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HELWAN UNIVERSITY

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Computer engineering department

Smart vitals monitor using IOT

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Acknowledgments

we would like to thank our supervisor Dr Hader Ahmed for her continuous guidance and support throughout the course of the project execution, we couldn’t have executed this project without her patience and presence.

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Introduction

In this chapter we discuss the problem and the alternative existing solution right now.

Covid-19 made a huge impact in our daily life, changed the way we looked, cared, tracked now it became more important than ever to take a good care for our elders, people with chronic diseases as they are sadly more likely to suffer more severe symptoms of covid-19 and have a higher rate of death.

Chronic diseases are the diseases that you have to learn, adapt and treat carefully in order to live a healthy life for the rest of your life.

In this paper we are interested in certain diseases (hypertension, hypotension, diabetes, heart problems, fever and covid-19 symptoms continuous monitoring to avoid sudden escalations of symptoms and permanent damage to the body.

1.1 Hypertension:

What is hypertension?

Blood pressure is the force exerted by circulating blood against the walls of the body's arteries, the major blood vessels in the body. Hypertension is when blood pressure is too high.

An estimated 1.13 billion people worldwide have hypertension, most (two-thirds) living in low- and middle-income countries.

In 2015, 1 in 4 men and 1 in 5 women had hypertension.

Fewer than 1 in 5 people with hypertension have the problem under control.

Hypertension is a major cause of premature death worldwide.

Blood pressure is written as two numbers. The first (systolic) number represents the pressure in blood vessels when the heart contracts or beats. The second (diastolic) number represents the pressure in the vessels when the heart rests between beats.
Hypertension is diagnosed if, when it is measured on two different days, the systolic blood pressure readings on both days is ≥140 mmHg and/or the diastolic blood pressure readings on both days is ≥90 mmHg.

What are the risk factors for hypertension?

Modifiable risk factors include unhealthy diets (excessive salt consumption, a diet high in saturated fat and trans fats, low intake of fruits and vegetables), physical inactivity, consumption of tobacco and alcohol, and being overweight or obese.

Non-modifiable risk factors include a family history of hypertension, age over 65 years and co-existing diseases such as diabetes or kidney disease.

What are the complications of uncontrolled hypertension?

Among other complications, hypertension can cause serious damage to the heart. Excessive pressure can harden arteries, decreasing the flow of blood and oxygen to the heart. This elevated pressure and reduced blood flow can cause:

Chest pain, also called angina.

Heart attack occurs when the blood supply to the heart is blocked and heart muscle cells die from lack of oxygen. The longer the blood flow is blocked, the greater the damage to the heart.

Heart failure occurs when the heart cannot pump enough blood to body organs.

Irregular heart beat which can lead to a sudden death.

Hypertension can also burst or block arteries that supply blood and oxygen to the brain, causing a stroke.

In addition, hypertension can cause kidney damage, leading to kidney failure.

1.2 Hypotension:

Low blood pressure might seem desirable, and for some people, it causes no problems. However, for many people, abnormally low blood pressure (hypotension) can cause dizziness and fainting. In severe cases, low blood pressure can be life-threatening.

Risk factors

Low blood pressure (hypotension) can occur in anyone, though certain types of low blood pressure are more common depending on your age or other factors:

- Age Drops in blood pressure on standing or after eating occur primarily in adults older than 65. Neuralgy mediated hypotension primarily affects children and younger adults.
- Medications. People who take certain medications, for example, high blood pressure medications such as alpha blockers, have a greater risk of low blood pressure.
- Certain diseases. Parkinson's disease, diabetes and some heart conditions put you at a greater risk of developing low blood pressure.

1.3 Diabetes:

There are 4 types of diabetes but only 2 are the main interest because they are the majority, diabetes is when the concentration of glucose in blood is too high “hyperglycemia’’ which can happen with type 1 and type 2 diabetes.

In the show table (1) Comparison between type 1 and type 2:

Table 1:type 1 vs type 2 comparison

Causes	response	weight/obesity
Commonality/incident rate	Not common/about 10% of the population	Common/about 90% to 95%
Onset	Rapid	Slow
Risk Factor	Family history of diabetes	Prediabetes/overweight/obesity/family history/gestational diabetes/polycystic ovarian syndrome
Age	Common in children and adolescents	Common in people 45 years old and above
Geography	Prevalent in people living farther away from the equator	African-American, American Indian, Hispanic or Latino American, and Alaska Native
Prevention	Cannot be prevented	Can be prevented through a healthy lifestyle
Insulin	Insulin shot/insulin pump	Not necessarily/blood sugar can be controlled with exercise and diabetes medication might be needed by the body to utilize insulin effectively. Insulin may be needed in late stages and in emergencies.

Type 1 complications:

- Cardiac and blood vessel-related diseases
- Neuropathy (nerve damage)
- Nephropathy (kidney damage)
- Foot damage (possible amputation)
- Eye damage
- Bacterial and fungal infection of the skin and mouth
- Complications during pregnancy

Type 2 complications:

- Cardiac and blood vessel-related diseases
- Neuropathy (nerve damage)
- Nephropathy (kidney damage)
- Foot damage (possible amputation)
- Eye damage
- Bacterial and fungal infection of the skin and mouth
- Complications during pregnancy

1.4 heart disease:

Heart rhythm problems (heart arrhythmias) occur when the electrical impulses that coordinate your heartbeats don't work properly, causing your heart to beat too fast, too slow or irregularly.

Types of arrhythmias:

Doctors classify arrhythmias not only by where they originate (atria or ventricles) but also by the speed of heart rate they cause:

- Tachycardia, this refers to a fast heartbeat — a resting heart rate greater than 100 beats a minute.
- Bradycardia, this refers to a slow heartbeat — a resting heart rate less than 60 beats a minute.

By monitoring the rhythm of heart beat continuously it will help a lot to rescue any patient on time when one of these heart disorders.

1.5 Covid-19 symptoms:

Covid-19 can cause a lot of symptoms the most common ones are troubles breathing, hypertension, fever and other symptoms but what we can monitor at home are spo2(blood oxygen concentration), temperature, blood pressure).

1.6 Monitoring method available:

Blood pressure: there are 2 methods available for every one usage at home

1. PHYGMOMANOMETER:

It consists of a mercury manometer and inflatable cuff. The cuff is called a "Riva Rocci" cuff. The manometer is U shaped tube. One limb is being broader than the other. The broader limb is the reservoir for mercury and the narrow limb is graduated from O to 300 mm with the smallest division corresponding to a reading of 2 mm.

2. Electronic PHYGMOMANOMETER:

measure by the use of sound and detection of blood sound turbulence (Korotkoff sounds). A microphone positioned against an artery compressed by the device cuff detects the Korotkoff sounds, enabling the unit to directly determine systolic and diastolic values blood pressure value, as shown in the table (2) below the comparison between methods of blood pressure

Table 2: blood pressure methods comparison

	PHYGMOMANOMETER	Electronic PHYGMOMANOMETER
Advantages	The most accurate method and it's the one used for calibration.	Doesn't need a trained person to do the measure.
Disadvantages	Require a trained person to do the measure and takes a lot of setting.	Less accurate than the manual one.

Glucose: There are several ways to monitor glucose levels in blood as shown in the below table (3) comparison between method of measuring: -

Table 3: comparison between glucose measuring methods

	Finger-prick test	HbA1c blood test	Continuous glucose monitoring	Flash glucose monitoring
Advantages	1. Accurate. 2. Can be done at home. 3. Gives instant results.	1. Most accurate method.	1. Accurate. 2. Blood levels monitored continuously many times along the day.	1. Accurate. 2. Blood levels stored for along 8 hours and plotted on a screen.
Disadvantages	1. Painful. 2. Invasive method. 3. Need blood sample. 4. High cost.	1. Must be done at labs or hospital. 2. Results obtained in 2 or 3 days. 3. High cost.	1. Sensor inserted below the skin. 2. Painful. 3. Sensor should be changed regularly.	Same as CGM

Oxygen levels: pulse oximeter is used to measure oxygen saturation level (spo2) and pulse rate.

Pulse oximetry is a noninvasive procedure, which means it does not introduce any instrument into the body. In fact, it is done using only a small, clip-on device called the pulse oximeter sensor, which is attached to a part of the body, usually on a finger, toe, or earlobe. Pulse oximetry sensors vary in size and shape and are offered in both reusable and single-use applications.

The procedure is often utilized in the critical care setting and in doctors' offices because of its portability and efficiency.

- working principle

The principle of pulse oximetry is based on the differential absorption characteristics of oxygenated and the de-oxygenated hemoglobin. Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. Whereas deoxygenated hemoglobin absorbs more red light and allowing more infrared light to pass through.

ECG (Electrocardiogram): it refers to the recording of electrical changes that occurs in heart during a cardiac cycle. It may be abbreviated as ECG or EKG.

Working principle of electrocardiograph:

- It works on the principle that a contracting muscle generates a small electric current that can be detected and measured through electrodes suitably placed on the body.
- For a resting electrocardiogram, a person is made to lie in the resting position and electrodes are placed on arms, legs and at six places on the chest over the area of the heart. The electrodes are attached to the person’s skin with the help of a special jelly.
- The electrodes pick up the current and transmit them to an amplifier inside the electrocardiograph. Then electrocardiograph amplifies the current and records them on a paper as a wavy line.

Body temperature: there are different types of thermometers to measure body temperature as shown in table (4) below the comparison between them.

Table 4: temperature measuring methods comparisons

	Clinical thermometer	Digital thermometer	Infrared ear thermometer
Advantages	Accurate. Low cost.	Easy to use, doesn’t need trained person. Low cost.	Easy to use remotely.
Disadvantages	Mercury inside the tube may be harmful for humans. Need trained person to read.	Need battery change regularly.	Less accurate. High cost.

Related work

In our project we have used different methods to monitor glucose level and blood pressure. These methods made the smart monitor wearable and the measurements are easy to be monitored. Also, glucose monitoring became non-invasive that means that there is no need for needle insertion to take any blood samples.

These methods are discussed in details in this chapter based on scientific papers we used to implement these devices.

2.1 Non-invasive optical blood pressure sensing

The paper presented design of non-invasive optical device to measure blood pressure using microcontroller, Bluetooth module to transfer signal to mobile.

As shown in the figure (1) below the block diagram of the presented idea.

It is a monitoring system that uses an IR light source and a luminosity sensor to measure the blood pressure. The optical pulsatile method of blood pressure measurement is used to gather pulse data obtained from various parts of body. Blood pressure readings are calculated with the help of developed algorithm and transmitted via Bluetooth module to the computer. Numerical reading values of systolic and diastolic blood pressure are recorded and displayed on the computer.

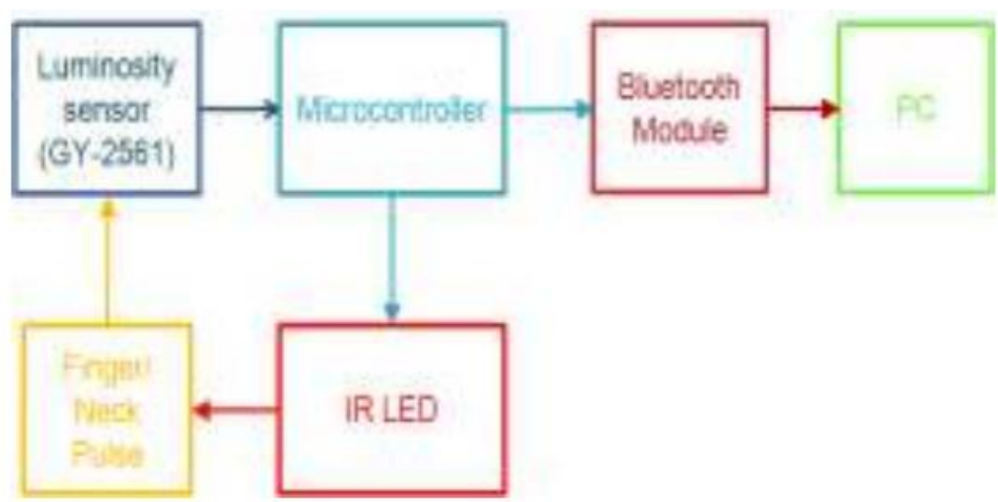


Figure 1:block diagram blood pressure measuring method presented.

Advantages of this method

- It does not need any cuff or any supervision.
- You can use it easily.
- It an optimal solution to monitor blood pressure.

2.2 Non-invasive blood glucose NIR-Technique based

as shown in figure (2) below the block diagram of the glucose measuring method.

In this method NIR optical signal is transmitted through one side of the fingertip and then received from its other side through which blood glucose's molecular count is predicted by analyzing the variation in the received signal's intensity

After its reflection and this data can be wirelessly transmitted to a remote pc or as we have done in our project signal is transmitted and recorded using a mobile application.

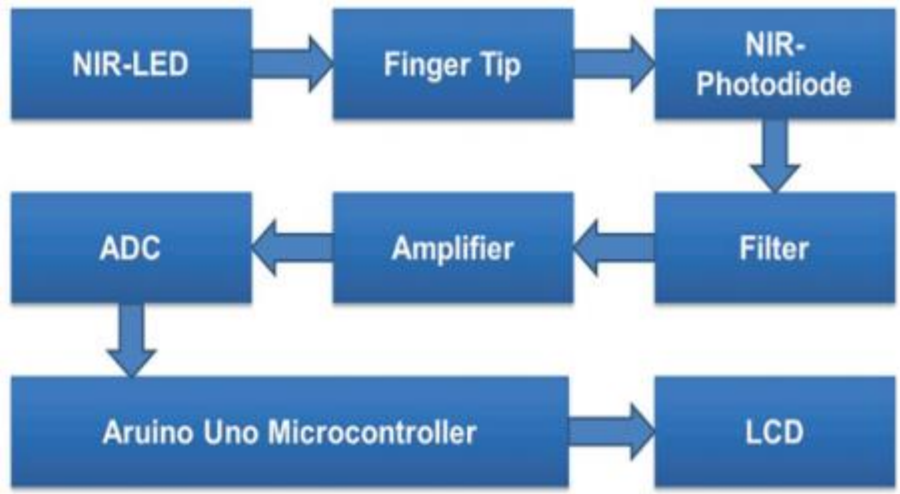


Figure 2: glucose measuring method block diagram

Advantages of this method

- No need for needle insertion.
- It is considered as CGM.
- No need for any supervision.
- No pain.
- Low cost due to no need for using strips or needles.

Proposed System.

3.1 System description:

The system is as shown in the block diagram consists of 4 controllers and mobile app, each module is calibrated and tested to measure the required vital.

The results are:

- Glucometer: 90% accuracy.
- Blood pressure:91% accuracy.
- Thermometer: 95% accuracy.
- Heart rate: 97% accuracy.

3.2 Block diagram:

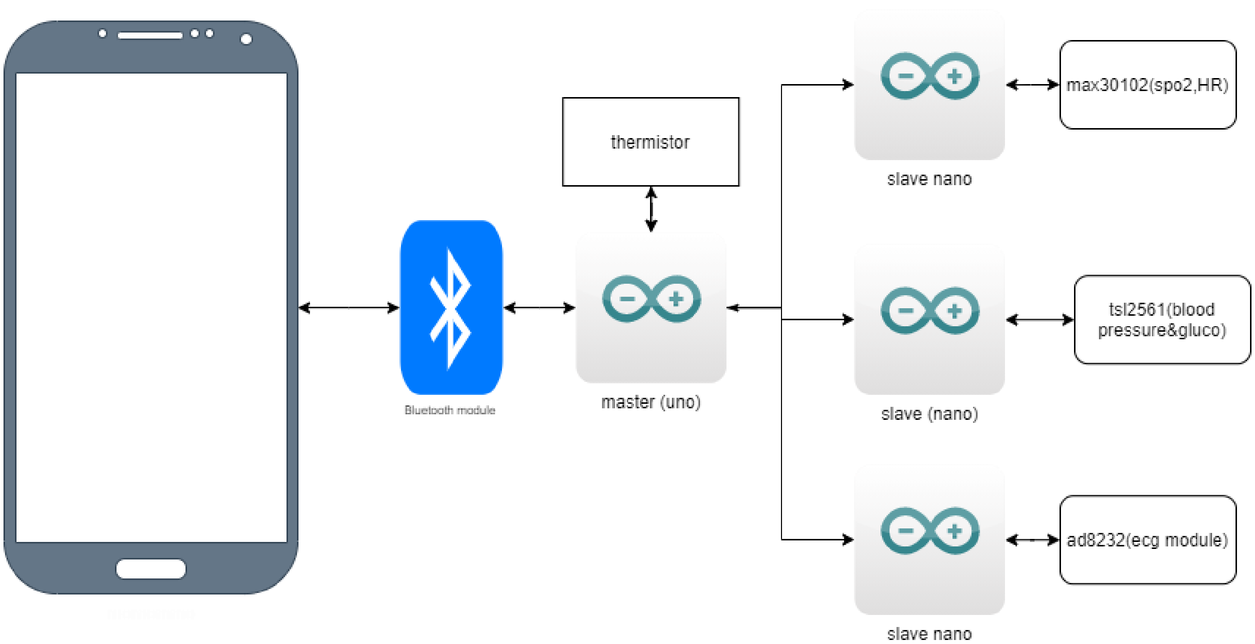


Figure 3:system block diagram

3.3 Advantages:

We are presenting a new system that has the following advantages over the existing solutions:

- Medical oriented (its main purpose is medical history and monitoring).
- Continuous high accuracy monitoring with cheap, efficient, no help required.

- Remote monitoring so it gives the partners of elder people the ability to be away for some time without worrying of any emergencies
- Can be used in covid patients monitoring to lower the risk of infection for the medical team, family.
- No piercing required to measure glucose level, low cost (no strips needed).
- It gives the whole package of multiple devices which are essential in every home in one small light easy to use package.
- Keep the whole history of the users to make it easier for doctors to diagnose.

3.4 Disadvantages:

- Require calibration every once in a while.
- Sensitive to light noise.
- Need constant internet connection.

3.5 Future work:

- Better casing to ensure more comfortable usage.
- ECG storing and sharing.
- Spo2 measurements.
- Doctor change medications and live chat

3.6 Use case:

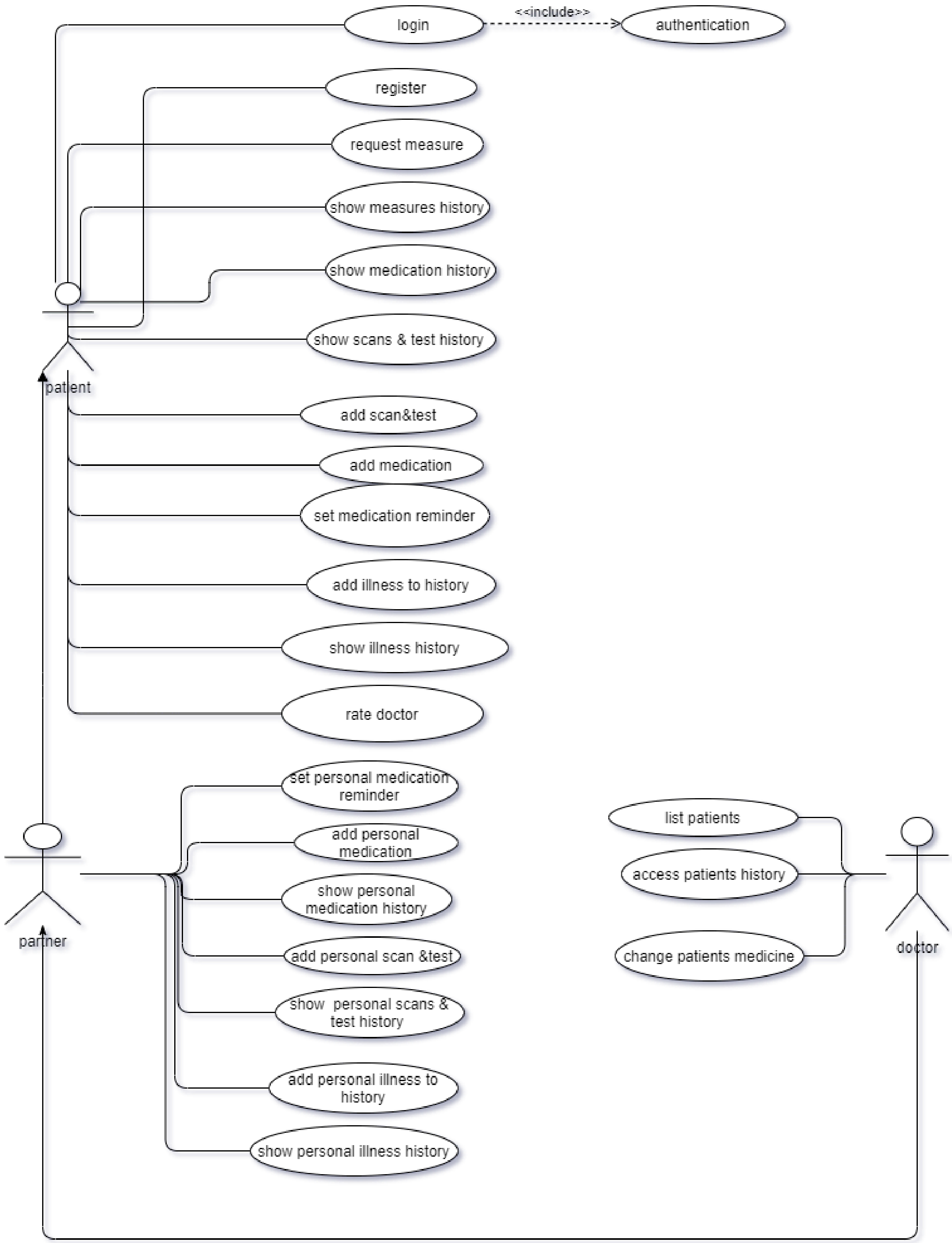


Figure 4: use case.

