DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

A TELEMETRY APPLICATION OF SMART CLOTHES

by

Erdem KÖSEOĞLU

May, 2009

İZMİR

A TELEMETRY APPLICATION OF SMART CLOTHES

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In Partial Fulfillment of the Requirements for the Degree of Master of Science
in Electrical and Electronics Engineering

by
Erdem KÖSEOĞLU

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İZMİR

M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"A TELEMETRY APPLICATION OF SMART CLOTHES"** completed by **ERDEM KÖSEOĞLU** under supervision of **ASST.PROF.DR. ÖZGE ŞAHİN** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

ASST.PROF.DR. ÖZGE ŞAHİN

Supervisor

(Jury Member)

(Jury Member)

Prof.Dr. Cahit HELVACI

Director

Graduate School of Natural and Applied Sciences

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A TELEMETRY APPLICATION OF SMART CLOTHES

ABSTRACT

In this study, a telemetry application using smart cloth is performed. The essential of this application is that it gives necessary alert messages for the people, who are in certain risk group, such as high cardiac insufficiency, handicapped, elderly, just operated, also babies and little children. These alerts can be sent to their parents or doctors to call for help on time when the blood pressure, body temperature and pulse rate reach to critical values for the human body, even if these people are living at their homes or work places.

The telemetry system consists of a transducer unit as an input device, a transmission medium in the form of radio waves, signal processing units and parts for displaying data. All telemetry data are securely transferred and stored in the database under the clinicians' ownership and control.

During this study, systolic-diastolic pressures, pulse rate and body temperature are measured and the obtained values are transmitted to another system via RF(Radio Frequency). Receiver part is connected to the computer by RS-232 port, and alert limit values of these obtained data are determined by an interface on the computer. According to these limit values, if any of the obtained data exceeds these limits, related alert message is sent to a mobile phone that is defined on the interface.

Keywords: Smart clothes, biomedical application of smart clothes, pressure sensor, temperature sensor, pulse rate, telemetry.

AKILLI GİYSİLERİN BİR UZAKTAN ÖLÇÜM UYGULAMASI

ÖZ

Bu çalışmada akıllı elbise kullanarak bir uzaktan ölçüm uygulaması gerçekleştirilmiştir. Bu uygulamanın en önemli noktası, belirli risk grubundaki insanlar (örneğin yüksek kalp yetmezliği olanlar, zihinsel ve bedensel özürlüler, yaşlılar, ameliyattan henüz çıkmışlar hatta bebekler ve küçük çocuklar) için gerekli uyarı mesajlarını vermesidir. Bu uyarı mesajları, tansiyon, nabız ve vücut sıcaklığı insanlar için kritik değerlere ulaştığında, bu insanlar evlerinde ya da işyerlerinde olsalar bile, zamanında yardım çağırmak için hastaların yakınlarına ya da doktorlarına gönderilebilir.

Bu uzaktan ölçüm sistemi, bir giriş aygıtı olarak bir dönüştürücü birim, radyo dalgaları şeklinde bir aktarım aracı, sinyal işleme birimleri ve veri görüntülemek için bölümler içerir. Bütün uzaktan ölçüm verileri, klinik tedavi uzmanlarının sahipliği ve kontrolü altındaki veri tabanına güvenli bir biçimde aktarılır ve depolanır.

Bu çalışma süresince, büyük-küçük tansiyon, nabız ve vücut sıcaklığı ölçülür ve elde edilen değerler RF aracılığıyla bir başka sisteme aktarılır. Alıcı parça, RS-232 bağlantı birimi ile bilgisayara bağlanır ve bu elde edilen verilerin uyarı sınır değerleri bilgisayar üzerinde bir arayüz ile tespit edilir. Bu sınır değerlere göre, elde edilen verilerin herhangi biri bu sınırları aşarsa, ilgili uyarı mesajı arayüz üzerinde belirlenen bir mobil telefona gönderilir.

Anahtar Sözcükler: Akıllı giysiler, akıllı giysilerin biyomedikal uygulaması, basınç sensörü, sıcaklık sensörü, nabız, uzaktan ölçüm.

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CHAPTER ONE

INTRODUCTION

1.1 Researches on Smart Clothes

Clothes themselves are naturally near to a user. Therefore, clothing provides an ideal platform to embed sensors inside garments and to perform measurements that apply personal psychological signals. In addition user measurements, it is often beneficial to perform measurements from the surrounding environment.

Results from these measurements can be used for controlling the devices that are integrated into the clothing. These kinds of systems are called smart clothes. Their purpose is to enhance or augment the functions of ordinary clothes via added electrical and non-electrical intelligent components.

The electronics that facilitate our daily pursuits and interactions may soon be integrated into textiles in all areas of our environment. These smart clothes may find niches in many traditional textile applications. Opportunities exist for smart clothes in fashion and industrial apparel, residential and commercial interior, military, medical and industrial textile markets. Smart clothes technologies may one day integrate multiple electronic devices directly into textile and apparel products using shared resources increasing the mobility, comfort, and convenience of such devices (Klemm & Locher, 2003). For example, communication devices may be integrated into products such as the garments in Figure 1.1.

Figure 1.1 Integrated Textile Keypad (Softswitch, 2001)

Textiles integrated with sensory devices driven by a Global Positioning System (GPS) can detect users' exact location anytime and in any weather (Aniolczyk, Koprowska, Mamrot & Lichawska, 2004). Smart clothes with integrated GPS, such as the ski suit in Figure 1.2, enhance safety by quickly locating the wearer and allowing the suit to be heated. Parent can easily keep track of a child's location with garments containing integrated GPS. GPS can also provide added safety for emergency personnel by facilitating offsite monitoring of vitals.

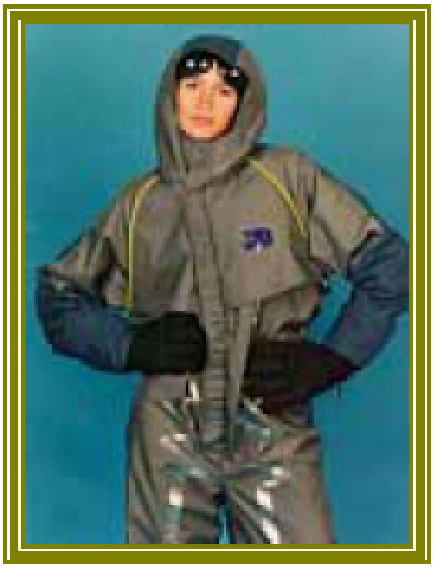

Figure 1.2 Electronic ski-suit
(Philips, 2001)

Including the electrical wiring into the structure of the textile material is the basic step in developing textronics incorporated electrical connections which cannot be distinguished from the clothing used at present would be the best result. It will be possible to realize such a vision when user-friendly electronic woven and knitted fabrics and nonwovens are developed and the functional elements would be integral components of the product. Therefore the basic aim was to approach the development of new textile technologies which would include electronic circuits, electro-conductive-, piezo- and opto-electronic elements and other sensors into the textile structures. A new property of clothing would be the possible to exchange information. If clothing would be capable of recording, analyzing, storing, sending and displaying data, a new dimension of intelligent high-tech clothing could be reached (Satava, 1995). Especially applications for the health and military sector are already guessed a great demand. Considering the needs of "the warriors of the future", some military materials become a part of the uniforms. Global positioning systems, chemical detectors, personal physiological status sensors, helmet systems that equipped with displays, microphones, head phones, local networks, protective uniforms for environmental conditions, special fabrics for providing the best camouflage are some of the examples of such systems.

Textile firms that understand how to incorporate emerging smart clothes technologies into their new product strategies will establish and sustain financial and competitive advantages. Wearable electronics are already finding many opportunities in non-textile products such as implanted microchips and digital jewelry.

Many of the wearable computing devices developed to date are cumbersome and awkward (Figure 1.3) typically strapped or carried on the body. But, textile-based wearable electronics that allow interactive touch, voice, and body heat activation are being developed. The current versions use integrated wiring and carrying devices that add bulk and weight to the garments making them uncomfortable and impractical daily use (Lukowicz & Kirstein, 2004). These items are also expensive and present issues are related to maintenance, flexibility, and user safety.

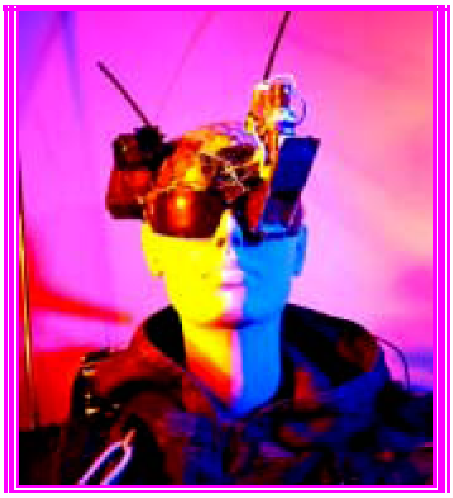

Figure 1.3. Wearable computing devices
(Mann D., 1998)

To develop more appealing wearable electronics, conductive materials are being used to transform traditional textile and apparel products into lightweight, wireless wearable computing devices. Materials; such as metallic and optical fibers, conductive threads, yarns, fabrics, coatings and inks are being used to supply conductivity and create wireless textile circuitry.

The technologies previously discussed are used to create textiles that have the ability to conduct electricity. Additional components including input and output devices, sensors, and power supplies are necessary to create a smart cloth. Input devices keyboards and speech and handwriting recognition systems are some options being explored for smart clothes data entry (Laerhoven & Gellersen, 2004). The output technologies under investigation include Cathode Ray Tubes (CRT), Liquid Crystal Displays (LCD), mirror displays and flexible light emitting displays. Sensors are small electronic devices that can receive and respond to stimuli enabling electronic textile functions to be related to the user. They can either be attached to or integrated into a textile substrate. Power supply Technologies, typically batteries, provide the electrical power for activating the components in an electronic textile. In recent years batteries have not only become smaller and more powerful, some varieties are mechanically flexible, water-resistant, and lower cost. Solar energy and energy created by the human body are also being studied as sources of electrical power for smart clothes.

In order to simplify the connections between electronic devices, new wireless Technologies may be used. Commonly used wireless devices, such as cellular phones and pagers, use Radio Frequency Local Area Networks (RF LAN's), but the limited radio frequency spectrum is quickly being filled (Inoue, 2007). Personal Area Networks (PANs) provide an alternative. PANs enable electronic devices to exchange digital information, power, and control signals within the user's personal space (Loren & Weinmann, 2003). PANs work by using the natural electrical conductivity of the human body to pass incredibly small amounts of current through the body.

Developments in telecommunication, information technology and computers are the main technical tools for Telemedicine (Telecare, Telehealth, e-health) now being introduced in health care (Lymberis, 2002). Telemedicine - medicine at a distance - provides the many possibilities for doctors to more easily consult each other.

This project ensures dependable, non-intrusive, secure, real-time automated health monitoring. And also gives more freedom for patients to roam around and allow the health personnel to keep in touch with patient without being around the hospital bedside. Besides, by this system nurses and doctors can see their patient's blood pressure and body temperature instantly without being near them (Koseoglu & Sahin, 2008)

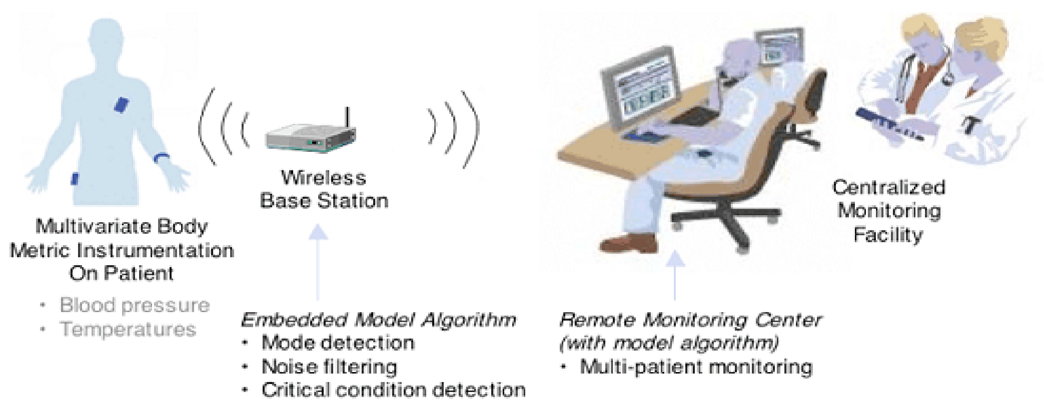

Figure 1.4. A sample health monitoring system

1.2 Purpose and Scope

The aim of this telemetry application using the smart cloth is to notice recognizable extreme points of blood pressure, body temperature and pulse rate for the people who are in certain risk group, such as high cardiac insufficiency, handicapped, elderly, just operated, also babies and little children. The essential of this system is that it gives necessary alert messages to their parents or doctors to call for help on time when the blood pressure, body temperature and pulse rate reach to critical values for the human body, even if these people are being living at their homes or work places. It will especially be useful for predicting deaths from heart attack or snoring while sleeping. By using this system, a nurse is not necessary for coexisting with the patients who are confined to bed. In addition, the patients carrying some risk group mentioned above are ensured to recognize on time these alerts without restricting their activities or living areas at their homes or work places.

This system can be safely used at home or work place or in a hospital. When it is being used at home or work place, the obtained data can be stored in a database of a computer. Thus, the data can be examined and instantaneous changes can be informed to the doctor or defined person by a mobile phone message. The patients can also self-control the measured values by detecting the colours of LEDs on the receiver part. It can also be used in a hospital for multiple patients. The blood pressure, body temperature and pulse rate of the patients can be measured automatically without the need of any nursery check. These data can be stored in a nursery computer. Therefore, it will be possible to measure these data continuously and get alert messages if any of these values exceed the limits.

1.3 Utilities of This Research

The blood pressure and body temperature measurement project consists of two parts. One of them is receiver part and the second is transmitter part. Transmitter part roughly includes a temperature sensor (DS18B20), a pressure sensor (MPX2050GP), a PIC (18F452), an RF remote control circuit and an LCD. Also receiver part roughly includes a PIC (18F452), an LCD, and an RF remote control circuit. This system monitors two parameters, the body temperature and blood pressure. The patient may wear the RF transmitter as a wrist watch or attached to his/her belt. The device can transmit the parameters to the receiver and by an interface; these values can be seen on doctor's computer instantly. Via the RS232, it can be connected to nurse's, doctor's and emergency's computers. By the LCD on the transmitter part, patients can see their blood pressure and body temperature instantly, also by using control panel on the interface, doctors can set the limit values of the sensors. After this step, if pressure sensor and temperature sensor measure higher than these set values, pressure and temperature LED on the receiver part, gives signal. When measured values are lower than the set values, LED gives up giving signal.

This device gives more freedom for patients to roam around and allow the health personnel to keep in touch with patient without being around the hospital bedside. Besides, by this system nurses and doctors can see their patients' blood pressure and body temperature instantly without being near them. If the patient's values pass over the limits when they are not looking at the monitor, LEDs which are on the receiver part give signals. So he/she can understand which measured values are over or under the limits.

1.4 Outline of the Thesis

The first chapter is an introduction chapter. Benefits of this project, researches on smart clothes and outline of the thesis are explained at this chapter. The second chapter explains the basic background needed during the thesis design and realization. General information about smart clothes, biomedical applications and telemetry are explained at second chapter. At Chapter 3, the hardware requirements are determined and based on this information hardware design is explained. Software design is included in Chapter 4. Measurement results are given and explained in Chapter 5.

CHAPTER TWO

SMART CLOTHES AND TELEMETRY

2.1 Smart Clothes

So-called "smart clothing" is a futuristic form of clothing that functions as an active device, for example releasing chilled water vapor when it senses its wearer is hot. The term "smart clothing" denotes the presence of embedded electronics. Some forms of smart clothing have been created, but none have really been mass-produced, and many more are the subject of science fiction stories and cannot be made with current technology.

The development of wireless computing and miniaturization of electrical components have accelerated the production of different wearable devices such as pocket computers and mobile phones. This equipment is worn or carried almost constantly (Carmen & Yuan-Ting, 2004). Instead of having separate devices located in pockets, wearable systems can be integrated into clothes where they can form a network of intelligent devices.

Clothes themselves are naturally near to a user. Therefore, clothing provides an ideal platform to embed sensors inside garments and to perform measurements that apply personal psychological signals. In addition user measurements, it is often beneficial to perform measurements from the surrounding environment.

Results from these measurements can be used for controlling the devices that are integrated into the clothing. These kinds of systems are called smart clothes. Their purpose is to enhance or augment the functions of ordinary clothes via added electrical and non-electrical intelligent components.

Figure 2.1. GSM/GPS jacket (Minatec, 2003)

Including the electrical wiring into the structure of the textile material is the basic step in developing textronics incorporated electrical connections which cannot be distinguished from the clothing used at present would be the best result (Michalak & Surma, 2006). It will be possible to realize such a vision when user-friendly electronic woven and knitted fabrics and nonwovens are developed and the functional elements would be integral components of the product. Therefore the basic aim was to approach the development of new textile technologies which would include electronic circuits, electro-conductive-, piezo- and opto-electronic elements and other sensors into the textile structures.

A new property of clothing would be the possible to exchange information. If clothing would be capable of recording, analyzing, storing, sending and displaying data, a new dimension of intelligent high-tech clothing could be reached (Lukowicz & Kirstein, 2002). Especially applications for the health and military sector are already guessed a great demand. Considering the needs of 'the warriors of the future', some military materials become a part of the uniforms. Global positioning systems, chemical detectors, personal physiological status sensors, helmet systems that equipped with displays-microphones-head phones, local networks, protective uniforms for environmental conditions, special fabrics for providing the best camouflage are some of the examples of such systems (Taylor & Stoianovici, 2003).

Nanotechnology will play a major role in the development of the new generation of army uniforms and equipment. By changing the properties of materials, such as by introducing tiny nanoparticle reinforcements into polymers, nanotechnology will enable such advances as making helmets 40-60% lighter and creating tent-fabric that repairs itself when it rips. With the advent of nanotechnology, chemical protective over garments, which shield soldiers against hazardous chemicals and deadly microorganisms, will enter a new phase of development. The new uniforms will be breathable and 20% lighter in weight than the standard battle-dress over garment (Brower, 2001). With nanotechnology, some properties can be added to materials that weren't there before.

There are some institutes and research centers that work on military products of the future. Much of the smart-fabric, "soldier of the future" research is centered at the US Army Soldier Systems Center. There, scientists and technologists are studying on variety of textiles that can transport power and information. One example is a soldier sticking his intelligent glove finger into water to see if it is safe to drink (Bill, 2002).

Scientists are studying on animals to develop technology that could be used for chameleon-like battle wear that changes color depending on its surroundings. The researchers are trying to catch the interest of the military with fabrics that change color when conductive fibers stitched into the cloth heat and cool the material's thermo chromatic inks. If a soldier is leaning against a marble wall, the suit changes coloration to that, or if a soldier is lying on a black tarmac, it changes to that as shown in Figure 2.2.

Figure 2.2 Chameleon Like Battle Wear

It may be developed within a decade. It is an “all-seasons” waterproof suit that adjusts to the soldier’s internal body temperature, eliminating the need to change clothing. He can actually go from Arctic cold to desert heat and back again (Elert, n.d.). The desire of the army is achieve a fully addressable, interactive camouflage, accomplishing that would be like a space program for e-textiles.

Invisible rain coat, which is shown in Figure 2.3, is a recently developed sample of another optical camouflage technology. This product offers a fascinating sense as if the wearer is transparent. Even if it cannot provide a fully invisible dressing, this extraordinary cloth makes it possible to see the objects and persons behind it. Optical camouflage technology works with a lens that placed on the back of the cloth. This lens perceives the back vision and reflects the image to the front side to provide a transparency.

Figure 2.3 Invisible Rain Coat (Tachi S., 2003)

2.2 Biomedical Applications of Smart Clothes

Last years many efforts have been made for developing “smart” biomedical devices, which can change in high level the way of the healthcare provision for a large amount of population (Mann, n.d.). For instance, people who suffer from chronic diseases such as diabetes or neurological disorders, the elderly and some groups of people with special needs can easily check repeatedly many times per day their health status. This check up could happen without any removal of the patient’s home or work thanks to the advances in communication technology and suitable digital devices or sensors, which can derive information from patient body and his environment.

Figure 2.4 The da Vinci robot consisting of two manipulation arms and one camera arm (Mantas J.G. & Petropouolu S.G., 2005)

Intelligent biomedical clothing and wearable or embeddable electronics are very promising research and development areas, which extend monitoring of physiological signals. The development of intelligent biomedical clothing is based on multidisciplinary research and requires a strong cooperation between scientists and engineers of different scientific fields such as mobile and wireless communication, microsystems and nanotechnologies, biomedical engineering, telemedicine as well as public health and healthcare.

There are many possible applications of intelligent biomedical clothing spanning from the citizen's health watch to patient's disease and life management, including rehabilitation, diabetes management, cardiovascular diseases prevention and emergency intervention, drug delivery and stress management.

2.3 Telemetry

Telemetry is a technology that allows the remote measurement and reporting of information of interest to the system designer or operator. Telemetry typically refers to wireless communications (i.e. using a radio system to implement the data link), but can also refer to data transferred over other media, such as a telephone or computer network or via an optical link or when making a robot it can be over a wire.

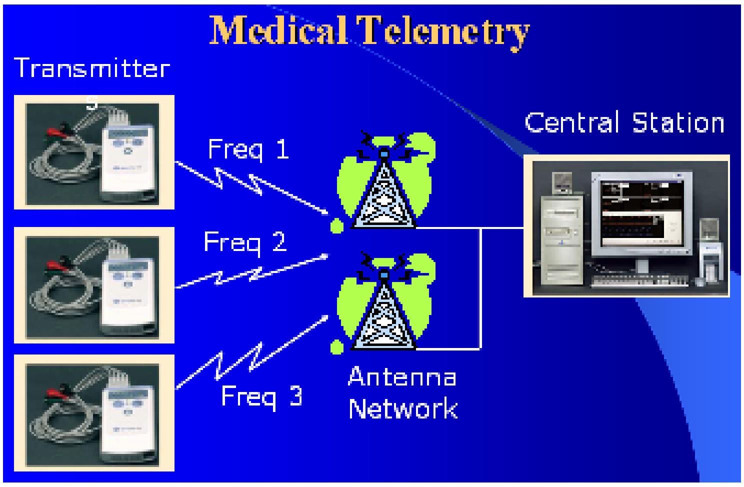

Figure 2.5 Medical telemetry intercommunication

Developments in telecommunication, information technology and computers are the main technical tools for Telemedicine (Telecare, Telehealth, e-health) now being introduced in health care. Telemedicine - medicine at a distance - provides the many possibilities for doctors to more easily consult each other. For individuals, e.g. with chronic diseases, "Telemedicine" means, the possibility to stay in contact with their health care provider for medical advice. This provides new possibilities for personalized health and health care. The results of the researches will make a positive impact on the quality of life for individuals in the real life.

Telemetry is now being used to study wildlife, and has been particularly useful for monitoring threatened species at the individual level. Animals under the study may be fitted with instrumentation ranging from simple tags to cameras, GPS packages and transceivers to provide position and other basic information to scientists and stewards.

Telemetry is used in hydroacoustic assessments for fish which have traditionally employed mobile surveys from boats to evaluate fish biomass and spatial distributions. Conversely, fixed-location techniques use stationary transducers to monitor passing fish. While the first serious attempts to quantify fish biomass were conducted in 1960s, major advances in equipment and techniques took place at hydropower dams in the 1980's. Some evaluations monitored fish passage 24 hours a day for over a year, producing estimates of fish entrainment rates, fish sizes, and spatial and temporal distributions.

Telemetry has been a key factor in modern motor racing. Engineers are able to interpret the vast amount of data collected during a test or race, and use that to properly tune the car for optimum performance. Systems used in some series, namely Formula One, have become advanced to the point where the potential lap time of the car can be calculated and this is what the driver is expected to meet. Some examples of useful measurements on a race car include accelerations in 3 axes, temperature readings, Wheel speed, and the displacement of the suspension. In Formula 1, the driver inputs are also recorded so that the team can assess driver performance and, in the case of an accident, the International Automobile Federation (IAF) can determine or rule out driver error as a possible cause.

In addition, there exist some series where "two way" telemetry is allowed. "Two way" telemetry suggests that engineers have the ability to update calibrations on the car in real time, possibly while it is out on the track. In Formula 1, two-way telemetry surfaced in the early nineties from TAG electronics, and consisted of a message display on the dashboard which the team could update. Its development continued until May 2001, at which point it was first allowed on the cars. By 2002 the teams were able to change engine mapping and deactivate particular engine sensors from the pits while the car was on track. For the 2003 season, the FIA banned two-way telemetry from Formula 1, however the technology still exists and could eventually find its way into other forms of racing or road cars.

Telemetry is an enabling technology for large complex systems such as missiles, Remotely Piloted Vehicle (RPVs), spacecraft, oil rings and chemical plants because it allows automatic monitoring, alerting, and record-keeping necessary for safe, efficient operations. Space agencies such as NASA, ESA, and other agencies use telemetry/telecommand systems to collect data from operating spacecraft and satellites.

Telemetry is vital in the development phase of missiles, satellites and aircraft because the system might be destroyed after/during the test. Engineers need critical system parameters in order to analyze and improve the performance of the system. Without telemetry, these data would often be unavailable.

Telemetry applications are:

- Agriculture
- Water management
- Defense, space and resource exploration systems
- Rocketry
- Enemy intelligence
- Resource distribution
- Motor racing
- Medicine
- Fisheries and Wildlife Research and Management
- Retail businesses
- Law enforcement

CHAPTER THREE

HARDWARE DESIGN OF RESEARCH

A circuit is designed that can measure patient's blood pressure and body temperature and transmit these values via RF to the receiver part. Via RS232, these values are transferred to the personnel computer and when measured values exceed the set values, which are determined on personnel computer; related messages are sent to the doctor's mobile phone. Therefore, the circuit can be separated into two parts as transmitter part and receiver part. Both of them are programmed by using microcontroller. A Peripheral Interface Controller (PIC) is used as the microcontroller device. Its code was written in CCSC programming language. Block diagram is shown in Figure 3.1.

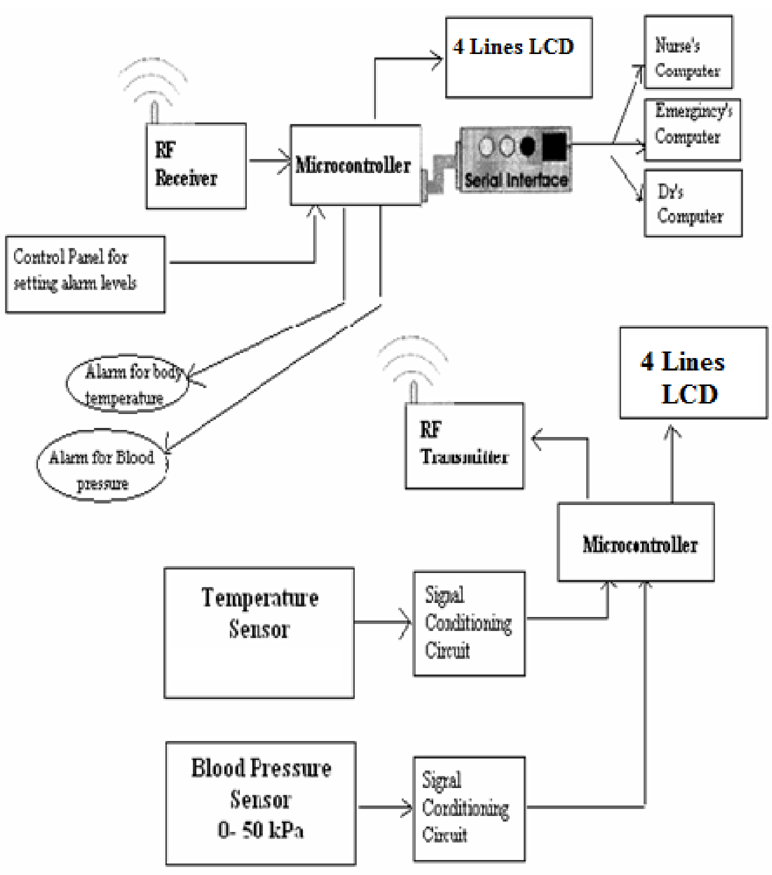

Figure 3.1 Block diagram of the system

The transmitter part consists of three main parts: External hardware (such as cuff, motor, valve, and LCD), analog circuit, and microcontroller. The analog circuit converts the pressure value inside the cuff into readable and usable analog waveforms. The Micro Controller Unit (MCU) samples the waveforms and performs A/D conversion so that further calculations can be made. In addition, the MCU also controls the operation of the devices such as the button and LCD display. In this part, all of the components are combined in one package which allows a user to take it anywhere and perform a measurement whenever and wherever he/she wants.

