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Addis Ababa Institute of Technology**

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Designing Low-Cost Radio Frequency Based In-Patient Monitoring System for Low Resource Settings

By:

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**A thesis submitted in partial fulfillment of the requirements for the Degree of Master of
Science in Biomedical Engineering**

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Addis Ababa, Ethiopia, September 2020

Declaration

I, the undersigned, declare that this thesis is my original work. It has never been presented for a degree in any other institution and that all sources of materials used in it have been duly acknowledged.

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This MSC thesis has been submitted for examination with my approval as an advisor.

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Certificate of Examination

This is to certify that the thesis prepared by Selamawit Wondie entitled: *Designing Low-Cost Radio Frequency Based In-Patient Monitoring System for Low Resource Settings* submitted in partial fulfillment of the requirements for the degree of Master of Science in Biomedical Engineering (Bioinstrumentation and Imaging stream) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Patients in critical condition are not well attended due to lack of adequate number of medical professionals and insufficient number of patient monitor machine in recovery room. This needs a system which resolves gap and improve continuous patient's follow-up. The objective of this thesis is to design a low-cost radio frequency based central in-patient monitoring system to facilitate timely decision making for critical patients in recovery rooms in low resource setting hospitals. Also to compare the cost with the existing networked centrally managed patient monitoring system.

This was done in three hospitals of Addis Ababa namely, Yekatit 12 Hospital Medical College, Zewditu Memorial Hospital and St. Paul Millennium Medical College were selected purposively. Data was collected using the structured interview guide and key informant interview was used to collect information from administrative provost, anesthesia case team coordinators and nurse of these hospital. Additionally Observation method was used to explore the situation in the recovery rooms of the hospital. Literature review was done to better understand the problem and identify an alternative solution and design.

Radio Frequency (RF) based in-patient monitoring system was designed to transmit and receive the patient vital physiological signals collected from multiple sensors to a central room. The system basically contains blood pressure sensor, temperature sensor and heartbeat sensor in order to measure the vital signals and a microcontroller is used for processing the signal. The processed signal will be transmitted to the central microcontroller which is placed in the central monitoring room using radio frequency transceiver module. The microcontroller compares the value to know whether the received value is within or out of the expected physiological range. Finally, the result is displayed using a Liquid Crystal Display (LCD) screen that is connected to the central microcontroller. The vital signal value will be interpreted and displayed in the central microcontroller room to alarm health care workers. Moreover, cost comparison was made with the networked centrally managed patient monitoring system and prototype was produced. In conclusion, it was possible to design and produce prototype a low cost radio frequency based central in-patient monitoring system with a cheaper cost.

Keywords: Patient Monitor, Microcontroller, RF, Vital Signs, Trans-receiver.

Acknowledgement

Before everything, I would like to give thanks to God and his Mother Saint Marry for helping me to reach this time. Next, I wish to sincerely thank all those who have contributed in one way or another to this study. Words can only inadequately express my deep gratitude to my advisor Dr. Balakrishnan even if he is not alive now. His insightful suggestions, his patience, and his concern for teaching new things to me are not forgettable throughout life beyond this thesis.

I also would like to thank my advisor Dr. Masreshaw for supporting me in every possible way since the beginning of my research. I wish to express my sincere gratitude to my supportive guide Lelisa who supports me in every possible way in every aspect of the research. Without his guidance and encouragement, my research would have never come out in the present form. I need to say thanks to my Brother Dr. Tamiru Wondie, for his critical and careful reading of my writing has saved me from a lot of errors. I wish to express heartfelt love, appreciation, and thanks to my husband for his endless supportiveness to finish my thesis. Finally, I need to thank my friend Yesuneh who supports me from the beginning to the ending of this thesis and all my family who give me morals to finish this work.

Acronyms

AC	Alternative Current
ADC	Analog to Digital Converter
BP	Blood Pressure
BR	Baud Rate
CPU	Central Processing Unit
DAC	Digital to Analog Converter
EEPROM	Electrically Erasable Programmable Read Only Memory
FMOH	Federal Ministry of Health
GND	Ground
GPIO	General-Purpose Input/ Output
GSM	Global System for Mobile Communication
GTP	Growth and Transformation Plan
HSTP	Health Sector Transformation Plan
HP-LP	High Pass-Low Pass
IC	Integrated Circuit
ICU	Intensive Care Unit
ID	Identification
IDE	Integrated Development Environment
IR	Information Revolution
KII	Key Informant Indicator
LCD	Liquid Crystal Display
PIC	Peripheral Interface Controller
PCB	Printed Circuit Board
OR	Operation Room
PC	Personal Computer

PR	Pulse Rate
PWM	Pulse Width Modulation
RAM	Random Access Memory
RF	Radio Frequency
ROM	Read-Only Memory
RR	Respiration Rate
RMS	Root Mean Square
RX	Receiver
SMS	Short Message Service
SPI	Serial Peripheral Interface
T ⁰	Temperature
TTL	Transistor-Transistor Logic
TX	Transmitter
UART	Universal Asynchronous Receiver Transmitter
USART	Universal Synchronous/Asynchronous Receiver Transmitter
USB	Universal Serial Bus
XCTU	X bee Configuration & Test Utility

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Chapter One

1. Introduction

1.1. Background

Technology and innovation in biomedical engineering have solved most health and health related problem in the world. Use of patient monitoring technology have improved health outcomes of the patient. Developed counties have used this patient monitor system since long and have improved the patient out come and life expectancy. The use of this technologies is limited in the developing countries for many reasons low access, cost, capacity, training etc. Ethiopian experience in the use of this technology is limited in Addis Ababa and few urban hospitals. In low resource settings, the experience in the use of central patient monitoring system is almost nil [1].

From my internship experience in Yekatit 12 Hospital Medical College, I have observed that there are high number of patients which is beyond the capacity of the hospital with small number of patient monitoring machines in the recovery rooms. The number of patient monitors is not proportional to the number of patients in the recovery room and ICU (Intensive care unit). As a result, the hospital management is often forced to transfer acutely ill but stable patients early to different wards to utilize the limited number of patient monitors for very critical patients. In their day to day activity, nurses are recording the vital signs of the patients on the chart in irregular time interval. However, patients with critical conditions require continues monitoring and follow-up which leads us to see a mechanism to have continual information about patients.

According to multiple literatures, setting up a recovery room demand comprehensive understanding of the context of the institution and the context of the country. Depending on the nature of the country, whether they have high or low economic status, the availability of equipment and the number of healthcare personnel and readiness of the infrastructure would matter how to set a standard regarding the recovery room. Patients after surgery could be transferred to recovery room in three levels depending on their critical status. These are high, medium and low critical care demanding patients.

In critical case, it demands a high level infrastructure readiness as the patients are critically ill or in coma, which needs a mechanical ventilation. This level requires 2 or 3 nurses to care for a single

patient as a standard. On the other hand, in countries with limited resource, where there is low socioeconomic status, shortage of human resource, limited infrastructure and medical equipment's this standard could not be possible to meet. Hence, one health care worker could care up to 5 critical patients in the recovery room. Generally, the standard of care in the recovery room, regarding the nurse to patient ratio could vary depending on the availability of resource which could range from 2 nurses for a single patient to 1 nurse for 5 patients [2].

One of the focus area in the Ethiopian Health Sector Transformation Plan (HSTP: 2016-2020) improving quality of patient care and it also encourage innovation and technology in health science. Accordingly, this research is in line with the Ethiopian health transformation plan and could contribute to improve the quality of patient care through the use of innovation [3, 4]. Designing Low Cost Radio Frequency Based In-Patient Monitoring system will have paramount importance in the recovery room to improve the quality of care of the patient.

1.2. Problem Statement

Public hospitals in Ethiopia have been providing health care services for most of the population of the country. Those hospitals are mostly categorized as low resource settings and their service delivery is unsatisfactory [5]. Although these public hospitals are giving healthcare services for most of the population of the country, their financial status are low for employment of adequate number of healthcare staffs. A range of 2 nurses for a single patient to 1 nurse for 5 patients could be variable to set a standard for a recovery room depending on economic level of the hospitals and the patient condition in recovery room i.e. 1:1 for the sickest patient, 1:2 or 1:3 for patients who are acutely ill but stable [2]. The situation in Ethiopia looks different and a range of 3 to 5 patients are often cared by one general nurse. Thus, in most of government hospitals the recovery rooms are attended by few nurses assigned. Moreover, the number of functional patient monitors is not enough to monitor all critical patients. For this reason, there is too much burden on nurses in the hospitals that would ultimately lower the quality of the healthcare provision. That means it is very difficult for the nurse to treat and follow up the patients effectively and timely.

Sometimes in the absence of a caretaker, the health of the patient may become critical. The urgency of the decision in such emergency condition needs timely, reliable and real-time information. This thesis proposed low-cost real-time patient monitoring system for critical patients in recovery room.

The system continuously records vital physiological parameters such as heartbeat, blood pressure, and body temperature; check the severity based on the expected precondition set. It then reports/transmits continuously to the central nurse's room using RF technology so that; nurses can take the necessary action.

1.3. Objective

1.3.1. General Objective

The general objective of this paper was to design a multi-parameter sensing system for monitoring vital physiological signals of a critical patient and transmit patient status to central room through wireless media.

1.3.2. Specific Objectives

- Design Radio Frequency based in-patient monitoring system for low resource setting hospitals.
- Develop a prototype for the designed system of in-patient monitoring.
- To compare the cost of this RF based patient monitoring system with networked centrally managed patient monitoring system.

1.4. Significance

Designing wireless patient monitoring system in critical patients is significant to improve early identification of problems and support decision making by nurses and physicians in low resource settings public hospitals. It can significantly improve the health services and reduce unexpected deaths. This system also supports nurses to make a continuous assessment of the physiological status of the patient. In addition, the system shows the progress of new events like improvement or deterioration of the health condition of the patient. That can help the physician make the right clinical decision such as ward transfer, discharge etc.

1.5. Scope of the Research

The scope of this thesis is to design and prototype low cost RF-based in-patient monitoring system for low-resource setting and comparing cost of designed system with networked centrally managed patient monitoring system.

1.6. **Organization of the Thesis**

The thesis is organized into six chapters. Chapter one provides background information about the study, problem statement, objectives, significance of the paper and scope of the study. Chapter two presents a literature review on different patient monitoring systems with different tools and mechanisms of monitoring approaches. Chapter three discusses all hardware components and their working principles. Also, software and compilers used are discussed in this chapter. Chapter four presents system design, including all component connections, working flow charts, cost comparison of designed RF based patient monitoring system with networked centrally managed patient monitoring system. Chapter five presents and discusses the results obtained. Chapter six concludes the thesis work and suggests some recommendations.

Chapter Two

2. Literature Review

A patient monitoring system is the most needed and essential device for monitoring the patient vital signs. This is because the medical professional will not follow patients continuously all the time. In line with this, different research's and journals state about different microelectronic types of equipment for monitoring patients in real-time.

Ch.Sandeep Kumar Subudhi, *et al.* [6] Designed the system to monitor the human vital signs and tracking the patient location. The values of vital signs detected in the working environment sensed by using respective sensors. The sensor information will be transmitted from the patient unit to the main controller unit through multiplexer with the help of Zigbee communication system which has connection with both transmitter and receiver microcontroller units. The main controller unit will send sensed data using Global System for Mobile (GSM) module and the location of that patient through Global Positioning System (GPS) Module to the observer/doctor mobile phone.

To inform patient location the system uses GPS and GSM module to send data to observer mobile phone, but these exceeds additional cost for low resource setting hospitals. And it also exposes patient information security.

Purnima et al. and K. Navyal, et al. [7, 8] Designed patient monitoring system which enable the doctor to monitor patient's health parameter (temperature, heartbeat, Electrocardiogram (ECG),etc) in real time. The system starts measuring signals from the patient by using different physiological sensors and feed to central processing microcontroller, which monitor and control all peripheral device connected in the system. It uses ZigBee Wireless communication to transfer signal from controller unit to monitoring PC. It has also direct connection to GSM module to inform the Doctor on his/her mobile phone.

The way of information provision is to the doctor's mobile phone and it uses GSM module for transfer media. These way is not recommended as fast or alarm way of decision making for critical patients.

