Palestine Polytechnic University

Continuous Heart Rate and Body Temperature Monitoring

Project Team

Ahmad Hmeid **Marah abu Mfareh**

Supervisor:

Dr. Abdallah-Arman

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By the guidance of our supervisor , and by the acceptance of all members in the testing committee ,this project is delivered to department of electrical and computer engineering in the college of engineering and technology , to be as a partial fulfillment of the requirement of the department for the degree of B.sc .

Supervisor signature

Testing committee signature

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The head of department signature

جامعة بوليتكنك فلسطين

الخليل – فلسطين

كلية الهندسة

دائرة الهندسة الكهربائية

Continuous Heart Rate and Body Temperature Monitoring

فريق المشروع

أحمد حميد **مرح أبو مفرح**

بناء على نظام كلية الهندسة وإشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة المناقشة , تم تقديم هذا العمل إلى دائرة الهندسة الكهربائية . وذلك للوفاء بمتطلبات درجة البكالوريوس في هندسة الأجهزة الطبية.

توقيع المشرف

توقيع اللجنة المناقشة

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توقيع رئيس الدائرة

إهداء

إلى......

إلى الأرض الطهور؛ أرض الرسالات ومهجع الأنبياء؛ منبع القادة والعظماء؛ أرض الإسراء والمعراج...فلسطين

إلى من ضحوا بدمائهم الزكية من أجل رفعة هذا الوطن العظيم؛ إلى نبراس الحرية ومنارة طريق العزة ؛

إلى الأكرم منا جميعاً .... الشهداء

إلى أعظم الكائنات في هذا الزمان؛ إلى ينبوع الحب والحنان؛ إلى القلب الدافئ دائم العطاء؛ إلى الوجه الذي نرى فيه كل صباح طريق الأمل؛ والأغنية التي نترنم على ألحانها في أوقات العمل؛ إلى المربية الساهرة القائمة العاملة الحنونة العطوف الغالية

إلى وإلى وإلى .... أمي

إلى من تعجز عن وصفه الكلمات؛ وتقف حائرة أمام عظمة تضحياته الحروف؛ إلى من يحرق سنوات عمره ليضيء لنا بها طريق النجاح؛ ماذا أقول فيك وأنت أجمل ما قيل.. لن أقول سوى أعانني الله على برك

لن أقول لك إلا ...."أنا ومالي لأبي"

إلى الجواهر الثمينة الذين بدونهم لا يكتمل معنى الحياة؛ إلى عقد اللآلئ الثمين .. إخوتي

"إن الحوت في البحر؛ والطير في السماء؛ ليصلون على معلم الناس الخير"

إلى من حملوا أقدس رسالة في الحياة؛ إلى الذين مهدوا لنا طريق العلم والمعرفة؛

إلى جميع أساتذتنا الأفاضل ...نخص منهم الدكتور عبدالله عرمان والمهندسة فداء الجعافرة والدكتور رمزي القواسمة والدكتور علي عمرو على الكم الهائل من الجهد والدعم الذي قدموه لنا

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Abstract

The project is a portable device for continuous heart rate and body temperature monitoring. Heart related diseases especially cardiovascular diseases are increasing day by day ; therefore, an accurate, affordable and portable heart rate and body temperature measuring device is essential for taking action in proper time. Such a device is more essential in a situation where there is no doctor or clinic nearby (e.g., rural areas) and patients are unable to recognize the urgency of their condition.

The system that we design consists of microcontroller system , transmission system and Android based application. The system gives information of heart rate and body temperature simultaneously acquired on the portable device in real time and shows it through the connected Android application instantly. The developed system is more affordable compared to other developed devices due to the use of easily available microcontroller and an Android phone. A wristband personal monitoring device is also easier to use by any customer compared with other measuring devices.

الملخص

الأمراض المتعلقة بالقلب خاصة الوعائية منها تزداد يوما بعد يوم , لذلك سوف نقوم بعمل هذا البحث ليتم تقديم جهاز محمول متكامل لتطوير نظام مراقبة معدل ضربات القلب ودرجة حرارة الجسم حيث سيتكون هذا المشروع من جهاز قياس نبض القلب وآخر لقياس درجة حرارة الجسم , الجهاز محمول وتكلفته معقولة وهذه المراقبة أمر ضروري لاتخاذ الإجراءات في الوقت المناسب . هذا الجهاز أكثر أهمية في حالات عدم تواجد طبيب أو عيادة قريبة (على سبيل المثال ، منطقة ريفية) وحيث لا يستطيع المرضى كشف الاصابة بنوبة قلبية او اختلاف مفاجئ لحالتهم الطبيعية.

يتكون النظام المتطور لهذا المشروع من نظام متحكم Arduino ، ونظام النقل والتطبيق القائم على Android . يوفر النظام معلومات حول معدل ضربات القلب ودرجة حرارة الجسم التي يتم الحصول عليها في وقت واحد على الجهاز المحمول ويظهر ذلك من خلال تطبيق Android المتصل على الفور بالجهاز. النظام المتطور هو سيتوفر بأسعار معقولة منخفضة مقارنة مع الأجهزة المتقدمة الأخرى بسبب سهولة استخدام Arduino والهواتف الذكية مثل جهاز Android ويُظهر الجهاز المطوّر نتائج مقبولة عند مقارنته بأجهزة قياس أخرى.

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List of abbreviation

Table 1.1 List of abbreviation

Abbreviation	**Full meaning**
PPG	Photoplethysmography
HR	Heart Rate
SKT	Skin Temperature
BPM	beats per minute
LF	Low frequency
HF	High frequency
ECG	Electrocardiogram
LCD	liquid-crystal display
CAD	Coronary Artery Disease
RR	Respiration rate

Chapter One

<u>Introduction</u>

1.1 Overview
1.2 Project idea
1.3 Project importance
1.4 Project motivation
1.5 Objectives
1.6 Literature review
1.7 List of abbreviation
1.8 Estimated cost
1.9 Scheduling table

1.1 Overview

In this project we will measure the Heart Rate (HR) and Body Temperature continuously using a non-invasive method. We will design and build a wearable wristband that uses photoplethysmography (PPG) sensor which obtains an optically measured signal that contains the frequency information coming from the patient's HR. This sensor can be used for non-invasive patient monitoring or for patients use as a tool for measuring physical activity. In addition, we will use a skin temperature sensor that measures human skin temperature with accuracy of 0.1°C in the human body temperature range of 20°C - 42°C. [1]

Figure 1.1 Project expected prototype

1.2 Project Idea

In this project , a portable , wireless , noninvasive heartbeat and temperature monitoring system will be designed and implemented. This device will measure HR and body temperature based on a microcontroller (Arduino Nano). Nowadays, most monitoring systems that are in use work in offline mode but our system is designed in a way that enables patient to be monitored remotely in real time. The proposed approach consists of sensors which measures heartbeat and body temperature of a patient, which are controlled by the microcontroller. Both of the readings are displayed in LCD monitor. Wireless system is used to transmit the measured data to the andro id system.

1.3 Objectives

- The main objective of the project is to design and implement a Wearable Wrist that can measure both heart rate and body temperature.
- Design and implement a sensor to track and transmit biomedical signal to mobile device that functions as receiver, user interface and control panel for the user.

1.4 Project importance

- We built the portable device at a low cost.
- The wearable wristband monitoring device easy to use.
- The device gives result continuously.
- The device very important for people who more vulnerable to stroke, heart attack.

1.5 Project motivation

- Cardiovascular diseases have been quite common in recent years due to modernization, lack of exercises and sedentary habits and life style especially in young people. Coronary Artery Disease (CAD) is now the leading cause of death worldwide [4].
- Heart rate and body temperature are the most important vital signs, but there is no device that measures them both at a low cost in an easily wearable way such as a wristband , so we designed a portable device that can be used by any patient anywhere or at hospitals and laboratories.

- Design a circuit that measures the heart rate by non-invasive methods.
- Design a circuit that measures the body temperature.
- Monitoring the heart rate in real time.
- Monitoring body temperature in real time.

1.6 Literature Review

1. Wearable heart rate (HR) monitors typically implement photoplethysmography (PPG) technology and are used in research as an alternative to electrocardiogram (ECG). However, questions surrounding the accuracy of PPG technology exist. To provide an answer regarding the question of accuracy, Dustin T. Weiler, Stefanie O. Villajuan, Laura Edkins, Sean Cleary, and Jason J. Saleem conducted a study to compare average HR readings of two different HR technologies (PPG vs. ECG) after an interval style cardio-based workout. A total of 30 trials were conducted and average HR readings from the two HR technologies were compared using an ANOVA. Results revealed no significant difference between the two technologies.[6]

   Depending on the result of the previous study, we decided to use the PPG technology because there are still some obstacles with ECG wearable technology.

2. Thumb PPG.

   In 2012 a team of Ki Chon, professor and head of biomedical engineering at WPI developed a smart phone application that can measure heart rate, heart rhythm, respiration rate and blood oxygen saturation using the phone's built in camera as a photo detector and LED flash light as a light source. Author capture video of thumb with flash light, apply ROI on that video frames. Captured video is processed by using ICA and FFT filtering technique and measure heart rate.

3. Wristwatch type PPG array Sensors Module. Yong Kwi et al (2010) [9] developed the Wristwatch -type PPG array Sensor module which can be used to calculate heart rate by recording signals from radial and ulnar artery of the wrist.

1.7 Estimated Component Cost

Table 1.2 Estimated Component Cost

Component	**Cost $**
Arduino	15
skin temperature sensor	20
PPG optical sensor	10
Analog switch	5
PCD printing cost	10
Battery	5
LCD	10
Bluetooth model	10
Cables and other components	20
Total cost	**105$**

1.8 Scheduling table

Table 1.3 Scheduling table

Week / Task	1^{ST}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}	8^{th}	9^{th}	10	11	12	13	14	15
Task 1	■	■	■	■											
Task 2					■	■	■	■							
Task 3									■	■	■	■	■		
Task 4					■	■	■	■	■	■	■	■	■	■	
Task 5													■	■	■

- **Task 1 :** System Definition .
- **Task 2 :** System Analysis .
- **Task 3 :** System Design .
- **Task 4 :** Documentation .
- **Task 5 :** Presentation Preparing .

Chapter Two

Anatomy and Physiology

2.1 Introduction

Vital signs are measurements of the body's most basic functions. The main vital signs routinely monitored by medical professionals and health care providers include the following : body temperature and heart rate.

These signs are useful in detecting or monitoring health problems. Vital signs can be measured in a medical setting, at home, at the site of a medical emergency, or elsewhere.

2.2 Cardiac Anatomy

2.2.1 Heart Structure

The human heart is a muscular organ -with a cone shaped- containing four chambers that is situated slightly to the left of the midline of the thoracic cavity ,and extended from the level of the second rib to about the level of the sixth rib. It is approximately the size of a man's closed fist.

