DESIGN OF A MICROCONTROLLER DEVICE FOR HUMAN HEALTH MONITORING

A THESIS SUBMITTED TO
THE FACULTY OF ARCHITECTURE AND ENGINEERING
OF
EPOKA UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
ELECTRONICS AND DIGITAL COMMUNICATION ENGINEERING

FEBRUARY, 2024

Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **“Design of a microcontroller device for human health monitoring”** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

DESIGN OF A MICROCONTROLLER DEVICE FOR HUMAN HEALTH MONITORING

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One of the most critical issues that indicates the quality of life and the efficiency of the life of a human is the periodic monitoring of health. In this project, the aim is the development of an innovative microcontroller-based system that gives the possibility for an advanced and personalized health monitoring system. With the upturn of chronic diseases and the hopeless need for early detection and possibly the prevention of them, health monitoring has become a principal topic for new research and studies. The technology is one of the biggest helpers even on our health journey. This time technology is the biggest data collector of sequential data, helping in the identification of even the smallest health issues.

Throughout the development of this project, the aim is to donate as much as we can to the advancement of human health surveillance technology and provide a better comprehension of the connection between health parameters and health technology. We are looking forward to a positive outcome of this project, which may remarkably help in the avocation of the diagnosis and a personalized journey of health supervising, leading to a more qualitative life and health of individuals. Consequently, this research will have a positive influence on the increase of health monitoring overall, helping all those affected by health difficulties.

Keywords: *Health monitoring, microcontroller, chronic disease, heart rate, pulmonary system, cardiovascular system, Arduino Uno*

ABSTRAKT

PROJEKTIMI I NJË PAJISJES MIKROKONTROLLIKE PËR MONITORIMIN E SHËNDETIT TË NJERIUT

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Udhëheqësi: Assoc. Prof. Dr. Arban Uka

Një nga problemet kritike që ndikon në cilësinë dhe efikasitetin e jetës së një njeriu është monitorimi periodik i shëndetit. Qëllimi i këtij projekti është të zhvillojmë një sistem inovativ duke përdorur mikrokontrollera, i cili na jep mundësinë për të zhvilluar një sistem të avancuar dhe të personalizuar për të monitoruar shëndetin. Me rritjen e sëmundjeve kronike dhe nevojën e pa shpresë për zbulim të hershëm dhe mundësinë për ti parandaluar ato, monitorimi i shëndetit është bërë një temë për të zhvilluar punë kërkimore dhe studimore të reja. Kësaj here, teknologjia është mbledhësi i madh i të dhënave të vazhdueshme, duke ndihmuar në identifikimin edhe të problemeve më të vogla shëndetësore.

Gjatë gjithë zhvillimit të këtij projekti, synohet të dhurojmë sa më shumë për avancimin e teknologjisë së mbikëqyrjes së shëndetit njerëzor dhe të sigurojmë një kuptim më të mirë të lidhjes midis parametrave shëndetësorë dhe teknologjisë shëndetësore. Presim një rezultat pozitiv të këtij projekti, i cili do të ndihmojë në mënyrë të jashtëzakonshme në avokimin e diagnozës dhe një udhëtim të personalizuar të mbikëqyrjes shëndetësore, duke çuar në një jetë dhe shëndet me cilësor të individeve. Rrjedhimisht, kërkimi do të ndikojë pozitivisht në rritjen e monitorimit shëndetësor në përgjithësi, duke ndihmuar të gjithë ata që janë të prekur nga vështirësitë shëndetësore.

Fjalë kyce: *Monitorimi i shëndetit, mikrokontroller, sëmundje kronike, rrahjet e zemrës, sistemi pulmonar, sistemi kardiovaskular, Arduino Uno*

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor, Dr. Arban Uka who has guided me and helped me during my whole cycle of study years. Without his continuous help and encouragement, the goal of this research master thesis wouldn’t have been reached. Thank you for your advice and for motivating me.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Health issues have always been one of the biggest challenges over centuries, the early detection of any kind of disease or even the slightest changes in the body have prevented even deaths, leading the health science world to a pre-detection of the constant body changes. This has brought us to the invention of the monitoring systems of health. In this evolved world chronic diseases, are the most difficult to observe by doctors in person. This project aims to go beyond the simple concept of monitoring and binging on the table to a new way of monitoring it.

With the use of an innovative system using microcontrollers, this project will offer each individual a personalized way of monitoring their health mainly taking into consideration each change of the system based on their needs. That would not be just another simple technique system, it would be a trustworthy partner for each individual that will take care of preventing the evolution of a disease in its early phases.

Health monitoring is not only another aspect of the health issue system-it is an increment of quality for each one's daily life. In this new area that is ruled by technology, there are hundreds of ways to build new personalized systems serving each of us and different age groups of course.

1.2 Motivation

The decision for this topic was made taking into consideration some reasons as listed below. Good health is the biggest treasure for us all as individuals but also as a community. Health care is a key integral aspect of people's well-being and quality of life. For this reason, is important to find and evolve with new innovative ways to monitor and protect our health. The increase in chronic illnesses like diabetes and hypertension has increased the value of health surveillance making it even more critical. Technology offers us powerful tools for managing all of it. The advancement of technology and the availability of sophisticated electronic devices and microcontrollers has opened up new opportunities to monitor and have everything under our surveillance and control.

1.3 Aim and Objectives

This project is an attempt not only to contribute to healthcare improvements but also to technology, knowing the challenges and the importance of the well-being of each of us not only as individuals but also as a community. Through technology will be working forward on a detailed scientific approach to advancing this important aspect.

Regardless of the huge technological development that we are all aware of, that has brought to life different equipment to survey health, frequently can measure not more than one or two vital parameters. Even if it was the other way around the costs of the devices are high and obviously for the majority is not affordable at all. The lack of these devices is also the maintenance of the data, these do not keep a record of it so the measurements are only instantaneous, and it becomes difficult to keep track of the history of the disease. Given these problems, came the idea to give it a solution, practically to create a complex system that realizes the measurements of some of the body parameters, easily installed on the body, but above all, having the capability of saving all of the measured data. Data recording can be given to the doctors to witness the health progression helping in the early diagnosis of and constant maintenance of the illnesses.

Inside this project will be providing previous study cases for health monitoring, studying these devices and their functionalities, highlighting their positive and negative sides, of course, leading to the construction of our device. Follow up also with a detailed study of the human body organism which we will supervise. This will be a big help also for the hardware side of building the device, as well as for the software part that deals with programming the device. Knowing the anatomy, we are capable of distinguishing the parts of the body to establish and optimize the sensors for the highest results with accuracy.

The main focus of the project is the planning and the construction of a system that will implement sensors and microcontrollers even in other electronic systems which will be capable of monitoring some of the main health parameters, also being easy to use, and having a high accuracy.

The goal of this development is to be a valuable contribution to improving the quality of life and health and a big step towards a positive change in the way we monitor and take care of health. Using technology in a detailed scientific approach, we aim to help in the progress of an important aspect of monitoring health. This project has the potential to influence the quality of each day's living, hoping this will also have an impact on the society and well-being of each individual.

1.4 Organization of the Thesis

This thesis is divided into six main chapters where the first chapter is about the introduction of the idea of the whole project, its motivation and the whole aim of it. In the second chapter, we will proceed with similar study cases, analyzing the situation of how the sensors can be fitted with the human body. Different devices are spotted for more flexible daily use.

The third chapter focuses on vital processes like breathing and heart beating, each of them followed by the chronic diseases that are most common nowadays. The focus is to fully understand each of the processes and their complicity in order to interact with each of them.

In the fourth chapter, we will have a detailed introduction of and identification of the devices that will be used in the construction of the device. Analyzing the sensors and the microcontrollers in detail will make it easier for us to implement and conclude the result with the programming code.

The fifth chapter will be a representation of all our measurement outcomes including the detailed process of the operational way, including formulas. This will also be the conclusion of the first version of our device monitoring breathing frequency, body temperature, heartbeats, and oxygen levels in the blood.

The sixth chapter consists of concluding the steps of the development work. Surely a space for future work and guidance on the improvement of the device.

CHAPTER 2

INTRODUCTION

2.1 Similar study cases

The monitoring of parameters like the level of heartbeats, oxygen level in the blood (SpO2), breathing frequency, and body temperature is really important for the evaluation of the overall condition of a person's health. These parameters help in the identification of potential changes and symptoms of pathologies.

Monitoring these parameters mentioned above, are important for diagnosing and the follow-up of one's health. To be able to do this there are specialized devices that are used to monitor health, such as electronic thermometers used to measure body temperature, devices that are used to measure heartbeats and SpO2, as well as other applications for mobiles that help with breathing rate monitoring.

Technology innovation has made possible the construction of intelligent devices to measure all of these parameters and monitor all of them permanently.

This is important for identification of the possible changes in health at any time, so we can help prevent bigger issues. The equipment used for health monitoring is important for people with chronic health issues like arterial hypertension, diabetes, or any other health issue that needs constant monitoring that is classified as chronic. One case is a patient suffering from asthma, in this case is needed to keep track of their breathing frequency and oxygen level rushing on blood to identify their reactions through the medication used. The whole point of this chapter is to show us the ways of monitoring health parameters, which will help us with the construction of our device using microcontrollers that will be capable of measuring health parameters like heart rate, oxygen level in blood, breathing frequency, and body temperature.

2.2 Breathing monitoring

Breathing monitoring is one of the essential parameters of human health. But what is exactly breathing frequency? Breathing frequency is the calculation of the number of breath cycles that each individual completes within a specific arc of time, mostly measured in breaths per minute (bpm). This is a process that we usually forget that we are doing it so, it is automatic but essential. A normal breath frequency is mostly 12 to 20 breaths per minute. A high frequency or a lower one will be an alert for us that something is not on its proper routine. We have the information that a higher breath frequency which is estimated to be over 20 breaths per minute, can be an indicator of a high stress level, pulmonary diseases, heart diseases and many other ones. On the other hand, a low breathing frequency which varies between 4 to 10 breaths per minute can be an alert for asthma, sleep apnea and heart failure which lately has shown an indicative incensement.

In understanding the process of the breathing process and the breathing rate, we can notice how a life changer can early prevention of malfunctioning of the pulmonary system or the slight changes can affect the cure and the quality of the life of a person. So, breathing frequency is not just another number, but it is a window that is opened for us to better understand our health specifics and make important decisions to continuously be healthy.

Breathing monitoring through shirk of the diaphragm

A benefit that is in our favor is that the diaphragm contractions are easily detected (as shown in figure 1.1b) and the relax to create a device based on the pressure sensors. For example, researchers have used an electromechanical film (EMFit) to develop a breath rate sensor designed as a belt.

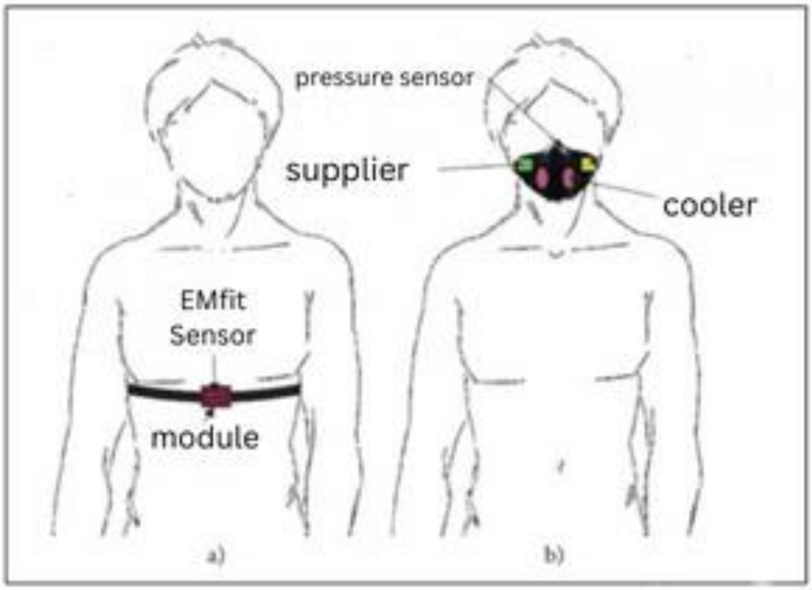


Figure 1. a) Usage of a pressure sensor to measure breathing b) The system development for the measurement of breathing impedance based on the forced oscillation technique

They connected the belt with the sensor in a way that, the moment the chest widens during the inhale process a force is applied on the sensor to produce a change in the proportional pressure. EMFit is a capacitive pressure sensor having a thin porous polypropylene film structure with a sensitivity of 30-170pC/N [1]

One other way to use the pressure sensor is their direct use in contact with the pressure of inhaled and exhaled air during breathing. The mask shown measures the resistance of the respiratory breathing and was targeted for home and clinical applications. The solution consists of two pressure transducers, two low-power fans, a set of field-programmable gates, and a real-time processing engine. The device is based on the technique of forced oscillations, which is a non-standard test of lung function. The idea is to use fans to introduce a periodic sinusoidal air pressure signal and measure the opposing force produced by the respiratory tract. [1]

EMFit sensor is less interventionist and performs better on the discovery of the rhythm of the breathing rate. However, body movements affect the measurement exactness, so the sensor worked better on the patients who had calmer movements or moderated ones. The mask sensor also performed better and appreciated the breathing resistance pleasantly. Still, that was a porotype and its usage was not pretty comfortable. [1]

2.3 Monitoring using strain sensors

The strain sensor is an additional less expensive alternative to the EMFit sensor. The sensor itself is made up of a thin metallic layer of piezo resistance placed over a silicone elastomer substrate. To increase the strain-related resistance, which forms the foundation of the sensing mechanism, the thin metal sheet is purposefully shattered. The thin film itself features hierarchical (nano- and micro-sized) wrinkle structures that operate as both strain-relieving and crack-propagation-controlling qualities, the sensor can have a greater dynamic range while maintaining sensitivity. The sensor design used in this study has a broad operating range; at maximum, it can cycle up to 2000 times and deliver an output between 156% and 226%. Even in the case when there is a considerable diffusion on the maximum length between the sensors, the failure point remains above the breathing interval measurement. The sensors that were specially used for the subject's testing exhibit a linear response (R2 to 0.96 and 1.0) with quantifiable variables that range from 0.85 to 2.64 at 40% strain.[2]

Strain sensors were positioned on the chest cavity and abdomen, similar to RIP, to monitor the expansion and contraction of the relevant tissues while breathing. The sensors measured just 21 mm by 10 mm by 0.5 mm, and their placement was perpendicular to each other to minimize crosstalk. A double-sided adhesive that has received FDA approval was used to affix the sensors to the skin. The tape was split with strain relief patterns to allow the sensor to sit flat with the skin because it is not inherently flexible.

In order to keep the sensor from completely separating from the body skin when it is compressed, the ends of the sensor were adhered to the skin, and a single piece of double-sided adhesive tape was affixed with a strap across the middle of the sensor. As a result, the sensor could bend and stretch with the skin. Medical tape was used to secure the sensor's wires and ends. [2]

The spirometer (blue circle) was placed in the mouth and held in place using a strap; a nasal plug was used to prevent breathing through the nose. Strain sensors (gray rectangles) were placed perpendicular to each other on the chest and abdomen.

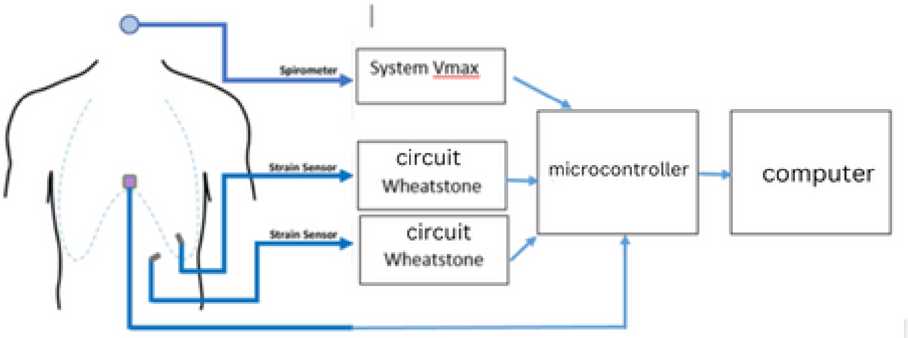


Figure 2. Hardware configuration scheme for human test

Right below the sternum was where the accelerometer (Purple Square) was positioned. Spirometry was used to monitor airflow, which was then processed by the Vmax Encore system and delivered in real-time to one of the digital acquisition system's analog inputs. Using 4.7 kΩ resistors, two Wheatstone bridges were utilized to determine the resistance. The digital acquisition system immediately measured the accelerometer's output. [2]

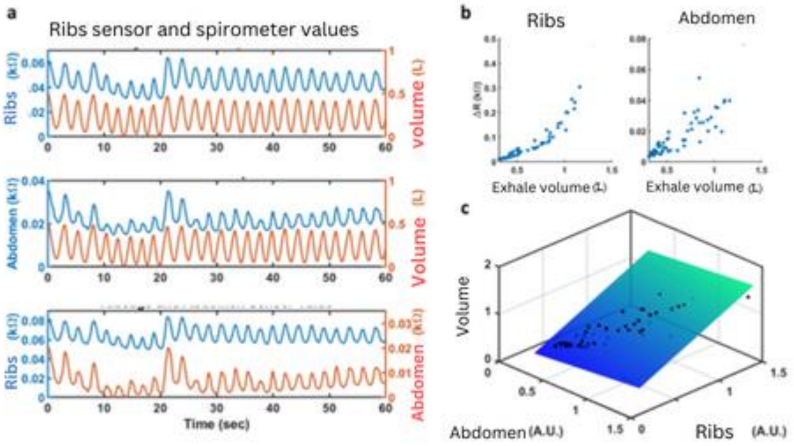


Figure 3. Data acquisition and processing

The voltage obtained by strain sensors in the belly (middle) and ribcage (top) are shown against simultaneous tidal volume as representative examples. The graph below displays the sensor resistances for the chest and abdomen together. To make waveforms easier to see, they are offset and shrunk down. Plotting the resistance change (ΔR) for the strain sensors in the abdomen (right) and thorax (left) against the extracted volume represents their distribution.

