The Smart Solution of Bed Pressure ulcers

Project team

Ahmad Saed Azhar Itbasheh Hamza Amayreh

Supervisor:

Dr. Ayman wazwaz

Submitted to the College of Engineering
In partial fulfillment of the requirements for the degree
Of Bachelor degree in Biomedical and Electrical engineering

Palestine polytechnic university

June – 2021

Abstract

The idea of this project is to design a medical mattress with water pillows to reduce the incidence of clinical ulcers. Most hospitals suffer from a problem facing patients who are forced to sleep on the bed for long periods of time, which is clinical ulcers. Several solutions appeared that were not as effective, including patient manual turn and position and air pillows. Our project will give an explanation of this problem and develop a smart technical solution to reduce the complication of these ulcers. The project works to reduce the form of clinical retardation of patients who sit on the bed for long periods without moving, through pumping and sucking of water within two balms installed on the medical bed, the shape of which is proportional to the shape of the human body and its pressure points. In addition, monitoring the patient's vital state, such as temperature and heart rate, by sending information from the medical mattress via Wi-Fi to a phone carried by the pathogen.

المُلَخَّصْ

حيث فكرة هذا المشروع هي تصميم فرشة طبية بوسائد مائية لتقليل حدوث القرحات السريرية، تعاني معظم المستشفيات من مشكلة تواجه المرضى الذين يضطرون إلى ملازمة السرير لفترات طويلة من الزمن ، وهي القرحة السريرية.

ظهرت العديد من الحلول التي لم تكن بتلك الفعالية ، كفكرة الوسائد الهوائية و التقليب اليدوي للمريض حيث الطرق التقليدية التي تتبعها أغلب المستشفيات، سيقوم مشروعنا بشرح هذه المشكلة وتطوير حل تقني ذكي للوقاية من هذه التقرحات.

Table of Contents

List of Figures

List of tables

1. Chapter one

Introduction

1.1. Overview

In this chapter we will present the basic idea of the project represented in how to take advantage of the water pillows technology to reduce the incidence of clinical ulcers suffered by people who sit for long periods on the same destination, and how we can enhance this idea through the use of smart technology with microcontrollers, In addition to that, we will present some of the previous projects (Related work) in the same regard and the main objectives that we want to obtain from this idea.

1.2. Motivation

The design (The Smart Solution of Bed ulcers) is based on the treatment of clinical ulcers that face some hospitals patients, these ulcers are a chronic infection that affects the skin due to sitting or leaning for long periods on the same side after that it develops and affects the tissues and damages them, and may sometimes reach The patient's bones and may lead to death if not treated or detected as soon as possible.

Furthermore , the nurse responsible for these disease states is obliged to actively follow up at all times, and he may often resort to manual turn and position patients and this leads to fatigue of the nurse, as the technology will help the nurse to follow the patient remotely through the Wi-Fi.

What also prompted us to do this was the idea that most of the technologies in hospitals are ineffective well. Air pillows are one of the technologies used in Palestinian hospitals. The principle of work of these pillows is to pump air at specific intervals, which relieves pressure on the target area, this technique is useless in many times and is not ideal in the treatment of chronic ulcers, as the patient's turning has become the alternative used in most cases of disease.

1.3. Objective

In this project, we aim to reduce the rate of formation of clinical ulcers in patients who sit for long periods of time in the same position by designing a suitable and safer medical mattress.

1.3.1. Goals

1. Design the medical mattress that contains the water pillows so that it fits in its design all the pathological cases and all the reclining positions and the various weights (regarding the shape and location of the spaces or water pillows in the design of the medical mattress).

2. Design the appropriate technique for turning the patient's position in a smooth, safer, and more hygienic way (the mechanical method of turning the patient should be smooth and not irritating to the patient).

3. Comfort the nurse and the patient by replacing manual position turning with water pillows technology, especially for people with high weights.

4. Design a mobile application connected with the design that sends the nurse the health information of the patient that helps him to follow up the patient's vital processes remotely and alerts in some cases.
5. Monitor the patient's temperature by installing temperature sensors.
6. Monitor the heart rate by installing special sensors.

1.4. Methodology

The design is based on what is shown in the **Figure 1. 1** on the use of the water pillows installed on the mattress, this is done by pumping and withdrawing water (suction) according to the target area temperature and pressure on it (the area of the ulcer), this works to raise the surrounding area and reduce the pressure, and thus reducing the percentage of Ulceration. The design makes the nurse able to monitor the patient's health status in terms of temperature and heart rate. It is sent via Wi-Fi to the nurse's phone. All devices in this system are controlled by a microcontroller.

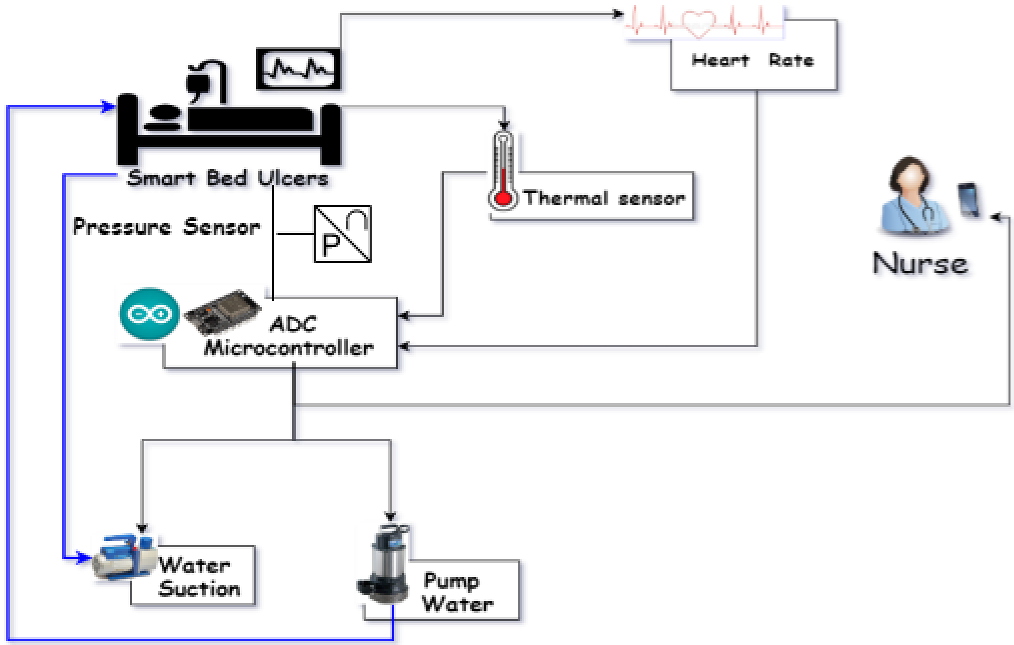


Figure 1-1-1 Project Design

1.5. Related work

There are some inventions that have tried to solve the problem of clinical ulcers. And we will mention some of these inventions and compare them with the design that we have come up with:

1.5.1. Super Care – Air mattress

The mattress for both types of bed sores is one of the most important and first steps in preventing superficial and chronic skin ulcers from forming in the future, especially when accelerating their use at the onset of the disease, which requires sitting in bed for long periods that may extend for months or perhaps years. The pneumatic device with a mattress can bear up to 80 kg and it is the maximum load that the mattress can carry and perform its duties in treating and preventing the emergence of new ulcers [1].

Figure 1-1-2 Air mattress

1.5.2. ICU-OptiCare

The new integrated mattress for ICU – OptiCare – provides patient with optimizing care. The system detects when the patient has entered the bed. This automatically initiates the optimization process, thereby saving the time normally required for nurses to set the mattress parameters. The mattress settings are automatically optimized for each patient based on the patient’s weight, height, and even the patient’s position on the mattress.

Six detectors within the mattress sense the patient’s level of immersion and facilitate the automatic adjustment of the pressure throughout the mattress to adjust to each patient’s weight, height, and position. The pressure on the patient’s body is low in all places and optimally distributed. The even distribution across the entire body area eliminates excessive pressure at the risk points thanks to above-standard immersion and envelopment.

* IMMERSION: the depth of the patient’s level in relation to the mattress surface.

* ENVELOPMENT: the degree to which the patient is surrounded by the mattress.

Figure 1-3 ICU-OptiCare [2]

One of the similar projects is a previous project for students from our university, which is monitoring the vital processes of the body and touching on the location of ulcers in a simple way in terms of their causes and damages resulting from them, and here we will find a solution for the failure of this problem and its treatment.

In Summary:

We conclude that most of the previous projects were trying to treat ulcers after they occurred or treat ulcers by traditional methods such as air mattresses or medical pillows, and here we will be the first to design a medical bed that prevents clinical ulcer.

1.6. Estimated Cost and Budget

The initial cost of this project is about, distributed as follows in the **Table 1-1**:

Component	Required number	Price $
Medical matterss	1	880
NOBILITY BRASS	36	105.5
Arduino MEGA	1	41
ESP wemos	1	13
Temperature Sensor DS18B20	5	50
Pressure Sensor MPS20N0040D	4	10
Pump-Suction	2	48
Connections and pipes	1	15
Soldering board	1	8
Really module 8Ch	1	15
Really module 1Ch	1	2
Micro Electrical Valves	8	11
Electrical jumpers and sockets	10	10
Heart rate sensor	1	20
Total cost		1228$

Table 1-1-1 Estimated cost

1.7. Time plane

The project schedule will be divided into the following **Table 1-2**:

Task	Duration (weeks)															
	First semester								Second semester							
	2	4	6	8	10	12	14	16	2	4	6	8	10	12	14	16
Planning																
Project Requirements																
System analysis																
System Design																
Project development																
Project testing and maintenance																
Documentation																

Table 1-1-2 Timing plane for the first semester

2. Chapter Two:

Theoretical background

In this chapter, we will discuss a set of concepts that we will use in our project. A brief explanation of each concept will be provided. We'll cover skin, bed ulcers, Arduino MEGA, water pump and suction, pressure and temperature sensor and valves, heart rate sensor.

2.1. Skin

2.1.1. Introduction to skin

The skin covers the entire external surface of the human body and is the principal site of interaction with the surrounding world. It serves as a protective barrier that prevents internal tissues from exposure to trauma, ultraviolet (UV) radiation, temperature extremes, toxins, and bacteria.

Other important functions include sensory perception, immunologic surveillance, thermoregulation, and control of insensible fluid loss.

The integument consists of 2 mutually dependent layers, the epidermis and dermis, which rest on a fatty subcutaneous layer, the panniculus adiposus. The epidermis is derived primarily from surface ectoderm but is colonized by pigment-containing melanocytes of neural crest origin, antigen-processing Langerhans cells of bone marrow origin, and pressure-sensing Merkel cells of neural crest origin [3].

The skin is one of the largest organs of the body and is responsible for providing protection to the other systems of the body. Skin prevents water loss and dehydration, shields the internal organs in the event of injury, regulates body temperature, senses outside stimuli such as touch as well as heat and cold, and serves as a barrier to infection. As seen in figure 2-1, the skin is made up of three layers: the outer epidermis, the dermis and the deep subcutis layer.

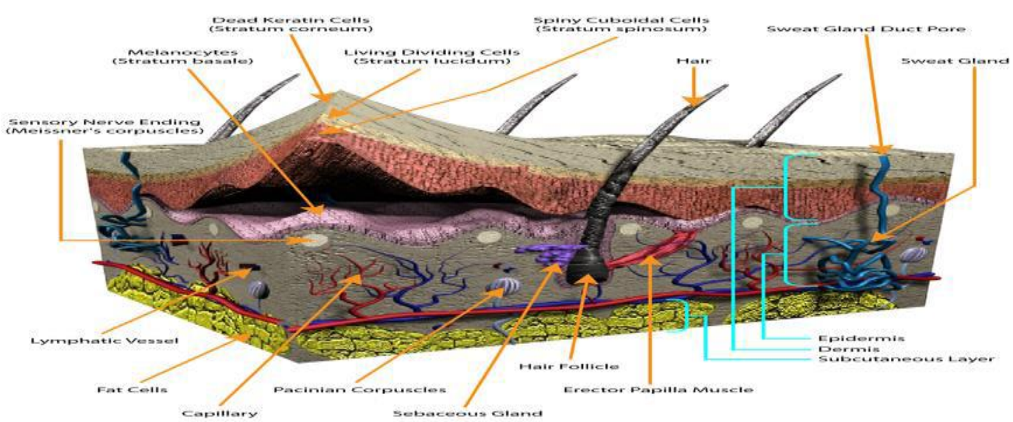


Figure 2-1 Skin layer

Other important elements of the skin include: hair follicles, sweat glands and nerve endings. Hair follicles protrude into the dermis layer and help regulate body temperature.

Microscopic pores on the surface of the skin are connected to sweat glands which also help maintain homeostasis [4].

2.1.2. Skin Layers

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

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

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

Epidermis

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

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

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

Hypodermis

The hypodermis, or subcutaneous tissue, is immediately deep to the dermis. It is a major body store of adipose tissue, and as such can vary in size between individuals depending on the amount of fatty tissue present.

2.1.3. Skin Functions

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

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

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

Anything that interferes with skin function or causes changes in appearance (see Effects of Aging on the Skin) can have major consequences for physical and mental health. Many problems that appear on the skin are limited to the skin. Sometimes, however, the skin provides clues to a disorder that affects the entire body. Consequently, doctors often must consider many possible diseases when evaluating skin problems. They may need to order blood tests or other laboratory tests to look for an internal disease in people who come to them with a skin problem [5].

2.1.4. Skin Ulcers

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

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

There are many different types of ulcers of the skin. The two most common types include venous skin ulcers which generally affect the feet and the legs and are caused by a reduction in blood flow and therefore swelling. The other common type is pressure ulcers which can be caused by excessive pressure on the skin on any part of the body. Both conditions can cause similar symptoms of itchy and painful reddened or blistered skin and open crater-like sores [6].

2.2. Bed Ulcers

Pressure ulcers (also known as pressure sores or bedsores) are injuries to the skin and underlying tissue, primarily caused by prolonged pressure on the skin.

They can happen to anyone, but usually affect people confined to bed or who sit in a chair or wheelchair for long periods of time.

2.2.1. Symptoms of pressure ulcers

Symptoms appear according to the stages of the ulcer, which are as follows:

- **The first stage:**

Redness and warmth to the touch compared to surrounding skin, and may be blue or purple. The patient may also complain of burning, pain, or itching.

- **The second phase:**

The affected area is damaged by the appearance of a fluid-filled blister or an open sore that is pink or red. The victim may also complain of pain, as well as a change in the color of the skin around the area.

• **Third level:**

The area is characterized by a crater-like appearance (deep wound); the damage extends down the layers of the skin, including the lipids.

• **The fourth stage:**

The area is severely damaged; Tissue has been lost on a large scale, and it may reach the muscles, tendons, bones and joints. Infection is also a great risk at this stage [7]

2.2.2. Who's most at risk of getting pressure ulcers

Anyone can get a pressure ulcer, but the following things can make them more likely to form:

- Being over 70 – older people are more likely to have mobility problems and skin that's more easily damaged through dehydration and other factors.
- Being confined to bed with illness or after surgery.
- Inability to move some or all of the body (paralysis).
- Obesity.
- Urinary incontinence and bowel incontinence.
- A poor diet.
- Medical conditions that affect blood supply, make skin more fragile or cause movement problems – such as diabetes, peripheral arterial disease, kidney failure, heart failure, multiple sclerosis (MS) and Parkinson's disease [8].

2.2.3. Common sites of pressure ulcers

For people who use wheelchairs, bedsores often occur on skin over the following sites:

- Tailbone or buttocks.
- Shoulder blades and spine.
- Backs of arms and legs where they rest against the chair.

For people who need to stay in bed, bedsores may happen on*:*

- The back or sides of the head.
- The shoulder blades.
- The hip, lower back or tailbone.
- The heels, ankles and skin behind the knees [9].

2.2.4. Possible complications

Without proper and timely treatment, a bed sore can lead to serious complications such as:

- Cellulitis, which may later cause sepsis and spread the infection to all parts of the patient's body.
- Infections of bones and joints.
- Poisoning in the blood.

2.3. Block Diagram

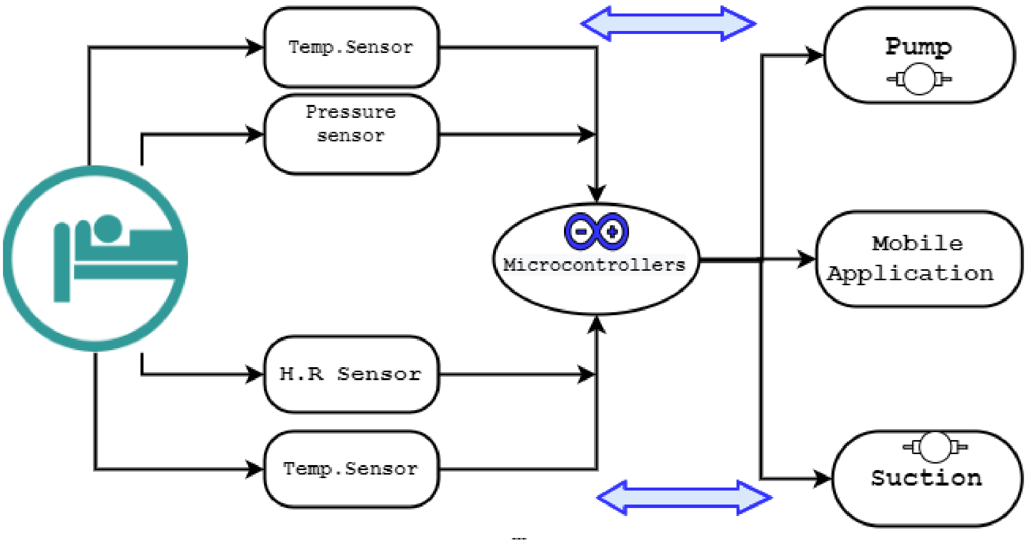


Figure 2-2 System's Block Diagram

We can summarize the mechanism of the project into two parts:

The main objective of the design:

When the temperature of the patient’s target area exceeds 39.5 ° C and a compressive force exceeds the critical value within a period of time to be determined according to the actual circumstance, the information is sent via a network of thermal sensors installed on the medical "pillow" mattress to the Arduino Mega, after which the pump is switched on , So that the water is pumped to the target area "surrounding the area with a high temperature", this process leads to a rise in the surrounding area, from there to reduce the level of pressure on the target area, and from there to reduce the temperature and return to its normal position, where the order is given to the pumping process through the Arduino Mega, where the duration of the temperature and pressure increase is set by applying the phone linked to the mattress via Wi-Fi Arduino, and the same process continues on all active points in the sensor network installed on the mattress. After the temperature of the target area decreases, the water is suctioned out from the areas containing the water, and it returns to the previous state. This process is done by measuring the temperature so that it is below Critical 39.5.

Another work done by the medical bed, the patient is turned in successively every period of time that is set to be adjusted through the application, to change the conditions and pressure points in the patient’s body, and this process does not follow the temperature of the affected area, rather it is a special process aimed at continuous flipping of the patient’s body.

Secondary objective:

The patient's temperature and heart rate are monitored through secondary temperature sensors installed on the mattress "pillows" in addition to heart rate sensors, these sensors send information to the secondary Arduino installed in the design, and then the patient's vital signs are sent to a phone application carried by the nurse or person who Follow-up of the patient.

2.4. Medical mattress for bed ulcers

There are many designs for preventing the formation of clinical ulcers, those designs are based on reducing the incidence of ulcers through several techniques, and one of these techniques is the use of air pillows (balloons) where the air is pumped through pneumatic pumps (air pumps) inside these pillows, the air is pumped sequentially so that The pressure is distributed on more than one point, this type of designs is common and used in most hospitals in the world, and it may be useful at times to prevent the formation of ulcers, but it is not very feasible for some special cases such as high weights.

Figure 2-3 Air medical bed

. wheelchair-friendly enough for a person to sit [10].

Figure 2-4 Diamond Pillows Bed

Figure 2-5 Cylindrical Pillows Bed

Figure 2-6 People with disabilities bed

Figure 2-7 Cubes Pillows Bed

2.5. Microcontroller Unit

A microcontroller is an integrated circuit (IC) device used for controlling other portions of an electronic system, usually via a microprocessor unit (MPU), memory, and some peripherals. These devices are optimized for embedded applications that require both processing functionality and agile, responsive interaction with digital, analog, or electromechanical components.

It is also microcomputer manufactured to control the functions of embedded systems in office machines, robots, home appliances, motor vehicles, and a number of other gadgets. A microcontroller is comprises components like – memory, peripherals and most importantly a processor. Microcontrollers are basically employed in devices that need a degree of control to be applied by the user of the device [11].

Basic Microcontroller

Any electric apparatus that stores, measures, shows data or ascertains include a microcontroller chip inside it. The fundamental structure of a microcontroller involves:

CPU – Microcontrollers mind is named as CPU. Computer chip is the gadget which is utilized to get information, translate it and toward the end total the appointed assignment effectively. With the assistance of CPU all the parts of microcontroller is associated into a solitary framework. Guidance brought by the programmable memory is decoded by the CPU.

Memory – In a microcontroller memory chip works same as microprocessor. Memory chip stores all programs & data. Microcontrollers are built with certain amount of ROM or RAM (EPROM, EEPROM) or flash memory for the storage of program source codes.

I/O ports are fundamentally utilized to interface or drive various apparatuses, for example, printers, LCD's, LED's, and so on.

ADC (Analog to digital converter) – ADC is employed to convert analog signals to digital ones. The input signals need to be analog for ADC. The digital signal production can be employed for different digital.

- Interpret Control- This controller is employed for giving delayed control for a working program [12].