Approximately 7,000 L of blood is pumped by the heart every day. In an average person's life, the heart will contract about 2.5 billion times. Blood flow throughout the body begins its return to the heart when the capillaries return blood to the venules and then to the larger veins. The cardiovascular system, therefore, consists of a closed circuit: the heart, arteries, arterioles, capillaries, venules, and veins. (see figure 2-1). [3]

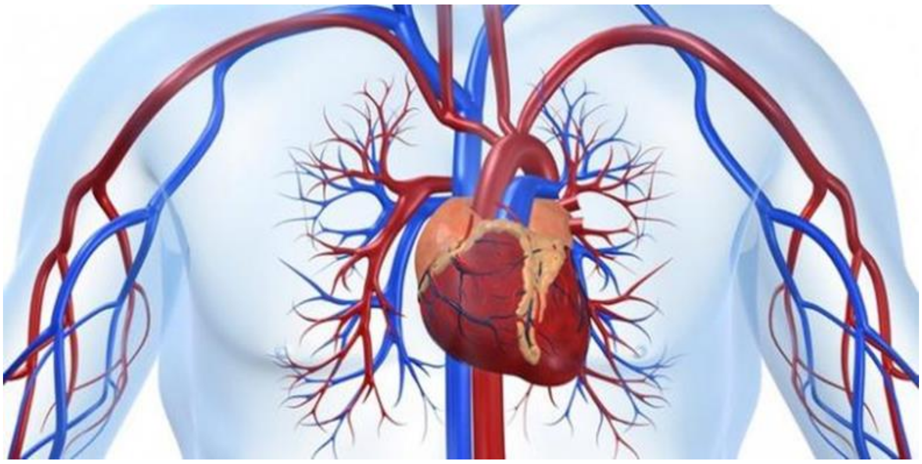

Figure 2.1 Hearts' arteries ,veins and capillaries. [4]

The venules and veins are part of the pulmonary circuit because they send deoxygenated blood to the lungs to receive oxygen and unload carbon dioxide. The arteries and arterioles are part of the systemic circuit because they send oxygenated blood and nutrients to the body cells while removing wastes. All body tissues require this circulation to survive.

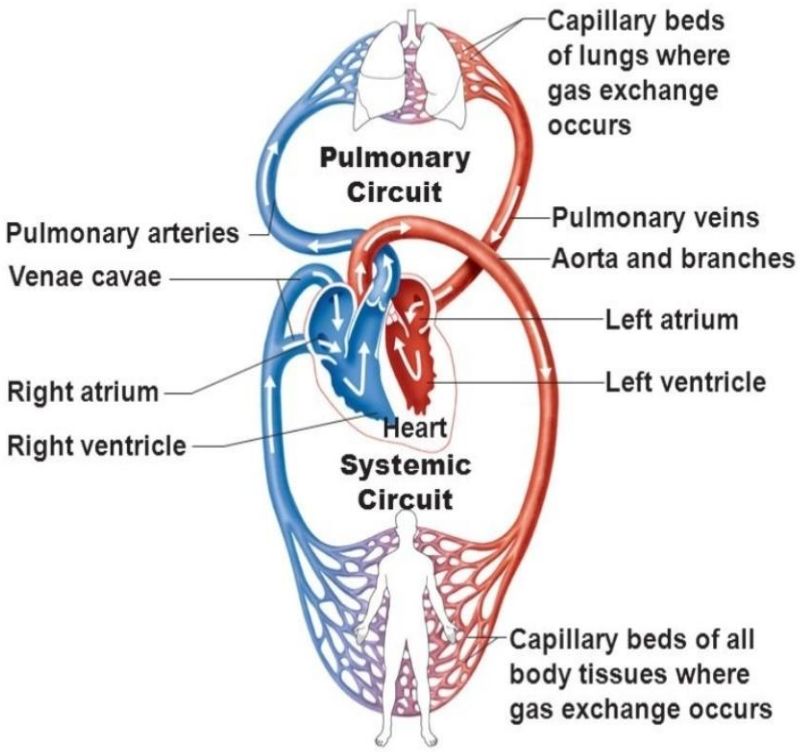

Figure 2.2 The circulatory system.[4]

The heart pumps blood through the arteries, which connect to smaller arterioles and then even smaller capillaries. It is here that nutrients, electrolytes, dissolved gases, and waste products are exchanged between the blood and surrounding tissues. The capillaries are thin walled vessels interconnected with the smallest arteries and smallest veins. The upper two chambers (atria) are divided by a wall like structure called the interatrial septum. The lower two chambers (ventricles) are divided by a similar structure called the interventricular septum. Between each atrium and ventricle, valves allow blood to flow in one direction, preventing backflow. Blood flow through the heart is shown in Figure 2.3

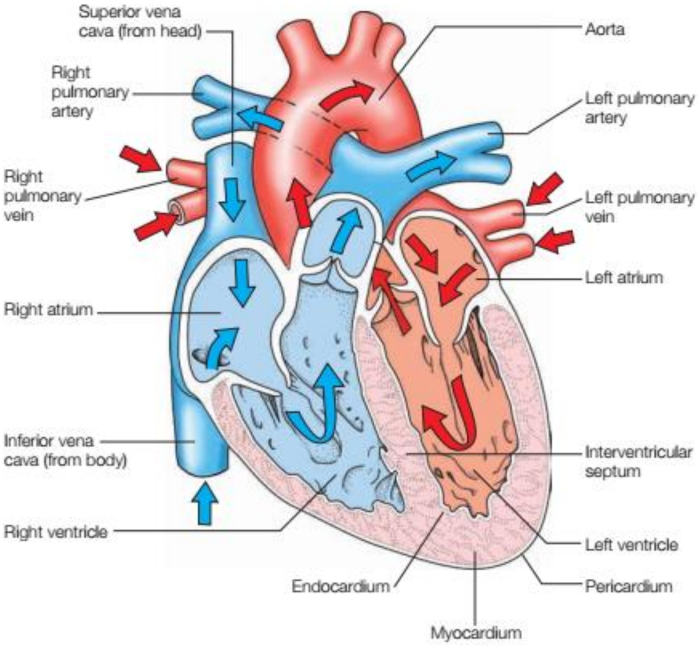

Figure 2.3 Blood flow through the heart. [2]

There is a valve through which blood passes before leaving each chamber of the heart. The valves prevent the backward flow of blood. These valves are actual flaps that are located on each end of the two ventricles (lower chambers of the heart). They act as one-way inlets of blood on one side of a ventricle and one-way outlets of blood on the other side of a ventricle. Each valve actually has three flaps, except the mitral valve, which has two flaps. The four heart valves include the following: (see figure 2.4)

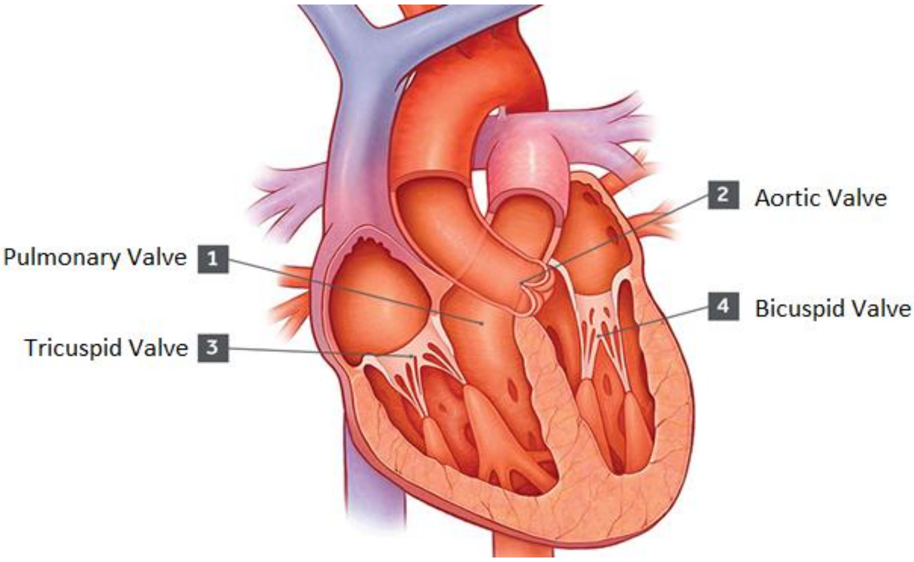

Figure 2.4: Heart Valves [5]

1. Pulmonary Valve: located between the right ventricle and the pulmonary artery which prevents blood from flowing back into the right ventricle.

2. Aortic Valve: located between the left ventricle and the aorta which prevents blood from flowing back into the left ventricle.

3. Tricuspid Valve: located between the right atrium and the right ventricle which prevents blood from flowing back into the right atrium when the right ventricle contracts.

4. Bicuspid Valve: located between the left atrium and the left ventricle which prevents blood from flowing back into the left atrium when the left ventricle contracts.

2.2.2 Heart Rate

Two major sounds of the normal heart can be heard "lub dub". The "lub" is the first heart sound, it is caused by turbulence caused by the closure of mitral and tricuspid valves at the start of systole. The second heart sound, "dub" ,which is caused by the closure of the aortic and pulmonic valves, marking the end of systole. Thus the time period elapsing between the first heart sound and the second sound defines systole (ventricular ejection) and the time between the second sound and the following first sound defines diastole (ventricular filling).

2.2.3 Normal range of Heart Rate

Heart rate values vary from one to another depending on age and human activity . These are the normal heart rate values (see table 2-1) . A heart rate above the normal values is referred to tachycardia, a heart rate below the normal values is referred to as bradycardia. [9]

Table 2.1 : Normal Range of HR [9]

Age	Normal Range
Infants	100 to 160 beats per minute
Children 1 to 10 years	70 to 120 beats per minute
Children over 10 and adults	60 to 100 beats per minute
Athletes	40 to 60 beats per minute

2.2.4 Abnormal range of heart rate and indicators

An abnormal heart rhythm is when your heart beats too fast, slow, or irregularly. This is also called an arrhythmia.

Within the heart, there is a complex system of valves, nodes, and chambers that control how and when the blood is pumped. If the functions of this vital system are disrupted, damaged, or compromised, it can change the pattern with which your heart beats. Arrhythmias can cause no symptoms, or you may feel discomfort, fluttering, pain, or pounding in your chest. [12]

A number of things may cause an abnormal heartbeat, including high blood pressure. Other common causes are**:**

Coronary heart disease

This serious heart problem occurs when cholesterol and other deposits block the coronary arteries.

Medications

Some medications or substances may cause your heart rate to change. These include:

- Caffeine.
- Amphetamines, which are drugs that stimulate the brain.
- Beta-blockers, which are used to reduce high blood pressure.

Other causes

A number of other factors can also cause alterations in your heart's rhythm. These include:

- Changes in your heart's muscle after illness or injury.
- Healing after heart surgery.
- Low potassium and other electrolytes.
- Abnormalities of the heart.
- Other health conditions.

2.3 Human Body Temperature

2.3.1 Temperature definition

It is the degree of heat maintained by the body or it is the balance between heat produced in the tissues and heat lost to the environment. [4]

The temperature T in degrees Fahrenheit (°F) is equal to the temperature T in degrees Celsius (°C) times 9/5 plus 32

$$T(°F) = T(°C) \times 9/5 + 32$$

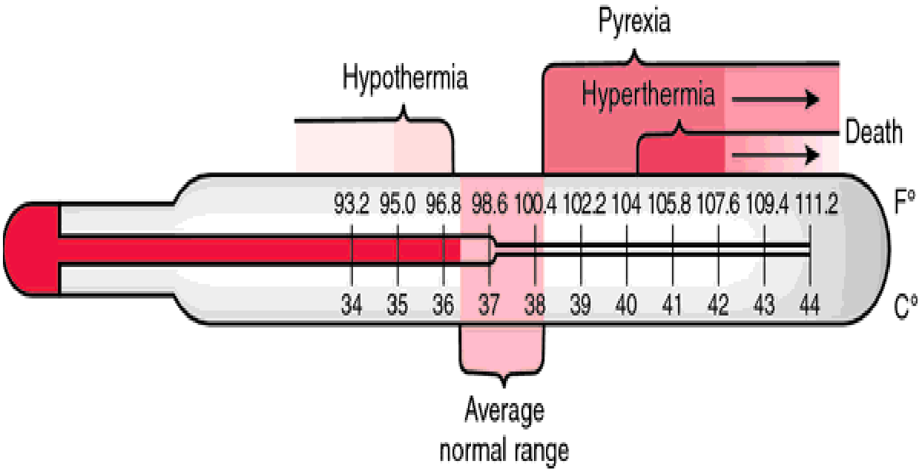

Figure 2.5 normal body temperature [4]

2.3.2 Importance of body temperature

Measuring body temperature is very important in medicine. A number of diseases are characterized by a change in body temperature. With other illnesses, the course of the disease can be followed by measuring body temperature. This allows the doctor to analyze the effectiveness of treatments based on body temperatures.

