**Palestine Polytechnic University**

**College of Engineering & Technology**
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# Monitoring Patient's Vital Signs During Sleep

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# الأهداء

أيام مضت من عمرنا بدأناها بخطوة وها نحن اليوم نقطف ثمار مسيرة أعوام كان هدفنا فيها واضحا وكنا نسعى في كل يوم لتحقيقه والوصول له مهما كان صعبا وها نحن اليوم نقف أمامكم وها نحن وصلنا وبيدينا شعلة علم وسنحرص كل الحرص عليها حتى لاتنطفئ ونشكر الله أولا وأخير على أن وفقنا وساعدنا على ذلك

ثم نتقدم بالشكر إلى القلب الحنون من كانت بجانبنا بكل المراحل التي مضت من تلذذت بالمعاناه وكانت شمعه تحترق لتنير دربنا
**....إلى أمهاتنا الحبيبات**

وإلى من علمنا أن نقف وكيف نبدأ الألف ميل بخطوة إلى يدنا اليمنى إلى من علمنا الصعود وعيناه تراقبنا ....
**.... الى والدنا**

لمن كان يتحملنا بأخطائنا وكانوا عوناً لنا
**.... الى أخوتنا واخواتنا**

ال من انجب اهالينا وفخروا لوصولنا الى هنا ، نهدي نجاحنا اليهم ، الى من تحت التراب منهم وكنا نتمنى ان يروا انجازنا هذا
**.... الى اجدادنا وجداتنا الاحياء منهم والاموات.**

لمن أمسك بيدينا وعلمنا حرفا ..حرفا ..سنهدي له نجاحنا اليوم إلى من كانوا سندا لنا إلى من لهم الفضل بإرشادنا إلى طريق العلم والمعرفه
**....إلى أساتذتنا الأفاضل**

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**....إلى أصدقاءنا وزملاؤنا والجنود المجهولون**

ولن ننسى هذا المكان الذي جمعنا بمقاعده وأبوابه حتى فنائه إلى كل جزء به ...
**.... الى جامعتنا العريقة جامعة بوليتكنك فلسطين**

ولن ننسى وطننا المعبق بأريج الحب لن ننساه وسنقدم كل مابوسعنا له وسنجعل كل ركن به يشهد بما سنقدم وسنكون كالمطر ولن نبخل بما تعلمنا وسنكون كالماء أينما وقعنا نفعنا
**.... الى وطننا الحبيب فلسطين**
**الى اسرانا وشهداؤنا والقدس الشريف.**

نشكركم بكل ماتحملة كلمة شكر من معنى ونهدي لكم كل عمرنا يا أجمل مامضى به
نشكركم تنطقها قلوبنا على ألسنتنا نشكركم كلمة تعني لنا الكثير وتحمل من الشعور الكثير
تخوننا كل عبارات الشكر في تقديم مايليق بكم لن ننسى الفضل ولن ننساكم أبدا.

**الملخص**

الكثير من التغيرات على العلامات الحيوية يمكن أن تحدث للمرضى الذين يلازمون الفراش لفترات طويلة وخصوصاً خلال النوم، كثير من هذه الحالات المرضية يمكن أن تسبب الأذى للانسان وتؤدي لحدوث تقرحات في جسده وذلك كنتيجة متوقعة لقلة الحركة، وأحياناً أخرى يمكن ان تودي بحياته في حالات مثل توقف اتنفس أو الجلطات القلبية.

جاءت فكرة المشروع لتقديم حل لهذه المشكلة وذلك من خلال تصميم نظام يقوم على مراقبة المرضى الأكثر عرضة للجلطات القلبية، توقف التنفس أو للتقرحات الجلدية. الفكرة المقترحة ستعمل على بناء نظامين موصولين بقطعة بلوتوث.

حيث يقوم النظام الاول بتسجيل المتغيرات الحيوية من خلال مجسات الحركة (Force Sensor) والتنفس ( Thermistor Sensor) ونبض القلب (Heart Rate) مثبتة على المريض ومن ثم يتم معالجتها عن طريق المتحكم الدقيق.

ويقوم النظام على تحليل الاشارات التي وصلت من المجسات ومقارنة هذه الإشارات بقيم مرجعية ويتم عرضها فيما بعد على شاشة LCD مع عرض لحالة المريض "طبيعية او غير طبيعية". اذا كانت هذه الاشارات اقل او اكثر من المعدل الطبيعي المحدد سوف يتفعل نظام الانذار الصوتي والمرئي الموجود في النظام الثاني.

## Abstract

A lot of changes to vital signs can happen to patients who stay in bed for long time, especially during sleep. Many of these conditions can cause harm to a person and cause ulcers in his body, as a result of the expected lack of movement, and sometimes can lead to his life in cases such as breathing stops or heart attacks.

The idea of the project came to offer a solution to this problem by designing a system that monitors patients most susceptible to heart attacks, breathing stops or skin ulcers.

Where the  system records the vital variables through the motion sensors (Force Sensor), breathing (Thermistor Sensor) and the heart rate (Heart Rate) installed on the patient and then is processed by the microcontroller to analyzing the signals that have arrived from the sensors and comparing these signals with reference values and is later displayed on the LCD screen with a display of the patient's condition . If these signals are less or more than the normal set, the audible and visual alarm system in the system will be activated.

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# List of Abbreviations

| Abbreviations | Full Word |
|---|---|
| REM | Rapid Eye Movement |
| IVC | Inferior Vena Cava |
| SVC | Superior Vena Cava |
| bpm | beats per minute |
| SA node | A stands for sinoatrial |
| AV node | atrioventricular |
| OSA | Obstructive sleep apnea |
| UV | ultraviolet |
| MEMS | Micro-Electro-Mechanical Sensors |
| DRS | Data-Ready signal |
| So | sensitivity |
| Read-only memory | ROM |
| Random Access Memory | RAM |
| Input/output | I/O |
| instruction register | IR |

| | |
|---|---|
| data register | DR |
| Serial Port Protocol | SPP |
| register selector | RS |
| Heart rate | HR |
| Respiration Rate | RR |
| plastic quad flat pack | TQFP |
| Voltage | V |
| Micro /milli Ampere | /m Aμ |
| Integrated circuit | IC |
| Analog-to-digital converter | ADC |
| Infrared LED | IR LED |

# Chapter One

Introduction

**1.1 Project objectives**

**1.2 Methodology**

**1.3 Literature review**

**1.4 Project timeline**

Many physiological variables are controlled during wakefulness at levels that are optimal for the body's functioning. Our temperature, blood pressure, and levels of oxygen, carbon dioxide, and glucose in the blood remain quite constant during wakefulness. During sleep, however, physiological demands are reduced and temperature and blood pressure drop. In general, many of our physiological functions such as brain wave activity, breathing, and heart rate are quite variable when we are awake or during REM sleep.

The project is a system that monitors the vital sings to its user. By creating various metrics to measure it during sleep, the project could be used to determine the factors that lead to an optimal sleep at an individual level.

While sleeping, changes can occur in the body without the patient feeling, and maybe a lot happening, the project to monitor several variables like heart attack, apnea and to prevent ulcers in the patient's body by comparing normal values with the patient's biomarkers and if the values is abnormal the alarm will be active, and display the values on the LCD.

The bulk of the monitoring device measures heart rate using an IR sensor, along with movement via a force sensor. Breathing is recorded using a thermistor sensor, which it resistance change by changing the temperature of the patient's exhalation and inhalation Two mega Arduino mounted in a box in the alarm system one for collecting data from the force sensor and another to collect data from heart rate sensor and respiration sensor and analysis the data and display it on a LCD every 30 second for heart rate and breathing and the 5 minutes for motion sensor but this value is updating on 2 hours and if there is an abnormal value the alarm is active.

## 1.1 Project objectives:

The main objective of the project:

1-Monitor patient heart rate.

2- Monitor patient breathing rate.
3- Monitor patient moving while sleeping.
4-alarm circuit if there is abnormal values.
5-dislay all values in a LCD display.
6-Design the project in lowest cost.

## 1.2 Methodology

The first step is to make sure that all materials that we will use in the project is available in market.

**The Belt**

The belt serves as a remote sensor worn by the user, relaying data to the base station in real-time. It consists of force sensors that fixed on the patient's back by a shirt.

**Base station**

The base station houses the mega microprocessors, LCD display, and the alarm circuit. It performs all of the calculations and analysis, and provides an easy to use interface to display the data.

The heart rate sensor consists of an IR transmitter, and IR phototransistor, The IR LED emits infrared light into the user's finger, of which portions are reflected back out of the finger and hit the phototransistor. The amount reflected changes with blood pressure and blood oxygen level..

In order to read the breathing rate of the user, a thermistor sensors used, which it resistance change by changing the temperature of the patient's exhalation and inhalation, exhalation temperature is defriend from the inhalation temperature, so the thermistor is used to sense those two temperature, after that the output will be the rate of berating, the thermistor will be installed on the patient mouth by mask.

In order to monitor the movement of the patient during sleep a force sensor is fixed on the patient's back by the belt and give the microprocessor data if patient moved or not.

The force sensor is connected to mega Arduino in the base station and the respiration sensor and the heart rate sensor are connected to other mega arduino with the LCD and the alarm circuit, the mega arduinos , LCD, alarm circuit all are mounted in box.

## 1.3 Literature review:

Long-term sleep monitoring of patients is interesting for the diagnosis of sleep disorders and for the continuous monitoring of the health state. However, traditional polysomnography is not suited for long-term monitoring due to various reasons and new intelligent solutions are required for the continuous and unobtrusive monitoring of sleep parameters. In this review made the Mobility Monitor, a portable sleep monitoring system which has been developed specifically for elderly care facilities. The system informs the nursing staff about the patient's movement patterns during the night. This information can be used for the assessment of the risk of pressure ulcer, to monitor bed exits or to observe the influence of medication on sleep behavior but this review made for hospitals and just stay in hospital but the project will make to available everywhere.

Evaluating daily life quality is important in ambient intelligence applications targeted for health status monitoring. When we consider the fact that people approximately spend one-third of their lives sleeping, we need to monitor the sleep quality as well as the activities of daily living in order to be able to provide a seamless health monitoring system. In this review, a seamless activity recognition system that makes use of multi-modal wireless sensor networks (WSNs) and mobile phones is proposed. The proposed system is then used to collect life-log and sleep behavior data from actual users. In the lights of this information, important factors affecting the sleep quality of a person is extracted but in project will take the parameters when anything is affect of the patient when he sleeping and comapring these parameters for reference value will saved in the system when anything is wrong will gives alarm.

## 1.4 Project timeline

| Week / Task | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Project idea** | | | | | | | | | | | | | | |
| **Proposal** | | | | | | | | | | | | | | |
| **Searching for information** | | | | | | | | | | | | | | |
| **Sorting the information and documentation** | | | | | | | | | | | | | | |
| **First edition** | | | | | | | | | | | | | | |
| **Print the final book** | | | | | | | | | | | | | | |

**Table 1.1** Project Timeline.

| Weeks / Activities | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Full Designing** | | | | | | | | | | | | | | | |
| **Purchasing components** | | | | | | | | | | | | | | | |
| **System Implementation** | | | | | | | | | | | | | | | |
| **System Analysis** | | | | | | | | | | | | | | | |
| **Print documentation** | | | | | | | | | | | | | | | |

**Table 1.2** Activities Schedule of the Second Semester

# Chapter Two

Anatomy and Physiology of Cardiovascular, Respiratory Systems, and Skin.

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## 2.1 Cardiovascular System

2.1.1 Introduction of Cardiovascular System

2.1.2 Structure of Cardiovascular System

2.1.3 The circulatory system and Blood flow

2.1.4 Normal and abnormal Cardiac Rhythms

2.1.5 Cardiovascular Activity and Normal resting heart rate During Sleep.

2.1.5 Rhythms

## 2.2 Respiratory System

2.2.1 Introduction Respiratory of System

## 2.1 Cardiovascular system

### 2.1.1 Introduction of Cardiovascular System

The heart has four separate compartments or chambers. The upper chamber on each side of the heart, which is called an atrium, receives and collects the blood coming to the heart. The atrium then delivers blood to the powerful lower chamber, called a ventricle, which pumps blood away from the heart through powerful, rhythmic contractions. [1]

### 2.1.2 Structure of Cardiovascular System

1. **Heart**

The heart is a muscle about the size of a fist, and is roughly cone-shaped, it is about 12cm long, 9cm across the broadest point and about 6cm thick. The pericardium is a fibrous covering which wraps around the whole heart. It holds the heart in place but allows it to move as it beats. The wall of the heart itself is made up of a special type of muscle called cardiac muscle, the heart has two sides, the right side and the left side. The heart has four chambers. The left and right side each have two chambers, a top chamber and a bottom chamber. The two top chambers are known as the left and right atria (singular: atrium). The atria receive blood from different sources. The left atrium receives blood from the lungs and the right atrium receives blood from the rest of the body. The bottom two chambers are known as the left and right ventricles. The ventricles pump blood out to different parts of the body. The right ventricle pumps blood to the lungs while the left ventricle pumps out blood to the rest of the body. The ventricles have much thicker walls than the atria which allows them to perform more work by pumping out blood to the whole body as shown in figure 2.1. [2]

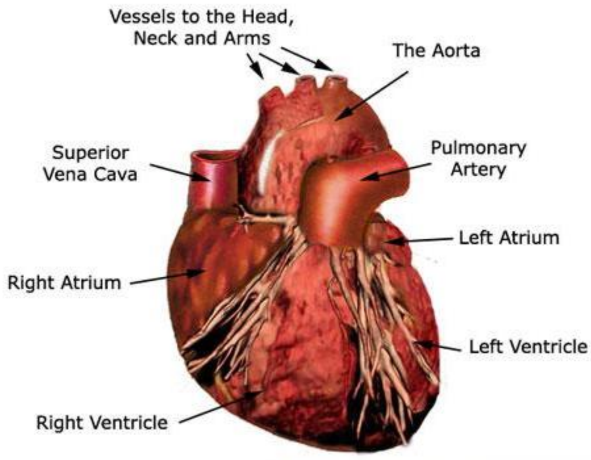



**Figure 2.1** Structure of heart. [3]

### 2. Blood Vessels

Blood Vessels are tubes which carry blood. Veins are blood vessels which carry blood from the body back to the heart. Arteries are blood vessels which carry blood from the heart to the body. There are also microscopic blood vessels which connect arteries and veins together called capillaries. There are a few main blood vessels which connect to different chambers of the heart. The aorta is the largest artery in our body. The left ventricle pumps blood into the aorta which then carries it to the rest of the body through smaller arteries. The pulmonary trunk is the large artery which the right ventricle pumps into. It splits into pulmonary arteries which take the blood to the lungs. The pulmonary veins take blood from the lungs to the left atrium. All the other veins in our body drain into the inferior vena cava (IVC) or the superior vena cava (SVC). These two large veins then take the blood from the rest of the body into the right atrium. [4]

### 3. Valves

Valves are fibrous flaps of tissue found between the heart chambers and in the blood vessels. They are rather like gates which prevent blood from flowing in the wrong direction.

They are found in a number of places. Valves between the atria and ventricles are known as the right and left atrioventricular valves, otherwise known as the tricuspid and mitral valves respectively. Valves between the ventricles and the great arteries are known as the semilunar valves. The aortic valve is found at the base of the aorta, while the pulmonary valve is found the base of the pulmonary trunk. There are also many valves found in veins throughout the body. However, there are no valves found in any of the other arteries besides the aorta and pulmonary trunk. [5]

### 2.1.3 The circulatory system and Blood flow

The circulatory system is an organ system that permits blood and lymph circulation to transport nutrients (such as amino acids and electrolytes), oxygen, carbon dioxide, hormones, blood cells, etc. to and from cells in the body to nourish it and help to fight diseases, stabilize body temperature and pH, and to maintain homeostasis. [6]

The circulatory system divided in two types:

1. **Pulmonary circulation**

The pulmonary circulatory system shown in figure2.2 is the portion of the cardiovascular system in which deoxygenated blood is pumped away from the right ventricle via the pulmonary artery, to the lungs and returned, oxygenated, to the left atrium via the pulmonary vein, Deoxygenated blood from the superior and inferior vena cava, enters the right atrium of the heart and flows through the tricuspid valve (right atrioventricular valve) into the right ventricle, from which it is then pumped through the pulmonary semi lunar valve into the, pulmonary artery to the lungs. Gas exchange occurs in the lungs, whereby CO is released from the blood, and oxygen is absorbed, pulmonary vein returns the now oxygen-rich blood to the left atrium. [7]

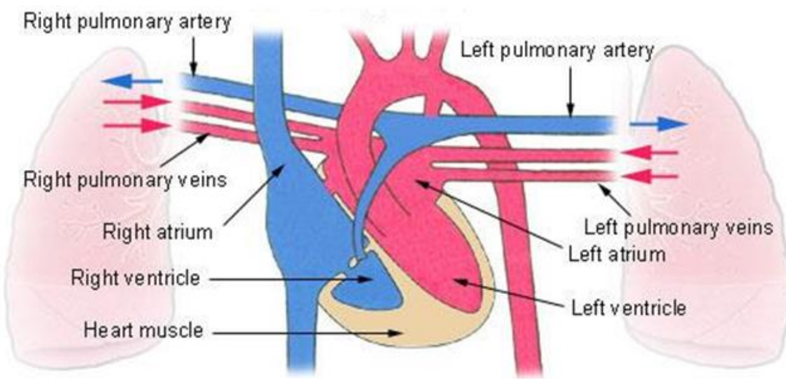



**Figure 2.2** Pulmonary circulations. [8]

2. **Systemic circulation**

Systemic circulation as shown in figure 2.3 is the circulation of the blood to all parts of the body except the lungs. Systemic circulation is the portion of the cardiovascular system which transports oxygenated blood away from the heart through the aorta from the left ventricle where the blood has been previously deposited from pulmonary circulation, to the rest of the body, and returns deoxygenated blood back to the heart. Systemic circulation is, distance-wise, much longer than pulmonary circulation, transporting blood to every part of the body. [9]

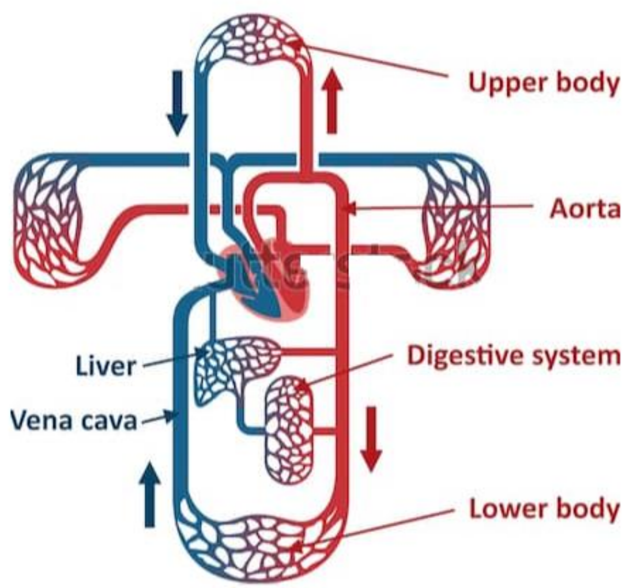



**Figure 2.3** Systemic circulation. [10]

### 2.1.4 Normal and abnormal cardiac rhythms

Each beat of the normal human heart originates in the SA node. The normal heart rate is approximately 70 beats per minute (bpm). The rate is slowed (bradycardia) during sleep and is accelerated (tachycardia) by emotion, exercise, fever, and many other stimuli. Detailed aspects of the control that the nervous system has over heart rate are beyond the scope of this book; the reader interested in further discussion is referred to Rowell (1993). Because many parts of the heart possess an inherent rhythmicity (e.g., nodal tissue, Purkinje fibers of the specialized conduc- tion system, and atrial tissues), any part under abnormal conditions can become the dominant cardiac pacemaker. This can happen when the activity of the SA node is depressed, when the bundle of His is interrupted or damaged, or when an abnormal (ectopic) focus or site in the atria or in specialized conduction-system tissue in the ventricles discharges at a rate faster than the SA node. When the bundle of His is interrupted completely, the ventricles beat at their own slow inherent rate (the idioventricular rhythm). The atria continue to beat independently at the normal sinus rate, and complete or third-degree block is said to occur .The idioventricular rate in human beings is approximately 30 to 45 bpm.

When the HIS bundle is not completely interrupted, incomplete heart block is present. In the case of first-degree heart block, all atrial impulses reach the ventricles, but the P-R interval is abnormally prolonged because of an increase in transmission time through the affected region [Figure 4.17(b)]. In the case of second-degree heart block, not all atrial impulses are conducted to the ventricles. There may be, for example, one ventricular beat every second or third atrial beat (2:1 block, 3:1 block, and so on). In another form of incomplete heart block involving the AV node, the P-R interval progressively lengthens until the atrial impulse fails to conduct to the ventricle (Wenckebach phenomenon). The first conducted beat after the pause (or dropped beat) has a shorter P-R interval (sometimes of normal length) than any subsequent P-R interval. Then the process of the lengthening of the P-R interval begins anew, progressing over several cardiac cycles until another beat is dropped. The electrocardiographic sequence starting with the ventricular pause and ending with the next blocked atrial beat constitutes a Wenckebach period. The ratio of the number of P waves to QRS complexes determines the block (for example, 6:5 or 5:4 Wenckebach periods). When one branch of the bundle of HIS is interrupted, causing right-or left- bundle-branch block, excitation proceeds normally down the intact bundle and then sweeps back through the musculature to activate the ventricle on the blocked side. The ventricular rate is normal, but the QRS complexes are prolonged and deformed. [11]

### 2.1.5 Cardiovascular Activity and Normal resting heart rate During Sleep

One of the possible functions of sleep is to give the heart a chance to rest from the constant demands of waking life. As compared to wakefulness, during non-REM sleep there is an overall reduction in heart rate and blood pressure. During REM sleep, however, there is a more pronounced variation in cardiovascular activity, with overall increases in blood pressure and heart rate. Additionally, changes in blood flow that cause erections to occur in males or swelling of the clitoris in females is characteristic of REM sleep The underlying reason for these considerable neural and physiological variations in REM sleep is currently unknown, and may be a by-product of REM-related changes in nervous system activity or related to dream content.

The normal resting heart rate for adults over the age of 10 years, including older adults, is between 60 and 100 beats per minute (bpm). [12]

### 2.1.6 Arrhythmias

A portion of the myocardium (or the AV node or specialized conduction system) sometimes becomes "irritable" and discharges independently. This site is then referred to as an ectopic focus. If the focus discharges only once, the result is a beat that occurs before the next expected normal beat, and the cardiac rhythm is therefore transiently interrupted. (With respect to atrial, nodal, or ventricular ectopic beat.) If the focus discharges repetitively at a rate that exceeds that of the SA node, it produces rapid regular tachycardia rapidly and irregularly discharging focus or, more likely, a group of foci in the atria or ventricles maybe the underlying mechanism responsible for atrial or ventricular fibrillation .Rhythm disturbances can arise from sources other than ectopic foci or competing pacemakers. A feasible alternative is a circus re-excitation or re-entrant mechanism (Allessie et al., 1973). This concept assumes a region of depressed conductivity within the atrium, Purkinje system, or ventricle. It is therefore ischemic (deficient in its blood supply) relative to surrounding normal tissue. This brings about pronounced electrophysiological changes in the ischemic zone and decreased velocity of conduction. [13]

During REM sleep it is perfectly natural and common for the heart to "miss a beat" for a couple seconds. Such misses only reflect the shifting of gears by the body (known as changes in autonomic tone in medical jargon). This condition is also called bradyarrhythmia syndrome or brady-arrhythmia syndrome. REM sleep is also a period of increased risk (however small) for myocardial ischemia.

