DEVELOPMENT OF A LOW COST MICROCONTROLLER AND PC BASED PATIENT MONITORING SYSTEM FOR INTENSIVE CARE UNIT OF HOSPITALS

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Contents

List of Figures viii

Acknowledgements xii

Abstract xiii

1 Introduction 1

1.1 ICU System 1

1.1.1 Different Types of ICU 2

1.1.2 Monitoring System 3

1.1.3 Computerized Intensive Care Unit 6

1.1.4 Data Acquisition 8

1.2 Objective of the Present Work 9

1.3 Thesis Outline 9

2 Pulse Oximetry Signal Monitoring System 11

2.1 Introduction 11

2.2 Principles of Pulse Oximetry 11

2.3 Calibration of Pulse Oximeter 15

2.4 Design of Pulse Oximetry instrumentation 18

2.4.1 Circuit Diagram 18

2.4.2 Description of all circuits 18

2.5 Processing by Microcomputer and typical records of a patients 30

3 Electrocardiogram Signal Monitoring System **35**
3.1 Introduction 35
3.2 ECG Paper 35
3.3 Electrical Potential 36
3.4 Cardiac System 38
3.5 Waves and intervals 40
3.6 ECG Leads 43
3.6.1 Limb leads (Bipolar) 43
3.6.2 Augmented Limb Leads (Unipolar) 46
3.6.3 Chest Leads 48
3.7 Circuit Diagram 49
3.7.1 Description of Circuits 49
3.8 Processing the Signals and Typical Results 52

4 Temperature Monitoring System **58**
4.1 Introduction 58
4.2 Temperature Sensing Probe 58
4.3 Measurement of Temperature by Using Thermistor Sensor 61
4.4 Circuit Diagram 63
4.4.1 Description of all Circuits 63
4.4.2 Processing the Signal and Typical Results 65

5 Multiscreen Display of Several Patient Condition **69**
5.1 Introduction 69
5.1.1 Filtering 69
5.1.2 Multiscreen Display 70

6 Conclusions and Future Works **74**

References **75**

A Appendix **77**

A.1 Signals of Various parts of Circuits 77

A.1.1 Pulse oximetry Circuit 77

A.1.2 ECG Monitoring Circuit 77

A.1.3 Temperature Monitoring Circuit 80

A.1.4 Power Supply Circuit 80

A.1.5 Full Circuit 80

A.2 Programs for pulse oximetry,ecg,temperature signals display at bedside monitor 81

A.2.1 MATLAB Code for displaying all signals in a same screen 81

A.2.2 MATLAB Code for initializing of Advantech channel 88

A.2.3 MATLAB Code for taking signal: 90

A.2.4 MATLAB Code for processing pulse oximetry signal 90

A.2.5 MATLAB Code for processing ECG signal: 91

A.2.6 MATLAB Code for processing Temperature signal 92

A.2.7 AVR Microcontroller Code: 92

A.3 Software for central ICU unit display 94

List of Figures

Figure 1.1	Data Acquisition Card	8
Figure 2.1	Pulse Oximeter Probe	12
Figure 2.2	Pulse Oximeter	12
Figure 2.3	Absorption levels of oxygenated and deoxygenated blood	13
Figure 2.4	light absorption Property	15
Figure 2.5	Transmission of light through finger	16
Figure 2.6	Two relationships between the ratio R and the Oxygen Saturation of the patient	17
Figure 2.7	Pulse Oximeter (OXICLIQ A)	17
Figure 2.8	Pin Configuration of Pulse Oximeter (OXICLIQ A)	18
Figure 2.9	Circuit Diagram of Pulse Oximetry (Part 1)	19
Figure 2.10	Circuit Diagram of Pulse Oximetry (Part 2)	20
Figure 2.11	Circuit Diagram of Pulse Oximetry (Part 3)	21
Figure 2.12	Timing Signals for the LED drivers	22
Figure 2.13	Standard analog buffering circuit	23
Figure 2.14	Pulses from Pulse Oximeter	23
Figure 2.15	Current to Voltage converter circuit	24
Figure 2.16	Input to the Analog MUX	25
Figure 2.17	Separation of Red LED and Infra-Red LED Signal	26
Figure 2.18	Red LED Signal	26
Figure 2.19	Infra-Red LED Signal	27
Figure 2.20	Peak Detection	27

Figure 2.21	Buffering and Amplification	28
Figure 2.22	Low pass Filter	28
Figure 2.23	Isolation Circuit	29
Figure 2.24	Pulse from Microcntroller	30
Figure 2.25	Typical pulsatile signals detected in the intensity of detected light when light is shone through a finger	31
Figure 2.26	Pulse Oximetry Signals before filtering	32
Figure 2.27	Infra - Red LED Signal	33
Figure 2.28	Red LED Signal	34
Figure 3.1	ECG Paper	36
Figure 3.2	Action Potential	37
Figure 3.3	Depolarization	38
Figure 3.4	Cardiac conduction system	39
Figure 3.5	ECG signal	41
Figure 3.6	Amplitude and Duration of the waves and intervals	42
Figure 3.7	Einthoven Triangle	44
Figure 3.8	Lead I connection	45
Figure 3.9	Output of Lead I	45
Figure 3.10	Lead II connection	46
Figure 3.11	Output of Lead II	46
Figure 3.12	Lead III connection	47
Figure 3.13	Output of Lead III	47
Figure 3.14	Position of the three Limb Leads	48
Figure 3.15	Position of the three Augmented Limb Leads	49
Figure 3.16	Position of the Chest Leads	50
Figure 3.17	Lead Connection of Augmented Vector Right	50
Figure 3.18	Lead Connection of Augmented Vector Foot	51
Figure 3.19	Lead Connection of Augmented Vector Left	51
Figure 3.20	Circuit Diagram of ECG Signal	53

Figure 3.21	Buffer and Differential Amplifier	54
Figure 3.22	Amplifier, filter and buffer	54
Figure 3.23	Isolation circuit	55
Figure 3.24	ECG Signal before filtering	55
Figure 3.25	ECG Signal after filtering	56
Figure 3.26	ECG Signal after filtering	57
Figure 4.1	Catheter type thermistor temperature sensor	59
Figure 4.2	Medical Temperature Sensors	60
Figure 4.3	Relationship between resistance and temperature	62
Figure 4.4	Block Diagram of Temperature measurement	63
Figure 4.5	Temperature measurement Circuitry	64
Figure 4.6	Differential Amplifier	65
Figure 4.7	Tri-angular wave generation	66
Figure 4.8	Input and output curves of the comparator	67
Figure 4.9	Optocoupler Isolation	67
Figure 4.10	Temperature Signal from DAQ	68
Figure 5.1	Finite Impulse Response of the filter	70
Figure 5.2	Information in a single monitor	71
Figure 5.3	Multiscreen Software	72
Figure 5.4	Information of two patients in a single monitor with IP address of two PCs	73
Figure A.1	Pulse from Microcntroller	77
Figure A.2	Input to the Analog MUX	78
Figure A.3	Red LED Signal	78
Figure A.4	Infra-Red LED Signal	79
Figure A.5	ECG Signal after filtering	80
Figure A.6	Temperature Signal from DAQ	81
Figure A.7	Pulse oximetry Circuit	82

Figure A.8 ECG Monitoring Circuit 83
Figure A.9 Temperature Monitoring Circuit 84
Figure A.10 Power Supply Circuit 85
Figure A.11 Full Circuit 86
Figure A.12 Multiscreen Software 94
Figure A.13 Multiscreen 95
Figure A.14 Multiple screens in a single monitor 96
Figure A.15 Information of two patients in a single monitor 97
Figure A.16 Information of two patients in a single monitor with IP address of two PCs 98

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Authors

Abstract

In Intensive Care Unit (ICU), the physiological information such as pulse rate, oxyzen saturation, ECG and temperature are constantly monitored and proper treatment is provided according to these information.This thesis paper is introducing a design of a Real-Time Data Acquisition System for monitoring patients in ICU (Intensive Care Unit). The Proposed design is implemented by using Microcntroller and PC with low cost hardware and data acquisition card. In this work, all information of a patient has been shown within a single screen.If all information is available in the same time so easily, then it is easy to take decision about the patient. For displaying the conditions of a member of patients a suitable network solution has been developed. Also measures has been taken for displaying the conditions of the ICU patients to the visitors of the patients outside ICU room.

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Chapter 1

Introduction

Intensive Care Unit (ICU) is a very important unit that provides over-secured care to the critical patients in a hospital. The patients who are seriously ill, requiring continuous care are admitted into the intensive care unit. Different types of equipments and systems are arranged in the intensive care unit. Constant monitoring system, respiratory and cardiac support equipments and other variable types of emergency monitoring equipments are arranged for the critical condition of the patients.

1.1 ICU System

In the Intensive Care Unit (ICU), many kinds of information are required to estimate the condition of the patient to cure in critical stage. Continuous monitoring is very important in case of a patient in ICU. For these many types of equipment are used. There are patients who need to be maintained very serious observation. To assist breathing through an endotracheal tube, there is a mechanical ventilator. Cardiac monitors including telemetry, external pacemakers, dialysis equipment for renal problems, feeding tubes, nasogastric tubes, suction pumps, drain and catheters and a wide array of drugs are arranged for the emergency condition of the patients. Every step is maintained very carefully. Different types of information such as pulse oximetry[1]-[2], heart rate, blood pressure, temperature, electro-cardiography etc are very important information in case of the critical patients. So

to handle such important information need the experienced skilled persons. Many modern technologies are used in this case. Many electronics materials has made the system so easier to get the information. Data storing capacity, display system has been improved in modern technology. For monitoring and analyzing the physiological signals high-speed computers are being used. It has become easy to analyze and display multiple physiological signals simultaneously on the monitor. The technology is helping us day by day to improve our process in case of monitoring the condition of the patients. With modern invention and emerging new technology, the system is going to become cheaper.

1.1.1 Different Types of ICU

There are different types of intensive care units. Some special types are [3],

- Neonatal intensive care unit (NICU),
- Special Care Nursery (SCN),
- Pediatric Intensive Care Unit (PICU),
- Psychiatric Intensive Care Unit (PICU),
- Coronary Care Unit (CCU) for heart disease,
- Cardiac Surgery Intensive Care Unit (CSICU),
- Cardiovascular Intensive Care Unit (CVICU),
- Mobile Intensive Care Unit (MICU),
- Medical Surgical Intensive Care Unit (MSICU),
- Medical-Surgical Critical Care Intensive Care Unit (MSCC),
- Surgical Intensive Care Unit (SICU),

- Overnight Intensive Recovery (OIR),
- Neuroscience Critical Care Unit (NCCU),
- Neurological Intensive Care Unit (NICU),
- Neuro Intensive Care Unit (NICU),
- Burn Wounds Intensive Care Unit (BWICU),
- Trauma Intensive care Unit (TICU),
- Shock Trauma Intensive care Unit (STICU),
- Trauma-Neuro Critical Care Intensive Care Unit (TNCC),
- Respiratory Intensive Care Unit (RICU) and
- Geriatrics Intensive Care Unit (GICU),

Different types of ICU are designed to provide care to the patients with a range of conditions or to provide specialized care to patients with specific conditions. Neonatal ICU is used to care for infants who are ill, born prematurely which require constant monitoring. Neuro ICU is designed to care the patients with acute conditions involving the nervous system. Their requirement is to monitor and assess the brain cord. Coronary care unit is designed for the patients with heart attacks, unstable angina and various other cardiac conditions that require continuous monitoring and treatment. Trauma ICU is the hospital part that provides specialized injury and wound care for patients[3].

1.1.2 Monitoring System

There are many types of equipments which are used in case of monitoring system in the intensive care unit. This monitoring system may be configured to continuously measure and display a number of parameters via electrodes and sensors that are connected to the

patient. These may include the electrical activity of the heart via an ECG [4], respiration rate (breathing), blood pressure, body temperature, cardiac output, and amount of oxygen [5]and carbon dioxide in the blood. Each patient bed in an ICU has a physiologic monitor that measure these body activities.In modern systems all monitors are networked to a central nurses' station [3].

To monitor the saturation of oxygen in the blood, pulse oximeter is used. It is attached to a patient's finger, or it may be smaller and clipped onto the earlobe. To monitor electrical activity of the heart, cardiac monitors are used. The monitor looks like a computer screen with lines, or tracings, moving across the screen. The monitor has electrodes that are attached to the patient's chest with sticky pads. To measure the amount of fluid filling the heart as well as to determine how the heart is functioning, a Swan-Ganz, or pulmonary artery catheter is used. It is inserted through the large vessels of the neck or upper chest and threaded into the heart. Arterial lines are used for continuous monitoring of blood pressure. Catheters are inserted into an artery, usually in the wrist or, less often, in the bend of the elbow or groin. Arterial lines produce a tracing on a monitor that is similar to that of a heart monitor but with a different wave form [3].

Another life support and emergency equipment is ventilator which controls pulmonary ventilation in patients who cannot breathe on their own. Ventilators consist of a flexible breathing circuit, gas supply, heating/humidification mechanism, monitors, and alarms. They are microprocessor-controlled and programmable, and regulate the volume, pressure, and flow of patient respiration. Ventilator monitors and alarms may interface with a central monitoring system or information system. Infusion pumps employ automatic, programmable pumping mechanisms to deliver continuous anesthesia, drugs, and blood infusions to the patient [3].

Diagnostic equipment is used in the intensive care unit. Mobile x-ray units are used for bedside radiography, particularly of the chest. Mobile x-ray units use a battery-operated generator that powers an x-ray tube. Portable clinical laboratory devices, or point-of-care analyzers, are used for blood analysis at the bedside. A small amount of whole blood is required, and blood chemistry parameters can be provided much faster than if samples were sent to the central laboratory [3].

ICU is a demanding environment for the critical patients which requires various types of equipment to support and monitor the condition of the patients. So, it is important to observe the situation when operating ICU equipment, staff should pay attention to the types of devices and the variations between different models of the same type of device so they do not make an error in operation or adjustment. Clinical staff should be sure to check all devices and settings to ensure patients' safety. It is essential that equipment be properly maintained, particularly devices that are used for life support. Staff in the ICU should perform daily checks on equipment and inform biomedical engineering staff when equipment needs maintenance, repair, or replacement.

In ICU monitoring technology, there are two main advances that are taking place. The first is in the technology to monitor physio-logic processes. The advancements in computers and computer science has allowed for successive generations of computers that can handle and process information faster and more accurately. This has allowed for multiple physio-logic signals to be analyzed and displayed simultaneously on the bedside monitor. In addition, technology applied at the tissue and extra-cellular levels has enabled measurement of physiologic processes those were previously immeasurable. Many of these new devices are constructed to monitor oxygen or substrate metabolism at either the organ or tissue level. The second advance is in the type of statistical measurement, used to characterize a physiologic signal. However, there is clear evidence for disparity

between current technological capabilities of bedside monitoring devices and the quality and quantity of clinical information that is routinely monitored, recorded and evaluated by ICU physicians and nurses. Changes in the majority of physiologic signals in the ICU are nonspecific in that they provide little direct physiologic meaning as currently measured [3].

1.1.3 Computerized Intensive Care Unit

In modern technology, ICU is depends largely on the computers.In case of reducing the cost of the equipment of ICU, the computer has brought a revolutionary change in the intensive care unit. The individual medical equipments are so costly that the total cost of equipments in an ICU is very high. But computer based intensive care unit reduces the total cost drastically.

Data can be collected under control of the computer; this not only results in a substantial saving of time and effort, but also reduces the number of errors in the data. When data are expected at irregular intervals, the computer can continuously scan all input sources and accept data whenever they are actually produced. In some cases, the computer can be programmed to reject unacceptable readings and provide an indication of possible trouble in the associated instrumentation. If the data originate in analog form, the computer usually controls the sampling and digitizing process as well as identification and formatting of the data.

The biomedical field provides ample opportunities to make use the capability of the computer to store and retrieve large quantities of data. In the intensive care unit, large amount of data are accumulated from many sources. Without a computer, the storage of the vast amount of information is both space and time-consuming. Manual retrieval of the data is tedious and for some types of information, almost impossible. Any or all of the information can be retrieved on command whenever desired and can be manipulated to

provide output reports in tabular or graphic form to meet the needs of the intensive care unit.

Data would be quite useless if retrieved from the computer in raw form. To obtain meaning-ful information from such data, some form of data reduction or transformation is necessary to represent the data as a set of specific parameters. These parameters can then be analyzed, compared with other parameters or otherwise manipulated. Many kinds of information such as heart rate, oxygen saturation information, temperature, blood pressure information can be extracted for patient-monitoring purposes. Special transformations are also required to reconstruct images in computerized axial tomo-graphy. The size and complexity of many of these transformation and data reduction problems are such that manual methods would be completely impractical.

Many important physiological variables cannot be measured directly, but must be calculated from other variables that are accessible. For example, many of the respi-ratory parameters can be calculated from the results of a few simple breathing tests and gas concentration measurements. If a computer is connected on-line with the measuring instru-mentations, the calculated results can often be obtained while the patient is still connected to the instruments. To reduce certain types of physiological data into useful parameters, it is often necessary that important features of a physiological waveform or an image be identified. For example, analysis of the ECG waveform requires that the important amplitudes and intervals of the electrocardiogram be recognized and identified. Digital computer programs are available to search the data representing the ECG signal for certain predetermined characteristics that identify each of the important peaks.

It is easy to display all the necessary physiological signals on a single monitor in the computerized ICU system. For recording the patient information, computer is very important equipment in the intensive care unit. To make the decision for any patient,

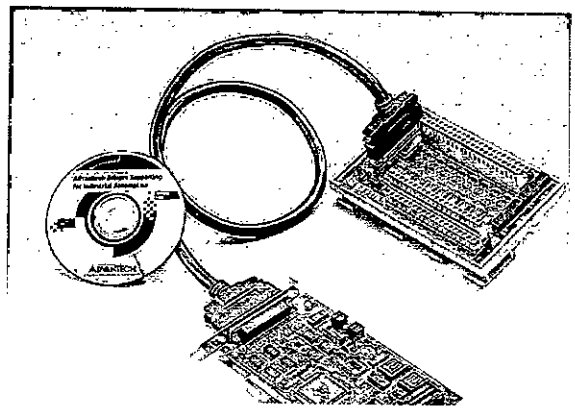

Figure 1.1: Data Acquisition Card

the data from the computer plays an important rule. There are many hidden signals in an apparently normal signal which would not be possible to notice with the unaided eye. Electronic eye i.e. the computer is much more reliable in this aspect. To take the input, acquisition card is used which has sufficient input ports to satisfy the need. Touch-screen, keyboard or wireless keyboard entry may be made to support. Computers are better suited to ensure long lifespan of the integrated monitoring equipment system. Reliability of equipment is very important matter in any system. In this respect computerized equipments are much more reliable.

1.1.4 Data Acquisition

At first, data is collected by using Data Acquisition Card. PCI 1711 has been used which has 16 single-ended analog inputs. It is a multifunction data acquisition card. It provides multiple measurement and control functions. Its sampling rate is up to 100 kHz. It has 16 channel digital inputs and 16 channel digital outputs.Data Acquisition Card is shown in Figure 1.1.

1.2 Objective of the Present Work

The objectives or this research is to design, develop and fabricate a low cost patient monitoring system for intensive care units of hospitals in Bangladesh. This will include following objectives and outcome,

- Initially to establish the techniques of getting patient information of oxygen level of blood, cardiac situation by electrocardiogram (ECG) and temperature.
- Practically implement the above techniques by proper design of acquisition circuits (amplifier, preprocessor, isolation and interface with microcontroller and PC).
- Biomedical signals require proper filtering, amplification, noise removal and post processing before they can properly be displayed and recorded. This stage will involve proper programmed implementation of monitoring, displaying and recording of each signal by microcontroller and a PC.
- A Central ICU patient monitoring scheme will be designed and implemented for simultaneous monitoring and display of conditions of multiple patients at a central observation station via a computer network. The display may also be extended to the outside of the ICU for display at visitors' room to reduce the visit of relatives to the bedsides of the patient and hence improve the ICU environment.

1.3 Thesis Outline

This thesis consists of six chapters. At first it follows introduction. It provides a description of the traditional ICU.Chapter two presents the system for monitoring the signal from Pulse Oximeter.It presents the principles of Pulse Oximetry, calibration of the meter,the description of the circuit diagram which has been implemented and at last the processes which are developed by microcomputer. The next chapter provides Electrocardiogram

signal monitoring system. It describes the cardiac system, different types of ECG waves, ECG Leads,the descriptions of the different parts of the circuit which is used for this system and the techniques which are used to process the signal.Chapter four presents temperature monitoring system.Different types of temperature probes, the description of the circuit and the steps which has taken to process the signals are mentioned in this chapter. The next chapter provides the information for multiscreen display of several patients' condition. The last chapter gives conclusion of the thesis and future works related to this thesis.

In case of oxygen saturation measurement in blood, a type of sensor named OXICLIQ-sensor has been used. In this system, a patient-dedicated adhesive bandage has been used. The variation of the amplitudes of the infra-red and red LED signals consisting of two different wavelengths indicates the percentage of the oxygen saturation in the blood.In case of getting information from Cardiographic signal, two-stage amplifier with common mode rejection for power line frequency has been used and in the same way the information has been taken by using data acquisition card. In case of temperature monitoring YSI Precision Thermistor Probe has been taken as a sensor. These three types of signals has been taken with the data acquisition card PCI-1711 which provides 16-channel Single-Ended A/D input and by using MATLAB these information has been processed and shown within the same screen. In case of taking information, proper isolation has been arranged. For proper display and record, filtering, amplification, noise removal processing has been taken. To monitor, display and record the signals, programmed implementation has been developed by using microcontroller and PC. For displaying the conditions of multiple patients a suitable network solution has been developed. Also measures has been taken for displaying the conditions of the ICU patients to the visitors of the patients outside ICU room.

Chapter 2

Pulse Oximetry Signal Monitoring System

2.1 Introduction

In an intensive care unit, monitoring the measurement of the oxygen content in the blood is very important.Pulse oximetry is used for this purpose. It is a non-invasive system to monitor the percentage of haemoglobin which is saturated with oxygen [2]. It consists of a probe attached to the patient's finger or ear lobe [1]. Acceptable normal ranges are from 95 to 100 percent, although values down to 90% are common. In the intensive care unit, there may be risk of respiratory failure, so to know how well the arterial blood is oxygenated is very important for the patients. Pulse oximetry is also being used in the monitoring of pulmonary disease in adults and in the investigation of sleep disorders . In the neonatal intensive care unit many premature infants undergo some form of ventilator therapy; in this case pulse oximetry is necessary [6]. A pulse Oximetry probe is shown in Figure 2.1.

2.2 Principles of Pulse Oximetry

The principle of the pulse oximetry is based on two physical principles. One is the presence of a pulsatile signal generated by arterial blood, which is relatively independent of non-pulsatile arterial blood, venous and capillary blood and other tissues and the another one

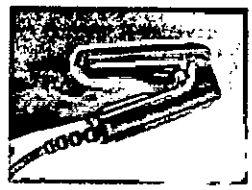

Figure 2.1: Pulse Oximeter Probe

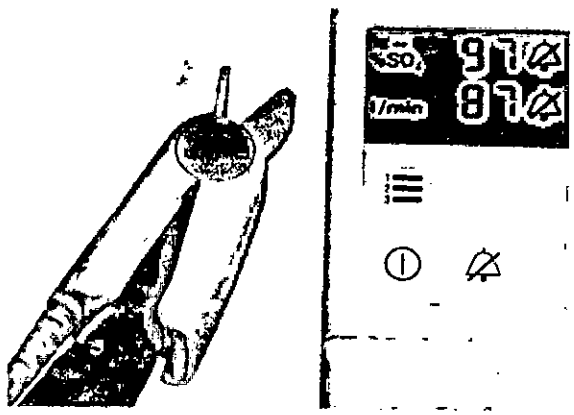

Figure 2.2: Pulse Oximeter

is the fact that oxyhaemoglobin and reduced hemoglobin have different spectra. A pulse Oximeter is shown in Figure 2.2.