Plotting the 3D distribution of transformed ΔR for the thorax and abdomen versus the ejection volume also displays the best-fit plan. [2]

2.4 Ways to monitor heartbeats

The heart is one of the core organs of the living process, our heart pumps blood in our body and secures oxygen distribution to all the needed systems and other organs, as with all the other substances and vitamins that are needed for our cells to proceed with the living process. The speed of the contractions is regulated by its electrical system. The rhythm of the heartbeats is the number of heart shots measured in one minute that has a great impact on our body. The monitoring of the heartbeat is an important component of maintaining and understanding our body’s responses better.

Heart rate monitors are well-known devices that are often found on wearable technology, such as fitness trackers and smartwatches. Many of these gadgets are networked via waves with computers and smartphones as well. This makes it simpler for consumers to update their data at any moment. The following are typical uses for heart rate monitors:

- Following the heartbeat rhythm during the workout
- Monitoring of the stress level during workouts and the day
- Observation of sleep during the night
- Monitoring the signs of life at home, especially when having certain disturbances

Pulse and the heartbeat are two different ways to keep track of your heart activity.

Usually, there is no difference between heartbeats or pulses (or at least the difference is too small). However, some health conditions, drugs, or other conditions can make it more difficult the disclose the pulse in your arms. This can intervene in the ways these devices work.

The term “monitoring heart rate” refers to the devices that can discover the heart rates or pulses. These devices are used in two different ways:

- Electric (electrocardiography): your heart generates a small electric current in each heartbeat. Monitors that are used for the heartbeat with the ability of the electric discovery can track that current.

- Optical (photoplethysmogram): these devices use infrared light to look to see the extension of the heart arteries whereas the heart pumps blood through them. These devices follow the rhythm of your pulse and some of them can evaluate the oxygen level in your blood. [3]

2.5 Blood oxygen level monitoring

The oxygen levels in the blood are another main aspect of the well-functioning of the human body and it is also the expression of the percentage of hemoglobin which is united with the oxygen that is transported to each cell of the body. This parameter known also as SpO2, is an important indicator for overall health and helps in the evaluation of the quality of breathing and supplying oxygen all the body. In this study, we will consider the importance of the measurement of the oxygen levels in the blood.

Measuring SpO2 is an easy way and accessible to control your health. Household devices of the SpO2 will allow you to measure the oxygen level in the blood at home and you will understand how your respiratory system is working. This is important to identify level changes of the oxygen that can be related to certain possible health problems, which can be pulmonary or cardiovascular.

Low levels of oxygen in the blood, otherwise known as hypoxia, are disturbing and can cause serious health problems. Devices that are used to measure SpO2 help identify the first phases of the hypoxia. This can help in the prevention of serious complications and taking the necessary medical actions.

Patients who suffer from a chronic respiratory complication, like asthma or COPD (Chronic obstructive pulmonary disease), should monitor their oxygen blood level regularly. Measuring SpO2 can help them to evaluate how the treatment they are using is indicating and help them understand when they need more oxygen or added medicals.

This helps the doctors and nurses to make fast decisions on the right treatments.In exceptional situations, taking into consideration the COVID-19 pandemic, measuring devices of SpO2 were the main devices to monitor the large population's health. The usage of this can be a big help in the early discovery of the possible cases of hypoxia and monitoring their evolution.

After all, measuring levels of oxygen that are found in the blood is an important mechanism for our health evaluation. This parameter is an indicator of how our respiratory system is functioning and how good is our oxygen supply, and helping in identifying the other deregulations of the body in an earlier phase. The usage of SpO2 is important for our personal health and monitoring process of any kind of irregularity that one has during hospitalization.

Oxygen levels in the blood are measured by the same device that is also used for measuring the heart beating rate, which we have already mentioned in the above paragraph.

The LED on the sensor enlightens the skin in the exact place where the sensor is placed. In the meanwhile, the light enlightens the skin, and the sensor detects the blood pulsations that move through the big blood capillary on the area where the sensor is placed. The blood pulsations occur as a result of regular heart contractions, which circulate the blood in the body.

The sensor gets the signal of blood pulsations and registers the change in the intensity of light over time. This signal is used to calculate the oxygen percentage related to hemoglobin found in blood (Spo2). More specifically, the sensor evaluates how much of the hemoglobin is bonded with oxygen and how much of is free (deoxygenized hemoglobin). The result specifies SpO2 with percentage(%).

The measured SpO2 results are usually shown on a specific screen of the device. The average value of SpO2 for a healthy person is between 95% to 100%. Lower values can be an indicator of possible problems with the breathing process and the oxygen provision.

2.6 Body temperature monitoring

The evaluation of one's body temperature is another crucial aspect of wellness. It helps in identifying body changes by displaying the body's usual rate. In this study, we'll look at the significance of body temperature in terms of health and how it may be used to help with disease diagnosis and treatment. The immune system's normal and typical response to infections is an increase in body temperature. An individual's body temperature rises right away after contracting a virus to combat foreign bodies. By keeping an eye on body temperature, we can spot changes early and greatly assist in the diagnosis and management of illnesses in an early phase.

The measurement of body temperature can be useful in the diagnosis of some illnesses. It is known that the typical range for body temperature is 36.1 to 37 degrees Celsius. Frequent monitoring of body temperature can be especially important for people with chronic conditions or those who may experience consequences. Patients with diabetes, for example, can monitor their body temperature to spot any indications of an infection, which could be very dangerous for them. Additionjobsally, taking a patient's body temperature can be beneficial for those having surgery or intensive care.

In conclusion, measuring one's body temperature is essential for evaluating one's health and spotting medical issues. This procedure may assist in diagnosing and treating illnesses, track treatment effectiveness, and avert any consequences. Because of this, it's critical to monitor and maintain our body temperature constantly.

Chapter 3

Cardiovascular and respiratory system

3.1 Main body systems

The cardiovascular system and respiratory systems are pretty important to our functioning and our survival. These two systems are similar to each other in their way of functioning but also they are closely related to each other because blood circulation is necessary for the transport of the oxygen molecules and other nutrients in all the body cells.

The cardiovascular system is made of the heart which is the primary organ, arteries, vena and capillary. All of these components are responsible for transporting all of the blood to each organ of our body. As mentioned heart is the main orchestrator of this process and has the role of a pomp that pumps out blood to deliver it to the bigger arteries. Blood needs to move freely on the whole body to supply oxygen and nutrients.

The respiratory system includes the breathing organs, such as the lungs and diaphragm. The process of breathing is a natural action that we do without being conscious. Through breathing, the body captures oxygen from the air and removes carbon dioxide, providing a regular source of oxygen that cells need to function.

These two systems are closely related. Oxygen captured by breathing is transported via blood from the heart to all cells of the body. Thus, the cardiovascular and respiratory systems help each other to ensure that the body has the necessary oxygen and to remove carbon dioxide, a product of the exchange of substances produced in our cells.

A person's health and lifestyle have a major impact on the functioning of these two systems. High waves of stress, food rich in fats, and lack of physical activity can negatively affect the health of the cardiovascular and respiratory systems. Therefore, it is important to take care of both of these systems by exercising, eating healthy, and following a balanced lifestyle.

3.2 Respiratory system

The network of tissues and organs that facilitates breathing is known as the respiratory system. It covers the blood vessels, lungs, and airways. The respiratory system is also entered by the muscles that support this function. Together, these components enable the organism to absorb oxygen and expel carbon dioxide. The following structures make up the respiratory system (Figure 2.1): The nose is made up of the nasal fossa, nasal cavity, pharynx (muscular tube), larynx (cartilaginous tube), and trachea. The trachea bifurcates into two major bronchi, which enter the pulmonary lobes before dividing into bronchioles, ducts, and alveoli, which are the structures where gas exchange takes place.

The area between the nose and the bronchioles (where gas exchange is not possible) is called an airway. The air is conducted, filtered, heated, and humidified by structures up to the trachea.

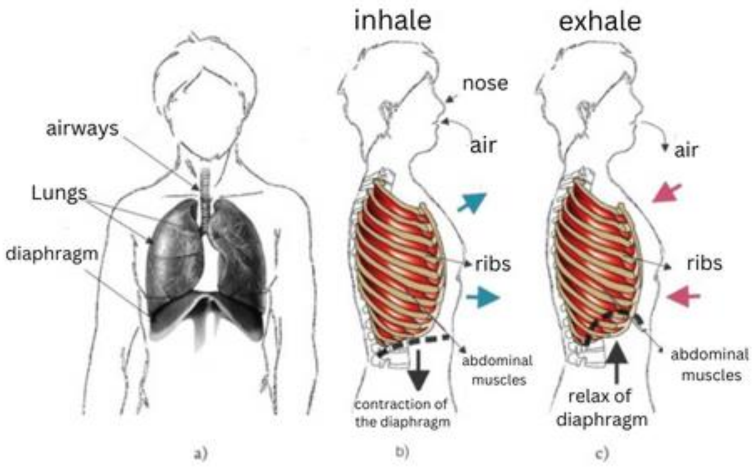


Figure 4.a. Respiration parts ***Figure 4.b.*** inhale process ***Figure 4.c.*** Exhale process

The visceral pleura, a membrane of connective-elastic tissue, envelops the lungs, the primary respiratory organs. The parietal pleura, which surrounds the chest cavity, is another. Pleural fluid is one of them and it helps with breathing mechanics. [1]

The breathing phases are restricted by the direction of air flow. Breathing happens in two stages. The first is the movement of oxygen (O2) from the surrounding environment into the cells during respiration. The release of carbon dioxide (CO2) into the atmosphere is the second. The purpose of respiration is to remove CO2 from the body and provide cells with enough oxygen (O2) to sustain homeostasis [1].

Breathing regulation is based on pressure-volume variations in the lungs, which are positioned in an airtight environment. In contrast to lung pressure, intrathoracic pressure is negative. The lung is an elastic organ that is resistant to distortion. Compliance is the term for the lungs' capacity to expand [4] and is expressed as equation (1).

$$\mathrm{C} = \mathrm{dV} \,/\, \mathrm{dP} \qquad \text{(Equation 1)}$$

$$\mathrm{C}_{\boldsymbol{T}} = \frac{\mathrm{dV}}{\mathrm{dP}_{\boldsymbol{T}}} \qquad \text{(Equation 2)}$$

$$\mathrm{C}_{\boldsymbol{L}} = \frac{\mathrm{dV}}{\mathrm{dP}_{\boldsymbol{L}}} \qquad \text{(Equation 3)}$$

$$\mathrm{C}_{LT} = \frac{\mathrm{dV}}{\mathrm{dP}_{LT}} \qquad \text{(Equation 4)}$$

3.3 Muscles participating for breathing process

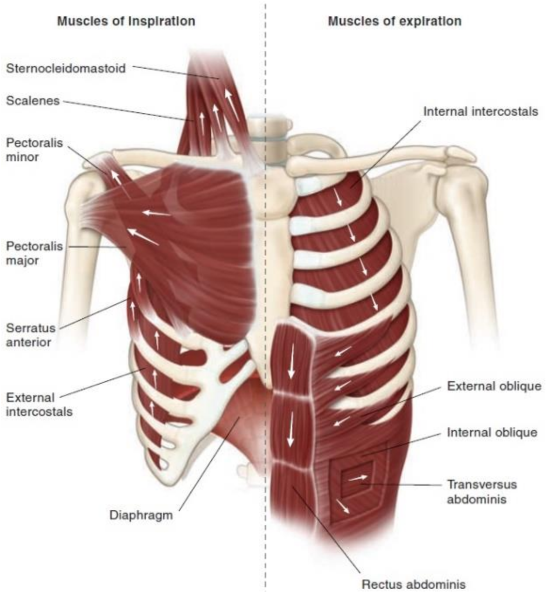


Figure 5.Respiratory system muscles

The diaphragm is the respiratory apparatus's most vital muscle. The lung capacity increases and the intrapleural pressure decreases as it contracts. Concurrently, the lower thoracic cavity expands as a result of an increase in abdominal pressure that travels via the deployment zone to the chest. The lower rib cage extends in response to diaphragm contraction. The anteroposterior width of the chest increases when the sternum elevates and moves forwards during breathing. The diaphragm's contraction also adds to the chest's increased longitudinal diameter.

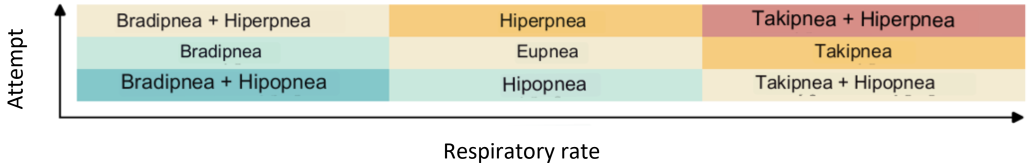
The scalene muscle, sternocleidomastoid muscle, and intercostal muscle are accessory muscles of respiration. During forced expiration, the abdominal muscles contract, and the diaphragm is pushed up, thus causing a decrease in the diameter of the chest. The abdominal muscle is also important for coughing. [1]

The figure presents more detailed information on the muscles that are set in motion for the respiratory system. There we can distinguish the muscles that are set in motion for breathing that in this figure are shown on the left side and the right are the muscles for exhalation. In this figure, we can also see the way these muscles move. This information will help us to determine the positioning of the sensors that we will use for this project.

3.4 Breathing patterns

Normal breathing is called eupnea and is defined by almost sinusoidal movements of the chest with RR between 12 and 18 breaths/min [4]. Tachypnea is characterized by higher RRs than eupnea. It may be caused either by increased demand for oxygen (e.g., during exercise or fever), by a reduced ability to gas exchange (e.g., through asthma, pneumonia, pulmonary embolism), or by supplying excess CO2 through, e.g. metabolic acidosis. The causes of tachypnea can also be met with an increased respiratory effort (RE) (deeper breathing), which is then called hyperpnea. Hyperventilation means a pathologically increased exchange caused by tachypnea, hyperpnea, or a combination of the two. It is defined as a pathologically reduced gas exchange. Bradypnea and hypopnea, defined by lower RR or RE, respectively, are common reasons for hypoventilation. However, unlike hyperventilation, it can also be caused by decreased pulmonary diffusion capacity and manifest in tachy- or hyperpnea. [6]

Breathing is controlled by the respiratory center, located in the brain stem as part of the autonomic nervous system. Because the respiratory center is close to the narrow cranio-neck junction, where the spinal cord leaves the cranial cavity, it can be disturbed by increased intracranial pressure, traumatic brain injuries and meningism (inflammation of the protective membranes of the spinal cord). Intoxication can also affect its functions. All the conditions mentioned above can reduce its activity and thus lead to bradipnea and hypopnea, which can also develop into respiratory arrest (apnea). Significant damage to the respiratory center manifests as a pathological pattern called Biot's respiration, characterized by periods of adequate breathing randomly interspersed with periods of apnea. [6]



Bradipnea + Hiperpnea	Hiperpnea	Takipnea + Hiperpnea
Bradipnea	Eupnea	Takipnea
Bradipnea + Hipopnea	Hipopnea	Takipnea + Hipopnea

Figure 6. Differentiation of breathing rate and depth pattern. Hyperventilation and hypoventilation are marked in red and blue, respectively. The more saturated the color, the more pronounced

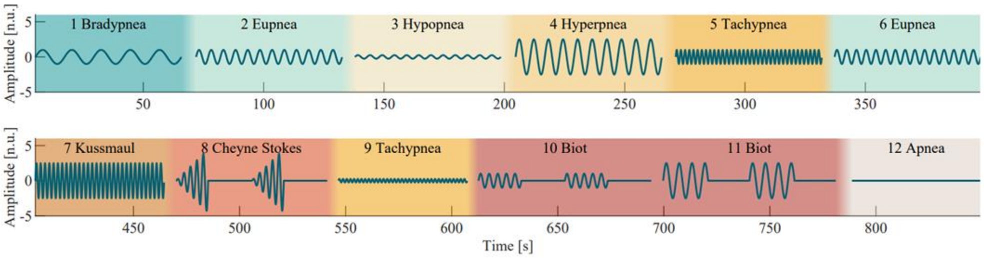


Figure 7. Visual representation of the breathing pattern reference signal. A pause is placed between each breathing pattern to allow subjects to breathe freely.

