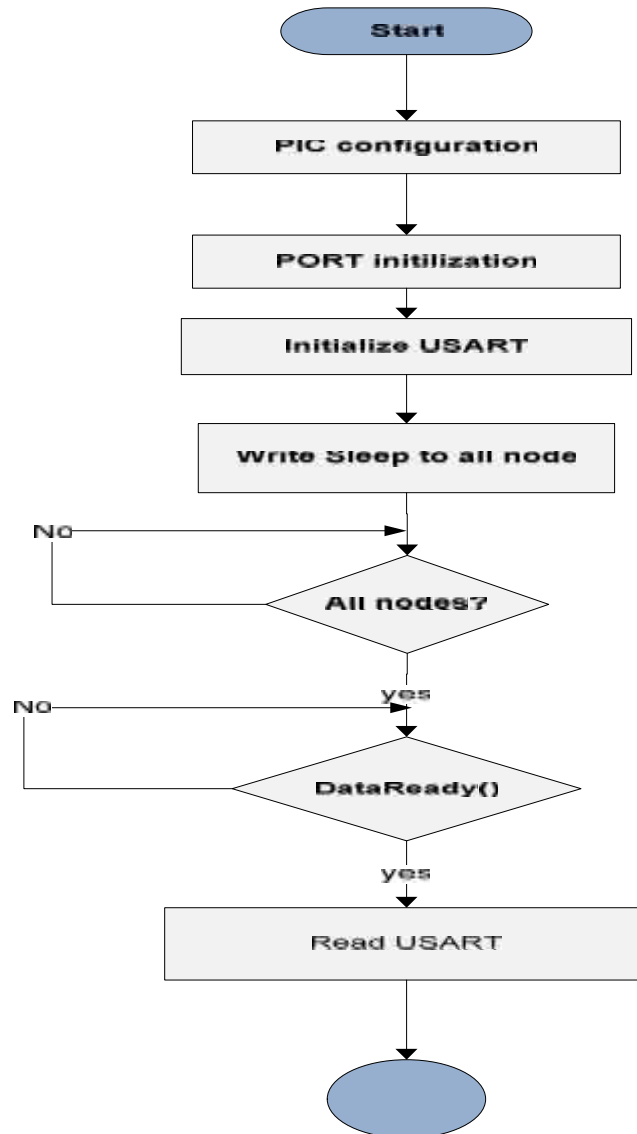


Figure (5-8) Serial port connection flow chart

The following flow chart show the base station program that achieve communication with the server in both directions and the Remote stations, this program implemented in C programming language.

The program does the following:

- Listen to the serial port to get user commands.
- Listen to the receiver data lines to get data from remote stations after applying run command.



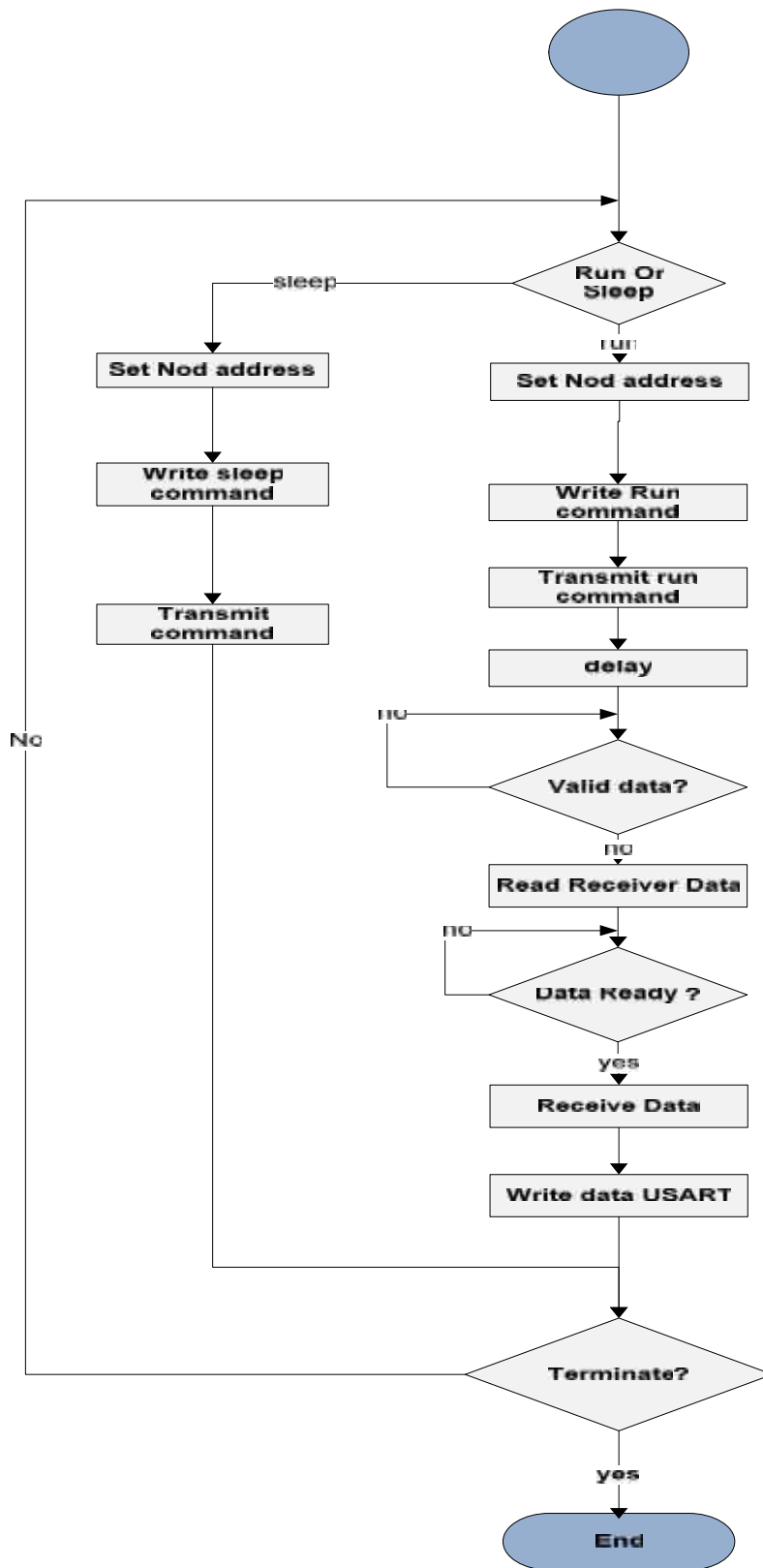
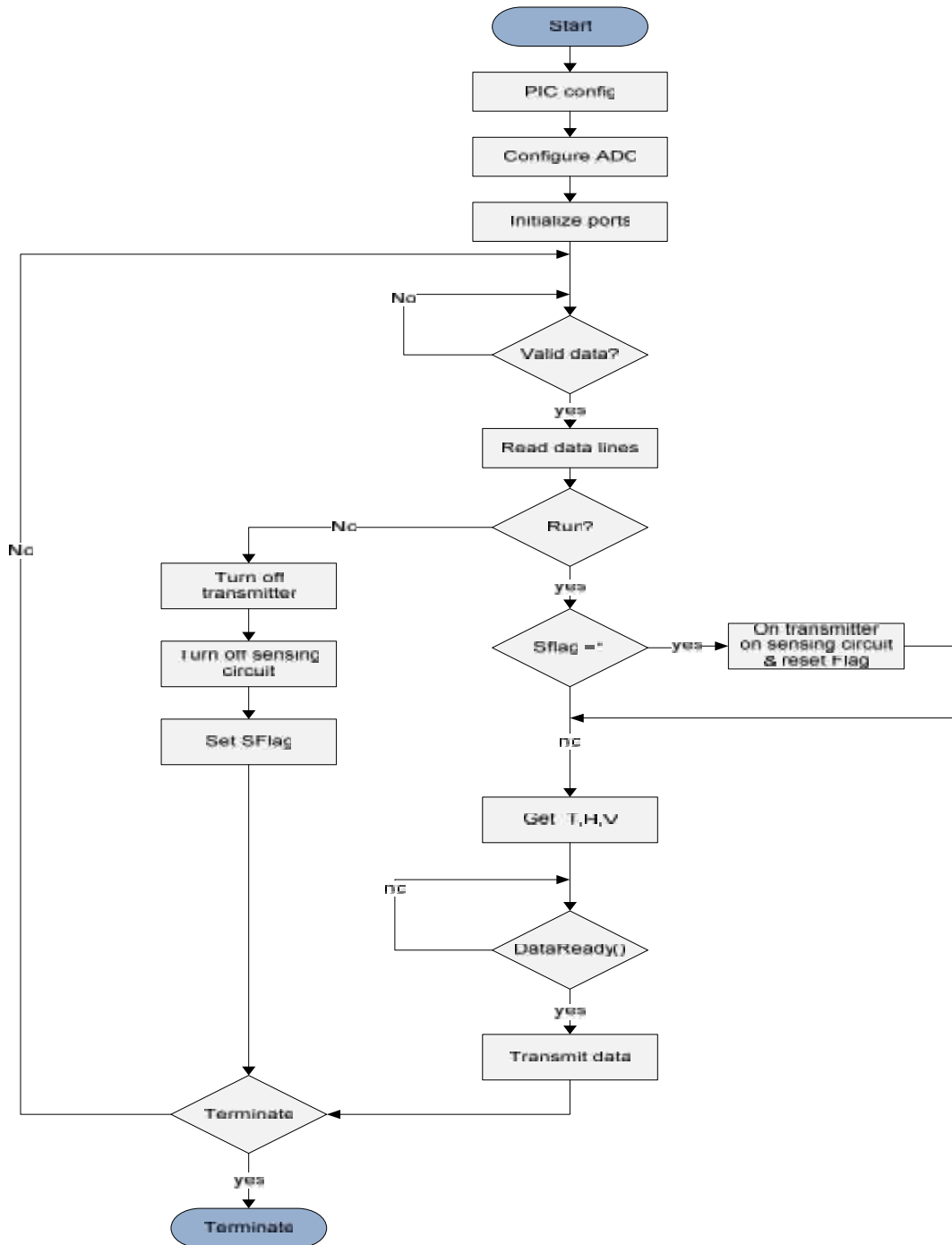


Figure (5-9) BS flow chart

The following flow charts show the Remote station, flow chart and its functions, also Rs flow chart implemented in C programming language.