Pulse Oximeter [7] is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. The light is partly absorbed by haemoglobin, by amounts which differ depending on whether it is saturated or desaturated with oxygen. By calculating the absorption at the two wavelengths the processor can compute the proportion of haemoglobin which is oxygenated. Oxygenated hemoglobin absorbs more infrared light and allows more red lights to pass through. Deoxygenated (or reduced) hemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band. Infrared light is in the 850-1000 nm wavelength light

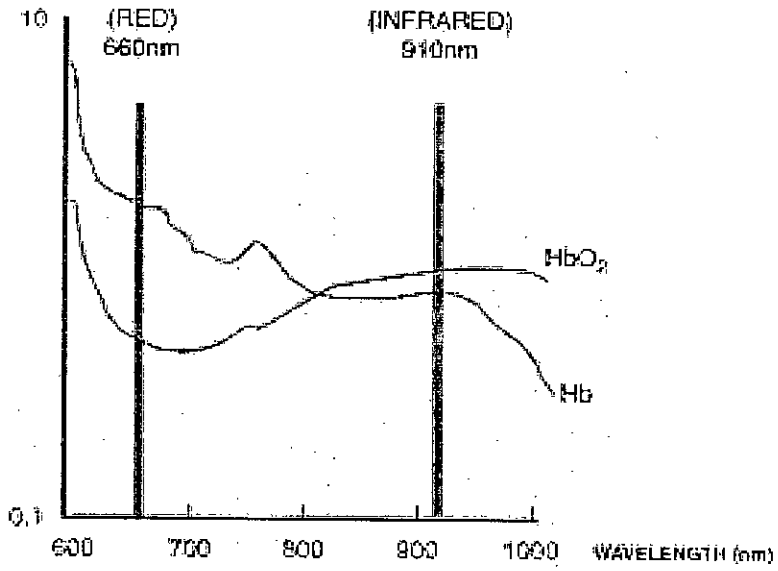

Figure 2.3: Absorption levels of oxygenated and deoxygenated blood

band. Absorption levels of oxygenated and deoxygenated blood at different wavelengths are shown in Figure 2.3.

Haemoglobin is the iron-containing protein. It is attached to the red blood cell that transports oxygen from the lungs to the rest of the body. It bonds with oxygen in the lungs, exchanges it for carbon dioxide at cellular level, and then transports the carbon dioxide back to the lungs to be exhaled. Haemoglobin abnormalities result in very serious hereditary diseases, such as sickle-cell anaemia and thalassemia.

Light passing through the ear or finger will be absorbed by skin pigments, tissue, cartilage, bone, arterial blood, venous blood. Most of the absorbances are fixed and do not change with time. Even blood in the capillaries and veins under steady state metabolic circumstances is constant in composition and flow, over short period of time. The blood flow in the arteries and arterioles is pulsatile. Measuring the changing signal measures the

absorbance due to arterial blood and makes possible the determination of arterial oxygen saturation (SaO2).

A typical finger tip oximeter probe has two LEDs, one that transmits infrared light, the other transmits red light. The absorption of these select wavelengths of light through living tissues is significantly different for oxygenated haemoglobin and reduced haemoglobin. The absorption of these selected wavelengths of light passing through living tissue is measured with a photosensor.

Most probes have a single photodetector, so the light sources are generally sequenced on and off. To compensate for ambient light the time when both LEDs are off, the light level is measured and then subtracted from each light channel between cycles. Depending on the make and model of pulse oximeters, the drive currents of LEDs, pulse widths, off and on cycles between pulses and cycle times can vary.

The output of the photodiode is a raw signal. There will be one signal that represents the absorption of red light and one that represents infrared light [8]. The ac signal is due to the pulsing of arterial blood while the dc signal is due to all the non-pulsing absorbers in the tissue.Oxygen saturation is estimated from the ratio of pulse-added red absorbance at 660 nm to the pulse-added red absorbances at 940 nm.The Ratio [9] is given by,

$$R = \frac{ac660/dc660}{ac940/dc940} \tag{2.1}$$

The light absorption property is shown in Figure 2.4.

The signal from the sensor is a current. The first amplifier stage is a current to voltage converter. The voltage signal then goes through the amplifiers to amplify the signal, noise filters to remove different kinds of interference, then the interleaved red and infrared signals are separated, the low frequency components from the pulsatile, higher frequency components are separated and an analog-digital converter to convert the continuously varying

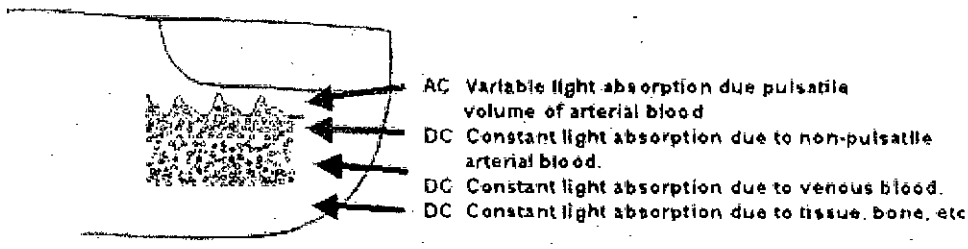

Figure 2.4: light absorption Property

signal to a digital representation.Transmission of light through finger is shown in Figure 2.5.

2.3 Calibration of Pulse Oximeter

Oximeters are calibrated during manufacture and automatically check their internal circuits when they are turned on. They are accurate in the range of oxygen saturations of 70 to 100%, but less accurate under 70%. Most manufacturers have their own look-up tables based on calibration curves derived from healthy subjects at various SpO2 levels. Typically a R/IR ratio of 0.5 equates to approximately 100% SpO2, a ratio of 1.0 to approximately 82% SpO2, while a ratio of 2.0 equates to 0% SpO2. The Beer-Lambert law [9] does not take into account the multiple scattering of light by the red blood cells. The following figure shows two relationships, one using the Beer-Lambert law and the other based on empirical data, between the ratio R and the oxygen saturation of the patient.Two relationships between the ratio R and the Oxygen Saturation of the patient is shown in Figure 2.6.

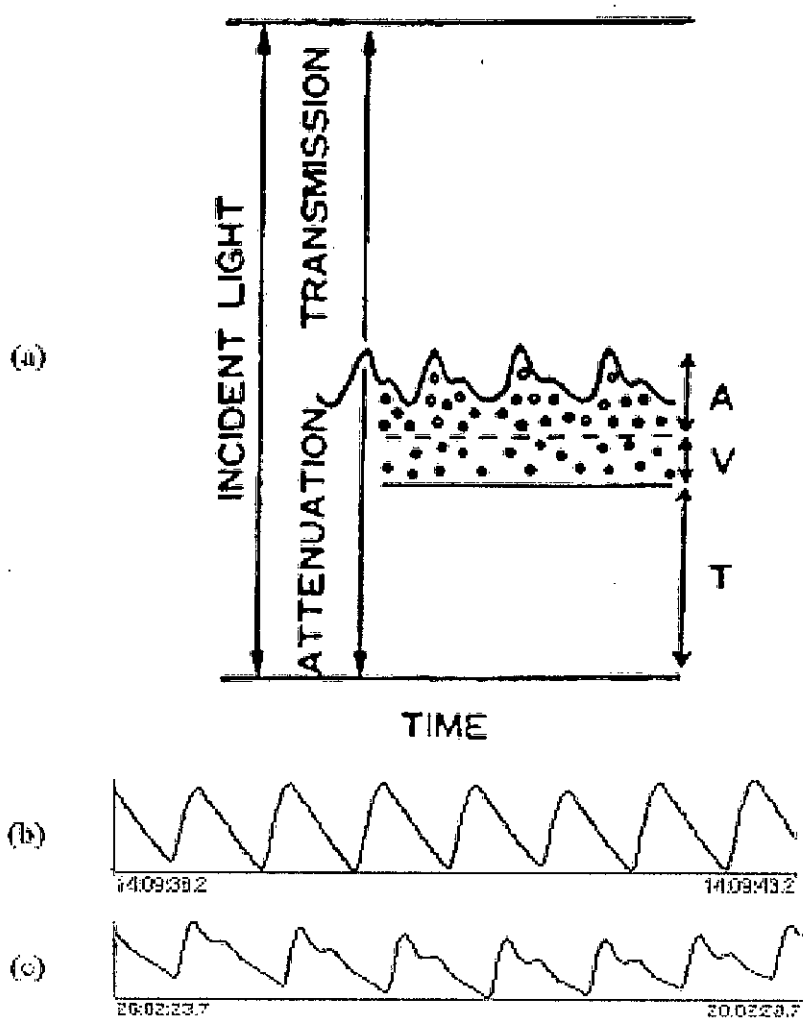

Figure 2.5: Transmission of light through finger

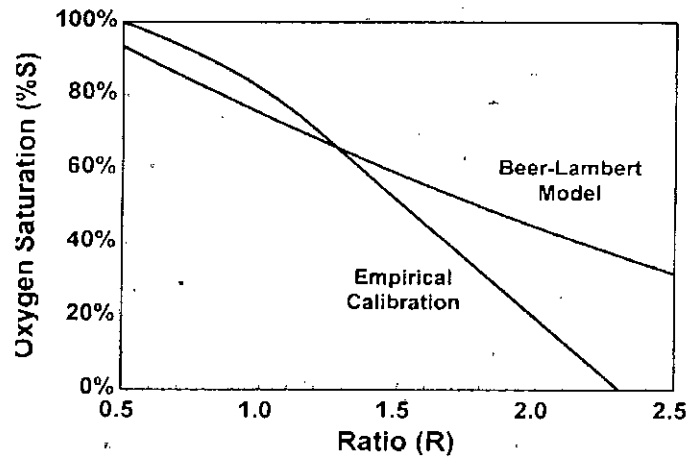

Figure 2.6: Two relationships between the ratio R and the Oxygen Saturation of the patient

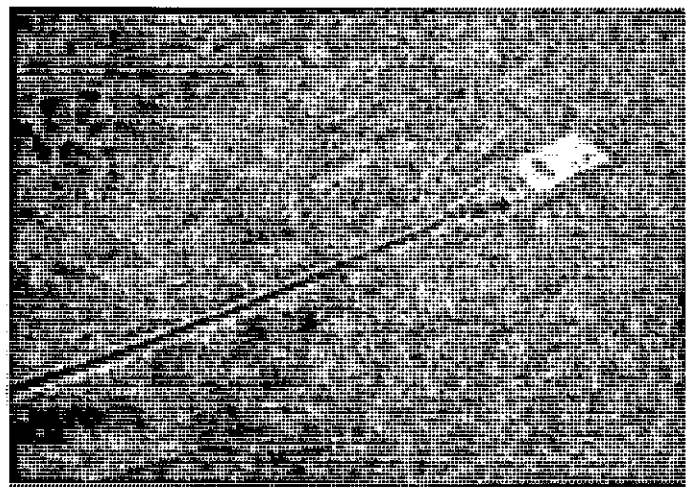

Figure 2.7: Pulse Oximeter (OXICLIQ A)

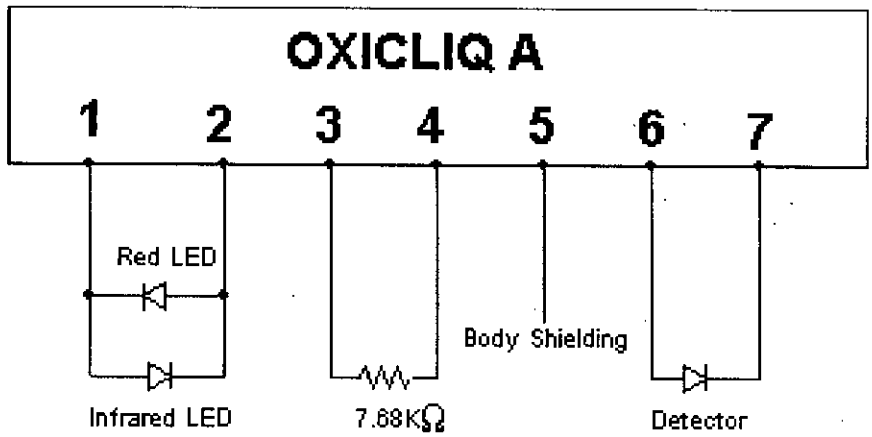

Figure 2.8: Pin Configuration of Pulse Oximeter (OXICLIQ A)

2.4 Design of Pulse Oximetry instrumentation

In this thesis the pulse oximeter model named OXICLIQ A has used as a sensor. The OXICLIQ System combines a reusable cable with a sterile, adhesive sensor to form a cost-effective adhesive alternative. Each sterile, single-patient-use bandage is made of self-adhesive material that provides a second-skin fit and reduces the possibility of cross-contamination. A Pulse Oximeter (OXICLIQ A) is shown in Figure 2.7 This device has seven contacts. The configuration of the pins is shown in Figure 2.8

2.4.1 Circuit Diagram

The Circuit Diagram is shown in Figure 2.9, Figure 2.10 and Figure 2.11.

2.4.2 Description of all circuits

The description of the different parts of the circuit is given below.

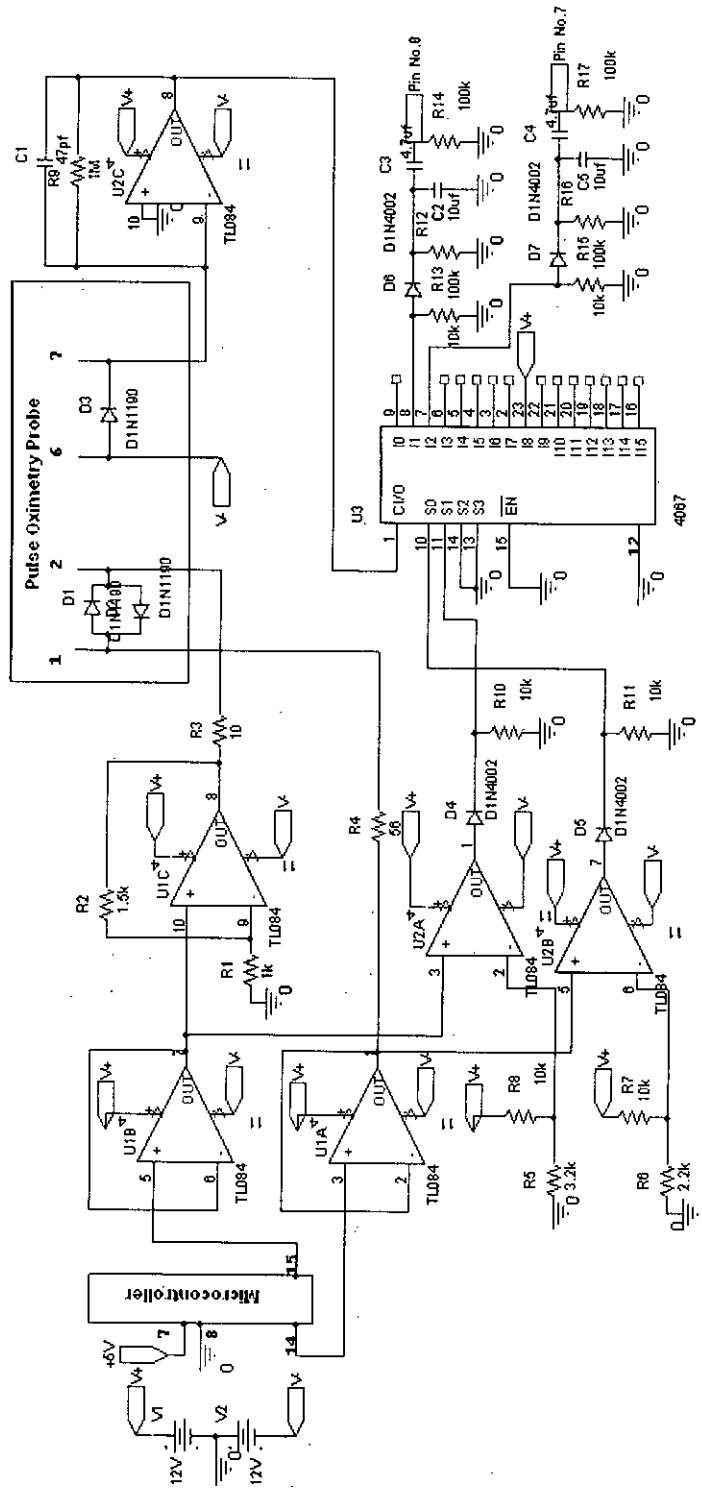

Figure 2.9: Circuit Diagram of Pulse Oximetry (Part 1)

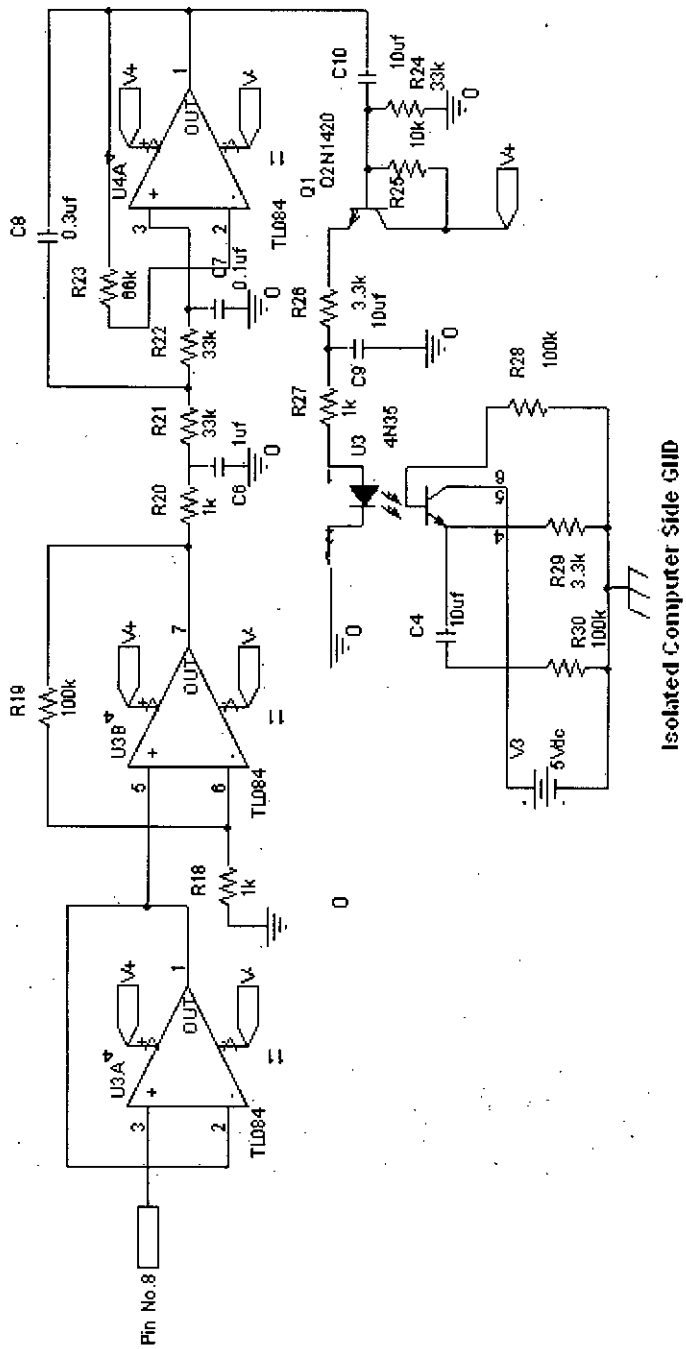

Figure 2.10: Circuit Diagram of Pulse Oximetry (Part 2)

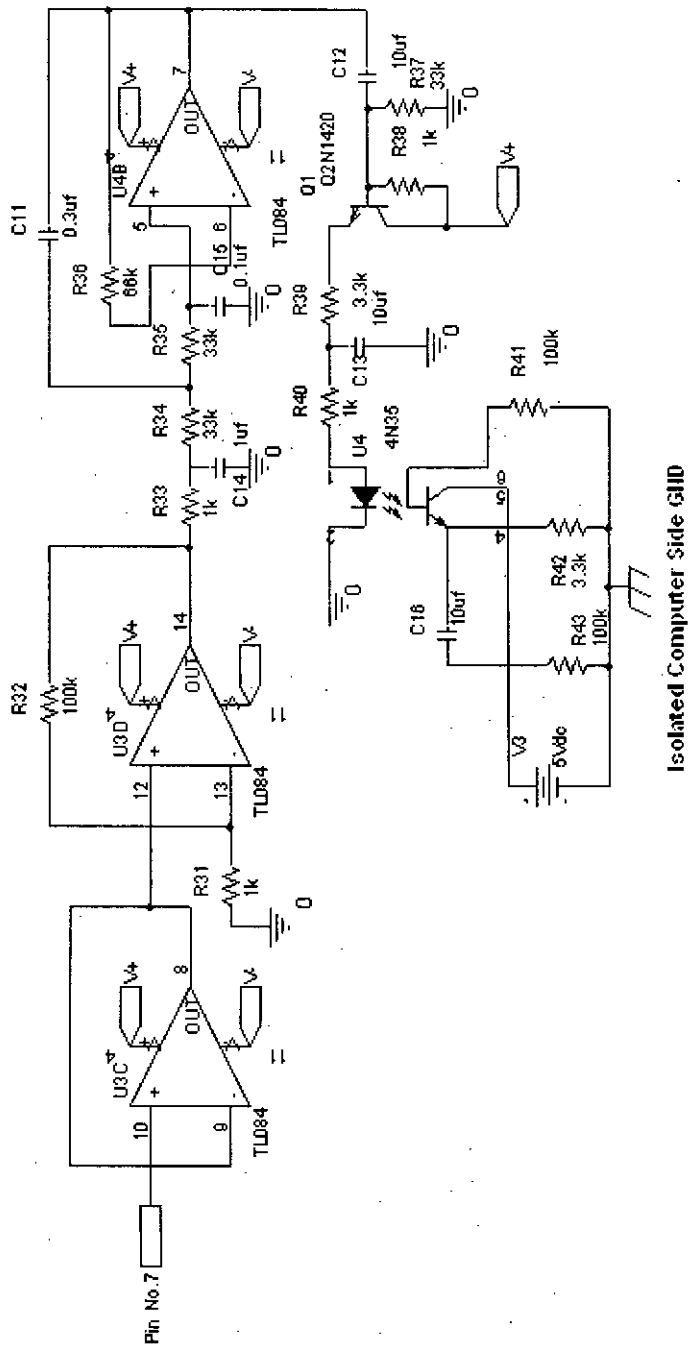

Figure 2.11: Circuit Diagram of Pulse Oximetry (Part 3)

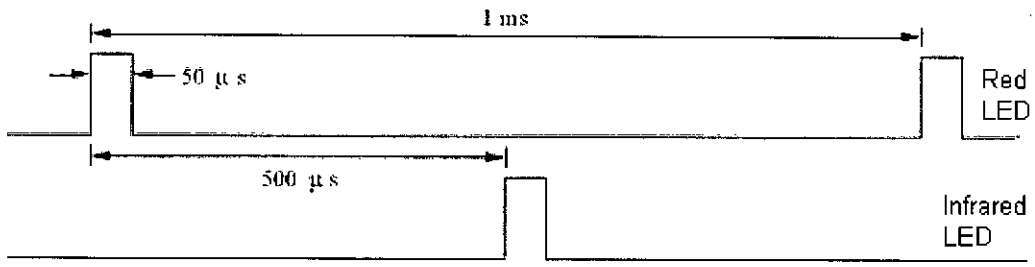

Figure 2.12: Timing Signals for the LED drivers

Pulse generation

OXICLIQ-sensor has a single photo detector, so the light sources are to be generally sequenced on and off. For this, the system for pulse generation has followed a technique that such as 50μ s pulses to the red and Infrared LED drivers at a repetition rate of 1 kHz which is shown in Figure 2.12.

Microcontroller has been used to create the pulses. At this, ATmega8 is used, its pin PB0 and PB1 are used. The width of the pulse is 50μ s. Pulses from the microcontroller (shown in Figure 2.13) goes through buffer circuits.

Microcontroller code is given in the Appendix.

Pulse Oximetry Probe

Two pulses go to two pins of the pulse oximeter probe. The pulse from the out2 goes to Pin no.1 of the oximeter probe. The pulse from the out1 goes to Pin no.2 of the oximeter probe according to Figure 2.14. There are two LEDs, one is Red LED between pin no.1 and pin no.2 and another is Infra-Red LED between pin no.2 and pin no.1 of the pulse oximeter probe. There is a detector between pin no.7 and pin no.6.