A common example of Microcontrollers is the **Arduino.**

2.5.1. Arduino

Arduino is an electronic development board that consists of an open source electronic circuit with a microcontroller on one board that is programmed by the computer and is designed to make the process of using interactive electronics in multidisciplinary projects easier. Arduino is mainly used in the design of interactive electronic projects or Projects that target building different environmental sensors (such as temperature, wind, pressure, etc.). The Arduino can be connected to different programs on the personal computer. Arduino relies on programming it on the open source programming language, processing, and the programming code for the Arduino language is distinguished by that it is similar to the C ++ programming language and is considered one of the easiest programming languages used in writing microcontroller programs.

History: the story begins in 2005 in the Italian city of Ivrea, where Massimo Banzi, in cooperation with David Cuartielles and Gianluca Martino, launched the Arduin of Ivrea project, and the project was named after the most famous historical figure in the city. The main objective of the project was to create an open source 100 percent accurate development environment for microcontrollers, and this project included creating a software development environment for microcontrollers, which is free at the same time. It also included the work of small-sized development boards at a low cost, which is currently about $ 27 to be able. Students and techies bear the price, and as of 2013, more than 700,000 Arduino boards had been shipped [12].

Why we will use Arduino?

We have many of Microcontrollers example, like parallax, fundamental stamp, NetMedia's BX-24 phidgets, and Raspberry PI, all of which have solid capacities and capacity to control different electronic parts and programming, which obviously is of shifting inclination yet not What recognizes Arduino is a gathering of things that have any kind of effect among him and others, the most significant of which are:

1. Effortlessness: Arduino's record is intended to meet everybody's requirements, experts, instructors, understudies and intelligent gadgets devotees.

2. The Thin: Arduino is more affordable than different plates of a similar sort and Arduino is close to $50 for the most costly Arduino.

3. Multi stage: The Jordanian program can work on Windows, Mac OS, Linux and most other electronic controls run uniquely on Windows.

Straightforward and simple programming climate: The programming climate is intended to be simple for learners, steady and amazing for experts [13].

Type of Arduino

Recently, the number of Arduino boards has reached nearly 40 types, all of them follow the same programming language, each type has its own feature and application according to the request of the user and programmer, but the most widespread are:

- **Arduino Uno**
- **Arduino Nano**
- **Arduino Mega**

In this Project we have to use Arduino MEGA, because it contains some properties that we need to build the project.

2.5.2. Arduino MEGA

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

Figure 2-8 MEGA Arduino Module [14]

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

Table 2-1 Technical Details of Arduino MEGA

2.5.3 Wi-Fi Module (ESP wemos)

Some types of Arduino do not support internet connection except by connecting it to an electronic piece called (ESP), which represents the link between the Arduino and the device connected to the Internet.

The Arduino WiFi Shield allows an Arduino board to connect to the internet using the 802.11 wireless specification (WiFi). It is based on the HDG204 Wireless LAN 802.11b/g System in-Package. An AT32UC3 provides a network (IP) stack capable of both TCP and UDP. Use the WiFI library to write sketches which connect to the internet using the shield. The WiFI shield connects to an Arduino board using long wire-wrap headers which extend through the shield. This keeps the pin layout intact and allows another shield to be stacked on top.

The Wi-Fi Shield can connect to wireless networks which operate according to the 802.11b and 802.11g specifications.

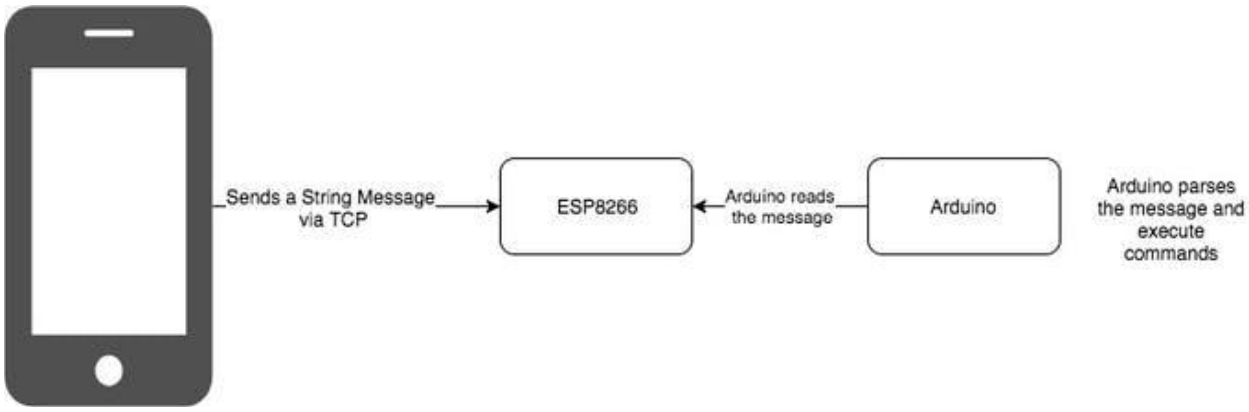


Figure 2-9 ESP connect with Arduino

In this project we have to use ESP wemos d1 mini r1

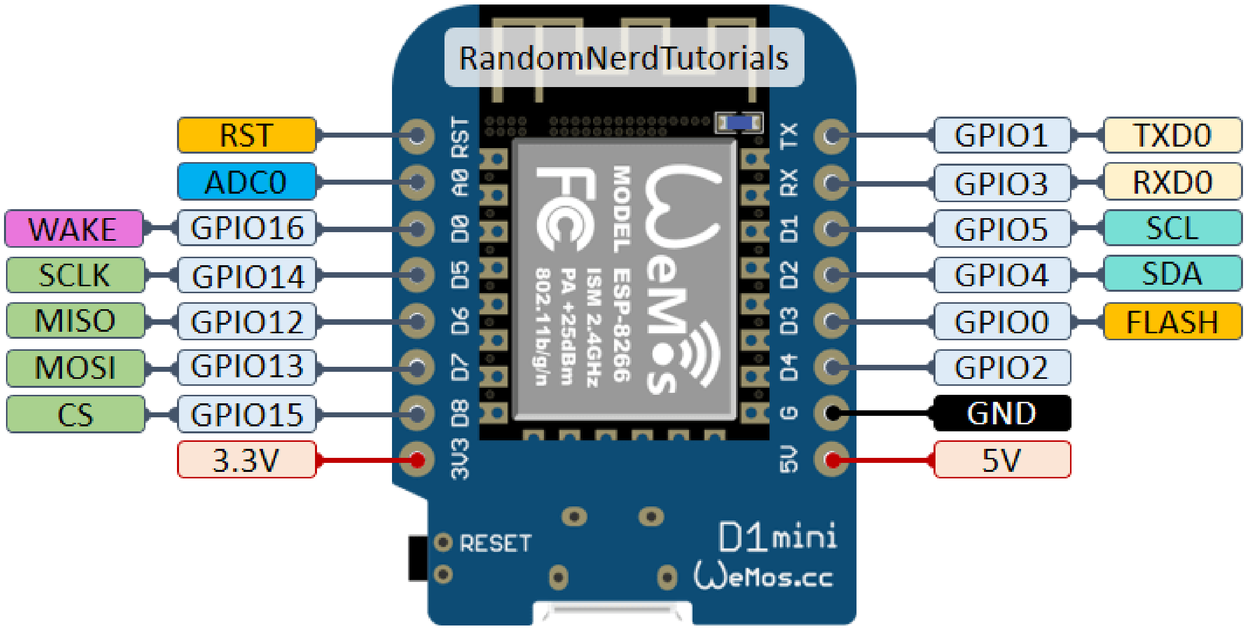


Figure 2-10 wemos d1 mini r1 Pins

2.6. Water Pump-Suction

The pump pushes specific quantities of water during a specific time and flow. We have many types of pumps available, with electrical capabilities and special specifications.

In our project, we will use a number of small pumps, about 10 pumps for all mattress, although multi-channel pumps are available, but they are expensive, so we have chosen small pumps, the Volt each of them is 12VDC

We will use 12 volt, 1 bar water pump, this work as pump and suction.It contains two entrances (on, out).

In the case of pumping, we will use the (On Pin), and in the case of suction we will use (OT Pin).


.

Figure 2-11 Self suction water pump [16]

2.7. Micro Electrical Valves

A valve is a gadget or characteristic item that manages coordinates or controls the progression of a liquid (gases, fluids, fluidized solids, or slurries) by opening, shutting, or halfway hindering different paths. Valves are actually fittings, however are normally talked about as a different class. In an open valve, liquid streams toward a path from higher strain to bring down pressing factor.

These valves work when electric current is passed through their coils (on and off).Its internal structure contains a magnet and an electric coil. When the electric current passes, the positive and negative electrodes of the magnet are attracted to the magnet, which closes the valve.

Figure 2-12 Janatics Solenoid Valves [18]

- **Valve specifications**

Pressure	2 to 10 Bar
Structure	Square /Round/ Rectangular Body
Coil Voltage	12V, 24V, 110V
Mounting Type	Line / Sub-base Mounting
Ip Rating	IP66
Port Size	1, 2, 4, G1/4", 3.5 and G1/8"

2.8. Pressure Sensor

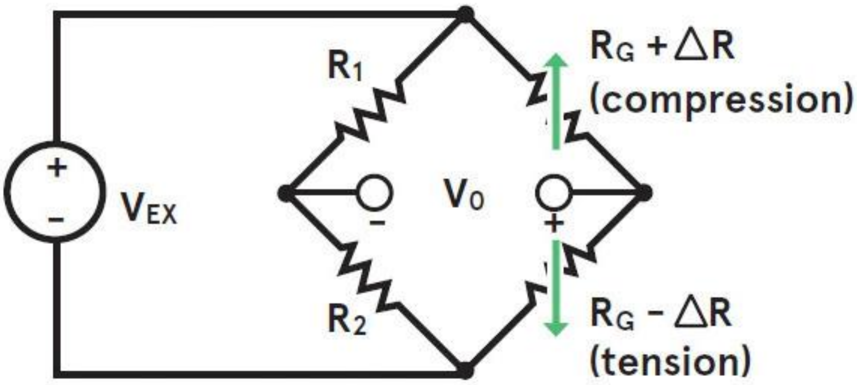
Pressure sensors are instruments or devices that translate the magnitude of the physical pressure that is being exerted on the sensor into an output signal that can be used to establish a quantitative value for the pressure. There are many different types of pressure sensors available, which function similarly but rely on different underlying technologies to make the translation between pressure and an output signal. This article will discuss the most common types of pressure sensors, describe the working principals of pressure sensors, review the common specifications associated with pressure sensors, and present examples of applications.

One difference to note is that pressure sensors are different from pressure gauges. Pressure gauges by their design provide a direct output reading of a pressure value referred to as gauge pressure. This can be in the form of an analog (mechanical) display using a needle and graduated scale, or via a direct digital display of the pressure reading. Pressure sensors, on the other hand, do not directly provide a readable output of pressure, but instead generate an output signal value which is proportional to the pressure reading, but which first needs to be conditioned and processed to convert the output signal level to a calibrated pressure reading.

- How it is Work?

Pressure transducers generate a higher level of voltage or frequency output by having additional signal amplification capabilities built-in to boost the magnitude of the output signal to say 5V or 10V, and the frequency output to 1-6kHz. The increased signal strength allows for the use of pressure transducers at a greater range from the electronics, say 20 feet. These devices use a higher supply voltage level such as 8-28VDC. Higher output voltages reduce current consumption, making pressure transducers useable in applications where the equipment is battery powered.

While pressure sensors and pressure transducers generate a voltage output, pressure transmitters produce a low impedance current output, typically used as analog 4-20mA signals in a 2-wire or 4-wire configuration. Pressure transmitters feature good electrical noise immunity (EMI/RFI) and are therefore suitable for applications where it is necessary to transmit signals over longer distances. These devices do not require regulated power supplies, but the higher current output and power consumption make them unsuitable for applications with battery-powered equipment when the devices are operated at or near full pressure.



2.8.1.1. Figure 1: A strain gauge pressure sensor using a Wheatstone bridge

2.8.1. Pressure measurement technologies

There are six primary pressure sensor technologies used to sense pressure. These are:

- Potentiometric pressure sensors
- Inductive pressure sensors
- Capacitive pressure sensors
- Piezoelectric pressure sensors
- Strain gauge pressure sensors
- Variable reluctance pressure sensors

2.8.2. Types of Pressure sensor

- Aneroid Barometer Sensors
- Manometer Sensors
- Bourdon Tube Pressure Sensors
- Vacuum Pressure Sensors
- Sealed Pressure Sensors

In this project we used MPS20N0040D Pressure sensor from Potentiometric pressure sensors family.

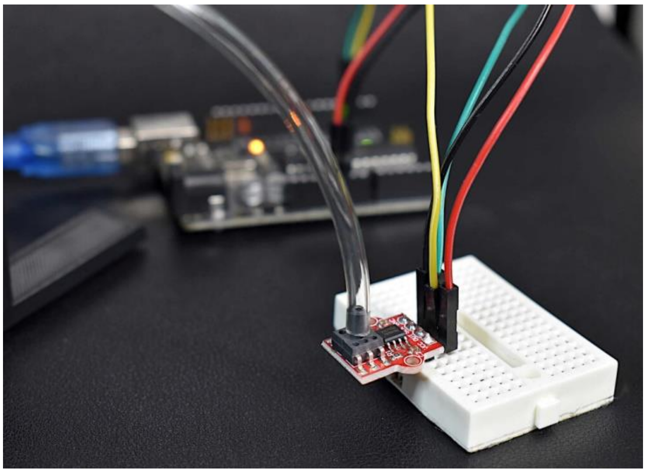


Figure 2-13 Pressure sensor

2.9. Heart Rate Sensor

2.9.1. Description

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

2.9.2. Non-Invasive methods of heart rate measurement

Electrocardiograph (ECG):

ECG stands for electrocardiogram. The abbreviations for the word electrocardiogram (derived from the Greek electro for electric, cardio for heart, and graph for “to write”) and the German word electrocardiogram. ECG feature extraction has been studied from early time and lots of advanced techniques as well as transformations have been proposed for accurate and fast ECG feature extraction. During each heartbeat that is detected and amplified by ECG. Each heart muscle cell has a negative charge, called the membrane potential, across its cell membrane. Decreasing this negative charge toward zero and depolarizing it, which activates the mechanisms in the cell that cause it to contract [19].

During each heartbeat, a healthy heart will have an orderly progression of a wave of depolarization that is triggered by the cells in the sinoatrial node, spreads out through the atrium, and passes through the atrioventricular node and then spreads all over the ventricles. This is detected as small rises and falls in the voltage between two electrodes placed either side of the heart, which is displayed as a wavy line either on a paper or on screen [20].

This figure indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle [21]:

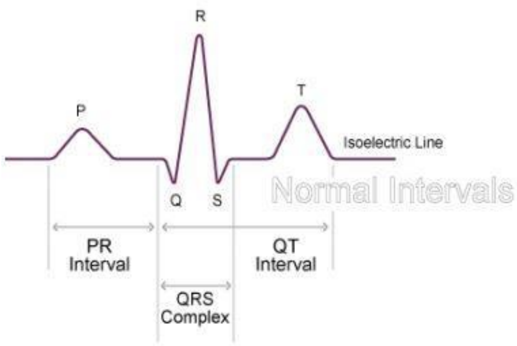


Figure 2-14 Normal Intervals

P-R interval = 0.12 - 0.20 sec

QRS width = 0.08 - 0.12 sec

Q-T interval 0.35 - 0.43 sec

2.9.3. Photoplethysmography (PPG) Signal

Photoplethysmography (PPG) Signal PPG is an optical measurement technique that can be used to detect blood volume changes in the microvascular bed of tissue. It has widespread clinical application, with the technology utilized in commercially available medical devices, for example in pulse oximetry, vascular diagnostics and digital beat-to-beat blood pressure measurement systems [22].

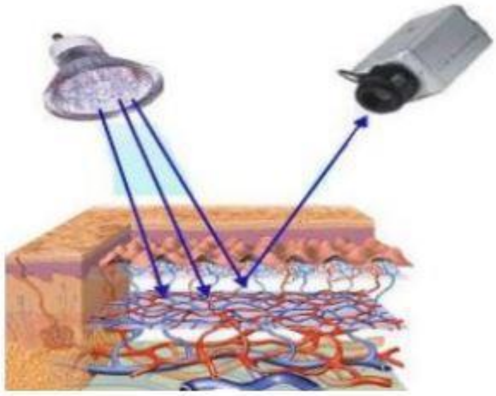


Figure 2-15 PPG signals using photo detector and Light source

The basic form of PPG technology requires only a few optoelectronic components: a light source to illuminate the tissue (e.g. skin), and a photo detector to measure the small variations in light intensity associated with changes in perfusion in the catchment volume. PPG is most often employed noninvasively and operates at a red or a near infrared wavelength. The most recognized waveform feature is the peripheral pulse, and it is synchronized to each heartbeat. Despite its simplicity the origins of the different components of the PPG signal are still not fully understood.

It is generally accepted, however, that they can provide valuable information about the cardiovascular system [23].

2.10. Temperature Sensor (DS18B20)

DS18B20 Sensor Specifications

- Programmable Digital Temperature Sensor
- Communicates using 1-Wire method
- Operating voltage: 3V to 5V
- Temperature Range: -55°C to +125°C
- Accuracy: ±0.5°C
- Output Resolution: 9-bit to 12-bit (programmable)
- Unique 64-bit address enables multiplexing
- Conversion time: 750ms at 12-bit
- Programmable alarm options
- Available as To-92, SOP and even as a waterproof sensor

2.10.1. Where to use DS18B20 Sensor

The **DS18B20** is a 1-wire programmable Temperature sensor from maxim integrated. It is widely used to measure temperature in hard environments like in chemical solutions, mines or soil etc. The constriction of the sensor is rugged and also can be purchased with a waterproof option making the mounting process easy. It can measure a wide range of temperature from **-55°C** to **+125°** with a decent accuracy of **±5°C**. Each sensor has a unique address and requires only one pin of the MCU to transfer data so it a very good choice for measuring temperature at multiple points without compromising much of your digital pins on the microcontroller.

2.10.2. How to use the DS18B20 Sensor

The sensor works with the method of 1-Wire communication. It requires only the data pin connected to the microcontroller with a pull up resistor and the other two pins are used for power as shown below.

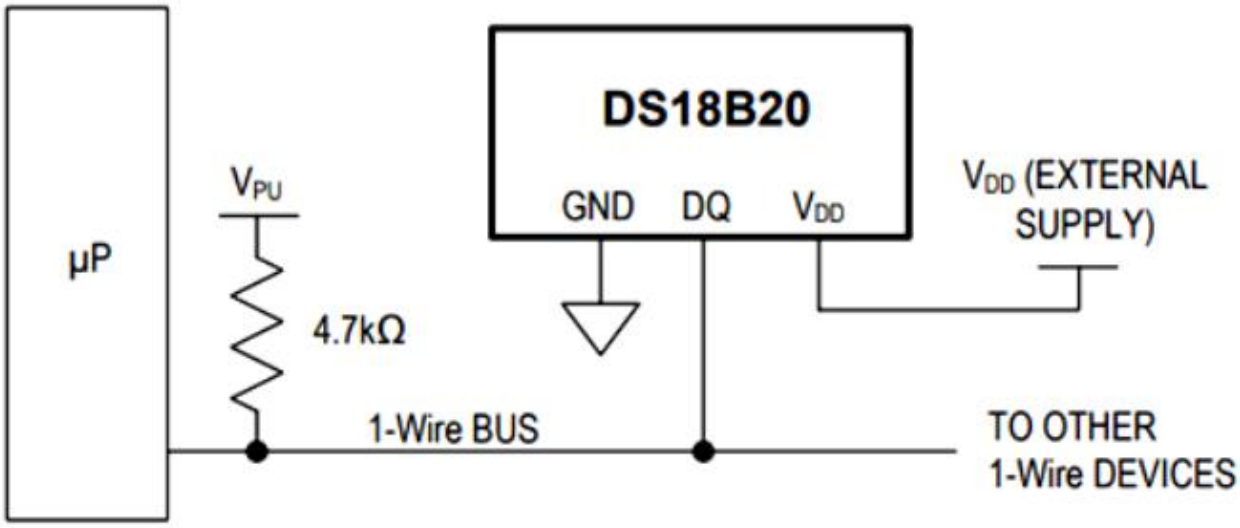


Figure 2-16 DS18B20 Sensor

The pull-up resistor is used to keep the line in high state when the bus is not in use. The temperature value measured by the sensor will be stored in a 2-byte register inside the sensor. This data can be read by the using the 1- wire method by sending in a sequence of data. There are two types of commands that are to be sent to read the values, one is a ROM command and the other is function command. The address value of each ROM memory along with the sequence is given in the datasheet below. You have to read through it to understand how to communicate with the sensor.

If you are planning to interface it with Arduino, then you need not worry about all these. You can develop the readily available library and use the in-built functions to access the data.

Application

- Measuring temperature at hard environments.
- Liquid temperature measurement.
- Applications where temperature has to be measured at multiple points.

3. Chapter Three:

System Design

3.1. Introduction

This part will explain the mechanism of design work, starting from clarifying and studying all possible positions of the patient's body to lean on the bed, passing through thermal sensors that sense the temperature of the patient's active area, in addition to the principle of the pressure sensor's work, after that, this data will be sent to the Arduino For its analysis, when the critical temperature and the critical pressure value is reached, the Arduino will analyze the data, after which the stirring process (i.e. pumping or suctioning water) will be delayed for a period of appropriate time to be determined through the application. Then the Arduino will send an electronic signal to the water valve to open the valve and operate the pump directly to pump within the area around the active zone, this process raises the area around the active zone and reduces the pressure on the active zone. If the effective area temperature is low, the thermal sensor sends a signal to the Arduino to signal the water valve to draw water from the area surrounding the active area. As for the secondary objective of the design, the body will be rotated and positioned routinely every period of time will be set through the application through secondary water balloons installed on the bed and connected directly to the Arduino, which in turn turns on the pump to pump water or draw water from those areas.

