Study and Analysis of Patient Monitoring compatibility with LabVIEW

A

Thesis report

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submitted by

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JULY 2010

DEDICATED TO MY

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CERTIFICATE

This is to certify that my work presented in this thesis entitled ***"Study and Analysis of patient monitoring compatibility with LabVIEW"*** *submitted in partial fulfillment of the requirement for the award of the degree of* ***Master of Engineering in Electronic Instrumentation and Control Engineering*** *at* ***Thapar University, Patiala****, is an original record under supervision and guidance of* ***Mr. Sunil Kumar Singla (Asst. Professor) and Mr. Vishal Preet Arora (Lecturer).***

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Abstract

Current patient monitoring systems are based on embedded systems hardware and employs complex software algorithms. Large numbers of preventable deaths occur in hospitals each year, due to adverse events such as cardiac arrest and unplanned admission into Intensive Care Units (ICUs) from other hospital wards. The development of such patient monitoring systems is time consumption. Patient monitoring using LabVIEW has been considered for improving the quality of healthcare to an increased number of patients, including those suffering from physical and cognitive disabilities. For such patients, there is a need to design a comprehensive LabVIEW patient monitoring system.

Development of patient monitoring system in LabVIEW saves a lot of time using its interactive GUI interface. LabVIEW offers design and analysis all together in one package. The system can be tested along with the design phase for its reliability. The design files can then be embedded directly in the micro-controller for ease of development. In this work the study has been presented to compare of the patient monitoring system implementation in LabVIEW with its equivalent general approach to hardware implementation.

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Chapter 1

Introduction

1.1 Introduction

One area of biomedical instrumentation that is becoming increasingly familiar to the general public is that of patient monitoring. Patients are being monitored such that a potential serious and life-threatening situation can be detected in time for medical doctors to take action. Patients suffering from for example heart deceases need often or continually monitoring of their cardiovascular system i.e. heart and blood function. To enhance the life quality of these patients monitoring units should be as mobile, discreet, and autonomic as possible such that patients will not feel a burden by being attached to units making a regular daily life impossible. They should also feature wireless communication for transmission of data for evaluation by a professional and send out emergency signals. Another example, where mobile and autonomic solutions would be to great benefit, is for people involved in traumatic accidents. In this case rescuers attach monitoring units to the wounded patients such that their condition can be followed during transport to hospital or by doctors ready to receive the patient at the hospital [1].

1.1.1 Patient Monitoring Systems (PMS)

Patient monitoring is the routine collection, compilation and analysis of data on patients at every visit over time, using information taken directly from paper forms or entered into a computer [2]. Patient monitoring is often referred to as 'patient tracking'. Patient management is clinical team action to provide care and treatment on behalf of and in consultation with an individual patient over time (assisted by written records). Patient management may also be referred to as 'clinical management' or 'clinical monitoring'. Programme monitoring is the routine tracking of priority information about a programme, including its outputs (e.g. number of people served) and outcomes. Monitoring at the health centre level requires many types of information, including summarized patient information.

The Patient Monitoring System (PMS) is a very critical monitoring systems, it is used for monitoring physiological signals including Electrocardiograph (ECG), Respiration, Invasive and Non-Invasive Blood Pressure, Oxygen Saturation in Human Blood (SpO_2), Body Temperature and other Gases etc. In PMS, the multiple sensor and electrodes is used for receiving physiological signals like as ECG Electrodes, SpO_2 Finger Sensor, Blood Pressure Cuff and Temperature Probe to measure the physiological signals. During treatment, it is highly important to continuously monitor the vital physiological signs of the patient. Therefore, patient monitoring systems has always been occupying a very important position in the field of medical devices. In this work ECG, SpO_2 and respiration are used as parameters for patient monitoring system and logic or program is developed using LabVIEW 8.5. The continuous improvement of technologies not only helps us transmit the vital physiological signs to the medical personnel but also simplifies the measurement and as a result raises the monitoring efficiency of patients.

1.1.2 Patient Monitoring as a process

Patient monitoring is a systematic process of observation, interpretation and evaluation of the patient’s condition with the goal to bring the condition toward or keep it at what the clinician thinks is optimal for the patient. This optimum is usually operationally defined as a prescribed range for certain variables, e.g., “the heart rate should remain between 60 and 80 beats per minute.” Thus, patient monitoring is a feedback process. The diagnosis is not a once-only event; it is required continually, because the patient’s condition is or could become unstable [3].

Patient monitoring predominantly takes place in several specialized units of a hospital. In the 1960s, external defibrillation devices became available. They made it possible to save the victims of a sudden heart attack without an emergency operation, which was required before that time to provide access to the heart. If these patients were located throughout the hospital, assistance often came too late. More success came about when all patients for who sudden heart standstill threatened were concentrated in one unit where the necessary equipment and trained personnel were constantly available.

The coronary care unit (CCU) came into existence. The first CCUs were designed for rapid defibrillation in event of a heart attack and mainly relied on ECG monitoring. Soon it was discovered that heart standstill is often preceded by arrhythmias (heart rhythm irregularities), and it was also discovered that therapies that prevented arrhythmias also prevented heart attacks. As soon as the types of arrhythmias that precede standstill were identified and appropriate therapies were designed, the emphasis in the CCU shifted to prevention. Monitoring became less critical and was concentrated in one central station, where the ECGs of all patients are presented and where automatically generated alarms sound when rhythm irregularities are discovered.

The intensive care unit (ICU) is meant for critically ill patients who require more care than is available elsewhere. These patients form a more heterogeneous group than those in the CCU and thus require a larger variety of measurement devices. In large hospitals, more specialized intensive care units exist, where patients are more homogeneous and where monitoring devices thus can be better standardized. In ICU patients, the respiratory and circulatory systems must, due to their time-critical nature, be monitored most frequently and intensively.

The operating room (OR) is the domain of surgeon and anesthetist. It is the anesthetist's task to keep the patient in such a condition that the patient can success-fully undergo an operation by the surgeon. In major operations, this condition implies painlessness, unconsciousness, amnesia and muscle relaxation. The last is required in order to prevent reflex movements, but it also means that the patient's respiratory muscles do not function anymore and that the patient must be artificially ventilated. Elimination of the patient's consciousness and reactions to pain require an "external intelligence," that of the anesthetist, to function as a "patient monitor," usually supported by a large variety of measurement equipment.

1.2 Classes of Patient Monitoring System

In recent years, the technological improvements pertaining to measurement and information transmission has led to more comprehensive performance and stable quality of the patient monitoring products.

In the past, the dominant products manufactured by medical device manufacturers are mainly those for single parameter measurement. Nowadays however, a multi-parameter patient monitor is commonly used. Now in current industry the patient monitoring systems is available in two classes [4].

1.2.1 Single Parameter Patient Monitoring Systems

Single parameter monitoring systems are capable for measuring only single physiological sign. It is quite old technology but nowadays, it is continue to be used in developing countries like in India, Pakistan, Bangladesh, etc. The single parameter monitoring systems is available in very low cost and it is very easy to manufacturer and maintain.

The single parameter monitoring system is available for measuring blood pressure of a human body, ECG (Electrocardiograph) monitor, SpO_2 (Oxygen Saturation in Blood) monitor etc.

1.2.2 Multi Parameters Patient Monitoring Systems:

A multi-parameters Patient Monitoring System (PMS) is used for multiple critical physiological signs of the patient to transmit the vital information like Electrocardiograph, Respiration Rate, Blood pressure etc. Therefore, multi parameter PMS has always been occupying a very significant position in the field of medical devices. Due to continuous improvement of technologies in PMS help to put out the vital multiple physiological measurements signs to the medical personnel. The latest PMS simplifies the measurement of physiological sign and increases the monitoring effectiveness. So nowadays PMS is very flexible and it can monitor multiple physiological signals in a single monitoring system. In developed part of the world, multi parameter monitors have supplanted them, in some cases because of statutory requirements (for example the US FDA) and also because if a clinician requires to monitor one channel then other channels are also needed to complement the data and get a fuller picture of the patient's vital signs (for example: ECG+SpO_2+Respiration or SpO_2+ NIBP or ECG+SpO_2+Resp or ECG+SpO2+Resp+NIBP+Temp+Pressure with or without $EtCO_2$). The present work falls under this category.

1.3 Monitoring in the present

Guidelines relating to contain the rules of monitoring for most of the specialties are currently set by medical associations (a medical association is “an organization of practitioners who judge one another as professionally competent and who have banded together to perform social functions which they cannot perform in their separate capacities as individuals”). The Hungarian Society of Anesthesiology and Intensive Care laid down the conditions of minimal monitoring requirements for anesthesiology and intensive care in 1994. Continuous ECG registration, measurement of blood pressure, pulse-oximetry and capnography are obligatory when an operation is performed under general anesthesia [5]. The minimally required equipment for a bed in an intensive care unit has likewise been specified; legislationon the principle was passed in 2004. The European Society of Intensive Care Medicine published the European standards concerning monitoring in intensive care under the title “Recommendations on Optimal Requirements for Intensive Care Departments” (see Intensive Care Med 23:226–32, 1997). The ASA(American Association of Anesthesiologists) guidelines state that all surgical interventions require the possibility of the invasive or noninvasive measurement of blood pressure, ECG, capnography (if an endotracheal tube or a laryngeal mask is applied) pulse-oximetry, appropriate lighting to visualize an exposed portion of the patient, and an apparatus with which to measure temperature.

The use of integrated monitor sand other patient-guarding equipment is becoming more frequent (these monitors check pressure, temperature, etc. in parallel).

- Many special-purpose monitors are available (e.g. gastrointestinal tonometers).

- There are many problems with existing monitors (e.g. cost, complexity, reliability and artifacts), but in fact many disorders (e.g. hypoxia, air emboli, complications during surgery or drug overdoses) are not readily detectable without high-tech monitors.

1.4 Bedside Patient Monitoring system

The advent of microcomputers has marked the beginning of a fundamentally new direction in patient monitoring systems. Such systems are intended to replace the traditional monitoring devices with a single general purpose unit capable of recognizing the nature of the signal source and processing them appropriately. The hardware responsible for physiological signal analysis, information display and user interaction is actually a set of firmware modules implemented in terms of microcomputer program [6]. The firmware gives the systems its functional personality and the usual switches, knobs, dials and meters can be replaced by a touch- sensitive character display.

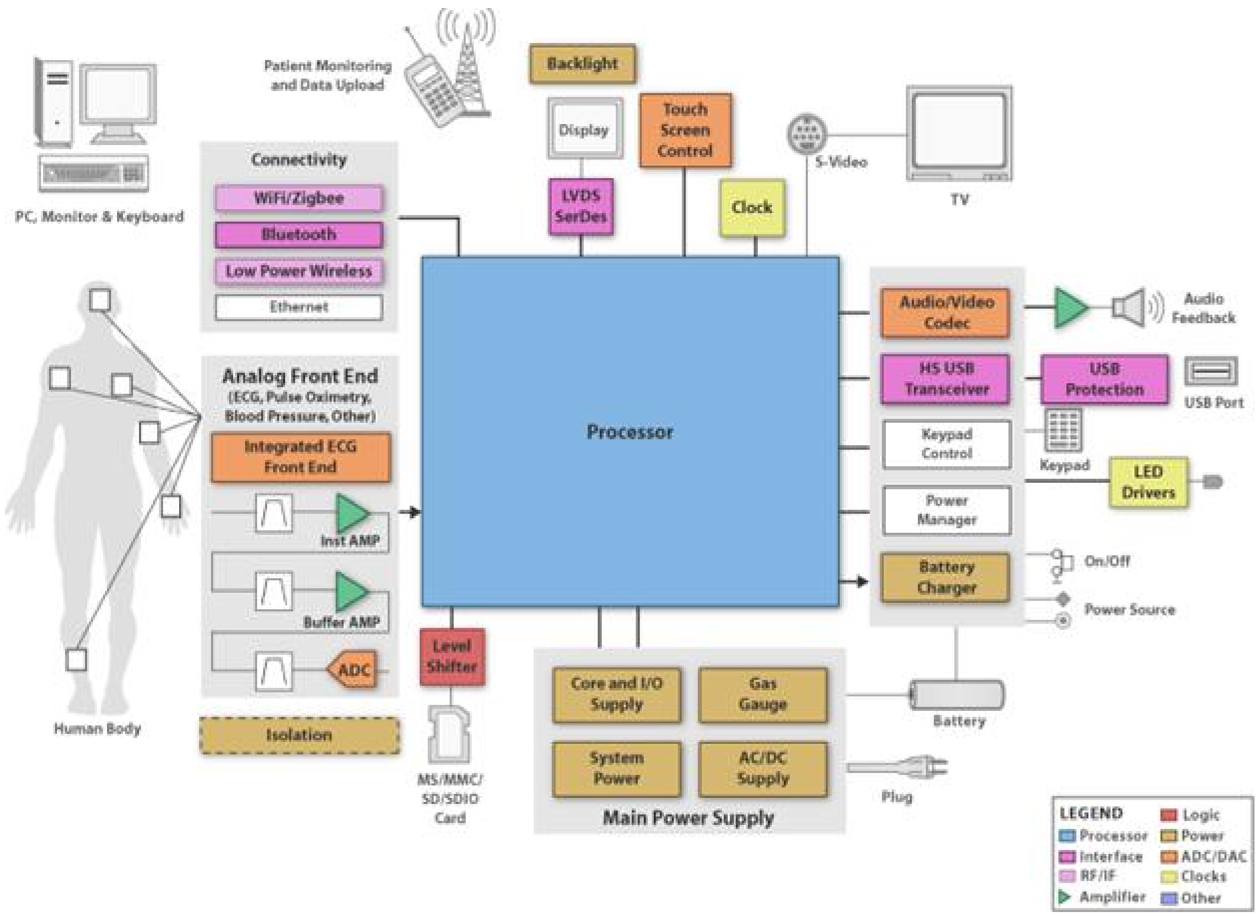


Figure 1.1: Block diagram of Patient monitoring system based on Microprocessor

A microprocessor based bedside patient monitoring instrument is shown in figure 1.1. The system is designed to display electrocardiogram, heart rate with high and low alarms, pulse rate, dynamic pressure or other waveforms received from external preamplifiers. It also gives immediate and historical data on the patient for trend information on heart rate, temperature, and systolic and diastolic blood pressure. The system basically consists of three circuit blocks: Preamplifier section, Logic boards and Display part. The preamplifiers incorporate patient isolation circuits based on optical couplers. The ECG waveform has facilities for lead-off detection, ‘pacer’ detection and quick recovery circuit for overload signals. Various amplified signals are carried to a multiplexer and then to an analog to digital converter, included in the logic board. The central processing unit along with memory gives the X and Y output for the CRT display. The character generator output is mixed with the Y output for the numeric display on the

CRT. The alarm settings, sections switches for different parameters and the defibrillator synchronization system communicate with the CPU. The alarm signals are also initiated under its control.

Rapid growth of LabVIEW in following years will allow a range of new medical applications that will significantly improve the quality of health care. Wider acceptance of physiological monitoring hardware will allow development of devices based on natural human-computer interfaces.

1.5 Patient Monitoring Displays

An important feature of any patient monitoring system is its ability to display the physiological waveforms being monitored. Clear, faithful reproduction of the ECG, SpO_2 and respiration and other variables enable the medical staff to periodically check a patient's progress and make vital decisions at time of crisis.

Figure1.2: Traditional patient monitor

Although paper chart recording are often used to provide a permanent record of the data, the principal display device for patient monitoring is the Cathode ray tube. CRT provides a continuous, current presentation of one or more waveforms from a given patient or simultaneous waveforms from several patients [7]. Here LabVIEW front panel is used as patient monitoring display.

1.6 Requirement Criteria

Before we can analyze the implementation of patient monitoring system in LabVIEW, it is require to list out the requirement criteria which we have to consider during the process.

I. The functionality of patient monitoring system should be embedded completely in LabVIEW without compromising any functional block

II. There should be no dead time in the transfer of data

III. The display should be interactive and easy to use

IV. The signal to noise ratio should be better or at least at par with the current patient monitoring systems

V. The system should offer easy and quick design and testing process

VI. It should offer better control features

Based on the analysis and the understanding of different blocks of the patient monitoring systems [8]-[9]-[10], we implemented the same blocks in LabVIEW to confirm the portability of the concept and the result is shown in the following table 1.1.

Devices	Hardware Based	LabVIEW
ADC	Applicable	NI-DAQ Card incorporates the ADC
Controller Board	Applicable	It is not required because LabVIEW, with its graphical interface ,with the PC offers all the microcontroller functionality in itself
Data Storage	Applicable	The memory within the PC can be used by LabVIEW for storing the required data
Display	Applicable	LabVIEW offers different graphical display to choose from

Table 1.1: Comparison table for portability of blocks of patient monitoring system

1.7 Problem Definition

Patient monitoring is a major problem in modern healthcare, and there is no widely accepted approach to dealing with it. When patients exhibit an unexpected therapeutic response to a prescription drug regimen, physicians often have great difficulty discerning whether the response is due to non-response, which means that the patient's body is not reacting to the medication, or to non-compliance (Burnier, 2003). If a patient was not recovering from a bout of pneumonia for example, his or her physician would have to decide how to adapt his therapeutic approach. The physician may conclude that his patient is non-responsive to the medication he originally prescribed, and may thus choose to change the prescription. If the patient's enduring pneumonia symptoms were actually due to non-compliance as opposed to non-response, this adaptation of the prescription would be unnecessary and could potentially present a higher risk of side effects, among other possible consequences. Either way, as exemplified, it is extremely difficult for a physician to distinguish between non-response and non-compliance. As a result, patient responses due to non-compliance are often misinterpreted and attributed to non-response.

Electronic monitoring, which was introduced in 1986, is a relatively new methodology that has been championed by some medical experts as a promising solution to the problem of non-compliance (Claxton, 2001). Electronic monitoring uses computer technology, in place of the pencil and paper approach many physicians currently employ, to monitor and measure patient compliance.