The respiratory muscles and neural pathways' integrity are linked to chest mobility. Measurements of the amplitude of the thoracic and abdominal cavities during respiratory movement are useful in clinical practice to reveal changes in the respiratory system or potential disorders. Patients with chronic obstructive pulmonary disease (COPD), with lung hyperinflation, weakness, or muscle paralysis, among other conditions, may exhibit some paradoxical movements.

Changes in the relationship between thoracic and abdominal mobility can also result from other ailments, such as orthopnea, dyspnea, alternative breathing, etc. Wearable technology can track the contribution of different muscles, and modifications in movement patterns can track an individual's breathing and overall health. [1]

3.5 Lung parameters

Lung parameters, including vital capacity, Inhalation and exhalation frequency, as well as lung resistance, are key elements of the respiratory system that affect human health and performance. Vital capacity indicates our potential to take in oxygen, while lung frequency and resistance affect how our body adapts to environmental changes and stress. In this chapter, we will explore these parameters in-depth and discuss their importance to the health of the respiratory system. By taking care of these important aspects of health, we can improve the quality of our breathing and help our bodies function optimally.

Vital capacity

Vital capacity (VC) is the maximum amount of air that can be inhaled and exhaled from the lungs in a slow, precise deep breath. KV is one of the parameters used to evaluate lung function and respiratory performance. Vital capacity can be measured in two ways: by spirometry or by using lung magnetic resonance imaging (MRI). In spirometry, a patient breathes into a machine that records the amount of air he or she breathes in. If the person breathes in deeply and slowly, the amount recorded is the vital capacity. Normal values of vital capacity vary depending on a person's age, gender and height. A healthy, adult person is expected to have an average vital capacity of about 4-5 liters. However, vital capacity values can vary depending on factors such as stress, physical activity, change in height of the wearer, and lung diseases. Vital capacity is an important parameter used by doctors in the diagnosis of lung diseases such as asthma, emphysema, chronic bronchitis, and cystic fibrosis. If the vital capacity is lower than expected, this may indicate lung damage and require additional evaluation and treatment. [5]

Frequency of inhalation and exhalation

The frequency of inhalation and exhalation is the number of times a person breathes in one minute. This value varies between individuals and can be influenced by factors such as age, health status and physical activity. The normal respiratory rate is between 12 and 20 breaths per minute for adults under normal conditions and without any additional impetus. Whereas, the frequency of exhalation can be even lower compared to the frequency of breathing, being calculated in the number of breaths we have in a period of 60 seconds. High or low respiratory and expiratory frequency values may indicate the presence of a possible lung or respiratory system problem. For example, a high respiratory rate can be a sign of stress, anxiety, or breathing problems such as asthma or bronchitis. A low respiratory rate can be a sign of lung diseases, such as pneumonia, or it can be a sign of the body's insistence on keeping more oxygen in the body, as in cases of diseases such as anemia. [6]

3.6 Cardiovascular System

The cardiovascular system is a crucial organ system that provides all cells with the essential vitamins to carry out basic functions. Often referred to as the cardiovascular system, it is a network made up of the blood itself, which is used to carry different substances, the blood arteries that carry blood throughout the body, and the heart, which functions as a centralized pump. The pulmonary circuit, which is shorter and transfers blood between the heart and lungs to provide oxygen, and the systemic circuit, which is longer and supplies blood to all the other organs and tissues, are the two separate loops that make up the circulatory system. The heart is where both of these circuits start and finish.

The circulatory system's main functions include delivering oxygen to the body's tissues and removing carbon dioxide produced during metabolism. Hemoglobin is a class of molecules found on the surface of red blood cells in blood that is linked to oxygen. The systemic circulation returns carbon dioxide-containing, deoxygenated blood to the right side of the heart. After being forced into the pulmonary circulation, gas exchange takes place in the lungs. Instead of adding carbon dioxide to the blood, oxygen is added. The blood returns to the left side of the heart after receiving oxygen. After being pushed into the systemic circuit and supplying oxygen to the tissues, it subsequently returns to the right side of the heart. Blood is also an excellent transport system for hormones and other nutrients, such as electrolytes. The liver removes waste products from the blood that are carried by it. [13]

3.7 Components of the cardiovascular system

Heart

This whole process orchestrator is the heart but it has some other main associates that have a big contribution on the vital process. The other component that will indicate on the blood transportation process contributing on the transportation process of the vitamins and essential nutrients that our all-organ need is also the blood that carries the oxygen and transports it to the respiratory system. This process is done through the arteries that have the function of one big pipe that carries the exchange of the oxygen and carbon dioxide molecules through lung. The biggest helpers of the arteries are capillaries and veins that make a large distribution of the substances in the body parts.

The passage of blood via the arteries, capillaries, and veins is referred to as blood circulation. The force that blood applies to blood vessel walls when it passes through them is measured as pressure. The term "pulse" describes the regular expansion of an artery brought on by the ventricles' release of blood. An artery that is near the surface and rests on a solid object can be felt. Systolic pressure over diastolic pressure is the result of measuring blood pressure with a sphygmomanometer. Peripheral resistance, blood volume, cardiac output, and viscosity are the four primary elements that interact to affect blood pressure. Blood pressure rises in response to these factors. To adapt cardiac output to the body's changing demands, regulatory factors rely on the atrioventricular node to raise or lower the heart rate. The cardiac center located in the brain's medulla oblongata controls the majority of heart rate changes. Heart rate can be influenced by peripheral variables such as body temperature, ion concentration, and emotions. [15]

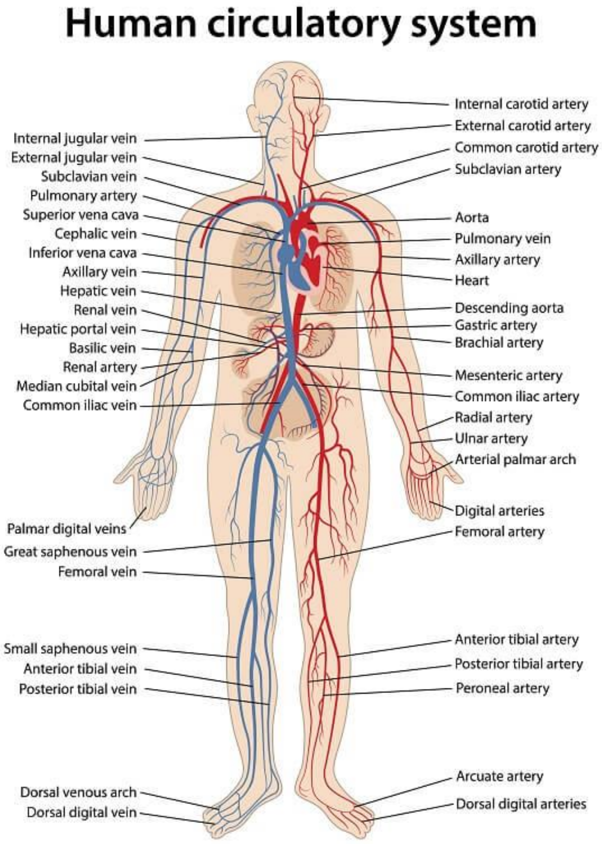


Figure 8. Components of the cardiovascular system

Chapter 4

Component used to create the system

4.1 Microcontroller

A small integrated circuit called a microcontroller is made to control a single function inside an integrated system. A microcontroller is a single chip that consists of a CPU, memory, and input/output (I/O) peripherals.

Microcontrollers, also known as embedded controllers or microcontroller units (MCUs), are found in a variety of products, including cars, robotics, office equipment, medical equipment, mobile radio transmitters, vending machines, and home appliances. They are essentially tiny, basic personal computers (PCs) with simple operating systems (OS) that are meant to control certain functions of larger components.

How do microcontrollers work?

A system's microcontroller is used to manage a single device function. It accomplishes this by using its central processor unit (CPU) to analyze the data it receives from its input/output peripherals. The microcontroller receives temporary data, which is stored in its data memory. To interpret and apply the data, the processor accesses the program memory and executes the instructions there to decode and apply the data. It then communicates and takes the necessary steps using its I/O peripherals. Numerous gadgets and systems make use of microcontrollers. Many microcontrollers are frequently used in devices, and they cooperate to carry out their functions.

Supporting elements of a microcontroller include:

Analog to Digital Converter (ADC) - A circuit that transforms analog signals into digital signals is called an ADC. It makes it possible for the microcontroller's central CPU to communicate with analog external devices like sensors.

Digital to Analog Converter (DAC) - By carrying out the opposite operation of an ADC, a DAC enables the microcontroller's central processor to transmit its output signals to external analog components.

System Bus - The connection that joins each microcontroller component to the next is called the system bus.

Serial Port - One type of I/O port that the microcontroller can use to connect to external components is a serial port. It functions similarly to a parallel or USB interface, but it exchanges bits differently. Both Harvard architecture and von Neumann architecture, which offer various techniques for memory and inter-processor data interchange, can serve as the foundation for microcontroller design. The data bus and instructions are kept apart in a Harvard architecture, enabling simultaneous transfers. A bus serves as both data and instructions in a Von Neumann architecture. Complex computation of groups of instructions (CISC) or reduced instruction set computing (RISC) can be the foundation of microcontroller processors. In general, RISC contains roughly 30 instructions, compared to about 80 for CISC. Additionally, RISC has more addressing modes—12–24—than RISC, which only has 3-5. Because CISC requires more clock cycles to execute instructions than other architectures, it may perform less well even though it is easier to implement and makes better use of memory. Due to its simpler instruction set, additional design simplicity, and emphasis on software rather than hardware, RISC computers—which place more emphasis on software—often outperform CISC processors, which place more emphasis on hardware .Each ISC is used varies depending on the application.

When they first became available, microcontrollers used only the language assembly. Today, the C programming language is a popular option. Other common language microprocessors include Python and JavaScript.

MCUs feature input and output pins to implement peripheral functions. Such functions include analog-to-digital converters, liquid crystal display (LCD) controllers, real-time clock (RTC), universal synchronous/asynchronous transmitters (USART), timers, universal asynchronous receiver transmitters (UART) and universal serial bus (USB connection). Sensors that collect data about humidity and temperature, among others, are also often attached to the microcontroller.

4.2 Arduino Uno

A microcontroller board based on the ATmega328 is called the Arduino Uno. It contains six analog inputs, six digital input/output pins (six of which can be used as PWM outputs), a 16 MHz ceramic resonator, a USB port, a power jack, an ICSP header, and a reset button. It comes with everything required to support the microcontroller; all you need to do is power it with a battery or an AC-to-DC adapter or connect it to a computer via a USB cable to get going. Unlike all other boards, the Arduino Uno does not take advantage of the FTDI USB-to-series. Rather, it has the Atmega16U2 (or Atmega8U2 up to version R2), which is configured to function as a serial-to-USB converter. [10]

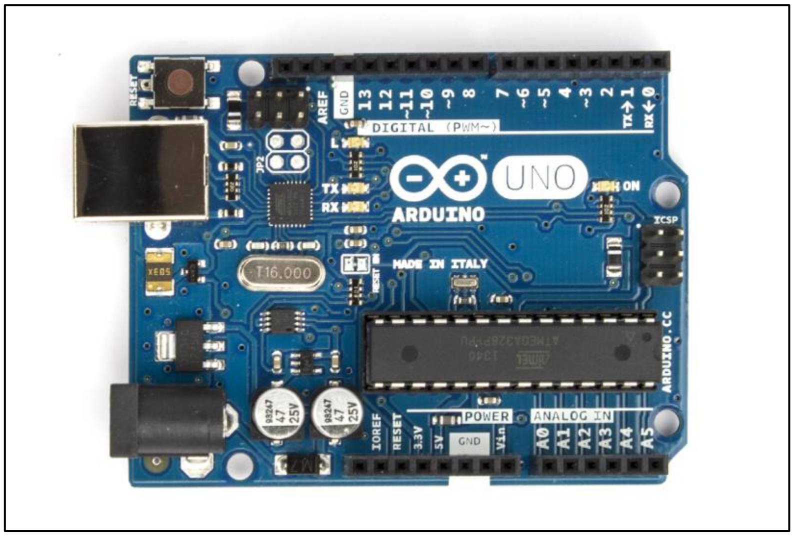


Figure 9.Arduino Uno

Table 1. Overview of the Arduino Uno

Microcontroller	Atmega328
Operating voltage	5V
Input voltage	7-12V
Input voltage limit	6-20V
Digital pins H/D	14 (6 of which provide exit on PEM)
Analog entrance Pins	6
DC current for pins H/D	40 mA
DC current for pins 3.3V	50 mA

Bootloader flash memory	32KB (Atmega328) of which 0.5KB are used from bootloader
SRAM	2KB
EEPROM	1KB
Clock Speed	16 MHz

4.3 Why ATmega328?

The microcontroller called the ATmega328 is produced by Microchip Technology, formerly known as the Atmel Corporation. It is a well-liked ATmega family dependency that is widely used in many different kinds of electronic projects. The ATmega328 provides a strong basis for creating microcontroller applications and is frequently utilized in projects related to electronics hobbies, robotics, home automation, and many other fields. [4]

The ATmega328's primary characteristics are as follows:

Processor: The ATmega328 has an 8-bit RISC processor with a maximum speed of 20 MHz. This processor has a wide range of instructions, including several controllers, logical operations, and arithmetic. The main features of the ATmega328 are as follows:

Memory: The 32-kilobyte internal Flash memory of the ATmega328 is used to store the program code. There is a one-kilobyte EEPROM memory and a two-kilobyte SRAM memory for temporary use to store data.