Yadav Satyendra Satyanarayan, *et al.* [9] Designed real time patient monitoring with various sensors to continuously taking the measurement of the patient's heartbeat, body temperature etc. Microcontroller getting the data from these sensors, it compares according to their abnormal limits

then generates the alert signals and messages. The information about patient's health is provided within every prescribed interval of time to the doctor via wireless GSM modem and display similar information to the LCD as well. For the case if doctor has not received the message, the system will give a miss call to the doctor's cell phone so that the doctor's will understand he will check message inbox.

The information transferred to the doctor with wireless GSM modem but there will be information loss and this is not preferable for critical patient's follow-up.

Mohammed Fezari et al. and Sharief F. Babiker, et al. [10, 11] Designed to measure only heartbeat (pulse count). Heart rate of the patient was measured from the thumb finger using Infrared Device sensor. It transfers the signals to the microcontroller through the amplifier and filter circuit. Then the controller checks whether the heart rate is normal or not and text information will be sent to the doctor's mobile phone in case of abnormal condition. In addition, patient heart rate status will be displayed. The system uses keypad as an input to insert doctor's mobile number on duty to get text information.

Using GSM module is not compulsory for its timely information delivery for care takers. And its not affordable for low resource setting hospitals.

Nisha Singh, *et al.* [12] Designed patient monitoring system as the physical states and movement parameters were acquired with sensors and then the signal was being transferred to signal conditioning unit to be amplified and filtered. Analog to Digital Convertor (ADC) transforms the analogue signal to digital signal and the main function of micro controller is to integrate the data with defined frame format. Lastly, the transceiver communication module sends it to remote monitoring system or display. IEEE 802.15.4 standard, low rate wireless personal area network Transmitter Receiver (TX/RX) pair operating at 315 MHz. is selected as the wireless transmission standard because of its short-range.

Hung Cao, *et al.* [13] Designed infant monitoring system. The system contains sensor circuit which has a two stage amplifier. The first stage is for buffering and follows by a differential amplifier. An analog multiplexer or AND GATE, depending on applications, multiplexes the signals in the time domain. For simple monitoring purpose AND GATE provides the functionality of an alarm signal. The Identification (ID) of the infant has been sent out along with the alarm if the output from the sensors are lower than the threshold. A comparator for each sensor is implemented after the two

stage amplifier and the threshold is adjustable for different environmental condition. In addition, the alarm signal, we multiplex and transmit all sensor signals along with the infant's ID for diagnosis purposes. At the receiver side an alarm will be triggered as soon as an alarm is sent by the identified transmitter using RFID while the server starts to record the data.

In our case, we proposed to design low cost Radio Frequency based in-patient monitoring system for low resource setting. Fetch vital information of critical patients and transfer it to the nurse's in central room. Three sensors, which are measuring heart rate, blood pressure and temperature, are attached to the patient body will collect the information and transfer the value to the microcontroller. The system analyzes whether or not the measured or sensed physiological signals like heart rate, blood pressure and temperature deviates from the expected normal range and send this value to the central monitoring room by using radio frequency transceiver with a respective patient tag to display on LCD.

The advantages of using radio frequency in our proposed system includes, it covers a large area, to give 24-hour reliable service for the in-patients without any interruption like lack of network, no need to have a cell phone and do not need to consider the signal blockage outside the treatment hospital.

Chapter Three

3. Methods and Materials

3.1. Methods

Qualitative research method is used to gain and understand reasons, opinions and trends for service delivery of different low resource setting hospitals. Based on purposive sampling from 12 public hospitals available in Addis Ababa, the study was conducted at August 2018 in three hospitals namely, Yekatit 12 Hospital medical college, Zewditu Memorial Hospital and St. Paul Millennium Medical College. These hospitals are selected due to presence of recovery room, high patient load, convenient in terms of distance proximity and ease of communication with hospital managers.

3.1.1. Data Collection and Analysis

Key informant interview method was utilized for data collection and 3 KII (key informant interview) from in each of the three hospital was conducted using a structured in review questioner or guide. The participants were administrative and management provost, anesthesia case team coordinator and nurses in the hospitals.

The data was analyzed using a manual content/ thematic analysis methods.

The research questions are composed of five general context structured questions i.e.

1. How medical professionals and patient monitoring machines in recovery room are organized?
2. Do you use technology-based patient monitoring system for your in-patients?
3. How do you try to solve your in-patient dissatisfaction?
4. What are the challenges in finding the solution for the existing system?
5. What type of system can support your day-to-day activity?

In addition to physical observation the first question intended to collect information about the number of recovery rooms, the patients served at a time, patient monitoring machine, and the number of nurses to be assigned as shown on table 1.

Table 1: Medical professionals and patient monitoring machines in recovery room

Name of the Hospitals	No of Recovery room	No of bed	Patient monitoring machine	No of Nurses	Remark
Yekatit 12 Hospital Medical college	1	6	6	Day - 6 Night - 3	
St. Paul's Hospital Millennium Medical college	3	10	8	Day - 4 Night - 3	2 units defect
Zewditu Memorial Hospital	1	4	2	Day - 2 Night - 2	

Currently, in the hospitals from which sample data is collected the organization of Operation Room (OR) and recovery room is proportional in number, but the number of backlog patients waiting for OR is greater in number compared to the available beds. To make the operation for backlog patients in OR the beds and monitoring machines must be free and ready in recovery rooms. But since there is shortage of monitoring machine in the hospitals it makes difficult to do operation as expected.

Regarding question number 2, all respondents agree that there is a patient monitoring system with some limitation. The main limitation is shortage of the patient monitoring machines, because to install enough monitoring machine it requires high financial capital, for low resource setting hospitals this is unattainable. In addition, in the existing system, some of existing patient monitoring machines do not work properly.

Question number 3, is how they are trying to solve the patient dissatisfaction and how to improve the patient treatment environment in the hospital. They replied as they are giving attention in increasing the number of nurses, preparing on job training to upgrade their skill and knowledge for better handling of in-patients.

Relating to question number 4, the interviewees have agreed that there is financial shortage to improve in-patient healthcare in recovery room using technology-based patient monitoring systems. For question 5, they suggest central monitoring system will help us to handle many patients at time.

From those investigations, all interviewees had shared same view on the existence of the problem in hospitals. From this, it requires to research a mechanism to design radio frequency based in-patient monitoring system to alleviate the problems stated above.

The interview responses for the entire questions are converted to the behavioral design of the system requirement. Some of the work procedures in the existing process are altered and used to ease the workflow of the hospital services in our system.

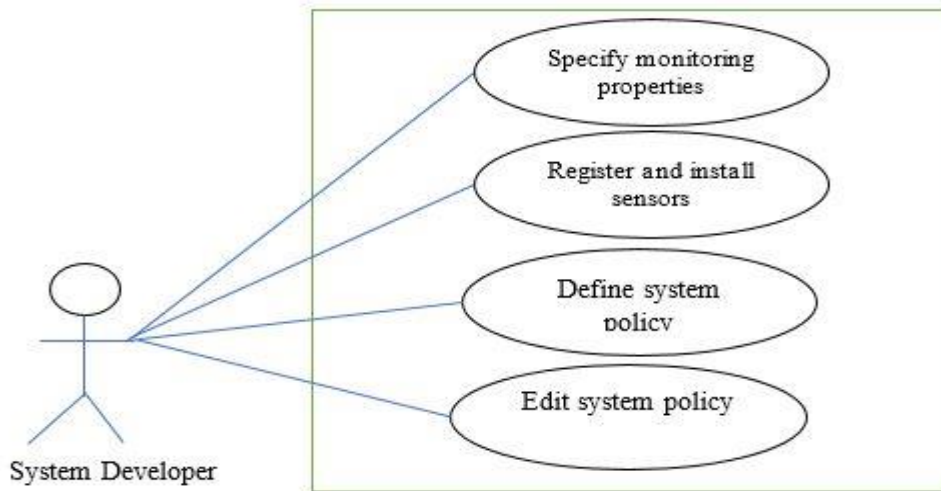


Figure 1: Use case diagram of system administration

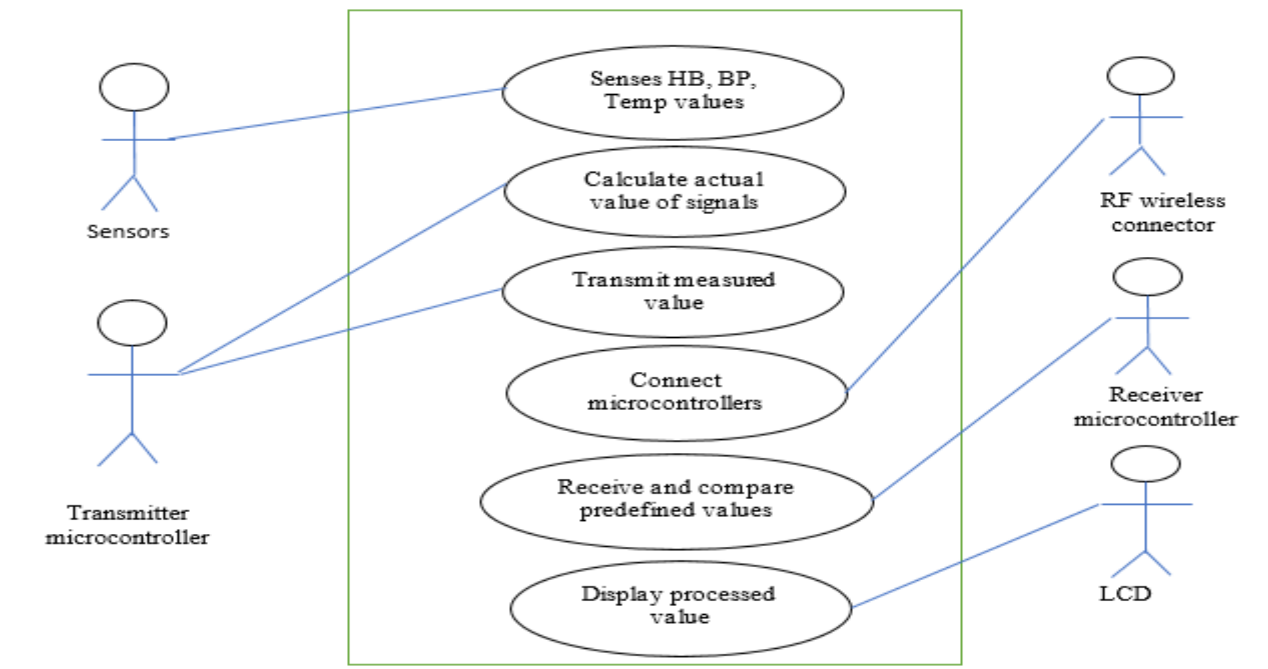


Figure 2: Use case diagram of system functionality

Behavioral modeling is used to describe the interaction in the system, it shows the dynamic nature of the system. One of behavioral modeling technique is use case diagram which shows dynamic sequence of flow in the system as shown on figure 1 and 2. It shows what happen or what is supposed to happen when a system responds to a stimulus (data or event) from its environment.

3.2. Materials

The materials used in this thesis are divided into two parts. These are software and hardware parts.