This part will include the details of each element and its working mechanism within the design.

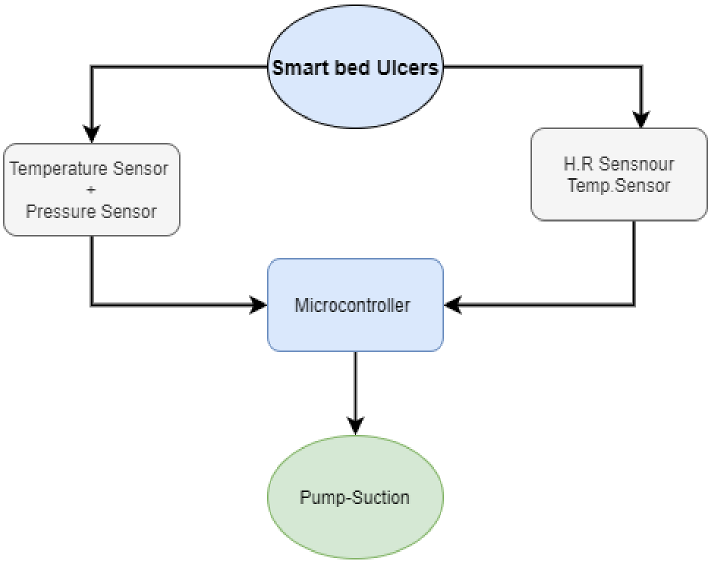


Figure 3-1 Simple diagram of the design work mechanism

3.2. Bed Ulcers Pillow Design

3.2.1. Most bed ulcers position

In the beginning, we will clarify the active areas in the bed, i.e. the areas most likely to form ulcers. These areas were designed based on studying all the positions of the patient's body separately, and accordingly, the water pillows were designed in a manner consistent with the shape of each area to gain as much effectiveness as possible.

Areas which are most likely to form ulcers:

A. The upper region: the head region includes three positions:
   I. The position of head inclination to the left.
   II. The position of head inclination to the right.
   III. The position of face to up.

B. The back and abdomen region includes three positions:
   I. The position of lying on the back.
   II. The position of lying on the abdomen.
   III. The position of lying on the left and right side.

C. The middle region: includes the left and right sides, includes three positions:
   I. The position of lying on the back.
   II. The position of lying on the abdomen.
   III. The position of lying on the left and right side.

D. The lower region: It includes the legs, includes three positions:
   I. The position of lying on the back.
   II. The position of lying on the abdomen.
   III. The position of lying on the left and right side.

Each lying position of the body has special weakness points, these points are most likely to form ulcers, according to several studies that have been conducted [26].

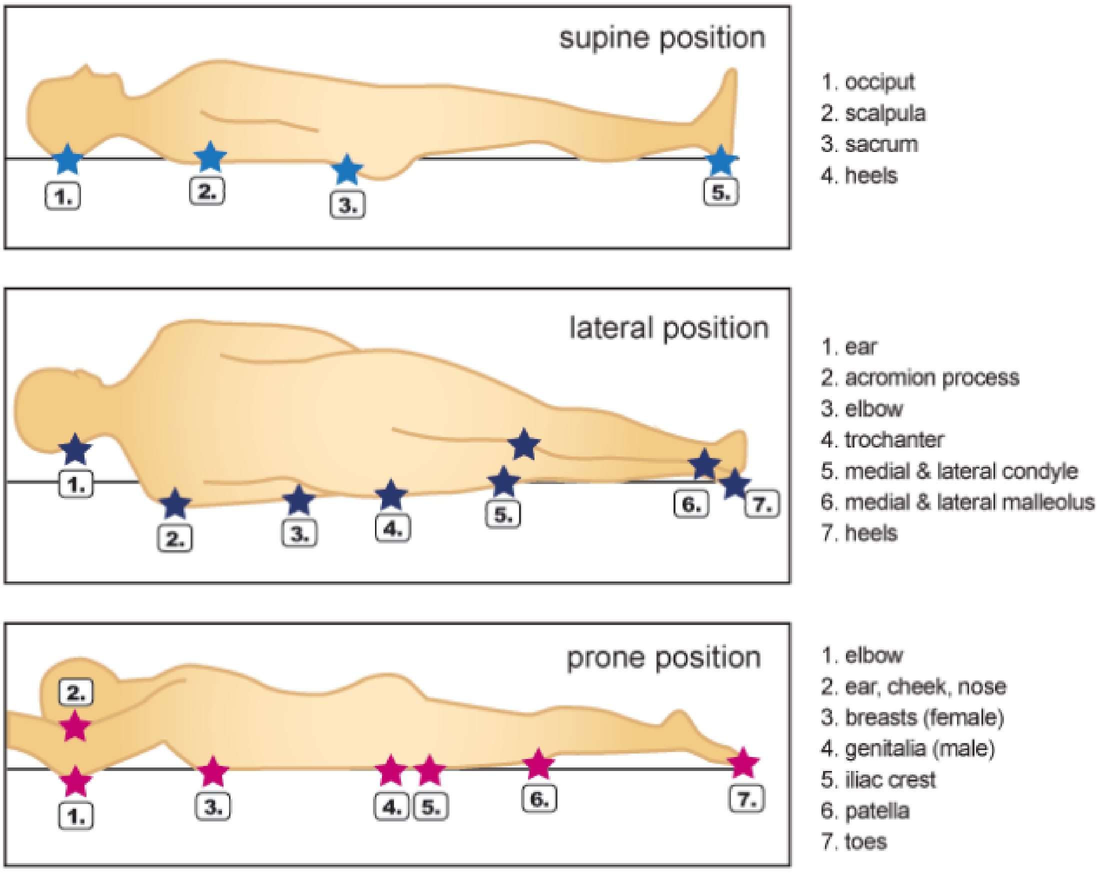


Figure 3-2 Most bed ulcers position

3.2.2. The design of Pillows section of bed ulcers

Now, after studying the areas most likely to form ulcers, we have divided the mattress "pillow" into four sections, each section of the pillow is designed to match the shape of the four sections of the body with its different positions. These four designs for the position of the pillow suit the areas most prone to ulceration, as it is based on reducing pressure through pumping and drawing water inside these water balloons. These areas were divided based on the common points of each body position as shown in the figure.

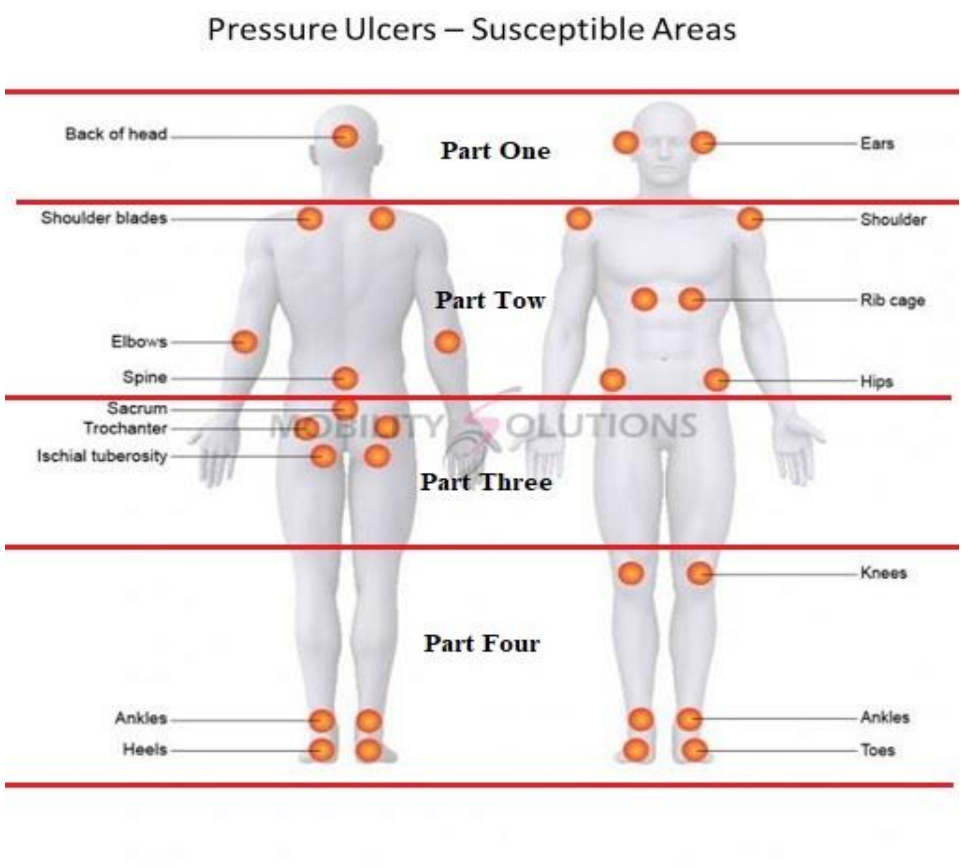


Figure 3-3 the share Points of bed Ulcers Position of each section

After studying the most comfortable positions for the patient in order to reduce the amount of pressure on these points "the area's most prone to ulceration", the first section of the pillow was designed, the design of this pillow took into account all the health aspects of the patient, as it reduces the amount of pressure on the spine.

A. For part one:

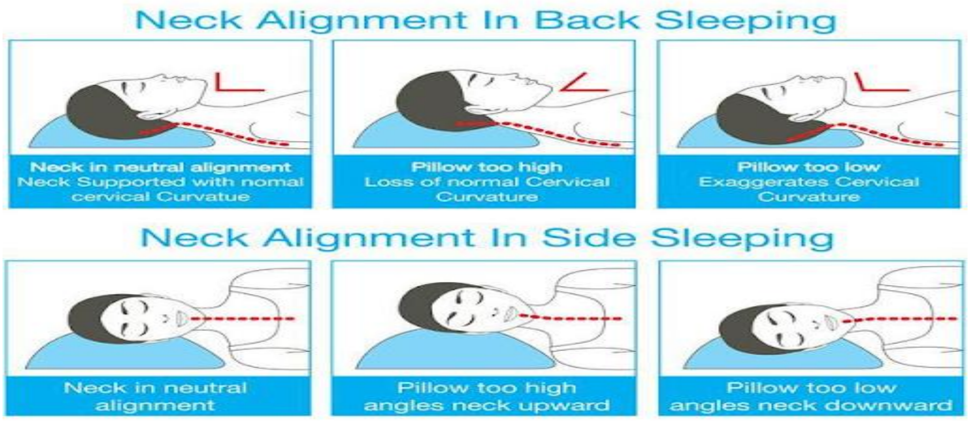


Figure 3-4 Best pillow's position for neck

A bent neck in any way for an extended period of time will wake you up with neck pain. Hence, it is essential to keep your head raised at an apt height while sleeping. The aptness of your pillow's height is determined by your sleeping posture and achieved by its firmness**.**

Side sleepers like myself should look for a rectangular firm pillow with raised edges. Soft pillows would not provide adequate support under your head and would require your neck to be extended on either of the sides in order to conform to the pillow.

B. For part two, three and four:

It is regarded the worst position because it flattens the natural curve of the spine, which can lead to lower back pain. Sleeping all night with the head turned to one side also strains the neck. If this is the preferred position, try using pillows to gradually train the body to sleep on one side. Lower back twinges**.**

Back Sleepers

This position is good for spine and neck health, because the back is straight and not forced into any contortions. In other words, you'll have fewer problems with back and neck pain than with other positions. Sleeping on your back also puts less wrinkle-inducing pressure and friction on your face. "If you're sleeping on your back already, you can easily add another pillow under your head to help with puffiness under the eyes," says dermatologist Doris Day. The slight elevation keeps fluid from building up under your eyes as you sleep.

For those not expecting, sleeping on the left side can also ease heartburn and acid reflux, making it easier for people with these conditions to doze off [27].

Figure 3-5 Best Sleeping Position for Backbone Health

We will install the medical mattress according to the principle of (zero gravity position), this positioning of the mattress ensures the greatest amount of comfort and balance, as it is based on the distribution of the centers of gravity of the body according to the weight of each body.

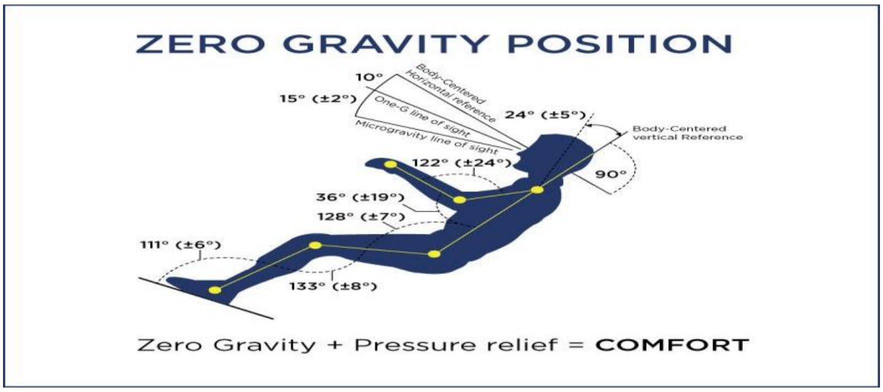


Figure 3-6 Zero Gravity Position

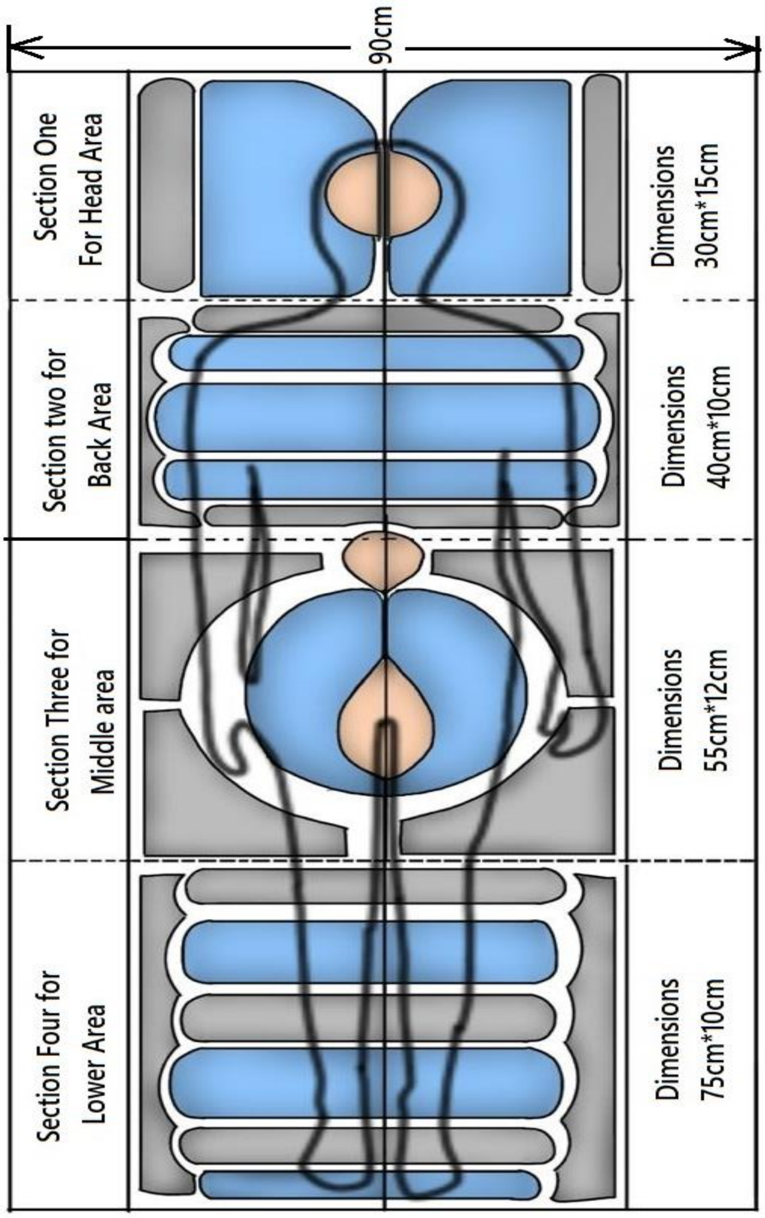


Figure 3-7 Final Design of the Pillow

As mentioned above, the body was divided into four sections, each with a number of water balloons consistent with the shape of the body.

The blue color represents the active areas and contains balloons as the figure shows, in these areas water is pumped or suctioned according to the data coming from the temperature sensor installed on each piece of balloons.

The gray color represents static areas of the body, in which water is routinely pumped every 30 minutes.

As for the red color, it represents dead areas, meaning a vacuum, and these areas represent the strongest pressure point on the head, in addition to the upper back of the body (the coccyx).

The white color represents inactive areas that are sponges made of the same material the pillows are made of, and it does not contain water.

3.3. Pressure Sensor Design and Working

The amount of pressure exerted by the pressure of each body part on each section of the mattress is analyzed by converting the amount of weight into a pressure value (Pa). After that, the pressure sensor will sense the amount of pressure applied to it, if it is within the normal range, nothing will happen, but if it is not within the normal range, it will send information to the controller to start.

After that, the weight of each part of the body is analyzed and the weight is converted into a pressure value (Pa).

Solid pressing on confined fluid

When a liquid or gas is confined in a container or cylinder, you can create a pressure by applying a force with a solid piston. The pressure created in the cylinder equals the force applied divided by the area of the piston: **P = F/A**.

In a confined fluid—neglecting the effect of gravity on the fluid—the pressure is the same throughout the container, pressing equally on all the walls. In the case of a bicycle pump, the pressure created inside the pump will be transmitted through the hose into the bicycle tire. But the air is still all confined.

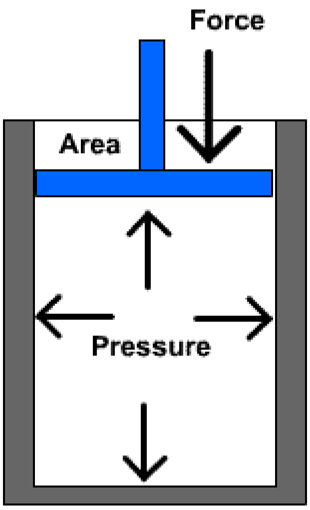


Figure 3-8 Pressure is in all directions in a fluid

Increasing the force will increase the pressure inside the cylinder.

Is our pressure sensor A= Л*3mm, Л=3.14

For Example: if we have 10kg Pressure.

That is mean, 10kg = 100N also we have A= Л*3mm

So the pressure in (Pa): **P = F/A** = 100/(0.000283) = 353Kpa .

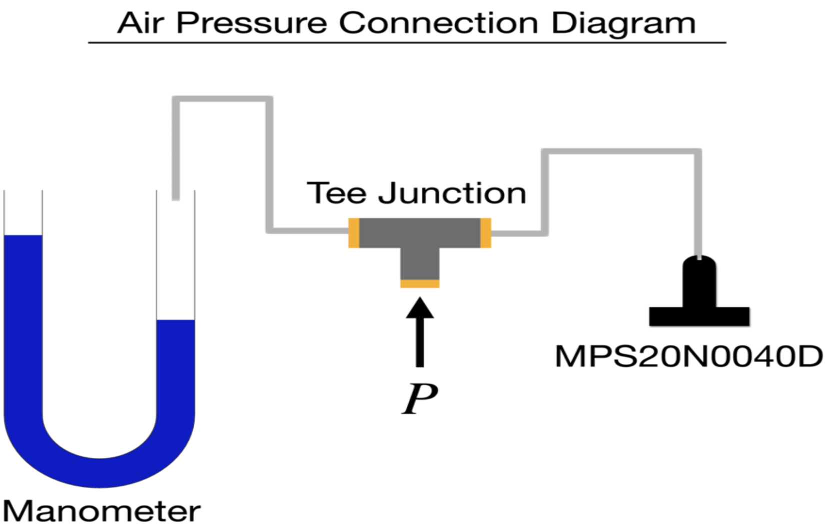


Figure 3-9 Air Pressure Connection

Women		Men	
weight	Length	Weight (Kg)	Length (Cm)
43-48	142	53-58	155
44-50	145	55-61	157
46-51	147	56-62	160
47-52	150	57-63	162
48-54	152	58-65	165
50-55	155	61-66	167
51-57	157	62-69	170
52-58	160	64-71	172
54-61	162	66-72	175
56-63	165	86-75	177
58-65	167	70-77	180
60-66	170	71-79	183
62-68	172	73-81	185
63-70	175	76-84	188
65-72	177	78-86	190

Table 3-1 Ideal weight for men and women

And through the processes of converting the values of weight into pressure, the value of each pressure formed for each part of the body is known.