Figures (5-10) RS flow chart

The following flow chart show the getTemp() function that read the temperature value from lm35 sensor, the getvolt() function the same as the getTemp() but the channel will be set to 1.

These algorithms use the following functions:

- ConvertADC() : start analog to digital conversion process
- BusyADC() : return 1 if the conversion process not complete,
- ReadADC(): read the digital value after conversion process finished.

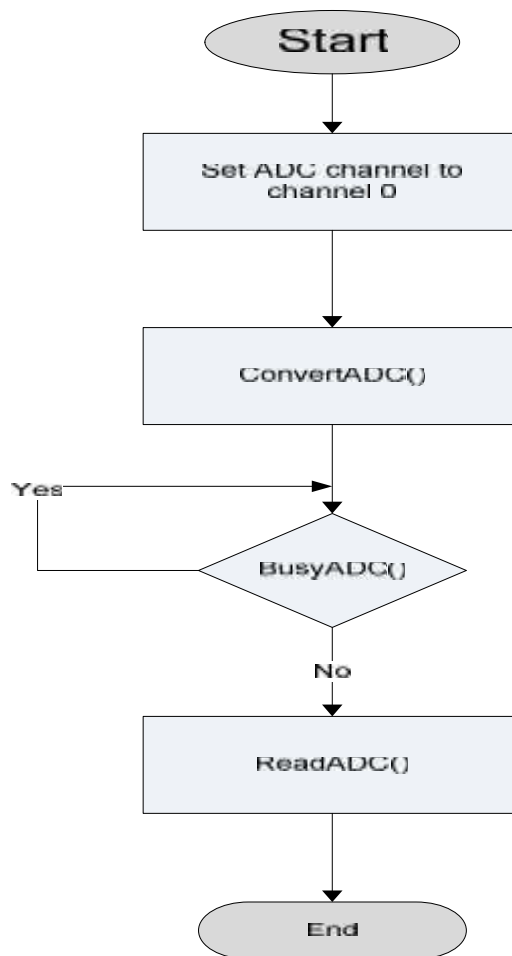


Figure (5-11) reading temperature flow chart

Figure (5-12) describe the gethumidity() function, The relative humidity can be calculated related to frequency as the following

$$\text{R.H.} = 565.1 - 0.0767 * f$$

Three components are needed to implement a period measurement in the PIC 18 to measure the frequency.

- A timer
- An input pin capable of seeing edges
- Some storage area to keep track of the number of time intervals between edges.

Timer 3 is configured to be the timer directly tied to the CCP1 pin. This is necessary because timer3 will start incrementing the CCPR1 register when an interrupt is sensed on the CCP1 pin. When the CCPR1 register overflows, timer3 will generate an interrupt allowing the PIC to increment a variable called tmr3_ov. This accounts for overflow. Also, the frequency is tied to the CCP1 pin and it is set to be an input. Afterwards, the internal oscillator is chosen to be the oscillator timer 3 uses to generate its interrupts. When this is done, both timer3 and CCP1 interrupts are enabled. The following list shows the initiation of timer3 and CCP1.

- `T3CCP1 = 1; //sets timer3 to the CCP1 register`
- `T3CKPS1 = 0; //prescale timer 3 by 1`
- `T3CKPS0 = 0;`
- `T3CS = 0; //use internal oscillator for timer 3`
- `TMR3ON = 1; //turn on timer3`
- `bitset(TRISC,2); //sets CCP1 as an input`

- `CCP1CON = 0x07; //sets the CCP1 to interrupt every 16th rising edge`
- `CCP1IE=1; //enables CCP1 interrupts`
- `TMR3IE =1; //enables timer3 interrupts`

The software handles the sequence of events to calculate the period. When the CCP1 pin sees a rising edge, timer3 will start incrementing CCPR1 until the 16th rising edge is sensed and an interrupt is generated. Should the CCPR1 register overflow, because it is a 16-bit register and the clock is incrementing in nano-seconds, an overflow variable will be incremented in the interrupt service routine (ISR). Then the difference in the number of tics from the capture is decremented by the number of tics from the last, which is stored in a variable, giving the change in time, taking in account any overflow encountered. Afterward, this value is divided by16 in order to render the timer tics in a single period.

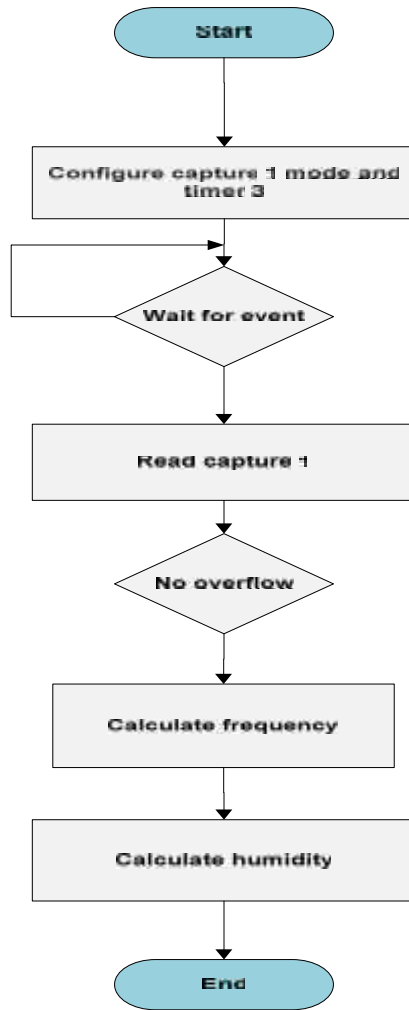


Figure (5-12) humidity calculation flow chart

5.5 Summary

By the end of this chapter we have provided a description about our system software requirement specifications including a detailed description for the PIC program and PC program. Also we have presented algorithms and flowcharts that describe our system.

System Implementation and Testing

6.1 Overview

6.2 Sub System Testing

6.3 Over All System Testing

6.4 Summary

6.1 Overview

This chapter demonstrates the methods and procedures used to test and examine the system operation and behavior. System testing is an important and critical step in implementing a system. It senses the effectiveness of that system just before introducing it to its users.

This system has more than one issue to be tested. Some testing parts reflect a software, or hardware case. Also, testing procedures concentrate on a single device independent from the overall system.

After finishing the design of the system and drawing the system schematic, the next step was to test each part individually, and then implement the system using the wire wrapping.

6.2 Subsystems Testing

At this stage each subsystem was tested independently to ensure that the component realizes its specified function. This way of testing simplifies trouble shooting detection.

1. Base station testing:

This part shows the steps of testing the different parts of the base station as follows:

- **PIC18F4550 Microcontroller Testing**

The PIC18F4550 with was built as shown in Figure (6-1), this testing needs the use of the programmer in order to program the microcontroller with the test program to

ensure that the microcontroller response to its desired function. USB cable used to connect the PICKit2 programmer to the PC, five wires are connected from the PICKit2 programmer to the PIC Vss, Vcc, PGC, PGD and Vpp.

The following figure (6-1) shows the PIC microcontroller and PICKit2 programmer connection and testing

