NEAR EAST UNIVERSITY

FACULTY OF ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

2013/2014 SPRING ACADEMIC YEAR

BME 402

GRADUATION PROJECT 2

PULSE MEASUREMENT FROM FINGERTIP

MEHMET M. ERME	**20112995**
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ABSTRACT

This Project presented the design and development of a new integrated device for measuring heart rate using fingertip to improve estimating the heart rate. As heart related diseases are increasing day by day, the need for an accurate and affordable heart rate measuring device or heart monitor is essential to ensure quality of health. However, most heart rate measuring tools and environments are expensive and do not follow ergonomics. Our proposed Heart Rate Measuring (HRM) device is economical and user friendly and uses optical technology to detect the flow of blood through index finger.

Keywords; Heart rate,optical technology,index finger

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CHAPTER 1

INTRODUCTION

1.1 Human Heart: Anatomy, Function & Facts

The human heart is an organ that pumps blood throughout the body via the circulatory system.

1.1.2 Human heart anatomy

In humans, the heart is roughly the size of a large fist and weighs between 9 and 12 ounces (250 and 350 grams). It has four chambers: two upper chambers (the atria) and two lower ones (the ventricles). The right atrium and right ventricle together make up the "right heart," and the left atrium and left ventricle make up the "left heart." A wall of muscle called the septum separates the two sides of the heart.

A double-walled sac called the pericardium encases the heart, which serves to protect the heart and anchor it inside the chest. Between the outer layer, the parietal pericardium, and the inner layer, the serous pericardium, runs pericardial fluid, which lubricates the heart during contractions and movements of the lungs and diaphragm.

The heart's outer wall consists of three layers. The outermost wall layer, or epicardium, is the inner wall of the pericardium. The middle layer, or myocardium, contains the muscle that contracts. The inner layer, or endocardium, is the lining that contacts the blood.

The tricuspid valve and the mitral valve make up the atrioventricular (AV) valves, which connect the atria and the ventricles. The pulmonary semi-lunar valve separates the left ventricle from the pulmonary artery, and the aortic valve separates the right ventricle from the aorta. The heartstrings, or chordae tendinae, anchor the valves to heart muscles.The sinoatrial node produces the electrical pulses that drive heart contractions.[1]

1.1.3 Human heart function

The heart circulates blood through two pathways: the pulmonary circuit and the systemic circuit.In the pulmonary circuit, deoxygenated blood leaves the right ventricle of the heart via the pulmonary artery and travels to the lungs, then returns as oxygenated blood to the left atrium of the heart via the pulmonary vein.

In the systemic circuit, oxygenated blood leaves the body via the left ventricle to the aorta, and from there enters the arteries and capillaries where it supplies the body's tissues with oxygen. Deoxygenated blood returns via veins to the venae cavae, re-entering the heart's right atrium.

Electrical "pacemaker" cells cause the heart to contract, which happens in five stages. In the first stage (early diastole), the heart is relaxed. Then the atrium contracts (atrial systole) to push blood into the ventricle. Next, the ventricles start contracting without changing volume. Then the ventricles continue contracting while empty. Finally, the ventricles stop contracting and relax. Then the cycle repeats.Valves prevent backflow, keeping the blood flowing in one direction through the heart.[1]

1.1.4 Facts about the human heart

- A human heart is roughly the size of a large fist
- The heart weighs between 9 and 12 ounces (250 and 350 grams)
- The heart beats about 100,000 times per day (about three billion beats in a lifetime)
- An adult heart beats about 60 to 80 times per minute
- Newborns hearts beat faster than adult hearts, about 70 -190 beats per minute
- The heart pumps about 6 quarts (5.7 liters) of blood throughout the body
- The heart is located in the center of the chest, usually pointing slightly left [1]

1.2 What is heart rate?

The heart rate is one of our vital signs - it is the number of times a minute that our heart contracts or beats.The rate of heart contractions is equal to the pulse, which is how many times a minute that our arteries expand because of the increase in blood pressure originated by our heartbeat.

- Heart rate varies - we have a resting heart rate, which does exactly what it says on the tin: it is the rate at which our heart beats when we are relaxed.
- Our heart rate goes up with exertion - the purpose of which is to deliver more oxygen and energy for the activity.

The heart rate shoots up dramatically in response to adrenaline, preparing us for a 'fight or flight' reaction. Adrenaline is a hormone, also known as epinephrine. Being frightened or surprised automatically makes the heart rate higher via adrenaline, preparing us to use more oxygen and energy in the fight or flight reaction.[2]

1.2.1 How is heart rate measured?

Heart rate is usually measured by finding the pulse in the body. The pulse is felt by the pads of the index and middle fingers of the examiner.

At each beat the heart pumps blood into the blood vessels. As the blood flows into the blood vessels the blood vessels expand and this is felt as a pulse.

This pulse rate is felt at any part of the body where the arterial pulsation is transmitted to the skin surface especially when it is compressed against an underlying structure like bone.

Some of the pulse sites include:

- Temporal artery by the sides of the forehead
- Facial artery at the angle of the jaws
- Carotid artery in the neck

- Brachial artery
- Radial artery at the wrist
- Femoral artery at the groin
- Popliteal artery behind the knees
- Posterior tibial artery
- Dorsalis pedis artery over the foot [3]

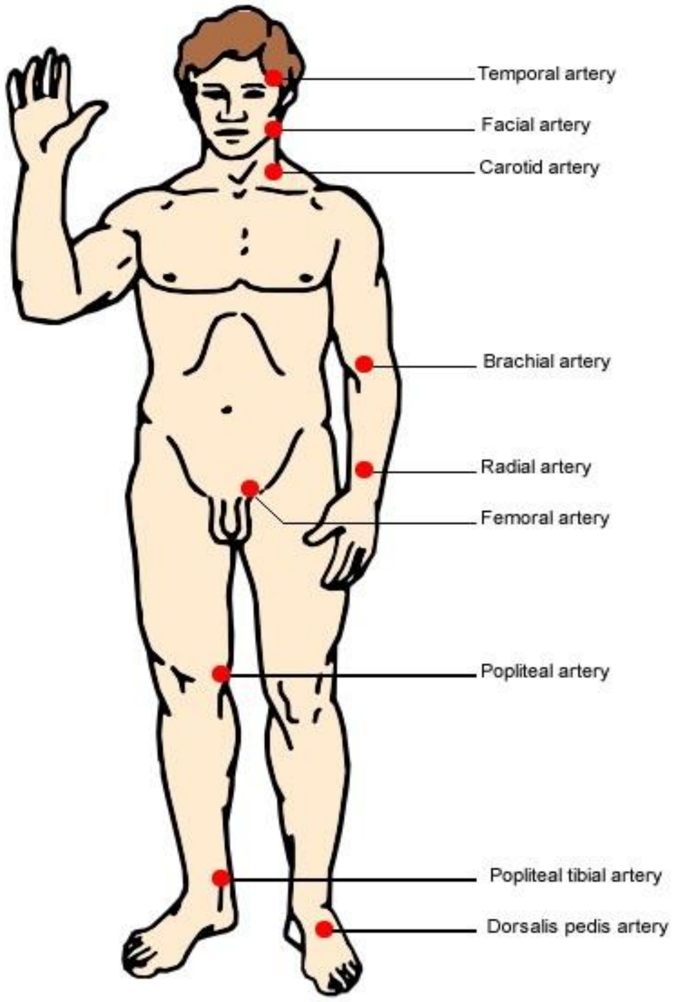


Figure1

1.2.2 Methods For Measuring Pulse Rate

You may have found it difficult to accurately count the heartbeats you heard with the stethoscope because of interference from other noises in the room. An easier way to count heartbeats is to feel the pulse caused each time the heart pumps blood. There are two methods for measuring pulse. You should sit quietly for several minutes before measuring your "resting" pulse rate.[3]

1.2.2.1 Wrist Method

With the palm of your partner's hand facing up, place the tips of your first two fingers on the fleshy part of your partner's thumb. Slide your fingers about 2 inches toward the wrist, stop, and press firmly to feel the pulse of blood which each heart beat sends through the artery. To measure heart rate, count the number of pulses in 30 seconds. Multiply that number by 2, and you will have the number of beats per minute ("bpm"). [3]

figure2

1.2.2.2 Neck Method

Place the tips of your first two fingers on either side of your windpipe, near the lump, called an Adam's apple, in the middle of your neck. Press gently until you can feel a pulse. To measure heart rate, count the number of pulses in 30 seconds. Multiply that number by 2, and you will have the number of beats per minute ("bpm").[3]

figure3

1.2.2.3 Monitor Method

A heart rate monitor or ECG/EEG can be used to get a more accurate heart rate measurement. There is now also a heart rate phone App that can measure heart rate too.This is particularly important during exercise where the motion of exercise often makes it hard to get a clear measurement using the manual method. Using a heart rate monitor is also useful when you wish to record heart rate changes over short time periods, where the heart rate may be changing. Many heart rate monitors are able to record the heart rate values to be reviewed later or downloaded to a computer.[4]

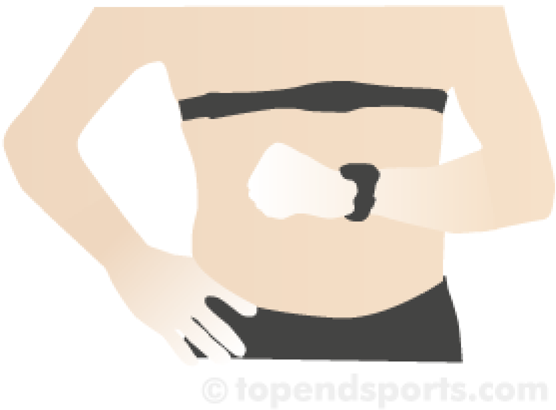


figure4

1.2.3 What is Max Heart Rate?

Your heart rate is measured as the number of times your heart beats per minute (bpm). Your resting heart rate is the measure of your heart rate at rest, which decreases as you get in better shape. Your max heart rate, on the other hand, is the maximum heart rate that you can attain that is based on your genetics. A high, or low max heart rate does not predict athletic performance, or even fitness level.[5]

1.2.4 Why is Max Heart Rate important?

If you have a reasonable estimate of your Max Heart Rate, then you can create target training zones to help you improve your cardiovascular capacity and progress the intensity of your workouts.