Software

4.1 Framework:

Flutter using Visual Studio Code (A framework to implement all the mobile application components in one place)

Languages:

- Dart (for Front-end implementation)
- PHP (Back-end implementation)

4.2 Architecture:

As shown in the figure below the software architecture hardware connected to mobile app, mobile app is connected to server which offers the services.

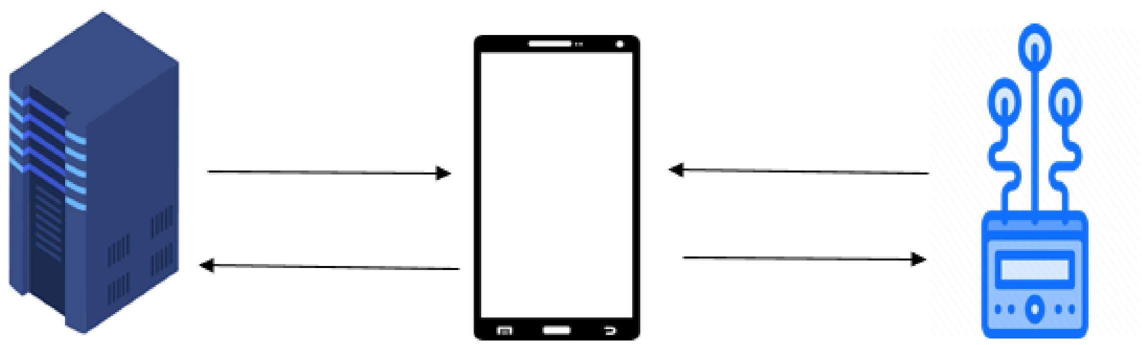


Figure 5: software architecture block diagram.

4.3 Functional requirements

This section function requirements contains specification of the functional requirements of the system. the table below is lists of functional requirements.

4.3.1User Registration [UR]

Requirement ID	Requirement Description
UR	Users should be able to register in the system.

4.3.2 User Login [ULI]

Requirement ID	Requirement Description
ULI	Users should be able to login the system

4.3.3 Patient's Rating of the Doctor [PRD]:

Requirement ID	Requirement Description
PRD	Users should be able to rate the doctor

4.3.4 Upload User's History [UUH]:

Requirement ID	Requirement Description
UUH-1	Users should be able to upload his illness history.
UUH-2	Users should be able to upload his medication history.
UUH-3	Users should be able to upload his scans history.

4.3.5 Retrieve User's History [RUH]:

Requirement ID	Requirement Description
RUH-1	Users should be able to Retrieve his illness history.
RUH-2	Users should be able to Retrieve his medication history.
RUH-3	Users should be able to Retrieve his scans history.

4.3.6 User’s Medication Reminder [UMR]:

Requirement ID	Requirement Description
UMR	Users should be able to set his medication reminder.

4.3.7 Doctor List Patients [DLP]:

Requirement ID	Requirement Description
DLP	Users should be able to list his patients’ names, vitals and medications.

4.3.8 Display user info [DUI]

Requirement ID	Requirement Description
DUI	Users should be able to display his profile data.

4.3.9 Update user info [UUI]

Requirement ID	Requirement Description
UUI	Users should be able to update his profile data.

4.3.10 Display paired Bluetooth devices [DPBD]

Requirement ID	Requirement Description
DPBD	Users should be able to display his paired Bluetooth devices.

4.3.11 Display scanned Bluetooth devices [DSBD]

Requirement ID	Requirement Description
DSBD	Users should be able to display scanned (unpaired) Bluetooth devices.

4.3.12 Receive Data from Bluetooth [RDB]

Requirement ID	Requirement Description
RDB-1	Application should receive ECG data.
RDB-2	Application should receive Heart Rate data.
RDB-3	Application should receive Temperature data.
RDB-4	Application should receive Blood Pressure data.
RDB-5	Application should receive SPO2 data.
RDB-6	Application should receive Glucose data.

4.3.13 Display a graph [DG]

Requirement ID	Requirement Description
DG-1	Application should display a graph of ECG.

4.3.14 Upload data to server [UDS]

Requirement ID	Requirement Description
UDS-1	Application should receive ECG data.
UDS -2	Application should upload Heart Rate data.
UDS -3	Application should upload Temperature data.
UDS -4	Application should upload Blood Pressure data.

UDS -5	Application should upload SPO2 data.
UDS -6	Application should upload Glucose data.

4.3.15 Retrieve data from server [RDS]

Requirement ID	Requirement Description
RDS-1	Application should Retrieve ECG data.
RDS -2	Application should Retrieve Heart Rate data.
RDS -3	Application should Retrieve Temperature data.
RDS -4	Application should Retrieve Blood Pressure data.
RDS -5	Application should Retrieve SPO2 data.
RDS -6	Application should Retrieve Glucose data.

4.4 Non-functional requirements

4.4.1 Performance

- System must respond to the user fast.
- System must do the graphing in real-time.
- System must be compatible with modern mobile phones.
- System must provide Bluetooth Connection.
- System can work in background.

4.4.2 Safety and security

● System must provide safe login and logout to user.

● System must secure patient information.

4.4.3 Reliability

● System must be designed in modular manner.

● System must provide catching of exceptions, so that unintended results do not accrue such as system crashes or data validation failures.

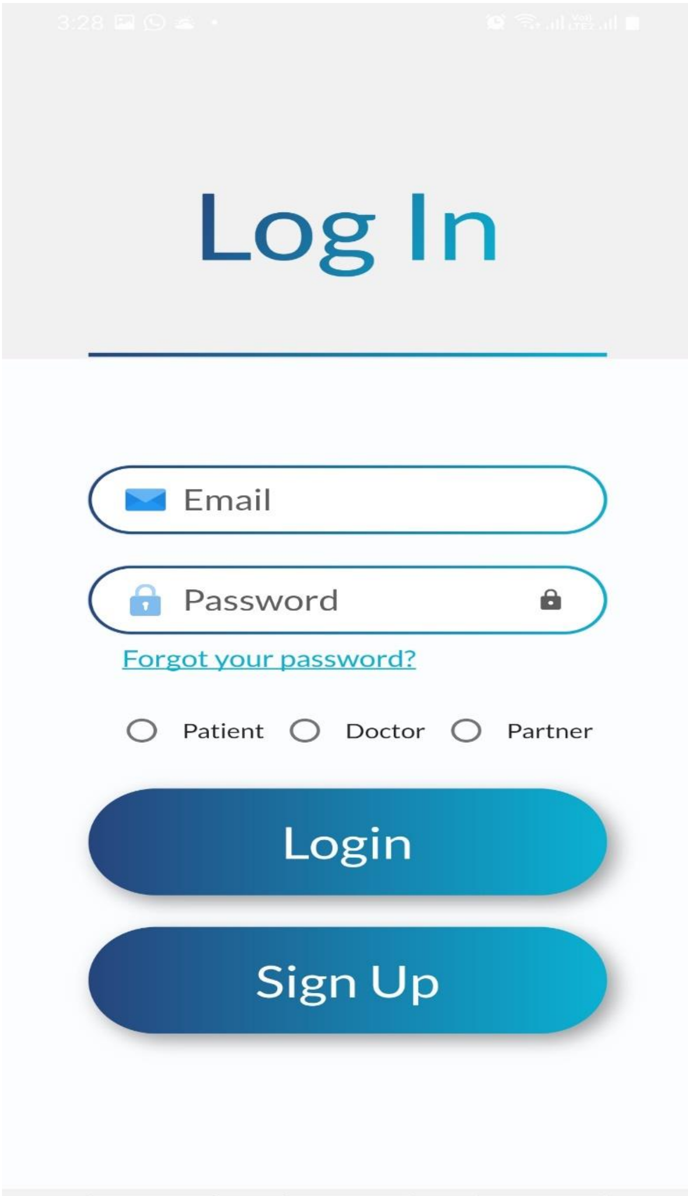
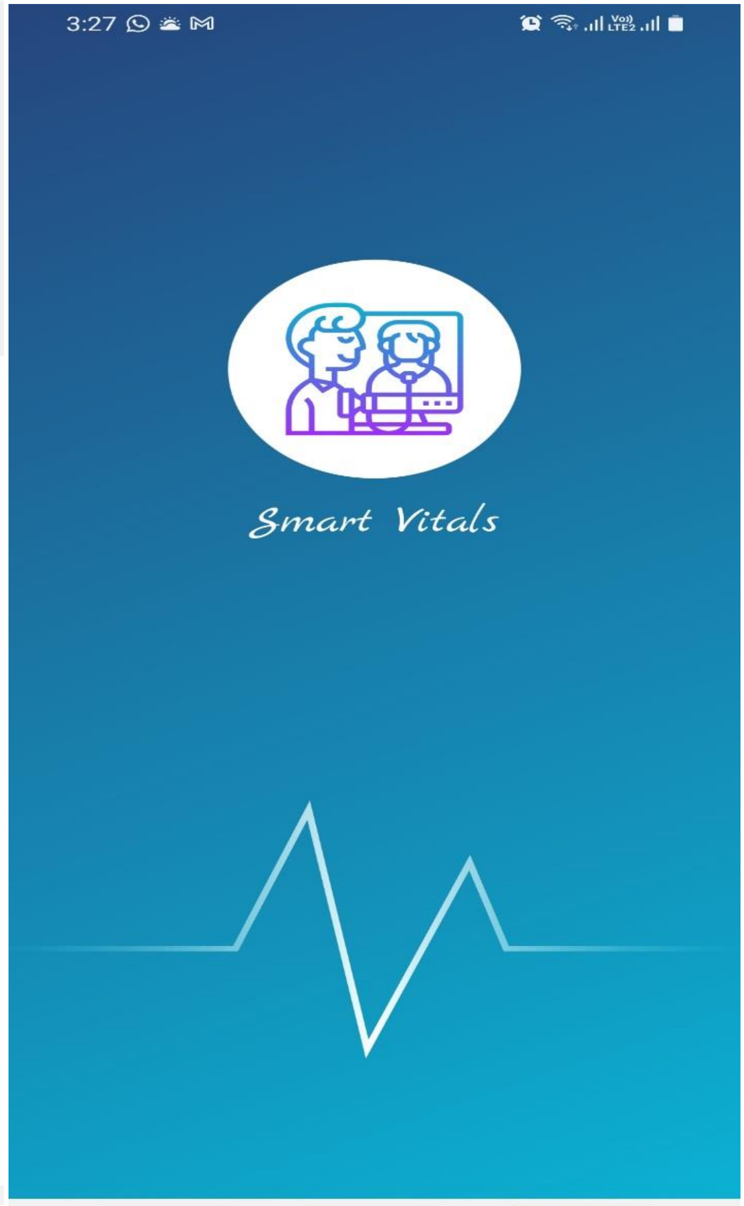
4.4.4 Usability

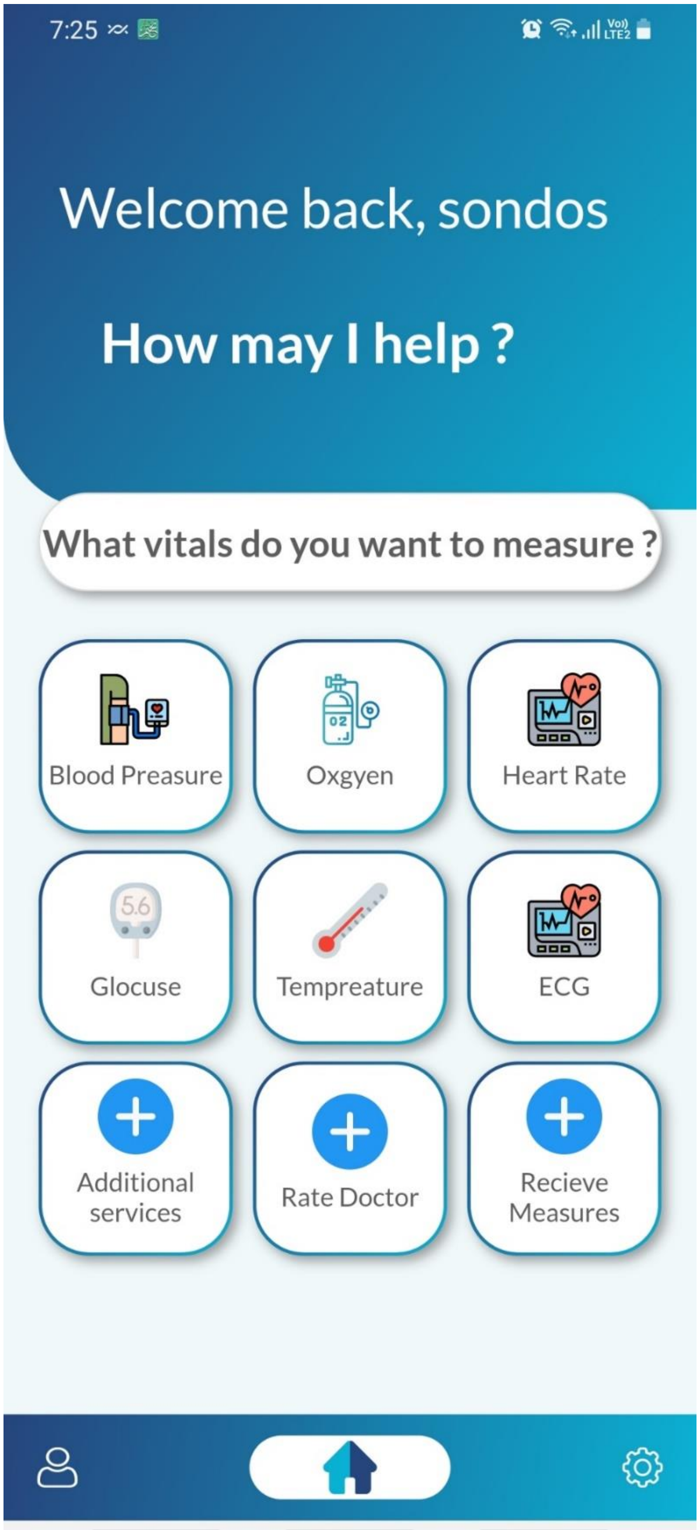
● System should have user-friendly interface.

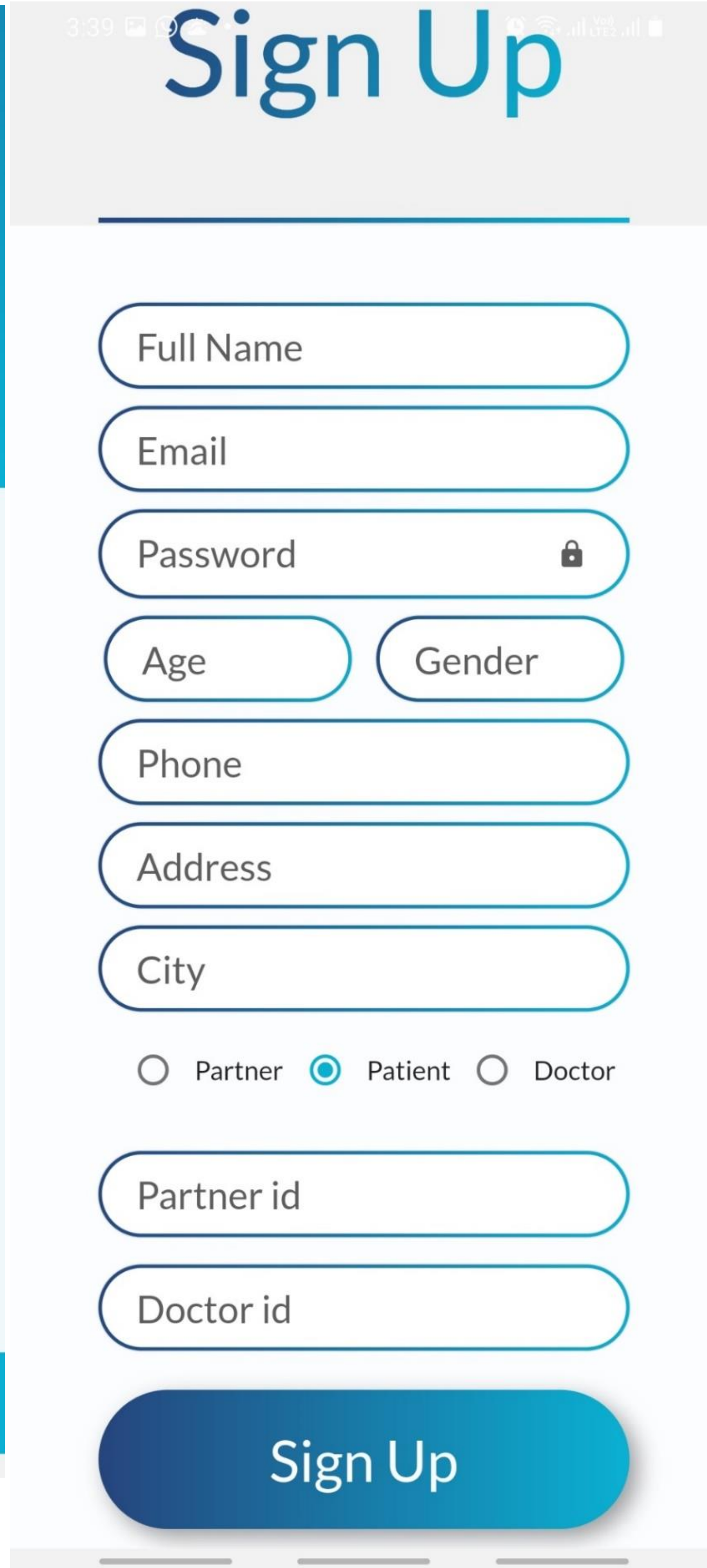
● System must be easy to use.