3.1 Used Circuit Elements

3.1.1 Microcontroller

In this research, two PIC18F452 are used as microcontrollers. Their codes are written using the CCSC programming language. Pin diagram of PIC18F452 is shown in Figure 3.2.

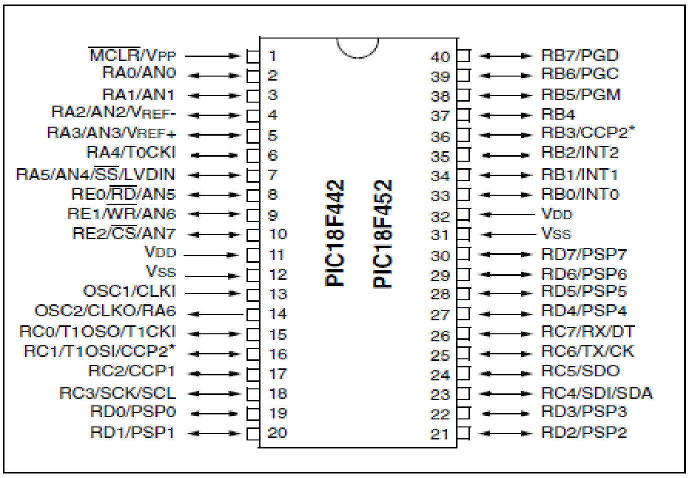

Figure 3.2 Pin diagram of 18F452

3.1.2 Pressure Sensor

For measuring blood pressure, MPX2050GP sensor is used. The MPX2050 series device is a silicon piezoresistive pressure sensor providing a highly accurate and linear voltage output directly proportional to the applied pressure. The sensor is a single, monolithic silicon diaphragm with the strain gauge and a thin–film resistor network integrated on–chip. The chip is laser trimmed for precise span and offset calibration and temperature compensation.

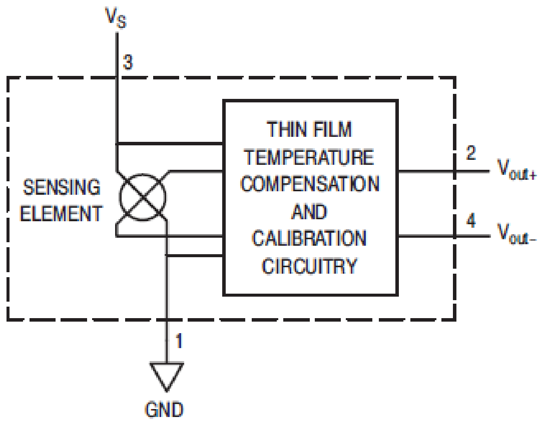

Figure 3.4 Temperature Compensated Pressure Sensor Schematic

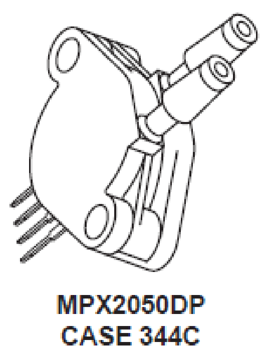

Figure 3.5 Pressure Sensor

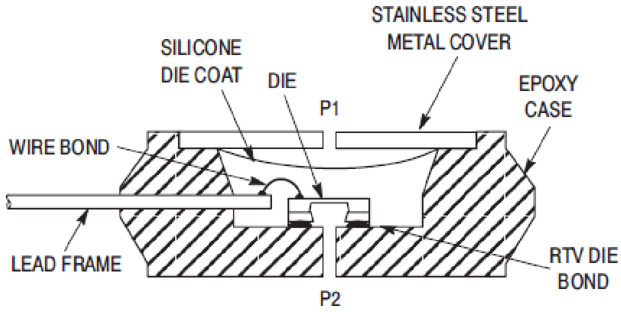

Figure 3.6 Cross–Sectional Diagram

The differential voltage output of the sensor is directly proportional to the differential pressure applied. The output voltage of the differential or gauge sensor increases with increasing pressure applied to the pressure side (P1) relative to the vacuum side (P2). Similarly, output voltage increases as increasing vacuum is applied to the vacuum side (P2) relative to the pressure side (P1).

The pressure transducer produces the output voltage proportional to the applied differential input pressure. The tube, from the cuff, is connected to one of the inputs and another input is left open. By this way, the output voltage will be proportional to the difference between the pressure in the cuff and the air pressure in the room. The transfer characteristic is shown in Figure 3.7.

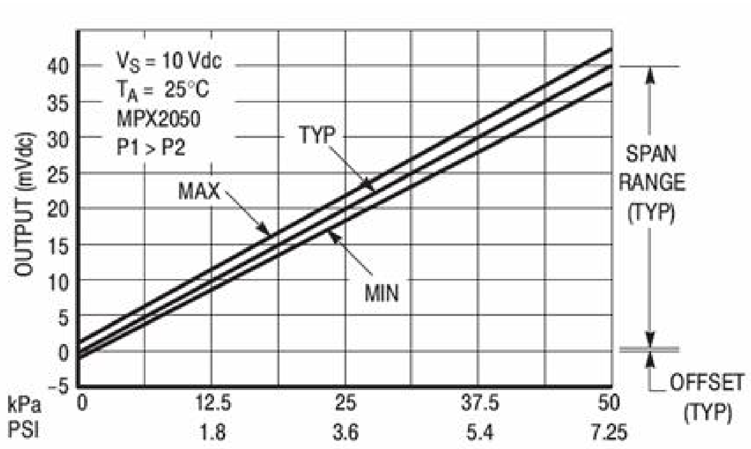

Figure 3.7 Output voltage vs. Differential input pressure

3.1.3 RF Transmitter and Receiver

In this research, 433 MHz ATX34-S RF transmitter is used in the transmitter part of the project and also 433 MHz ARX34 RF receiver is used in the receiver part of the project for wireless data transmission.

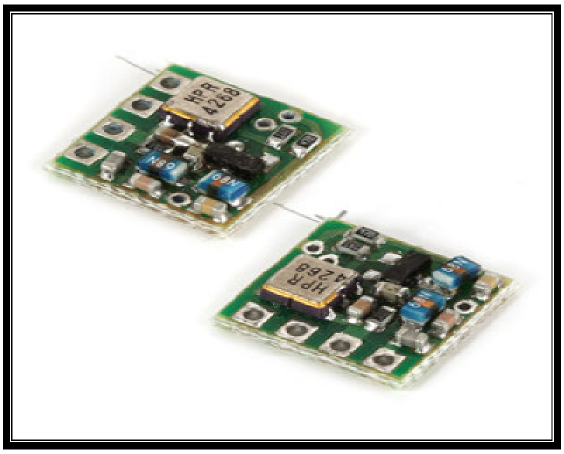

Figure 3.8 RF transmitter

This RF transmitter is used with PT2262 remote control encoder. And also PT2262 is a remote control encoder paired with PT2272 utilizing CMOS technology. It encodes data and address pins into a serial coded waveform suitable for RF or IR modulation. PT2262 has a maximum of 12 bits of tri-state address pins providing up to 531,441 (or 312) address codes; thereby, drastically reducing any code collision and unauthorized code scanning possibilities. Application circuit of RF transmitter with PT2262 remote control encoder is shown in Figure 3.9.

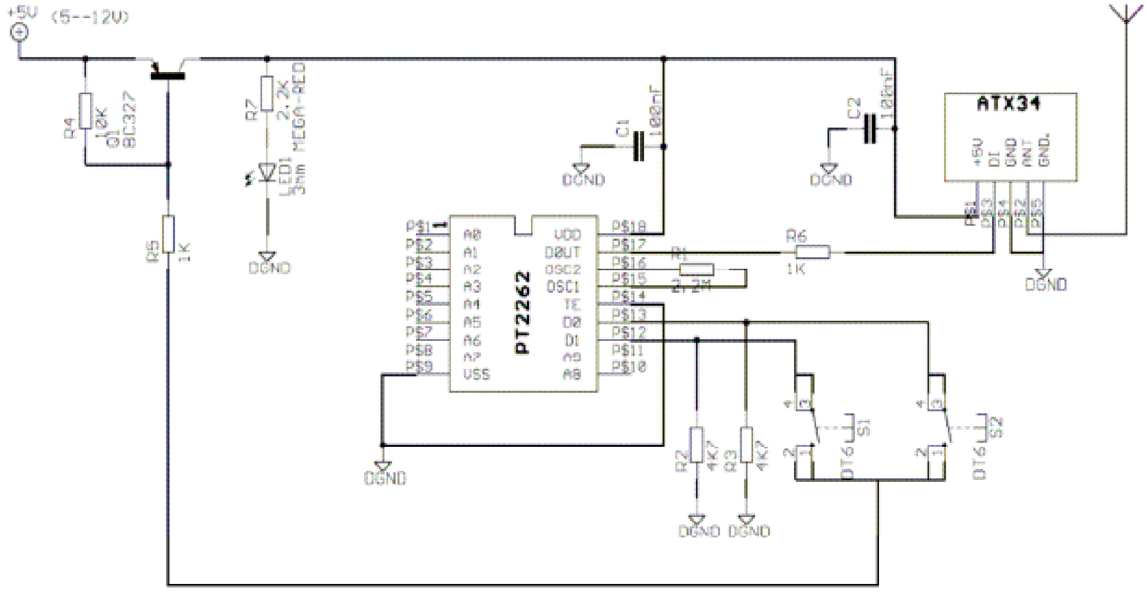

Figure 3.9 Application circuit of ATX34-S with PT2262

The ARX-34 UHF ASK data receiver is developed to cover a band plan ERC Recommendation on Short Range Device (SRD) in the range of 433MHz ISM band. Figure of this ARX-34 is below.

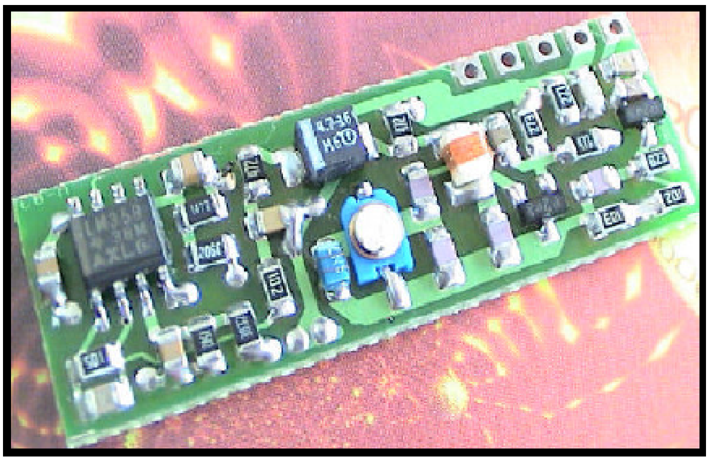

Figure 3.10 ARX-34 RF Receiver

Also this RF receiver is used with PT2272M4 remote control decoder. PT 2272 is a remote control decoder paired with PT 2262 utilizing CMOS Technology. It has 12 bits of tri-state address pins providing a maximum of 531,441 (or 312) address codes; thereby, drastically reducing any code collision and unauthorized code scanning possibilities. PT 2272 is available in several options to suit every application need: variable number of data output pins, latch or momentary output type.

Best range is achieved if the transmitter and receiver antenna have a direct visual connection. Any object in between the transmitter and receiver antenna, and metallic objects in particular, will decrease the range. The transmission is influenced by possibility to have data error by overlaying the direct and reflected signal. Application circuit of RF receiver with PT2272M4 remote control decoder is shown in Figure 3.11.

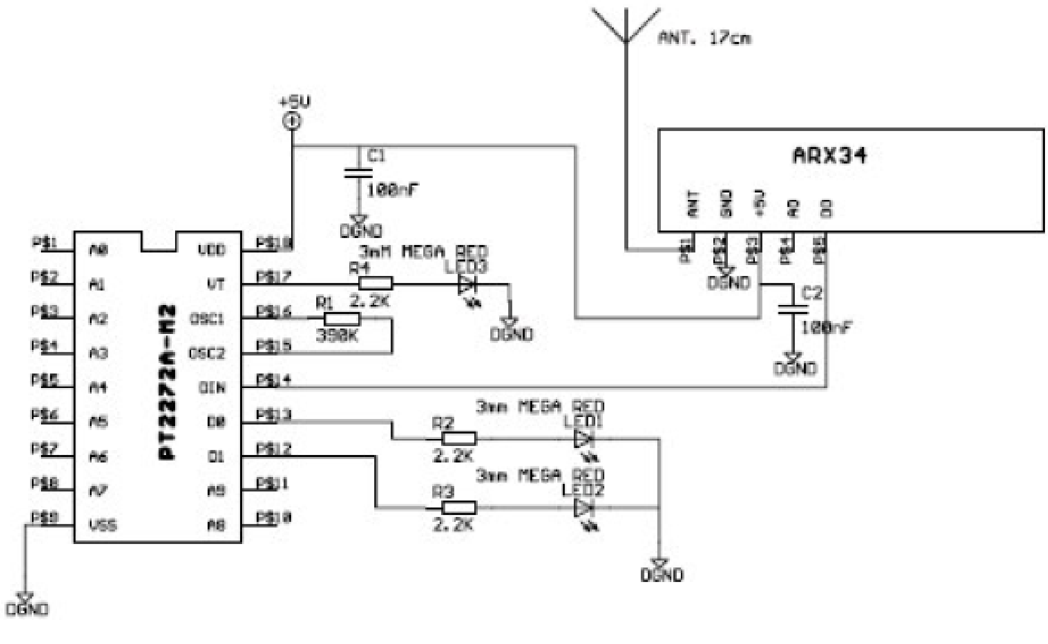

Figure 3.11 Application circuit of ARX34 with PT2272M4

3.1.4 Power Supply Layer:

The circuit that is designed consists of analog and digital parts. In order to increase the accuracy of the measurement, power supplies of these parts are realized separately. Power supply of the digital part is shown in Figure 3.12.

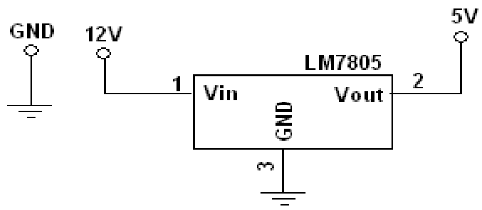

Figure 3.12 Power supply of the digital part

LM78MXX series of three-terminal positive voltage regulators employ built-in current limiting, thermal shutdown, and safe-operating area protection which make them virtually immune to damage from output overloads. By using LM7805 output voltage can be fixed to 5V. Input voltage can be chosen between 5V and 24V. It has a cooling block, so it can prevent itself from high temperature.

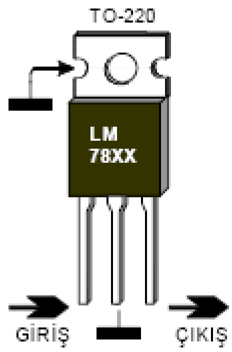

Figure 3.13 LM7805

3.1.5 Temperature Sensor

In this research, four DS18B20 temperature sensors are used. The reason of using four sensors is to obtain more correct measurement results. All temperature sensors measure and then their average value is taken and sent to the LCD. By this method, body temperature can be measured in accordance with the real value. The DS18B20 Digital Thermometer provides 9 to 12–bit centigrade temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. It has an operating temperature range of –55°C to +125°C and is accurate to ±0.5°C over the range of –10°C to +85°C. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply.

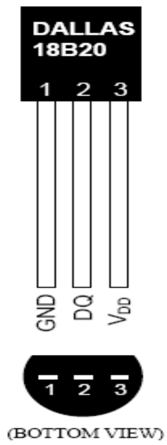

Figure 3.14 DS18B20
Temperature Sensor

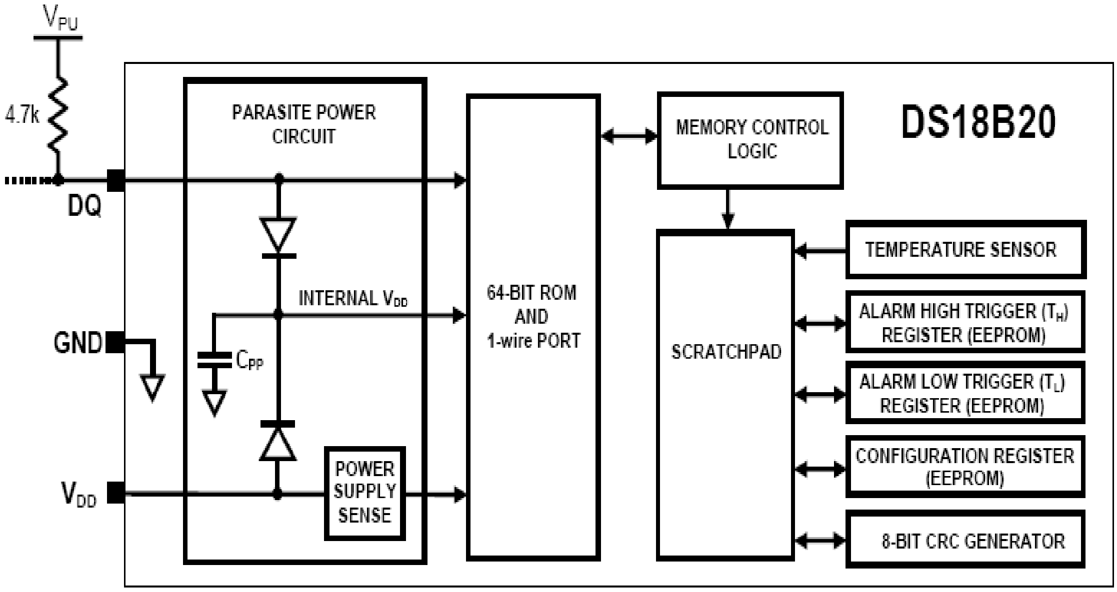

Figure 3.15 Block diagram of temperature sensor

3.1.6 Digital Display Panel

In this research, one LCD, as shown in Figure 3.16, is used for the transmitter part and one for the receiver part. These LCDs include four lines and twenty characters. 5V activation voltage is needed and 0-20KΩ potentiometer is used for adjusting contrast of display. Input -output block diagram of the LCD is shown in Figure 3.17.

Figure 3.16 Four lines, twenty characters liquid crystal display

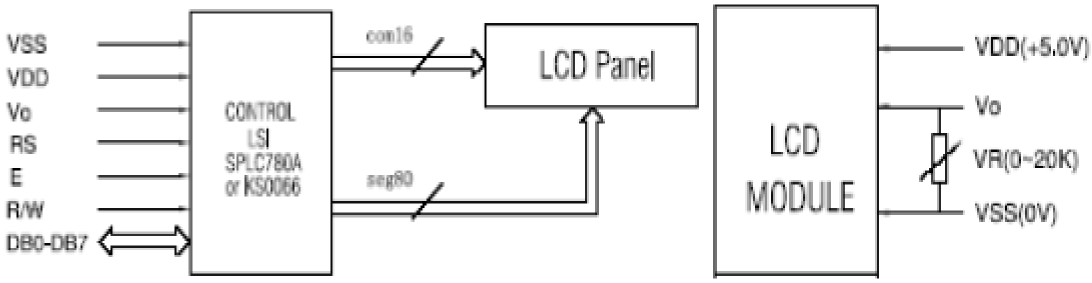

Figure 3.17 Input-Output Block Diagram of LCD

3.2 Blood Pressure Measuring

Blood pressure measurements consist of two numbers. A typical reading will look something like “120/80” (read “120 over 80”) and is measured in mmHg. The first number is the systolic blood pressure, which is the pressure in the vascular tissue when the heart is pumping blood away from the heart. The second number is the pressure when the blood is flowing back to the heart, so the first number is always higher than the second.

When measuring blood pressure with a sphygmomanometer and stethoscope, a cuff is inflated around the user’s arm until it completely restricts the flow of blood through the arm. The operator listens with the stethoscope and can tell that the blood is no longer flowing when there is no sound in the stethoscope. Once this point is reached, the air in the cuff is released slowly, decreasing the pressure, which is read from the sphygmomanometer. When the blood resumes flowing in the arteries, it will create sound in the stethoscope. The pressure where this occurs is the systolic pressure. The pressure in the cuff is decreased more until the sound stops. This is the diastolic pressure. At the diastolic pressure, the arterial pressure is greater than the cuff pressure and no sound is heard in the stethoscope.

To perform a measurement, a method called “oscillometric” is used. In this method, the air will be pumped into the cuff to be around 20 mmHg above average systolic pressure (about 120 mmHg for an average). After that the air will be slowly released from the cuff causing the pressure in the cuff to decrease. As the cuff is slowly deflated, the titchy oscillation in the air pressure of the arm cuff will be measured. The systolic pressure will be the pressure at which the pulsation starts to occur and the diastolic pressure will be taken at the point in which the oscillation starts to disappear. The MCU is used to detect the point at which this oscillation happens and then records the pressure in the cuff. When the measurement is finished, the pressure in the cuff is suddenly decreased.

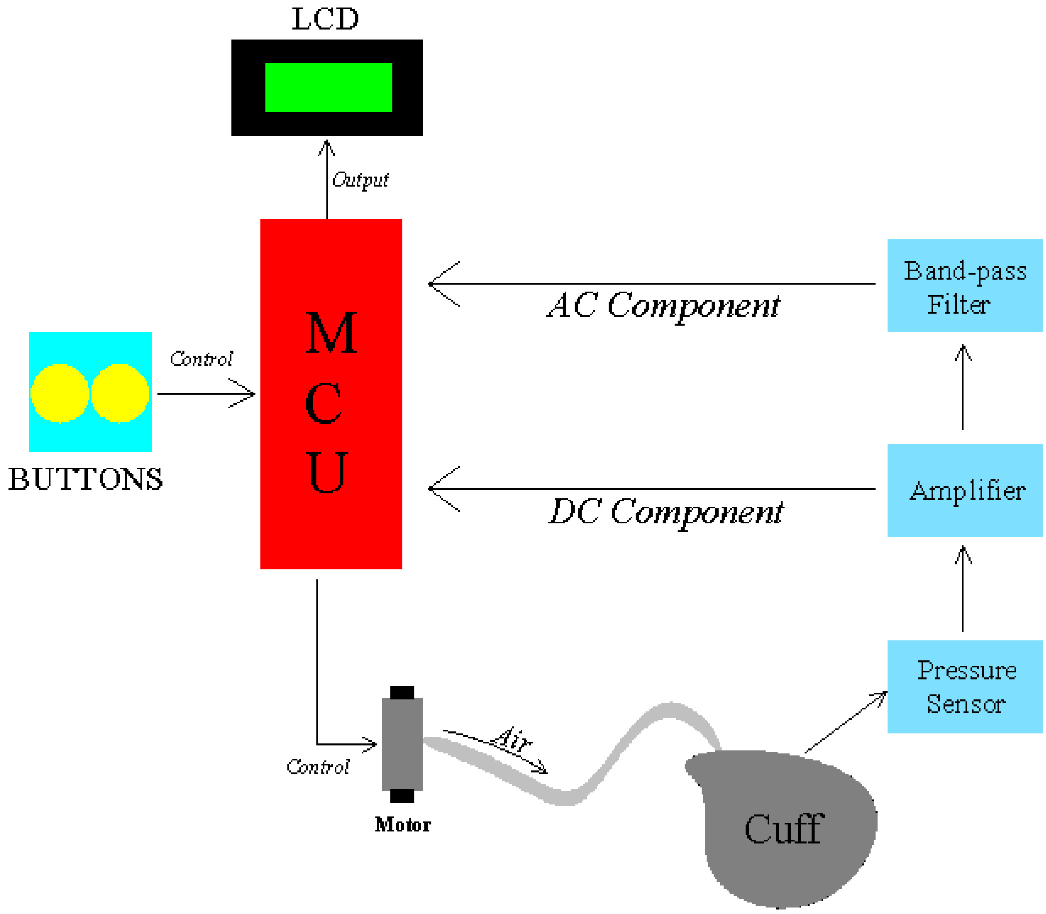

Figure 3.18 Hardware Diagram

The diagram above shows how designed device is operated. The user will use START/STOP buttons to control the operations of the whole system. The MCU is the main component which controls all the operations such as motor and valve control, A/D conversion, and calculation, until the measurement is completed. After measurement is finished, all the results are transmitted to the LCD.

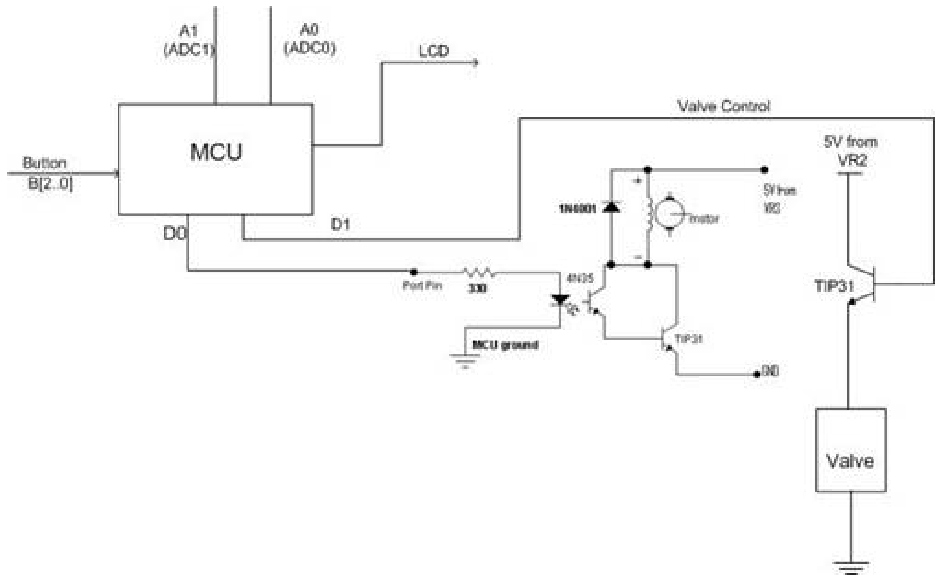

Figure 3.19 Schematics of Motor and Valve Control

3.2.1 Analog Circuit

To amplify both the DC and AC components of the output signal of pressure transducer, the analog circuit is used. Thus, the MCU is used to process the signal and obtain useful information about the health of the user. The differential voltage output of the pressure sensor is directly proportional to the differential pressure applied and the output voltage of the pressure sensor ranges from 0 to 40 mV. But in this research, the arm cuff is pumped to only 160 mmHg and it is approximately equal to 21.33 kPa, so this mean in this project the output voltage of the pressure sensor is approximately 18 mV. Thus, the pressure sensor needs a gain of approximately 200 to be perceived by the MCU.

Then the signal from the DC amplifier will be passed on to the band-pass filter. The filter is designed to have large gain at around 1-4 Hz and to attenuate any signal that is out of the pass band. To determine when to capture the systolic/diastolic pressures and the heart rate of the user, the AC component from the band-pass filter is the most important factor. For providing the DC bias level independently, the 47μF capacitor is used to coupling only AC component of the signal. Also, two identical resistors are used to provide a constant DC bias level at approximately 2.5 volts in the AC coupling stage.