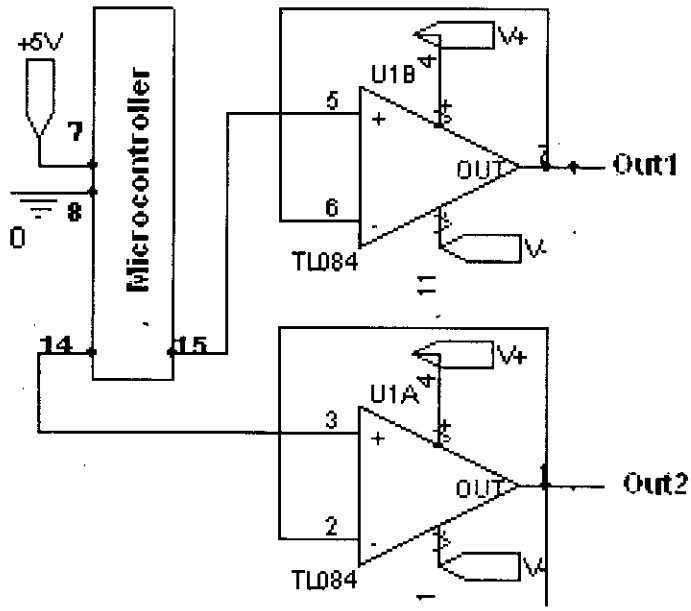

Figure 2.13: Standard analog buffering circuit

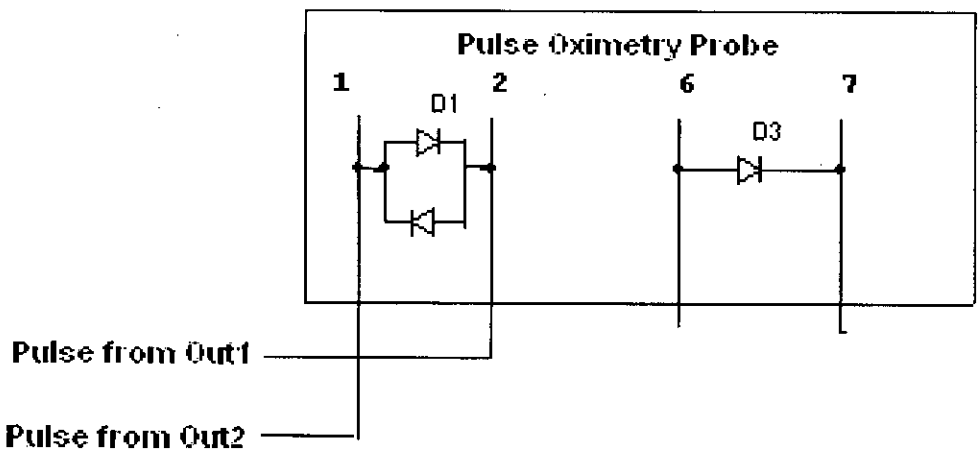

Figure 2.14: Pulses from Pulse Oximeter

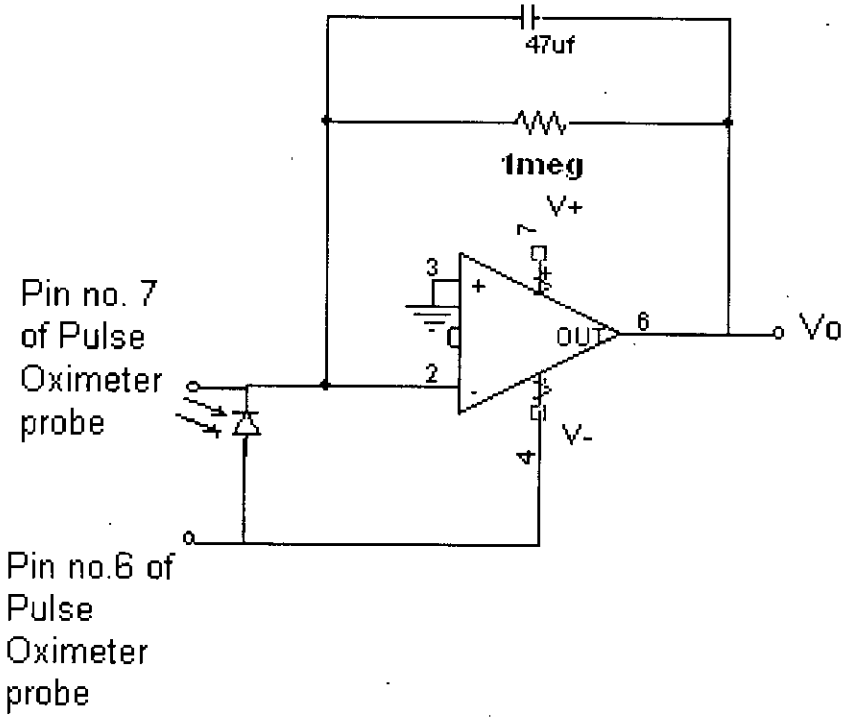

Figure 2.15: Current to Voltage converter circuit

Current to Voltage Converter Circuit

The transmitted light detected by the photodiode is amplified and converted to a voltage using an op-amp configured as a current-to-voltage converter shown in Figure 2.15

This circuit is used to convert current to voltage. For the high junction resistance of the reverse-biased photodiode, the op-amp should be an FET type with very high input impedance. The negative input of the op-amp acts like a virtual earth, the output voltage of the circuit is Vo= - IRL. The feedback resistance is chosen a very large valued resistance as high as several times of Mega ohms.

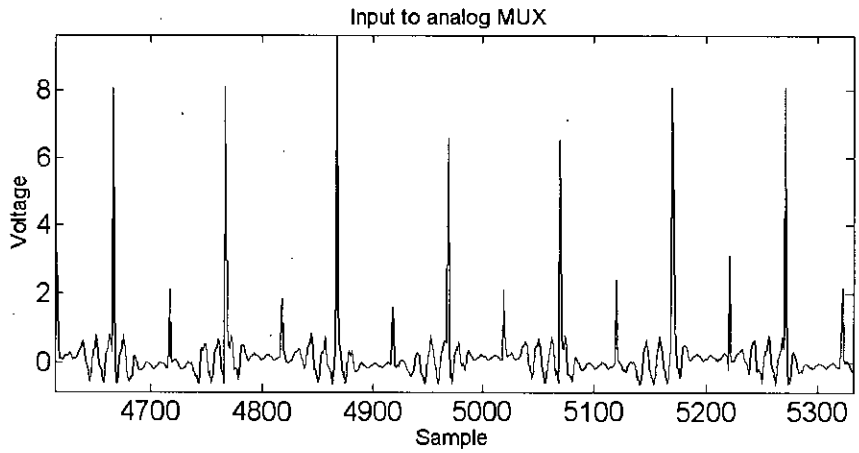

Figure 2.16: Input to the Analog MUX

Separation of Two Signals

For separation of the signals of Red LED and Infra-Red LED, Analog MUX (4067) has been used. Input to the analog MUX is shown in Figure A.2. For this, the pulses generated from the microcontroller are used. At first, the pulses go through two separate comparator. Then they are connected through a diode and a resistor branch to pin 11 and pin 10 of Analog MUX. On the other side, the output of the current to voltage converter circuit goes to the input point of the Analog MUX shown in Figure 2.17and two output signals of Analog MUX in Figure A.3 and Figure A.4.

Peak Detector Circuit

To detect the peak of the signals of Red LED and Infra-Red LED, peak detector circuit has been used (shown in Figure 2.20). Then the signals go to the separate buffer circuits.

Buffering and Amplification

Two separate signals go through two separate buffer circuits and amplifiers which gain is 100 times of the output of the buffer circuit shown in Figure 2.21.

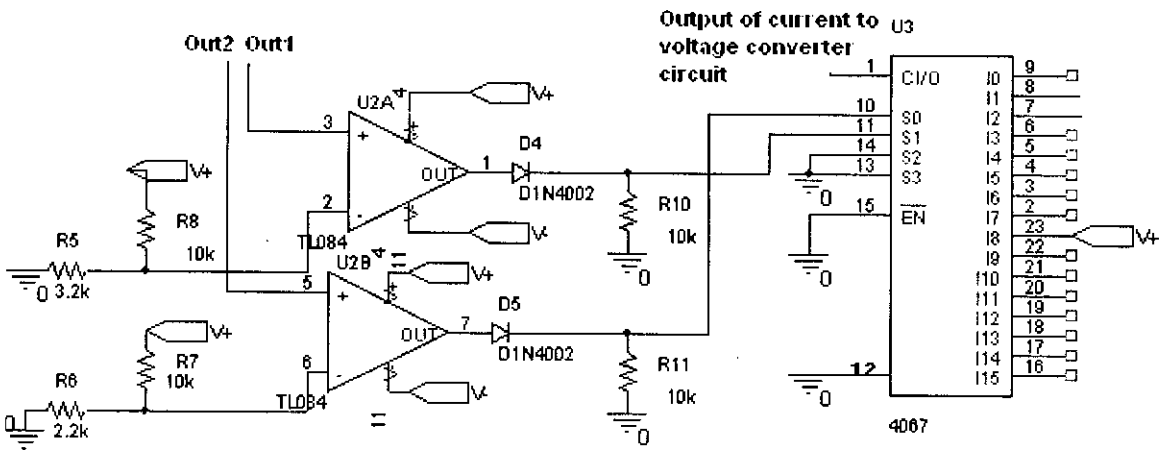

Figure 2.17: Separation of Red LED and Infra-Red LED Signal

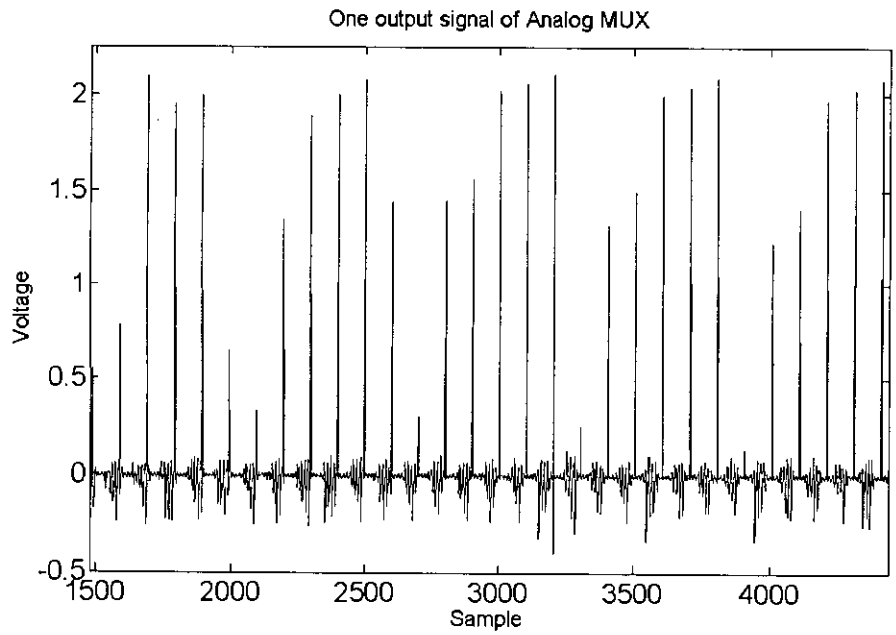

Figure 2.18: Red LED Signal

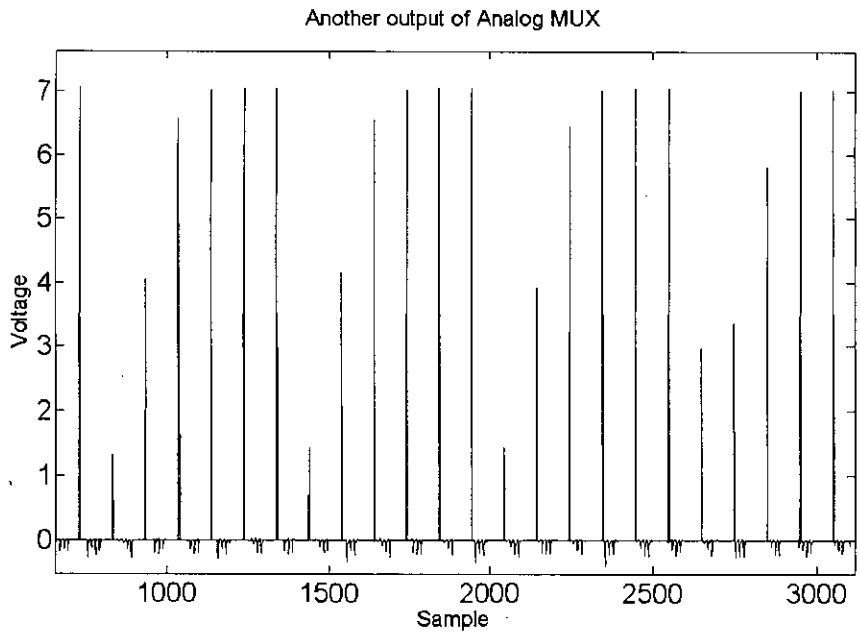

Figure 2.19: Infra-Red LED Signal

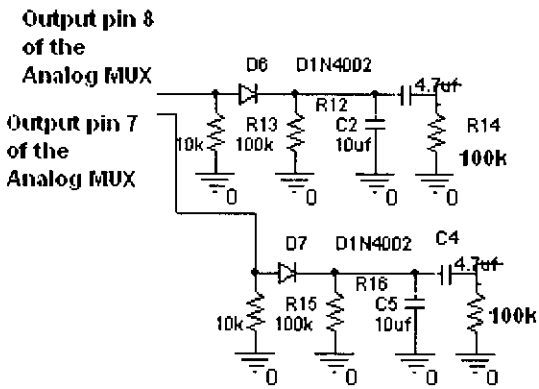

Figure 2.20: Peak Detection

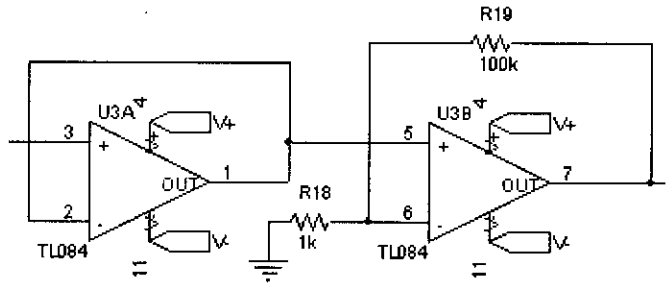

Figure 2.21: Buffering and Amplification

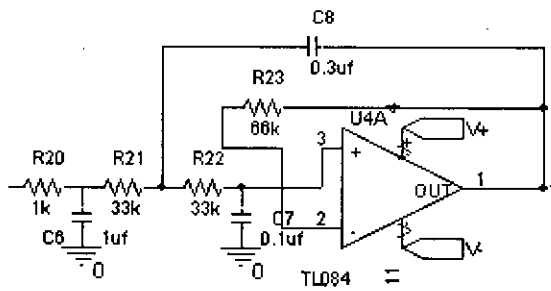

Figure 2.22: Low pass Filter

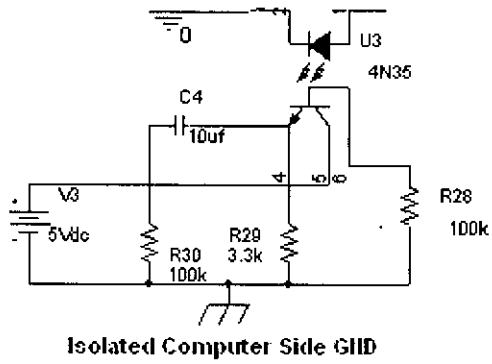

Figure 2.23: Isolation Circuit

Filtering

To eliminate the high frequency signals a low pass filter (-40 dB/decade)(shown in Figure 2.22) has been used. Here the cut off frequency is,

$$f = \frac{0.707}{2\pi * 33k * 0.1\mu f} = 34Hz$$

Isolation Circuit

After amplification of two signals, isolation circuit(shown in Figure 2.23) has been used for the safety of the patients.

Using DAQ

Two signals are collected by using data acquisition card and using MATLAB the difference between the maximum value and the minimum value of two signals are calculated. From this data, pulse rate and percentage of oxygen saturation are calculated. MATLAB code is given in the Appendix.

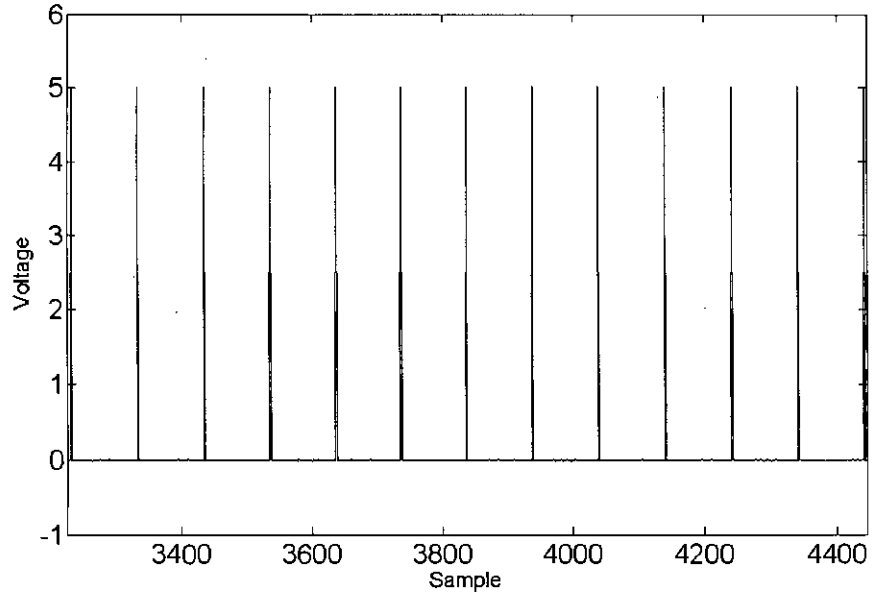

Figure 2.24: Pulse from Microcntroller

2.5 Processing by Microcomputer and typical records of a patients

At first to extract the signal from the Pulse Oximeter probe pulses have been produced by the microcontroller which is shown in Figure A.1.The width of the pulse is 50μ s.To detect two signals of different wavelengths it is required to produce two pulses which frequencies are very high because time to change blood pulse for the reception of the lights is very low. On the other side the pulses should be such that one is on when another is off.So, microcontroller has used to produce such type of pulse. Microcontroller code is given in the Appendix.This signal is filtered to remove noise. A typical pulsatile signal is shown in Figure 2.25.

At first the signal from the probe of Pulse oximeter goes to the input of the analog MUX to separate the two signals. In the Figure 2.26, the signals from the output of

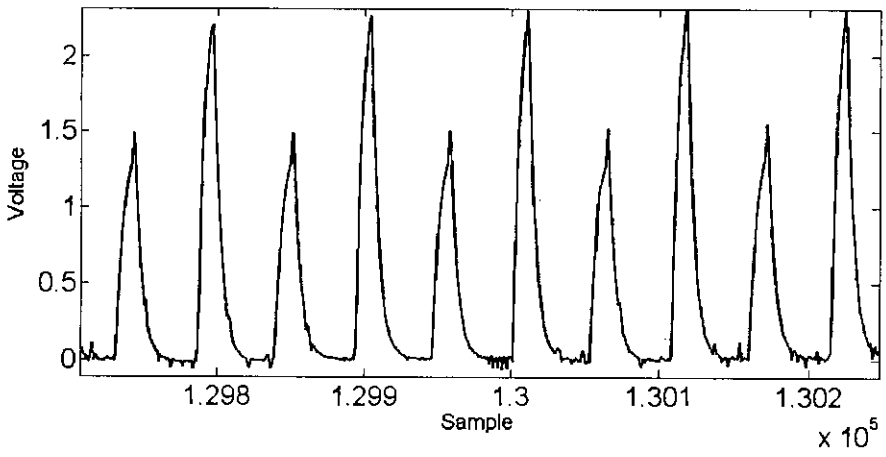

Figure 2.25: Typical pulsatile signals detected in the intensity of detected light when light is shone through a finger

the analog MUX is shown. To calculate the saturation of oxygen content in blood it is necessary to know the maximum and minimum value of the red LED signal and infra-red LED signal. So, analog MUX has been used and the separate red LED signal is shown in Figure 2.28 and infra-red LED signal is shown in Figure 2.27.By using MATLAB pulse rate and oxygen saturation(SPO_2) is calculated. MATLAB code is given in the Appendix.In case of determining the oxygen saturation, ratio R is used. Here the ratio is given by,