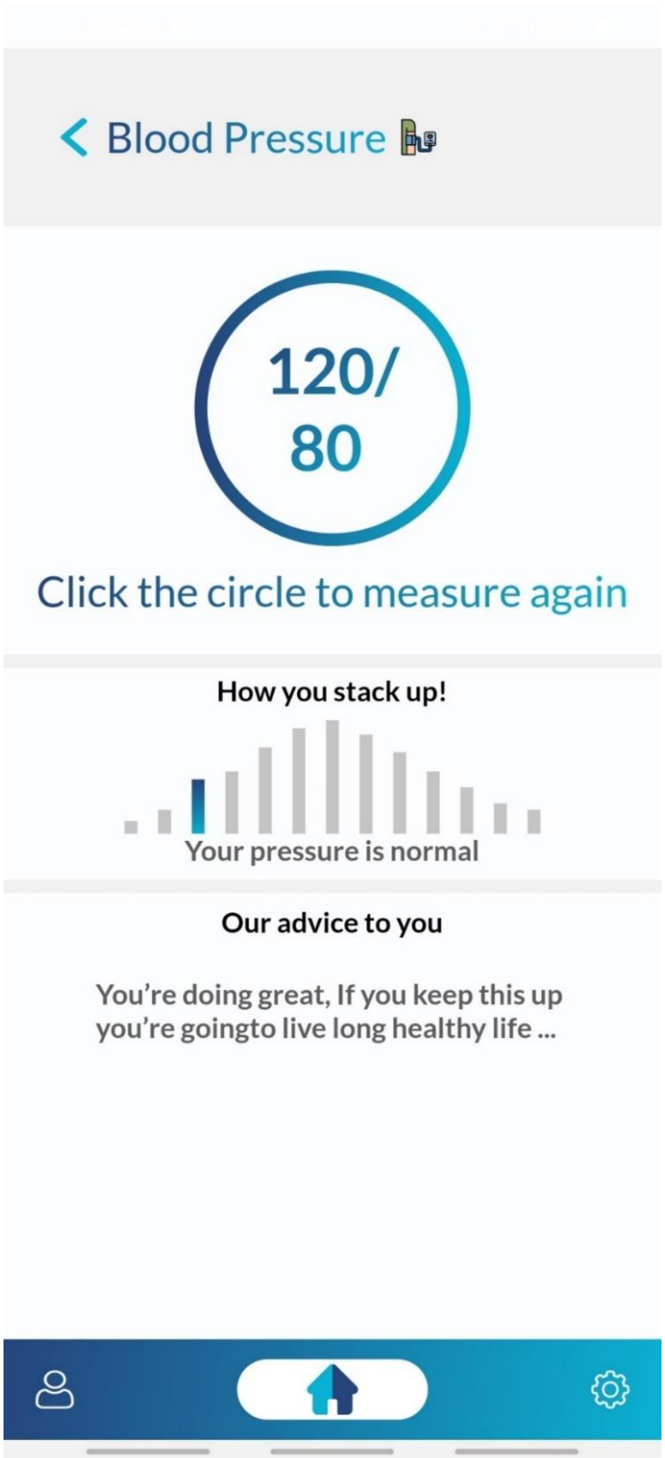
4.5 Interface:

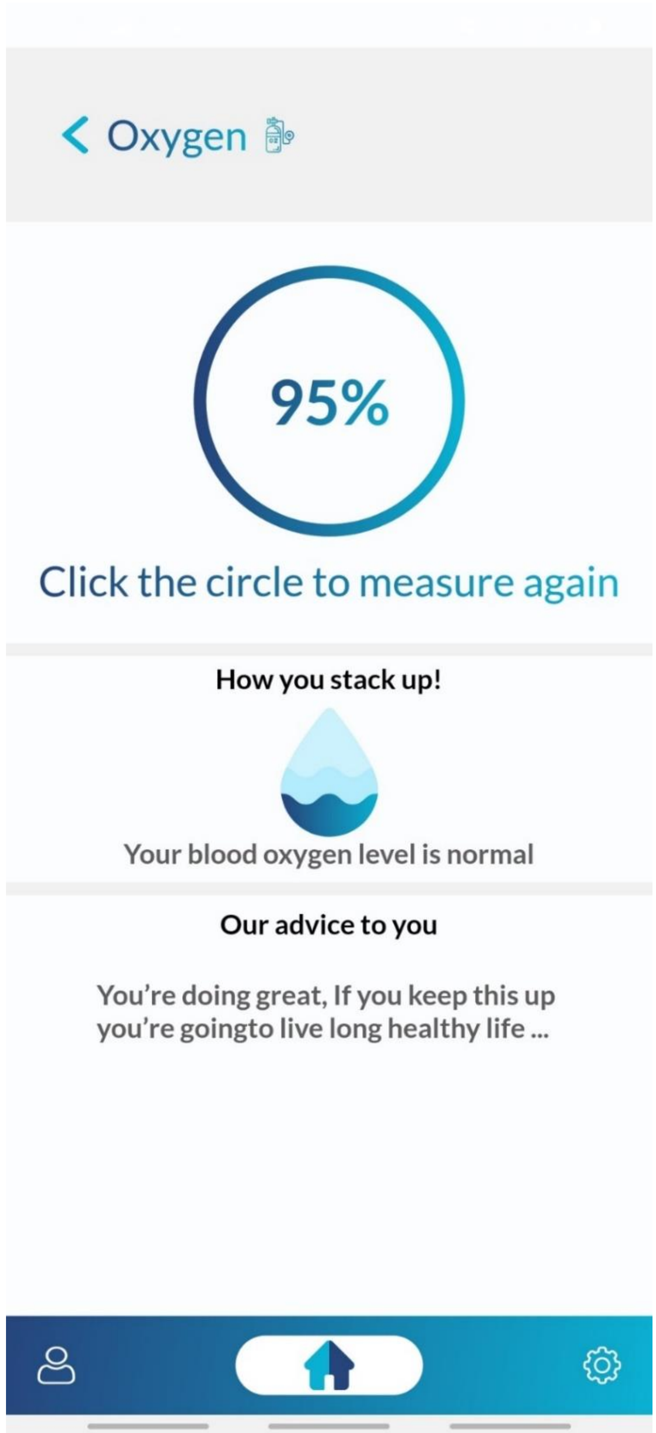
4.5.1 Patient Interface:

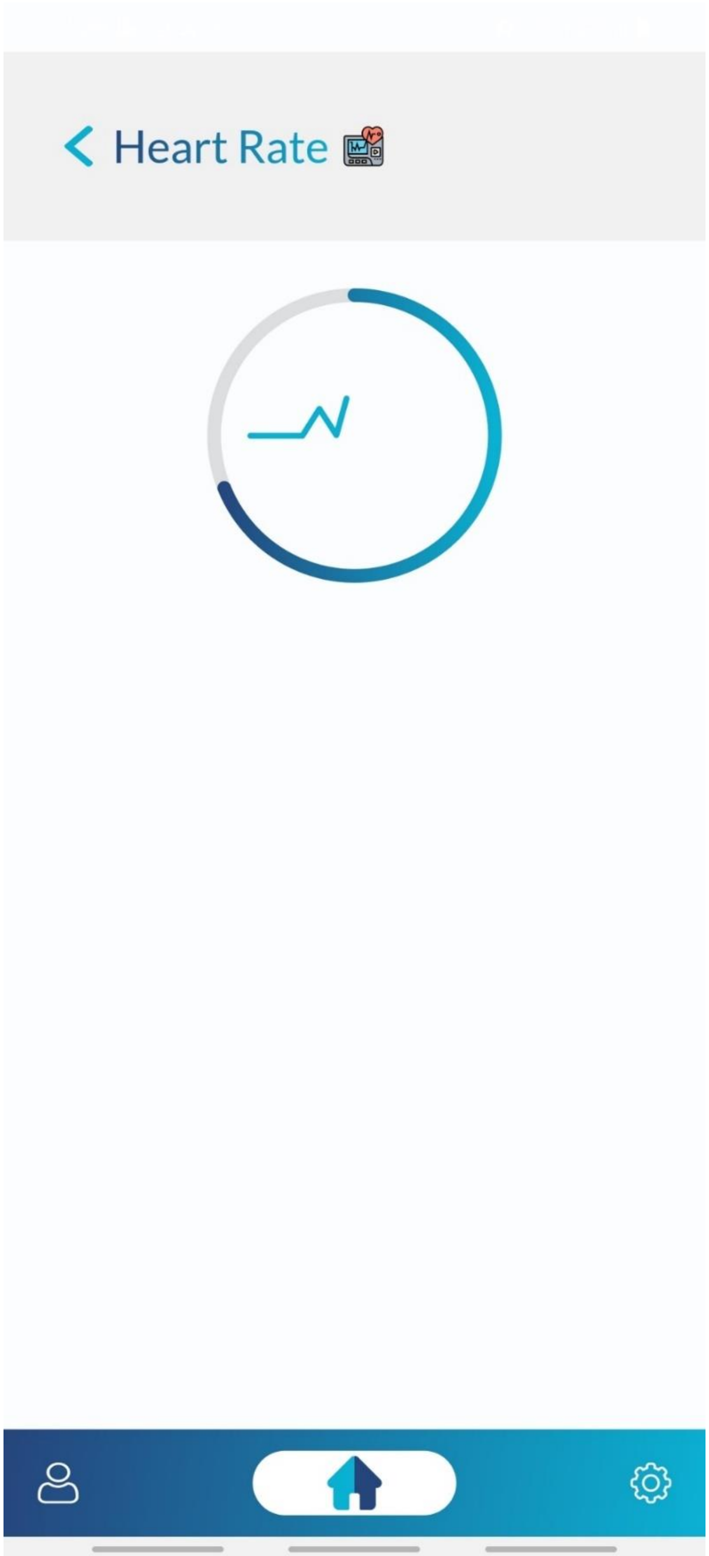

3:28
Log In
Email
Password
Forgot your password?
Patient
Doctor
Partner
Login
Sign Up

3:27
Smart Vitals

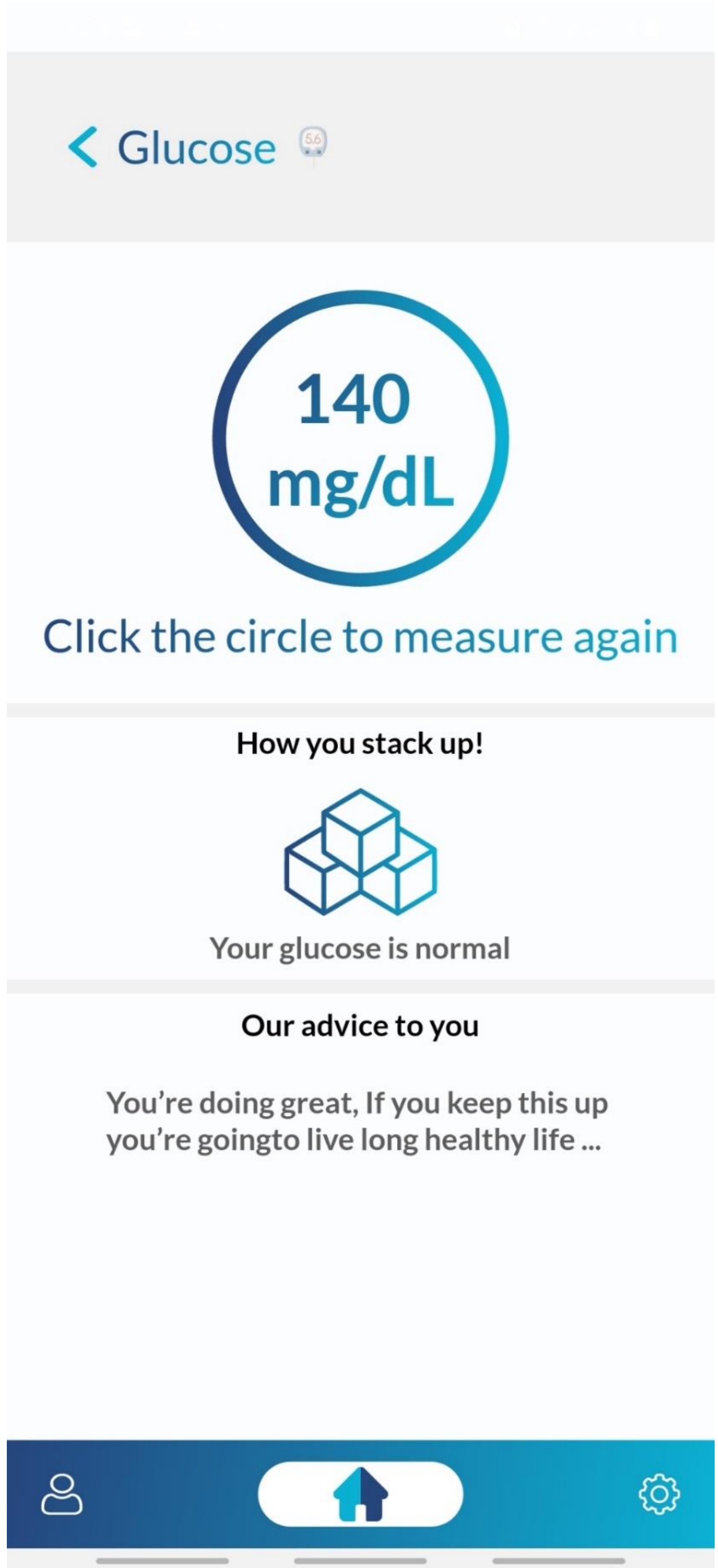

7:25
Welcome back, sondos
How may I help ?
What vitals do you want to measure ?
Blood Preasure
Oxgyen
Heart Rate
Glocuse
Tempreature
ECG
Additional services
Rate Doctor
Recieve Measures

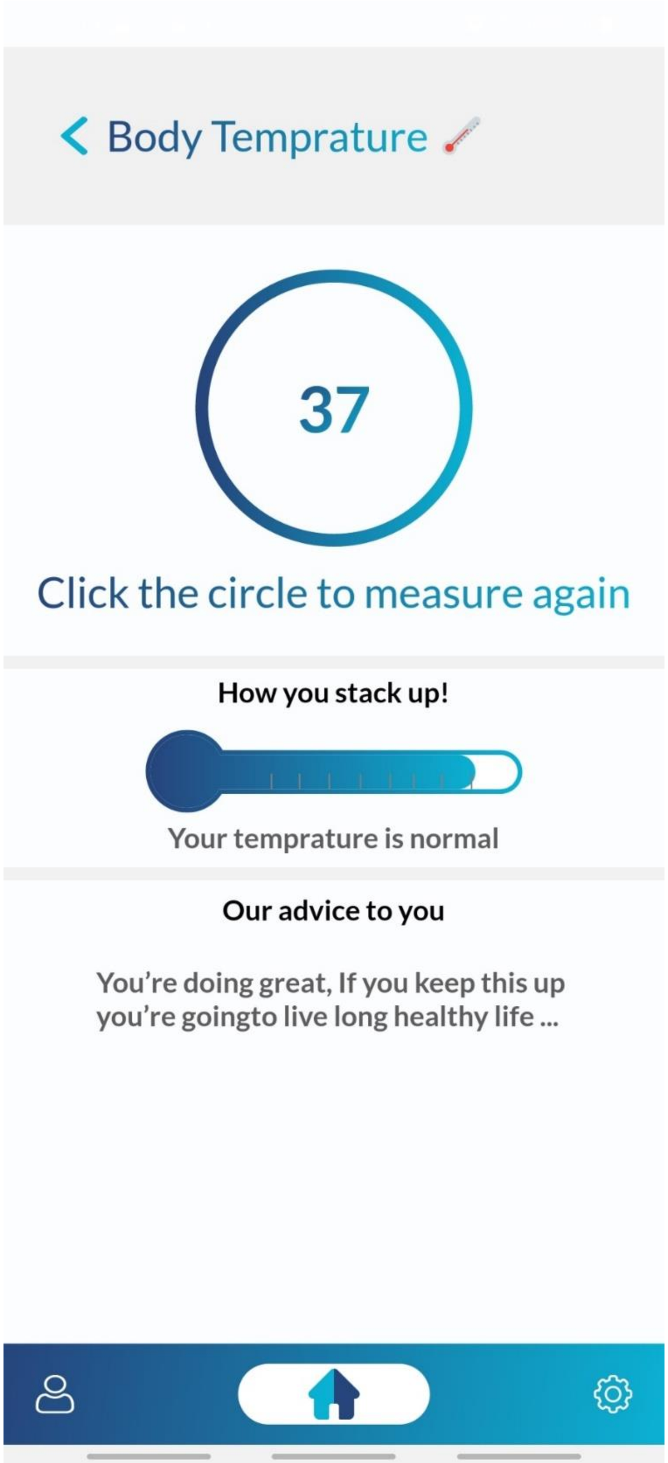

Sign Up
Full Name
Email
Password
Age
Gender
Phone
Address
City
Partner
Patient
Doctor
Partner id
Doctor id
Sign Up

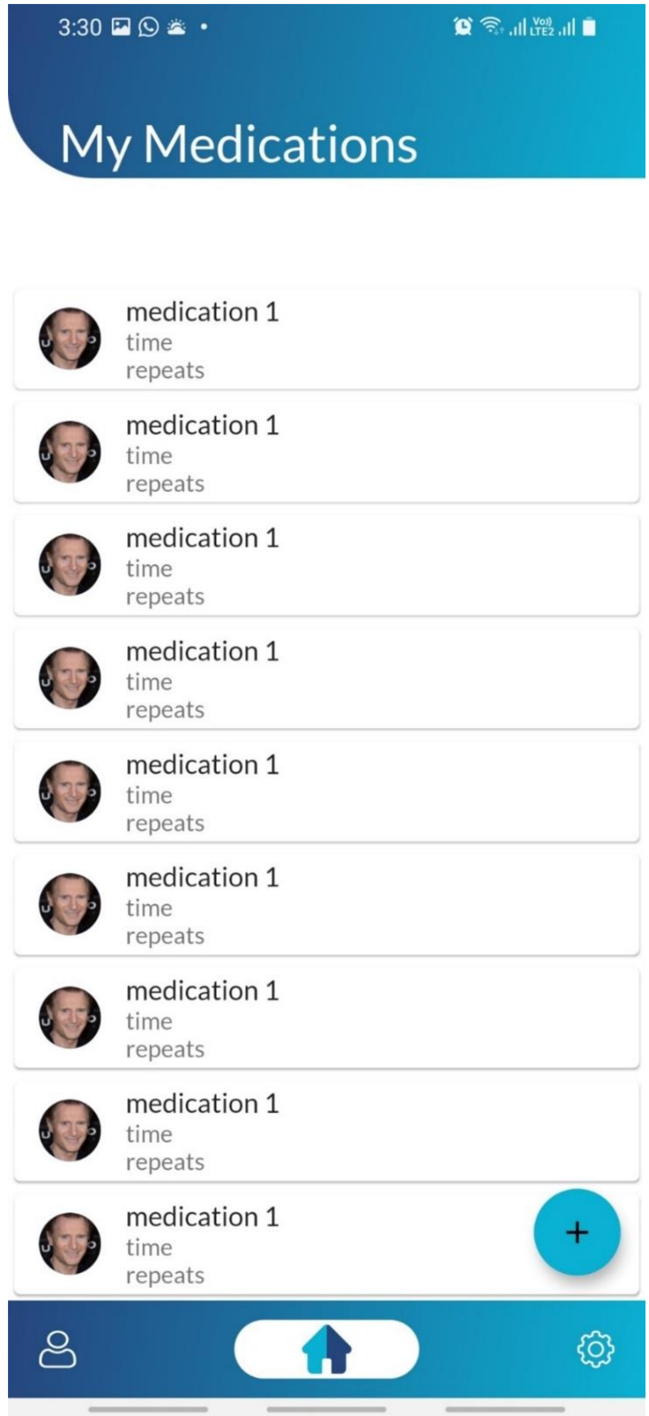

Blood Pressure
120/
80
Click the circle to measure again
How you stack up!
Your pressure is normal
Our advice to you
You're doing great, If you keep this up
you're goingto live long healthy life ...


Oxygen
95%
Click the circle to measure again
How you stack up!
Your blood oxygen level is normal
Our advice to you
You're doing great, If you keep this up
you're goingto live long healthy life ...