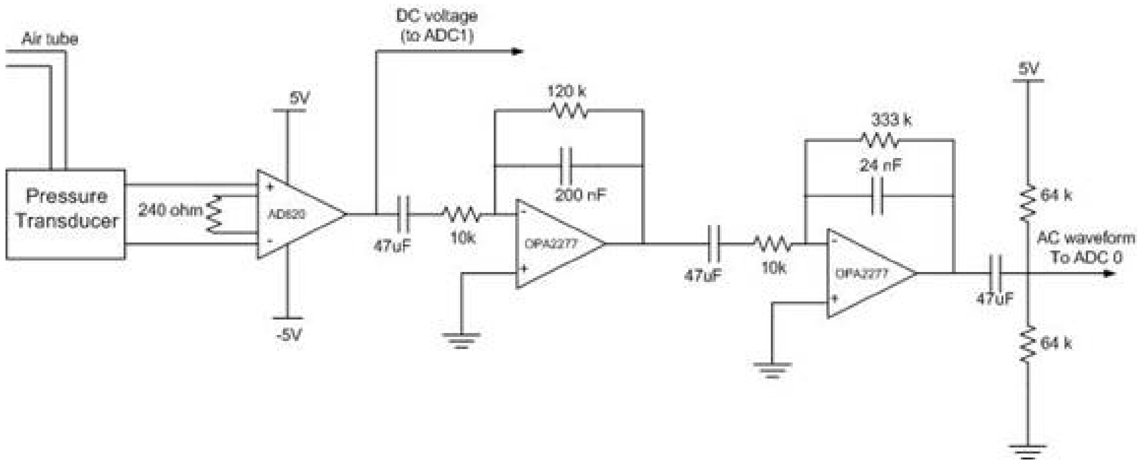

Figure 3.20 Schematics of Analog Circuit

3.2.2 DC Amplifier

The signal is amplified for further processing, since the output voltage of the pressure transducer is very small. The instrumentation amplifier AD620 from Analog Devices is used. The R_G resistor is used to determine the gain of the amplifier according to the equation;

$$R_G = \frac{49.4k\Omega}{G-1} \tag{3.1}$$

Since the gain of approximately 200 is need, the resistor R_G is chosen to be 240 ohms. This will give the gain of 206 according to the equation. However, the gain must be measured from the finished circuit, and the measured gain is 213. The schematic of the AD620 amplifier is shown in Figure 3.21.

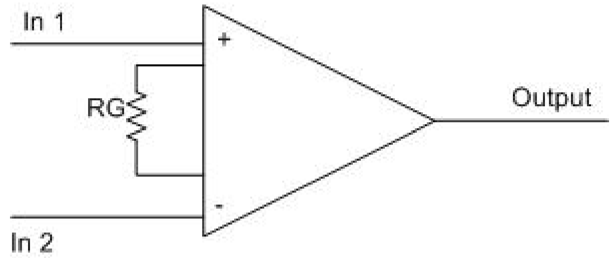

Figure 3.21 Schematic of DC amplifier

3.2.3 Band Pass Filter

As a cascade of two active band-pass filters are designed in the band-pass filter stage. The overall band-pass stage would provide a large gain and the frequency response of the filter will have sharper cut off than using only single stage, for this reason two-active band-pass filters are used. By this method, the signal to noise ratio of the output will improve. The schematics for both filters are shown in Figure 3.20.

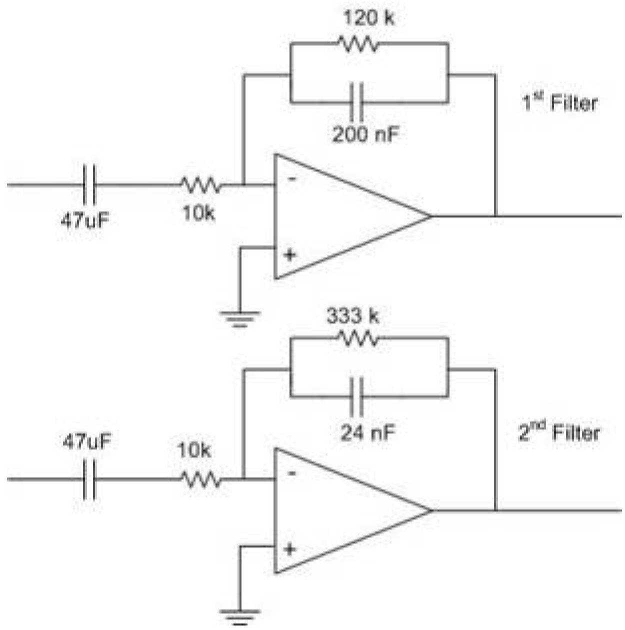

Figure 3.22 Band-pass Filter Stage

First Band-pass filter :

The lower cutoff frequency is;

$$f_{low} = \frac{1}{2\pi(47\mu F)(10k)} = 0.338Hz \tag{3.2}$$

The higher cutoff frequency is;

$$f_{high} = \frac{1}{2\pi(200nF)(120k)} = 6.631Hz \tag{3.3}$$

The mid-band gain of the first filter is;

$$A = -\frac{120k}{10k} = -12 \tag{3.4}$$

Second Band-pass filter:

The lower cutoff frequency is;

$$f_{low} = \frac{1}{2\pi(47\mu F)(10k)} = 0.338Hz \tag{3.5}$$

The higher cutoff frequency is;

$$f_{high} = \frac{1}{2\pi(24nF)(33k)} = 19.91Hz \tag{3.6}$$

The mid-band gain of the second filter is;

$$A = -\frac{333k}{10k} = -33.3 \tag{3.7}$$

Thus for the band-pass stage, the overall gain is 399.6. The total AC gain for the circuit when combining this gain with the gain from the DC amplifier, is equal to;

$399.6 \times 213 = 8.51 \times 10^4$.

The choice of high and low cut-off frequency is good enough to give very clean AC waveform.

3.3 Body Temperature Measurement

Body heat is dynamic, always changing, always moving across tissue boundaries. Heat transfer occurs when there is a difference in heat content of adjacent areas. The sum of the differences between one area and another is called “gradient”. So, actually measured data while the body temperature is measuring, is energy in motion in search of equilibrium from warmer to cooler.

One requirement of a temperature measurement site is that it has to be near an artery, since the blood is the main vehicle for heat loss or heat conservation. Sites can be characterized as “core” or “shell” sites, meaning deep inside the body or near the surface, but even sites classified in that manner do not necessarily behave in the same way.

The core functionality of the DS18B20 is its direct-to-digital temperature sensor. The resolution of the temperature sensor is user-configurable to 9, 10, 11, or 12 bits, corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively.

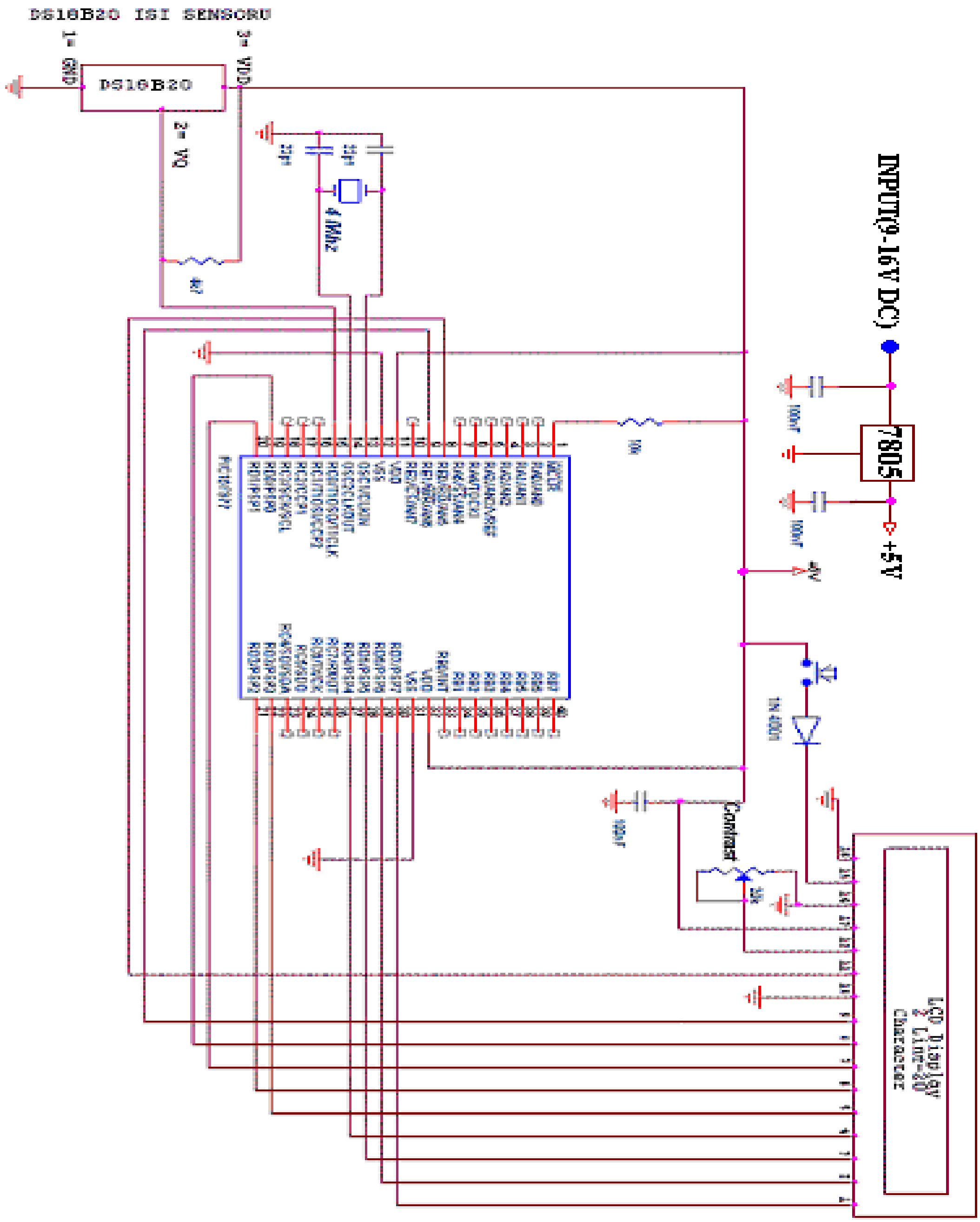

Figure 3.23 Body temperature measurement circuit

CHAPTER FOUR

SOFTWARE DESIGN OF RESEARCH

4.1 Designing the Operating Control of Blood Pressure Measurement

The block diagram for operating control totally consists of seven states. First, the START state is started, where the program waits for the user to push the START button of the device. Once the START button is pushed, the measurement process begins by inflating the hand cuff. While the cuff is being inflated, if the user feels very uncomfortable or painful, he/she can push the STOP button (emergency button) to stop the motor, quickly deflate the cuff and stop the measurement. This will ensure that the safety of the user is well maintained while using the device. Anyhow, if the cuff-inflating procedure goes smoothly, the air will be pumped into the cuff until the pressure inside the cuff reaches 160 mmHg and then, the motor will be stopped and the air will slowly be released from the cuff. Again, at this point, the user can abort the process by pressing the STOP button. Once the MCU has obtained the values of systolic, diastolic and heart rate, the valve will be opened to release air from the cuff quickly. Then it will report the result of the measurement by displaying the obtained data on the LCD screen. Approximately after 20 seconds, the program will start the next measurement and it continues in this loop until STOP button is pushed.

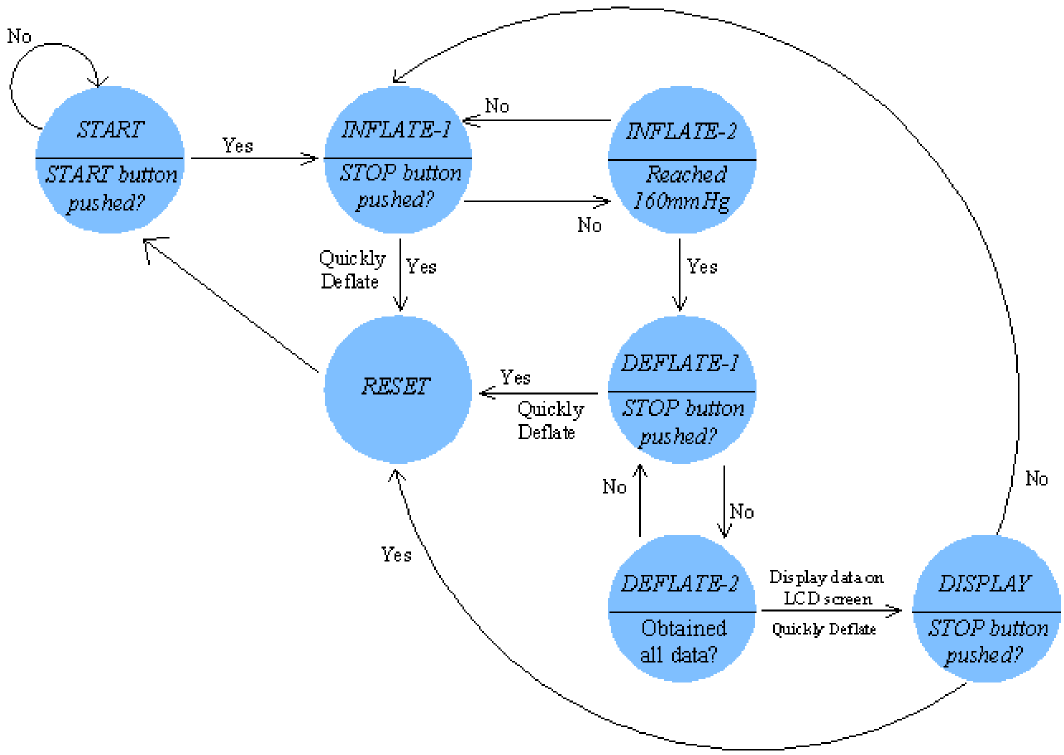

Figure 4.1 Block diagram of operating control for blood pressure

4.2 Design for measuring the components of blood pressure

First the motor pumps the air into the cuff until the pressure exceeds 160 mmHg, then the motor stops pumping more air and the cuff is deflated through the slightly-opened valve. At that time, the pressure in the cuff starts decreasing approximately linearly and the program enters the measurement mode. The MCU looks at the AC signal through the ADC0 pin and determines the systolic, diastolic pressure values and the heart rate of the user respectively (Suampun W. & Wattanapanitch W.). For this project, the oscillometric method, in which the program monitors the titchy pulsations of the pressure in the cuff, is performed for measurement. The state diagram of the blood pressure measurement is shown in Figure 4.2

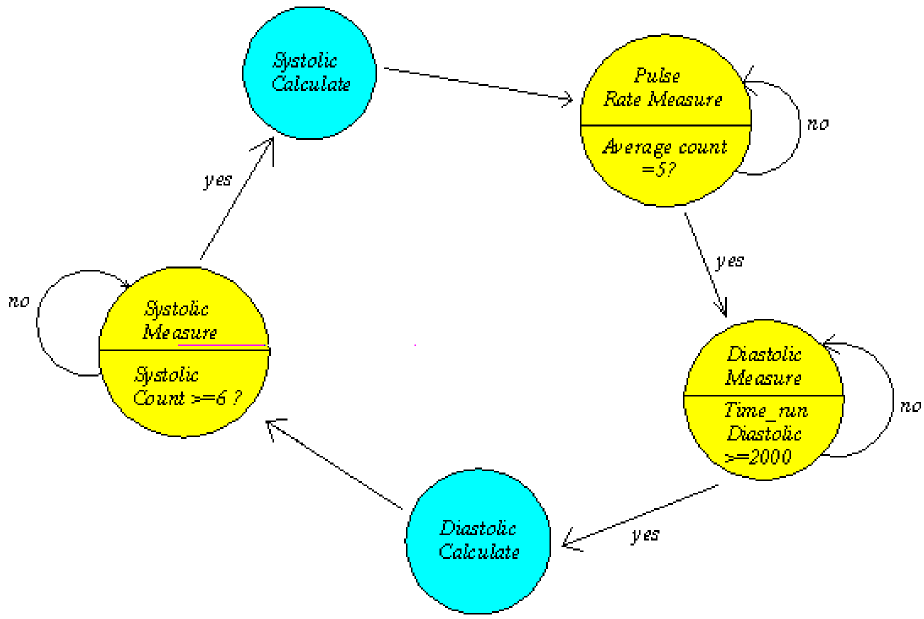

Figure 4.2 State diagram of the blood pressure measurement

4.2.1 Systolic Pressure Measurement

After the motor pumps the pressure up to 160 mmHg which is approximately more than the systolic pressure of normal healthy people, motor stops automatically and valve opens. Then the cuff starts deflating and the program enters "Systolic Measure" state. At this state, the program looks at the AC waveform from ADC0 pin. When the pressure in the cuff decreases to a definite value, the blood begins to flow through the arm so the systolic pressure can be obtained at the beginning point of this oscillation.

In the program, a threshold voltage of 4V is set for the AC waveform. In the beginning, there is no pulse and the voltage at the ADC0 pin is constant at approximately 2.5 V. Then when the pressure in the cuff decreases until it reaches the systolic pressure value, the oscillation starts and grows. After that, the number of pulses, that has maximum values above the threshold voltage, is counted. If the program counts up to six, the program enters the "Systolic Calculate" state. At this state, the program records the DC voltage from pin ADC1 and then it converts this DC voltage value to the pressure in the cuff to determine the systolic pressure of the patient.

From the transfer characteristic of the pressure sensor and the measured gain of the DC amplifier, the systolic pressure is determined by looking at the DC voltage of the ADC1 pin. In the conversion procedure, first the DC voltage that is read off from the ADC1 pin be “DC_voltage”, and the gain of the DC amplifier is “DC_gain”.

Then the differential voltage that comes out of the DC amplifier is calculated as;

$$transducer\_voltage = \frac{DC\_voltage}{DC\_gain} \tag{4.1}$$

From the pressure sensor's transfer characteristic given in Figure 3.7, the pressure can be calculated based on the “transducer_voltage”. The slope of the typical curve is calculated as;

$$slope = \frac{40mV}{50kPa} = 8 \times 10^{-4} V / kPa \tag{4.2}$$

Thus, the pressure in the cuff in the unit of kPa can be calculated as;

$$pressure\_kPa = \frac{transducer\_voltage}{slope} \tag{4.3}$$

Then the pressure can be converted back to mmHg unit by multiplying by $\frac{760mmHg}{101.325kPa}$. Thus the pressure in the mmHg unit is expressed as;

$$pressure\_mmHg = pressure\_kPa \times \frac{760mmHg}{101.325kPa} \tag{4.4}$$

Combining these conversions all together, the formula is obtained for converting the DC voltage to the pressure in the cuff as;

$$pressure\_mmHg = \frac{DC\_output}{DC\_gain} \times 9375 \tag{4.5}$$

After the program finishes this calculation, it enters the "Pulse Rate Measure" state to determine the pulse rate of the patient.

4.2.2 Pulse Rate Measurement

After the program finished calculating the systolic pressure, it starts monitoring the pulse rate of the patient. The pulse rate is determined truly after determining the systolic pressure because at this point the oscillation of the waveform is strongest. The program samples the AC waveform every 40 millisecond, then it records the time interval when the values of the AC waveform cross the voltage value of 2.5 volts. It takes the average of five time intervals to calculate the heart rate as accurate as possible. The "Average count" variable is used for counting the number of time intervals as shown in the state diagram. After the heart rate is determined, the program enters the "Diastolic Measure" state to measure the diastolic pressure of the patient.

4.2.3 Diastolic Pressure Measurement

After the pulse rate is determined, the program enters the "Diastolic Measure" state. In this state, the program is still sampling the signal at every 40 millisecond. Then the threshold voltage is defined to measure the diastolic pressure. While the cuff is deflating, at some point before the pressure reaches diastolic pressure, the amplitude of the oscillation will decrease. To determine the diastolic pressure, the DC value is recorded at the point when the amplitude of the oscillation decreases to below the threshold voltage. At the time interval of 2 seconds if the AC waveform does not exceed the threshold, it means the amplitude of the oscillation is actually below the threshold. At that point the DC value of the ADC1 pin can be converted back to the pressure in the arm cuff using the same procedure as described in the Systolic Pressure Measurement section.

Please take notice that determining the diastolic pressure is quite difficult and ambiguous since the voltage threshold varies from person to person. Thus, the voltage threshold is adjusted so that the value of diastolic pressure which is obtained corresponds to the known value that is get when it is measured by using the available commercial product.

After the program finishes calculating the diastolic pressure, it calculates the body temperature immediately and then the program will open up the valve and the cuff will deflate quickly after the information acquired from the measurement on the LCD is displayed.

4.3 Receiver Part Design

In the receiver part of this project, measurement values from transmitter part are taken via RF and shown on the LCD. These transmitted values are also shown on the interface of the computer via RS-232 port. On the interface, the limit values can be set, and according to these set values, GSM modem which is connected to the PC with RS-232, sends related messages to the mobile phone. The mobile phone number, that takes the related messages, can be written to the interface. To send Short Message Service (SMS) to the mobile phone, a SIM card is put into the GSM modem.

A GSM modem is a wireless modem that works with a GSM wireless network. A wireless modem behaves like a dial-up modem. The main difference between them is that a dial-up modem sends and receives data through a fixed telephone line while a wireless modem sends and receives data through radio waves.

4.3.1 Configuring and Testing GSM Modem

To define which modems are to be utilized by the gateway, select the "Short Message Service Center (SMSC)" tab from the gateway configuration dialog box:

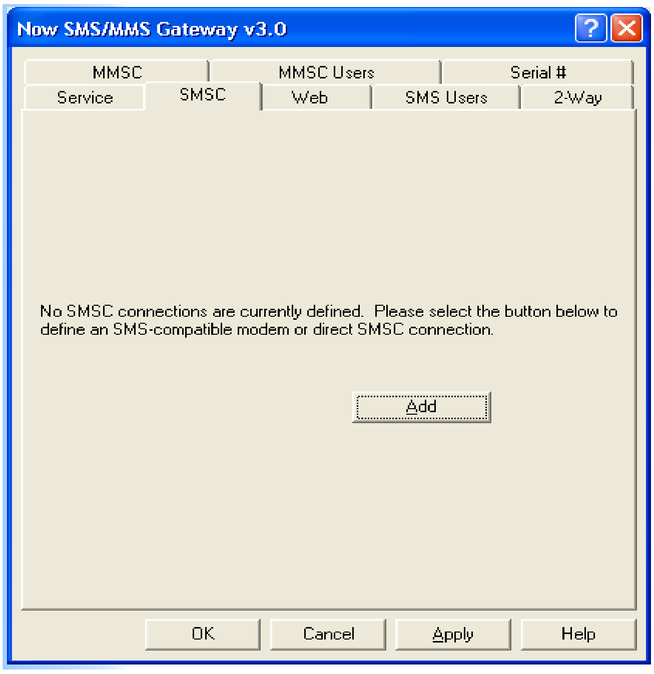

Figure 4.3 SMSC configuration dialog

If no modems are yet to be defined, only the "Add" button will be available on this dialog. Select "Add", and then "GSM Phone or Modem" displays the list of available modem drivers on the computer.

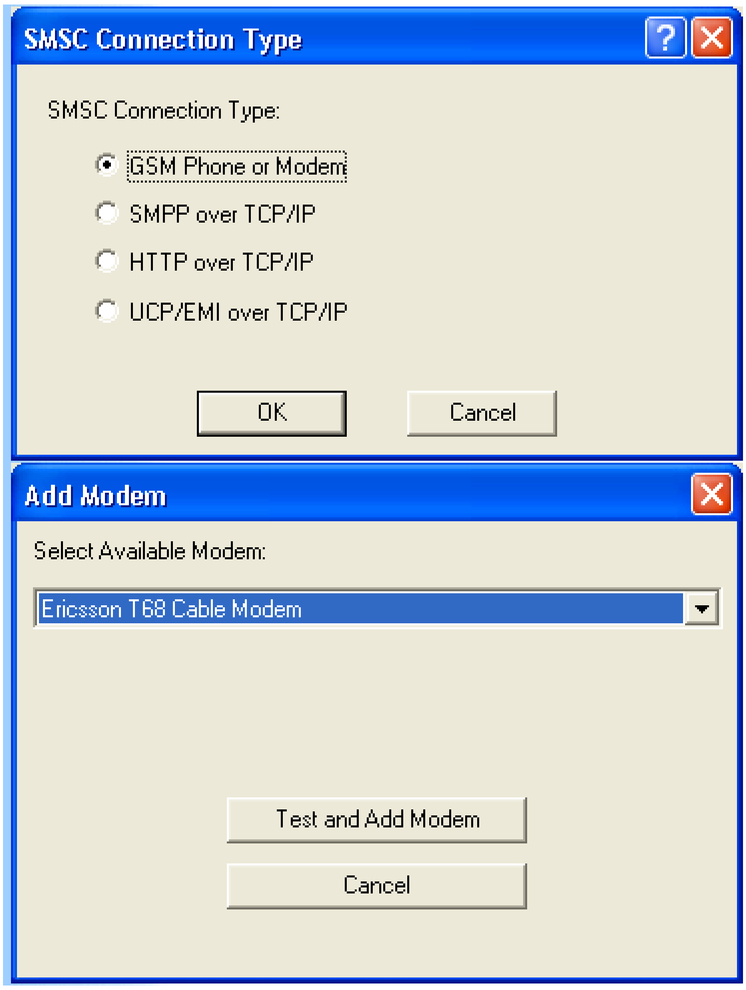

Figure 4.4 Modem configuration type

After selecting an available modem, the "Test and Add Modem" button is pressed. The gateway will then attempt to initialize the modem, and confirm that the modem supports the necessary interfaces to send and receive SMS messages. The modem will only be added to the configuration if the gateway confirms that it can properly communicate with the modem.

4.3.2 Creating Database for Patients

By the interface on the computer, a database can be made for the patients, and measured values can gradually be saved on the patients file. Then saved data can open and new measurements can be saved on it. By this, all the results of the related patient can be seen.

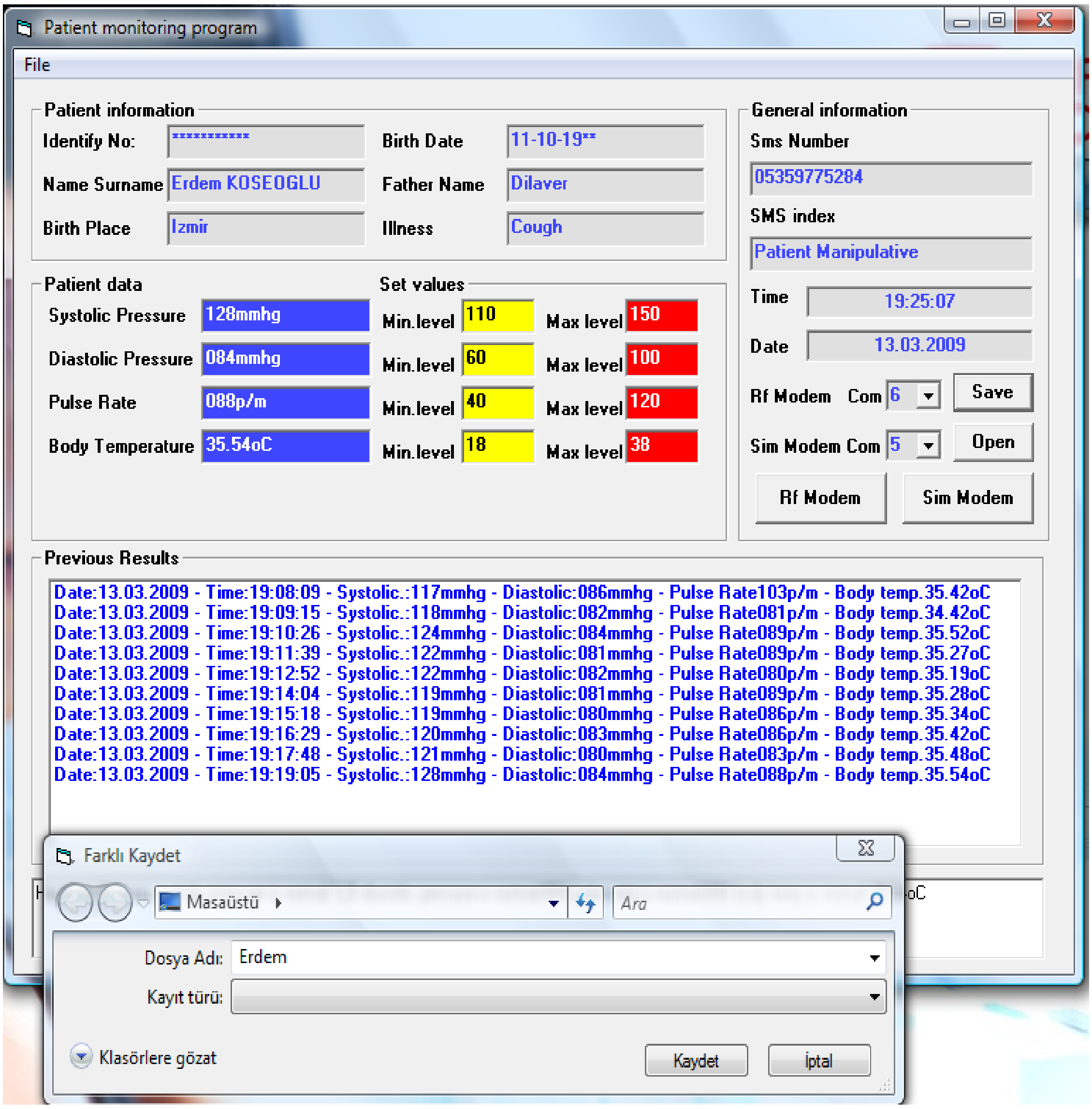

Figure 4.5 Creating database after measuring

CHAPTER FIVE

RESEARCH RESULTS

5.1 Measurement Results

When this system is first started, images in Figures 5.2 and 5.3 are produced on the transmitter part and receiver part LCDs. Also interface on the computer is shown in Figure 5.3.