A fever is the reaction to a disease-specific stimuli. The body changes its normal temperature to support the body's own defence mechanisms. Fever is the most common form of disease-related (pathological) increase in body temperature. [5]

2.3.3 Position of body temperature measurement

Body Temperature Can be Taken Either:

- Orally : By mouth - glass thermometer, or a digital thermometer.
- Rectally - Temperatures taken rectally tend to be 0.5 to 0.7 degrees F higher than when taken by mouth.
- Forehead (Skin) - A special thermometer can quickly measure the temperature of the skin on the forehead.
- Ear - A special thermometer can quickly measure the temperature of the ear drum, which reflects the body's core temperature.
- Axillary - Temperature taken under the arm (armpit) tend to be 0.3 to 0.4 degrees F lower than those temperatures taken by mouth.[6]
- Wrist : the temperature of the body can be measured by wrist and this the method we are going to use in our device.

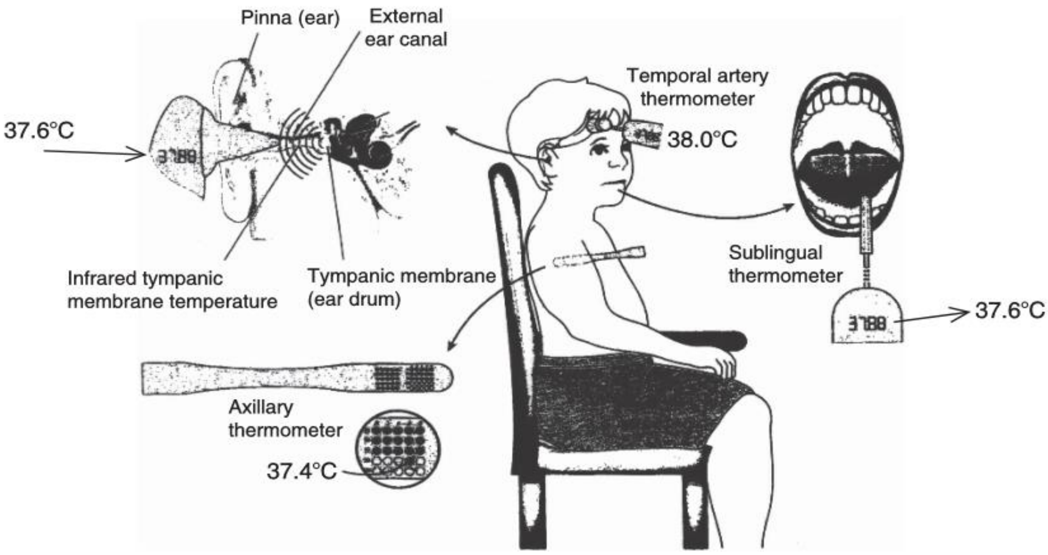

Fig 2.6 : Anatomical site of temperature readings showing febrile recordings from different sites [10]

2.3.4 normal range of body temperature

The measured body temperature always depends on which part of the body the measurement was taken from. For this reason, and contrary to popular opinion, there is no general normal temperature.

The body temperature of a healthy person also changes throughout the day and depending on what activities they undertake. With a rectal temperature measurement, the body temperature is normally 0.5 degrees Celsius higher in the evening than other times of the day for physiological reasons. In addition, body temperature is increased by any physical exertion. [5]

No single temperature is normal for all people . The average of normal oral temperature is 37C. The acceptable temperature of human being ranges from 36 c – 38 C. [6]

- The Normal Body Temperature for a Baby :
  The American Academy of Pediatrics (AAP) states a normal body temperature for a healthy baby is between 97 and 100.3 degrees Fahrenheit. If the rectal temperature is 100.4 degrees or higher, they are considered to have a fever.

- The Normal Body Temperature for Children :
  The average normal body temperature for children is about 37°C (98.6°F). A child's temperature usually averages from around 36.3°C (97.4°F) in the morning to 37.6°C (99.6°F) in the afternoon.

- The Normal Body Temperature for Adults :
  - Temperature in the mouth (oral) is about 36.8°C (98.2°F).
  - Temperature under the arm (axillary) is about 36.5°C (97.7°F).
  - Temperature in the anus (rectum/rectal), vagina, or in the ear (otic) is about 37.5°C (99.5°F). [6]

2.3.5 Abnormal range of body temperature

Temperature of 34°C to 41 °C is the approximate range within which body cells can function. If body temperature decreases under 34°C or increases above 41°C , body cells cannot function. [4]

Abnormal body temperature can occur for a number of reasons. For example, if you're quiet and relaxed, your body temperature may drop a bit. But if you're active and racing around during the day, it may elevate to the higher end within the normal range.

Other factors that affect body temperature include metabolic rate, weight, exercise, age, hormones, pregnancy, and gender.

The body's biological clock also affects body temperature. For example, prior to going to sleep the body cools its body temperature somewhat to help bring on sleep. As we wake up, the biological clock increases body temperature so that we can function normally during the day. [10]

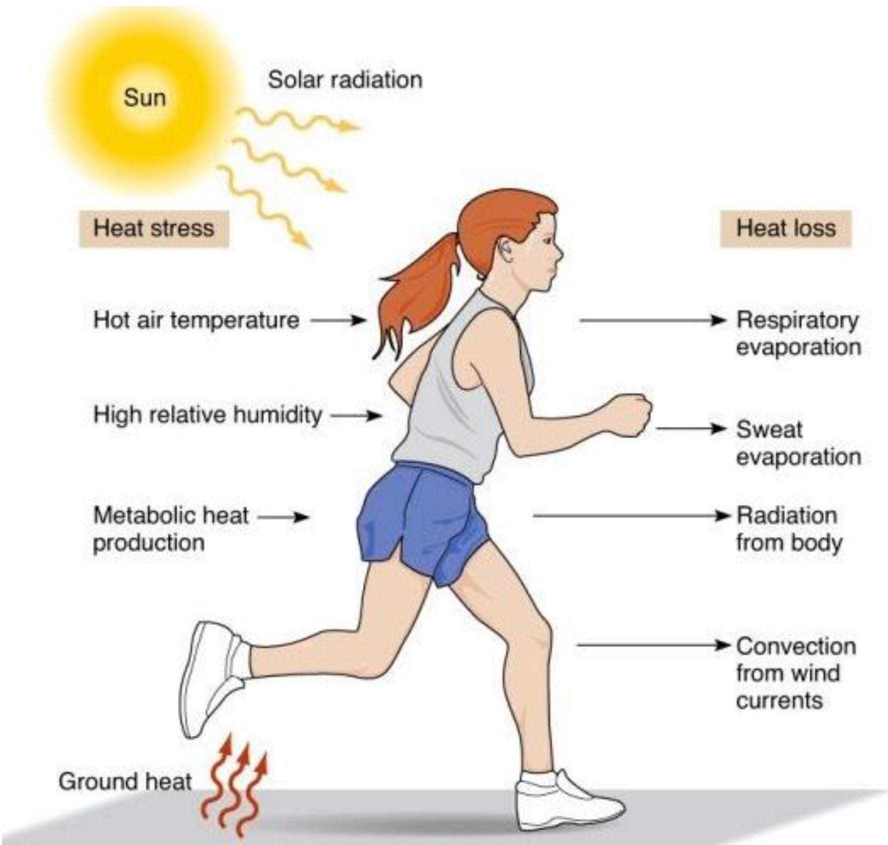

Figure 2.7 temperature rises and loses [10]

2.4 Wrist Structure

The wrist anatomy includes the bones, muscles, tendons and other structures around the wrist joint. The wrist or the carpus is a part of the hand. It joins the forearm bones with the metacarpal bones of the hand. It is made of 8 small bones called the carpal bones. [9] These are:

- Scaphoid.
- Lunate.
- Triquetral.
- Pisiform.
- Trapezium.
- Trapezoid.
- Capitate.
- Hamate.

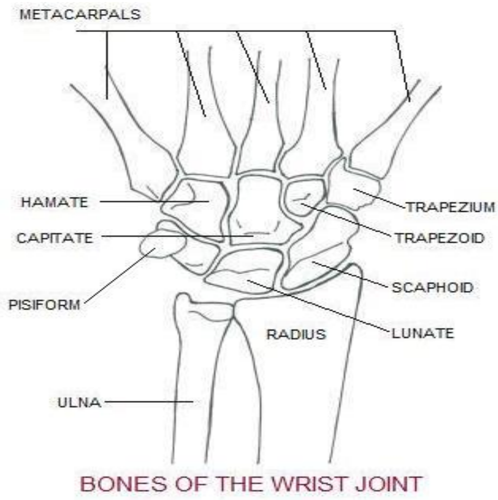

Figure 2.8 wrist structure [9]

2.4.1 wrist and artery

The scaphoid, lunate and triquetral bones articulate with the articular surface of the lower end of the radius to form the radio-carpal or wrist joint.

The radial artery crosses the wrist joint and is the main blood supply of the hand. The radial pulse can be palpated at the wrist by gently pressing over the lower end of the radius bone.

The ulnar artery and nerve also cross the wrist joint through the ulnar tunnel. This ulnar tunnel is formed by the superficial and deep parts of the flexor retinaculum.

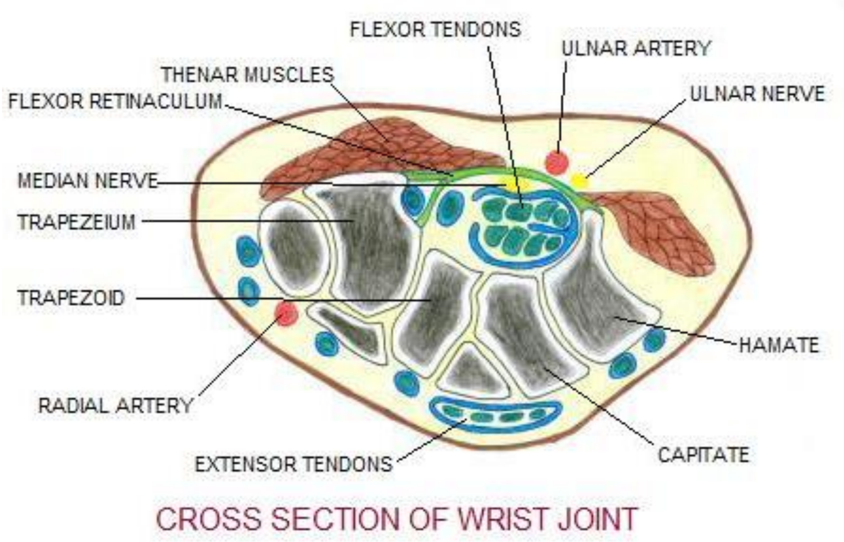

Figure 2.9 cross section of wrist [9]

2.4.2 wrist and skin layers

The skin is the largest organ of the body, with a total area of about 20 square feet. The skin protects us from microbes, helps regulate body temperature, and permits the sensations of touch, heat, and cold.

Skin has three layers:

- The epidermis, the outermost layer of skin, provides a waterproof barrier and creates our skin tone.
- The dermis, beneath the epidermis, contains tough connective tissue, hair follicles, and sweat glands.
- The deeper subcutaneous tissue (hypodermis) is made of fat and connective tissue.