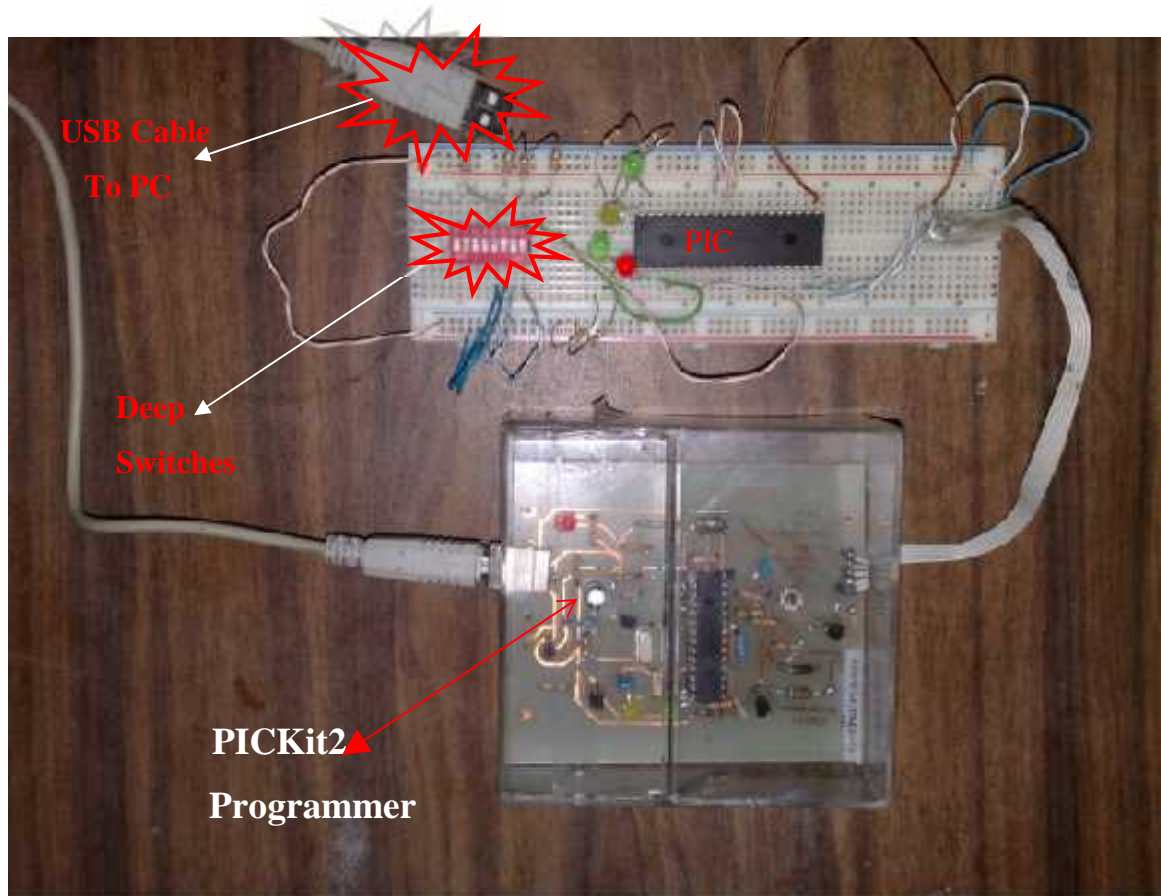


Figure (6-1) Microcontroller testing

The following program initialize PIC ports as inputs and outputs, the program read the switches values and turn on or off the LEDs.

```
#include<p18f4550.h>
#include<delays.h>
#pragma config WDT = OFF
#pragma config FOSC = INTOSC_HS
```

```

#pragma config PBADEN = OFF
#pragma config LVP = OFF
void main(void)
{
ADCON1=0B00001111;
TRISB=0;
TRISA=0;
TRISD=0;
while(1)
{
If(PORTCBits.RC4)
{
PORTD=0;
Delay1KTCYx(99);
PORTD=255;
Delay1KTCYx(99);
}
If(PORTCBits.RC5)
PORTD=255;
} }

```

- **Wireless communication Testing**

The testing and verification of the wireless communication between the different parts of the system requires the presence and use of both the transmitter unit and the receiver unit with the decoder in receiver side and encoder in transmitter side. This testing was accomplished using the following equipments:

- Function generator with 5 volt power supply, breadboard and LEDs indicators.
- Multi-meter to measure the voltage
- RT4-433,9 transmitter with HT12E encoder
- RR3-433.9 receiver with HT-12D

RT4-433.9 transmitter wired with the HT-12E encoder as shown in Figure (6-2). Specifying the address of the transmitter and receiver to be the same through the 8 bit address lines at encoding/decoding chips. Putting pin 4 of the transmitter connected to the antenna. Changing the wire in the data line from 0 to 1 and vice versa the output in the receiver side will change

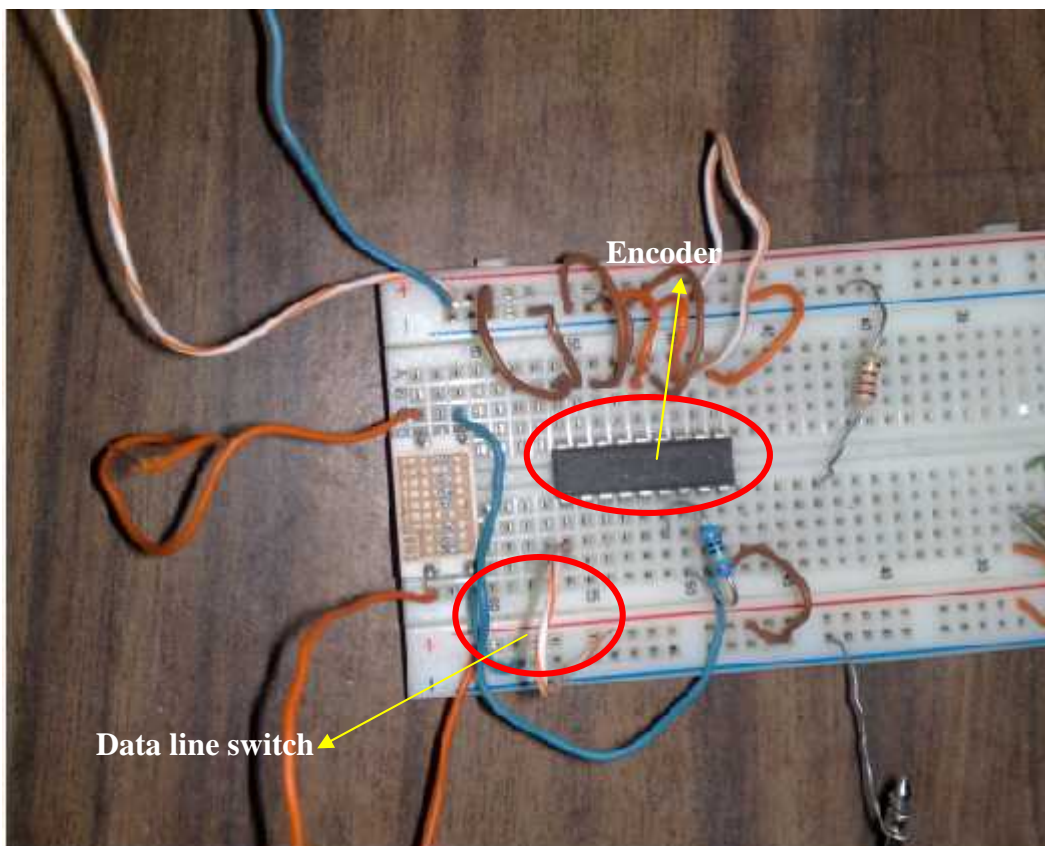


Figure (6-2) RT4-433.9 transmitter

RR3-433.9 receiver wired with the HT-12D decoder as shown in figure (6-3). Putting pin 3 of the receiver connected to the antenna the address must be the same as transmitter address.

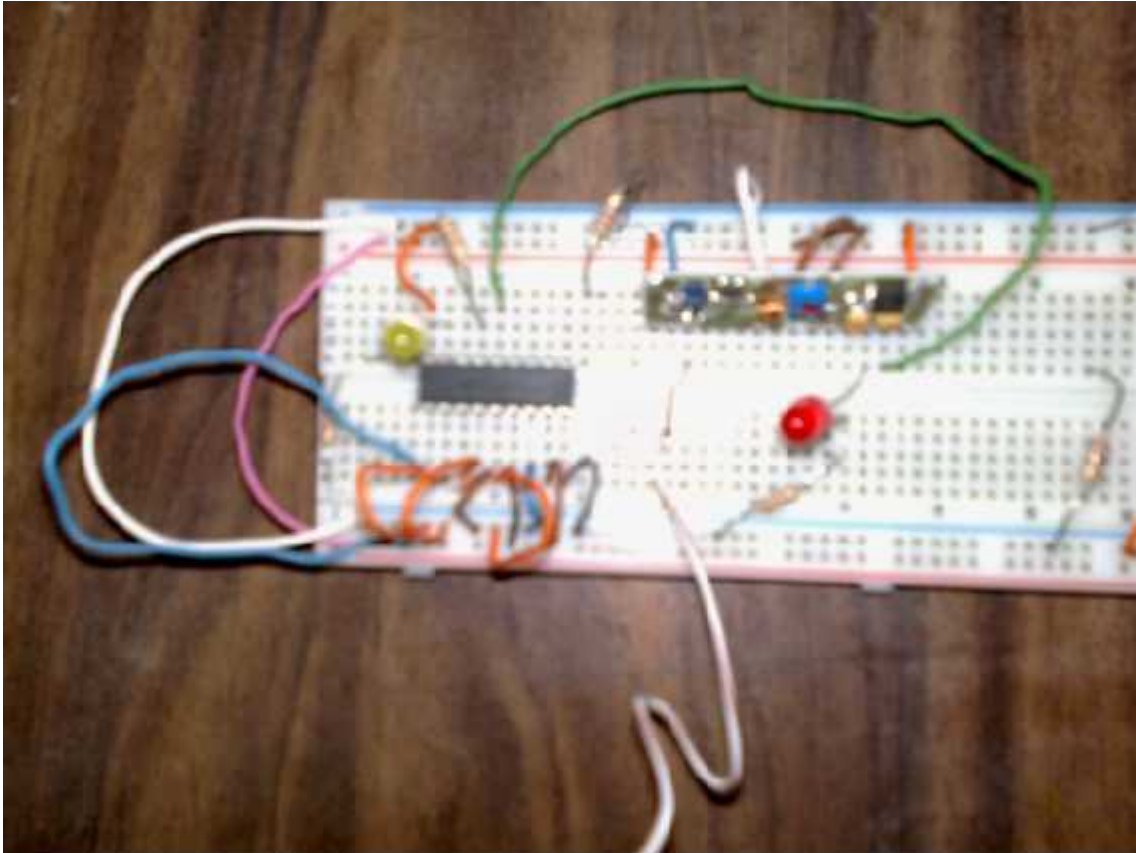


Figure (6-3) RR3-433.9 receiver

In order to test this circuit four bit data was sent at the data lines in the encoder to ensure that the data at the receiving side LEDs lights up on the 4 bit data on the decoder.

Now turn on the transmitter circuit. The output of the data pins depends on whether the signal being transmitted. The signal itself can be seen by attaching the

Oscilloscope to pin 17 of the encoder. The wave form shown in figure (6-4) was taken from the transmitter test out.