3.2.1. Hardware Part

The Hardware part of the system consists of five major components. These are the power supply unit, different physiological sensors, RF, LCD and microcontroller as shown on figure 3

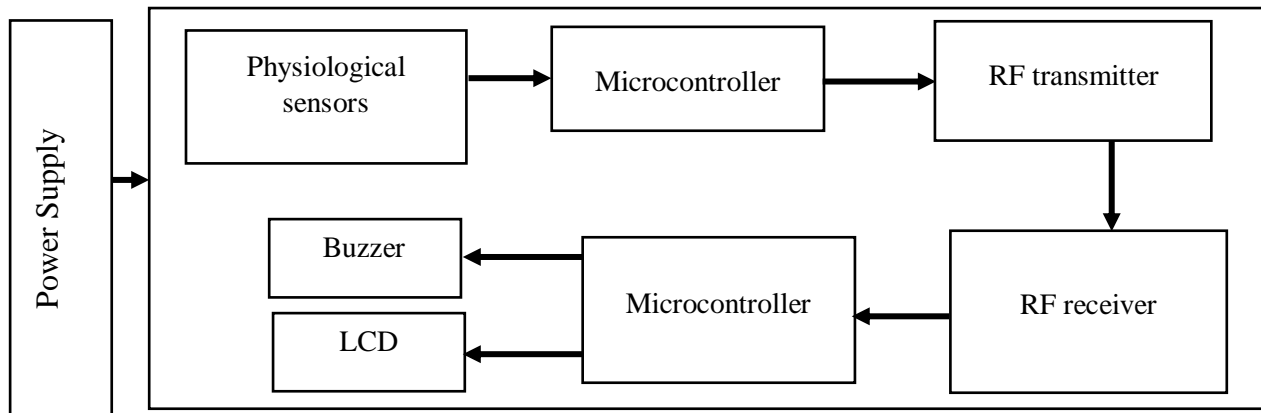


Figure 3: System component block diagram

3.2.1.1. Power Supply

Power supply is an electric device that supplies electric energy to an electric load. In our case the loads are all components of the system. Which are need power source of 5V with the maximum limit and its respective current value. So, with regard to this specification there are different power supply has available in the market from these we can take 5V/1A power supply device.

3.2.1.2. Heart Rate Sensor

We can use XD-58C pulse sensor. The sensor has two sides, on one side the Light Emitting Diode (LED) is placed along with an ambient light sensor and on the other side we have some circuitry. This circuitry is responsible for the amplification and noise cancellation work. The LED on the front side of the sensor is placed over a vein in our human body. This can either be Fingertip or ear

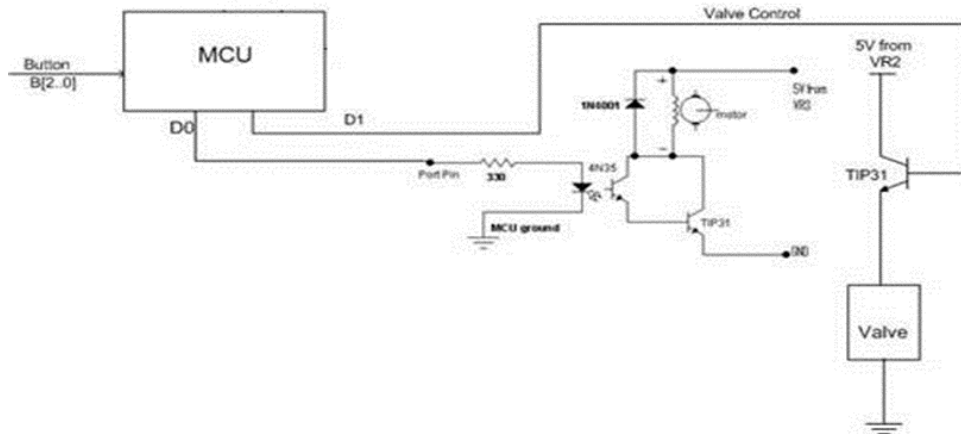


Figure 5: Blood pressure sensor circuit diagram [15]

3.2.1.4. Body Temperature Sensor

Temperature sensing is done using LM35. LM35 series is a low cost and precision integrated circuit temperature sensor whose output voltage is proportional to the Centigrade temperature scale. The LM 35 temperature sensor has three-pin one is the input voltage V_s and the other pin is the output pin which is connected to the microcontroller and the third pin is connected to the ground as shown on figure 4. It can operate over a $-55\text{ }^{\circ}\text{C}$ to $150\text{ }^{\circ}\text{C}$ temperature range. Its output is linearly proportional to the Centigrade Temperature Scale and its output changes by $10\text{ mV per }^{\circ}\text{C}$ [14]. It has zero offset voltage, which means that the output is 0V at $0\text{ }^{\circ}\text{C}$. Thus, for the maximum temperature value ($150\text{ }^{\circ}\text{C}$), the maximum output voltage of the sensor is $150 * 10\text{ mV} = 1.5\text{V}$. For supply voltage (5V) as V_{ref+} ADC, the resolution will be poor as the input voltage will go only up to 1.5V and the power supply voltage variations may affect ADC output. So, it is better to use a stable low voltage above 1.5 as V_{ref+} . We should supply negative voltage instead of Ground (GND) to LM35 for measuring negative Temperatures. But here since it is body temperature and it will probably don't go under zero degrees centigrade, so the negative voltage pin is supplied with zero volts which will make it measure a temperature of above zero degrees centigrade only [16]. Circuit diagram of LM 35 sensor is shown on figure 6.

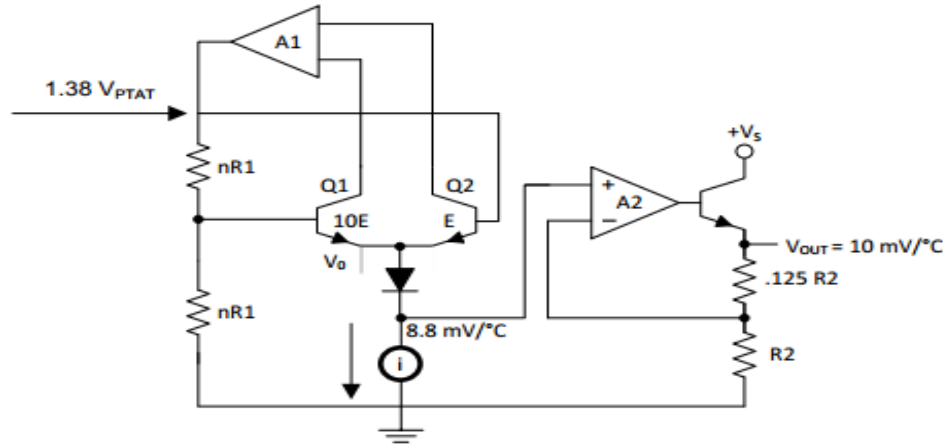


Figure 6: LM-35 body temperature sensor circuit diagram [16]

3.2.1.5. 9xtend RF Transceiver

It is the communication channel of between the patient and central monitoring room. We used the 9xtend RF transceiver, it is the RF module by itself. It operates on Transistor-Transistor level (TTL) through its serial port at frequency of 925 MHz and sustains up to 115.2 Kbps data throughput that provides reliable delivery of critical data between remote devices. The module transfers a standard asynchronous serial data stream and, the module can communicate with any Universal Asynchronous Receiver Transmitter (UART) voltage compatible device or through a level translator to any serial device [17].

Devices that have a UART interface can connect directly to the pins of the RF module as shown on figure 7.

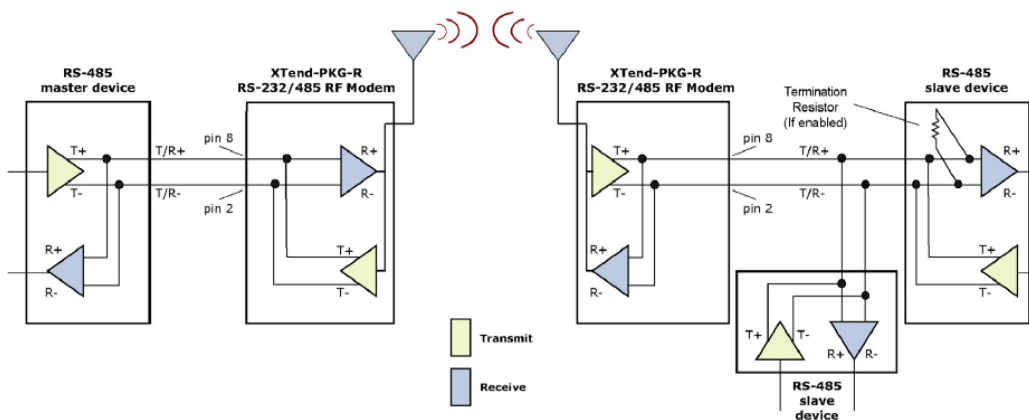


Figure 7:9Xtender circuit diagram [17]

3.2.1.6. *16x2 LCD Display*

It is used for display the patient's physiological measured value. In our case the 16 x 2 intelligent alphanumeric dot matrix displays are capable of displaying 224 different characters and symbols and requires a single power supply (+5V). The LCD display 16 pins have their purpose. Pin1-3 is voltage supply pins, pin7-14 referred as D0-D7 8-bit data bus used for data send in bytes and also provides chunks of 4-bit data send when there are limited number of General-Purpose Input Output(GPIO) lines on microcontroller, voltage supply: pin1-3, ground, +5v, voltage adjustment respectively.

Data Bus: Pin 7-14, 8-bit data bus referenced as D₀-D₇. As it is an 8-bit data bus, we can send the data/CMD to LCD in bytes. Register Select (RS): Pin 4, the LCD has two registers namely a data register and command register. Any data that needs to be displayed on the LCD has to be written to the data register of LCD. The command can be issued to LCD by writing it to the command register of LCD. This signal is used to differentiate the data/cmd received by the LCD. If the RS signal is low, then the LCD interprets the 8- bit info as command and write it command register and performs the action as per the command. If the RS signal is high, then the LCD interprets the 8- bit info as data and copies it to the data register. After that, the LCD decodes the data for generating the 5x7 pattern and finally displayed on the LCD.

Read Write (RW): Pin5, this signal is used to write the data/cmd to LCD and reads the busy flag of LCD. For a write operation, the RW should be low and for reading operation, the RW should be high.

Enable (EN): pin 6, this pin is used to send the enable trigger to LCD. After sending the data/cmd, selecting the data/cmd register, selecting the write operation. A high-to-low pulse has to be sent on this enabled pin which will latch the info into the LCD register and triggers the LCD to act accordingly and backlight anode and cathode LED, pin 15/16 pin for brightening LCD screen [18].

3.2.1.7. *PIC16F877A Microcontroller*

It is the main part of the system, which manipulate over all input and output parameters from the sensor and to the display through the RF, in both transmitter and receiver side we used PIC16F877A microcontroller. It is a single integrated circuit, commonly with a central processing unit ranging from small and simple 4-bit processors to complex 32- or 64-bit processors. Volatile

memory or Flash memory for data storage, for the program and operating parameter storage. Discrete input and output bits, allowing control or detection of the logic state of an individual package pin. Microcontrollers have modules with different purposes [19].

GPIO Module: Microcontrollers usually contain from several to dozens of GPIO. GPIO pins module is software configurable to either an input or an output state. When GPIO pins are configured to an input state, they are often used to read sensors or external signals. When they are configured to the output state, GPIO pins can drive external devices such as LEDs or motors.

ADC Module: Many embedded systems need to read sensors that produce analog signals. This is the purpose of the ADC Module. Since processors are built to interpret and process digital data, i.e. 1s and 0s, they are not able to do anything with the analog signals that may be sent to it by a device. So the Analog to digital converter module is used to convert the incoming data into a form that the processor can recognize. A less common feature on some microcontrollers is a Digital-to-Analog Converter (DAC) that allows the processor to output analog signals or voltage levels. This module reduces the number of chips and the amount of wiring and circuit board space that would be needed to produce equivalent systems using separate chips.

Timer Module: Many embedded microprocessors include a variety of timer module. One of the most common types of timers is the Programmable Interval Timer (PIT). A PIT may either count down from some value to zero or up to the capacity of the count-register, overflowing to zero. Once it reaches zero, it sends an interrupt to the processor indicating that it has finished counting.

Dedicated Pulse Width Modulation Module: dedicated Pulse Width Modulation (PWM) block makes it possible for the Central Processing Unit(CPU) to control power converters, resistive loads, motors, etc., without using lots of CPU resources in tight timer loops.

UART Module: UART block makes it possible to receive and transmit data over a serial line with very little load on the CPU. Dedicated on-chip hardware also often includes capabilities to communicate with other devices chips in digital formats such as I²C and Serial Peripheral Interface (SPI).

3.2.2. Software Part

The software part consists of a programming PIC16F877A microcontroller using microcontroller compiler form. The microcontroller is a device that cannot act on its own; it is a device that can be tailored to perform a specific function.