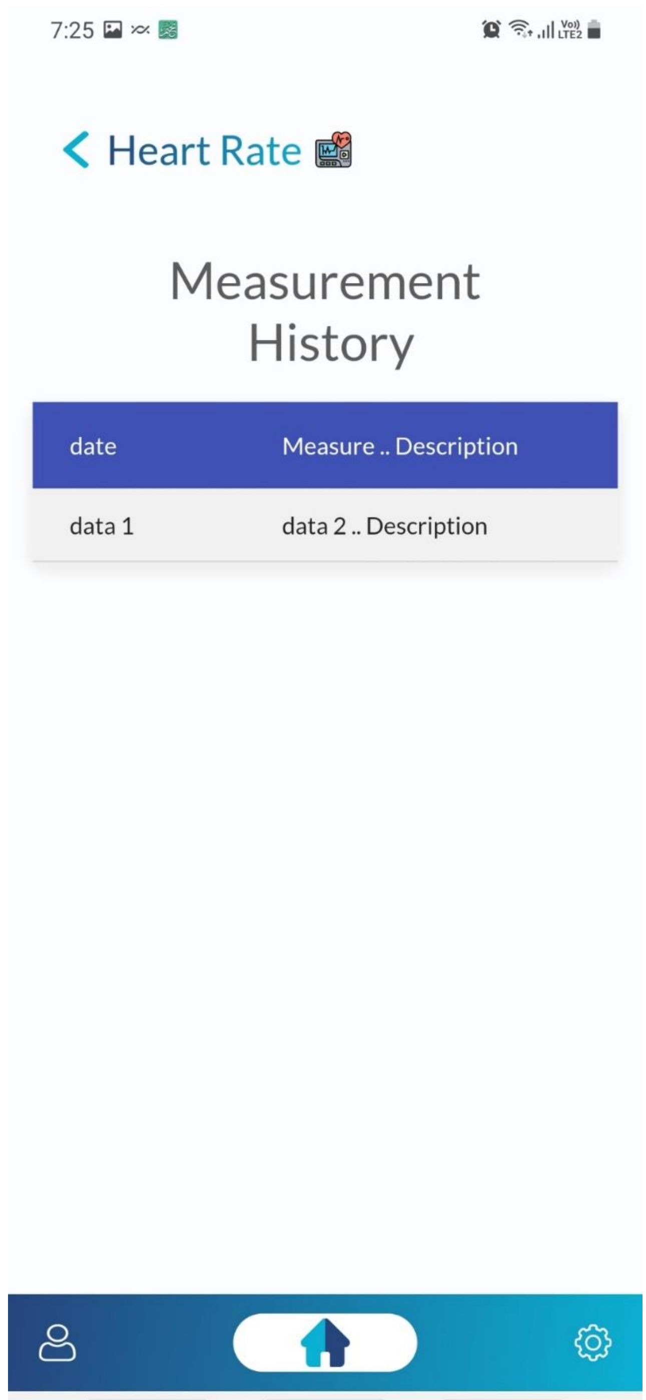

Heart Rate

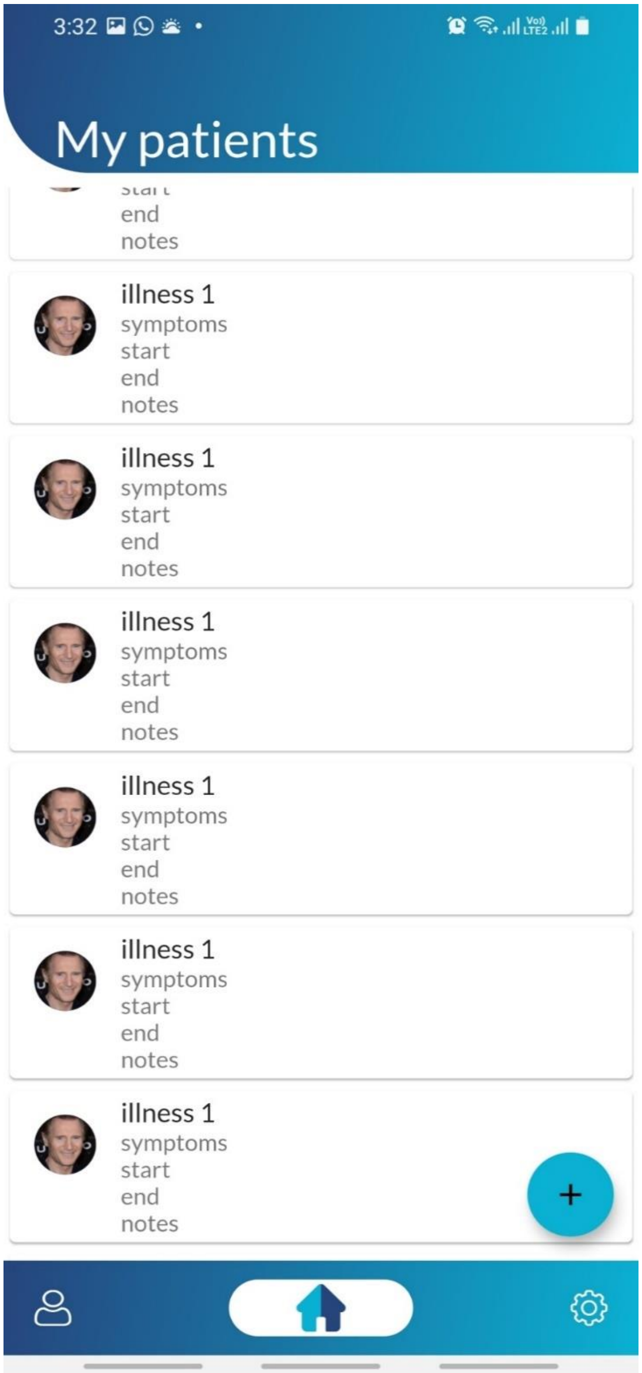

Glucose
140
mg/dL
Click the circle to measure again
How you stack up!
Your glucose is normal
Our advice to you
You're doing great, If you keep this up you're goingto live long healthy life ...

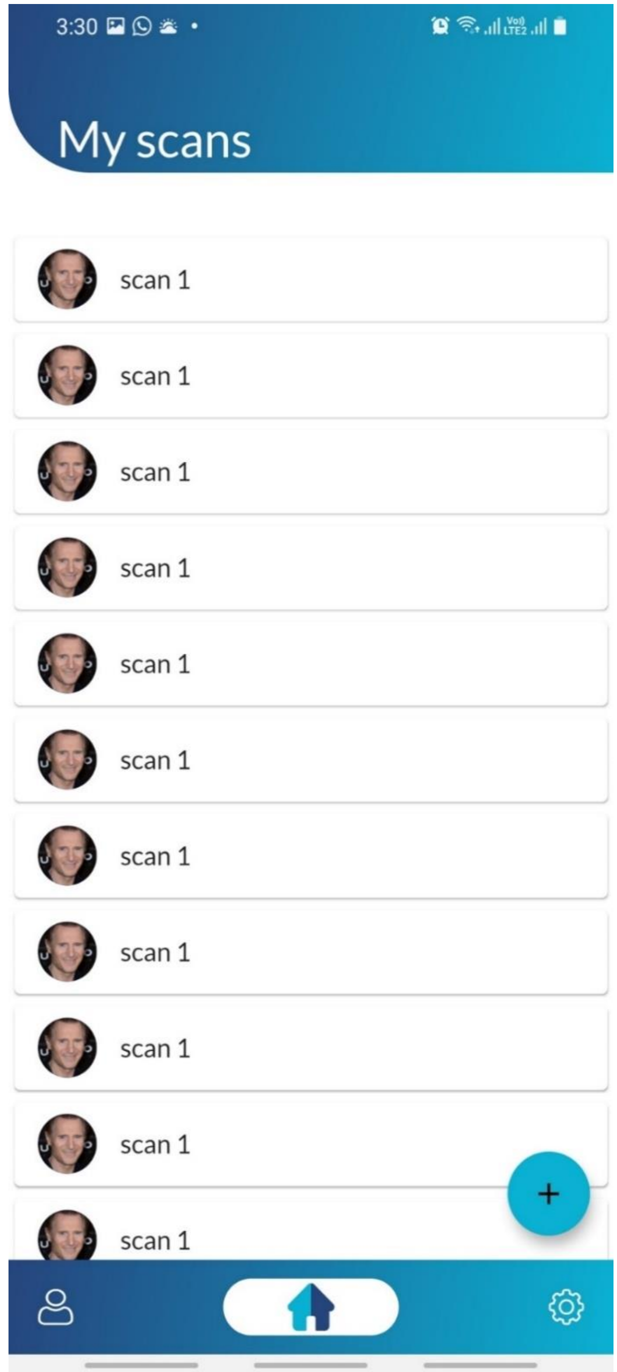

Body Temprature
37
Click the circle to measure again
How you stack up!
Your temprature is normal
Our advice to you
You're doing great, If you keep this up you're goingto live long healthy life ...

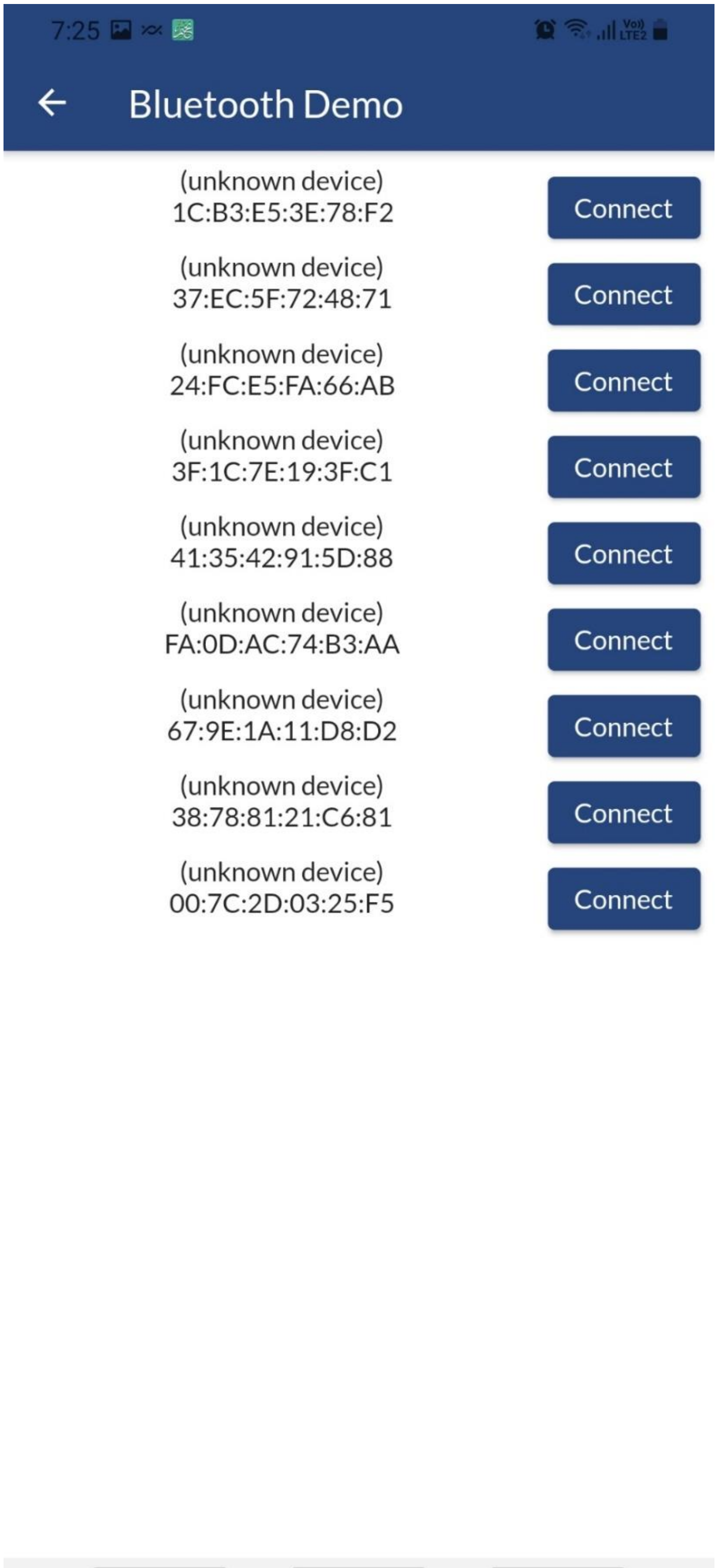

3:30
My Medications
medication 1
time
repeats
medication 1
time
repeats
medication 1
time
repeats
medication 1
time
repeats
medication 1
time
repeats
medication 1
time
repeats
medication 1
time
repeats
medication 1
time
repeats
medication 1
time
repeats


3:30
additional servecies
Medication reminder
my scans & diagnosis history
my medication history
my illness history


7:25
Heart Rate
Measurement History
date
Measure .. Description
data 1
data 2 .. Description


3:32
My patients
end
notes
illness 1
symptoms
start
end
notes
illness 1
symptoms
start
end
notes
illness 1
symptoms
start
end
notes
illness 1
symptoms
start
end
notes
illness 1
symptoms
start
end
notes
illness 1
symptoms
start
end
notes
+


3:30
My scans
scan 1
scan 1
scan 1
scan 1
scan 1
scan 1
scan 1
scan 1
scan 1
scan 1
scan 1
+


7:25
Bluetooth Demo
(unknown device)
1C:B3:E5:3E:78:F2
Connect
(unknown device)
37:EC:5F:72:48:71
Connect
(unknown device)
24:FC:E5:FA:66:AB
Connect
(unknown device)
3F:1C:7E:19:3F:C1
Connect
(unknown device)
41:35:42:91:5D:88
Connect
(unknown device)
FA:0D:AC:74:B3:AA
Connect
(unknown device)
67:9E:1A:11:D8:D2
Connect
(unknown device)
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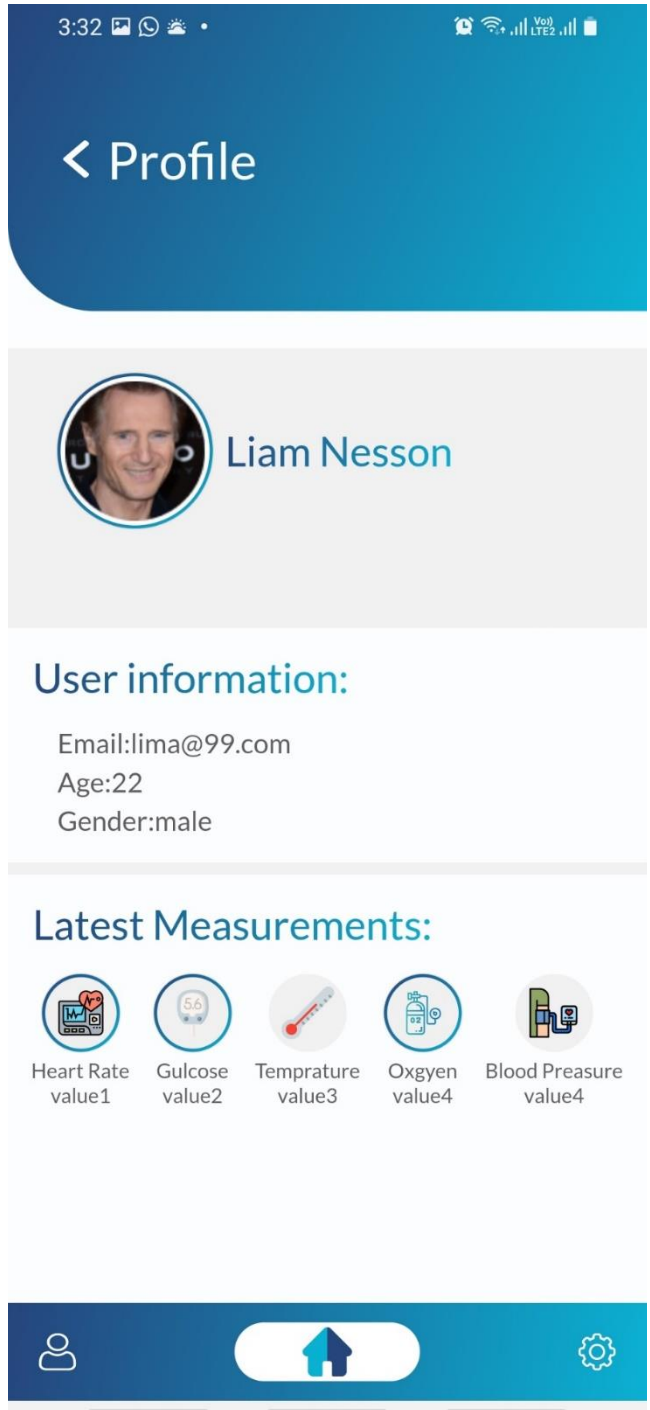
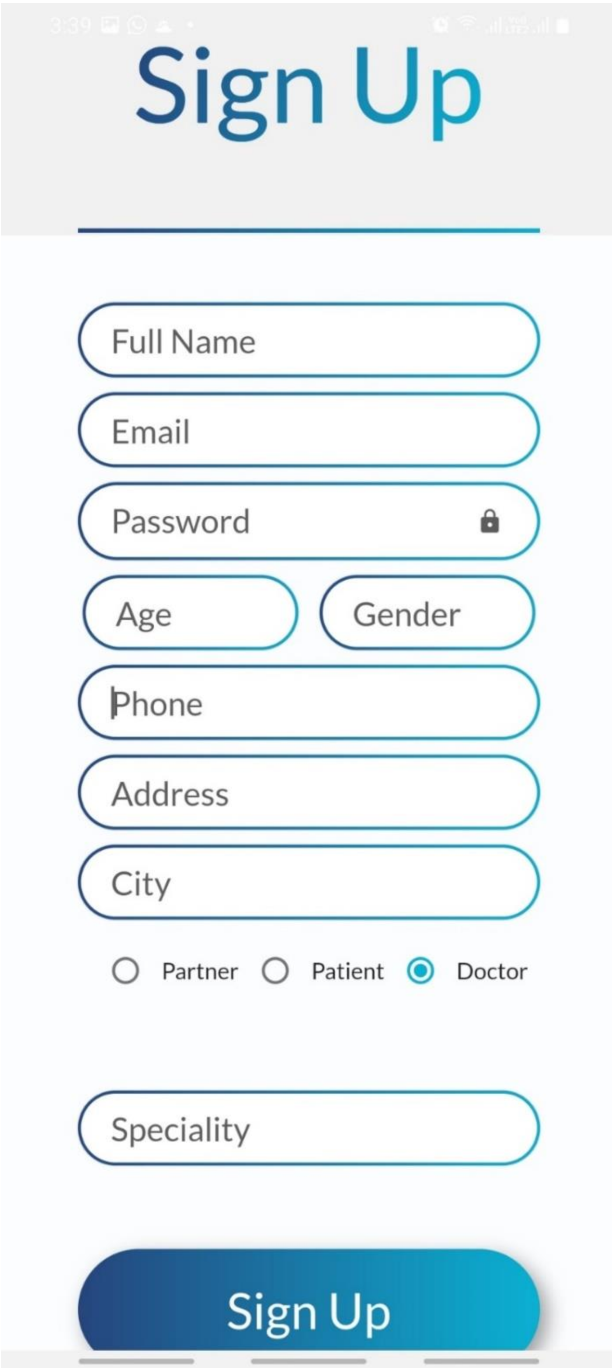
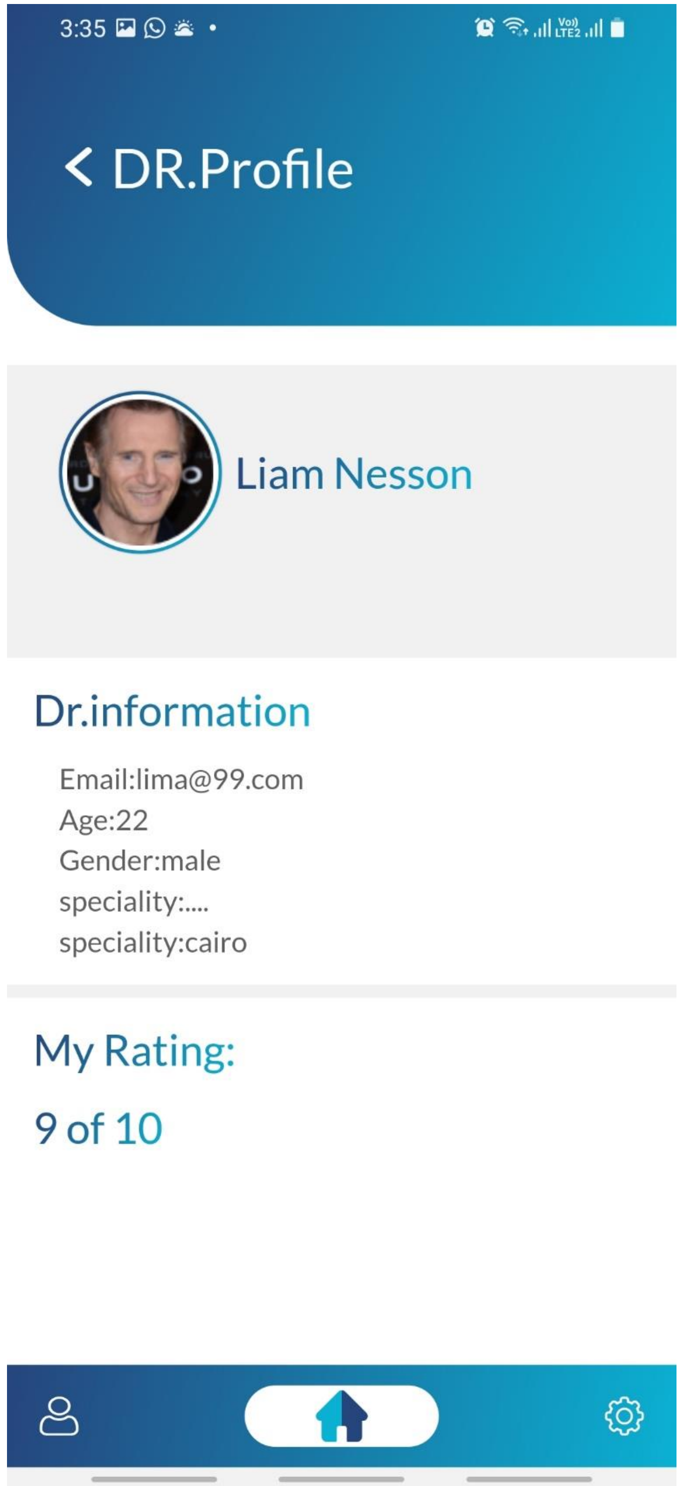
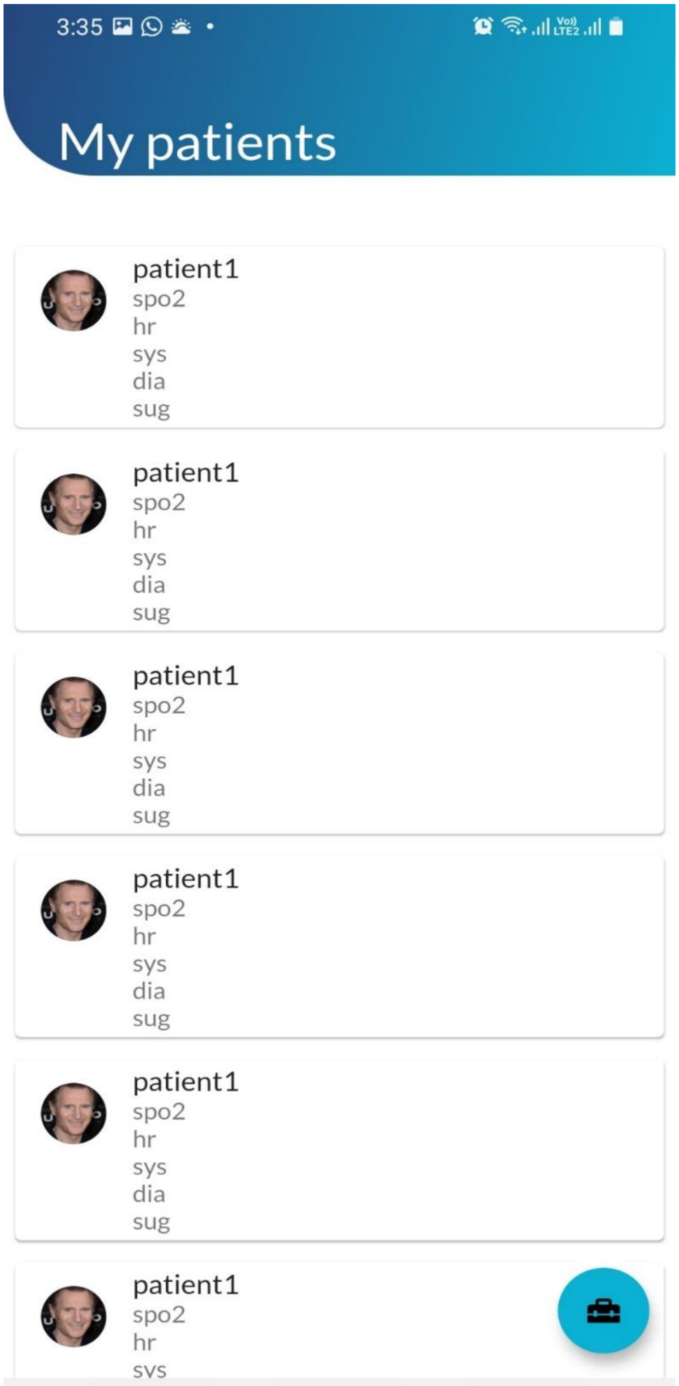
Connect
(unknown device)
00:7C:2D:03:25:F5
Connect