1.8 Objectives

The objective of patient monitoring is to have a quantitative assessment of the important physiological variables of the patients during critical periods of their biological functions. The system designed fulfills the project objectives. The system consists of successful interfaced of the peripherals. The hardware phase becomes time consuming and complex when the system uses components which are programmable. The system program successfully met the project objectives that are relevant to software component. The program is user friendly and produces consistent and relevant patient health risk evaluation and risk recommendations about the user. The following attributes and calculations patient risk analysis was successfully performed and recommendations offered. The whole work is focused on the following objectives:

To develop computer based patient monitoring system i.e. the proposed system was constructed to perform and gather the required data from the Polyrite Recorder to computer as the main input data required are ECG, Respiration and Spo2 signal. The software on PC uses the data and acquires it, to perform simple calculations to determine the patient monitoring.

Chapter 2

Literature Survey

2.1 Introduction

Rapid rise in the size of aging population combined with the rise in the health care costs is demanding cost effective and reliable patient monitoring systems. Monitoring patients and maintaining their health records is important for effective disease and health management. Technologies that support effective patient monitoring will not only reduce burden on the existing healthcare system but also mitigate healthcare cost impact on the overall economy of the nation [11].

2.2 Patient Monitoring Parameters

In order to decide on what to monitor in a specific patient, it is important to know what can be monitored. The following list is far from complete; new devices appear continually. Many devices, however, do not live up to expectations. They may be less accurate than practice requires, or demand more of the clinician’s time than the extra information that they offer warrants. The following parameters can be measure [12]:

- Circulatory: Electrocardiogram (ECG) and derived variables; blood gases, blood electrolytes and variables derived from blood properties, e.g., haematocrit and thromboelastogram (TEG); transesophageal echocardiogram (TEE); non-invasive arterial blood pressure; invasive arterial, central venous, and pulmonary artery and wedge pressures; oxygen saturation (SaO_2); cardiac output (CO).

- Respiratory: Airway pressure and derived variables; airway flow and derived variables; gas concentrations of CO_2, O_2, N_2 several anesthetic agents and derived variables
- Oxygenation: To ensure adequate oxygen concentration in the inspired gas and in the blood. Measure the oxygen concentration in the breathing system. Visual access to the patient must allow assessment of skin colour. Pulse oximetry is encouraged.

2.2.1 Respiration

Respiration is the process by which human beings and other living things obtain and use oxygen [13]. Except for certain microorganisms, all living things require oxygen to live. Respiration also involves the elimination of carbon dioxide, a gas produced when cells use oxygen. Respiration may be divided into three phases:

- External respiration,
- Internal respiration, and
- Cellular respiration.

In external respiration, or breathing, a plant or animal takes in oxygen from its environment and releases carbon dioxide. In internal respiration, oxygen is carried to the cells of the organism and carbon dioxide is carried away from them. In cellular respiration, oxygen is used in chemical reactions within the cells. These reactions release energy and produce carbon dioxide and water as waste products. Organisms carry out external respiration in various ways, depending on their size and environment. For example, single-celled organisms, such as diatoms, and amoebas, exchange oxygen and carbon

Humans need a continuous supply of oxygen for cellular respiration, and they must get rid of excess carbon dioxide, the poisonous waste product of this process. Gas exchange supports the supports this cellular respiration by constantly supplying oxygen and removing carbon dioxide. The oxygen we need is derived from the Earth's atmosphere, which is 21% oxygen. This oxygen in the air is exchanged in the body by the respiratory surface. In humans the alveoli in the lungs serve as the surface for gas exchange.

Gas exchange in humans can be divided into five steps:

1. Breathing
2. External Respiration
3. Gas Transport
4. Internal Respiration
5. Cellular Respiration

Breathing consists of two phases, inspiration and expiration. During inspiration the diaphragm and the intercostal muscles contract. The diaphragm moves downwards increasing the volume of the thoracic (chest) cavity, and the intercostal muscles pull the ribs up expanding the rib cage and further increasing this volume. This increase of volume lowers the air pressure in the alveoli to below atmospheric pressure. Because air always flows from a region of high pressure to a region of lower pressure, it rushes in through the respiratory tract and into the alveoli. This is called negative pressure breathing, changing the pressure inside the lungs relative to the pressure of the outside atmosphere. In contrast to inspiration, during expiration the diaphragm and intercostal muscles relax. This returns the thoracic cavity to its original volume, increasing the air pressure in the lungs, and forcing the air out [14].

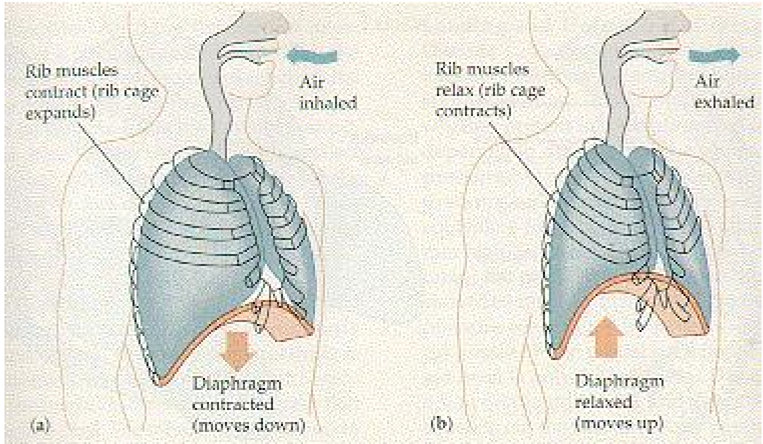


Figure: 2.1 Breathing Process

When a breath is taken, air passes in through the nostrils, through the nasal passages, into the pharynx, through the larynx, down the trachea, into one of the main bronchi, then into smaller broncial tubules, through even smaller broncioles, and into a microscopic air sac called an alveolus. It is here that external respiration occurs. Simply put, it is the exchange of oxygen and carbon dioxide between the air and the blood in the lungs. Blood enters the lungs via the pulmonary arteries. It then proceeds through arterioles and into the alveolar capillaries. Oxygen and carbon dioxide are exchanged between blood and the air. This blood then flows out of the alveolar capillaries, through venuoles, and back to the heart via the pulmonary veins. Figure 2.1 shows the breathing process.

2.2.2 Gas Transport

If 100mL of plasma is exposed to an atmosphere with a pO_2 of 100mm Hg, only 0.3mL of oxygen would be absorbed. However, if 100mL of blood is exposed to the same atmosphere, about 19mL of oxygen would be absorbed. This is due to the presence of haemoglobin, the main means of oxygen transport in the body. The respiratory pigment haemoglobin is made up of an iron-containing porphyron, haem, combined with the protein globin. Each iron atom in haem is attached to four pyrole groups by covalent bonds. A fifth covalent bond of the iron is attached to the globin part of the molecule and the sixth covalent bond is available for combination with oxygen. There are four iron atoms in each haemoglobin molecule and therefore four haem groups.

2.2.2.1Oxygen Transport

In the loading and unloading of oxygen, there is co-operation between these four haem groups. When oxygen binds to one of the groups, the others change shape slightly and their attraction to oxygen increases. The loading of the first oxygen, results in the rapid loading of the next three (forming oxyhaemoglobin). At the other ends, when one group unloads its oxygen, the other three.

Rapidly unload as their groups change shape again having less attraction for oxygen. This method of co-operative binding and release can be seen in the dissociation curve for haemoglobin. Over the range of oxygen concentrations where the curve has a steep slope, the slightest change in concentration will cause haemoglobin to load or unload a substantial amount of oxygen. Notice that the steep part of the curve corresponds to the range of oxygen concentrations found in the tissues. When the cells in a particular location begin to work harder, e.g. during exercise, oxygen concentration dips in that location, as the oxygen is used in cellular respiration. Because of the co-operation between the haem groups, this slight change in concentration is enough to cause a large increase in the amount of oxygen unloaded.

As with all proteins, haemoglobin's shape shift is sensitive to a variety of environmental conditions. A drop in pH lowers the attraction of haemoglobin to oxygen, an effect known as the Bohr shift. Because carbon dioxide reacts with water to produce carbonic acid, an active tissue will lower the pH of its surroundings and encourage haemoglobin to give up extra oxygen, to be used in cellular respiration. Haemoglobin a notable molecule for its ability to transport oxygens from regions of supply to regions of demand.

2.2.2.2 Carbon Dioxide Transport

Out of the carbon dioxide released from respiring cells, 7% dissolves into the plasma, 23% binds to the multiple amino groups of haemoglobin (Carboxyhaemoglobin), and 70% is carried as bicarbonate ions. Carbon dioxide created by respiring cells diffuses into the blood plasma and then into the red blood cells, where most of it is converted to bicarbonate ions. It first reacts with water forming carbonic acid, which then breaks down into H^+ and CO_3^-. Most of the hydrogen ions that are produced attach to haemoglobin or other proteins.

2.2.3 Internal Respiration

The body tissues need the oxygen and have to get rid of the carbon dioxide, so the blood carried throughout the body exchanges oxygen and carbon dioxide with the body's tissues. Internal respiration is basically the exchange of gasses between the blood in the capillaries and the body's cells.

2.2.3.1 Airways

During respiration, the air is drawn in through the mouth or nose into the body. When respired through the nose, the air is at first cleaned, moistened and warmed by the mucosae and hairs. Subsequently, the air passes along the pharyngeal cavity, larynx and vocal cords to the windpipe (trachea). The windpipe passes on to both branches of the bronchi, which branches out again (bronchioles). At the end, it reaches the alveoli in the lungs, whose fine membranes transfer the oxygen into the capillary vessels and in return releases carbon dioxide from the blood into the lungs.

2.2.4 Respiratory mechanics

During inhalation (inspiration), the volume of the ribcage increases by the constriction of the chest muscles and the diaphragm. Thereby, the lungs expand causing a low pressure, and air flows into the lungs. The pleurae (located between the lungs and the ribcage) and the diaphragm respectively allow the lungs to expand with the ribcage. The membrane surrounding the lungs and on the inner side of the ribcage (pleura) as well as on the diaphragm and the pleura parietalis stick to each other like glass plates with a liquid in between. On the one hand, this enables the repositioning of the concerned structures and on the other, respectively hinders a collapse of the lung during low pressure and enables its expansion. During exhalation (expiration), the lungs constrict again causing high pressure and the air goes out through the airways.

2.2.5 Respiratory control

The respiration is controlled by the brain and the breathing center in the medulla oblongata. The reaction of the chemo receptors to the carbon dioxide content (and/or carbon dioxide partial pressure) of the blood is the crucial factor. If it rises above a certain threshold value, the stimulus to breathe is initiated. Receptors, which react to the pH value of the arterial blood as well as to the lack of oxygen (hypoxia), have only a secondary significance as a stimulus to breathe.

2.2.6 Measurement

The breathing rate and the tidal volume serve as measurements of the breathing regulation. The breathing rate, which is the number of the inhalation and exhalation of air, amounts to

- about 12 per minute in adults
- about 20 per minute in young people

- about 30 per minute in small children
- about 40 per minute in babies.

2.2.7 Lung Volumes

Of primary importance to lung functioning is the movement and mixing of gases within the respiratory system. Depending on the anatomic level under consideration, gas movement is determined mainly by diffusion or convection.

Without the thoracic musculature and rib cage, as mentioned above, the barely inflated lungs would occupy a much smaller space than they occupy in situ. However, the thoracic cage holds them open. Conversely, the lungs exert an influence on the thorax, holding it smaller than should be the case without the lungs. Because the lungs and thorax are connected by tissue, the volume occupied by both together is between the extremes represented by relaxed lungs alone and thoracic cavity alone. The resting volume VR, then, is that volume occupied by the lungs with glottis open and muscles relaxed.

Among the basic pulmonary tests are those designed for determination of lung volumes and capacities. These parameters, which are a function of an individual's physical characteristics and the condition of his breathing mechanism, are given in Figure2.2. Lung volumes greater than resting volume are achieved during inspiration. Maximum inspiration is represented by Inspiratory Reserve Volume (IRV). IRV is the maximum additional volume that can be accommodated by the lung at the end of inspiration. Lung volumes less than resting volume do not normally occur at rest but do occur during exhalation while exercising (when exhalation is active). Maximum additional expiration, as measured from lung volume at the end of expiration, is called Expiratory Reserve Volume (ERV). Residual volume is the amount of gas remaining in the lungs at the end of maximal expiration [15].

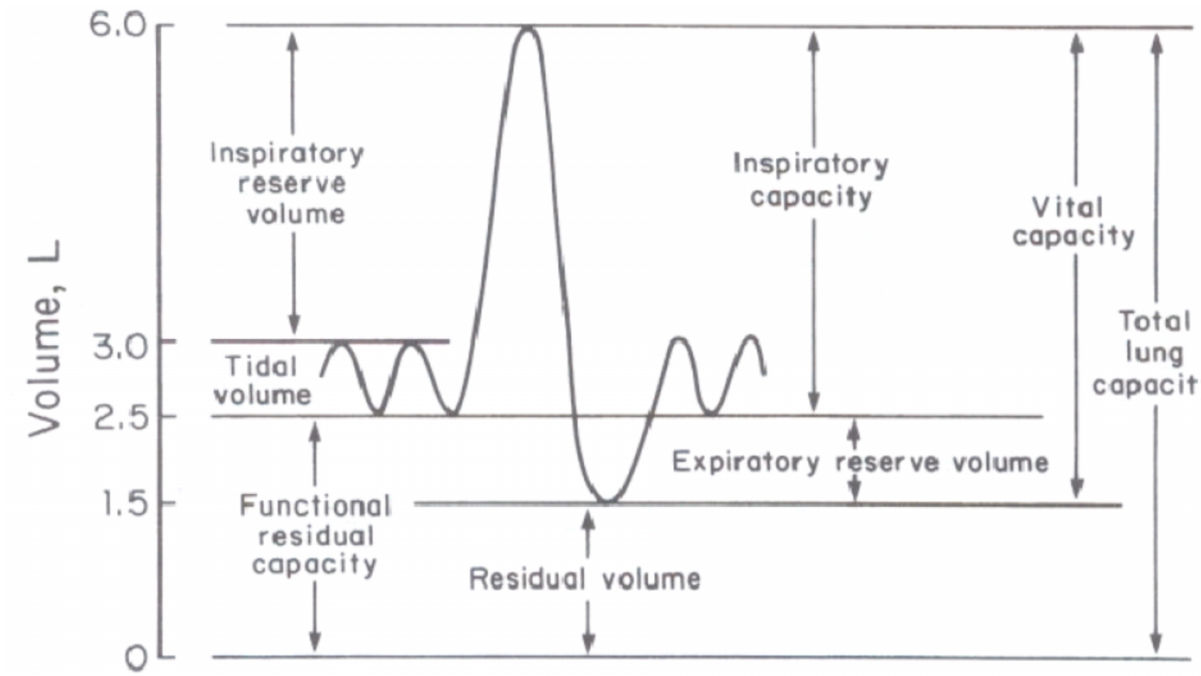


Figure 2.2: Lung volumes and capacities

Tidal volume (*VT)* is normally considered to be the volume of air entering the nose and mouth with each breath. Alveolar ventilation volume, the volume of fresh air that enters the alveoli during each breath, is always less than tidal volume. The extent of this difference in volume depends primarily on the anatomic dead space, the 150- to 160-ml internal volume of the conducting airway passages. The term dead is quite appropriate, since it represents wasted respiratory effort; i.e., no significant gas exchange occurs across the thick walls of the trachea, bronchi, and bronchiolus. Since normal tidal volume at rest is usually about 500 ml of air per breath, one can easily calculate that because of the presence of this dead space, about 340 to 350 ml of fresh air actually penetrates the alveoli and becomes involved in the gas exchange process. An additional 150 to 160 ml of stale air exhaled during the previous breath is also drawn into the alveoli [16].

The term volume is used for elemental differences of lung volume, whereas the term *capacity*is used for combination of lung volumes. Figure illustrates the interrelationship between each of the following lung volumes and capacities [17]:

1. Total lung capacity (TLC): The amount of gas contained in the lung at the end of maximal inspiration.

2. *Forced vital capacity* (FVC): The maximal volume of gas that can be forcefully expelled after maximal inspiration.

3. *Inspiratory capacity* (IC): The maximal volume of gas that can be inspired from the resting expiratory level.

4. *Functional residual capacity* (FRC): The volume of gas remaining after normal expiration. It will be noted that functional residual capacity (FRC) is the same as the resting volume. There is a small difference, however, between resting volume and FRC because FRC is measured while the patient breathes, whereas resting volume is measured with no breathing. FRC is properly defined only at end-expiration at rest and not during exercise.

Equivalent model of respiratory mechanics can be represented using the following equations [18]:

$$\Delta p_{MUS} + (p_{PL} - p_{BS}) = \frac{1}{Cst_W} v_L \qquad \text{Equation 2.1}$$

$$p_{AWO} - p_{PL} = \frac{1}{Cst_L} v_L + R_{AW} \dot{v}_L \qquad \text{Eqation2.2}$$

Where:

- Δp_{MUS} =Representation of the average force per unit area on the chest wall, which would cause the same movements produced by the active contraction of the respiratory muscles during breathing (muscles pressure difference)
- p_{PL} =Representation of the average force per unit area acting on the pleural surfaces (inter pleural pressure)

- $p_{BS)}$ =Hydrostatic pressure acting on the body surface, except at the airway opening
- $v_{L=}$Volume of the gas space in the system, assumed to be entirely within the lungs and airways
- p_{AWO} =Hydrostatic pressure at the airway opening
- Cst_{w} =Chest-wall static compliance
- Cst_{L} =Pulmonary static compliance
- R_{AW} =Airway resistance
- $\dot{v}_{L}$ =Instantaneous rate of volume change

Among the above mentioned variables, only a very limited are measured directly. These include volume flow of gas through the mouth and nose, pressure at the mouth and nose and body surface; concentrations of various gases in gas mixtures passing through the airway opening and in discrete samples of blood in vitro and temperature. The values of all other variables are inferred from the measurement of other variables. Pressure sensors, flowmeter and spirometer are employed to measure the above mentioned variables.

2.3 Electrocardiogram

The electrocardiogram (ECG) is a technique of recording bioelectric currents generated by the heart [18]. Clinicians can evaluate the conditions of a patient's heart from the ECG and perform further diagnosis. ECG records are obtained by sampling the bioelectric currents sensed by several electrodes, known as leads. An ECG signal is shown in figure 2.3.