The principal element in the circuit is the PIC16F887A microcontroller that manipulates voltage signals acquired from the sensors. These acquired signals are then processed in the ADC module of the microcontroller separately. So that it converts voltage waveforms to digital 0s and 1s to make perceive the microcontroller. The microcontroller uses these converted signals for further analysis and communicates with the RF transmitter. The central microcontroller receives a signal from RF transmitter and does analysis based on the program on it and transfer to the LCD for all abnormal and warning physiological incoming signals.

3.2.2.1. *Software Language*

Microcontrollers were originally programmed only in assembly language, but various high-level programming languages are now also in common use to target microcontrollers. These languages are either designed especially for the purpose or versions of general-purpose languages such as the C programming language. Compilers for general-purpose languages will typically have some restrictions as well as enhancements to better support the unique characteristics of microcontrollers. Some microcontrollers have environments to aid in developing certain types of applications. Microcontroller vendors often make tools freely available to make it easier to adopt their hardware. We program the chip by c programming language since this language syntax is easier to learn than the assembly, and c program is easier for making complex programs and has more developing staffs in its library than assembly, even if the assembly language has an advantage of programming the hardware directly without a compiler.

3.2.2.1.1. Micro C Compiler

The Micro C Compiler for PIC16F877A is a powerful, feature-rich development tool for PIC microcontrollers. It is designed to provide the programmer with the easiest possible solution to developing applications for embedded systems, without compromising performance or control. Which provides a successful match featuring, highly advanced Integrated Development

Environment (IDE), American National Standards Institute (ANSI) compliant compiler, broad set of hardware libraries, comprehensive documentation, and plenty of ready-to-run examples.

It allows quickly developing and deploying complex applications. While writing C source code the built-in code editor performs code and parameter assistants, code folding, syntax highlighting, auto correct, code templates, and more from PIC libraries to dramatically speed up the development to data acquisition, memory, displays, conversions, communication, etc. It generates commented human-readable assembly, and standard HEX compatible with all programmers. We use the integrated microC which is in-circuit debugger and real-time debugging tool to monitor program execution on the hardware level. Inspect program flow and debug executable logic with the integrated Software Simulator. Get detailed reports and graphs: Random Access Memory (RAM) and Read Only Memory (ROM) map, code statistics, assembly listing, calling tree, and more [20].

After the program is written in C programming language on the microC compiler, the program is loaded to the microcontroller by using the K150 kit which has a Universal Serial Bus (USB) interface to the computer and loads the program to the microcontroller [21].

3.2.2.1.2. Proteus (8)

Proteus is simulation software which simulates various designs with electronics and microcontroller. It is mainly popular because of the availability of almost all microcontrollers in it. So it is a handy tool to test programs and embedded designs. Proteus simulation has the advantage of making Printed Circuit Board (PCB) design after simulating with it which is an all in one package for students and hobbyists.

Chapter Four

4. System Design

4.1. System Architecture

In this section, we will explain the system designed based on existing requirements determined as shown on figure 8. The system contains three types of sensors: blood pressure sensor, temperature sensor, and heart rate sensors to measure the status of the patient. Microcontroller used as the main component that calculate vital signs of the patient periodically and transmit to the central monitoring station using Radio Frequency transceiver module. The central controlling system placed in monitoring room receives the status of patients using an RF transceiver module. Also, this controller will analyze the received data perform a comparison with pre-defined physiological values of expected normal, warning or abnormal range. The received data is stored on the Electrically Erasable Programmable Read Only Memory (EEPROM) of the central microcontroller module. Whenever abnormal conditions occurred, it displays the data using a 16x2 generic LCD with respective patient IDs.

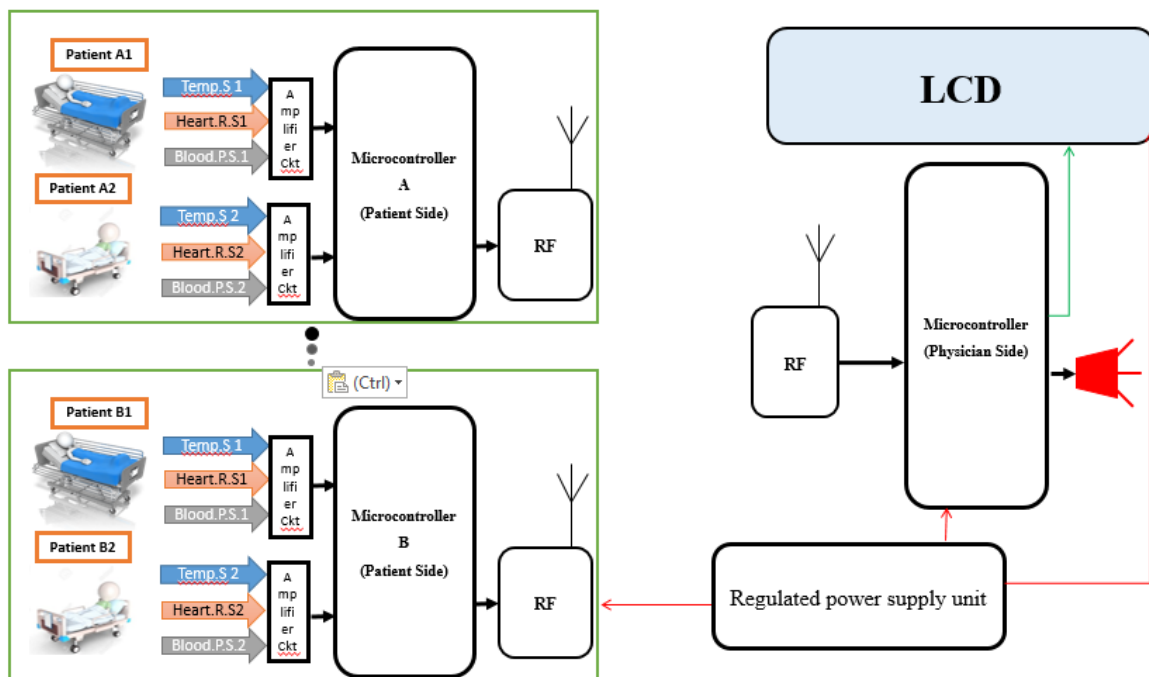


Figure 8: System block diagram

The system has four subunits those are sensors subunit: blood pressure, temperature and heart rate sensors for sensing physiological signals, Microcontrollers subunit: as a main part that calculate and process vital signs of the patient, Radio Frequency transceiver subunit: transmit the signals to central monitoring station, and LCD subunit: for displaying the expected abnormal and warning value of the physiological signals in monitoring station.

4.1.1. Heart Rate Measurement

Heart rate sensor works based on the principle of photo-plethysmography, by sensing a transmitted light through a fingertip. It measures the change in volume of blood through any organ of the body which causes a change in the light intensity through that organ. The flow of blood volume is decided by the rate of heart pulses and since light is absorbed by the blood, the signal pulses are equivalent to the heartbeat pulses.

The sensor consists of a photodiode, comparator IC, LM358, and some resistors. When tissue is illuminated with the light source, i.e. light emitted by the led, it either absorbs or transmits the light. Some of the light is absorbed by the blood and the transmitted light is received by the photodiode. The amount of light absorbed depends on the blood volume in that tissue. The detector output is in the form of the electrical signal and is proportional to the heartbeat rate. This signal is a DC signal relating to the tissues and the blood volume. And the AC component synchronous with the heartbeat and caused by pulsatile changes in arterial blood volume which are superimposed on the DC signal. Thus, the major requirement is to isolate that AC component as it is of prime importance. To achieve the task of getting the AC signal, the output from the detector is first filtered using a 2 stage High Pass Low Pass (HP-LP) circuit and is then converted to digital pulses using a comparator circuit or using simple ADC. The inverting terminal of the comparator LM358 is connected to the potential divider arrangement which is set to the threshold voltage and the non-inverting terminal is connected to the photodiode filtered output.

The heartbeat sensor will generate a pulse whenever the heart beats. This pulse is amplified to the amplitude range of more than 3V so that it can be detected by the microcontroller. This output signal of the heart rate sensor is connected to digital input pin RB₂ of the microcontroller. The microcontroller then calculates the time between two successive pulses and calculates the patient's heart rate range in bit per minute. Finally, this patient side microcontroller sends these values to the physician side microcontroller using 9xtend RF transceiver module. Then the microcontroller

placed in the central monitoring room receives the data through 9xtend RF transceiver module and displays the range that the value lays in between expected warning or abnormal using LCD. The following block shows the algorithm to calculate a heart bit rate.

```
If (there is pulse)
{
  x=catch the timer
}
If (there is not pulse)
{
  y=catch the timer
}
Period=y-x;
Pulse rate=1second/period(y-x)
```

4.1.2. Blood Pressure Measurement

Arterial pressure is defined as the hydrostatic pressure exerted by the blood over the arteries as a result of the heart's left ventricle contraction. Systolic arterial pressure is the higher blood pressure reached by the arteries during systolic ventricular contraction, and diastolic arterial pressure is the lowest blood pressure reached during diastolic ventricular relaxation. In a healthy young adult at rest, systolic arterial pressure is around 110 mmHg and diastolic arterial pressure is around 70 mmHg. Blood flow is the blood volume that flows through any tissue in a determined period typically represented as ml/min to bring tissue oxygen and nutrients transported in the blood. Blood flow is directly affected by the blood pressure as blood flows from the area with more pressure to the area with less pressure. Greater the pressure difference, the higher is the blood flow. Blood is pumped from the left ventricle of the heart out to the aorta where it reaches its higher-pressure levels. Blood pressure falls as blood moves away from the left ventricle until it reaches 0 mm Hg when it returns to the heart's right atrium.

A blood pressure sensor operation is based on the oscillometric method. This method takes advantage of the pressure pulsations taken during measurements with a vibration detection device; a cuff is inflated over the upper arm or wrist. The pressure of the cuff will rise to the pressure of

about 20 mm Hg above systolic pressure for an average individual. When the cuff is fully inflated to this pressure, no blood flow occurs through the artery. As the cuff is deflated below the systolic pressure, the reducing pressure exerted on the artery allows blood to flow through it and sets up a detectable vibration in the arterial wall. This vibration is then measured using the SEN-09199 piezoelectric vibration sensor from spark fun.

The blood pressure sensor senses the pressure on the blood vessel whenever there is a blood transmission and not. The signal output of the sensor is again amplified to the required level basically more than 3V and connected to the AN₃ pin of the PIC16F877A microcontroller. The microcontroller then multiplies the signal by a scalar value of 0.576 to calculate the actual pressure in Millimeter of Mercury (mmHg). The pressure that will be sensed whenever there is a transmission of blood is termed as systolic and the pressure that will be sensed whenever there is no transmission of blood is termed as diastolic. Finally, this patient side microcontroller sends these values to the physician side microcontroller using 9xtend RF transceiver module. Then the physician side microcontroller receives the data through the 9xtend RF transceiver module and displays the range that the value lays in between Warning or Abnormal using an LCD display. The following block shows the algorithm of a blood pressure sensor.

```
Analog reading *0.576
Keep giving pressure
If (blood transmission==1)
{Read the circuit pressure=systolic
}
If (blood transmission=0)
{
Read the circuit pressure=diastolic
}
```

4.1.3. Body Temperature Measurement

The temperature sensor gives an analog value that lies between 0V and 5V. Every increment of 10mV of an output signal indicates a ⁰C increment in temperature. The sensor output is connected to the AN₄ of the microcontroller. The microcontroller then multiplies the received value by 0.48876 to get an actual temperature. Finally, this patient side microcontroller sends these values to the physician side microcontroller using 9xtend RF transceiver module. Then the physician side

microcontroller receives the data through 9xtend RF transceiver module and displays the range that the value lays in between warning or abnormal using an LCD.

4.1.4. RF Module and Configuration

9xtend RF transceiver module working at 900MHz is used to establish immediate long-range wireless links between the patient side and physician side circuit. This module has been selected due to its various capabilities, such as security, 256-bit AES - Advanced Encryption Standard, higher channel capacity up to 10 hope sequence share 50 frequencies, long-range of indoor communication up to 450m due to its high power output up to 1W, continuous asynchronous RF data stream up to 115200 bps and it consume low power. It has a high degree of flexibility and configured with X Bee Configuration &Test Utility (XCTU) software [22]. XCTU is a free multi-platform application designed to enable users to interact with RF modules through a simple to use graphical interface. This software facilitates the configuration of every property such as baud rate, transmission power, receiver, transmitter ID, mode of operation indoor/outdoor, network topology peer to peer, peer to multipoint, multipoint to multipoint and so on.