However, if cardiac arrhythmia occurs primarily due to breathing disorders during sleep then it might become serious and may lead to even death due to congestive heart failure. [14]

## 2.2 Respiratory System

### 2.2.1 Introduction Respiratory of System

The respiratory system consists of all the organs involved in breathing. These include the nose, pharynx, larynx, trachea, bronchi and lungs. The respiratory system does two very important things: it brings oxygen into our bodies, which we need for our cells to live and function properly; and it helps us get rid of carbon dioxide, which is a waste product of cellular function. The nose, pharynx, larynx, trachea and bronchi all work like a system of pipes through which the air is funnelled down into our lungs. There, in very small air sacs called alveoli, oxygen is brought into the bloodstream and carbon dioxide is pushed from the blood out into the air. When something goes wrong with part of the respiratory system, such as an infection like pneumonia, it makes it harder for us to get the oxygen we need and to get rid of the waste product carbon dioxide. Common respiratory symptoms include breathlessness, cough, and chest pain.

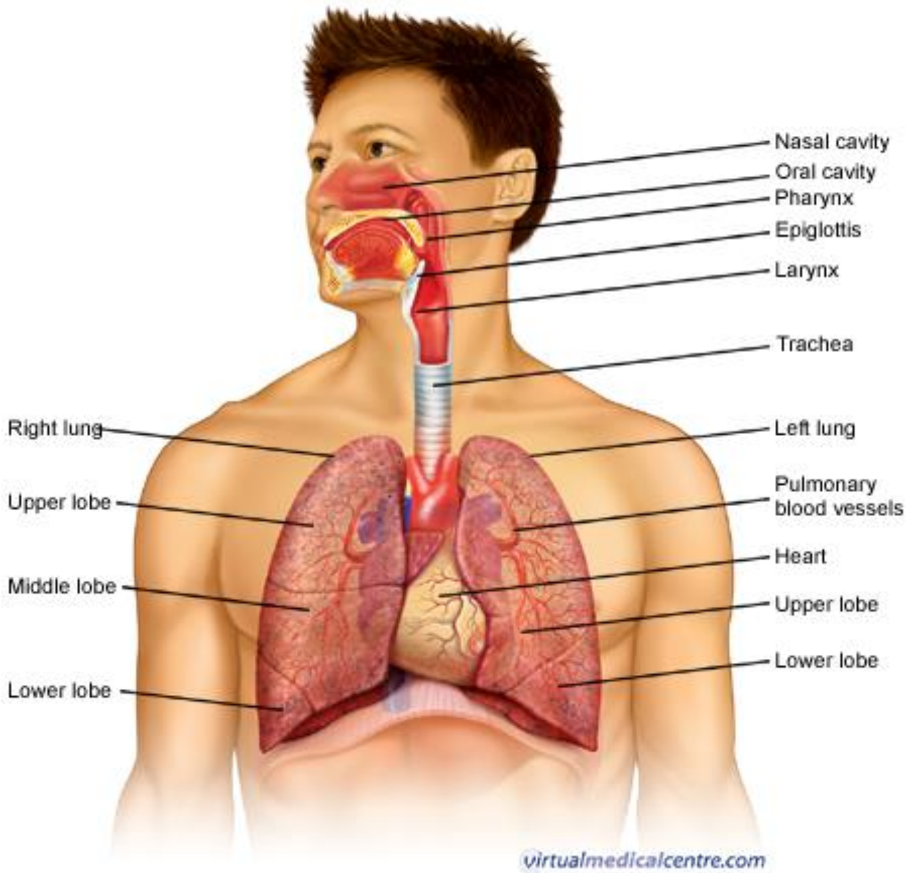



**Figure 2.4** Structure of Respiratory system. [15]

### The Upper Airway and Trachea

When you breathe in, air enters your body through your nose or mouth. From there, it travels down your throat through the larynx (or voicebox) and into the trachea (or windpipe) before entering your lungs. All these structures act to funnel fresh air down from the outside world into your body. The upper airway is important because it must always stay open for you to be able to breathe. It also helps to moisten and warm the air before it reaches your lungs.

### 2.2.2 Structure of the Lungs

The lungs are paired, cone-shaped organs which take up most of the space in our chests, along with the heart. Their role is to take oxygen into the body, which we need for our cells to live and function properly, and to help us get rid of carbon dioxide, which is a waste product. We each have two lungs, a left lung and a right lung. These are divided up into 'lobes', or big sections of tissue separated by 'fissures' or dividers. The right lung has three lobes but the left lung has only two, because the heart takes up some of the space in the left side of our chest. The lungs can also be divided up into even smaller portions, called 'bronchopulmonary segments'. These are pyramidal-shaped areas which are also separated from each other by membranes. There are about 10 of them in each lung. Each segment receives its own blood supply and air supply.

### 2.2.3 Principle of lungs work

Air enters your lungs through a system of pipes called the bronchi. These pipes start from the until they eventually form little thin-walled air sacs or bubbles, known as the alveoli. The alveoli are where the important work of gas exchange takes place between the air and your blood. Covering each alveolus is a whole network of little blood vessel called capillaries, which are very small branches of the pulmonary arteries. It is important that the air in the alveoli and the blood in the capillaries are very close together, so that oxygen and carbon dioxide can move (or diffuse) between them. So, when you breathe in, air comes down the trachea and through the bronchi into the alveoli. This fresh air has lots of oxygen in it, and some of this oxygen will travel across the walls of the from the blood in the capillaries into the air in the alveoli and is then breathed out. In this way, you bring in to your body the oxygen that you need to live, and get rid of the waste product carbon dioxide.alveoli into your bloodstream. Travelling in the opposite direction is carbon dioxide, which crosses bottom of the trachea as the left and right bronchi and branch many times throughout the lungs,

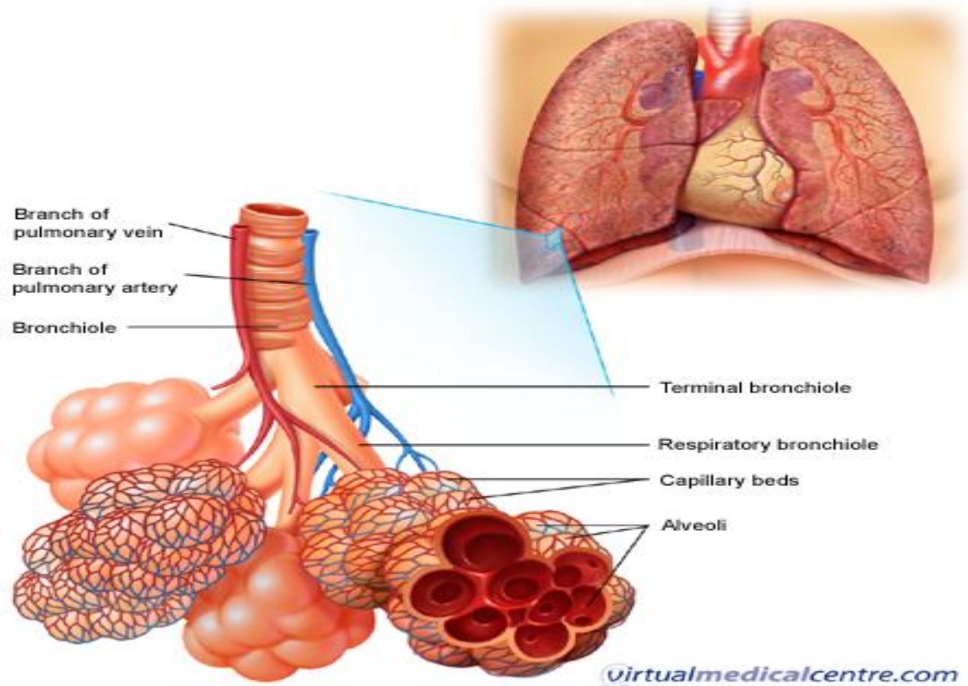



**Figure 2.5** Structures of Lungs. [15]

## 2.2.4 The Work of Breathing

**The Pleurae**

The lungs are covered by smooth membranes that we call pleurae. The pleurae have two layers, a ‘visceral’ layer which sticks closely to the outside surface of your lungs, and a ‘parietal’ layer which lines the inside of your chest wall (ribcage). The pleurae are important because they help you breathe in and out smoothly, without any friction. They also make sure that when your ribcage expands on breathing in, your lungs expand as well to fill the extra space.

### 2.2.5 The Diaphragm and Intercostal Muscles

When you breathe in (inspiration), your muscles need to work to fill your lungs with air. The diaphragm, a large, sheet-like muscle which stretches across your chest under the ribcage, does much of this work. At rest, it is shaped like a dome curving up into your chest. When you breathe in, the diaphragm contracts and flattens out, expanding the space in your chest and drawing air into your lungs. Other muscles, including the muscles between your ribs (the intercostal muscles) also help by moving your ribcage in and out. Breathing out (expiration) does not normally require your muscles to work. This is because your lungs are very elastic, and when your muscles relax at the end of inspiration your lungs simply recoil back into their resting position, pushing the air out as they go. [16]

#### 2.2.6 Respiratory Changes

Breathing patterns change during sleep. In awake condition, breathing is usually quite irregular, since it is affected by speech, emotions, exercise, posture, and other factors. As progress from wakefulness through the stages of non-REM sleep, breathing rate slightly decreases and becomes very regular. During REM sleep, the pattern becomes much more variable again, with an overall increase in breathing rate . The normal respiration rate for an adult at rest is 12 to 20 breaths per minute. A respiration rate under 12 or over 25 breaths per minute while resting is considered abnormal. Among the conditions that can change a normal respiratory rate are asthma, anxiety, pneumonia, congestive heart failure, lung disease, use of narcotics or drug overdose. [17]

### 2.2.7 Apnea

Sleep-induced apnea and disordered breathing refers to intermittent, cyclical cessations or reductions of airflow, with or without obstructions of the upper airway (OSA). In the presence of an anatomically compromised, collapsible airway, the sleep-induced loss of compensatory tonic input to the upper airway dilator muscle motor neurons leads to collapse of the pharyngeal airway. In turn, the ability of the sleeping subject to compensate for this airway obstruction will determine the degree of cycling of these events. Several of the classic neurotransmitters and a growing list of neuromodulators have now been identified that contribute to neurochemical regulation of pharyngeal motor neuron activity and airway patency. [18]

### 2.2.8 Sleep Apnea

Sleep apnea is a condition in which a person suffers pauses in breathing or episodes of shallow breathing during sleep. The most common form of sleep apnea is obstructive sleep apnea, or OSA. In OSA, as sleep apnea sufferers relax into sleep, more relaxed muscle tone around the larynx and esophagus leads to closure of the airways, so that the person with sleep apnea can't breathe. [19]

As blood oxygen drops, the body signals the brain to disrupt your sleep until breathing has resumed. The body wakens either partially or totally to restore oxygen flow. For sufferers of severe sleep apnea, deep and uninterrupted sleep can be rare or nonexistent, since interruptions occur repeatedly. The result can be daytime fatigue, high blood pressure, pain, and long-term impacts on brain function. [19]

## 2.3 Skin

### 2.3.1 Introduction to skin

The skin covers the entire external surface of the human body and is the principal site of interaction with the surrounding world. It serves as a protective barrier that prevents internal tissues from exposure to trauma, ultraviolet (UV) radiation, temperature extremes, toxins, and bacteria. Other important functions include sensory perception, immunologic surveillance, thermoregulation, and control of insensible fluid loss.

The integument consists of 2 mutually dependent layers, the epidermis and dermis, which rest on a fatty subcutaneous layer, the panniculus adiposus. The epidermis is derived primarily from surface ectoderm but is colonized by pigment-containing melanocytes of neural crest origin, antigen-processing Langerhans cells of bone marrow origin, and pressure-sensing Merkel cells of neural crest origin. [20]

The skin is one of the largest organs of the body and is responsible for providing protection to the other systems of the body. Skin prevents water loss and dehydration, shields the internal organs in the event of injury, regulates body temperature, senses outside stimuli such as touch as well as heat and cold, and serves as a barrier to infection. As seen in figure 2.6, the skin is made up of three layers: the outer epidermis, the dermis and the deep subcutis layer.

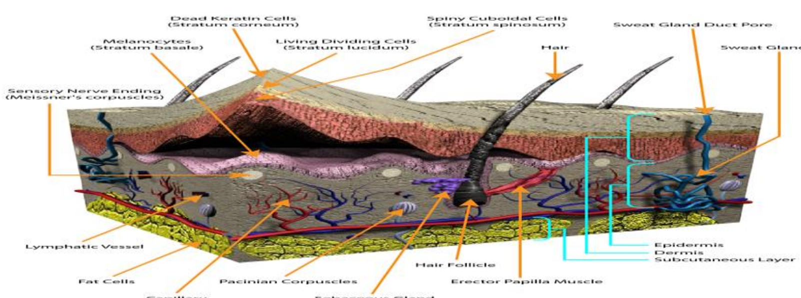



**Figure 2.6** Skin layer. [20]

Other important elements of the skin include: hair follicles, sweat glands and nerve endings. Hair follicles protrude into the dermis layer and help regulate body temperature. Microscopic pores on the surface of the skin are connected to sweat glands which also help maintain homeostasis [21].

### 2.3.2 Skin Layers

The skin is a vital organ for the human body. Man cannot live comfortably without skin covering the whole body. It is also the largest organ of the body, which can make out one-third of a normal person's total body weight [21].

The skin is mainly divided into three layers: the epidermis, dermis, and hypodermis. The outermost layer is the epidermis. The innermost layer is the subcutaneous layer also called hypodermis. The dermis is the middle layer that is sandwiched between both the epidermis and hypodermis. All three layers take role in the functions performed by the skin according to their respective order and construction.

The epidermis is 0.1 mm (approximately) thick and contains no blood vessels [10]. It is subdivided into four parts that lie one beneath the other: the stratum basale (basal layer), the stratum spinosum (spinous or prickle-cell layer), the stratum granulosum (granular layer), and the uppermost stratum corneum (surface layer). This last layer is the one that is in direct contact with the environment.

**Epidermis**

The epidermis is the most superficial layer of the skin, and is largely formed by layers of keratinocytes undergoing terminal maturation. This involves increased keratin production and migration toward the external surface, a process termed cornification [21].

The dermis is the thickest sub-layer of the skin. Thickness, however vary noticeably according to the area that skin covers and might also differ from male and female as well as thickness depends on age. This sub-layer exists under the epidermis directly. It supplies the epidermis and itself with nutrients and oxygen carried by the blood. The dermis many useful structures such as blood vessels, sensory nerve endings, hair follicles, and sweat glands. This sub layer also give the skin it strength and elasticity. It contains two distinct regions: the papillary dermis and the reticular dermis [21].

This sub-layer lies under the dermis in the skin. It contains fat-filled adipose cells. This layer exerts control on heat conservation for the human body and preserves fat which is one of the primary sources of energy to muscles [21].

### Hypodermis

The hypodermis, or subcutaneous tissue, is immediately deep to the dermis.

It is a major body store of adipose tissue, and as such can vary in size between individuals depending on the amount of fatty tissue present [21].

### 2.3.3 Skin Functions

The skin is the body's largest organ. It serves many important functions, including

- Protecting the body against trauma
- Regulating body temperature
- Maintaining water and electrolyte balance
- Sensing painful and pleasant stimuli
- Participating in vitamin D synthesis

The skin keeps vital chemicals and nutrients in the body while providing a barrier against dangerous substances from entering the body and provides a shield from the harmful effects of ultraviolet radiation emitted by the sun. In addition, skin color, texture, and folds (see Descriptions of Skin Marks, Growths, and Color Changes) help mark people as individuals.

Anything that interferes with skin function or causes changes in appearance (see Effects of Aging on the Skin) can have major consequences for physical and mental health.

Many problems that appear on the skin are limited to the skin. Sometimes, however, the skin provides clues to a disorder that affects the entire body. Consequently, doctors often must consider many possible diseases when evaluating skin problems. They may need to order blood tests or other laboratory tests to look for an internal disease in people who come to them with a skin problem [22].

### 2.3.4 Skin Ulcers

The average person moves about 9-12 times an hour during sleep, some people moves more , or maybe less by 2 or 3 times , if the movement is very little or no movement at all , that causes the skin ulcers [22].

Skin ulcers are open sores which are often painful, and they are commonly accompanied by the sloughing-off of tissue which is inflamed. A vast variety of reasons can develop skin ulcers, for example, trauma, problems with blood circulation, exposure to cold or heat temperatures, or irritation caused by the exposure to various caustic materials.

There are many different types of ulcers of the skin. The two most common types include venous skin ulcers which generally affect the feet and the legs and are caused by a reduction in blood flow and therefore swelling. The other common type is pressure ulcers which can be caused by excessive pressure on the skin on any part of the body. Both conditions can cause similar symptoms of itchy and painful reddened or blistered skin and open crater-like sores [23].

### 2.3.5 Sleep movement

Movement during sleep varies from person to person, depending on the nature, disease status, age and several other factors of the body, there are three types of people according to the picture.


**Figure 2.7** sleep movement types.

# Chapter Three

Technology Back Ground

---

3.3.3 Principle of Whetstone Bridge work

## 3.4 Heart Rate Sensor

3.4.1 Description

3.4.2 Non Invasive methods of heart rate measurement :

3.4.3 Photoplethysmography ( PPG) Signal

## 3.5 Microcontroller Unit

3.5.1 Mega Arduino

## 3.6 Serial Communication

3.6.1 Types of Communication Protocols

## 3.7 Display Circuit

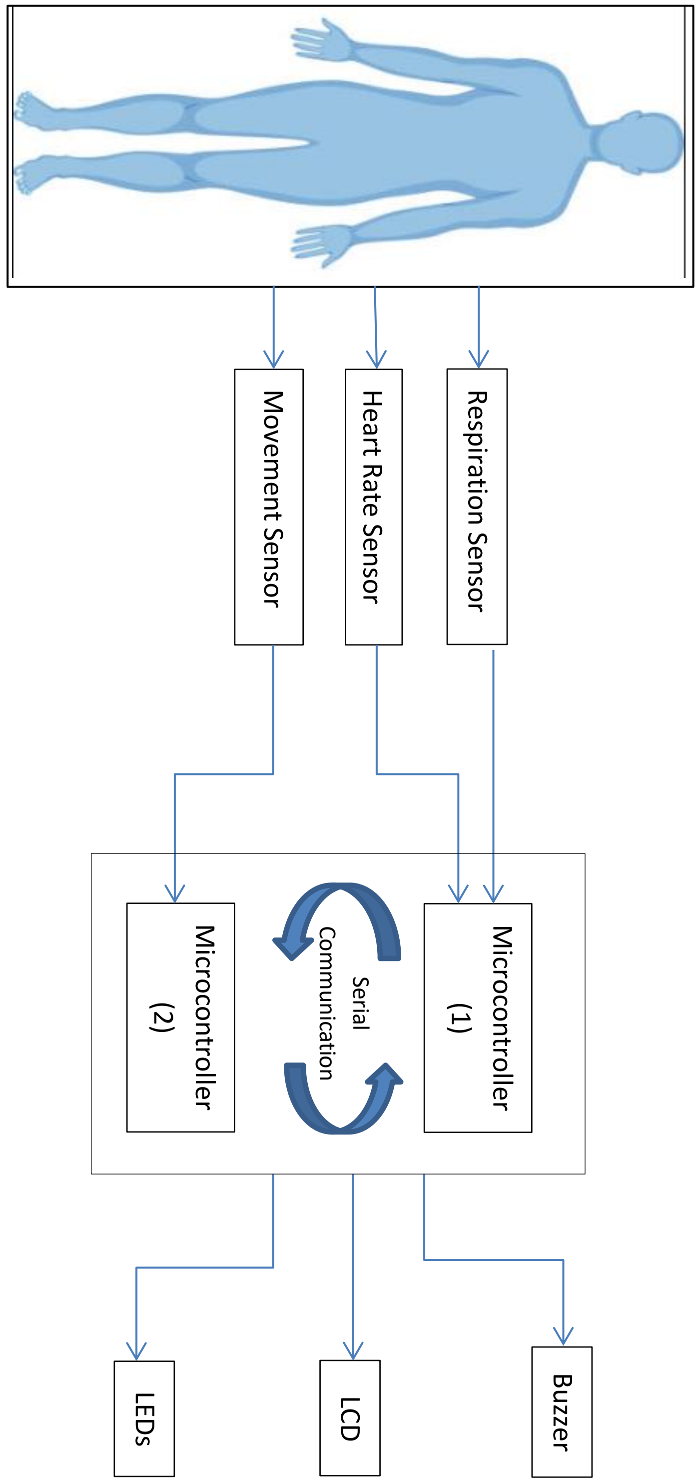
## 3.8 Alarm Circuit

3.8.2 LED

3.8.1 Buzzer

## 3.1 System Block Diagram

### 3.1.1 Block diagram



### 3.1.2 Explanation of block diagram

It start by taking various statistics from the data: breathing rate, heart rate, and movement . the breathing rate is measured by Respiration Sensor, Heart Rate is measured by Heart Rate Sensor and the movement is measured by Flexiforce Sensor , the values of these statistics will send to ADC in the microcontroller (1 & 2) " Mega Arduino", all of these values relyed to the basestation by the Serial comunication to analyis the data and compared the values with a reference values in the microcontrollers "Mega Arduino" and display the values on a LCD, if the values is normal the LCD will display all values, then if the values is abnormal the LCD display the abnormal value 'caution X is abnormal' ." where X is the abnormal parameter ,then the buzzer and LED ( alarm systm) will actived.

In order to read the breathing rate of the user, conductive stretchable cord is used that changes its resistance as it expands and contracts , this used as the top half a voltage divider in order to sense the compression or expansion of the user Chest/Abdomen ,corresponding to when they are inhaling or exhaling , the output of the voltage divider is reading an ADC connected to the a Mega ,whose reading are relayed to the microcontroller for analysis.

The heart beat sensor is mounted inside the index finger in the glove, so that it slips on the user's finger when they wear it.

Such as the respiratory rate and heart rate are measured at the same time and are linked to the same Arduino, the reading is updated every 30 seconds while the movement is on a separate Arduino and the motion sensors read every 5 minutes while the reading is updated to compare it with the reference values every two hours so that the patient is not disturbed during his sleep.

## 3.2 Force Sensing Resistors

### 3.2.1 Description

FlexiForce force sensors are ultra-thin and flexible printed circuits, which can be easily integrated into force measurement applications. FlexiForce sensors are available off-the-shelf, or can be customized for unique product designs [36].

Printed, thin, and flexible sensors have caused quite the buzz around the design engineering community in recent years. This is due largely to the boom of smart, lightweight, and power-efficient technologies, which have become entrenched in our everyday lives. Naturally, when designing these compact but powerful devices and products, the embedded components that make them game-changing innovations should also share those same traits [37].

### 3.2.2 Principle of work

Most engineers have learned that the formula for force is an object's mass multiplied by its acceleration (or, F=M*A), or, applied pressure multiplied by the contact area (F=P*Area). There are several engineering units to represent "F" in these equations, such as Newtons (N), pound-force (lbf), and others.