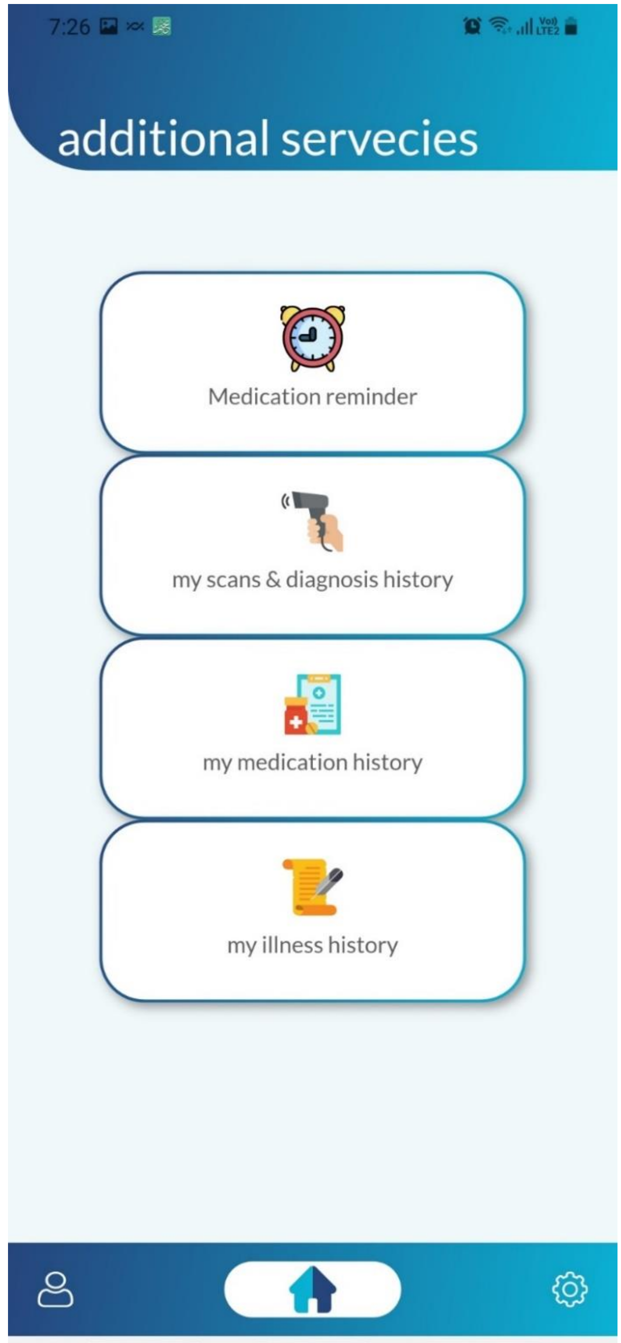

3:32
Profile
Liam Nesson
User information:
Email:lima@99.com
Age:22
Gender:male
Latest Measurements:
Heart Rate
value1
Gulcose
value2
Temprature
value3
Oxgyen
value4
Blood Preasure
value4

4.5.2 doctor interface:

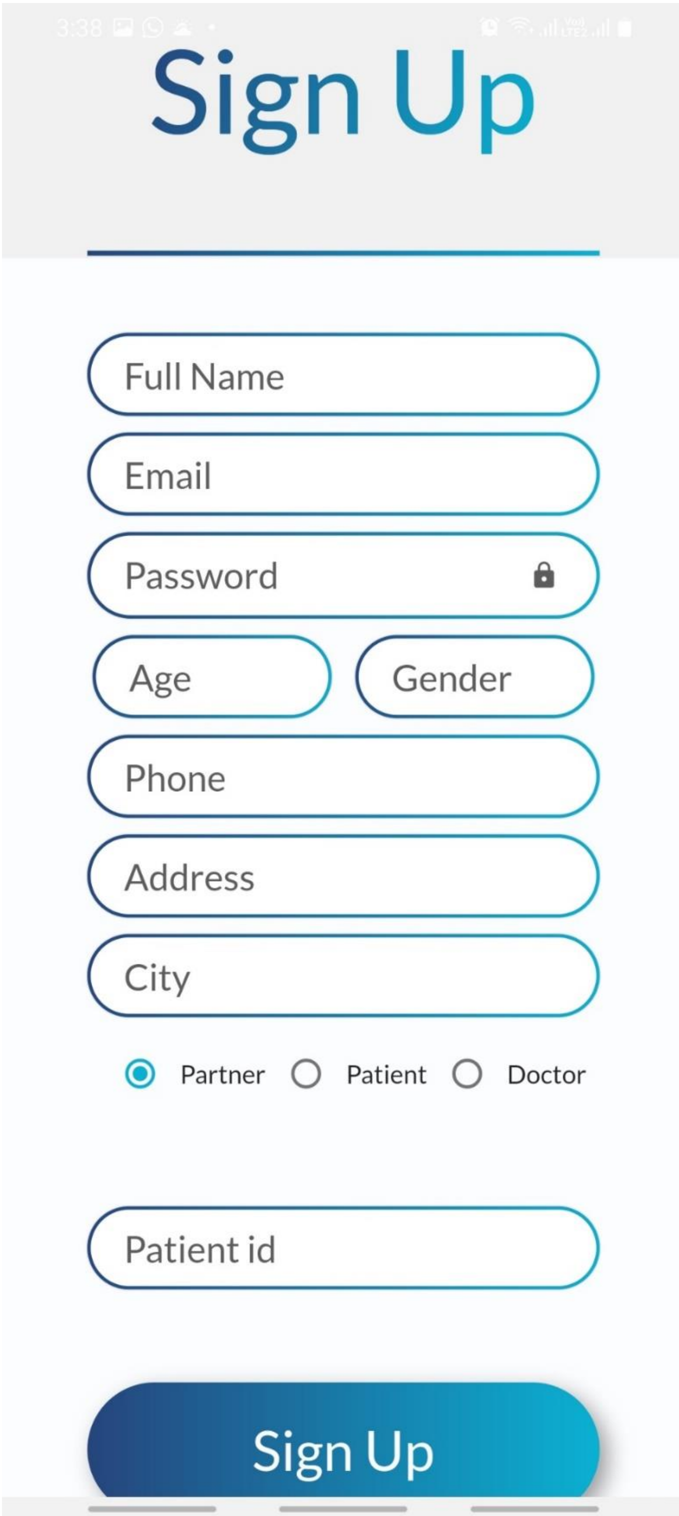




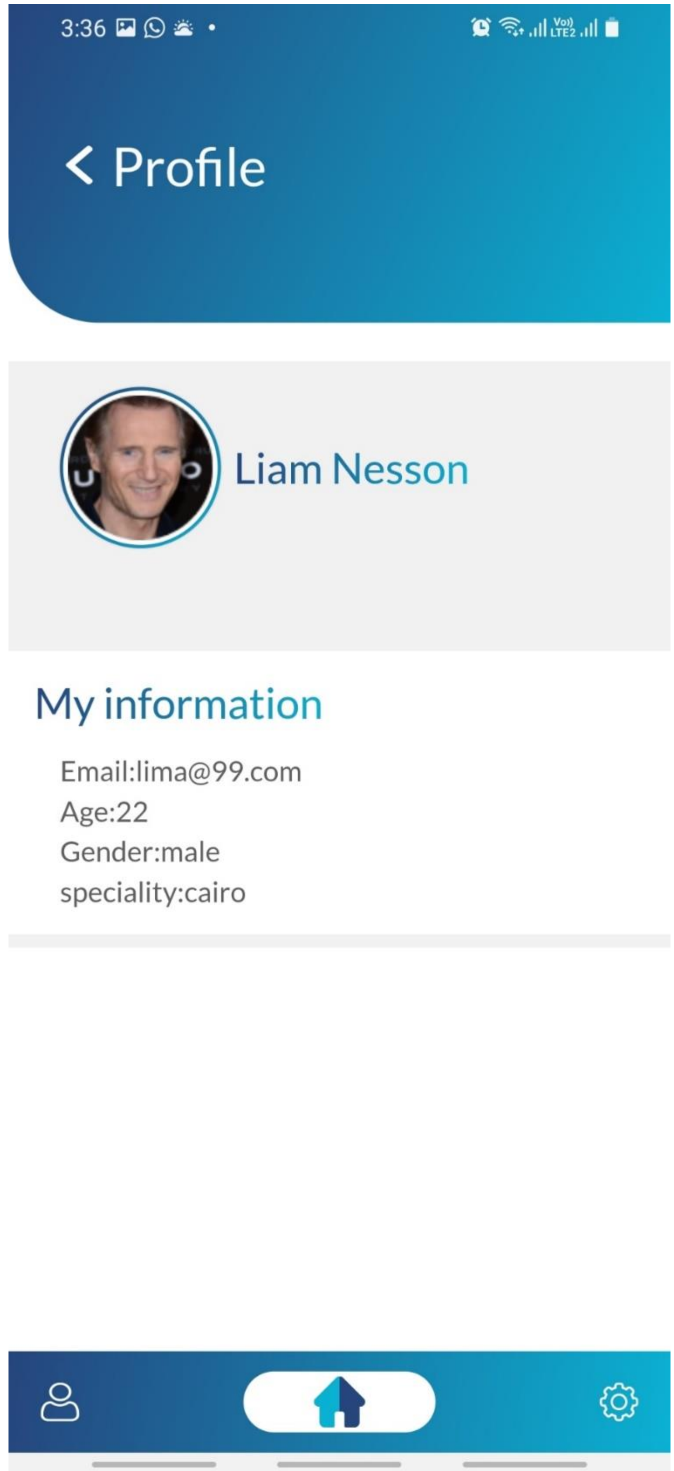




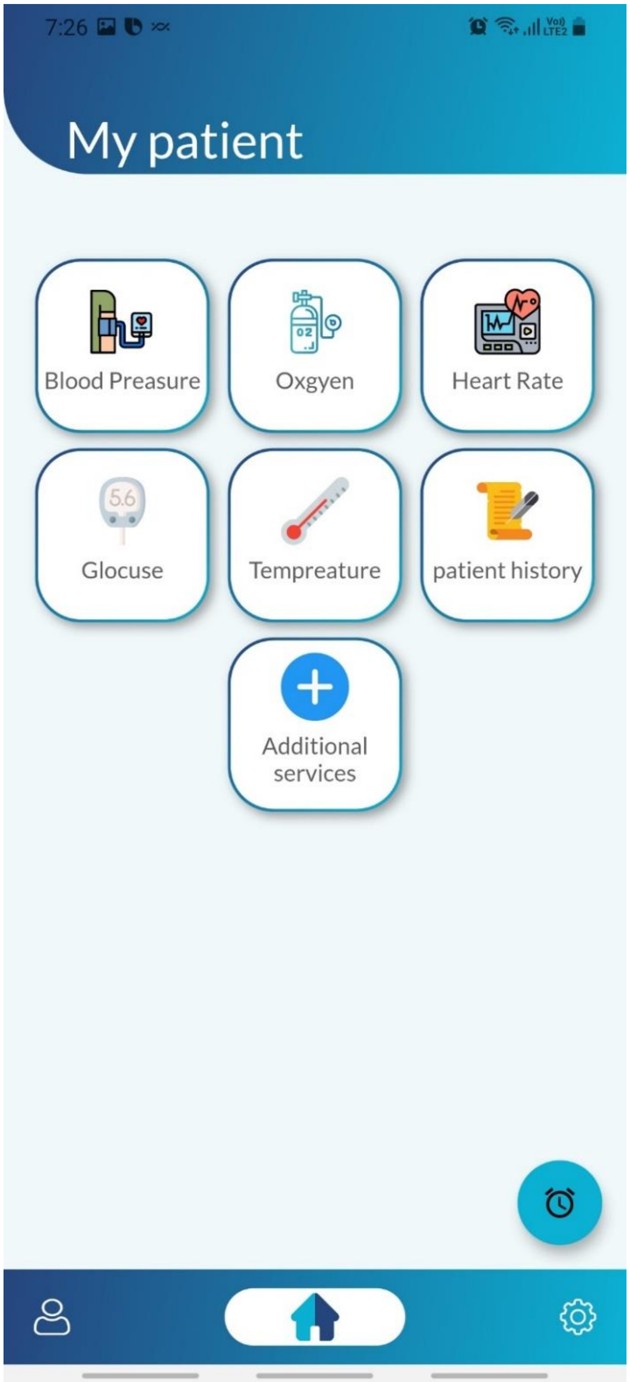
4.5.3 partner interface:

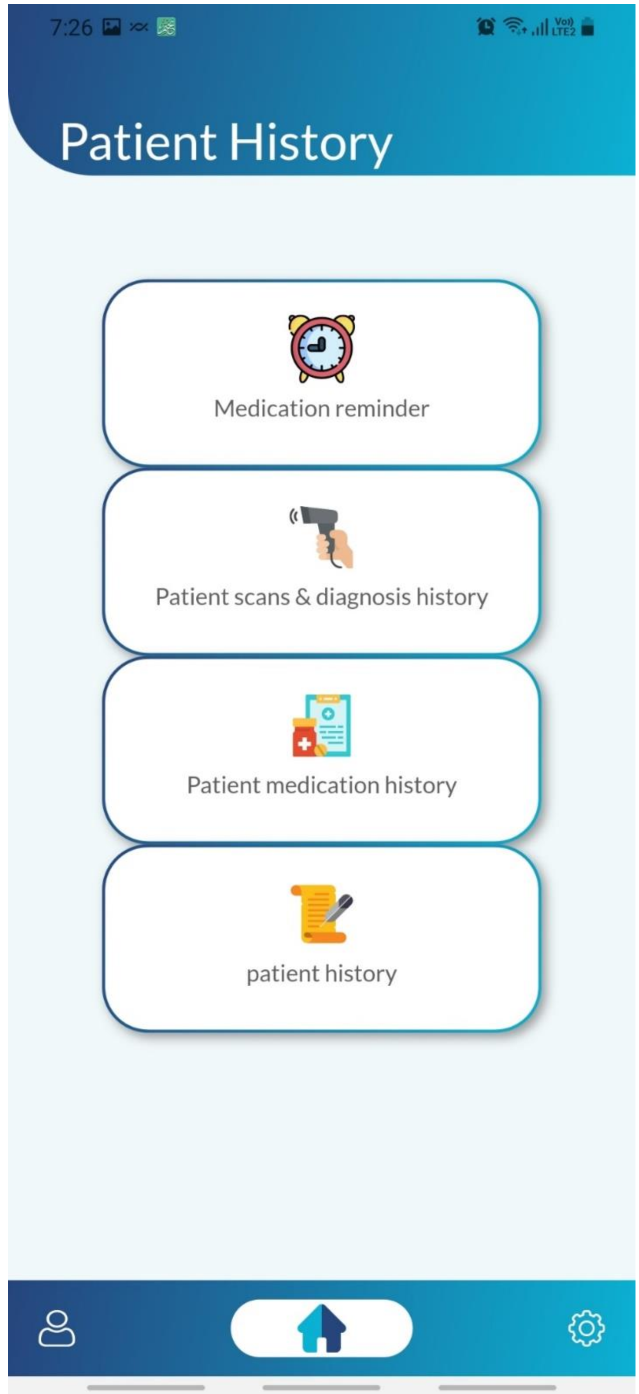


Sign Up
Full Name
Email
Password
Age
Gender
Phone
Address
City
Partner
Patient
Doctor
Patient id
Sign Up



3:36
Profile
Liam Nesson
My information
Email:lima@99.com
Age:22
Gender:male
speciality:cairo


7:26
My patient
Blood Preasure
Oxgyen
Heart Rate
Glocuse
Tempreature
patient history
Additional
services


7:26
Patient History
Medication reminder
Patient scans & diagnosis history
Patient medication history
patient history

4.6 Backend:

In this chapter we discuss the backend of the application.