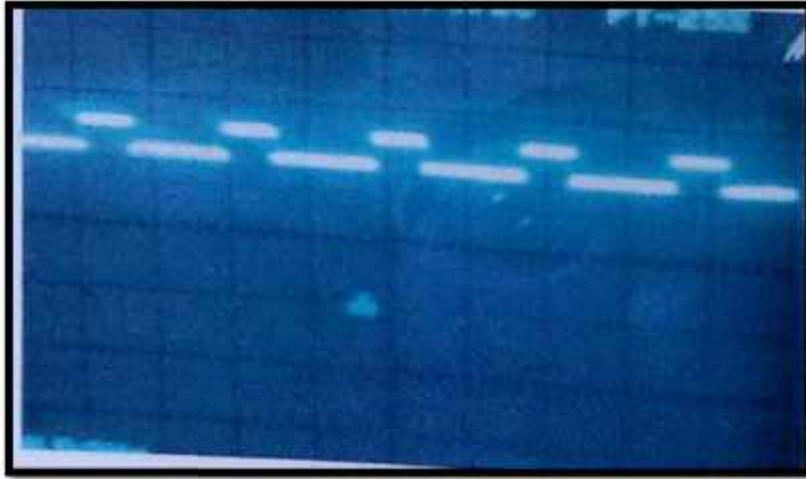


Figure (6-4) RF-transmitter signal

Here we connect the receiver circuit, the signal can be seen by attaching the oscilloscope to pin 14 of the decoder as shown in figure (6-5). This signal shows how the decoding circuit checks the incoming address in order to specify accepting or rejecting data, here the sent address was 00000000.



Figure (6-5) RF Receiver signal

2. Remote station testing

The remote station also built around PIC18F4550 and uses the wireless communication these parts were tested in the previous part. Here we will continue in testing the other parts of the RS as follows:

- Temperature sensor testing

Temperature sensor circuit was built as shown in figure (6-6), the output of temperature sensor forwarded to the amplifier, and then the output of the amplifier goes to the microcontroller. The potentiometer used to configure the amplifier (rest amplifier).

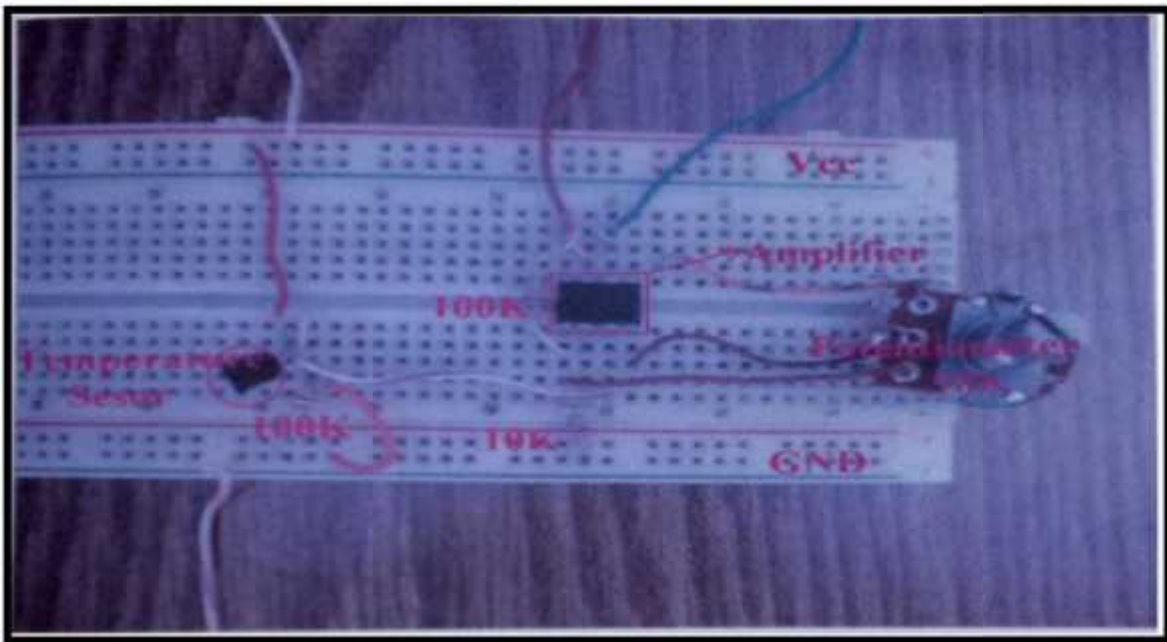


Figure (6-6) temperature sensor circuit

The previous circuit was tested and the results were gathered in table (6-1), depending on using the amplifier the table shows the values.

Temperature degree in C	Voltage
60	5.9
40	4
20	2
15	1.4
10	0.9
8	0.8
5	0.7

Table (6-1) temperature degree various voltage

The voltage obtained from the amplifier passed to the analog-to-digital (A/D) port in the microcontroller, where reading values calculated depending on the following rules:

- The (A/D) converts an analog input signal to corresponding 10-bit digital number as shown in figure (6-7).
- 10-bit digital number can be read as integer number (N)
- N is converted to its corresponding voltage value using the following equation :

$$N = V_{in} * 2^{10} / (V_{ref+} + V_{ref-})$$

Where

$$V_{ref-} = 0\text{Volt and } V_{ref+} = 5\text{Volt}$$

For example if the temperature is 25 C, then $N = 1024/(5-0) * 2.5 = 512$

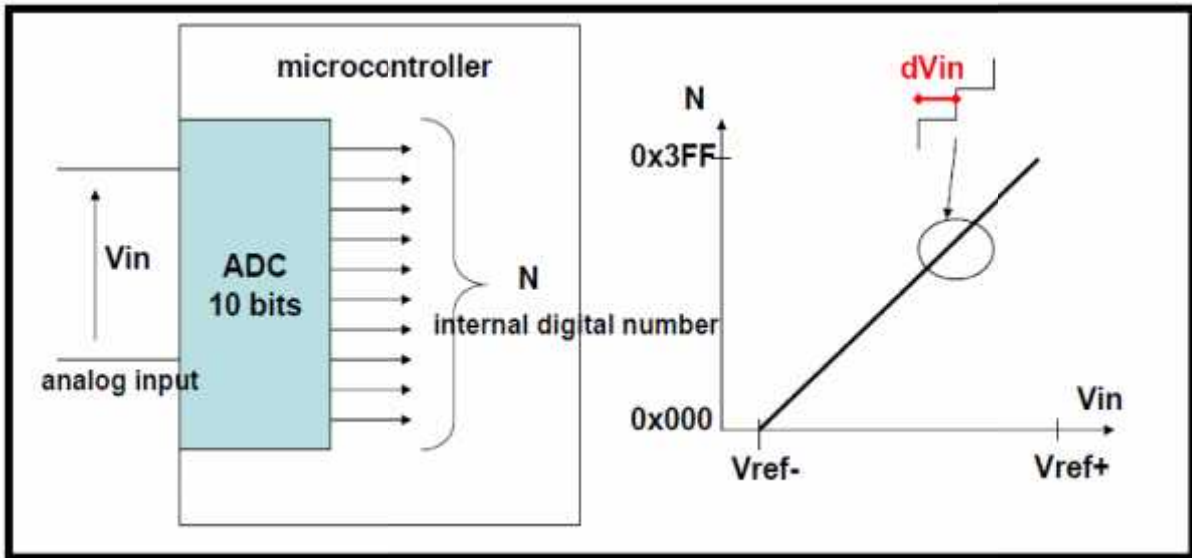


Figure (6-7) Analog-to-digital convertor modules

The following code was written to read the value of temperature sensor its perform 5 acquisitions from 2 channels.

```
void main(void)
{
    int i;
    short N;
    //configure adc
    OpenADC(ADC_FOSC_64 & ADC_RIGHT_JUST & ADC_2_TAD,
    ADC_INT_OFF & ADC_REF_VDD_VSS,00);
    for(i=0;i<5;i++)
    {
```

```
SetChanADC(ADC_CH0); // Channel 0

ConvertADC();

while (BusyADC() == 1);

N = ReadADC();

SetChanADC(ADC_CH1); // Channel 1

ConvertADC();

while (BusyADC() == 1);

N = ReadADC();

}

CloseADC();

}
```

- **Humidity sensing circuit testing**

As we mentioned before the humidity is relative to the frequency, the circuit designed for the humidity outputs a frequency. However, it is a clock signal that is received at the input pin of the PIC. Because there are edges in this signal, a starting point can be established and a time frame can be defined allowing a measure with respect to time. Therefore, measuring a time lapse between two either falling or rising edges will give the period of a clock signal frequency. The following figure shows the humidity sensing circuit