On their own, force sensing resistors are not pre-calibrated to correlate a force reading to a known engineering unit. However, the force measurement output captured by a force sensing resistor can be correlated to the applied force through a calibration procedure.

Force sensing resistors are a piezo resistive sensing technology. This means they are passive elements that function as a variable resistor in an electrical circuit. As shown in Figure 3.1, when unloaded, the sensor has a high resistance (on the order of Megaohms (MΩ)) that drops as force is applied (usually on the order of Kiloohms (KΩ)). When you consider the inverse of resistance (conductance), the conductance response as a function of force is linear within the sensor's designated force range.

Because of their resistance/conductance linear relationship, force sensing resistors can be calibrated with as little as two-to-three known loads. Also, if your circuit is designed with adjustable components, the sensor's sensitivity can be adjusted for optimal performance in your specific force range [38].

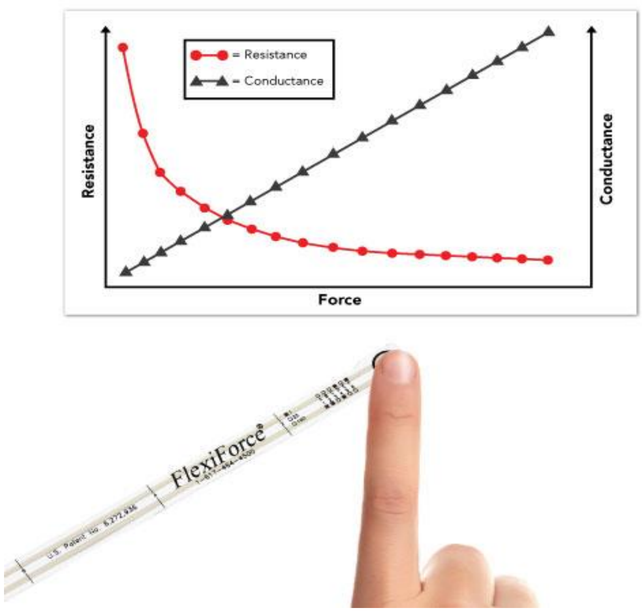


**Figure 3.2** Flexi force sensor [38].

## 3.3 Respiration Sensor

The sensor used in this application is the thermistor in the whetstone bridge.

### 3.3.1 Description

Thermistors are a type of semiconductor, meaning they have greater resistance than conducting materials, but lower resistance than insulating materials. The relationship between a thermistor's temperature and its resistance is highly dependent upon the materials from which it's composed. The manufacturer typically determines this property with a high degree of accuracy, as this is the primary characteristic of interest to thermistor buyers.

Thermistors are made up of metallic oxides, binders and stabilizers, pressed into wafers and then cut to chip size, left in disc form, or made into another shape. The precise ratio of the composite materials governs their resistance/temperature "curve." Manufacturers typically control this ratio with great accuracy, since it determines how the thermistor will function.

Thermistors, derived from the term thermally sensitive resistors, are a very accurate and cost- effective sensor for measuring temperature. Available in 2 types, NTC (negative temperature coefficient) and PTC (positive temperature coefficient), it is the NTC thermistor that is commonly used to measure temperature.

Thermistors are available in two types: those with Negative Temperature Coefficients (NTC thermistors) and those with Positive Temperature Coefficients (PTC thermistors). NTC thermistors' resistance decreases as their temperature increases, while PTC thermistors' resistance increases as their temperature increases. Only NTC thermistors are commonly used in temperature measurement.

Thermistors are composed of materials with known resistance. As the temperature increases, an NTC thermistor's resistance will increase in a non-linear fashion, following a particular "curve." The shape of this resistance vs. temperature curve is determined by the properties of the materials that make up the thermistor [39].

NTC Thermistors provide an excellent solution in applications requiring accurate temperature measurement. Because of their high sensitivity, NTC Thermistors are ideal for detecting small changes in temperature. However, the characteristic curves for these thermistors are highly non-linear. The resistance is generally an exponential function of the temperature, as shown in Equation (1)

$$ln\left(\frac{R}{R_o}\right) = \beta\left(\frac{1}{T} - \frac{1}{T_o}\right)$$ eqn (1).

where R0 is the resistance at a reference temperature, T0, while ß is a constant, characteristic of the material, T0, the reference temperature, is generally taken as 298 °K (25 °C) [40].

### 3.3.2 Structure Temperature with a Wheatstone bridge

In the Wheatstone bridge of Figure 1, R1, R2, and R3 are known and Rx is the unknown resistance. When the potential (voltage) P1 (see the figure) is the same as potential P2, the bridge is said to be balanced.In this condition, no current flows (as indicated by the "zero" reading of the meter) through the galvanometer and the ratio of resistance in the Rl – R2 path must equal the ratio in the R3 – Rx path [41].

The major challenge of accurate resistance measurement is to alleviate the loading effect of the circuit by the meter.Such an inaccuracy is caused by the drawing of power by the meter, although the amount of power drawn is negligibly small, from the circuit, even if it has a very high-impedance (e.g 10 MΩ) [41].

### 3.3.3 Principle of Wheatstone Bridge work

For measuring temperature, a Wheatstone bridge is used in out of balance where the out-of-balance voltage, ΔV, can be measured and related to the resistance of the thermistor. See this simple DC bridge circuit as shown in Figure 3.2 that is used for such precision measurement using the thermistor. A correct choice of resistors R2 and R3 will remove the mean DC value of ΔV.

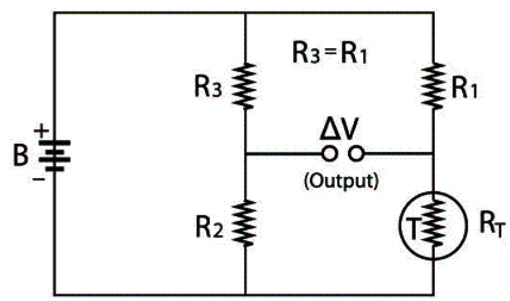



**Figure 3.3** simple DC bridge circuit

Considering this circuit, we now derive the relation between T and .V. In general,

$$\Delta V = E\left(\frac{R_2}{R_2 + R_3} - \frac{R_T}{R_1 + R_T}\right) \qquad \text{eqn(2)}$$

## 3.4 Heart Rate Sensor

### 3.4.1 Description

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.

### 3.4.2 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 [42].

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 apaper or on screen [43].

This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle [44].

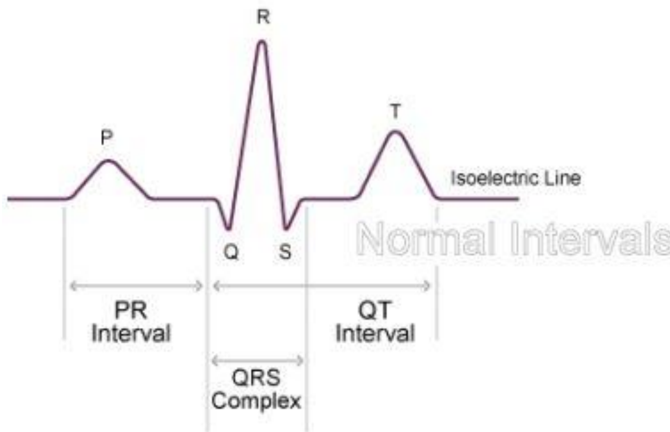



**Figure 3.4** Normal Intervals

P-R interval = 0.12 - 0.20 sec

QRS width = 0.08 - 0.12 sec

Q-T interval 0.35 - 0.43 sec

### 3.4.3 Photoplethysmography ( PPG) Signal

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 [45].

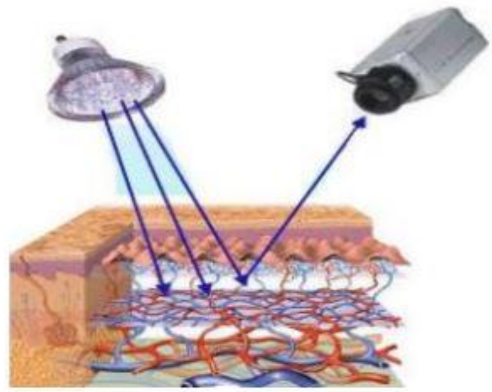


**Fig 3.5** PPG signals using photo detector and Light source [45].

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 [46].

## 3.5 Microcontroller Unit

A microcontroller is a computer present in a single integrated circuit which is dedicated to perform one task and execute one specific application.

It contains memory, programmable input/output peripherals as well a processor. Microcontrollers are mostly designed for embedded applications and are heavily used in automatically controlled electronic devices such as cellphones, cameras, microwave ovens, washing machines, etc. [49]

Features of a microcontroller:

- Far more economical to control electronic devices and processes as the size and cost involved is comparatively less than other methods.
- Operating at a low clock rate frequency, usually use four bit words and are designed for low power consumption.
- Architecture varies greatly with respect to purpose from general to specific, and with respect to microprocessor, ROM, RAM or I/O functions.
- Has a dedicated input device and often has a display for output.
- Usually embedded in other equipment and are used to control features or actions of the equipment.
- Program used by microcontroller is stored in ROM.
- Used in situations where limited computing functions are needed. [49]

The Arduino software is easy to use and flexible enough for advanced users. It runs on mac, windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instrument. There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, net media's BX-24, phi gets, MIT's handy board, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy to use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, and interested amateurs over other systems. [47]

The control unit is the system brain which sends orders and receives data from other system components. An Arduino Nano are used. The following sections describe their function

### 3.5.1 Mega Arduino

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega 2560 board is compatible with most shields designed for the Uno and the former boards Duemilanove or Diecimila.The Mega 2560 is an update to the Arduino Mega, which it replaces [48].

**Figure 3.6** Arduino Mega [48].

## 3.6 Serial Communication

Serial communication is the most widely used approach to transfer information between data processing equipment and peripherals. In general, communication means interchange of information between individuals through written documents, verbal words, audio and video lessons.

Every device might it be your Personal computer or mobile runs on serial protocol. The protocol is the secure and reliable form of communication having a set of rules addressed by the source host (sender) and destination host (receiver). To have a better insight, I have explained the concept of serial communication [49].

In embedded system, Serial communication is the way of exchanging data using different methods in the form of serial digital binary [49].

### 3.6.1 Types of Communication Protocols

There are different types of data transfer available in the digital electronics such as serial communication and parallel communication. Similarly the protocols are divided into two types such as Serial Communication Protocol and Parallel Communication Protocols. Examples of Parallel Communication Protocols are ISA, ATA, SCSI, PCI and IEEE-488. Similarly there are several examples of Serial Communication Protocols such as CAN, ETHERNET, I2C, SPI, RS232, USB, 1-Wire, and SATA etc [50].

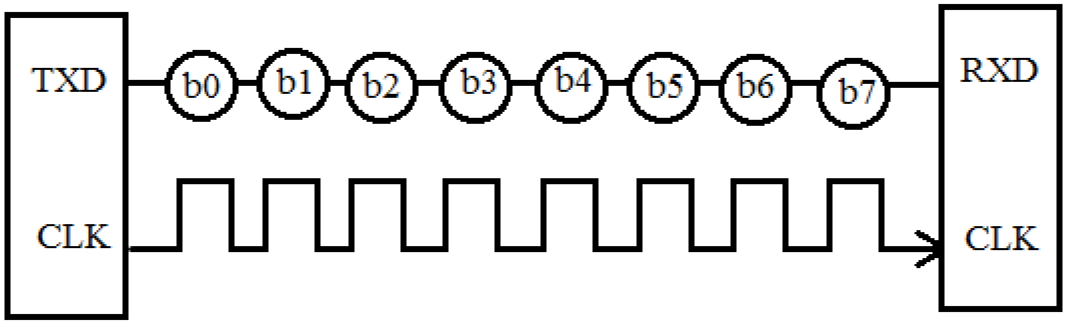



**Figure 3.7** Serial Communication Protocol [50].

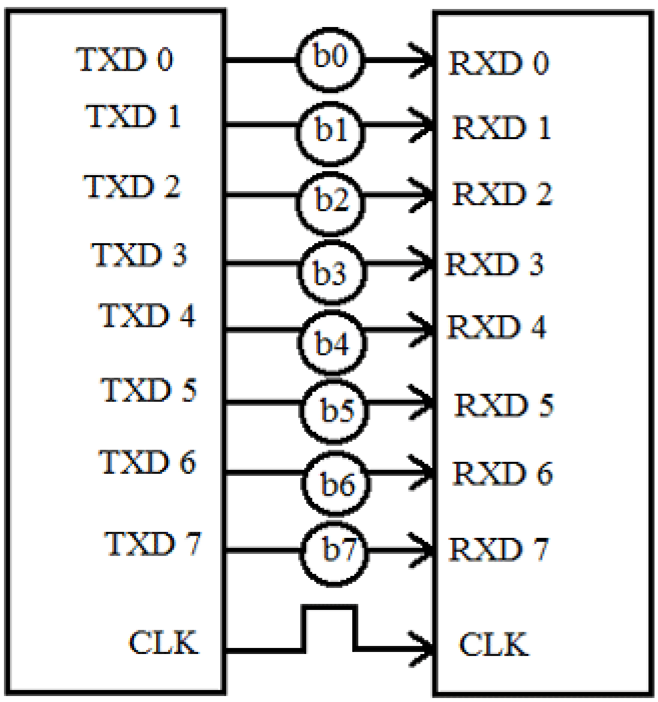



**Figure 3.8** Parallel Communication Protocol [50].

## 3.7 Display Circuit

The LCD display Module is built in a LSI controller, the controller has two 8-bit registers, an instruction register (IR) and a data register (DR). The IR can only be written from the MPU. The DR temporarily stores data to be written or read from DDRAM or CGRAM. When address information is written into the IR, then data is stored into the DR from DDRAM or CGRAM. By the register selector (RS) signal, these two registers can be selected.

It's easily controlled by MCU such as 8051,PIC,AVR,ARDUINO,ARM and Raspberry Pi.It can be used in any embedded systems, industrial device ,security, medical and hand-held equipment.

The display device that will be used in the project is LCD (4*16); it can display sixteen characters on four rows which is very good for the project. The data displayed on the LCD are HR, RR and Motion [32].

**Figure 3.9** LCD 4*16 [32]

## 3.8 Alarm Circuit

Alarms are intended to draw attention to a problem before it harmful. Most stand-alone monitors can generate an alarm when a monitored variable crosses fixed or adjustable limits.

Alarms with this design are used to warn the patient and patient's family, that there is something wrong in breathing, heart beating or in patient movement while sleeping.

### 3.8.1 Buzzer

A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzer and beepers are as alarm devices. A buzzer is an integrated structure of electronic transducers, a DC power supply, widely used in computers, printers, copiers, alarms, electronic toys, automotive electronic equipment, telephones, timers and other electronic products needing sound devices. Here it is used when something get wrong with one of the parameters In this situation the buzzer is chosen with the criteria of the sound not being too high and its voltage trigger must also be suitable for the output voltage Arduino hardware (see figure) a voltage is 5 volt DC [33]. TMB12A05 Buzzer Datasheet in appendix


**Fig 3.10** Types of buzzer [33].

### 3.8.2 LED

Light Emitting Diode is a very important meric of the conversion of electrical energy into emitted optical energy. LEDs produce more light per watt than incandescent bulbs; this is useful it n battery powered or energy saving devices, LEDs can emit light of an intended color without the use of color filters that traditional lighting methods require. This is more efficient and can lower initial costs. LEDs can have a relatively long useful life. LEDs has a life time of about 50,000 hours, whereas Fluorescent tubes typically are rated at about 30,000 hours, and incandescent light bulbs at 1,000-2,000 hours. In this project two color used red for danger situation when something wrong happened with one of the parameters [34]. Figure 3.10 shows several LEDs.

**Figure 3.11** several LEDs

# Chapter Four

## System Design

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### 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 Respiration Rate Design.

4.3.1 Thermistor Wheatstone bridge.

4.3.2 Differential Amplification

### 4.4 Force Sensing Resistors

## 4.5 Microcontroller (MCU).

## 4.6 Serial Communication.

## 4.7 Display Circuit.

## 4.8 Power Supply

## 4.9 Alarm Circuit

## 4.10 Flow Chart

## 4.1 Introduction

This chapter talks about the system design including all the hardware and software components required. Each stage of the system will be explained in detail, the hardware components of each stage are chosen carefully to achieve the desired objectives.

The main system architecture is depicted in Figure 4.1, it is composed of two main parts, sensing and processing parts. The sensing part contains Heart Rate sensor to measure heart rate beat per minute within sleeping, Respiration sensor to measure the respiration rate during sleeping and the Motion sensor to measure the number of motion during sleeping. The main functions of the processing parts are receiving data from the sensing parts and process the output signal of each sensor, and send the results to the Microcontroller to, compare with standard values, and display it using display device. The overall system is supplied by Arduino and the Arduino is supplied by home power.

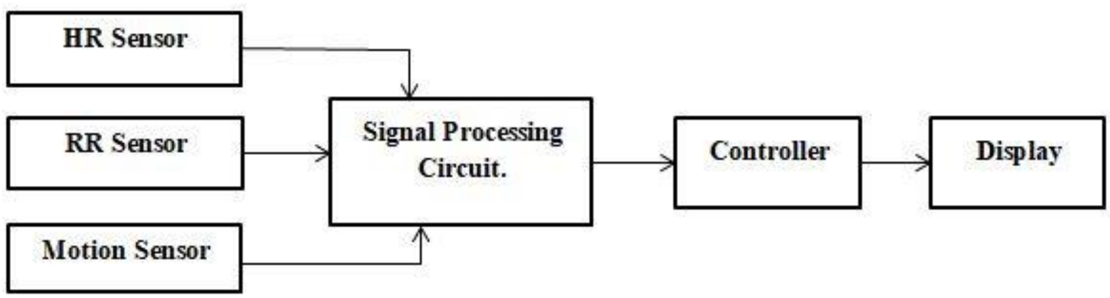



**Figure 4.1** Main Block Diagram of the System.

. An explanation of each stage within the system is given in the following section

## 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 finger 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.

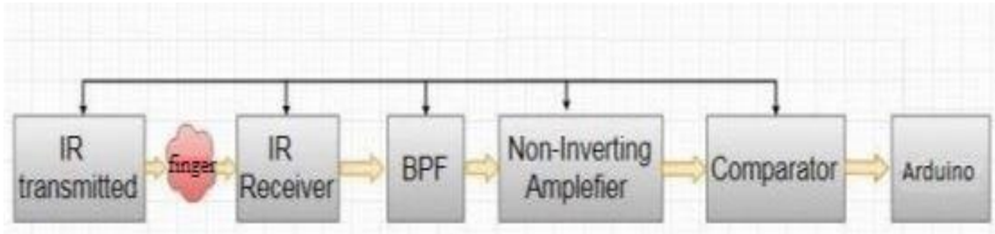



**Figure 4.2** Block diagram for HR Sensor.

### 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 finger. 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 finger,as shown in Figure 4.3.

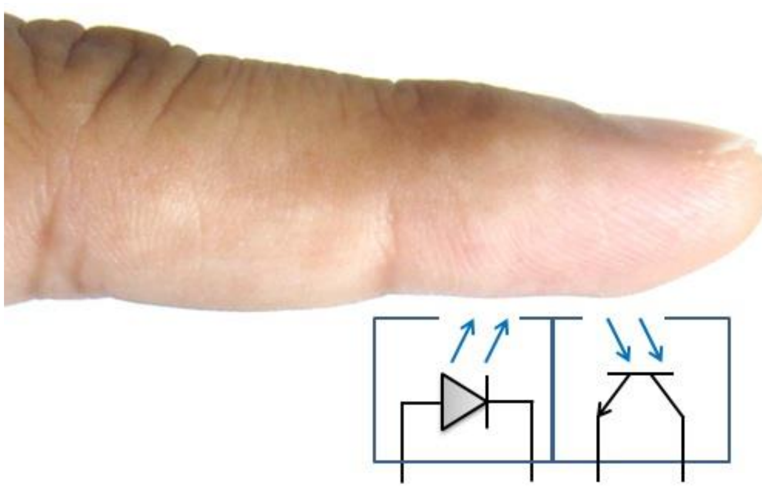


**Figure 4.3** Finger photoplethysmography (reflectance approach).

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 finger or the wrist. 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.

The following circuit showed in Figure 4.4, 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 photo transistor output (VSENSOR) contains the PPG signal that goes to a two-stage filter and amplifier circuit for further processing.

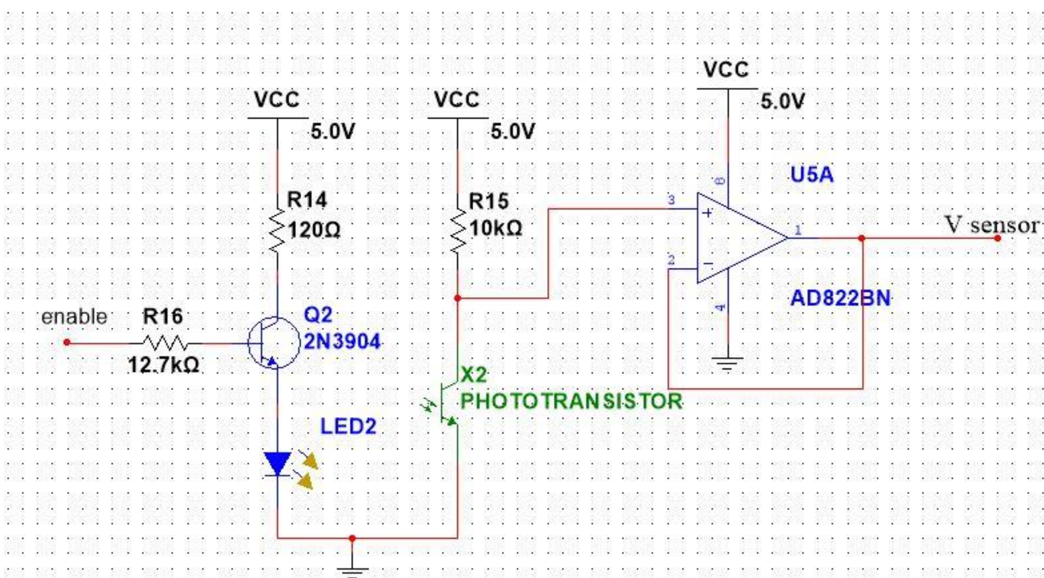



**Figure 4.4** IR transceiver circuit.

The transistor (2N3940) is chosen to deliver a constant current for IR- LED According to TCRT-1000 data sheet, the forward current ($I_F$) 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 IC=20mA.By using equation 4.1, the base current ($I_B$) given by the following equation:

$$I_\beta = I_C/\beta \qquad 4.1$$

$I_\beta$=20/60*1000=0.33mA.

The resistance R3 that generates the desired Iβ is calculated by the following equation(4.2):

$$R_3=V_{CC}-V_{BE}/I_B \quad 4.2$$

The base-emitter voltage (VBE) and VCC are 0.8V and 5V respectively, hence the value of R3 equal 12.7KΩ.

The Enable is the Feed source from Arduino, and the AD822 is will be buffer we don't want a next stage make a loading(current) to occur and the signal will be the same without any interactions.