Figure 5.1 LCD of the transmitter part before starting measurement

Figure 5.2 LCD of the receiver part before starting measurement

Figure 5.3 Personnel Computer Interface before starting measurement

SMS number part on the interface, explains the related mobile phone number to whom the alert messages will sent. And also, SMS Index part explains the related title which will be added to the alert message to give some important clues about the patient.

GSM modem only sent the alert message if there is an existence of any LEDs on the receiver part. And also, it was limited 160 characters on one SMS. So, SMS index part on the interface must be contained minimum character as it can be.

When Start button was pushed, measuring starts and cuff starts to inflate. After that, Figure 5.4 was shown on the transmitter part LCD.

Figure 5.4 LCD of the transmitter part after “START” button was pushed

After Start button was pushed, in transmitter part measuring starts and followings are shown on the receiver and transmitter LCDs.

Figure 5.5-a Measurement results on the LCD of the transmitter part when "START" button was pushed

Figure 5.5-b Measurement results on the LCD of the receiver part when "START" button was pushed

Some pre-trials are made and some data are got about the performance of the system.

Figure 5.6-a Measurement results on the LCD of the transmitter part after the 1st measurement

Figure 5.6-b Measurement results on the LCD of the receiver part after the 1st measurement

As shown in Figure 5.6-a and 5.6-b, in the first measurement systolic pressure was measured 117 mmHg, diastolic pressure was 80 mmHg, pulse rate was 74 p/m and the body temperature was 35.69 °C. By the serial port of the computer, these measurement results were transmitted to the interface on the PC and Figure 5.6-c was taken.

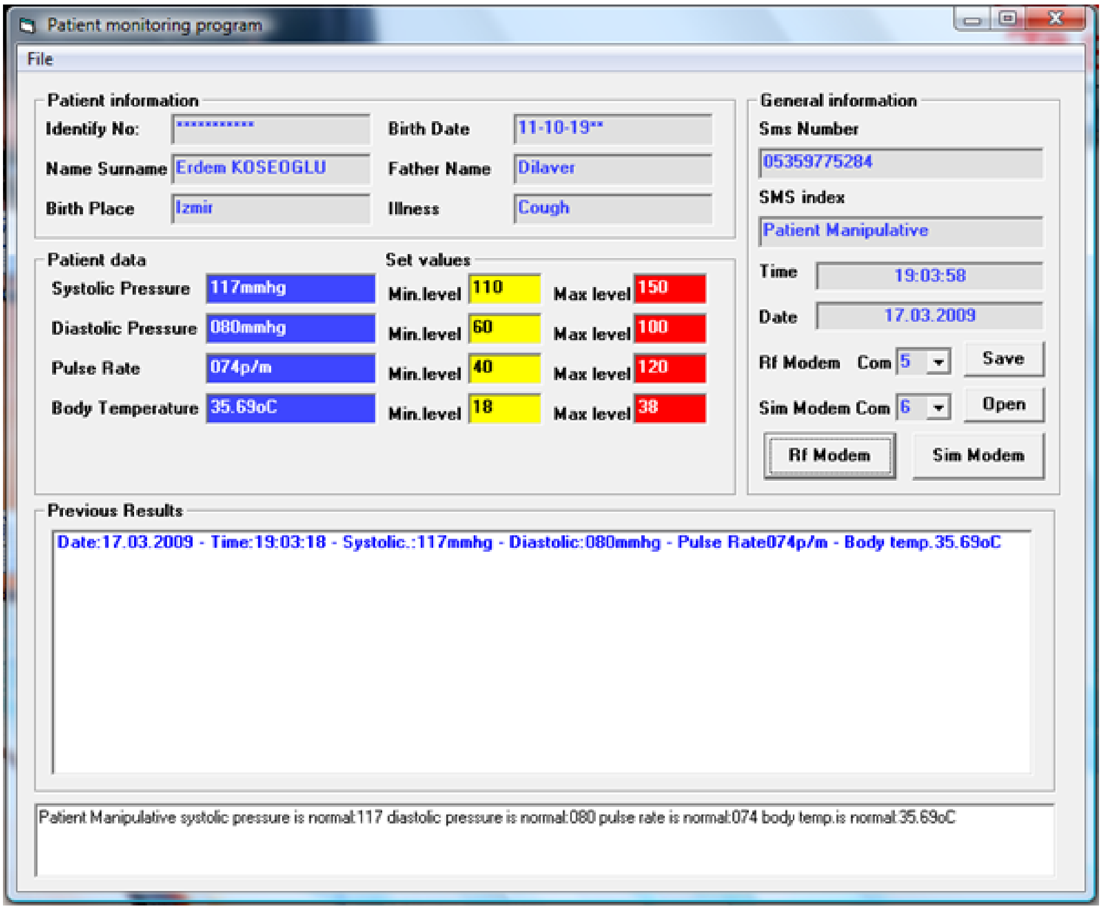

Figure 5.6-c Measurement results at the interface after the 1st measurement

Between Figure 5.7-a and Figure 5.21-c, other trials measurement results are given.

Figure 5.7-a Measurement results on the LCD of the transmitter part after the 2nd measurement

Figure 5.7-b Measurement results on the LCD of the receiver part after the 2nd measurement

Figure 5.7-c Measurement results at the interface after the 2nd measurement

These measurement values, which are above, were taken approximately 2 minutes later after first measurement. And in these 2 minutes, blood pressure, pulse rate and body temperature values didn’t change a lot as it was shown in figures.

Figure 5.8-a Measurement results on the LCD of the transmitter part after the 3rd measurement

Figure 5.8-b Measurement results on the LCD of the receiver part after the 3rd measurement

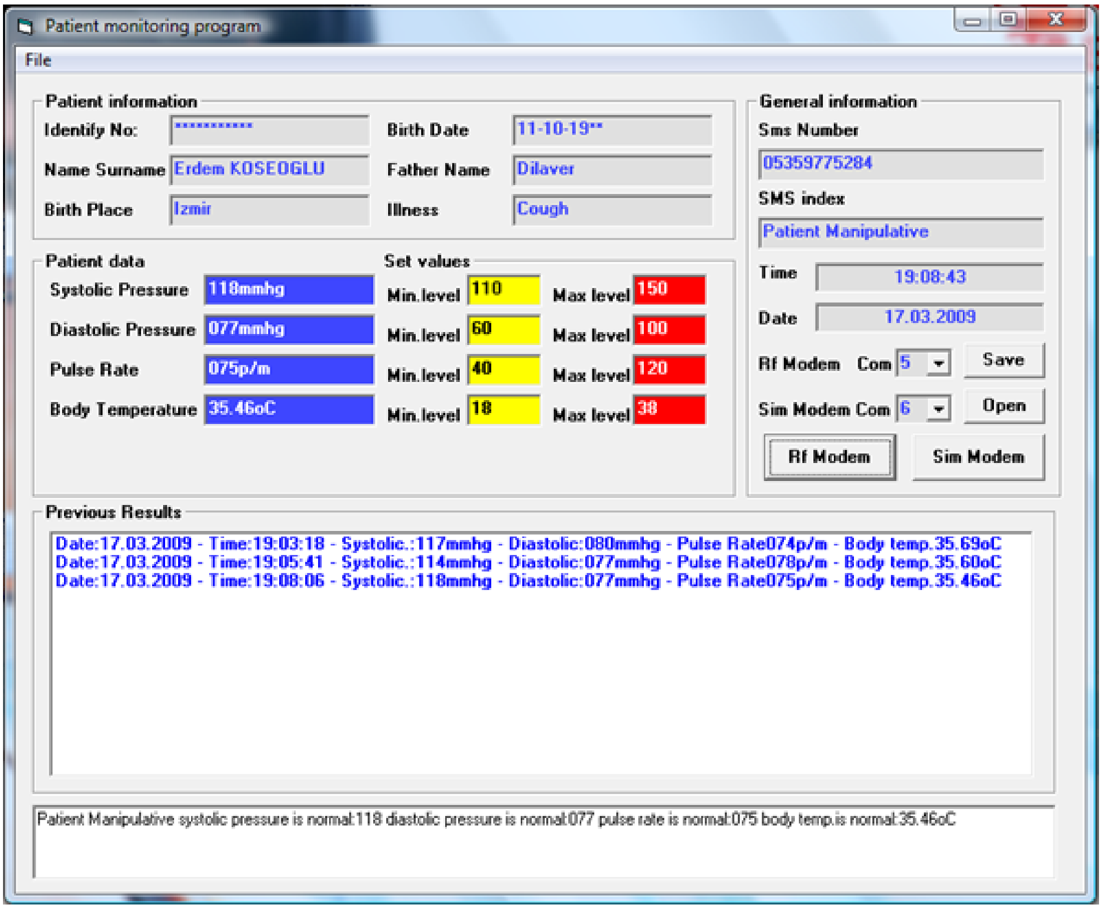

Figure 5.8c Measurement results at the interface after the 3rd measurement

Third measurement results show that, systolic-diastolic pressures, pulse rate and body temperature values were still between the set values.

Figure 5.9-a Measurement results on the LCD of the transmitter part after the 4th measurement

Figure 5.9-b Measurement results on the LCD of the receiver part after the 4th measurement

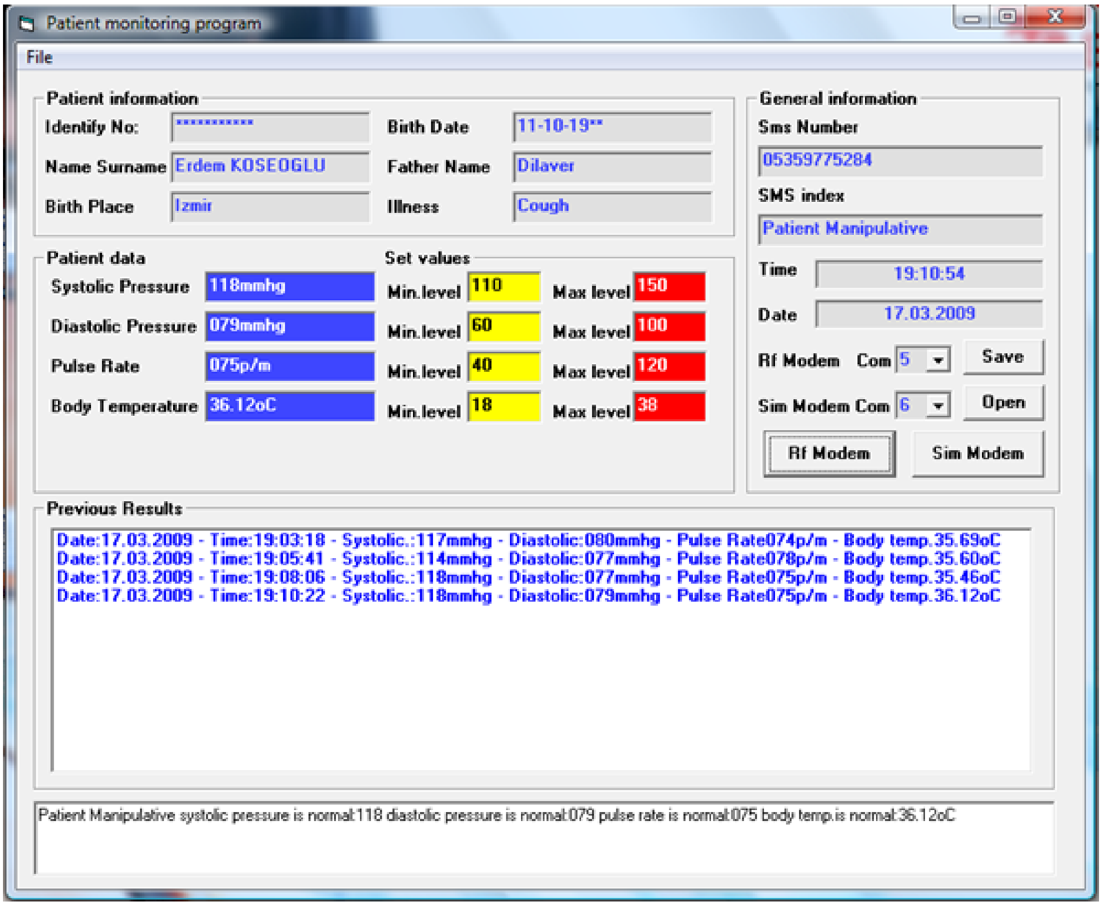

Figure 5.9-c Measurement results at the interface after the 4th measurement

As shown in figures which are above, fourth measurement results were too close to first measurement results. So it means, in these time interval, systolic-diastolic pressures, pulse rate and body temperature values didn’t change a lot.

Figure 5.10-a Measurement results on the LCD of the transmitter part after the 5th measurement

Figure 5.10-b Measurement results on the LCD of the receiver part after the 5th measurement

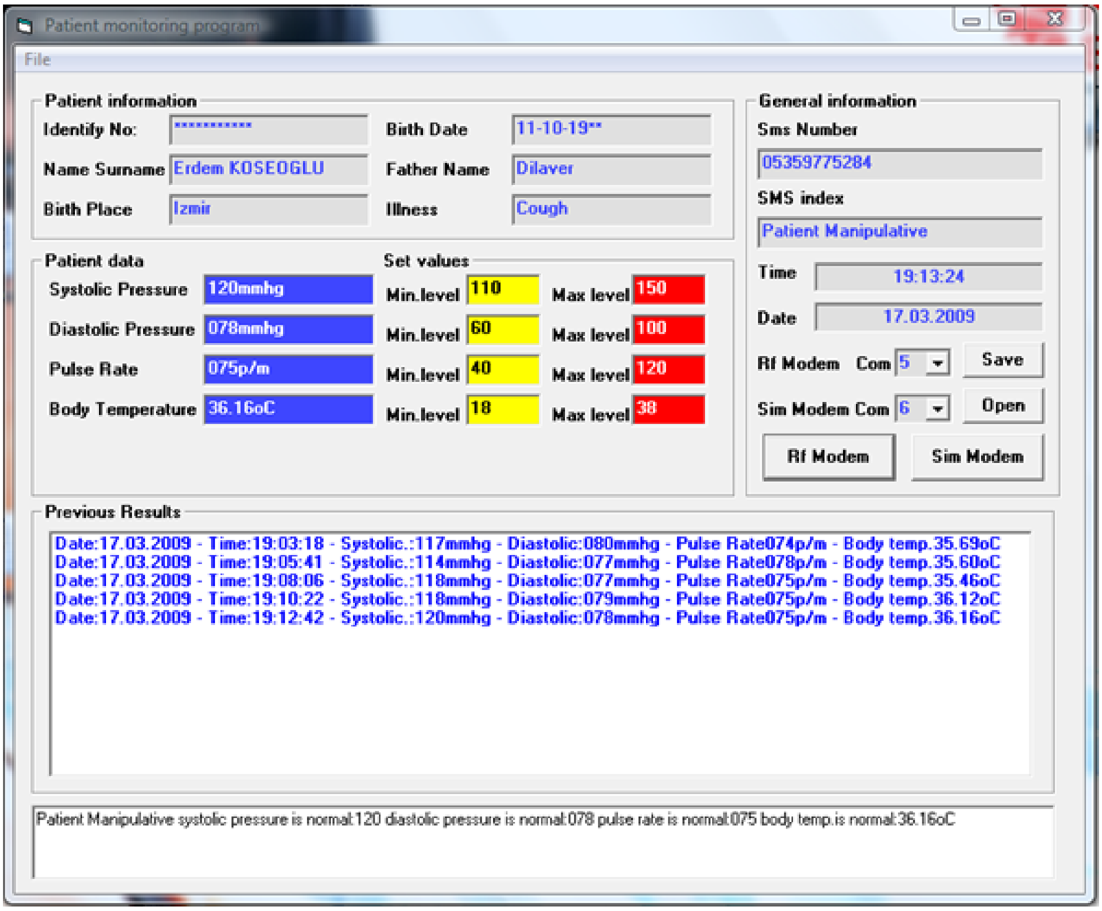

Figure 5.10-c Measurement results at the interface after the 5th measurement

As shown in Figure 5.10-c, all measurement results were still between the set values on the interface. So any LEDs, on the receiver part, didn't give any signal. From the first measurement approximately passed 10 minutes, but in this time interval there were not any undesirable measurement results.

Figure 5.11-a Measurement results on the LCD of the transmitter part after the 6th measurement

At sixth measurement, systolic pressure was measured 119mmHg, diastolic pressure was measured 77mmHg, pulse rate was measured 75p/m and the body temperature was measured 36.16°C. All these measurement results were transmitted correctly to the receiver part as shown in Figure 5.11-b.

Figure 5.11-b Measurement results on the LCD of the receiver part after the 6th measurement

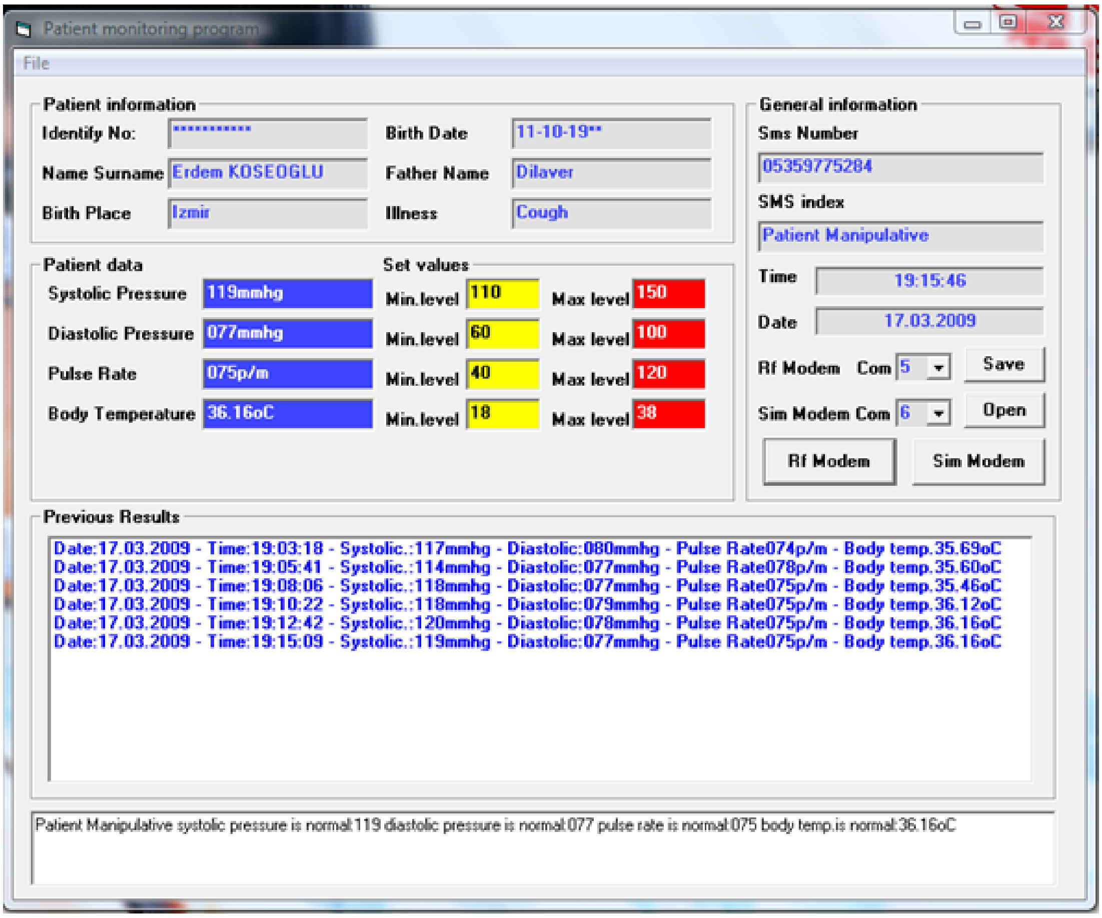

Figure 5.11-c Measurement results at the interface after the 6th measurement

All measurement results, as shown in figures which are above, were between the set values. Because of this, LEDs on the receiver part didn't give any signal. These six measurement results were verified with other blood pressure and body temperature measurement devices.

After set values of the system were changed, measurement results are given in the following figures.

Figure 5.12-a First measurement results on the LCD of the transmitter part after set values were changed

Figure 5.12-b First measurement results on the LCD of the receiver part after set values were changed

Figure 5.12-c First measurement results at the interface after set values were changed

As shown in Figure 5.12-c, set values were changed. And some of the measurement values exceeded the set values. So, as shown in Figure 5.12-c, two LEDs which were related to diastolic pressure and pulse rate, gave signal because, diastolic pressure and pulse rate measurement values exceeded the set values of the system.

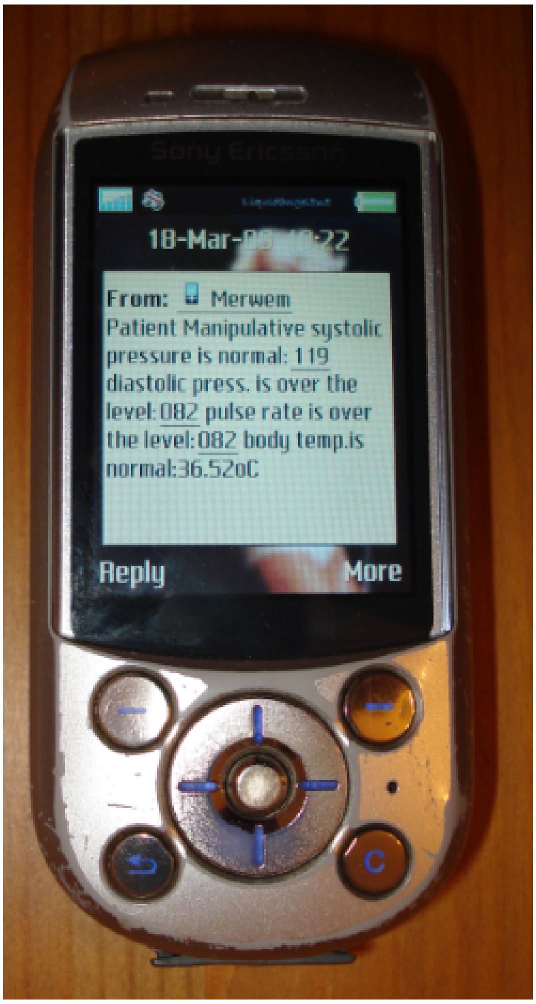

Figure 5.12-d First measurement results on the mobile phone after set values were exceeded

When diastolic pressure and pulse rate exceeded the set limits on the interface, an alert message, as shown in Figure 5.12-d, was sent to the related mobile phone which was written on the interface.

Figure 5.13-a Second measurement results on the LCD of the transmitter part after set values were changed

Figure 5.13-b Second measurement results on the LCD of the receiver part after set values were changed

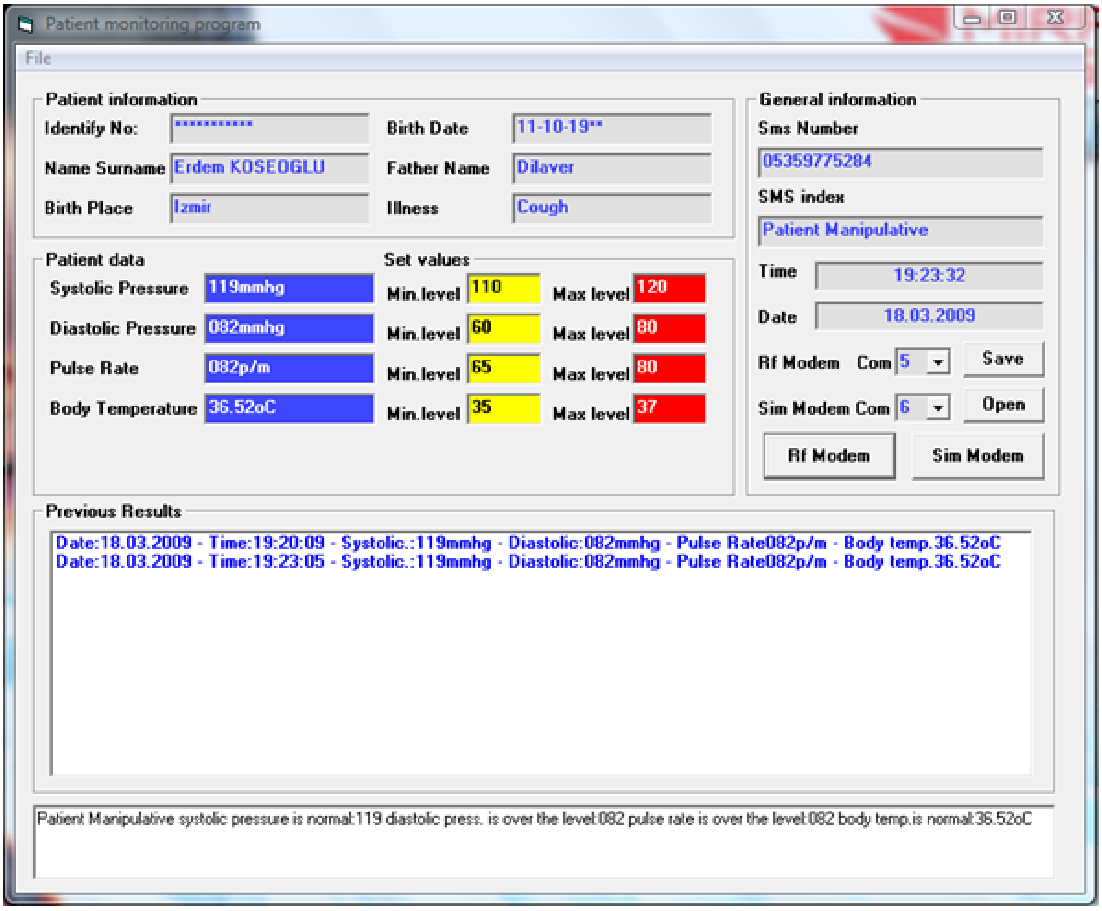

Figure 5.13-c Second measurement results at the interface after set values were changed

Second measurement results were the same with first measurement results, as shown from Figure 5.13-a, 5.13-b and 5.13-c. So, same LEDs on the receiver part again gave signals due to the exceeded of the set values.

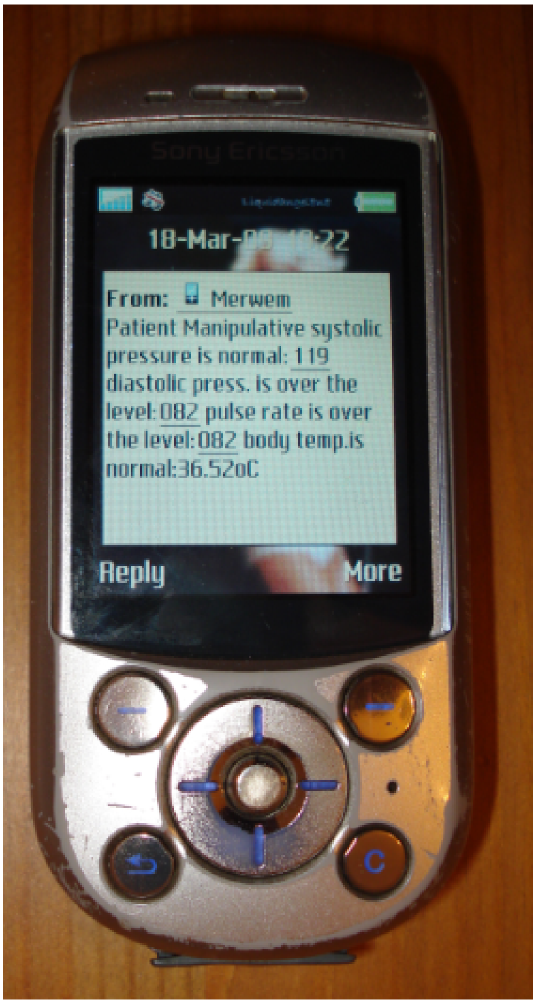

Figure 5.13-d Second measurement results on the mobile phone after set values were exceeded

In second measurement, again diastolic pressure and pulse rate exceeded the set limits on the interface. For this reason, same alert message, as shown in Figure 5.12-d, was sent to the related mobile phone which was written on the interface.