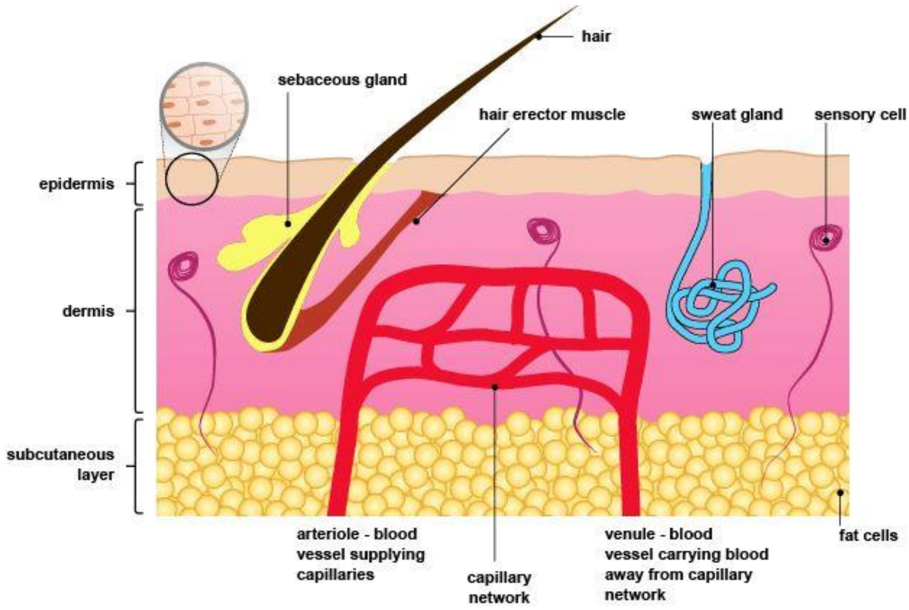

Figure 2.10 main layers of skin [9]

The skin's color is created by special cells called melanocytes, which produce the pigment melanin. Melanocytes are located in the epidermis.[9]

Chapter Three

Theoretical Background

3.1 Measurements Techniques of Heart Rate

3.1.1 Introduction

3.1.2 Invasive methods of heart rate measurement

3.2 Measurements of body temperature

3.2.1 Introduction

3.2.2 The Thermometer

3.2.3 Non Invasive Measurements

3.1 Measurements Techniques of Heart Rate

3.1.1 Introduction

In heart rate measurement procedure different methods are used. Some of them are characterized as invasive methods and others as noninvasive ones. This project will use a noninvasive method to measure the heart rate and here is a list of the most important noninvasive methods:

3.1.2 Non Invasive methods of heart rate measurement :

Electrocardiograph (ECG):

ECG stands for electrocardiogram. The abbreviations for the word electrocardiogram (derived from the Greek electro for electric, cardio for heart, and graph for "to write") and the German word electrocardiogram. ECG feature extraction has been studied from early time and lots of advanced techniques as well as transformations have been proposed for accurate and fast ECG feature extraction.

During each heartbeat that is detected and amplified by ECG. Each heart muscle cell has a negative charge, called the membrane potential, across its cell membrane. Decreasing this negative charge toward zero and depolarizing it, which activates the mechanisms in the cell that cause it to contract. [13]

During each heartbeat, a healthy heart will have an orderly progression of a wave of depolarization that is triggered by the cells in the sinoatrial node, spreads out through the atrium, and passes through the atrioventricular node and then spreads all over the ventricles. This is detected as small rises and falls in the voltage between two electrodes placed either side of the heart, which is displayed as a wavy line either on a paper or on screen [14] . This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle. [15]

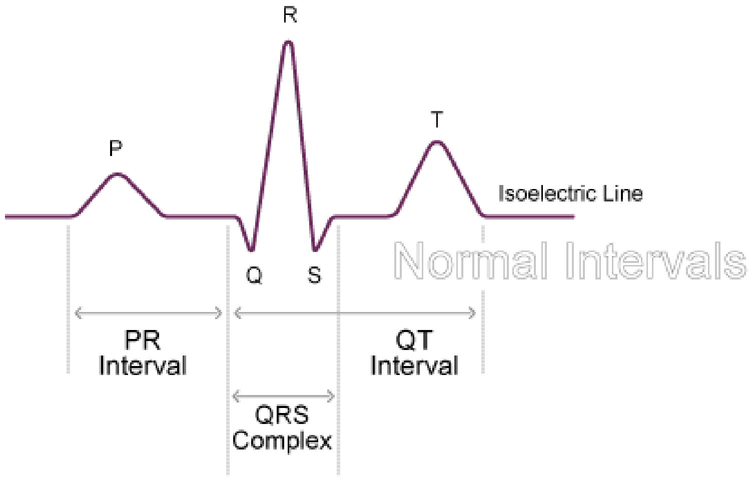

Figure 3.1: Normal Intervals

P-R interval = 0.12 - 0.20 sec

QRS width = 0.08 - 0.12 sec

Q-T interval 0.35 - 0.43 sec [18]

Advantages:

a) Non-invasive techniques to monitor heart rate.

b) This technique can be used for monitoring many cardio logical parameters such as heart rate, respiration rate, heart rate variability, arterial fibrillation, blood pressure, oxygen saturation level etc.

c) Accuracy of results is high.

Limitation:

a) Extra hardware settings are required.

b) Bulkiness.

c) Complex to be used.

Photoplethysmography (PPG) Signal

PPG is an optical measurement technique that can be used to detect blood volume changes in the microvascular bed of tissue. It has widespread clinical application, with the technology utilized in commercially available medical devices, for example in pulse oximetry, vascular diagnostics and digital beat-to-beat blood pressure measurement systems.

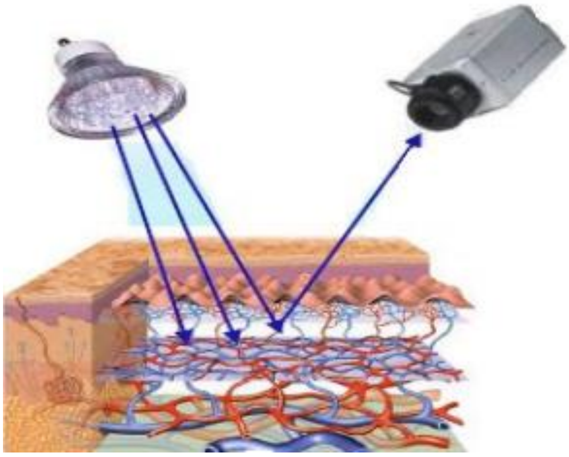

Fig 3.2 PPG signals using photo detector and Light source [18]

The basic form of PPG technology requires only a few optoelectronic components: a light source to illuminate the tissue (e.g. skin), and a photo detector to measure the small variations in light intensity associated with changes in perfusion in the catchment volume. PPG is most often employed non-invasively and operates at a red or a near infrared wavelength. The most recognized waveform feature is the peripheral pulse, and it is synchronized to each heartbeat. Despite its simplicity the origins of the different components of the PPG signal are still not fully understood. It is generally accepted, however, that they can provide valuable information about the cardiovascular system. [16]

The Following techniques use the PPG signals to measure heart rate :

1) **Wristwatch-type PPG array Sensors Module .**
   Yong Kwi et al [20] developed the Wristwatch-type PPG array Sensor module which can be used to calculate heart rate by recording signals from radial and ulnar artery of the wrist. Figure 3 shows working architecture of wristwatch type PPG device to measure heart rate.

2) **Earpiece PPG .**
   Earpiece PPG sensors are also available and provide greater comfort for the user. In this design, a reflective photo sensor is embedded into each ear bud, as shown in Figure. The sensor ear buds are inserted into the ear and positioned against the inner side of the tragus to detect the amount of light reflected from

the subcutaneous blood vessels in the region. The PPG sensor ear buds look and work like a regular pair of earphones, requiring no special training for use.

Advantages:

a) The system can monitor HR, RR and SpO2 level on a single device and it is Non-Invasive and less costly.
b) No extra hardware required.
c) It acts as a “take anywhere “physiological monitor.
d) It can be utilized for personal and clinical use.

Table 3.1 Comparison of all Methods[16]

	ECG	Wristwatch PPG	Ear-Piece PPG	Magnetic Earring PPG	Thumb PPG	Face PPG	Thermal Imaging
Easy to Handle	No	Yes	Yes	Yes	Yes	Yes	Yes
Accuracy	High	Low	Low	Low	Medium	Medium	Medium
Invasiveness	Yes	Yes	Yes	Yes	Yes	No	No
Cost	High	Medium	Medium	Medium	Low	Low	Medium
Experimental setup	complex	Easy	Easy	Easy	Easy	Easy	complex

3.2 Measurements of body temperature

3.2.1 Introduction

In body temperature measurement procedure different methods are used. In this project we will use a noninvasive method to measure the body temperature and here is a list of the most important noninvasive methods:

3.2.2 The Thermometer

The requirements of the ideal thermometer are numerous. Firstly, the accuracy level must be ±0.1°. In addition, the thermometer cannot be sensitive to outside influences such as changes in air temperature or irrelevant areas of the body such as limbs and skin. It must be stable from the point of accuracy and calibration. The size of the thermometer must be suitable for the area of use (e.g. mouth, oesophagus, rectum). An additional and important condition for its use is that the area where it is placed does not influence the accuracy of the thermometer. Additional difficulties that may impair a true measurement include the sensor not being thermodynamically balanced with the measured medium, negligence or noncompliance in the method of measuring, (e.g. possible differences in the rectal measurement depending on the depth of insertion of the thermometer), local body heat fields and short measurement times that do not allow for reaching thermodynamic balance.[13]

3.2.3 Noninvasive Measurements

Oral

This method has the advantages of easy accessibility and the ability to change quickly with changes in body Tc. It is the most popular method for measuring body temperature and is used in most clinical experiments. However, since environmental influences might result with the head or face being cooler than the rest of the body, oral temperature (Toral) registers lower than Tc. The method is problematic for small children and babies because of their behaviour. In adults it becomes problematic because of the possibility of error caused by cold or hot drinks being consumed, smoking before the measurement is taken or irregular breathing patterns. For athletes, rapid mouth breathing interferes with a correct measurement, and in cases of severe thermal illness, neurological compromise makes compliance difficult. In addition, there is the possibility of differences in temperature in different parts of the mouth cavity, where the preferred place is the sublingual pocket (i.e. under the tongue).

Axilla

Measuring fever at the axilla takes longer (necessary time for reaching equilibrium) in contrast to oral measurement. Studies found that measuring temperature in the axilla is less accurate compared with the rectum, mouth or tympanic membrane, [18] and that the measured temperature is generally much lower than Tc, particularly in athletes. Since this measurement can be inaccurate, it is not an advisable method to use in the clinic.

Tympanic Membrane

The tympanic membrane receives blood from the branches of the internal carotid artery that supply blood to the thermoregulatory centre in the hypothalamus of the brain. Therefore, the thermometer was developed to include this area. In addition, the ear canal is easily accessible for measuring temperature. However, many studies have demonstrated that this method of measurement is problematic, especially during physical effort in the heat, and can lead to errors in the measurements as a result of dirt, inaccurate placement and lack of skill of the measurer, and thus does not provide an accurate reflection of T_c.

Chapter Four

System Design

4.1 Introduction

4.2 Heart Rate Sensor Design

4.2.1 Transceiver

4.2.2 Band Pass Filter

4.2.3 Comparator

4.3 Skin Temperature Design

4.3.1 Temperature sensor Discretion

4.3.2 Functional Block Diagram

4.3.3 Temperature sensor Output Transfer Function

4.3.4 Application Information

4.4 Power Design

4.5 Microcontroller

4.6 Liquid-Crystal Display (LCD)

4.7 Android system

4.1 Introduction

This chapter offers a thorough description of the operating system. The following block diagram demonstrates the implementation of the proposed project. A number of project steps are included to show the logical succession of the project tasks in order to achieve the desired requirements. The general block diagram is divided into a sub-blocks to briefly illustrate the function of each step separately. Additionally, the needs of each stage, whether it's hardware or software, is determined. Finally, the alternative parts, based on the functions and the availability, are stated.