Peripherals: Numerous built-in peripherals are available on this microcontroller, such as ports GPIO (General Purpose Input/Output) for attaching to external components, SPI (Serial Peripheral Interface), UART (Universal Asynchronous Receiver/Transmitter) for serial communication, and I2C (Inter-Integrated Circuit) for attaching to other devices. The 10-bit analog-to-digital converter (ADC) on the ATmega328 enables it to read analog values from sensors or other devices. For this microcontroller to operate at the intended execution speed, either an external or internal oscillator can be used. For the Arduino Uno, the ATmega328 is specifically selected due to its availability, ease of use, and performance. It offers enough GPIO connections to connect additional components and a comprehensive set of programming instructions. The ATmega328 also features an integrated ADC for reading analog values, and a memory capacity appropriate for standard Arduino programming. Furthermore, the ATmega328 microcontroller is supplied in an easy-to-assemble box and has a bootloader pre-installed, making it simple to program the Arduino via the USB serial interface. Because of this, the Arduino Uno is a popular option among enthusiasts, learners, and engineers who are just getting started with microcontrollers and electronics projects. [4]

4.4 Power and H/D pins

An external electrical power source or a USB connection can be used to power an Arduino Uno. The power supply is chosen for you automatically. External power sources (other than USB) include the battery and an AC-to-DC adaptor. It is possible to insert poles from a battery into the connector's Gnd and Vin pin headers. An external supply of 6 to 20 volts can power the plate. The board may become unstable if the 5V pin receives less than 7V, as it is capable of providing less than five volts. The voltage regulator may overheat and harm the board if you use more than 12 V. It is advised to use 7 to 12 volts. [10]

The power pins are as follows:

- VIN. When the Arduino board is powered externally (as opposed to using 5 volts from the USB connection or another regulated power source), the input voltage is known as VIN. This pin can be used to supply voltage or to access voltage if it is supplied by the socket current.
- 5V. This pin uses the board's regulator to provide a controlled 5V output. The board's VIN pin (7–12 V), the USB connector (5 V), or the DC power jack (7–12 V) can all be used to power the plate. By bypassing the regulator, the supply voltage applied to the 5V or 3.3V pins has the potential to harm your board. We do not suggest it.
- 3V3. The on-board regulator generates a 3.3-volt supply. There is a 50mA maximum current draw.
- GND. Ground pins. [10]

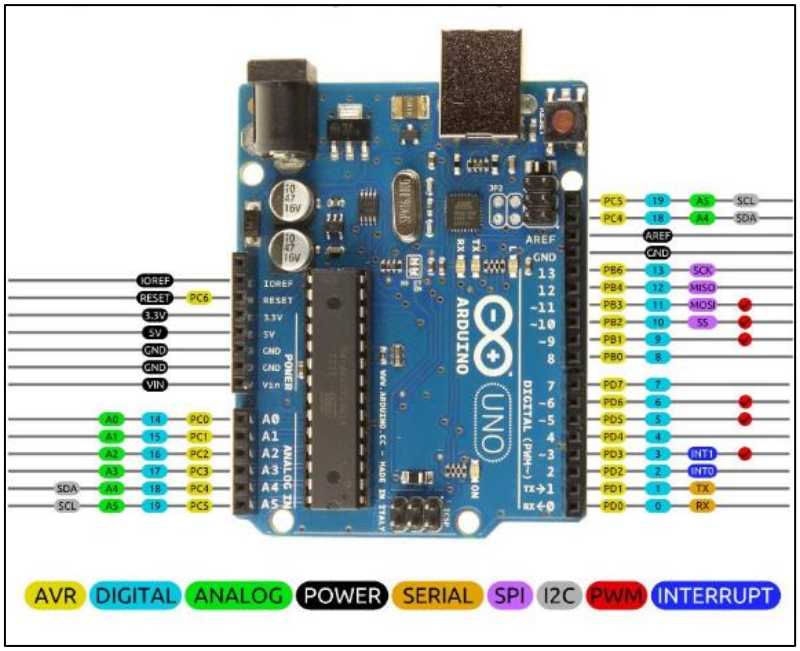


Figure 10. How the Arduino Uno works

Entry and Exit:

The pinModel(), digitalWrite(), and digitalRead() routines can be used to use any of Uno's 14 digital pins as an input or output. Five volts power them. Each pin has an inbuilt resistance pull-up of 20–50 kOhms, which is unconnected by default and may supply or receive a maximum of 40mA. Furthermore, certain pins serve specific purposes:

- Serial: 0 (RX) and 1 (TX). It is utilized for serial data TTL transmission (TX) and reception (RX). These pins are linked to the ATmega8U2 USB-to-TTL serial chip's matching pins.
- External interrupts: 2 and 3. These pins can be set up to respond to changes in value, rising or falling edges, or low values by triggering an interrupt.
- PWM: 3, 5, 6, 9, 10 and 11. Provide the analogWrite() function with an 8-bit PWM output.
- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication by using the SPI library.
- LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH, the LED is on, when the pin is LOW, it turns off. The Uno has 6 analog inputs, labeled A0 to A5, each of which provides 10 bits of resolution (1024 different values). By

default, those measured from ground to 5 volts, although it is possible to change the upper end of the range using the AREF pin and the analogReference() function.

- TWI: pin A4 or SDA and pin A5 or SCL. Supports TWI communication using the Wire library.
- AREF. Reference voltage for analog inputs. Used with analogReference().
- Reset. Bring this line LOW to reset the microcontroller. [10]

4.5 Arduino programming

Arduino programming is based on the C++ language and uses an IDE (Integrated Development Environment) called the Arduino IDE to develop and load code into the ATmega328 microcontroller (or other microcontroller variants used on the Arduino platform).

The programming environment that comes with Arduino is called the Arduino IDE. It may be installed on your PC by downloading it from the official Arduino website. Programming code can be created, edited, and uploaded to the Arduino microcontroller using the straightforward and visually appealing Arduino IDE interface.

In Arduino, programs are called "sketches". Each sketch is a separate program that includes various functions and procedures to control and communicate with the components connected to the Arduino. Arduino sketches include a function called setup (). This function is executed only once at startup and is used to configure the initial parameters and necessary initializations. After executing the setup () function, the Arduino executes the loop () function again and again. This function executes in an infinite loop, enabling a repetitive code check. Through the loop () function, you can control the Arduino's actions based on external conditions and events.

The Arduino IDE comes with a wide set of ready-made libraries and functions that make programming Arduino projects easy. These libraries provide ready-made commands to control GPIO ports, communicate with sensors, connect to serial communication, manage timing, etc.

After writing the code in the Arduino IDE, you must compile it to check for syntax errors. If the compilation is successful, you can upload the code to the Arduino microcontroller via a USB connection. The Arduino IDE converts the code into a format understandable by the microcontroller and loads it into it.

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

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

Figure 11. Layout of the Arduino programming environment.

4.6 **Flex sensor**

Electronic devices known as "flex sensors" are capable of detecting and quantifying variations in the concentration or state of flexibility of materials like carbon-based materials, rubber, and plastic. These sensors are widely utilized in many different applications, including controls for video games, wearable electronics, robots, etc. Electronic interfaces known as flex sensors adjust their electrical resistance in response to variations in their pliability. Typically, the structure of these sensors includes a flexible substance.[11] Materials are classified as substrates, insulators, conductors, or semiconductors based on the most typical function they are found to play in flexible sensors. For conductive materials, the most frequently talked-about properties are bending stability and field effect mobility, while for semiconductors, the focus is on conductivity and transparency. The dielectric constant and breakdown voltage of dielectrics are used to compare them. From their use as contacts in organic thin-film transistors to their use as bending sensitive layers in pressure and strain sensors, conductive materials play significant roles. Metals, amorphous oxides, and carbon conductors are the three primary conductor types found in flex sensors [11].

4.7 Semiconductors

Amorphous indium-gallium-zinc oxide (a-IGZO) is the most commonly utilized metal oxide semiconductor in flexible sensors, like the TFT channel, whereas ZnO is commonly employed in electromagnetic radiation sensors. Tin oxide and indium zinc oxide (IZO) are two more metal oxides that have also been employed as semiconductors in flexible sensors (SnO). Because of its mechanical stability when bent in the micrometer range radius and its low-temperature processing and solution procedures that result in the processing compatibility of polymer and large surfaces, n-type a-IGZO has become widely used for flexible circuits and sensors.

In addition to a-IGZO, flexible ZnO has also been utilized extensively in flexible sensors. Because of its large exciton binding energy (60 meV), high mobility, and band gap of 3.37 eV, it is primarily used as the sensitive layer of UV sensors. Flexible sensors have made extensive use of metal oxide semiconductors because of their advantageous features [11].

4.8 Flexible Silicon

Amorphous silicon fails due to crack formation when bent under a tensile strain of 0.5%. Originally employed as an active material in LCD matrices, it was later switched to flexible sensors as a strain-sensitive layer, a semiconductor in on-site signal processing circuits, or as part of X-ray photodetectors. The creation of low-temperature polycrystalline silicon (LTPS) was driven by the low mobility of Si when compared to the values offered by other options. Although LTPS has been utilized in flexible sensors, it is expensive and difficult to fabricate this material using ELA. [11]

4.9 Using the flex sensor for health monitoring

Flexible sensors can be simply incorporated into living tissue to deliver a range of parameters relevant to health in real-time. Body sensors were typically laminated and glued to the skin with adhesive. Scientists have integrated many biomedical sensor types to create e-skins. Bluetooth, near-field communication (NFC), and radio communication were used to communicate with implants. Generally, corrugated architectures, liquid metals, nanowire/nanoparticle networks, serpentine interconnects, etc. were used to preserve the connections of these flexible biological sensors. Lithium-ion batteries, solar cells, pyroelectric, triboelectric, and plasmonic nanogenerators are the power sources for these sensors.

Clinical medicine is supported by biomedical applications, which offer intelligent diagnostic tools. Flexible electronics applications for biomonitoring allow precise mapping and detection of heart rate as well as more complex human muscle functions including eating, breathing, swallowing, and coughing. [11]

Blood pressure, heart rate, skin temperature, and pressure can all be measured with these instruments. Sensor devices supporting extra functionalities are necessary for medical applications in order to guarantee safety. Another crucial component of biological research and clinical medicine is the intimate and long-term coupling of flexible electronics to biological systems. Examples of this include electrical interfaces with the brain or other organs and the leak-free, encapsulated capabilities of implantable flexible sensors for monitoring tasks like heart electrophysiology and respiratory rate measurement.

Biomimetic smart electronics is a category of smart implants that can gently attach to biological tissue and mimic the structural and actuation properties of a biological tissue to support, for example, the regeneration of nerve tissue.

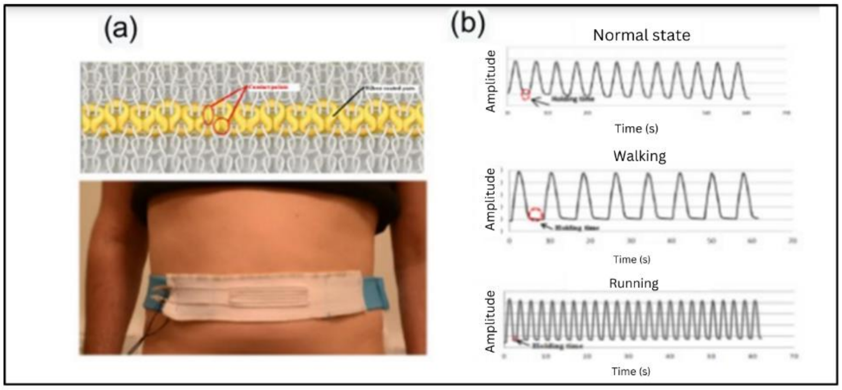


Figure 12. a) Schematic diagram showing the sensor geometry of the silver-coated yarn (yellow) (top) woven into a normal yarn, used in the production of the breathing belt (bottom), b) Responses obtained for breathing [4]

Using nanoporous Al in a commercially available elastomer, diaphragm breathing and joint movement were detected in distinct directions. Using woven graphene fabrics, human skin deformation was also detected on a small scale. An alternative method performs landing feeling on the fingers, elbow, and knee using a functionalized sponge. A wearable smart ring composed of functionalized cotton fibers was able to recognize the human body's posture and activity, including standing, walking, and running, as well as hand muscle flexion. [11]

Additional biomedical uses for the flexible technology include the use of a polyester-based strain sensor film for newborn breathing and a plethysmograph (PPG) sensor for the detection of sleepiness. To sum up, flexible sensors have demonstrated their enormous promise for creating smart implants and prostheses with sophisticated sensing features, as well as for helping ambulatory patients with handy and simple-to-use diagnostic instruments.

4.10 How to connect flex sensor to Arduino

Arduino can be connected to a flex sensor to control and monitor the level of movement of the sensor. The physical connection can be made by using a soft cable to connect the flex sensor contacts to the analog ports of the Arduino. When the flex sensor is used with the Arduino, you can use a programming code to read the resistance value of the flex sensor at a point certain. This value will change depending on the movement of the sensor.

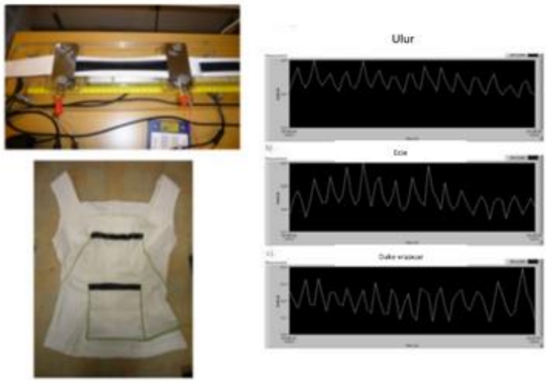


Figure 13. Implementation of conductive rubber on textile material and the measurements on the three states of the patient

To connect the flex sensor to the Arduino, you can follow these steps:

- Connect one of the extremities of the flex sensor to the supply voltage (5V) of the Arduino.
- Connect the other end of the flex sensor to a 10K Ohm resistor to the ground.
- Connect one of the resistor connection points to the GND of the Arduino.
- Connect the other point of the resistor connection to one of the analog ports of the Arduino (e.g. A1).

After making the physical connection, you can use a programming code to read the analog value of the sensor and receive notifications or control a certain action based on the real value. Be careful to have a 10K Ohm resistor on the connection to GND, because this creates a voltage divider for accurate reading of the analog value of the flex sensor. Also, make sure you can provide the correct voltage for the sensor (5V in this case), if the Arduino is working with a different voltage source. [4]

4.11 Heart rate and SpO2 measurement sensor, MAX30100

The MAX30100 sensor is an optical sensor used to monitor SpO2 (blood oxygen level) and heart rate non-invasively. This sensor is used in medical devices and other devices to monitor people's health. Let's take a closer look at how the MAX30100 sensor works:

The MAX30100 sensor uses infrared (IR) and target red (RED) light to perform the measurement. These lights are shone on the patient's skin. An infrared LED and a red LED are used to send these lights to the skin.

When infrared light and red light touch the skin, they interact with the blood under the skin. Hemoglobin in the blood is able to absorb red light and infrared light in different ways. The level of oxygen in the blood affects the ability of hemoglobin to absorb red light. After the light is absorbed by the blood, the light is reflected back to the sensor. The sensor records the amount of light that is reflected. This is a repetitive process that occurs at a high frequency to monitor changes in light absorption by blood over time.

The sensor has internal electronics that analyze the recorded light data. It studies how the intensity of light reflected in red light and infrared light changes over a period of time. This change in intensity is related to the pulsation of the blood in the artery, which is the rhythm of the heart. Also, this difference is related to the ratio between the absorbance of infrared light and red light, which is used to calculate SpO2.

Based on data analysis, the sensor uses algorithms to calculate heart rate and blood oxygen level (SpO2). Heart rate is calculated from blood pulsations, while SpO2 is calculated from the ratio between the absorbance of infrared light and red light.

Calculated heart rate and SpO2 data can be displayed on a device screen where the sensor is used, or can be transmitted for further use via an internal connection of the device to a microcontroller or an external computer. [19]

Figure 14. Sensor MAX30100

4.12 How does the MAX30100 work?

The MAX30100 is an integrated solution for pulse oximetry and heart rate monitoring. It combines two LEDs, a photodetector, optimized optics and low-noise analog signal processing to detect pulse oximetry and heart rate signals. The MAX30100 operates with 1.8V and 3.3V power supplies and can be turned off via software with limited standby current consumption, allowing the power supply to remain connected at all times. The figure below shows how the MAX30100 sensor works.

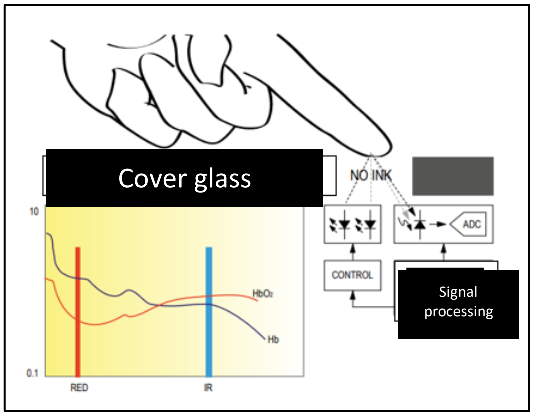


Figure 15.Block diagram of the system

The complete pulse oximetry and heart rate monitoring solution facilitates design:

- It combines integrated LEDs, a photosensor, and a high-performance analog front-end.
    - It is very small, with dimensions of 5.6mm x 2.8mm x 1.2mm, and is an integrated optical system-enhanced package.
    - Very low power consumption increases battery life for wearable devices.
    - It has normalized sampling frequency and LED current distribution for energy saving.
    - It has a very low consumption in standby mode (about 0.7µA, in normal).
    - Advanced functionality improves measurement performance:
    - The high signal-to-noise ratio ensures strong resistance to motion artifacts.
    - This sensor is a convenient solution for pulse oximetry and heart rate monitoring and is widely used in medical devices and wearable health monitoring devices. [19]

4.13 Electronic Characteristics

The MAX30100 sensor has several electrical characteristics that help its correct use and fit into your project. The following are some of the main electrical characteristics of the MAX30100 sensor:

The sensor operates with a power supply from 1.8V to 3.3V. This makes it suitable for use on most microcontrollers and different platforms.

The sensor has a low power consumption in normal operations and during the standby state. This is important for battery applications and wearables that need extended battery life. Standby power consumption is about 0.7µA (typ).

The sensor allows current control for its infrared and red LEDs. This allows for adjusting the lighting according to the needs of your project and saving energy. The sensor is able to follow the signal distribution in a wide range of frequencies. This allows for accurate heart rate measurement and SpO2 calculation.
The output of the MAX30100 sensor is an analog signal. This means you need to use an ADC (Analog-to-Digital Converter) to read the data to a microcontroller or other platform. The sensor is suitable for use in different temperature conditions. The working temperature ranges from -40°C to +85°C. The sensor is designed to provide a high signal-to-noise ratio. This makes it suitable for applications where maintaining accuracy is important, such as heart rate monitoring and pulse oximetry.