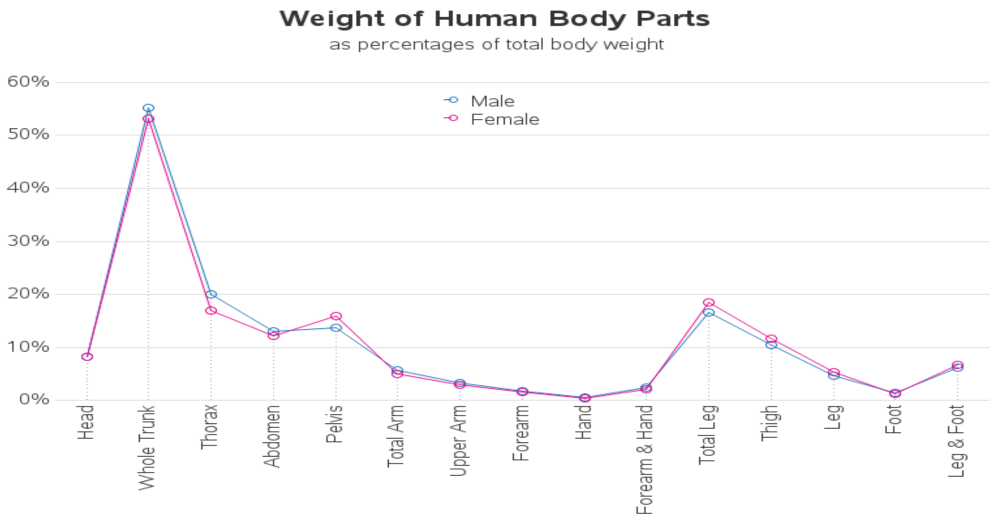


Figure 3-10 Weight of Human Body Parts

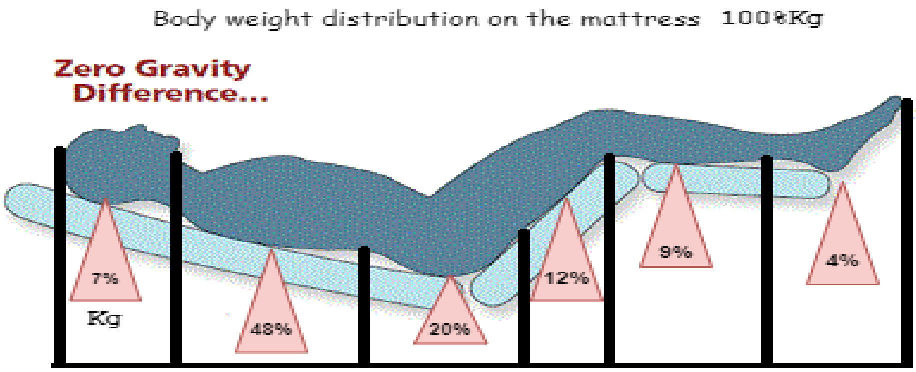


Figure 3-11 Body Weight distribution on the mattress

In our project, the weight values will be converted into pressure values (Pa) directly through the application, we only have to put the weight of the sick person, and then the values will be analyzed automatically.

3.4. Temperature Sensor Design

DS18B20 1-Wire Temperature Sensor

DS18B20 is 1-Wire interface Temperature sensor manufactured by Dallas Semiconductor Corp. The unique 1-Wire Interface requires only one digital pin for two way communication with a microcontroller.

The sensor comes usually in two form factors. One that comes in TO-92 package looks exactly like an ordinary transistor. Other one in a waterproof probe style which can be more useful when you need to measure something far away, underwater or under the ground.

Figure 3-12 Types of DS18B20 Temperature Sensor

In our project we use Waterproof DS18B20 Temperature Sensor because it used to measure temperature in hard environments like in chemical solutions, mines or soil etc. The constriction of the sensor is rugged and also can be purchased with a waterproof option making the mounting process easy.

3.4.1. DS18B20 Sensor Pinout

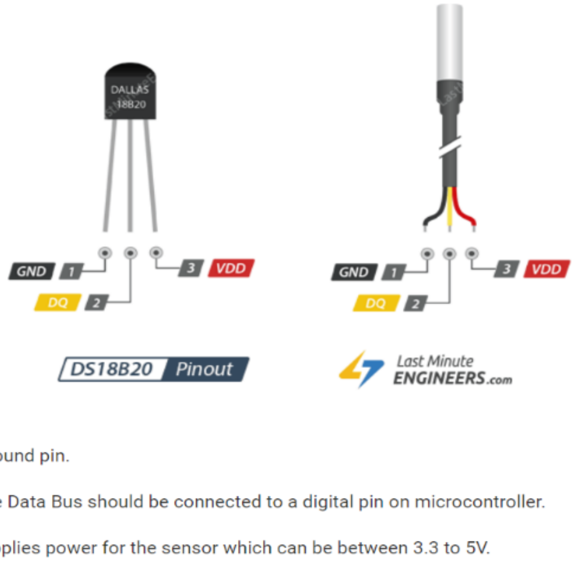


Figure 3-13 DS18B20 Sensor pinout

- **Waterproof DS18B20 Temperature Sensor to Arduino**

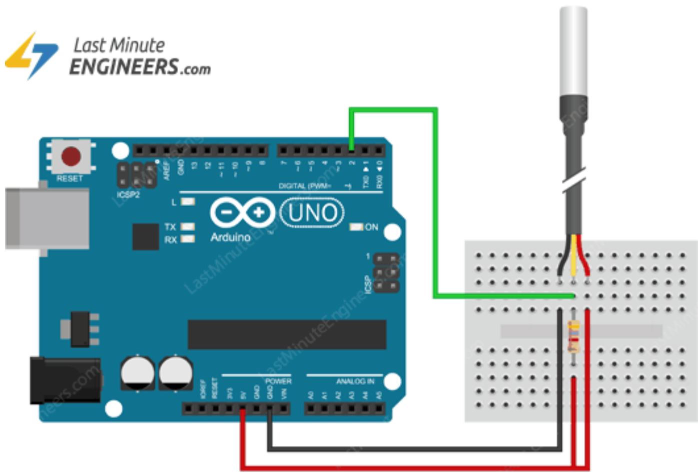


Figure 3-14 Waterproof DS18B20 Temperature Sensor to Arduino

The connections are fairly simple. Start by connecting connect Red stripe to 5V, Black connects to ground and Yellow Stripe is data that goes to digital pin 2 on Arduino.

3.5. Build Timer with Arduino MEGA

Within our code, we may wish to delay for a period of time. We can use the os_delay_us() function to suspend processing for a given period measured in microseconds. There are 1000 microseconds in a millisecond and 1000 milliseconds in a second.

We can configure a timer to be called on a periodic basis with a callback granularity of milliseconds. A data structure called os_timer_t holds the state of the timer. We can define the user function to be called when the timer fires using the os_timer_setfn() function. Note that we can only set the callback function when the timer is disarmed. When ready, we can arm the timer so that it starts ticking and fires when ready. We do this using the os_timer_arm() function.

The repeat flag indicates whether the timer should restart after it has fired. We can suspend or cancel the firing of the timer using os_timer_disarm ().

Here is an example:

```
os_timer_t myTimer;
void timerCallback(void *pArg) {
os_printf("Tick!");
} // End of timerCallback
void user_init(void) {
uart_init(BIT_RATE_115200, BIT_RATE_115200);
os_timer_setfn(&myTimer, timerCallback, NULL);
os_timer_arm(&myTimer, 1000, 1);
} // End of user_init
```

Another aspect of working with time is time calculations and measurement. The function system get time() returns a 32 bit unsigned integer (unit32) value which is the microseconds since the device booted. This value will roll over after 30 minutes. We can also explicitly block execution for a period of time using os _delay_ us ().

3.6. MEGA Relay Module

After Reading the Temp-Sensor, and the timer, we have to run the Valve also run the Pump-Suction, that’s will done with relay module.

A relay is an electrically operated switch and like any other switch, it that can be turned on or off, letting the current go through or not. It can be controlled with low voltages.

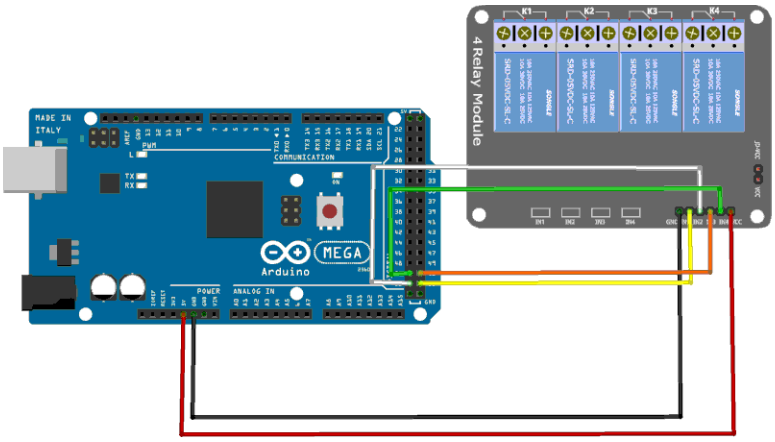


Figure 3-15 MEGA With relay

The mapping for associating pin numbers with physical connectors is in this document:

Pin out map on ARDUINO DUE

Pin out map on ARDUINO MEGA 2560

Pin out map on ARDUINO MICRO

Pin out map on ARDUINO NANO

Pin out map on ARDUINO UNO

Pin out map on ARDUINO YUN

For example, the led '13' which is connected to the ARDUINO MEGA board with the physical terminal 13 is related to the PIN 26. In all our texts, the term "pin" will always refer to PIN code XX as referenced in the technical documents of ARDUINO cards. The mention of a physical connector will be done with the term 'terminal'.

3.7. Pump-Suction

3.7.1. Pump-Suction Model

DP 12v circulation pump mini diaphragm pump high pressure dc water pump is applied to convey water and chemical, medium temperature can reach 60 °C(140°F).

It is low noise, corrosion resistance, high pressure, excellent self-priming 5 m(16.4ft) and easy dismantling. Safe low voltage, ensures personal safety.

Built-in pressure switch to protect pump running from being damaged and built-in relief valve control the normal operation of the pump.

Figure 3-16 Pump-Suction Model

3.7.2. Calculation of Pump-Suction Water flow

We can calculate the Water Flow and Power of Pump-Suction with following equation:

$P_{h(kW)} = q\ \rho\ g\ h / (3.6\ 10^6$

$= q\ p / (3.6\ 10^6)$ (1)

Where

$P_{h(kW)}$ = hydraulic power (kW)

q = flow (m^3/h)

ρ = density of fluid (kg/m^3)

g = acceleration of gravity (9.81 m/s^2)

h = differential head (m)

p = differential pressure (N/m^2, Pa)

The hydraulic Horse Power can be calculated as:

$P_{h(hp)} = P_{h(kW)} / 0.746$ (2)

Where

$P_{h(hp)}$ = hydraulic horsepower (hp)

Or - alternatively

$P_{h(hp)} = q_{gpm}\ h_{ft}\ SG / (3960\ \eta)$ (2b)

Where

q_{gpm} = flow (gpm)

h_{ft} = differential head (ft)

SG = Specific Gravity (1 for water)

η = pump efficiency

Example - Power pumping Water

1 m^3/h of water is pumped a head of 10 m. The theoretical pump power can be calculated as

$P_{h(kW)} = (1\ m^3/h)\ (1000\ kg/m^3)\ (9.81\ m/s^2)\ (10\ m)\ /\ (3.6\ 10^6)$

= <u>0.027</u> kW

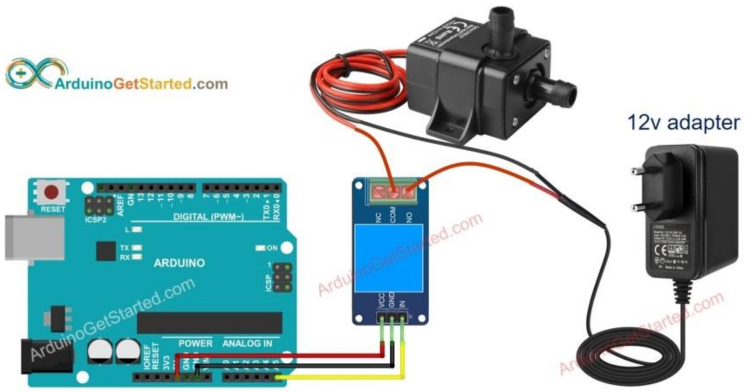


Figure 3-17 Pump Power connection with Arduino

3.7.3. Shaft Pump Power

The shaft power - the power required transferred from the motor to the shaft of the pump - depends on the efficiency of the pump and can be calculated as

$P_{s(kW)} = P_{h(kW)} / \eta$ (3)

Where

$P_{s(kW)}$ = shaft power (kW)

η = pump efficiency

Product details

Working Principle:	Diaphragm, DC12V/24V
Main applications:	Chemical, water
Max.permissible fluid temperature:	60°C(140°F)
Casing parts material:	Nylon, glass fiber reinforce
Maximum current:	7A
Maximum drive rating:	40W(0.054HP)
Maximum speed:	1300r/min
Maximum discharge-side pressure:	130psi(9bar)
Maximum suction:	5m(16.4ft)
Flow rate range:	1-12L/min(0.26-3.17US.GPM)

Table 3-2 Product details

3.8. Heart rate Sensor Design

The heart rate sensor, explained in the previous chapter, will be used in this project to monitor the user's heart rate. The chosen transducer uses the Photoplethysmography technique. This technique depends on the change of blood volume in the finger that is produced by heart beat rate. The block diagram shown in Figure 3-12 is built to illustrate the basic design of the proposed heart rate system.

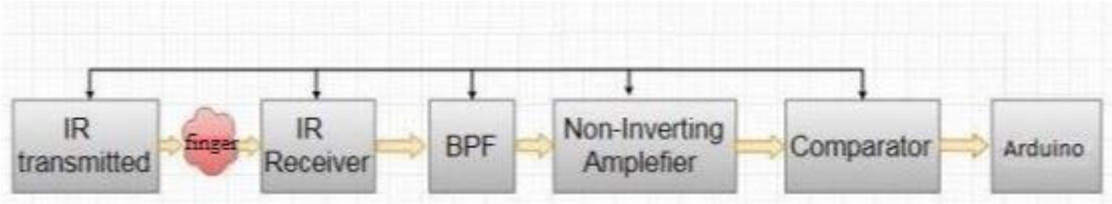


Figure 3-18 Block diagram for HR Sensor

3.8.1. Transceiver

The Photoplethysmography technique, discussed in the preceding chapter depends on the amount of infra- red (IR) lights that reflected from the finger. Hence an IR LED is used to transmit IR light, where a photo transistor sensing the portion of light that is reflected back. The intensity of the reflected lights depends upon the blood volume. A "TCRT1000 IR device as sensor" will be used in this project. It consists of IR emitting-light source (LED) on wave length 940nm and light detector phototransistor) [Appendix-A]. The LED and phototransistor are arranged in the same direction to sense the reflective IR-beam from the changes in arterial blood volume in the patient’s finger, as shown in the figure below.

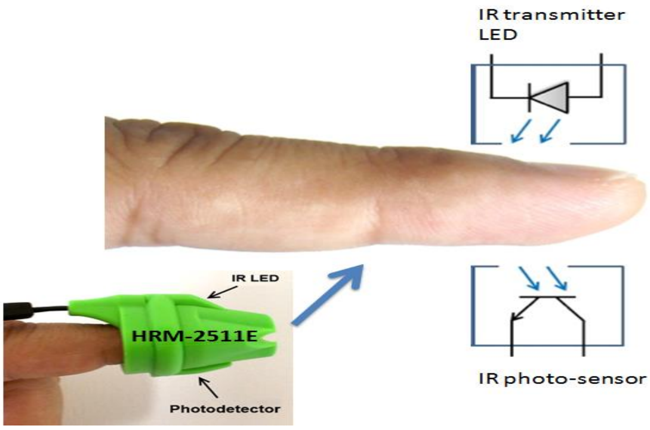


Figure 3-19 Finger photoplethysmography (reflectance approach)

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

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

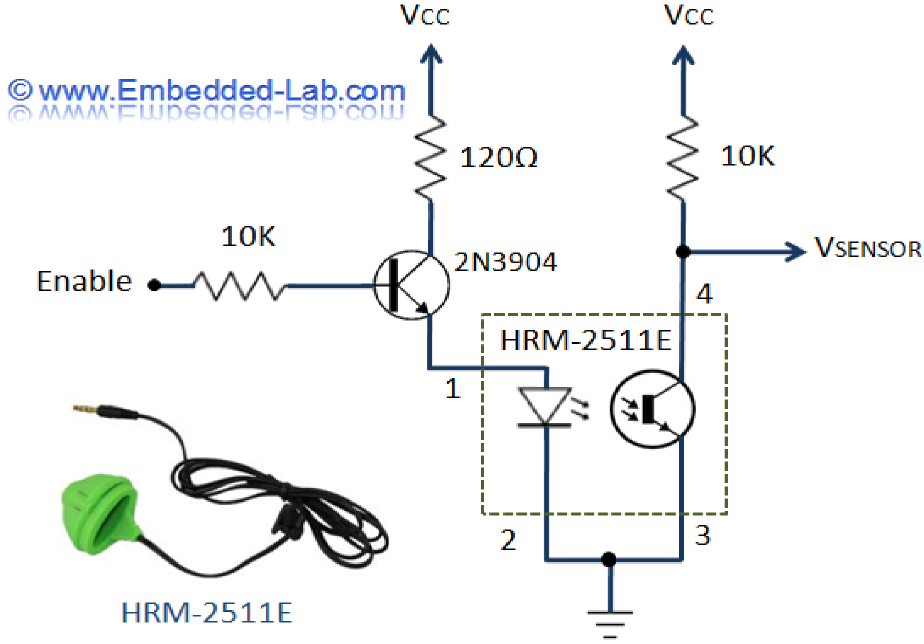


Figure 3-20 ON/OFF control scheme for the infra-red light source

3.8.2. Band Pass Filter

The PPG signal coming from the photo detector is weak and noisy. So we need an amplifier and filter circuits to boost and clean the signal. In Stage I instrumentation as shown in the Figure 3-15, the signal is first passed through a passive (RC) high-pass filter (HPF) to block the DC component of the PPG signal.

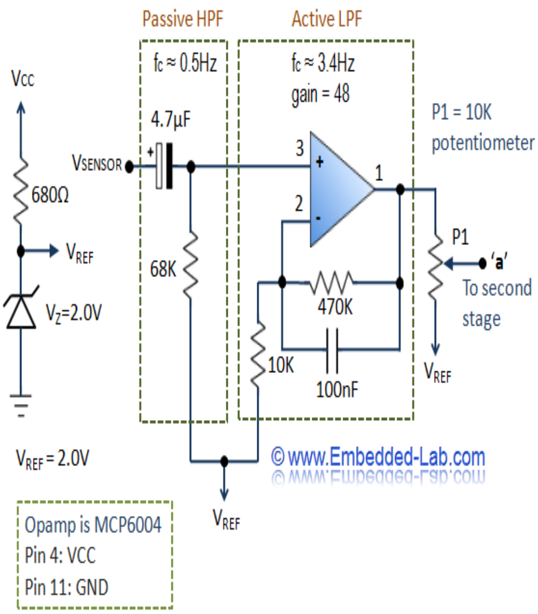


Figure 3-21 Band Pass Filter circuit

The cut-off frequency of the HPF is 0.5Hz, FC can be calculated by using R4 and C1 as expressed in equation (3.3):

$$FC=1/2\pi R4C1 \qquad 3.3$$

Let C1 =4.7µF, the resistor values for R4 calculated through:

$$R4=1/2\pi FCC1 \qquad 3.4$$

So the resister R4 is equal: R4 =68KΩ

The output from the HPF goes to an Op-amp-based active low-pass filter (LPF), the cutoff frequency of the LPF is 3.4Hz, FC can be calculated by using R6 and C2 as expressed in equation (3.5):

$$FC=1/2\pi R6C2 \qquad 3.5$$

Let C2 =100nF, the resistor values for R6 calculated through:

$$R6=1/2\pi FCC2 \qquad 3.6$$

So the resister R6 is equal: R6 =470KΩ.

The Op-amp operates in non-inverting mode and has gain 48, gain can be calculated by using equation (3.7):

$$G=1+(R6/R5) \qquad 3.7$$

At the output is a potentiometer (P1 (R7)) that acts as a manual gain control. The output from the active LPF now goes to Stage II instrumentation circuit, which is basically a replica of the Stage I circuit. Note that the amplitude of the signal going to the second stage is controlled by P1(R7). The Op-amp used in this project is AD822 from Microchip, this op-amp operates with a single supply, and rail to rail amplifier, has very high input impedance, and has high slew rate and Quad-Op-amp.

The two-step amplified and filtered signal is now fed to a third Op-amp, which is configured as a non-inverting buffer with unity gain. The output of the buffer provides the required analog PPG signal. The potentiometer P1(R7) can be used to control the amplitude of the PPG signal appearing at the output of the buffer stage.

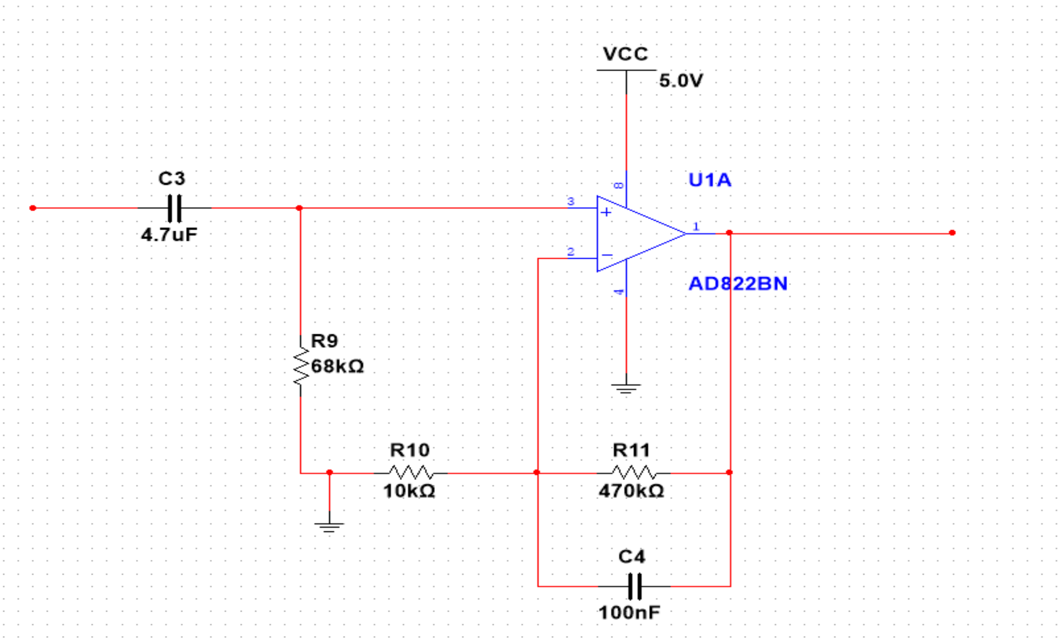


Figure 3-22 Second stage BPF and buffer circuit.