For example, if your max heart rate is 190 bpm, then I can give you a training plan that instructs you to run at 70% of your max heart rate for 30 minutes, or 133 bpm. So your target heart rate in this case is 133 bpm, which is a very useful benchmark for future workouts.[5]

1.2.5 Max Heart Rate Calculations:

Since the '70s, the general suggestion for determining your maximum target health rate has been to subtract your age from 220, but as The New York Times points out, that formula's not particularly accurate. [5]

1.2.6 Factors affecting your Max Heart Rate (MHR)

Warm-up

Both the duration and intensity of your warm-up will affect your heart rates in your test. A longer warm-up of moderate intensity will give higher readings than a quick, light jog, because your body temperature and muscle blood flow will be greater.[6]

Previous activity

You need to be fresh to be able to perform at your true max. If you have trained hard on the previous couple of days, you are unlikely to be able to run at sufficient intensity to register your genuine MHR.[6]

Protocol

Rather than one continuous run to exhaustion, or a graded test, try a couple of hard three-minute bursts after a thorough warm-up.[6]

Running environment

Research has shown that you are likely to get slightly higher readings if you run on a treadmill rather than outside. A treadmill can also help you keep level pace in your three-minute bursts, and may help to prevent you setting off way too fast and fatiguing early.[6]

Modeofexercise

Its important that you use the mode of activity that youre training for. For example, your MHR from a cycle test is almost certain to be lower than your running MHR, unless youre also a highly trained cyclist.[6]

1.2.7 What's a normal resting heart rate?

Resting heart rate (Resting HR) is the number of beats in one minute when you are at complete rest. Your resting heart rate indicates your basic fitness level. The more conditioned your body, the less effort and fewer beats per minute it takes your heart to pump blood to your body at rest.[7]

1.2.8 Target heart rate

Target heart rate is defined as the minimum number of heartbeats in a given amount of time in order to reach the level of exertion necessary for cardiovascular fitness, specific to a person's age, gender, or physical fitness.[8]

Age (Years)	Average Maximum Heart Rate (bpm)	Target HR Zone 60-90% (bpm)
20	200	120-180
25	195	117-176
30	190	114-171
35	185	111-166
40	180	108-162
45	175	105-157
50	170	102-153
55	165	99-148
60	160	96-144
65	155	93-139
70	150	90-135

Table1

1.3 Electrical System of the Heart

1.3.1 What controls the timing of your heartbeat?

Your heart's electrical system controls the timing of your heartbeat by regulating your:

- Heart rate, which is the number of times your heart beats per minute.
- Heart rhythm, which is the synchronized pumping action of your four heart chambers.

Your heart's electrical system should maintain:

- A steady heart rate of 60 to 100 beats per minute at rest. The heart's electrical system also increases this rate to meet your body's needs during physical activity and lowers it during sleep.
- An orderly contraction of your atria and ventricles (this is called a sinus rhythm).[9]

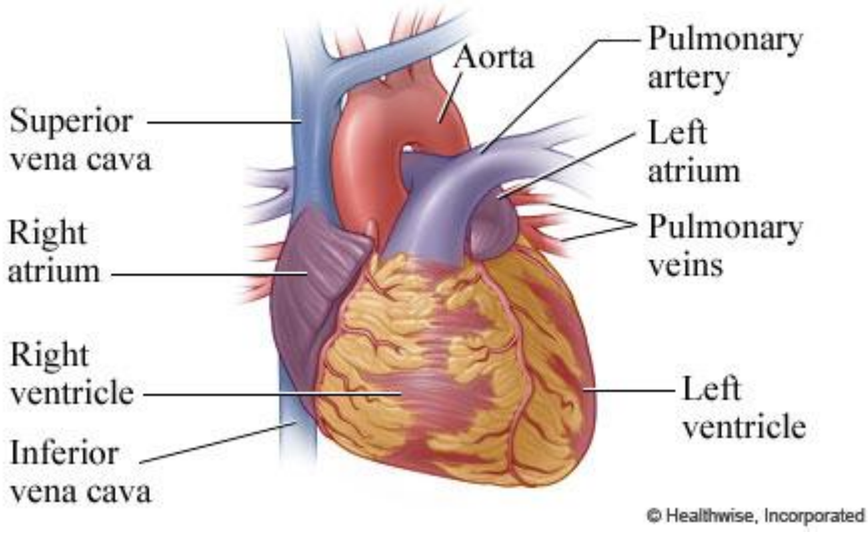


Figure5

1.3.2 How does the heart's electrical system work?

Your heart muscle is made of tiny cells. Your heart's electrical system controls the timing of your heartbeat by sending an electrical signal through these cells.

Two different types of cells in your heart enable the electrical signal to control your heartbeat

- Conducting cells carry your heart's electrical signal.
- Muscle cells enable your heart's chambers to contract, an action triggered by your heart's electrical signal.

The electrical signal travels through the network of conducting cell "pathways," which stimulates your upper chambers (atria) and lower chambers (ventricles) to contract.

The signal is able to travel along these pathways by means of a complex reaction that allows each cell to activate one next to it, stimulating it to "pass along" the electrical signal in an orderly manner. As cell after cell rapidly transmits the electrical charge, the entire heart contracts in one coordinated motion, creating a heartbeat.The electrical signal starts in a group of cells at the top of your heart called the sinoatrial (SA) node. The signal then travels down through your heart, triggering first your two atria and then your two ventricles. In a healthy heart, the signal travels very quickly through the heart, allowing the chambers to contract in a smooth, orderly fashion.

The heartbeat happens as follows:

1. The SA node (called the pacemaker of the heart) sends out an electrical impulse.
2. The upper heart chambers (atria) contract.
3. The AV node sends an impulse into the ventricles.
4. The lower heart chambers (ventricles) contract or pump.
5. The SA node sends another signal to the atria to contract, which starts the cycle over again.[9]

This cycle of an electrical signal followed by a contraction is one heartbeat.

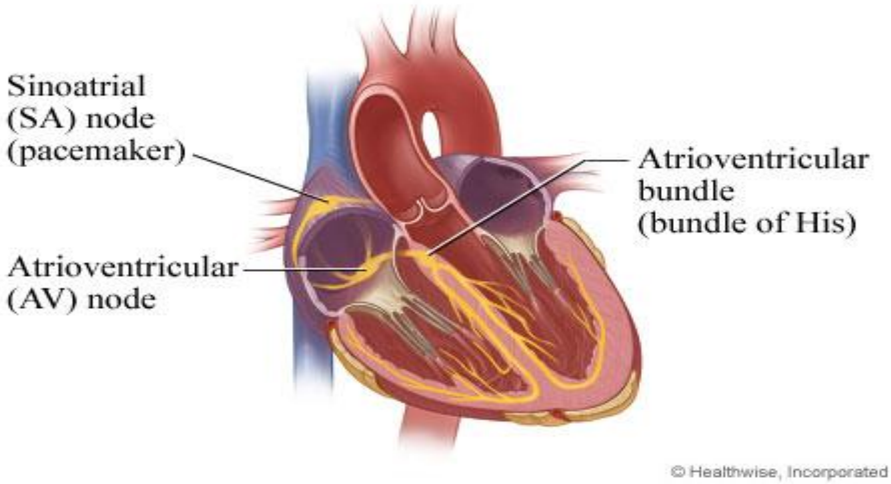


Figure6

1.3.3 SA node and atria

When the SA node sends an electrical impulse, it triggers the following process:

- The electrical signal travels from your SA node through muscle cells in your right and left atria.
- The signal triggers the muscle cells that make your atria contract.
- The atria contract, pumping blood into your left and right ventricles.[9]

1.3.4 AV node and ventricles

After the electrical signal has caused your atria to contract and pump blood into your ventricles, the electrical signal arrives at a group of cells at the bottom of the right atrium called the atrioventricular node, or AV node. The AV node briefly slows down the electrical signal, giving the ventricles time to receive the blood from the atria. The electrical signal then moves on to trigger your ventricles.

When the electrical signal leaves the AV node, it triggers the following process:

- The signal travels down a bundle of conduction cells called the bundle of His, which divides the signal into two branches: one branch goes to the left ventricle, another to the right ventricle.
- These two main branches divide further into a system of conducting fibers that spreads the signal through your left and right ventricles, causing the ventricles to contract.
- When the ventricles contract, your right ventricle pumps blood to your lungs and the left ventricle pumps blood to the rest of your body.After your atria and ventricles contract, each part of the system electrically resets itself.[9]

1.3.5 How does the heart's electrical system regulate your heart rate?

The cells of the SA node at the top of the heart are known as the pacemaker of the heart because the rate at which these cells send out electrical signals determines the rate at which the entire heart beats (heart rate).

The normal heart rate at rest ranges between 60 and 100 beats per minute. Your heart rate can adjust higher or lower to meet your body's needs.[9]

1.3.6 What makes your heart rate speed up or slow down?

Your brain and other parts of your body send signals to stimulate your heart to beat either at a faster or a slower rate. Although the way all of the chemical signals interact to affect your heart rate is complex, the net result is that these signals tell the SA node to fire charges at either a faster or slower pace, resulting in a faster or a slower heart rate.

For example, during periods of exercise, when the body requires more oxygen to function, signals from your body cause your heart rate to increase significantly to deliver more blood (and therefore more oxygen) to the body. Your heart rate can increase beyond 100 beats per minute to meet your body's increased needs during physical exertion.

Similarly, during periods of rest or sleep, when the body needs less oxygen, the heart rate decreases. Some athletes actually may have normal heart rates well below 60 because their hearts are very efficient and don't need to beat as fast. Changes in your heart rate, therefore, are a normal part of your heart's effort to meet the needs of your body.[9]

1.4 ABNORMALITIES OF HEART RATE

Tachycardia is a fast or irregular heart rhythm, usually more than 100 beats per minute and as many as 400 beats per minute. At these elevated rates, the heart is not able to efficiently pump oxygen-rich blood to your body.

Causes of tachycardia include:

- Heart-related conditions such as high blood pressure (hypertension)
- Poor blood supply to the heart muscle due to coronary artery disease (atherosclerosis), heart valve disease, heart failure, heart muscle disease (cardiomyopathy), tumors, or infections
- Other medical conditions such as thyroid disease, certain lung diseases, electrolyte imbalance, and alcohol or drug abuse
- Emotional stress or drinking large amounts of alcoholic or caffeinated beverages.[10]

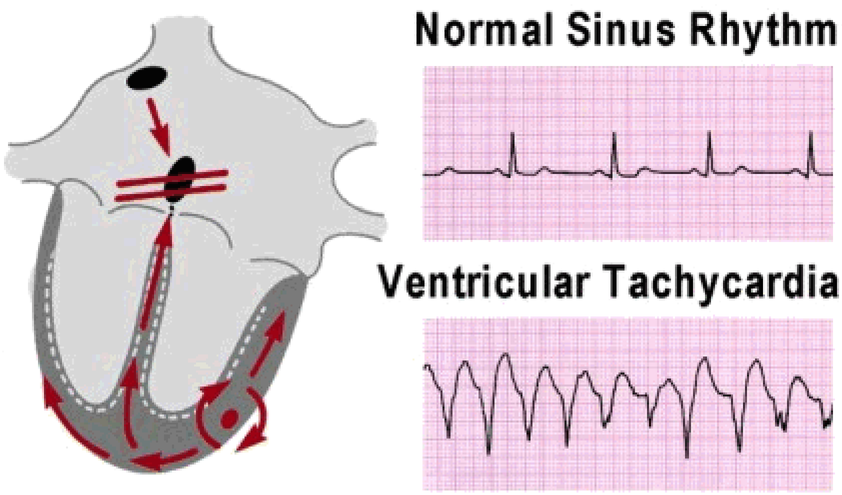


Figure7

1.4.1 Bradycardia

A heart rate of less than 60 beats per minute (BPM) in adults is called bradycardia. What's too slow for you may depend on your age and physical condition.