$$R = \frac{ac660/dc660}{ac940/dc940} \tag{2.2}$$

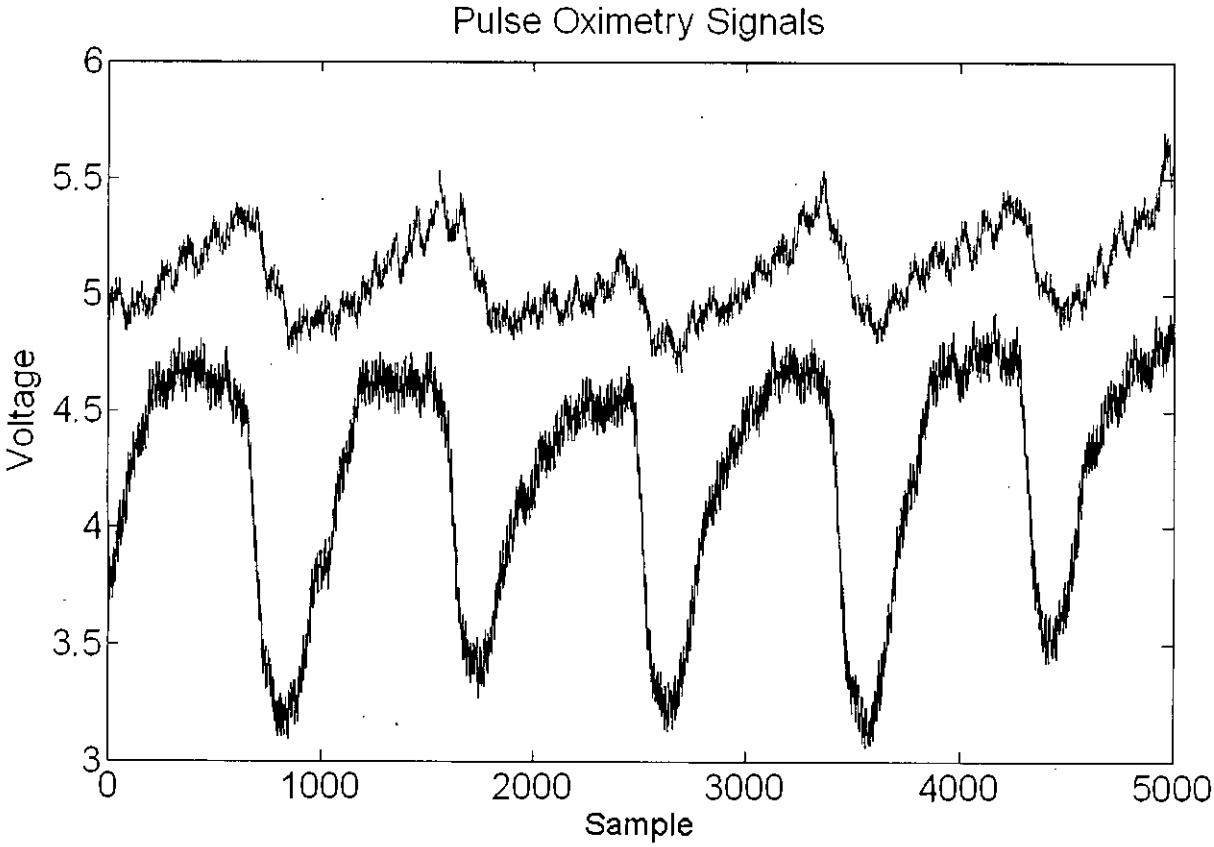

Figure 2.26: Pulse Oximetry Signals before filtering

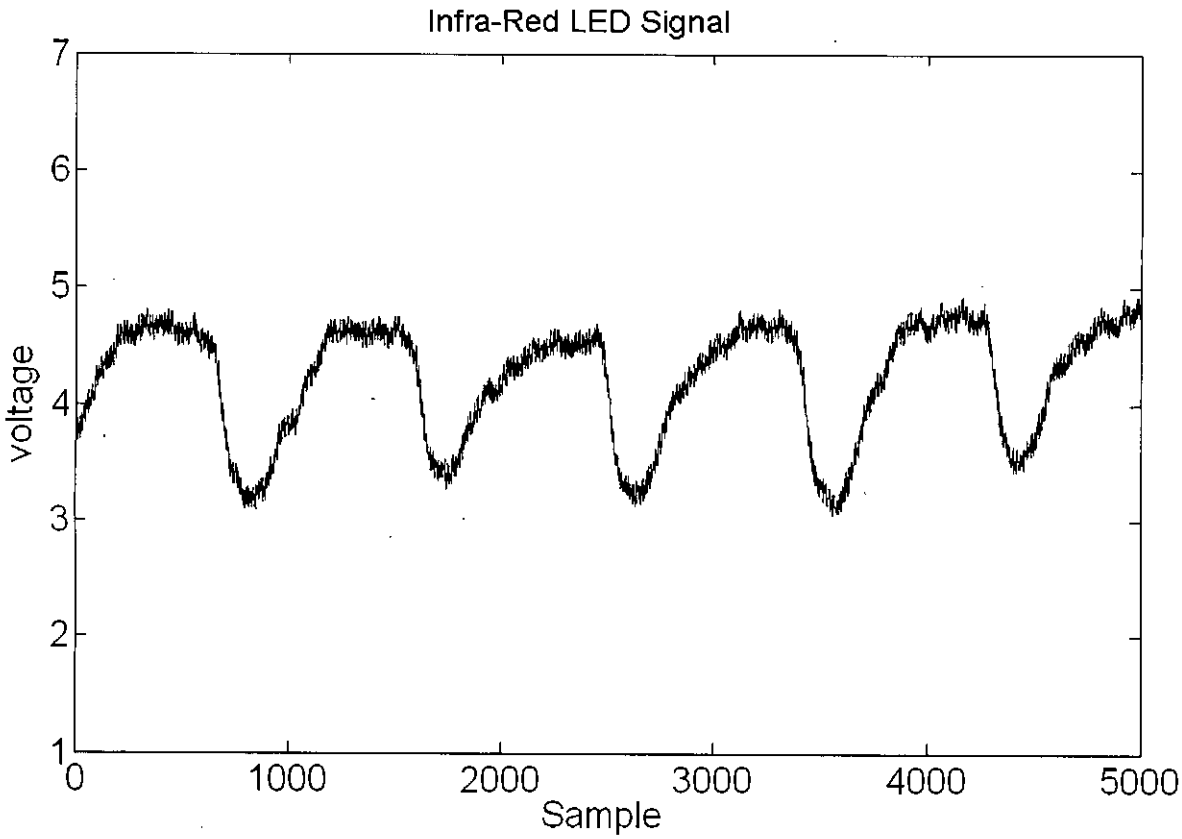

Figure 2.27: Infra - Red LED Signal

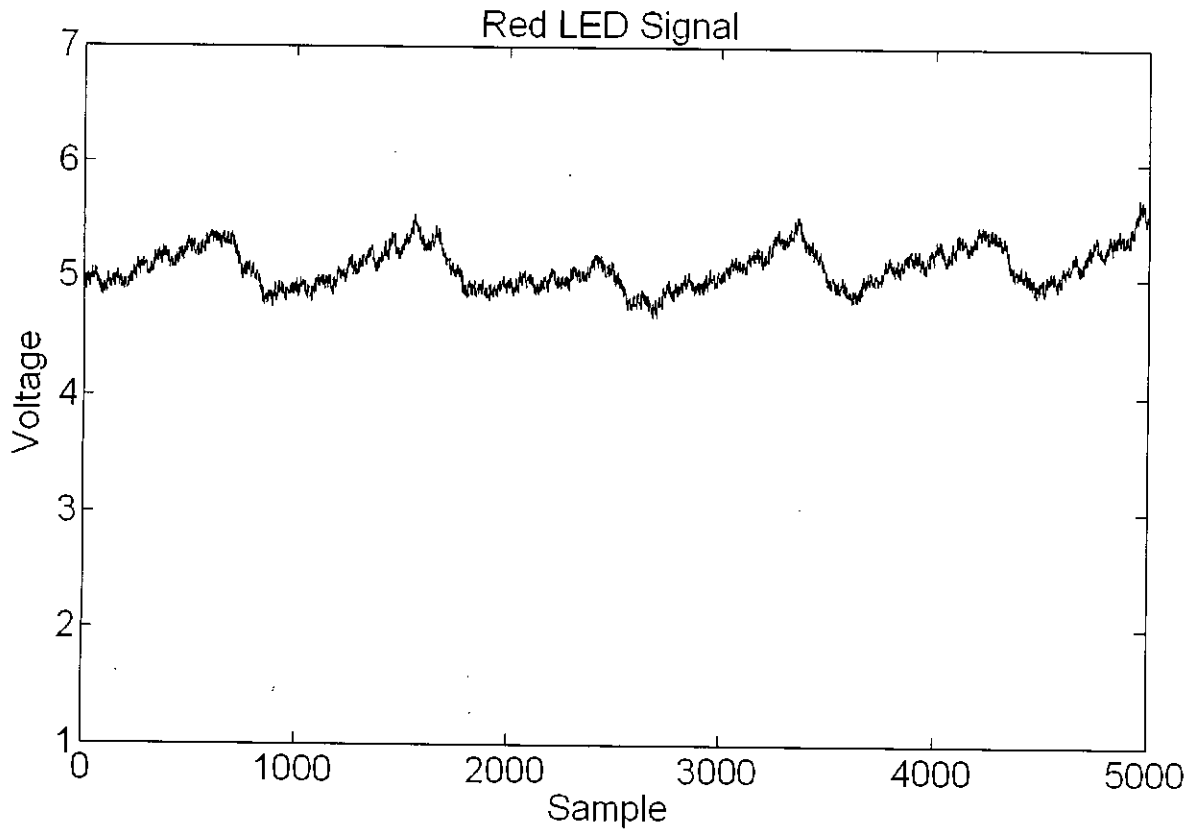

Figure 2.28: Red LED Signal

Chapter 3

Electrocardiogram Signal Monitoring System

3.1 Introduction

Electrocardiogram (ECG) measures the electrical activity of the heart. The heart is a muscular organ that beats in rhythm to pump the blood through the body. The heart muscles create electrical waves when they pump. These waves pass through the body and can be measured at electrodes attached to the skin.

An ECG displays the voltage between pairs of these electrodes and the muscle activity that they measure from different directions [10]. This display indicates the overall rhythm of the heart and weaknesses in different muscles. To measure and diagnose abnormal rhythms of the heart, particularly abnormal rhythms caused by damage to the conductive tissue that carries electrical signals, abnormal rhythm caused by levels of salts, such as calcium that are too high or low, ECG is the best test [11].

3.2 ECG Paper

An electrocardiograph runs at a paper speed of 25mm/s. Each small block of ECG paper is 1mm2. One small block of ECG paper translates into 0.04 s. Five small blocks make up 1 large block, which translates into 0.20 s. So, there are 5 large blocks per second. A

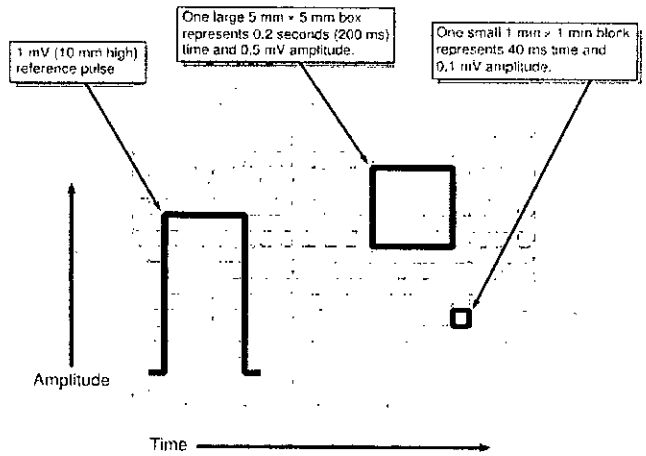

Figure 3.1: ECG Paper

diagnostic quality 12 lead ECG is calibrated at 10 mm/mV, so 1 mm translates into 0.1 mV.A ECG paper is shown in Figure 3.1.

3.3 Electrical Potential

The body acts as a conductor of the electrical currents generated by the heart. The resting potential is about -90mV because potassium channels are open and K+ conductance [gK+] and K+ currents [IK] are high. From the figure we can know that positive potassium ions are leaving the cell and thereby making the membrane potential more negative inside. At the same time Na+ channels and Ca++ channels are closed.

If the muscle is stimulated electrically to induce self-propagating action potentials, a wave of depolarization would sweep across the muscle. Then the outside of the cell would be negative relative to the inside. Then the cells are rapidly depolarized to a voltage about +10 mV. There is a depolarization that is caused by a transient increase in fast Na+-channel conductance (gNa+) through fast sodium channels. This increases the inward directed,

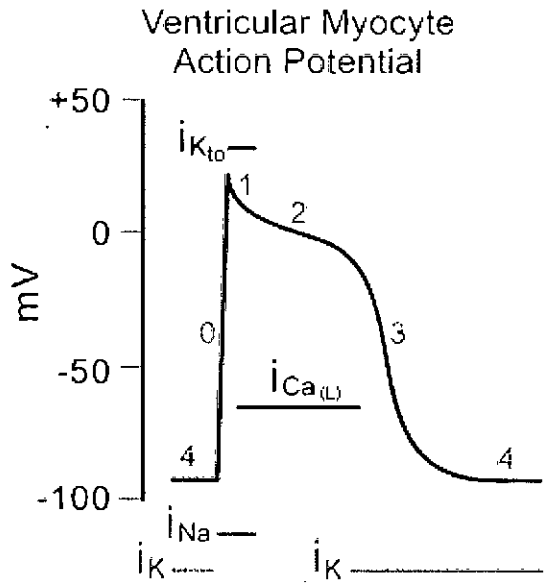

Figure 3.2: Action Potential

depolarizing Na+ currents (INa)[3].

At the same time sodium channels open, gK+ and outward directed K+ currents fall as potassium channels close. A cell that has been excited and that displays an action potential (+20mV) is called depolarized. The process of changing from the resting state to the action potential is called depolarization shown in Figure 3.3.

The rush of sodium ions through the cell membrane has stopped, the ionic currents that lowered the barrier to sodium ions are no longer present and the membrane reverts back to its original, the passage of the sodium ions from the outside to the inside of the cell is again blocked. Then it would take a long time for a resting potential to develop again. By an active process, called sodium pump, the sodium ions are quickly transported to the outside of the cell and the cell again becomes polarized and assumes its resting potential. This process is called repolarization.

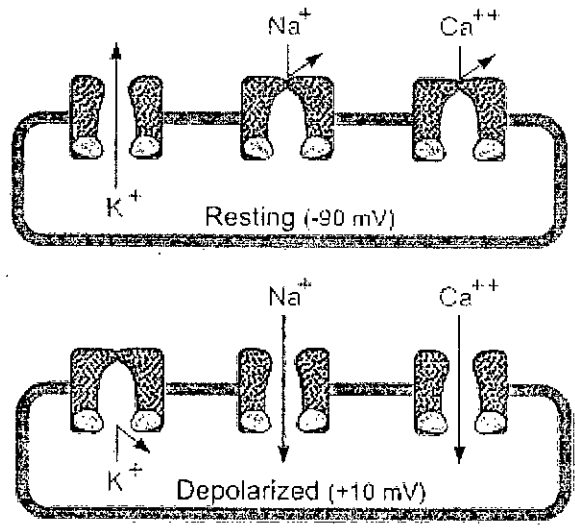

Figure 3.3: Depolarization

3.4 Cardiac System

At the junction of the right atrium and superior vena cava is situated the sinoatral node (SA node), which is the pacemaker or initiator of the electrical impulse that excites the heart. The right ventricle is situated below and to the left of the right atrium. Communication between the atrium and ventricle is accomplished only via the AV node. Between the anterior wall of the ventricle and the septum is a muscular ridge that is a part of the hearts electrical conduction system, known as the Bundle of HIS.

At the junction of the right and left atrium and the right ventricle of the septum, there is another node, the atrioventricular node. The Bundle of HIS is attached to this node.

The prime function of the electrical conduction system of the heart is to transmit minute electrical impulses from the SA node to the atria and ventricles, causing them to contract. The SA node lies in the wall of the right atrium near the inlet of the superior

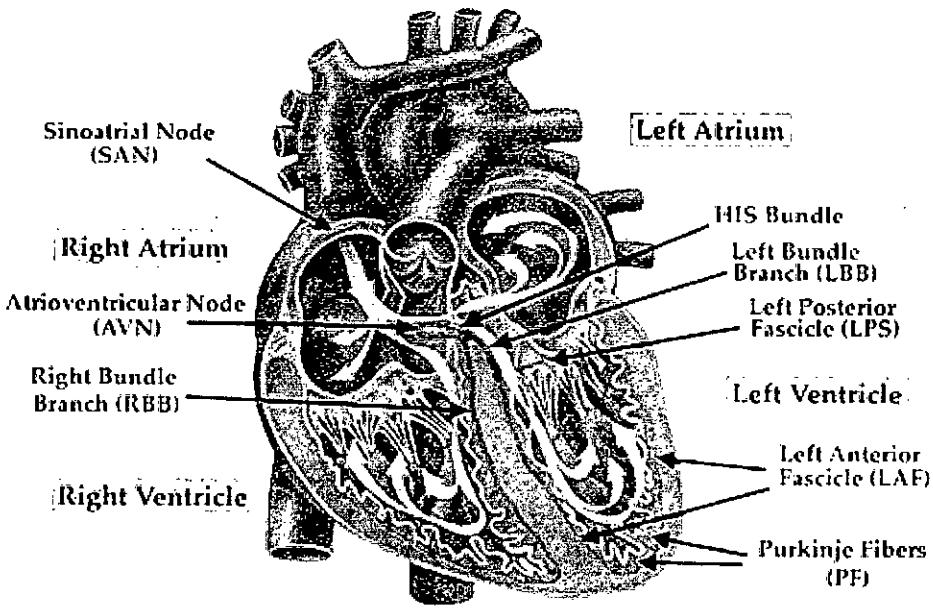

Figure 3.4: Cardiac conduction system

vena cava. It consists of pacemaker cells that generate electrical impulses automatically and regularly. The three internodal atrial conduction tracts, running through the walls of the right atrium between the SA node and the AV node, conduct the electrical impulses rapidly from the SA node to the AV node in about 0.03 second. The AV node lies partly in the right side of the interatrial septum in front of the opening of the coronary sinus and partly in the upper part of the intervintricular septum above the base of the tricuspid valve. The primary function of the AV node is to relay the electrical impulses from the atria into the ventricles in an orderly and timely way.

The bundle of HIS lies in the upper part of the interventricular septum, connecting the AV node with the two bundle branches. Once the electrical impulses enter the bundle of HIS, they travel more rapidly in their way to the bundle branches, taking 0.03 to 0.05 second. The bundle branches and their fascicles subdivide into smaller and smaller

branches, the smallest ones connecting with the Purkinje network [3], an intricate web of tiny Purkinje fibers spread widely throughout the ventricles. The ends of the Purkinje fibers finally terminate at the myocardial cells. The bundle of HIS, the right and left bundle branches and the Purkinje network are also known as the HIS-Purkinje system of the ventricles.

The electrical impulses travel very rapidly to the Purkinje network through the bundle branches in less than 0.01 second. It normally takes the electrical impulses less than 0.2 second to travel from the SA node to the Purkinje network in the ventricles. The electrical impulses that are responsible for the contraction and relaxation of myocardial cells are the result of rapid flow of positively charged ions primarily sodium and potassium ions and to a lesser extent, calcium ions. The difference in the concentration of such ions across the cell membrane is called the electrical potential and is measured in mill volts.

ECG is a graphic record of the changes in magnitude and direction of the electrical activity, specifically, the electric current that is generated by the depolarization and repolarization of the atria and ventricles.

3.5 Waves and intervals

An ECG signal normally consists of a P wave, a QRS complex and a T wave. A small U wave is normally visible in 50 to 75 percent of ECG. The P wave represents depolarization of the atrial musculature, the QRS complex is the combined result of the repolarization of the atria and the depolarization of the ventricles which occurs almost simultaneously. The T wave is the wave of ventricular repolarization and the U wave, if present, is generally believed to be the result of the after potentials in the ventricular muscles.An ECG Signal is shown in Figure 3.5.

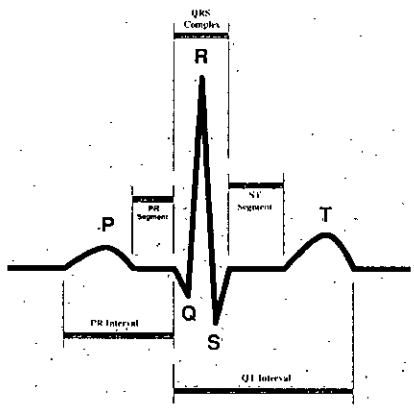

Figure 3.5: ECG signal

During normal atrial depolarization, the main electrical vector is directed from the SA node towards the AV node and spreads from the right atrium to the left atrium. This turns into the P wave on the ECG. It is usually 0.08 to 0.1 seconds (80-100 ms) in duration. P-R interval is the period from the P wave to the beginning of the QRS complex. This interval represents the time between the onset of atrial depolarization and the onset of ventricular depolarization. It is usually of 0.12 to 0.2 seconds in duration.

The duration of the QRS complex is normally 0.06 to 0.1 seconds. It represents ventricular depolarization. The ST segment connects the QRS complex and the T wave and has a duration of 0.08 to 0.12s (80 to 120ms). It is the period between depolarization and repolarization of the ventricle muscle.

The T wave represents the repolarization of the ventricles.The Q-T interval represents the time for both ventricular depolarization and repolarization to occur, and therefore roughly estimates the duration of an average ventricular action potential. This interval can range from 0.2 to 0.4 seconds depending upon heart rate. At high heart rates, ventricular action potentials shorten in duration, which decreases the Q-T interval. The U wave is not

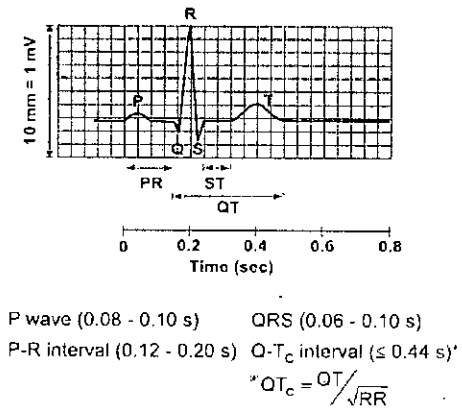

Figure 3.6: Amplitude and Duration of the waves and intervals

always seen. These waves are thought to represent repolarization of the papillary muscles or Purkinje fibers.The intervals are shown in Figure 3.6[3].

Normal values for amplitudes and duration of important ECG parameters are as follows:

Wave	Amplitude
P wave	0.25 mV
R wave	1.60 mV
Q wave	25% Of R wave
T wave	0.1 to 0.5 mV

Interval	Duration
PR wave	0.12 to 0.20 sec
QT wave	0.35 to 0.44 sec
ST segment	0.05 to 0. 15 sec
P wave	0. 11 sec
QRS interval	0.06 sec to 0.1 sec

3.6 ECG Leads

ECG signal is measured from electrodes applied to the surface of the body, the waveform of this signal is varied dependent on the placement of the electrodes. The term lead is used to indicate a particular group of electrodes. Electrodes are placed on each arm and leg, and six electrodes are placed at defined locations on the chest. These electrode leads are connected to a device that measures potential differences between selected electrodes in order to produce the characteristic electrocardiograph tracings. There are two basic types of ECG leads: bipolar and unipolar. Bipolar leads utilize a single positive and a single negative electrode between which electrical potentials are measured. Unipolar leads (augmented leads and chest leads) have a single positive recording electrode and utilize a combination of the other electrodes to serve as a composite negative electrode. Depending on the placing of electrodes there are three types of electrodes - Limb leads, Augmented leads, Chest leads.

3.6.1 Limb leads (Bipolar)

Einthoven, who developed the first clinically usable ECG in 1901 [3]. He choose the two arms Right arm (RA), Left arm (LA) and Left leg (LL), designating the three different recording schemes as,

- Lead I (RA-LA)
- Lead II (RA-LL)
- Lead III (LA-LL)

These three type of leads are called bipolar limb leads. Einthoven [3] postulated that at any given instant of the cardiac cycle, the frontal plane representation of the electrical axis of the heart is a two dimensional vector. The ECG measured from any one of the three basic limb lists is a time-variant signal-dimensional component of that vector. He made that

assumption that the heart is near the center of an equilateral triangle, the apexes of which are the right and left shoulder and the crotch. This triangle is known as the Einthoven triangle (shown in Figure 3.7). He showed that the instantaneous voltage measured from

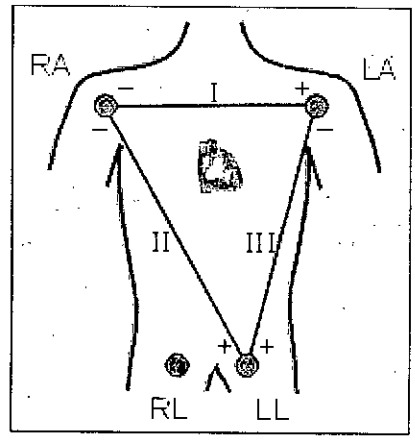

Figure 3.7: Einthoven Triangle

any one of the three limb lead positions is approximately equal to the algebraic sum of the other two or that the vector sum of the projections on all three lines is equal to zero.

Lead I has the positive electrode on the left arm, and the negative electrode on the right arm, and therefore measures the potential difference between the two arms. In this and the other two limb leads, an electrode on the right leg serves as a reference electrode for recording purposes.Lead I connection is shown in Figure 3.8 and Output of Lead I is shown in Figure 3.9.

In case of lead II configuration, the positive electrode is on the left leg and the negative electrode is on the right arm.Lead II connection is shown in Figure 3.10 and Output of Lead II is shown in Figure 3.11.

In case of lead III configuration, the positive electrode is connected to the left leg and the negative electrode to the left arm.Lead III connection is shown in Figure 3.12 and

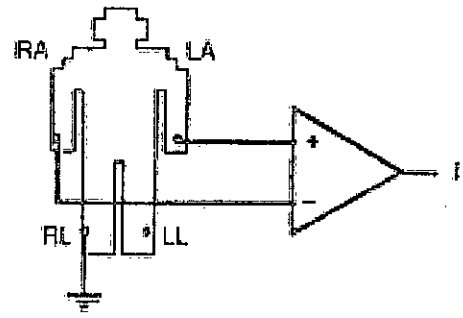

Figure 3.8: Lead I connection

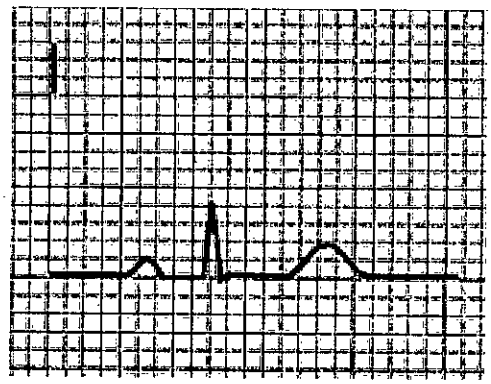

Figure 3.9: Output of Lead I

Output of Lead III is shown in Figure 3.13.

If the three limbs of Einthoven's triangle (assumed to be equilateral) are broken apart, collapsed and superimposed over heart, then the positive electrode for lead I is said to be at zero degrees relative to the heart (along the horizontal axis). Similarly the positive electrode for lead II will be +60o relative to the heart and the positive electrode for lead III will be +120o relative to the heart.The position of three limb Leads is shown in Figure 3.14.