3.8.3. Comparator

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

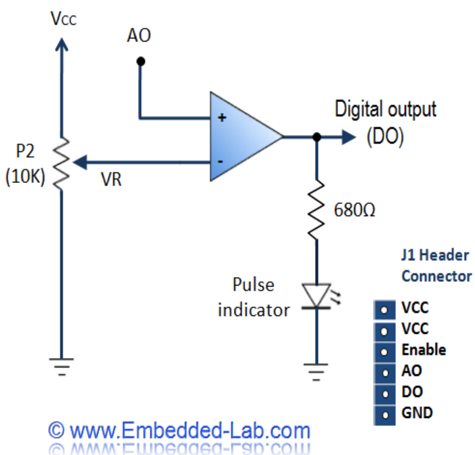


Figure 3-23 Comparator circuit

The magnitude of V can be set anywhere between 0 and 5 through potentiometer P2 (R12) Every time the PPG pulse wave exceeds the threshold V, the output of the comparator goes high.

Thus, this arrangement provides an output digital pulse synchronous to heart beat, which enable the microcontroller to count heartbeat.

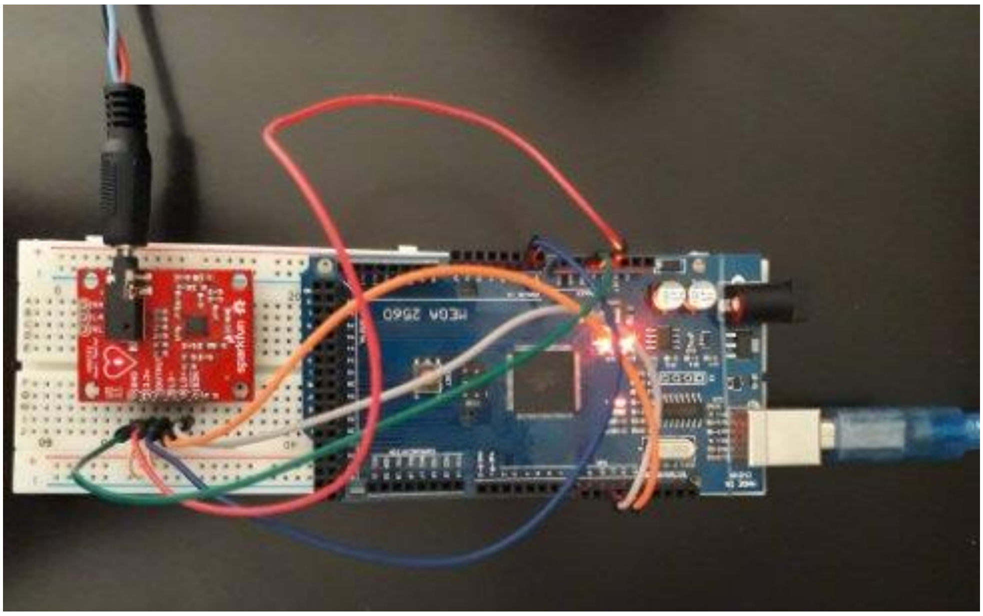


Figure 3-24 Heart Rate Sensor With MEGA

3.9. Arduino MEGA 2560 with WiFi Built-in - ESP Module

3.9.1. WIFI part

When working with a WIFI oriented device, it is important that we have at least some Understanding of the concepts related to Wi-Fi. At a high level, WIFI is the ability to participate in TCP/IP connections over a wireless communication link. Wi-Fi is specifically the set of protocols described in the IEEE 802.11 Wireless LAN architecture.

Within this story, a device called a Wireless Access Point (access point or AP) acts as the hub of all communications. Typically, it is connected to (or acts as) as TCP/IP router to the rest of the TCP/IP network. For example, in your home, you are likely to have a WiFi access point connected to your modem (cable or DSL). Wi-Fi connections are then formed to the access point (through devices called stations) and TCP/IP traffic flows through the access point to the Internet.

Figure 3-25 ESP Module WiFi Mobile Application

3.9.2. ESP Module Part

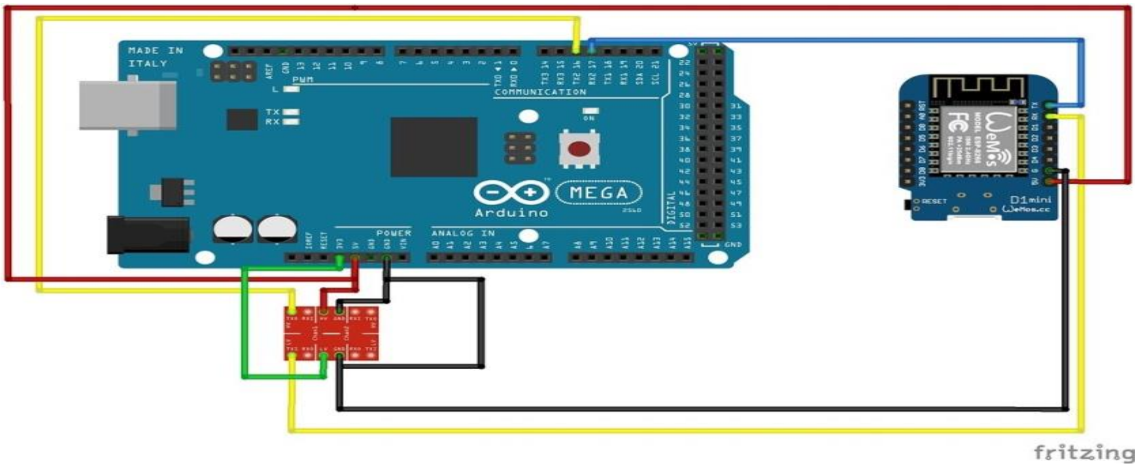


Figure 3-26 ESP Module Part

- TX (pin 16) / Logic Level Shift Converter / RX
- RX (pin 17) /TX
- 5v/5v (It is stepped down on the Wemos)
- Gnd/Gnd

Here is a sample code

```
void setup() {
  // put your setup code here, to run once:
Serial2.begin(115200);
Serial.begin(115200);
}

void loop() {
  // put your main code here, to run repeatedly:
 if(Serial2.available()>0)    //Checks is there any data in
buffer
  {
    Serial.print("We got:");
    Serial.print(char(Serial2.read()));  //Read serial data byte
and send back to serial monitor
  }
  else
  {
    Serial2.write("AT\r\n");
    delay(1000);                      // Wait for a second
  }

}
```

3.9.3. Mobile Application Part

The design will be connected through the Internet, so that a phone application will be designed for the Arduino, showing the patient's temperature in addition to other vital signs, this process enables the nurse to monitor the patient remotely, an application called Dabble will be used, which is a program developed by programmers.

The application will be designed to show the pressure points on each area of the mattress as follows:

- White color: the normal state of heat and pressure.
- Red color: for temperature critical condition.
- Yellow: the critical state of pressure.

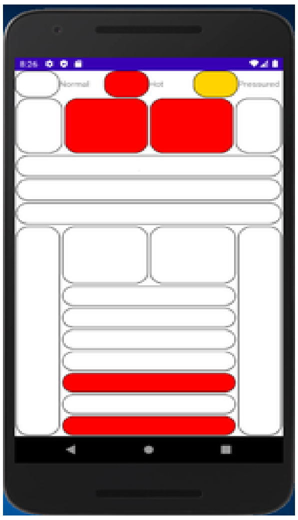


Figure 3-27   cases of bed ulcer

The critical pressure and temperature values will also be from the mobile app and the time delay as shown:

Figure 3-28   time delay and temp & pressure critical value

3.10. Final design

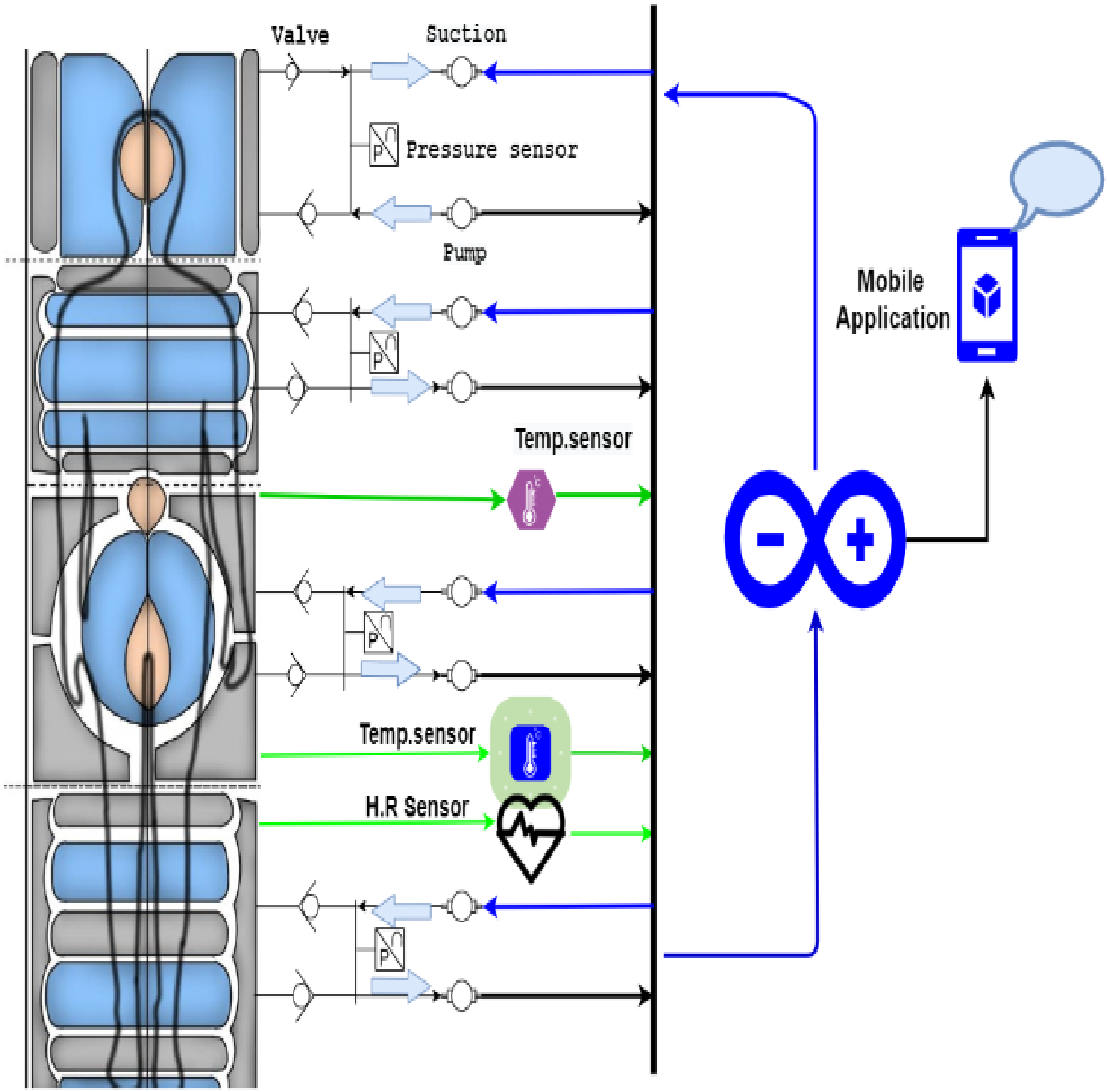


Figure 3-29 Final design for the system

3.11. Flowchart

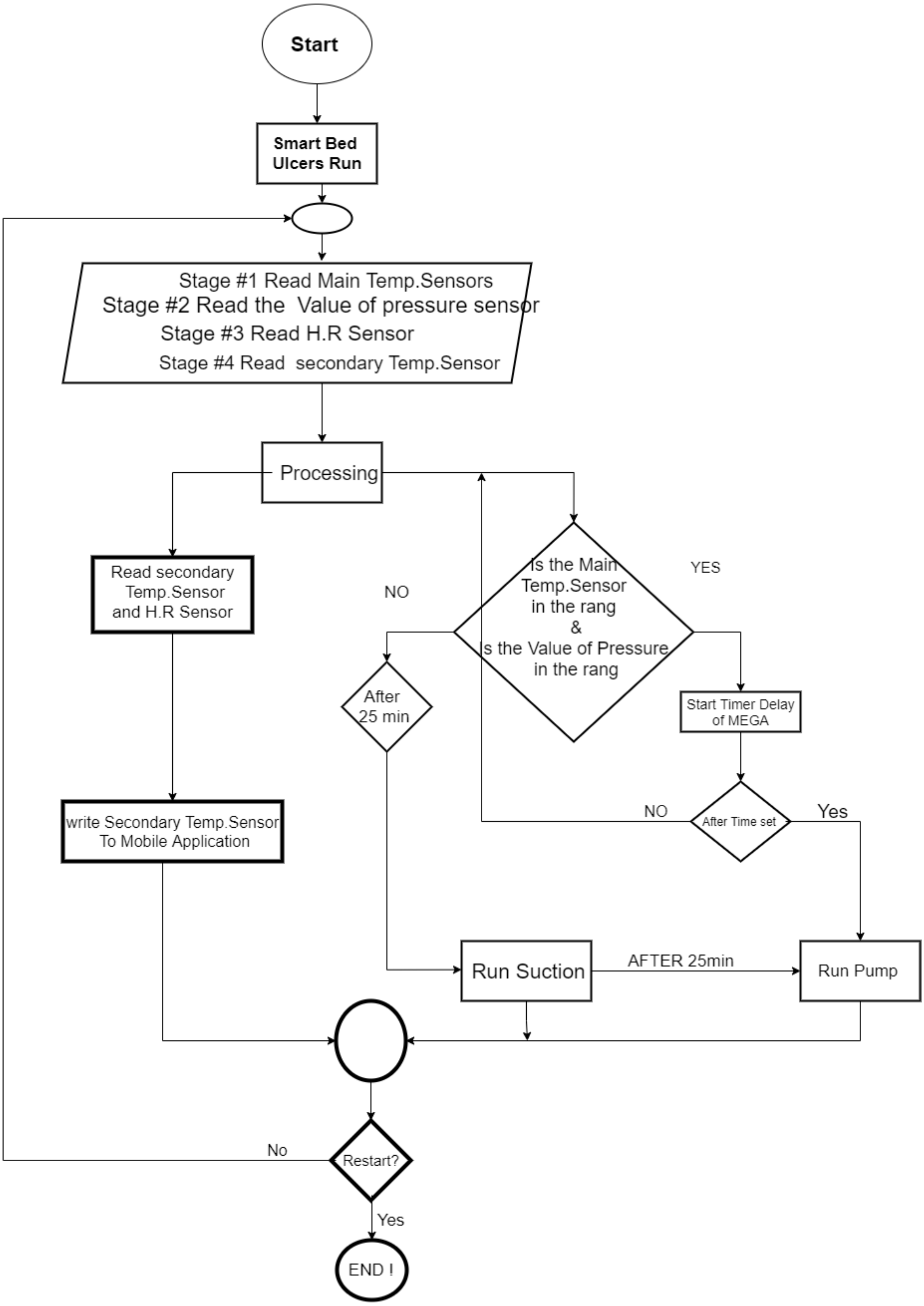


Figure 3-30 Flowchart

4. Chapter Four:

System Implementation and Testing

4.1. Medical mattress design and testing

4.1.1. Draw the medical mattress before implementation

4.1.2. Test the strength of the pressure bed by pumping the water with a large force in addition to exposing it to an external force.

4.1.3. Final Design of the mattress

4.2. Test the pump and connect it with the mattress

4.2.1. Test the pump

4.2.2. Connecting the pump to the medical mattress through a network of pipes.

4.3. Arduino Connections and Test

4.3.1. Arduino Test

4.3.2. Relay Test

4.3.3. Connect Relay with ESP

4.3.4. Connect Temperature sensor Arduino

4.3.5. Connect Pressure sensor Arduino

4.3.6. Connect H.R sensor with Arduino

4.4. Building a mobile application

4.4.1. Draw parts of the mattress on the mobile app

4.4.2. Set Normal Value of Temperature on mobile app

4.4.3. Set Normal Value of Pressure sensor on mobile app

4.5. Final Design

4.1. Medical mattress design and testing

4.1.1. Draw the medical mattress before implementation

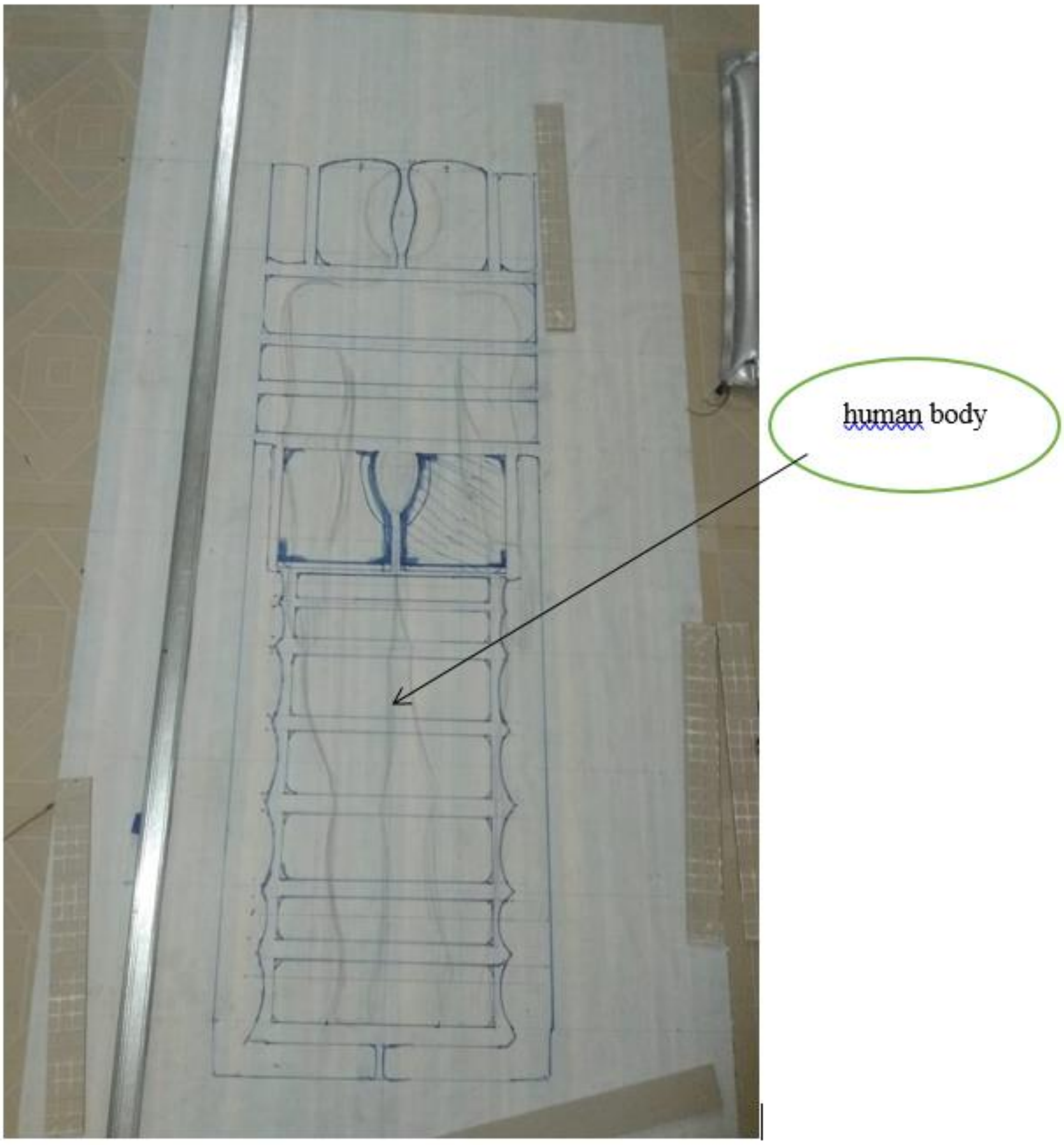


Figure 4-1 drawing a medical mattress

The sections of the medical mattress were drawn to suit the human figure, taking into account the comfort of every part of the human body.

4.1.2. Test the strength of the pressure bed by pumping the water with a large force in addition to exposing it to an external force.

