

# **Palestine Polytechnic University**



**College of Engineering & Technology  
Electrical and Computer Engineering Department  
Biomedical Engineering**

**Graduation Project  
Interface Module  
For Monitoring ECG Signal and Temperature**

## **Project Team**

Abd Ull-raheem Estetah

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## **Project Supervisor**

Dr. Omar Al – Surakhy

## **Co – Supervisor**

Dr. Daoud Zatari

**Hebron – Palestine**

**June, 2004**

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**By:**

Abd Ull-raheem Estetah

Osama Othman

Islam Odeh

With prosperity from Allah and the guidance of our supervisor Dr. Daoud Zatari, and upon the acceptance of all members of the testing committee, this report were delivered to department of electrical and computer engineering in the college of engineering and technology as a partial fulfillment for the requirements of the degree of bachelor.

**Supervisor Signature**

.....

**Examination Committee Signature**

.....

**Chief of the Department Signature**

.....

## Abstract

This project describes the design and implementation of the Interface Module for monitoring ECG signal and temperature (IM). This Module is a flexible interface to communicate sensor data such as biomedical signals – with computer for reading and analyzing it. The IM is controlled by computer. Using this module with graphical language program LABVIEW enable the user to read biomedical signals and to utilize the computer in analyzing it.

هذا المشروع يوضح تصميم وتطبيق (IM) عرض إشارة تخطيط القلب الكهربائي وقياس درجة الحرارة، هذه الأداة هي أداة ربط مرنة تستخدم لوصول بيانات المجسات مع الحاسوب لقراءة وتحليل هذه البيانات. (IM) يتم التحكم به عن طريق الحاسوب. باستخدام هذه الأداة مع البرنامج المرافق وهو LABVIEW يستطيع المستخدم أن يقرأ إشارات طبية ويستفيد من الحاسوب لتحليلها.

## الإهداء

إلى الزهرة التي لا تذبل.....	....نبع العنان.....	إلى أمي.....
إلى العاص الذي لا ينحسر.....	....نبع العطاء....	إلى والدي.....
إلى ملائكة الأرض.....	....شقائق الزعمان....	إلى أشقائي.....
إلى من قتلته رهبانيتي.....	....	إلى حبيبتي.....
إلى قناديل الدرب.....	....الشموع التي لا تنطفئ.....	إلى أستاذتي.....
إلى رفاق الدرب.....	....بناة المستقبل.....	إلى أصدقائي.....
إلى صناع الكرامة.....	....رايات المجد.....	إلى شهدائنا.....
إلى من رفضوا الخضوع.....	....من طلبوا العزة.....	إلى.....
إلى كل المخلصين.....	....العاملين للإسلام.....	إلى حملة الدعوة.....
		أسرانا

إليكم جميعاً أحبتي أهدي هذا الجهد المتواضع

أسامه عثمان  
محمد الرحي استيتيه  
إسلام موحده

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## Table of Contents

<b>Abstract.....</b>	<b>IV</b>
<b>Dedication.....</b>	<b>V</b>
<b>Acknowledgment.....</b>	<b>VI</b>
<b>Table of Content.....</b>	<b>VII</b>
<b>List of Tables.....</b>	<b>X</b>
<b>List of Figures.....</b>	<b>XI</b>
<b>Chapter One: Introduction.....</b>	<b>1</b>
1.1 System Overview.....	2
1.2 Problem Definition.....	3
1.3 Applications of IM.....	3
1.4 Where we can use IM? .....	3
1.5 Estimated Cost.....	4
1.6 About this Report.....	5
<b>Chapter Two: Biomedical Signals.....</b>	<b>7</b>
2.1 Preview.....	8
2.2 Biomedical Sensor .....	8
2.3 Cardiac Signals.....	11
2.4 Temperature.....	20
<b>Chapter Three: Design Concept.....</b>	<b>22</b>
3.1 Preview.....	23

3.2 General Block Diagram.....	24
3.3 Detailed Block Diagram.....	25
3.4 How the System Works.....	26
<b>Chapter Four: Hardware.....</b>	<b>27</b>
4.1 Overview.....	28
4.2 LM35 Temperature Sensor.....	29
4.3 ECG Circuit.....	30
4.4 Analog to digital converter.....	34
4.5 Buffer.....	38
4.6 Parallel Port.....	38
<b>Chapter Five: Software System Design.....</b>	<b>43</b>
5.1 Overview.....	44
5.2 Lab View.....	45
5.3 Parallel Port Configuration.....	45
5.4 Temperature Program.....	47
5.5 ECG Program.....	49
5.6 General Program.....	54
<b>Chapter six: Testing.....</b>	<b>55</b>
6.1 Introduction.....	56
6.2 Unit Testing.....	56
6.3 Sub-system Testing.....	58
6.4 System Testing.....	58
6.5 Problems.....	59
6.6 Results.....	60
<b>Chapter Seven: Future Work.....</b>	<b>61</b>
<b>Chapter eight: Conclusion.....</b>	<b>63</b>
<b>References.....</b>	<b>65</b>



**Appendix .....67**

## List of Tables

Table 1.1 Hardware Costs.....	4
Table 2.1 the Main Energy.....	10
Table 4.1: Comparison between Serial & Parallel Ports.....	38
Table 4.2 Data Register.....	40
Table 4.3 Status Register.....	40
Table 4.4 Control Register.....	41
Table 4.5 Status and Control Register Connector.....	42
Table 6.1 Unit System Testing.....	57

## List of Figures

Figure 2.1 Sensing a Human Signal.....	9
Figure 2.2 Conduction System of the Heart.....	12
Figure 2.3 ECG Signal.....	14
Figure 2.4 Bipolar Limb Lead and Unipolar Limb Lead.....	17
Figure 2.5 Unipolar Chest Lead.....	18
Figure 3.1 General Block Diagram of the Project.....	24
Figure 3.2 Detailed Block Diagram of UIM.....	25
Figure 4.1 Temperature Sensor Circuit.....	30
Figure 4.2 Instrumentation Amplifier.....	30
Figure 4.3 High Pass Filter.....	32
Figure 4.4 Low Pass Filter.....	33
Figure 4.5 Free Running Circuit.....	35
Figure 4.6 $\pm 5V$ Analog Inputs.....	36
Figure 4.7 Connect 8-ADCs with Parallel Port.....	37
Figure 4.8 Parallel Port.....	39
Figure 4.9 Diagram of the 25 Pin Connector Used On Most Computers.....	41
Figure 4.10 Status and Control Register Connector.....	42
Figure 5.1 out Port Icon.....	45
Figure 5.2 in Port Icon.....	46
Figure 5.3 Configuration of Parallel Port (Diagram Panel).....	46
Figure 5.4 Diagram Panel of Temperature Program.....	48
Figure 5.5 Front Panel for Temperature Program.....	49
Figure 5.6 ECG Signal.....	50
Figure 5.7 Diagram Panel ECG Program.....	51
Figure 5.8 Front Panel for ECG Program.....	52
Figure 5.9 Calculation of Heart Rate.....	53
Figure 5.10 General Program.....	54
Figure 6.1 the ECG Signal from Our Project.....	60

# **Chapter One**

## **Introduction**

- 1.1 System Overview.
- 1.2 Problem Definition.
- 1.3 Application our project.
- 1.4 Where we can use UIM?
- 1.5 Estimated Cost.
- 1.6 About this Report.

# **Chapter One**

## **Introduction**

It is obvious that Biomedical Engineering is so important for the healthcare which makes our life easier and more comfortable. It also offers us all what we need to make our life looks easy and the human's being the reason to live as longer as he can.

The development of Biomedical Engineering is strongly related to computer advances. So people can't design or implement any medical equipment without using computer utilities.

### **1.1 System Overview**

The purpose of this project is to design and implement an Interface Module (IM) which is a flexible communication interface between biomedical sensor data and computer.

The data which come from IM is to be analyzed for biomedical purposes by the graphical programming language Lab VIEW.

A general IM is used in multiple applications including education, art installations, interactive computer applications, computer interface, instrumentation research and interactive computer music performance. The IM must be of low cost and applied in biomedical purposes.

The IM is controlled by a computer; the user selects the channel which he wants to use by the software. So he selects the sensor or device that is connected with the IM.

IM is connected with computer by parallel port to receive and transmit data to the IM which we can connect with many sensors after we make the amplification and filtering (conditioning signal) stage or any device which give us any signal.

The (API) is used to communicate with the IM via the computer. The set of API instructions include functions to initialize the IM, and to read and request data from an I/O devices then analyzing the data for the biomedical purposes.

## **1.2 Problem Definition**

The main goal of this project is to design a flexible system to read biomedical signals such as (Temperature and ECG signals) by using common sensors to analyze it through computer based system.

## **1.3 Application of IM**

There are many applications which can be implemented in this module. We chose the following applications:

- 1- Monitoring ECG for diagnosing purposes and calculating the Heart Rate from the ECG signal.
- 2- Measuring the Temperature.

## **1.4 Where we can use IM?**

IM could be used in many places such as in universities' Biomedical Lab, hospitals and other places.

## 1.5 Estimated Cost of the Project

### 1.5.1 Hardware Cost

The following table shows the cost of the hardware components:

Table 1.1 Hardware Costs

Item No.	Component	Estimated Cost in (\$)
1	A/D converter	5*8
2	Temperature sensor	5*3
3	Amplifier	1*5
4	Cable	5*2
5	Inverter	1*2
6	Based	9
7	Weirs, resistor and capacitor	10
8	Other devices	20
9	Old devices (Microcontroller & ADC)	100\$
	Total	200\$

### **1.5.2 Team Cost**

Team consists of 3 students; the project takes 6 months to be completed so the team cost is:

$$6 * 20 \text{ day/month} = 120 \text{ days}$$

$$120 * 3 \text{ hours/day} = 360 \text{ hours}$$

$$360 * 5 \$ = 1800 \$$$

$$1800 * 3 = 5400 \$ \text{ for the whole team.}$$

### **1.6 About this Report**

This report organized as:

Chapter one gives an overview of the system, defined problem described the application of IM, where used, and hardware cost.

Chapter two illustrates the theories used in this system, the biomedical and the electronics signals are analyzed to discuss how to be measured in the system.

Chapter three gives an overview about the design of the IM; it illustrates the main block diagram and how system work.

Chapter four explains the chosen parts for the system and detailed description of their functionality. The main circuits and schematics are included in this chapter.

Chapter five shows the necessary algorithms for the IM, it illustrates the labView programs.

Chapter six describes the testing process by showing testing stages by details.



Chapter seven gives the developers slight ideas how to develop the IM.

Chapter eight: conclusions.

## **Chapter Two**

# **Biomedical Signals**

2.1 Preview

2.2 Biomedical Sensor

2.3 Cardiac Signals

2.4 Temperature

## **Chapter Two**

### **Biomedical Signals**

#### **2.1 Preview**

In this chapter we will discuss the application of our project by talking about the physiological theory of cardiac and temperature. At first, we will discuss the biomedical sensor, its definition, how measurement can be done by sensor and classification of sensor. Because we can't measure any signal without using sensor or transducer.