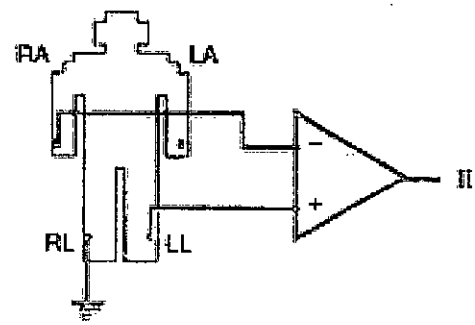

Figure 3.10: Lead II connection

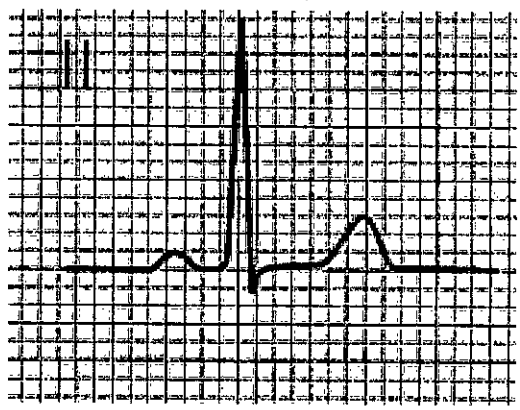

Figure 3.11: Output of Lead II

3.6.2 Augmented Limb Leads (Unipolar)

There are three types of limb Leads which are also named unipolar leads [3]. These three leads are referred to as aV_R (right arm), aV_L (left arm) and aV_F (left leg) and also record a change in electric potential in the frontal plane. There is a single positive electrode that is referenced against a combination of other limb electrodes. These leads are unipolar in that they measure the electric potential at one point with respect to a null point. This null point is obtained for each lead by adding the potential from the other two leads. For example, in lead aV_R , the electric potential of the right arm is compared to a null point which is

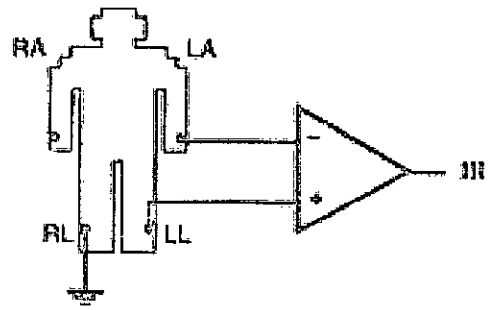

Figure 3.12: Lead III connection

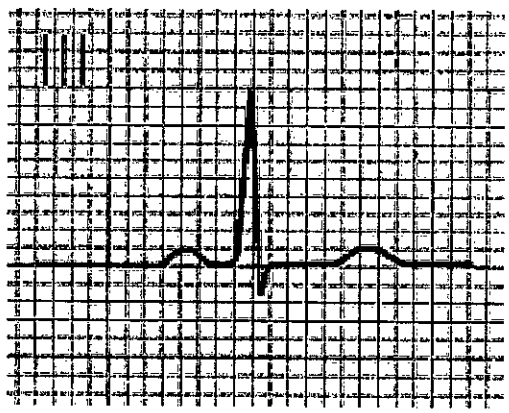

Figure 3.13: Output of Lead III

obtained by adding together the potential of lead aV_L and lead aV_F .

Augmented Vector Right (aV_R) has the positive electrode on the right arm. The negative electrode is a combination of the left arm electrode and the left leg electrode. Augmented Vector Left (aV_L) has the positive electrode on the left arm and the negative electrode is a combination of the right arm electrode and left leg electrode. Augmented Vector Foot has the positive electrode on the left leg and the negative electrode is a combination of the right arm electrode and the left arm electrode. Circuit Diagrams of Augmented Limb Leads are shown in Figure 3.17,Figure 3.18 and Figure 3.19.

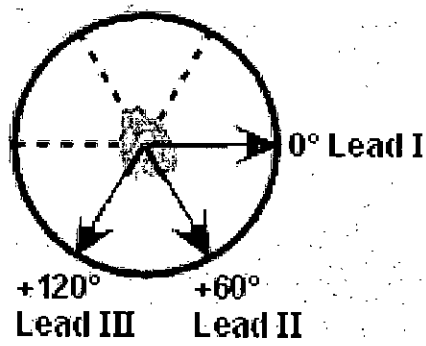

Figure 3.14: Position of the three Limb Leads

The aV_L lead is at -30^o relative to the Lead I axis; aV_R is at -150^o and aV_F is at $+90^o$. If a wave of depolarization is spreading from right-to-left along the 0^o axis, then Lead I will show the greatest positive amplitude. Likewise, if the direction of the electrical vector for depolarization is directed downwards ($+90^o$), then aV_F will show the greatest positive deflection. If a wave of depolarization is moving from left-to-right at $+150^o$, then aV_L will show the greatest negative deflection according to the rules of ECG interpretation.The position of the augmented Limb Leads is shown in Figure 3.15.

3.6.3 Chest Leads

There are six precordial, unipolar chest leads. These leads are named V1-V6. In order to record electrical activity in a plane perpendicular to the frontal plane, six positive electrodes are placed on the surface of the chest over different regions of the heart.The position of the chest Leads is shown in Figure 3.16

Lead V1, V2 and V3 are called right precordial leads and V4, V5 and V6 are called left pre cordial leads. V1 is placed in the fourth inter costal space to the right of the sternum, V2 is placed in the fourth inter costal space to the left of the sternum.

V3 is placed directly between leads V2 and V4. V4 is placed in the fifth intercostals space in the midclavicular line, Lead V5 is placed horizontally with V4 in the anterior

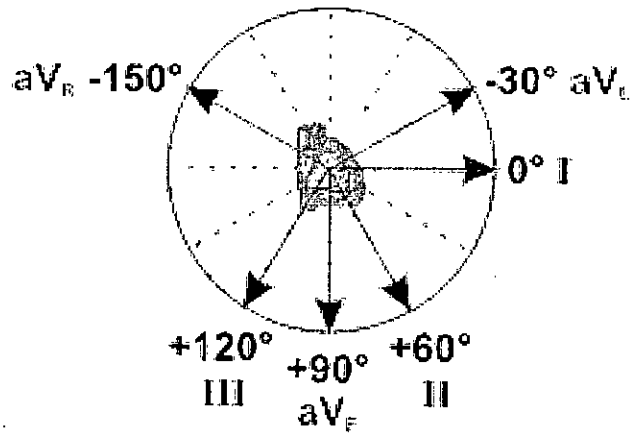

Figure 3.15: Position of the three Augmented Limb Leads

auxiliary line and Lead V6 is placed horizontally with V4 and V5 in the mid auxiliary line.

These 12 ECG Leads provide different views of the same electrical activity within the heart. In this thesis work Lead I connection has been used.

3.7 Circuit Diagram

Circuit Diagram of ECG is shown in Figure 3.20.

3.7.1 Description of Circuits

The detailed description of the circuit is discussed below.

Buffer and Differential Amplifier

In this thesis work, Lead I configuration has been used. At first, two separate buffer amplifiers are used. The electrode from the right arm (RA) is connected to +ve input of the differential amplifier and the electrode from the left arm (LA) is connected to ve input of the differential amplifier. This amplifier provides a gain of 10 times to the differential

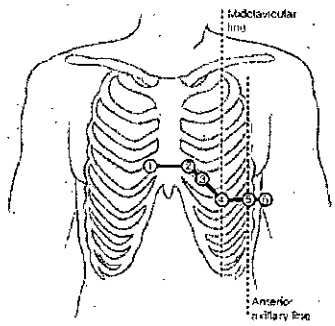

Figure 3.16: Position of the Chest Leads

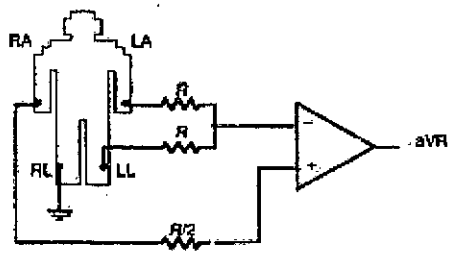

Figure 3.17: Lead Connection of Augmented Vector Right

voltage generated from the two limb electrodes. The electrode from the right leg (RL) is connected to ground.Buffer and Differential Amplifier is shown in Figure 3.21.

Amplification, filtering and buffering

The output of the differential amplifier goes to an amplifier which gain is 100 times of the output of the differential amplifier. Then the signal is filtered. The filtered signal goes through buffering and amplification process. After filtering the signal goes to the input of the optpcoupler.This circuit is shown in Figure 3.22.

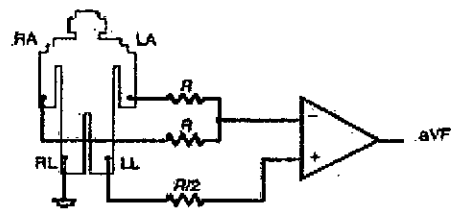

Figure 3.18: Lead Connection of Augmented Vector Foot

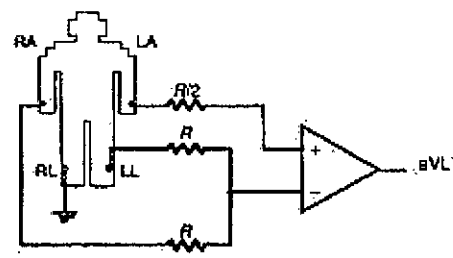

Figure 3.19: Lead Connection of Augmented Vector Left

Isolation circuit

For the safety of the patient, the patient side ground and computer side ground is different. For this, optocoupler has been used on the computer side.Isolation Circuit is shown in Figure 3.23.

Using DAQ

The ECG signal has been extracted from the output of the optocoupler using Data Acquisition card. Using MATLAB, this signal again goes through the filtering process. MATLAB code of the filter is given to the Appendix.

3.8 Processing the Signals and Typical Results

Ecg signal is extracted from the probe of ECG. In this thesis, Lead I connection has been used.From Figure 3.24, it is seen that the signal which is extracted from the probe is full of noise. At this, a filter is used by using MATLAB. The coefficient of the filter is given by,

$$b(z) = b(1) + b(2)z^{-1} + \ldots\ldots\ldots\ldots + b(n+1)z^{-n} \tag{3.1}$$

The signal after filtering is shown in Figure 3.25.The signal of one cycle after filtering is is shown in Figure A.5.

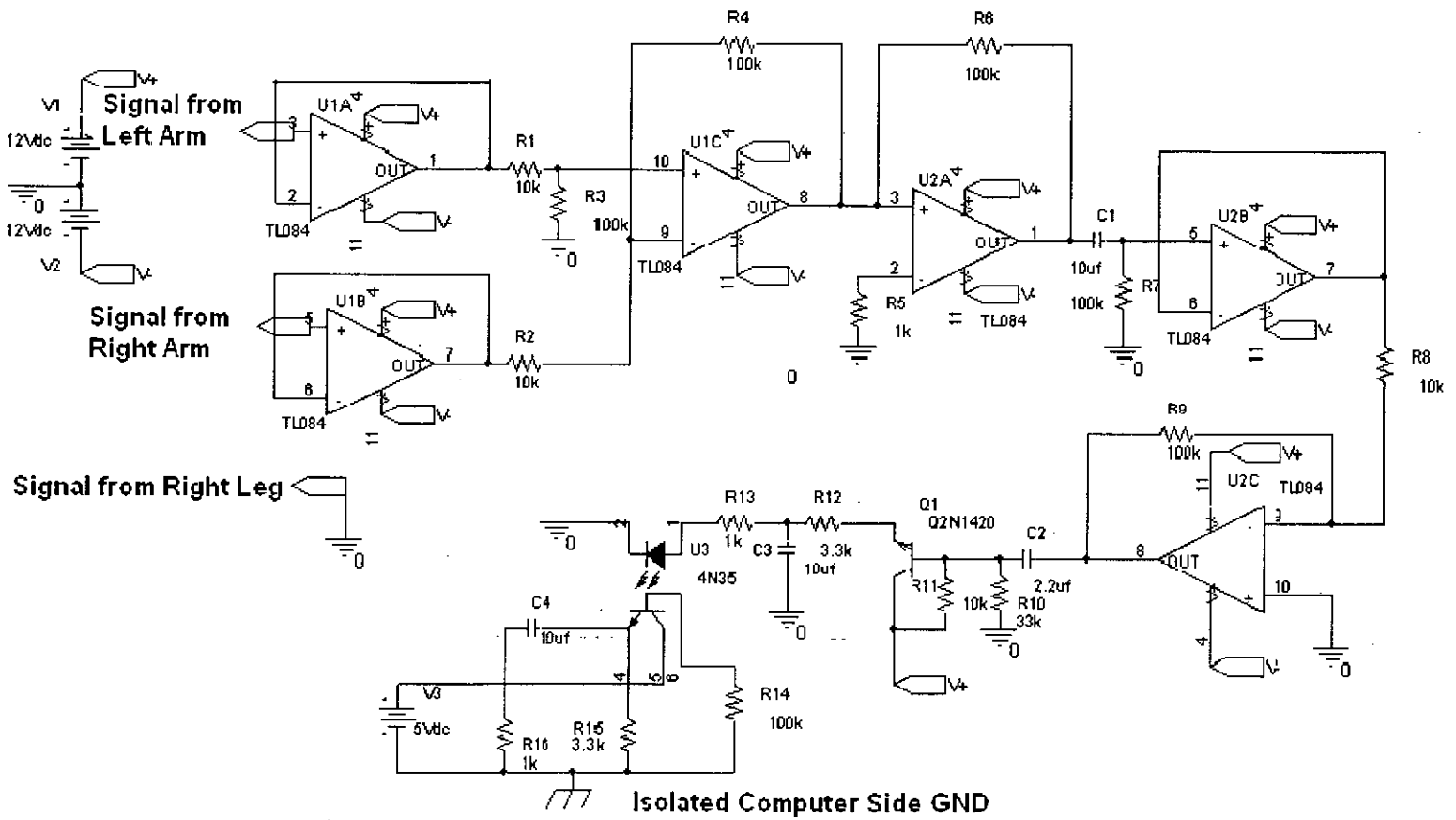

Figure 3.20: Circuit Diagram of ECG Signal

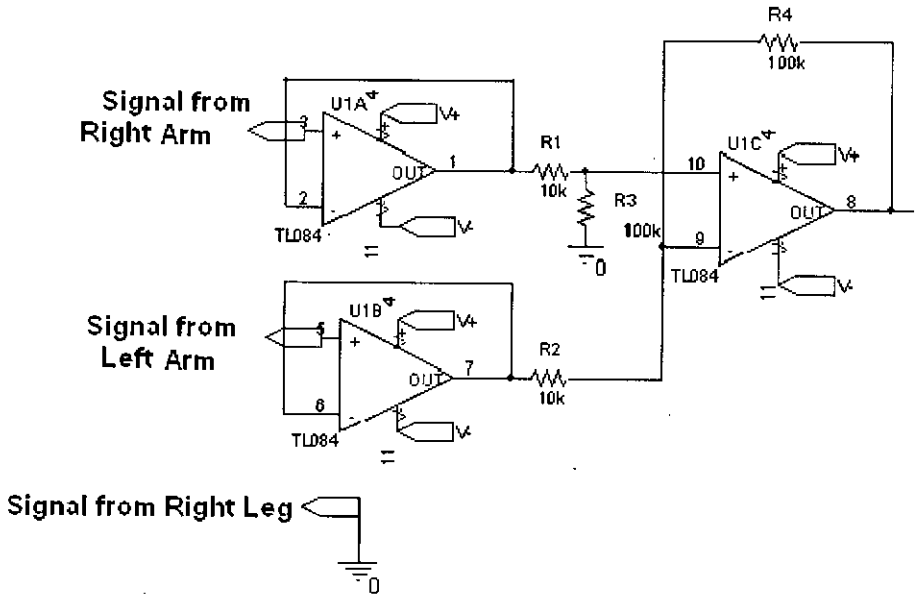

Figure 3.21: Buffer and Differential Amplifier

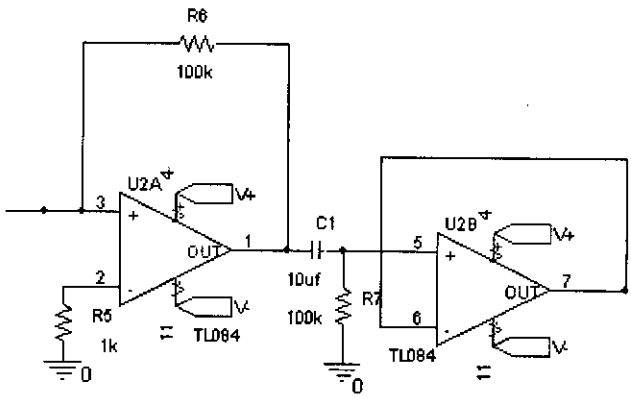

Figure 3.22: Amplifier, filter and buffer

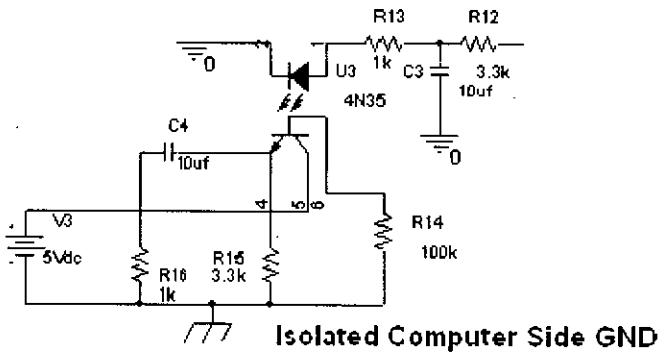

Figure 3.23: Isolation circuit

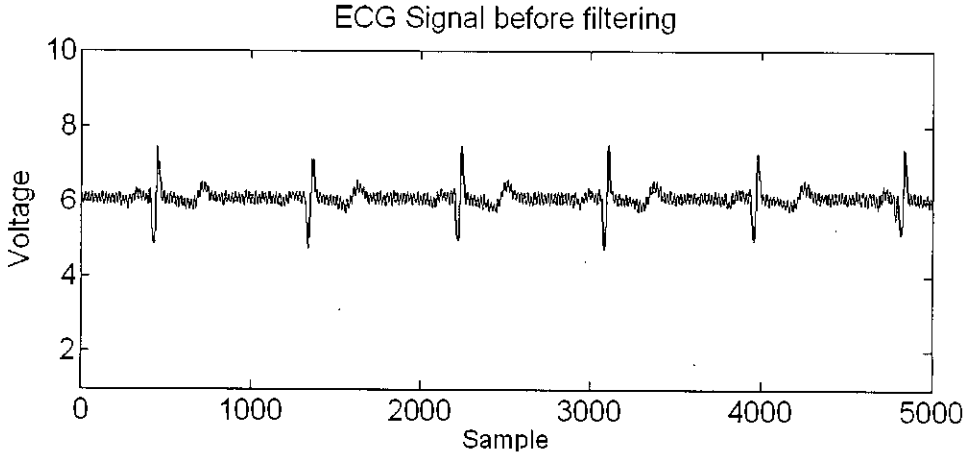

Figure 3.24: ECG Signal before filtering

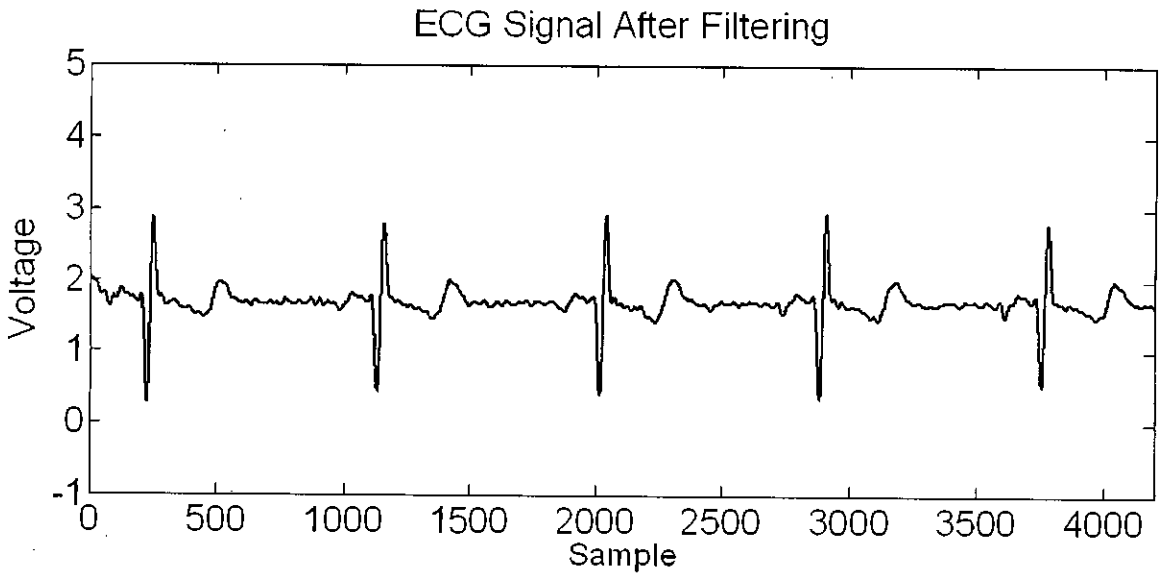

Figure 3.25: ECG Signal after filtering

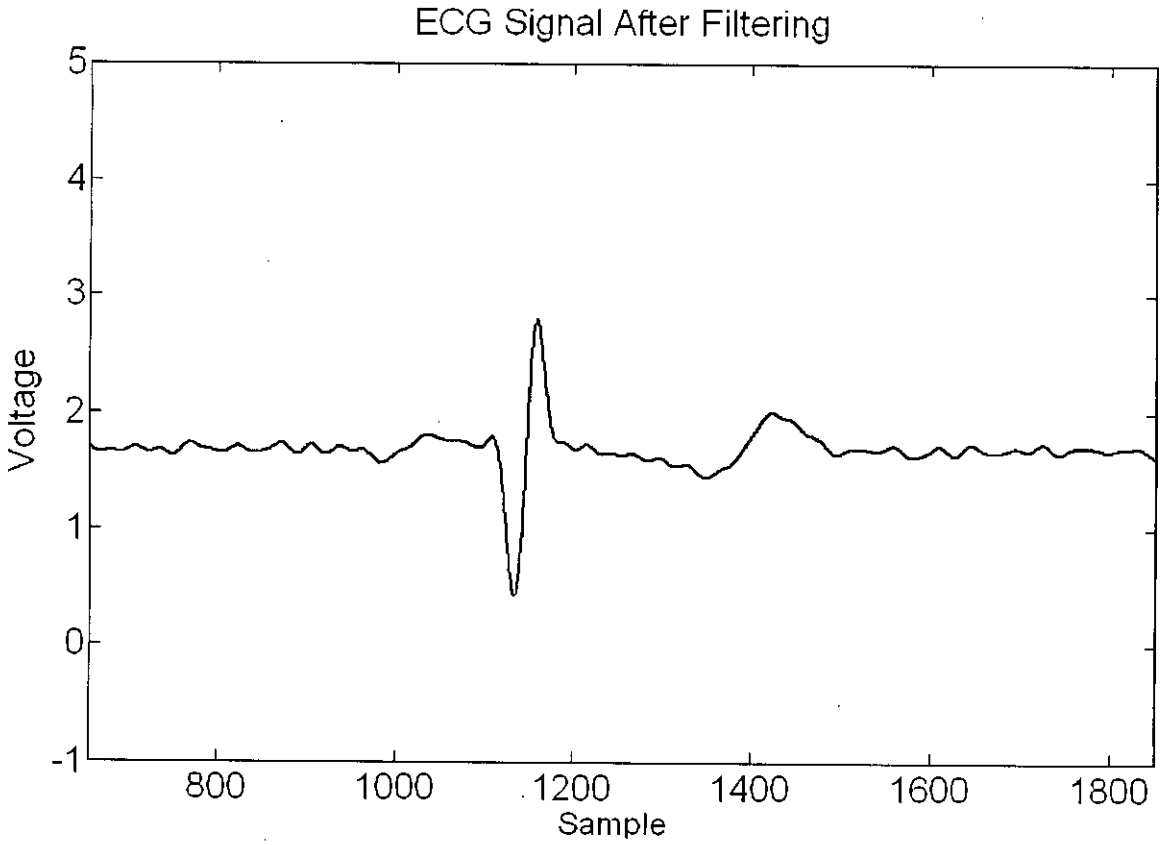

Figure 3.26: ECG Signal after filtering

Chapter 4

Temperature Monitoring System

4.1 Introduction

In the intensive care unit, a patient's body temperature is very important feature. It indicates the measure of the bodys ability to generate and get rid of heat. It is an indication of many types of illness. It can provides useful information about the severity of the illness. When the body is too hot, the blood vessels in the skin expand (dilate) to carry the excess heat to the skin's surface. Patients may begin to sweat, and as the sweat evaporates, it helps to cool the body. When the body is too cold, blood vessels narrow (contract) so that blood flow to the skin is reduced to conserve body heat. It may start shivering, which is an involuntary, rapid contraction of the muscles. This extra muscle activity helps generate more heat. Under normal conditions, this keeps patient's body temperature within a narrow, safe range [12]-[13].

4.2 Temperature Sensing Probe

The truest, accessible, core temperature is measurement of the pulmonary artery temperature with a thermistor catheter. Similar thermistor catheters can be placed in the esophagus and bladder for core temperature measurement, but other factors may affect their accuracy. A catheter type thermistor [14] temperature sensor is shown in Figure 4.1.