4.6.1 Systems actors:

Patient: monitor his vitals and keep up with history.

Doctor: monitor patients and change medicines when required.

Partner: monitor patient to make sure he is okay while away

Admin: deals with the system.

4.6.2 Sequence diagrams:

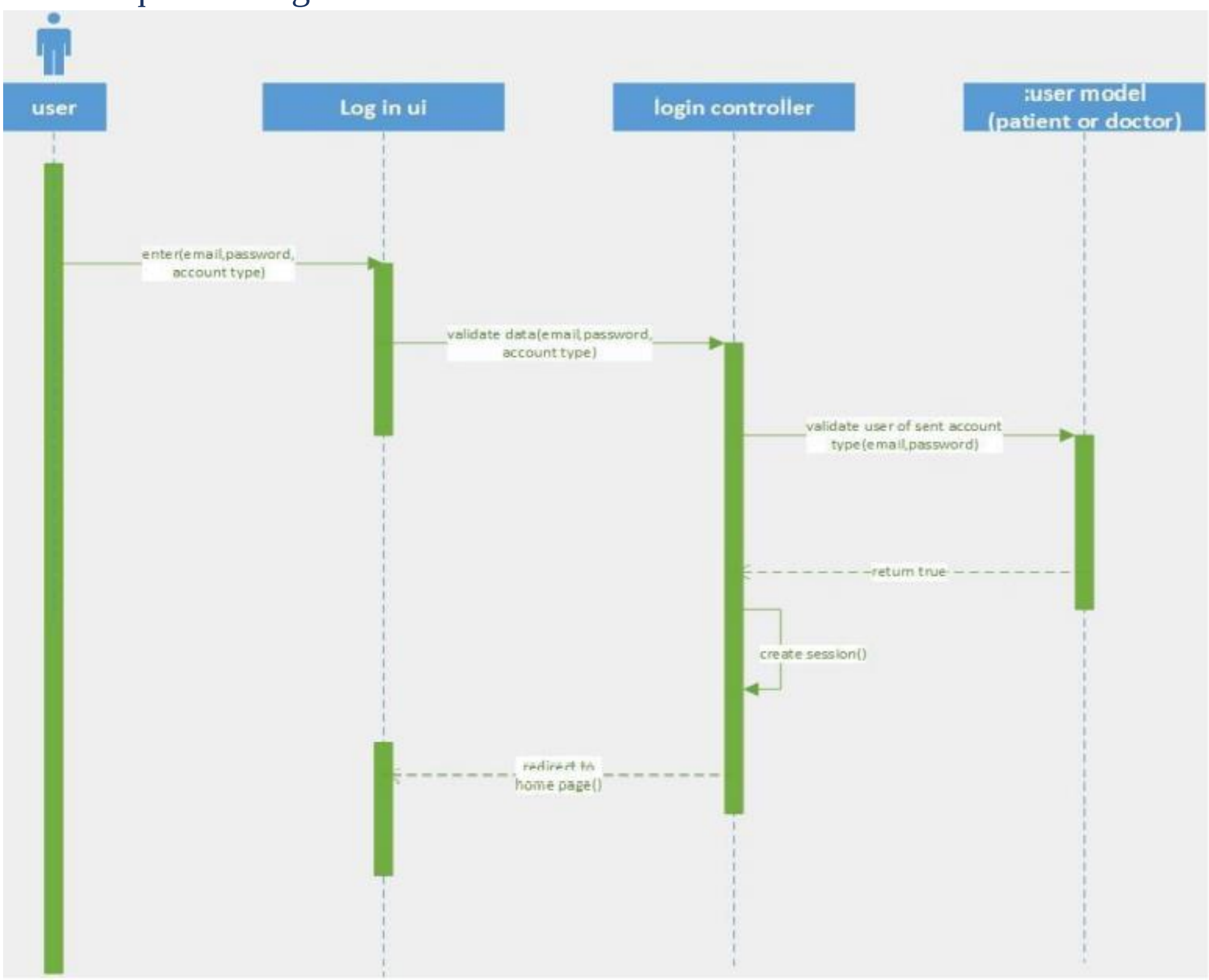


Figure 6:login sequence diagram

Request measure sequential diagram:

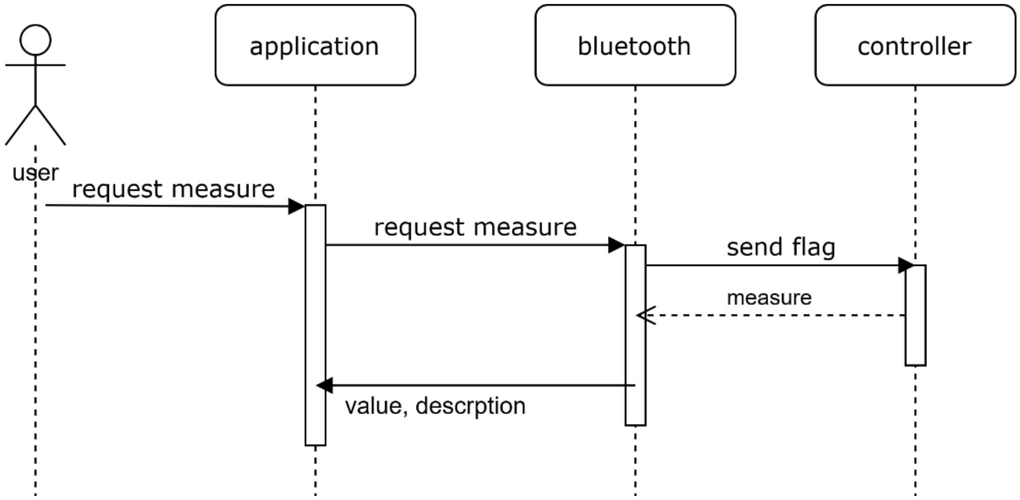


Figure 7: request measure sequential diagram

Register sequential diagram:

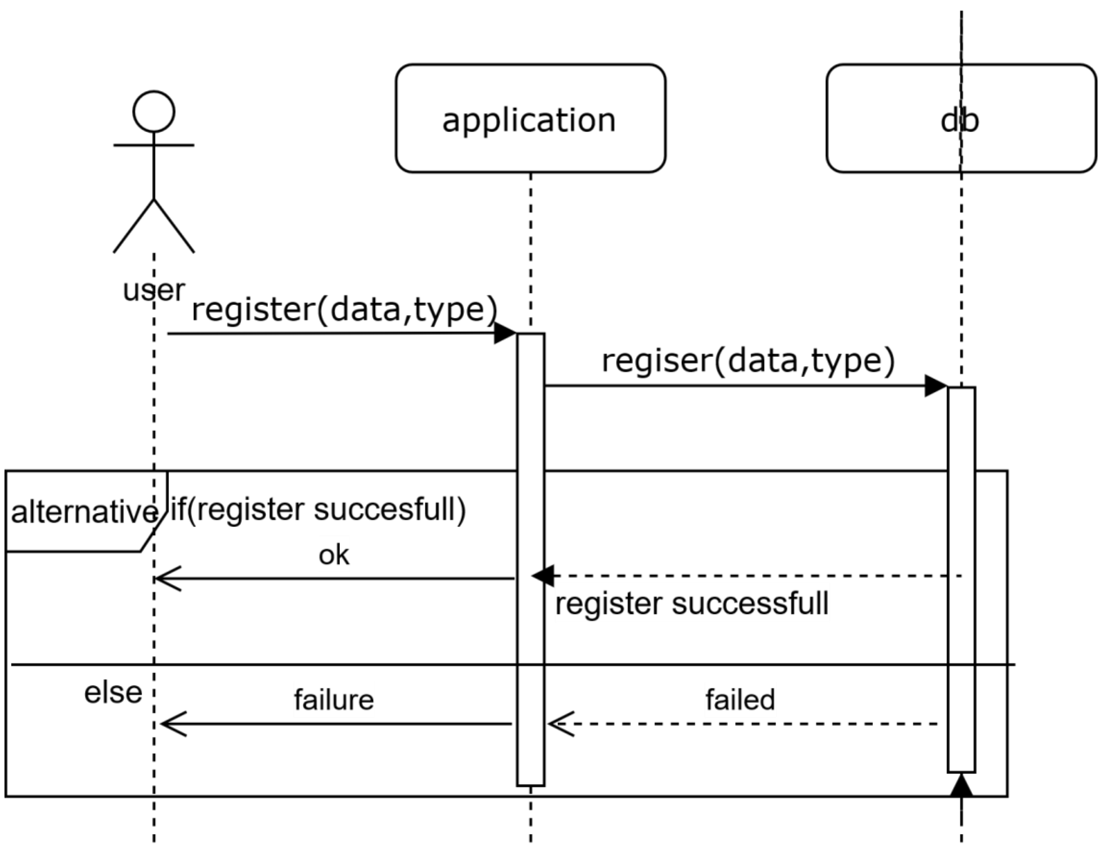


Figure 8: register sequential diagram

4.6.1 Activity diagrams:

Login activity diagram:

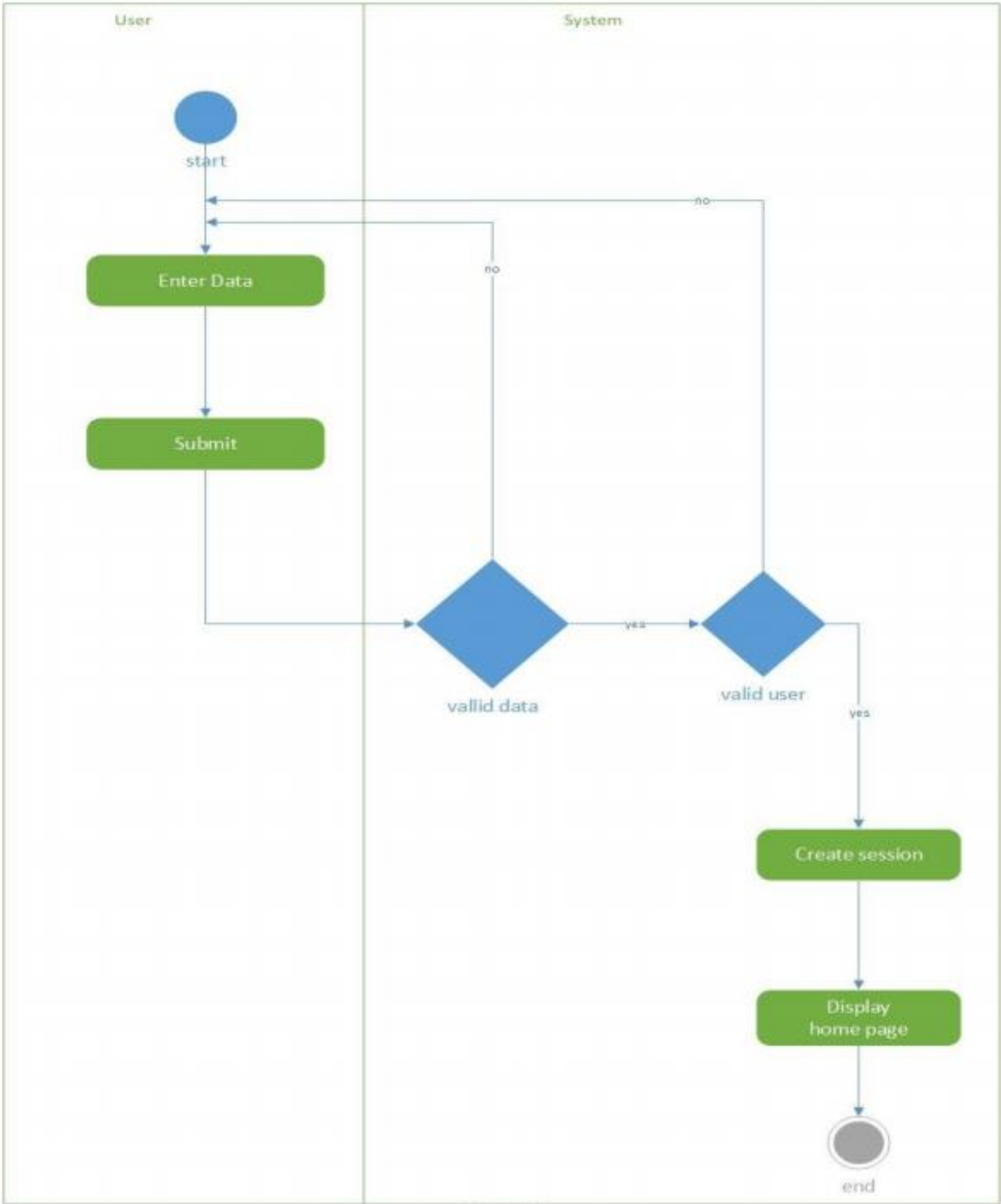


Figure 9: login activity diagram

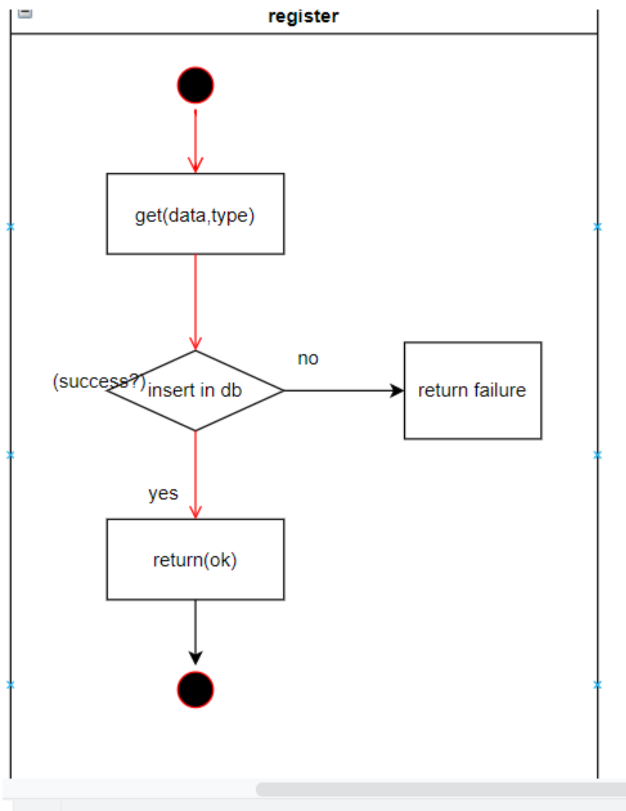
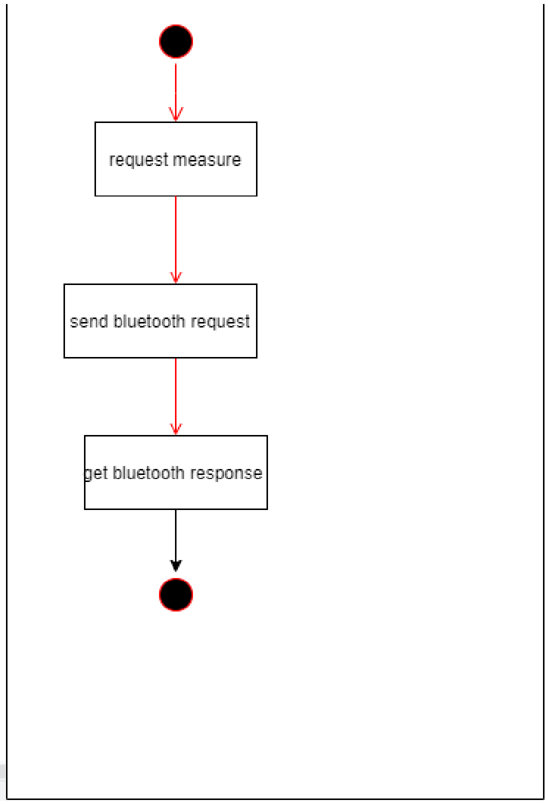


Figure 10:register activity diagram.



///////

Figure 11: request measure activity diagram.

4.6.4 ERD:

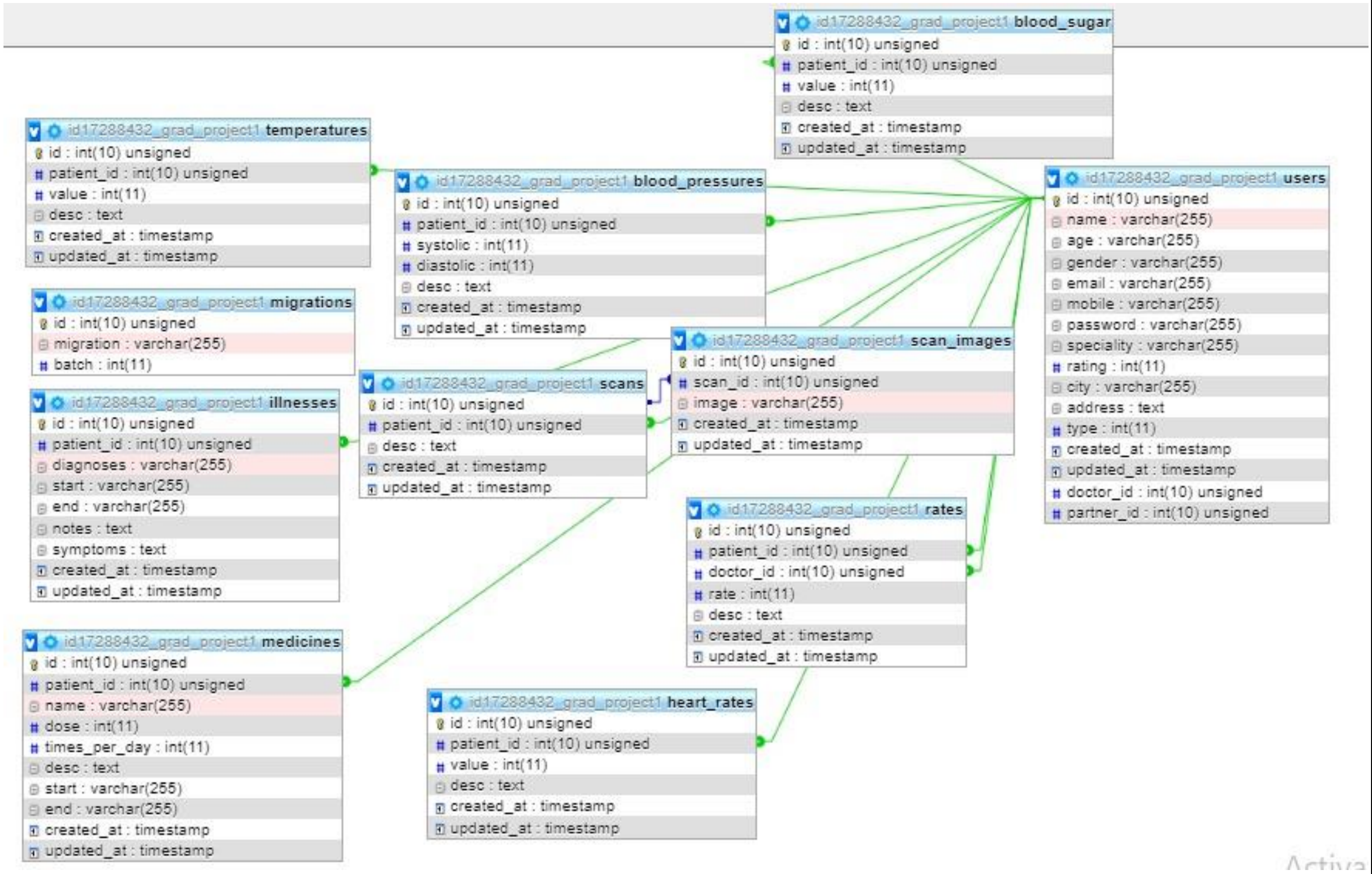


Figure 12:ERD

Embedded Systems

In this chapter we discuss the hardware part of the system.