Supply tolerance: The sensor has a good power supply tolerance. This means that it can work under slightly different voltages, including the voltages supplied by most power sources. [19]

Standby power usage: The sensor has a very low standby current consumption, typically around 0.7µA. This is a great advantage when you want the device to always be ready to measure SpO2 and heart rate, but you don't want to consume unnecessary energy.

Analog output: the MAX30100 sensor provides an analog output of the detected signal, which means that you need to use an ADC (Analog-to-Digital Converter) to read the detected values.

The sensor communicates with the selected microcontroller or platform through a communication protocol, usually I2C (Inter-Integrated Circuit) or SPI (Serial Peripheral Interface). This communication is easy to integrate into your project and allows reading the data detected by the sensor.

The MAX30100 sensor must be stored within a certain temperature range to guarantee its performance. The storage temperature is usually from -40°C to +85°C.

The sensor allows adjustment of the infrared and red LED current values. This parameter affects the intensity of the light and can be used to adjust the brightness of the light according to the needs of your application. [19]

The MAX30100 sensor uses the I2C protocol to communicate with the microcontroller and transmit detected data. In this case, SDA and SCL are used to send and receive sensor data. Let's see how this works in the context of a timeline:

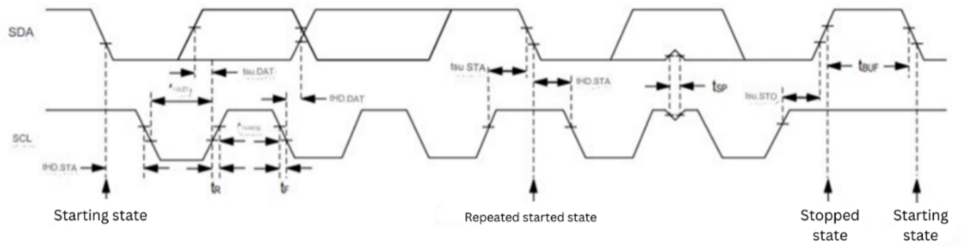


Figure 3.10: Time diagram of MAX30100 sensor

Figure 16.Time diagram for MAX30100 sensor

Communication begins with a start sign. The microcontroller initiates communication with the sensor by sending a start signal, where SDA goes from high to low while SCL is high.

The microcontroller sends the address of the device (the MAX30100 sensor) through SDA to let the sensor know it wants to communicate with it. For example, the most significant bit of this address indicates whether the microcontroller wants to read (bit 1) or write (bit 0) data from/to the device. This shows for example if the microcontroller wants to receive the data detected by the sensor. All this data is sent through the SDA line, while the SCL line is used to synchronize the transmission time.

After each data transmission, the sensor can respond with an acknowledgment signal to notify the microcontroller that it has received the data or command successfully. Communication ends with a stop sign. The microcontroller sends a stop signal, where SDA goes from low to high while SCL remains high. [19]

4.14 Pins configuration

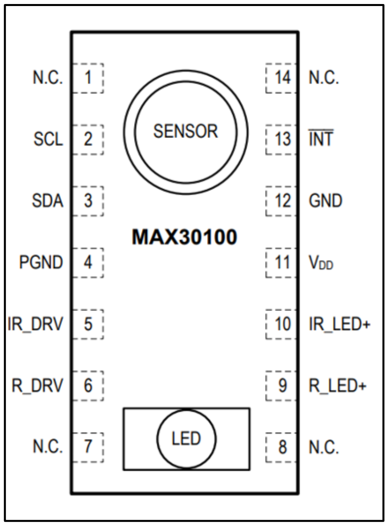


Figure 17. Pins sensor for MAX30100

Table 2. MAX30100 sensor pin data

PIN	Name.	Function
1,7,8,14	N.C.	Unconnected, they serve for mechanical stability
2	SCL	Input for I2C clock
3	SDA	Input for data clock, bidirectional
4	PGND	Ground for the LED block
5	IR_DRV	IR LED cathode and LED driver connection point
6	R_DRV	Red LED cathode and LED driver connection point
9	R_LED +	Anod of red LED
10	IR_LED+	Anod of LED IR
11	VDD	Analog power input
12	GND	Analog ground
13	INT	Interapteri active-low

4.15 Temperature monitoring sensor, LM35

The LM35 series of devices is a group of temperature devices that operate with a precision integrated circuit and have their output voltage linearly proportional to temperature in Celsius. These devices are advantageous over linear temperature sensors calibrated in Kelvin because they do not require a large output voltage to build a suitable Celsius scale. LM35 devices offer high accuracy, typically with a tolerance of ± ¼°C at room temperature and ± ¾° C over the full temperature range from -55°C to 150°C. The benefit of this accuracy comes from the calibration and characteristics of the equipment used to determine the temperature.

LM35 devices do not require any external calibration or interference to ensure high accuracy. They are naturally configured to ensure accurate temperature scaling. This allows users to use the devices immediately after they are connected to the circuit, without the need for any special adaptations.

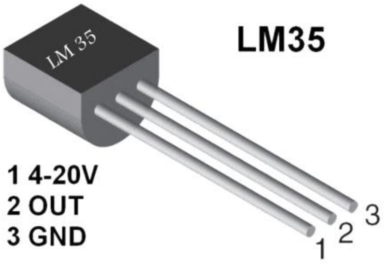


Figure 18. LM35 sensor

LM35 devices provide a voltage output that is linear with temperature, making it easy to connect to readout or control circuits. They can operate with a single power supply or with positive and negative voltage supplies.

Another advantage of LM35 devices is their low power consumption, drawing only 60µA from the supply. This means the devices produce little additional heat to the environment, and have a very low self-heating of less than 0.1°C in still air.

The LM35 devices are suitable for a wide temperature range and are rated to operate over a temperature range of -55°C to 150°C. The LM35C version is available for a temperature range of -40°C to 110°C with improved accuracy.

The LM35 series devices are available in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the TO-92 plastic transistor package. The LM35D version has an 8-lead surface mount package and a TO-220 plastic package. This type of explanation makes the operation and characteristics of the LM35 temperature monitoring devices clearer.

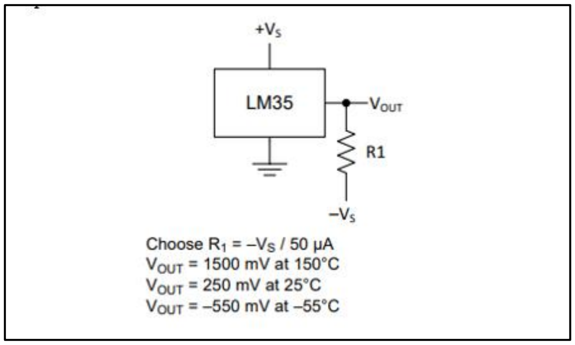


Figure 19. Sensor output signal at different temperatures

The LM35 sensor is a device with three thermal materials separated by a silicon substrate. These thermal materials are located in a way that one of them is in contact with the environment (the temperature you want to monitor), while the other two are in close contact with each other. The LM35 sensor produces an analog voltage based on the ambient temperature. Its output voltage is in direct proportion to temperature in degrees Celsius. Accordingly, for each degree Celsius increase in temperature, the output voltage increases by 10mV.

To physically understand how the output voltage of the LM35 sensor changes with temperature, it is important to understand that this sensor is built using thermal material and a silicon core. These are some of the physics details of his work.

The LM35 sensor uses the Seebeck thermoelectric effect to produce the voltage. This effect is a characteristic of thermoelectric materials, which means that if two different points of a material are at different temperatures, then an electric voltage will be created between them. This is why the LM35 sensor is built with three thermal materials connected in a specific way.

When the temperature of the thermal material in contact with the environment changes, the resistance of this thermal material also changes. The change in resistance creates changes in the output voltage of the sensor according to the thermoelectric Seebeck effect. This altered voltage produced by the change in thermal material resistance is converted to an analog voltage by the internal components of the sensor. This analog voltage is the direct temperature scale in degrees Celsius.

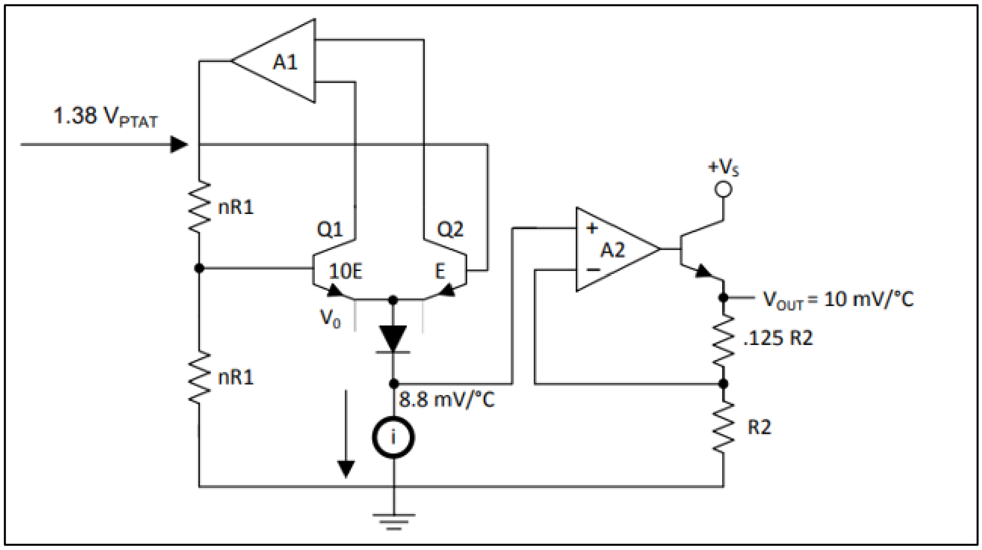


Figure 20. Block sensor diagram

So, the voltage output from the LM35 sensor changes based on the temperature changes through the change in the resistance of the thermal material, and this is possible thanks to the Seebeck thermoelectric effect. This voltage is very sensitive to temperature changes and is used to monitor the temperature in the environment where the sensor is placed.

The thermoelectric element is mainly made of a special thermoelectric material known for its ability to produce a thermoelectric voltage. Its hot point is the one in contact with the environment, while its cold point is located in an environment with a lower temperature. This material has special thermoelectric characteristics that are used to create the thermoelectric voltage.

The A/D converter is an electronic part which is capable of reading the analog voltage coming from the thermoelectric element and converting it into a readable digital form. It uses a certain scale to express the output voltage to a digital temperature value. The voltage processor in the LM35 sensor is used to create a direct connection between the output voltage and the temperature. The scaling is typically 10mV for each degree

Celsius. This means that the voltage changes by 10mV for every 1°C change in temperature.

The stabilization resistor is a component that can be used to compensate for temperature changes in the internal device of the sensor and ensure that the temperature reading is stable.

This resistor is used to adjust the output voltage of the sensor depending on the internal temperature of the device.

A reference voltage converter is a component that supplies a known voltage that is used as a reference for converting voltage to temperature values.

This reference voltage ensures that the temperature reading is accurate and consistent through the A/D converter.

The sensor output is where the converted voltage is output from the sensor and is ready for use in other applications.

This output voltage is a direct measure of temperature and can be used to read temperature or control other devices based on temperature.

4.16 Other system components

Other important components for the construction of this system are the 16x2 LCD, which will serve to display the information received from the sensors and processed by the microcontroller, as well as an SD card module which will save all the data received from the microcontroller.

4.17 LCD screen

Liquid Crystal Displays or LCD screens (Liquid Crystal Display) are a widely used technology in the world of electronics and engineering to display various information in a clear and pleasant way for the user. One of the most common models of LCD screens is 16x2, where the number 16 represents the number of characters that can be displayed on each line, while the number 2 indicates the number of lines available on the screen.

16x2 LCD screens offer the capacity to display text, numbers, special characters and various symbols. This type of screen is ideal for displaying various information in a way that is understandable and usable by users. This is an important aspect for applications such as information devices, thermostats, or any device that needs to display information.

They are used to display important information in various devices such as industrial control devices, medical devices, telecommunication devices and many other fields. LCD screens are known for their low power consumption and ability to stay active for long periods of time. This attribute makes them ideal for devices that need a continuous display of information and don't have to worry about power consumption.

When connected to an I2C communication protocol, they become more controllable and suitable for use with microcontrollers and other devices.

16x2 LCD (Liquid Crystal Display) screens are common text displays that can display 16 characters in a line and have 2 lines. The description "16x2" indicates the number of characters that can appear on each line and the number of available lines. These extremes are known for being calm and contrast, which makes them suitable for displaying text and symbols.

Figure 21. Block sensor diagram 16x2 LCD with I2C communication proto

Each character is made up of tiny pixels and these characters can be displayed in a variable string of ASCII characters. 16x2 LCD screens are voltage-sensitive, so they usually require a voltage source in the 5V range.

The I2C (Inter-Integrated Circuit) protocol is a serial way of communicating between electronic devices in a microcontroller or other control system. This protocol includes two main lines: SDA (Serial Data) and SCL (Serial Clock), and is divided into a master unit and a slave unit.

To connect a 16x2 LCD display with the I2C protocol, an I2C converter is usually used that is equipped with a special address for the device. This special address allows the microcontroller to communicate with the LCD screen.

The I2C protocol helps simplify connection and communication with the 16x2 LCD display, as only two pins can be used for communication (SDA and SCL) and a common I2C device can be connected to many other I2C devices on a single bus.

To control the 16x2 LCD via I2C, you usually need to use a library tailored to your microcontroller or programming platform. [20]

4.18 SD card module

An SD Card module is an electronic device used to connect and control SD (Secure Digital) memory cards in electronic projects. This module provides an easy and stable way to read and write data on SD cards, whether SDHC (High Capacity) or SDXC (Extended Capacity).

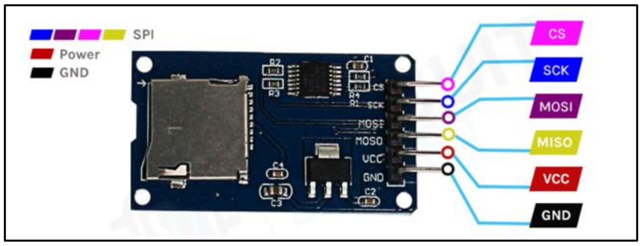


Figure 22. SD card module

The Micro SD Card module has 6 pins; they are GND, VCC, MISO, MOSI, SCK and CS. All pins of this sensor module are digital except VCC and Ground. The point of a Micro SD card module is shown below:

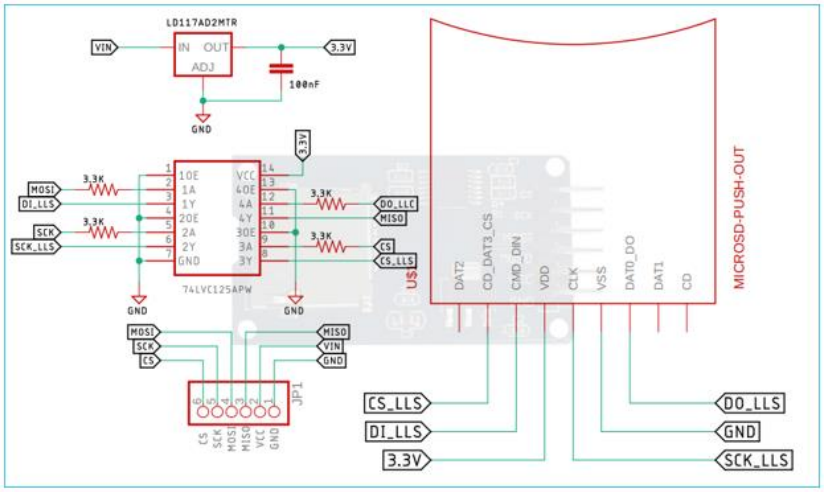


Figure 23. Block diagram of SD card module

GND is the ground pin of the micro-SD card module and should be connected to the Arduino ground box.

VCC is the micro-SD card module power supply pin which can be connected to 5V or 3.3V supply. MISO stands for Master In Slave Out. This is the SPI data from the SD card module.

The acronym for Master Out Slave In is MOSI. This pin on the SD card module is its input. As the name suggests, SCK stands for Serial Clock, and it is the data synchronization pulse produced by the Arduino. Chip Select, or CS for short, is a pin that the Arduino may control to turn the module on or off. The push-out type Micro SD Card connector is shown in the schematic above, and it is coupled to a logic level shifter integrated circuit. Given that the module's maximum operational voltage is 3.6V, the logic level shifter integrated circuit becomes crucial.