### 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 4.5, the signal is first passed through a passive (RC) high-pass filter (HPF) to block the DC component of the PPG signal.

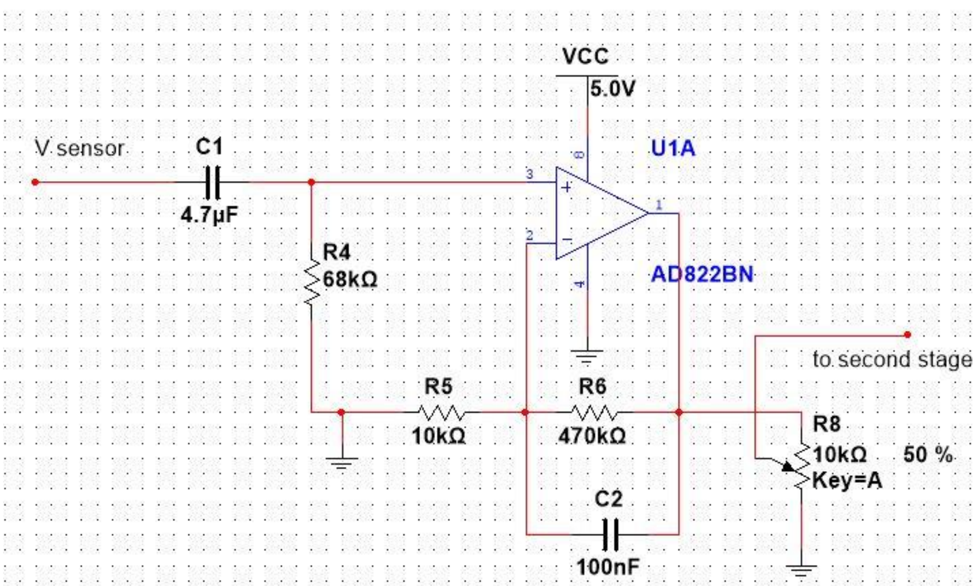



**Figure 4.5** Band Pass Filter circuit.

The cut-off frequency of the HPF is 0.5Hz, $F_C$ can be calculated by using $R_4$ and $C_1$ as expressed in equation (4.3):

$$F_C=1/2\pi R_4C_1 \qquad 4.3$$

Let $C_1$ =4.7μF, the resistor values for $R_4$ calculated through:

$$R_4=1/2\pi F_CC_1 \qquad 4.4$$

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 $C_2$ as expressed in equation (4.5):

$$F_C=1/2\pi R_6C_2 \qquad 4.5$$

Let $C_2$ =100nF, the resistor values for $R_6$ calculated through:

$$R_6=1/2\pi F_CC_2 \qquad 4.6$$

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):

$$G=1+(R_6/R_5) \qquad 4.7$$

At the output is a potentiometer ($P1(R_7)$) 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 $P1(R_7)$. The Op-amp used in this project is AD822 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 4.7. 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($R_7$)can be used to control the amplitude of the PPG signal appearing at the output of the buffer stage.

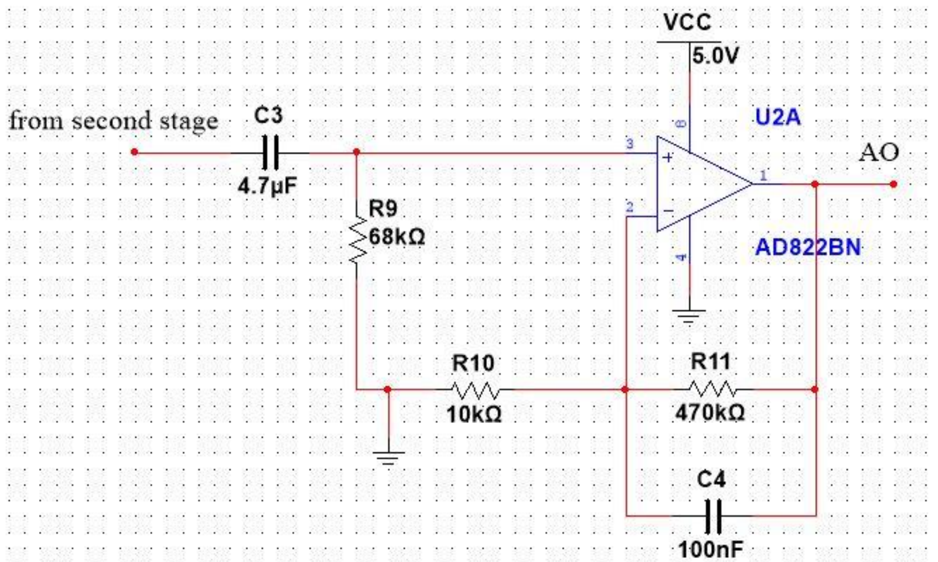



**Figure 4.6** Second stage BPF and buffer circuit.

### 4.2.3 Comparator

The fourth Op Amp inside the AD822 device is used as a voltage comparator as shown in the Figure 4.8. The analog PPG signal is fed to the positive input.

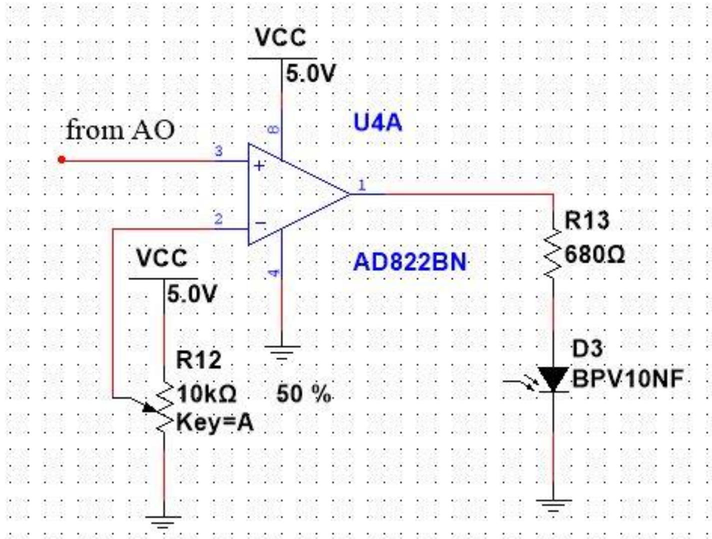



**Figure 4.7** Comparator circuit.

The magnitude of V can be set anywhere between 0 and 5 through potentiometer P2($R_{12}$) Every time the PPG pulse wave exceeds the threshold V, 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.

## 4.3 Respiration rate Sensor Design

The respiratory rate (RR) is the number of breaths taken within a set amount of time (typically 60 seconds) .Normal respiration rates for an adult person at rest range from 12 to 16 breaths per minute. A normal respiratory rate is termed as apnea an increased respiratory rate is termed as tachypnea and a lower than the normal respiratory rate is termed as bradypnea**.**

The breath rate sensor, explained in the previous chapter, will be used in this project to monitor the user's breath rate. Traditional methods used for breath rate sensors include Thoracic Expansion Measurement, Thoracic Impedance Pneumography and Capnography. The main shortcoming of these methods is that they are expensive, complicated and unacceptable for long term sleeping patients. NTC Thermistors are ideal for detecting small changes in temperature. However, the characteristic curves for these thermistors are highly non-linear. The resistance is generally an exponential function of the temperature, as shown in Equation 4.8

$$ln\left(\frac{R}{R_o}\right) = \beta\left(\frac{1}{T} - \frac{1}{T_o}\right) \quad 4.8$$

In this project will use a negative temperature coefficient 10k Thermistor (NTC 10k). This Thermistor has wider resistance range up to 10k and it is cost-effective. The temperature ranges from 55°C to +125°C]. The Thermistor is mounted within the mask near to the nostrils to give the temperature feedback of inhaled and exhaled air.

### 4.3.1 Thermistor Wheatstone bridge.

In the Wheatstone bridge of Figure 4.9, $R_1$, $R_2$, and R3 are known and $R_T$ is the unknown resistance. When the potential (voltage) P1 (see the figure) is the same as potential P2, the bridge is said to be balanced.

In this condition, no current flows (as indicated by the "zero" reading of the meter) through the **galvanometer** and the ratio of resistance in the $R_l$ – $R_3$ path must equal the ratio in the $R_2$– $R_T$ path.

For measuring temperature, a Wheatstone bridge is used in out of balance where the **out-of-balance voltage**, ΔV, can be measured and related to the resistance of the thermistor. See this simple **DC bridge circuit** as shown in Figure 4.9 that is used for such precision measurement using the thermistor. A correct choice of resistors $R_2$ and $R_3$ will remove the mean DC value of ΔV.

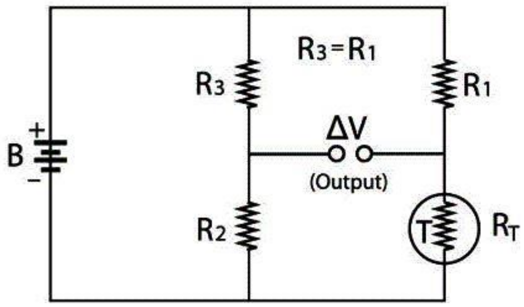



**Figure 4.8** simple **DC bridge circuit**

Considering this circuit, the relation between T and .V. In general is:(equation 4.10)

$$\Delta V = E\left(\frac{R_2}{R_2+R_3}-\frac{R_T}{R_1+R_T}\right) \quad 4.10$$

Assume R1 = R3. Then,

$$\Delta V = E\left(\frac{R_2}{R_1+R_2}-\frac{R_T}{R_1+R_T}\right) \quad 4.11$$

Rearranging for RT, then the relation between T and RT is given by:(equation4.12)

$$R_T = R_0 \exp\left(\beta\left[\frac{1}{T}-\frac{1}{T_0}\right]\right) \quad 4.12$$

We added resistance in parallel to solve the problem of non-linearity and its value is an average value between the reference value and the maximum value as a maximum of 40 degrees Celsius In this project the reference value is a room temperature of 25 degrees Celsius as well as the temperature that the sensor will measure and it is variable according to the existing room temperature and environment by the person .

Then the all value will have produced explain in figure 4.10.

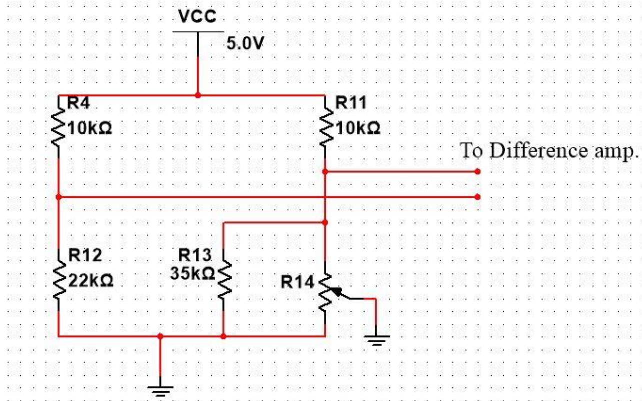



**Figure 4.9** The All Value.

### 4.3.2 Differential Amplification

The differential amplifier will uses is INA122. This amplifier has excellent performance with low quiescent current of 60mA. It has a wide power supply range from 2.2V to 36V .The amplifier has a low offset voltage of 250mV max, low input bias current of 25nA max, low offset drift of 3mV/°C max and low noise of 60nV/√Hz .

The Figure 4.12 shows the internal circuitry of differential amplifier INA122. The amplification gain can be adjusted by connecting suitable resistor to the pin 1 and pin 8. And gain and amplified output voltage can be calculated using formula given below .

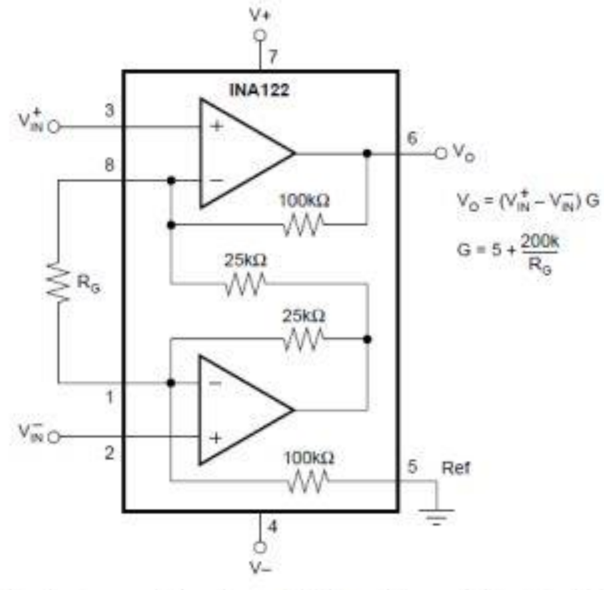



**Figure 4.10** Internal circuitry of differential amplifier INA122.

The $R_G$ will calculated from gain equation ,when the gain is 1 then:

$$Gain=5+200k/R_G \qquad 4.13$$

$$1=5+200K/R_G \qquad 4.14$$

So the resister $R_G$ is equal: $R_G$ =50KΩ.

After that the O/P Voltage goes to Arduino Mega 1.

## 4.4 Force Sensing Resistors

(FSR) are a polymer thick film (PTF) device which exhibits a decrease in resistance with an increase in the force applied to the active surface. Its force sensitivity is optimized for use in human touch control of electronic devices. FSRs are not a load cell or strain gauge, though they have similar properties. FSRs are not suitable for precision measurements.

The graph below displays the resistance vs force curve for the FSR 402 sensor. Note that the data is plotted on logarithmic scales. The response is not linear! As you can see there is a huge drop in resistance when a small amount of pressure is applied. After that, the resistance is inversely proportional to the applied force. At around 10 kg (not shown in the graph) the sensor is saturated and an increase in force yields little to no decrease in resistance.

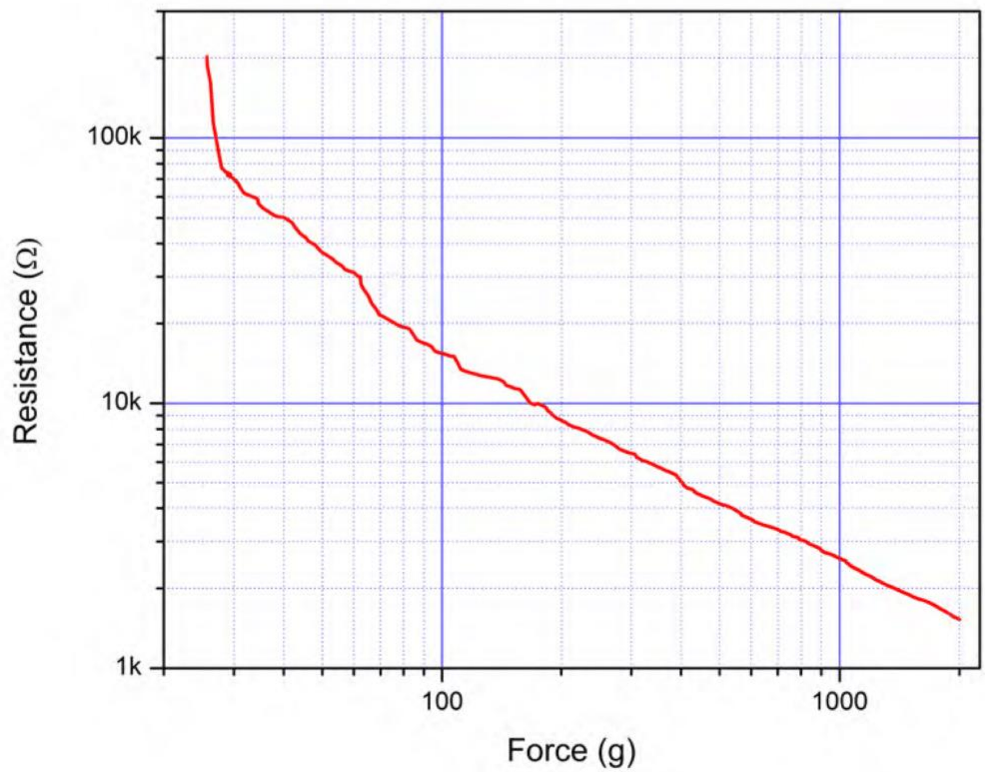



**Figure 4.11** Resistance vs Force curve for FSR 402

**Voltage divider circuit**

In order to measure the applied force with an Arduino you will need to build a voltage divider circuit with the FSR and a pull-down resistor. This circuit creates a variable voltage output that can be read by the ADC (analog to digital converter) input of the microcontroller.

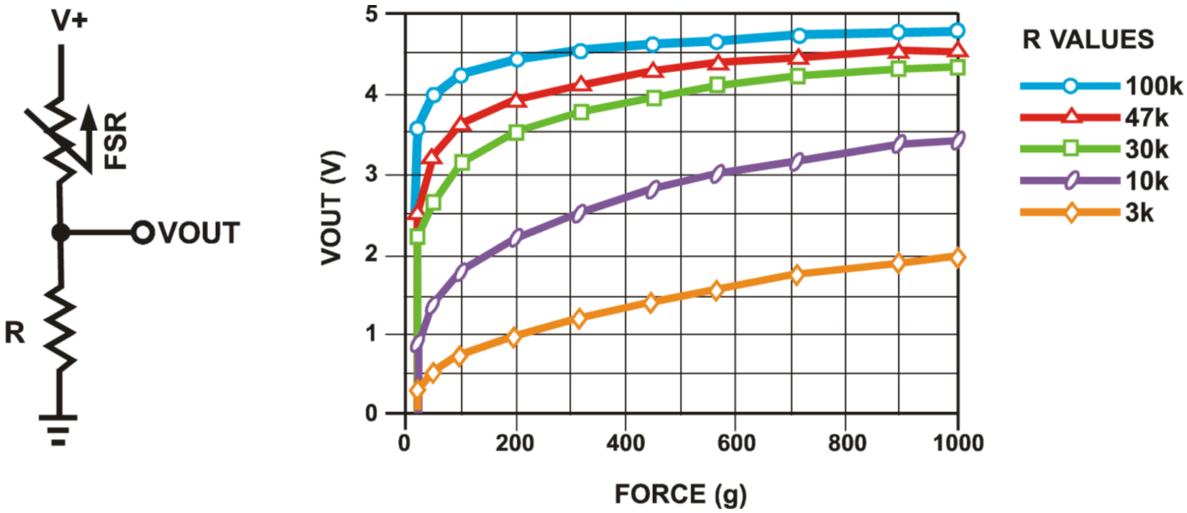



**Figure 4.12** Voltage divider circuit and Vout vs Force curves for different R values. Data represents output for Interlink 402 FSR and V+ equal to 5V.

The output voltage (Vout) that we measure with the Arduino is described by the following equation:

**Vout = Vcc x R / (R + Rfsr)**

So the voltage is inversely proportional to the FSR resistance. Note that the output voltage you measure is the voltage drop across the pull-down resistor, not across the FSR.

When no force is applied, the FSR resistance will be really high, take 10MΩ as an example. I used a 10kΩ pull-down resistor and a Vcc of 5V for this tutorial, which results in the following output when no force is applied:

**Vout = 5V x 10kΩ/ (10kΩ + 10MΩ) = 0.005V**

So almost 0 V. If you press really hard on the FSR, the resistance will go down to roughly 200 Ω. This results in the following output voltage:

**Vout = 5V x 10kΩ/ (10kΩ + 200Ω) = 4.9V**

As you can see, you should be able to measure an output voltage between 0 and 4.9V depending on the amount of force you apply to the sensor.

Voltage divider circuit and Vout vs Force curves for different R values. Data represents output for Interlink 402 FSR and V+ equal to 5V. Reference: Interlink integration guide.
Selecting the right size resistor to match your sensor can be a bit tricky and depends on the force range you want to measure.

The graph above shows the Vout vs Force curves for different values of R (the pull-down resistor). A **10 kΩ resistor** works well if you want to use the sensor over its entire force range (100g to 10kg). I like to buy these assortment boxes from Amazon so I always have a range of resitors on hand.

## 4.5 Microcontroller (MCU):

In this project, the microcontroller chosen is a Mega Arduino board which is based on ATMEGA2560 controller. Mega Arduino is a complete board with the same functionality of Arduino Duemilanove just in different package. The Mega Arduino is has a power jack.

It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

**Figure 4.13** Mega Arduino.

## 4.6 Serial Communication

On Uno, Nano, Mini, and Mega, pins 0 and 1 are used for communication with the computer or Connecting anything to these pins can interfere with that communication, including causing failed uploads to the board.

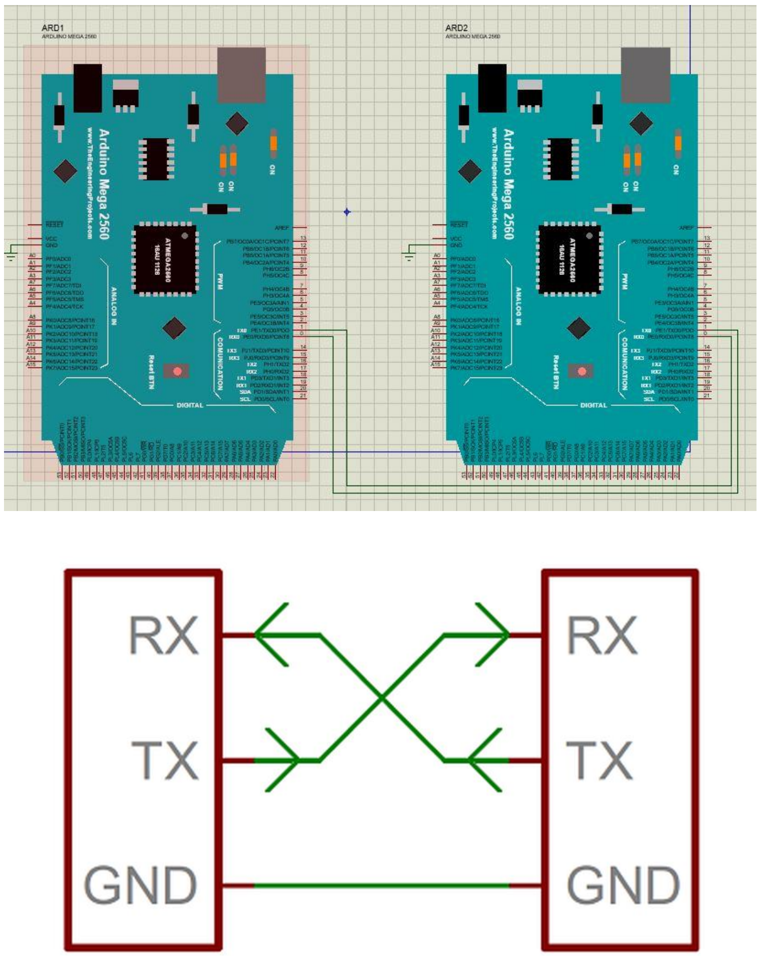



**Figure 4.14** Serial Communication between two arduino.

## 4.7 Display Circuit

The display device that will be used in the project is LCD (4*16); it can display sixteen characters on four rows which is very good for the project. The data displayed on the LCD are HR , RR and Motion. Figure 4.17 shows the LCD and Arduino.