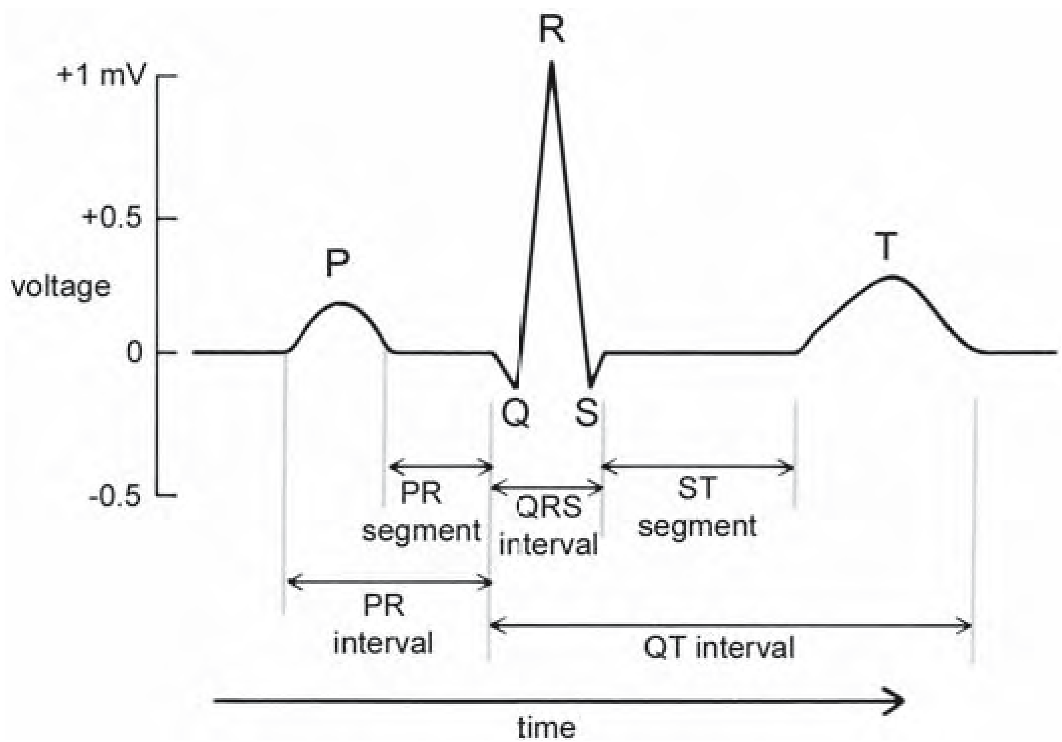


Figure 2.3: Standard ECG waveform

Generally, the recorded ECG signal is often contaminated by noise and artifacts that can be within the frequency band of interest and manifest with similar characteristics as the ECG signal itself. In order to extract useful information from the noisy ECG signals, you need to process the raw ECG signals.

ECG signal processing can be roughly divided into two stages by functionality: preprocessing and feature extraction (as shown in Figure 2.4). The preprocessing stage removes or suppresses noise from the raw ECG signal and the feature extraction stage extracts diagnostic information from the ECG signal [19].

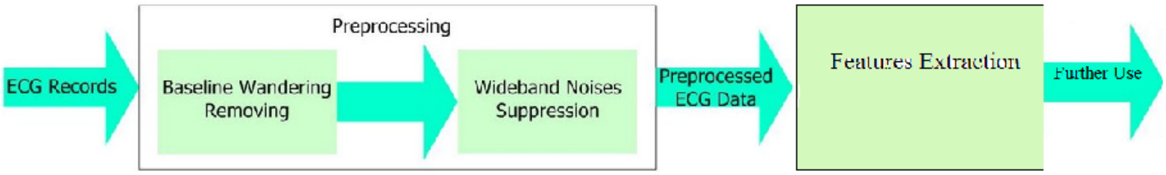


Figure 2.4: Preprocessing of ECG signal

With LabVIEW and related toolkits, such as the Advanced Signal Processing Toolkit (ASPT) and the Digital Filter Design Toolkit (DFDT), one can conveniently build signal processing applications for both stages, including baseline wandering removing, noise cancellation, QRS complexes detection etc.

2.3.1 Preprocessing ECG Signals

Preprocessing ECG signals helps remove contaminants from the ECG signals. Broadly speaking, ECG contaminants can be classified into the following categories:

- Power line interference
- Electrode pop or contact noise
- Patient–electrode motion artifacts
- Electromyographic (EMG) noise
- Baseline wandering

Among these noises, the power line interference and the baseline wandering are the most significant and can strongly affect ECG signal analysis. Except for these two noises, other noises may be wideband and usually a complex stochastic process which also distort the ECG signal. The power line interference is narrow-band noise centered at 60 Hz (or 50 Hz) with a bandwidth of less than 1 Hz. Usually the ECG signal acquisition hardware can remove the power line interference. However the baseline wandering and other wideband noises are not easy to be suppressed by hardware equipments. Instead, the software scheme is more powerful and feasible for offline ECG signal processing. Can be use the following methods to remove baseline wandering and the other wideband noise.

2.3.2 Removing Baseline Wandering

Baseline wandering usually comes from respiration at frequencies wandering between 0.15 and 0.3 Hz, and can be suppressed by a highpass digital filter. Also one can use the wavelet transform to remove baseline wandering by eliminating the trend of the ECG signal. Removal of baseline wandering is necessary because without it features cannot be extracted [20].

a. Digital Filter Approach

The LabVIEW DFDT provides an intuitive and interactive way to design and implement finite impulse response (FIR) or infinite impulse response (IIR) filters easily and effectively. For example, you can use the Classical Filter Design Express VI to design a Kaiser Window FIR highpass filter to remove the baseline wandering.

b. Wavelet Transform Approach

In addition to digital filters, the wavelet transform is also an effective way to remove signals within specific sub bands. The LabVIEW ASPT provides the WA Detrend VI which can remove the low frequency trend of a signal

This example uses the Daubechies6 (db06) wavelet because this wavelet is similar to the real ECG signal. In this example, the ECG signal has a sampling duration of 60 seconds, and 12000 sampling points in total; therefore the trend level is 0.5 according to the following equation:

$$\text{Trend level} = \frac{\log_2 2t}{\log_2 n} \qquad \text{Equation 2.3}$$

Where t is the sampling duration and N is the number of sampling points. Figure 2.5 shows the original ECG signal and the resulting ECG signals processed by the digital filter-based and wavelet transform-based approaches. Also it can be observed that the resulting ECG signals contain little baseline wandering information but retain the main characteristics of the original ECG signal. It is also observed that the wavelet transform-based approach is better because this approach introduces no latency and less distortion than the digital filter-based approach.

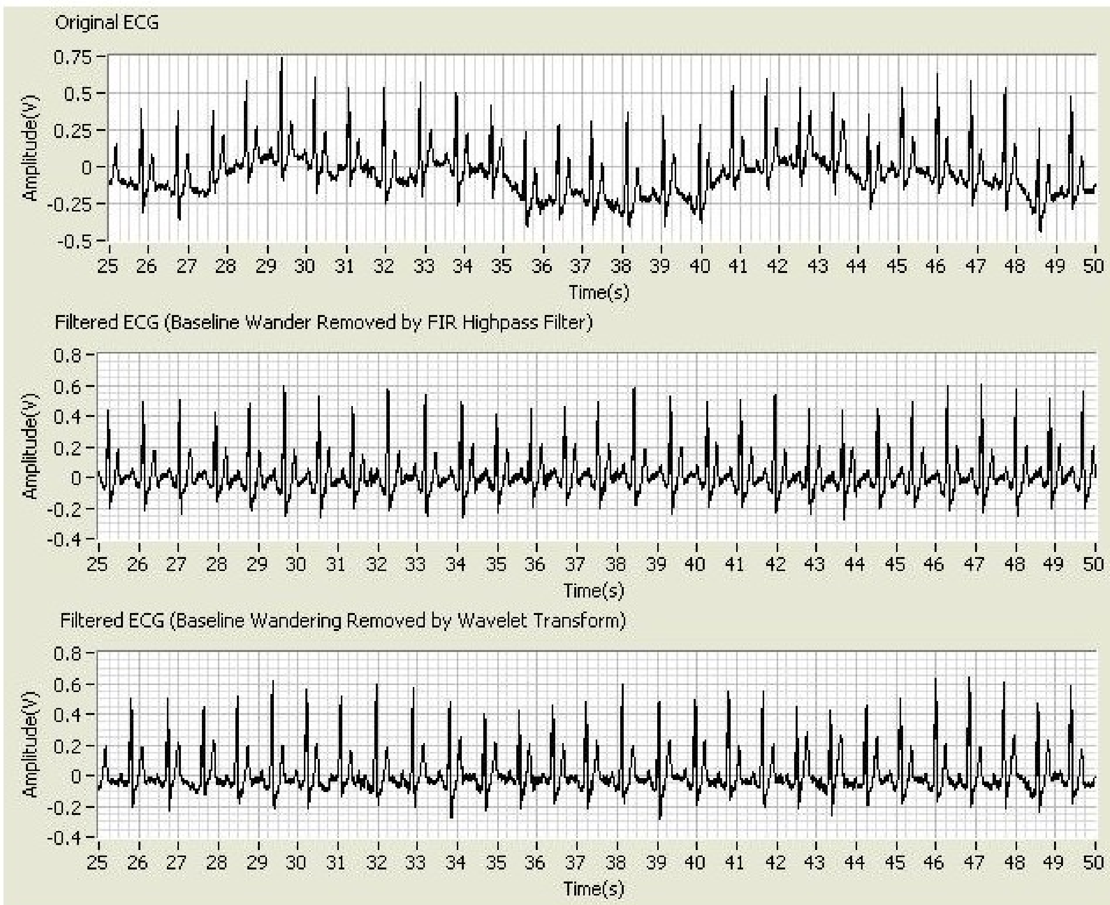


Figure 2.5: ECG waveforms with baseline wandering, and after removed by both techniques.

2.3.3 Removing Wideband Noise

After removing baseline wandering, the resulting ECG signal is more stationary and explicit than the original signal. However, some other types of noise might still affect feature extraction of the ECG signal. The noise may be complex stochastic processes within a wideband, so cannot be removed by using traditional digital filters. To remove the wideband noises, one can use the Wavelet Denoise Express VI.

This Express VI first decomposes the ECG signal into several sub-bands by applying the wavelet transform, and then modifies each wavelet coefficient by applying a threshold or shrinkage function, and finally reconstructs the denoised signal.

2.4 Pulse Oximetry

Pulse Oximetry represents the greatest advance in patient monitoring in many years. It has the unique advantage of continuously monitoring the saturation of haemoglobin with oxygen, easily and noninvasively, providing a measure of cardio-respiratory function. By virtue of its ability to quickly detect hypoxaemia, it has become the standard of care during anaesthesia as well as in the recovery room and intensive care unit. Pulse oximetry should be used to monitor any patient who is heavily sedated or is likely to become hypoxic [21].

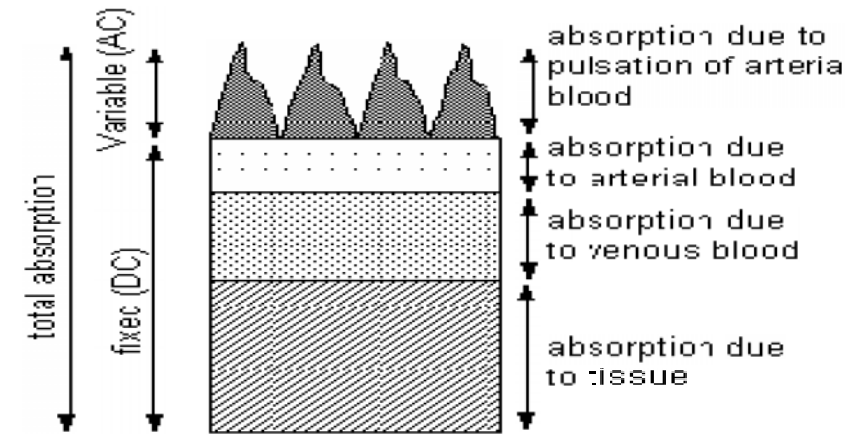


Figure 2.6: Infrared light absorption in the finger

The fundamental physical property that allows the pulse oximeter to measure the oxygen saturation of haemoglobin is that blood changes colour as haemoglobin absorbs varying amounts of light depending on its saturation with oxygen [22]. Oxyhaemoglobin does not absorb much red light, but as the haemoglobin oxygen saturation drops, more and more red light is absorbed and the blood becomes darker. At the near infrared range of light however, oxyhaemoglobin absorbs more light than reduced haemoglobin.

Pulse oximetry is thus based upon two physical principles:

a) The light absorbance of oxygenated haemoglobin is different from that of reduced haemoglobin, at the oximeter's two wavelengths, which include red and near infrared light; and

b) The absorbance of both wavelengths has a pulsatile component, which is due to the fluctuations in the volume of arterial blood between the source and the detector.

Two wavelengths of light are used; 660 nanometers (red) and 940 nanometres (near infrared). At 660nm, reduced haemoglobin absorbs about ten times as much light as oxyhaemoglobin. At the infrared wavelength, (940nm), the absorption coefficient of oxyhaemoglobin is greater than that of reduced haemoglobin. The pulse oximeter directly senses the absorption of red and infra-red light, and the ratio of pulsatile to nonpulsatile light at the red and infrared wavelengths are translated through complex signal processing to a function of the arterial oxygen saturation [23].

2.5 Related Research in this Field

UpkarVarshney and SwetaSneha[24] have proposed a Wireless and mobile technologies are finding a role in patient monitoring in diverse environments including hospitals and nursing homes. However, the quality and reliability of patient monitoring have not been highly satisfactory due to unpredictable and spotty coverage of infrastructure-oriented wireless networks such as wide-area cellular networks and wireless LANs. Recently, the use of ad hoc wireless networks among mobile and wearable devices for patient monitoring has been proposed. Although very exciting, there are many challenges in using ad hoc wireless networks for patient monitoring including how to support reliable patient monitoring and how to manage power transmission from patients' devices. In this paper, we provide several solutions for enhancing the reliability of patient monitoring and for improving the power management of devices in normal and emergency messages transmission.

Tia Gao, Dan Greenspan and Matt Welsh [25] have described that the Patients at disaster scenes can greatly benefit from technologies that continuously monitor their vital status and locations until they are admitted to the hospital. We have designed and developed a patient monitoring system that integrates vital signs sensors, location sensors, ad-hoc networking, electronic patient records, and web portal technology to allow remote monitoring of patient vital-sign status. This system shall facilitate collaboration between providers at the disaster scene, medical professionals at local hospitals, and specialists or experts who might be available for consultation from distant facilities.

Ying Zhang, Christine Tsien Silvers, and Adrienne G. Randolph [26] has showed that the Rapid interpretation of physiological time-series data and accurate assessment of patient state are crucial to patient monitoring in critical care. Algorithms that use artificial intelligence techniques have the potential to help achieve these tasks, but their development requires well annotated patient data. In this study, we designed a data acquisition system for synchronized collection of physiological time-series data and clinical event annotations at the bedside to support the evaluation of alarm algorithms in real time, and implemented this system in a pediatric intensive care unit (ICU). This system captured vital sign measurements at 1 Hz and 325 clinical alarms generated by the bedside monitor and the 2 instances of false negatives during a monitoring period of 196 hours. The alarm annotations in real time at the bedside indicate that about 89% of these alarms were clinically relevant true positives; 6% were true positives without clinical relevance; and 5% were false positives. These findings show an improved specificity of the alarm algorithms in the newer generation of bedside monitoring systems and demonstrate that the designed data acquisition system enables real-time evaluation of patient monitoring algorithms for critical care.

Emil Jovanov, DejanRaskovic, John Price, John Chapman, Anthony Moore and Abhishek Krishnamurthy [27] have been developed a A wearable device for monitoring multiple physiological signals (polysomnograph) usually includes multiple wires connecting sensors and the monitoring device. In order to integrate information from intelligent sensors, all devices must be connected to a Personal Area Network (PAN). This system organization is unsuitable for longer and continuous monitoring, particularly during the normal activity. For instance, monitoring of athletes and computer assisted rehabilitation commonly involve unwieldy wires to arms and legs that restrain normal activity. We propose a wireless PAN of intelligent sensors as a system architecture of choice, and present a new design of wireless personal area network with physiological sensors for medical applications. Intelligent wireless sensors perform data acquisition and limited processing. Individual sensors monitor specific physiological signals (such as EEG, ECG, GSR, etc.) and communicate with each other and the personal server. Personal server integrates information from different sensors and communicates with the rest of telemedical system as a standard mobile unit. They present our prototype implementation of Wireless **I**ntelligent Sensor (WISE) based on a very low power consumption microcontroller and a DSP-based personal server. In future we expect all components of WISE integrated in a single chip for use in a variety of new medical applications and sophisticated human computer interfaces. Existing growth of wireless infrastructure will allow a range of new telemedical applications that will significantly improve the quality of health care.

PéterVárady, ZoltánBenyó, and BalázsBenyó [28] has been described that a Computer-aided bedside patient monitoring is applied in areas where real-time vital function analysis takes place. Modern bedside monitoring requires not only the networking of bedside monitors with a central monitor but also other standard communication interfaces. In this paper, a novel approach to patient monitoring is introduced. A patient monitoring system was developed and implemented based onan existing industry standard communication network, using standard hardware components and software technologies. The open architecture system design offers scalability, standard interfaces, and flexible signal interpretation possibilities.