5.1 Definition:

An embedded system is a computer system—a combination of a computer processor, computer memory, and input/output peripheral devices—that has a dedicated function within a larger mechanical or electrical system. It is embedded as part of a complete device often including electrical or electronic hardware and mechanical parts. Because an embedded system typically controls physical operations of the machine that it is embedded within, it often has real-time computing constraints. Embedded systems control many devices in common use today. Ninety-eight percent of all microprocessors manufactured are used in embedded systems.

How does a Micro Controller work?

A microcontroller is embedded inside of a system to control a singular function in a device. It does this by interpreting data it receives from its I/O peripherals using its central processor. The temporary information that the microcontroller receives is stored in its data memory, where the processor accesses it and uses instructions stored in its program memory to decipher and apply the incoming data. It then uses its I/O peripherals to communicate and enact the appropriate action. Microcontrollers are used in a wide array of systems and devices. Devices often utilize multiple microcontrollers that work together within the device to handle their respective tasks. For example, a car might have many microcontrollers that control various individual systems within, such as the anti-lock braking system, traction control, fuel injection or suspension control. All the microcontrollers communicate with each other to inform the correct actions. Some might communicate with a more complex central computer within the car, and others might only communicate with other microcontrollers. They send and receive data using their I/O peripherals and process that data to perform their designated tasks.

The AVR microcontrollers are based on the advanced RISC architecture. ATmega32 is a low power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. AVR can execute 1 million instructions per second if cycle frequency is 1MHz. 5.2 ATMEGA32 Micro Controller:

There’s a variety of Microcontrollers around the Embedded Systems market, we chose the ATMEGA32:

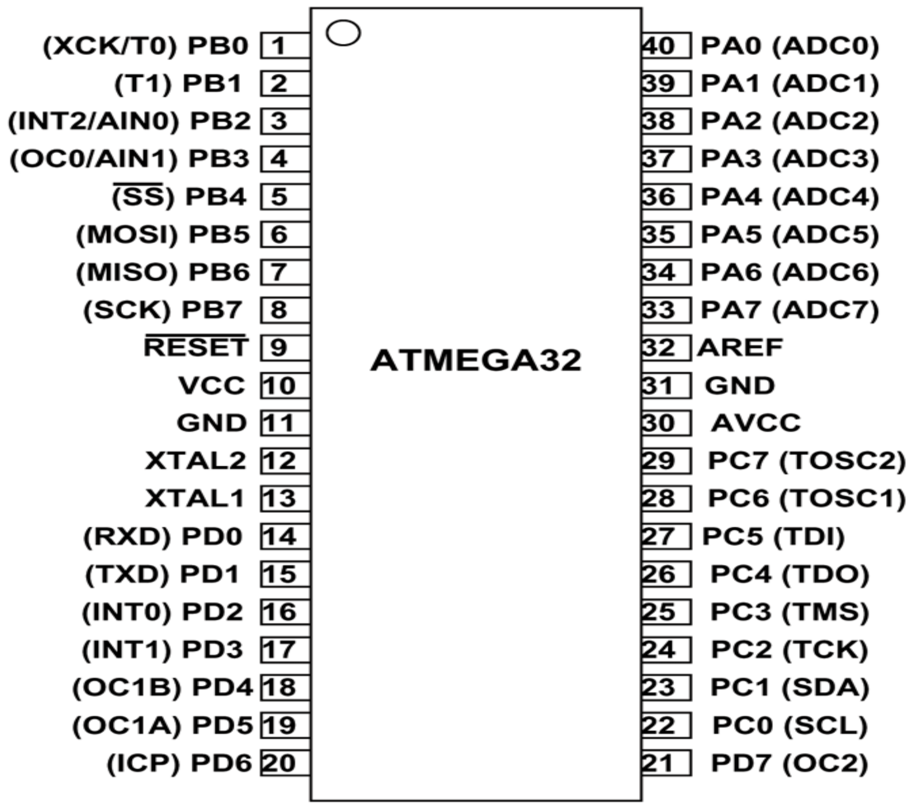


Figure 13: atmega32 pinout

5.3 Key Features

▣ 32 x 8 general working purpose registers.

▣ 32K bytes of in system self-programmable flash program memory

▣ 2K bytes of internal SRAM

▣ 1024 bytes EEPROM

▣ Available in 40 pin DIP, 44 lead QTFP, 44-pad QFN/MLF

▣ 32 programmable I/O lines

▣ 8 Channel, 10-bit ADC

▣ Two 8-bit timers/counters with separate prescalers and compare modes

▣ One 16-bit timer/counter with separate prescaler, compare mode and capture mode.

▣ 4 PWM channels

▣ In system programming by on-chip boot program

▣ Programmable watch dog timer with separate on-chip oscillator.

▣ Programmable serial USART

▣ Master/slave SPI serial interface Special Microcontroller Features:

▣ Six sleep modes: Idle, ADC noise reduction, power-save, power-down, standby and extended standby.

▣ Internal calibrated RC oscillator

▣ External and internal interrupt sources

▣ Power on reset and programmable brown-out detection.

▣ All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle.

▣ The power-down saves the register contents but freezes the oscillator. All other chip functions will be disabled until the next external interrupt arises. Asynchronous timer allows the user to maintain a timer based in power-save mode while the rest of the device is sleeping.

▣ ADC noise reduction mode stops the CPU and all I/O modules except ADC and asynchronous timer. In standby mode, except crystal oscillator the rest of the device is sleeping. Both the main oscillator and asynchronous timer continue to run in extended standby mode.

5.4 Overview

The main goal of using the Embedded Systems in our project is to be able to analyze and process different signals and use them for useful purposes. This calls for having Sensors in order to take in the signals which we want to process using the Atmega32 micro controller chip.

5.5 Sensors

In the broadest definition, a sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. And we will Discuss the types of sensors we used.

5.5.1 Electrocardiography Sensor (ECG):

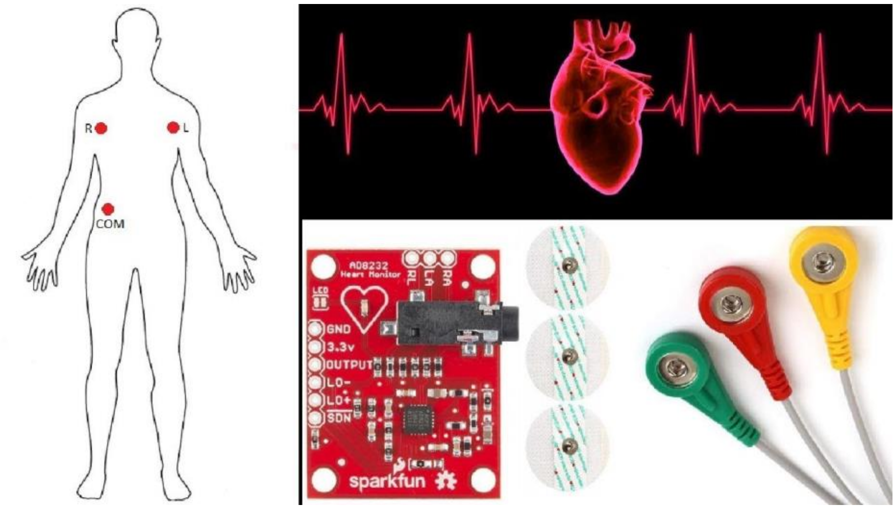


Figure 14: ad8232

5.5.1.1 Circuit of ECG:

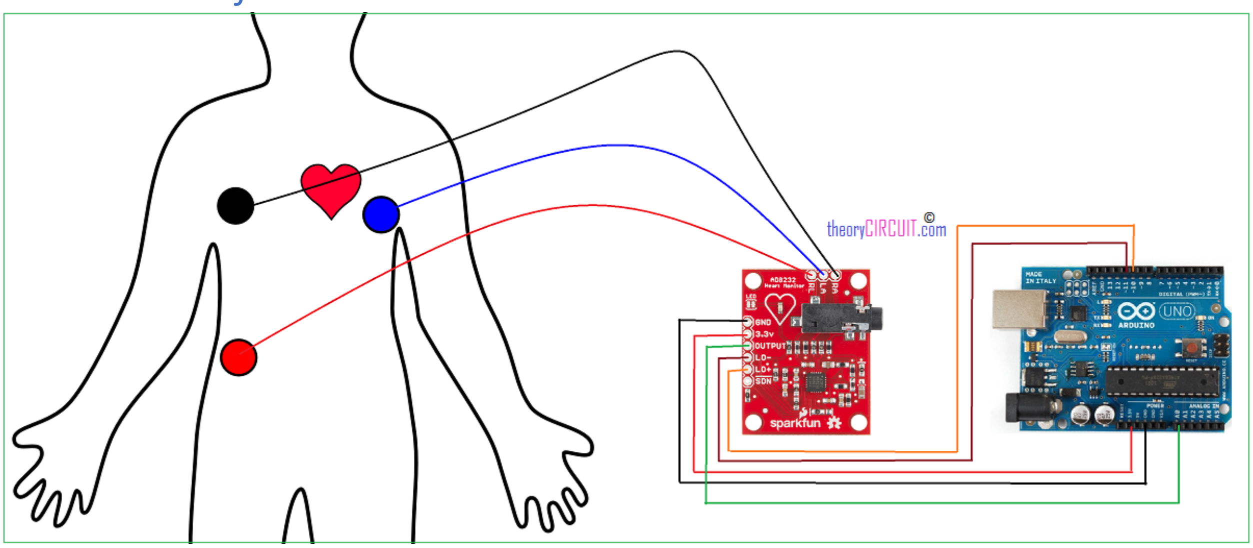


Figure 15: circuit of ECG

5.5.1.2 Connection of AD8232 with Arduino:

- Arduino 3.3V --------- 3.3V pin
- Arduino pin 10 -------- L0+

- Arduino Pin 11 -------- L0-
- Arduino Analog 1 (A1) ------- Output
- Arduino Gnd ----------- Gnd

Electrode pad location shown in fig (15).

AD8232 Pins as shown in fig (14):

- RA - Input 1
- LA - Input 2
- RL - Input 3

To measure the ECG signal, we used AD8232 Sensor, The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications. It is designed to extract, amplify, and filter small biopotential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement. This design allows for an ultralow power analog-to-digital converter (ADC) or an embedded microcontroller to acquire the output signal easily. The AD8232 can implement a two-pole high-pass filter for eliminating motion artifacts and the electrode half-cell potential. This filter is tightly coupled with the instrumentation architecture of the amplifier to allow both large gain and high-pass filtering in a single stage, thereby saving space and cost. An uncommitted operational amplifier enables the AD8232 to create a three-pole low-pass filter to remove additional noise. The user can select the frequency cutoff of all filters to suit different types of applications. To improve common-mode rejection of the line frequencies in the system and other undesired interferences, the AD8232 includes an amplifier for driven lead applications, such as right leg drive (RLD). The AD8232 includes a fast restore function that reduces the duration of otherwise long settling tails of the high-pass filters. After an abrupt signal change that rails the amplifier (such as a lead off condition), the AD8232 automatically adjusts to a higher filter cutoff.

This feature allows the AD8232 to recover quickly, and therefore, to take valid measurements soon after connecting the electrodes to the subject. The AD8232 is available in a 4 mm × 4 mm, 20-lead LFCSP and a LFCSP_SS package.

Performance for the A grade models is specified from 0°C to 70°C and the models are operational from −40°C to +85°C. Performance for the W grade models is specified over the automotive temperature range of −40°C to +105°C.

5.5.1.3 Features:

- Fully integrated single-lead ECG front end
- Low supply current: 170 µA (typical)
- Common-mode rejection ratio: 80 dB (dc to 60 Hz)
- Two or three electrode configurations
- High signal gain (G = 100) with dc blocking capabilities
- 2-pole adjustable high-pass filter
- Accepts up to ±300 mV of half cell potential
- Fast restore feature improves filter settling
- Uncommitted op amp
- 3-pole adjustable low-pass filter with adjustable gain
- Leads off detection: ac or dc options
- Integrated right leg drive (RLD) amplifier
- Single-supply operation: 2.0 V to 3.5 V
- Integrated reference buffer generates virtual ground
- Rail-to-rail output
- Internal RFI filter
- 8 kV HBM ESD rating
- Shutdown pin
- 20-lead, 4 mm × 4 mm LFCSP and LFCSP_SS package
- Qualified for automotive applications.

5.5.1.4 Algorithm:

- Include SPI library
- Set bit no.7 as input
- Set bit no.8 as input
- Specify baud rate (9600)
- Make MISO pin OUTPUT
- Set bit (SPE)in SPCR Register
- Make flag= false
- Enable interrupt

- Initialize sensor
- If sensor not connected
- Print sensor not found
- If request come from master
- Go to SPI_Interrupt to receive request and make flag up
- Take measures from sensor and set it in SPDR Register and send it to master.

5.5.2 MAX30102:

MAX30102 sensor is used to detect blood oxygen and heart rate. First, infrared radiation is sent and reflected by hitting the finger, and then the amount of oxygen in the blood is determined by measuring the wave amplitude. Heart rate is also obtained by analyzing the time series response of this radiation.

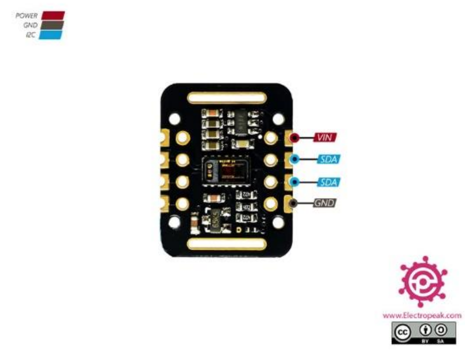


Figure 16:max30102

The MAX30102 is an integrated module compatible with the Arduino and STM32. It integrates a red LED with an infrared LED, a photoelectric detector, an optical device, and a low noise electronic circuit for ambient light suppression. Heart rate and blood oxygen data are also transmitted to the Arduino or other microcontrollers via I2C communication.

5.5.2.1 MAX30102 Pinout:

This sensor has 8 pins as shown in figure (16) above. 4 pins are more useful:

- **VCC:** Module power supply – 3 to 5 V
- **GND**: Ground
- **SCL**: I2C clock bus
- **SDA**: I2C data bus

5.5.2.2 Working principle:

When the heart pumps blood, there is an increase in oxygenated blood as a result of having more blood. As the heart relaxes, the volume of oxygenated blood also decreases. By knowing the time between the increase and decrease of oxygenated blood, the pulse rate is determined.

It turns out, oxygenated blood absorbs more infrared light and passes more red light while deoxygenated blood absorbs red light and passes more infrared light. As shown in figure (17) This is the main function of the MAX30102: it reads the absorption levels for both light sources and store them in a buffer that can be read via I2C.

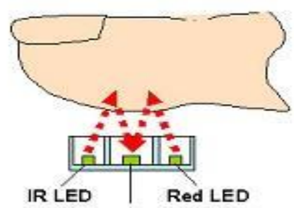


Figure 17: working principle of max30102

5.5.2.3 Features:

●Working voltage: 1.8-5.5V

●Integrates both complete pulse oximeter and heart rate sensor including the optics. No need for a separate probe.

●Ultra-Low-Power Operation Increases Battery Life

● Easy-to-use I2C interface.

● Heart-Rate Monitor and Pulse Oximeter Sensor in LED Reflective Solution

● Tiny 5.6mm x 3.3mm x 1.55mm 14-Pin Optical Module

- Integrated Cover Glass for Optimal, Robust Performance

● Ultra-Low Power Operation for Mobile Devices:

- Programmable Sample Rate and LED Current for Power Savings
- Low-Power Heart-Rate Monitor (< 1mW)
- Ultra-Low Shutdown Current (0.7µA, typ)

● Fast Data Output Capability:

- High Sample Rates

● Robust Motion Artifact Resilience:

- High SNR

● -40°C to +85°C Operating Temperature Range.

5.5.2.4 Algorithm:

- Include wire.h library
- Include max30102 library
- Include SPI library
- Include heartrate library
- Specify baud rate (9600)
- Make MISO pin OUTPUT
- Set bit (SPE)in SPCR Register
- Make flag = false
- Enable SPI interrupt
- Initialize sensor
- If sensor not connected
- Print sensor not found
- If request come from master
- Go to SPI_Interrupt to receive request and make flag up
- Take measure (beat average) from sensor and set it in SPDR Register and send it to master.

5.5.3Tsl2561 light sensor:

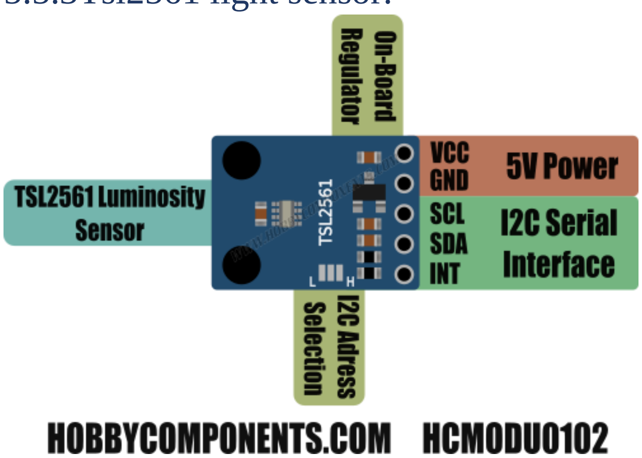


Figure 18: tsl2561 explained

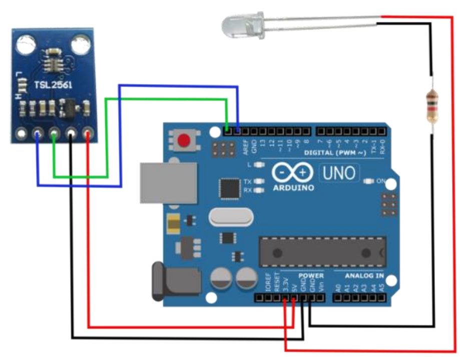


Figure 19: max30102 arduino circuit connection

Used for non-invasive blood pressure and non-invasive blood glucose level.

Shown in figure (18) The TSL2560 and TSL2561 are light-to-digital converters that transform light intensity to a digital signal output capable of direct I2C (TSL2561) or SMBus (TSL2560) interface. Each device combines one broadband photodiode (visible plus infrared) and one infrared-responding photodiode on a single CMOS integrated circuit capable of providing a near-photopic response over an effective 20-bit dynamic range (16-bit resolution). Two integrating ADCs convert the photodiode currents to a digital output that represents the irradiance measured on each channel. This digital output can be input to a microprocessor where illuminance (ambient light level) in lux is derived using an empirical formula to approximate the human eye response. The TSL2560 device permits an SMB-Alert style interrupt, and the TSL2561 device supports a traditional level style interrupt that remains asserted until the firmware clears it.

While useful for general purpose light sensing applications, the TSL2560/61 devices are designed particularly for display panels (LCD, OLED, etc.) with the purpose of extending battery life and providing optimum viewing in diverse lighting conditions. Display panel backlighting, which can account for up to 30 to 40 percent of total platform power, can be automatically managed. Both devices are also ideal for controlling keyboard illumination based upon ambient lighting conditions. Illuminance information can further be used to manage exposure control in digital cameras. The TSL2560/61 devices are ideal in notebook/tablet PCs, LCD monitors, flat-panel televisions, cell phones, and digital cameras. In addition, other applications include street light control, security lighting, sunlight harvesting, machine vision, and automotive instrumentation clusters.

5.5.3.3 Wiring up the sensor:

- As shown in figure (19) above Connect the **VCC** pin to a 3.3V or 5v power source (Whatever the logic level of your microcontroller is!)
- Connect **GND** to the ground pin.
- Connect the i2c **SCL** clock pin to your i2c clock pin. On the classic Arduino Uno this is Analog **pin 5**
- Connect the i2c **SDA** data pin to your i2c data pin. On the classic Arduino Uno this is Analog **pin 4.**

TIL32 is a low cost 3mm IR LED package (shown in figure (20)). It has wavelength of 940 nm. Maximum forward voltage for TIL32 is 1.6V and maximum forward current is 20mA.