#### **2.2 Biomedical Sensor**

Because signals from the body are constantly varying, computers are a must for quick progress in the development of biosensors and transducers. When a signal from the human body is acquired, amplified, filtered, and displayed, it is in analog form. Since digital computers require binary numbers, a converter device is needed before analog signals can be accepted and processed in digital machines. This requires an analog-to-digital converter.

##### **2.2.1 Sensors and Transducers**

###### **2.2.1.1 Definition of Sensors and Transducers**

The words sensor and transducer are both used in referring to measurement systems. Sensor is derived from the word sentire meaning to perceive whereas transducer is from transducer meaning to lead across.

To distinguish between the two, a sensor is a device that detects a change in a physical stimulus and turns it into a signal which can be measured or recorded, and a transducer is a device that transfers power from one system to another in the same or in a different form. Normally, the sensor is just the sensing element itself and the transducer is the sensing element plus any associated circuitry. [1]

Sensors and transducers may sense either analog or digital signals. An analog signal is a continuous measurable quantity, and a digital signal is a quantity that is sampled at fixed intervals. A higher sampling rate increases the accuracy of measurement. Because the human body produces analog signals, analog-to-digital converters are required in measuring with digital sensors.

#### 2.2.1.2 Measurement Systems

The amount of confidence in the results of a measurement is greatly increased when all factors influencing the measurement are fully understood. This requires a detailed knowledge of the measurement process and the possible interactions of the measurement process on the system being measured. These interactions can come from direct physical influences as well as biochemical, physiological, and psychological interactions with the measuring process. A measuring system is required to compare a quantity with a standard or to provide an output that can be related to the quantity being measured. The quantity to be measured is detected by the input transducer or sensor.

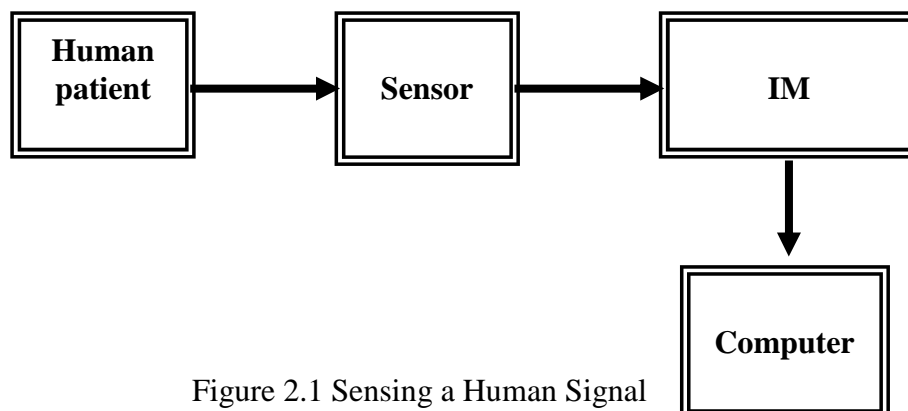


Figure 2.1 Sensing a Human Signal

Because sensors and transducers are so broad and widely used, it is impossible to pinpoint the first invention. They have been around since the beginning of time. All life forms use sensors and transducers. [5]

#### 2.2.1.4 Classifications of Sensor and Transducer

Sensors and transducers must be classified according to the physical property that they use (piezoelectric, photovoltaic, etc.) or according to the function that they perform (measurement of length, temperature, etc.). Since energy conversion is an essential characteristic of the sensing process, the various forms of energy should be considered. The following table lists the main forms of energy and their occurrence:

Table 2.1 The Main Energy

Type of energy	Occurrence	Example
Radiant	Radio waves, visible light, infrared	SpO <sub>2</sub>
Mechanical	Motion, displacement, forces	Blood pressure
Thermal	kinetic energy of atoms and molecules	Temperature
Electrical	Electric fields, currents	ECG
Chemical	Binding energy between nuclei	Spectrophotometer

For measurement purposes, five types of signals are important: radiant, mechanical, thermal, electrical, and chemical. The signal is fed into an input transducer, which changes the form of energy, usually into electrical.

In this project we used two types of energy, electrical (ECG) and thermal (human temperature). [5]

## **2.3 Cardiac Signals**

The cells that constitute the ventricular myocardium are coupled together by gap junctions which, for the normal healthy heart, have a very low resistance. As a consequence, activity in one cell is readily propagated to neighboring cells. It is said that the heart behaves as a syncytium; a propagating wave once initiated continues to propagate uniformly into the region that is still at rest. We have quantitatively examined the electrophysiological behavior of a uniform fiber. Now we can apply these results to the heart if we consider it to be composed of uniform fibers. These equivalent fibers are a valid representation because they are consistent with the syncytial nature of the heart. In fact, because the syncytium reflects connectivity in all directions, we may choose the fiber orientation at our convenience (so long as the quantitative values of conductivity assigned to the fibers correspond to those that are actually measured). [1]

### **2.3.1 The Conduction System of the Heart**

Located in the right atrium at the superior vena cava is the sinus node (sinoatrial or SA node) which consists of specialized muscle cells. The sinoatrial node in humans is in the shape of a crescent and is about 15 mm long and 5 mm wide see Figure 2.2. The SA nodal cells are self-excitatory, pacemaker cells. They generate an action potential at the rate of about 70 per minute. From the sinus node, activation

propagates throughout the atria, but cannot propagate directly across the boundary between atria and ventricles, as noted above. [1]

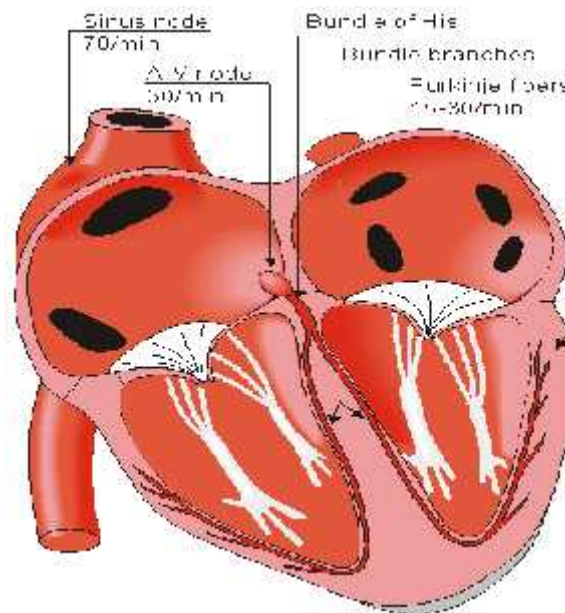


Figure 2.2 Conduction System of the Heart

The atrioventricular node AV node is located at the boundary between the atria and ventricles; it has an intrinsic frequency of about 50 pulses/min. However, if the AV node is triggered with a higher pulse frequency, it follows this higher frequency. In a normal heart, the AV node provides the only conducting path from the atria to the ventricles. Thus, under normal conditions, the latter can be excited only by pulses that propagate through it. [1]

Propagation from the AV node to the ventricles is provided by a specialized conduction system. Proximally, this system is composed of a common bundle, called the bundle of His (named after German physician Wilhelm His, Jr., 1863-1934). More distally, it separates into two bundle branches propagating along each side of the septum, constituting the right and left bundle branches. (The left bundle

subsequently divides into an anterior and posterior branch.) Even more distally the bundles ramify into Purkinje fibers (named after Jan Evangelista Purkinje (Czech; 1787-1869)) that diverge to the inner sides of the ventricular walls. Propagation along the conduction system takes place at a relatively high speed once it is within the ventricular region, but prior to this (through the AV node) the velocity is extremely slow.

From the inner side of the ventricular wall, the many activation sites cause the formation of a wave front which propagates through the ventricular mass toward the outer wall. This process results from cell-to-cell activation. After each ventricular muscle region has depolarized, repolarization occurs. Repolarization is not a propagating phenomenon, and because the duration of the action impulse is much shorter at the epicardium (the outer side of the cardiac muscle) than at the endocardium (the inner side of the cardiac muscle), the termination of activity appears as if it were propagating from epicardium toward the endocardium.

Because the intrinsic rate of the sinus node is the greatest, it sets the activation frequency of the whole heart. If the connection from the atria to the AV node fails, the AV node adopts its intrinsic frequency. If the conduction system fails at the bundle of His, the ventricles will beat at the rate determined by their own region that has the highest intrinsic frequency. [1]

### **2.3.2 ECG Signal**

An electrocardiograph (ECG) is a graphical recording of the changes occurring in the electrical potentials between different sites on the skin as a result of cardiac activity. The electrical activity of the heart is a sequence of depolarization and repolarization. Depolarization occurs when the cardiac cells, which are electrically polarized, lose their internal negativity. The spread of depolarization travels from cell to cell, producing a wave of depolarization across the entire heart. This wave



represents a flow of electricity that can be detected by electrodes placed on the surface of the body. Once depolarization is complete, the cardiac cells are restored to their resting potential, a process called repolarization.

This flow of energy takes on the form of the ECG wave, and is characterized by an initial P wave, followed by the QRS complex, and then the T wave. The P wave is associated with depolarization of the atria. The QRS complex is associated with depolarization of the ventricles, and the T wave with repolarization of the ventricles. This flow of electricity can also be sensed by recording electrodes. As shown in figure 2.3. [1]

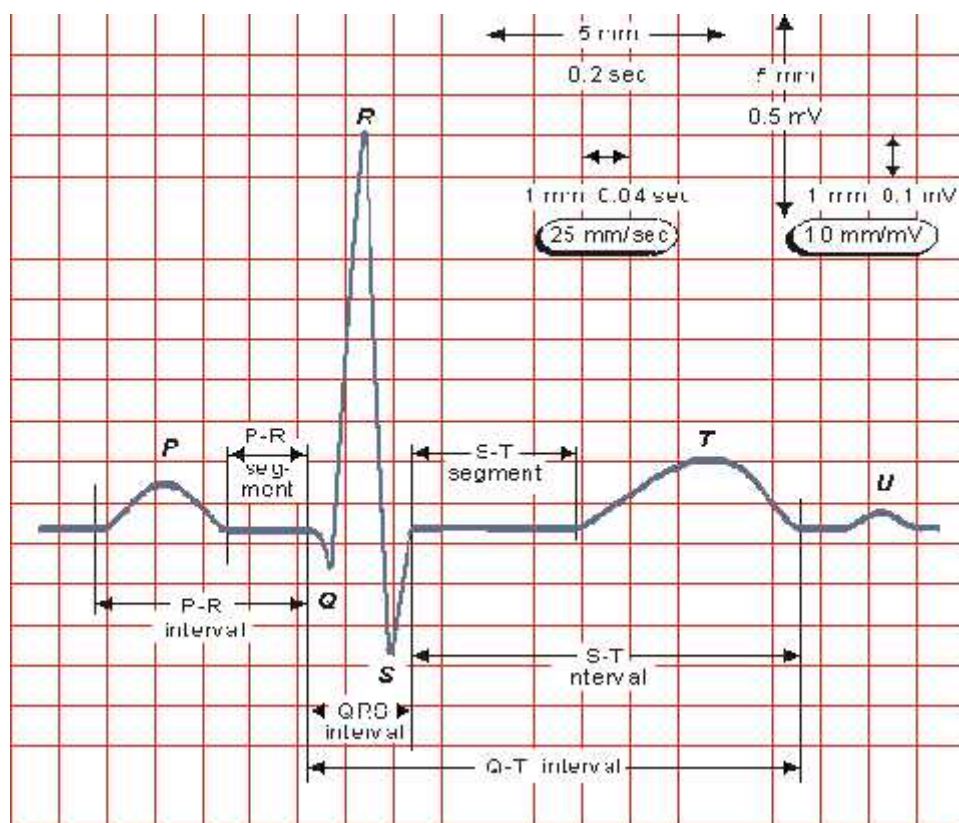


Figure 2.3 ECG signal

- P wave: the sequential activation (depolarization) of the right and left atria
- QRS complex: right and left ventricular depolarization (normally the ventricles are activated simultaneously)
- ST-T wave: ventricular depolarization
- U wave: origin for this wave is not clear - but probably represents "after depolarization's" in the ventricles
- PR interval: time interval from onset of atrial depolarization (P wave) to onset of ventricular depolarization (QRS complex)
- QRS duration: duration of ventricular muscle depolarization
- QT interval: duration of ventricular depolarization and repolarization
- RR interval: duration of ventricular cardiac cycle (an indicator of ventricular rate)
- PP interval: duration of atrial cycle (an indicator of atrial rate).