Ashwin K. Whitchurch,Jose K. Abraham, Senior and Vijay K. Varadan [29] have proposed a Remote patient monitoring is an alternative to regular home check-ups of patients with certain special medical conditions or the elderly who are unable to regularly visit a healthcare facility. This technology reduces the number of home visits which are now only required when special attention is needed. This paper presents the design and development of a remote point-of-care patient monitoring system which allows the patient to be monitored remotely while remaining in the comfort of their home. The system described here allows wireless data acquisition from eight patient-worn sensors. The number and type of sensors are configurable according to the subject's specific condition. The system uses the standard Bluetoothg technology for communication with a home based monitor which in turn relays this data to the remote healthcare facility using the internet. This data can be used for real-time evaluation of the patient's conditions as well as data logging for later analysis. Since this is a configurable system, a few selected sensors are connected to demonstrate the concept of remote patient monitoring; these include Electrocardiogram (ECG), Electroencephalogram (EEG), Airflow, respiration, patient movement and body temperature. The results obtained from these tests are also presented in this paper.

Ho Sung Lee, SeungHun Park, and Eung Je Woo [30] have presented a real-time remote patient monitoring service through World-Wide Web (WWW), which allows physicians to monitor their patients in remote sites using popular Web browsers. The real-time patient monitoring consists of two services: Patient Locator Service-(PLS) and Vital

Sign Monitoring Service (VSMS). The PLS provides the information of patients currently being monitored. The VSMS allows the user to observe a stream of vital sign data of a specific patient such as ECG, respiration, temperature, SpOz, invasive blood pressure, non-invasive blood pressure, and others in real-time.

I. Martı´nez, J. Ferna´ ndez, M. Galarraga, L. Serrano, P. de Toledo, S. Jime´ nez-Ferna´ ndez, S. Led, M. Martı´nez-Espronceda and J. Garcı´a [31] has been presented a patient monitoring solution for intensive care unit environments. It is end-to-end standard-based, using ISO/IEEE 11073 (X73) in the bedside environment and EN13606 to communicate the information to an electronic healthcare record (EHR) server. At the bedside end, the system is a plug-and-play sensor network communicating with a gateway that collects medical information and sends the data to a monitoring server. The monitoring server transforms this information into an EN13606 extract to be stored on the EHR server. The system has been implemented to comply with the last X73 and EN13606 available versions and tested in a laboratory environment to demonstrate the feasibility of an end-to-end standard-based solution.

E. Chan, D. Wang, and M. Pasquier [32] had been investigated in this paper the problem of intelligent patient monitoring, whereby a combination of smart sensor technology and computational intelligence techniques is used to observe then understand the behaviour of a person in a self-care context, such as a patient in his hospital room or an elderly in her home. The key objective is to automatically derive a model that encompasses salient details pertaining to the health and well-being of the patient monitored, and subsequently to apply decision support tools to diagnose any behavioural variation from the model and recommend remedial action. Encouraging results were obtained using a prototype system consisting of various positional sensors and a computer vision module for behavioural pattern recognition coupled with a novel self-organizing neuro-fuzzy system for classification and prediction purposes. The case study reported here is that of monitoring the motions of a patient lying in bed to detect or even anticipate falls.

PravinPawar, Bert-Jan van Beijnum, Hailiang Mei, Hermie Hermens [33] have been presented in this paper that In the mobile (M)-Health domain, the Remote Patient

Monitoring System (RPMS) facilitates continuous collection, transmission and viewing of the patient vital signs data. Furthermore, in case of an emergency it provides context-aware Emergency Response Services (ERSs) such as the doctor, paramedic, ambulance and hospital to the patient. In the existing RPMS, the components responsible for the discovery and selection of ERSs are centralized; and the ERS are selected and invoked reactively; i.e. on the occurrence of an emergency. However, in the distributed RPMS, such reactive approach could take a significant amount of time. If ERSs could be discovered and selected proactively before an emergency occurs, it could save valuable time in dealing with the patient emergency. However, such proactive approach requires more resources as compared to the reactive approach. Herein they present a logical architecture for the distributed RPMS, investigate the issues involved in the proactive context-aware ERSs selection.

Chapter 3

System Implementation

3.1 Introduction

Patient monitoring also known as Vital sign monitoring as they are primarily designed to measure and display vital physiological parameters. Figure 3.1 shows the system block diagram of LabVIEW based patient monitoring system. The whole system works under the control of LabVIEW.

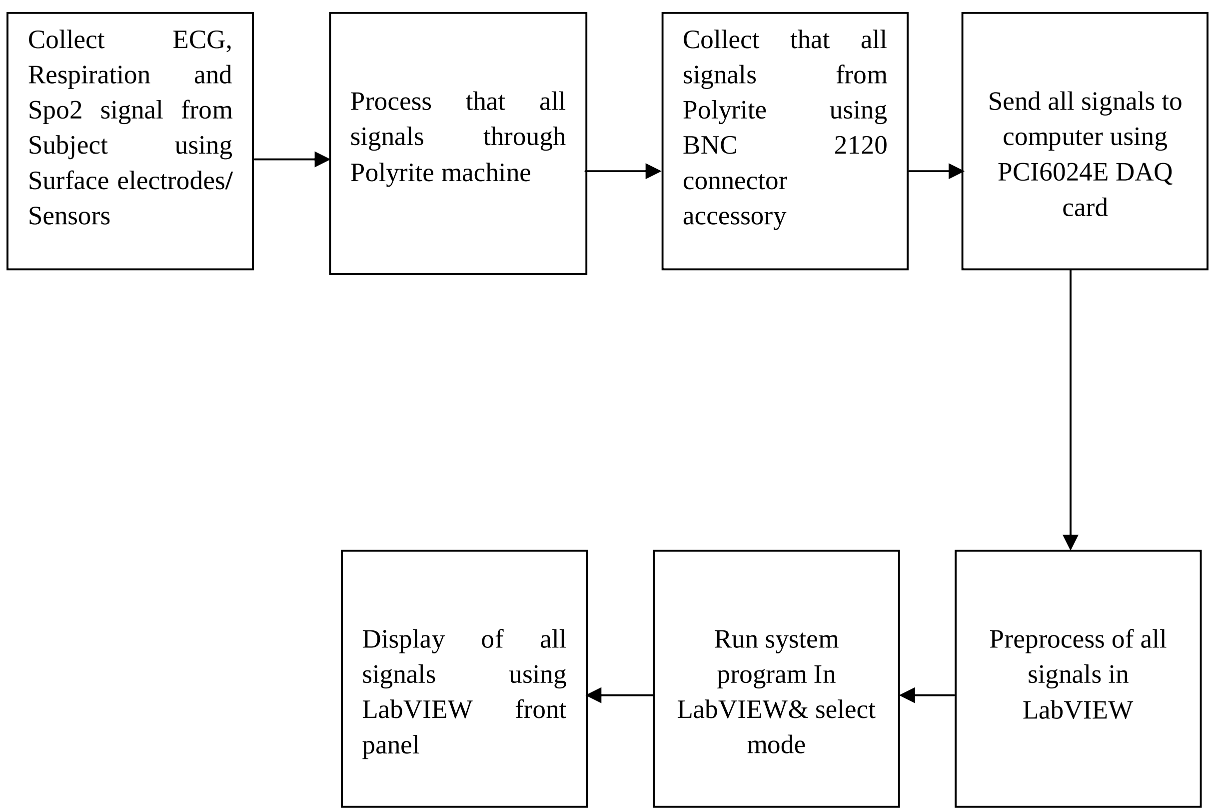


Figure 3.1: Block diagram of LabVIEW based Patient monitoring system

3.2 Hardware Requirements

The various hardware requirements for “LabVIEW based Patient monitoring system” are:

1. Surface Electrodes with Connecting Leads
2. Sensors
3. Polyrite machine
4. BNC 2120 connector accessory
5. PCI6024E DAQ card
6. P.C. with LabVIEW

3.2.1 Surface Electrodes with Connecting Leads

A surface electrode is a small device that is attached to the skin to measure or cause electrical activity in the tissue under it. The surface electrode including:

(a) A flexible, at least partially-conductive surface layer for physically contacting the skin surface, and for delivering electrical signal.

(b) An electrically conductive layer operatively connected to the partially-conductive surface layer, for transferring the electrical signal, wherein the at least partially-conductive surface layer has a thickness of less than 0.5 mm, and preferably contains a conductive gel or artificial skin.

These electrodes are connected with leads to collect the ECG signal.

3.2.1.1 Three Limb Leads (Bipolar)

In the normal electrode placement shown in figure 3.2, four electrodes are used to record the electrocardiogram; the electrode on the right leg is only for ground reference. Because the input of ECG recorder has only two input terminals, a selection must be made among the available active electrode. The bipolar limb lead selections first introduced by Einthoven are as follows:

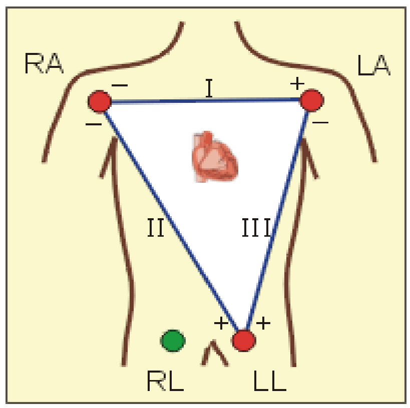


Figure 3.2 Electrodes Placement

Lead I: Left Arm (LA) and Right Arm (RA)

Lead II: Left Leg (LL) and Right Arm (RA)

Lead III: Left Leg (LL) and Left Arm (LA)

These three leads are called Bipolar because for each lead the electrocardiogram is recorded from two electrodes and the third electrode is not connected. In each of this Lead position, The QRS of a normal heart is such that R wave is positive.

In working with electrocardiogram from these three basic limb leads, at any given instant of the cardiac cycle, the frontal plane representation of the electrical axis of the heart is two dimensional vector. Further, the ECG measured from any one of three basic limb leads is a time-variant single-dimensional component of that vector.

Whether the limb leads are attached to the end of the limb (wrists and ankles) or at the origin of the limb (shoulder or upper thigh) makes no difference in the recording because the limb can simply be viewed as a long wire conductor originating from a point on the trunk of the body.

3.2.1.2 Augmented Limb Leads (Unipolar)

In addition to the three bipolar limb leads described above, there are three augmented unipolar limb leads. These are termed unipolar leads because there is a single positive electrode that is referenced against a combination of the other limb electrodes. The positive electrodes for these augmented leads are located on the left arm (aV_L), the right arm (aV_R), and the left leg (aV_F). In practice, these are the same electrodes used for leads I, II and III. (The ECG machine does the actual switching and rearranging of the electrode designations). The three augmented unipolar leads, coupled with the three bipolar leads, constitute the six limb leads of the ECG. These leads record electrical activity along a single plane termed the frontal plane relative to the heart. Using the axial reference system and these six leads, it is simple to define the direction of an electrical vector at any given instant in time.

3.2.2 Sensor

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.

3.2.2.1 Bio sensor

In biomedicine and biotechnology, sensors which detect analytes thanks to a biological component, such as cells, protein, nucleic acid or biomimetic polymers, are called biosensors. Whereas a non-biological sensor, even organic (=carbon chemistry), for biological analytes is referred to as sensor or nanosensor (such a microcantilevers). This terminology applies for both in vitro and in vivo applications. The encapsulation of the biological component in biosensors, presents with a slightly different problem that ordinary sensors, this can either be done by means of a semi permeable barrier, such as a dialysis membrane or a hydrogel, a 3D polymer matrix, which either physically constrains the sensing macromolecule or chemically (macromolecule is bound to the scaffold.

3.2.2.2 Respiratory flow sensor

A respiratory flow sensor to be connected between a breathing tube and an endotracheal catheter, which has a flow channel, an orifice, which is formed by a foil recessed in the flow tube, in which an orifice flap is formed by an incision, and has connections to the flow channel on both sides of the orifice to pick up the pressure difference generated over the orifice. The respiratory flow sensor is reusable and makes possible accurate measurement even at low flow rates and low pneumatic resistance. The foil is a metal foil, which is interrupted by a central incision in the area carrying the orifice flap to f form two hinge elements which are narrow compared with the width of the orifice flap. A first flow rectifier is arranged in the flow channel between the orifice flap and the connection for the endotracheal catheter.

Although the respiration sensor is frequently called a strain gauge, the Thought Technology sensor does not use an actual strain gauge to measure respiration. The Respiration sensor is sensitive to stretch.

3.2.2.3 Measurement method of Respiration

The instrument used to measure respiration (lung capacity and volume) is called Spirometer. Basically, the record obtained from this device is called spirogram. Spirometers are calibrated containers that collect gas and make measurements of lung volume or capacity that can be expired.

3.2.2.3.1 Spirometer

Respiratory measurements can be adequately carried out by the classic water sealed spirometer. This consists of an upright, water filled cylinder containing an inverted counter weighted bell. Breathing into the bell changes the volume of gases trapped inside, and the change in volume is translated into vertical motion, which is recorded on the moving drum of a Kymograph. The excursion of the bell will be proportional to the tidal volume. For most purposes, the bell has a capacity of the order6-81. Unless a special light weight bell is provided, the normal spirometer is only capable of responding fully to slow respiratory rates and not to rapid breathing, sometimes encountered after anaesthesia. Also, the frequency response of a spirometer must be adequate for the measurement of the forced expiratory volume.

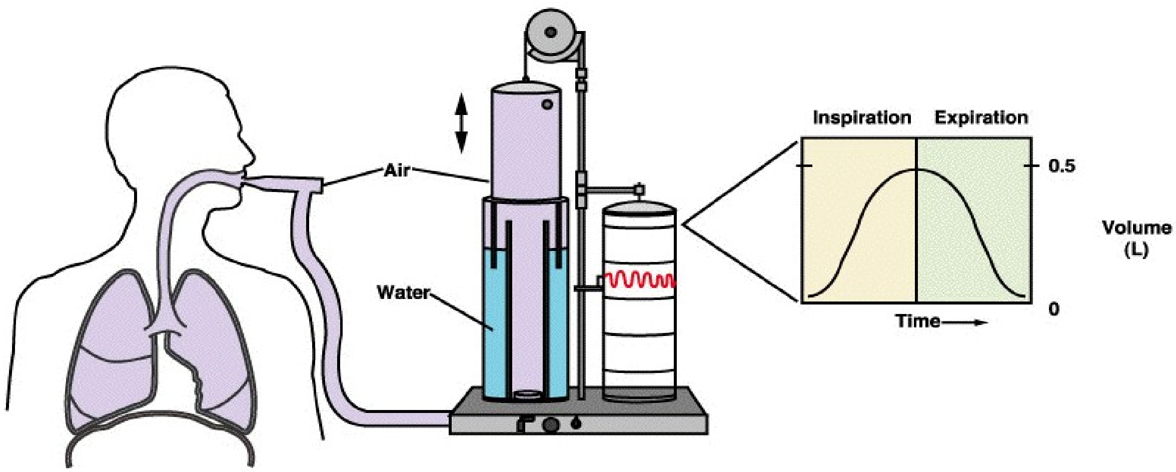


Figure 3.3: Spirometer

The spirometer is a mechanical integrator, since the input is air flow and the output is volume displacement. An electrical signal proportional to volume displacement can be obtained by using a linear potentiometer connected to the pulley portion of the spirometer. The spirometer is a heavily damped device so that small changes in inspired and expired air volumes are not recorded. The spirometers can be fitted with a linear motion potentiometer, which directly converts spirometer volume change into an electrical signal.

The signal may be used to feed a flow volume differentiator for the evaluation and recording of data.

3.2.2.4 Pulse oximeter sensor

A pulse oximeter sensor is provided in which the wrap which encloses and secures the light source and detector to the body includes a sheet of metallized material. The metallized material reflects body heat back to the body and provides opacity to interfering ambient light. The wrap may be formed in a "T" shape, with the light sensor and detector aligned with the stem of the "T", or in a disposable elongated configuration with the light sensor and detector longitudinally aligned with the wrap. The wrap is secured during use through either adhesive means or by the use of hook and loop fabric patches.

3.2.2.4.1 Measurement of SpO_2

SpO_2 is the short form of Oxygen Saturation. The ratio of oxyhaemoglobin to the total concentration of hemoglobin present in the blood is known as the oxygen saturation. Hemoglobin is an iron-containing respiratory pigment of vertebrate red blood cells that consists of a globin composed of four subunits each of which is linked to a haem molecule, that functions in oxygen transport to the tissues after conversion to oxygenated form in the gills or lungs, and that assists in carbon dioxide transport back to the gills or lungs after delivery of its oxygen. Oxyhaemoglobin is bright red hemoglobin that is a combination of hemoglobin and oxygen from the lungs.

The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. A light emitter with red and infrared LEDs is used in Pulse oximeter. SpO_2 is measure by passing light through the finger, pinna or lobe of the ear and light that passes through the finger, pinna or lobe of the ear is receive by the photodetector . Two methods are use to passing light through the finger, pinna or lobe of the ear, Transmission and Reflectance. In transmission method, the emitter and photodetector are opposite to each other with the finger. In the reflectance method, the emitter and the photodetector are next to each other on top the finger.