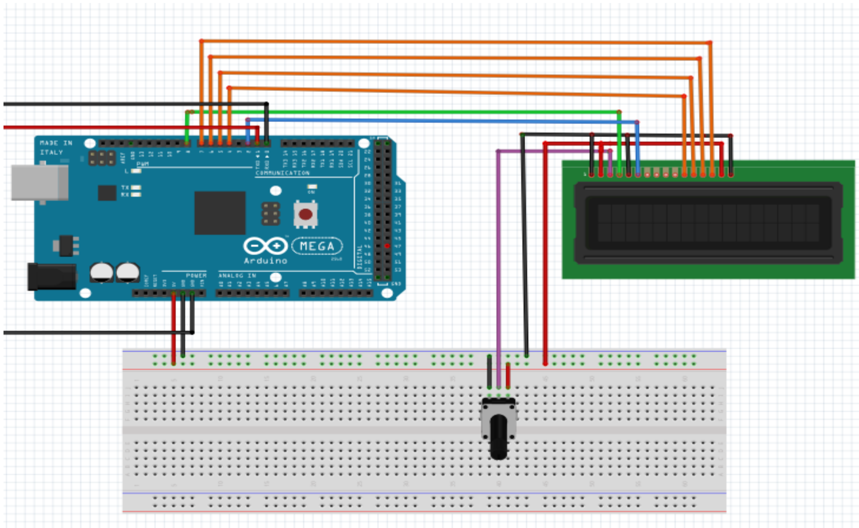


**Figure 4.15** Mega Arduino and LCD screen.

## 4.8 Power Supply

The hardware system needs power supply to provide its components with the required power. As the system is required to be portable a battery that has the following characteristics is required: light weight, provide required system power and has relatively long but when the project was implemented in practice, it was found that the batteries are insufficient and do not have the ability to spend a long time, and the existing system needs a high voltage and current of more than 2.5 amperes and 5 volts.

Therefore, the resort was made to make the system not portable and to rely on feeding the system on the Arduino, and the Arduino is fed through home power.

## 4.9 Alarm Circuit

Alarms with this design are used to warn the patient and patient's family, that there is something wrong in breathing, heart beating or in patient movement while sleeping .

This alarm will be is Audio and Visual alarm by using the TMB12A05 buzzer audio and using the led with red color to attenuate the patient in wrong case, the connection and circuit of buzzer and led show in Figure 4.16 and 4.19.

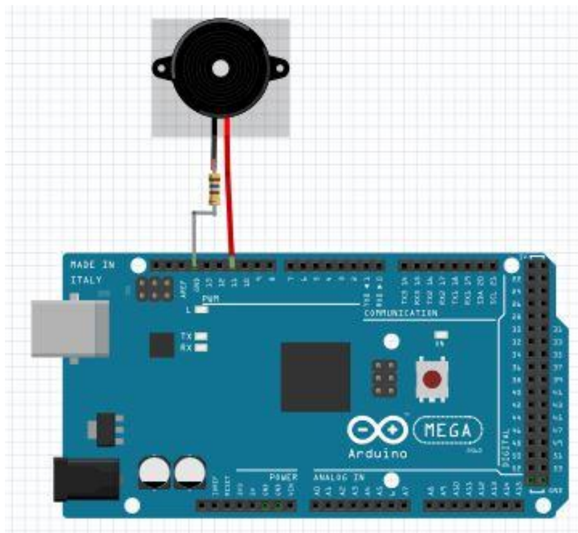


**Figure 4.16** buzzer connection with arduino

The resistance of protection for buzzer:

$$R=\Delta V/I \quad 4.17$$

R=(5-1.8)/20m=160Ω.

The resistance of protection for red LED's:

$$R=\Delta V/I \quad 4.17$$

R=(5-2)/20m=150Ω.

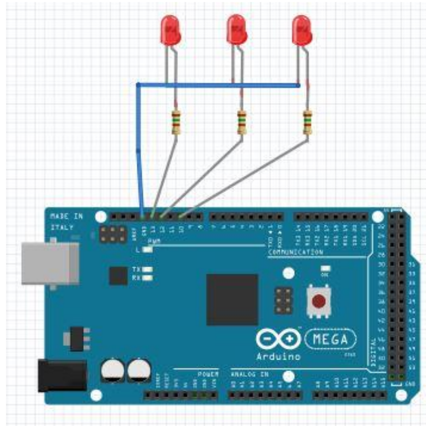
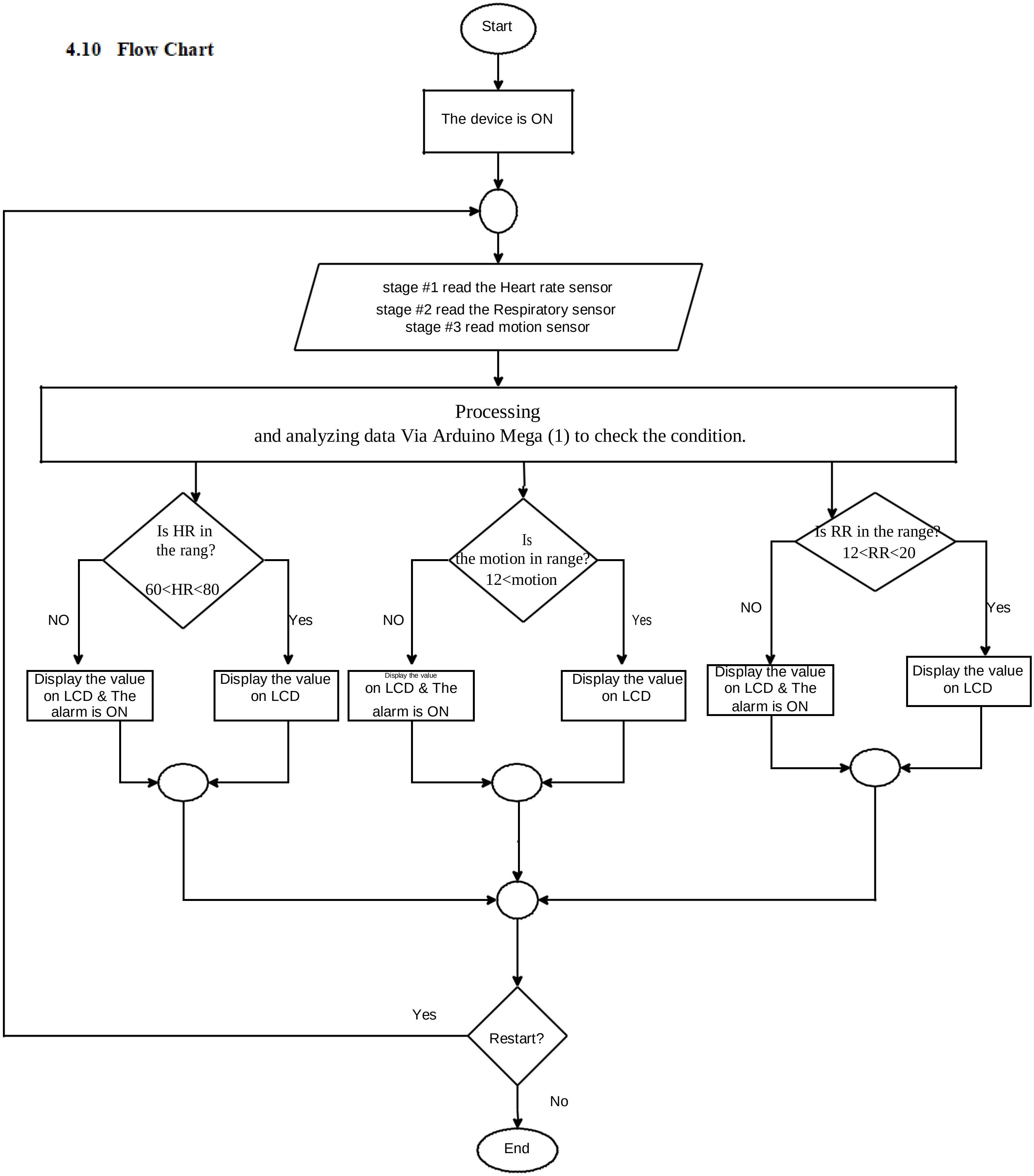


**Figure 4.17** LED's connections with base station Arduino.

### 4.10 Flow Chart



# Chapter Five

## System Implementation and Testing

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**5.1 Main circuit.**

**5.2 Force sensor circuit.**

**5.3 Heart Rate sensor circuit.**

**5.4 Respiration Rate sensor circuit**

**5.4.1 Thermistor Simulation.**

**5.5 LCD circuit.**

**5.6 Alarm Circuit.**

**5.7 Arduino Connection.**

## 5.1 Main circuit

This board combines the circuits of the three sensors and the alarm circuit

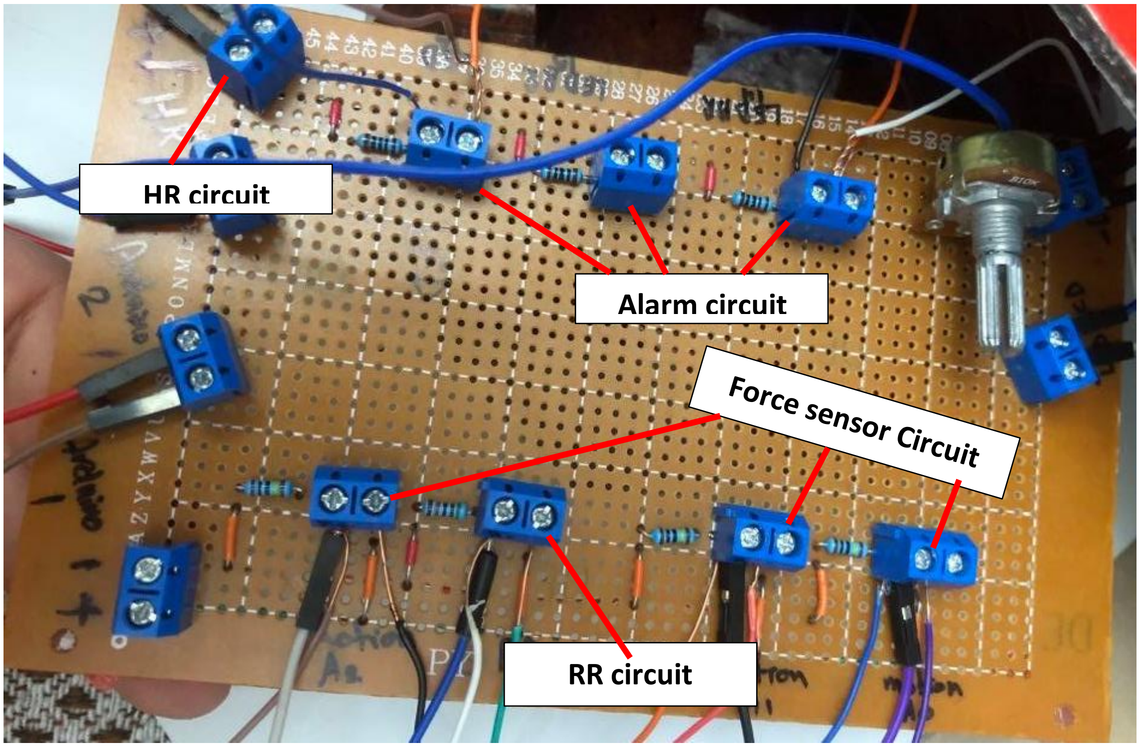


**Figure 5.1** main board

## 5.2 Force sensor circuit

The force sensors are used for count the patient movement during sleep by fixed the sensors on a shirt and depends on patient weight when he move then send the signal to the Arduino “2” to analysis the data.

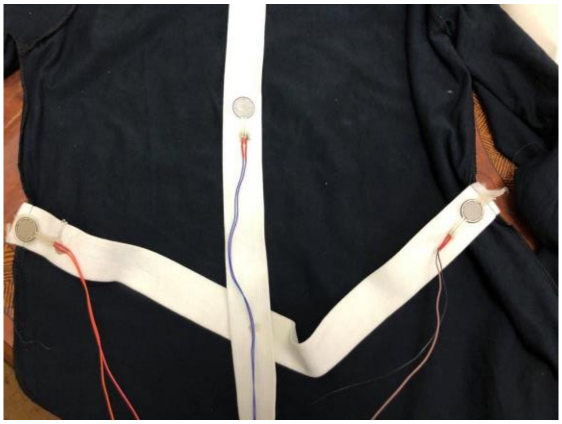

**Figure 5.2** Force sensors

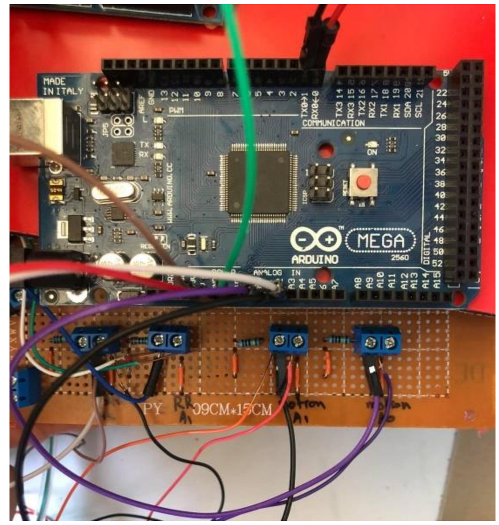


**Figure 5.3** Force sensors Connections with Arduino”2”

## 5.3 Heart Rate sensor circuit

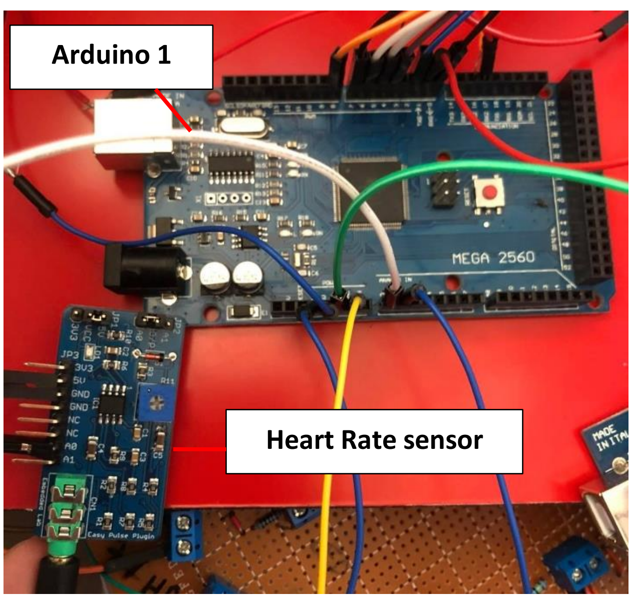


**Figure 5.4** Heart rate sensor connection with Arduino”1”

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## 5.4 Respiration Rate sensor circuit

The respiration rate was calculated by thermistor sensor by fixed the thermistor inside a mask and by the temperature of the inhale and exhale of patient's breathing.

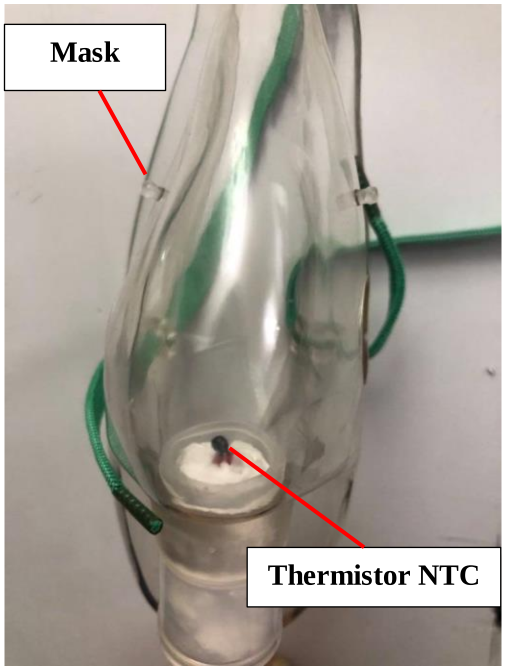


**Figure 5.5** Thermistor with Mask

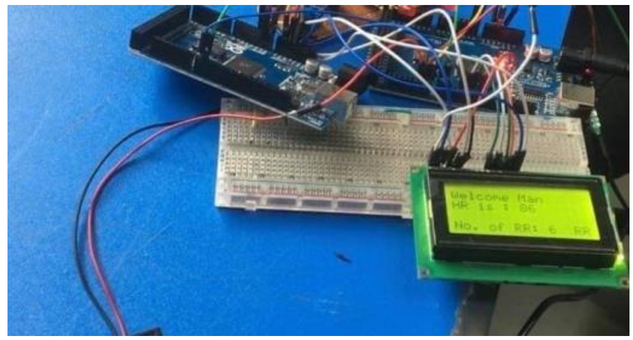

**Figure 5.6** Thermistor connection with Arduino"1"

### 5.4.1 Thermistor Simulation

The exhalation temperature is the same temperature of the human body (35c◦) and the inhalation temperature is the same of room temperature (25c◦), the table below show the resistance of the thermistor in inhalation and exhalation.

| Status | Temperature | Resistance |
|---|---|---|
| Inhalation | 25 c◦ | 47.000 kΩ |
| Exhalation | 35 c◦ | 30.334 kΩ |

**Table 5.1** the resistance of the thermistor in inhalation and exhalation.

## 5.5 LCD circuit

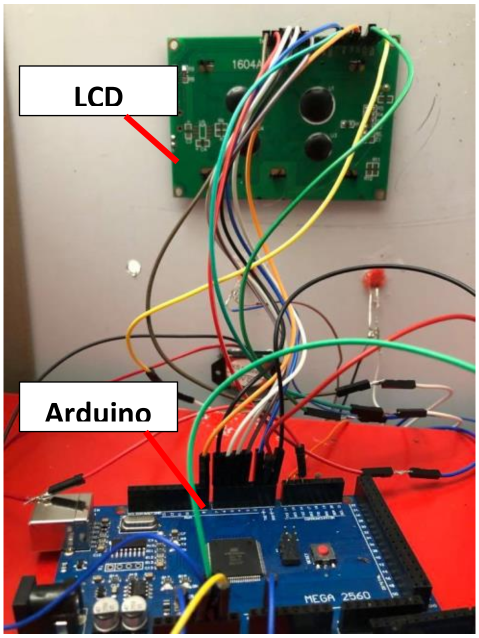


**Figure 5.7** LCD Connection with Arduino "1"

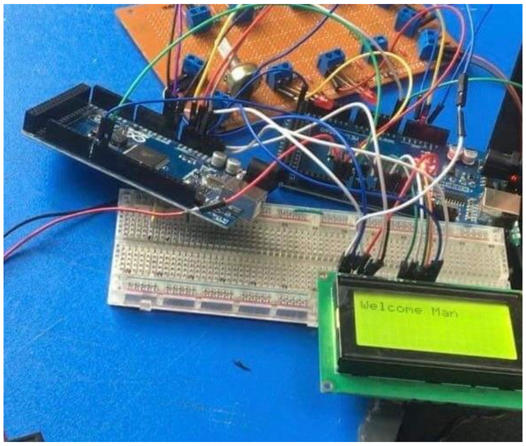


**Figure 5.8** LCD simulation

## 5.6 Alarm Circuit

The alarm circuit is used to caution the patient and his family that one or more of the parameters are abnormal.

The alarm circuit is made of buzzer and LEDs for each parameter.

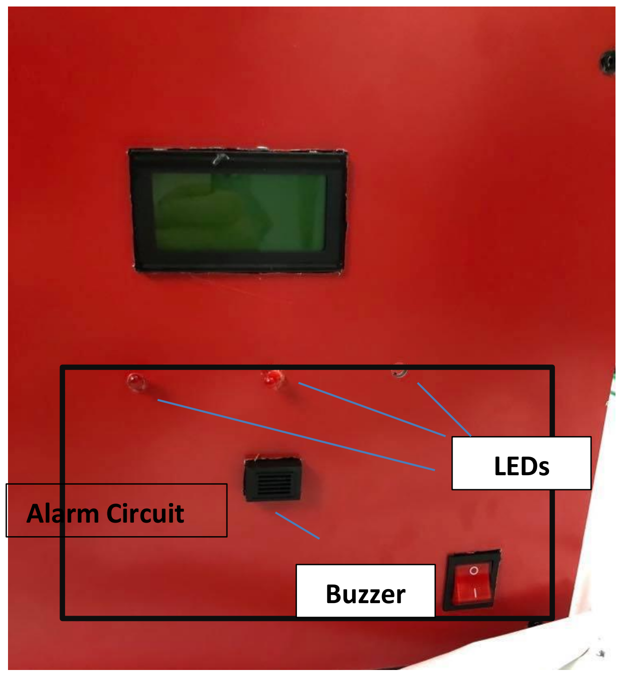


**Figure 5.9** LED's Connection .

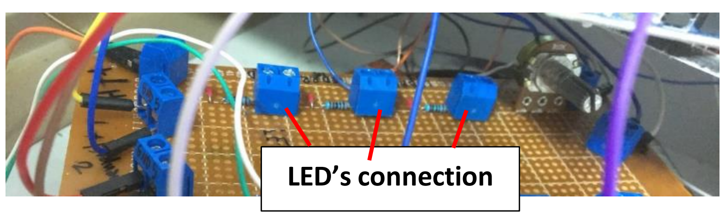


**Figure 5.10** LED's Connection.

## 5.7 Arduino Connections

The arduino is used for comparing the signal from the three sensors with the reference values and the arduinos are connected with each other in serial connection.

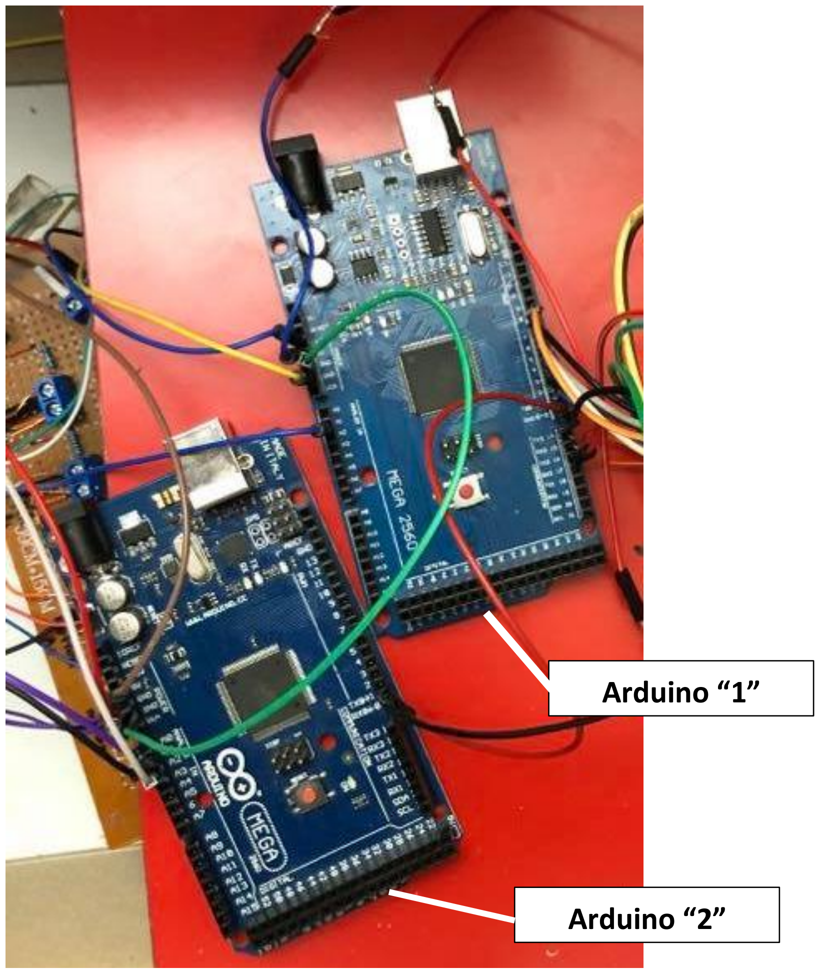


**Figure 5.11** Arduinos Connection.

# Chapter Six

Result Analysis and Conclusion

## 6.1 Results

After the project is installed, the readings are examined on nine persons; 6 of them have problems in each parameter. The result of all readings is approximately close to the real readings. Table 6.1 shows these readings:

| Person # | HR(per minuet) | RR(Per minuet) | MR(per 2 hours) | Alarm |
|---|---|---|---|---|
| #1 | 55 | 13 | 13 | on |
| #2 | 66 | 9 | 16 | on |
| #3 | 72 | 16 | 4 | on |
| #4 | 74 | 14 | 17 | off |
| #5 | 68 | 17 | 20 | off |
| #6 | 80 | 19 | 22 | off |
| #7 | 88 | 12 | 12 | on |
| #8 | 76 | 24 | 20 | on |
| #9 | 74 | 13 | 25 | off |

**Table 6.1** Table of the results

## 6.2 Challenges

Many challenges have been faced while designing the project:

- Not all required components are available in the Palestinian market; some of the components were imported from the outside of Palestine and late to arrive due to COVID-19.
- The batteries couldn't survive too much because it need a batteries have a special specifications.
- The connection of heart rate sensor, respiration sensor and the force sensor in the same Arduino cause the Arduino to receive data from heart rate sensor and respiration sensor

faster than the force sensor so it had to connect the force sensor on another Arduino by itself.