- Physically active adults often have a resting heart rate slower than 60 BPM but it doesn't cause problems.
- Your heart rate may fall below 60 BPM during deep sleep.
- Elderly people are more prone to problems with a slow heart rate.[11]

Causes of bradycardia

- Problems with the sinoatrial (SA) node, sometimes called the heart's natural pacemaker
- Problems in the conduction pathways of the heart (electrical impulses are not conducted from the atria to the ventricles)
- Metabolic problems such as hypothermia
- Damage to the heart from heart attack or heart disease.[11]

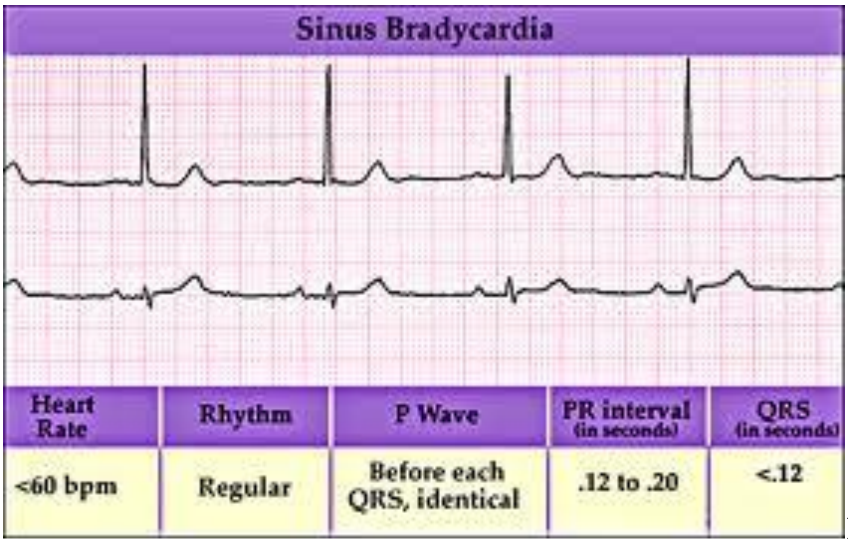


Figure8

1.4.2 Arrhythmia

An arrhythmia is an irregular heartbeat - the heart may beat too fast (tachycardia), too slowly (bradycardia), too early (premature contraction) or too irregularly (fibrillation). Arrhythmias are heart-rhythm problems - they occur when the electrical impulses to the heart that coordinate heartbeats are not working properly, making the heart beat too fast/slow or inconsistently.

Many heart arrhythmias are harmless. We all occasionally experience irregular heartbeats, which may feel like a racing heart or fluttering. Some arrhythmias, however, especially if they veer too far from a normal heartbeat or result from a weak or damaged heart, may cause troublesome and even potentially fatal symptoms.

Rapid arrhythmias are called tachycardias, while slow ones are called bradycardias. Irregular arrhythmias - when the heartbeat is irregular - are called fibrillations, as in atrial or ventricular fibrillation. When a single heartbeat occurs earlier than it should it is called premature contraction. [12]

1.5 Hand Anatomy

Few structures of the human anatomy are as unique as the hand. The hand needs to be mobile in order to position the fingers and thumb. Adequate strength forms the basis for normal hand function. The hand also must be coordinated to perform fine motor tasks with precision. The structures that form and move the hand require proper alignment and control in order for normal hand function to occur.[13]

Figure9

1.5.1 Important Structures

The important structures of the hand can be divided into several categories. These include

- bones and joints
- ligaments and tendons
- muscles
- nerves
- blood vessels

The front, or palm-side, of the hand is referred to as the *palmar* side. The back of the hand is called the *dorsal* side.[13]

1.5.2 Bones and Joints

There are 27 bones within the wrist and hand. The wrist itself contains eight small bones, called *carpals*. The carpals join with the two forearm bones, the *radius* and *ulna*, forming the wrist joint. Further into the palm, the carpals connect to the *metacarpals*. There are five metacarpals forming the palm of the hand. One metacarpal connects to each finger and thumb. Small bone shafts called *phalanges* line up to form each finger and thumb.

The main knuckle joints are formed by the connections of the phalanges to the metacarpals. These joints are called the*metacarpophalangeal joints* (MCP joints). The MCP joints work like a hinge when you bend and straighten your fingers and thumb.

The three phalanges in each finger are separated by two joints, called*interphalangeal joints* (IP joints). The one closest to the MCP joint (knuckle) is called the *proximal IP joint* (PIP joint). The joint near the end of the finger is called the *distal IP joint* (DIP joint). The thumb only has one IP joint between the two thumb phalanges. The IP joints of the digits also work like hinges when you bend and straighten your fingers and thumb.

The joints of the hand, fingers, and thumb are covered on the ends with *articular cartilage*. This white, shiny material has a rubbery consistency. The function of articular cartilage is to absorb shock and provide an extremely smooth surface to facilitate motion. There is articular cartilage essentially everywhere that two bony surfaces move against one another, or *articulate*.[13]

Figure10

1.5.3 Ligaments and Tendons

Ligaments are tough bands of tissue that connect bones together. Two important structures, called *collateral ligaments*, are found on either side of each finger and thumb joint. The function of the collateral ligaments is to prevent abnormal sideways bending of each joint.

In the PIP joint (the middle joint between the main knuckle and the DIP joint), the strongest ligament is the *volar plate*. This ligament connects the proximal phalanx to the middle phalanx on the palm side of the joint. The ligament tightens as the joint is straightened and keeps the PIP joint from bending back too far (hyperextending). Finger deformities can occur when the volar plate loosens from disease or injury.

The tendons that allow each finger joint to straighten are called the*extensor tendons*. The extensor tendons of the fingers begin as muscles that arise from the backside of the forearm bones. These muscles travel towards the hand, where they eventually connect to the extensor tendons before crossing over the back of the wrist joint. As they travel into the fingers, the extensor tendons become the *extensor hood*. The extensor hood flattens out to cover the top of the finger and sends out branches on each side that connect to the bones in the middle and end of the finger.

The place where the extensor tendon attaches to the middle phalanx is called the *central slip*. When the extensor muscles contract, they tug on the extensor tendon and straighten the finger. Problems occur when the central slip is damaged, as can happen with a tear.[13]

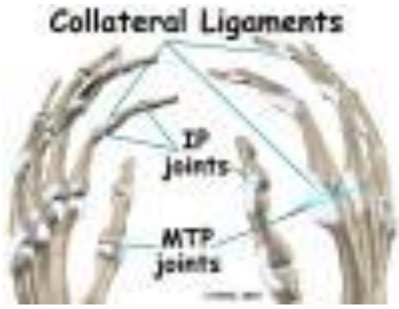


Figure11

1.5.4 Muscles

Many of the muscles that control the hand start at the elbow or forearm. They run down the forearm and cross the wrist and hand. Some control only the bending or straightening of the wrist. Others influence motion of the fingers or thumb. Many of these muscles help position and hold the wrist and hand while the thumb and fingers grip or perform fine motor actions.

Most of the small muscles that work the thumb and pinky finger start on the carpal bones. These muscles connect in ways that allow the hand to grip and hold. Two muscles allow the thumb to move across the palm of the hand, an important function called *thumb opposition*.

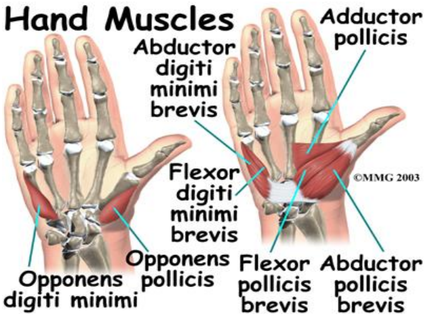


Figure12

The smallest muscles that originate in the wrist and hand are called the *intrinsic muscles*. The intrinsic muscles guide the fine motions of the fingers by getting the fingers positioned and holding them steady during hand activities.[13]

1.5.5 Nerves

All of the nerves that travel to the hand and fingers begin together at the shoulder: the *radial nerve*, the *median nerve*, and the *ulnar nerve*. These nerves carry signals from the brain to the muscles that move the arm, hand, fingers, and thumb. The nerves also carry signals back to the brain about sensations such as touch, pain, and temperature.

The radial nerve runs along the thumb-side edge of the forearm. It wraps around the end of the radius bone toward the back of the hand. It gives sensation to the back of the hand from the thumb to the third finger. It also supplies the back of the thumb and just beyond the main knuckle of the back surface of the ring and middle fingers.

The median nerve travels through a tunnel within the wrist called the *carpal tunnel*. This nerve gives sensation to the thumb, index finger, long finger, and half of the ring finger. It also sends a nerve branch to control the *thenar muscles* of the thumb. The thenar muscles help move the thumb and let you touch the pad of the thumb to the tips each of each finger on the same hand, a motion called opposition.

The ulnar nerve travels through a separate tunnel, called *Guyon's canal*. This tunnel is formed by two carpal bones, the *pisiform* and*hamate*, and the ligament that connects them. After passing through the canal, the ulnar nerve branches out to supply feeling to the little finger and half the ring finger. Branches of this nerve also supply the small muscles in the palm and the muscle that pulls the thumb toward the palm.

The nerves that travel to the hand are subject to problems. Constant bending and straightening of the wrist and fingers can lead to irritation or pressure on the nerves within their tunnels and cause problems such as pain, numbness, and weakness in the hand, fingers, and thumb.[13]

Figure13

1.5.6 Blood Vessels

Traveling along with the nerves are the large vessels that supply the hand with blood. The largest artery is the *radial artery* that travels across the front of the wrist, closest to the thumb. The radial artery is where the pulse is taken in the wrist. The *ulnar artery* runs next to the ulnar nerve through Guyon's canal (mentioned earlier). The ulnar and radial arteries arch together within the palm of the hand, supplying the front of the hand, fingers, and thumb. Other arteries travel across the back of the wrist to supply the back of the hand, fingers, and thumb.[13]

Figure14

CHAPTER 2

MEASURING THE HEART RATE

2.1 Overview

This chapter provides measurement of heart rate techniques.

2.1.1 ECG

Electrocardiography is the recording of the electrical activity of the heart. Traditionally this is in the form of a transthoracic (across the thorax or chest) interpretation of the electrical activity of the heart over a period of time, as detected by electrodes attached to the surface of the skin and recorded or displayed by a device external to the body. The recording produced by this noninvasive procedure is termed an **electrocardiogram** (also ECG or EKG). It is possible to record ECGs invasively using an implantable loop recorder.

An ECG is used to measure the heart's electrical conduction system. It picks up electrical impulses generated by the polarization and depolarization of cardiac tissue and translates into a waveform. The waveform is then used to measure the rate and regularity of heartbeats, as well as the size and position of the chambers, the presence of any damage to the heart, and the effects of drugs or devices used to regulate the heart, such as a pacemaker.