The push-out type Micro SD Card connector is shown in the schematic above, and it is coupled to a logic level shifter integrated circuit. Given that the module's maximum operational voltage is 3.6V, the logic level shifter integrated circuit becomes crucial. We are utilizing an LM1117 LDO to power the SD card and logic level converter, allowing this module to operate at both 3.3V and 5V logic levels. The connector at the bottom of the micro-SD card module is represented by the JP1 connector at the bottom of the schematic. [21]

Chapter 5

The health monitoring system

5.1 HealthScan

Monitoring health parameters is very important both for people with health problems and for people who are healthy. Keeping the main health parameters under monitoring can save your life. This is because you can detect disorders such as arrhythmia, decreased oxygen level, frequent breathing, high temperature, and catching various diseases in time. Health monitoring devices are also a must for people with chronic diseases, who must constantly be under monitoring. Since health monitoring devices are of such great importance, in this degree project HealthScan was designed and built, a device that monitors some of the vital parameters and records these data for you to compare with reference data.

5.1 Wiring diagram and components used

To implement this system, some electronic components have been used which have been studied in the previous chapters. The main component is the microcontroller, for which I have chosen to use the Arduino Uno, which has an Atmega328P microcontroller. This microcontroller enables receiving data from sensors, processing these data, and saving them in an external memory.

Other very important components of the system are the sensors. To monitor the health parameters, three types of sensors were used. The Max30100 sensor is the sensor that uses light to measure heart rate and blood oxygen level. The sensor used for temperature monitoring is the LM35 which, through the balance method, gives an analog voltage that changes with the temperature change and through calculations, we can determine the body temperature at a certain moment. A conductive rubber cord was used to measure the breathing frequency, which, by changing the length of the cord, changes the resistance and gives a variable analog voltage, enabling us to measure the breathing frequency.

The peripheral devices used are the LCD Display, which is the screen where the information is displayed, the command buttons, which are the Next button and the Ok button. The Next button gives the possibility to move to the system menu while the Ok button executes the commands that the menu offers. The component used for data storage is a memory card which uses an SD card module to communicate with the Arduino. We save the data we receive from the sensors to this SD card and through Excel processing we extract the chart with the patient's data.

The selected components are wearable components, which can easily be worn on the human body and through a function implemented in Arduino, perform the automatic measurement of all health parameters.

The Proteus 8 application was used to design the system, which offers the possibility of the electronic components used. This application has helped me to realize the electrical scheme of the system.

The diagram below shows all the components used for this electronic system. The Proteus application helped me to make the electrical connections and choose the components used.

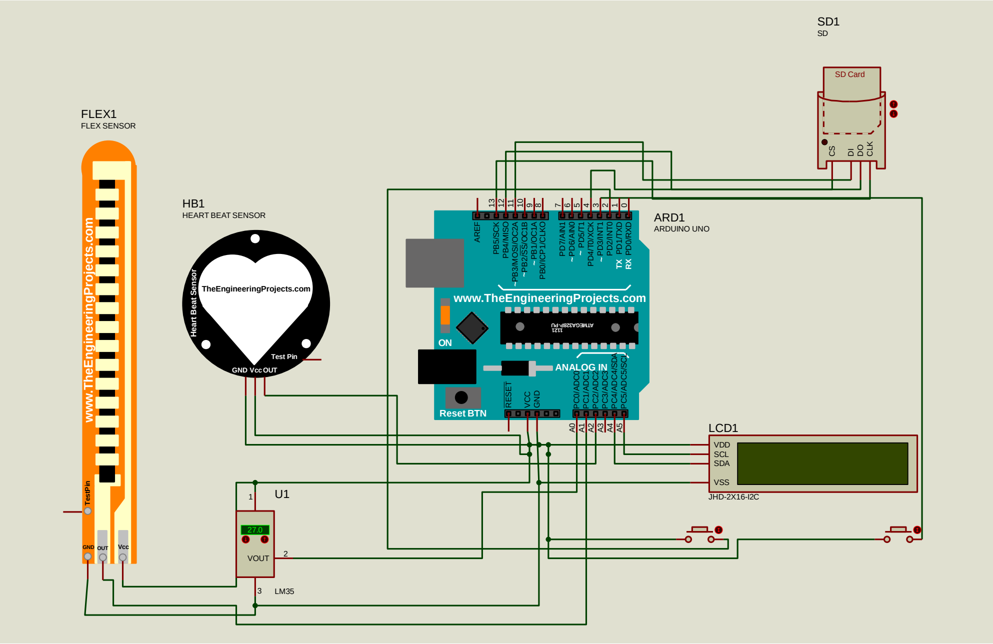


Figure 24. HealthScan

5.2 HealthScan functions

HealthScan is a device that offers several functions. Its functions are displayed on the LCD screen and selected through the Next and Ok buttons.

Turning on the device:

The moment the device is turned on, the configuration of the sensors and the SD card is performed. The name of the device will appear on the LCD screen and it is ready to perform functions. As long as none of the buttons are pressed, the device displays HealthScan. To bring up the menu of functions, press the Next button. The device will remain in the menu for 5 seconds and will return to its primary state. The functions performed by HealthScan are: Information, Temp Measurement, BPM and SPO2, Breathing Rate, Automatic. Each of the functions is selected by the Ok button.

Figure 25.Presentation in normal conditions of the device

Information

Information is a very important function of HealthScan as it informs the user about health parameters. This function displays the optimal parameters that HealthScan is capable of measuring.

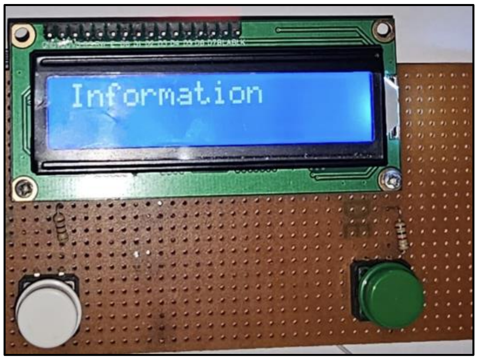


Figure 26. Information menu, if the Ok button (in green) is pressed, information about the health parameters measured by the device is opened.

Temperature Measurement

The second function of HealthScan is temperature measurement. In the analog input A0 of the Arduino comes with the voltage value coming from the LM35 sensor. This value is received by the Arduino and saved to a variable. Based on the datasheet of the sensor, through different voltage values, we determine the temperature of the human body. This is done through the formula:

voltage = reading * (5.0 / 1024.0); (4.1) temperatureC = voltage * 100 (4.2)

The sensor is placed on the forearm in order to be the least annoying for the patient. In order to make the measurement, the temperature of the sensor must be placed in balance with the temperature of the human body, and therefore HealthScan requires 100 seconds to respond with an answer. During these 100 seconds, 100 different temperature values are obtained from the Arduino and we estimate their average. This is done in order to increase accuracy. In order to have a greater accuracy in the measurement, it is recommended that the sensor is placed on the body 5 minutes before giving the measurement command.

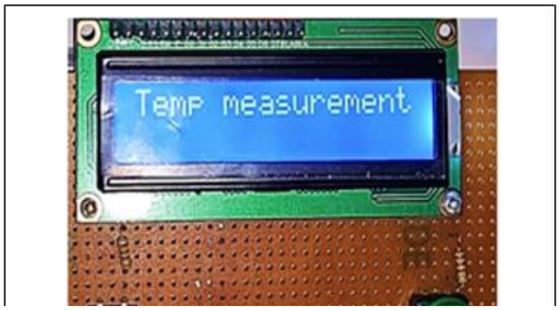


Figure 27. Menu for temperature measurement

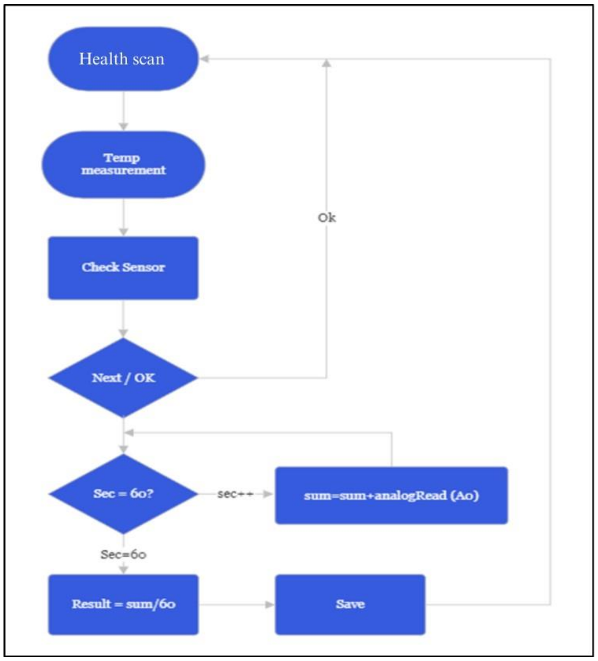


Figure 28. Running the Temp measurement menu

BPM and SPO2

This function measures heart pulse and blood oxygen level. The sensor used is the MAX30100, a sensor that uses an LED and a photodetector to detect color changes in the blood and detect when there are pulsations. Blood with different oxygen levels has different colors. The MAX30100 sends light and performs the calculation of the oxygen level from the reflection of the light. Pulsations are also detected through the light, due to the change of light during the blood supply. The sensor will be placed on the index finger, as it is the part of the body that can be illuminated more easily than others. To use this sensor, we used a library that offers ready-made functions and calculates the heart rate and SPO2 level.

Figure 4.6: Menu for BMP and SpO2 measurement

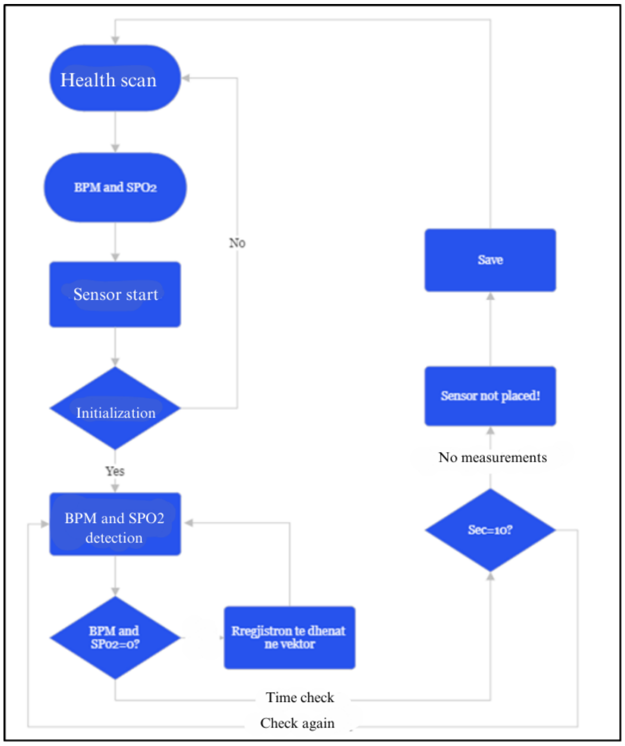


Figure 29. Running the BPM and SPO2 menu

Breathing Rate

This function performs the measurement of breathing frequency. This function is realized by using a rubber cord which gives different tension values during pulling. This sensor is connected via three pins to the Arduino and gives an analog voltage value. By performing some measurements of how the resistance value changes, we find a reference value for the voltage that will be input to the analog port. When the voltage exceeds the calculated value, then a breath is recorded. The breathing variable will be incremented as soon as the sensor is extended and gives a value greater than that reference. To derive the respiratory rate value, the response is given after 1 minute. Once this value is obtained, the data is recorded on the SD card.

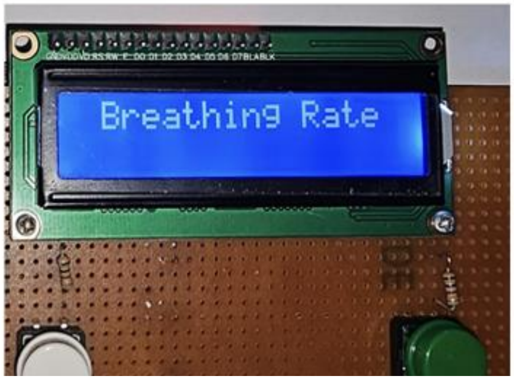


Figure 30. Menu for breathing monitoring

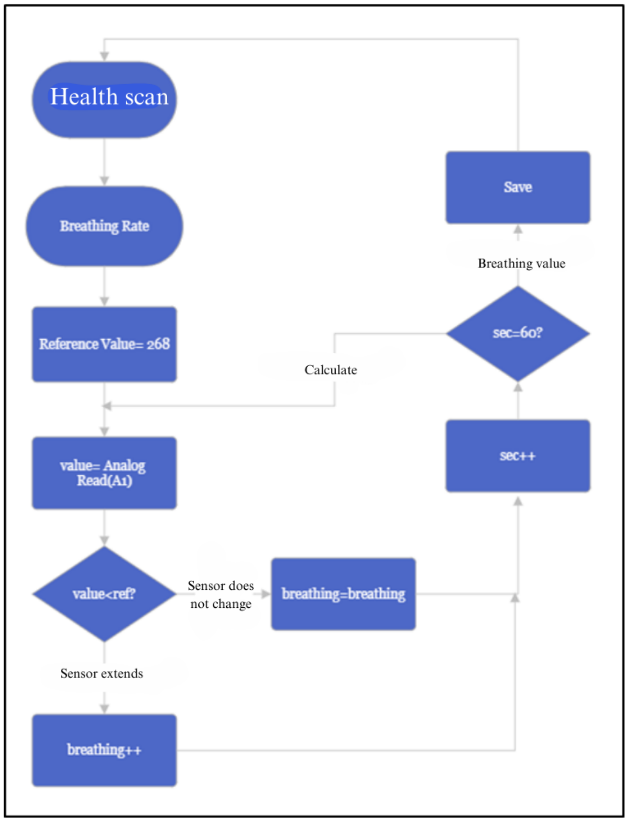


Figure 31.Running the Breathing Rate menu

Automatic

This function measures all the above-mentioned parameters, automatically only by selecting the Auto menu and placing all the sensors of HealthScan.

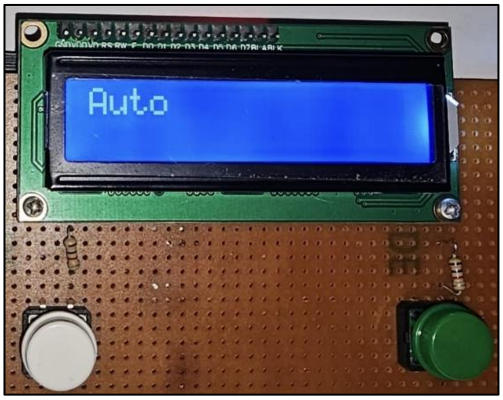


Figure 32. Auto menu

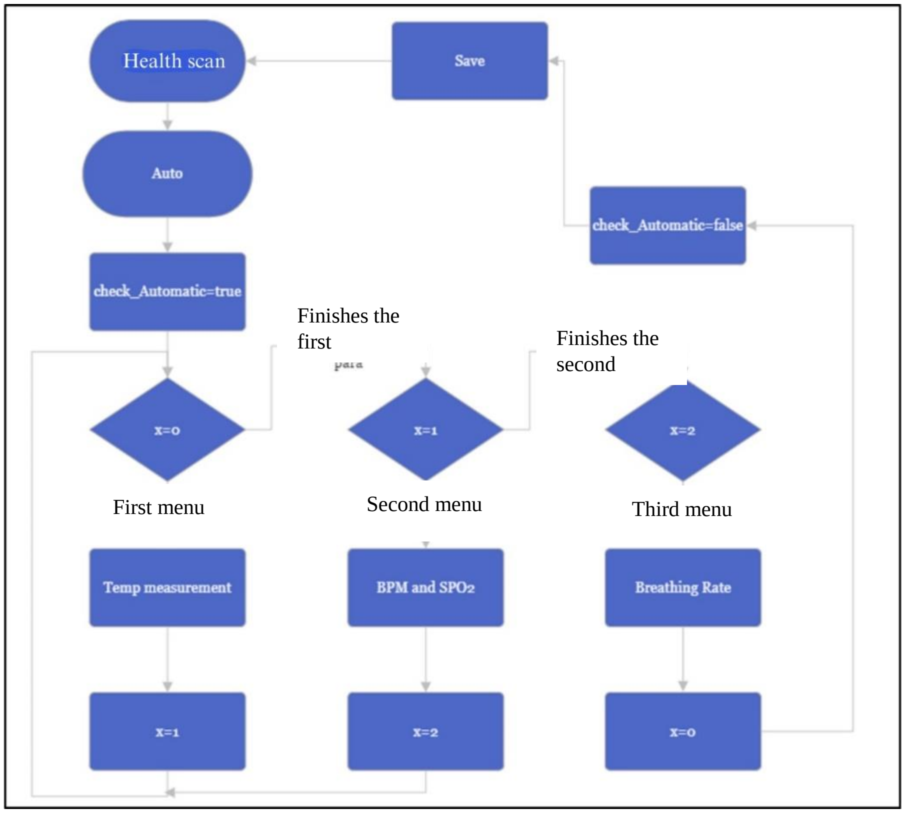


Figure 33. Running the auto menu

4.3. Device execution

The following figures will show the use of the system to perform measurements for each parameter.