The 9xtender serial communications depend on the two UARTs to be configured with compatible settings of baud rate, parity, start bits, stop bits and data bits using XCTU software which is primarily designed for this purpose.

When serial data enters the module through the Digital Input (DI) pin (pin 5), the data is stored in the DI Buffer until it can be processed. When the RB and RO parameter thresholds are satisfied to refer to the 'Transmit Mode' section for more information, the module attempts to initialize an RF connection. If the module is already receiving RF data, the serial data is stored in the module's DI Buffer. The DI buffer stores at least 2.1 KB. If the DI buffer becomes full, hardware or software flow control must be implemented to prevent overflow (loss of data between the host and RF module) by Send messages that are smaller than the DI buffer size or Interface at a lower Baud Rate (BD) than the RF data rate. Further operation of the RF module can be referred from the datasheet.

Since the 9xtender have so many channels transferring many information i.e. many patient's data at the same time and the transmission of the original data is with the starting and stopping bit the chance of data loss is low, using this RF module is advisable for hospitals having number of blocks so that the physician can see the information without any error.

In our case we have configured the module using XCTU software [22] to operate indoor at data rate of 115200bps to attain higher speed, output power of 0.5W due to mid-range indoor link, point to multi-point, arbitrary assigned receiver and transmitter ID, flow control is None, data bits is 8, parity is none and stop bits is 1 as shown on figure 9.

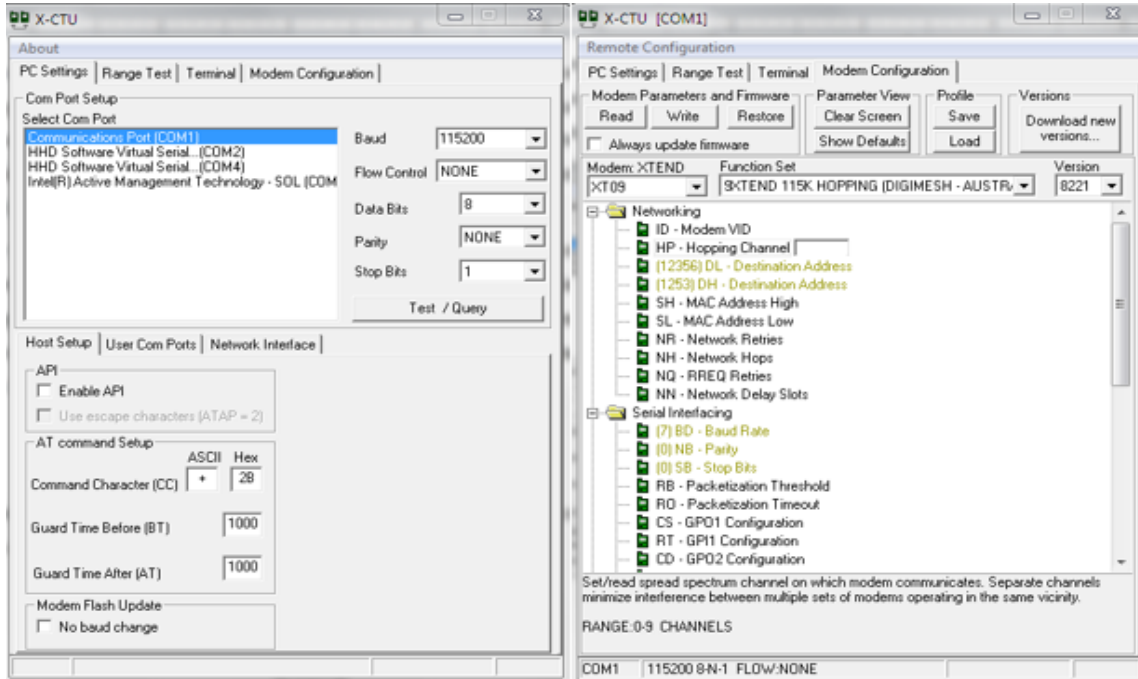


Figure 9: XTEND RF module configuration by X-CTU software

Since it operates at TTL level, the Tx and Rx pin of the module is directly connected to Rx and Tx pin of the microcontroller using RS232 serial data interfacing protocol respectively as shown on figure 10.

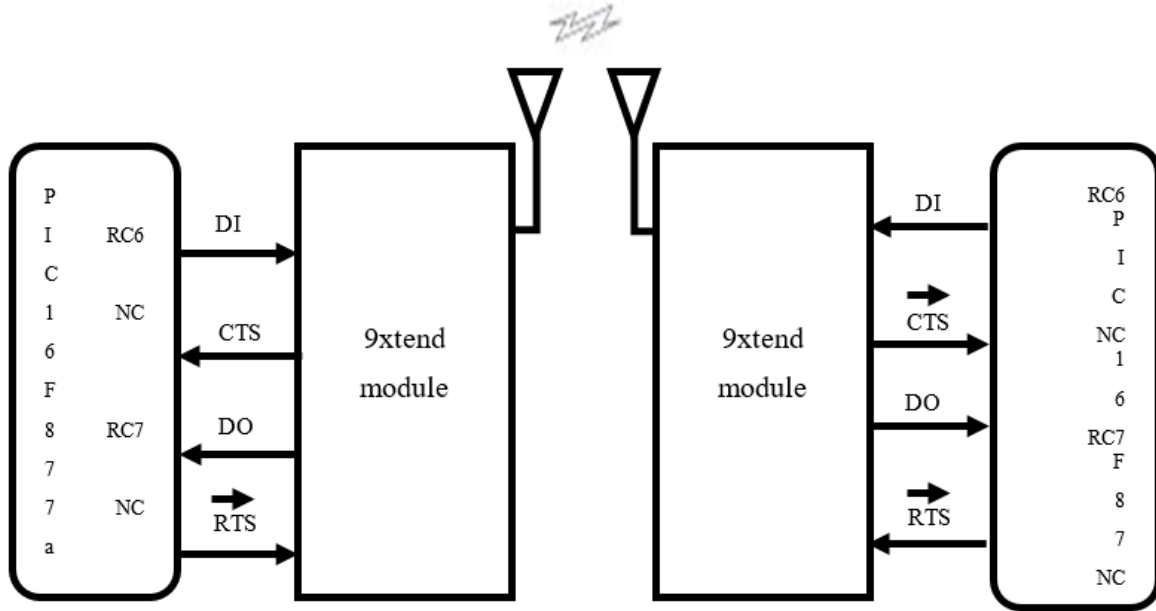


Figure 10:9XTEND pin connection with microcontroller

4.1.5. Transmitter Flow-Chart

Programming the transmitter side microcontroller starts from the initialization of required ports for the input sensed data and modules. After initialization, reading the data and work out the necessary calculations for all input signals is the next work. The final step is coping or sending the data to the UART for transmission with a one-second difference. For the communication, stability check in communication protocols three preambles are sent before the data as shown on figure 11.

4.1.6. Receiver Flow-Chart

As the transmitter microcontroller, the program starts by initializing the required ports and modules and display a welcome message. After this, it read all transmitted signals from the corresponding temperature, systolic, diastolic and heartbeat sensor from UART interrupt and also record this value. Then the program does the comparison to the expected values i.e. from the lower range to the sever range to know about whether the value is within which range. Finally, if there is a condition out of the normal range the value is displayed with an alarm as shown on figure 12.