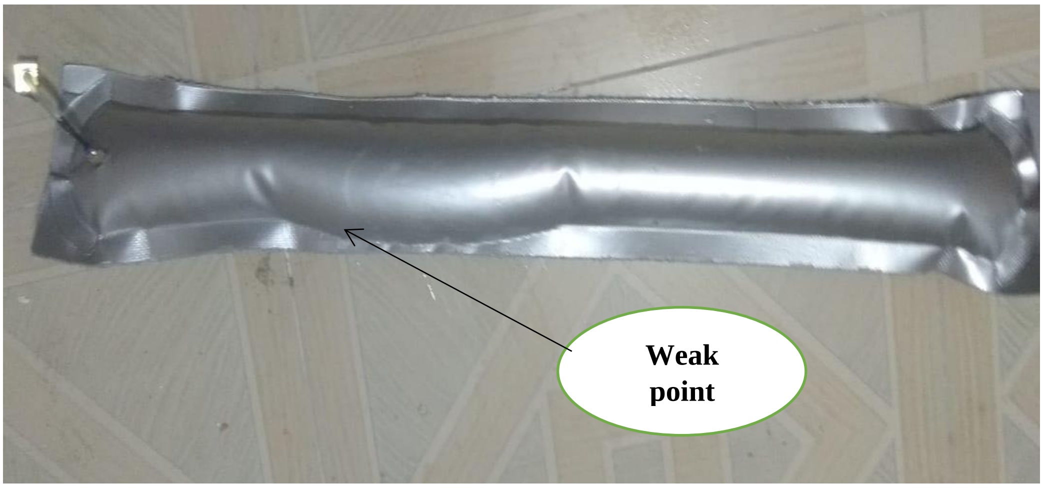


Figure 4-2 Pumping water into the mattress

Before making the medical mattress, a small part of the mattress was tested to know the ability of the material from which the mattress is made to withstand water pressure, and it was found that the weaknesses as shown on one of the sides, this problem was solved by strengthening the welding points between the parts of the brush.

Figure 4-3   The balloon explodes after massive pressure

During the process of testing the strength of the balloon, it showed us weak points, which are on one side. This problem was solved by connecting all parts of the mattress together, and strengthening the welding points.

4.1.3. Final Design of the mattress

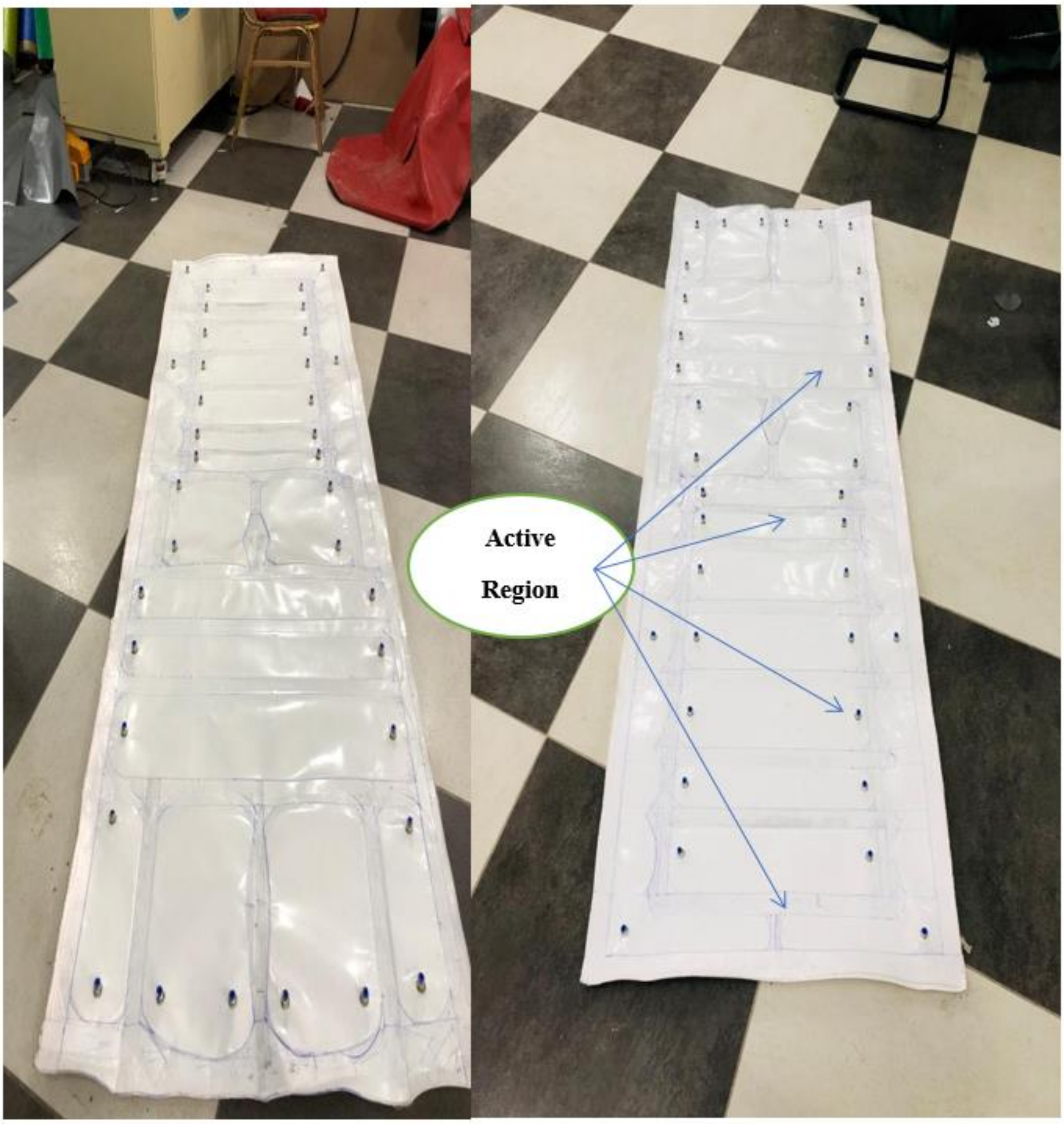


Figure 4-4 Final Design mattress result

After the medical mattress was made, the Nobility Brass was installed as an inlet to the water. This Nobility Brass withstands a pressure of 100 bar.

4.2. Test the pump and connect it with the mattress

4.2.1. Test the pump

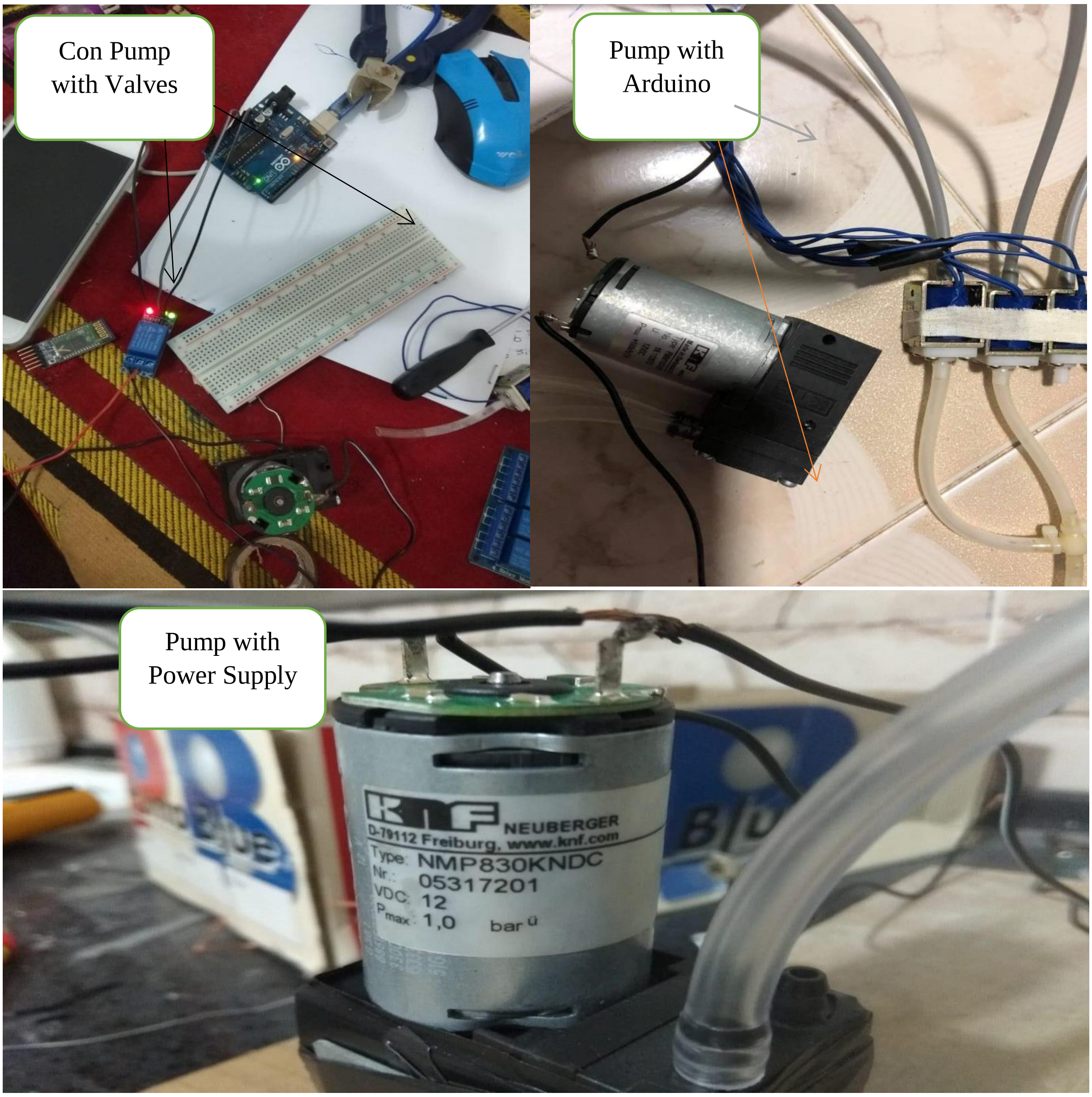


Figure 4-5 Testing the pump Stages

The water pump's endurance was tested for the flow of water inside the water pillows and passed the test, which can bear a 1.5 bar of pressure.

4.2.2. Connecting the pump to the medical mattress through a network of pipes.

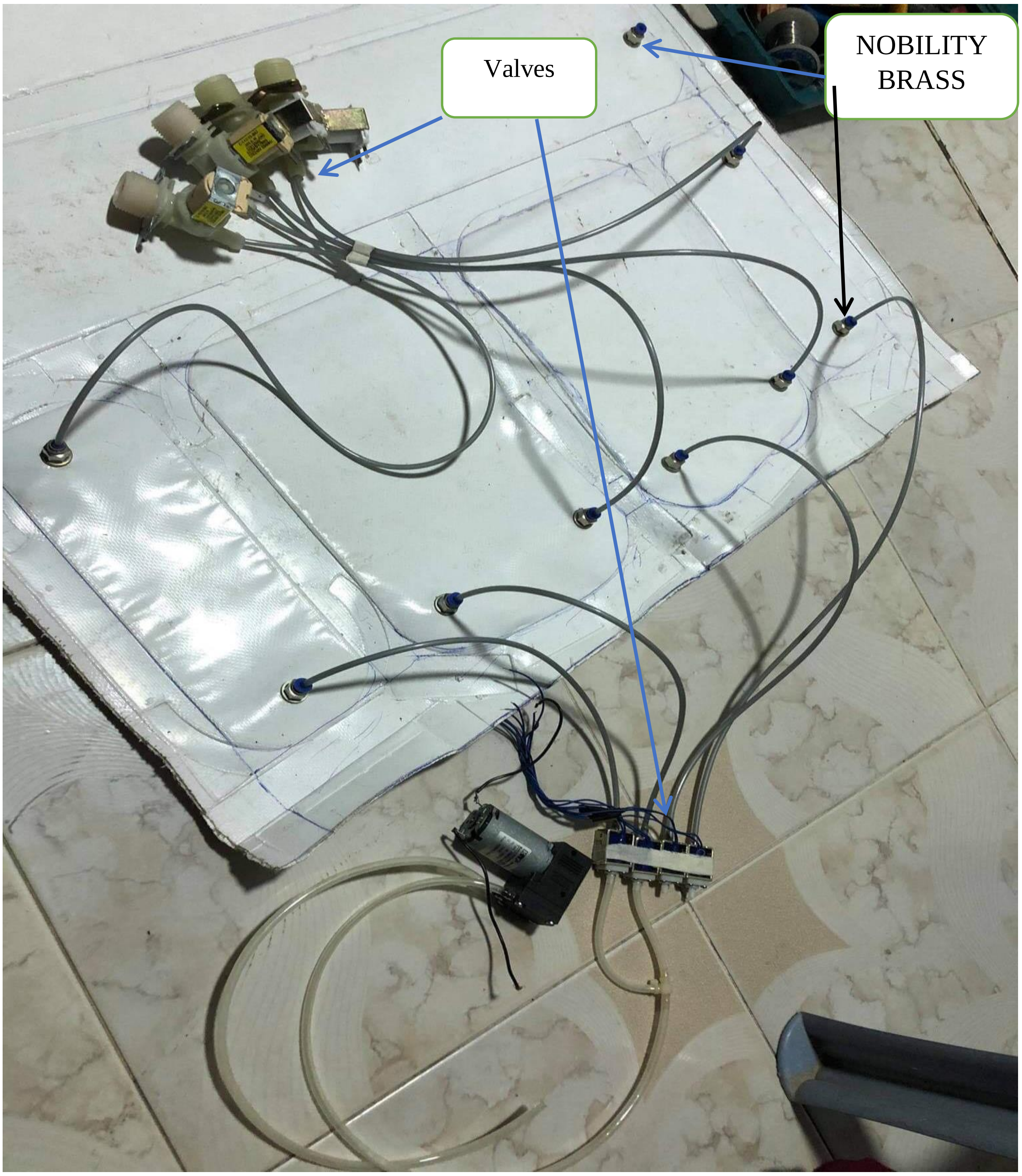


Figure 4-6   Connecting the pump to the medical mattress through a network of pipes.

4.3. Arduino Connections and Test

4.3.1. Arduino Test

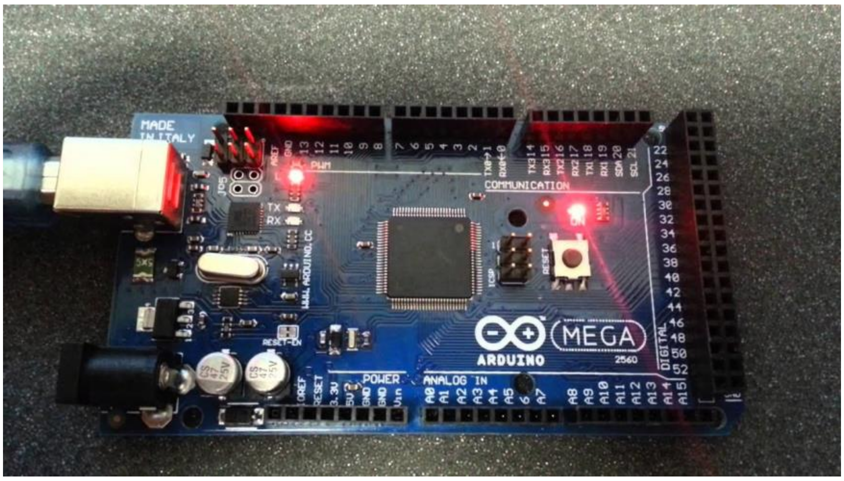


Figure 4-7 Run the Arduino

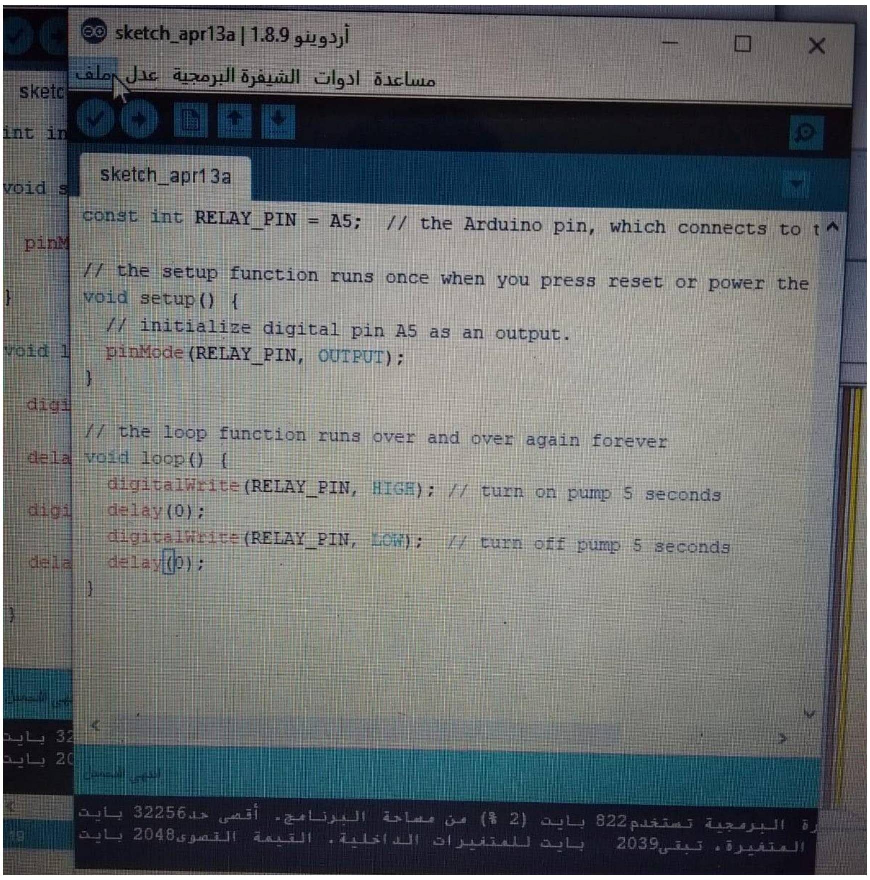


Figure 4-8 Arduino code test

Before connecting the rest of the electronic parts, the (Arduino Mega) was checked, to ensure its work by implementing a trial code during which the pump was running for a period of time.

4.3.2. Relay Test

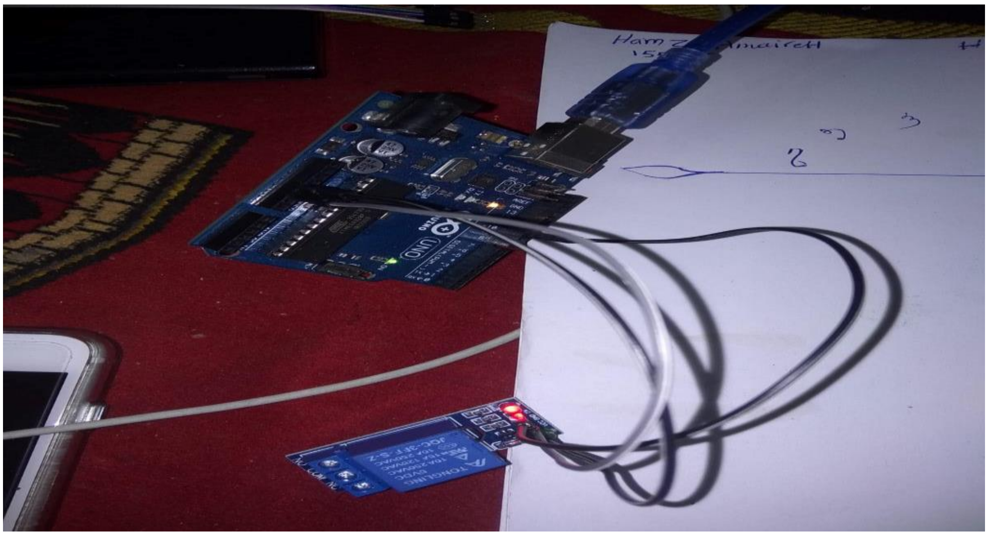


Figure 4-9 Arduino With Relay Testing

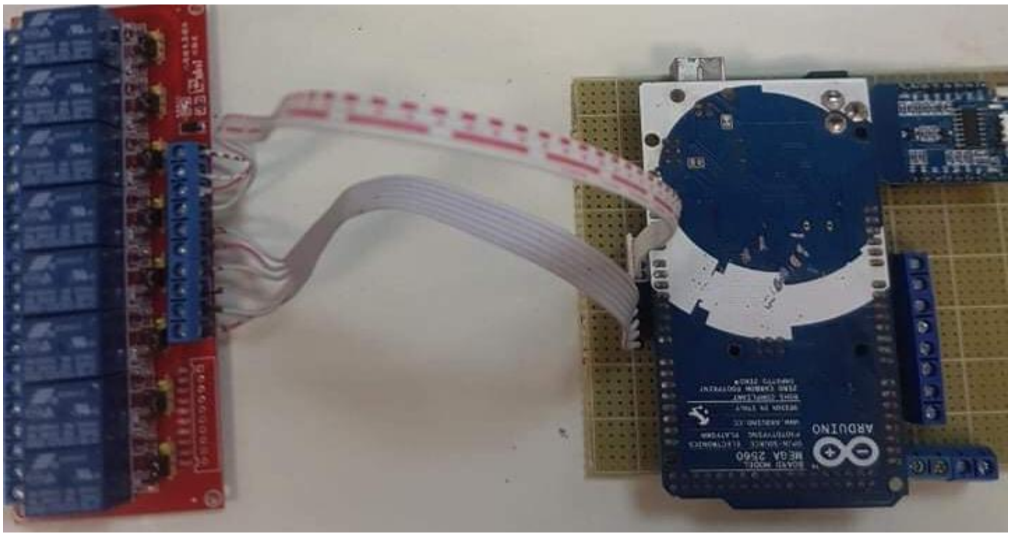


Figure 4-10 connect Arduino Relay

Relays have been connected to the Arduino Mega and make sure it is turned on. These Relays will be used to control the operation of the pumps by converting the source voltage into a voltage compatible with the Arduino.