Obtaining accurate data from an electrocardiogram depends partially on the specific electrode placement and site preparation. One of the most important considerations in site preparation is reducing the amount of impedance between the electrode and the skin's surface. Impedance, which is essentially the same as resistance, is the measure of opposition to the current in an electrical circuit. High impedance can be caused by excess dry skin, long hair, or the presence of scar tissue, and has the detrimental effect of adding noise to the signal of interest. Proper skin preparation must take place so that the least amount of impedance is present and optimal skin contact is obtained. Electrode gel can then be applied to the electrode in order to further increase its performance.

Once an acceptable electrode set-up is achieved, a check can be made to determine the resistance by hooking up pairs of electrodes to an electrode tester. This will directly determine the resistance between the two selected electrodes. Impedance levels as low as 1 to 2 Kilo ohms can be maintained with proper skin preparation,

however a 5 to 10 Kilo ohm is acceptable. Impedance levels will improve over time as the electrode conductivity gel begins to adhere better between the skin and electrode.

### **2.3.3 The Standard Lead System**

Willem Einthoven described in 1901 the first electrocardiograph and with it he was able to register the electrical activity of the heart. For this he got in 1924 the Nobel price. Einthoven used three leads, which later became the standard leads or Einthoven leads.

Later Goldberger and Wilson added other leads, now an ECG exists of 12 leads:

- 3 bipolar limb leads (Einthoven).
- 3 unipolar limb leads (Goldberger).
- 6 unipolar chest leads (Wilson).

Bipolar limb leads (frontal plane):

- Lead I: RA (-) to LA (+) (Right Left, or lateral).
- Lead II: RA (-) to LF (+) (Superior Inferior).
- Lead III: LA (-) to LF (+) (Superior Inferior).

Augmented unipolar limb leads (frontal plane):

- Lead aVR: RA (+) to [LA & LF] (-) (Rightward).
- Lead aVL: LA (+) to [RA & LF] (-) (Leftward).
- Lead aVF: LF (+) to [RA & LA] (-) (Inferior).

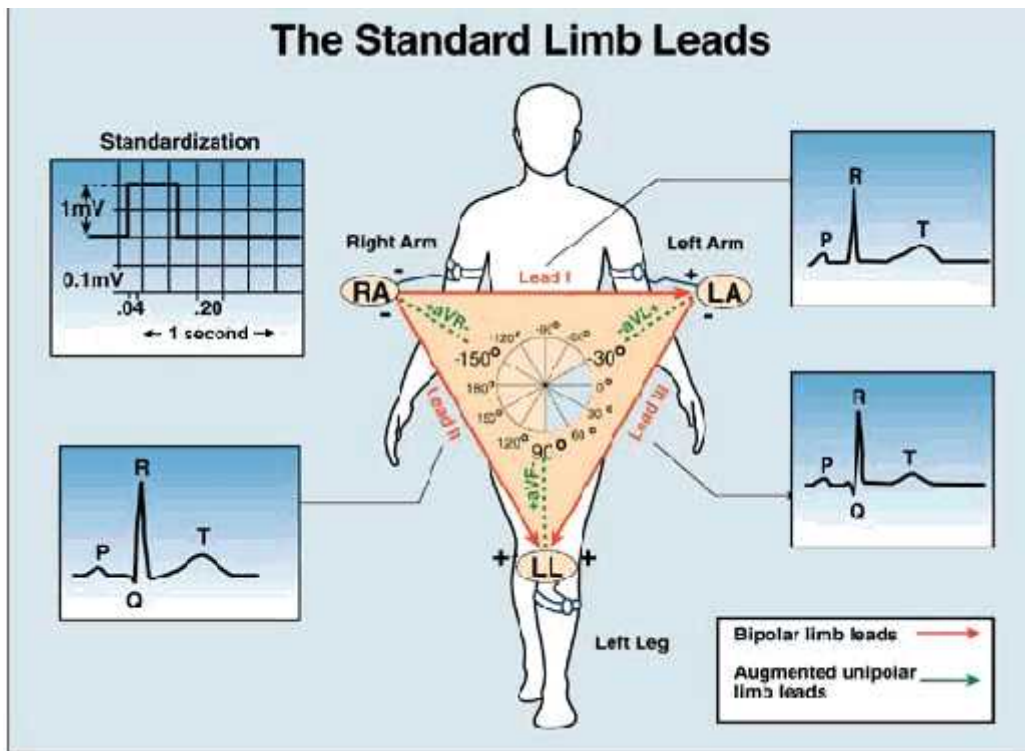


Figure 2.4 Bipolar Limb Lead and Unipolar Limb Lead [1]

Unipolar (+) chest leads (horizontal plane):

- Leads V1, V2, V3: (Posterior Anterior).
- Leads V4, V5, V6 :( Right Left or lateral).

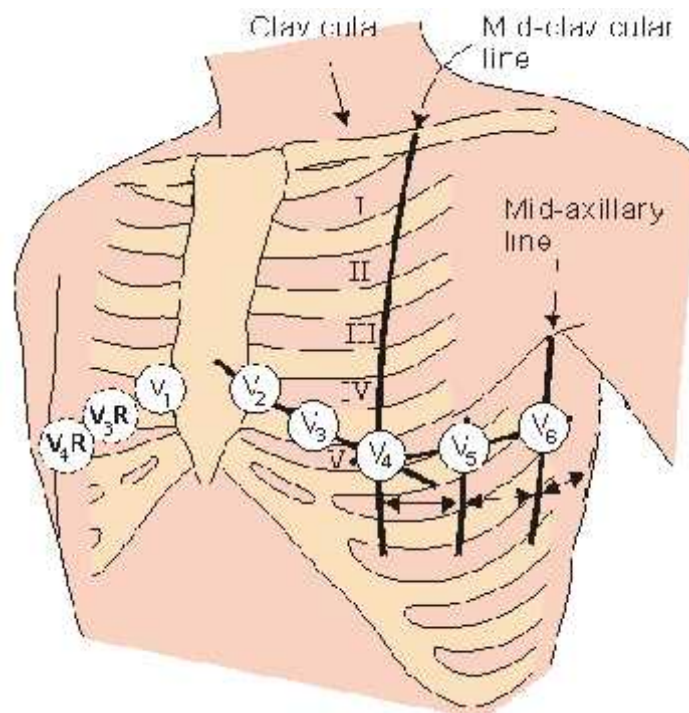


Figure 2.5 Unipolar Chest Lead [1]

- V1: right 4<sup>th</sup> intercostal space
- V2: left 4<sup>th</sup> intercostal space
- V3: halfway between V2 and V4
- V4: left 5<sup>th</sup> intercostal space, mid-clavicular line
- V5: horizontal to V4, anterior axillary line
- V6: horizontal to V5, mid-axillary line

### **2.3.4 Heart Rate**

A heartbeat is a two-part pumping action that takes about a second. As blood collects in the upper chambers (the right and left atria), the heart's natural pacemaker (the SA node) sends out an electrical signal that causes the atria to contract. This contraction pushes blood through the tricuspid and mitral valves into the resting lower chambers (the right and left ventricles). This part of the two-part pumping phase (the longer of the two) is called the diastole.

The second part of the pumping phase begins when the ventricles are full of blood. The electrical signals from the SA node travel along a pathway of cells to the ventricles, causing them to contract. This is called systole. As the tricuspid and mitral valves shut tight to prevent a back flow of blood, the pulmonary and aortic valves are pushed open. While blood is pushed from the right ventricle into the lungs to pick up oxygen, oxygen-rich blood flows from the left ventricle to the heart and other parts of the body.

After blood moves into the pulmonary artery and the aorta, the ventricles relax, and the pulmonary and aortic valves close. The lower pressure in the ventricles causes the tricuspid and mitral valves to open, and the cycle begins again. This series of contractions is repeated over and over again, increasing during times of exertion and decreasing while you are at rest. [6]

#### **2.3.4.1 The Measurement of Heart Rate**

From ECG signal we can calculate Heart Rate by detecting the R-waves so we can calculate time between two R-waves and then divide 60 by the time between two R-waves. Note the following example: if the time between two R-waves equal 0.75 second then Heart Rate equal  $60/0.75 = 80$  beat per sec.

## 2.4 Temperature

A patient's body temperature gives the physician important information about the physiological state of the individual.

External body temperature is one of many parameters used to evaluate patients in shock, because the reduced blood pressure of a person in circulatory shock results in low blood flow to the periphery. A drop in the big-toe temperature is a good early clinical warning of shock. Infection, on the other hand, is usually reflected by an increase in body temperature, with a hot, flushed skin and loss of fluids. Increased ventilation, perspiration, and blood flow to the skin result when high fevers destroy temperature-sensitive enzymes and proteins.

Anesthesia decreases body temperature by depressing the thermal regulatory center. In fact, physicians routinely induce hypothermia in surgical cases in which they wish to decrease a patient's metabolic processes and blood circulation.

In the study of arthritis, physicians have shown that's temperature of joints are closely correlated with the amount of local inflammation can be detected by thermal measurements. [3]

The specific site of body-temperature recoding must be selected carefully so that it truly reflects the patient's temperature. Also, environmental changes and artifacts can cause misleading readings.

### 2.4.1 The Measurement of Temperature

We measured the temperature by using temperature sensor (LM 35). It convert the temperature to voltage as  $10 \text{ mV}/1 \text{ C}^\circ$  but the output from the sensor is very low, so we must use amplifier to amplify voltage before sending it to the ADC then to computer. By using computer we calculate temperature. Such as the following

example: the sensor converts temperature to voltage and amplify voltage by using amplifier with voltage gain 10, if the output voltage of the amplifier equals 2.1 the temperature is 21.



## **Chapter Three**

### **Design Concepts**

- 3.1 Preview.
- 3.2 General Block Diagram
- 3.3 Detailed Block Diagram
- 3.3 How the system works.