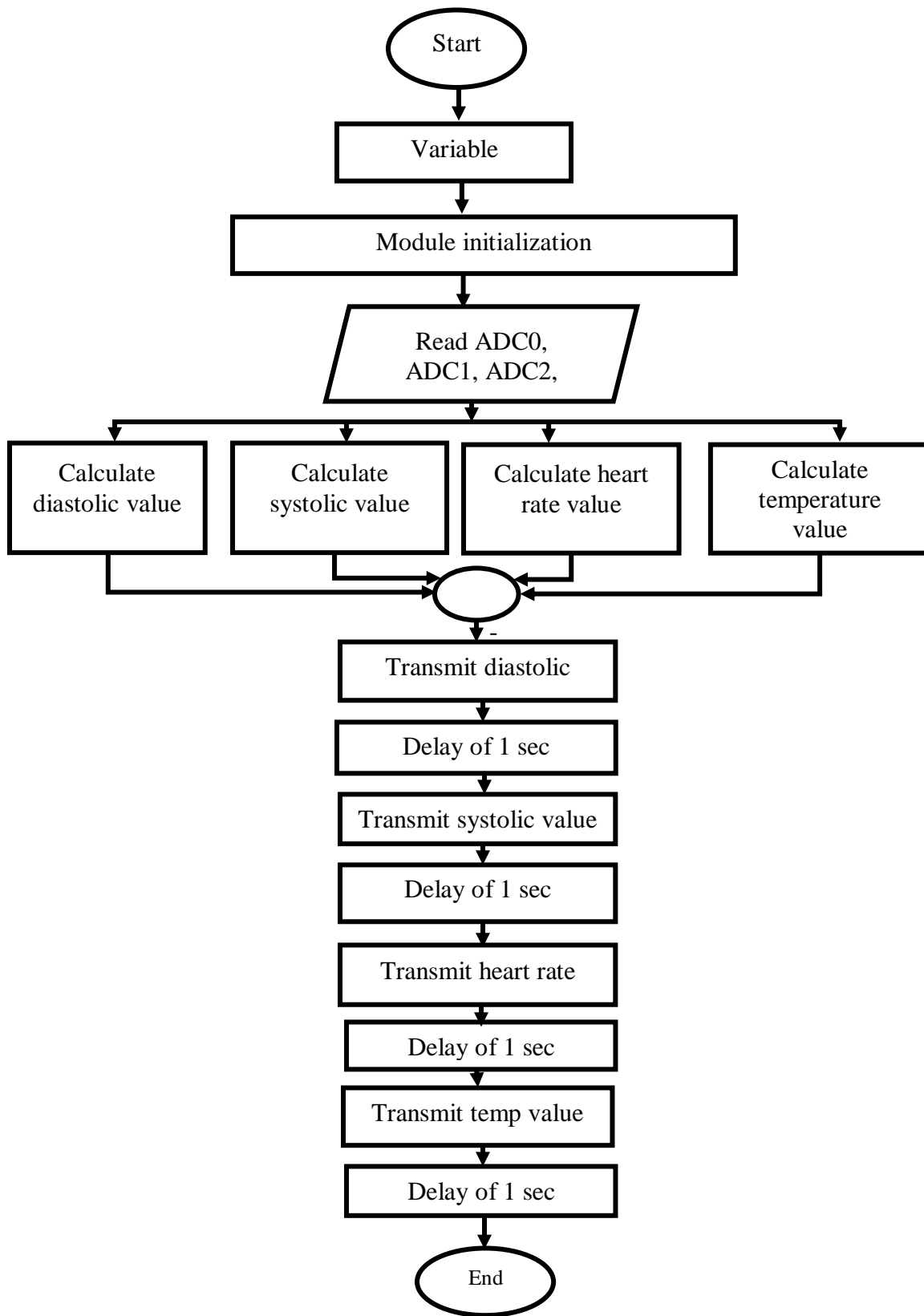


Figure 11: Transmitter flow chart

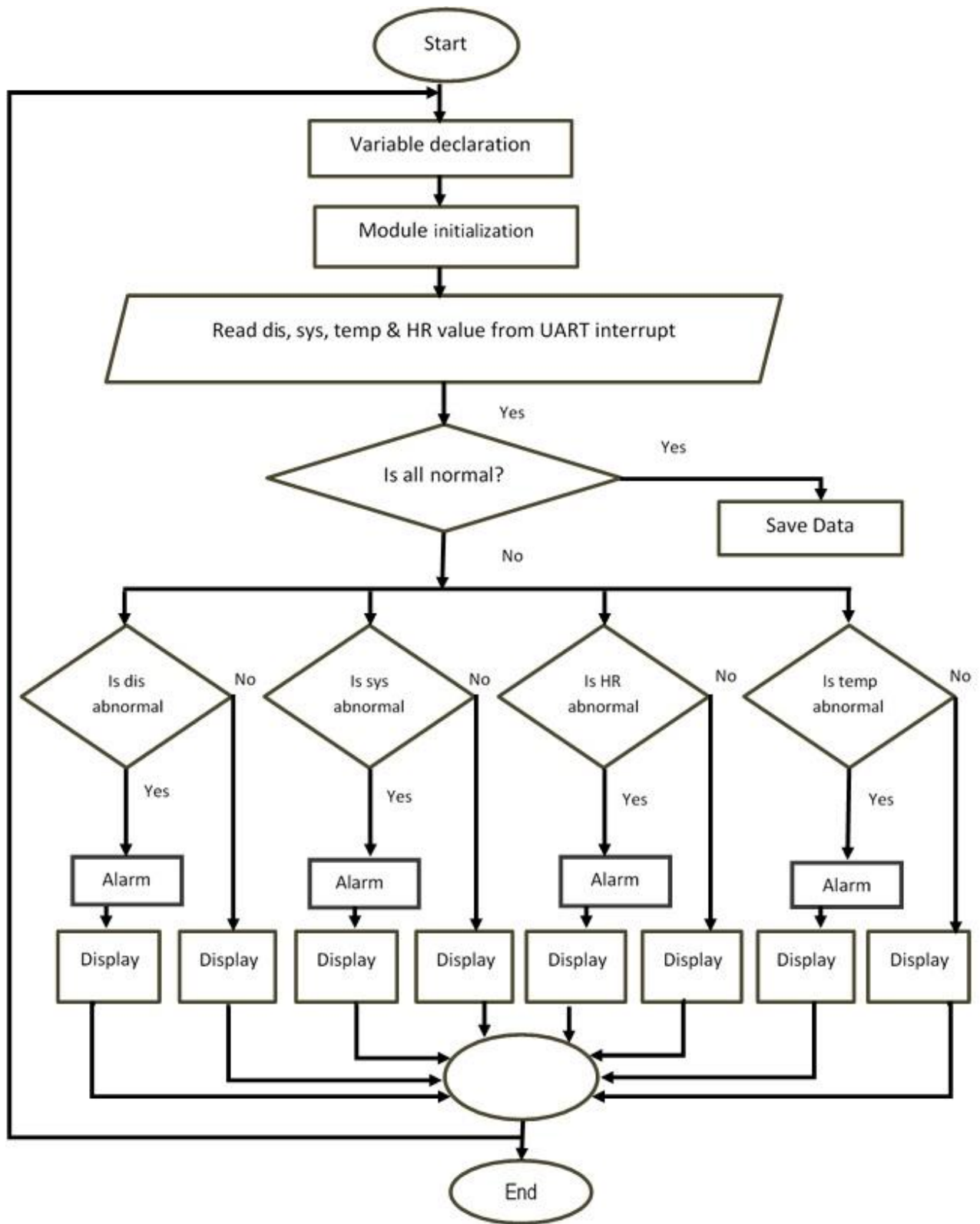


Figure 12: Receiver flow chart

4.2. Cost Break Down for System Implementation

Table 2: Cost for RF based patient monitoring system for 4 patients

Materials Cost					
No	Materials	Unit	Quantity	Unit price(birr)	Total cost
1	5 volte power supply	No	2	132.8	265.6
2	Hear rate sensor	No	4	680	2720
3	Body temperature sensor	No	4	5960	23840
4	Blood pressure sensor	No	4	1920	7680
5	PIC16F877A microcontroller	No	3	160	480
6	9xtend RF transeiver	No	2	8800	17600
7	16x2 LCD Display	No	1	880	880
8	Connecting wire	Roll	9	500	4500
9	Buzzer	No	1	40	40
10	Active and passive electrical elements	No		200	200
11	Trunk	No	10	80	800
12	packing				4000
Labor Cost					
13	System installation	No	2	500	1000
14	Training for professionals	No	1	500	500
Other Expenses (Hidden Cost)					
15	Electricity	/Yr	1	400	400
16	packaging		4	500	2000
17	Transport				400
Total					67,305.6

4.3. Cost Break Down for Centerallize Patient Monitoring Management System

Multi parameter central patient monitoring system is a system consists of central monitoring software and high performance computer/server/. Based on server based network installation, by considering multi parameter centrally patient monitoring system managing four patient monitor machines centrally costs 168,100.00 birr as shown on table 3 and compared with our system it is expensive for low resource setting hospitals. So we recommend our system to be used for centrally monitoring different patients where there is large volume of inpatient which needs continuous follow up to reduce burden of duty nurses in manual recording and avoid unseen sudden cases of

patients. By considering four patients our system development and installation costs 67,305.6 birr as shown on table 2.

Table 3: Cost for Networked centrally managed patient monitoring system for 4 patients

Materials Cost					
No	Materials	Unit	Quantity	Unit price(birr)	Total cost()
1	Patient monitoring machine	No	4	25000	100000
2	Server computer	No	1	40000	40000
3	Switch 24 port	No	1	3000	3000
4	Cable /USB/UTP/	Roll	1	4500	4500
5	Rack /8U/	No	1	5000	5000
6	Trunk	No	25	80	2000
7	RJ 45	No	20	5	100
Labor Cost					
8	System installation	No	4	500	2000
9	System configuration	Roll	4	300	1200
10	Training for professionals	No	1	300	300
11	Other expenses				10,000
Total					168,100.00

Generally from our analysis and perspectives the system we have developed is better to use and affordable option that it can support multiple patients at a time and ease nurses work burden. And it can also be maintained and administered easily and its scalability is high if it is needed to expand the service further.

Chapter Five

5.1 Results and Discussion

This chapter presents the system development result and discussions related to the output of the system on in-patient monitoring system. The system incorporates blood pressure sensors, temperature sensors, and heart rate sensor which are used to measure the status of the patient vital sign. Then, if at least one of the status is beyond predefined value i.e. expectation warning range or expectation abnormal condition, it sends these values to the centrally placed LCD to alarm standby nurses.

The system starts by gathering data using sensors from the patients, the data flow in different phases. The 1st phase to develop the patient side monitoring module, the 2nd phase to develop the physician side monitoring module and the 3rd phase connecting both modules by integrating the RF module. While testing the 2nd phase to see if the LCD is working properly, we face a challenge that never thought that would have happened. The LCD module won't display proper data rather it displays junk data that gives unexpected output. After long and tedious troubleshooting, we found that the initialized UART interrupts and remains unconnected. Since there was an AC motor working around, a very small electromagnetic induction to the circuit UART pin leads the microcontroller to remain in the UART interrupt service routine. So that it kept in displaying junk and noise data. By simply deactivating the UART interrupt, we were able to overcome this problem.

Here it is explained in detail on how much the system is capable to assist the nurses from a technical perspective, and have achieved the maximum possible level of performance:

- i. Since pic16f877a has got 8 analog input pins, by using one analog input pin for body temperature sensing, one analog pin for blood pressure sensing and a digital input pin for heart-rate sensing, we attain to monitor 2 patients using only one controller module.
- ii. 9xtend RF transceiver module can receive from various modules with 10 hopping channels each with 65,000 network addresses available. Therefore, using this capability, only one receiver RF is enough to receive data from many transmitter RF in a recovery room.

- iii. The system works based on the range of values of adult vital signs, by measuring these values, the system displays expected abnormal and warning state of the patient. But in case of different patient conditions and ages the warning displayed may not show the expected range of the condition, the predefined values must be adjusted based on the department or patient case implemented.

To demonstrate this, let`s look at patient-specific cases below to understand how the system functions.

Specific patient case: a case of a very sick child whose age 2 years with a condition of second-degree skin burn admitted in a critical care room with high-level follow-up [24,25]. In this case the information we need to understand for analysis and interpretation of the vital signs are age and the condition of the patient. Age of the patient: Age is one of the physiologic determinants of the vital sign. At normal circumstances, the normal values of the vital signs specifically, the Respiratory Rate (RR), Pulse Rate/ Heart Rate (PR/HR) and Blood Pressure (BP) changes as the newborn or infant or child grows and ages. It is only temperature (T^O) that is constant throughout the age.

The RR is inversely related to the age of a child as shown below:

- ✓ The RR of a healthy child during 0 to 3-month old is around 40- 70 breaths per minutes
- ✓ The RR of a healthy child age 3 to 12 months old is around 25-45 breaths per minute
- ✓ The RR of a healthy child age 1 to 3 years old is around 20- 30 breaths per minute
- ✓ The RR of a healthy child age 12 years old and above/adults is around 12- 18 breaths per minute

The PR/HR is inversely related to the age of a child as specified underneath:

- ✓ The HR of a healthy child during 0 to 3-month old is around 100- 150 beats per minute
- ✓ The PR of a healthy child age 3 to 12 months old is around 80- 120 beats per minute
- ✓ The PR of a healthy child age 1 to 3 years old is around 70- 110 beats per minute
- ✓ The PR of a healthy child age 12 years old and above/adults is around 55- 85 beats per minute

The BP measured as Systolic Blood Pressure/Diastolic Blood Pressure (SBP/DBP) is directly related to the age of the child as stated below:

- ✓ The SBP and DBP of a healthy child during 0 to 3 months are around 65-85/35-45 mm Hg.
- ✓ The SBP and DBP of a healthy child age 3 to 12 months old are around 80-100 /50-65 mm Hg.
- ✓ The SBP and DBP of a healthy child age 1 to 3 years old are around 90-105 /55-70 mm Hg.
- ✓ The SBP and DBP of a healthy child age 12 years old and above/adults are around 110-135 /65-85 mm Hg.

Body temperature is constant throughout the age of the patient:

- ✓ The normal body temperature does not change with age and normal temperature ranges between 36.1-37.9°C.

Normal vital signs according to age [25].

The condition of the patient i.e. Second-degree skin burn for our case scenario: will alter the vital sign pathologically in any direction upward or downwards. Accordingly, nurses must consider different conditions of the patient to change predefined values.

The hardware demonstration results for different sample value of adult vital signs and the entire system functionalities which is displayed on the LCD is presented on figures 13 to 18.