Temperature monitoring

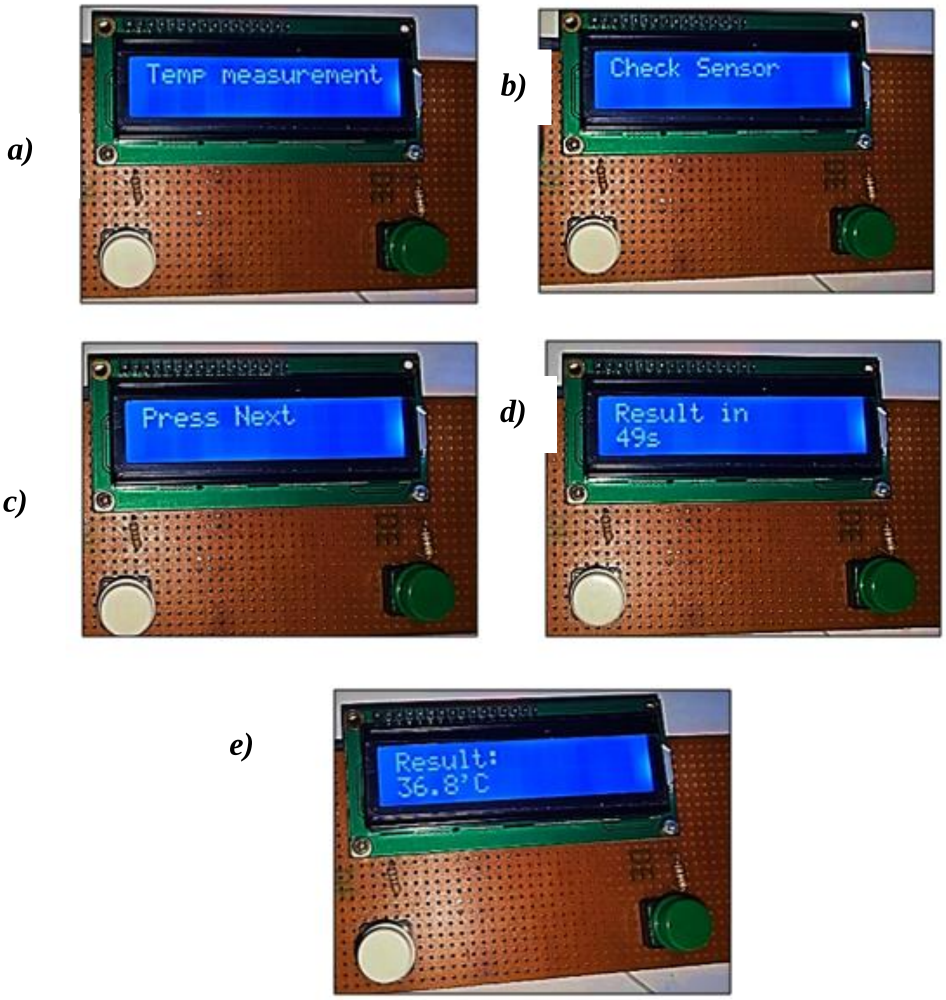


Figure 34. a) Menu selection, b) asks the patient to check the sensor, c) asks for next if the button is set, ok to cancel, d) the measurement result is displayed for 60 seconds, e) the result presented in °C.

Monitorng of BPM dhe SpO2

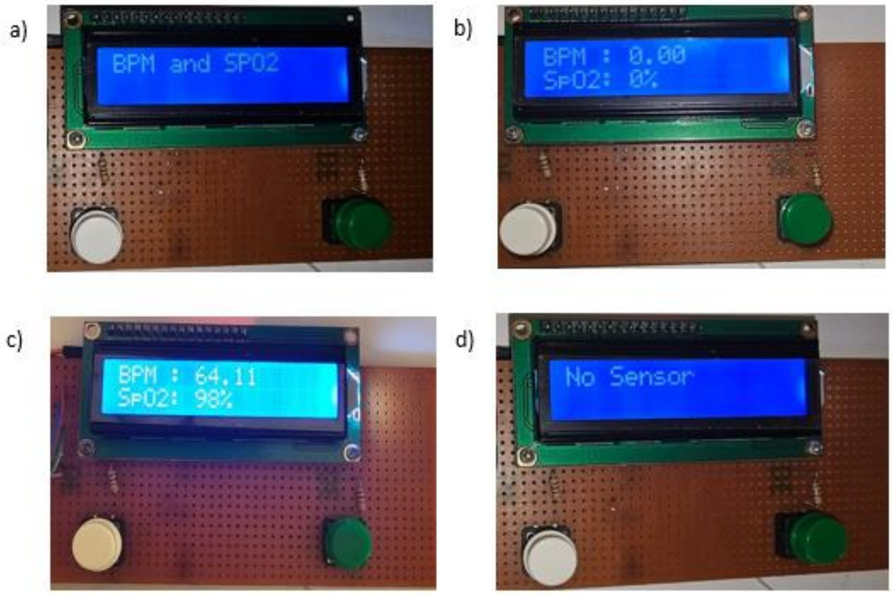


Figure 35. a) menu selection, b) switching on the sensor and initialization, c) result from the performed measurement, d) measurement stops when the sensor does not detect a patient

Breathing monitoring

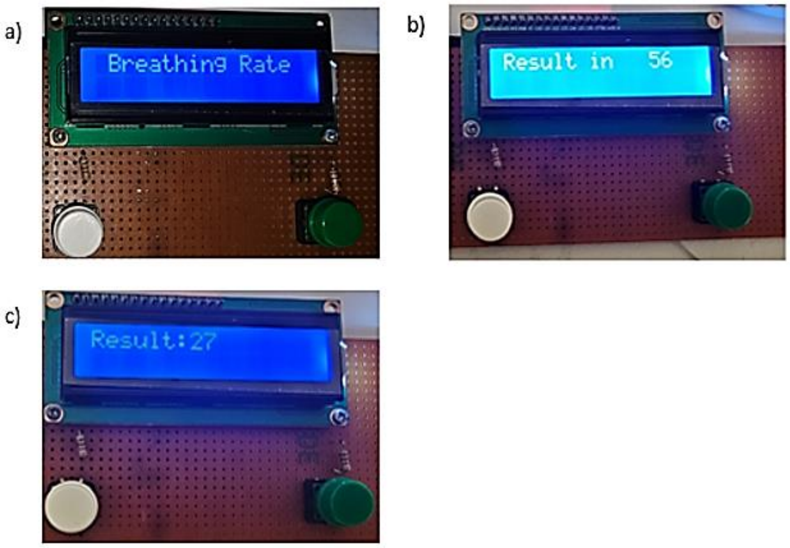
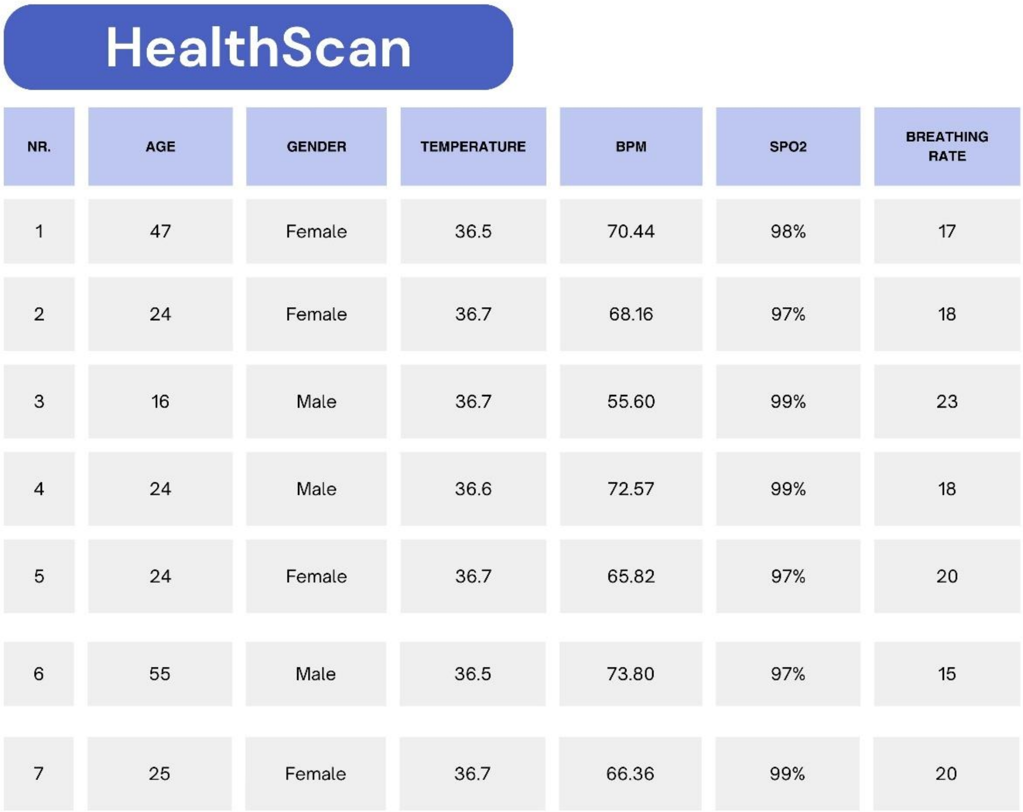


Figure 36. a) menu selection, b)timer till the end of the results, c) end result

These are some real data measurements done on my closest friends and family where the results are also refined and shown on the following diagrams.



HealthScan

NR.	AGE	GENDER	TEMPERATURE	BPM	SPO2	BREATHING RATE
1	47	Female	36.5	70.44	98%	17
2	24	Female	36.7	68.16	97%	18
3	16	Male	36.7	55.60	99%	23
4	24	Male	36.6	72.57	99%	18
5	24	Female	36.7	65.82	97%	20
6	55	Male	36.5	73.80	97%	15
7	25	Female	36.7	66.36	99%	20

Figure 37.All persons measured data

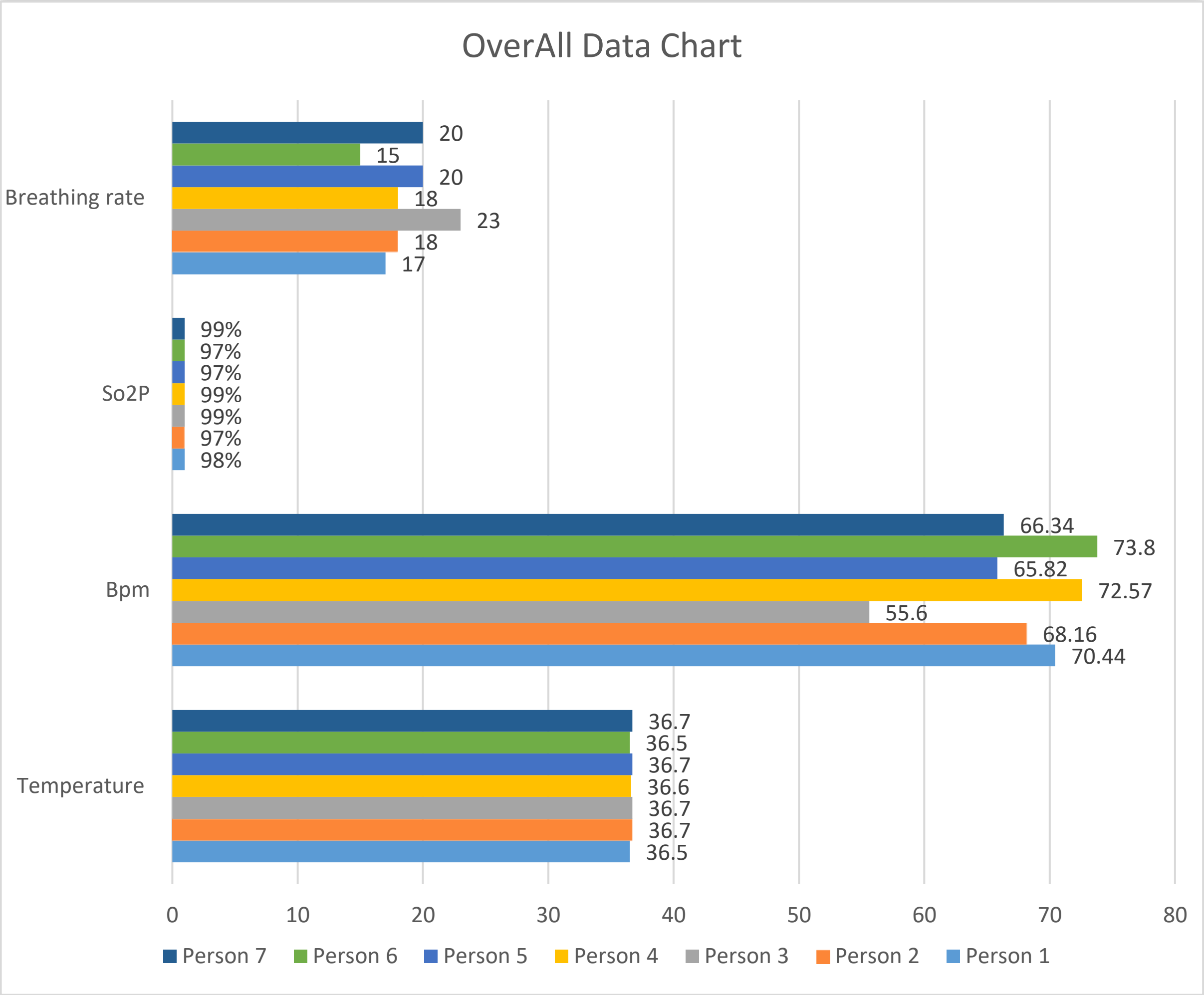
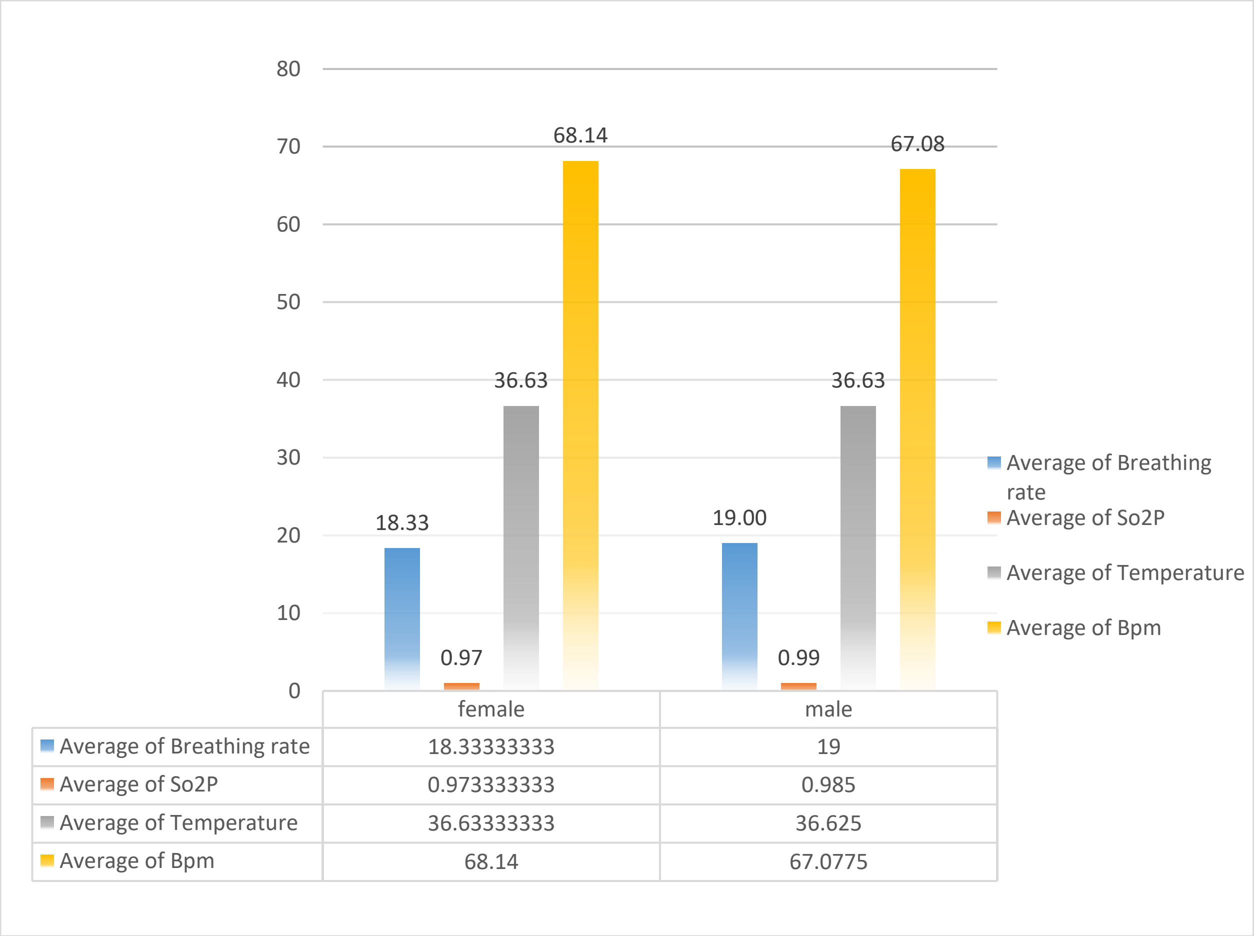