## **Chapter Three**

### **Design Concepts**

#### **3.1 Preview**

The IM is a flexible interface to communicate sensor data with computer. This interface is controlled by computer, which communicates sensor data from an A/D converter to a computer through parallel port. The IM works as an intermediate stage between the sensor data and the computer to handle all the interfacing functions required. The application programmer uses a set of simple Application Interfaces (APIs) to communicate with the IM. The set of APIs includes functions to initialize the IM, and to read requested data from an I/O device.

The API is LABVIEW which is used to transmit data from computer to the IM and receive it.

### 3.2 General Block Diagram

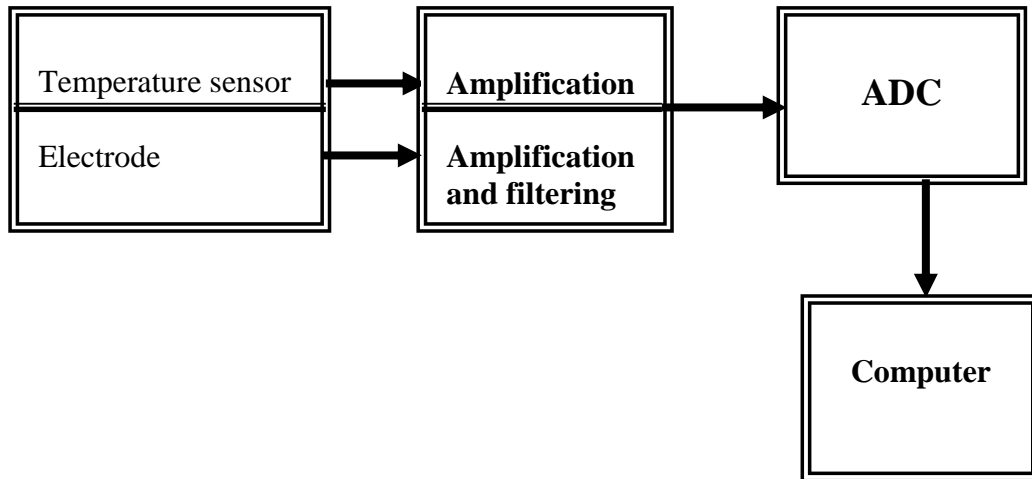


Figure 3.1 General Block Diagram of the Project

### 3.3 Detailed Block Diagram

The following figure shows a detailed block diagram of the IM:

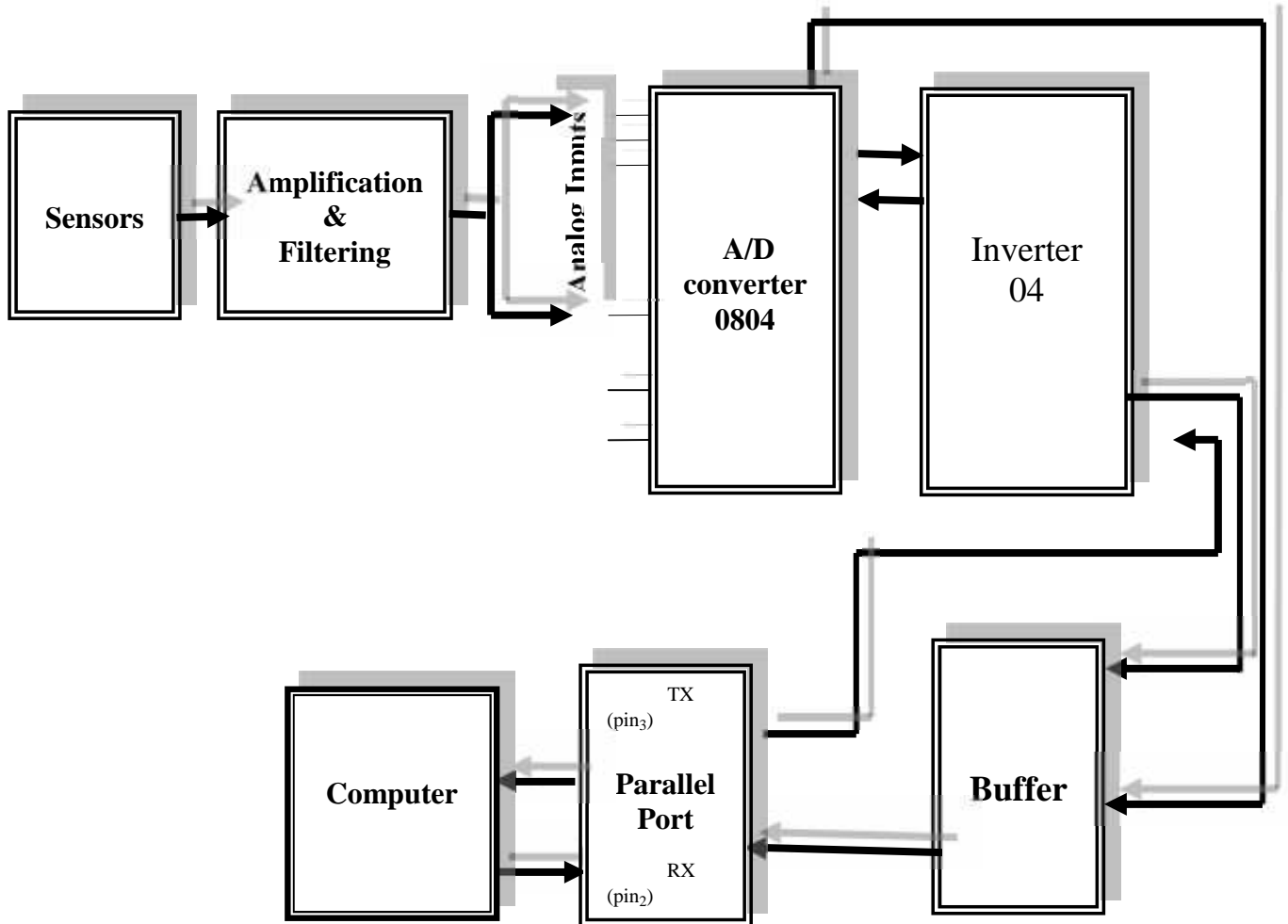


Figure 3.2 Detailed Block Diagram of IM

The computer is responsible of the whole process it initializes the A/D converter to start reading the analog data and converts it into digital then it schedule the interrupts to receive this digital data and pass it to the computer through states and control line.

### **3.4 How the system works**

From the details block diagram figure 3.2 the system works as following steps:

- 1- Connecting sensor to IM (temperature or electrode).
- 2- Then the data will go to the amplification circuit if it is temperature or to the amplification and filtering circuit if it is ECG.
- 3- Computer sends the address to select channel (ADC to be active).
- 4- ADC starts conversion data from analog to digital and sends data to computer for analysis to display ECG signal and calculating heart rate if computer selects ECG channel or measuring temperature if the computer selects the temperature channel.
- 5- We used inverter in this project because the parallel port uses inverter in the same lines.
- 6- Buffer is used for protection purpose.

## **Chapter Four**

### **Hardware**

4.1 Overview

4.2 LM35 Temperature Sensor

4.3 ECG Circuit

4.4 Analog to Digital Converter

4.5 Buffer

4.6 Parallel Port

## **Chapter Four**

### **Hardware**

#### **4.1 Overview**

This chapter describes the IM parts and components that are best suited for its functionality and operability. The chips were selected to be as much compatible as possible to ensure undesired or unexpected faults.

Another key factor of choosing system hardware is availability; there is a lack of electronics chips in Palestine so designers must consider this point when outlining the IM system hardware.

## 4.2 LM35 Temperature Sensor

### 4.2.1 Features of the Sensor

- ⇒ Calibrated directly in ° Celsius (Centigrade).
- ⇒ Linear +10 mV/°C scale factor.
- ⇒ 0.5 °C accuracy guarantee able (at +25°C ).
- ⇒ Rated for full -55 to +150 °
- ⇒ Suitable for remote application.
- ⇒ Low cost due to wafer-level trimming.
- ⇒ Operates from 2 to 30 volts
- ⇒ Less than 60 μA current drain.
- ⇒ Low self-heating 0.08 °C in still air.
- ⇒ Nonlinearity  $\pm 1/4$  °C typical.
- ⇒ Low impedance output, 0.1 Ohm for 1 mA load.

### 4.2.2 Temperature Sensor Circuit

Temperature sensors are used to convert the temperature into electrical voltage. Since the output values of voltage are small we used amplifier with temperature to increase the voltage to the level analog to digital converter (ADC). Figure (4.1) show the interface between temperature sensor LM35 and the amplifier LM324.

One of the most important characteristic of this sensor is:

- ⇒ It operates in low temperature environment (below 100° C).
- ⇒ The relation between temperature and voltage is linear, gives 10 mV/C°.



⇒ To raise the output voltage the sensor, to the level of the ADC input voltage which has a value between (0-5V), we used LM324 amplifier with voltage gain 10.[2]

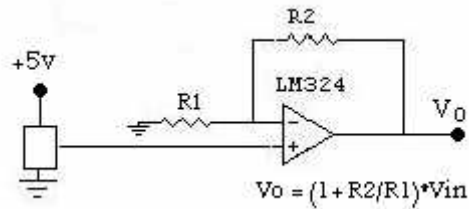


Fig 4.1 Temperature Sensor Circuit

## 4.3 ECG Circuit

### 4.3.1 Instrumentation Amplifier

The ECG signal gained by the sensor must be amplified using the following circuit.

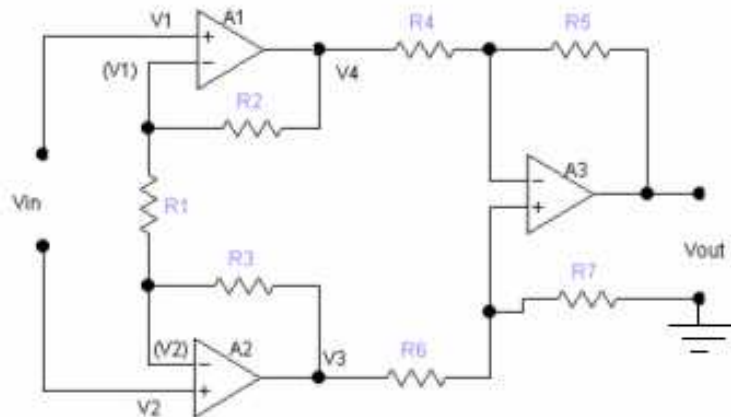


Figure 4.2 Instrumentation Amplifier

This circuit uses three op-amps (A1, A2, and A3), the two input amplifier A<sub>1</sub> and A<sub>2</sub> are connected in the inverting follower configuration, while the A<sub>3</sub> is connected in the simple dc differential amplifier. [4]

Now we want to find the voltage output, assume that V<sub>1</sub> is applied to the non-inverting input of amplifier A<sub>1</sub>, and V<sub>2</sub> is applied to the non-inverting input of amplifier A<sub>2</sub>. Additionally, V<sub>3</sub> is the output of A<sub>2</sub> and V<sub>4</sub> is the output of A<sub>1</sub>. There are two contribution sources to V<sub>3</sub> and V<sub>4</sub>. In the case of V<sub>3</sub>:

$$V_3 = V_2 * (R_3 / R_1 + 1) - (V_1 * R_3 / R_1) \dots 1$$

And for V<sub>4</sub>:

$$V_4 = V_1 * (R_2 / R_1 + 1) - (V_2 * R_2 / R_1) \dots 2$$

If we set R<sub>2</sub> = R<sub>3</sub> (not essential but it simplifies the analysis), and then combine equation 1 and 2 we may write:

$$\begin{aligned} (V_3 - V_4) &= (V_2 - V_1) (R_2 / R_1 + 1) + (V_2 - V_1)(R_2 / R_1). \\ &= (V_2 - V_1) [R_2 / R_1 + 1 + R_2 / R_1] \\ (V_3 - V_4) &= (V_2 - V_1) [2R_2 / R_1 + 1]. \end{aligned}$$

The gain of the A<sub>1</sub> / A<sub>2</sub>, is given by:  $A_v = 2R_2 / R_1 + 1$ .