Figure 4.1: Catheter type thermistor temperature sensor

Many people consider the glass-mercury thermometer is the standard due to its ease of use, portability, cost and availability. However, there are accuracy issues related to this "ideal" device. Glass is porous and the mercury can evaporate within six months which may affect accuracy. These devices need to be "shaken down" before use, which is a competency issue. Electronic thermometers have similar advantages as glass-mercury. However, the method of measurement is faster because it is calculated. This is performed in a process called "predictive mode" where the metal sensor in the tip of the thermometer takes sequential readings and the final number is calculated [?]. This is one of the controversial points. For example, a nurse may obtain a temperature of a patient with an electronic thermometer and question the reading, Then he/she takes the patient's temperature again with a different thermometer and obtains a different reading, sometimes significantly different, and questions the accuracy of the first thermometer. The potential issue exists in the calculation of the temperature due to variance in blood flow to that area, or the patient moved the thermometer after it was placed by the nurse.

Different Type of medical Temperature Sensors are shown in Figure 4.2.

Single or Multi-use chemical thermometers are very popular with the general public, but they have some accuracy issues for clinical use. The two basic types are: Flexible strips that have dot-like depressions filled with a series of chemicals that melt and change color in relation to the patient's temperature. Re-usable strips of plastic, where the chemical within the strip is activated by the patient's temperature and a numerical reading is displayed. The accuracy issues related to both are based on where on or in the body the measurement is

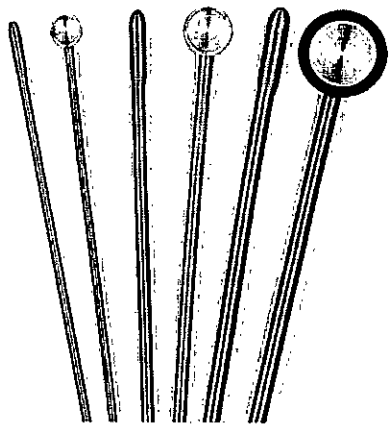

Figure 4.2: Medical Temperature Sensors

obtained, because vaso-motor activity and ambient temperatures will affect the results. The last device is infrared radiation readers (IRs) such as those used in tympanic thermometers. These devices in contrast to the previously mentioned devices that rely on conductive heat transfer, measure naturally emitted electromagnetic radiation. Infrared radiation is the electromagnetic radiation just beyond the red end of the visible spectrum (>1mm wavelength) [?]. These devices function without contact to the point of measurement, and for effective functioning of any non-contact-IR thermometer it must contain the following components:

(a)An IR sensor to measure the net thermal radiation flux. (b)A reference sensor to measure the ambient temperature of the IR sensor. (c)An optical system to focus the thermal radiation. (d)A computational means to calculate the target temperature.

The intensity of the IR varies with the temperature from the surface of the object it is measured from.

4.3 Measurement of Temperature by Using Thermistor Sensor

For the measurement of temperature thermistor based sensor is used. Thermistor is a type of resistor with resistance varying according to its temperature. For accurate temperature measurements, the resistance- temperature curve of the device must be described in more detail. The Steinhart-Hart equation is a widely used third-order approximation [3]:

$$\frac{1}{T} = a + bln(R) + cln^3(R) \tag{4.1}$$

where a, b and c are called the Steinhart-Hart [3] parameters, and must be specified for each device. T is the temperature and R is the resistance. To give resistance as a function of temperature, the above can be rearranged into:

$$R = e^{(\beta - \frac{\alpha}{2})^{\frac{1}{3}} - (\beta + \frac{\alpha}{2})^{\frac{1}{3}}} \tag{4.2}$$

where

$$\alpha = \frac{\alpha - \frac{1}{T}}{c} \tag{4.3}$$

and

$$\beta = \sqrt{(\frac{b}{3c})^3 + \frac{\alpha^2}{4}} \tag{4.4}$$

The error in the Steinhart-Hart equation is generally less than 0.02^oC in the measurement of temperature. As an example, typical values for a thermistor with a resistance of 3000 Ω at room temperature ($25^oC = 298.15K$) are:

$$a = 1.40 * 10^{-3}$$

$$b = 2.37 * 10^{-4}$$

$$c = 9.9 * 10^{-8}$$

Relationship between resistance and temperature is shown in Figure 4.3.

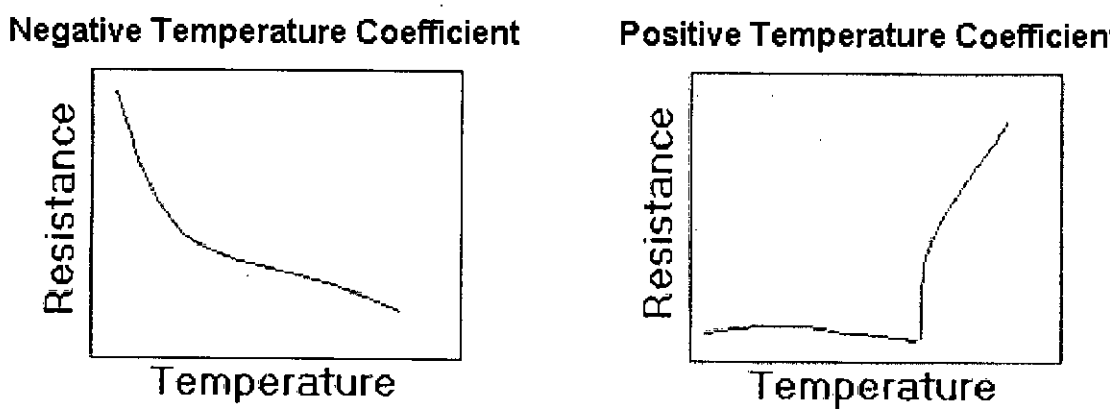

Figure 4.3: Relationship between resistance and temperature

In this thesis work YSI Precision Thermistor Probe has been used to collect the data for temperature. It offers high precision thermistor elements, customizable probes and assemblies to provide precise and reliable temperature measurement in the most demanding applications. It provides highly accurate and stable temperature sensing for measurement, control, indication and compensation. The tight interchangeability of the precision components allows precise measurement without calibration of circuitry to match individual components. This thermistor offers two interchangeability tolerances $(0.2^oC, 0.1^oC)$. Standard resistances from 2252 ohms to 30 Kohms at 25^oC.

As the normal room temperature is about , the DC output voltage is around 0.5V. Optocoupler isolation amplifier circuit cannot be used for interfacing because of the DC output voltage. So this DC voltage is converted to time varying signal using chopping with Tri-angular or Saw-tooth wave to have a pulsed DC. The DC voltage is compared with the Tri-angular signal, so the output is square wave depending upon the magnitude of DC value. The block diagram for temperature measurement is shown in Figure 4.4.

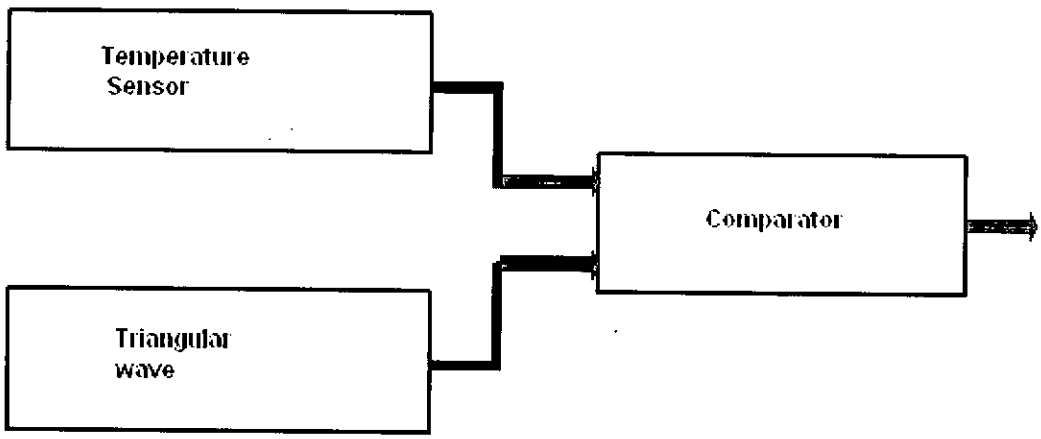

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Figure 4.4: Block Diagram of Temperature measurement

4.4 Circuit Diagram

Temperature measurement Circuitry is shown in Figure 4.5.

4.4.1 Description of all Circuits

The schematic of the temperature measurement is shown in fig. The detailed description is given below:

Differential Amplifier- The temperature sensor with voltage divider circuit has been connected to +ve input of the opamp (TL084). Then a buffer circuit was used. A dc voltage

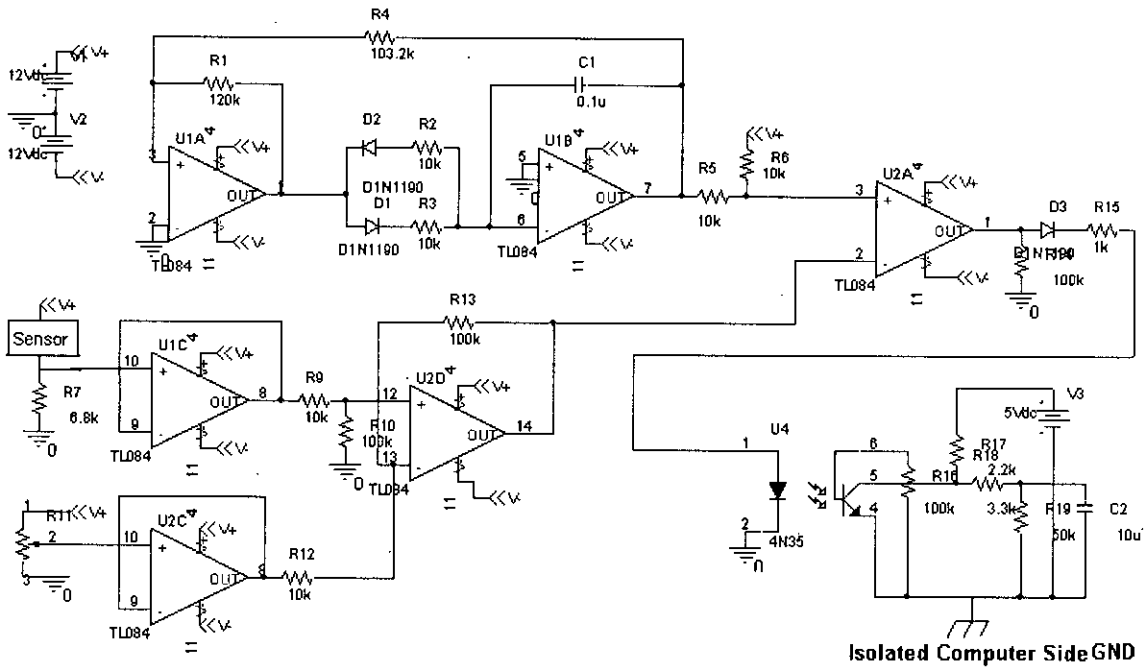

Figure 4.5: Temperature measurement Circuitry

which is generated from a potentiometer with voltage divider circuit was connected to +ve input of another opamp (TL084). Then a buffer circuit was also used. The outputs of two buffer circuits were connected to another opamp. The sensor output was connected to the +ve input and another one was connected to the -ve input. At this moment, this amplifier acts as an differential amplifier. This circuit was used for better estimation of the sensitivity of the sensor. The change of the resistivity of the sensor with temperature becomes significant for this differential amplifier circuit.This circuit is shown in Figure 4.6.

Tri-angular wave generation- To convert the output signal of the differential amplifier to the time-varying signal Tri-angular wave has been used. The output of the differential amplifier was compared with the Tri-angular wave.This circuit is shown in Figure 4.7.

Comparator- For the comparison between the two outputs a square-wave was generated for

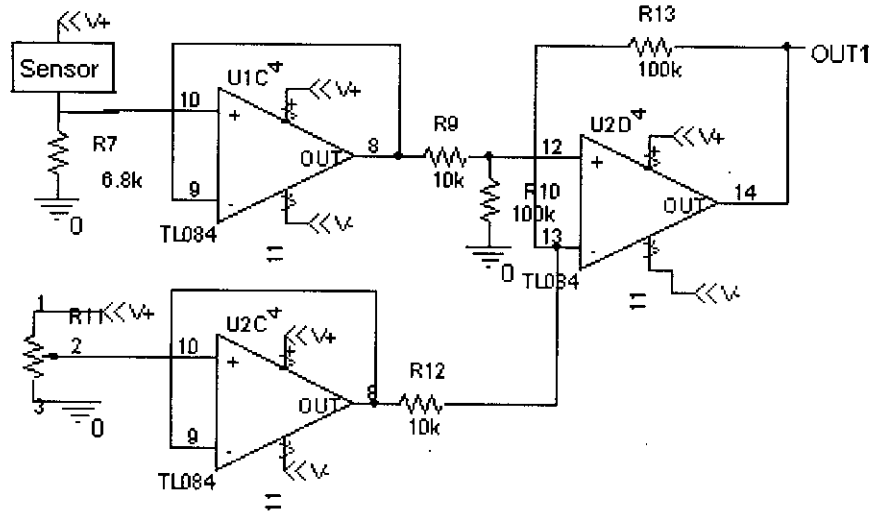

Figure 4.6: Differential Amplifier

the different level of the output of the differential amplifier. The width of the square-wave was changed with the change of the resistivity of the sensor. Input and output curve of the comparator is shown in Figure 4.8.

Isolation circuit-The output of the comparator was connected to the optocoupler with a diode and a resistor. The patient side circuitry has been isolated from the other parts using optocoupler. The figure of the optocoupler is shown in Figure 4.9.

Using DAQ- The resultant output was connected to the Data Acquisition Card. PCI-1711 has been used as a DAQ. It provides 16-channel Single-Ended A/D input. By using MATLAB this signal has been processed for filtering, noise elimination, amplification, display and record.

4.4.2 Processing the Signal and Typical Results

In this thesis YSI Precision Thermistor Probe has been used. It can change its resistivity within the temperature range from 80^oF to 110^oF. The resistivity of this thermistor decreases with the increase of the temperature. In this thesis, a voltage divider circuit has been

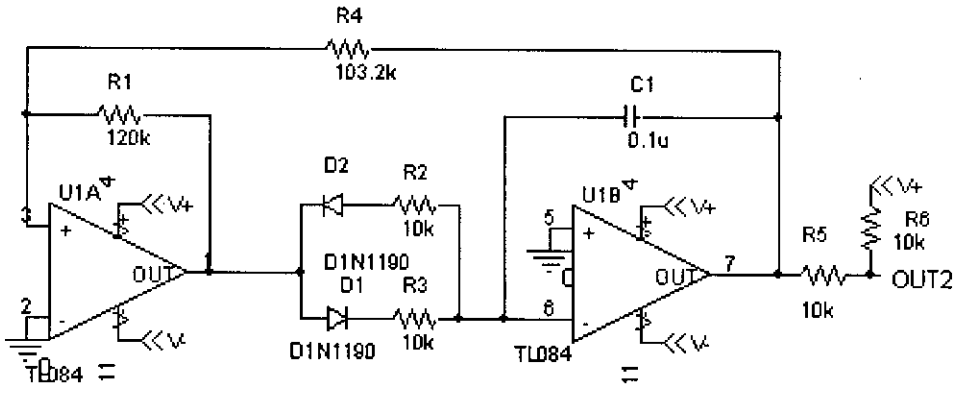

Figure 4.7: Tri-angular wave generation

used to increase the voltage with the change of the resistivity of the probe. Temperature Signal from DAQ is shown in Figure A.6. At this, it is seen that voltage is increasing with the change of time and at last it goes to a steady stage. By using MATLAB this signal has been filtered and temperature of the patient has been calculated by converting the voltage to temperature. MATLAB code is given in the Appendix.

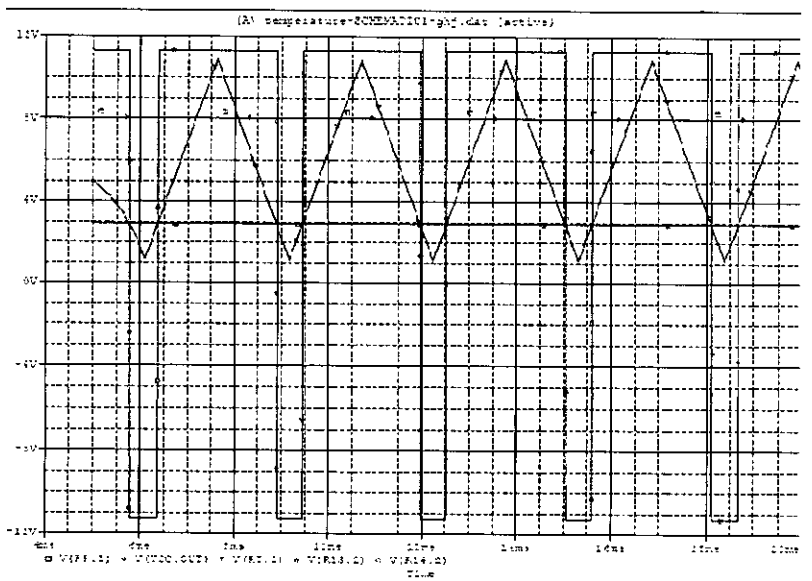

Figure 4.8: Input and output curves of the comparator

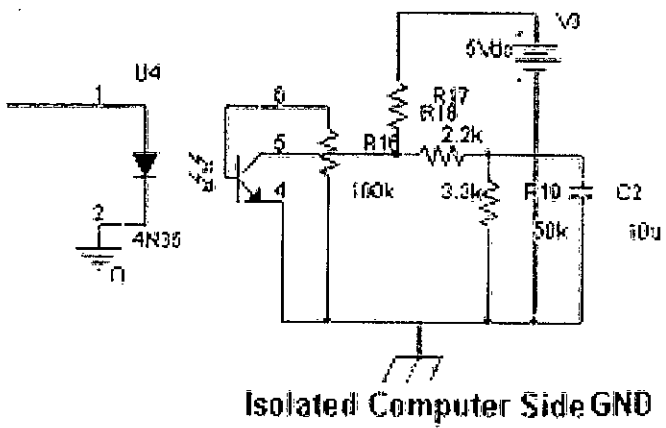

Figure 4.9: Optocoupler Isolation

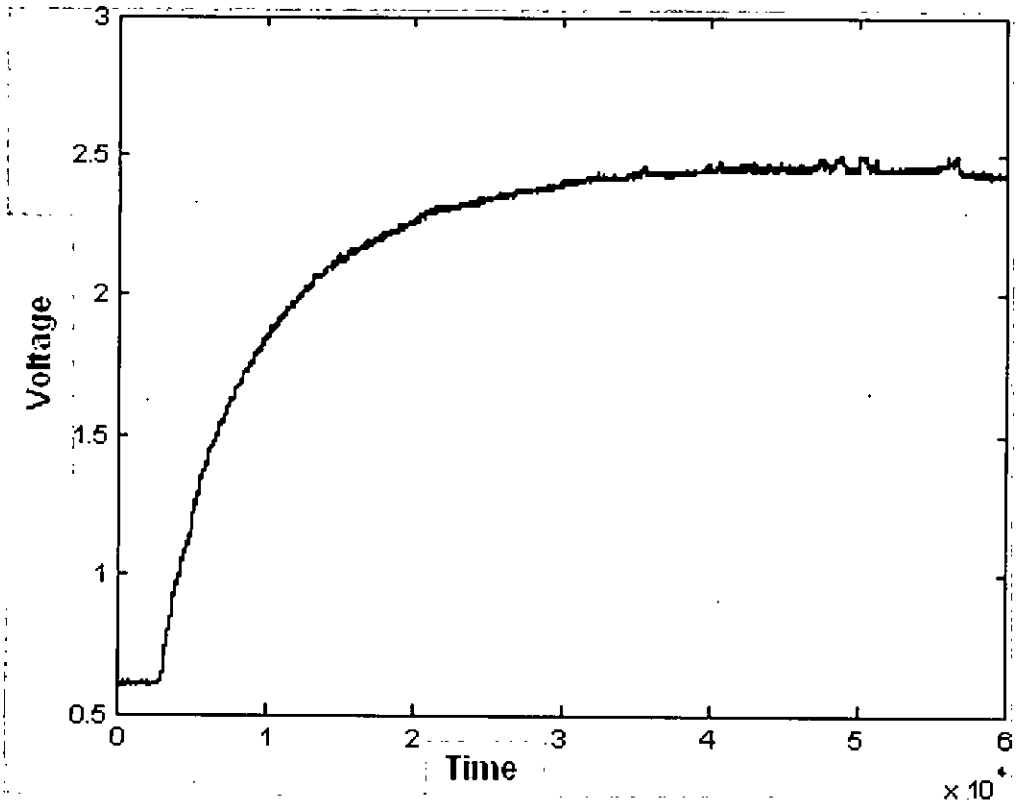

Figure 4.10: Temperature Signal from DAQ

Chapter 5

Multiscreen Display of Several Patient Condition

5.1 Introduction

All signals has been collected by using Data Acquisition Card PCI-1711 which provides 16-channel Single-Ended A/D input. By using MATLAB these signals has been processed. Different types of processes i.e. filtering, amplification, noise elimination and at last showing all information in a same screen are performed by using MATLAB.

5.1.1 Filtering

In this thesis work, frequency sampling-based finite impulse response filter is used. Here vector b contains n+1coefficients of an order n FIR filter. f is a vector of frequency points in the range from 0 to 1, where 1 corresponds to the Nyquist frequency. The first point of f must be 0 and the last point 1. The frequency points must be in increasing order. m is a vector containing the desired magnitude response at the points specified in f. f and m must be the same length.The diagram of the filter is shown in Figure 5.1. The output filter coefficients, b, are ordered in descending powers of z.

$$b(z) = b(1) + b(2)z^{-1} + ... + b(n+1)z^{-n} \tag{5.1}$$

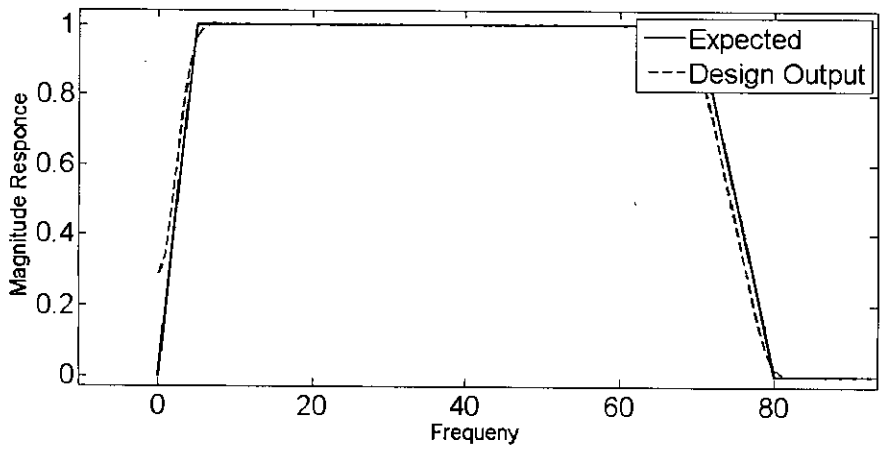

Figure 5.1: Finite Impulse Response of the filter

5.1.2 Multiscreen Display

In a intensive care unit, it is very important to observe all information of a patient.At any moment, the patient can fall in risk.If all information is clear by showing in a screen, it is easy to observe the patient and take any decision in case of his treatment so quickly.

On the other hand, in a intensive care unit, there are many patients. If it is able to observe all patients from a same monitor, it will be easier for giving proper treatment of all patients.Besides this, if patient's family can show the condition of his patient from the waiting room, it will lessen the tention at many cases. For this reason, this work has been done in this thesis. By using a software it is easy to observe many monitors in a single monitor with low cost.The name of the software multiscreen remote desktop.In this thesis, two monitors are observed from another monitor. IP address of the two PCs are 172.16.92.137 and 172.16.92.122. Monitor showing information of a single patient is given in Figure 5.2.