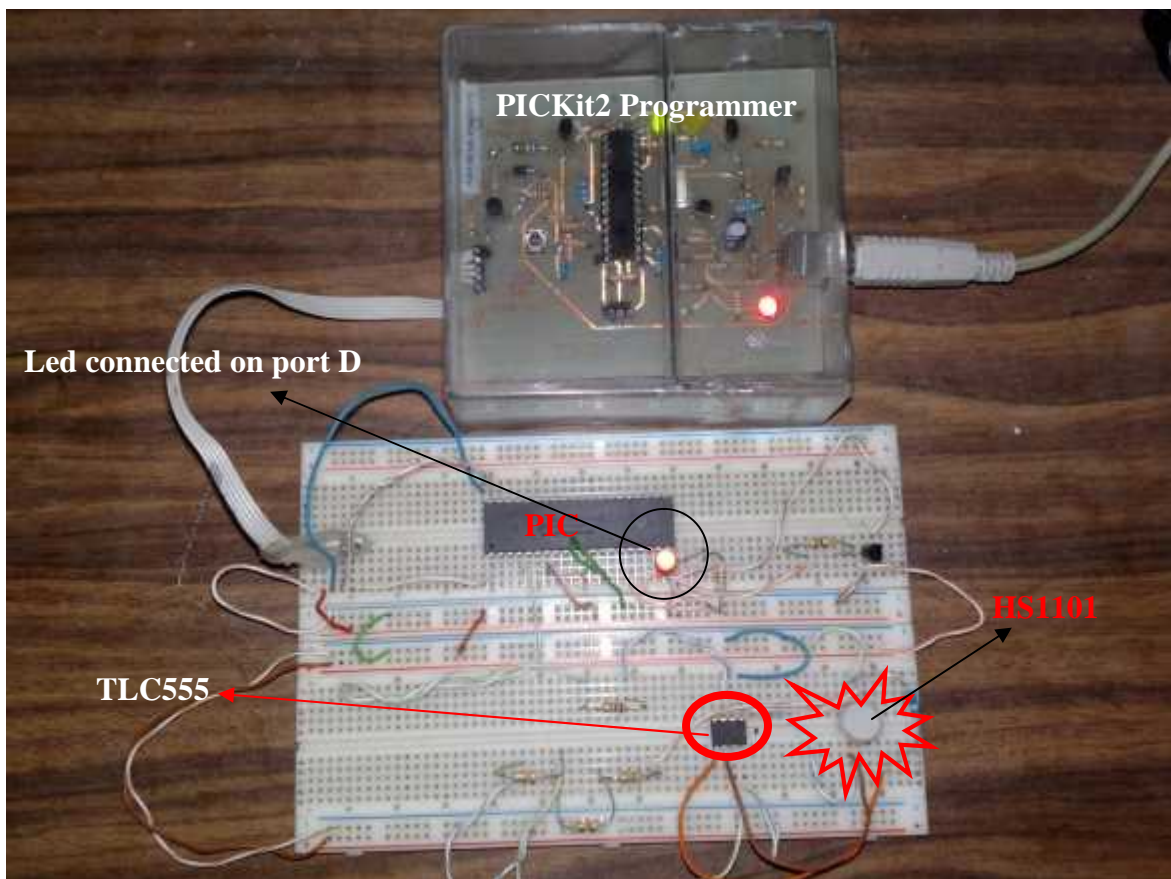


Figure (6-8) humidity sensing circuit

The following program were written to test the HS1101 circuit, when applying this code to the PIC it will start flashing the led according to it.

```
#include <p18f4620.h>
#include <capture.h>
#include <timers.h>
#include <stdlib.h>

long pulse,i;
long rise, fall;

void main( void )
{

// Configure Capture1

OpenCapture1(C1_EVERY_RISE_EDGE & CAPTURE_INT_OFF);
OpenCapture2(C2_EVERY_FALL_EDGE & CAPTURE_INT_OFF);

// Configure Timer1
OpenTimer1(TIMER_INT_OFF & T1_SOURCE_INT & T1_SOURCE_CCP & T1_PS_1_1 &
T1_16BIT_RW);
TRISD=0;
while(1)
{
rise = ReadCapture1();
fall = ReadCapture2();
pulse=rise-fall;
if (pulse<0)
pulse=pulse*(-1);
for (i=0; i<pulse;i++)
{
PORTD = 0x1;
PORTD = 0x0;
}
for (i=0; i<pulse;i++)
```

```
{
```

```
PORTD = 0x0;}}
```

6.3 Integrated testing (software testing)

In this section we will test the overall system including circuit on Bs and the software implemented in server and PIC.

1. Base station with the Serial Port Connection testing:

In order to test base station it was connected to the serial port (COM1) of server according to the following circuit in figure (6-9).

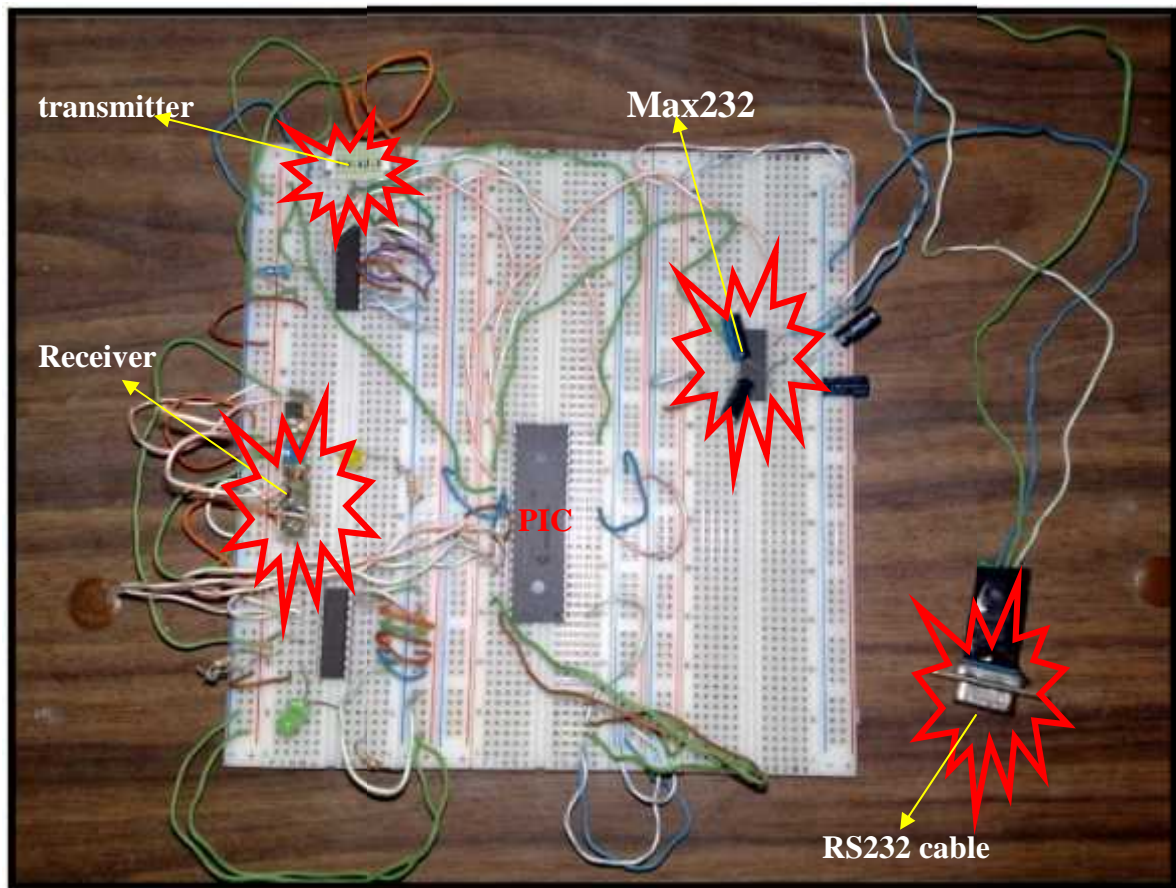


Figure (6-9) Base station with serial port connection

To test BS and serial port connection we used the HyperTerminal program in order to verify its operation. The following steps demonstrate how BS and serial port was tested.

1. Establish a hyper terminal connection with COM1

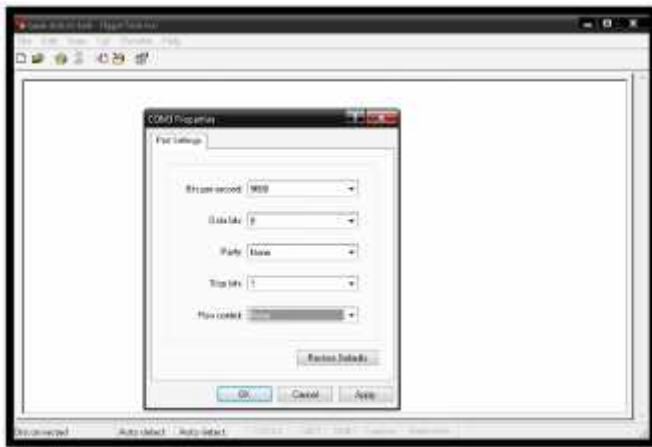
In this step a hyper terminal connection with COM1 should be established, with the same default serial port configurations of BS .First, start the hyper terminal and make a new connection as shown in the steps in figure (6-10) and enter the name of connection.



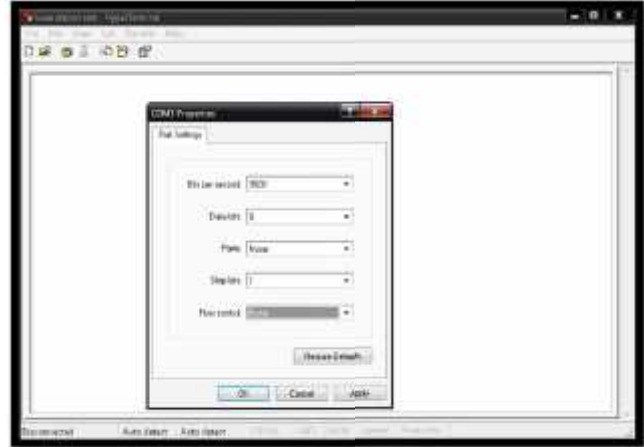
(1)



(2)



(3)



(4)

Figure (6-10) hyper terminal new connection

2. Transmit from BS to the HyperTerminal

When the Bs is powered on, it sends the “OK” message which can be seen in the hyper terminal connection, figure (6-11).