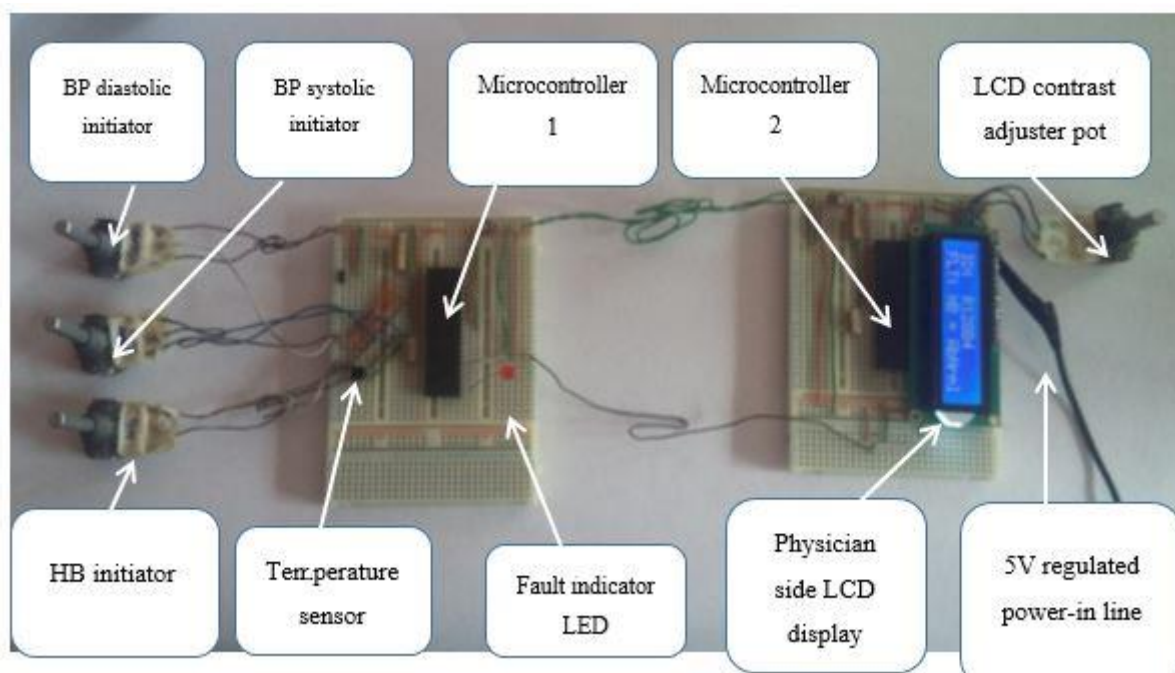


Figure 13: System hardware prototype

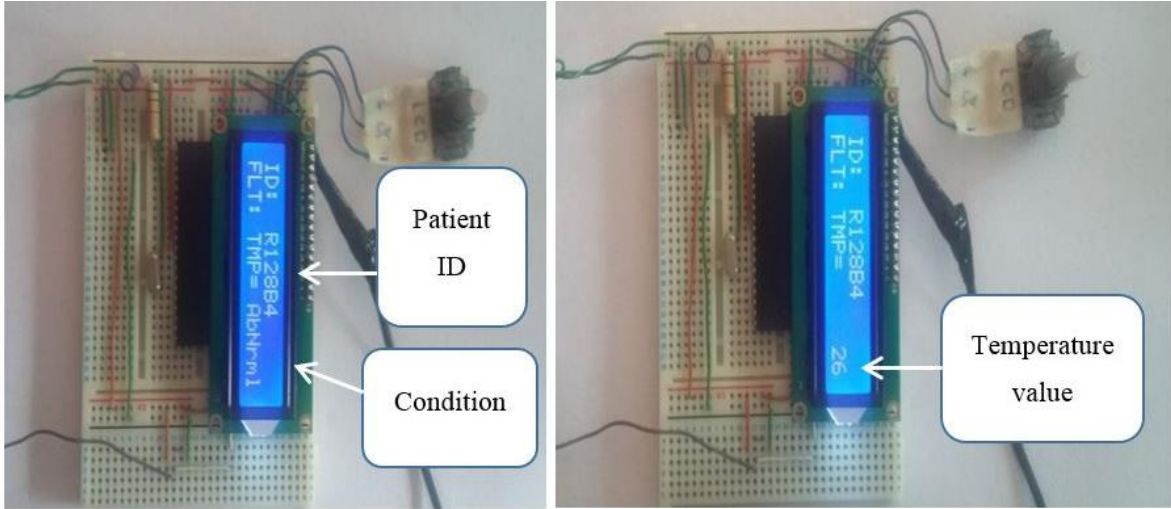


Figure 14: Sample abnormal value of temperature

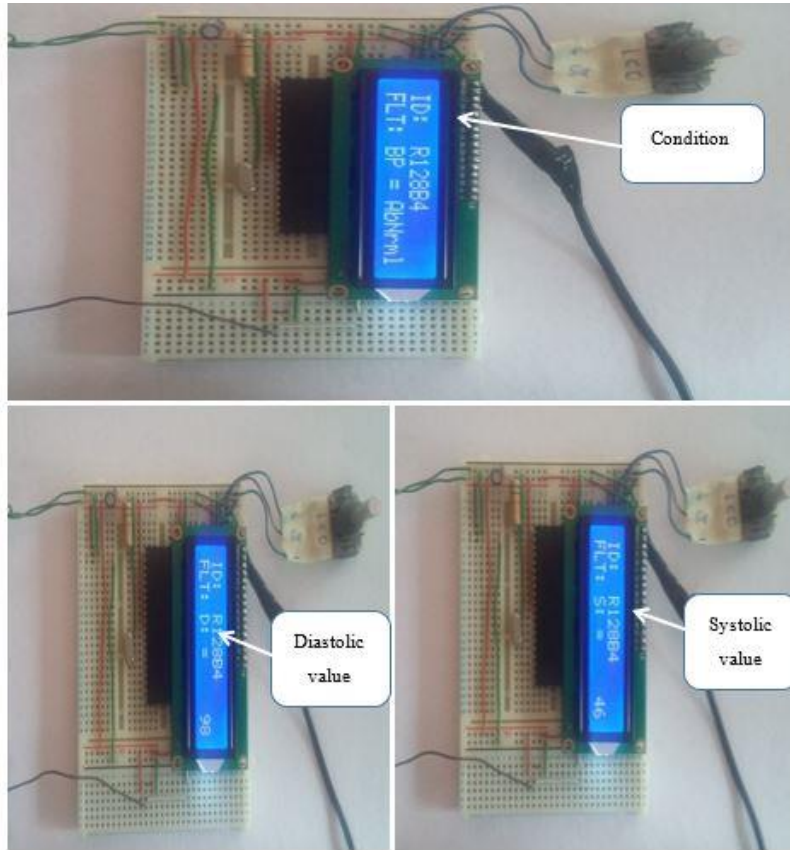


Figure 15: Sample abnormal value of blood pressure

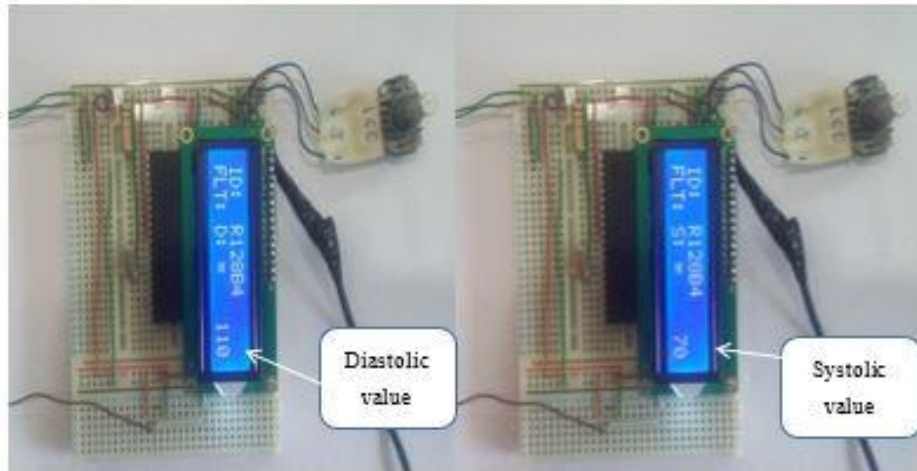
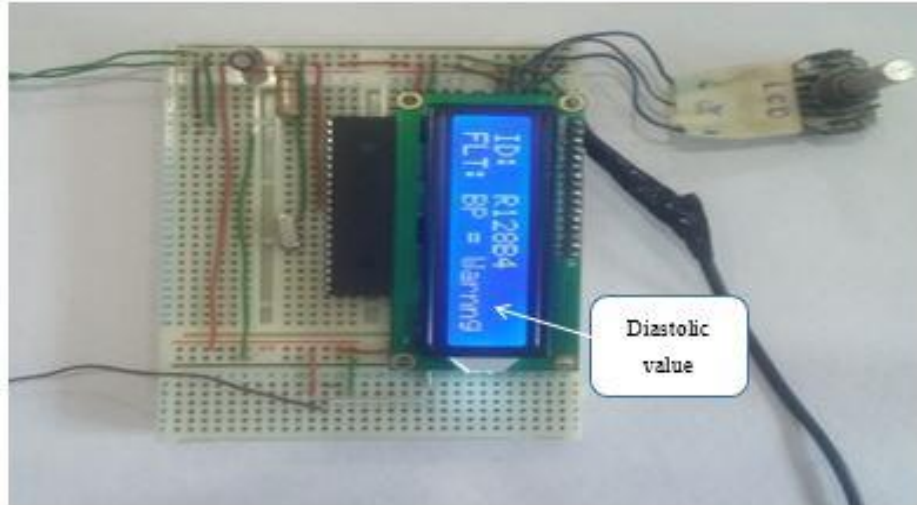


Figure 16: Sample warning value blood pressure

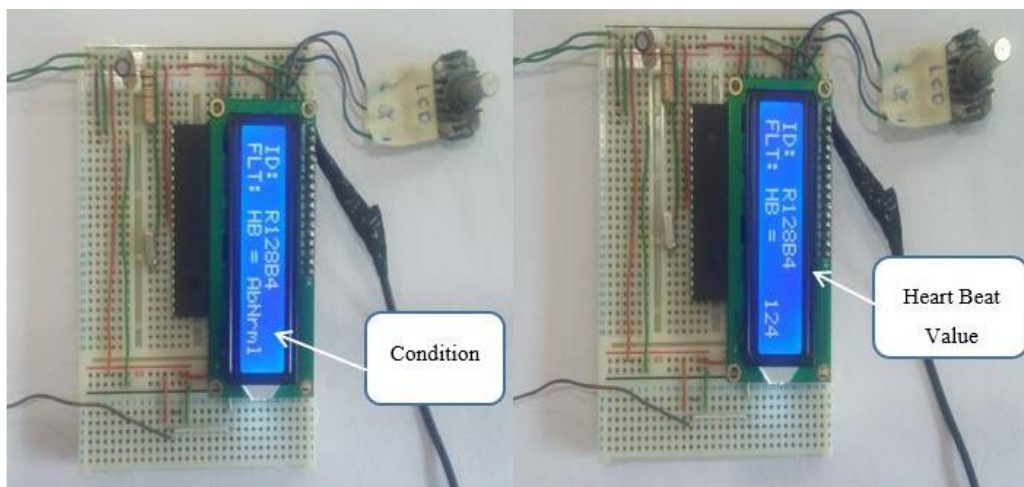


Figure 17: Sample abnormal value of heart beat

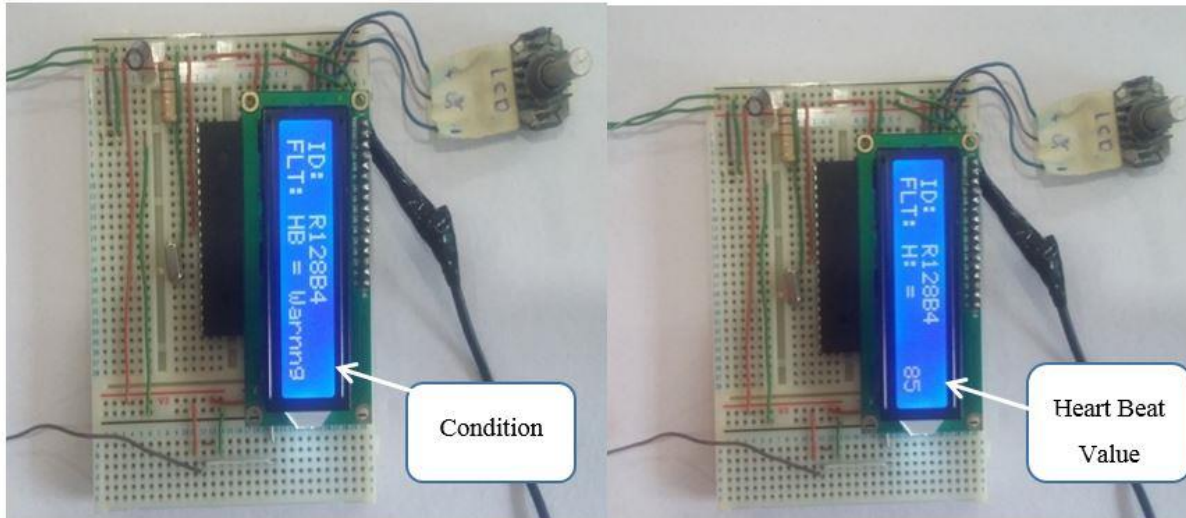


Figure 18: Sample value of warning heartbeat.

As the result shows, our system covers wide-range wireless links and establishes fast communication between the patient and central monitoring system. The measured value taken by the sensors in the system are transferred to the microcontroller without any data loss. In addition 900 MHz RF which is included in ultrahigh frequency range is less to be exposed to noise. For the system security it uses AES algorithm for data encryption to avoid any patient information loss and information hacking at transfer time. AES encryption mechanism is easy and has no performance overhead on the system. The RF module covers indoor communication of up to 450m, continuous asynchronous RF data stream up to 115.2Mbps and it consume low power. The system has stable power source which prevents it from fluctuation. From system availability perspective since all the devices are easy for maintenance, replacement and the mean time to restore the system to function is very minimum.