The conceptual design of the system is shown in Figure 4-1. As the figure shows, it includes two main parts a sensing and a processing part. The sensing part contains heart rate sensor (HR) to determine the number of heart rate per minute. The second part is the skin temperature sensor (SKT) which reads the skin temperature and its commonly used as an indicator for body temperature.

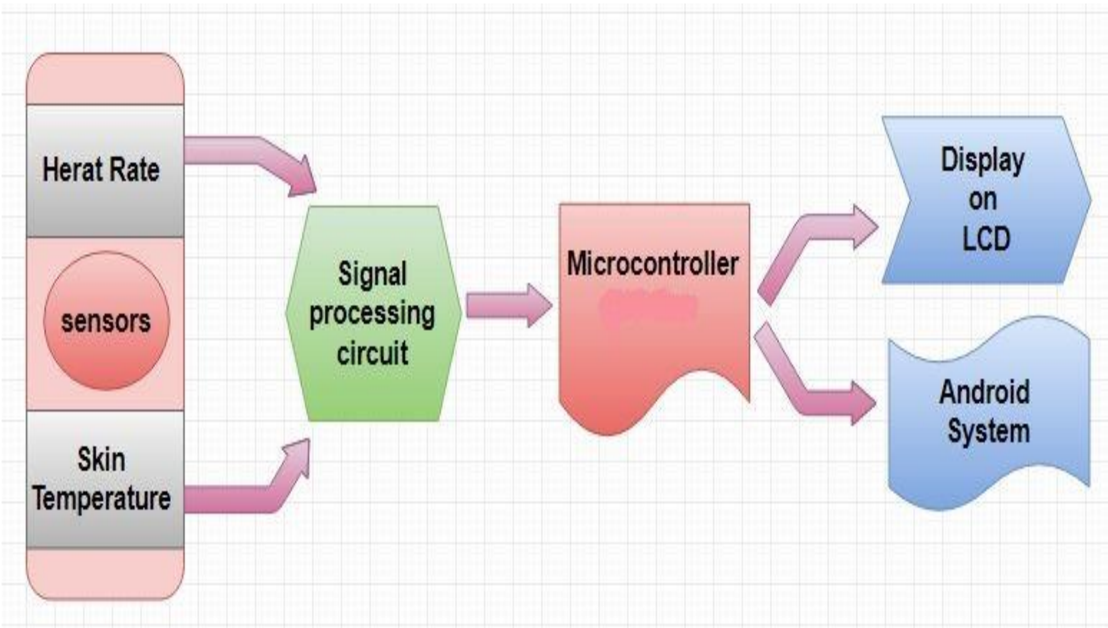

Figure 4.1: Main Block Diagram for the System

On the other hand, the main functions of the processing parts are receiving data from the sensing parts and processing the signal for each sensor. The processing parts then send the collected data to the Microcontroller to analyze it, compare it with standard values to use it in alarm , and display data by LCD . In this part, a description of the android system will be provided .

It's should be stated that the main system supply is 5 volt battery that will be used to supply all sections in the system.

The following sections describe the operating principle for each stage in more details.

4.2 Heart Rate Sensor Design

The heart rate sensor, explained in the previous chapter, will be used in this project to monitor the user's heart rate. The chosen transducer uses the Photoplethysmography technique. This technique depends on the change of blood volume in the wrist that is produced by heart beat rate. The block diagram shown in Figure 4.2 is built to illustrate the basic design of the proposed heart rate system.

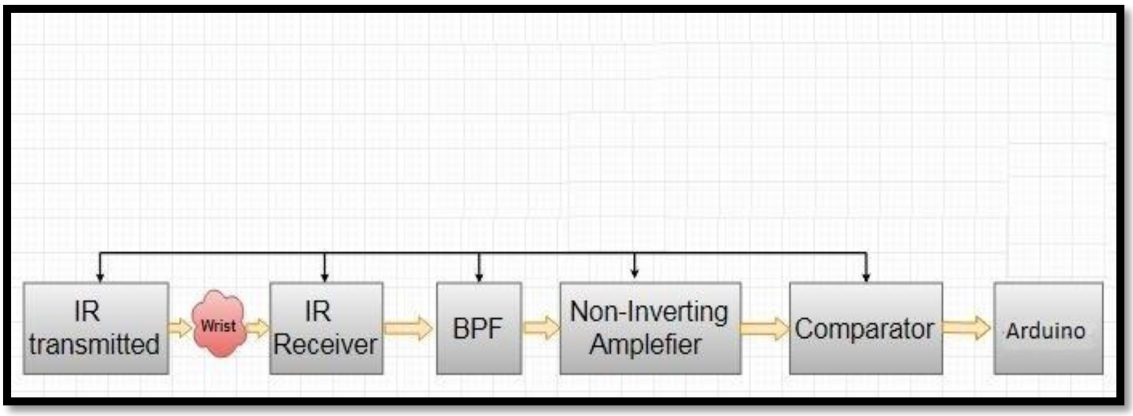

Fig 4.2 Block diagram for HR Sensor

4.2.1 Transceiver

The Photoplethysmography technique, discussed in the preceding chapter, depends on the amount of infra-red (IR) lights that reflected from the wrist. Hence an IR LED is used to transmit IR light, where a photo transistor sensing the portion of light that is reflected back. The intensity of the reflected lights depends upon the blood volume.

A "TCRT1000 IR device as sensor" will be used in this project. It consists of IR emitting-light source (LED) on wave length 940nm and light detector (phototransistor) [Appendix-A]. The LED and phototransistor are arranged in the same direction to sense the reflective IR-beam from the changes in arterial blood volume in the patient's wrist, as shown in the Figure 4.3.

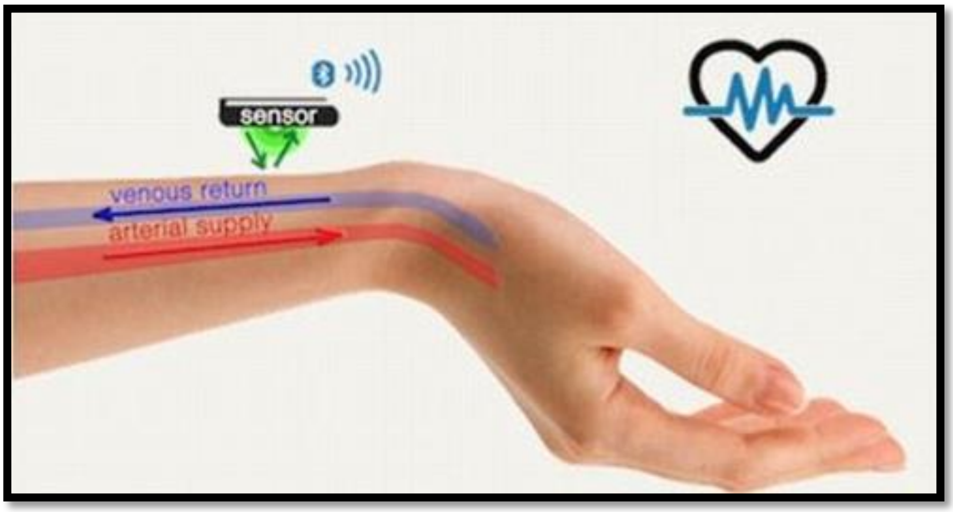

Figure 4.3 HR Sensor[6]

Transmittance and reflectance are two basic types of Photoplethysmography. For the transmittance PPG, a light source is emitted in to the tissue and a light detector is placed in the same side of the tissue to measure the resultant light. Because of the limited penetration depth of the light through organ tissue, the transmittance PPG is applicable to a restricted body part, such as the wrist or the ear lobe. However, in the reflectance PPG, the light source and the light detector are both placed on the same side of a body part. The light is emitted into the tissue and the reflected light is measured by the detector. As the light doesn't have to penetrate the body, the reflectance PPG can be applied to any parts of human body. In either case, the detected light reflected from or transmitted through the body part will fluctuate according to the pulsatile blood flow caused by the beating of the heart.

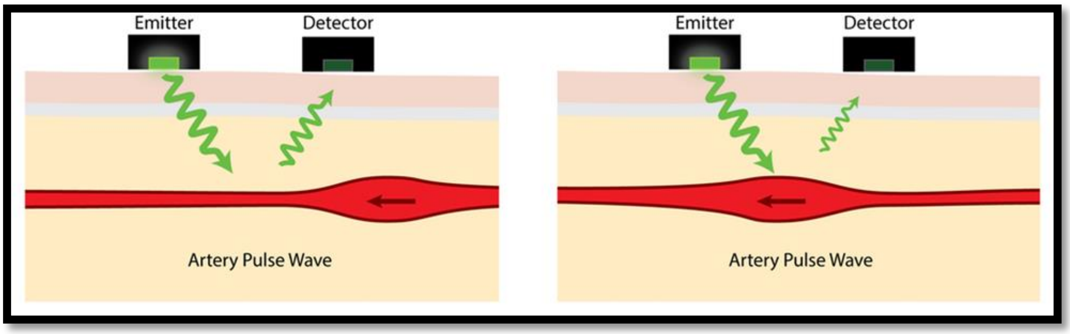

Fig 4.4 The sensor and blood flow [5]

The following circuit showed in Figure 4.5, the ON/OFF control scheme for the infra-red light source. Note that the Enable signal must be pulled high in order to turn on the IR LED. The photodetector output (V_{SENSOR}) contains the PPG signal that goes to a two-stage filter and amplifier circuit for further processing.

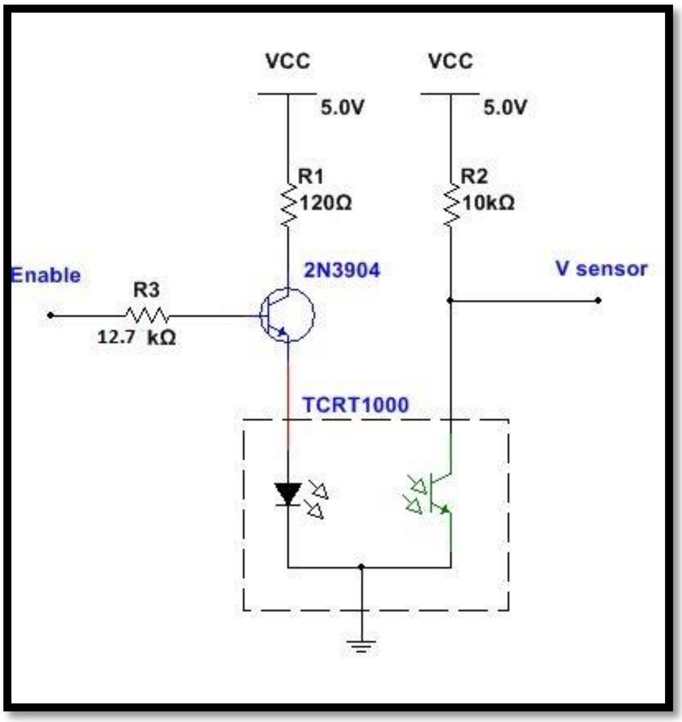

Figure 4.5 IR transceiver circuit

The transistor (2N3940) is chosen to deliver a constant current for IR- LED. According to TCRT-1000 data sheet [Appendix- C], the forward current (IF) at which the LED will transmit the desired wave length is at 20mA. This current is delivered by the transistor as collector current (I_C). From data sheet of the transistor the DC gain current (β) is equal 60 when I_C=20mA.By using equation 4.1, the base current (I_B) given by the following equation:

$$I_\beta = \frac{I_c}{\beta} \qquad (4.1)$$

$$I_\beta = \frac{20}{60*1000} = 0.33\text{mA}$$

The resistance R_3 that generates the desired I_β is calculated by the following equation(4.2)

$$R_3 = \frac{V_{cc} - v_{BE}}{I_B} \qquad (4.2)$$

The base-emitter voltage (V_{BE}) and V_{CC} are 0.8V and 5V respectively, hence the value of R_3 equal 12.7KΩ.[23]

4.2.2 Band Pass Filter

The PPG signal coming from the photo detector is weak and noisy. So we need an amplifier and filter circuits to boost and clean the signal. In Stage I instrumentation as shown in the Figure 4.6, the signal is first passed through a passive (RC) high-pass filter (HPF) to block the DC component of the PPG signal.