4.3.3. Connect Relay with ESP

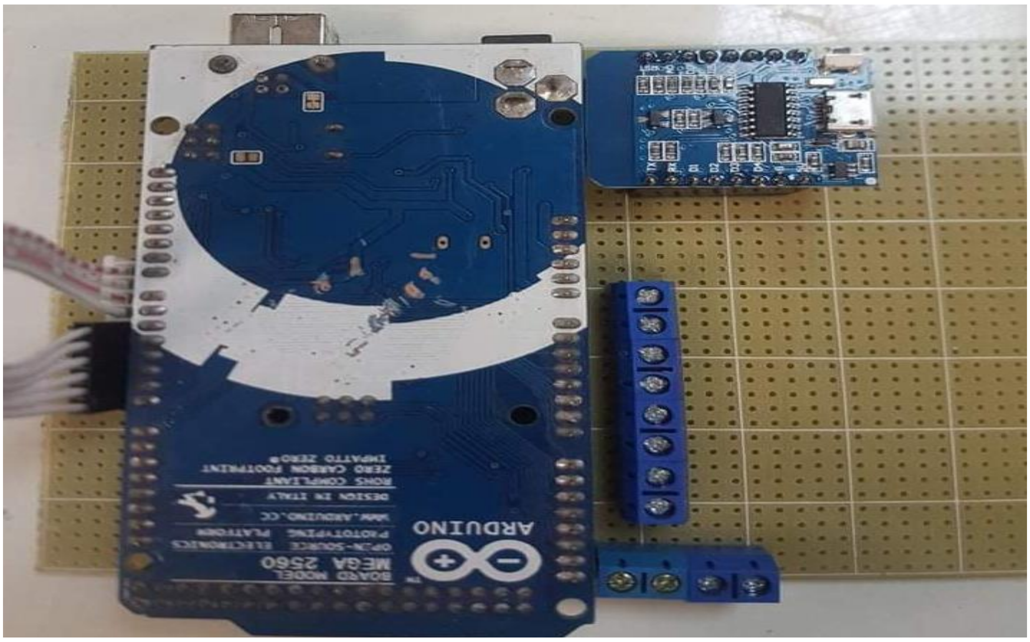


Figure 4-11 connect Arduino ESP

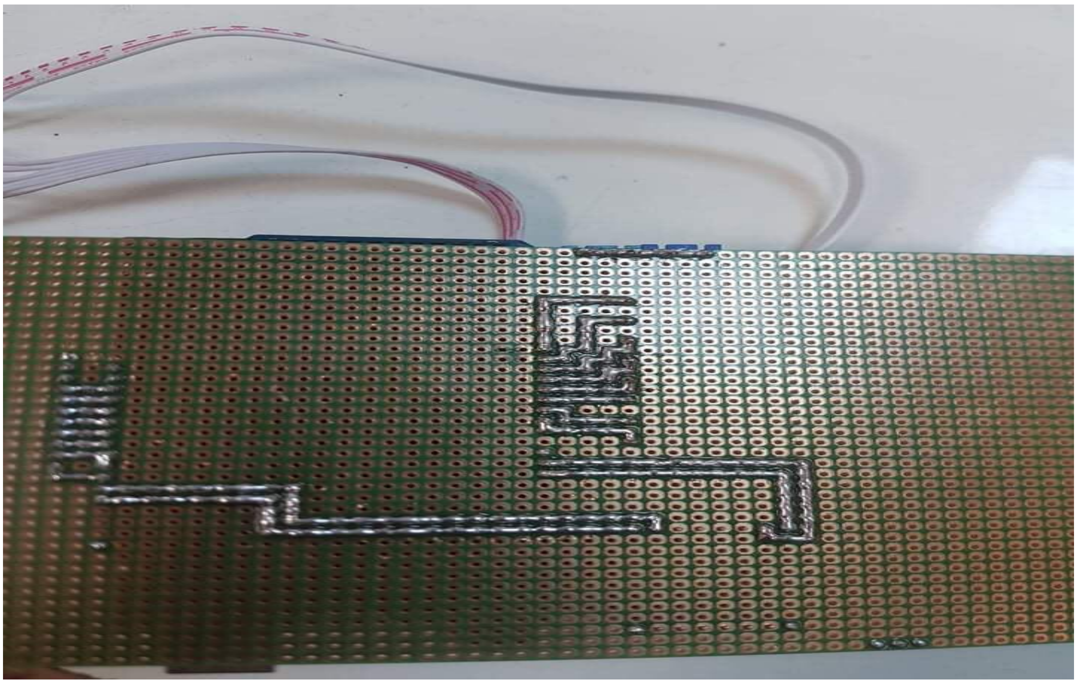


Figure 4-12 connect Arduino ESP

Connecting the ESP module to the Arduino and making sure of its work. This electronic piece will allow us to send information from the design to the mobile application via Wi-Fi.

4.3.4. Connect Temperature sensor Arduino

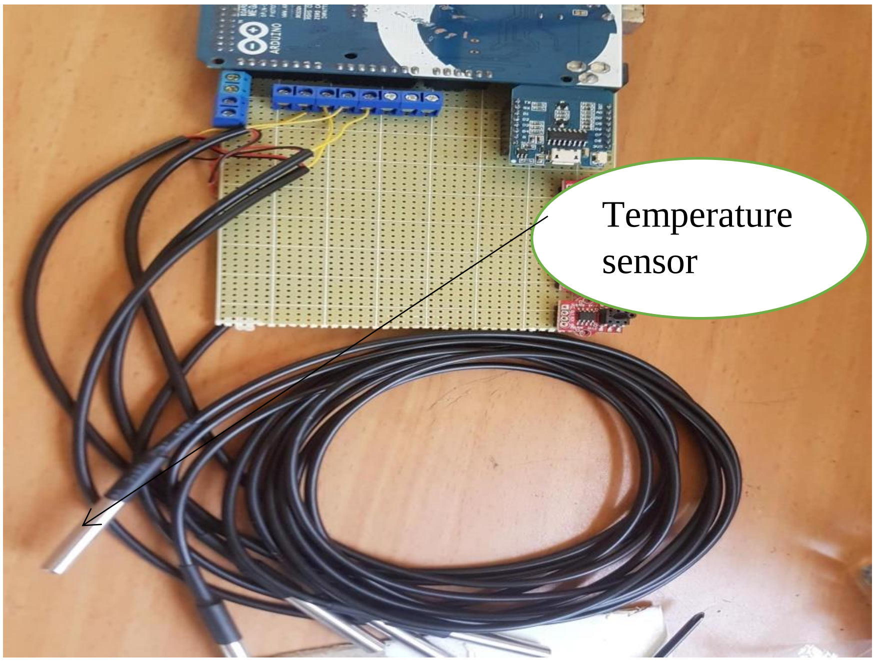


Figure 4-13 Temperature sensor Arduino

Connecting the temperature sensors with the Arduino and making sure to give the desired results. These sensors have three ports that are connected directly to the Arduino. This sensor measures the temperature of the sick person

4.3.5. Connect Pressure sensor Arduino

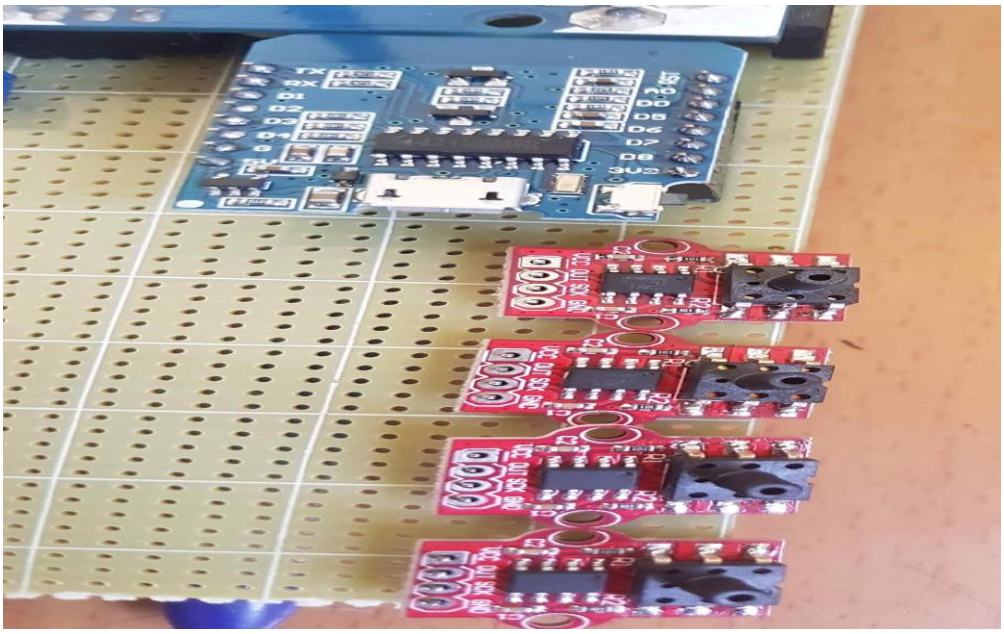


Figure 4-14 Connect Pressure sensor Arduino

Connecting the pressure sensors with the Arduino and making sure of its work. These sensors will measure the pressure at each of the working points on the medical mattress, as the sensor predicts the occurrence of abnormal pressure before it occurs.

4.3.6. Connect H.R sensor with Arduino

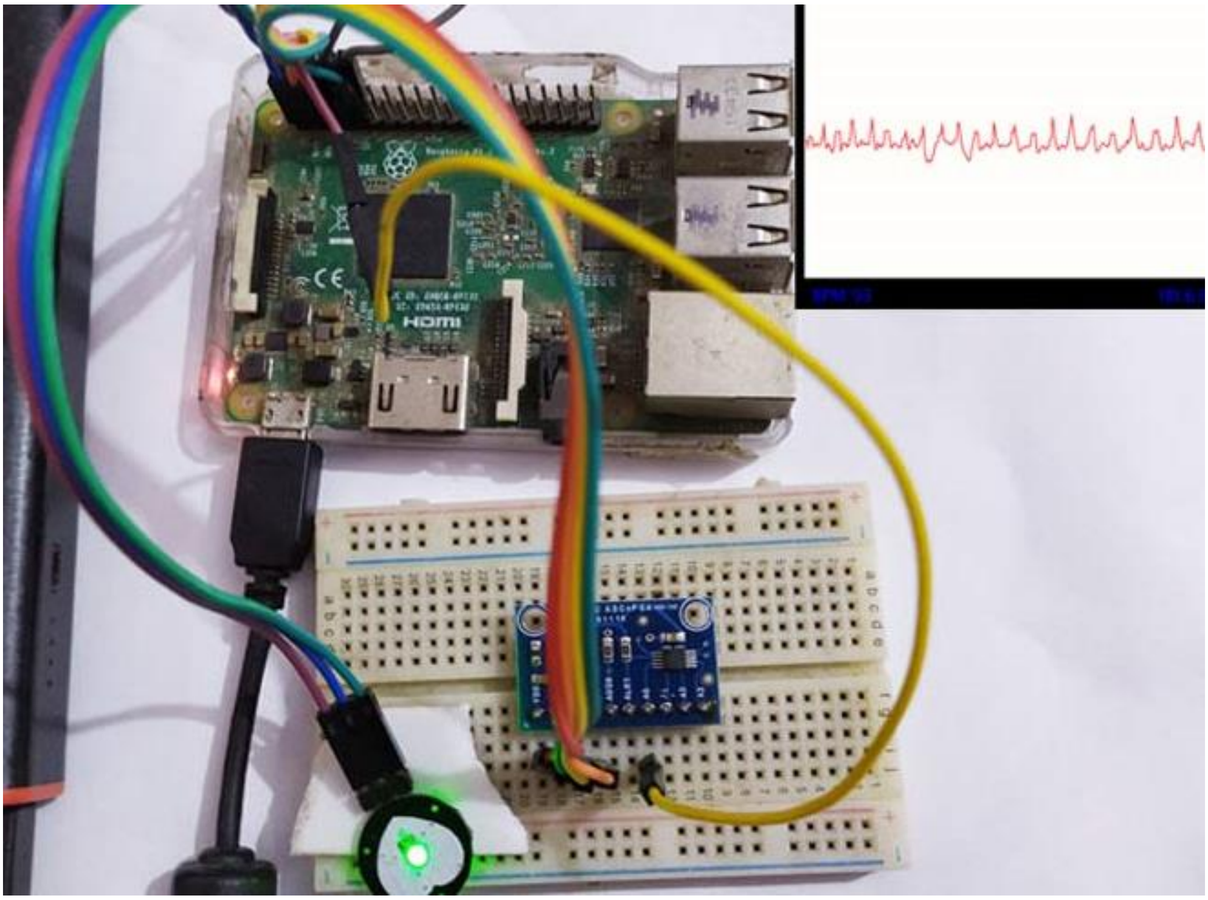


Figure 4-15 connect H.R sensor with Arduino

Connecting the heart rate sensor to the Arduino, this sensor will know the heart rate of the sick person, we need to know the heart rate to monitor the patient's vital condition, as the heart rate will be sent to the phone app of the nurse who monitors the patient

4.3.7. Connect Valves with Arduino

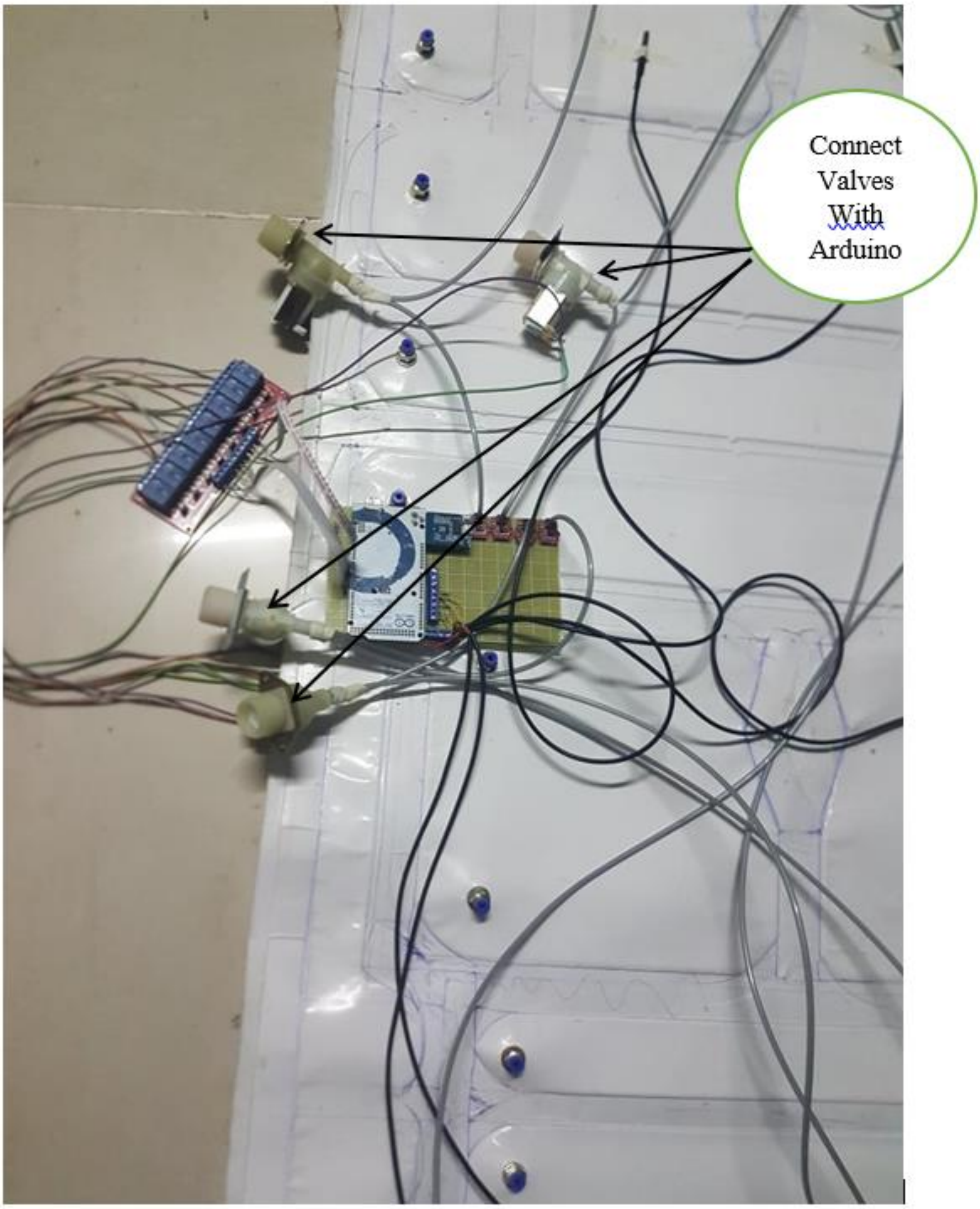


Figure 4-16 connect Valve with sensor with Arduino

Valves are connected directly between the pump and the medical mattress. These Valves will control the pumping and suction operations of water to and from the mattress. These Valves work when receiving the command from the Arduino as the case may require.

4.4. Building a mobile application

4.4.1. Draw parts of the mattress on the mobile app

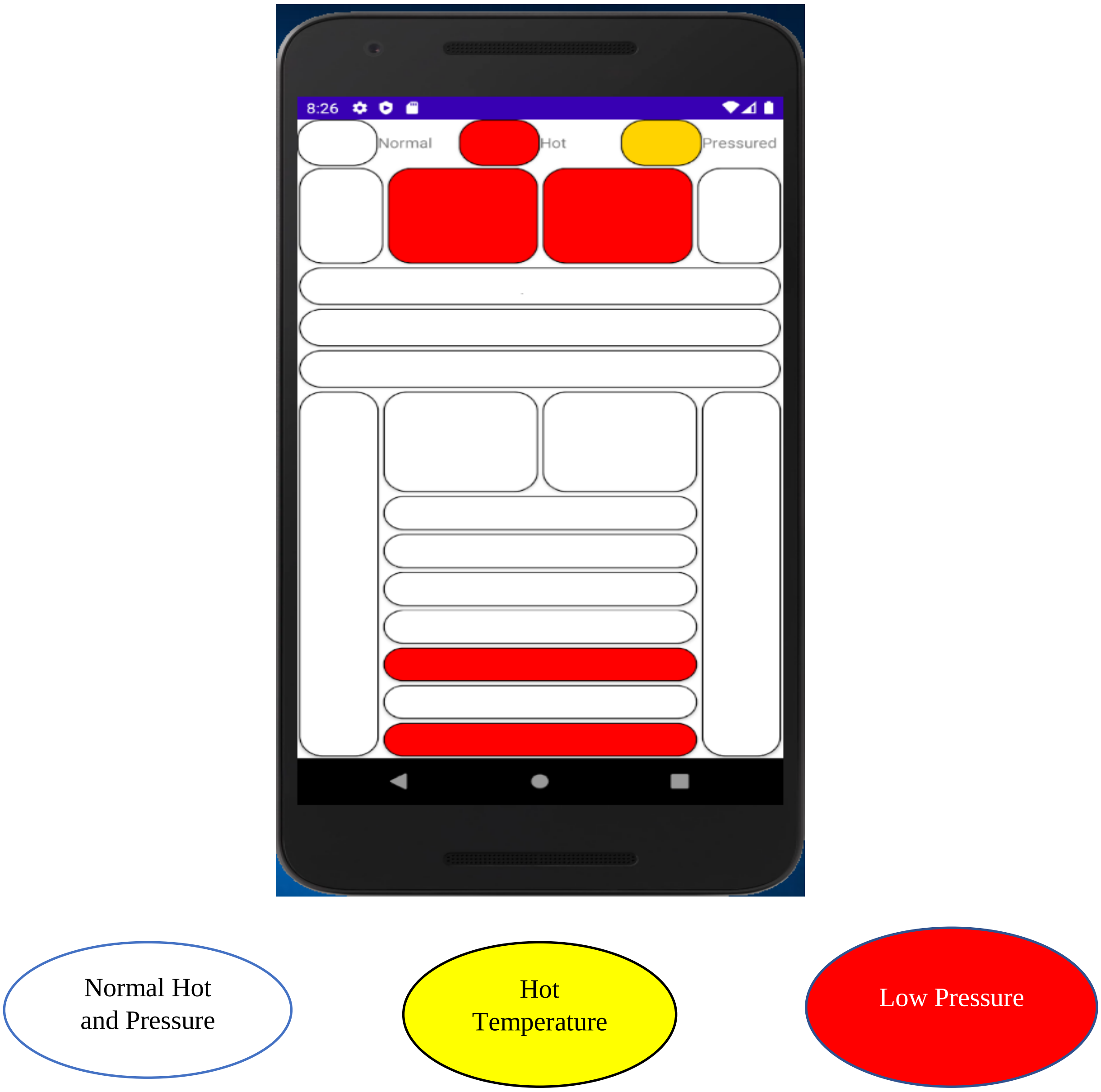


Figure 4-17 parts of the mattress on the mobile app

The phone application is designed through the applications supported by the Arduino program, through this application the medical mattress will be monitored remotely through an application that is downloaded by the nurse who follows the patient, as it contains the shape of the medical mattress, the color of the water pillow changes according to the current state of pressure and temperature. An alarm will be sent in critical and unwanted situations. The application only supports Android.