The gain of an instrumentation amplifier in fig 4.2 given by:

$$A_v = V_{out} / V_{in} = [2R_2 / R_1 + 1](R_5 / R_4).$$

If R<sub>2</sub> = R<sub>3</sub>, R<sub>4</sub> = R<sub>6</sub>, R<sub>5</sub> = R<sub>7</sub>.

### 4.3.2 Filtering Circuit

Filters that use op-amps as the active element provide several advantages over passive filters (R, L, and C element only). The op-amp provides gain, so that the signal is not attenuated as it passes through filter. The high input impedance of the op-amp prevents excessive loading of the driving source, and low output impedance of the op-amp prevents the filter from being affected by the load that it is driving.

Active filter are also easy to adjust over a wide frequency range without altering the desired response.

The filter can be defined as a type of electronic circuit that passes or blocks certain frequencies to the exclusion of all other. Because the ECG signal is so small, between 0.05-100 Hz for diagnostics and 0.05-45 Hz for monitoring, so we need a filter to pass these values and reject all other large frequencies. [4]

The categories of active filters are low pass filter, and high pass filter.

### 4.3.2.1 High Pass Filter

A high pass filter is one that significantly attenuates all frequencies below  $f_c$ , and passes all frequencies above  $f_c$ . The critical frequency, at that the output voltage is 70.7% of the pass band voltage. Figure 4.3 shows high pass filter circuit, this useful for amplifying a small ac voltage that rides on top of a large dc voltage, because the capacitor C block the dc.[4]

The equation of critical frequency will be as in low pass filter:

$$f_c = 1 / 2 \pi (RC) = 0.05 \text{ Hz}$$

The ration of feedback to input impedance:

$$V_{out}(j\omega) / V_{in}(j\omega) = -R_2(j\omega) / R_1 * (1 + j\omega RC)$$

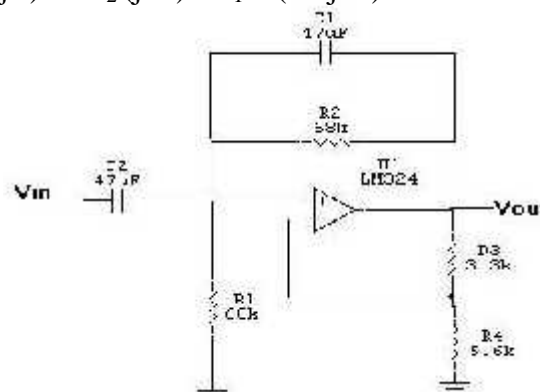


Figure 4.3 High Pass Filter

### 4.3.2.2 Low Pass Filter

The low pass filter is defined to be from 0 Hz (dc) up to the critical (cutoff) frequency  $f_c$ , at which the output voltage is 70.7 % of the pass band voltage. The figure (4.4) shows the low filter circuit. The low pass filter can be obtained by using one op-amp circuit, the advantages of this circuit are that it is capable of gain and that it has very low output impedance, and useful for attenuating high frequency noise.[4]

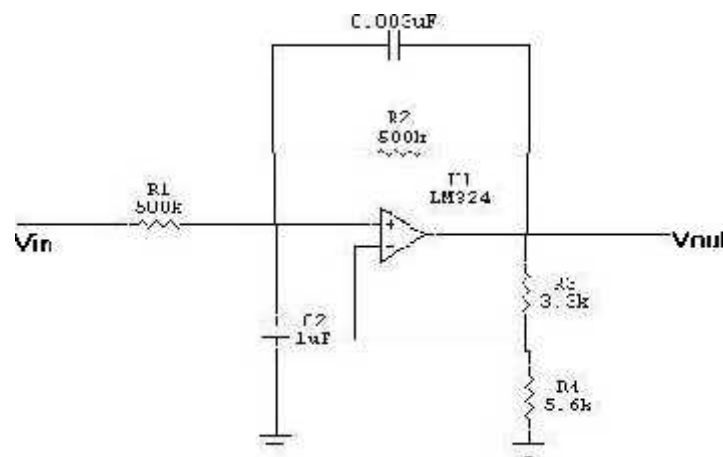


Figure 4.4 Low Pass Filter

The critical frequency is 100Hz; the filter will reject all frequencies above 100Hz, and passes all frequencies below this value. The equation for this filters, where  $R_1 = R_2$ :

$$f_c = 1 / 2 (RC) = 100 \text{ Hz}$$

The ration of feedback to input impedance:

$$V_{out}(j) / V_{in}(j) = -R_2 / R_1 + j$$

## 4.4 Analog to Digital Converter

### 4.4.1 General Description

The ADC0804 is CMOS 8-bit successive approximation A/D converter that uses a differential potentiometric ladder-similar to the 256R products.

This converter is designed to allow operation with the NSC800 and INS8080A derivative control bus with TRI-STATE output latches directly driving the data bus. These A/Ds appear like memory locations or I/O ports to the microprocessor and no interfacing logic is needed.

Differential analog voltage inputs allow increasing the common-mode rejection and offsetting the analog zero input voltage value. In addition, the voltage reference input can be adjusted to allow encoding any smaller analog voltage span to the full 8 bits of resolution.

### 4.4.2 Features

- ⇒ Compatible with 8080  $\mu$ P derivatives—no interfacing logic needed - access time - 135 ns.
- ⇒ Easy interface to all microprocessors, or operates “stand alone”
- ⇒ Logic inputs and outputs meet both MOS and TTL voltage level specifications
- ⇒ Works with 2.5V (LM336) voltage reference.
- ⇒ On-chip clock generator.
- ⇒ 0V to 5V analog input voltage range with single 5V supply.
- ⇒ No zero adjusts required.
- ⇒ 0.3" standard width 20-pin DIP package.
- ⇒ 20-pin molded chip carrier or small outline package.

- ⇒ Operates ratio metrically or with 5 VDC, 2.5 VDC, or analog span adjusted voltage reference.
- ⇒ Conversion time 100 μs.

#### 4.4.3 Self-Clocking in Free-Running Mode

We connect the ADC by using Free-Running mode as show in figure 4.5 this meaning we are controlling ADC without microcontroller but we using computer to enable the ADC by sending data through the data line of parallel port.

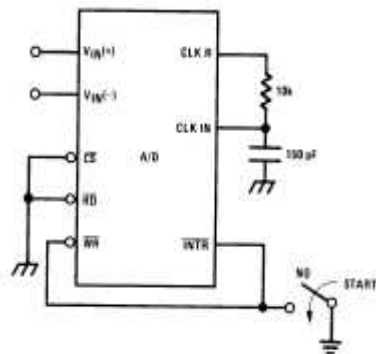


Figure 4.5 Free Running Circuit

#### 4.4.4 Handling ±5V Analog Inputs

This circuit may us to input analog voltage to the ADC as ECG signal or any negative voltage. This circuit works as the following

When enable ADC by computer the  $V_{cc}$  (5V) divided into two equal values each of them equal 2.5V then goes to the  $V_{in+}$  so show always 2.5V minimum in  $V_{in+}$  and the input voltage divided into two equal value. One of them goes to  $V_{in+}$  and sum it with the 2.5V from  $V_{cc}$  so the range in  $V_{in+}$  between (0-5V) but the input voltage (-5 – 5V) as following equation:

$$V_{in}/2 + 5/2 = V_{in+}$$

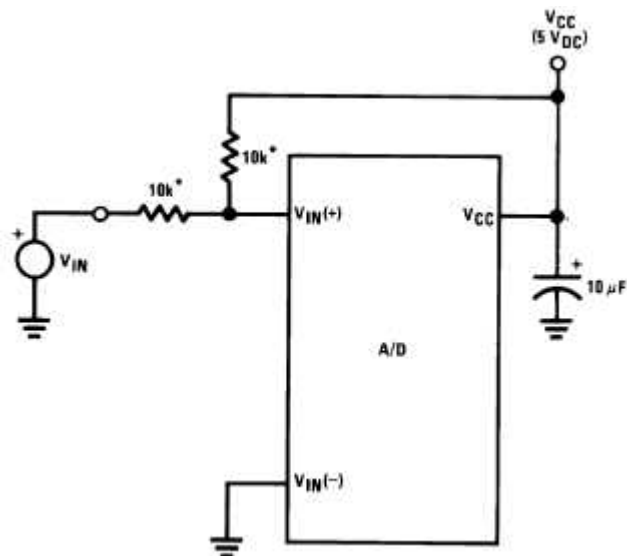


Figure 4.6  $\pm 5V$  Analog Inputs

#### 4.4.5 Connect Several ADCs

To connect Several ADC we connect pin (7, 9, and 10) with together in every ADC (in the same ADC and between many ADC) then to ground and the output pines together in several ADC (just between ADC's) then to parallel port by status and control register.

Connect pin 20 for every ADC together then to Vcc and pin 19, 14 to clocking circuit. And then input in every ADC just is alone as pin 1 and 2 we connect them together in the ADC and connect them in to data line as show in figure 4.7.