Most ECGs are performed for diagnostic or research purposes on human hearts, but may also be performed on animals, usually for diagnosis of heart abnormalities or research.[14]

Figure15

2.1.2 Principles of ECG

The ECG device detects and amplifies the tiny electrical changes on the skin that are caused when the heart muscle depolarizes during each heartbeat. At rest, each heart muscle cell has a negative charge, called the membrane potential, across its cell membrane. Decreasing this negative charge toward zero, via the influx of the positive cations, Na^+ and Ca^{++}, is called depolarization, which activates the mechanisms in the cell that cause it to contract. During each heartbeat, a healthy heart will have an orderly progression of a wave of depolarisation that is triggered by the cells in the sinoatrial node, spreads out through the atrium, passes through the atrioventricular node and then spreads all over theventricles. This is detected as tiny 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 screen or on paper. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle.

Usually, more than two electrodes are used, and they can be combined into a number of pairs (For example: left arm (LA), right arm (RA), and left leg (LL) electrodes form the three pairs LA+RA, LA+LL, and RA+LL). The output from each pair is known as a **lead**. Each lead looks at the heart from a different angle. Different types of ECGs can be referred to by the number of leads that are recorded, for example 3-lead, 5-lead, or 12-lead ECGs (sometimes simply "a 12-lead"). A 12-lead ECG is one in which 12 different electrical signals are recorded at approximately the same time and will often be used as a one-off recording of an ECG, traditionally printed out as a paper copy. Three- and 5-lead ECGs tend to be monitored continuously and viewed only on the screen of an appropriate monitoring device, for example during an operation or whilst being transported in an ambulance. There may or may not be any permanent record of a 3- or 5-lead ECG, depending on the equipment used.[14]

2.1.3 Determining Heart Rate from the Electrocardiogram

The term "heart rate" normally refers to the rate of ventricular contractions. However, because there are circumstances in which the atrial and ventricular rates differ (e.g., second and third degree AV block), it is important to be able to determine both atrial and ventricular rates. This is easily done by examining an ECG rhythm strip, which is usually taken from Lead II. In the example below, there are four numbered R waves, each of which is preceded by a P wave. Therefore, the atrial and ventricular rates will be the same because there is a one-to-one correspondence. Atrial rate can be determined by measuring the time intervals between P waves (P-P intervals).

Ventricular rate can be determined by measuring the time intervals between the QRS complexes, which is done by looking at the R-R intervals.

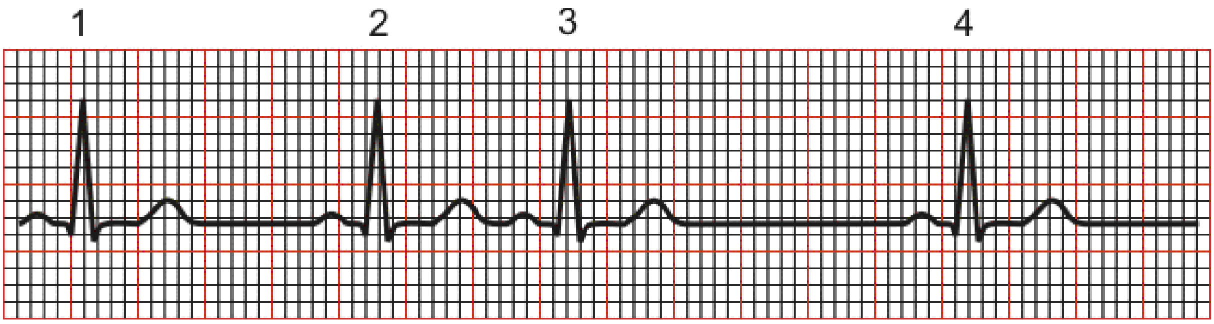


Figure16

There are different short-cut methods that can be used to calculate rate, all of which assume a recording speed of 25 mm/sec. One method is to divide 1500 by the number of small squares between two R waves. For example, the rate between beats 1 and 2 in the above tracing is 1500/22, which equals 68 beats/min. Alternatively, one can divide 300 by the number of large squares (red boxes in this diagram), which is 300/4.4 (68 beats/min). Another method, which gives a rough approximation, is the "count off" method. Simply count the number of large squares between R waves with the following rates: 300 - 150 - 100 - 75 - 60. For example, if there are three large boxes between R waves, then the rate is 100 beats/min. One must extrapolate, however, between boxes. Atrial rate can be determined like the ventricular rate, but using the P waves. Remember, if the heart in in sinus rhythm and there is a one-to-one correspondence between P waves and QRS completes, then the atrial rate will be the same as ventricular rate. In the above examples, the ventricular rate was determined based on the interval between the first two beats. However, it is obvious that the rate would have been faster had it been calculated using beats 2 and 3 (104 beats/min) because because of a premature atrial beat, and slower if it had been calculated between beats 3 and 4 (52 beats/min). This illustrates an important point when calculating rate between any given pair of beats. If the rhythm is not steady, it is important to determine a time-averaged rate over a longer interval (e.g., over ten seconds or longer). For example, because the recording time scale is 25 mm/sec, if there are 12.5 beats in 10 seconds, the rate will be 75 beats/min.[15]

2.2 Pulse Oximeter

Pulse oximeters measure the absorption of red and infrared light by pulsatile blood. They are inexpensive, continuous and portable. Accuracy declines below a SpO_2 of 90%.[16]

Figure17

2.2.1 How do Pulse Oximeters work?

Oxygenated blood absorbs light at 660nm (red light), whereas deoxygenated blood absorbs light preferentially at 940nm (infra-red). Pulse oximeters consist of two light emitting diodes, at 600nm and 940nm, and two light collecting sensors, which measure the amount of red and infra-red light emerging from tissues traversed by the light rays. The relative absorption of light by oxyhemoglobin (HbO) and deoxyhemoglobin is processed by the device and an oxygen saturation level is reported. The device directs its attention at pulsatile arterial blood and ignores local noise from the tissues. The result is a continuous qualitative measurement of the patients oxyhemoglobin status. Oximeters deliver data about pulse rate, oxygen saturation (SpO_2) and even cardiac output. They are, however, far from perfect monitors.

The use of pulse oximeters is limited by a number of factors: they are set up to measure oxygenated and deoxygenated haemoglobin, but no provision is made for measurement error in the presence of dyshemoglobin moieties – such as carboxyhemoglobin (COHb) and methemoglobinemia. COHb absorbs red light as well as HbO, and saturation levels are grossly over-represented. Arterial gas analysis or use of co-oximetery is essential in this situation. Co-oximeters measure reduced haemoglobin, HbO, COHb and methemoglobin. Abnormal movement, such as occurs with agitated patients, will cause interference with SpO_2 measurement. Low blood flow, hypotension, vasoconstriction and hypothermia will reduce the pulsatility of capillary blood, and the pulse-oximeter will under-read or not read at all. Conversely, increased venous pulsation, such as occurs with tricuspid regurgitation, may be misread by the pulse-oximeter as arterial blood, with a low resultant reading. Finally, it is generally accepted that the percentage saturation is unreliably reported on the steep part of the oxyhemoglobin dissociation curve. While the trend between the SaO_2 (arterial saturation) and SpO_2 appears accurate, the correlation between the two numbers is not. Thus a drop in the SpO_2 below 90% must be considered a significant clinical event.[16]

CHAPTER 3

DESIGN OF A DEVICE TO MEASURE HEART RATE FROM THE FINGER

3.1 Overview

This chapter shows how to design heart rate measurement from finger.All information about device like hardware and software you can find in this chapter.

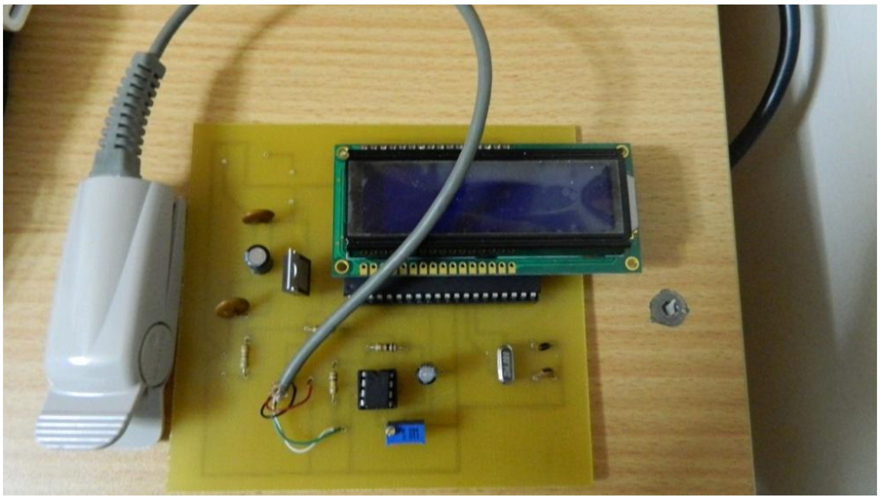


Figure18

3.1.1 Sensor Assembly

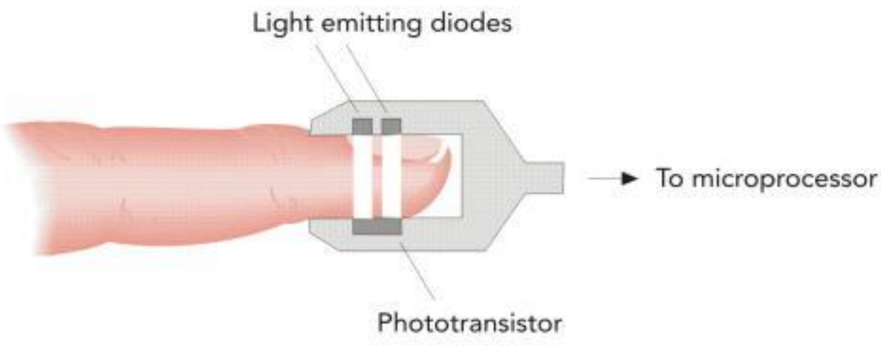


Figure 8-11 Pulse oximeter sensor

Figure19

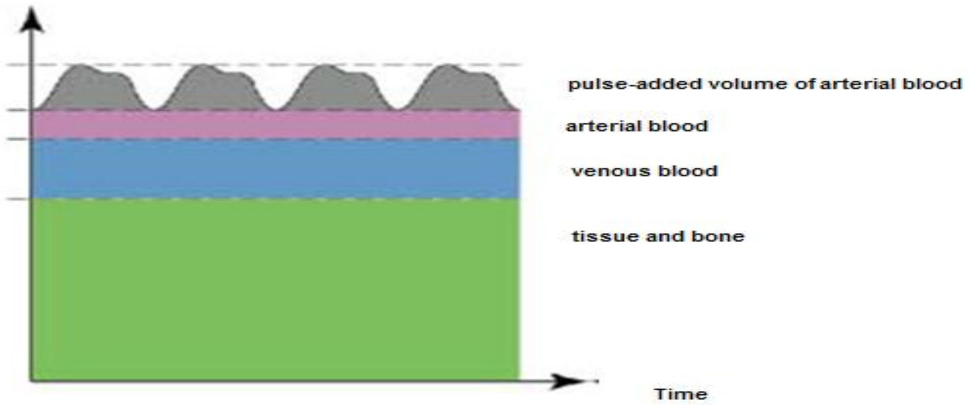
Most sensors work on extremities such as a finger, toe or ear. The sensor measures the amount of red and infrared light received by the detector and calculates the amount absorbed. Much of it is absorbed by tissue, bone and venous blood, but these amounts do not change dramatically over short periods of time.