4.4.2. Set Normal Value of Temperature on mobile app

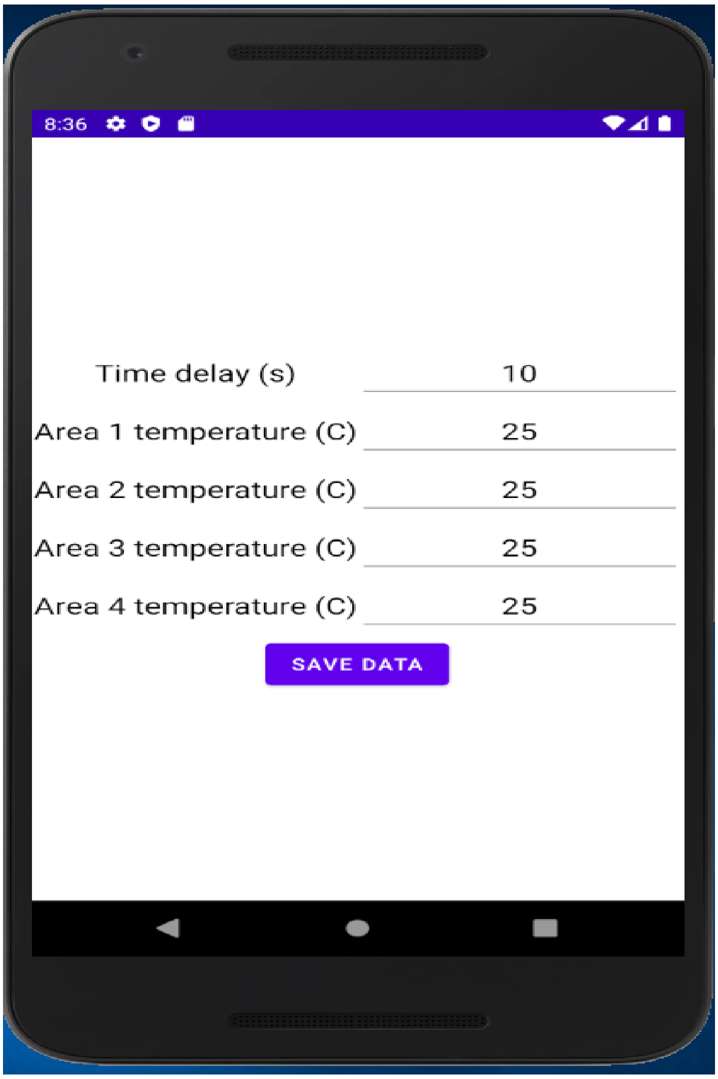


Figure 4-18 Values of the Normal Temperature sensor at the body

A platform within the phone application, through which it is possible to determine the critical temperature at which the system starts working. In addition to the waiting period before starting work, the temperatures are determined taking into account the surrounding conditions, as they vary from one diseased condition to another. These values are determined by the nurse.

4.4.3. Set Normal Value of Pressure sensor on mobile app

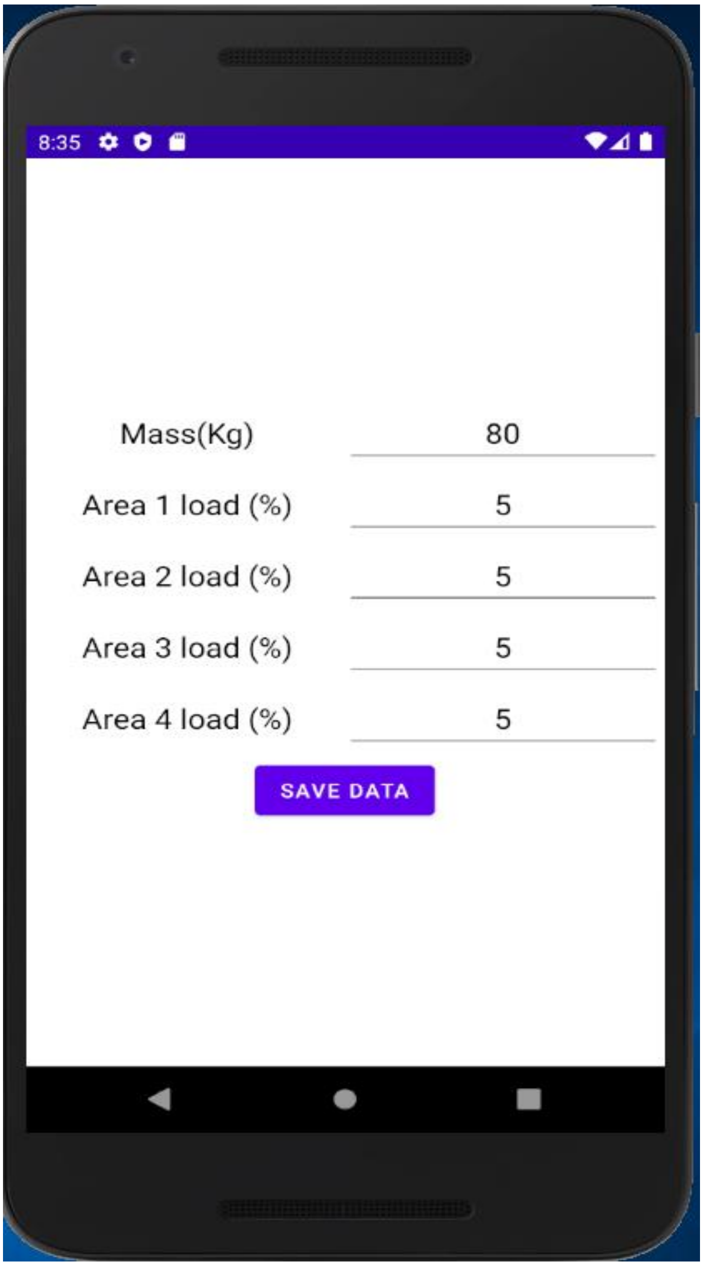


Figure 4-19 Value of the Weight of the body and the Pressure Sensor result

A platform within the mobile application through which the weight of the sick person is determined, in addition to the amount of pressure formed for each area of the medical mattress.

4.5. Final Design

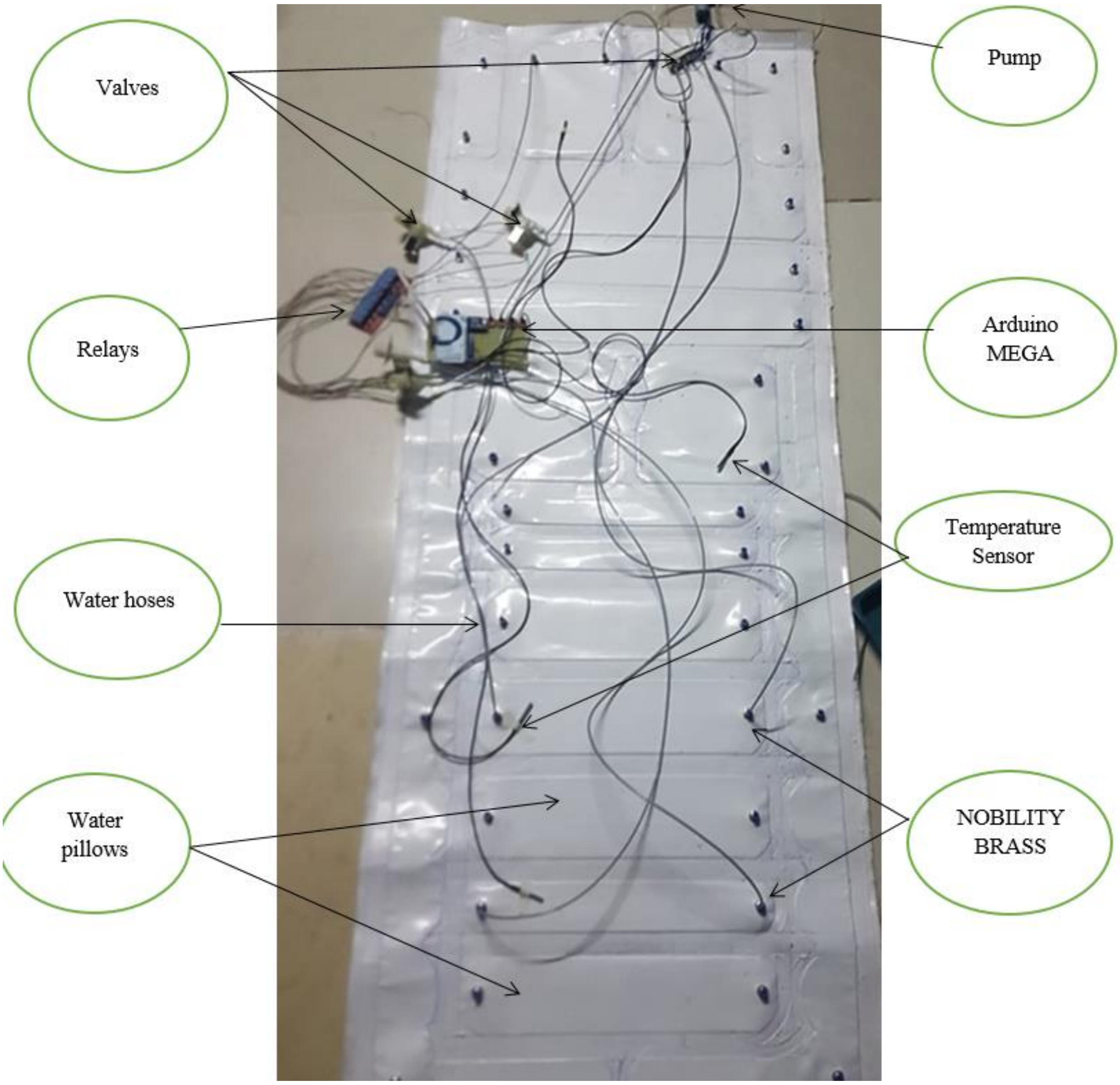


Figure 4-20 Final design

5. Result

Analysis and Conclusion

5.1. Results

The results of this project can be explained as follows:

First, regarding the design of the medical mattress: It was designed as planned in terms of the number of water pillows, whether the effective areas or the surrounding areas, and it was found that it bears a water pressure force higher than the values assumed during planning, as it bears weights of up to 200 kilos distributed over all parts The mattress.

Secondly, with regard to the processes of pumping and suction by the pump: this process was carried out as planned, so that whenever the temperature and pressure rise, the process of pumping and suction begins through the operation of the pump.

Third, with regard to temperature and heart sensors and sending information to the phone application: The body temperature was detected quickly and with a small error, in addition to the heart rate as planned. This information was sent to the phone application, which in turn showed us the pressure points for each area in addition to a warning in critical cases.

Finally, to sum up: We can say that the medical mattress, and through the results that appeared with us on the patient, helped reduce and predict the occurrence of clinical ulcers at high rates, in addition to the comfort of the nurse from manual turn and position patients through the design that was built.

5.2. Challenges

- The prices of some pieces used in the project are high.
- Not all required components are available in the Palestinian market; some of the components were imported from the outside of Palestine.
- Difficulty in determining the temperature at which the ulcers occur.
- Some of the results for heat and pressure sensors were inaccurate because of the presence of water.
- Lack of technical experts in the manufacture and design of medical brushes.

5.3. Conclusion

The project works to reduce the form of clinical retardation of patients who sit on the bed for long periods without moving, through pumping and sucking of water within two balms installed on the medical bed, the shape of which is proportional to the shape of the human body and its pressure points. In addition, monitoring the patient's vital state, such as temperature and heart rate, by sending information from the medical mattress via Wi-Fi to a phone carried by the pathogen. Additional features:

• The mattress is suitable for all sizes and patient weights.

• Pressure points on the body can be monitored through a remote phone app.

• The mattress is suitable for all paralyzed and sedentary patients.

5.4. Recommendation

• Add additional sensors whether heat or pressure on the mattress to give more accurate information.

• The design could be modified to match newborn and paralytic patients

• Design adjustment to fit the wheelchair

6. Appendix

6.1. Datasheets

6.1.1. Pump suction

6.1.2. MEGA Microcontroller

6.1.3. Pressure sensor

6.1.4. Temperature sensor

6.1.5. Heart Rate Sensor

6.2. Arduino Code

Appendix

Datasheets Pump suction

Appendix

MEGA Microcontroller

Appendix

Pressure sensor

Appendix

Temperature sensor

Appendix

Heart Rate Sensor

Appendix

Arduino Code

```
#include "FirebaseESP8266.h"
#include <ESP8266WiFi.h>
#include "DHT.h"
#define DHTPIN 12
#define DHTTYPE DHT22
DHT dht(DHTPIN, DHTTYPE);
#define WIFI_SSID "Main"
#define WIFI_PASSWORD "357511aa"
FirebaseData firebaseData;
FirebaseJsonArray arr;
#define FIREBASE_HOST "https://smartfarming-46dbe-default-
rtdb.firebaseio.com/"
#define FIREBASE_AUTH "zoWv72M3SW4nvrE5JTh7VO6WpqQ2Ya5vwqZXvDRi"
int s1,s2;
int
cm=0,hr=30,hs=30,l1=1,l2=1,l3=1,lr=50,ls=50,tr=20,ts=20,door=2;
void printResult(FirebaseData &data);
String path = "/Const/1";
const int r1=2;
const int r2=0;
const int r3=4;
const int up_door=13;
const int down_door=15;

const int up_switch=14;
const int down_switch=16;
const int analogInPin = A0;

void setup() {
Serial.begin(9600);
```

```
pinMode(r1,OUTPUT);
pinMode(r2,OUTPUT);
pinMode(r3,OUTPUT);
pinMode(up_door,OUTPUT);
pinMode(r3,OUTPUT);
pinMode(up_switch,INPUT);
pinMode(down_door,INPUT);

dht.begin();
WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
    Serial.print("Connecting to Wi-Fi");
    while (WiFi.status() != WL_CONNECTED)
    {
        Serial.print(".");
        delay(300);
    }
    Serial.println();
    Serial.print("Connected with IP: ");
    Serial.println(WiFi.localIP());
    Serial.println();

    Firebase.begin(FIREBASE_HOST, FIREBASE_AUTH);
    Firebase.reconnectWiFi(true);
    firebaseData.setBSSLBufferSize(1024, 1024);
    firebaseData.setResponseSize(1024);
}

void loop() {
if (Firebase.get(firebaseData, path ))
printResult(firebaseData);
```

```
  ls = analogRead(analogInPin)/10.23;
 // hs = dht.readHumidity();
 // ts = dht.readTemperature();
  update_sensors();
// String line = (String)ls+","+(String)hs+","+(String)ts;
//Serial.println(line);

 s1=not(digitalRead(up_switch));
 s2=not(digitalRead(down_switch));
}
void printResult(FirebaseData &data){
FirebaseJson &json = data.jsonObject();
String jsonStr;
json.toString(jsonStr, true);
size_t len = json.iteratorBegin();
String key, value = "";
int type = 0;
String li="";
for (size_t i = 0; i < len; i++){
json.iteratorGet(i, type, key, value);
//trts
if(i==0){cm=value.toInt();}
if(i==1){door=value.toInt();}
if(i==2)hr=value.toInt();
if(i==4)l1=value.toInt();
if(i==5)l2=value.toInt();
if(i==6)l3=value.toInt();
if(i==7)lr=value.toInt();
if(i==9)tr=value.toInt();
}
```

```
String line =
(String)l1+","+(String)l2+","+(String)l3+","+(String)door;

Serial.println(line);

json.iteratorEnd();

control();

}

void control(){

  if(cm==0){

  if(l1==1)digitalWrite(r1,HIGH);

  if(l1==0)digitalWrite(r1,LOW);

  if(l2==1)digitalWrite(r2,HIGH);

  if(l2==0)digitalWrite(r2,LOW);

  if(l3==1)digitalWrite(r3,HIGH);

  if(l3==0)digitalWrite(r3,LOW);

if(door==0 &&
!s2){digitalWrite(down_door,HIGH);digitalWrite(up_door,LOW);}

 else if(door==1 &&
!s1){digitalWrite(down_door,LOW);digitalWrite(up_door,HIGH);}

 else {digitalWrite(down_door,LOW);digitalWrite(up_door,LOW);}

  }

  else if (cm==1){

    if(lr>ls)digitalWrite(r1,HIGH);

    else digitalWrite(r1,LOW);


    if(tr>ts)digitalWrite(r2,LOW);

    else digitalWrite(r2,HIGH);


     if(hr>hs)digitalWrite(r3,HIGH);

    else digitalWrite(r3,LOW);

    }
```

```
  }
void update_sensors(){
  Firebase.setFloatDigits(2);
  if (Firebase.setInt(firebaseData, path + "/ls" , ls)){}
  if (Firebase.setInt(firebaseData, path + "/ts" , ts)){}
  if (Firebase.setInt(firebaseData, path + "/hs" , hs)){}
  }
```

7. References

[1] K. Barrington, " BedAdvisor.com," 29 june 2020. [Online].

Available:https://bedadvisor.com/best-mattress-prevent-bedsores/?fbclid=IwAR3nlhLjk1Uas0C1q1yoV930pqw6S1K7hLf7eMO4ImO-KqADya-Yc7rtsb8.

[Accessed 25 Dec 2020].

[2] "lint.com," [Online]. Available:

https://www.linet.com/en/health-care/mattresses/antidecubitus-systems/opticare.

[Accessed 25 Dec 2020].

[3] B. Amirlak, linet.com, vol. 77, 2017, pp. 1-6.

[4] "TeachMeAnatomy,"[Online].

Available: https://teachmeanatomy.info/thebasics/ultrastructure/skin/?fbclid=IwAR0PmEK

Dg4LdnxbSi5DT31OkITOA8q_JOLLuh7-Sbae0BaZG4ZGPdtDbdFo. [Accessed 1 jan 2021].

[5] "MSD MANUALS," [Online]. Available: https://www.msdmanuals.com/?fbclid=IwAR0oCWs

Wh7DRClHhiK7qdMrrY_smC2ahkx9TufdL1R_NvXGJ4x8iEFn5G6s. [Accessed 1 jan 2021].

[6] "byebyedoctor.com," [Online]. Available: https://byebyedoctor.com/skin-ulcer/

?fbclid=IwAR0UXUMjfy1-ODCjQx1L8fRGgRig67jZREpgac7ee-z2Z5Fg5CDntRt2D_I.

[Accessed 1 jan 2021].

[7] "https://www.oflynnmedical.com/," [Online].

Available: https://www.oflynnmedical.com/product-category/air-mattress/. [Accessed 3 jan 2021].

[8] "oflynnmedical.com," [Online].

Available: https://www.oflynnmedical.com/product-category/air-mattress/. [Accessed 3 jan 2021].

[9] [Online].

Available: https://www.olx.com.pk/item/air-bed-mattress-bedsore-iid-857547721.

[Accessed 2 jan 2021].

[10] [Online]. Available: https://www.chemicalsafetyfacts.org/polyvinyl-chloride/. [Accessed 4 jan 2021].

[11] [Online]. Available: arduino.cc/en/Guide/Introduction. [Accessed 29 Dec 2020].

[12] [Online]. Available: https://www.arduino.cc/en/Guide/Introduction. [Accessed 29 12 2020].

[13] [Online]. Available: https://www.arduino.cc/en/Guide/ArduinoUno. [Accessed 29 Dec 2020].

[14] "www.instructables.com," [Online]. Available: https://www.instructables.com/ESP32-BLE-Android-App-Arduino-IDE-AWESOME. [Accessed 29 Dec 2020].

[15] Kolban, Kolban's Book on the ESP8266 and ESP32, 2016.

[16] "12volt.com," [Online]. Available: https://www.12volt.com.au/redirect.html?a=%2FGeneral%20Htmls%2Fwebcat2003%2Fpumps.html&fbclid=IwAR287W3Yn8E-gWrmw6KVDuc_VIoB5wzmzZKBv0ljpLBEObuwXAG89Zn4ofA. [Accessed 24 Dec 2020].

[17] "pumpfundamentals.com," [Online]. Available: https://www.pumpfundamentals.com/centrifugal-pump-tips.htm?fbclid=IwAR11r4lz8VtpKJFUyAAckD1Q2ofzlmpqtzN9E7eCyOOb8vlL2FvG3qeoOLY. [Accessed 24 Dec 2020].

[18] [Online]. Available: http://www.tenho-china.com/yueqing-tenho-pneumatic-coltd-solenoid-valve-15885933376634228.html?gclid=CjwKCAiAxeX_BRASEiwAc1QdkWPqPz7x508zlJT1Mq_HSw2dtiqV0789CX13P_IOze6a8VyefyoChoCaxEQAvD_BwE&fbclid=IwAR2xPPngqL_pIXfxgnjB4rkyVhBxEozoxsm_Sese3LHYu6qfpGtCx. [Accessed 24 Dec 2020].

[19] A. D. Bland JM, Comparing two methods of clinical measurement, 1995.

[20] J. JR, The thermodilution method for the clinical assessment of cardiac.

[21] N. S. A. M. a. I. P. M. Garbey, Contact-free measurement of cardiac pulse based on the analysis of thermal imagery, IEEE Trans, 2007.

[22] S. M. M. a. V. P. Veiko, Laser Assisted Microtechnology, 2nd ed, Germany: Springer-Verlag: R. M.Osgood, Jr., Ed. Berlin, 1998.

[23] C. T. a. Y. Ohta, Heart rate measurement based on a timelapse image,Med, 2007.

[24] "evilmadscientist.com," [Online]. Available: https://shop.evilmadscientist.com/productsmenu/716. [Accessed 5 Jan 2021].

[25] "adafruit.com," [Online]. Available: https://learn.adafruit.com/dht. [Accessed 5 Jan 2021].

[26] [Online]. Available: https://www.healthabove60.com/blog/pressure-sore.html. [Accessed 6 Jan 2021].

[27] "hihearts.com," [Online]. Available: http://hihearts.com/find-out-which-are-best-and-worst-sleeping-positions-and-how-they-can-effect-to-your-health/. [Accessed 7 Jan 2021].