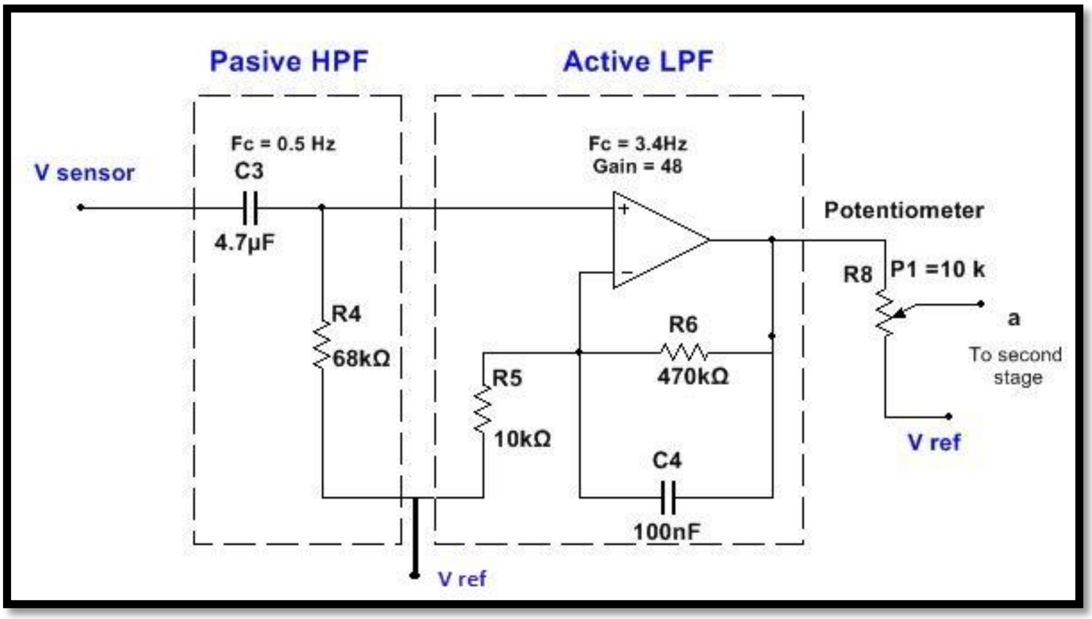

Figure 4.6 Band Pass Filter circuit

The cut-off frequency of the HPF is 0.5Hz, F_C can be calculated by using R_4 and C_3 as expressed in equation (4.3):

$$F_C = \frac{1}{2\pi R_4 C_3} \qquad (4.3)$$

Let C_3 =4.7µF, the resistor values for R_4 calculated through:

$$R_4 = \frac{1}{2\pi f_c C_3} \qquad (4.4)$$

So the resister R_4 is equal:

R_4 =68KΩ

The output from the HPF goes to an Op-amp-based active low-pass filter (LPF), the cut-off frequency of the LPF is 3.4Hz, F_C can be calculated by using R_6 and C_4 as expressed in equation (4.5):

$$F_C = \frac{1}{2\pi R_6 C_4} \qquad (4.5)$$

Let C_4 =100nF, the resistor values for R_6 calculated through:

$$R_6 = \frac{1}{2\pi f_c C_4} \tag{4.6}$$

So the resister R_6 is equal:

R_6 =470KΩ

The Op-amp operates in non-inverting mode and has gain 48, gain can be calculated by using equation (4.7):

$$G = 1 + \frac{R_6}{R_5} \tag{4.7}$$

In order to achieve a full swing of the PPG signal at the output, the negative input of the Op-amp is tied to a reference voltage (Vref) of 2.0V. The Vref is generated using a zener diode, Figure 4.7 shows the circuit of Vref.

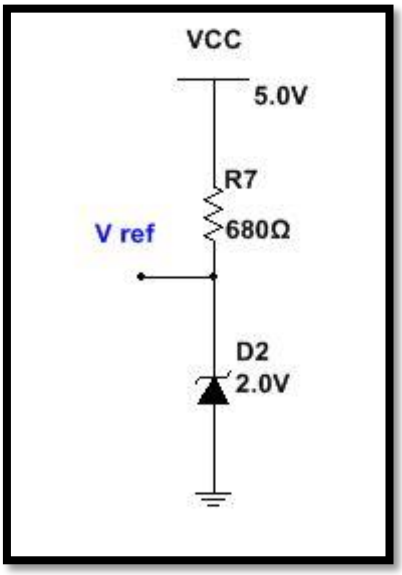

Figure 4.7 Reference voltage circuit

At the output is a potentiometer (P1) that acts as a manual gain control. The output from the active LPF now goes to Stage II instrumentation circuit, which is basically a replica of the Stage I circuit. Note that the amplitude of the signal going to the second stage is controlled by P1. The Op-amp used in this project is MCP6004 from Microchip, this op-amp operates with a single supply, rail to rail amplifier, has very high input impedance, and has high slew rate and Quad-Op-amp.

The second stage also consists of similar HPF and LPF circuits as shown in the Figure 4.8. The two-step amplified and filtered signal is now fed to a third Op-amp, which is configured as a non-inverting buffer with unity gain. The output of the buffer provides the required analog PPG signal. The potentiometer P1 can be used to control the amplitude of the PPG signal appearing at the output of the buffer stage.

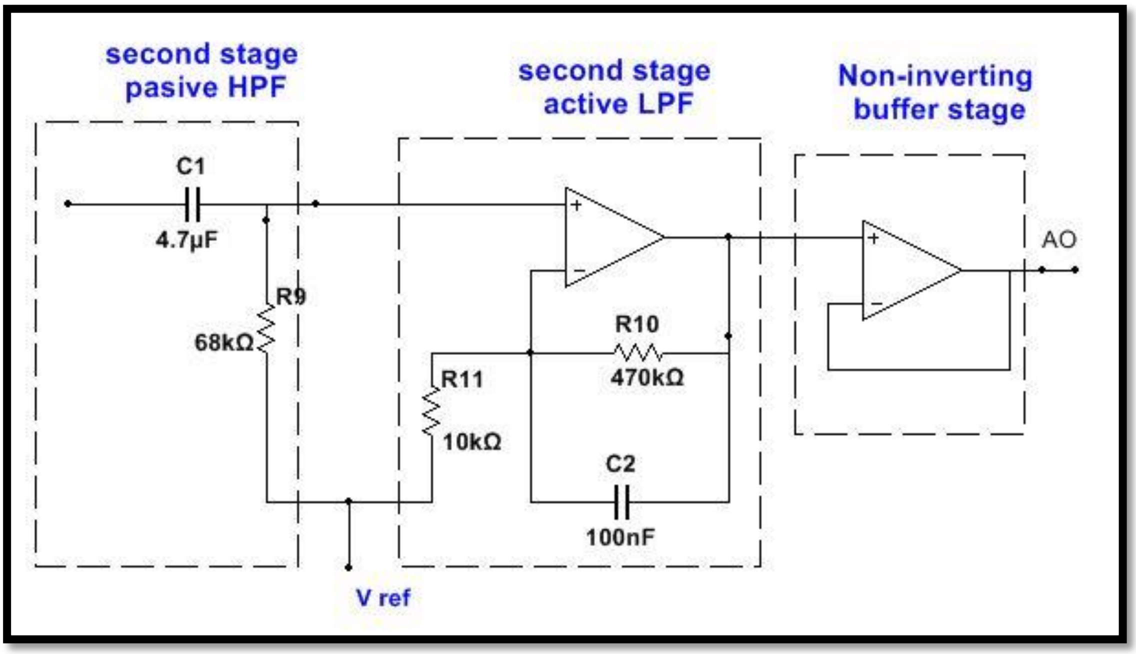

Figure 4.8 Second stage BPF and buffer circuit

4.2.3 Comparator

The fourth Op Amp inside the MCP6004 device is used as a voltage comparator as shown in the Figure 4.9. The analog PPG signal is fed to the positive input and the negative input is tied to a reference voltage (Vref).

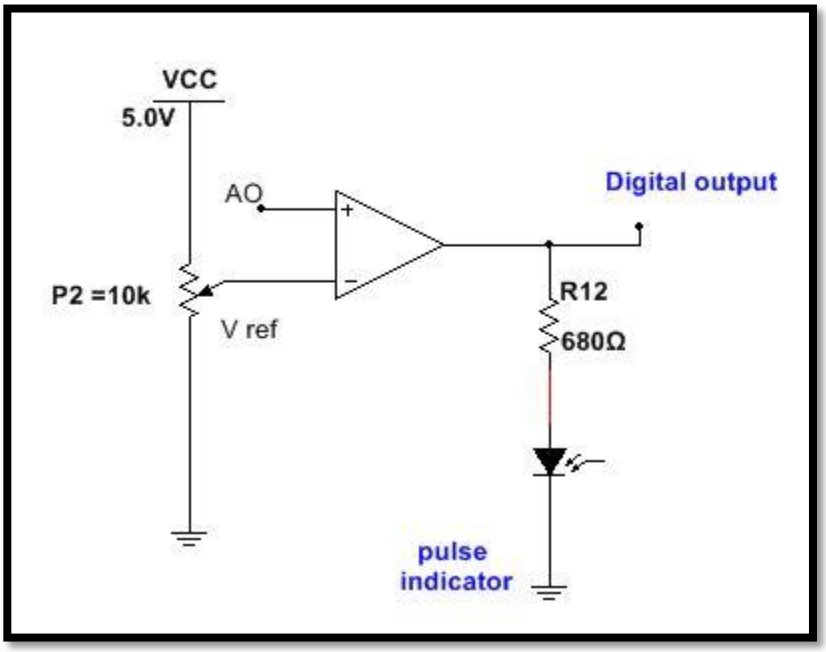

Figure 4.9 Comparator circuit

The magnitude of Vref can be set anywhere between 0 and 5 through potentiometer P2 Every time the PPG pulse wave exceeds the threshold Vref, the output of the comparator goes high. Thus, this arrangement provides an output digital pulse synchronous to heart beat, which enable the microcontroller to count heartbeat. Note that the width of the pulse is also determined by Vref. An LED connected to the digital output blinks accordingly.

Note : all amplifiers have a VCC = +5v and VEE -5v.

4.3 Skin Temperature Design

The block diagram shown in Figure 4.10 is built to illustrate the basic design of the proposed system.