The amount of arterial blood does change over short periods of time due to pulsation (although there is some constant level of arterial blood). Because the arterial blood is usually the only light absorbing component which is changing over short periods of time, it can be isolated from the other components.[17]

3.1.2 Absorption at the Sensor Site

The amount of light received by the detector indicates the amount of oxygen bound to the hemoglobin in the blood. Oxygenated hemoglobin (oxyhemoglobin or HbO2) absorbs more infrared light than red light. Deoxygenated hemoglobin (Hb) absorbs more red light than infrared light. By comparing the amounts of red and infrared light received, the instrument can calculate the SpO2 reading.[17]

Absorption



3.2 Circuit Diagram

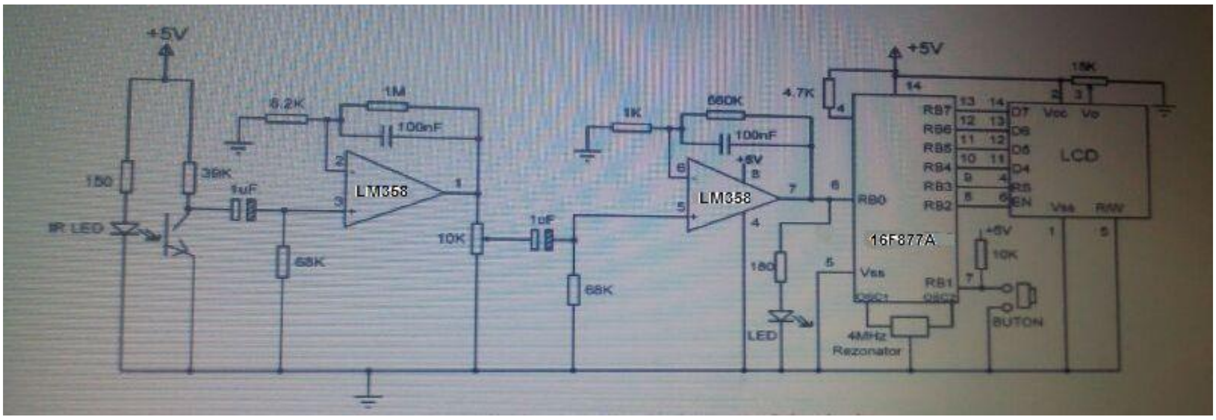


Figure20

The signal conditioning circuit consists of two identical active low pass filters with a cut-off frequency of about 2.5 Hz. This means the maximum measurable heart rate is about 150 bpm. The operational amplifier IC used in this circuit is LM358, a dual OpAmp chip from Microchip. It operates at a single power supply and provides rail-to-rail output swing. The filtering is necessary to block any higher frequency noises present in the signal. The gain of each filter stage is set to 101, giving the total amplification of about 10000. A 1 uF capacitor at the input of each stage is required to block the dc component in the signal. The equations for calculating gain and cut-off frequency of the active low pass filter are shown in the circuitdiagram. The two stage amplifier/filter provides sufficient gain to boost the weak signal coming from the photo sensor unit and convert it into a pulse. An LED connected at the output blinks every time a heartbeat is detected. The output from the signal conditioner goes to the T0CKI input of PIC16F877A.[18]

3.2.1 Signal Extraction

A band pass filter to remove any interference caused by ambient light and level detection distortions. The filter used will have a cutoff frequency of 2.5 Hz to allow a maximum heart rate of 125 bpm to be measured by the device with accuracy. This roll off provides an attenuation of 60Hz, by 23.5dB. The pulse has a –14 dB Signal to Noise Ratio (SNR) before it passes through the filter. The pass-band frequencies are amplified by a factor of 40 dB with a small signal amplifier. We used DC blocking to prevent immeasurable pulses caused by a high DC offset from ambient light.[19]

3.2.2 Pulse Amplification

The extracted signal is analyzed by an amplifier to provide a pulse of high amplitude to be fed into the microcontroller input. The amplifier detects the peak of each pulse and creates a corresponding pulse of high amplitude. This stage of the design requires that the amplified and filtered heart pulse signal have a SNR of 20 dB to obtain a clean pulse of high amplitude. The time between each successive rising of high amplitude pulse edge is interpreted by the microcontroller as the period between each heart pulse. To detect signal amplification an LM358 is used and the heart signal is amplified twice after passing through band pass fitler.Finally, the amplified output that the microcontroller uses it as its input and calculates the heart rate. [19]

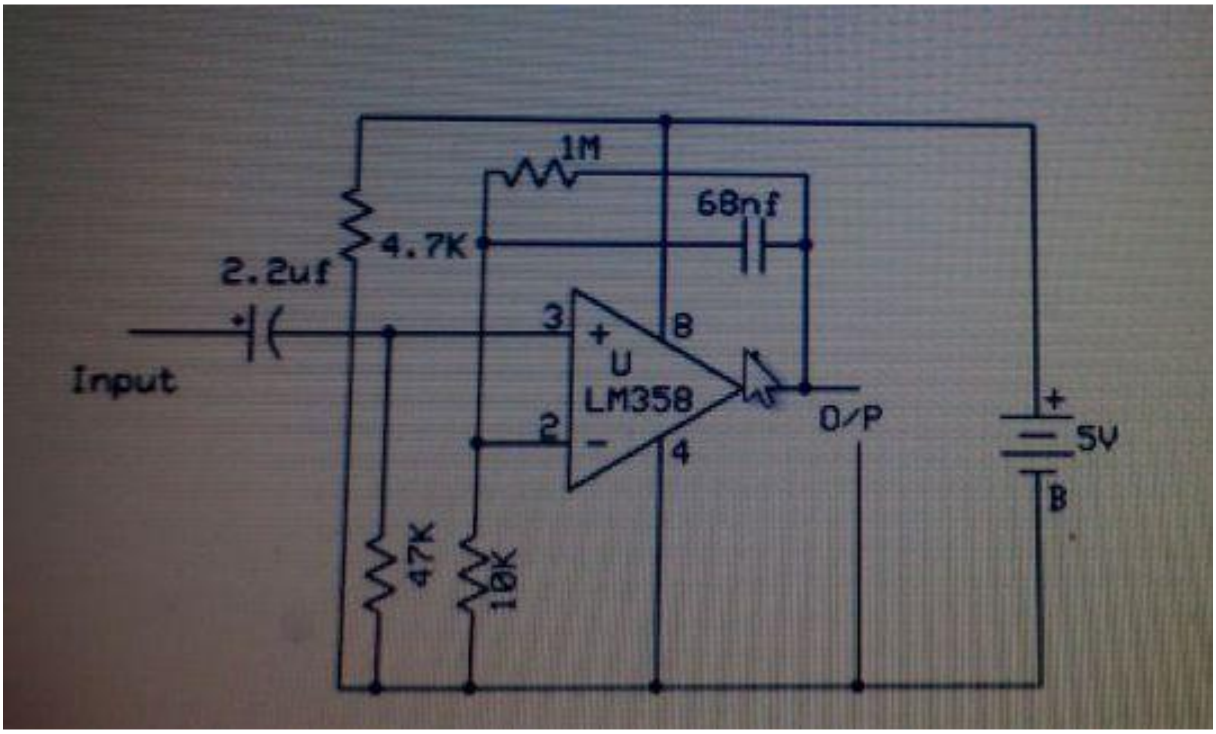


Figure21

3.3 Microcontroller and Display Circuit

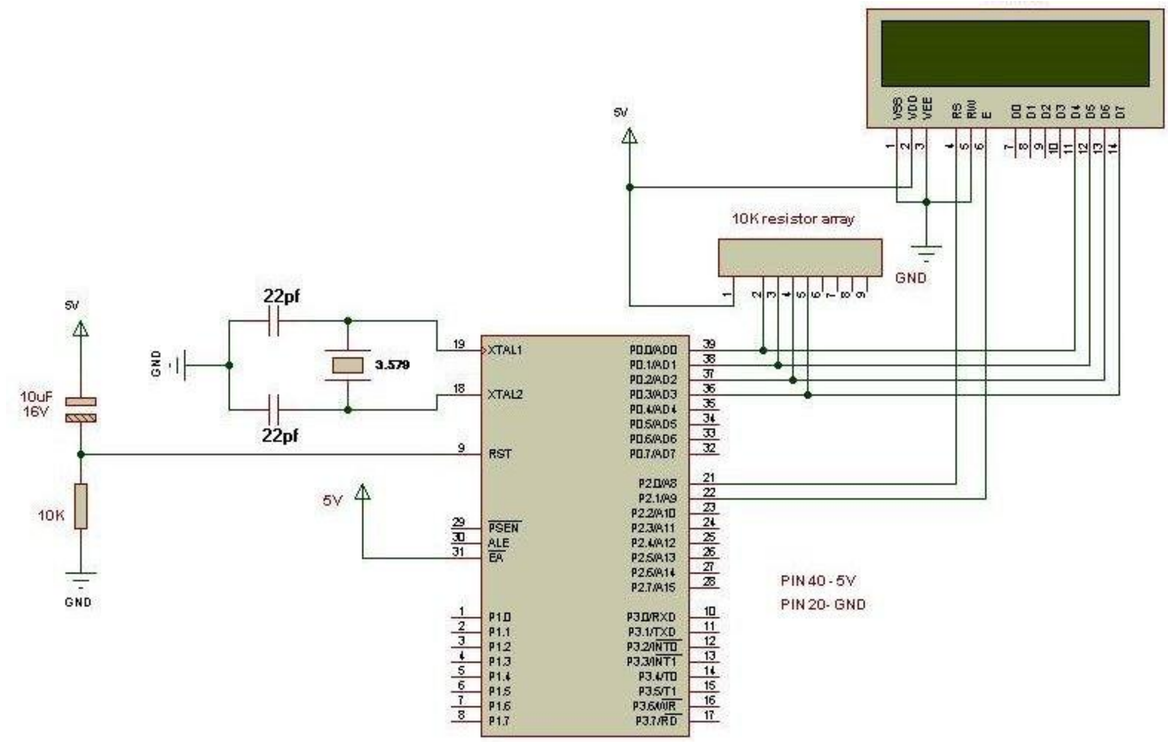


Figure22

A microcontroller is an economical means of counting the pulse rate and controlling a LED display.The schematic diagram shown as upper side is represent how to connect LCD to microcontroller.