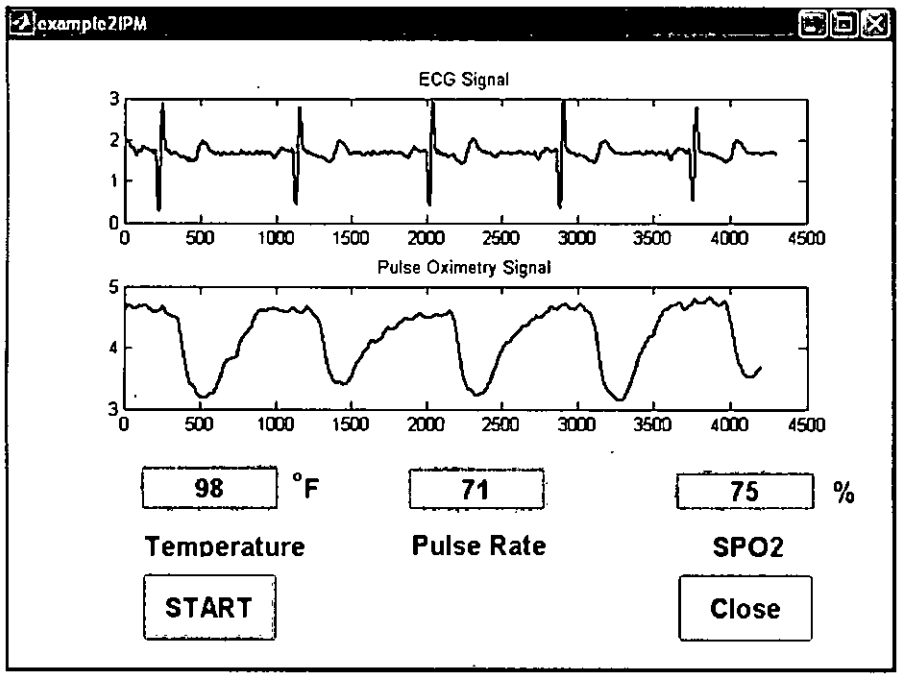

Figure 5.2: Information in a single monitor

The figures are shown in Figure A.12, and Figure A.16.

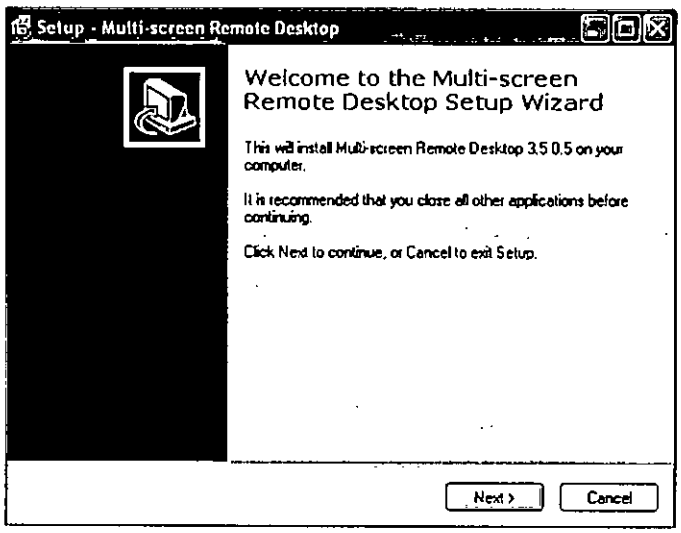

Figure 5.3: Multiscreen Software

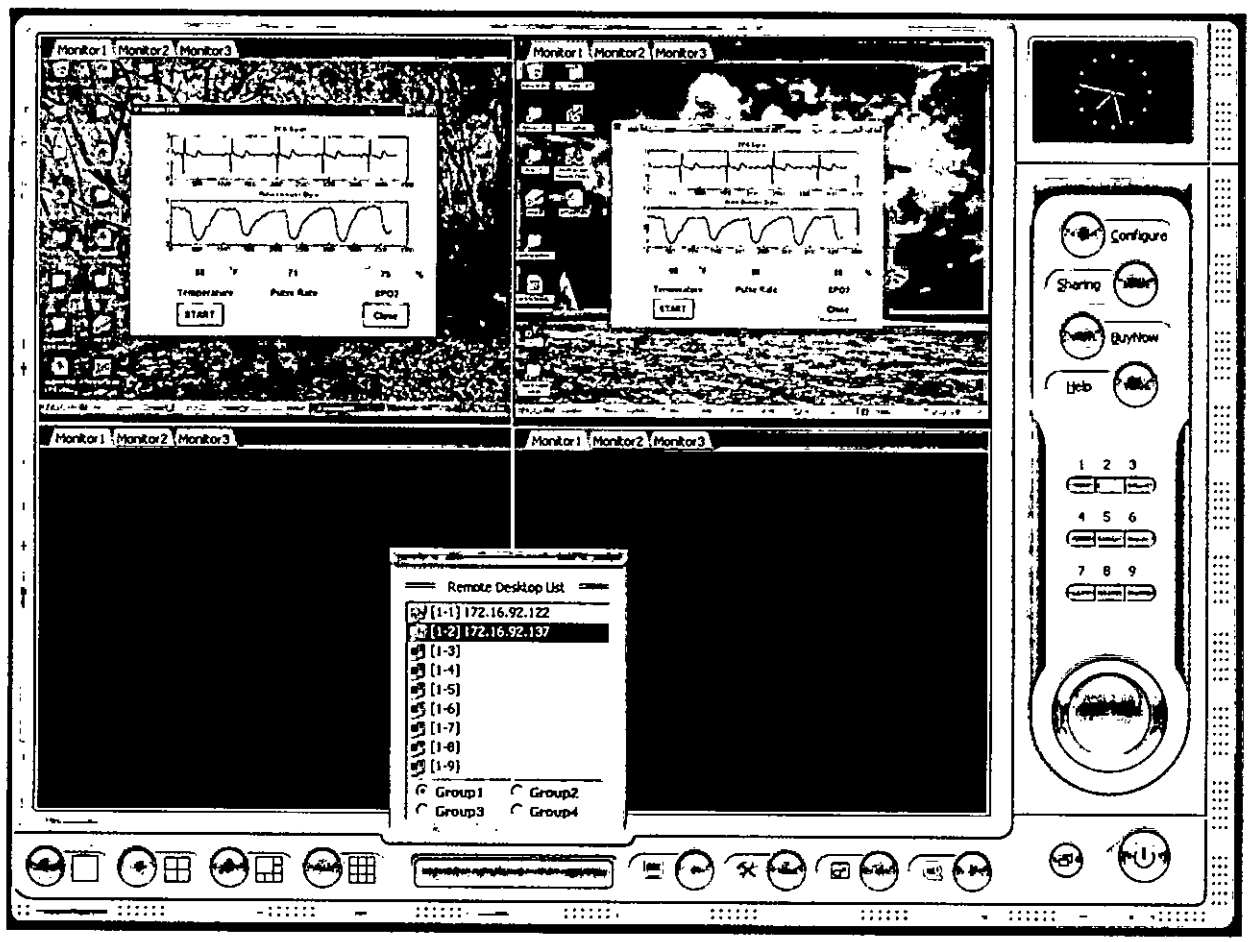

Figure 5.4: Information of two patients in a single monitor with IP address of two PCs

Chapter 6

Conclusions and Future Works

The cost of existing intensive care unit system is very much high. The technology which is developed in this thesis is very cheap. Because of high cost many hospitals of developing country have no intensive care unit. At this, many patients die for lack of proper treatment. So, it is seen that cost is very important factor in this case. If a system is developed which is cheap and reliable, then it will give better opportunities to the serious patients in the developing country like Bangladesh. Beside these, for the higher cost of the treatment of ICU, many patients cannot continue their treatment and they suffer. The technology which is mentioned in this thesis is easy and cheap. It is possible to implement this technology in this country with local expertise and resources. For monitoring all information of a patient in the intensive care unit in low cost this thesis work will help very much. To collect all information of multiple patients at a time and display all signals in a single screen is also implemented. In future the work can be expanded by using modern technology. Wireless system can be used. Though isolation in the side of the patient has been used in this thesis work, yet there is some possibility of danger. The information from the patients can be collected by wireless system. In wireless system, there is no chance of accidental danger of the patient. Besides these, if wireless system is used, the computers which are needed for every patient will not be required. Only one computer will be required to observe the conditions of the patients centrally. Then cost will be reduced further.

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Appendix A

Appendix

A.1 Signals of Various parts of Circuits

Signals of Various parts of Circuits are shown in Figure A.1,Figure A.2,Figure A.3,Figure A.4,Figure A.5,Figure A.6,Figure A.7.

A.1.1 Pulse oximetry Circuit

Pulse oximetry Circuit is shown in Figure A.7.

A.1.2 ECG Monitoring Circuit

ECG monitoring circuit is shown in Figure A.8.

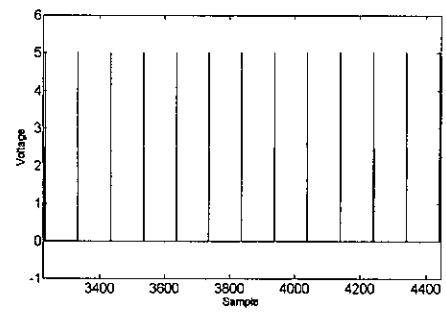

Figure A.1: Pulse from Microcntroller

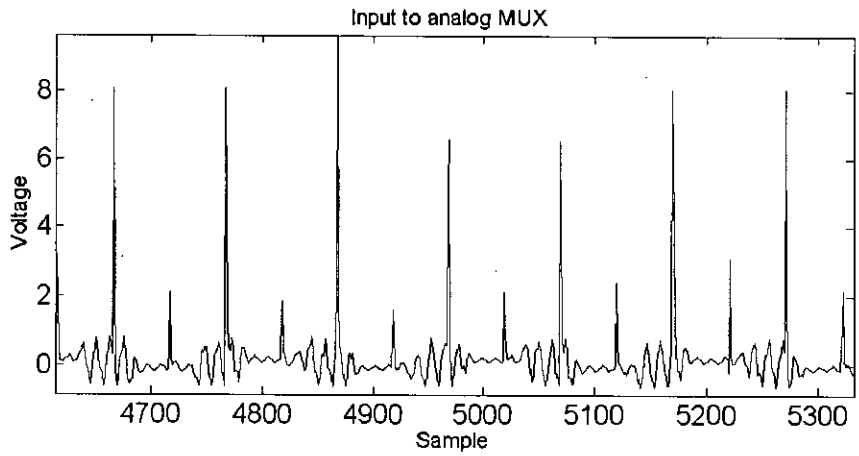

Figure A.2: Input to the Analog MUX

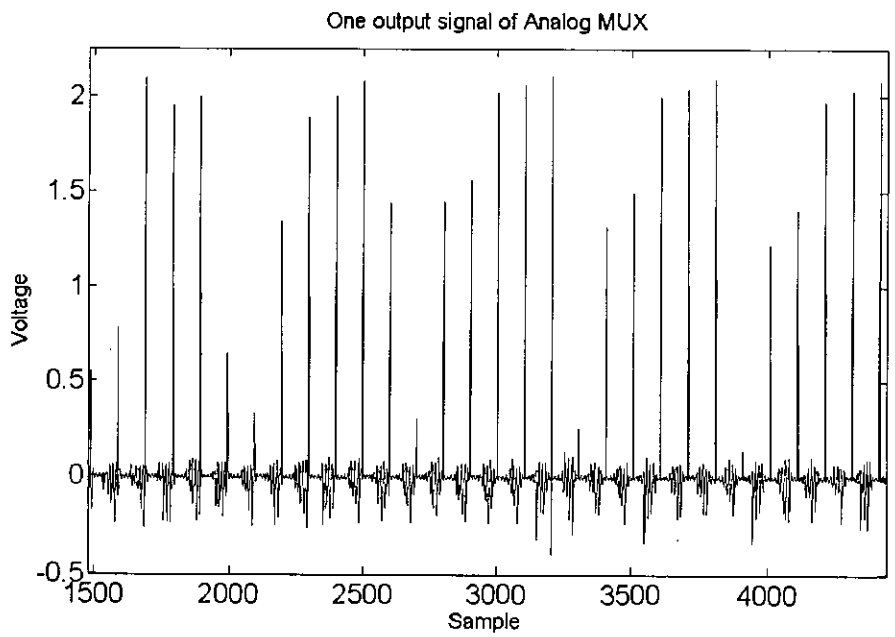

Figure A.3: Red LED Signal

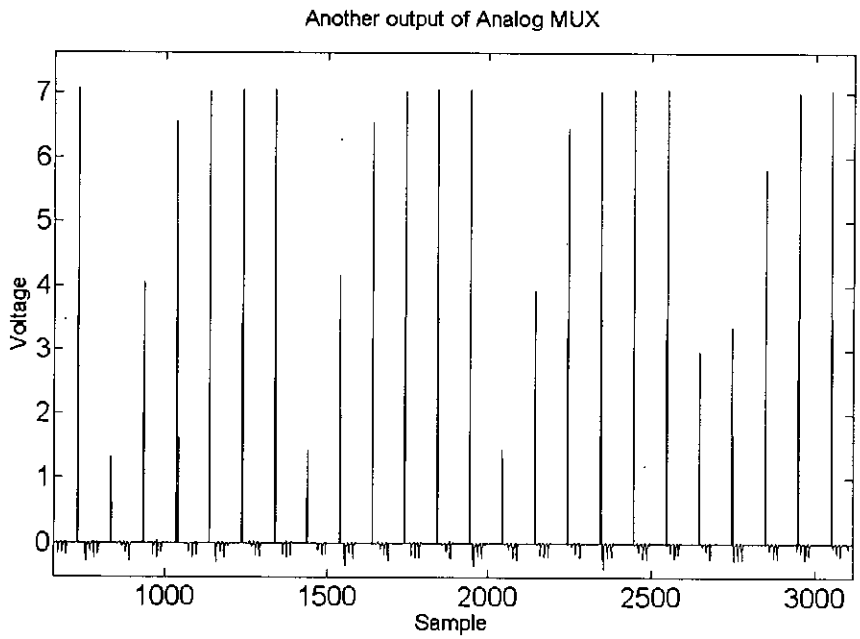

Figure A.4: Infra-Red LED Signal

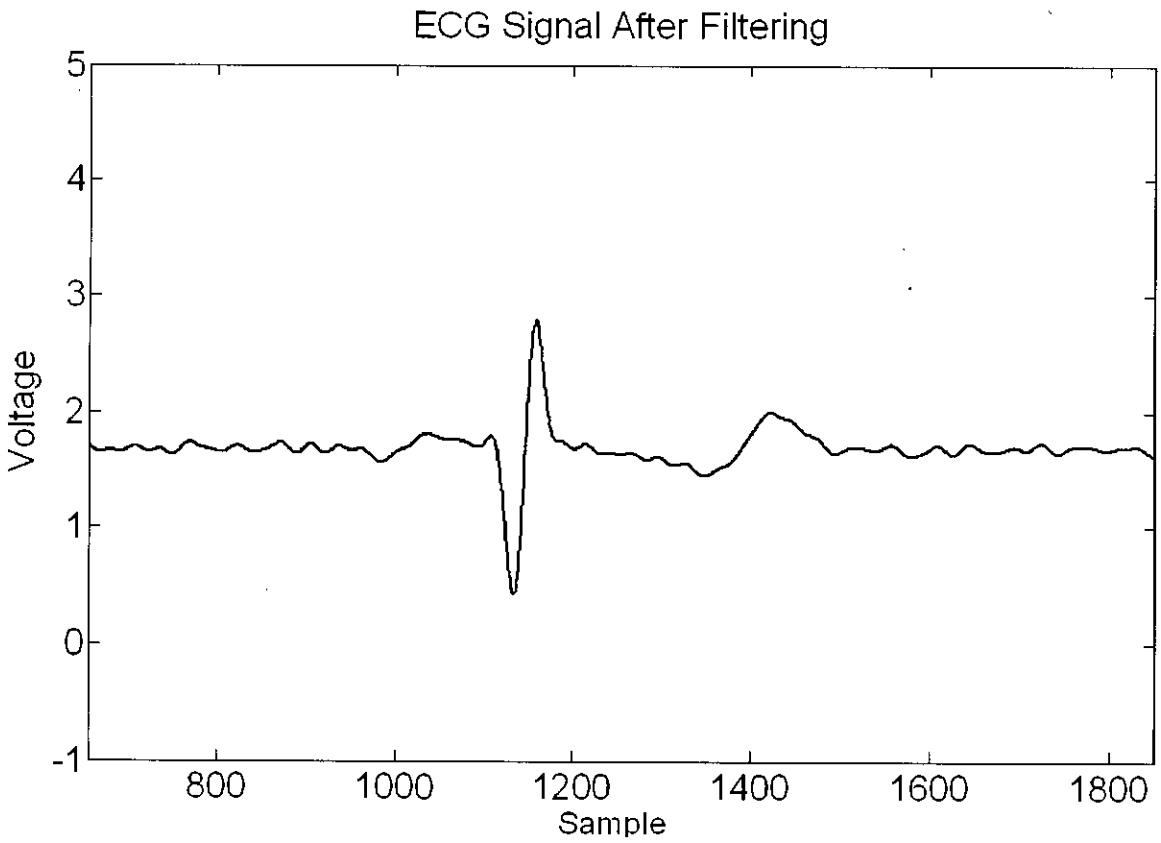

Figure A.5: ECG Signal after filtering

A.1.3 Temperature Monitoring Circuit

Temperature monitoring circuit is shown in Figure A.9.

A.1.4 Power Supply Circuit

Power Supply Circuit is shown in Figure A.10.

A.1.5 Full Circuit

Full circuit is shown in Figure A.11.

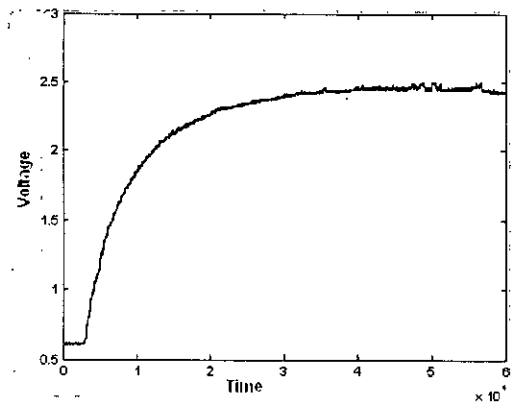

Figure A.6: Temperature Signal from DAQ

A.2 Programs for pulse oximetry,ecg,temperature signals display at bedside monitor

A.2.1 MATLAB Code for displaying all signals in a same screen

```
function varargout = IPM2(varargin)
% IPM2 M-file for IPM2.fig
%   IPM2, by itself, creates a new IPM2 or raises the existing
%   singleton*.
%
%   H = IPM2 returns the handle to a new IPM2 or the handle to
%   the existing singleton*.
%
%   IPM2('CALLBACK',hObject,eventData,handles,...) calls the local
%   function named CALLBACK in IPM2.M with the given input arguments.
%
%   IPM2('Property','Value',...) creates a new IPM2 or raises the
%   existing singleton*.  Starting from the left, property value pairs are
%   applied to the GUI before IPM2_OpeningFunction gets called.  An
%   unrecognized property name or invalid value makes property application
%   stop.  All inputs are passed to IPM2_OpeningFcn via varargin.
%
%   *See GUI Options on GUIDE's Tools menu.  Choose "GUI allows only one
%   instance to run (singleton)".
```

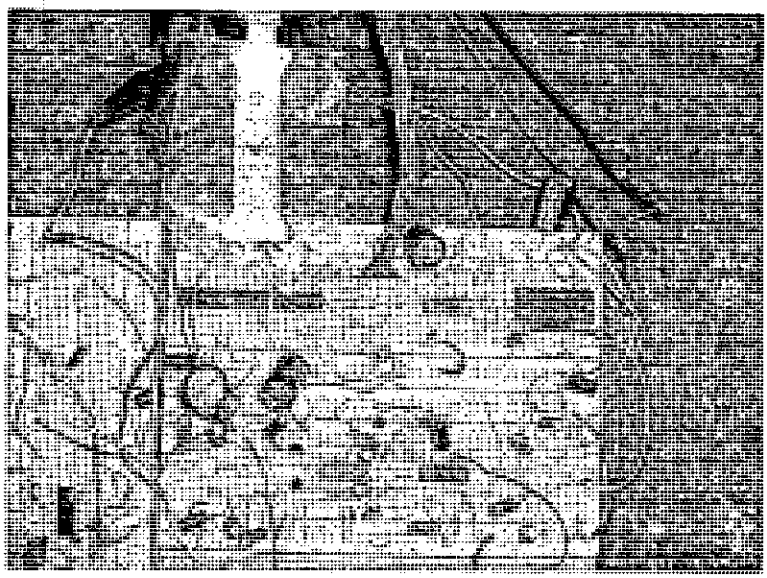

Figure A.7: Pulse oximetry Circuit

```
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help IPM2

% Last Modified by GUIDE v2.5 11-Dec-2008 17:53:59

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1; gui_State = struct('gui_Name',       mfilename,
...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @IPM2_OpeningFcn, ...
                   'gui_OutputFcn',  @IPM2_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
```

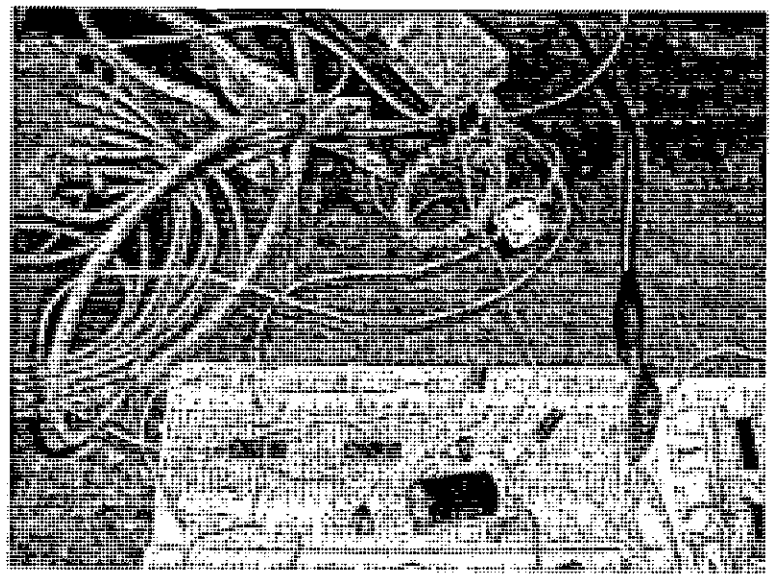

Figure A.8: ECG Monitoring Circuit

```
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT


% --- Executes just before IPM2 is made visible.
function IPM2_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to IPM2 (see VARARGIN)

% Choose default command line output for IPM2
handles.output = hObject;

% Update handles structure
guidata(hObject, handles);
```

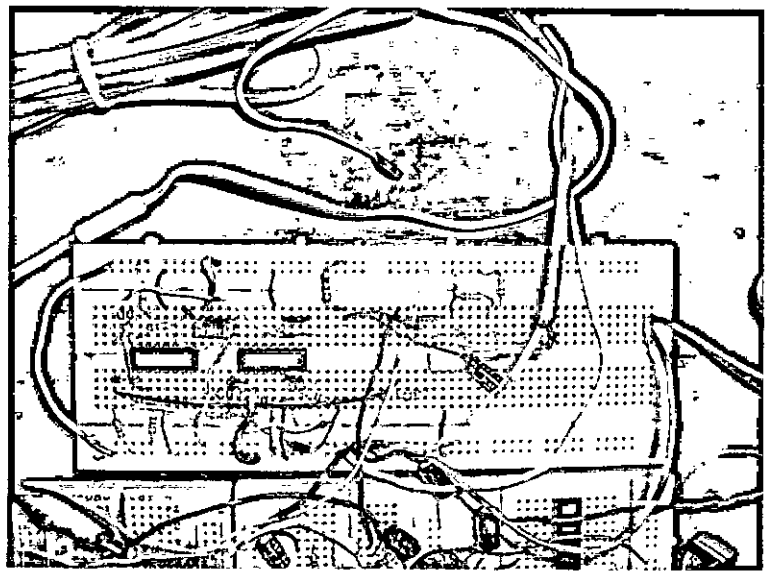

Figure A.9: Temperature Monitoring Circuit

```
% UIWAIT makes IPM2 wait for user response (see UIRESUME)
% uiwait(handles.figure1);


% --- Outputs from this function are returned to the command line.
function varargout = IPM2_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;


% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
```