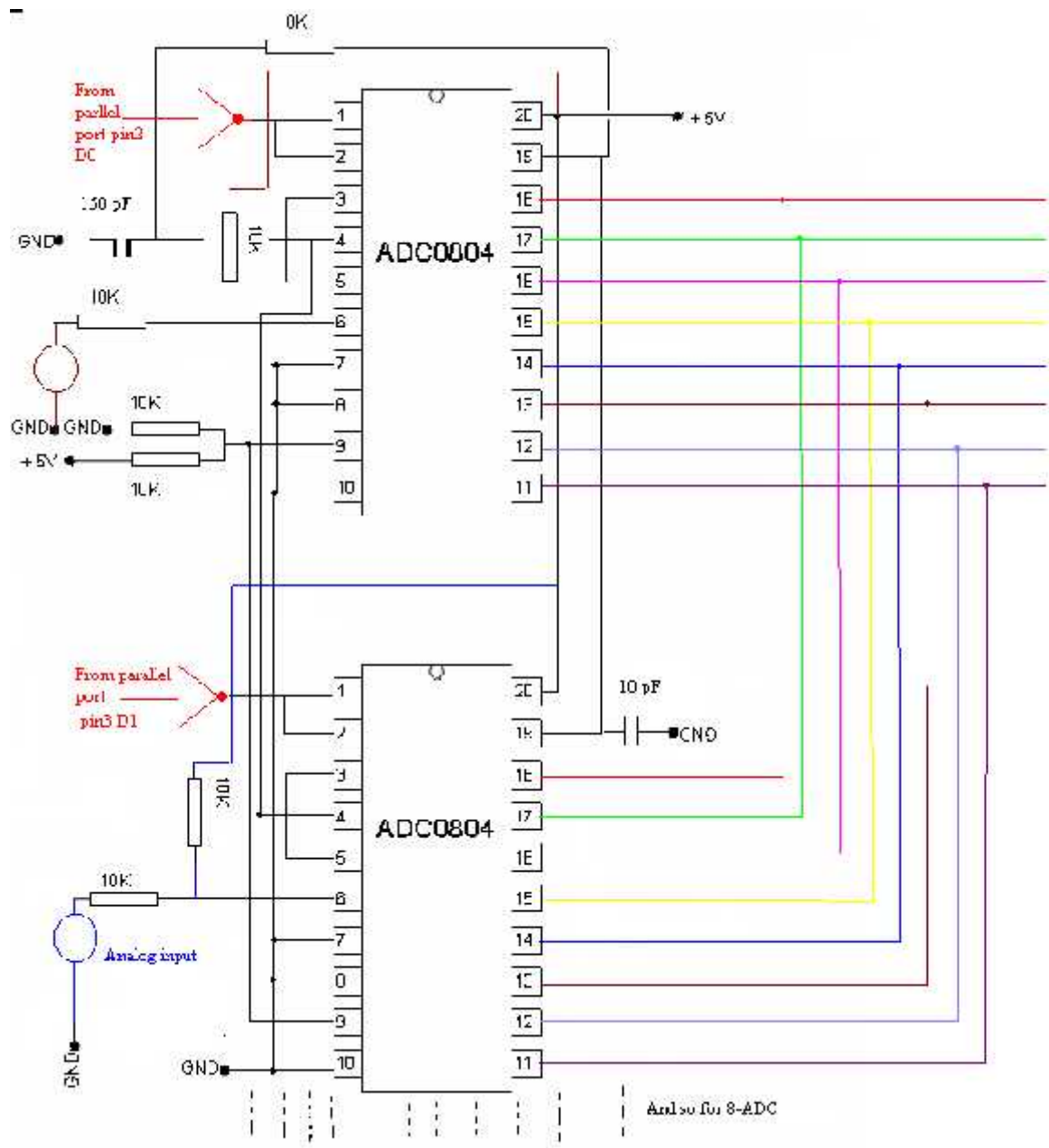


Figure 4.7 Connect 8-ADCs with Parallel Port



## 4.5 Buffer

In this project buffer is used for protection purpose.

### 4.5.1 Features

- ⇒ Octal bidirectional bus interface
- ⇒ Non-inverting 3-status outputs
- ⇒ Output capability: bus driver
- ⇒ ICC category: MSI

## 4.6 Parallel Port

Modern computers employ two basic methods for data transmission

- ⇒ Parallel data transmission.
- ⇒ Serial data transmission.

In the following table 4.1, we make comparison between parallel and serial data transmission.

Table 4.1: Comparison between Serial & Parallel Ports.

Parallel	Serial
Data are sent several bits at a time over several wires.	Data are sent one bit at a time over one wire.
Inexpensive.	Expensive.
Designed for short connections (6-10feet).	Design for long distances. Rs232 –80feet.

As shown in table 4.1, Parallel port is used for short connections, while Serial port used for long distances connections because of the following reasons:-

1-Problem of noise and cross-talk resulted, when using parallel port for long distance connection.

2-Parallel communication requires synchronization.

#### 4.6.1 Standard Parallel Port Hardware

The Parallel Port is the most commonly used port for interfacing home made projects. This port will allow the input of up to 9 bits or the output of 12 bits at any one given time, thus requiring minimal external circuitry to implement many simpler tasks. The port is composed of 4 control lines, 5 status lines and 8 data lines, as seen in figure 4.8. It's found commonly on the back of your PC as a D-Type 25 Pin female connector.

There may also be a D-Type 25 pin male connector. Parallel port has two commonly used base addresses, LPT1 378h or LPT2 278h, these addresses may change from one machine to another.

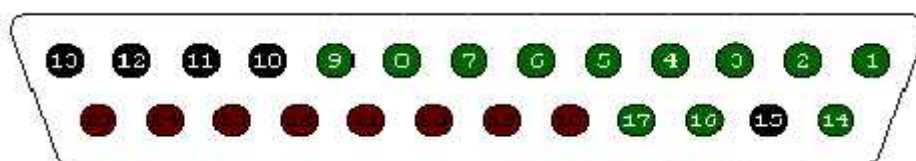


Figure 4.8: Parallel Port

#### 4.6.2 Parallel Port Registers:-

Standard parallel port consists of three registers, data, status, and control register, we will describe these registers and there address, and number of pins used for these registers.

**Data Register:-**the address of data register is (378h or 278h), it is used for outputting data on parallel port data lines (pins 2-9 in figure 4.12), normally a write only port, if you read from this port, (you will get last byte send to it).

Table 4.2 Data register

D7	D6	D5	D4	D3	D2	D1	D0
----	----	----	----	----	----	----	----

**Status Register:-**the address of data register is (379h or 279h), it is read only port, any data written to this port is ignored, the pins are 11, 10, 12, 13, and 15 in figure 3 shows S7 S7shows a logic 0 this means that there is +5V at pin 11.

Table 4.3 Status register

$\bar{S}7$	S6	S5	S4	S3	X	X	X
------------	----	----	----	----	---	---	---

X-not used.

**Control Register:-**the address of control register is (37Ah or 27Ah), it is writing only port, the pins are pin 17 (inverted), 16, 14(inverted), and 1(inverted) in figure 4.9.

For the following register C3 shows pin 17, C2 shows pin 16, C1 show 14 and C0 shows pin 1.

Table 4.4 Control Register

X	X	X	X	C3	C2	C1	C0
---	---	---	---	----	----	----	----

The other pins of the parallel port which are. Pin 18, 19... 25 not connected, so we can take the ground on any one of these pins.

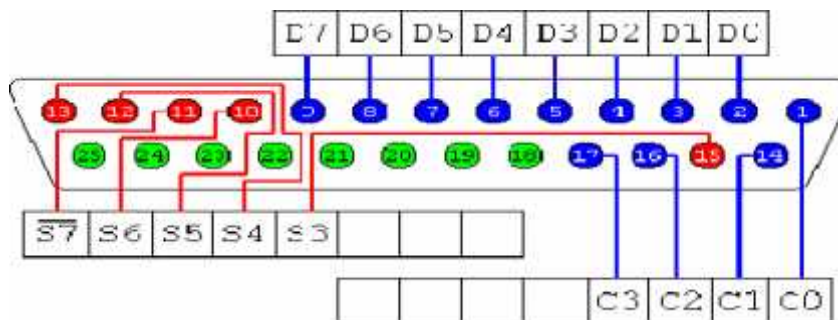


Figure 4.9 Diagram of the 25 Pin Connector used on most computers

### 4.6.3 Connect Parallel Port:

#### 4.6.3.1 Status and Control Register Connector

In this project the status register and control register are used as input to the computer where we connect five status register and three control register to get 8- inputs to computer as shown in the following figure and table.

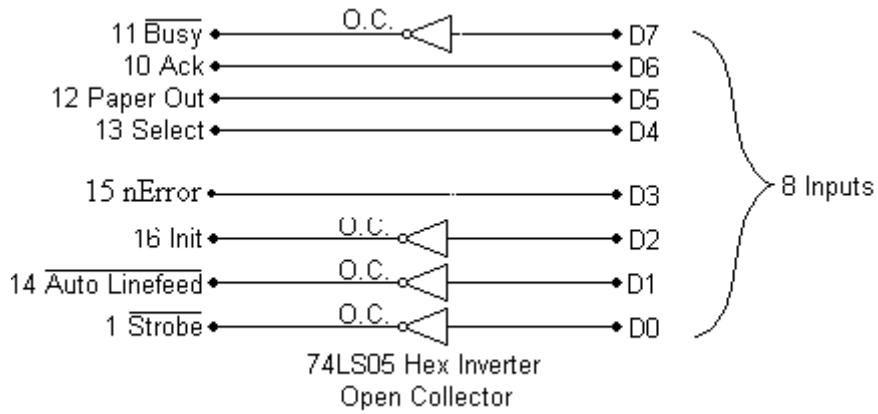


Figure 4.10 Status and Control Register Connector

Table 4.5 Status and control register connector

D7	D6	D5	D4	D3	D2	D1	D0
$\bar{S}7$	S6	S5	S4	S3	C2	C1	C0
11	10	12	13	15	16	14	1

#### 4.6.3.2 Data Register Connector

The data line connect to get output from computer to select which ADC to be Active so it controlling 8-ADC each ADC has special address and data line. Cannot enabling two ADC in the same time

## **Chapter Five**

### **Software System Design**

5.1 Overview

5.2 LabView

5.3 Parallel Port Configuration

5.4 Temperature Program

5.5 ECG Program

5.6 General Program

## **Chapter Five**

### **Software System Design**

#### **5.1 Overview**

The function of the project's software is to initiate the computer to send commands to the A/D converter to start reading from the sensors then convert this data and send it to the computer. This API will be written using the ideal graphical programming language LABVIEW.

The project composed of three programs to receive data from IM. First a program calculates temperature from temperature sensor. Second a program to read ECG signal and to display it on the screen then to calculate heart rate and to save it. The third program is to receive any signal and display it in order to save and process it.

## 5.2 LabView

LabView mean virtual instrumentation engineering work pinch.

LabView is a graphical language used two panels the first to built program called diagram panel and the second to display the result called front panel.

In this project we made three programs to read dada from IM as following:

- 1- Temperature program
- 2- ECG program
- 3- General program or virtual oscilloscope

## 5.3 Parallel Port Configuration

This program consists from two operations to configuration parallel port.

- 1- Data line send data to ADC's for start convert analog to digital

Defined the data register for output line by using the address of data register (378H) through using icon which called (out port) figure 5.1 we put port address and the channel which we needed to select.

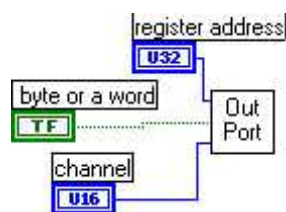


Figure 5.1 out – Port Icon



2- Stats and control register for input data.

Stats and control register for input data by defined them through icon (in port) figure 5.2 put the address port (379H for stats and 37AH for control) to read data.

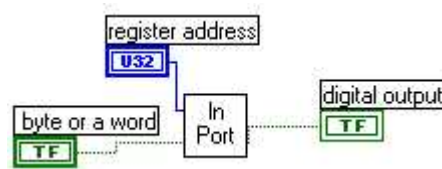


Figure 5.2 in – Port Icon

Now we will show the complete program which contain in port and out port to configuration parallel port in following figure.