## 6.3 Conclusions

In this project, work has been done to monitor vital signs, as the heart rate and respiratory rate are among the most important vital signs in a person and monitoring them helps the doctor and the person in charge of the patient know where the problem is and to resort to the correct method to know how to deal with it, as well as monitoring movement is important as inactivity may cause ulcers and pain in the back area To not move and stay in the same position for a long time. After designing, processing, implementing and testing these sensors, the overall system can provide the following features:

- This system can detect any change abnormal in any signs using sensors.
- This system is small and lightly.
- This system is very simply for using don't need a specialist person.
- The device is non-invasive.
- The device is chaep.

## 6.4 Recommendation and Future Work

- Add more parameters such as Spo2 and body temperature.
- When one or more of the parameters is abnormal, send a text message to the hospital emergency or one of the patient’s family.
- Add a small ventilator to the device for patients who can’t breathe.

## References


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# APPENDIX

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## Datasheets

# APPENDIX A

----------------------------------------------------------------------

Datasheet of Force Sensor

INTERLINK ELECTRONICS
Sensor Technologies

# FSR 402 Data Sheet

**FSR 400 Series Round Force Sensing Resistor**

## Description

Interlink Electronics FSR™ 400 series is part of the single zone Force Sensing Resistor™ family. Force Sensing Resistors, or FSRs, are robust polymer thick film (PTF) devices that exhibit a decrease in resistance with increase in force applied to the surface of the sensor. This force sensitivity is optimized for use in human touch control of electronic devices such as automotive electronics, medical systems, and in industrial and robotics applications.

The standard 402 sensor is a round sensor 18.28 mm in diameter. Custom sensors can be manufactured in sizes ranging from 5mm to over 600mm. Female connector and short tail versions can also be ordered.

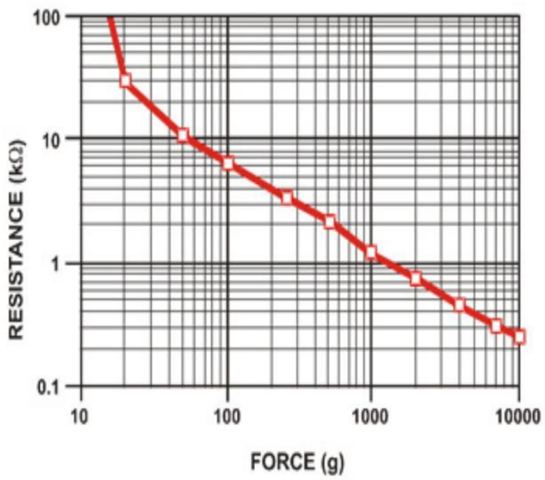
## Features and Benefits

- Actuation Force as low as 0.1N and sensitivity range to 10N.
- Easily customizable to a wide range of sizes
- Highly Repeatable Force Reading; As low as 2% of initial reading with repeatable actuation system
- Cost effective
- Ultra thin; 0.45mm
- Robust; up to 10M actuations
- Simple and easy to integrate

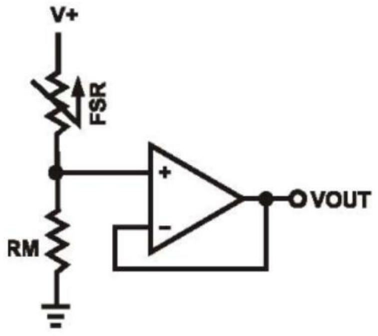
## Industry Segments

- Game controllers
- Musical instruments
- Medical device controls
- Remote controls
- Navigation Electronics
- Industrial HMI
- Automotive Panels
- Consumer Electronics

## Figure 1 - Force Curve




## Figure 2 - Schematic



INTERLINK ELECTRONICS
Sensor Technologies

# FSR 402
P/N: 30-81794

## Applications

**Detect & qualify press**
Sense whether a touch is accidental or intended by reading force

**Use force for UI feedback**
Detect more or less user force to make a more intuitive interface

**Enhance tool safety**
Differentiate a grip from a touch as a safety lock

**Find centroid of force**
Use multiple sensors to determine centroid of force

**Detect presence, position, or motion**
Of a person or patient in a bed, chair, or medical device

**Detect liquid blockage**
Detect tube or pump occlusion or blockage by measuring back pressure

**Detect proper tube positioning**

**Many other force measurement applications**

## Device Characteristics

| Feature | Condition | Value* | Notes |
|---|---|---|---|
| Actuation Force | | 0.1 Newtons | |
| Force Sensitivity Range | | 0.1 - 10.0[2] Newtons | |
| Force Repeatability[3] | (Single part) | ± 2% | |
| Force Resolution[3] | | continuous | |
| Force Repeatability[3] | (Part to Part) | ±6% | |
| Non-Actuated Resistance | | 10M W | |
| Size | | 18.28mm diameter | |
| Thickness Range | | 0.2 - 1.25 mm | |
| Stand-Off Resistance | | >10M ohms | Unloaded, unbent |
| Switch Travel | (Typical) | 0.05 mm | Depends on design |
| Hysteresis[3] | | +10% | $(R_{F+} - R_{F-})/R_{F+}$. |
| Device Rise Time | | <3 microseconds | measured w/steel ball |
| Long Term Drift | | <5% per $\log_{10}$(time) | 35 days test, 1kg load |
| Temp Operating Range | (Recommended) | -30 - +70 ºC | |
| Number of Actuations | (Life time) | 10 Million tested | Without failure |

* Specifications are derived from measurements taken at 1000 grams, and are given as one standard deviation / mean, unless otherwise noted.

1. Max Actuation force can be modified in custom sensors.
2. Force Range can be increased in custom sensors. Interlink Electronics have designed and manufactured sensors with operating force larger than 50Kg.
3. Force sensitivity dependent on mechanics, and resolution depends on measurement electronics.

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45-263-6501 Web:
www.interlinkelec.co.jp

**Korea**
Korea Sales Office Phone:
+82 10 8776 1972

# Application Information

FSRs are two-wire devices with a resistance that depends on applied force.

For specific application needs please contact Interlink Electronics support team. An integration guide is also available.

For a simple force-to-voltage conversion, the FSR device is tied to a measuring resistor in a voltage divider configuration (see Figure 3). The output is described by the equation:

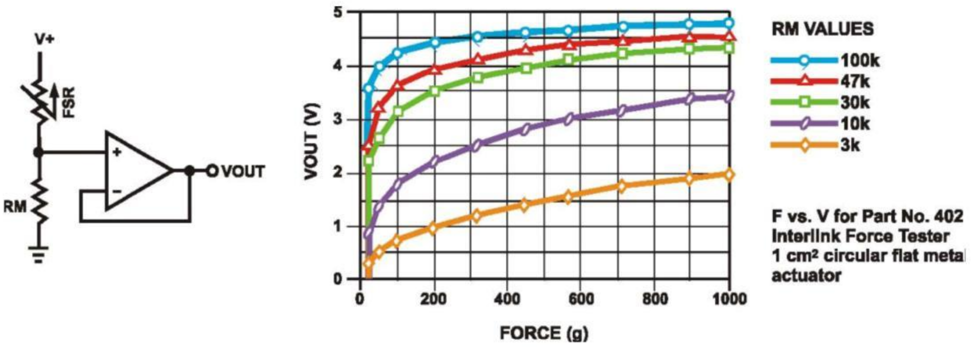
$$V_{OUT} = \left(\frac{R_M V+}{R_M + R_{FSR}}\right)$$

In the shown configuration, the output voltage increases with increasing force. If $R_{FSR}$ and $R_M$ are swapped, the output swing will decrease with increasing force.

The measuring resistor, $R_M$, is chosen to maximize the desired force sensitivity range and to limit current. Depending on the impedance requirements of the measuring circuit, the voltage divider could be followed by an op-amp.

A family of force vs. $V_{OUT}$ curves is shown on the graph below for a standard FSR in a voltage divider configuration with various $R_M$ resistors. A (V+) of +5V was used for these examples.

## Figure 3

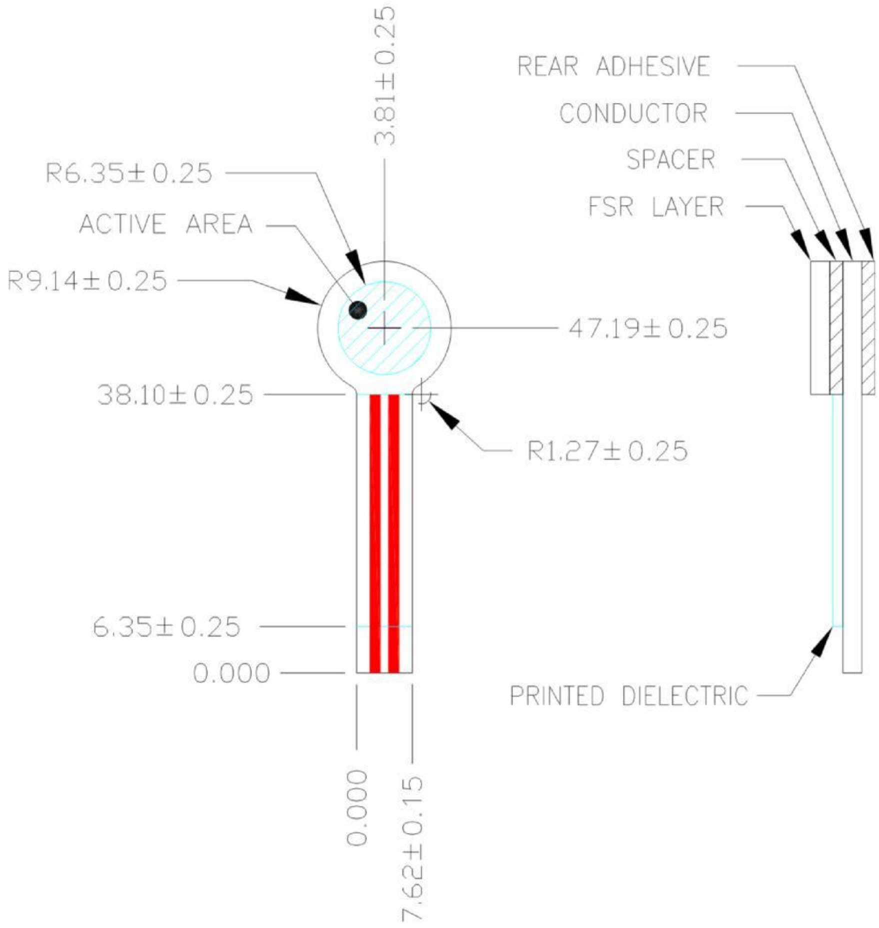


# FSR 402
P/N: 30-81794

## Part No. 402

- Active Area: 12.7mm
- Nominal thickness: 0.55 mm

## Mechanical Data



# APPENDIX B

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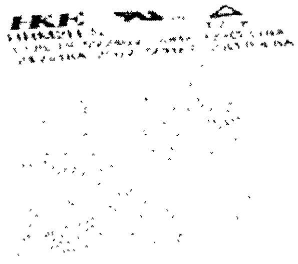
Datasheet of HRM-2511E Sensor

# HRM2(H) Relay



HRM2(H) Relay

## 1.COIL DATA

| | |
|---|---|
| 1-1.Nominal Voltage | 3 VDC to 48 VDC |
| 1-2.Coil Resistance | Refer to Table 1 |
| 1-3.Operate Voltage | Refer to Table 1 |
| 1-4.Release Voltage | Refer to Table 1 |
| 1-5.Nominal Power Consumption | 540 mW to 720 mW |

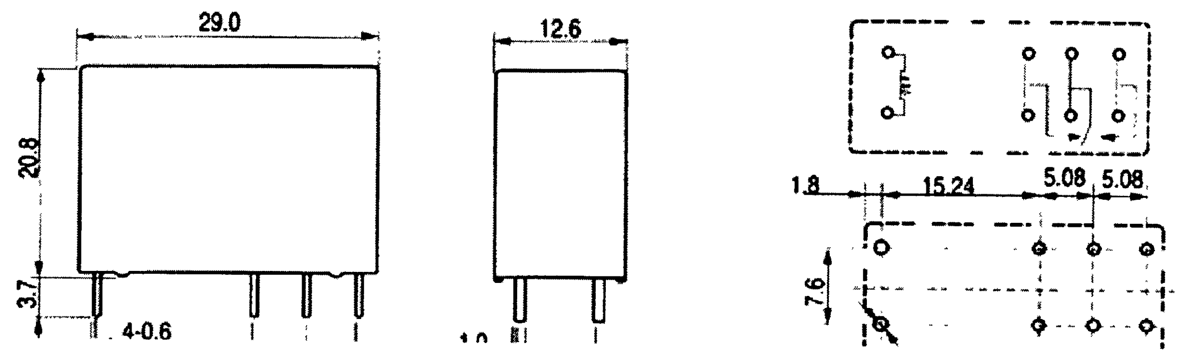
## 2.CONTACT DATA

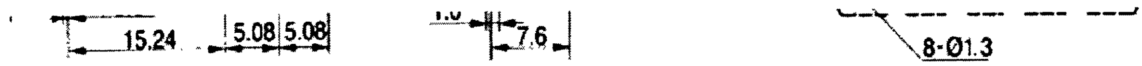
| | | |
|---|---|---|
| 2-1.Contact Arrangement | | 1 Form C , 1 Form A , 1 Form B |
| 2-2.Contact Material | | AgCdo |
| 2-3.Contact Rating | | Resistive Load : 16A 240VAC / 30VDC<br>Inductive Load : 8A 240VAD COS¦µ=0.4<br>8A 30VDC L/R=7ms |
| 2-4.Max. Switching Voltage | | 150 VDC / 250 VAC |
| 2-5.Max. Switching Current | | 16A |
| 2-6.Max. Switching Power | | 3840 VA , 480W |
| 2-7.Contact Resistance ( Initial ) | | 100 m¦¸. at 6 VDC 1A |
| 2-8.Life Expectancy | Electrical | 100,000 operations at nominal load<br>TV-8 120VAC<br>100,000 operations at COS¦µ=0.4 , L/R=7ms |
| | Mechanical | 10,000,000 operations |

## 3.GENERAL DATA

| | |
|---|---|
| 3-1.Insulation Resistance | Min.100M¦¸ at 500 VDC |
| 3-2.Dielectric Strength | 1,000VAC , 1min between open contacts<br>5,000VAC , 1min between contacts and coil |
| 3-3.Operate Time | Max. 15ms |
| 3-4.Release Time | Max. 8ms |
| 3-5.Temperature Range | -30 to +55 ¡æ (720 mW)<br>-30 to +70 ¡æ (540 mW) |
| 3-6.Shock Resistance | 10G |
| 3-7.Vibration Resistance | 10 - 55 Hz , Amplitude 1.5mm |
| 3-8.Weight | 13 gr. |
| 3-9.Safety Standard | UL NO. E164730<br>TUV NO. R 9859088 |

## 4.DIMENSIONS ( in mm )






i i

## 5.ORDERING CODE

**HRM2** **H-** **S** **DC 3V** **A** i i

- A — CONTACT ARRANGEMENT
  - **A**: 1 FORM A **B**: 1 FORM B **C**: 1 FORM C
- DC 3V — NOMINAL VOLTAGE:
  - DC3V , DC5V , DC6V , DC9V , DC12V , DC24V , DC
- S — ENCLOSURE
  - S ---- WASHABLE
- H- — COIL
  - NIL ---- STANDARD TYPE
  - H ------- HIGH SENSITIVE TYPE
- HRM2 — TYPE

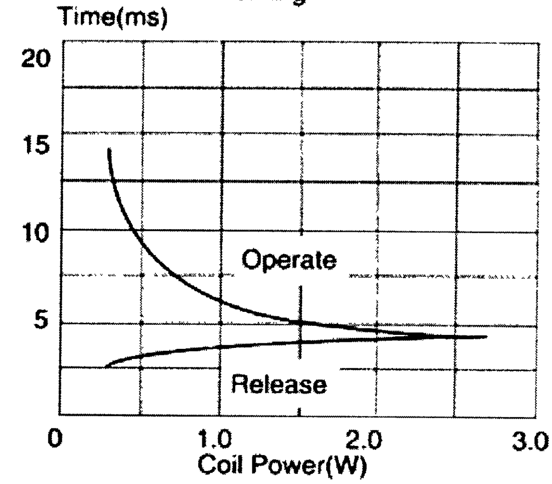
## 6.COIL DATA CHART

| ORDERING CODE | COIL NOMINAL VDC | COIL RESISTANCE ¦, +/- 10% | OPERATE VOLTAGE VDC | RELEASE VOLTAGE VDC | C NOM n |
|---|---|---|---|---|---|
| HRM2-S DC3V | 3 | 12.5 | 2.4 | 0.15 | |
| HRM2-S DC5V | 5 | 36 | 4.0 | 0.25 | |
| HRM2-S DC6V | 6 | 50 | 4.8 | 0.30 | |
| HRM2-S DC9V | 9 | 115 | 7.2 | 0.45 | 7 |
| HRM2-S DC12V | 12 | 200 | 9.6 | 0.6 | |
| HRM2-S DC24V | 24 | 820 | 19.2 | 1.20 | |
| HRM2-S DC48V | 48 | 3300 | 38.4 | 3.40 | |
| HRM2H-S DC3V | 3 | 17 | 2.4 | 0.15 | |
| HRM2H-S DC5V | 5 | 50 | 4.0 | 0.25 | |
| HRM2H-S DC6V | 6 | 68 | 4.8 | 0.30 | |
| HRM2H-S DC9V | 9 | 155 | 7.2 | 0.45 | 5 |
| HRM2H-S DC12V | 12 | 270 | 9.6 | 0.60 | |
| HRM2H-S DC24V | 24 | 1100 | 19.2 | 1.20 | |
| HRM2H-S DC48V | 48 | 4400 | 38.40 | 2.40 | |

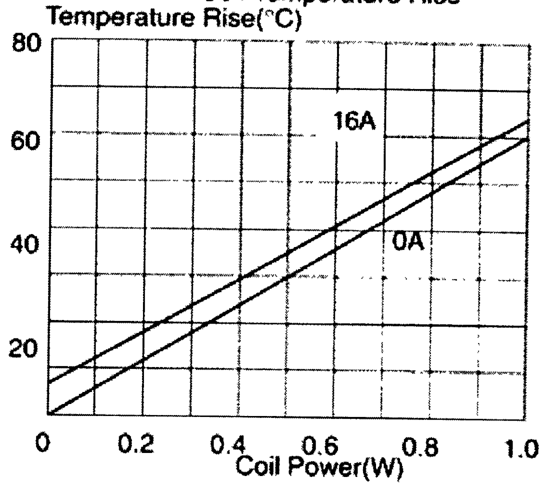
**Table 1**

## 7.HRM2(H) CHARACTERISTIC DATA

Timing

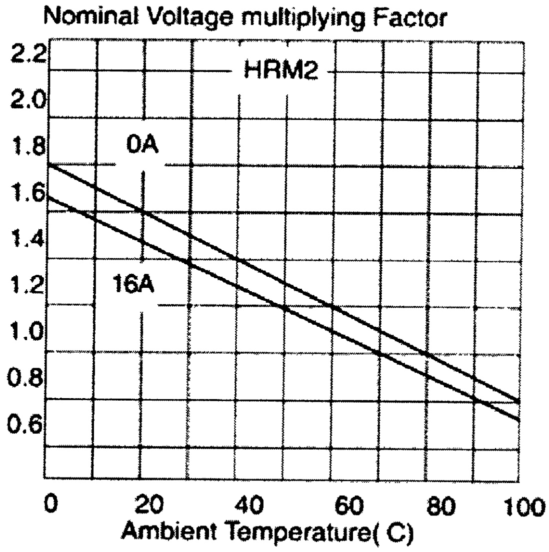



Coil Temperature Rise

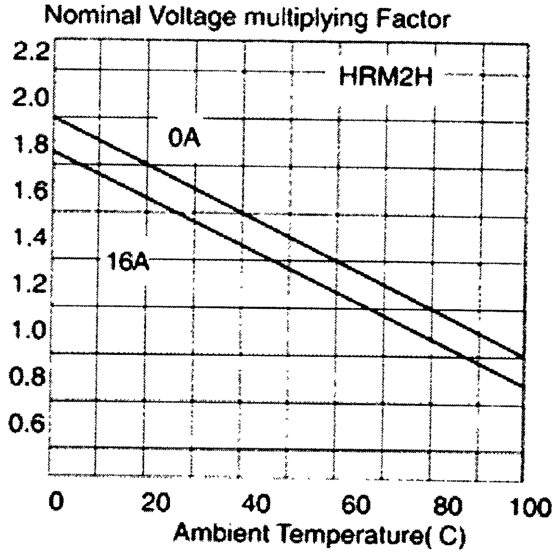



ii

Operating Range

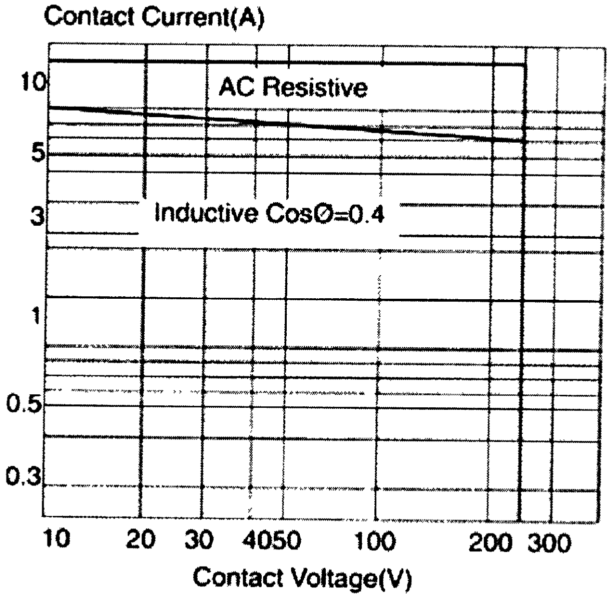



Operating Range

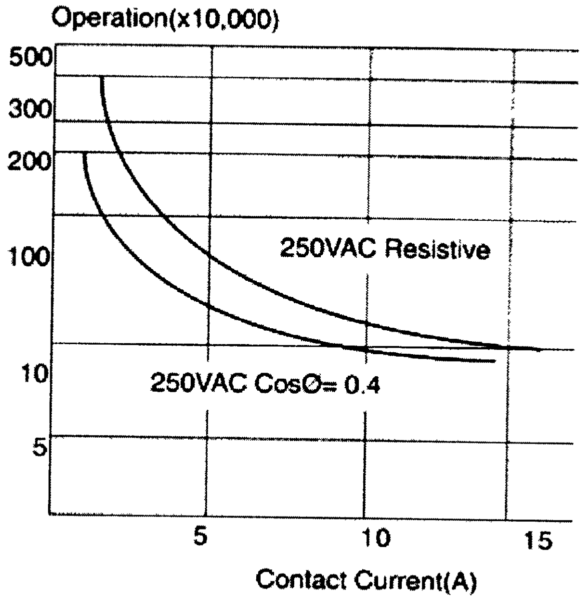



ii ii

Maximum Switching Power




Life Curve



# APPENDIX C

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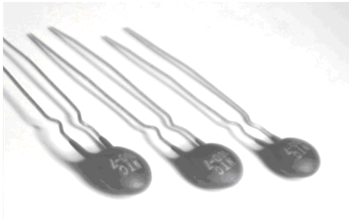
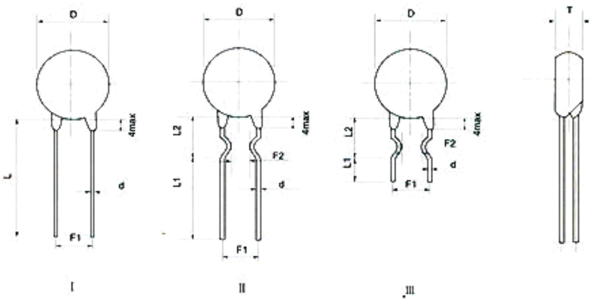
**Datasheet of Thermistor Sensor**

# PT Series –Power Type NTC Thermistor






unit：mm

PT series NTC thermistor has to be connected in series to the power source circuit to avoid the surge current at the instant when the electronic circuits are turned on. The device can effectively suppress the surge current, and its resistance and power consumption can be greatly reduced after that through the continuous effect of the current so as not to affect the normal work current. Therefore the Power NTC thermistor is the most convenient and efficient instrument to curb the surge current and protect the electronic devices from being damaged.