Figure 5.14-a Third measurement results on the LCD of the transmitter part after set values were changed

Figure 5.14-b Third measurement results on the LCD of the receiver part after set values were changed

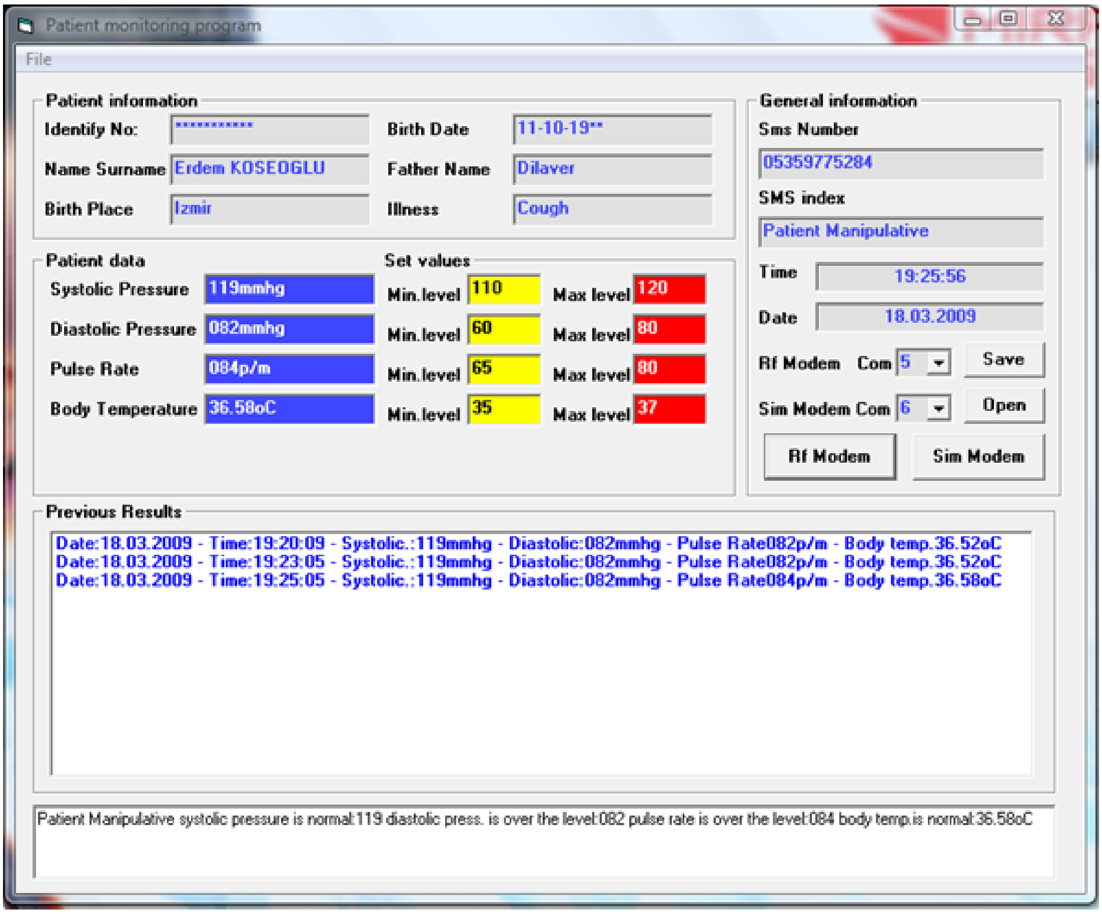

Figure 5.14-c Third measurement results at the interface after set values were changed

In third measurement, again same systolic-diastolic pressures were measured. But at this time, pulse rate was measured 84p/m and body temperature was measured 36.58°C. Again diastolic pressure and pulse rate measurement values exceeded the set values. Because of this, same LEDs on the receiver part gave signal as shown in Figure 5.14-b.

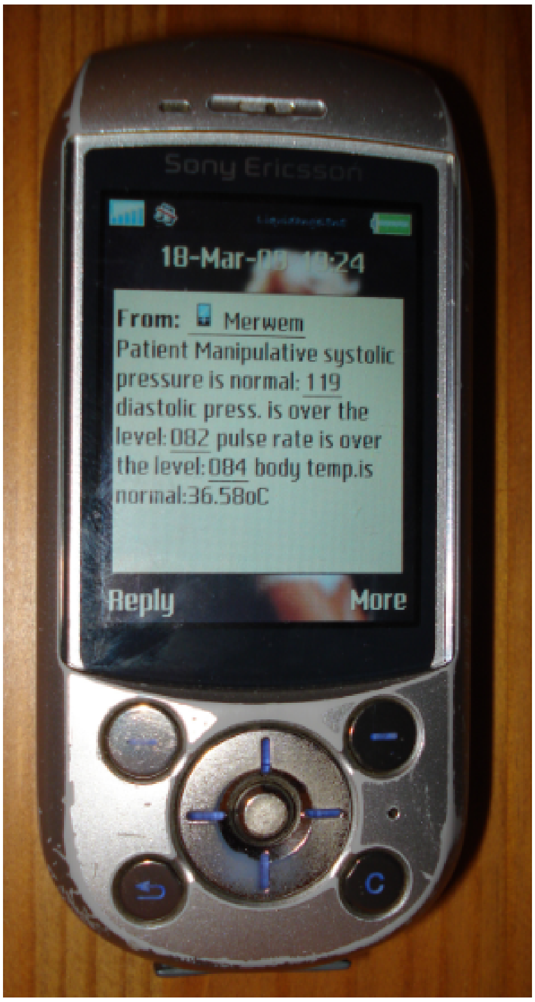

Figure 5.14-d Third measurement results on the mobile phone after the values were exceeded

As shown in Figure 5.14-d, at the third measurement diastolic pressure and pulse rate exceeded the set limits which were written on the interface.

Figure 5.15-a Fourth measurement results on the LCD of the transmitter part after set values were changed

Figure 5.15-b Fourth measurement results on the LCD of the receiver part after set values were changed

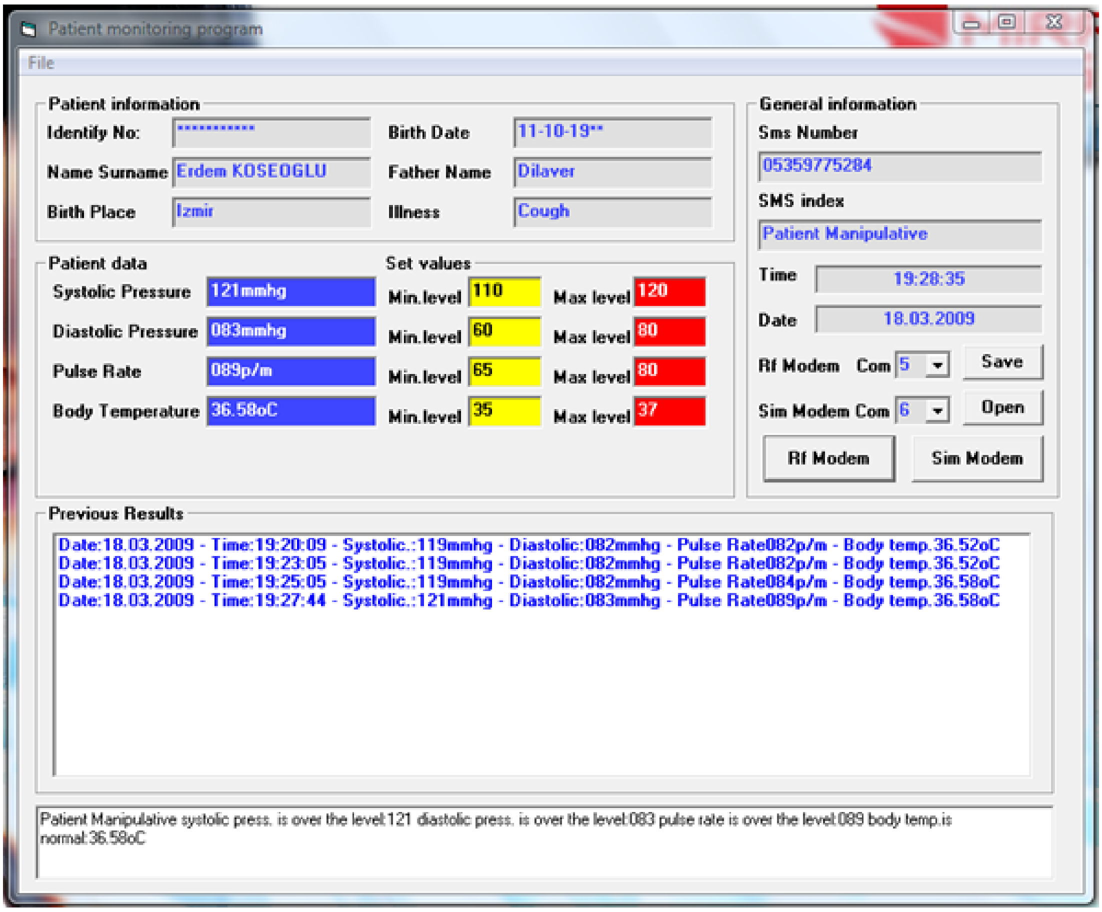

Figure 5.15-c Fourth measurement results at the interface after set values were changed

As shown in Figure 5.15-c, systolic-diastolic pressure and pulse rate measurement values exceeded the set values. Because of this, three LEDs on the receiver part, which were related to them, gave signal as shown in Figure 5.15-b.

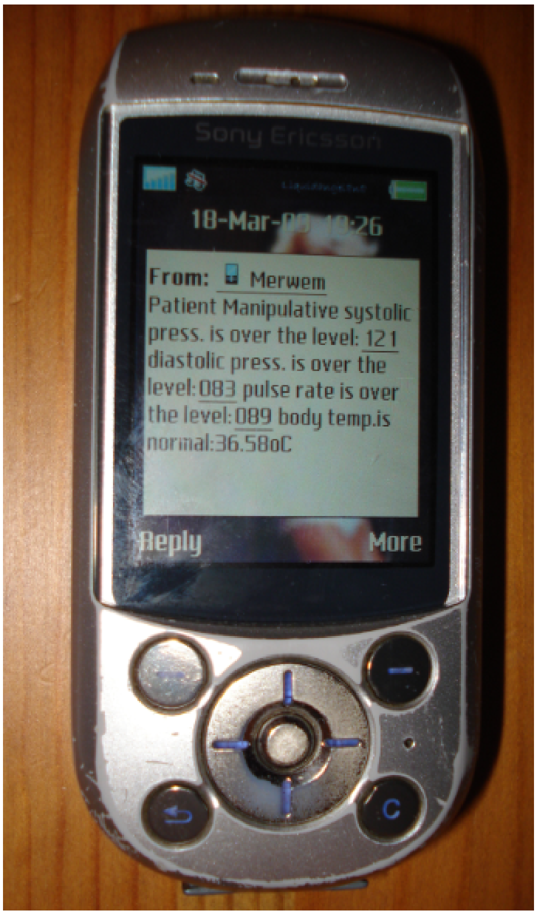

Figure 5.15-d Fourth measurement results on the mobile phone after set values were exceeded

In the last measurement, systolic-diastolic pressures and pulse rate measurement values exceeded the set limits which were written on the interface. So, an alert message about this situation was sent to the related mobile phone which was written on the interface.

In the following figures, set values of the system were changed in each measurement steps to take different alerts.

Figure 5.16-a First measurement results on the LCD of the transmitter part after changing the set values in each step

Figure 5.16-b First measurement results on the LCD of the receiver part after changing the set values in each step

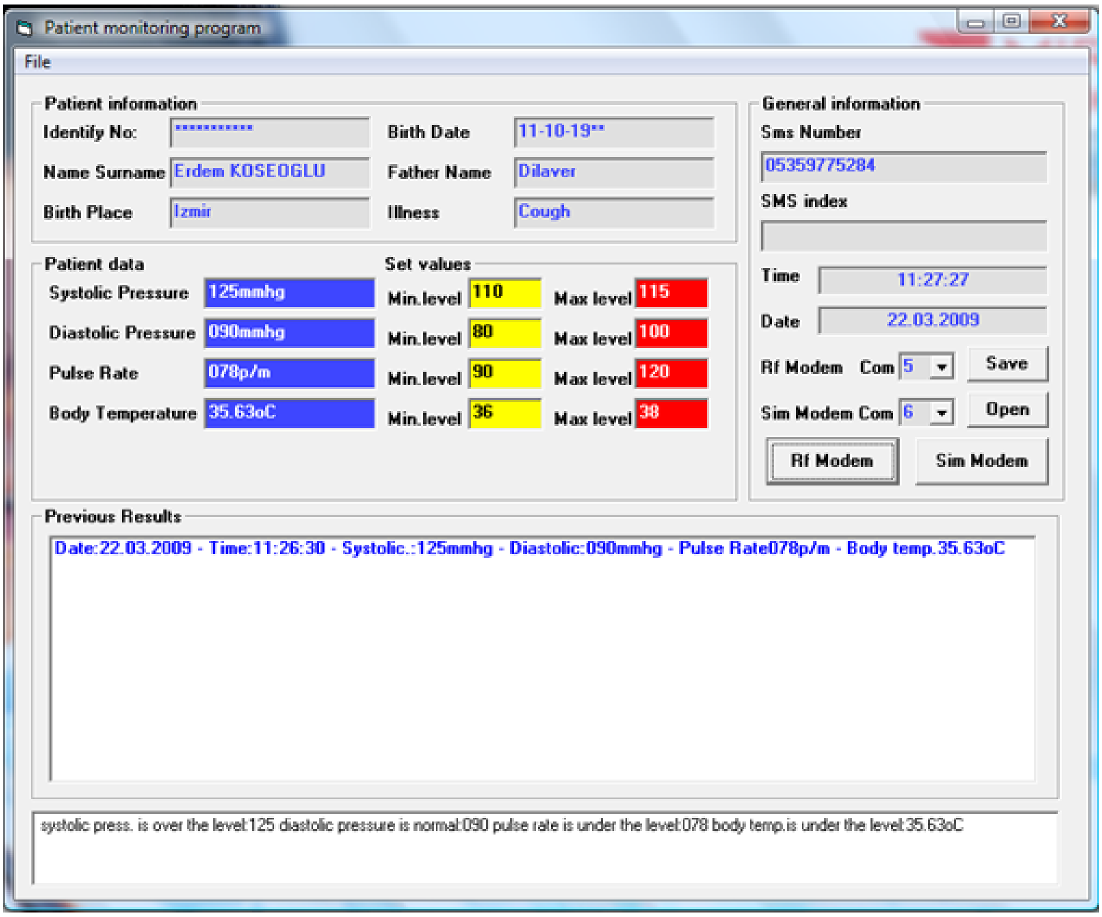

Figure 5.16-c First measurement results at the interface after changing the set values in each step

As shown in Figure 5.16-c, systolic pressure set values were minimum 110mmHg and maximum 115mmHg. But in the measurement result, systolic pressure was measured 125mmHg. So it exceeded the level and because of this, systolic pressure gave red signal as shown in Figure 5.16-b; which means, measurement result is over the set level. Similarly, pulse rate and body temperature measurement results were under the level. For this reason, pulse rate and body temperature gave blue signal as shown in Figure 5.16-b; which means, measurement results are under the set level. Although, diastolic pressure didn’t give any signal on the receiver part because, diastolic pressure was measured 90mmHg and at that moment it was between the set values.

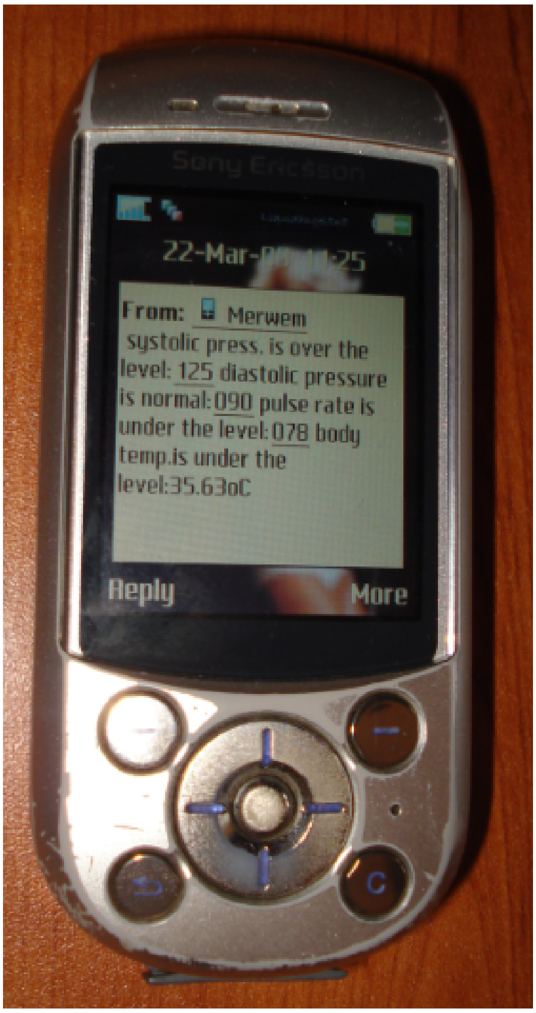

Figure 5.16-d First measurement results on the mobile phone after set values were exceeded

Some measurement results were not between the set values on the interface; so an alert message, as shown in Figure 5.16-d, was sent to the related mobile phone, which was written on the interface.

Figure 5.17-a Second measurement results on the LCD of the transmitter part after changing the set values in each step

Figure 5.17-b Second measurement results on the LCD of the receiver part after changing the set values in each step

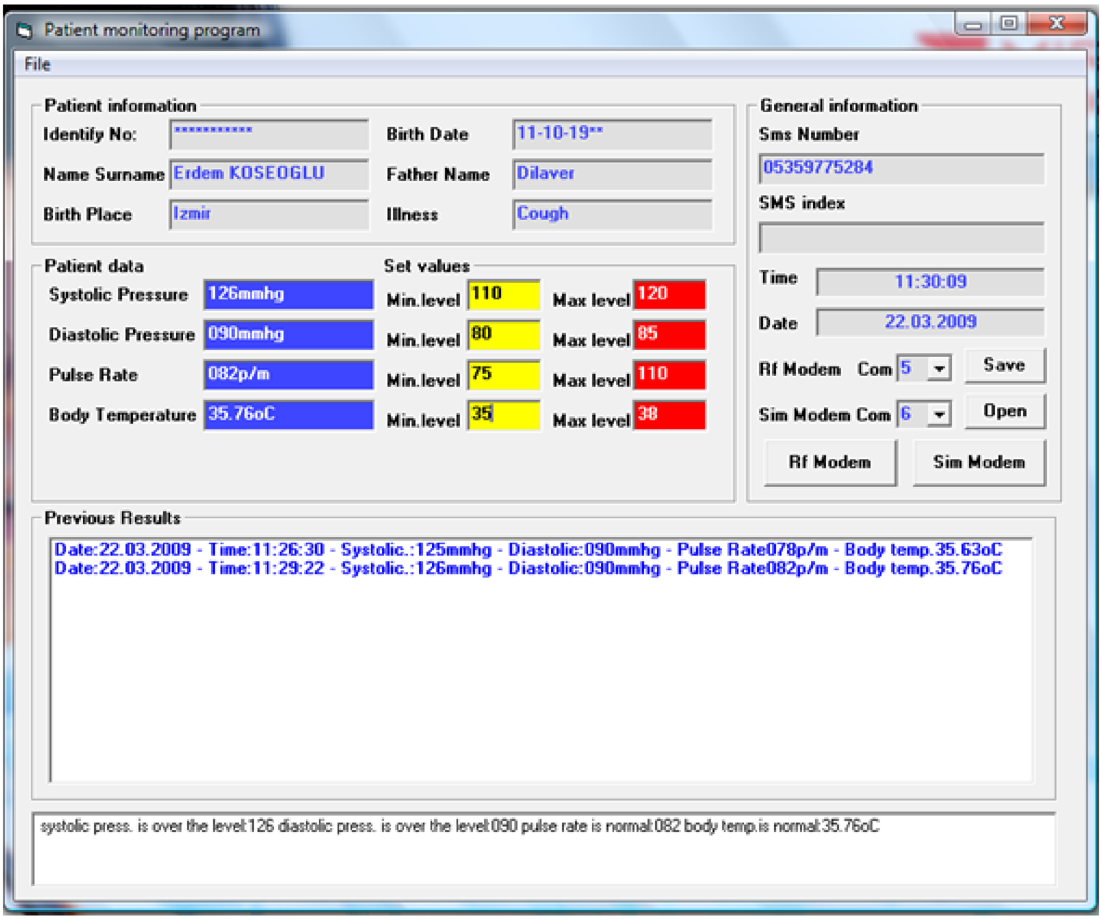

Figure 5.17-c Second measurement results at the interface after changing the set values in each step

At this measurement step, systolic pressure set values were set minimum 110mmHg, maximum 120mmHg but it was measured 126mmHg; so again systolic pressure exceeded the set values and gave red signal on the receiver part as shown in Figure 5.17-b. Also, diastolic pressure set values were changed and it was set to minimum 80mmHg, maximum 85mmHg and again at this time, it was measured 90mmHg and it exceeded the set values. For this reason, it gave red signal as shown in Figure 5.17-b. Similarly, at this measurement step, pulse rate set values were changed but at this time, it was measured between the set values; so it didn't give any signal on the receiver part. Body temperature minimum level was set at 35°C, and it was measured 35.76°C, because it was measured between the set values, it didn't give any signal on the receiver part.

An alert message for this situation, was shown in Figure 5.17-d

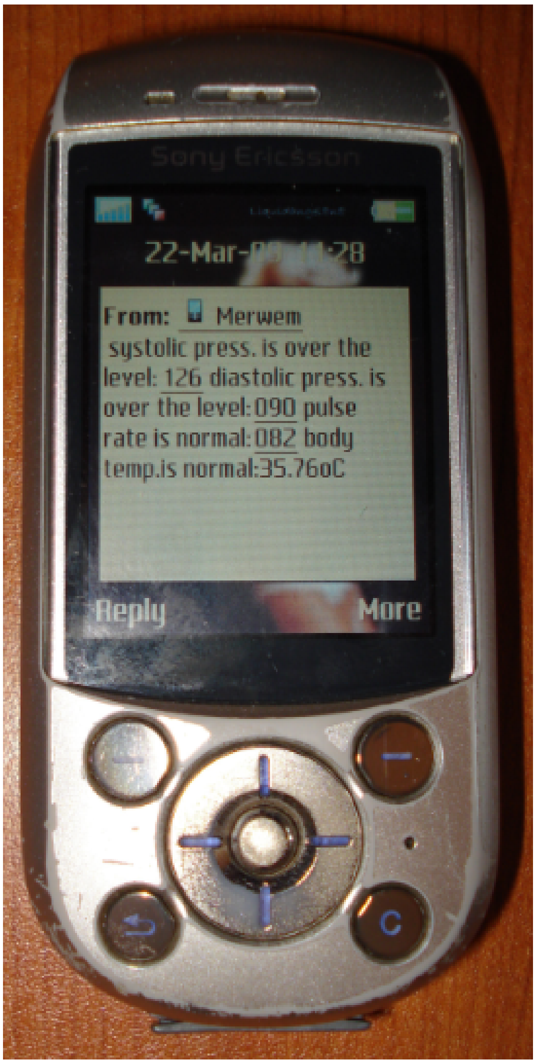

Figure 5.17-d Second measurement results on the mobile phone after set values were exceeded

Figure 5.18-a Third measurement results on the LCD of the transmitter part after changing the set values in each step

Figure 5.18-b Third measurement results on the LCD of the receiver part after changing the set values in each step

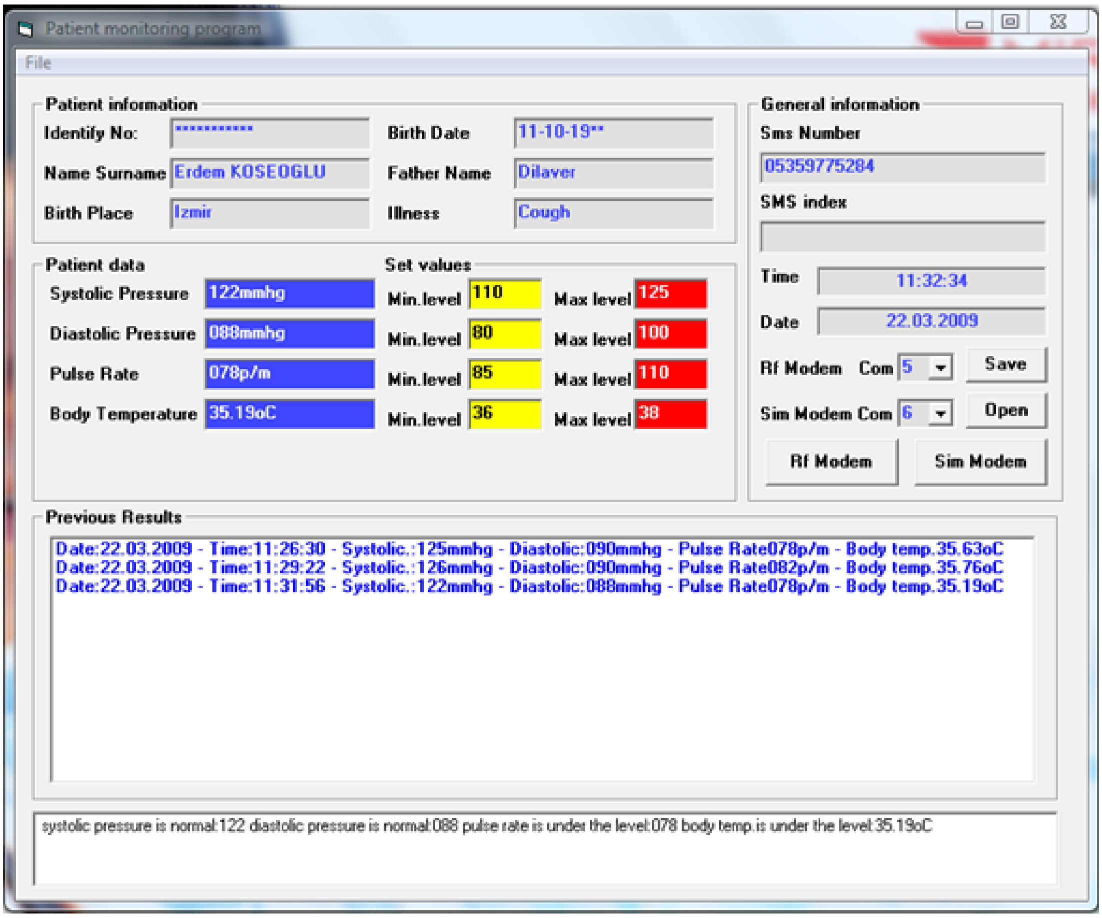

Figure 5.18-c Third measurement results at the interface after changing the set values in each step

As shown in Figure 5.18-c, only pulse rate and body temperature measurement results were not between the set values. They were measured under the limits; so pulse rate and body temperature gave blue signal, which means measurement is under the level, on the receiver part as shown in Figure 5.18-b.