CHAPTER 4

THE HARDWARE

4.1 Overview

In this chapter we will explain that which circuit components use to measure heart rate from finger and expalin their properties.

4.1.1 Sensor components

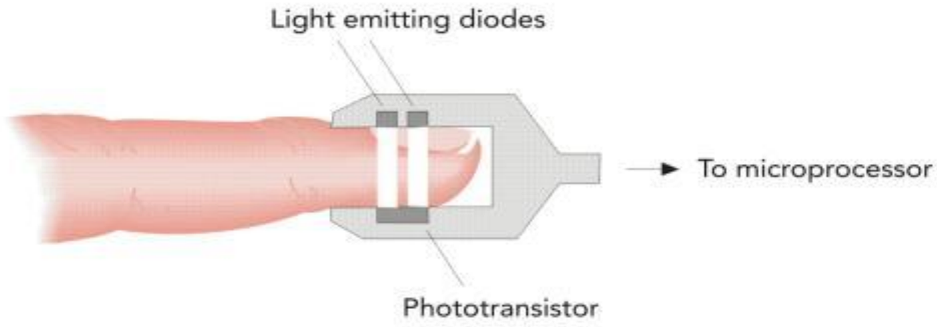


Figure 8-11 Pulse oximeter sensor

Figure23

Light emitting diodes and phototransistor is the most important components of the sensor unit.

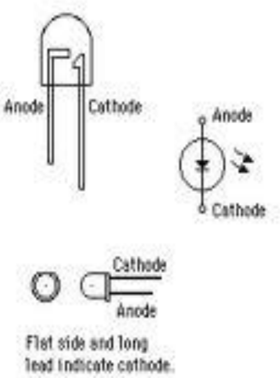
4.1.1.2 Light emitting diodes (LED)

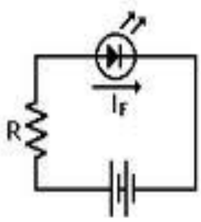
Light emitting diodes, commonly called LEDs, are real unsung heroes in the electronics world. They do dozens of different jobs and are found in all kinds of devices. Among other things, they form numbers on digital clocks, transmit information from remote controls, light up watches and tell you when your appliances are turned on. Collected together, they can form images on a jumbo television screen or illuminate a traffic light.

Basically, LEDs are just tiny light bulbs that fit easily into an electrical circuit. But unlike ordinary incandescent bulbs, they don't have a filament that will burn out, and they don't get especially hot.

They are illuminated solely by the movement of electrons in asemiconductor material, and they last just as long as a standard transistor.

The lifespan of an LED surpasses the short life of an incandescent bulb by thousands of hours. Tiny LEDs are already replacing the tubes that light up LCD HDTVs to make dramatically thinner televisions.[20]





a **b**

Figure b represents us schematic diagram of led and how connect it in electric circuit.

Figure24

4.1.1.3 Phototransistor

The phototransistor is a semiconductor light sensor formed from a basic transistor with a transparent cover that provides much better sensitivity than a photodiode .[21]

Figure25

Phototransistor structure

Although ordinary transistors exhibit the photosensitive effects if they are exposed to light, the structure of the phototransistor is specifically optimised for photo applications. The photo transistor has much larger base and collector areas than would be used for a normal transistor. These devices were generally made using diffusion or ion implantation.

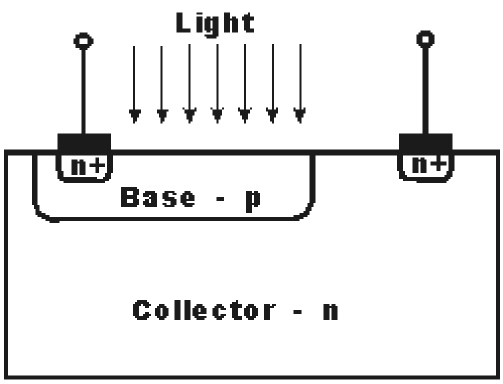


Figure26 Homojunction planar phototransistor structure

Early photo transistors used germanium or silicon throughout the device giving a homo-junction structure. The more modern phototransistors use type III-V materials such as gallium arsenide and the like. Heterostructures that use different materials either side of the p-n junction are also popular because they provide a high conversion efficiency. These are generally fabricated using epitaxial growth of materials that have matching lattice structures. These photo transistors generally use a mesa structure. Sometimes a Schottky (metal semiconductor) junction can be used for the collector within a phototransistor, although this practice is less common these days because other structures offer better levels of performance.[21]

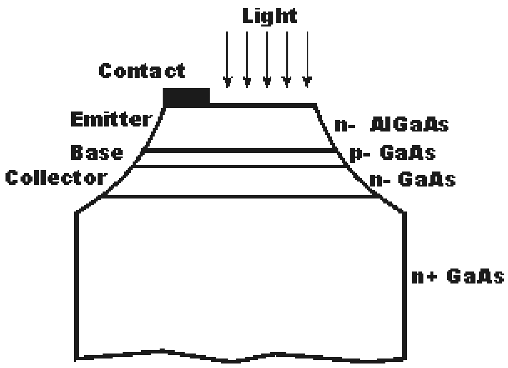


Figure27 Heterojunction mesa-structure phototransistor

4.1.2 PIC 16F877A (Microcontroller)

A microcontroller is an integrated chip that is often part of an embedded system. It includes a CPU, RAM, ROM, I/O ports, and timers like a standard computer, but because they are designed to execute only a single specific task to control a single system, they are much smaller and simplified so that they can include all the functions required on a single chip.

Unlike a microprocessor, which is a general-purpose chip used to create a multi-function

computer or device and requires multiple chips to handle various tasks, this device is meant to be more self-contained and independent, and functions as a tiny, dedicated computer.

The great advantage of microcontrollers, as opposed to using larger microprocessors, is that the parts-count and design costs of the item being controlled can be kept to a minimum. They are typically designed using complementary metal oxide semiconductor (CMOS) technology, an efficient fabrication technique that uses less power and is more immune to power spikes than other techniques. There are also multiple architectures used, but the predominant architecture is Complex Instruction Set Computer (CISC), which allows the chip to contain multiple control instructions that can be executed with a single macro instruction. Some use a Reduced Instruction Set Computer (RISC) architecture, which implements fewer instructions, but delivers greater simplicity and lower power consumption.[22]

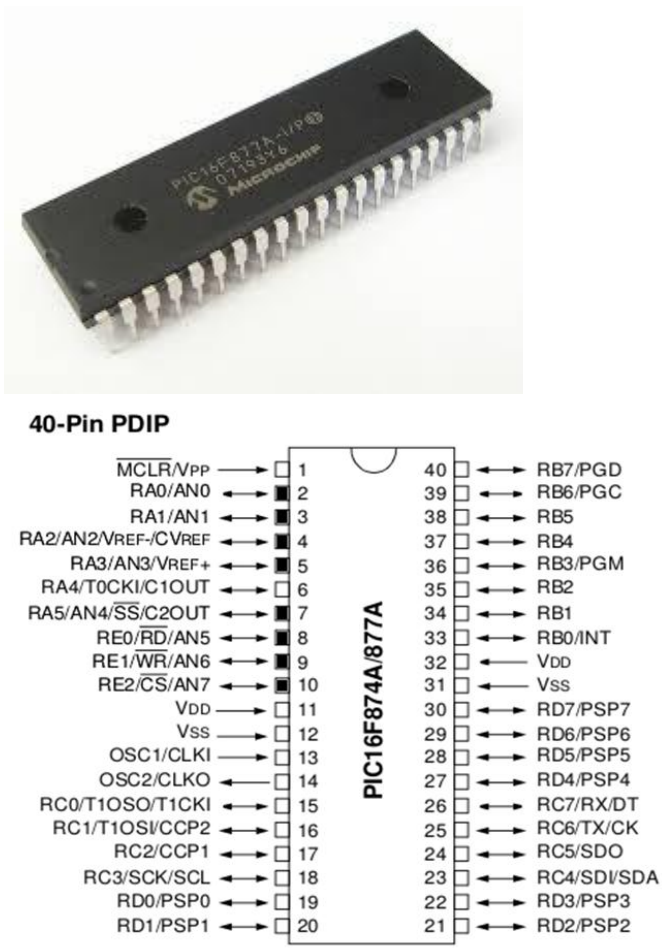


Figure28

4.1.3 LM358N OPAMP

As well as resistors and capacitors, Operational Amplifiers, or Op-amps as they are more commonly called, are one of the basic building blocks of Analogue Electronic Circuits.Operational amplifiers are linear devices that have all the properties required for nearly ideal DC amplification and are therefore used extensively in signal conditioning, filtering or to perform mathematical operations such as add, subtract, integration and differentiation.

An ideal Operational Amplifier is basically a three-terminal device which consists of two high impedance inputs, one called the Inverting Input, marked with a negative or “minus” sign, (-) and the other one called the Non-inverting Input, marked with a positive or “plus” sign (+).

The third terminal represents the Operational Amplifiers output port which can both sink and source either a voltage or a current. In a linear operational amplifier, the output signal is the amplification factor, known as the amplifiers gain (A) multiplied by the value of the input signal and depending on the nature of these input and output signals, there can be four different classifications of operational amplifier gain.

- Voltage – Voltage “in” and Voltage “out”
- Current – Current “in” and Current “out”
- Transconductance – Voltage “in” and Current “out”
- Transresistance – Current “in” and Voltage “out”

Since most of the circuits dealing with operational amplifiers are voltage amplifiers, we will limit the tutorials in this section to voltage amplifiers only, (Vin and Vout).[23]

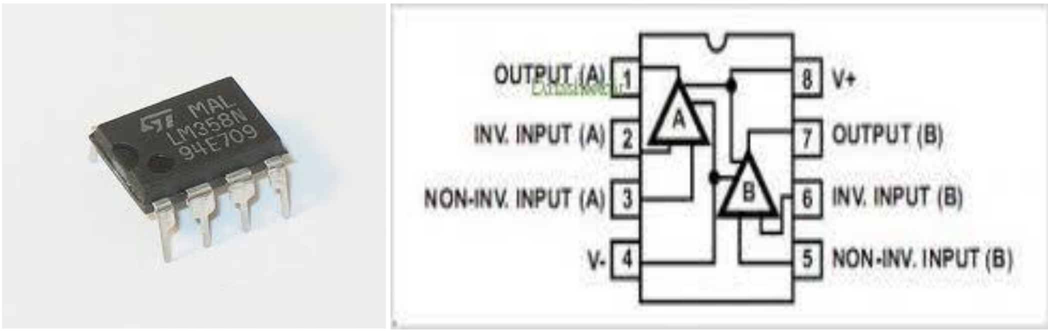
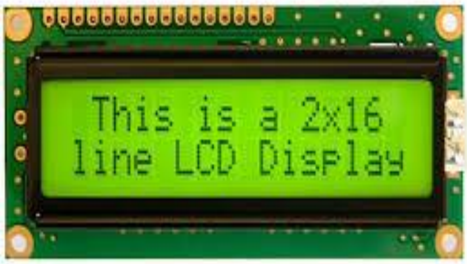


Figure29

4.1.4 2*16 LCD

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters,animations and so on.
A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.
The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.[24]



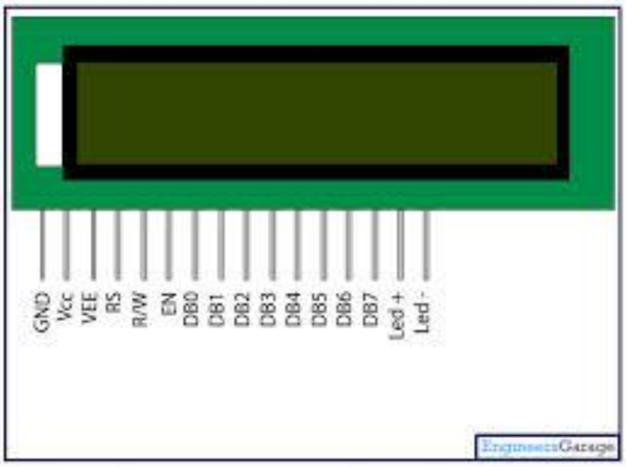


Figure30

4.1.5 7805 Regulator

7805 is a voltage regulator integrated circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output.