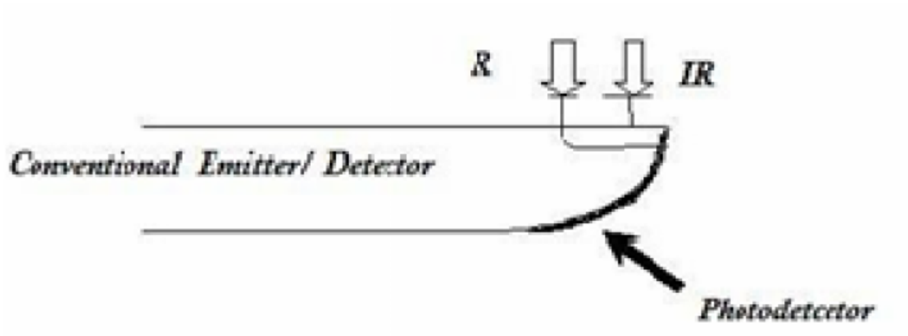


Figure 3.4: Transmission Method to pass light through finger

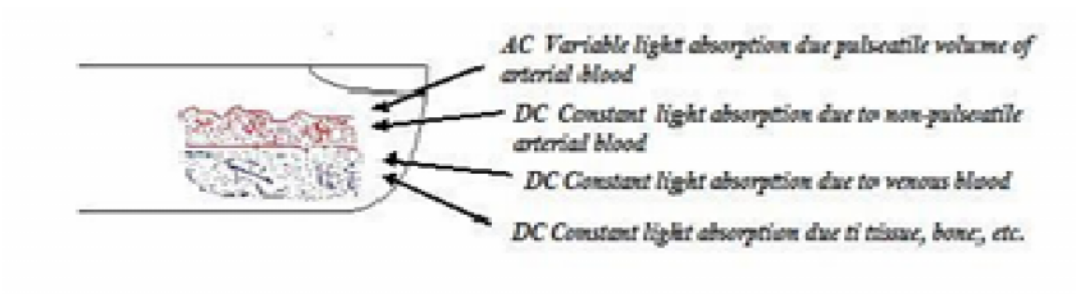


Figure 3.5: Reflectance Method to pass light through finger

3.2.3 PCI-6024E National Instruments Data Acquisition Card

National Instruments is one of the largest companies that provide electrical solutions. It is famous for providing data acquisition cards. Data acquisition cards are those cards that are used as interfaces between a plant and a computer in order to control the plant in real time environment. In the thesis the PCI-6024E DAQ card has been used. The 6024E features 16 channels of analog input, two channels of analog output, a 68-pin connector and eight lines of digital I/O. The PCI-6024E DAQ card uses the National Instruments DAQ-STC system timing controller for time-related functions. The DAQ-

STC consists of three timing groups that control analog input, analog output, and general-purpose counter/timer functions. The three groups include a total of seven 24-bit and three 16-bit counters and a maximum timing resolution of 50 ns. The DAQ-STC makes possible such applications as buffered pulse generation, equivalent time sampling, and seamless changing of the sampling rate. In many DAQ systems, it is not easy to synchronize several measurement functions to a common trigger or timing event. Such devices have the Real-Time System Integration (RTSI) bus to solve this problem. In the PCI-6024E DAQ card, the RTSI bus consists of the National Instruments RTSI bus interface and a ribbon cable to route timing and trigger signals between several functions on as many as five DAQ devices in a computer.

In order to use the PCI-6024E DAQ card, it is required to have PCI interface and NI-DAQ 7.x drivers.

NI-DAQ maintains a consistent software interface so that one can change platforms with minimal modifications to the programming code. The user programmed application uses the NI-DAQ driver software, as illustrated in Figure 3.6

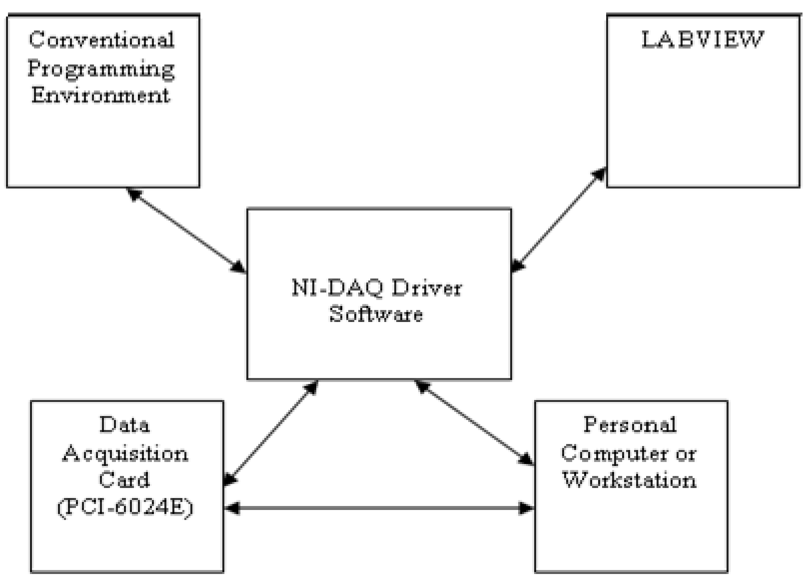


Figure 3.6: The relationship between the programming environment, NI-DAQ, and the PCI-6024E DAQ card

3.2.4 BNC-2120 Connector Accessory for Multifunction DAQ Devices

The BNC-2120 is a desktop or DIN rail-mountable accessory you can connect to E Series, S Series, and waveform generation Multifunction DAQ devices.

The BNC-2120 has the following features:

• Eight BNC connectors for analog input (AI) connection with the following optional features:

➢ Thermocouple connector

➢ Temperature reference

➢ Resistor measurement screw terminals

• Two BNC connectors for analog output (AO) connection

• Screw terminals for digital input/output (DIO) connection with state indicators

• Screw terminals for Timing I/O connections

• Two user-defined BNC connectors

• A function generator with the following outputs:

➢ Frequency-adjustable, TTL-compatible square wave

➢ Frequency- and amplitude-adjustable sine wave or triangle wave

• Quadrature encoder

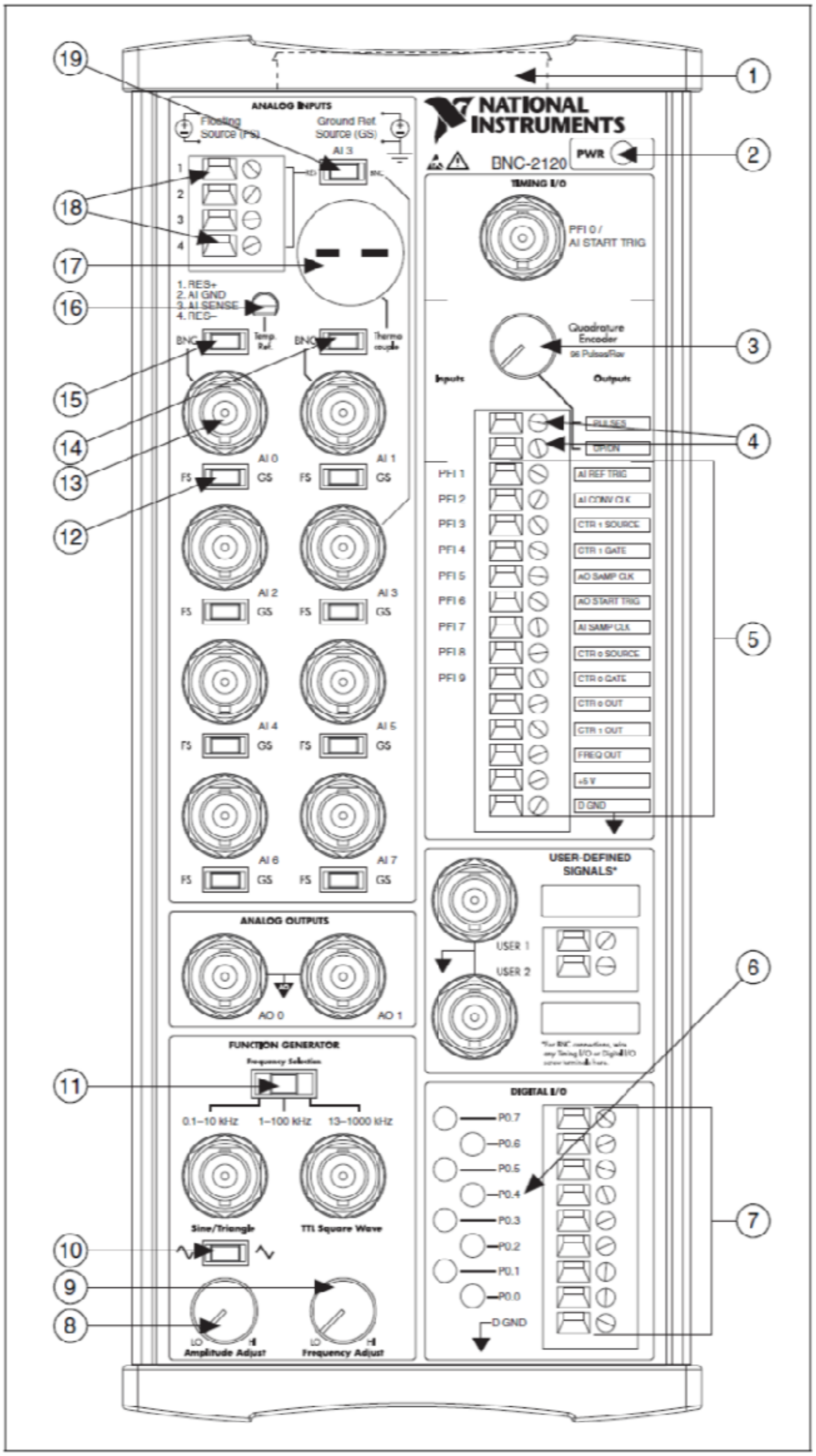
The BNC-2120 has a 68-pin input/output (I/O) connector that connects to your E Series, S Series, or waveform generation Multifunction DAQ device.

To set up and use BNC-2120 accessory, following are the requirements:

- BNC-2120 accessory

- BNC-2120 Installation Guide
- E Series, S Series, or waveform generation Multifunction DAQ device
- 68-position or 100-position cable
- BNC cables
- 24 AWG wire or smaller
- Wire strippers
- Flathead screwdriver (supplied)

The BNC-2120 has one 68-position connector on the rear panel to connect to DAQ device



1. 68-Position I/O Connector
2. Power Indicator LED
3. Quadrature Encoder Knob
4. Quadrature Encoder Output Screw Terminals
5. TIO Screw Terminals
6. DIO LED State Indicators
7. DIO Screw Terminals
8. Function Generator Amplitude Adjust Knob
9. Function Generator Frequency Adjust Knob
10. Sine/Triangle Waveform Selection Switch
11. Frequency Range Selection Switch
12. Floating Source (FS)/ Ground-Referenced Source (GS) Switch
13. BNC Connector
14. BNC/Thermocouple Selection Switch
15. BNC/Temperature Reference Selection Switch
16. Temperature Reference
17. Thermocouple Input Connector
18. Resistor Measurement Screw Terminals
19. Resistor/BNC Selection Switch

Figure 3.7: BNC 2120

3.2.5 Introduction of Polyrite

The POLYRITE Recorder is a highly sensitive oscillograph capable of simultaneously recording signals in different modes from many sources.

POLYRITE Recorders can be used by the medical profession for the recording of bioelectric potentials, in aerospace technology for recording telemetered information, in industry for recording of servo amplifier performance, all types of vibration pick-up and recording of temperature etc. The flexibility resulting out of modular construction of the POLYRITE allows a wide variety of physical phenomena to be recorded simultaneously.

The modular concept in construction allows the assembly to be custom tailored to exact performance requirements. Additional capabilities and functions can be added simply by acquiring the required amplifier modules appropriate transducers. Adaptation of the instrument for various uses merely requires the exchange of amplifiers and selection of suitable pick up devices. Widely diverse information can thus be recorded on a single instrument by the use of different amplifiers and appropriate transducers.

3.2.5.1 Basic Modules

Each separate record inscribed on the chart requires a separate channel, which consists of an amplifier and pen motor. The signal may be fed into the amplifier directly by the use of suitable electrodes or, if in the form of any energy other than electrical, it may be converted to electrical energy by the use of appropriate transducers and then fed into the amplifier. All modules are fully solid state and are designed using integrated circuits, high stability components and printed circuit boards. The technology used is true state-of-the art.

3.2.5.2 Amplifiers

The vertical pre-wired section houses the various amplifiers plug-in-modules and the power supply module. All interconnections between the amplifier channels and the recorder section channels are through pre-wired connectors. And the recorder section channels are through pre-wired connectors. Controls are kept to minimum at the same time ensuring a wide variety of adjustment.

Any number of channels can be selected as the polyrite is designed on a plug in modular system amplifier modules can be added subsequently depending upon requirements and resources. The use of amplifier permits the widely different applications such as temperature measurements or the bioelectric potential measurement to be made with the same recording channel. A wide range of amplifiers is available to meet the most requirements; others are being constantly developed and designed to meet the specific applications.

3.2.5.3 ADC

An analog signal is a signal that may assume any value within a continuous range. Analog information is transmitted by modulating a continuous transmission signal, by amplifying a signal's strength or varying its frequency to add or take away data. Biopotential signals are analog. In order to make them understandable by micro-controller, they are converted into digital signals. ADC is used to convert the analog signal into digital signal that consist of 1’s and 0’s. Digital information describes any system based on discontinuous data or events.

Analog-to-digital converters come in many forms. One example is the parallel comparator-type ADC, which basically consists of:

1. A set of comparators that compare the input analog voltage to different values of fixed voltages.

2. A corresponding set of D-type flip-flops that hold the digital outputs of the comparators.

3. An encoder that converts the outputs of the D-type flip-flops into the final output digital code.

Another implementation of the ADC is known as the successive-approximation ADC. This circuit consists of:

1. A sample and hold circuit to accept the analog input.
2. A successive approximation register (SAR) consisting of clocked flip-flops and gates designed to systematically and progressively approximate the digital code corresponding to the analog input.
3. An internal reference DAC that gets its digital inputs from the SAR.
4. A voltage comparator that compares the analog output of the internal DAC to the analog input.

3.2.5.4 Pen Motor

The heart of polyrite recording system, the pen motor is also designed in modular form and snaps into place in its receptacle. The pen motor is study and has smooth ball bearing movement.

The light weight ink writing capillary pens are 120mm effective length and have provision for fine adjustment of writing tension. Inkwells are placed in a composite receptacle and provided with pressure caps. A pen lift mechanism lifts all pens from the paper by manipulation of single lever.

Thus each pen motor consists of a stylus or pen that is immobilized by a torsion system mounted perpendicular to it. When a signal current from the amplifier flows through the coil the interaction of current and magnetic field rotates the coil against the torque of torsion system and causes a deflection in the stylus, which is proportional to the magnitude of the signal current. When the signal disappears the torsion system return the stylus system to its original position. When the stylus is in the contact with a moving charge, a fluctuating signal produces a continuous trace on which even minutes changes of signal amplitude can be readily detected.

3.2.5.5 Chart Drive

The chart drive is the unit, which moves the chart paper first and under the stylus of writing element. The polyrite ten speed chart drive gives precise paper speed by using a synchronous motor and a closed meshed gear system free from backlash.

3.2.5.6 Time and Event Channel

The time and event module is an optional accessory. This module permits double range time marking of 1 and 10 second (or 5 and 30 sec; or 10 sec and 1 minute). The event marker push button record the push button record the event by producing a 40 cycle wave for as long as the push button is depressed. This channel is also modular in construction and can be taken out by just unscrewing two thumb screws.

3.2.5.7 Circuit Analysis

The basic purpose of polyrite recorder is to amplify a very small signal and use it too cause a pen deflection that is proportional to the size of signal. It is translated into electrical signal by a transducer.

The very high CMRR of polyrite amplifier helps in eliminating 50 cycles interference, while at the same time not affecting the high frequency response of the amplifier.

3.2.5.8 Recorder Section

It refers to the complete horizontal assembly housing the chart drive mechanism and recording system. Figure 3.9 shows the procedure to get the ECG, Respiration and SpO2 signals.

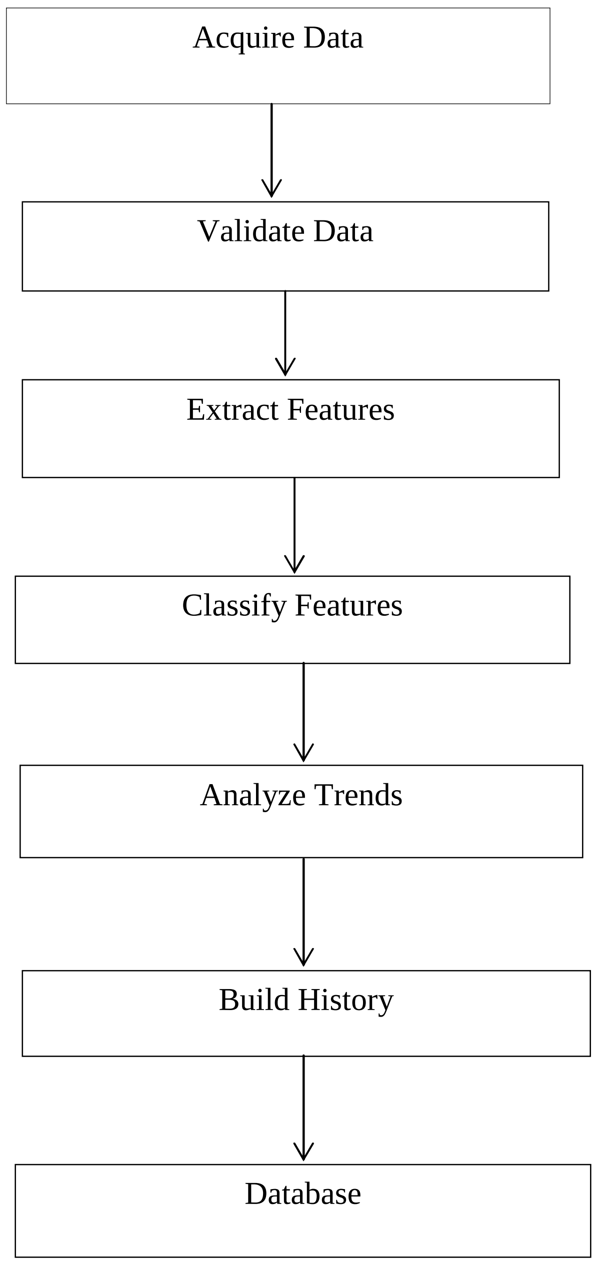


Figure 3.8: Flow chart for getting Signals

3.2.5.9 Procedure

1) Connect the desired electrodes to the subject. Connect these to the input cable to the amplifier input connector

2) Turn the console MAINS ON

3) Turn the amplifier to STANDBY

4) In model 201 turn the ½ AMP HI FREQ. control to 75. The 35 and 15 positions may be used to eliminate high frequency artifacts. The 0.1, 0.5 etc. positions may be used for averaging

5) Turn 50 Hz FILTER OFF

6) Turn the INPUT switch to the time constant 1 for EKG, 0.03, for EMG, 0.1 or 0.3 EEG. In the Model 201 the DC position may be selected for recording DC Potentials. In this case use the BALANCE controls to nullify any offset potentials

7) Calibrate the amplifier if needed

8) Select the desired position on the SENSITIVITY switch of the amplifier, when in don't always select a lower SENSITIVITY and then increase later on if needed. Select 1 mV for EKG, 0.1 mV for EEG etc.