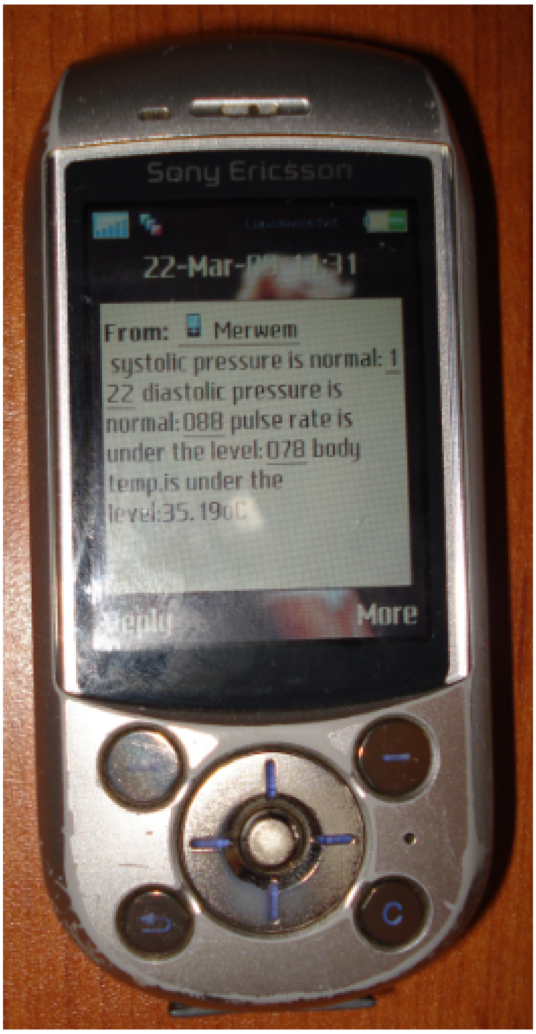

Figure 5.18-d Third measurement results on the mobile phone after set values were exceeded

In Figure 5.18-d, third measurement results were shown as an alert message. By this SMS alert message, measurement results conditions could be easily understood.

Figure 5.19-a Fourth measurement results on the LCD of the transmitter part after changing the set values in each step

In this step, systolic pressure was measured 123mmHg, diastolic pressure measured 86mmHg, pulse rate was measured 78p/m and the body temperature was measured 35.28°C. Also, these measured values were transmitted to the receiver part as shown in the following figure.

Figure 5.19-b Fourth measurement results on the LCD of the receiver part after changing the set values in each step

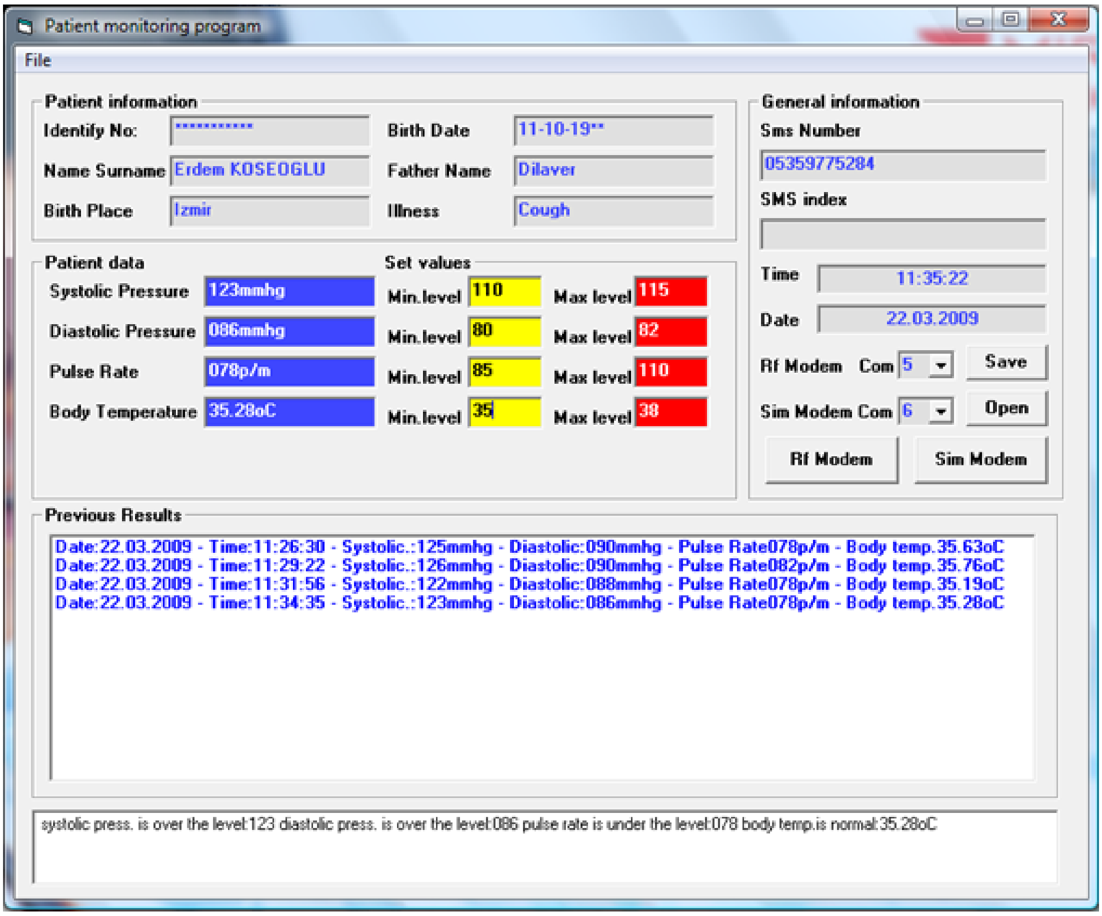

Figure 5.19-c Fourth measurement results at the interface after changing the set values in each step

At this measurement step, again systolic pressure exceeded the set values. Because it was measured 123mmHg and the limits were 110-115mmHg. So, related red signal was given on the receiver part. Similarly diastolic pressure set values were 80-82mmHg but the measured value was 86mmHg. Because of it, diastolic pressure gave red signal too. Besides, pulse rate was measured under the set values. For this reason it gave blue signal as shown in Figure 5.19-b.

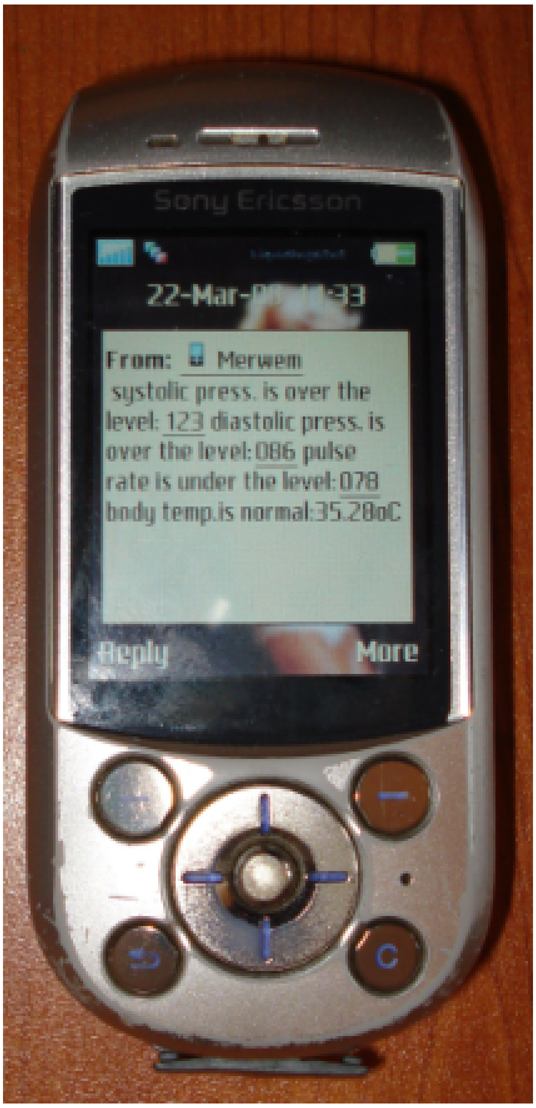

Figure 5.19-d Fourth measurement results on the mobile phone after set values were exceeded

An alert message, which is above, was sent to the related mobile phone after fourth measurement.

Figure 5.20-a Fifth measurement results on the LCD of the transmitter part after changing the set values in each step

Figure 5.20-b Fifth measurement results on the LCD of the receiver part after changing the set values in each step

Figure 5.20-c Fifth measurement results at the interface after changing the set values in each step

As shown from Figure 5.20-b and Figure 5.20-c, all measurement results were between the set values. So any alert message wasn't sent to any mobile phone.

Figure 5.21-a Sixth measurement results on the LCD of the transmitter part after changing the set values in each step

Figure 5.21-b Sixth measurement results on the LCD of the receiver part after changing the set values in each step

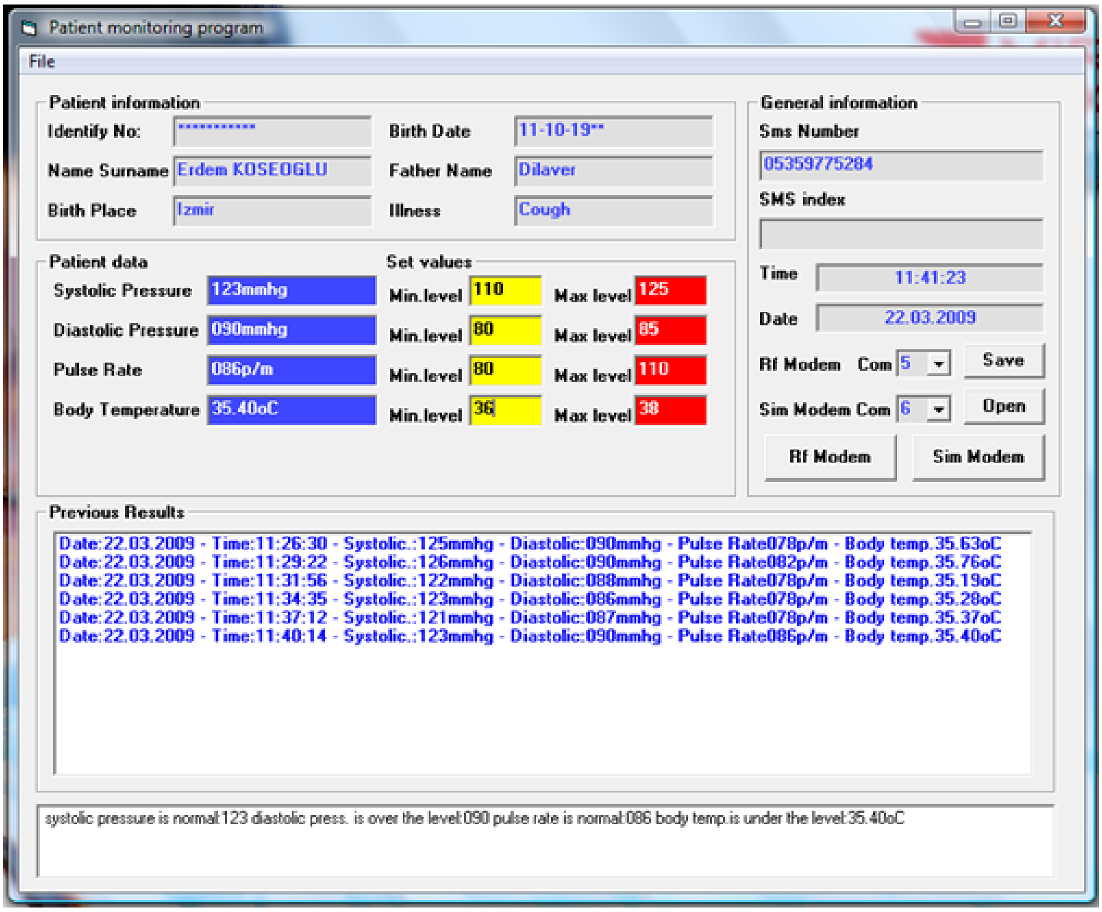

Figure 5.21-c Sixth measurement results at the interface after changing the set values in each step

At this sixth step in the measurements, differently from the previous step, all set values except systolic pressure set values were changed. For this reason, diastolic pressure was measured over the maximum set level and the body temperature was measured under the minimum set level. So, diastolic pressure gave red signal and the body temperature gave blue signal on the receiver part as shown in Figure 5.21-b.

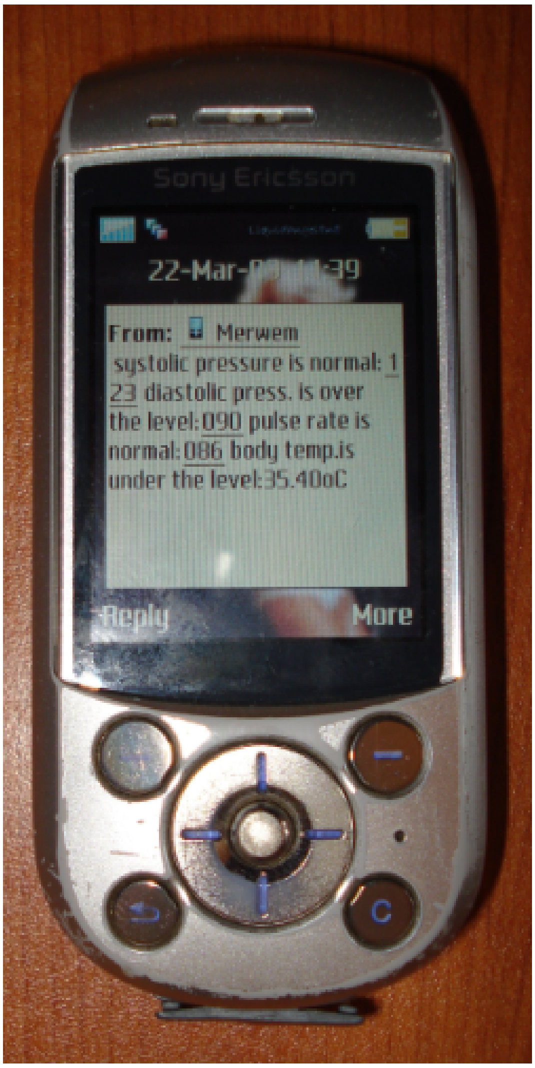

Figure 5.21-d Sixth measurement results on the mobile phone after set values were exceeded

Because of the existence any signal on the receiver part, an alert message as shown in Figure 5.21-d was sent to the related mobile phone, which was written on the interface.

The results of the project are as expected and satisfactory. If the user stays still during the operation, the device can measure blood pressures (both systolic and diastolic), heart rate and body temperature without any problem.

5.2 Duration of Measurement

Normally, from the start until all the measurements are done, it takes about 1.05 minutes. But as shown from figures which are above, it took more than 1.05 minutes. Because, related photos were taken to explain the operation principles so it took a few extra minutes in the measurement. However, duration of measurement also depends on each individual and how the cuff is worn. For each person, the amplitude of the waveforms may differ causing the operating time to vary. And also, transmission to the receiver part takes about 13 seconds. When the measurement values are shown on the receiver part, they instantly transmitted to the interface on the PC.

5.3 Accuracy

All the devices and the measurements are calibrated with the blood pressure measurement devices and the thermometers on the hospitals. Besides, these measurements were corrected by the doctors.

As mentioned earlier, all the measurements are mainly dependent on the waveforms from the circuit and the pressure sensor is very sensitive to even a slight movement of the user. As a result, it is possible that sometimes the device fails to obtain the desired data, especially if the user does not stay still or wear the cuff improperly. Also other wireless devices can affect the data transmission to the receiver part.

Regarding the four result values (systolic, diastolic, heart rate and body temperature), some of them has more success rate than the others. For the heart rate, the success rate is very high for getting an accurate value. To find the heart rate, the period of the AC waveform must be found. And since the period of heart rate stays pretty much constant throughout the measurement, it is relatively easy to obtain an accurate result. To find the pressure values, however, are harder because they depend on the amplitude of the waveform, and the amplitude varies a lot during the measurement.

Another topic that is worth mentioning is that the method of measurement that is called the oscillometric method. It is usually deployed in commercial products due to the reliability. However, this method is not as accurate as the auscultatory method, in which the doctor uses the microphone to listen to the noise in the artery.

Also body temperature is measuring by taking four temperature sensors average. So these sensors can put on the critical parts of the body, or anywhere on the body. This choice is too important for measuring the real body temperature. If all the temperature sensors are put on the foot, it can’t measure the real body temperature, because measured temperature from the foot can't reflect the body temperature. For measuring the body temperature truly, all the temperature sensors must be put on right places on the body. In this project, all sensors were put on the armpit during the measurements.

5.4 Safety in Design

Since this is a medical instrumentation device, the safety of the user is the first concern to me. The cuff while driven by 5 volts motor can squeeze the arm really hard and cause injury if being used improperly. So this device has 2 levels of security, making sure that the operation can be aborted by the user at anytime.

For the first safety design, the microcontroller is programmed in the way such that if the pressure in the cuff is greater than 160mmHg, the motor will stop. For most people, the pressure at 160mmHg will only cause a little discomfort to the arm. This design makes sure that the pressure inside the cuff will never exceed the maximum limit of 160mmHg.

The second safety design is to provide an emergency button for the user. While the motor is pumping and the cuff is being inflated, if the user encounters too much discomfort or pain, he/she can press this button to stop the operation immediately. The motor will be stopped and the valve will be opened to release the air out of the cuff.

Other than the cuff and motor concerns, this project is very safety to use because it is very well packaged in a plastic enclosure. The device is run by low-voltage (9 volts) battery which cannot cause any major harm to human body.

CHAPTER SIX

CONCLUSIONS

The biomedical smart clothes have several advantages, they avoid the necessity of placing the sensors by nurse or physician, the sensors are placed at the right place, they are protected, are not visible or discrete. They are user friendly and particularly adapted for monitoring in case of chronic diseases and monitoring of handicap peoples, elderly peoples, in case of chronic diseases and during professional, sport and military activities.

In this research, portable blood pressure and body temperature measuring system is designed. As well as measuring these parameters, measured values are transmitted to the receiver part of the system and by this; patient monitoring is become easier.

The measurements are acceptably accurate. The operations of the device are reliable and have not produced any major problems. The power consumption of the device is decent as lots of measurements (more than 20) were tried and the set of two 9-volt batteries has not died yet.

Regarding the batteries and power consumption, a big problem was encountered in this issue while testing the device. At the first place, one battery was used to power the MCU board, and the other to power the circuit, valve and motor. However after a couple of tries, the battery that powered the circuit and motor lost its power and could not provide a constant voltage during the measurement. In other words, the voltage across that battery drops constantly as the motor runs. As a result, the voltage that feeds all the chips in the circuit are not high enough (the AD620 and OPA2277 requires 5V and -5V) and causes the circuit to malfunction.

So this problem was fixed by separating the battery that runs the valve and motor from the rest of the circuit. Then the battery is used that supplies the MCU board to power the circuit instead. Now that the battery that supplies the valve and the motor is separated, it ensures that there will be no voltage drop in the circuit while the motor is running. This way, the power consumption of the 2 batteries will be more balanced, since the circuit and the MCU do not consume much power.

As it can be understood from its name, the pressure micro sensor is smaller than other sensors. The advantage of this small size is evident when comparing the size of the micro sensor to a muscle fiber. In normal human muscle, the adult muscle fiber diameter is reached at 12–15 years of age and varies over a narrow range. Adult muscle fibers range in diameter from 50 to 100 mm. Thus, the micro sensor is approximately the same diameter as a muscle fiber. This small size will permit minimally traumatic measurement of intramuscular pressure.

In the studies of designing and realizing the electronic structure, main purpose is to transmit the measurement values to the receiver part correctly. To obtain this correct transmission, a 433 MHz RF transmitter and receiver are used. But sometimes, this transmission can be effected from other radio frequencies. Especially mobile phones and wireless modems can effect this transmission badly and because of this, some of the received data in the receiver part of the system can be wrong. To solve this wrong data transmission, special RF transmitter and receiver modules can be used which are called UTX RF transmitter and receiver. But these equipments are more expensive than the other RF transmitter and receivers which is used in this project. And also, the antenna length is very important. Normally, for 433 MHz RF transmitter, the antenna length is approximately 17.3cm, but in this project approximately 8cm antenna is used. So, it effects the data transmission badly and because of the antenna length, sometimes, received data can be wrong.

The LCDs on the system, consume more of the battery life by their LEDs. For preventing this consumption, solar panels can be used in the future. By using them, rechargeable batteries can be loaded; so new batteries have not been bought anymore.

For the future research, graphic LCDs can be used in this system. On these LCDs, blood pressure oscillation can be seen easily. Besides, a buzzer can be put into the transmitter part and hear the measurement of the blood pressure or body temperature. Alternatively, measurement results can be heard from someone's voice, which is integrated into the system.

Some other sensors can be adapted into this system and by this; other special values can be measured portably. This system gives freedom to the patient and also it is a big convenience for hospital care. By using this system, patient's measurement values can be transmitted instantly to the hospital and to the doctor. If any critical measurement values exist, related messages are sent to the mobile phone of the doctor. Set values for each patient can also be arranged from the interface on the computer.

This project can be used in medical applications because it is convenient. For instance, in hospitals there are lots of patients but the number of nurse is not ample for observing the condition of them. By using this project; if there is a change in the patient's condition, it can be seen from afar and anyone need to be near the patient all the time for measuring their body temperature or blood pressure because near them there is an LCD and on it, the body temperature and blood pressure values can be seen instantly. The software may also be easily modified to provide better analysis of the systolic, diastolic blood pressure and body temperature of a person.

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APPENDIX A: PIC CCSC CODES OF TRANSMITTER PART

```
//ERDEM KOSEOGLU
//2006900204
#include <18F452.h>
#device ADC=10    //10 bit ADC is used.
#include <stdlib.h>
#include <math.h>

#FUSES NOWDT                    //No Watch Dog Timer
#FUSES XT                       //Crystal osc <= 4mhz
#FUSES NOPUT                    //No Power Up Timer
#FUSES NOPROTECT                //Code not protected from reading
#FUSES NODEBUG                  //No Debug mode for ICD
#FUSES NOBROWNOUT               //No brownout reset
#FUSES NOLVP                    //No low voltage prgming, B3(PIC16)
or B5(PIC18) used for I/O
#FUSES NOCPD                    //No EE protection

#use delay(clock=4000000)
#include <myLCD420.c>
#include <DS18B20.c>
//#use fast_io(c)
float temp,basinc1,basinc2,voltaj,sys_measure,dias_measure,farmer;
float pulse_period, total_pulse_period, pulse_per_min;
unsigned long int adc1,adc0,timerate,time_dias,tmr_basinc;
unsigned char  count_average,sys_count,tmrcount1;  //get value
//between 0-255.
int1     basinc_olcum,stop,yolla;
int gonder,sgonder1,sgonder2;
#bit bittest=gonder.7//the transmitted data's 7th bit
#priority RB,timer0
//*******************************************************************
#int_RB           //the interrupts on B4...B7
void B_degisim()  //interrupt funct. name
{
   disable_interrupts(INT_RB);
   delay_ms(30);
```

```
      if (input(pin_b4)==0)
      {
          tmr_basinc=15000;
          stop=0;
          enable_interrupts(INT_timer0);
      }
      if (input(pin_b5)==0)
      {
          output_low(pin_d1);             //Stop motor.
          output_low(pin_d2);             //open the valve and
//defecate the air.
          basinc_olcum=0;
          stop=1;
          disable_interrupts(INT_timer0);    //stop TMR0 interrupt.
      }

   enable_interrupts(INT_RB);
   delay_ms(30);
}
//*********************************************************************
#int_timer0           //makes an interrupt for 1ms.
void timer0_kesme()  //interrupt funct. name
{
   disable_interrupts(INT_timer0);
   set_timer0(131);
   tmr_basinc++;

   if (tmr_basinc>=15000)
      {
         farmer=3.99;
         output_high(pin_d1); //Start motor.
         output_high(pin_d2); //Close the valve
         tmr_basinc=0;
         basinc_olcum=1;
      }

   if (basinc_olcum==1)
      {
         tmr_basinc=0;
```

```
         if(tmrcount1>0) tmrcount1--;
         if(timerate<6000) timerate=timerate+1;
         if(time_dias<2000) time_dias=time_dias+1;
        }

   enable_interrupts(INT_timer0);
}

//*******************************************************************
float voltaj_read()  //calculate the voltage and go back.
{
   set_adc_channel(0);     //the signal at the RA1/AN1 will be
compute A/D.
   delay_us(20);
   adc0=read_adc();
   voltaj=(0.0048828125*adc0);
   return(voltaj);
}
//*******************************************************************
float basinc2_read()  //Calculate voltage and go back.
{
   set_adc_channel(1);     //the signal at the RA1/AN1 will be
compute A/D.
   delay_us(20);
   adc1=read_adc();
   basinc1=((0.0048828125*adc1)/337);
   basinc1=basinc1*2500;
   basinc2=(basinc1*760)/101.325;
   return(basinc2);
}
//*******************************************************************
void lcd_goster()
{
      lcd_gotoxy(1,1);
      printf(lcd_putc,"Systolic Press :%5.2fmmHg ", sys_measure);
      lcd_gotoxy(1,2);
      printf(lcd_putc,"Diastolic Press :%5.2fmmHg ", dias_measure);
      lcd_gotoxy(1,3);
      printf(lcd_putc,"Pulse Rate :%3.0f p/m ", pulse_per_min);
```

```
      lcd_gotoxy(1,4);
      printf(lcd_putc,"Body Temp :%4.2f %cC ",temp,223);
}
//********************************************************************
void lcd_goster_init()
{
      lcd_gotoxy(1,1);
      printf(lcd_putc,"Digital Blood press.");
      lcd_gotoxy(1,2);
      printf(lcd_putc,"& Temperature Measure");
      lcd_gotoxy(1,3);
      printf(lcd_putc,"Press Start Button");
      lcd_gotoxy(1,4);
      printf(lcd_putc,"For Measuring...");
}
//********************************************************************
void serigonder()
   {
      byte bitkaysayac;
      bitkaysayac=1;
      output_high(pin_d3);     //gives
      delay_ms(4);            //pine pals
      output_low(pin_d3);      //for
      delay_ms(2);            //senkron bit
      while(bitkaysayac<9)
            {
             if(bittest==1)             //if bittest 1
                  {
                  output_high(pin_d3);  //make the port value 1
                  delay_us(500);
                  output_low(pin_d3);   //make the port value 0
                  delay_us(1500);          //hold at 0  for 1ms
                  }
            else                        //if bittest 0
                  {
                  output_high(pin_d3);  //make the port value 1
                  delay_us(500);
                  output_low(pin_d3);   //make the port value 0
                  delay_us(1000);          //hold at 0  for 1ms
```

```
                }
            gonder=gonder<<1;           //shift left the gönder
            bitkaysayac++;              //increase the shift counter
            }
        output_high(pin_d3);  //STOP BİT
        delay_us(500);        //STOP BİT
        output_low(pin_d3);   //STOP BİT
        delay_ms(10);
    }
//*********************************************************************
void main()
{
   setup_psp(PSP_DISABLED);
   setup_spi(SPI_SS_DISABLED);
   setup_timer_0(RTCC_INTERNAL | RTCC_DIV_8);
   setup_timer_1(T1_DISABLED);
   setup_timer_2(T2_DISABLED,0,1);
   setup_adc_ports(ALL_ANALOG);     //All AN inputs are analog
   setup_adc(adc_clock_div_32);     //ADC clock frequancy fosc/32
   setup_CCP1(CCP_OFF);
   setup_CCP2(CCP_OFF);

   set_tris_a(0xFF); //A port input
   set_tris_b(0xFF); //All B ports are input.
   set_tris_c(0x0F); //C2:START BUTTON    C3: STOP BUTTON.
   set_tris_d(0x00); //D1:MOTOR1   D2:MOTOR2
   set_tris_e(0x0F); //E port input
   output_low(pin_d1);
   output_low(pin_d2);
   output_low(pin_d3);//RF module transmitter connection point
   delay_ms(100);
   lcd_init();
   set_timer0(131);
   lcd_send_byte(0x0c);
   enable_interrupts(INT_RB);
   enable_interrupts(GLOBAL);
   sys_count=0;
   tmrcount1=40;
   time_dias=0;
```

```
   farmer=3.99;
   sys_measure=0;
   dias_measure=0;
   pulse_per_min=0;
   basinc2=0;
   timerate=0;
   tmr_basinc=0;
   basinc_olcum=0;
   stop=0;yolla=0;

   lcd_goster_init();
   while(1)
   {
//*******************************************************************
   if (basinc_olcum==1)  //calculate the pressure and go back.
{
      if (stop==1) {goto exit;}
      sys_measure=0;
      dias_measure=0;
      pulse_per_min=0;
      temp=0;
      //lcd_goster();     //at the beginning of the measurement,
values on the LCD will be zero.
      lcd_send_byte(0x01); /* clear */
      while(basinc2<=160)
      {
         if (stop==1) {goto exit;}
         basinc2=basinc2_read();
         lcd_gotoxy(1,1);
         printf(lcd_putc,"Cuff Inflating:%5.2f ", basinc2);
      }
         lcd_send_byte(0x01); /* clear */
         lcd_gotoxy(1,1);
         printf(lcd_putc,"Measuring Systolic");
         lcd_gotoxy(1,2);
         printf(lcd_putc,"Pressure...");

      if (basinc2>=160)
      {
```

```
         output_low(pin_d1);  //the motor is stopped because
pressure have the defined value.
         tmrcount1=40;
         sys_count=0;
//*************************SYSTOLIC MEASUREMENT******************
         while(sys_count!=10)
                  {
                     if (stop==1) {goto exit;}
                     while(tmrcount1!=0){}
                     tmrcount1=40;
                     voltaj=voltaj_read();
                     if (farmer<=4.0 && voltaj>4.0){sys_count++;}
                     farmer=voltaj;
                     sys_measure=basinc2_read();
                     //lcd_gotoxy(1,1);
                     //printf(lcd_putc,"Sys Pr:%5.2fmmHg ",
//sys_measure);
                  }

         sys_count=0;
         tmrcount1=40;
         while(sys_count!=4)
                  {
                     if (stop==1) {goto exit;}
                     while(tmrcount1!=0){}
                     tmrcount1=40;
                     sys_measure+=basinc2_read();
                     sys_count++;
                  }
         sys_measure=sys_measure/4;             //takes the
arithmetic average of the 4 measurement.
         lcd_send_byte(0x01); /* clear */
         lcd_gotoxy(1,1);
         printf(lcd_putc,"Measuring Complated");
         lcd_gotoxy(1,2);
         printf(lcd_putc,"Systolic Press:%5.2f ", sys_measure);
//******************************PULSE RATE*********************
         lcd_send_byte(0x01); /* clear */
         lcd_gotoxy(1,1);
```

```
         printf(lcd_putc,"Measuring Pulse Rate");
         farmer = 2.4;
         count_average=0;
         tmrcount1=40;
         timerate=0;
         total_pulse_period=0;
         while(count_average<5)
             {
                  if (stop==1) {goto exit;}
                   //while(tmrcount1!=0){}
                   //tmrcount1=40;
                   voltaj=voltaj_read();
                  if(farmer<2.5 && voltaj>2.5)
                        {

total_pulse_period=total_pulse_period+timerate;
                           timerate=0;
                           count_average++; //finish reading one
//period
                         }
                  farmer=voltaj;
             }
        if(count_average==5)
            {
               pulse_period = total_pulse_period/5;   //total pulse
//divided 5 to take the average.
               pulse_per_min= 60000/pulse_period;
               lcd_send_byte(0x01); /* clear */
               lcd_gotoxy(1,1);
               printf(lcd_putc,"Measuring Complated");
               lcd_gotoxy(1,2);
               printf(lcd_putc,"Pulse: %3.0f p/m ", pulse_per_min);
            }
//***************************DIASTOLIC MEASUREMENT***************
         lcd_send_byte(0x01); /* clear */
         lcd_gotoxy(1,1);
         printf(lcd_putc,"Measuring Diastolic");
         lcd_gotoxy(1,2);
         printf(lcd_putc,"Pressure...");
```

```
        time_dias=0;
        while(time_dias<2000)
        {
           if (stop==1) {goto exit;}
           basinc2=basinc2_read();
           //lcd_gotoxy(1,1);
           //printf(lcd_putc,"Sys Pr:%5.2fmmHg ", basinc2);
           voltaj=voltaj_read();
           if(voltaj>4.8){time_dias=0;}
        }
        if(time_dias>=2000)
           {
              dias_measure=basinc2_read();
           }
        lcd_send_byte(0x01); /* clear */
        lcd_gotoxy(1,1);
        printf(lcd_putc,"Measuring Complated");
        lcd_gotoxy(1,2);
        printf(lcd_putc,"Diastolic Press:%5.2f", dias_measure);
        output_low(pin_d2);                 //Valve will be open.
//********************************************************************
   }
//********************************************************************
   basinc_olcum=0;
   tmr_basinc=0;
   temp=ds1820_read();
   lcd_goster();
   yolla=1;

   exit:
   if (stop==1)
   {
      sys_measure=0;
      dias_measure=0;
      pulse_per_min=0;
      yolla=0;
      lcd_goster_init();
   }
}
```

```
//***************************************************************
      //temp=ds1820_read();
      //lcd_goster();

if (yolla==1)
{
      disable_interrupts(GLOBAL);
      sgonder1=floor(sys_measure);
      sgonder2=floor((sys_measure-sgonder1)*100);
      gonder=sgonder1;
      serigonder();             //serial transmitting protocol runs
      gonder=sgonder2;
      serigonder();             //serial transmitting protocol runs

      sgonder1=floor(pulse_per_min);
      sgonder2=floor((pulse_per_min-sgonder1)*100);
      gonder=sgonder1;
      serigonder();             //serial transmitting protocol runs
      gonder=sgonder2;
      serigonder();             //serial transmitting protocol runs

      sgonder1=floor(dias_measure);
      sgonder2=floor((dias_measure-sgonder1)*100);
      gonder=sgonder1;
      serigonder();             //serial transmitting protocol runs
      gonder=sgonder2;
      serigonder();             //serial transmitting protocol runs

      sgonder1=floor(temp);
      sgonder2=floor((temp-sgonder1)*100);
      gonder=sgonder1;
      serigonder();             //serial transmitting protocol runs
      gonder=sgonder2;
      serigonder();             //serial transmitting protocol runs
      yolla=0;
      enable_interrupts(GLOBAL);
}
   }
}
```