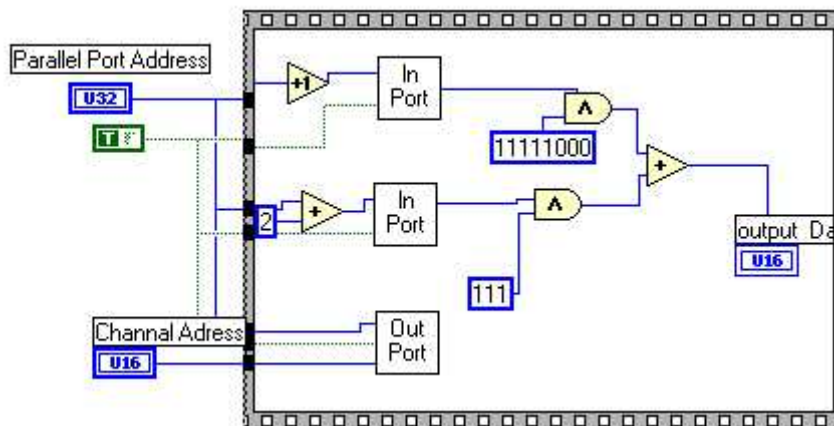


Figure 5.3 Configuration of Parallel Port (Diagram Panel)

This program work as will as:

- 1- first in port icon used for receive digital data from status line by put address in parallel port address (378) and it increment one to defined status line for

input line and the data will be received as one byte so we And it with this number 11111000 because we used five line just.

- 2- Second in port icon used for receive digital data from control line as step one but in this stat the address increment two and the received data will be And with this binary number 111 because we used three lines just.
- 3- The result from step one and step two will be added to get one byte.
- 4- Out port icon used for select channel by send address to channel by data line in parallel port which has address (378).

## 5.4 Temperature Program

Temperature program is composed to calculate temperature from sensor and display it in the computer for any application. In this program the temperature is calculated in three different modes (Celsius, Fahrenheit, and Kelvin).

This program work as following steps:

- 1- After data receive from sensor (such as channel 1) and arrive to computer as what happen in parallel port configuration.
- 2- This data will be binary or decimal we convert it to analog data by the following equation

$$V_{in} = (V_{out}/256)*V_{max}$$

Where  $V_{in}$ : voltage in  $V_{in+}$  in ADC

$V_{out}$ : output from ADC

$V_{max}$ : Maximum input value in ADC (in this project 5v).



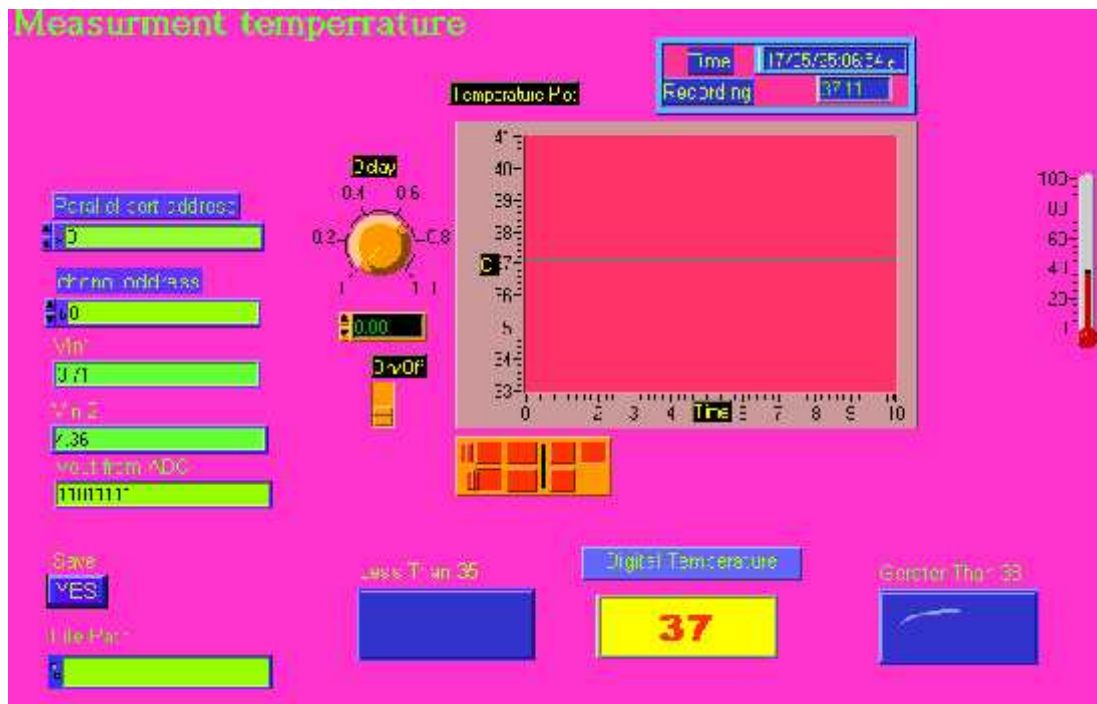


Figure 5.5 Front Panel for Temperature Program

## 5.5 ECG Program

### 5.5.1 ECG Program

An ECG is a small electrical signal, which is produced owing to the activity of the heart. Its source can be considered as a dipole located in the partially conducting medium of the thorax. This dipole induces a body-surface potential, which can be measured and used for diagnostic purposes. The signal ECG is characterized by five peaks and valleys labeled with successive letters of the alphabet P, Q, R, S, and a T.

The ECG is said to consist of the P wave, QRS complex and T wave. The reciprocal of the heart period as shown in figure 5.6

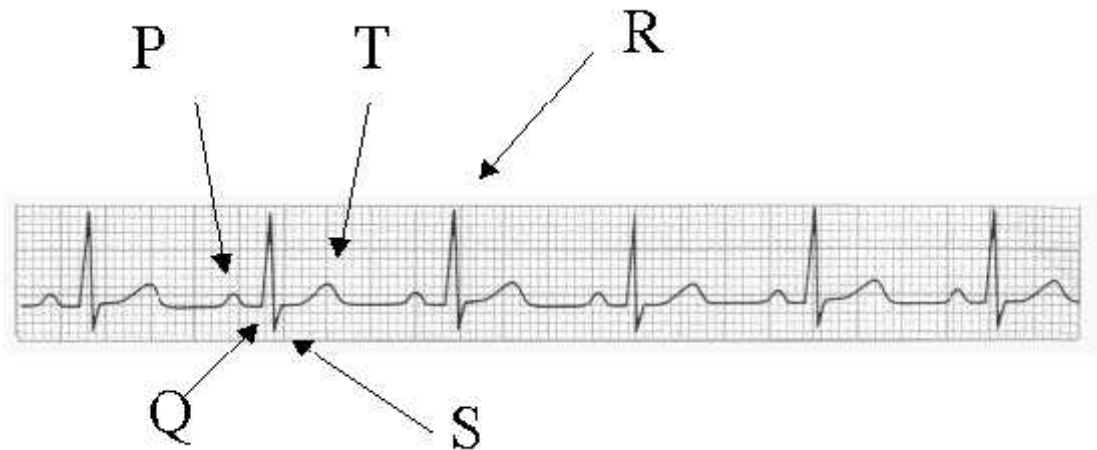


Figure 5.6 ECG Signal

The example shown in figure 5.6 is termed normal Sinus Rhythm. Impulses originate in the SA node regularly at a rate 60-100 per minute in adults and at faster rates in older children (90-110), small children (100-120) and infants (120-160). P waves upright in L2 and negative in AVR and of uniform size and contour from beat to beat.[1]

ECG program display ECG signal and heart rate in several case ( Adults, Small children, Large children and infants) and alarm in heart rate is normal, high heart rate or low and the necessary information as patient name, age and so.

The front panel and diagram panel for ECG program

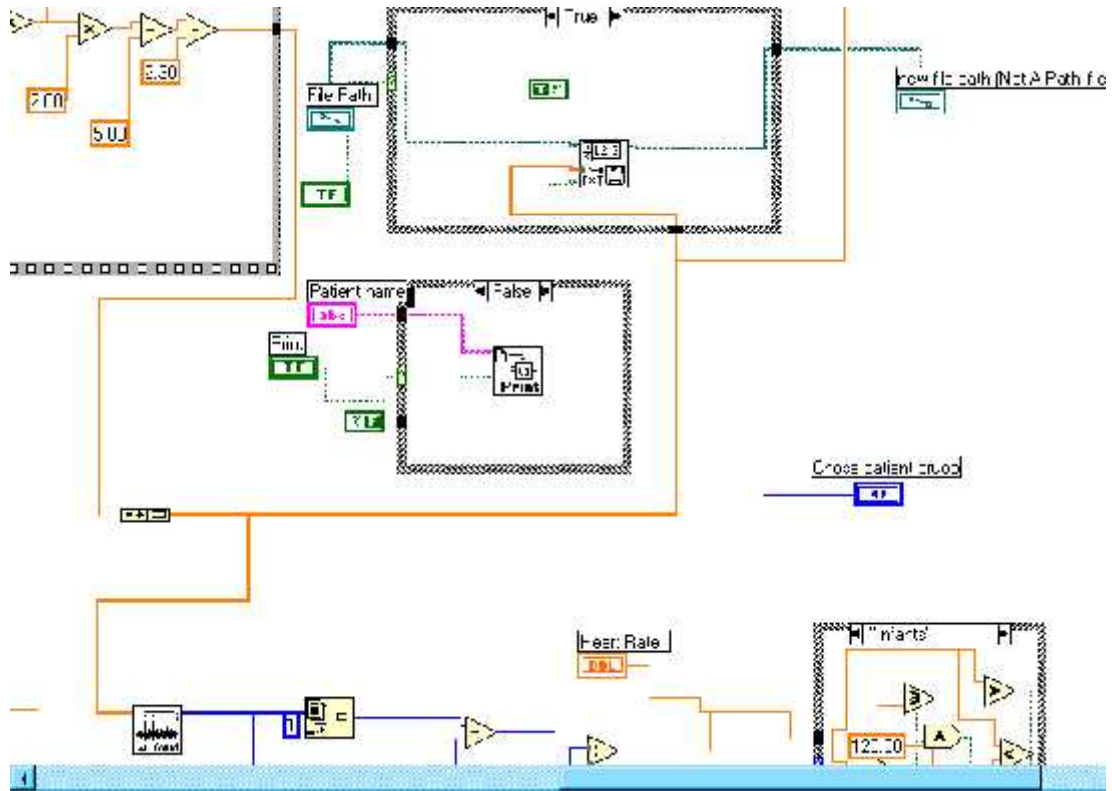


Figure 5.7 Diagram Panel for ECG Program



Figure 5.8 Front Panels for ECG Program

### 5.5.2 Calculating Heart Rate

The aim is count the number of peaks in an ECG signal. Only the peak higher than the threshold will be counted. The difference of the index of the first peak and the index of second peak generates the times in seconds between the two consecutive counts. Then divided 60 by the time that detected to calculate the heart rate. As the following example: if the time between two peaks 0.5 second then the heart rate equal 120.