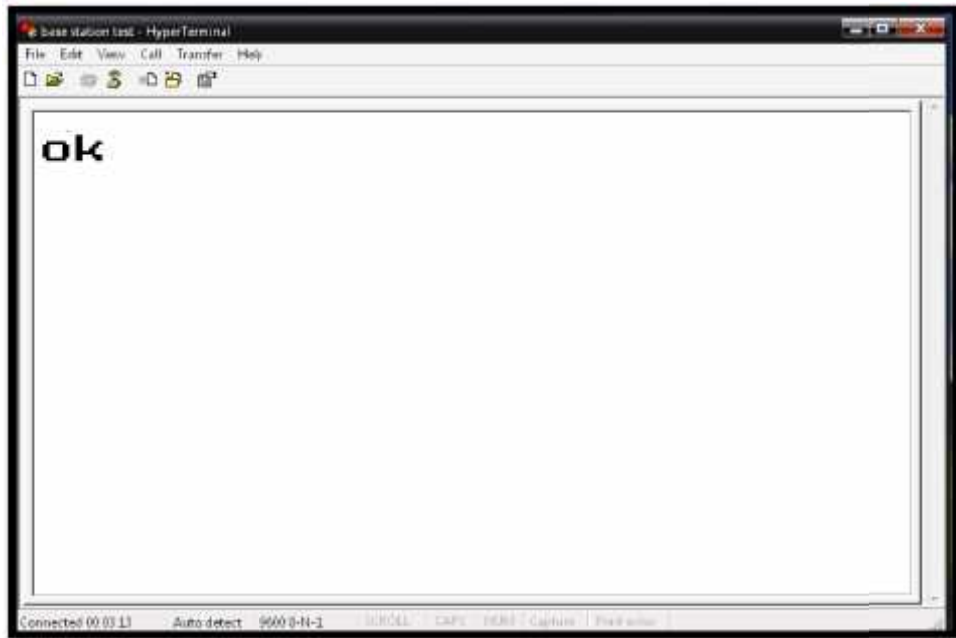


Figure (6-11): OK message from Bs to hyper terminal

The following code written on the base station to test the serial connection with the HyperTerminal.

```
#include<delays.h>
#include<p18f4550.h>
#include<usart.h>
void main(void)
{
char reception ;
```



```

unsigned int spbrg;

int i;

char u;

ADCON1=0x00;

OSCCON=126;

spbrg = 12 ;

OpenUSART(USART_TX_INT_OFF & USART_RX_INT_OFF &
USART_ASYNCH_MODE & USART_EIGHT_BIT & USART_CONT_RX &
USART_BRGH_LOW,spbrg);

while(BusyUSART()==1);

u = 'ok';

putcUSART(u);

}

CloseUSART();

Delay10KTCYx(100);

}

```

2. Base Station Vs java application (intermediate program) testing

Here we establish the connection between the base station and the server also we connect the java application with the database; we checked the transmission and reception between the database and the base station through the java application.

In order to get the remote station data and transfer the user command, the connection between the database and the base station is made, according to the values in

the com table the connection application will decide to write run command and read data or write the sleep command on the serial port.

First the write sleep command to the base station by setting s in the com table at the database as the figure (6-12) shows.

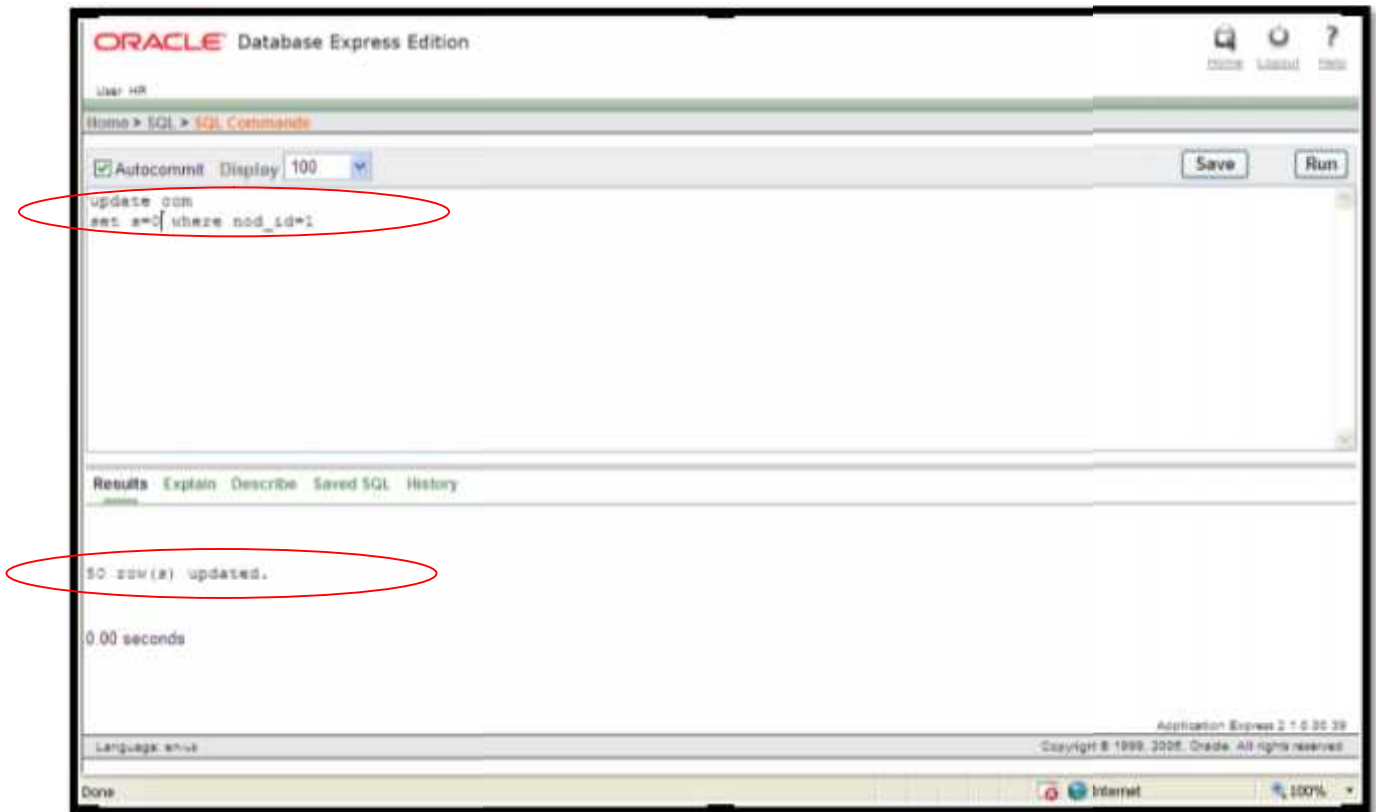


Figure (6-12) write sleep on command table

The java application will response to this change in the S filed of the com table in the database by writing sleep command (packet) that represent the desired node to the base station, Bs will transmit the command to the desired node as we will see later.

Figure (6-13) shows the java application response to sleep command:

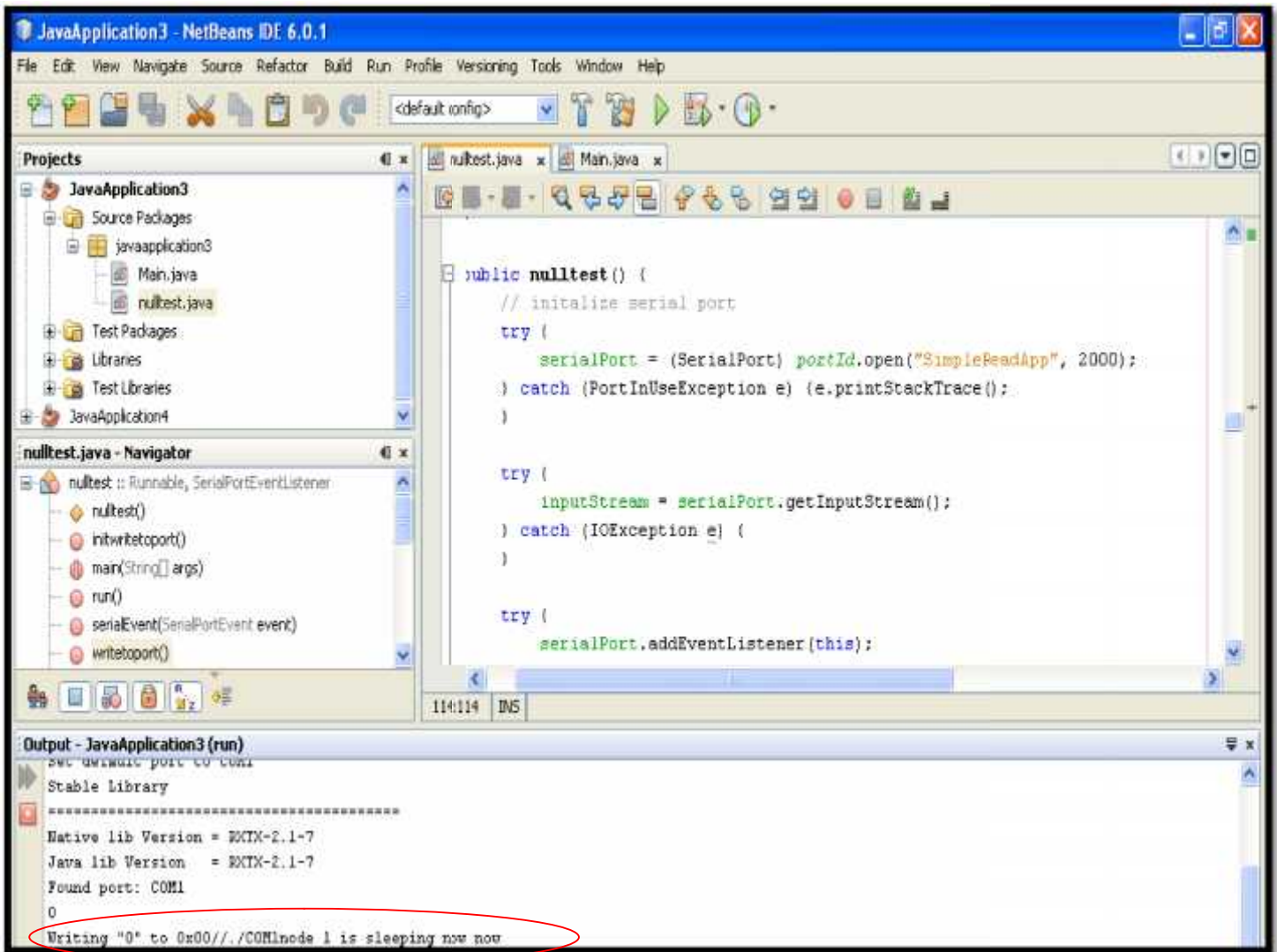


Figure (6-13) writing sleep command to BS

Also the application will response to the read command (r = 1 in com table)

- By writing run command to the base station including the desired node.
- Wait to get the node data Temperature, humidity and voltage.