9) Turn the USE CAL switch to USE

10) Adjust pen position as required, by rotating baseline control.

11) Set the chart speeds control on the console to the desired speed

12) Turn the amplifier ON

13) Turn the chart drive ON

3.2.6 PC

The speed of execution of verification system depends upon the computer in which the software is written. The minimum required clock and RAM for the system is that on which LabVIEW can run. The specifications of the used PC are 1.83 GHz clock frequency processor with 2.5 GB RAM.

3.2.6.1 Database

The term data storage can refer to anything with information recorded on it. The most popular definition of the term limits it to only the storage of information on computers and similar devices, and is the definition that is used in this article. Data storage has two types: Primary data storage and Secondary data storage. Primary data storage is constantly being erased and rewritten, most often from secondary data storage. Secondary data storage represents all of the other types of computer data storage not included in primary data storage. Though some experts previous used an additional category called tertiary data storage, technological advances have blurred the differences between the secondary and tertiary levels to the point that only one term is necessary. Internal hard disk drives, CD-ROM disks, and flash memory sticks are all examples of secondary data storage. Because there are so many different types of secondary data storage, this category can be further divided into three different areas: on-site, removable, and off-site data storage.

The database has been made by collecting ECG waveform, Respiration and Spo2 of 10 individuals. 5samples have been taken of each of them at different time for testing. In this way a database of 150 samples has been collected.

3.2.6.2 Software Platform

The software platform used by us was LabVIEW (Laboratory Virtual Instrument Engineering Workbench) 8.5.

3.2.6.3 LabVIEW

LabVIEW is a programming environment in which you create programs using a graphical notation (connecting functional nodes via wires through which data flows); in this regard, it differs from traditional programming languages like C, C++, or Java, in which you program with text. However, LabVIEW is much more than a programming language. It is an interactive program development and execution system designed for people, like scientists and engineers, who need to program as part of their jobs. The LabVIEW development environment works on computers running Windows, Mac OS X, or Linux. LabVIEW can create programs that run on those platforms, as well as Microsoft Pocket PC, Microsoft Windows CE, Palm OS, and a variety of embedded platforms, including Field Programmable Gate Arrays (FPGAs), Digital Signal Processors (DSPs), and microprocessors.

Using the very powerful graphical programming language that many LabVIEW users affectionately call "G" (for graphical), LabVIEW can increase your productivity by orders of magnitude. Programs that take weeks or months to write using conventional programming languages can be completed in hours using LabVIEW because it is specifically designed to take measurements, analyze data, and present results to the user. And because LabVIEW has such a versatile graphical user interface and is so easy to program with, it is also ideal for simulations, presentation of ideas, general programming, or even teaching basic programming concepts.

LabVIEW offers more flexibility than standard laboratory instruments because it is software-based.

LabVIEW also contains application-specific libraries of code for data acquisition (DAQ), General Purpose Interface Bus (GPIB), and serial instrument control, data analysis, data presentation, data storage, and communication over the Internet. The Analysis Library contains a multitude of useful functions, including signal generation; signal processing, filters, windows, statistics, regression, linear algebra, and array arithmetic.

3.2.6.3.1 How Does LabVIEW Work?

LabVIEW uses terminology, icons, and ideas familiar to scientists and engineers. It relies on graphical symbols rather than textual language to define a program's actions. Its execution is based on the principle of **dataflow**, in which functions execute only after receiving the necessary data. Because of these features, one can learn LabVIEW even if he/she has little or no programming experience. However, you will find that knowledge of programming fundamentals is very helpful.

A LabVIEW program consists of one or more **virtual instruments (VIs)**. Virtual instruments are called such because their appearance and operation often imitate actual physical instruments. However, behind the scenes, they are analogous to main programs, functions, and subroutines from popular programming languages like C or Basic. Hereafter, we will refer to a LabVIEW program as a "VI". Also, be aware that a LabVIEW program is always called a VI, whether its appearance or function relates to an actual instrument or not.

A VI has two main parts: a **front panel**, a **block diagram.**

- The **front panel** is the interactive user interface of a VI, so named because it simulates the front panel of a physical instrument . The front panel can contain knobs, push buttons, graphs, and many other controls (which are user inputs) and indicators (which are program outputs). You can input data using a mouse and keyboard, and then view the results produced by your program on the screen.

- The **block diagram** is the VI's source code, constructed in LabVIEW's graphical programming language. The block diagram is the actual executable program. The components of a block diagram are lower-level VIs, built-in functions, constants, and program execution control structures. You draw wires to connect the appropriate objects together to define the flow of data between them. Front panel objects have corresponding terminals on the block diagram so data can pass from the user to the program and back to the user.

3.2.6.4 Software Implementation

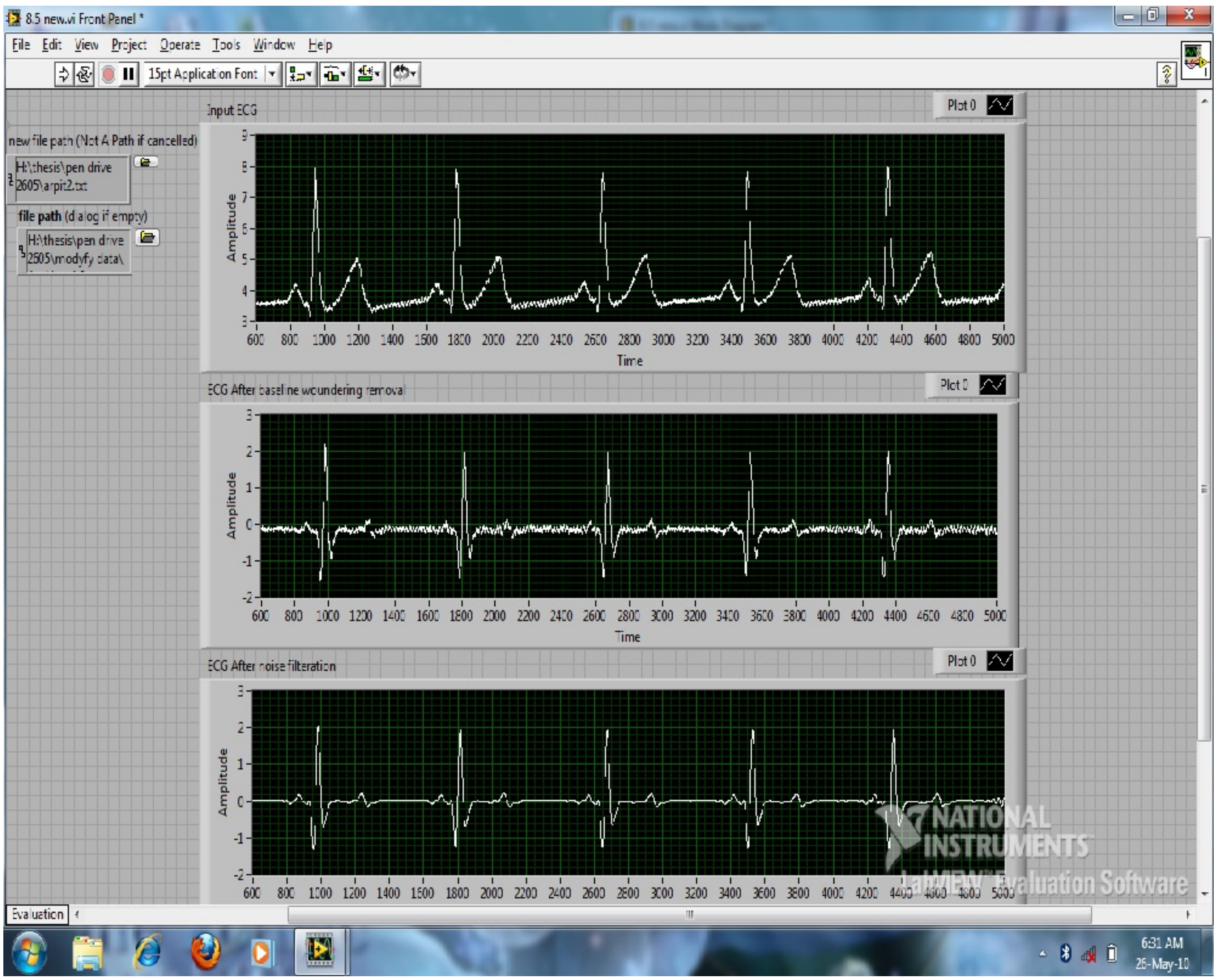


Figure 3.9: Front Panel of ECG display

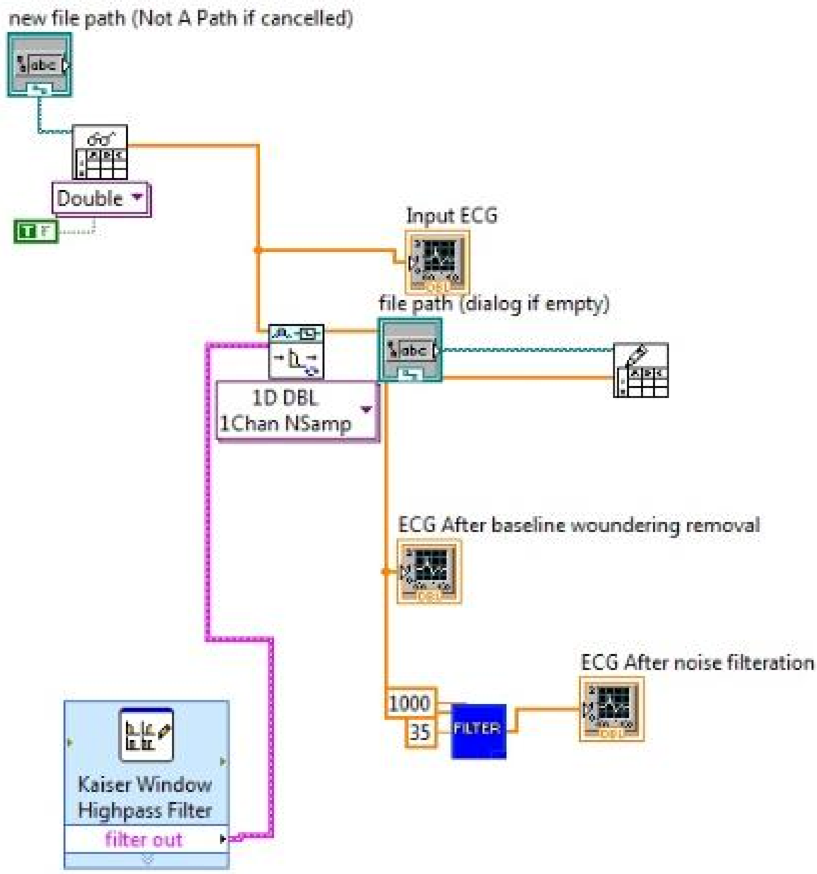


Figure 3.10: Block diagram of ECG display

3.2.6.5 Acquisition of Respiration, ECG and SpO_2 signal

The system then asks for patient monitoring parameters i.e. ECG, Respiration and SpO_2 signal, of the user to be passed on to the system. The flow chart for capturing the ECG signal is shown in the figure 3.11 and various steps are given below:

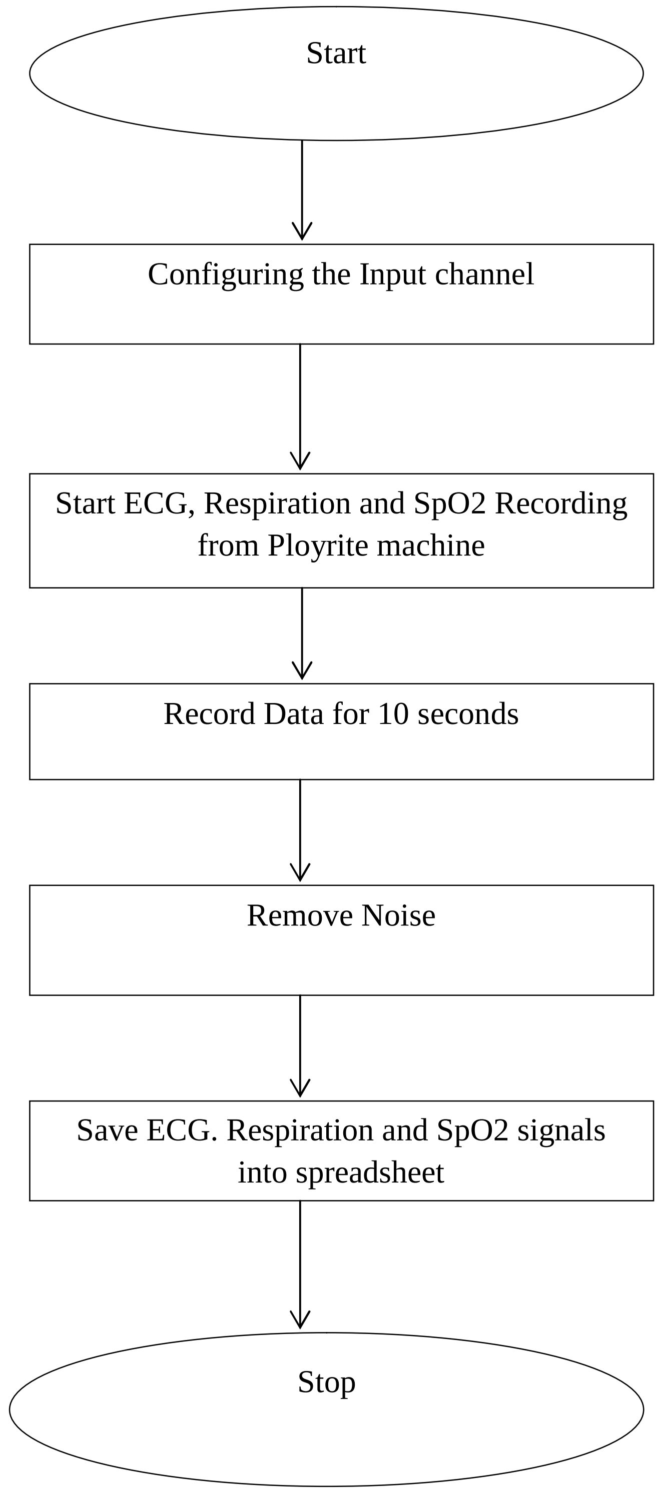


Figure 3.11: Flow Chart of Capturing the ECG, Respiration and SpO2 Signals

Configure the Input channel -: make a channel to measure the applied voltage on it, because ECG signal is a bio-potential, and can be measured in volts. The various steps for creating a channel are-:

a. Open the measurement & automation software installed with LabVIEW base package.

b. Go to Data Neighborhood option and select create new.

c. Select virtual channel and set it's configuration

i. Select analog input

ii. Set channel name and description

iii. Select type of input(voltage)

iv. Select unit and max-min range of input

v. Select the option for scaling

vi. Select what DAQ hardware is used

vii. Select the channel on DAQ hardware

viii. Press finish button, channel is created.

3.2.6.6 Removing Baseline Wandering

Baseline wandering usually comes from respiration at frequencies wandering between 0.15 and 0.3 Hz, and can be suppressed by a highpass digital filter. Also one can use the wavelet transform to remove baseline wandering by eliminating the trend of the ECG signal. Baseline wandering removal is necessary because without it features of the ECG wave cannot be extracted.

3.2.6.6.1 Digital Filter Approach

The LabVIEW DFDT (Digital Filter Design Toolkit) provides an intuitive and interactive way to design and implement finite impulse response (FIR) or infinite impulse response (IIR) filters easily and effectively. For example, one can use the Classical Filter Design Express VI to design a Kaiser Window FIR highpass filter to remove the baseline wandering. Figure 3.12 shows an example of the specifications of the highpass filter that is used to remove the baseline wandering and figure 3.13 shows block diagram of VI.

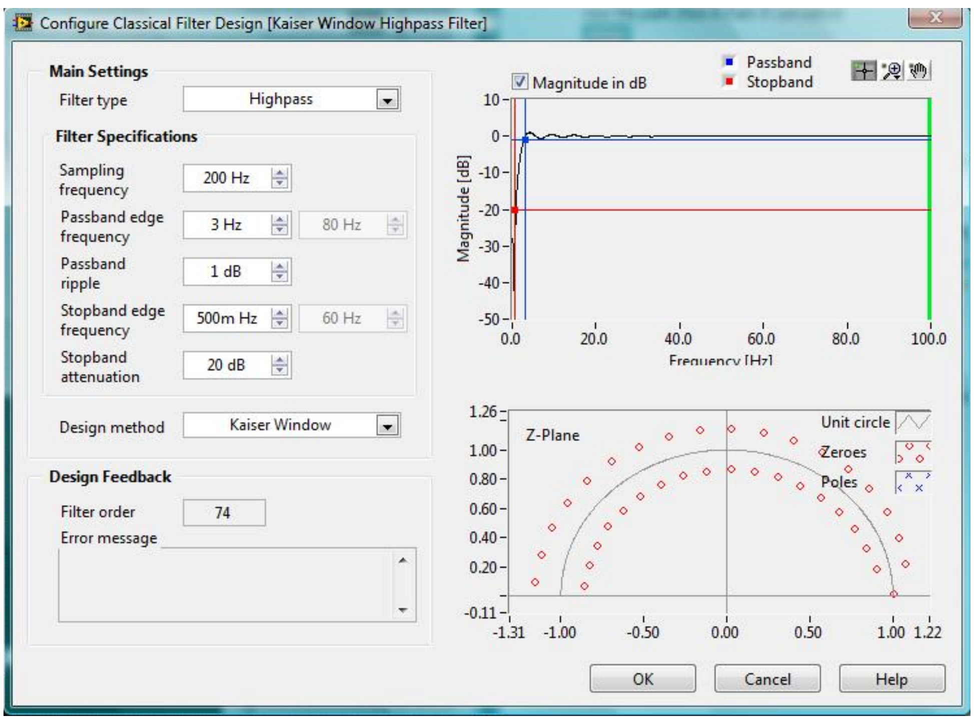


Figure 3.12: Kiser Window highpass filter

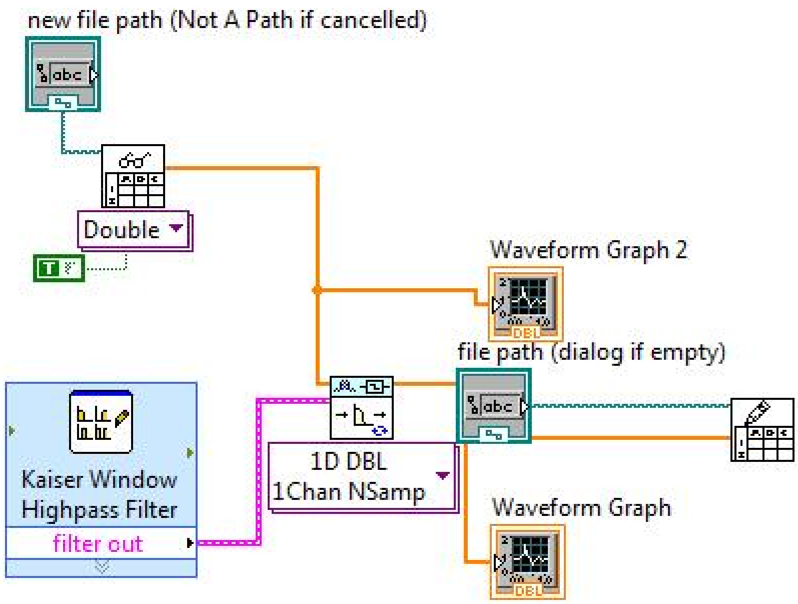


Figure 3.13: Block diagram for Baseline wandering removing VI.