APPENDIX B: PIC CCSC CODES OF RECEİVER PART

```
//ERDEM KOSEOGLU
//2006900204
#include <18F452.h>
#include <stdlib.h>
#include <math.h>

#FUSES NOWDT                  //No Watch Dog Timer
#FUSES XT                     //Crystal osc <= 4mhz
#FUSES NOPUT                  //No Power Up Timer
#FUSES NOPROTECT              //Code not protected from reading
#FUSES NODEBUG                //No Debug mode for ICD
#FUSES NOBROWNOUT             //No brownout reset
#FUSES NOLVP                  //No low voltage prgming, B3(PIC16)
//or B5(PIC18) used for I/O
#FUSES NOCPD                  //No EE protection
#FUSES WRT_50%                //Lower half of Program Memory is
//Write Protected

#use delay(clock=4000000)
#include <myLCD420_2.c>
#use rs232 (baud=9600, xmit=pin_C6, rcv=pin_C7, parity=N, stop=1)
//#use fast_io(a)
//#use fast_io(b)
#use fast_io(c)
#define data_pini pin_b0 //the data input pin which cames from RX
//module
float temp,sys_measure,dias_measure,pulse_per_min;
int16 tmr0_sayac;  //the control loop for sychronization
//byte buffer;
unsigned int16 buffer,sal1,sal2,sal3,sal4,sal5,sal6,sal7,sal8;
#bit bittest=buffer.0//the variable for buffer’s 0.bit
int bitkaysayac,led;//,sal1,sal2,sal3,sal4,sal5,sal6,sal7,sal8;
//counter for shift control
char klavye[20];

#int_rda
void serihaberlesme_kesmesi ()
```

```
{
   disable_interrupts(int_rda);
   //output_high(pin_b7);

   gets(klavye);
   led=atoi(klavye);

   if (bit_test(led,0)==1)
   {
      OUTPUT_BIT(pin_B4,1);
      OUTPUT_BIT(pin_A3,0);
   }
   else
   {
      OUTPUT_BIT(pin_B4,0);
      OUTPUT_BIT(pin_A3,1);
   }

   if (bit_test(led,1)==1)
   {
      OUTPUT_BIT(pin_B5,1);
      OUTPUT_BIT(pin_A2,0);
   }
   else
   {
      OUTPUT_BIT(pin_B5,0);
      OUTPUT_BIT(pin_A2,1);
   }

   if (bit_test(led,2)==1)
   {
      OUTPUT_BIT(pin_B6,1);
      OUTPUT_BIT(pin_A1,0);
   }
   else
   {
      OUTPUT_BIT(pin_B6,0);
      OUTPUT_BIT(pin_A1,1);
   }
```

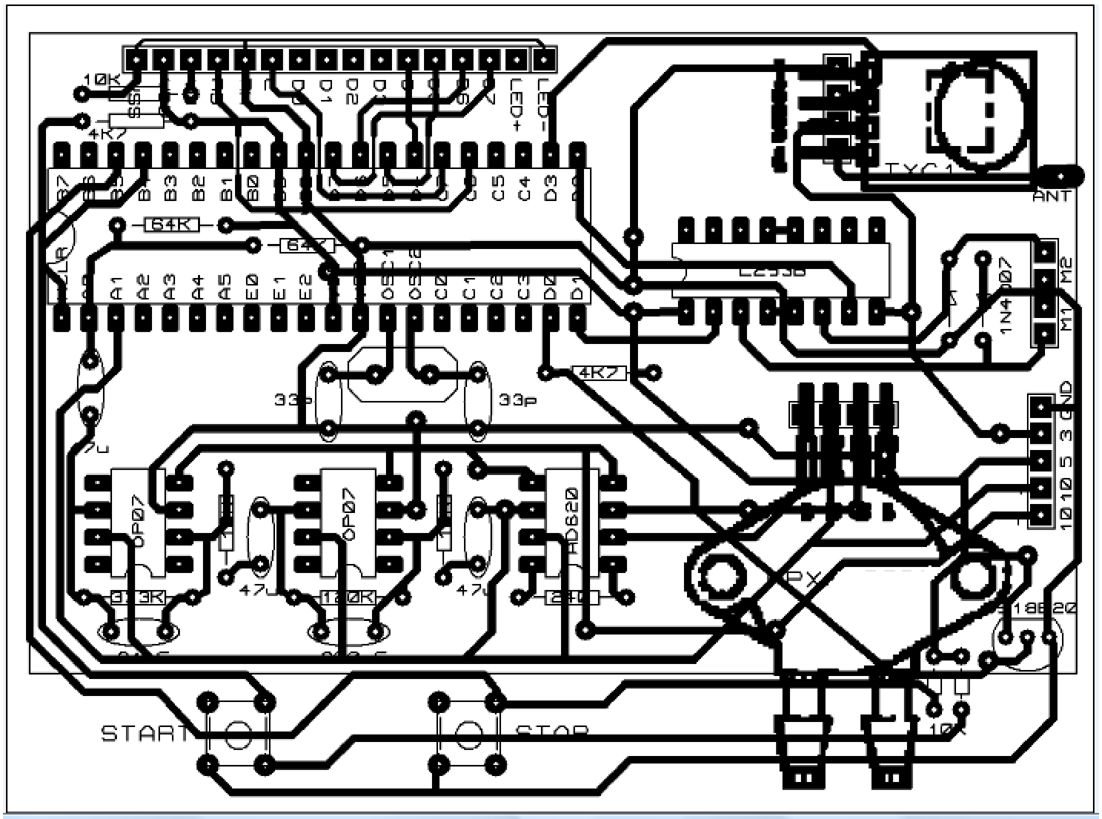
```
   if (bit_test(led,3)==1)
   {
      OUTPUT_BIT(pin_B7,1);
      OUTPUT_BIT(pin_A0,0);
   }
   else
   {
      OUTPUT_BIT(pin_B7,0);
      OUTPUT_BIT(pin_A0,1);
   }

   clear_interrupt(int_rda);
   disable_interrupts(int_rda);
   //enable_interrupts(int_rda); //when serial operation stops, this
interrupt will be active.
}
//*******************************************************************
#int_timer0           //makes an interrupt for 500us.
void timer0_kesme()  //interrupt funct. name
{
   set_timer0(131);
   tmr0_sayac++;
}
//*******************************************************************
void lcd_goster()
{
      lcd_gotoxy(1,1);
      printf(lcd_putc,"Systolic Press :%5.2fmmHg ", sys_measure);
      lcd_gotoxy(1,2);
      printf(lcd_putc,"Diastolic Press :%5.2fmmHg ", dias_measure);
      lcd_gotoxy(1,3);
      printf(lcd_putc,"Pulse : %3.0f p/m ", pulse_per_min);
      lcd_gotoxy(1,4);
      printf(lcd_putc,"Body Temp : %4.2f %cC ",temp,223);
}
//*******************************************************************
void serial()
   {
```

```
   //output_high(pin_b7);
      tmr0_sayac=0;buffer=0;bitkaysayac=1;
      while(input(data_pini)==0) //as long as pin is 0, wait here
            {
            }
      enable_interrupts(INT_timer0);
      while(tmr0_sayac<7)
            {
            if (input(data_pini)!=1) tmr0_sayac=0;
            }
      disable_interrupts(INT_timer0);
      tmr0_sayac=0;
      while(input(data_pini)==1) //wait until data is 0
            {
            }
      while(input(data_pini)==0) //wait until data is 1
            {
            }
      while(bitkaysayac<9)       //control the shift number
            {
                  while(input(data_pini)==1) //wait until data is 0
                        {
                        }
                  enable_interrupts(INT_timer0);
                  while(input(data_pini)==0) //wait until data is 1
                        {
                        }
                  disable_interrupts(INT_timer0);

            if (tmr0_sayac==2) bittest=0; //if data_pin is equal to
1, makes the buffer’s 0.bit 1
            if (tmr0_sayac==3) bittest=1;
            buffer=buffer<<1;    //shift left the buffer
            bitkaysayac++;                        //increase the shift
counter
            tmr0_sayac=0;
            }
      buffer=buffer>>1;
```

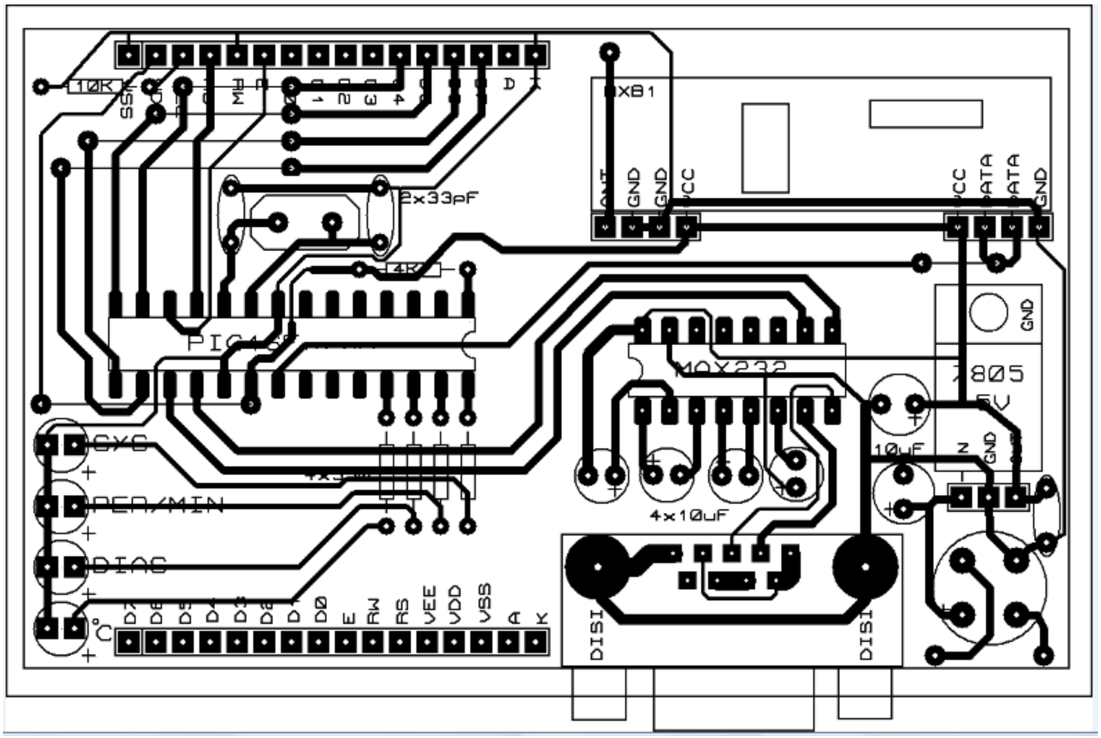
```
            while(input(data_pini)==1) //wait until the data is
equal to 0.
                 {
                 }
   }
//*********************************************************************
void main()
{
   setup_adc_ports(NO_ANALOGS);
   setup_adc(ADC_OFF);
   setup_spi(SPI_SS_DISABLED);
   setup_timer_0(RTCC_INTERNAL | RTCC_DIV_4);
   setup_timer_1(T1_DISABLED);
   setup_timer_2(T2_DISABLED,0,1);
   setup_CCP1(CCP_OFF);
   setup_CCP2(CCP_OFF);

   set_tris_a(0x00);
   set_tris_b(0x01);       //RF receiver input.
   set_tris_c(0x00);
   output_a(0x00);
   output_b(0x00);
   output_c(0x00);
   delay_ms(100);
   lcd_init();
   set_timer0(131);     //1*4*(256-131)=500us interrupt
   lcd_send_byte(0x0c);
   lcd_goster();
   clear_interrupt(int_rda);
   disable_interrupts(int_rda);
   disable_interrupts(INT_timer0);
   enable_interrupts(GLOBAL);
while(1)
     {
      serial();               //take serial data
      sal1=buffer;
      serial();               //take serial data
      sal2=buffer;
```

```
        serial();                //receive serial data
        sal3=buffer;

        serial();                //receive serial data
        sal4=buffer;

        serial();                //receive serial data
        sal5=buffer;

        serial();                //receive serial data
        sal6=buffer;

        serial();                //receive serial data
        sal7=buffer;

        serial();                //receive serial data
        sal8=buffer;

        lcd_send_byte(0x01);
        lcd_gotoxy(1,1);
        printf(lcd_putc,"Systolic Press :%3lu.%2lummHg ", sal1,sal2);
        lcd_gotoxy(1,2);
        printf(lcd_putc,"Diastolic Press :%3lu.%2lummHg ", sal5,sal6);
        lcd_gotoxy(1,3);
        printf(lcd_putc,"Pulse : %3lu p/m ", sal3);
        lcd_gotoxy(1,4);
        printf(lcd_putc,"Body Temp: %2lu.%2lu %cC ",sal7,sal8,223);

        printf("%c%c",sal1,sal2);
        delay_ms(1);
        printf("%c%c",sal3,sal4);
        delay_ms(1);
        printf("%c%c",sal5,sal6);
        delay_ms(1);
        printf("%c%c",sal7,sal8);
        enable_interrupts(int_rda);
      }

}
```

APPENDIX C: PRINTED CIRCUIT BOARD OF TRANSMİTTER PART



APPENDIX D: PRINTED CIRCUIT BOARD OF RECEİVER PART



APPENDIX E: DATASHEETS

MICROCHIP

PIC18FXX2

28/40-pin High Performance, Enhanced FLASH Microcontrollers with 10-Bit A/D

High Performance RISC CPU:

- C compiler optimized architecture/instruction set
  - Source code compatible with the PIC16 and PIC17 instruction sets
- Linear program memory addressing to 32 Kbytes
- Linear data memory addressing to 1.5 Kbytes

Device	On-Chip Program Memory		On-Chip RAM (bytes)	Data EEPROM (bytes)
	FLASH (bytes)	# Single Word Instructions		
PIC18F242	16K	8192	768	256
PIC18F252	32K	16384	1536	256
PIC18F442	16K	8192	768	256
PIC18F452	32K	16384	1536	256

- Up to 10 MIPs operation:
  - DC - 40 MHz osc./clock input
  - 4 MHz - 10 MHz osc./clock input with PLL active
- 16-bit wide instructions, 8-bit wide data path
- Priority levels for interrupts
- 8 x 8 Single Cycle Hardware Multiplier

Peripheral Features:

- High current sink/source 25 mA/25 mA
- Three external interrupt pins
- Timer0 module: 8-bit/16-bit timer/counter with 8-bit programmable prescaler
- Timer1 module: 16-bit timer/counter
- Timer2 module: 8-bit timer/counter with 8-bit period register (time-base for PWM)
- Timer3 module: 16-bit timer/counter
- Secondary oscillator clock option - Timer1/Timer3
- Two Capture/Compare/PWM (CCP) modules. CCP pins that can be configured as:
  - Capture input: capture is 16-bit, max. resolution 6.25 ns ($T_{CY}/16$)
  - Compare is 16-bit, max. resolution 100 ns (T_{CY})
  - PWM output: PWM resolution is 1- to 10-bit, max. PWM freq. @: 8-bit resolution = 156 kHz, 10-bit resolution = 39 kHz
- Master Synchronous Serial Port (MSSP) module, Two modes of operation:
  - 3-wire SPI™ (supports all 4 SPI modes)
  - I^2C™ Master and Slave mode

Peripheral Features (Continued):

- Addressable USART module:
  - Supports RS-485 and RS-232
- Parallel Slave Port (PSP) module

Analog Features:

- Compatible 10-bit Analog-to-Digital Converter module (A/D) with:
  - Fast sampling rate
  - Conversion available during SLEEP
  - Linearity ≤ 1 LSb
- Programmable Low Voltage Detection (PLVD)
  - Supports interrupt on-Low Voltage Detection
- Programmable Brown-out Reset (BOR)

Special Microcontroller Features:

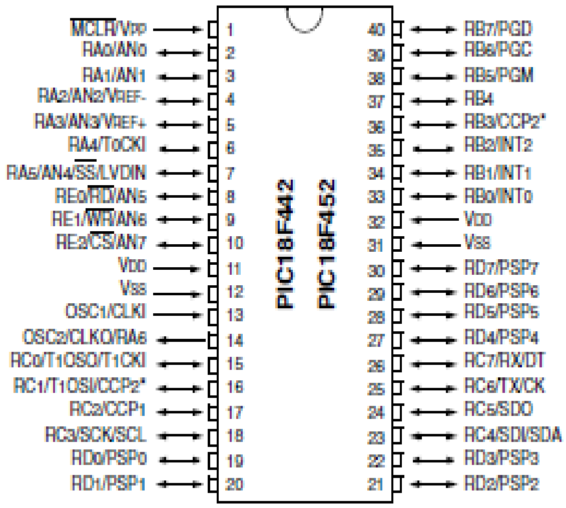
- 100,000 erase/write cycle Enhanced FLASH program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory
- FLASH/Data EEPROM Retention: > 40 years
- Self-reprogrammable under software control
- Power-on Reset (POR), Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own On-Chip RC Oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options including:
  - 4X Phase Lock Loop (of primary oscillator)
  - Secondary Oscillator (32 kHz) clock input
- Single supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins

CMOS Technology:

- Low power, high speed FLASH/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Industrial and Extended temperature ranges
- Low power consumption:
  - < 1.6 mA typical @ 5V, 4 MHz
  - 25 µA typical @ 3V, 32 kHz
  - < 0.2 µA typical standby current

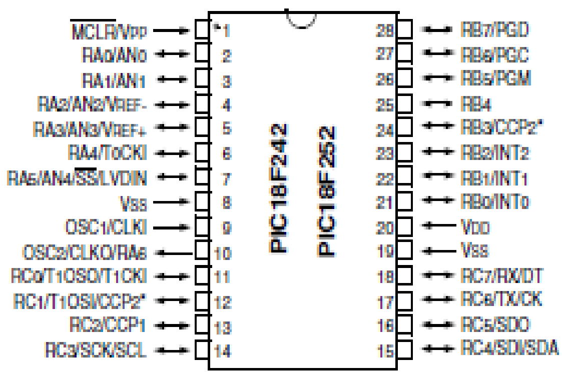
Pin Diagrams (Cont.'d)

DIP



Note: Pin compatible with 40-pin PIC16C7X devices.

DIP, SOIC



* RB3 is the alternate pin for the CCP2 pin multiplexing.

1.0 DEVICE OVERVIEW

This document contains device specific information for the following devices:

- PIC18F242
- PIC18F252
- PIC18F442
- PIC18F452

These devices come in 28-pin and 40/44-pin packages. The 28-pin devices do not have a Parallel Slave Port (PSP) implemented and the number of Analog-to-Digital (A/D) converter input channels is reduced to 5. An overview of features is shown in Table 1-1.

The following two figures are device block diagrams sorted by pin count: 28-pin for Figure 1-1 and 40/44-pin for Figure 1-2. The 28-pin and 40/44-pin pinouts are listed in Table 1-2 and Table 1-3, respectively.

TABLE 1-1: DEVICE FEATURES

Features	PIC18F242	PIC18F252	PIC18F442	PIC18F452
Operating Frequency	DC - 40 MHz	DC - 40 MHz	DC - 40 MHz	DC - 40 MHz
Program Memory (Bytes)	16K	32K	16K	32K
Program Memory (Instructions)	8192	16384	8192	16384
Data Memory (Bytes)	768	1536	768	1536
Data EEPROM Memory (Bytes)	256	256	256	256
Interrupt Sources	17	17	18	18
I/O Ports	Ports A, B, C	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C, D, E
Timers	4	4	4	4
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, Addressable USART	MSSP, Addressable USART	MSSP, Addressable USART	MSSP, Addressable USART
Parallel Communications	—	—	PSP	PSP
10-bit Analog-to-Digital Module	5 input channels	5 input channels	8 input channels	8 input channels
RESETS (and Delays)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST)
Programmable Low Voltage Detect	Yes	Yes	Yes	Yes
Programmable Brown-out Reset	Yes	Yes	Yes	Yes
Instruction Set	75 Instructions	75 Instructions	75 Instructions	75 Instructions
Packages	28-pin DIP 28-pin SOIC	28-pin DIP 28-pin SOIC	40-pin DIP 44-pin PLCC 44-pin TQFP	40-pin DIP 44-pin PLCC 44-pin TQFP

ANALOG DEVICES

Low Cost, Low Power Instrumentation Amplifier

AD620

FEATURES
EASY TO USE
Gain Set with One External Resistor
(Gain Range 1 to 1000)
Wide Power Supply Range (±2.3 V to ±18 V)
Higher Performance than Three Op Amp IA Designs
Available in 8-Lead DIP and SOIC Packaging
Low Power, 1.3 mA max Supply Current

EXCELLENT DC PERFORMANCE ("B GRADE")
50 µV max, Input Offset Voltage
0.6 µV/°C max, Input Offset Drift
1.0 nA max, Input Bias Current
100 dB min Common-Mode Rejection Ratio (G = 10)

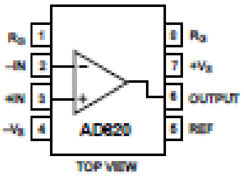
LOW NOISE
9 nV/√Hz, @ 1 kHz, Input Voltage Noise
0.28 µV p-p Noise (0.1 Hz to 10 Hz)

EXCELLENT AC SPECIFICATIONS
120 kHz Bandwidth (G = 100)
15 µs Settling Time to 0.01%

APPLICATIONS
Weigh Scales
ECG and Medical Instrumentation
Transducer Interface
Data Acquisition Systems
Industrial Process Controls
Battery Powered and Portable Equipment

CONNECTION DIAGRAM

8-Lead Plastic Mini-DIP (N), Cerdip (Q) and SOIC (R) Packages



PRODUCT DESCRIPTION

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 1000. Furthermore, the AD620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs, and offers lower power (only 1.3 mA max supply current), making it a good fit for battery powered, portable (or remote) applications.

The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50 µV max and offset drift of 0.6 µV/°C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications such as ECG and noninvasive blood pressure monitors.

The low input bias current of 1.0 nA max is made possible with the use of Superβeta processing in the input stage. The AD620 works well as a preamplifier due to its low input voltage noise of 9 nV/√Hz at 1 kHz, 0.28 µV p-p in the 0.1 Hz to 10 Hz band, 0.1 pA/√Hz input current noise. Also, the AD620 is well suited for multiplexed applications with its settling time of 15 µs to 0.01% and its cost is low enough to enable designs with one in-amp per channel.