- Store data on the WSN table.

Figure (6-14) shows how the application response to run command:

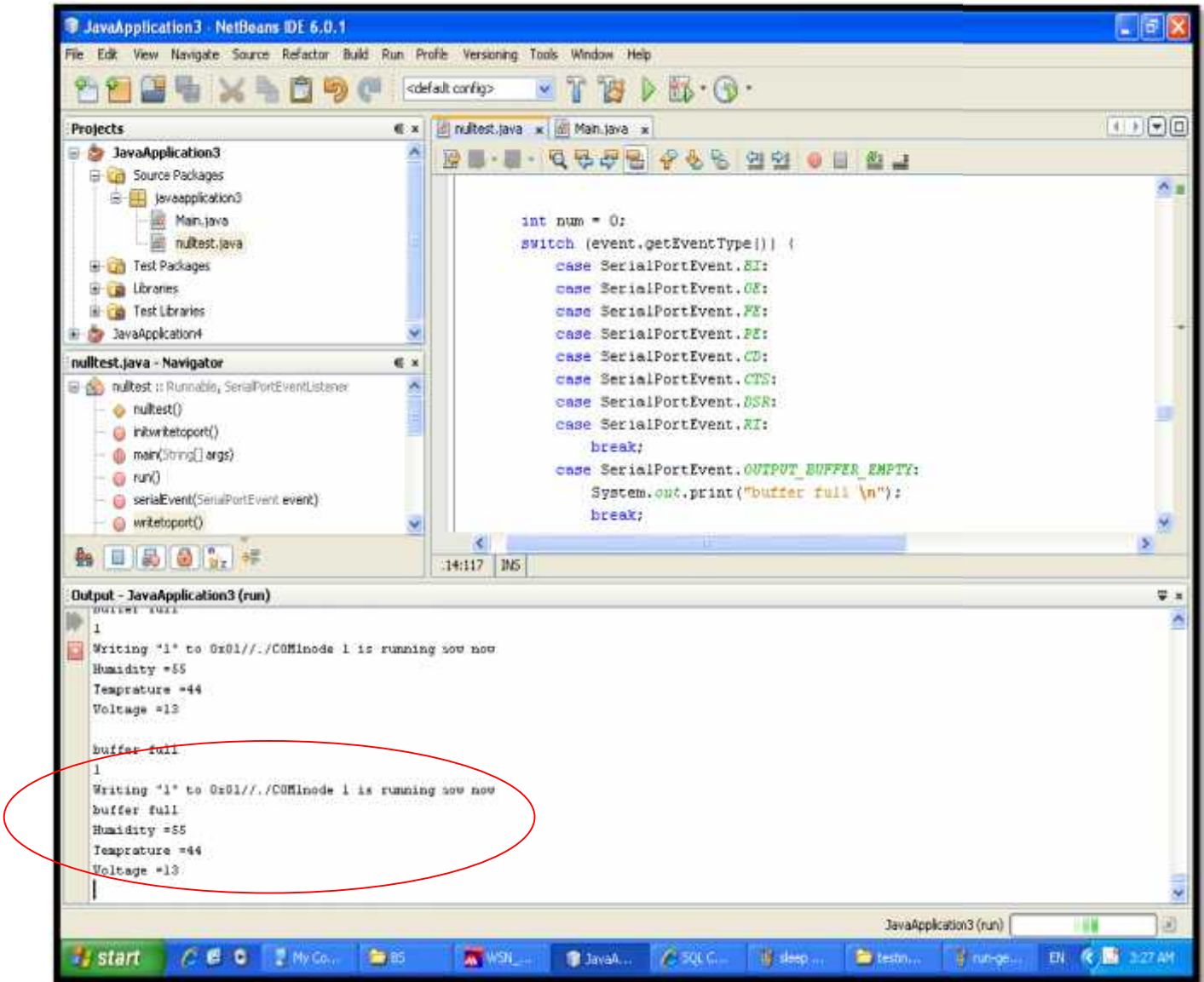


Figure (6-14) responding to run command

The following figure (6-15) shows the stored data in WSN table by the java application, in which we can note that incoming values from serial port are stored in the WSN table directly with its arrival time

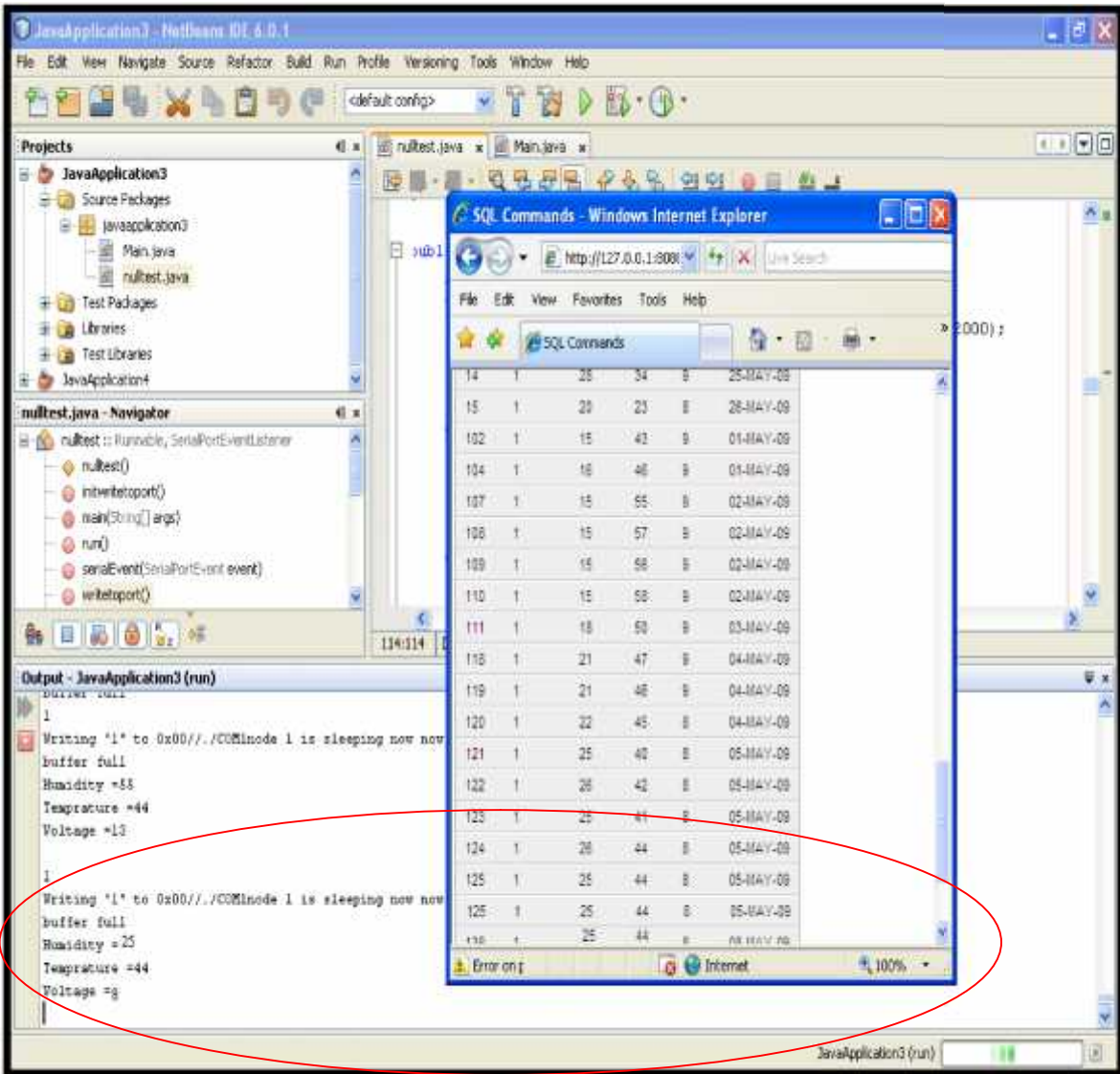


Figure (6-15) read data and store it in WSN table

Remote station, Base and the web application Station testing:

In this part the remote station integrated with base station as figure (6-16), as we see before the connection between the server and the base station were established, here we will apply the connection with the remote station from the web application as figure (6-17) shows the admin user select node number 1 and clicked run command the following sequence of operations will happen:

- Admin user click run command
- R will be set in com table ($R = 1$)
- Java application will get this change of R on the com table
- Java application select the node id and send the desired packet to the base station
- Base station will accept the command and prepare the desired packet for the required node.
- Base station will transmit the packet to the RS
- Base station will wait the data ready message from remote station
- When data ready received base station will start getting the data from RS T,H and Voltage.
- Base station will transmit the values to the data base(WSN table) through the java application
- The web application will keep reading from WSN table and visualize the data from it.