3.2.6.6.2 Removing Wideband Noise

After remove baseline wandering, the resulting ECG signal is more stationary and explicit than the original signal. However, some other types of noise might still affect feature extraction of the ECG signal. The designed filter to remove these noises has three inputs and one output.

One input is the ECG signal that has to be filtered. Second input is sampling rate at which this signal is picked and the last input is Window cut off that decides how strongly filter will remove the glitches from the input signal. The output is filtered ECG signal. The block diagram of ECG filter VI is shown in the figure 3.14.

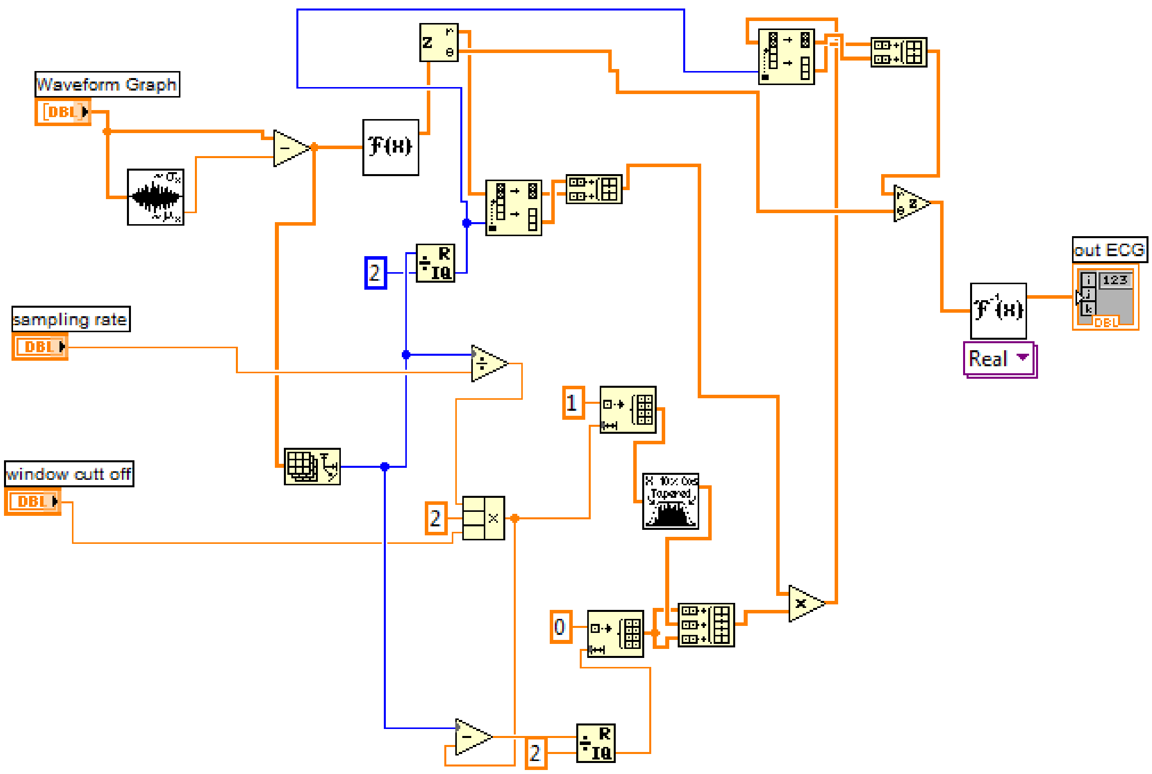


Figure 3.14: Filter for ECG signal

Chapter 4

Results and Discussion

4.1 Introduction

After performing various steps of the Patient Monitoring System, the present algorithm's results are presented here. These experiments are performed on Respiration, ECG and SpO_2 data collected with the help of polyrite machine and LabVIEW 8.2 was used for the program.

4.2 Acquisition and display of Signals

Respiration, ECG and SpO_2 are acquired, filtered, amplified and converted into digital form and enter into the PC with the help of parallel port interfaces, polyrite machine and then monitored, analyzed and displayed with the help of LabVIEW.

4.2.1 Acquisition and display of Respiration Signal

Figure 4.1 demonstrates how to take a simple heart and respiration rate measurement utilizing the Compact DAQ platform and the LabVIEW graphical programming environment. The Simple Heart and Respiration Rate Example_LabVIEW8.5.vi uses the NI 9239 module to measure the voltages returned from a Heart Rate/Blood Volume Pulse Sensor and a Respiration Sensor. These signals are then processed and filtered to remove high frequency noise components above 5 Hz. Signal Analysis can be performed to detect the number of peaks that occur within ten seconds from which an average beats per minute can be found.

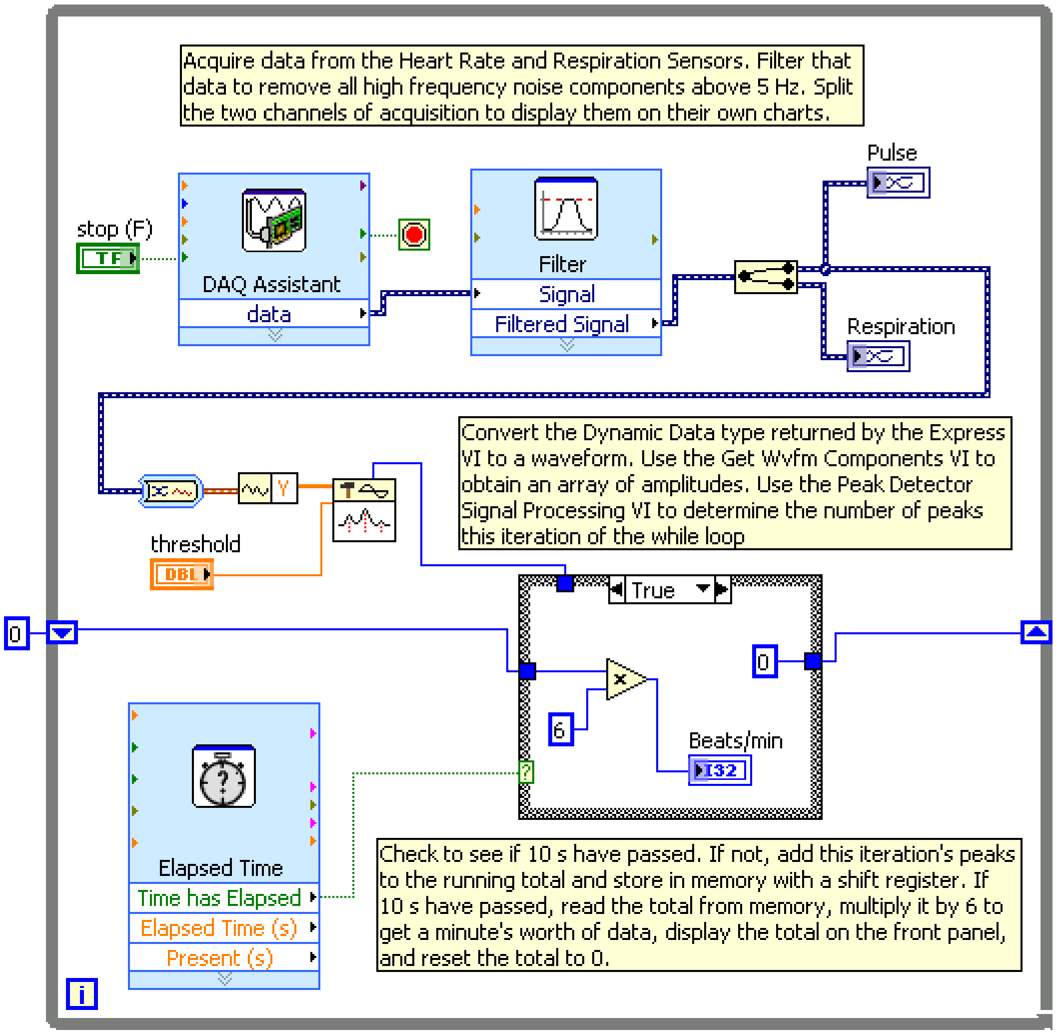
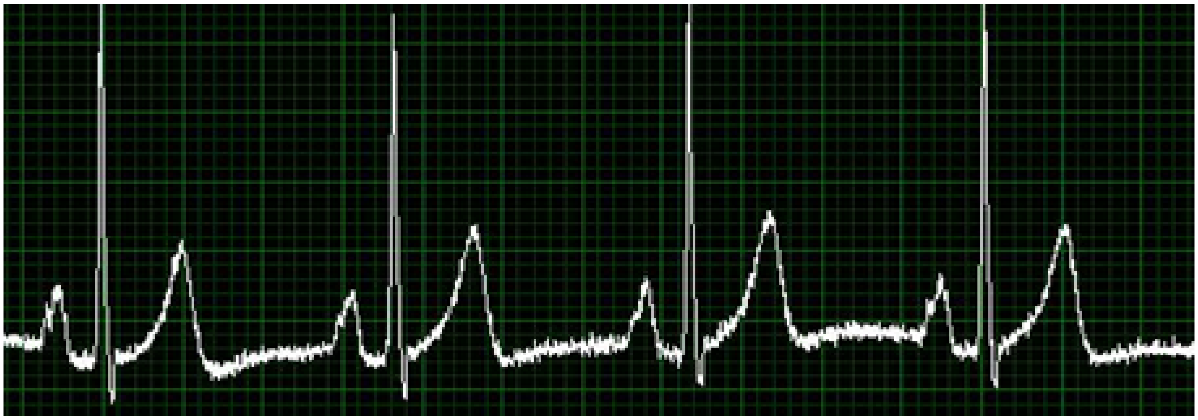


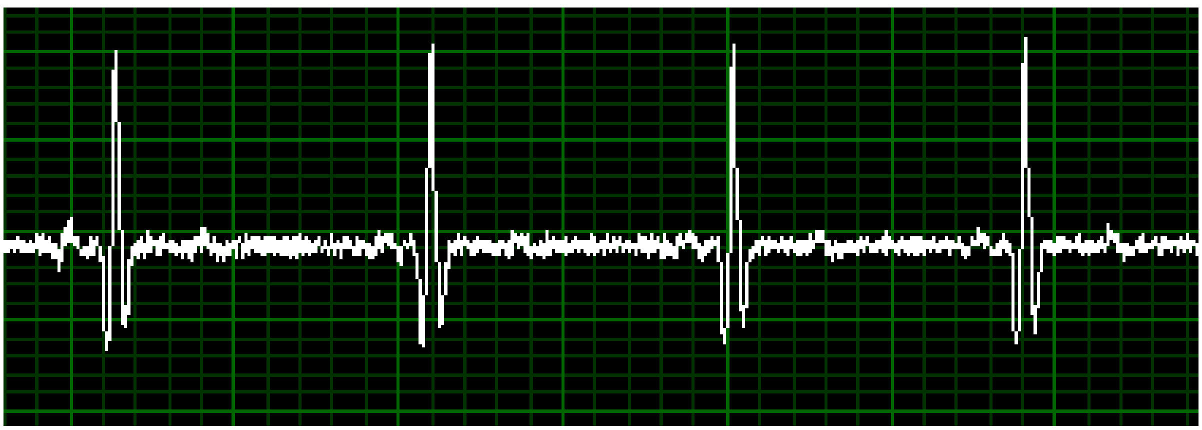
Figure 4.1: VI for Acquisition and display of Respiration Signal

4.2.2 Acquisition and display of ECG Signal

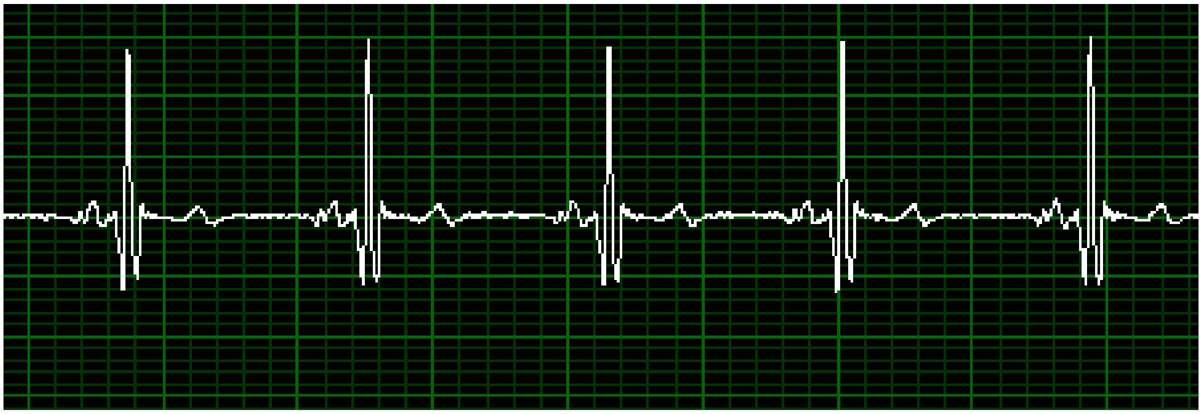
The ECG signal is measured by the human surface electrode. Its amplitude ranges about from 1mV to 3mV, and the frequency ranges from 0.05Hz to 150Hz. For receiving correct ECG signal, the ECG signal must be amplified. The ECG signal from the patient is given to the DAQ card through BNC connector where the signal is sampled and converted in to digital format. The output from DAQ board is given to the PC through buffers. These buffers provide the electrical isolation along with the unity gain to the signal. LabVIEW using driver software of National Instruments treats the signal received. The acquired data can be stored in memory or hard disk. The result can be displayed using graphs as analyzed waveforms. In LabVIEW user interface is known as front panel and we can addcodeusing icons of functions to control the front panel object. The block diagram contains the requisite code.



(A)



(B)



(C)

Figure 4.2: ECG signal at different stages of verification. (A) Input signal, (B) ECG signal after baseline wandering removal, (C) ECG signal after noise removal.

4.2.2.1 Baseline Wandering Removing

After ECG signal is recoded the first step is to remove baseline wandering. The waveform after the baseline wandering removal is shown in figure 4.5.

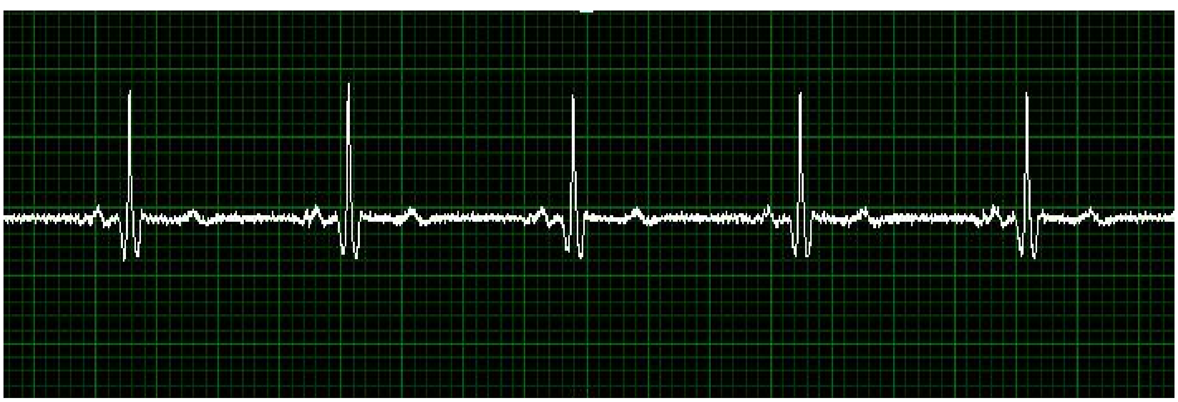


Figure 4.3: ECG signal after remove Baseline Wandering

4.2.2.2 Noise Removing

Noise is another problem after baseline wandering which can affect the feature extraction. So the filtration of ECG signal is necessary. Digital filtration is used in this approach. The figure 4.6 shows the ECG wave after filtration.