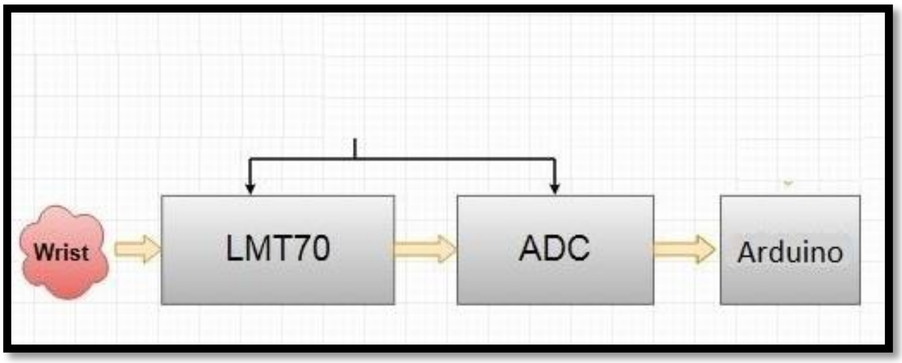

Figure 4.10: Block diagram for Skin Temperature sensor

4.3.1 Temperature sensor Discretion

The two major concerns for measuring body temperature using a wearable wristband are accuracy and speed. The LMT70 is a 4-pin analog temperature sensor that comes in a DSBGA package that is 0.88 mm x 0.88 mm. Its small size means small thermal mass thus quick response [Appendix-B]. The LMT70 also includes internal calibration making it one of the most accurate analog IC temperature sensors in the market. The LMT70's typical accuracy of 0.05°C from 25°C to 45°C makes it ideal for measuring body temperature. This application note will discuss the PCB layout considerations required to achieve good thermal conductivity as well as fast thermal response for the LMT70 as PCB layout can dramatically affect these parameters. [24]

4.3.2 Functional Block Diagram

The LMT70 is a precision analog output temperature sensor. It includes an output switch that is controlled by the T_ON digital input. The output switch enables the multiplexing of several devices onto a single ADC input thus expanding on the ADC input multiplexer capability. The temperature sensing element is comprised of simply stacked BJT base emitter junctions that are biased by a current source. The temperature sensing element is then buffered by a precision amplifier before being connected to the output switch. The output amplifier has a simple class AB push-pull output stage that enables the device to easily source and sink current. [24]

4.3.3 Temperature sensor Output Transfer Function

The LMT70 output voltage transfer function appears to be linear, but upon close inspection it can be seen that it is truly not linear and can be better described by a second or third order transfer function equation.

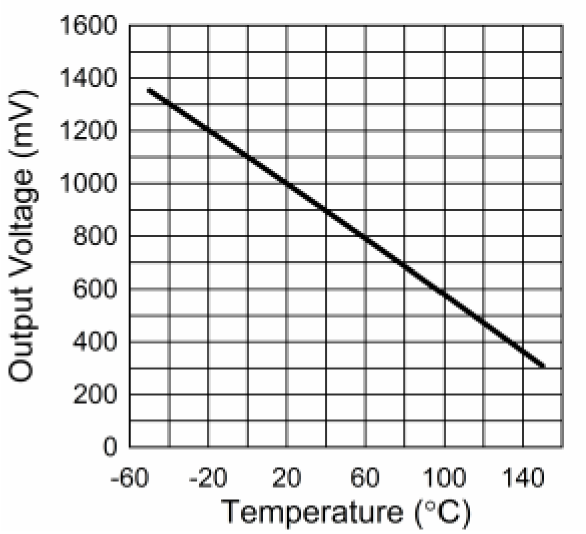

Figure 4.12 Temperature sensor Output Transfer Function [24]

4.3.4 Application Information

The LMT70 analog output temperature sensor is an ideal device to connect to an integrated 12-Bit ADC such as that found in the MSP430 microcontroller family. Applications for the LMT70 included but are not limited to: Io based temperature sensor nodes, medical fitness equipment (e.g. thermometers, fitness/smart bands or watches, activity monitors, human body temperature monitor), Class AA or lower RTD replacement, precision NTC or PTC thermistor replacement, instrumentation temperature compensation, metering temperature compensation (e. g. heat cost allocator, heat meter) [29].

4.4 Power Design

Due to limitation of power supply in any implanted system, choosing of system arts should fulfill the need for an optimal with minimum current consumption leading to increase the life time of the implanted battery. The system intended to operate using a rechargeable (9 volt) battery or power supply (9 volt), this battery will be used to directly supply all circuits and thermistor sensor, but all other stages need to operate within a voltage supply of (5 volt) . This stage use voltage regulator (LM317) to obtain these voltage values from battery keeping in mind the current consumption of all electrical parts used in the system. Table (4.3) explain the name of different parts used the internal part of the system with the power consumption relate to each one to find the overall system current consumption and verify that the power source able to give this desired value, also calculate the expected life time for the battery.

Table 4.3 Current Consumption of the Internal System Components.

Part Number	Function	Quantity	Current Consumption
Arduino	11 in/op pins 5 analog in pins	1	11*40mA=440mA
LCD	To Show	1	35mA
Sensors	To detect	2	2*25mA=50mA
Total Current Consumption =525mA			

After these estimation about the expected current and voltage values of all system component, now it's important to choose the power supply parameters to meet these requirements reaching to optimal system operation. Nickel- cadmium 9v rechargeable battery with (1050 mA) current.

This battery is good enough to supply the implantable system with its required power.

Figure 4.13 Shows the schematic electrical connection of voltage regulator to obtain (+5v) and (0v).

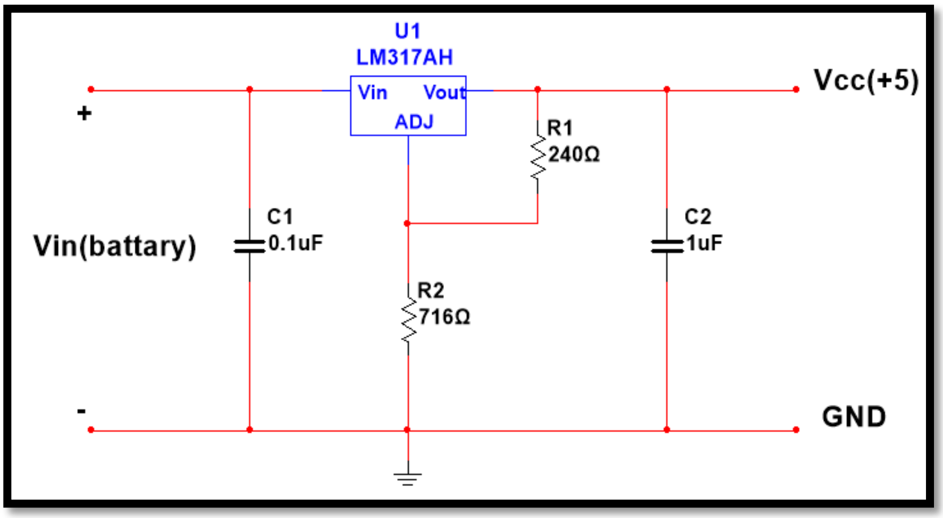

Figure 4.13 Circuit Diagram of Power Supply

LM317 (U1) was chosen as positive voltage regulator due to its relatively high output current capability (1.5A), adjustable output voltage, and low cost features. Desired output voltage can be computed according to the following formula.

$$V_{out} = 1.25V\left(1 + \frac{R_2}{R_1}\right) + I_{adj} R_2 \tag{4.8}$$

According to U1 datasheet, R_1, C_{in}, and C_o equal 240Ω, 0.1µF, and 1µF respectively. R_2 was adjusted to obtain 5v output voltage, also I_{adj} is controlled to less than 100µA, and the error associated with this term is negligible in most applications. Hence, substituting I_{adj} by 100µA into Equation (4.19) results in 5V output voltage as follows:

$$5 = 1.25v * \left(1 + \frac{R2}{240}\right) + 100\ \mu A * R_2 \tag{4.9}$$

Solving equation 10.2 for R_2, obtaining $\mathbf{R_2} = 716\ \Omega$.

4.5 Microcontroller (MCU):

The filtration of the measured signals, apply calculation on it and prepare it for transmission to the next unit mainly done by the m1icrocontroller unit.

In this project, the microcontroller chosen is a Nano Arduino board which is based on ATMEGA328 controller. Nano Arduino is a small and complete board with the same functionality of Arduino Duemilanove just in different package , and Arduino code that we used attached in [Appendix-C].

The only difference is that Nano Arduino doesn't have a power jack instead it works with mini-B USB.

It fits perfectly for this project as it's easy to use as well as it provides mobility feature due to its suitable size for a wearable device. Furthermore its ability to communicate with android applications via Bluetooth module as it supports serial port Bluetooth communication. [25]

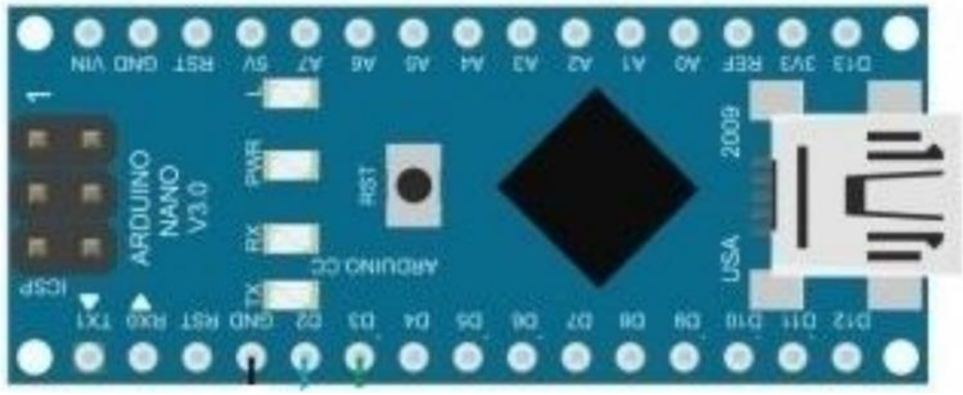

Figure 4.14 Nano Arduino [25]

4.6 Liquid-Crystal Display (LCD)

LCD is the abbreviation of liquid crystal display. LCD is an electronically-modulated optical device shaped into a thin, flat panel made up of any number of color or monochrome pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector. It is often utilized in battery powered electronic devices because it uses very small amounts of electric power. A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals.

Liquid crystals do not emit light directly. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images which can be displayed or hidden, such as preset words, digits, and 7-segment displays as in a digital clock. They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, hile other displays have larger elements.[26]

Figure 4.15 Nano Arduino and LCD screen

4.7 Android system

The HC-06 is a slave only BT module that is relatively easy to use with the Arduino using serial communication. Once it is connected, it simply relays what it receives by Bluetooth to the Arduino and whatever it receives from the Arduino, it sends to the connected device. There are several slightly different versions of the (HC-06) [28].

An application will be designed to receive the processed data and alarm the user in case of an abnormal reading of the two measured vital signs: heart rate and body temperature. And application code that we used attached in [Appendix-D].