The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7805 provides +5V regulated power supply. Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels.[25]

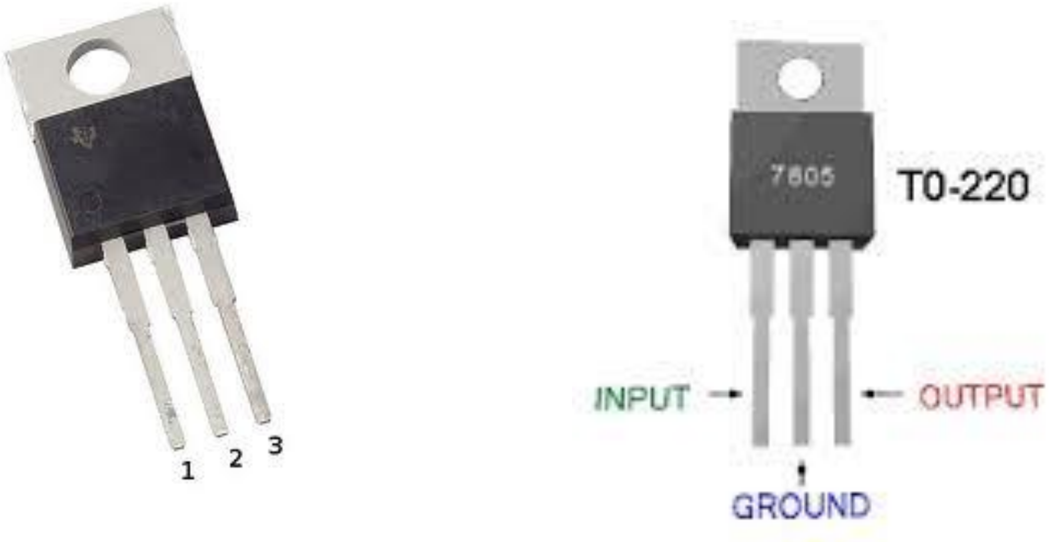


Figure31

4.1.6 Capacitors

In a way, a capacitor is a little like a battery. Although they work in completely different ways, capacitors and batteries both store electrical energy. Inside the battery, chemical reactions produce electrons on one terminal and absorb electrons on the other terminal. A capacitor is much simpler than a battery, as it can't produce new electrons , it only stores them.

Inside the capacitor, the terminals connect to two metal plates separated by a non-conducting substance, or dielectric**.** You can easily make a capacitor from two pieces of aluminum foil and a piece of paper. It won't be a particularly good capacitor in terms of its storage capacity, but it will work.

In theory, the dielectric can be any non-conductive substance. However, for practical applications, specific materials are used that best suit the capacitor's function. Mica, ceramic, cellulose, porcelain, Mylar, Teflon and even air are some of the non-conductive materials used. The dielectric dictates what kind of capacitor it is and for what it is best suited.

Depending on the size and type of dielectric, some capacitors are better for high frequency uses, while some are better for high voltage applications. Capacitors can be manufactured to serve any purpose, from the smallest plastic capacitor in your calculator, to an ultra capacitor that can power a commuter bus. Here are some of the various types of capacitors and how they are used.

- Air - Often used in radio tuning circuits
- Mylar - Most commonly used for timer circuits like clocks, alarms and counters
- Glass - Good for high voltage applications
- Ceramic - Used for high frequency purposes like antennas, X-ray and MRI machines
- Super capacitor - Powers electric and hybrid cars.[26]

Figure32

4.1.7 Resistors

A resistor is an electrical component that limits or regulates the flow of electrical current in an electronic circuit. Resistors can also be used to provide a specific voltage for an active device such as a transistor.

All other factors being equal, in a direct-current (DC) circuit, the current through a resistor is inversely proportional to its resistance, and directly proportional to the voltage across it. This is the well-known Ohm's Law. In alternating-current (AC) circuits, this rule also applies as long as the resistor does not contain inductance or capacitance.

Resistors can be fabricated in a variety of ways. The most common type in electronic devices and systems is the *carbon-composition resistor*. Fine granulated carbon (graphite) is mixed with clay and hardened. The resistance depends on the proportion of carbon to clay; the higher this ratio, the lower the resistance.[27]

Figure33

4.1.8 4 MHZ Crystal Oscillator

Frequency stability of the output signal can be improved by the proper selection of the components used for the resonant feedback circuit including the amplifier but there is a limit to the stability that can be obtained from normal LC and RC tank circuits.

To obtain a very high level of oscillator stability a Quartz Crystal is generally used as the frequency determining device to produce another types of oscillator circuit known generally as a Quartz Crystal Oscillator.

When a voltage source is applied to a small thin piece of quartz crystal, it begins to change shape producing a characteristic known as the Piezo-electric effect**.** This Piezo-electric Effect is the property of a crystal by which an electrical charge produces a mechanical force by changing the shape of the crystal and vice versa, a mechanical force applied to the crystal produces an electrical charge.Then, piezo-electric devices can be classed as Transducers as they convert energy of one kind into energy of another (electrical to mechanical or mechanical to electrical).

This piezo-electric effect produces mechanical vibrations or oscillations which are used to replace the LC tank circuit in the previous oscillators.There are many different types of crystal substances which can be used as oscillators with the most important of these for electronic circuits being the quartz minerals because of their greater mechanical strength.

The quartz crystal used in a Quartz Crystal Oscillator is a very small, thin piece or wafer of cut quartz with the two parallel surfaces metallised to make the required electrical connections. The physical size and thickness of a piece of quartz crystal is tightly controlled since it affects the final or fundamental frequency of oscillations. The fundamental frequency is called the crystals “characteristic frequency”.

Then once cut and shaped, the crystal can not be used at any other frequency. In other words, its size and shape determines its fundamental oscillation frequency.[28]

Figure34

4.1.9 Volt Battery

It used for produce necessary voltage for system work.

Figure35

4.2 Switch

It used for turn on or turn off of the system

Figure36

CHAPTER 5

THE SOFTWARE

5.1 Overview

This chapter is about necessary software for the system work.The program is written in C language and it was compiled by the compiler program then hex file loaded in the microprocessor.All part of software is at the end of the page,appendix part.