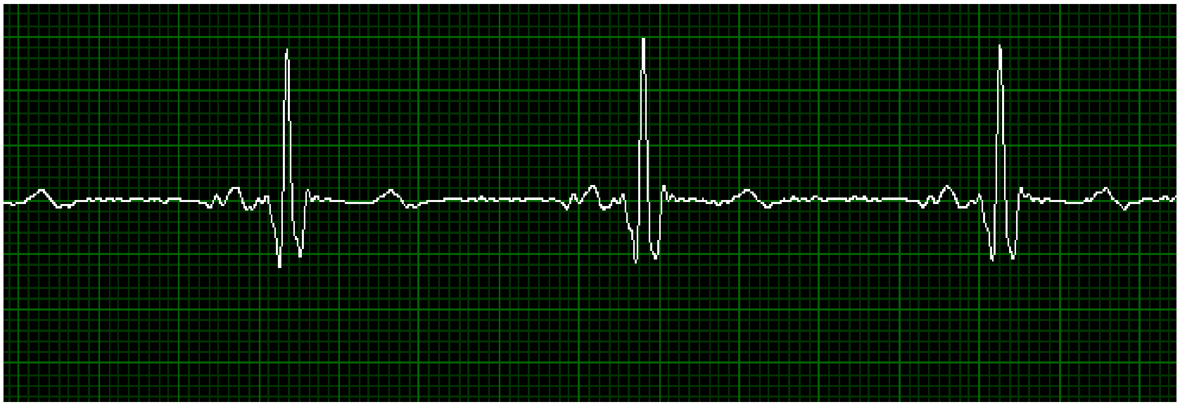


Figure 4.4: ECG wave after Filtration

4.2.3 Acquisition and display of SpO_2 Signal

Using LabVIEW, a program was written to read the red and infrared signals from the sensor prototype, display them with moderate filtering, perform spectral measurements (FFT), and calculate pulse rate, ratio R, and SPO_2. A block diagram of the system setup can be seen below.

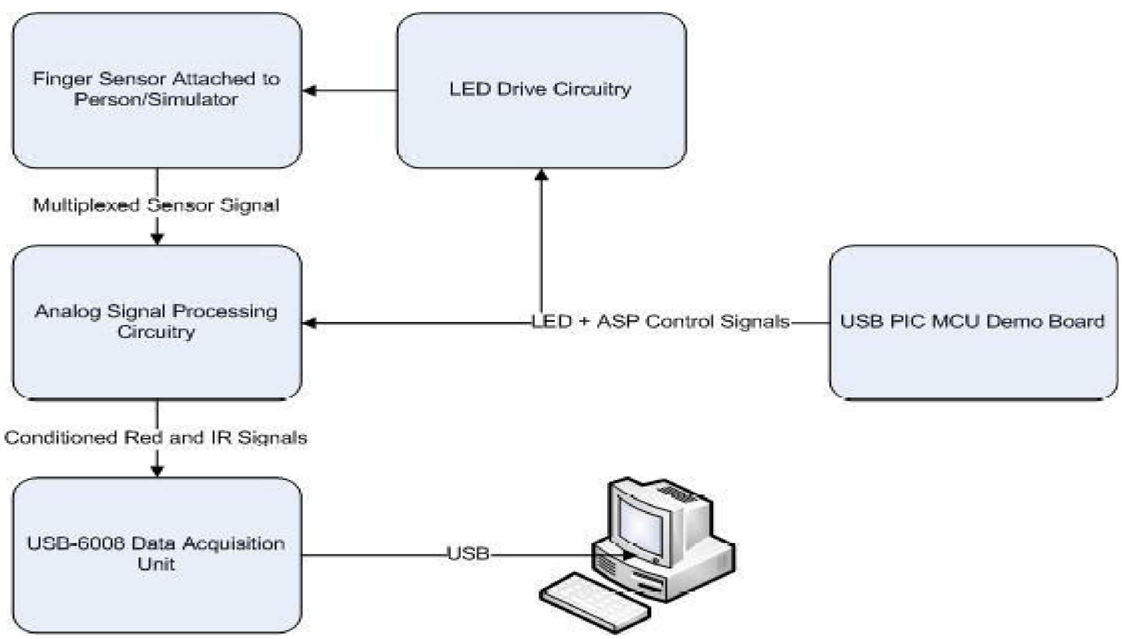


Figure 4.5: LabVIEW Test Circuit Block Diagram

A National Instruments data acquisition box (USB-6008) was used to record the measurements. Two 11 bit A/Ds were used. To simulate the effects of using a 10 bit A/D in the final design, the maximum voltage input was set to double the actual voltage. This effectively used only 10 bits.

Once the red and infrared LED signals are into the computer, a simple LabVIEW program processes the information. A sample output of this program can be seen below, acquiring a signal from the patient.

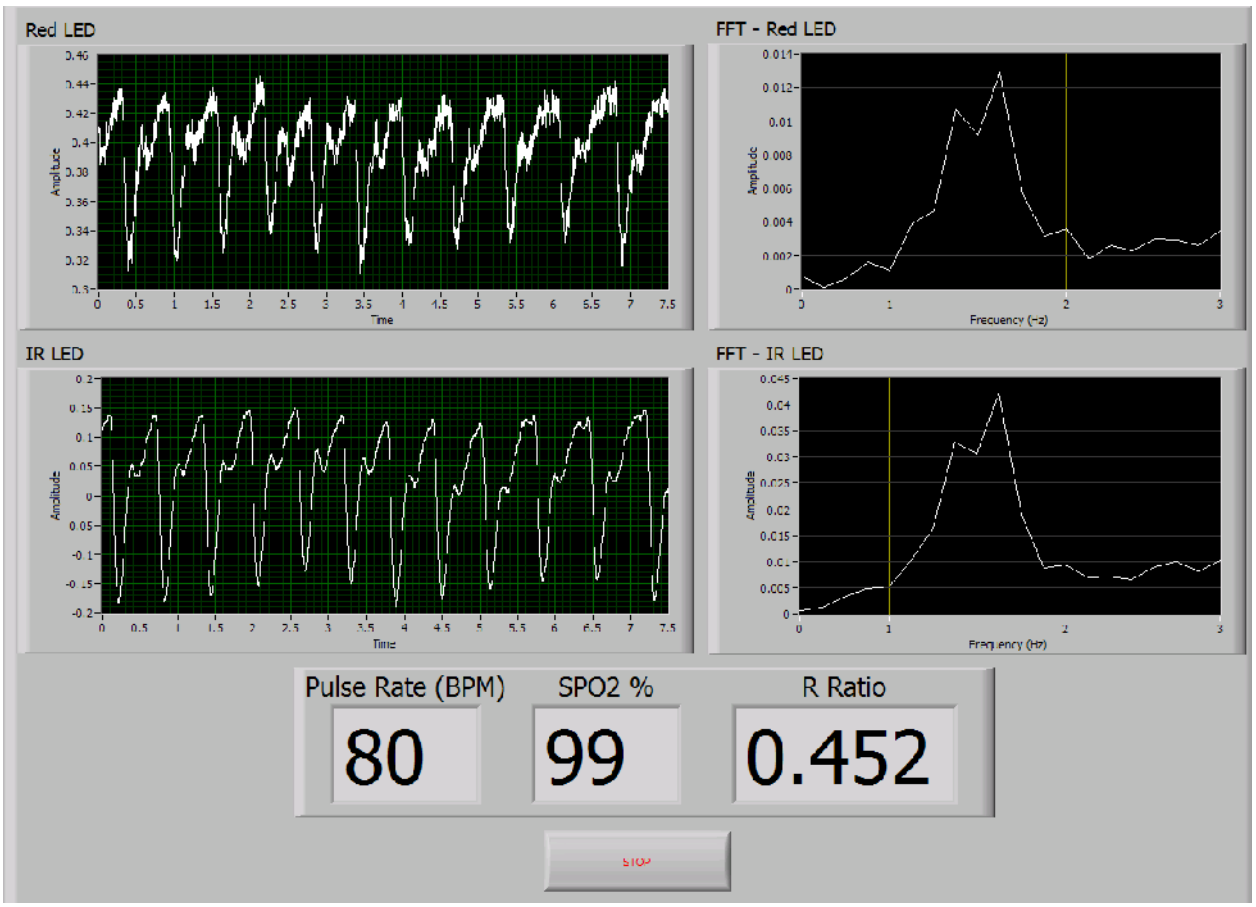


Figure 4.6: LabVIEW Test Program

The graph on the left show the digitally filtered signals from the analog sensor. A low pass FIR filter was used with a cutoff frequency of 40Hz. On the right are FFTs of the corresponding channel. The ratio of these two is used to determine the R Ratio, and from there, the SPO_2 %.

A simplified block diagram of the test program can be seen below.

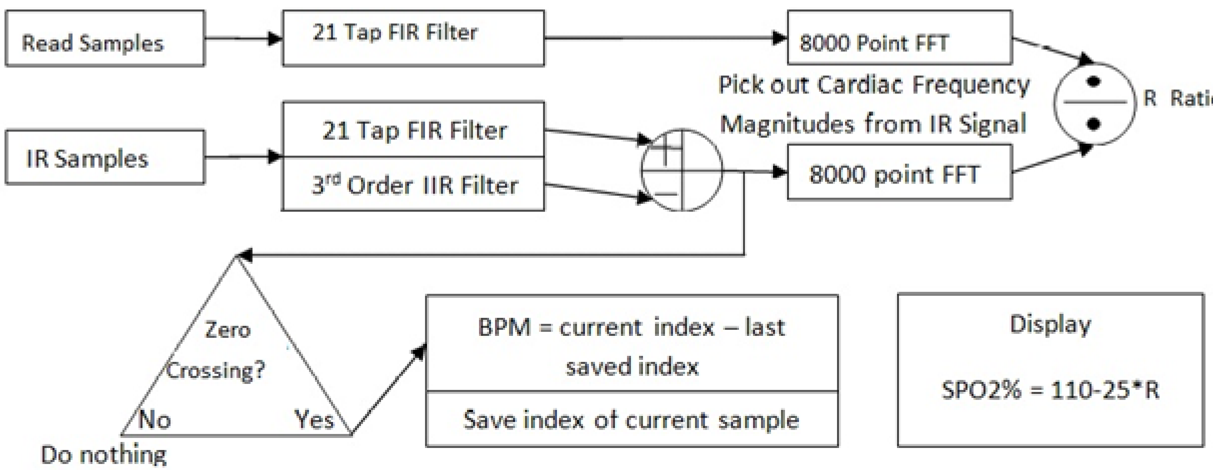


Figure 4.7: LabVIEW Test Program Block Diagram

The Red and Infrared samples go through simple filtering, to clean up the signal before graphing, running the FFTs, and calculating the BPM through a zero crossing method.

4.3 Results

The overall hardware connections of the patient monitoring system for experiment setup are shown below figure.

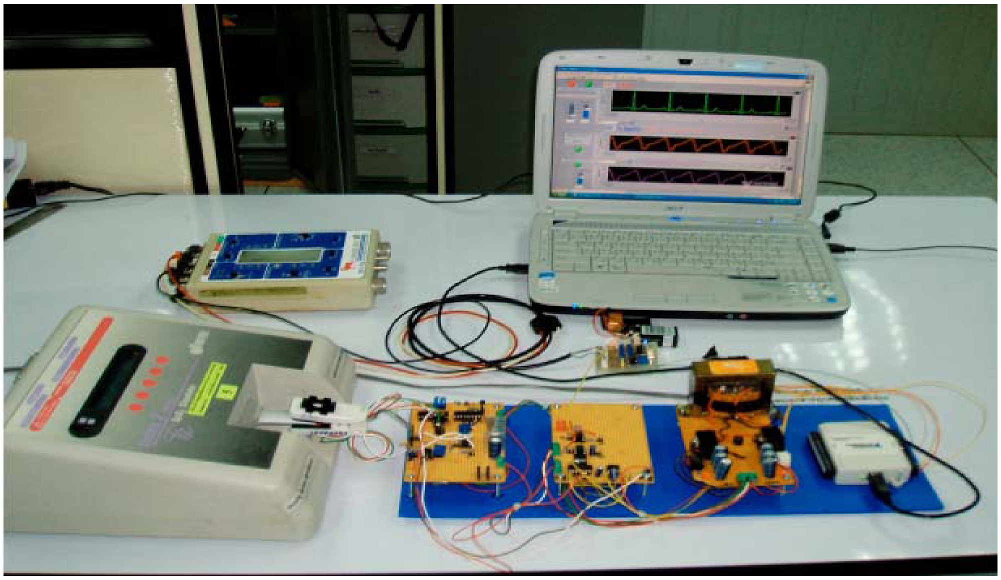


Figure 4.8: Overall connections of the Patient monitoring system

To continuously display and record the measured Respiration, ECG and SpO_2 data, the graphical user interface on the computer screen has been developed by using LabVIEW program.

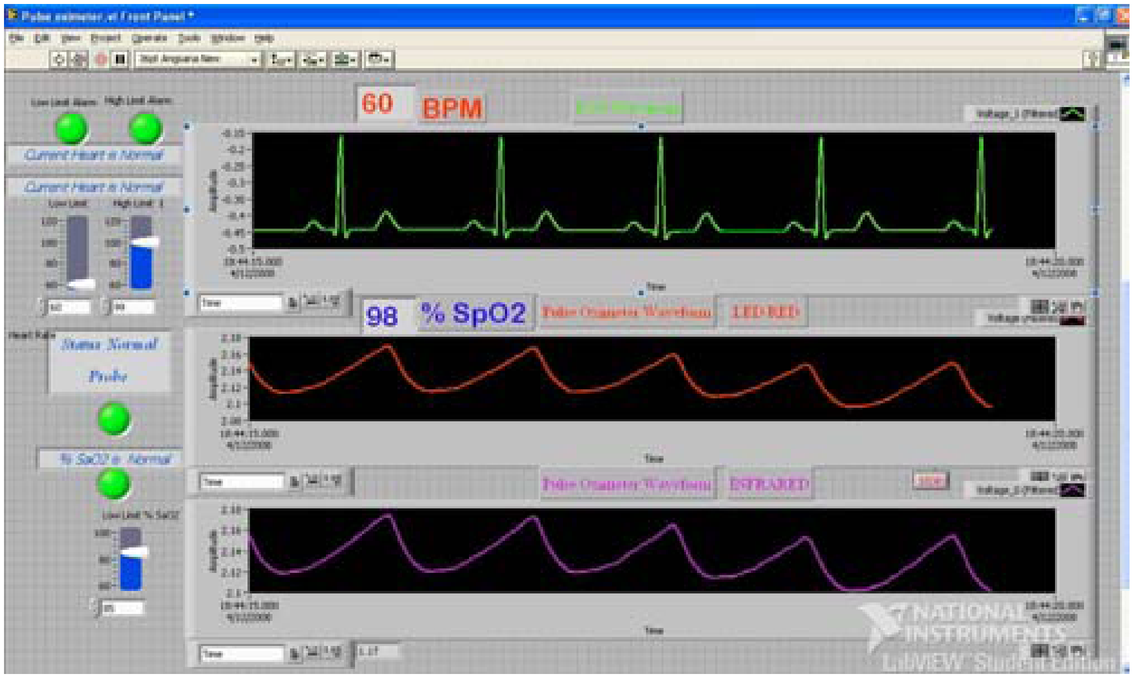


Figure 4.9: Sample of developed LabVIEW window

Measured results for ten different values of heart rate are summarized in Table 4.1. To test the repeatability, the measurement was repeated five times for each heart rate value. From Table 4.1, it is clearly seen that the maximum error of about 1.75% is obtained. Table 4.2 summarizes the experimental results from five repeat measurements for ten different values of $\%SpO_2$ level, From Table 4.2 it can be observed that the maximum error is about 1.95%. Table 4.3 summarizes the experimental results from five repeat measurements for ten different values of Respiration Rate (breath per min.) and the maximum error is about 7.27%.

TABLE 4.1
Measured Results for Ten Different Values of Heart Rate

Heart Rate (bpm)	Measured Value (bpm)					Average	Average Error (%)
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}		
120	118	116	117	119	121	118.2	1.5
115	113	111	114	116	117	114.2	0.69
110	112	111	108	107	106	108.8	1.09
105	104	103	102	105	107	104.2	0.76
100	100	98	97	99	102	99.2	0.8
95	97	99	97	96	94	96.6	1.68
90	89	86	88	91	93	89.4	0.67
85	87	88	86	83	84	85.6	0.07
80	77	76	78	79	83	78.6	1.75
75	74	76	77	79	78	76.8	2.4

TABLE 4.2
Measured Results for Ten Different Values of %SPO_2

% SpO_2	Measured Value %					Average	Average Error (%)
	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}		
100	97	99	98	100	102	99.2	0.80
98	96	94	95	97	99	96.2	1.83
96	93	92	94	96	98	94.6	1.45
94	96	97	94	97	95	95.8	1.91
92	90	89	91	93	91	90.8	1.95
90	89	87	89	92	90	89.4	0.67
88	89	86	85	87	89	87.2	0.90
86	85	86	87	88	85	86.2	0.23
83	82	81	80	82	84	81.8	1.44
80	78	77	79	81	82	79.4	0.75

TABLE 4.3

Measured Results for Ten Different Values of Respiration Rate (Breath per min.)

Breath per min.	Measured Value (bpm)					Average	Average Error (%)
	1st	2nd	3rd	4th	5th		
20	21	21	22	20	19	20.6	3.00
21	22	23	20	18	19	20.4	7.27
22	23	22	22	21	23	22.2	0.90
23	23	24	26	24	22	23.8	3.47
24	25	24	26	27	25	25.4	5.83
25	24	22	25	26	27	24.8	0.80
26	26	25	27	26	24	25.6	1.58
27	26	25	24	26	28	25.8	4.44
28	29	30	31	27	26	28.6	2.14
29	30	31	32	30	28	30.2	4.13

Chapter 5

Conclusion

Conclusion

The work discussed here "Study and Analysis of Patient Monitoring system compatibility with LabVIEW". The aim of this work was develop a patient monitoring system, which can measure and display the patient's vital signs.

It provides the low-cost patient monitoring system with the ability of record storage in digital format. The hardware implementations using commercially available devices and the software written in LabVIEW program for continuously monitoring and recording Respiration, ECG and SpO_2 data have been described. The task of noise removing was carried out by using different topology of filters and also the analysis was carried out by taking different types of filters and obtained result of around 90% accuracy in removing noise by using Kiser Window highpass filter. The experiment conducted on the collected database in the laboratory of 10 persons of different age having 10 samples each reveals that accuracy of 90% can be achieved with the proposed algorithm.

Advantages of Our Patient Monitoring System

The system we have developed has following advantages:

i. It is robust enough, to handle noise.
ii. Our system is rapid, because the time it takes for the acquisition and display step is very low.
iii. It is fully automated, and requires no special skill to handle it.
iv. The implementation cost is very less, compared to other techniques.

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