The TSL2561 is a light-to-digital converter that transforms light intensity to a digital signal output capable of direct I2C Interface. It combines one broadband photodiode (visible plus infrared) and one infrared-responding photodiode on a single CMOS integrated circuit capable of

Figure 20: IR LED

providing a near-photopic response over an effective 20-bit dynamic range (16-bit resolution). Two integrating ADCs convert the photodiode currents to a digital output that represents the irradiance measured on each channel. This digital output can be input to a microprocessor where illuminance (ambient light level) in lux is derived using an empirical formula to approximate the human eye response. The TSL2561 device supports a traditional level style interrupt that remains asserted until the firmware clears it.

5.5.3.4 METHODOLOGY:

* The Arduino Nano excites IR LED for light emission. The light reflected from blood is sensed by the GY2561 sensor.

* 5 consecutive readings taken from sensor are stored in 5 variables and their mean is calculated.

* The mean value is divided by some factor to obtain optical M.A.P. (Mean Arterial Pressure) value.

* Mean Arterial Pressure (M.A.P) is defined as the average blood pressure in a person‟s arteries during one cardiac cycle. [7]

* Mean Arterial Pressure (M.A.P) is considered a better indicator of perfusion to vital organs than systolic

blood pressure.

* Systolic and Diastolic M.A.P. values are derived from optical M.A.P. and sent to PC or mobile via Bluetooth Module.

5.5.3.5 Features:

- Approximates Human eye Response

- Precisely Measures Illuminance in Diverse Lighting Conditions
- Temperature range: -30 to 80 *C
- Dynamic range (Lux): 0.1 to 40,000 Lux
- Voltage range: 2.7-3.6V
- Interface: I2C
- Programmable Interrupt Function with User-Defined Upper and Lower Threshold Settings
- 16-Bit Digital Output with SMBus (TSL2560) at 100 kHz or I2C (TSL2561) Fast-Mode at 400 kHz

- Programmable Analog Gain and Integration Time Supporting 1,000,000-to-1 Dynamic Range
- Automatically Rejects 50/60-Hz Lighting Ripple
- Low Active Power (0.75 mW Typical) with Power Down Mode RoHS Compliant
- Power supply: 5V
- Interface: I2C (0x39 default, 0x29 or 0x49 optional)
  Module dimensions: 19mm x 14mm

5.5.3.6 Algorithm:

- Include wire.h library
- Include Tsl2561 library
- Include SPI library
- Include heartrate library
- Specify baud rate (9600)
- Make MISO pin OUTPUT
- Set bit (SPE)in SPCR Register
- Make flag = false
- Enable SPI interrupt
- Initialize sensor(tsl2561)
- If sensor not connected
- Print sensor not found
- If request come from master
- Go to SPI_Interrupt to receive request and make flag up
- Take measure (irvalue) from sensor and set it in SPDR Register and send it to master

5.5.4 Temperature Sensor (thermistor 10K NTC)

Figure 21: thermistor package

5.5.4.1 Features:

- NTC-resistor with metal head and connection wire
- Resistance: 10kohm at 25 C
- coefficient B (25 C/50 C): 3950
- Accuracy: ±1%
- Cable length: 100cm
- Head size: ø5x24mm
- Temperature gauge sensor
- Temp. Range -40 C to 200 C

Algorithm:

- Define A0 as input
- Specify baud rate (9600)
- Take reads and store it in variable(V0)
- R2 = R1 * (1023.0 / (float)Vo - 1.0);
- logR2 = log(R2)
- T = (1.0 / (c1 + c2*logR2 + c3*logR2*logR2*logR2)
- T = T - 273.15
- T → describes Temperature in Celsius

5.6 Analog to Digital Conversion using ATMEGA32

To summarize, the following steps should be followed for doing an A/D Conversion:

▣ Configure the A/D module:

- Configure analog pins/voltage reference (ADMUX)
- Select A/D input channel (ADMUX)
- Select A/D conversion clock- prescaler (ADCSRA)
- Turn on A/D module, bit ADEN (ADCSRA)

▣ Configure A/D interrupts (if desired).

▣ Start conversion:

- Set bit ADSC (ADCSRA)

▣ Wait for A/D conversion to complete, by either:

- Checking for the ADIF bit; OR
- Waiting for the A/D interrupt

▣ Read A/D result register pair (ADCL and ADCH), clear bit ADIF if required.

▣ For the next conversion, go to step 1 or step 2,

5.7 Communication Protocols Used in ATmega32

5.7.1 Serial Communication (Briefly)

In telecommunication and data transmission, serial communication is the process of sending data one bit at a time, sequentially, over a communication channel or computer bus. This is in contrast to parallel communication, where several bits are sent as a whole, on a link with several parallel channels.

5.7.2 Universal Asynchronous Receiver/Transmitter (UART)

A universal asynchronous receiver-transmitter (UART) is a computer hardware device for asynchronous serial communication in which the data format and transmission speeds are configurable. The electric signaling levels and methods are handled by a driver circuit external to the UART. A UART is usually an individual (or part of an) integrated circuit (IC) used for serial communications over a computer or peripheral device serial port. One or more UART peripherals are commonly integrated in microcontroller chips. A related device, the universal synchronous and asynchronous receiver-transmitter (USART) also supports synchronous operation.

5.7.2.1 Transmitting and receiving serial data

The universal asynchronous receiver-transmitter (UART) takes bytes of data and transmits the individual bits in a sequential fashion. At the destination, a second UART re-assembles the bits into complete bytes. Each UART contains a shift register, which is the fundamental method of conversion between serial and parallel forms. Serial transmission of digital information (bits) through a single wire or other medium is less costly than parallel transmission through multiple wires.

The UART usually does not directly generate or receive the external signals used between different items of equipment. Separate interface devices are used to convert the logic level signals of the UART to and from the external signaling levels, which may be standardized voltage levels, current levels, or other signals.

Communication may be simplex (in one direction only, with no provision for the receiving device to send information back to the transmitting device), full duplex (both devices send and receive at the same time) or half duplex (devices take turns transmitting and receiving).

5.7.2.2 Data framing:

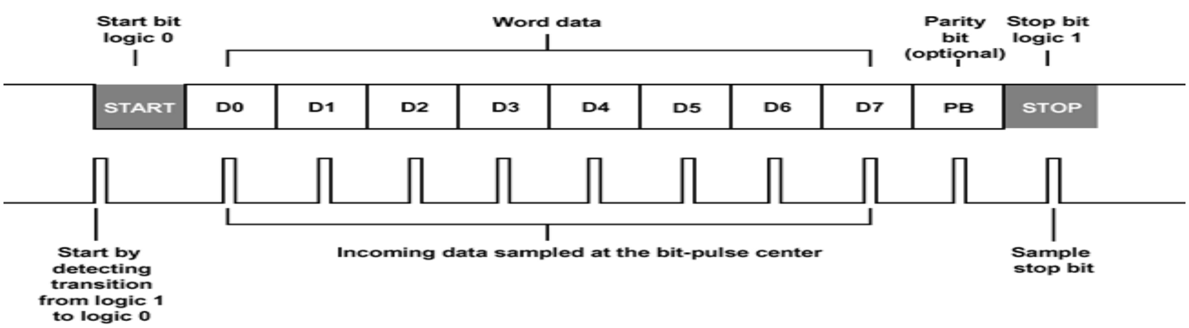


Figure 22: data framing

The idle, no data state is high-voltage, or powered. This is a historic legacy from telegraphy, in which the line is held high to show that the line and transmitter are not damaged. Each character is framed as a logic low start bit, data bits, possibly a parity bit and one or more stop bits. In most applications the least significant data bit (the one on the left in this diagram) is transmitted first, but there are exceptions (such as the IBM 2741 printing terminal).

The start bit signals the receiver that a new character is coming. The next five to nine bits, depending on the code set employed, represent the character. If a parity bit is used, it would be placed after all of the data bits. The next one or two bits are always in the mark (logic high, i.e., '1') condition and called the stop bit(s). They signal to the receiver that the character is complete. Since the start bit is logic low (0) and the stop bit is logic high (1) there are always at least two guaranteed signal changes between characters.

If the line is held in the logic low condition for longer than a character time, this is a break condition that can be detected by the UART.

Features:

▣ Full Duplex Operation (Independent Serial Receive and Transmit Registers)

▣ Asynchronous or Synchronous Operation

▣ Master or Slave Clocked Synchronous Operation

▣ High Resolution Baud Rate Generator

▣ Supports Serial Frames with 5, 6, 7, 8, or 9 Data bits and 1 or 2 Stop Bits.

5.7.3 Serial Peripheral Interface (SPI):

The Serial Peripheral Interface (SPI) interface is used for communication between multiple devices over short distances, and at high speed.

Typically, there is a single "master" device, which initiates communications and supplies the clock which controls the data transfer rate. There can be one or more slaves. For more than one slave, each one has its own "slave select" signal

5.7.3.1 SPI signals:

In a full-blown SPI system, you will have four signal lines:

- Master Out, Slave In (MOSI) - which is the data going from the master to the slave
- Master In, Slave Out (MISO) - which is the data going from the slave to the master
- Serial Clock (SCK) - when this toggle both the master and the slave sample the next bit
- Slave Select (SS) - this tells a particular slave to go "active".

When multiple slaves are connected to the MISO signal they are expected to tri-state (keep at high impedance) that MISO line until they are selected by Slave Select being asserted. Normally Slave Select (SS) goes low to assert it. That is, it is active low. Once a particular slave is selected it should configure the MISO line as an output so it can send data to the master.

This image shows the way that data is exchanged as one byte is sent:

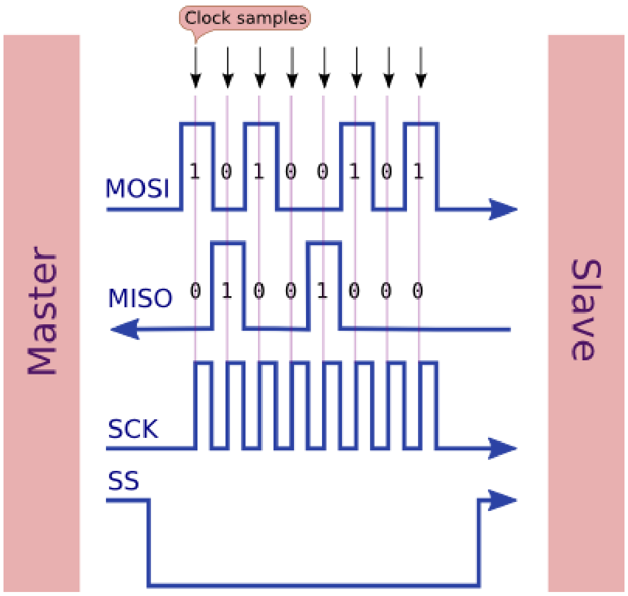


Figure 23:SPI signals

three signals are outputs from the master (MOSI, SCK, SS) and one is an input (MISO).

5.7.3.2 Timing:

The sequence of events is:

- SS goes low to assert it and activate the slave
- The SCK line toggles to indicate when the data lines should be sampled
- The data is sampled by both master and slave on the **leading** edge of SCK (using the default clock phase)
- Both master and slave prepare for the next bit on the **trailing** edge of SCK (using the default clock phase), by changing MISO / MOSI if necessary
- Once the transmission is over (possibly after multiple bytes have been sent) then SS goes high to de-assert it

Note that:

- The most significant bit is sent first (by default)
- Data is sent and received at the same instant (full duplex)

Because data is sent and received on the same clock pulse it is not possible for the slave to respond to the master immediately. SPI protocols usually expect the master to request data on one transmission, and get a response on a subsequent one.

5.7.3.3 Connecting to Arduino

Arduino Uno

Connecting via digital pins 10 to 13:

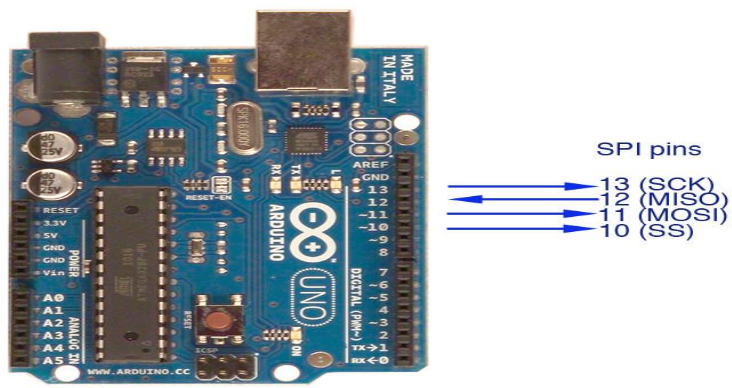


Figure 24:connecting arduino uno with spi

Multiple slaves

A master can communicate with multiple slaves (however only one at a time). It does this by asserting SS for one slave and de-asserting it for all the others. The slave which has SS asserted (usually this means LOW) configures its MISO pin as an output so that slave, and that slave alone, can respond to the master. The other slaves ignore any incoming clock pulses if SS is not asserted. Thus you need one additional signal for each slave, like this:

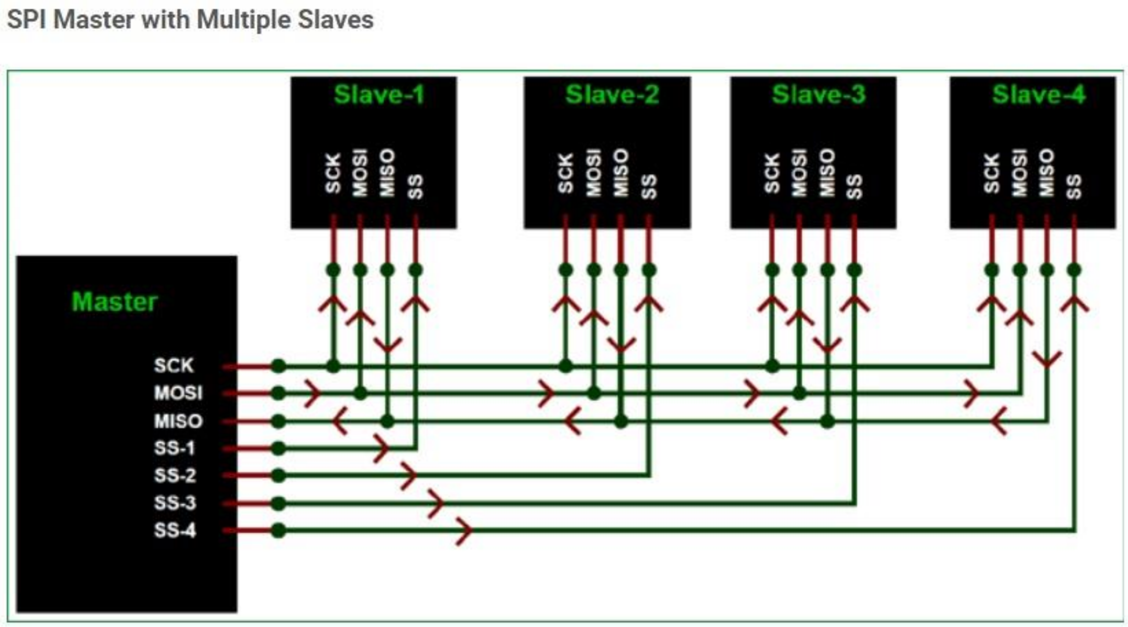


Figure 25: spi multiple slaves

Why use SPI?

- SPI is really the fastest method available on the Atmega328 (and similar) chips. The fastest rate quoted above is 888,888 bytes per second. Using I^2C you can only get around 40,000 bytes per second. The overhead of the I^2C is quite substantial, and if you are trying to interface really quickly, SPI is the preferred choice. Quite a few chip families (eg. MCP23017 and MCP23S17) actually support both I^2C and SPI so you often can choose between speed, and the ability to have multiple devices on a single bus.
- The SPI and I^2C devices are both supported in hardware on the Atmega328 so you could conceivably be doing a transfer via SPI simultaneously with I^2C which would give you a speed boost.

Both methods have their place. I^2C lets you connect many devices to a single bus (two wires, plus ground) so it would be the preferred choice if you needed to interrogate a substantial number of devices, perhaps fairly infrequently. However, the speed of SPI could be more relevant for situations where you need to output rapidly

5.7.4 I2C Communication Protocol:

I2C stands for **Inter-Integrated Circuit.** It is a bus interface connection protocol incorporated into devices for serial communication. It was originally designed by Philips Semiconductor in 1982. Recently, it is a widely used protocol for short-distance communication. It is also known as Two Wired Interface (TWI).

Working of I2C Communication Protocol:

It uses only 2 bi-directional open-drain lines for data communication called SDA and SCL. Both these lines are pulled high.

Serial Data (SDA) – Transfer of data takes place through this pin.
Serial Clock (SCL) – It carries the clock signal.

Table 5: I2c data

Wires Used	2
Maximum Speed	Standard mode= 100 kbps
	Fast mode= 400 kbps
	High speed mode= 3.4 Mbps
	Ultra fast mode= 5 Mbps
Synchronous or Asynchronous?	Synchronous
Serial or Parallel?	Serial
Max # of Masters	Unlimited
Max # of Slaves	1008

I2C operates in 2 modes –

- Master mode
- Slave mode

Each data bit transferred on SDA line is synchronized by a high to the low pulse of each clock on the SCL line.

According to I2C protocols, the data line cannot change when the clock line is high, it can change only when the clock line is low. The 2 lines are open drain; hence a pull-up resistor is required so that the lines are high since the devices on the I2C bus are active low. The data is transmitted in the form of packets which comprises 9 bits.

5.8 Using Bluetooth to Communicate with the Android Application

5.8.1 What Is Bluetooth?

Bluetooth is a wireless technology standard used for exchanging data between fixed and mobile devices over short distances using short-wavelength UHFradio waves in the industrial, scientific and medical radio bands, from 2.402 GHz to 2.480 GHz, and building personal area networks (PANs). It was originally conceived as a wireless alternative to RS-232 data cables.

5.8.2 Why did we choose Bluetooth?

Our application is built to be connected to a phone that is close to the patient and Bluetooth is designed to work well over short distances, so it was suitable for our application to be used. Also, it is a standard that comes with every smartphone now so it is widely used and would have no troubles communicating with any android application.

5.8.3 Bluetooth Module (HC-05)

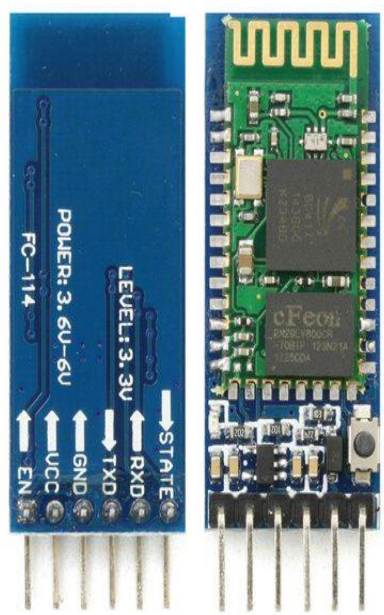


Figure 26 : hc05

HC-05 Bluetooth Module is an easy-to-use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Its communication is via serial communication which makes an easy way to interface with controller or PC. HC-05 Bluetooth module provides switching mode between master and slave mode which means it able to use neither receiving nor transmitting data.

5.8.3.1 Specification:

▣ Serial Bluetooth module for microcontrollers.

▣ Operating Voltage: 4V to 6V (Typically +5V).

▣ Operating Current: 30mA.

▣ Range:<100m.

▣Works with Serial communication (USART) and TTL compatible.

▣ Follows IEEE 802.15.1 standardized protocol.

▣ Uses Frequency-Hopping Spread spectrum (FHSS).

▣ Can operate in Master, Slave or Master/Slave mode.

▣ Can be easily interfaced with Laptop or Mobile phones with Bluetooth.

▣ Supported baud rate: 9600,19200,38400,57600,115200,230400,460800.

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