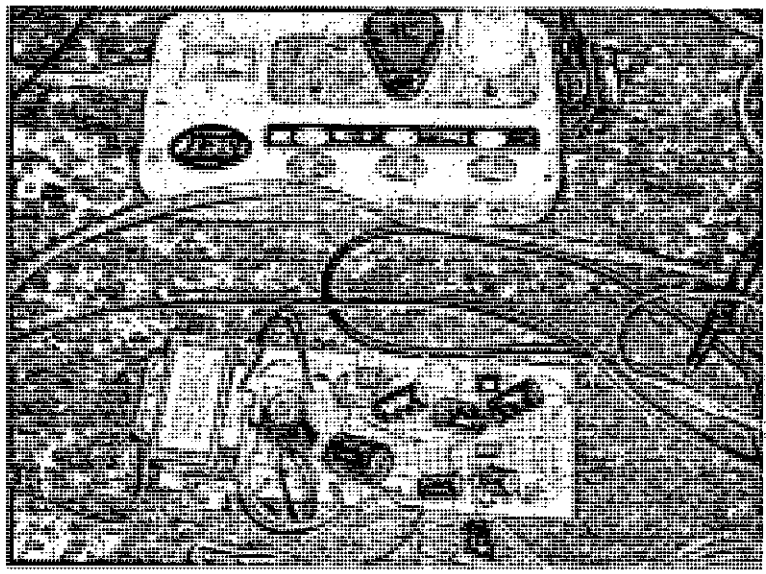

Figure A.10: Power Supply Circuit

```
% handles    structure with handles and user data (see GUIDATA)

[AI , duration] = Init_DAQ();

for i = 1 : 30
    data=take_signals(AI,duration);

    pulse_red = data(:,1);
    pulse_ir = data(:,2);
    ecgsignal = data(:,4);
    temperature_rawdata = data(:,3);


    [pulse_oxired,pulse_oxiir,Oxi_saturaton,pulse_rate]...
        = pulse_oxi(pulse_red,pulse_ir);
    set(handles.edit4,'String',num2str(Oxi_saturaton));
    set(handles.edit3,'String',num2str(pulse_rate));


    ecg_pulse = ecg_wave(ecgsignal);
```

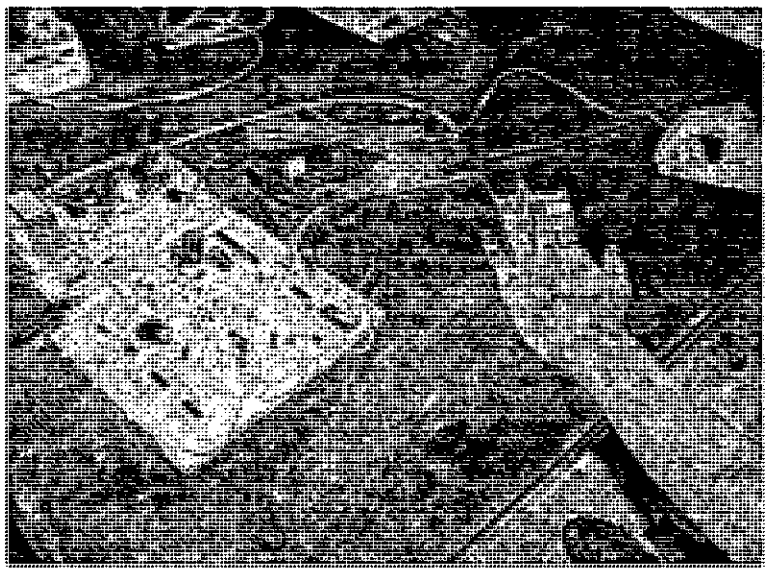

Figure A.11: Full Circuit

```
    temperature = temp_data(temperature_rawdata);
    set(handles.edit2,'String',num2str(temperature));

     subplot(3,1,1);plot(pulse_oxiir,'linewidth',2);
     drawnow;
     title('Pulse Oximetry Signal');
     pause(0.5);

     subplot(3,1,2);plot(ecg_pulse,'linewidth',2);
     drawnow;
     title('ECG Signal');
     pause(0.5);

end


function edit2_Callback(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
```

```
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit2 as text
%  str2double(get(hObject,'String')) returns contents of edit2 as a double

% --- Executes during object creation, after setting all properties.


function edit2_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),...
        get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end


% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton2 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
close all; clear all;

function edit3_Callback(hObject, eventdata, handles)
% hObject    handle to edit3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit3 as text
%  str2double(get(hObject,'String')) returns contents of edit3 as a double


% --- Executes during object creation, after setting all properties.
function edit3_CreateFcn(hObject, eventdata, handles)
```

```
% hObject    handle to edit3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),...
        get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end



function edit4_Callback(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit4 as text
%  str2double(get(hObject,'String')) returns contents of edit4 as a double


% --- Executes during object creation, after setting all properties.
function edit4_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),...
        get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

A.2.2 MATLAB Code for initializing of Advantech channel

```
function [AI , duration] = Init_DAQ()
```

```
% Purpose : MSC thesis

% Create and Initialize the analog input object.
% clear all; % to clear all previous objects
AI = analoginput('advantech','0');  % Type : daqhwinfo('advantech')
                                    % without semicolon.
                                    % to know the device ID.
                                    % Here the ID is '0'
                                    % Here the object is named AI.
                                    % You can give any name.
% To install the driver you must remember one thing:
% Step 1 : Insert the CD (For example of PCI1711L)
% Step 2 : Right button on My computer and click properties.
% Step 3 : Select -> hardware. Then select -> device manager.
% Step 4 : right button on ? marked PCI device.
% Step 5 : select -> update driver.Then select the location as the CD drive
pause(0.2);  % To Provide time to create the object.
addchannel(AI,10:13);% single or multiple contiguous channel may be created
                     % For contiguous channel example : addchannel(AI,1:6);


% Take samples for some duration and plot

duration = 5;   % second of acquisition
set(AI,'SampleRate',1000);   % Maximum sample rate is 100,000 sample/s
                             % with 16 bit resulation
ActualRate = get(AI,'SampleRate');
set(AI,'SamplesPerTrigger',duration*ActualRate);%to set Samples per trigger
set(AI,'TriggerType','Manual');  % To set trigger type as manual

AI.Channel(1).SensorRange = [-5 5]; AI.Channel(1).InputRange = [-5
5]; AI.Channel(2).SensorRange = [-5 5]; AI.Channel(2).InputRange =
[-5 5]; AI.Channel(3).SensorRange = [-5 5]; AI.Channel(3).InputRange
= [-5 5]; AI.Channel(4).SensorRange = [-5 5];
AI.Channel(4).InputRange = [-5 5];

%blocksize = get(AI,'SamplesPerTrigger');
%Fs = ActualRate;
% AI.Channel(1).SensorRange = [-10 10]; % maximum range is +/- 10
% AI.Channel(1).InputRange = [-10 10];  % By defalt it is 10
```

```
% start(AI);
% pause(0.1);
% trigger(AI);
% wait(AI,duration + 0.1);
% data = getdata(AI); % save to data. For single channel data is vector.
%                     % For multiple channel data is a matrix.
% plot(data);
```

A.2.3 MATLAB Code for taking signal:

```
function data=take_signals(AI,duration)

start(AI); pause(0.1);
 trigger(AI);
wait(AI,duration + 0.1);

data=getdata(AI);
```

A.2.4 MATLAB Code for processing pulse oximetry signal

```
function [pulse_oxired,pulse_oxiir,Oxi_saturaton,pulse_rate]...
    = pulse_oxi(pulse_red,pulse_ir)

f = [0 0.002 0.003 0.008 0.02 0.2 .3 .5 1]; m = [1 1 1 1 0 0 0 0 0];
b = fir2(1000,f,m,1000);

pulse_oxired_1 = filter(b,1,pulse_red); pulse_oxiir_1 =
filter(b,1,pulse_ir);

length_pulse_oxired_1 = length(pulse_oxired_1); length_pulse_oxiir_1
= length(pulse_oxiir_1);

pulse_oxired = pulse_oxired_1(800:(length_pulse_oxired_1-1));
```

```
pulse_oxiir = pulse_oxiir_1(800:(length_pulse_oxiir_1-1));


acpulse_oxired = (max(pulse_oxired)-min(pulse_oxired)) acpulse_oxiir
= (max(pulse_oxiir)-min(pulse_oxiir))

dcpulse_oxired =4 ; dcpulse_oxiir = 1.5;

R = ((acpulse_oxired/dcpulse_oxired)/(acpulse_oxiir/dcpulse_oxiir));

ratio_R = [0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 ...
    1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5];
Spo2 = [95 90 85 80 75 70 68 65 62 60 58 55 50 48 45 40 38 36 34 32
30];
% from Beer-Lambert Model

for i=1:20
        if(R<ratio_R(i))
            index = i;
            break;
        end
    i=i+1;
end

Oxi_saturaton = round(Spo2(index));

slopeSign = diff(pulse_oxired)>0; slopeSignChange =
diff(slopeSign)<0;
h = find(slopeSignChange) + 1; % finds all peaks

h(pulse_oxired(h,1) < 4.722) = [];

pulse_rate = round(length(h)*(60/(length(pulse_oxired)/1000)));
```

A.2.5 MATLAB Code for processing ECG signal:

```
function ecg_pulse = ecg_wave(ecgsignal)
```

```
f = [0 0.005 0.07 0.08 0.2 .3 .5 1]; m = [0 1 1 0 0 0 0 0]; b =
fir2(1000,f,m,1000);


ecg_pulse_f = filter(b,1,ecgsignal);

length_ecg_pulse_f = length(ecg_pulse_f); ecg_pulse =
ecg_pulse_f(700:length_ecg_pulse_f);
```

A.2.6 MATLAB Code for processing Temperature signal

```
function temperature = temp_data(temperature_rawdata)

mult_temp = 98/3.45; temperature =
round(mult_temp*mean(temperature_rawdata));
```

A.2.7 AVR Microcontroller Code:

Here Atmel AVR Series Microconller is used for producing required pulse in case of pulse oximeter.It is used, because it is easy to produce different types that means different pulses of different widths by using microcontroller.Microcontroller code is given below:

```
#include<avr\io.h>
#include<avr\interrupt.h>
int track;

ISR(TIMER1_COMPA_vect) {
   if(track == 1){
       PORTB &= ~(1 << PB3);
       OCR1A = 5000;
   }
   if(track == 2){
       PORTB |= (1 << PB2);
```

```
        OCR1A = 5060;
    }
    if(track == 3)
    {
        PORTB &= ~(1 << PB2);
        OCR1A = 10000;
    }
    if(track == 4){
        PORTB |= (1 << PB3);
        TCNT1 = 0;
        OCR1A = 60;
        track = 0;
    }
    track++;
}

void wave_init(void) {
    DDRB = 0xFF;
    PORTB |= (1 << PB3);
    PORTB &= ~(1 << PB2);
    TIMSK |= (1 << OCIE1A);
    TCNT1 = 0;
    OCR1A = 50;
    TCCR1B |= (1 << CS10);
}

int main(void) {
    track = 1;
    wave_init();
    sei();

    while(1)
    {
    }
}



%
```

A.3 Software for central ICU unit display

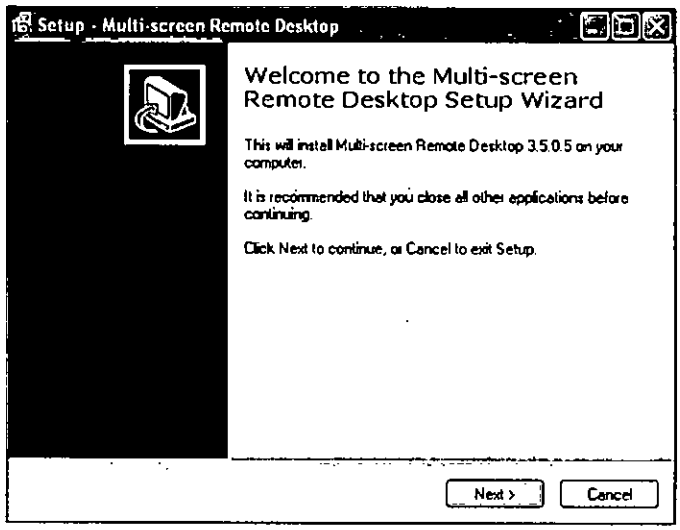

Figure A.12: Multiscreen Software

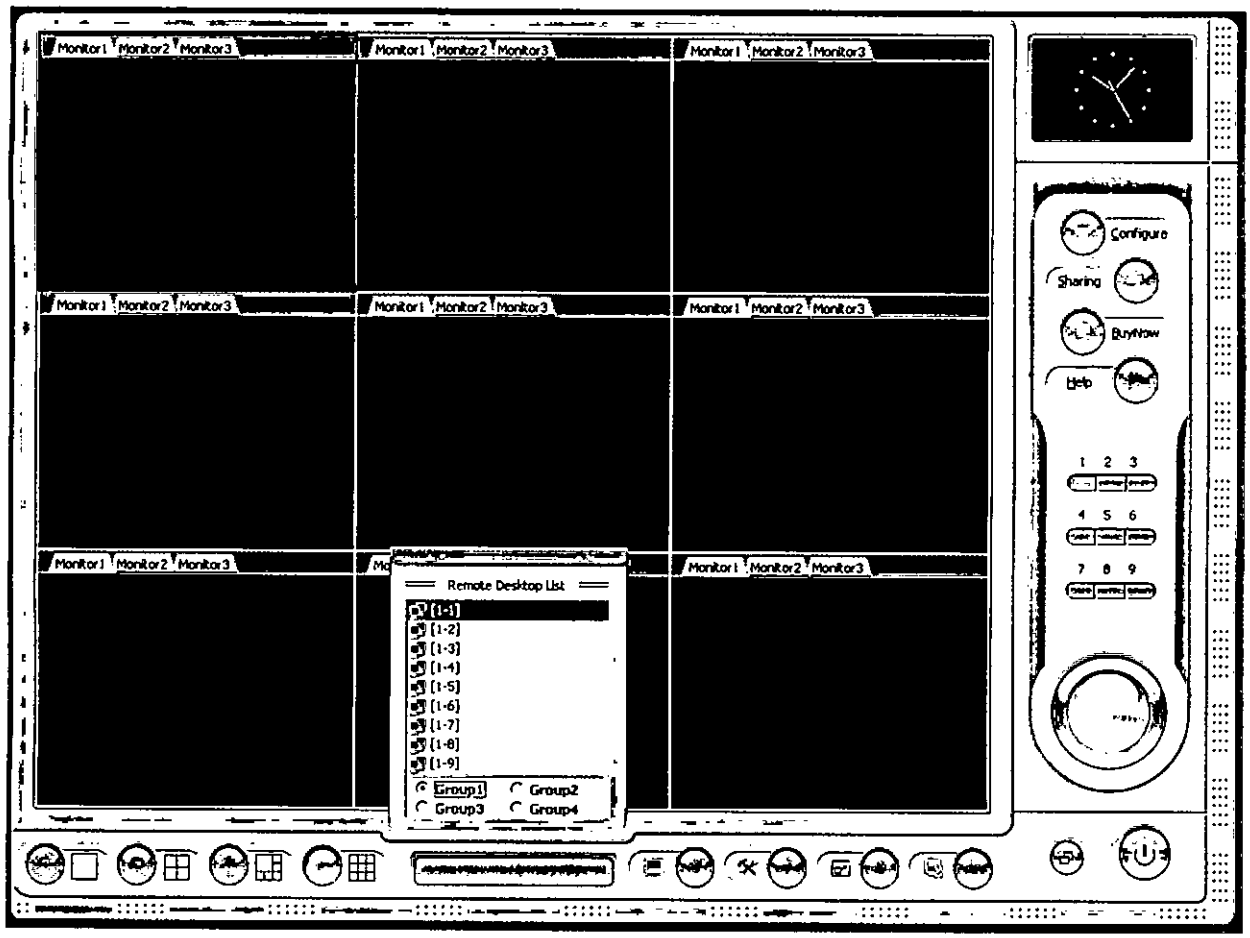

Figure A.13: Multiscreen

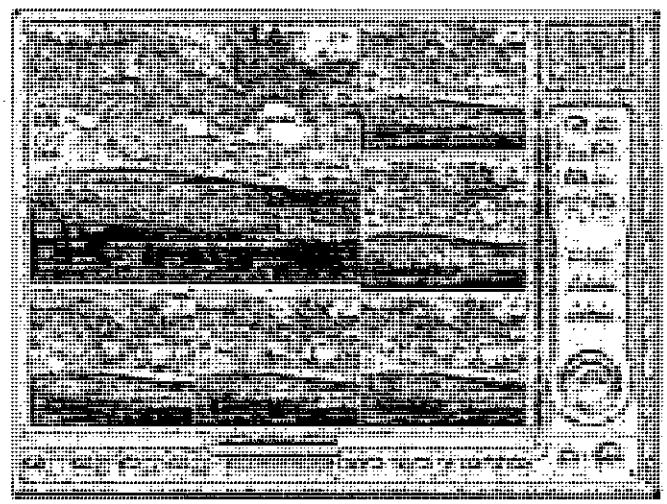

Figure A.14: Multiple screens in a single monitor

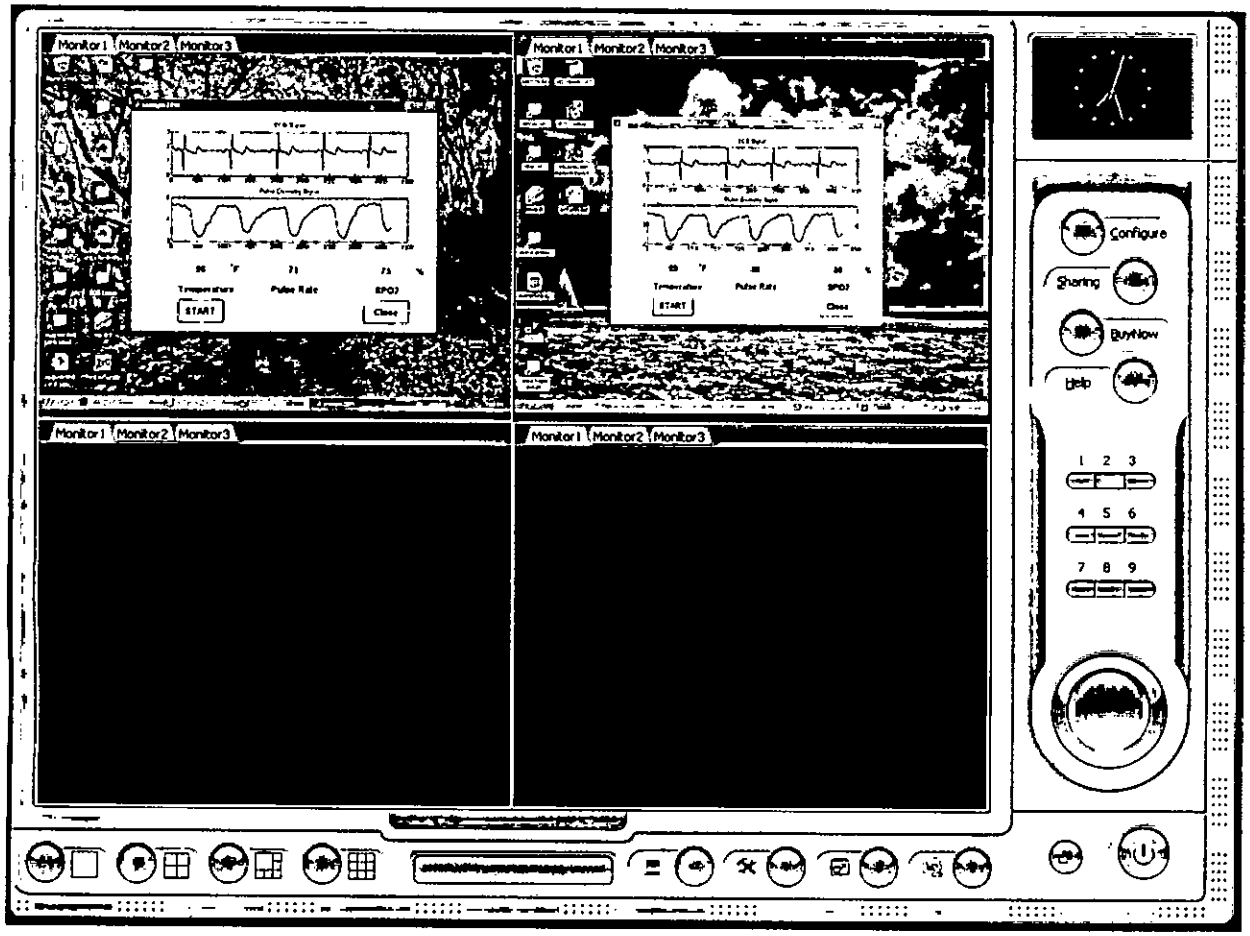

Figure A.15: Information of two patients in a single monitor

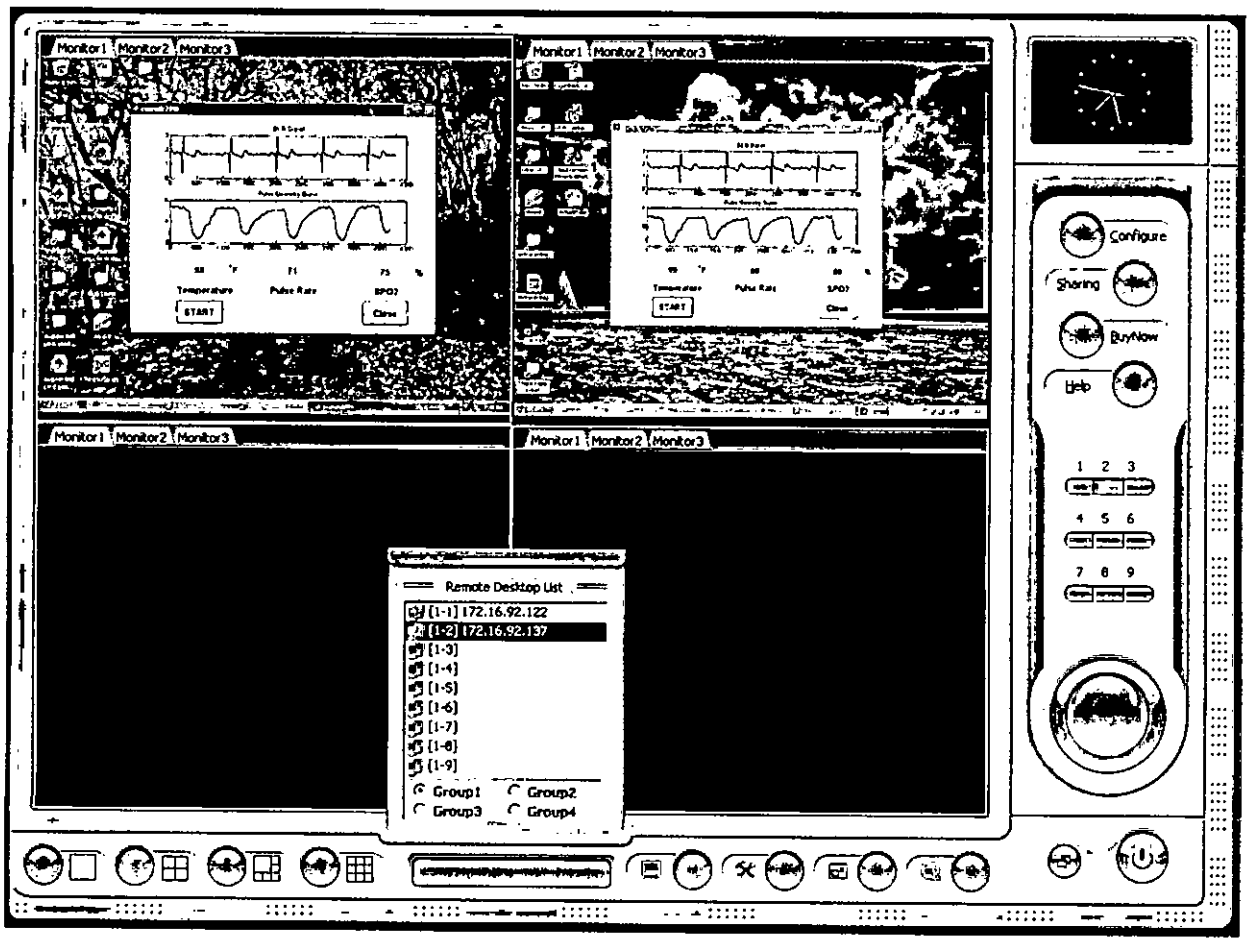

Figure A.16: Information of two patients in a single monitor with IP address of two PCs