Relating our system with the reviewed papers we identified designs, tools and best practices of different literatures. From those designs and materials we separated strong materials with minimum cost to use in our system in a way of approach to develop affordable patient monitoring system for low resource setting hospitals. For instance most of reviewed papers uses zigbee for wireless communication, but this technology covers small area in comparison with our RF wireless technology.

Therefore, the system developed with a performance described above for low resource setting hospitals at reasonable cost. And it helps easing nurse's day to day activity and improve patient's

wellbeing environment. The system avoids manual assessment of critical patient's physiological sign done by nurses and provides or displays them continuous patient signs for their decision and frequent follow-up.

5.2 Limitation of the Study

The designed RF based patient monitoring system and the prototype produced is tested by giving variable input signal from potentiometer and displayed output is seen. But the system is not tested on real patient with required ethical clearance.

Chapter Six

6. Conclusions and Recommendation

6.1. Conclusions

This research thesis presents a low-cost RF based patient monitoring system, as a solution for improvement of patient monitoring in low resource setting to overcome the shortage of medical professionals (physicians & nurses). For effective and in time decision making of critical patient treatment for low resource setting hospitals, we designed and developed RF based in-patient monitoring system. The system uses distributed sensors, programmable microcontroller and RF modules which work in an integrated way to provide patient vital status to the centrally assigned nurses at the right time. The sensors sense the vital physiological signals from the patient body and transmit signals to the patient side microcontroller. After some calculation and comparison with expectation range of vital signals of the body is done inside the microcontroller, it transmits the information to the LCD screen displayed as an abnormal value or warning in central monitoring office.

The cost of the RF based patient monitoring system is relatively cheaper than the network based patient monitor , which could be a preferred technology after real patient test and Full scale up.

In conclusion, it was possible to design and produce prototype a low cost radio RF based central in-patient monitoring system with a cheaper cost. And after real patient test it would contribute an alternative solution to answer the gaps and challenges of recovery room critical patient management through the use of innovation and technology in the field of biomedical engineering and health.

6.2. Recommendation

This study has the potential to influence the delivery and study of resuscitative care by allowing vital signs to be automatically collected from the patient and displayed on a central screen. Here are some of the additional features that we recommend to be added in the future to improve the functionality of the system.

- Using wireless sensors: Changing the sensors attached on patients by wireless sensors will not confine the patient to his bed and make free to move around the ward.

- Developing desktop Application: Developing desktop application and designing a database for saving patient's vital data and displaying on the desktop monitor will make the system better to use in for further findings.
- So, we recommend conducting the follow on project to test on real patient after ethical clearance from relevant agent to answer all the limitation and engage multiple actors in the process.

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Appendix 1: Transmitter Microcontroller Program

```
intadc_dystolic = 0;//to read the analog to digital converted value of the blood pressure (dystolic) sensor
intadc_systolic = 0;//to read the analog to digital converted value of the tempareture(systolic)sensor
intadc_hb = 0;//to read the analog to digital converted value of the heart beat sensor
intadc_temp = 0;//to read the analog to digital converted value of the temperature sensor
void main()
{
portb = 0x00; //set initial value of portb to 0x00
portd = 0x00;
porta = 0x00;
trisa = 0xff;//set the signal flow direction of porta to input
trisb = 0x00;
trisd = 0x00;
Delay_ms(100);
UART1_Init(9600);//initialize the uart module with data rate of 1200, no parity, stop bit Of 1 and data bit of 8
Delay_ms(100);
adcon1 = 0x00;//use port a as an analog input
Delay_ms(100);
adc_init();
delay_ms(100);
delay_ms(2000);

        while(1) //enter to an endless loop
        {
delay_ms(10);
adc_dystolic = adc_read(0);
delay_ms(100);
adc_systolic = adc_read(1);
delay_ms(100);
adc_hb = adc_read(2);
delay_ms(100);
adc_temp = adc_read(3);
delay_ms(100);
adc_dystolic /= 4;
adc_systolic /= 4;
adc_hb /= 4;
adc_temp *= 0.48876;
        UART1_Write(0x55);//preamble
delay_ms(10);
        UART1_Write(0xAA);//preamble
delay_ms(10);
        UART1_Write(0x02);//preamble data type
delay_ms(10);
        UART1_Write(adc_dystolic);
delay_ms(10);
```

```
        UART1_Write(adc_systolic);
delay_ms(10);
        UART1_Write(adc_hb);
delay_ms(10);
        UART1_Write(adc_temp);
delay_ms(1000);
        portd.rd2 = 1;
delay_ms(1000);
        portd.rd2 = 0;
delay_ms(1000);

}
}
```

Appendix 2: Receiver Microcontroller Program

```
intadc_dystolic;//to read the analog to digital converted value of the blood pressure(dystolic)sensor
intadc_systolic;//to read the analog to digital converted value of the tempareture(systolic)sensor
intadc_hb;//to read the analog to digital converted value of the heart beat sensor
intadc_temp;//to read the analog to digital converted value of the tempareture sensor
charlill[5];
inti = 0, l = 0, j = 0;
charrecieved;
voidInitUart(void);
void interrupt(void);
#define fault PORTD.RD2
// LCD module connections
sbit LCD_RS at RB4_bit;
sbit LCD_EN at RB5_bit;
sbit LCD_D4 at RB0_bit;
sbit LCD_D5 at RB1_bit;
sbit LCD_D6 at RB2_bit;
sbit LCD_D7 at RB3_bit;
sbitLCD_RS_Direction at TRISB4_bit;
sbitLCD_EN_Direction at TRISB5_bit;
sbit LCD_D4_Direction at TRISB0_bit;
sbit LCD_D5_Direction at TRISB1_bit;
sbit LCD_D6_Direction at TRISB2_bit;
sbit LCD_D7_Direction at TRISB3_bit;
// End LCD module connections
char text0[] = "R128B4";
char text1[] = " WELCOME TO ";
char text2[] = " POULOS HOSPITAL";
char text3[] = "ID:"; //petient ID
char text4[] = "FLT: "; //Fault type
char text5[] = "BP = "; //blood pressure
char text6[] = "TMP= "; //tempareture
char text7[] = "HB = "; //heart beat
char text8[] = "Warnng";
char text9[] = "AbNrml";
char text10[] = "Normal ";
char text15[] = "Hyper ";
char text16[] = "Hypo";
char text11[7];
char text12[7];
char text13[7];
char text14[7];
void main()
{
portb = 0x00; //set initial value of portb to 0x00
portd = 0x00;
porta = 0x00;
trisa = 0xff;//set the signal flow direction of porta to input
trisb = 0x00;
```

```

trisd = 0x00;
Delay_ms(100);
intcon.gie = 1;
intcon.peie = 1;
delay_ms(100);

InitUart(); //initialize the uart module with data rate of 1200, no parity, stop bit of 1 and data bit of 8
Delay_ms(100);
lcd_init();//initialize the LCD module
delay_ms(100);
lcd_cmd(_lcd_cursor_off);
lcd_cmd(_lcd_clear);
lcd_out(1,1,text1);
lcd_out(2,1,text2);
delay_ms(2000);
lcd_cmd(_lcd_cursor_off);
lcd_cmd(_lcd_clear);
lcd_out(1,1,text3);
lcd_out(2,1,text4);
lcd_out(1,6,text0);
while(1) //enter to an endless loop
{
delay_ms(10);
adc_dystolic = lill[0];
adc_systolic = lill[1];
adc_hb = lill[2];
adc_temp = lill[3];
delay_ms(10);
IntToStr(adc_dystolic, text11);
IntToStr(adc_systolic, text12);
IntToStr(adc_hb, text13);
IntToStr(adc_temp, text14);
/*if(((adc_hb>= 66) && (adc_hb<= 75)) && ((adc_temp>= 32) && (adc_temp<= 38)) &&
((adc_systolic>= 75) && (adc_systolic<= 85)) && ((adc_dystolic>= 115) && (adc_dystolic<= 125)))
{
UART1_Write('m');
lcd_out(2,6,text10);
fault = 0;
delay_ms(1000);
}*/
if((adc_dystolic>= 146) || (adc_systolic>= 96) || (adc_dystolic<= 100) || (adc_systolic<= 65)) //hypertention
{
//UART1_Write('c');
lcd_out(2,6,text5);
lcd_out(2,11,text9);
fault = 1;
delay_ms(1000);
lcd_out(2,6,"D:");
lcd_out(2,11,text11);
delay_ms(1000);
lcd_out(2,6,"S:");
}
}

```

```

lcd_out(2,11,text12);
delay_ms(1000);
}
else if(((adc_dystolic>= 126) && (adc_dystolic<= 145)) || ((adc_systolic>= 86) && (adc_systolic<= 95)) ||
((adc_dystolic>= 101) && (adc_dystolic<= 114)) || ((adc_systolic>= 66) && (adc_systolic< 75)))// if the
value of bp lies in between the warning range
{
// UART1_Write(text11);
lcd_out(2,6,text5);
lcd_out(2,11,text8);
fault = 1;
delay_ms(1000);
lcd_out(2,6,"D:");
lcd_out(2,11,text11);
delay_ms(1000);
lcd_out(2,6,"S:");
lcd_out(2,11,text12);
delay_ms(1000);
}
if((adc_temp< 32) || (adc_temp>= 45)) // if the value of temperature is greater than the set point
{
//UART1_Write('g');
lcd_out(2,6,text6);
lcd_out(2,11,text9);
fault = 1;
delay_ms(1000);
lcd_out(2,6,"TMP");
lcd_out(2,11,text14);
delay_ms(1000);
}
else if((adc_temp>= 39) && (adc_temp<= 44)) // if the value of temperature lies in between the warning
range
{
//UART1_Write('e');
lcd_out(2,6,text6);
lcd_out(2,11,text8);
fault = 1;
delay_ms(1000);
lcd_out(2,11,text14);
delay_ms(1000);
}
if((adc_hb<= 65) || (adc_hb>= 91)) // if the value of heart beat is greater than the set point
{
//UART1_Write('k');
lcd_out(2,6,text7);
lcd_out(2,11,text9);
fault = 1;
delay_ms(1000);
lcd_out(2,11,text13);
delay_ms(1000);
}
}

```

```

else if((adc_hb>= 76) && (adc_hb<= 90)) // if the value of heart beat lies in between the warning range
{
  //UART1_Write('i');
  lcd_out(2,6,text7);
  lcd_out(2,11,text8);
  fault = 1;
  delay_ms(1000);
  lcd_out(2,6,"H:");
  lcd_out(2,11,text13);
  delay_ms(1000);
}
}
}
void InitUart(void)
{
  trisc.rc6 = 0;
  trisc.rc7 = 1;
  spbrg = ((4000/16)/9.6) - 1;
  TXSTA.BRGH = 1;
  TXSTA.SYNC = 0;
  RCSTA.SPEN = 1;
  RCSTA.CREN = 1;
  RCSTA.SREN = 0;
  PIE1.TXIE = 0;
  PIE1.RCIE = 1;
  TXSTA.TX9 = 0;
  RCSTA.RX9 = 0;
  TXSTA.TXEN = 0;
  TXSTA.TXEN = 1;
}
void interrupt(void)
{
  if(PIR1.RCIF == 1) // If UART Rx Interrupt
  {
    recieved = rcreg;
    if((recieved == 0x55) && (l == 0))
    {
      l++;
    }
    else if((recieved == 0xAA) && (l == 1))
    {
      l++;
    }
    else if((recieved == 0x02) && (l == 2))
    {
      l++;
    }
    else if(l == 3)
    {
      lill[0] = recieved;
      l++;
    }
  }
}

```

```
}
else if(l == 4)
{
lill[1] =recieved;
l++;
}
else if(l == 5)
{
lill[2] =recieved;
l++;
}
else if(l == 6)
{
lill[3] =recieved;
l = 0;
portd.rd0 = 0;
delay_ms(200);
portd.rd0 = 1;
}
if(OERR) // If over run error, then reset the receiver
{
rcsta.CREN = 0;
rcsta.CREN = 1;
}
}
}
```