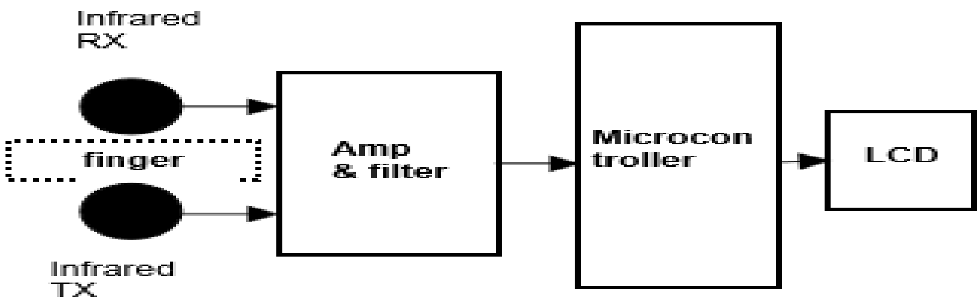


Figure 1. Block diagram of the measuring device

Figure37

CHAPTER 6

6.1 APPLICATIONS

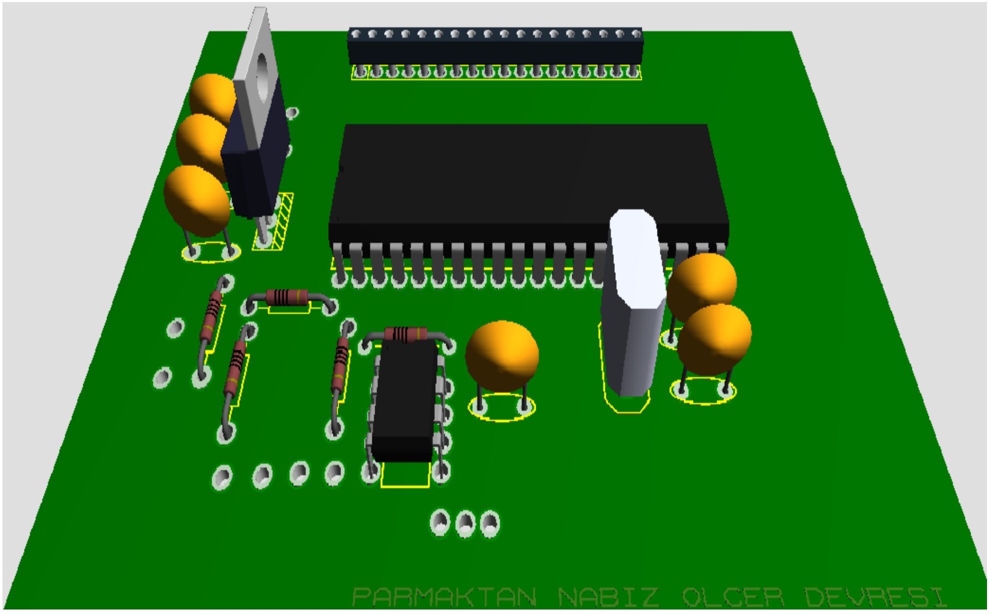


Figure38 3d image of the circuit

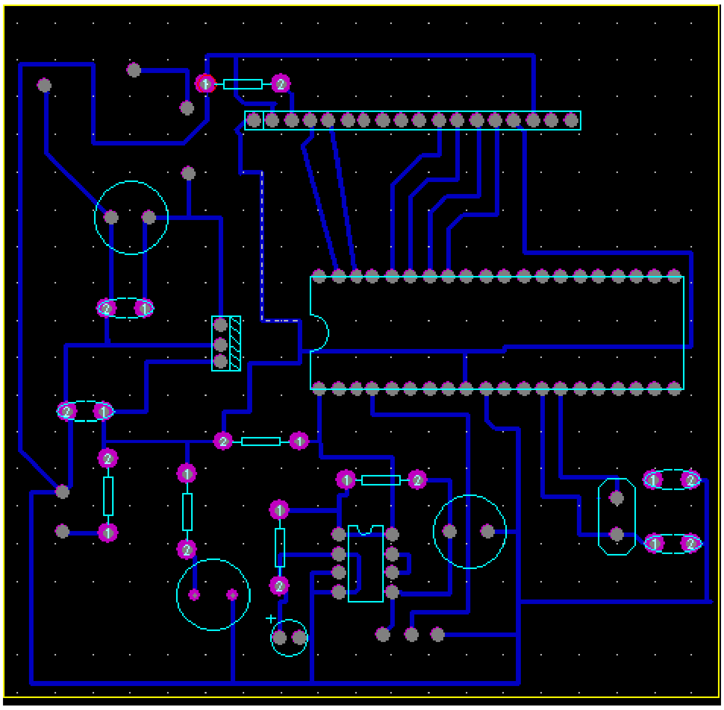


Figure39 Printed circuit card

Figure40 Prepare the printed circuit card

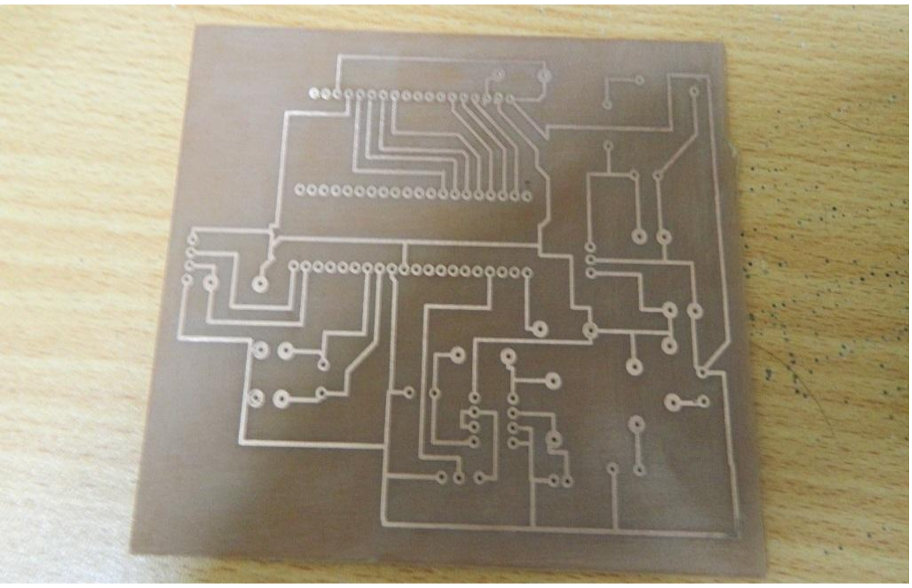


Figure41 Printed Circuit Card

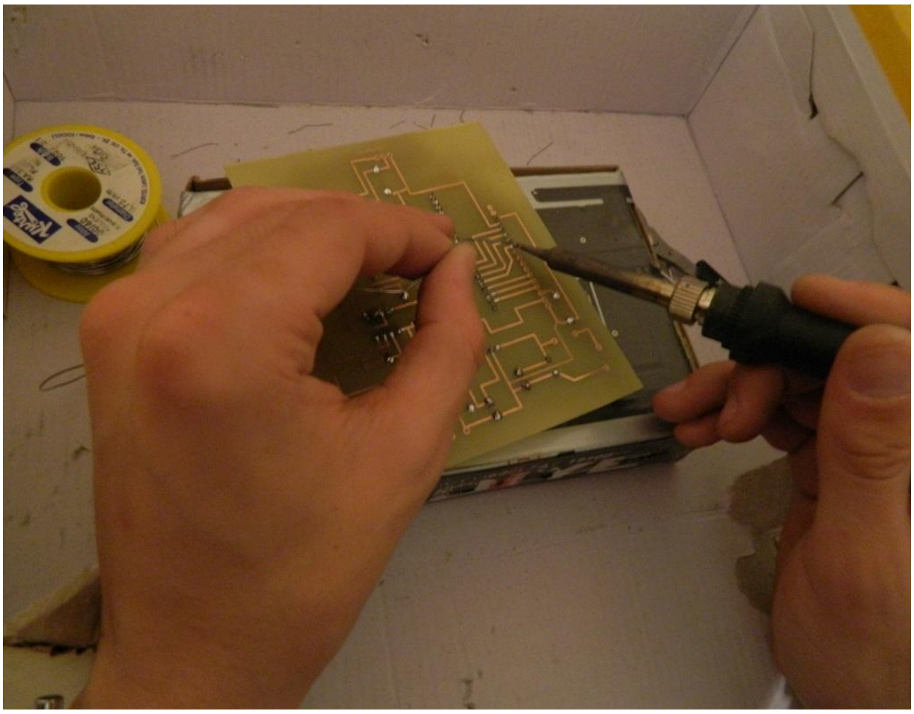


Figure42 Assembly components of the circuit

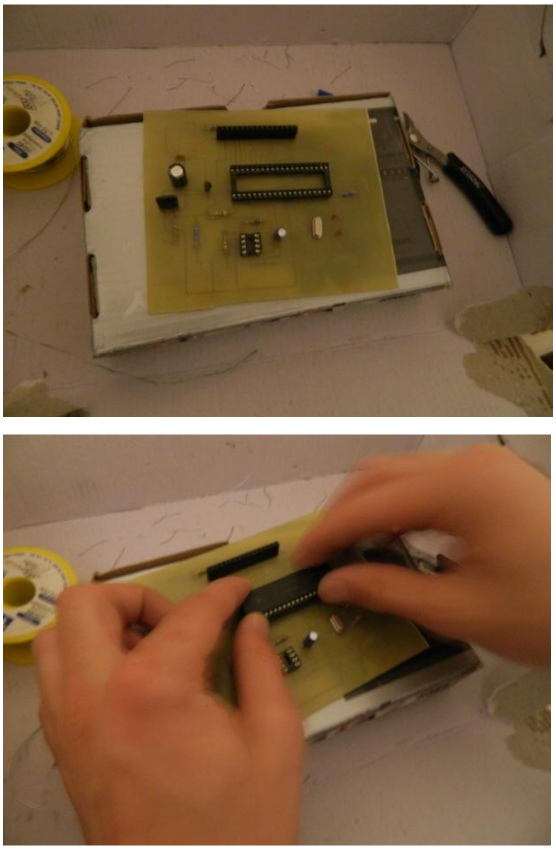


Figure43 Microcontroller assembly

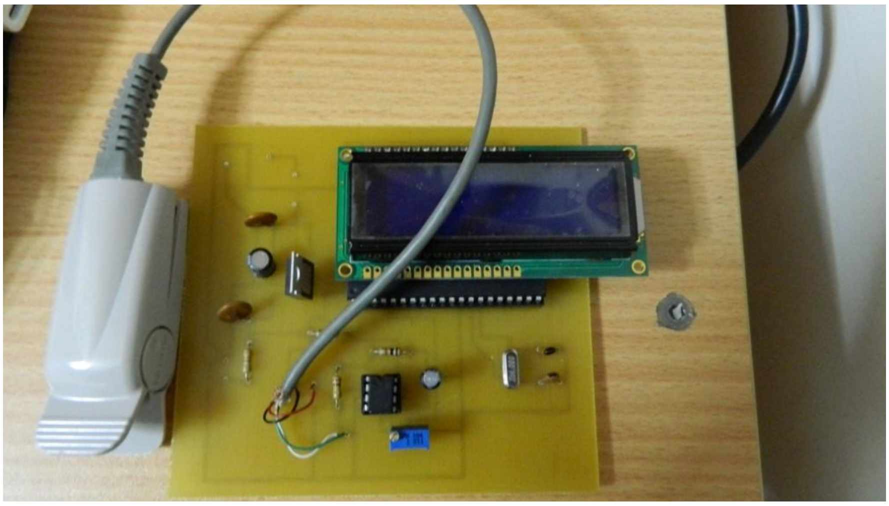


Figure44

CONCLUSIONS

In this project, we planned to develop low cost device for measuring pulse rate from finger.The device sensor unit has infrared led and phototransistor. The sensors are clipped to the finger of person and sensed changes of blood volume in the finger.Then this change is amplifed by opamp.The microcontroller calculates the heart rate and sends information to LCD for displaying.

The heart rate measurement device is efficient and easy to use.Both analog and digital signal processing techniques are combined to keep the device simple and to efficiently suppress the disturbance in signals.

Results showed that the heart rate can be filtered and converted to digital signal so that microprocessor can count pulse rate. The device is able to detect, filter, digitize and display the heart rate of a user ergonomically.One of the most important advantages of device is used by nonprofessional people safely and used in home conditions.

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APPENDIX

```
#include <16F877A.h>
#device adc=10

#FUSES NOWDT                    //No Watch Dog Timer
#FUSES HS                         //High speed Osc (> 4mhz for
PCM/PCH) (>10mhz for PCD)
#FUSES NOPUT                    //No Power Up Timer
#FUSES NOPROTECT                     //Code not protected from
reading
#FUSES NODEBUG                  //No Debug mode for ICD
#FUSES NOBROWNOUT               //No brownout reset
#FUSES NOLVP                         //No low voltage prgming,
B3(PIC16) or B5(PIC18) used for I/O
#FUSES NOCPD                    //No EE protection
#FUSES WRT_50%                  //Lower half of Program Memory
is Write Protected

#use delay(clock=4000000)
#use rs232(baud=9600,parity=N,xmit=PIN_C6,rcv=PIN_C7,bits=8)

#include <lcd.c>

int nabiz;

void main()
{
   setup_adc_ports(ALL_ANALOG);
   setup_adc(ADC_CLOCK_INTERNAL);
   setup_psp(PSP_DISABLED);
   setup_spi(SPI_SS_DISABLED);
   setup_timer_0(RTCC_INTERNAL|RTCC_DIV_1);
```

```
   setup_timer_1(T1_DISABLED);
   setup_timer_2(T2_DISABLED,0,1);
   setup_comparator(NC_NC_NC_NC);
   setup_vref(FALSE);

   // TODO: USER CODE!!
lcd_init();

delay_ms(5000);

while(true)

   {
     set_adc_channel(3);
     delay_us(20);
     nabiz=read_adc();

     if((nabiz>60)&&(nabiz<120))
     {
     set_adc_channel(3);
     delay_us(20);
     nabiz=read_adc();

      printf(lcd_putc,"\fNABIZ :%D  ",nabiz);
        //delay 500 ms between reading to prevent self heating
of sensor

     }






     else
     {
     set_adc_channel(3);
```

```
      delay_us(20);
      nabiz=read_adc();

      printf(lcd_putc,"\fNABIZ YOK  ");

delay_ms(3000);

      }
    }
}
```