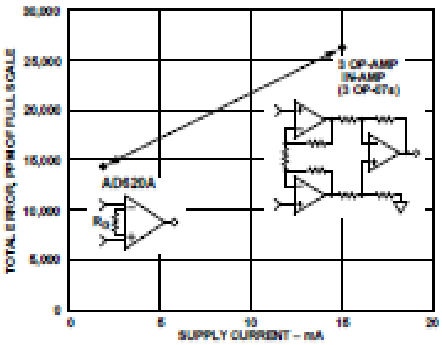


Figure 1. Three Op Amp IA Designs vs. AD620

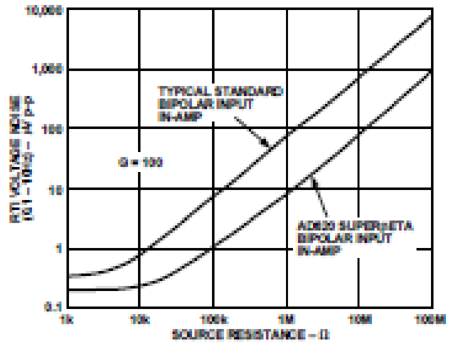


Figure 2. Total Voltage Noise vs. Source Resistance

REV. E

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781/329-4700 World Wide Web Site: http://www.analog.com
Fax: 781/326-8703

AD620–SPECIFICATIONS

(Typical @ +25°C, V_S = ±15 V, and R_L = 2 kΩ, unless otherwise noted)

Model	Conditions	AD620A			AD620B			AD620S[1]			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
GAIN	G = 1 + (49.4 k/R_G)										
Gain Range		1		10,000	1		10,000	1		10,000	
Gain Error[2]	V_{OUT} = ±10 V										
G = 1			0.03	0.10		0.01	0.02		0.03	0.10	%
G = 10			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 100			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 1000			0.40	0.70		0.35	0.50		0.40	0.70	%
Nonlinearity,	V_{OUT} = –10 V to +10 V,										
G = 1–1000	R_L = 10 kΩ		10	40		10	40		10	40	ppm
G = 1–100	R_L = 2 kΩ		10	95		10	95		10	95	ppm
Gain vs. Temperature											
	G =1			10			10			10	ppm/°C
	Gain >1[2]			–50			–50			–50	ppm/°C
VOLTAGE OFFSET	(Total RTI Error = V_{OSI} + V_{OSO}/G)										
Input Offset, V_{OSI}	V_S = ±5 V to ±15 V		30	125		15	50		30	125	µV
Over Temperature	V_S = ±5 V to ±15 V			185			85			225	µV
Average TC	V_S = ±5 V to ±15 V		0.3	1.0		0.1	0.6		0.3	1.0	µV/°C
Output Offset, V_{OSO}	V_S = ±15 V		400	1000		200	500		400	1000	µV
	V_S = ±5 V			1500			750			1500	µV
Over Temperature	V_S = ±5 V to ±15 V			2000			1000			2000	µV
Average TC	V_S = ±5 V to ±15 V		5.0	15		2.5	7.0		5.0	15	µV/°C
Offset Referred to the Input vs.											
Supply (PSR)	V_S = ±2.3 V to ±18 V										
G = 1		80	100		80	100		80	100		dB
G = 10		95	120		100	120		95	120		dB
G = 100		110	140		120	140		110	140		dB
G = 1000		110	140		120	140		110	140		dB
INPUT CURRENT											
Input Bias Current			0.5	2.0		0.5	1.0		0.5	2	nA
Over Temperature				2.5			1.5			4	nA
Average TC			3.0			3.0			8.0		pA/°C
Input Offset Current			0.3	1.0		0.3	0.5		0.3	1.0	nA
Over Temperature				1.5			0.75			2.0	nA
Average TC			1.5			1.5			8.0		pA/°C
INPUT											
Input Impedance											
Differential			10‖2			10‖2			10‖2		GΩ‖pF
Common-Mode			10‖2			10‖2			10‖2		GΩ‖pF
Input Voltage Range[3]	V_S = ±2.3 V to ±5 V	$-V_S + 1.9$		$+V_S - 1.2$	$-V_S + 1.9$		$+V_S - 1.2$	$-V_S + 1.9$		$+V_S - 1.2$	V
Over Temperature		$-V_S + 2.1$		$+V_S - 1.3$	$-V_S + 2.1$		$+V_S - 1.3$	$-V_S + 2.1$		$+V_S - 1.3$	V
	V_S = ±5 V to ±18 V	$-V_S + 1.9$		$+V_S - 1.4$	$-V_S + 1.9$		$+V_S - 1.4$	$-V_S + 1.9$		$+V_S - 1.4$	V
Over Temperature		$-V_S + 2.1$		$+V_S - 1.4$	$-V_S + 2.1$		$+V_S - 1.4$	$-V_S + 2.3$		$+V_S - 1.4$	V
Common-Mode Rejection Ratio DC to 60 Hz with											
1 kΩ Source Imbalance	V_{CM} = 0 V to ±10 V										
G = 1		73	90		80	90		73	90		dB
G = 10		93	110		100	110		93	110		dB
G = 100		110	130		120	130		110	130		dB
G = 1000		110	130		120	130		110	130		dB
OUTPUT											
Output Swing	R_L = 10 kΩ,										
	V_S = ±2.3 V to ±5 V	$-V_S + 1.1$		$+V_S - 1.2$	$-V_S + 1.1$		$+V_S - 1.2$	$-V_S + 1.1$		$+V_S - 1.2$	V
Over Temperature		$-V_S + 1.4$		$+V_S - 1.3$	$-V_S + 1.4$		$+V_S - 1.3$	$-V_S + 1.6$		$+V_S - 1.3$	V
	V_S = ±5 V to ±18 V	$-V_S + 1.2$		$+V_S - 1.4$	$-V_S + 1.2$		$+V_S - 1.4$	$-V_S + 1.2$		$+V_S - 1.4$	V
Over Temperature		$-V_S + 1.6$		$+V_S - 1.5$	$-V_S + 1.6$		$+V_S - 1.5$	$-V_S + 2.3$		$+V_S - 1.5$	V
Short Current Circuit			±18			±18			±18		mA

Model	Conditions	AD620A			AD620B			AD620S[1]			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
DYNAMIC RESPONSE											
Small Signal –3 dB Bandwidth											
G = 1			1000			1000			1000		kHz
G = 10			800			800			800		kHz
G = 100			120			120			120		kHz
G = 1000			12			12			12		kHz
Slew Rate		0.75	1.2		0.75	1.2		0.75	1.2		V/μs
Settling Time to 0.01%	10 V Step										
G = 1–100			15			15			15		μs
G = 1000			150			150			150		μs
NOISE											
Voltage Noise, 1 kHz	$\text{Total RTI Noise} = \sqrt{(e^2_{ni}) + (e_{no}/G)^2}$										
Input, Voltage Noise, e_{ni}			9	13		9	13		9	13	nV/√Hz
Output, Voltage Noise, e_{no}			72	100		72	100		72	100	nV/√Hz
RTI, 0.1 Hz to 10 Hz											
G = 1			3.0			3.0	6.0		3.0	6.0	μV p-p
G = 10			0.55			0.55	0.8		0.55	0.8	μV p-p
G = 100–1000			0.28			0.28	0.4		0.28	0.4	μV p-p
Current Noise	f = 1 kHz		100			100			100		fA/√Hz
0.1 Hz to 10 Hz			10			10			10		pA p-p
REFERENCE INPUT											
R_{IN}			20			20			20		kΩ
I_{IN}	V_{IN+}, $V_{REF} = 0$		+50	+60		+50	+60		+50	+60	μA
Voltage Range		$-V_S + 1.6$		$+V_S - 1.6$	$-V_S + 1.6$		$+V_S - 1.6$	$-V_S + 1.6$		$+V_S - 1.6$	V
Gain to Output			1 ± 0.0001			1 ± 0.0001			1 ± 0.0001		
POWER SUPPLY											
Operating Range[4]		±2.3		±18	±2.3		±18	±2.3		±18	V
Quiescent Current	$V_S = \pm 2.3$ V to ± 18 V		0.9	1.3		0.9	1.3		0.9	1.3	mA
Over Temperature			1.1	1.6		1.1	1.6		1.1	1.6	mA
TEMPERATURE RANGE											
For Specified Performance			–40 to +85			–40 to +85			–55 to +125		°C

NOTES
[1]See Analog Devices military data sheet for 883B tested specifications.
[2]Does not include effects of external resistor R_G.
[3]One input grounded. G = 1.
[4]This is defined as the same supply range which is used to specify PSR.
Specifications subject to change without notice.

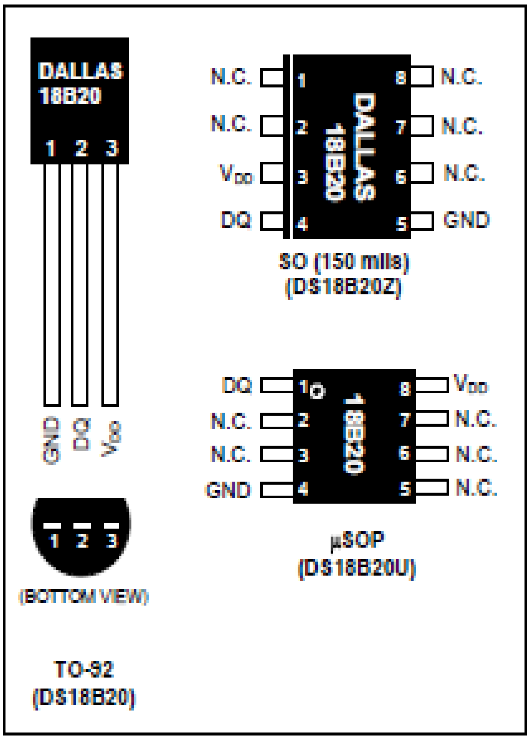
DS18B20
Programmable Resolution 1-Wire Digital Thermometer

www.maxim-ic.com

FEATURES

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Each Device has a Unique 64-Bit Serial Code Stored in an On-Board ROM
- Multidrop Capability Simplifies Distributed Temperature-Sensing Applications
- Requires No External Components
- Can Be Powered from Data Line; Power Supply Range is 3.0V to 5.5V
- Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
- ±0.5°C Accuracy from -10°C to +85°C
- Thermometer Resolution is User Selectable from 9 to 12 Bits
- Converts Temperature to 12-Bit Digital Word in 750ms (Max)
- User-Definable Nonvolatile (NV) Alarm Settings
- Alarm Search Command Identifies and Addresses Devices Whose Temperature is Outside Programmed Limits (Temperature Alarm Condition)
- Available in 8-Pin SO (150 mils), 8-Pin µSOP, and 3-Pin TO-92 Packages
- Software Compatible with the DS1822
- Applications Include Thermostatic Controls, Industrial Systems, Consumer Products, Thermometers, or Any Thermally Sensitive System

PIN CONFIGURATIONS



DESCRIPTION

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. It has an operating temperature range of -55°C to +125°C and is accurate to ±0.5°C over the range of -10°C to +85°C. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply.

Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Applications that can benefit from this feature include HVAC environmental controls, temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems.

1-Wire is a registered trademark of Maxim Integrated Products, Inc.

ORDERING INFORMATION

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
DS18B20	-55°C to +125°C	3 TO-92	18B20
DS18B20+	-55°C to +125°C	3 TO-92	18B20
DS18B20/T&R	-55°C to +125°C	3 TO-92 (2000 Piece)	18B20
DS18B20+T&R	-55°C to +125°C	3 TO-92 (2000 Piece)	18B20
DS18B20-SL/T&R	-55°C to +125°C	3 TO-92 (2000 Piece)*	18B20
DS18B20-SL+T&R	-55°C to +125°C	3 TO-92 (2000 Piece)*	18B20
DS18B20U	-55°C to +125°C	8 µSOP	18B20
DS18B20U+	-55°C to +125°C	8 µSOP	18B20
DS18B20U/T&R	-55°C to +125°C	8 µSOP (3000 Piece)	18B20
DS18B20U+T&R	-55°C to +125°C	8 µSOP (3000 Piece)	18B20
DS18B20Z	-55°C to +125°C	8 SO	DS18B20
DS18B20Z+	-55°C to +125°C	8 SO	DS18B20
DS18B20Z/T&R	-55°C to +125°C	8 SO (2500 Piece)	DS18B20
DS18B20Z+T&R	-55°C to +125°C	8 SO (2500 Piece)	DS18B20

+Denotes a lead-free package. A "+" will appear on the top mark of lead-free packages.
T&R = Tape and reel.
**TO-92 packages in tape and reel can be ordered with straight or formed leads. Choose "SL" for straight leads. Bulk TO-92 orders are straight leads only.*

PIN DESCRIPTION

PIN			NAME	FUNCTION
SO	µSOP	TO-92		
1, 2, 6, 7, 8	2, 3, 5, 6, 7	—	N.C.	No Connection
3	8	3	V_{DD}	Optional V_{DD}. V_{DD} must be grounded for operation in parasite power mode.
4	1	2	DQ	Data Input/Output. Open-drain 1-Wire interface pin. Also provides power to the device when used in parasite power mode (see the *Powering the DS18B20* section.)
5	4	1	GND	Ground

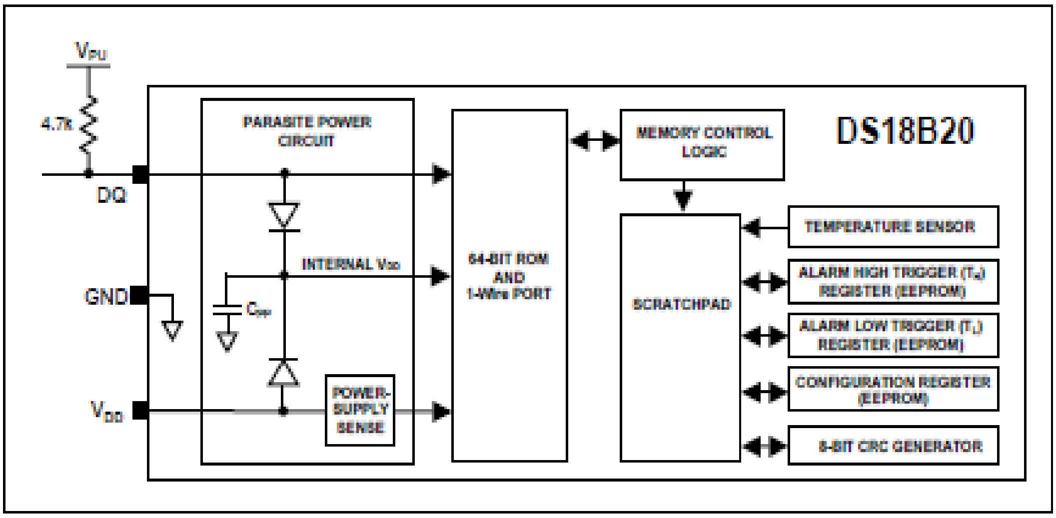
OVERVIEW

Figure 1 shows a block diagram of the DS18B20, and pin descriptions are given in the *Pin Description* table. The 64-bit ROM stores the device's unique serial code. The scratchpad memory contains the 2-byte temperature register that stores the digital output from the temperature sensor. In addition, the scratchpad provides access to the 1-byte upper and lower alarm trigger registers (T_H and T_L) and the 1-byte configuration register. The configuration register allows the user to set the resolution of the temperature-to-digital conversion to 9, 10, 11, or 12 bits. The T_H, T_L, and configuration registers are nonvolatile (EEPROM), so they will retain data when the device is powered down.

The DS18B20 uses Maxim's exclusive 1-Wire bus protocol that implements bus communication using one control signal. The control line requires a weak pullup resistor since all devices are linked to the bus via a 3-state or open-drain port (the DQ pin in the case of the DS18B20). In this bus system, the microprocessor (the master device) identifies and addresses devices on the bus using each device's unique 64-bit code. Because each device has a unique code, the number of devices that can be addressed on one bus is virtually unlimited. The 1-Wire bus protocol, including detailed explanations of the commands and "time slots," is covered in the *1-Wire Bus System* section.

Another feature of the DS18B20 is the ability to operate without an external power supply. Power is instead supplied through the 1-Wire pullup resistor via the DQ pin when the bus is high. The high bus signal also charges an internal capacitor (C_{PP}), which then supplies power to the device when the bus is low. This method of deriving power from the 1-Wire bus is referred to as "parasite power." As an alternative, the DS18B20 may also be powered by an external supply on V_{DD}.

Figure 1. DS18B20 Block Diagram



OPERATION—MEASURING TEMPERATURE

The core functionality of the DS18B20 is its direct-to-digital temperature sensor. The resolution of the temperature sensor is user-configurable to 9, 10, 11, or 12 bits, corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively. The default resolution at power-up is 12-bit. The DS18B20 powers up in a low-power idle state. To initiate a temperature measurement and A-to-D conversion, the master must issue a Convert T [44h] command. Following the conversion, the resulting thermal data is stored in the 2-byte temperature register in the scratchpad memory and the DS18B20 returns to its idle state. If the DS18B20 is powered by an external supply, the master can issue "read time slots" (see the *1-Wire Bus System* section) after the Convert T command and the DS18B20 will respond by transmitting 0 while the temperature conversion is in progress and 1 when the conversion is done. If the DS18B20 is powered with parasite power, this notification technique cannot be used since the bus must be pulled high by a strong pullup during the entire temperature conversion. The bus requirements for parasite power are explained in detail in the *Powering the DS18B20* section.

The DS18B20 output temperature data is calibrated in degrees Celsius; for Fahrenheit applications, a lookup table or conversion routine must be used. The temperature data is stored as a 16-bit sign-extended two's complement number in the temperature register (see Figure 2). The sign bits (S) indicate if the temperature is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. If the DS18B20 is configured for 12-bit resolution, all bits in the temperature register will contain valid data. For 11-bit resolution, bit 0 is undefined. For 10-bit resolution, bits 1 and 0 are undefined, and for 9-bit resolution bits 2, 1, and 0 are undefined. Table 1 gives examples of digital output data and the corresponding temperature reading for 12-bit resolution conversions.

Figure 2. Temperature Register Format

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
LS BYTE	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}

	BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8
MS BYTE	S	S	S	S	S	2^6	2^5	2^4

S = SIGN

Table 1. Temperature/Data Relationship

TEMPERATURE (°C)	DIGITAL OUTPUT (BINARY)	DIGITAL OUTPUT (HEX)
+125	0000 0111 1101 0000	07D0h
+85*	0000 0101 0101 0000	0550h
+25.0625	0000 0001 1001 0001	0191h
+10.125	0000 0000 1010 0010	00A2h
+0.5	0000 0000 0000 1000	0008h
0	0000 0000 0000 0000	0000h
-0.5	1111 1111 1111 1000	FFF8h
-10.125	1111 1111 0101 1110	FF5Eh
-25.0625	1111 1110 0110 1111	FE6Fh
-55	1111 1100 1001 0000	FC90h

**The power-on reset value of the temperature register is +85°C.*

OPERATION—ALARM SIGNALING

After the DS18B20 performs a temperature conversion, the temperature value is compared to the user-defined two's complement alarm trigger values stored in the 1-byte T_H and T_L registers (see Figure 3). The sign bit (S) indicates if the value is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. The T_H and T_L registers are nonvolatile (EEPROM) so they will retain data when the device is powered down. T_H and T_L can be accessed through bytes 2 and 3 of the scratchpad as explained in the *Memory* section.

Figure 3. T_H and T_L Register Format

BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
S	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Only bits 11 through 4 of the temperature register are used in the T_H and T_L comparison since T_H and T_L are 8-bit registers. If the measured temperature is lower than or equal to T_L or higher than or equal to T_H, an alarm condition exists and an alarm flag is set inside the DS18B20. This flag is updated after every temperature measurement; therefore, if the alarm condition goes away, the flag will be turned off after the next temperature conversion.

MOTOROLA
SEMICONDUCTOR TECHNICAL DATA

Order this document
by MPX2050/D

50 kPa On-Chip Temperature Compensated & Calibrated Silicon Pressure Sensors

MPX2050 SERIES

0 to 50 kPa (0 to 7.25 psi)
40 mV FULL SCALE SPAN
(TYPICAL)

The MPX2050 series device is a silicon piezoresistive pressure sensors providing a highly accurate and linear voltage output — directly proportional to the applied pressure. The sensor is a single, monolithic silicon diaphragm with the strain gauge and a thin–film resistor network integrated on–chip. The chip is laser trimmed for precise span and offset calibration and temperature compensation.

Features

- Temperature Compensated Over 0°C to +85°C
- Unique Silicon Shear Stress Strain Gauge
- Easy to Use Chip Carrier Package Options
- Ratiometric to Supply Voltage
- Differential and Gauge Options
- ±0.25% Linearity (MPX2050)

Application Examples

- Pump/Motor Controllers
- Robotics
- Level Indicators
- Medical Diagnostics
- Pressure Switching
- Non–Invasive Blood Pressure Measurement

Figure 1 shows a block diagram of the internal circuitry on the stand–alone pressure sensor chip.

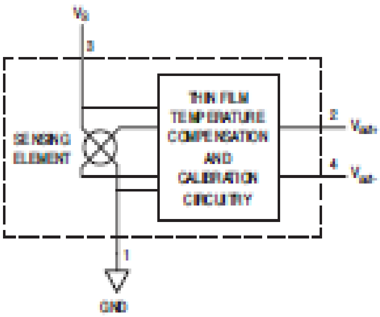
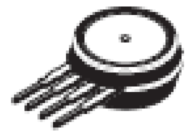


Figure 1. Temperature Compensated Pressure Sensor Schematic

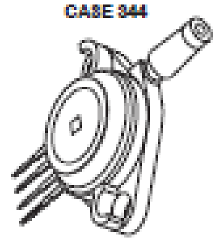
VOLTAGE OUTPUT versus APPLIED DIFFERENTIAL PRESSURE

The differential voltage output of the sensor is directly proportional to the differential pressure applied.

The output voltage of the differential or gauge sensor increases with increasing pressure applied to the pressure side (P1) relative to the vacuum side (P2). Similarly, output voltage increases as increasing vacuum is applied to the vacuum side (P2) relative to the pressure side (P1).

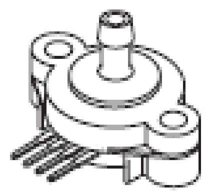


MPX2050D
CASE 344



MPX2050GP
CASE 344B

MPX2050DP
CASE 344C



MPX2050GSX
CASE 344F

PIN NUMBER			
1	Gnd	3	V_S
2	$+V_{out}$	4	$-V_{out}$

NOTE: Pin 1 is noted by the notch in the lead.

MPX2050 SERIES

MAXIMUM RATINGS(NOTE)

Rating	Symbol	Value	Unit
Maximum Pressure (P1 > P2)	P_{max}	200	kPa
Storage Temperature	T_{stg}	–40 to +125	°C
Operating Temperature	T_A	–40 to +125	°C

NOTE: Exposure beyond the specified limits may cause permanent damage or degradation to the device.

OPERATING CHARACTERISTICS (V_S = 10 Vdc, T_A = 25°C unless otherwise noted, P1 > P2)

Characteristic		Symbol	Min	Typ	Max	Unit
Pressure Range(1)		P_{OP}	0	—	50	kPa
Supply Voltage(2)		V_S	—	10	16	Vdc
Supply Current		I_o	—	6.0	—	mAdc
Full Scale Span(3)	MPX2050	V_{FSS}	38.5	40	41.5	mV
Offset(4)	MPX2050	V_{off}	–1.0	—	1.0	mV
Sensitivity		ΔV/ΔP	—	0.8	—	mV/kPa
Linearity(5)	MPX2050	—	–0.25	—	0.25	$\%V_{FSS}$
Pressure Hysteresis(5) (0 to 50 kPa)		—	—	±0.1	—	$\%V_{FSS}$
Temperature Hysteresis(5) (–40°C to +125°C)		—	—	±0.5	—	$\%V_{FSS}$
Temperature Effect on Full Scale Span(5)		TCV_{FSS}	–1.0	—	1.0	$\%V_{FSS}$
Temperature Effect on Offset(5)		TCV_{off}	–1.0	—	1.0	mV
Input Impedance		Z_{in}	1000	—	2500	Ω
Output Impedance		Z_{out}	1400	—	3000	Ω
Response Time(6) (10% to 90%)		t_R	—	1.0	—	ms
Warm–Up		—	—	20	—	ms
Offset Stability(7)		—	—	±0.5	—	$\%V_{FSS}$

NOTES:
1. 1.0 kPa (kiloPascal) equals 0.145 psi.
2. Device is ratiometric within this specified excitation range. Operating the device above the specified excitation range may induce additional error due to device self–heating.
3. Full Scale Span (V_{FSS}) is defined as the algebraic difference between the output voltage at full rated pressure and the output voltage at the minimum rated pressure.
4. Offset (V_{off}) is defined as the output voltage at the minimum rated pressure.
5. Accuracy (error budget) consists of the following:
   - Linearity: Output deviation from a straight line relationship with pressure, using end point method, over the specified pressure range.
   - Temperature Hysteresis: Output deviation at any temperature within the operating temperature range, after the temperature is cycled to and from the minimum or maximum operating temperature points, with zero differential pressure applied.
   - Pressure Hysteresis: Output deviation at any pressure within the specified range, when this pressure is cycled to and from the minimum or maximum rated pressure, at 25°C.
   - TcSpan: Output deviation at full rated pressure over the temperature range of 0 to 85°C, relative to 25°C.
   - TcOffset: Output deviation with minimum rated pressure applied, over the temperature range of 0 to 85°C, relative to 25°C.
6. Response Time is defined as the time for the incremental change in the output to go from 10% to 90% of its final value when subjected to a specified step change in pressure.
7. Offset stability is the product's output deviation when subjected to 1000 hours of Pulsed Pressure, Temperature Cycling with Bias Test.

LINEARITY

Linearity refers to how well a transducer's output follows the equation: $V_{out} = V_{off}$ + sensitivity x P over the operating pressure range. There are two basic methods for calculating nonlinearity: (1) end point straight line fit (see Figure 2) or (2) a least squares best line fit. While a least squares fit gives the "best case" linearity error (lower numerical value), the calculations required are burdensome.

Conversely, an end point fit will give the "worst case" error (often more desirable in error budget calculations) and the calculations are more straightforward for the user. Motorola's specified pressure sensor linearities are based on the end point straight line method measured at the midrange pressure.

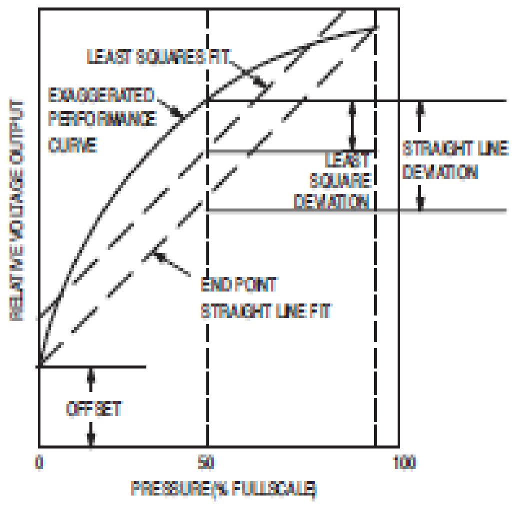


Figure 2. Linearity Specification Comparison

ON–CHIP TEMPERATURE COMPENSATION and CALIBRATION

Figure 3 shows the minimum, maximum and typical output characteristics of the MPX2050 series at 25°C. The output is directly proportional to the differential pressure and is essentially a straight line.

The effects of temperature on Full–Scale Span and Offset are very small and are shown under Operating Characteristics.

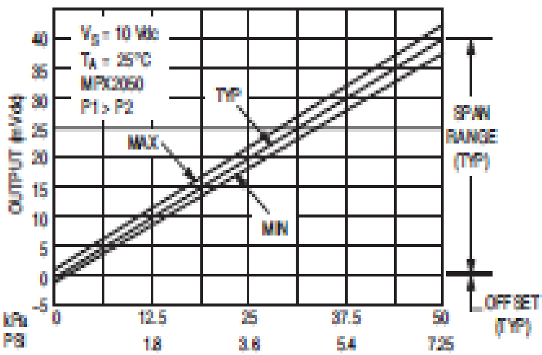


Figure 3. Output versus Pressure Differential

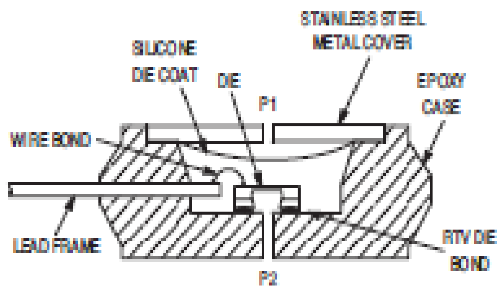


Figure 4. Cross–Sectional Diagram (not to scale)

Figure 4 illustrates the differential or gauge configuration in the basic chip carrier (Case 344). A silicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the silicon diaphragm.

The MPX2050 series pressure sensor operating characteristics and internal reliability and qualification tests are based on use of dry air as the pressure media. Media other than dry air may have adverse effects on sensor performance and long term reliability. Contact the factory for information regarding media compatibility in your application.