Figure 38. Measurements data for each person no matter the gender, for each parameter



	female	male
🟦 Average of Breathing rate	18.33333333	19
🟧 Average of So2P	0.973333333	0.985
▨ Average of Temperature	36.63333333	36.625
🟨 Average of Bpm	68.14	67.0775

Figure 39. Average for each parameter depending on the gender

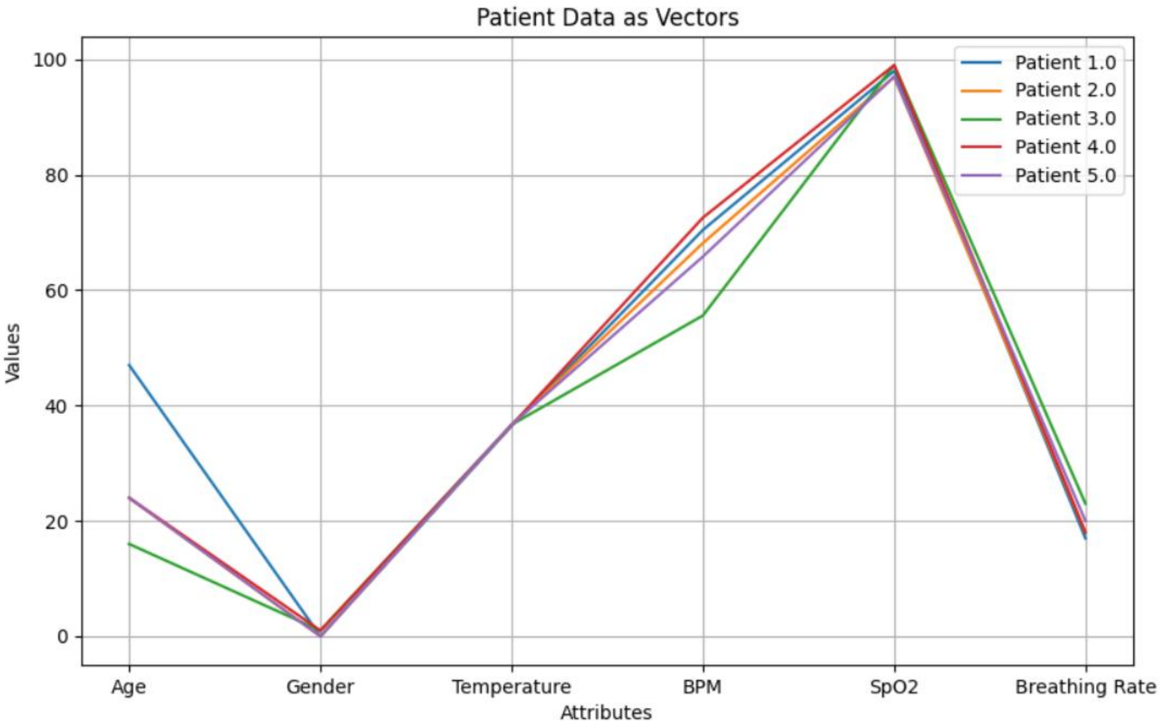


Figure 40. Each person data visualized as vectors with lines

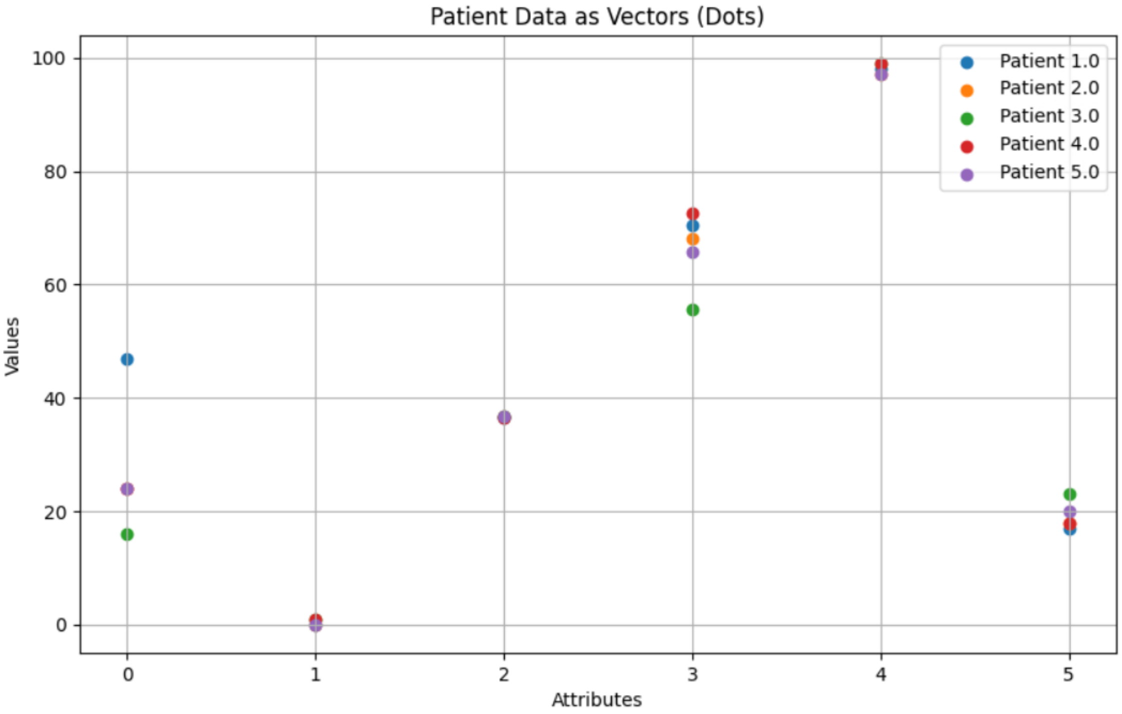


Figure 41. Each person data visualized as vectors with lines

CHAPTER 6

CONCLUSIONS

The device developed here in this work is a powerful tool for monitoring personal health parameters, giving individuals the opportunity to monitor and document their health status. The device offers the ability to monitor health in two ways: manually and automatically, thus facilitating use in different changes. The device is built with low costs and is affordable by many users. This fact makes it usable for a wide range of people. The device allows the storage and analysis of health monitoring data in an easy-to-process format, thus allowing the creation of specialized medical charts for health status monitoring. It is efficient in energy consumption and can be used with batteries, making it suitable for long-term use. Securing health data and respecting privacy are priorities of this system to ensure that user's personal data is adequately protected. The device can help increase users' awareness of their health status and help identify early changes and it offers the possibility of helping relatives and similar persons who need regular health monitoring. The system is easy to use and does not require deep technical knowledge or the help of health professionals to be efficient. The possibility of recording data in Excel format allows detailed medical analysis, which can help in the diagnosis and further treatment of diseases.

Jobs in the future

Even though the first version of the system worked as expected and is able to perform accurate monitoring of health parameters, there is a lot of room for iterations, especially from the hardware side. Below I will mention some of the ways that will make the system more reliable, more aesthetic and easier to use.

Replacing the ATmega328P microcontroller with another microcontroller that offers a larger dynamic memory and faster processing of processes, such as the Atmega2560. In this way we can add processes, sensors and operating systems such as FreeRTOS that offer the possibility of processing several actions at the same time.

a) Implementation of IoT in the system. In this way, the data obtained from the sensors can be sent directly to the hospital centers communicating directly with the doctor.

b) Replacement of the LM35 sensor with an infrared sensor. In this way, the measurement is faster and more accurate.

c) Replacing the sensor that monitors breathing with a sensor that stays more static on the body and is not affected by muscle movements.

d) Realization of the communication of the sensors with the microcontroller with Bluetooth. This would make the system more aesthetic and comfortable for the patient since the use of wires is eliminated.

e) Construction of a charging module, which makes it possible to charge the system's batteries.

Building an application that automatically receives the data, processes it and outputs the health status for each patient referencing to the normal values.

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ANNEX

```
#include <Wire.h>

#include <LiquidCrystal_I2C.h>

#include <SD.h>

#include "MAX30100_PulseOximeter.h"

#define REPORTING_PERIOD_MS 1000

bool check_automatic=false;

int x=0;

LiquidCrystal_I2C lcd(0x27, 16, 2);  // I2C address, 16 columns, 2 rows

int menu = 1;

int buttonNext = 2;

int buttonOK = 3;

int lastButtonNextState = LOW;

int lastButtonOKState = LOW;

byte smile[] = {

 B00000,

  B00000,

  B01010,

  B00000,

  B10001,
```

```
  B01110,

  B00000,

  B00000

};

byte heart[]={

  B00000,

  B01010,

  B11111,

  B11111,

  B01110,

  B00100,

  B00000,

  B00000

};

const int chipSelect = 4;

PulseOximeter pox;

uint32_t tsLastReport = 0;



File myFile;

void setup() {

  Serial.begin(9600);
```

```
  lcd.createChar(1, smile);

  lcd.createChar(2, heart);

  lcd.init();

  lcd.backlight();

  lcd.setCursor(1, 0);

  lcd.print("Helthcan");

  delay(1000);

  pinMode(buttonNext, INPUT_PULLUP);

  pinMode(buttonOK, INPUT_PULLUP);

  lcd.setCursor(0, 0); // move cursor to (2, 0)

  lcd.write(1);

  lcd.setCursor(9, 0); // move cursor to (2, 0)

  lcd.write(2);

}

void information_for_you() {

  lcd.clear();

  lcd.setCursor(0, 0);

  lcd.print("Information!");

  delay(2000);

  lcd.clear();

  lcd.setCursor(0, 0);
```

```
lcd.print("Normal breathing");

lcd.setCursor(0, 1);

lcd.print("12-20 BrPM");

delay(2000);

lcd.clear();

lcd.setCursor(0, 0);

lcd.print("Normal pulse:");

lcd.setCursor(0, 1);

lcd.print("60-100 BPM");

delay(2000);

lcd.clear();

lcd.setCursor(0, 0);

lcd.print("Normal temp:");

lcd.setCursor(0, 1);

lcd.print("36.5 C");

delay(2000);

lcd.setCursor(0, 0);

lcd.print("Normal SpO2:");

lcd.setCursor(0, 1);

lcd.print("95%-100%");

delay(2000);
```

```
  lcd.clear();
  setup();}
int i=0;
void loop() {
  int buttonOKState = digitalRead(buttonOK);
  int buttonNextState = digitalRead(buttonNext);
  delay(100);
  if (buttonNextState == LOW && lastButtonNextState == HIGH) {
    delay(200); // Delay for button debounce
    menu = (menu % 5) + 1; // Cycle through menus 1 to 5
    lcd.clear();
    lcd.setCursor(0, 0);
    switch (menu) {
      case 1:
        lcd.print("Information");
        i=0; break;
      case 2:
        lcd.print("Temp measurement");
        i=0;
        break;
      case 3:
```

```
     lcd.print("BPM and SPO2");
      i=0;
      break;
    case 4:
      lcd.print(" Breathing Rate");
      i=0;
      break;
    case 5:
      lcd.print("Auto");
      i=0;
      break;}}
if (buttonOKState == LOW && lastButtonOKState == HIGH) {
  delay(200); // Delay for button debounce
  lcd.setCursor(0, 1);
  switch (menu) {
    case 1:
      information_for_you();
      break;
    case 2:
      lcd.clear();
      temp_measurement ();
```

```
     break;
   case 3:
     lcd.clear();
     lcd.setCursor(0, 0);
     lcd.print("BPM and SPO2");
     delay(2000);
     bpm_spo();
     break;
   case 4:
     lcd.clear();
     breathingRate();
     break;
     case 5:
     automatic();
     break;}}
lastButtonNextState = buttonNextState;
lastButtonOKState = buttonOKState;
i++;
if(i==100){
  setup();}}
```

```
void temp_measurement (){

  if (check_automatic==false){

  delay(1000);

lcd.clear();

lcd.setCursor(0, 0);

lcd.print("Check Sensor");

delay(1000);



while (digitalRead(2) == LOW) {

  lcd.clear();

  lcd.setCursor(0, 0);

  lcd.print("Press Next");

  delay(100);

  if (digitalRead(3)==HIGH){

    setup();

    return;}}}

else {lcd.clear();lcd.print("AUTO Temp");delay(1000);}

lcd.clear();

lcd.setCursor(0, 0);

lcd.print("Result in");

delay(2000);
```

```
float sum =0.0 ;

float temperatures [60];



 for (int k = 60; k >= 0; k--) {

 lcd.setCursor(0, 13);



 float reading = analogRead(A0);

 float voltage = reading * (5.0 / 1024.0);

 float temperatureC = voltage * 100;

 temperatures[k] = temperatureC;

 sum += temperatures[k];

 lcd.print(k);

 lcd.print("s");

 delay(1000);

}

float average = sum / 60;



lcd.clear();

lcd.setCursor(0, 0);

lcd.print("Result: ");

lcd.setCursor(0, 1);
```

```
lcd.print(average);

lcd.print("'C");

delay(100);

save(1,average);

delay(5000);

lcd.clear();

if (check_automatic==false){

setup();}

else

automatic();

}

void bpm_spo(){

pox.begin();

pox.setIRLedCurrent(MAX30100_LED_CURR_7_6MA);

 int j=0;

 i=0;

if(check_automatic==true){

  lcd.clear();

  lcd.print ("Auto BPM/SPO2");

  delay (1000);}

  while (i<300){
```

```
    pox.update();

if (millis() - tsLastReport > REPORTING_PERIOD_MS) {

  lcd.clear();

  lcd.setCursor(0, 0);

  lcd.print("BPM : ");

  lcd.print(pox.getHeartRate());

  lcd.setCursor(0, 1);

  lcd.print("SpO2: ");

  int bpmValue=0;

  lcd.print(pox.getSpO2());

  lcd.print("%");

  tsLastReport = millis();

    if(pox.getHeartRate()==0.00){

      j++;

      }

      else {

        for (int i=0;i<50;i++){

          bpmValue=bpmValue+pox.getHeartRate();}

        j=0;}

    if(j==20){

      lcd.clear();
```

```
      lcd.setCursor(0,0);
      lcd.print("No Sensor");
      delay(2000);
      float value=bpmValue/50;
    //  save(2,value);
      if(check_automatic==false){ setup(); return;}
      else{ automatic();return;}}}}}
void save (int where,float value){
Serial.print("Initializing");
if (!SD.begin(4)) {
  setup();
  return;
  while (1);
}
delay(100);
Serial.println("done.");
delay(100);
if(where==1){
myFile = SD.open("temp.txt", FILE_WRITE);
myFile.println(value);
}
```

```
 if(where==2){

myFile = SD.open("bpm.txt", FILE_WRITE);

myFile.println(value);

}

 if(where==3){

myFile = SD.open("br.txt", FILE_WRITE);

myFile.println(value);

}

if (myFile) {

  myFile.close();

  Serial.println("done.");

  setup();

  return;

} else {

  Serial.println("error");

  return;}

myFile = SD.open("temp.txt");

myFile = SD.open("br.txt");

myFile=SD.open("bpm.txt");

if (myFile) {

  Serial.println("done");
```

```
    myFile.close();

    myFile.close();

    myFile.close();

  } else {

    Serial.println("error");}}

const int reference = 268;

unsigned int breathCount = 0;



 void breathingRate(){

  if(check_automatic==true){

    lcd.clear();

    lcd.print ("Auto Breathing");

    delay (1000);}

  lcd.clear();

  lcd.print("Result in");

  for (int i=600;i>=0;i--){

      int sensorValue = analogRead(A1);

      if (sensorValue <= reference) {

      breathCount++;}

  lcd.setCursor(12,0);

  lcd.print(i);
```

```
 delay(100);}
 lcd.clear();
 lcd.print("Result:");
 lcd.print(breathCount);
// save(3,breathCount);
 check_automatic=false;
 setup();}
 void automatic(){
 check_automatic=true;
 if (x==0){
    x=1;
   temp_measurement(); }
 if (x==1){
   x=2;
   bpm_spo();}
 if (x==2){
   x=0;
   breathingRate(); }}
```