This part from ECG program to calculate heart rate

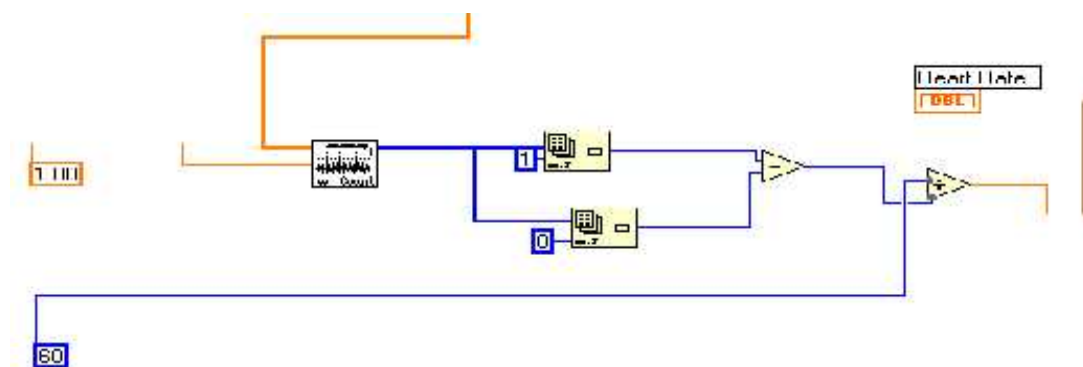


Figure 5.9 Calculation of Heart Rate



## 5.6 General Program (Virtual Oscilloscope)

The program designed to read any data from sensor or signal with low frequency and display on the front panel to calculate the voltage, frequency or any process required.

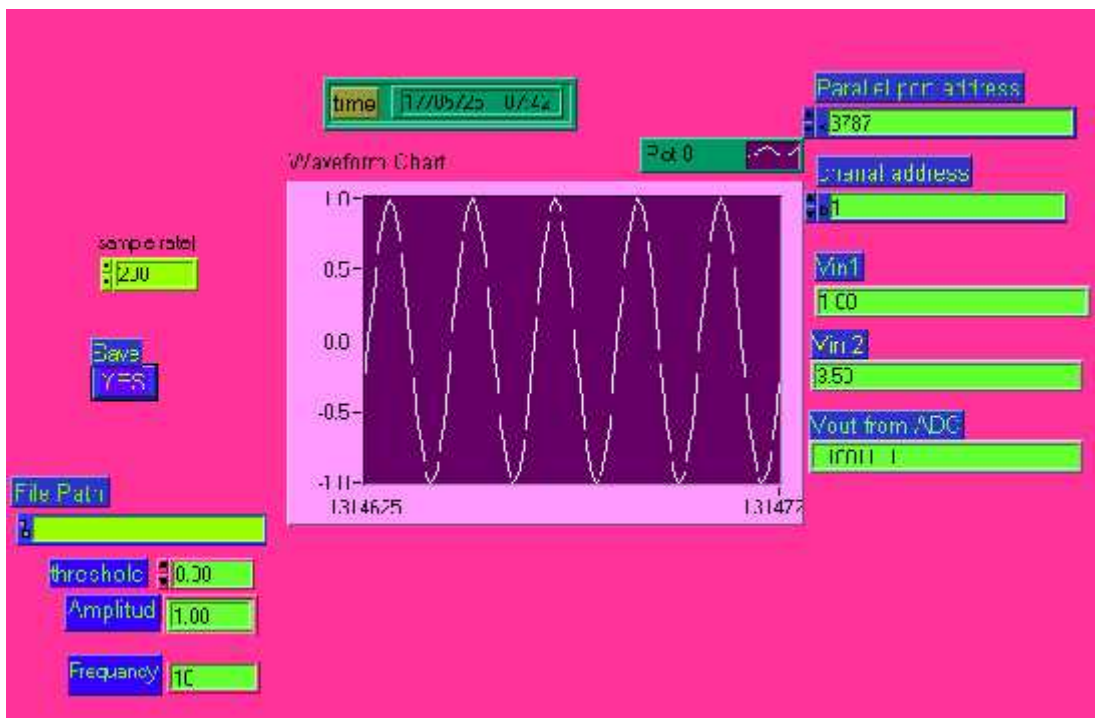


Figure 5.10 General Program

## **+Chapter six**

# **Testing**

6.1 Introduction

6.2 Unit Testing

6.3 Sub-system Testing

6.4 System Testing

6.5 Problems

6.6 Results

## **Chapter six**

### **Testing**

#### **6.1 Introduction**

System testing is an important stat in realizing the proposed system. This step can be done during the implementation. It is necessary to insure that the designed implemented system performs, operate, and satisfies the stated requirements.

The testing process includes the following stages:

- 1) Unit testing.
- 2) Sub-system testing
- 3) System testing

#### **6.2 Unit Testing**

At this stage, the individual components are tested to insure that they operate correctly. Each component should be tested independently.

Here, each component is tested independently. All the electrical components, ICs, and other devices are tested individually. Were components noticed to function properly.

The following table described in details the result of unit system.

Table 6.1 Unit System Testing.

<b>Device</b>	<b>Inputs</b>	<b>Expected value</b>	<b>Actual value</b>	<b>Notes</b>
Temperature sensor LM35	Temperature	Volt output for 10mv /1C°	Volt output for 10mv/ 1C°	Match
LM324 amplifier	Small input volt	Gain = 10	Gain = 10	Match
ADC	Variable inputs as 5v, 0, -5	For 5v output = 11111111 0v= 01111111 -5v=00000000	For 5v output = 11111111 0v= 01111111 -5v=00000000	Match
Inverter	5v or 0v	In 5v output = 0v 0v = 5v	In 5v output = 0v 0v = 5v	Match
Parallel port	Constant value in states lines 05055, control lines as 005 and data line input from computer 1	Output in computer in states 01011 control lines 001 and data line output in ADC = 5v	Output in computer in states 01011 And control lines 001 and data line output in ADC = 5v	Match

### **6.3 Sub-system Testing**

Here, the testing is performed over a collection of models which have been integrated into sub-system.

The following sub-systems were tested individually:

- 1- Sensor subsystem
- 2- Amplifier subsystem
- 3- ADC subsystem
- 4- Inverter subsystem
- 5- Parallel port subsystem

### **6.4 System Testing**

After finishing the testing of subsystems, the subsystem is integrated to make up a system. Testing here is concerned with error that generated from anticipated interaction between sub system and system component.

## 6.5 Problems

We changed the whole idea of the project because of the following problems:

- 1- The unavailability of project parts which we mentioned in (Introduction to Project).
- 2- The parts needed in our project aren't available so we had to look for them in other source which took us much time and effort.
- 3- The parts which we brought are:
  - a. Microcontroller (AT89s252).
  - b. ADC (TLC).

Unfortunately, we couldn't have able to program the microcontroller, due to the unavailable of the proper device to program the microcontroller in our university. So we had to build the necessary circuit to do the programming.

- 4- Therefore we were obliged to look for other parts in order to go with our project idea. Then we finally achieved this by using traditional parts which are not of high quality.

## 6.6 Results

There are the results that we have achieved so far

1- display the ECG signal as show in following:

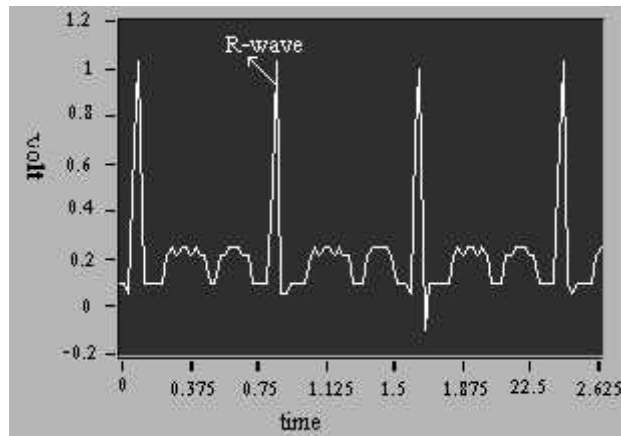


Figure 6.1 the ECG Signal from Our Project

- 2- Counting the heart rate from the ECG signals, the heart rate from above signal equal 120 because the time between two R-waves equal 0.75 second so the heart rate equal  $60/0.75 = 120$  beat per minute, and you can chose the patient group as (infants, small children, large children and adults) because they have a different rang of heart rate.
- 3- Measuring the human temperature, the result in our project is 37 and it is the ideal temperature for human.

## **Chapter Seven**

### **Future Work**



## **Chapter Seven**

### **Future Work**

The IM could be developed and become more sufficient since it has many aspects of interfacing with the ordinary PC's.

The IM needs a special Microprocessor based on systems since it's easily interfaced with the ordinary PC's, so many ideas and thoughts may storm the mind of developers to beget a new version of IM.

- Adding support for additional interfaces from the IM to the computer, such as USB, firewire, serial port and wireless.
  
- increasing IM functionality:
  - To enable support for streaming data from multiple ports.
  - To enable the user configurable baud rates.
  - To allow microcontroller initiated transfers of the acquired data.
  
- Designing an integrated serial programmer for the IM.
  
- Guaranteeing system performance.
  
- Adding support for digital outputs on the microcontroller.
  
- Etc...

## **References**

## References

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## **Chapter Eight**

## **Conclusion**

## **Chapter Eight**

### **Conclusion**

An interface module (IM) which is a flexible communication interface between biomedical sensor and computer is designed, constructed and tested. The system was tested successfully for monitoring ECG for diagnosing purposes, counting the heart rate from the ECG signal, measuring the temperature.

After testing the system, it is found that the performance of the system is satisfactory.

Since the ECG and temperature are important medical parameters it should be realized that the IM system help the physician in the diagnosing procedure. It is expected that further development on the system, will increase its value and benefit in the medical technology and medical diagnosis.

## **Appendix**

### **Data sheets**

## **Data sheets**

**ADC0804**

## **Data sheets**

**LM35**



## **Data sheets**

**74HC/HCT245**

## **Data sheets**

**74LS04**

**Data sheets**

**Parallel port**

<b>Pin No (D- Type 25)</b>	<b>Pin No (Centronics)</b>	<b>SPP Signal</b>	<b>Direction In/out</b>	<b>Register</b>	<b>Hardware Inverted</b>
1	1	nStrobe	In/Out	Control	Yes
2	2	Data 0	Out	Data	
3	3	Data 1	Out	Data	
4	4	Data 2	Out	Data	
5	5	Data 3	Out	Data	
6	6	Data 4	Out	Data	
7	7	Data 5	Out	Data	
8	8	Data 6	Out	Data	
9	9	Data 7	Out	Data	
10	10	nAck	In	Status	
11	11	Busy	In	Status	Yes
12	12	Paper-Out / Paper-End	In	Status	
13	13	Select	In	Status	
14	14	nAuto- Linefeed	In/Out	Control	Yes
15	32	nError / nFault	In	Status	
16	31	nInitialize	In/Out	Control	
17	36	nSelect- Printer / nSelect-In	In/Out	Control	Yes
18 - 25	19-30	Ground	Gnd		