## FEATURES

·Strong power and strong capability of surge current protection.
·Characteristics Fast response to the rapidly surge.
·Big material constant(B value),Small remain resistance.
·High reliability.
··Integral series, Extensive operating range.
·Operating Temp. -55℃～+200℃

## APPLICATION

switching power supply ·UPS power supply,
·electric heaters · electronic energy-saving lamps
·filament protection of color tubes
·incandescent lamps and other lights. ·electronic ballasts

## Part Number Identification

| NTC | _ | □ | D□ |
|---|---|---|---|
| ① | | ② | ③ |

| ① | | ② | | ③ | |
|---|---|---|---|---|---|
| | | 25℃ resistance | | Max. Dia. | |
| NTC | POWER NTC Thermistor | 5 | 5Ω | D5 | 5mm |
| | | 33 | 33Ω | D11 | 11mm |
| | | 120 | 120 Ω | D13 | 13mm |

## Electronic parameter Specification

| Part No. | R25℃ (Ω) | Max.Steady State Current （A） | Approx.R @ Max.Cur （Ω） | Dissipation factor (δ)(mW/℃) | Thermal time constant (s) |
|---|---|---|---|---|---|
| NTC-5D5 | 5 | 1 | 0.353 | 6 | 20 |
| NTC-10D5 | 10 | 0.7 | 0.771 | 6 | 20 |
| NTC-60D5 | 60 | 0.5 | 1.878 | 6 | 18 |
| NTC-200D5 | 200 | 0.1 | 6.259 | 6 | 18 |
| NTC-5D7 | 5 | 2 | 0.283 | 10 | 30 |
| NTC-8D7 | 8 | 1 | 0.539 | 9 | 28 |
| NTC-10D7 | 10 | 1 | 0.616 | 9 | 27 |
| NTC-12D7 | 12 | 1 | 0.816 | 9 | 27 |
| NTC-16D7 | 16 | 0.7 | 1.003 | 9 | 27 |
| NTC-22D7 | 22 | 0.6 | 1.108 | 9 | 27 |
| NTC-33D7 | 33 | 0.5 | 1.485 | 10 | 28 |
| NTC-200D7 | 200 | 0.2 | 6.233 | 11 | 28 |
| NTC-3D9 | 3 | 4 | 0.120 | 11 | 35 |
| NTC-4D9 | 4 | 3 | 0.190 | 11 | 35 |
| NTC-5D9 | 5 | 3 | 0.210 | 11 | 34 |
| NTC-6D9 | 6 | 2 | 0.315 | 11 | 34 |
| NTC-8D9 | 8 | 2 | 0.400 | 11 | 32 |
| NTC-10D9 | 10 | 2 | 0.458 | 11 | 32 |
| NTC-12D9 | 12 | 1 | 0.652 | 11 | 32 |
| NTC-16D9 | 16 | 1 | 0.802 | 11 | 31 |
| NTC-20D9 | 20 | 1 | 0.864 | 11 | 30 |
| NTC-22D9 | 22 | 1 | 0.950 | 11 | 30 |
| NTC-30D9 | 30 | 1 | 1.022 | 11 | 30 |
| NTC-33D9 | 33 | 1 | 1.124 | 11 | 30 |
| NTC-50D9 | 50 | 1 | 1.252 | 11 | 30 |

| | | | | | |
|---|---|---|---|---|---|
| NTC-60D9 | 60 | 0.8 | 1.502 | 11 | 30 |
| NTC-80D9 | 80 | 0.8 | 2.010 | 11 | 30 |
| NTC-120D9 | 120 | 0.8 | 3.015 | 11 | 30 |
| NTC-200D9 | 200 | 0.5 | 5.007 | 11 | 32 |
| NTC-400D9 | 400 | 0.2 | 9.852 | 11 | 32 |
| NTC-2.5D11 | 2.5 | 5 | 0.095 | 13 | 43 |
| NTC-3D11 | 3 | 5 | 0.100 | 13 | 43 |
| NTC-3D11 | 3 | 5 | 0.100 | 13 | 43 |
| NTC-4D11 | 4 | 4 | 0.150 | 13 | 44 |
| NTC-5D11 | 5 | 4 | 0.156 | 13 | 45 |
| NTC-6D11 | 6 | 3 | 0.240 | 13 | 45 |
| NTC-8D11 | 8 | 3 | 0.255 | 14 | 47 |
| NTC-10D11 | 10 | 3 | 0.275 | 14 | 47 |
| NTC-12D11 | 12 | 2 | 0.462 | 14 | 48 |
| NTC-16D11 | 16 | 2 | 0.470 | 14 | 50 |
| NTC-20D11 | 20 | 2 | 0.512 | 15 | 52 |
| NTC-22D11 | 22 | 2 | 0.563 | 15 | 52 |
| NTC-30D11 | 30 | 1.5 | 0.667 | 15 | 52 |
| NTC-33D11 | 33 | 1.5 | 0.734 | 15 | 52 |
| NTC-50D11 | 50 | 1.5 | 1.021 | 15 | 52 |
| NTC-3D11 | 3 | 5 | 0.100 | 13 | 43 |
| NTC-4D11 | 4 | 4 | 0.150 | 13 | 44 |
| NTC-5D11 | 5 | 4 | 0.156 | 13 | 45 |
| NTC-6D11 | 6 | 3 | 0.240 | 13 | 45 |
| NTC-8D11 | 8 | 3 | 0.255 | 14 | 47 |
| NTC-10D11 | 10 | 3 | 0.275 | 14 | 47 |
| NTC-12D11 | 12 | 2 | 0.462 | 14 | 48 |
| NTC-16D11 | 16 | 2 | 0.470 | 14 | 50 |
| NTC-20D11 | 20 | 2 | 0.512 | 15 | 52 |
| NTC-22D11 | 22 | 2 | 0.563 | 15 | 52 |
| NTC-30D11 | 30 | 1.5 | 0.667 | 15 | 52 |
| NTC-33D11 | 33 | 1.5 | 0.734 | 15 | 52 |
| NTC-50D11 | 50 | 1.5 | 1.021 | 15 | 52 |
| NTC-60D11 | 60 | 1.5 | 1.215 | 15 | 52 |
| NTC-80D11 | 80 | 1.2 | 1.656 | 15 | 52 |
| NTC-1.3D13 | 1.3 | 7 | 0.062 | 13 | 60 |
| NTC-1.5D13 | 1.5 | 7 | 0.073 | 13 | 60 |
| NTC-2.5D13 | 2.5 | 6 | 0.088 | 13 | 60 |
| NTC-3D13 | 3 | 6 | 0.092 | 14 | 60 |
| NTC-4D13 | 4 | 5 | 0.120 | 15 | 67 |
| NTC-5D13 | 5 | 5 | 0.125 | 15 | 68 |
| NTC-6D13 | 6 | 4 | 0.170 | 15 | 65 |

| | | | | | |
|---|---|---|---|---|---|
| NTC-7D13 | 7 | 4 | 0.188 | 15 | 65 |
| NTC-8D13 | 8 | 4 | 0.194 | 15 | 60 |
| NTC-10D13 | 10 | 4 | 0.206 | 15 | 65 |
| NTC-12D13 | 12 | 3 | 0.316 | 16 | 65 |
| NTC-15D13 | 15 | 3 | 0.335 | 16 | 60 |
| NTC-16D13 | 16 | 3 | 0.338 | 16 | 60 |
| NTC-20D13 | 20 | 3 | 0.372 | 16 | 65 |
| NTC-30D13 | 30 | 2.5 | 0.517 | 16 | 65 |
| NTC-47D13 | 47 | 2 | 0.810 | 17 | 65 |
| NTC-120D13 | 120 | 1.5 | 2.124 | 16 | 65 |
| NTC-1.3D15 | 1.3 | 8 | 0.048 | 18 | 68 |
| NTC-1.5D15 | 1.5 | 8 | 0.052 | 19 | 69 |
| NTC-3D15 | 3 | 7 | 0.075 | 18 | 76 |
| NTC-5D15 | 5 | 6 | 0.112 | 20 | 76 |
| NTC-6D15 | 6 | 5 | 0.155 | 20 | 80 |
| NTC-7D15 | 7 | 5 | 0.173 | 20 | 80 |
| NTC-8D15 | 9 | 5 | 0.178 | 20 | 80 |
| NTC-10D15 | 10 | 5 | 0.180 | 20 | 75 |
| NTC-12D15 | 12 | 4 | 0.250 | 20 | 75 |
| NTC-15D15 | 15 | 4 | 0.268 | 21 | 85 |
| NTC-16D15 | 16 | 4 | 0.276 | 21 | 70 |
| NTC-20D15 | 20 | 4 | 0.288 | 17 | 86 |
| NTC-30D15 | 30 | 3.5 | 0.438 | 18 | 75 |
| NTC-47D15 | 47 | 3 | 0.680 | 21 | 86 |
| NTC-120D15 | 120 | 2.5 | 1.652 | 22 | 87 |
| NTC-0.7D20 | 0.7 | 12 | 0.018 | 25 | 112 |
| NTC-1.3D20 | 1.3 | 9 | 0.037 | 24 | 113 |
| NTC-3D20 | 3 | 8 | 0.055 | 24 | 113 |
| NTC-5D20 | 5 | 7 | 0.087 | 23 | 112 |
| NTC-6D20 | 6 | 6 | 0.113 | 25 | 114 |
| NTC-8D20 | 8 | 6 | 0.142 | 25 | 115 |
| NTC-10D20 | 10 | 6 | 0.162 | 24 | 113 |
| NTC-12D20 | 12 | 5 | 0.195 | 24 | 114 |
| NTC-16D20 | 16 | 5 | 0.212 | 25 | 113 |
| NTC-0.7D25 | 0.7 | 13 | 0.014 | 30 | 151 |
| NTC-1.5D25 | 1.5 | 10 | 0.027 | 30 | 152 |
| NTC-3D25 | 3 | 9 | 0.044 | 32 | 150 |
| NTC-5D25 | 5 | 8 | 0.070 | 32 | 151 |
| NTC-8D25 | 8 | 7 | 0.114 | 33 | 151 |
| NTC-10D25 | 10 | 7 | 0.130 | 32 | 150 |
| NTC-12D25 | 12 | 6 | 0.156 | 32 | 150 |
| NTC-16D25 | 16 | 6 | 0.160 | 35 | 152 |

## Dimension

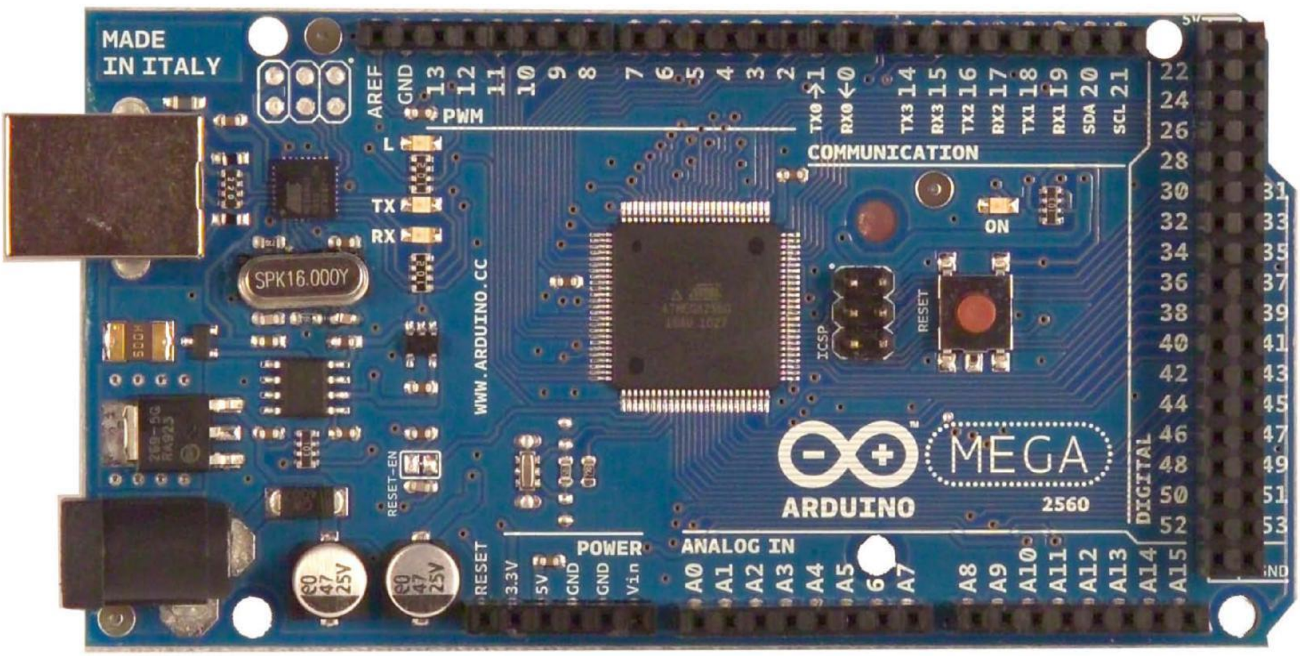
| | D +1 -2 | Tmax | d±0.05 | F 1 ±1 | F 2 ±1.5 | Straight lead | Bending lead | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Lmin | b L 1 min | L 2 ±2 |
| NTC-□D5 | 6.5 | 5 | 0.6/0.45 | 5/2.5 | 3 | 25 | 17/5 | 8 |
| NTC-□D7 | 8.5 | 5 | 0.6 | 5 | 3 | 25 | 17/5 | 8 |
| NTC-□D9 | 10.5 | 5.5 | 0.8/0.6 | 7.5/5 | 5/3 | 25 | 17/5 | 8 |
| NTC-□D11 | 12.5 | 5.5 | 0.8 | 7.5/5 | 5/3 | 25 | 17/5 | 8 |
| NTC-□D13 | 14.5 | 6 | 0.8 | 7.5 | 5 | 25 | 17/5 | 8 |
| NTC-□D15 | 16.5 | 6 | 0.8 | 10/7.5 | 5 | 25 | 17/5 | 8 |
| NTC-□D20 | 21.5 | 7 | 1.0 | 10/7.5 | / | 25 | / | / |
| NTC-□D25 | 26.5 | 8 | 1.0 | 10 | / | 25 | / | / |

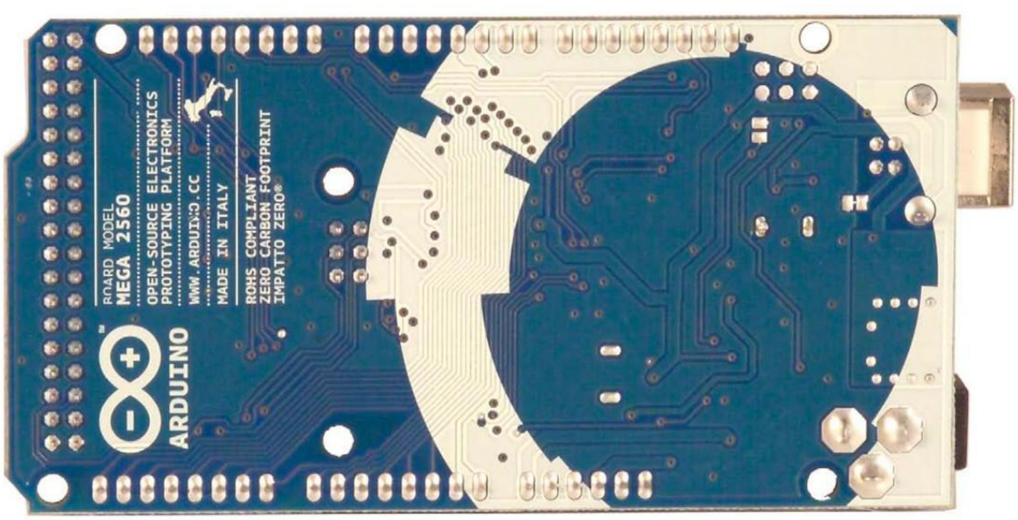
# APPENDIX D

---

Datasheet of Mega microcontroller

# Arduino Mega 2560





## Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

## Schematic & Reference Design

EAGLE files: arduino-mega2560-reference-design.zip

Schematic: arduino-mega2560-schematic.pdf

## Summary

| | |
|---|---|
| Microcontroller | ATmega2560 |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limits) | 6-20V |
| Digital I/O Pins | 54 (of which 14 provide PWM output) |
| Analog Input Pins | 16 |
| DC Current per I/O Pin | 40 mA |
| DC Current for 3.3V Pin | 50 mA |
| Flash Memory | 256 KB of which 8 KB used by bootloader |
| SRAM | 8 KB |
| EEPROM | 4 KB |
| Clock Speed | 16 MHz |

## Power

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

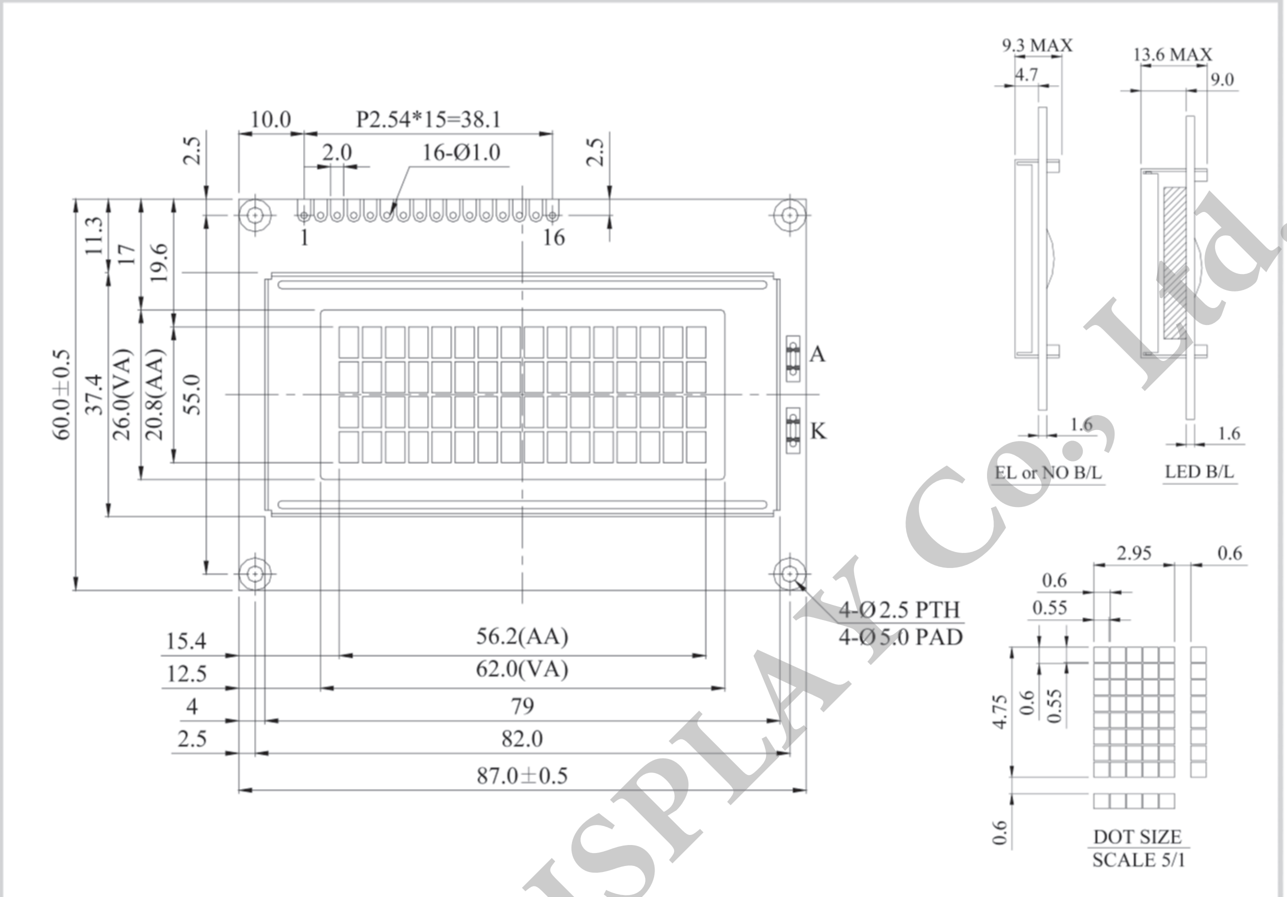
The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