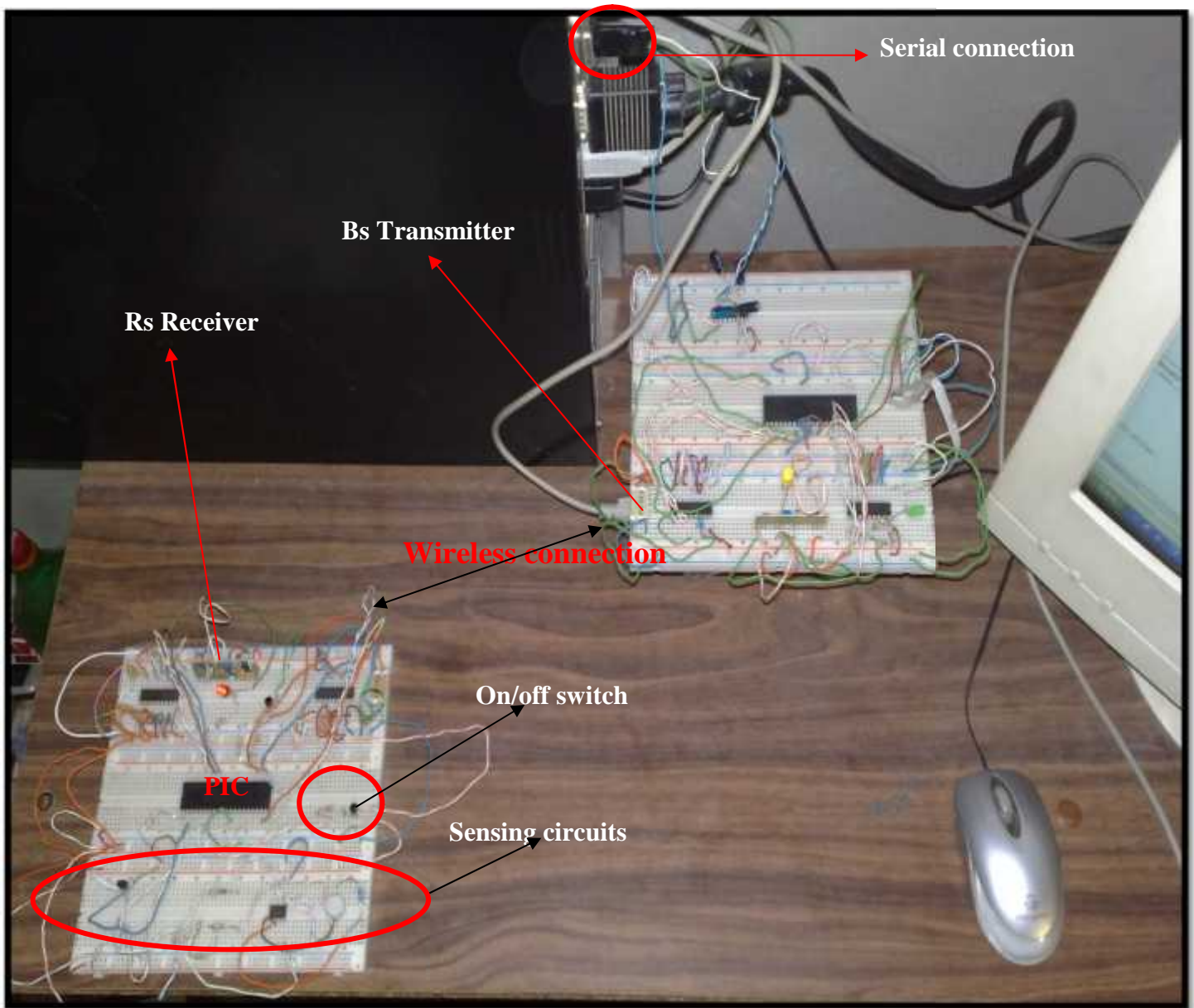


Figure (6-16) Remote station with base station

In figure (6-17) the admin user click on run button at the web page then the command will transfer to the remote station, and the data will start flowing to the data base.

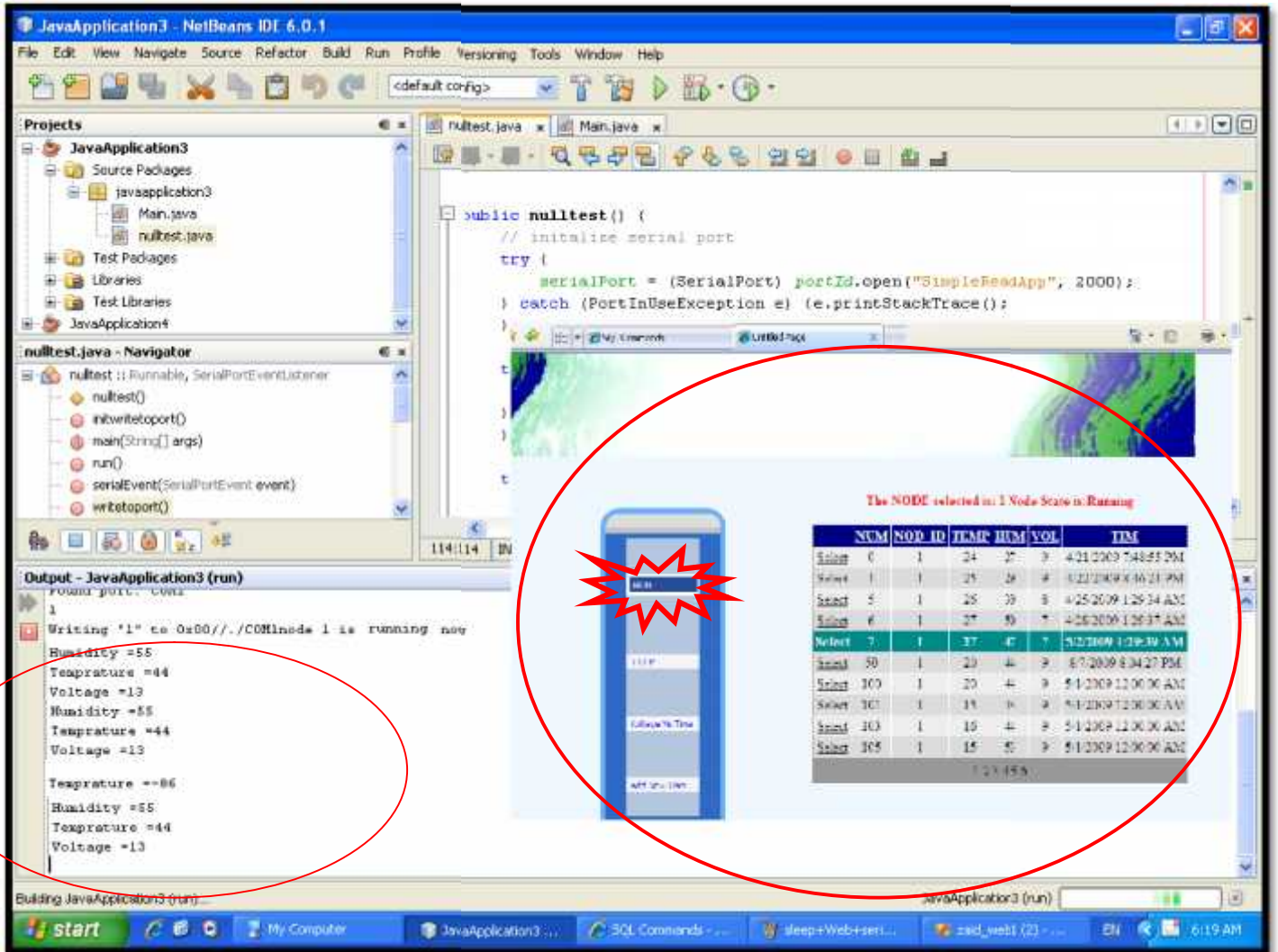


Figure 6-17 user command transfer to RS

6.4 Summary

At the end of this chapter, we have talked about system implementation and testing methods we used to verify system operation, supplying it with demonstrating figures and tables.

**Conclusions, Problems, and
Future Work**

7.1 Overview

7.2 Conclusions

7.3 Problems

7.4 Future Work

7.1 Overview

This chapter will address the learning outcomes of this project. It will also list the problems faced us in accomplishing the system, in addition, future work will be proposed.

7.2 Conclusions

In this project we have learned different approaches and experiences in developing projects and in the way of thinking to solve problems. Many conclusions and outcomes can be stated here, the most important ones are described as follows:

- By the end of this project, we have finished designing, implementing and testing a wireless sensor network that can be used to monitor surrounded environment.
- Applying theoretical information on practical applications is experienced. This include:
 - 1- How to program PIC.
 - 2- The use of wireless technology –RF technology.
- Team working is very useful; working is balanced on team members and so time and efforts will be saved. And we have concluded that group thinking is the best way in solving problems that faces projects, in which many points of views can be considered.

7.3 Problems

Problems are natural things, especially when one develops his first project, but solving problems is a success. Here are the most important problems which raised during system development.

- Project components aren't available at the start of semester, and the process of buying the components consumed much time.

- Damaging in some devices because of wrong connections, the PIC and RF modules were damaged so were bought new ones.

- when the RF module is connected to the circuit during the setup phase the values gotten from the voltmeter was unacceptable for the project (2.2 v – 3.2 v), so we think in many solutions and spent many time in solving this problem, the solution was in using the same power supply for the whole circuit then dived the power on each part as required using voltage regulator.

- When testing system at the first time, data was sent at a very high rate, this caused the response of server to be late; the problem is solved by adding a delay before sending each packet.

7.4 Future Work

Many ideas and applications can be developed upon this project. Here are some suggested ideas:

- Using the remote station to monitor more complex parameters
- Design a multi hope routing algorithm that can detect the distance between Remote stations and base station in order to have a better power management.
- Develop the system to have more than one base station (multi sub networks).

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[26] Appendix A HT12E Data sheet

[27] Appendix A HT12D Data sheet

[28] Appendix A HS1101 Data sheet

APPENDICES

Appendix A: Project Units' Data Sheets

Appendix B: Source Code

Appendix C: Final Remote and base station