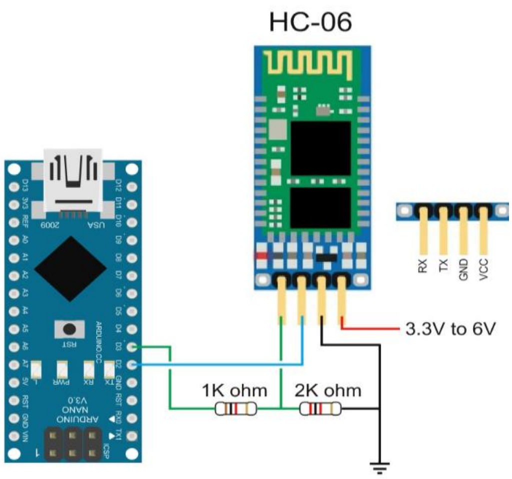

Figure 4.17 Bluetooth Connection via Arduino.[28]

4.8 Interfacing System

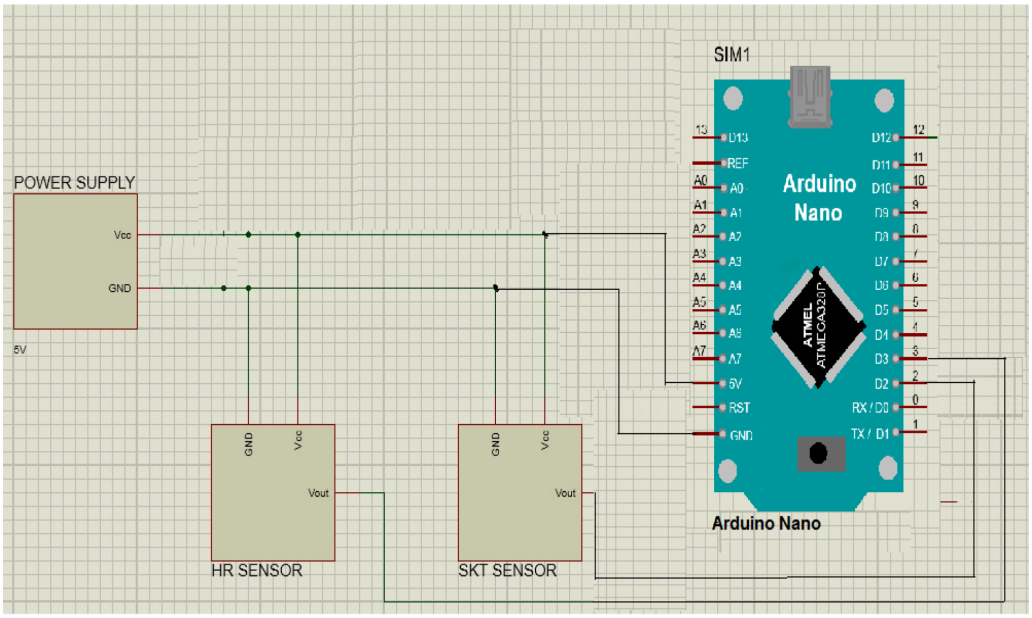

Figure 4.18 Arduino interfacing with HR sensor and SKT sensor

Chapter Five

<u>System Building and Results</u>

5.1 Introduction

After completing the theoretical section of the project, the practical section was started in order to build a complete integrated system containing all the parts that were explained in detail in previous chapters.

5.2 Connection the system

In this section we will explain the process of building and connecting the parts related to our project in practical terms as shown in the attached picture.

5.2.1 Connecting Sensors on the body

The attached image shows the places where the sensors are attached to the body in the wrist where the reading is taken :

Figure 5.1 Location of HR sensor and SKT sensor at a body

5.2.2 Connecting sensors to Arduino

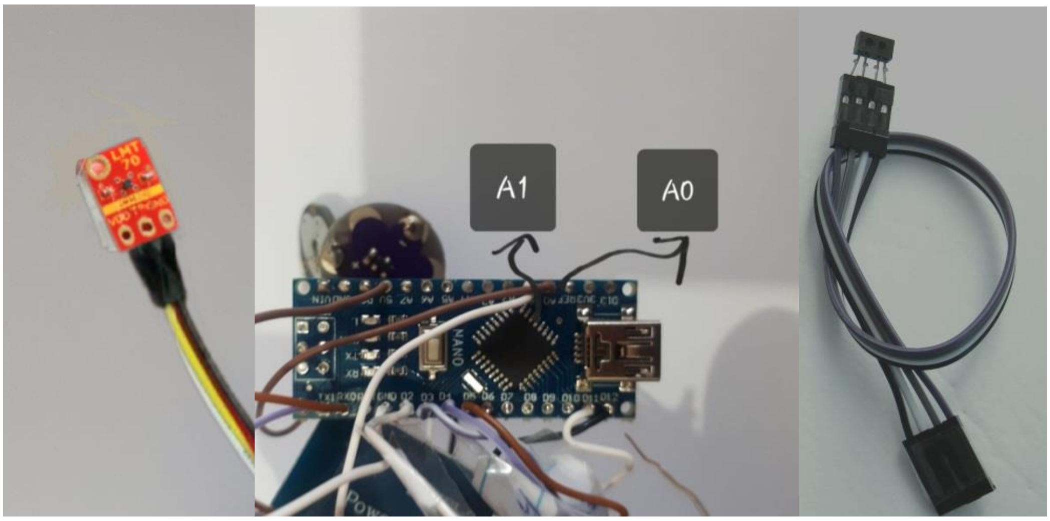

Figure 5.2 connection a HR sensor and SKT sensor to Arduino

The attached image shows the connection of the sensors with the Arduino where the heart rate sensor is connected to the A0 pin and the temperate with A1 pin , and [Appendix-C] shows the Arduino code that we used.

5.2.3 LCD and Bluetooth module

As we discussed in previous chapters, we used a screen to display the results as well as a Bluetooth module to send results to your Android device

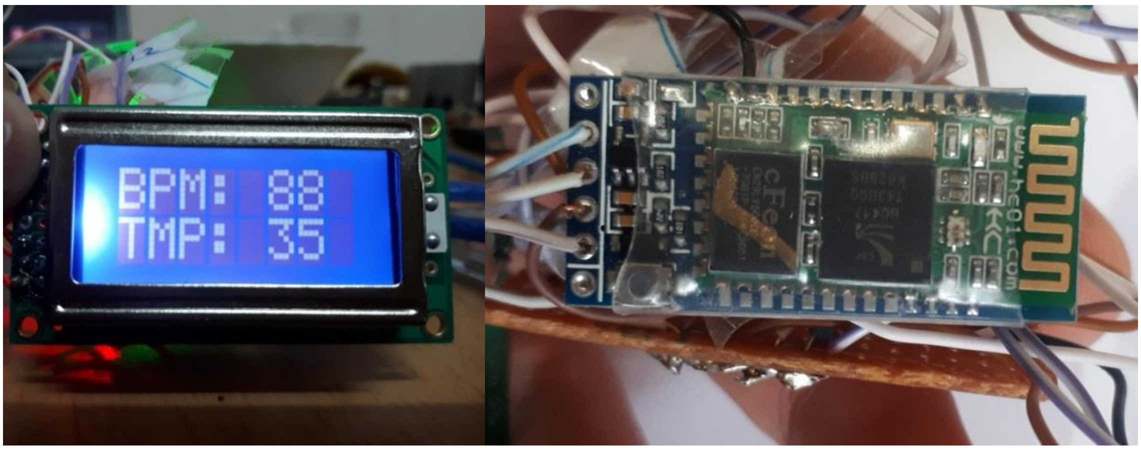

Figure 5.3 LCD and Bluetooth module which use in a project

5.2.4 Android application

The purpose of using the application is a warning system in hazardous situations where it can be linked to a hospital system , The figure 5.4 shows the user interface of the program and [Appendix-D] shows its input interface.

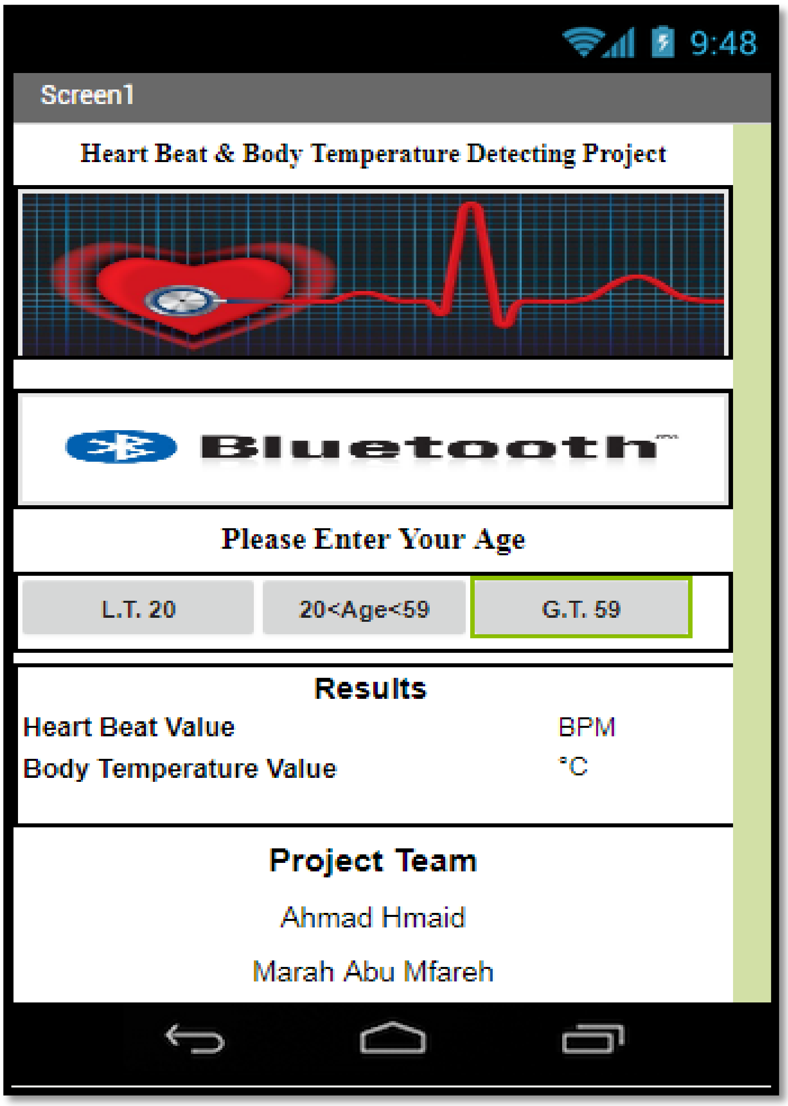

Figure 5.4 The user interface application in the project

5.2.5 Final Form of the Design

Figure 5.5 Final Form of the Design

5.3 Results and Readings

Since the beginning of the project, the main objective was to obtain results from the wrist area, similar to the results obtained from the other measurement and conventional places, which are done by modern and sophisticated devices, and this is what we have access to, taking into account the differences in readings, which can be considered simple differences and do not affect the results Our goal is to give an impression of the nature and condition of the patient. We cannot produce a 100% accurate result using these simple probes.

The following table shows a comparison between our project readings and device readings used by doctors in their own clinics

Table 5.1: Some reading by project

#	project readings		Age of patient
	HRS	TS	
1	85	34	8
2	81	34	10
3	82	34.5	13
4	81	35	17
5	82	34	23
6	85	36	23
7	81	34	30
8	78	34.7	37
9	81	34	41
10	77	35	46

Chapter Six

Conclusion and recommendations

6.1 Conclusion

6.2 Challenges

6.3 Recommendations and Future Work

6.1 Conclusion

Through the results of the chapter five we can say that we were able to design a device can measuring the heart rate and body temperature through the wrist with a a good measure of accuracy, where simple tools and instruments were used to obtain this educational model.

6.2 Challenges

We faced a many challenges when we are building our project. The most important thing was the project's size, which we tried as much as possible , to make it fit the size of the wristwatch, However, the components or pieces that were available to us in this model made it challenging to achieve that. Yet, it should be noted that this project is an educational model that can be improved in the future as will be clarified in the last section of this chapter.

One of the challenges we also faced was the measurement area, which is not considered a very precise or accurate measurement area, but we were able to get measurement readings that can be considered as adequate indication of the normal or abnormal state of the patient.

6.3 Recommendations and Future Work

As mentioned in the previous section, we have obtained an educational model that needs to be developed and improved where it can become commercially viable if it is adopted by an interested company. The future outlook of the device can be summarized as follows

- The size of the device can be reduced to the size of the normal wristwatch using a smaller size processor and a more sophisticated screen

- The system can be installed in a special system in the hospital or clinic to speed up the alert in dangerous situations

- It is possible to work on expanding the use of the ready by placing a clock and other additions

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[Appendix-A]

[Appendix-B]

[Appendix-C]

[Appendix-D]