# APPENDIX E

---

Datasheet of LCD

# **WH1604A** Character 16x4




## Feature

1.5x8 dots includes cursor
2.Bulit-in controller (ST7066 or Equivalent)
3.5V power supply ( Also available for 3V)
4.N.V, optional for 3V power supply
5.1/16 duty cycle
6.LED can be driven by PIN1, PIN2, PIN15, PIN16 or A and K
7.Interface : 6800, option SPI/I2C (RW1063 IC)

| Pin No. | Symbol | Description |
|---|---|---|
| 1 | $V_{SS}$ | Ground |
| 2 | $V_{DD}$ | Power supply for logic |
| 3 | $V_{O}$ | Contrast Adjustment |
| 4 | RS | Data/ Instruction select signal |
| 5 | R/W | Read/Write select signal |
| 6 | E | Enable signal |
| 7 | DB0 | Data bus line |
| 8 | DB1 | Data bus line |
| 9 | DB2 | Data bus line |
| 10 | DB3 | Data bus line |
| 11 | DB4 | Data bus line |
| 12 | DB5 | Data bus line |
| 13 | DB6 | Data bus line |
| 14 | DB7 | Data bus line |
| 15 | A | Power supply for B/L + |
| 16 | K | Power supply for B/L - |

## Mechanical Data

| Item | Standard Value | Unit |
|---|---|---|
| Module Dimension | 87.0 x 60.0 | mm |
| Viewing Area | 62.0 x 26.0 | mm |
| Mounting Hole | 82.0 x 55.0 | mm |
| Character Size | 2.95 x 4.75 | mm |

## Electrical Characteristics

| Item | Symbol | Standard Value | Unit |
|---|---|---|---|
| | | typ. | |
| Input Voltage | VDD | 3/5 | V |
| Recommended LCD Driving Voltage for Normal Temp. Version module @25ºC | VDD-VO | 4.35 | V |

## Display Character Address Code

| Display position | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DD RAM Address | 00 | 01 | | | | | | | | | | | | | | 0F |
| DD RAM Address | 40 | 41 | | | | | | | | | | | | | | 4F |
| DD RAM Address | 10 | 11 | | | | | | | | | | | | | | 1F |
| DD RAM Address | 50 | 51 | | | | | | | | | | | | | | 5F |

# APPENDIX F

---

**Datasheet of Red LED**

ELECTRONICS, INC.
44 FARRAND STREET
BLOOMFIELD, NJ 07003
(973) 748−5089
http://www.nteinc.com

# NTE3019
# Light Emitting Diode (LED)
# Red Diffused, 5mm

**Features:**
- Tapered Barrel T−1 3/4 Package
- High Intensity Red light source with various lens colors and effects
- Versatile Mounting on PC Board or Panel
- T−1 3/4 with Stand−off

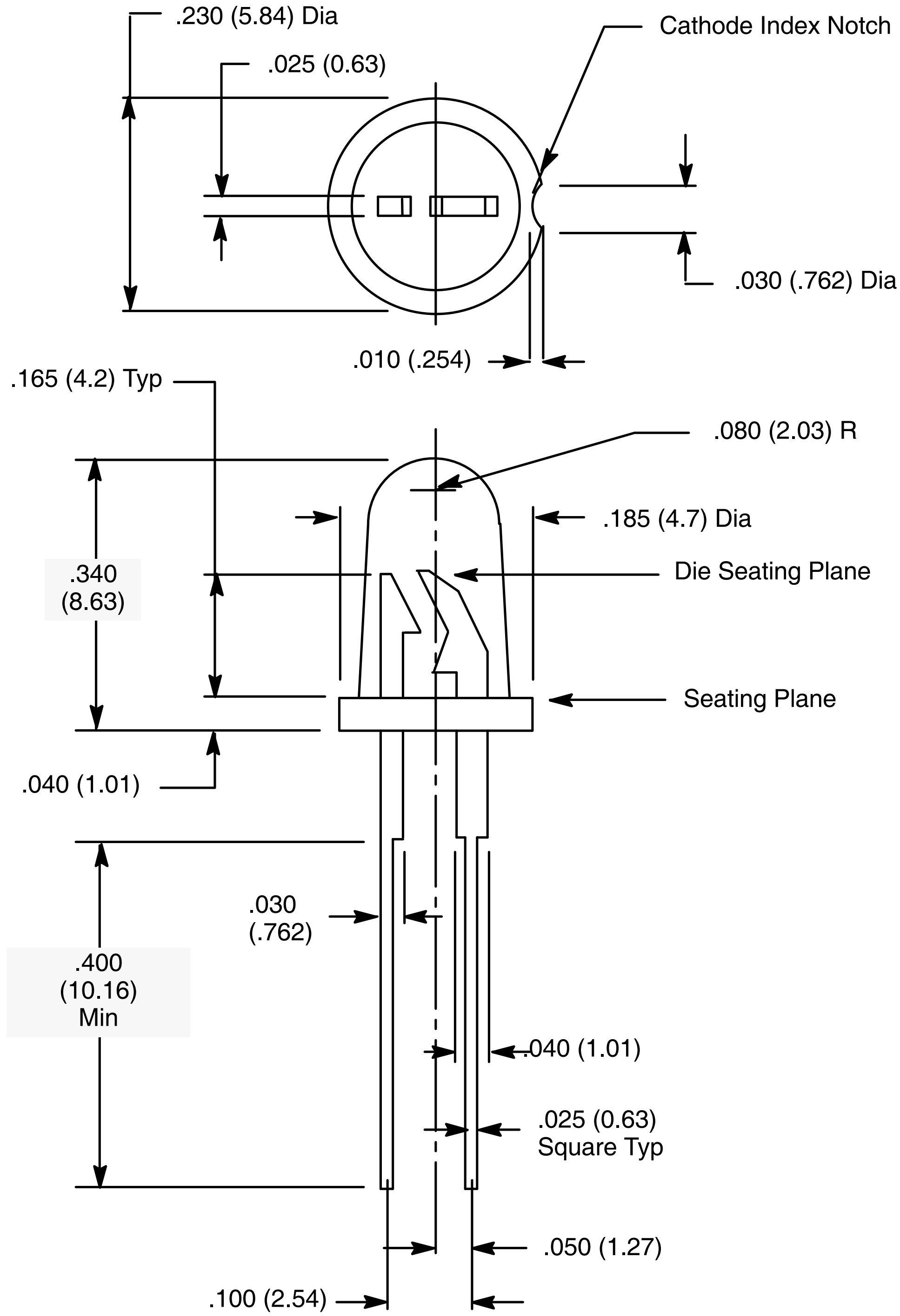
**Absolute Maximum Ratings:** ($T_A$ = +25°C unless otherwise specified)

Reverse Voltage, $V_R$ . . . . . . . . . . . . 5V
Peak Forward Current (Note 1, $I_F$ . . . . . . . . . . . . 1A
Power Dissipation ($T_A$ = +25°C), $P_D$ . . . . . . . . . . . . 180mW
Derate linearly from 25°C . . . . . . . . . . . . 2mW/°C
Operating Temperature Range, $T_{opr}$ . . . . . . . . . . . . −55° to +100°C
Storage Temperature Range, $T_{stg}$ . . . . . . . . . . . . −55° to +100°C
Lead Temperature (During Soldering, 1/16" (1.6mm) from case, 5sec max), $T_L$ . . . . . . . . . . +260°C

Note 1. Pulse Width = 1μs, 0.3% duty cycle.

**Electrical Characteristics:** ($T_A$ = +25°C unless otherwise specified)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Luminous Intensity | $I_V$ | $I_F$ = 20 mA | 0.9 | 3.0 | – | mcd |
| Peak Wavelength | $\lambda_p$ | $I_F$ = 20 mA | – | – | 660 | nm |
| Spectral Line Half Width | $\Delta\lambda$ | $I_F$ = 20 mA | – | 20 | – | nm |
| Forward Voltage | $V_F$ | $I_F$ = 20 mA | – | 1.65 | 2.0 | V |
| Reverse Current | $I_n$ | $V_R$ = 5.0V | – | – | 100 | λA |
| Reverse Voltage | λA | $I_R$ = 100 λA | – | 5.0 | – | V |
| Capacitance | C | V = 0 | – | 35 | – | pF |
| Viewing Angle | 2θ1/2 | Between 50% Points | – | 60 | – | degree |
| Rise Time | $t_r$ | 10% – 90% 50Ω | – | 50 | – | ns |
| Fall Time | $t_f$ | 90% – 10% 50Ω | – | 50 | – | ns |



.230 (5.84) Dia
.025 (0.63)
Cathode Index Notch
.030 (.762) Dia
.010 (.254)
.165 (4.2) Typ
.080 (2.03) R
.185 (4.7) Dia
.340
(8.63)
Die Seating Plane
Seating Plane
.040 (1.01)
.030
(.762)
.400
(10.16)
Min
.040 (1.01)
.025 (0.63)
Square Typ
.050 (1.27)
.100 (2.54)

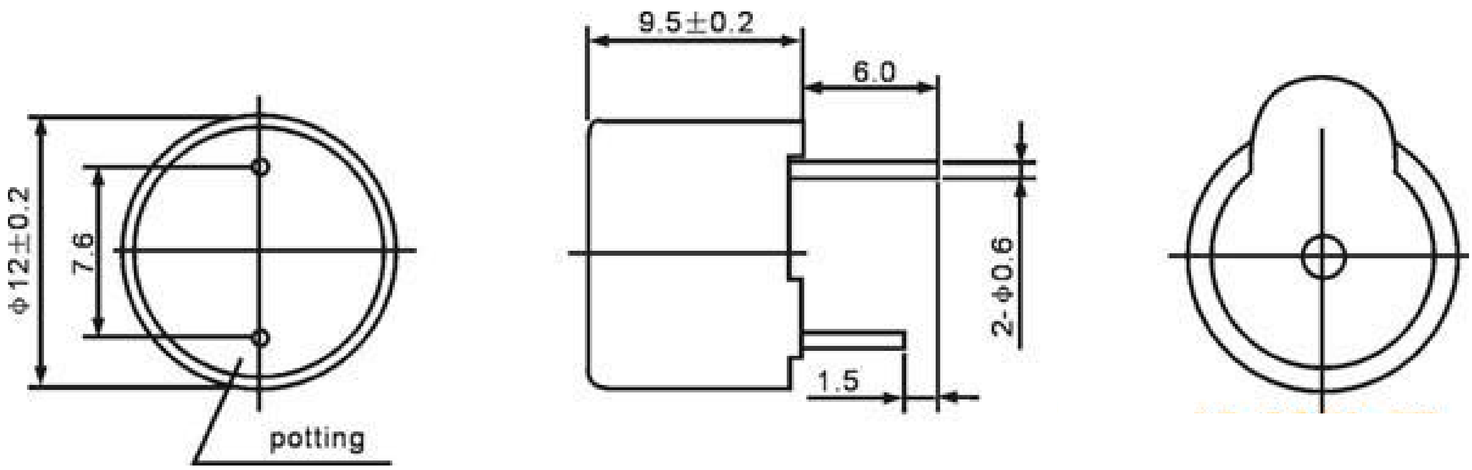
# APPENDIX G

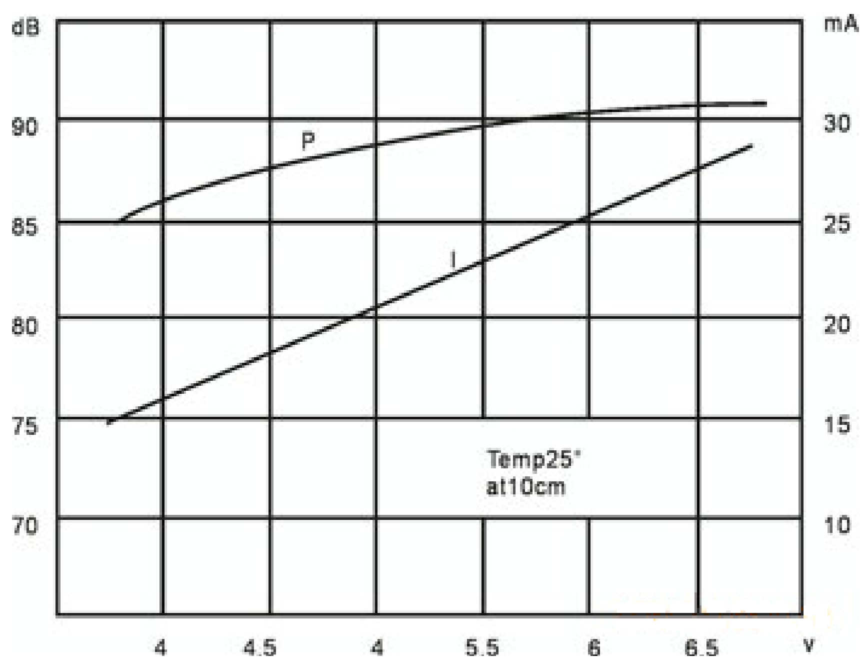
---

Datasheet of TMB12A05 Buzzer

TMB12A05 Buzzer Datasheet

| 型 号<br>Type | TMB-12A01 | TMB-12A03 | TMB-12A05 | TMB-12A12 |
|---|---|---|---|---|
| 额定电压(V)<br>Rated Voltage | 1. 5 | 3 | 5 | 12 |
| 电压范围(V)<br>Opcration Voltage | 1. 2～2. 5 | 2. 5～4 | 4～7 | 8～15 |
| 额定电流(mA)<br>Rated Current | ≤20 | ≤35 | ≤30 | ≤20 |
| 声压电平(dB)<br>Sound Output | ≥80 | ≥82 | ≥85 | ≥85 |
| 谐振频率(Hz)<br>Resonant Freq | 2300±500 | 2300±500 | 2300±500 | 2300±500 |
| 工作温度(℃)<br>Operating Temp | −20～+60 | −20～+60 | −20～+60 | −20～+60 |
| 储存温度(℃)<br>Storage Temp | −20～+70 | −20～+70 | −30～+85 | −30～+85 |
| 重 量(g)<br>Weight | 2 | 2 | 2 | 2 |



# APPENDIX H

---

**Arduino Code**

```
#include <LiquidCrystal.h> // includes the LiquidCrystal Library
LiquidCrystal lcd(8, 2, 4, 5, 6, 7); // Creates an LC object. Parameters:
(rs, enable, d4, d5, d6, d7) (1, 2, 4, 5, 6, 7)




//A0 analog pin for HR
//A1 analog pin for RR
int m;
int adc;
boolean counter;
int count;
int z;
unsigned long millisBefore;
unsigned long beatTime=20000; // HR minute time
const int threshold=500; // HR threshold
int ThermistorPin = 0;
int Vo; //
float R1 = 10000;
float logR2, R2, T;
float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;
int count2=0; //thermistor counter
unsigned long millisBefore2;
unsigned long beatTime2=20000; //thermistor minute time
const int threshold2=545; //thermistor threshold
int p=0; // to enter the loop of heart rate
int k=1; // to enter the loop of thermistor
int incomingByte = 0;
int y;




void setup() {
  // put your setup code here, to run once:

  counter = true;
  millisBefore = millis();

    // set up the LCD's number of columns and rows:
  lcd.begin(16, 4);
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Welcome Man"); // Prints "Arduino" on the LCD
  Serial.begin(9600);
    delay(5000);
 // lcd.clear();
    //lcd.print("Welcome");
```

```
}
void loop() {
   Serial.begin(9600);
    // lcd.noBlink();
  // lcd.setCursor(0,0);
  //lcd.print("Firas");
  // delay(10000);


    while (p==0){


   // Serial.println(adc);
    //delay(10);
     if ((millis() - millisBefore) < beatTime) {
      adc = analogRead(A0);
      delay(10);
     if (counter == true) {
      if (adc >= threshold) {
        count++;
        counter = false;
        Serial.print("Beat : ");
        Serial.println(count);
      }
    }
    if (adc < threshold) {
      counter = true;
    }
    if (adc==0){
      count=0;
      }

     } else {
    m=count*3;
   // Serial.print(m);
   // Serial.println(" BPM");
    //lcd.clear();
  //  if (y==0){

      //delay(3000);
     // y=1;
     // }

    lcd.setCursor(0, 1);
    lcd.print("HR is :");
    lcd.setCursor(8, 1);
    lcd.print(m);
    //delay(10000);
    count=0;
    k=0;
    millisBefore = millis();
    p=1;
```

```
    }
    }

//delay(3000);

          // if (Serial.available() > 0) {
          //  incomingByte = Serial.read();
           // lcd.setCursor(0, 2);
          //  lcd.print("Motion is :");
           // lcd.setCursor(12, 2);
          //  lcd.print(incomingByte);
          //  //Serial.print("Moyion is ");
          // // Serial.println(incomingByte);
          //  Serial.end();
            //delay(1000);

          // }









         while (k==0){


          if ((millis() - millisBefore) < beatTime2) {
           Vo = analogRead(A1);
         // Serial.print('\n');
          //Serial.print(Vo);
          //delay(500);
           if (Vo > threshold2){

           count2++;
           delay(3000);


          }

            }

       else {


          z=count2*3;
         Serial.print(count2);
         Serial.println(" RR");
         //lcd.clear();
         lcd.setCursor(0, 3);
         lcd.print("No. of RR:");
         lcd.setCursor(11, 3);
```

```
        lcd.print(z);
        lcd.setCursor(14, 3);
        lcd.print("RR");

        count2=0;
        p=0;
        millisBefore = millis();
        k=1;


       }

     }






           delay(1000);


Serial.begin(9600);
          if (Serial.available() > 0) {
           incomingByte = Serial.read();
           lcd.setCursor(0, 2);
           lcd.print("Motion is :");
           lcd.setCursor(12, 2);
           lcd.print(incomingByte);
           //Serial.print("Moyion is ");
          // Serial.println(incomingByte);
           Serial.end();
           //delay(1000);

           }






   }
```

```
// Flexiforce quick start example
// Reads A0 every 100ms and sends voltage value over serial

#include <LiquidCrystal.h> // includes the LiquidCrystal Library
LiquidCrystal lcd(1, 2, 4, 5, 6, 7); // Creates an LC object. Parameters:
(rs, enable, d4, d5, d6, d7) (1, 2, 4, 5, 6, 7)


int a; // sensor of the right side
int b; // sensor of the mid
int c; // sensor of the left side
```

```
int q=0; // constant value for right side
int w=0; // constant value for mid side
int e=0; // constant value for ledt side
int r=1; // constant 2 for right side
int t=1; // constant 2 for mid side
int y=1; // constant 2 for left side
int n;
int totalcouner;
int motionthreshold =400;
unsigned long millisBefore;
unsigned long motionTime=180000;
int counter=0;
void setup()
{

  lcd.begin(16, 4);
  lcd.clear();
  lcd.setCursor(0,1);
  lcd.print("Arduino"); // Prints "Arduino" on the LCD

  // Start serial at 9600 baud
  Serial.begin(9600);
  millisBefore = millis();

//delay(5000);
  lcd.clear();


}

    void loop()
{


Serial.begin(9600);



  // Read the input on analog pin 0:
    a = analogRead(A0);
    b = analogRead(A1);
    c = analogRead(A2);


    if(a > motionthreshold){

      q=1;

      //Serial.println("right");
      lcd.clear();
      lcd.setCursor(2, 2);
      lcd.print("Right side");

       }
```

```
   else if(b > motionthreshold){

     w=1;
//  Serial.println("mid");
     lcd.clear();
     lcd.setCursor(2, 2);
     lcd.print("Mid side");

     }

   else if(c > motionthreshold ){

     e=1;

     //Serial.println("left");

     lcd.clear();
     lcd.setCursor(2, 2);
     lcd.print("Left side");

     }

     while(q==1){

       a = analogRead(A0);
       b = analogRead(A1);
        c = analogRead(A2);

     if ((millis() - millisBefore) < motionTime) {


      if (a > motionthreshold){

      while(r==1){
       counter++;
       t=1;
       y=1;
       r=0;
       //Serial.println("firas");
        }

         }

       else if (b > motionthreshold){

         while (t==1){

           counter++;
           r=1;
           y=1;
           t=0;
           //Serial.println("firas2");
           }
```

```
        }

     else if (c > motionthreshold){

        while (y==1){

          counter++;
          r=1;
          t=1;
          y=0;

         }

       }

    }

    else {

// Serial.println(" number of motion :");
     totalcouner=totalcouner+counter;
    //Serial.print(counter);
    lcd.clear();
    lcd.setCursor(1, 1);
    lcd.print("No of Motion");
    lcd.setCursor(2, 2);
    lcd.print(counter);
    Serial.begin(9600);
    Serial.write(totalcouner);
    Serial.end();
   // while(n==0){

     //if (Serial.availableForWrite() >0){

   //   Serial.write(counter);
     // Serial.end();
     // n=1;

     // }

     // }

   // n=0;

   // delay(1000);

   counter=0;
  millisBefore = millis();



      }
```

```
 }


  while(w==1){

  Serial.begin(9600);
  a = analogRead(A0);
  b = analogRead(A1);
  c = analogRead(A2);

if ((millis() - millisBefore) < motionTime) {


 if (b > motionthreshold){

 while(r==1){
  counter++;
  t=1;
  y=1;
  r=0;
  //Serial.println("firas");
   }

    }

  else if (a > motionthreshold){

    while (t==1){

      counter++;
      r=1;
      y=1;
      t=0;
      //Serial.println("firas2");
      }

    }

 else if (c > motionthreshold){

    while (y==1){

      counter++;
      r=1;
      t=1;
      y=0;

     }

   }

}

else {
```

```
//Serial.println(" number of motion :");
  totalcouner=totalcouner+counter;
// Serial.print(counter);
  lcd.clear();
  lcd.setCursor(1, 1);
  lcd.print("No of Motion");
  lcd.setCursor(2, 2);
  lcd.print(counter);
  Serial.begin(9600);
  Serial.write(totalcouner);
  Serial.end();
    //  while(n==0){

 //  if (Serial.availableForWrite() >0){

  //  Serial.write(counter);
   // Serial.end();
   // n=1;

    //}

   // }

 // n=0;
 // delay(1000);


 counter=0;
millisBefore = millis();



    }



    }



    while(e==1){


    Serial.begin(9600);
    a = analogRead(A0);
    b = analogRead(A1);
    c = analogRead(A2);

  if ((millis() - millisBefore) < motionTime) {


   if (c > motionthreshold){
```

```
  while(r==1){
   counter++;
   t=1;
   y=1;
   r=0;
   //Serial.println("firas");
    }

     }

   else if (b > motionthreshold){

     while (t==1){

       counter++;
       r=1;
       y=1;
       t=0;
       //Serial.println("firas2");
       }

     }

  else if (a > motionthreshold){

     while (y==1){

       counter++;
       r=1;
       t=1;
       y=0;

      }

    }


 }

 else {

//Serial.println(" number of motion :");
 totalcouner=totalcouner+counter;
 //Serial.print(counter);
 lcd.clear();
  lcd.setCursor(1, 1);
  lcd.print("No of Motion");
  lcd.setCursor(2, 2);
  lcd.print(counter);
  Serial.begin(9600);
  Serial.write(totalcouner);
  Serial.end();
   //   while(n==0){
```

```
      // if (Serial.availableForWrite() >0){

      //  Serial.write(counter);
       // Serial.end();
       // n=1;

       // }

       // }

      //n=0;
      //delay(1000);


     counter=0;
    millisBefore = millis();



        }


        }


}
```