

**DESIGN AND IMPLEMENTATION OF A SMART WRISTBAND
FOR MONITORING PHYSIOLOGICAL AND EMOTIONAL STATUS
OF THE USER**

(KULLANICININ FİZYOLOJİK VE DUYGU DURUMUNU İZLEMEK İÇİN
AKILLI BİR BİLEKLİK TASARIM VE GERÇEKLENMESİ)

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ABSTRACT

Nowadays people become more interested with personal healthcare products in order to maintain their wellbeing. The development of specific hardware and software enabled people to monitor their own health status and be more interactive with their body. The advances in the internet of things (IOT) made it possible to interact with electronic devices used for these purposes. (Stuart, 2018). In this master thesis, we have designed and implemented a smart Wristband system based on an IOT platform which consist of several components. We have shown that the system is capable of acquiring the raw data from the user and transmitting it on server for smart analysis thereafter.

ÖZET

Günümüzde insanlar sağlıklı bir yaşam sürdürebilmek amacıyla kişisel sağlık ürünleriyle daha ilgilenir oldular. Özel donanım ve yazılımların geliştirilmesi sağlık durumlarını gözlemlene ve vücutlarıyla daha etkileşimli olabilme imkanı yarattı. Öte yandan Nesnelerin internetindeki ilerlemeler bu amaçla kullanılan elektronik cihazlarla etkileşime geçebilmeyi mümkün kıldı. Bu master tezi çalışmasında, birden çok bileşenden oluşan bir IOT platformunu temel alan akıllı bir bileklik sistemi tasarlanmış ve gerçekleştirilmiştir. Sistemin kullanıcılardan ham datayı toplayıp daha sonra akıllıca analiz edilebileceği sunucuya aktarımı gerçekleştirdiği gösterilmiştir.

1 INTRODUCTION

Our daily urban lifestyle has multiple negative impacts such as an increased stress level, cardiovascular problems due to lack of movement and obesity etc. According to world health organization (world health organization, 2016) 31 % percent of deaths is attributed to heart attacks globally. This information states the importance of continuous monitoring of the heart rate and other vital parameters from healthy as well as risky people.

Previously detection and monitoring of physiological data were restricted to the clinical area. The attempts to acquire data without attached leads were limited. Furthermore, because of the dreary instruments and lack of technology these approaches were not quite accurate and precise (Khudhur A. Alfarhan et al., 2016). Recent developments in IOT and electronics enabled measurement devices to upgrade the quality of their systems by adding new features such as skin resistance, blood pressure, temperature, skin moisture etc.

Among the aims of the project is to collect physiological data from people. Thanks to the technological developments of today's age, the market area of wearable devices has increased, the industry has developed, and the price has been favorable due to its accessibility. In this context, the most important parts are wireless and highly mobile physiological sensor types. Thanks to the development of wireless transmission, for example, thanks to Bluetooth 5.0 physiological sensors can instantly transmit data such as ECG, SR, PPG of people. For example, wireless transmission brings wide data network and power. Normally, as mentioned in the book (G. D. Clifford & McSharry, 2006), the data of the sensors must be passed through various filters and processed, for example, in the processing of an ECG signal, the data received from their contacts must be filtered. This process can be provided with hardware or software, but new types of sensors used in today's technologies can handle this filtering themselves.

The main goal of our design is to measure the physiological data of individuals, especially the changes related to stress. For this, basically, the design needs to measure the ECG, PPG and SR values of the people.

1.0.1 The Electrocardiogram ECG

The electrocardiogram (ECG or EKG) is a special type of graph that represents cardiac electrical activity. ECG can be described as signals generated a time-voltage information of heartbeat. The signal is generated by polarization and depolarization of cardiac tissue and translates into a waveform (Gupta, 2014). The ECG can be used as analysing the heart condition of people. The ECG is one of the key component of clinical diagnosis critical information. The signal for cardiac contraction is the spread of synchronized electrical currents through the heart muscle (Goldberger, 2006). The major analysis of signals handled by Willem Einthoven who is discovered a galvanometer. Einthoven used his invention to study how a human heart works by analyzing the ECG signal. He founds a lot cardiovascular disorders from ECG signal. He was awarded the Nobel Prize in Medicine in 1924 (Snellen, 1995).

Basically, ECG signal consists of P wave, QRS complex, ST segment, T wave and U waves. The P wave and QRS complex considered as depolarization, ST segment, T and U waves are considered as ventricular re-polarization. The P wave represents the spread of a stimulus through the atria (atrial depolarization). The QRS waveform, or complex, represents stimulus spread through the ventricles (ventricular depolarization). As the name implies, the QRS set of deflections (complex) includes one or more specific waves, labeled as Q, R, and S. The ST (considered both a waveform and a segment) and T wave (or grouped as the "ST-T" waveform) represent the return of stimulated ventricular muscle to the resting state (ventricular repolarization). Furthermore, the very beginning of the ST segment (where it meets the QRS complex) is called the J point. The U wave is a small deflection sometimes seen just after the T wave. It represents the final phase of ventricular repolarization, although its exact mechanism is not known (Goldberger, 2006).

Based on graph we can roughly explain the meaning of the intervals. P wave

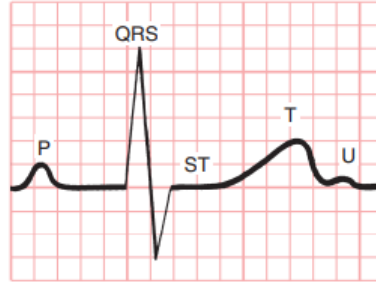


Figure 1.1: Ecg Signal definition

is represents atrial depolarization, QRS interval is represent complex ventricular depolarization , If we consider the signal visually, the first short part is the Q wave, which is generally small and thin, followed by the R wave, which can be thought of as the depolarization of the main mass of the ventricles. then the S wave signifies the final depolarization of the ventricles. The ST interval is the time which is for reflecting the period of zero potential between ventricular depolarization and re-polarization. T wave the re-polarization of the ventricles can be measured . Starting from P to QRS and finally T represents electrical power fluctuation of heart.(G. D. Clifford & McSharry, 2006). Based on those information ECG can be examined as two axis which are x for QRST signals and y for time. Based on those graphs any heart related problems can be found and diagnosis can be determined (Dubin, 2000). Based on ECG signal heart rate can be measured. In between two consecutive signals the time between R signals called as R-R Intervals. The R-R intervals can be considered as distance between two heart beats.

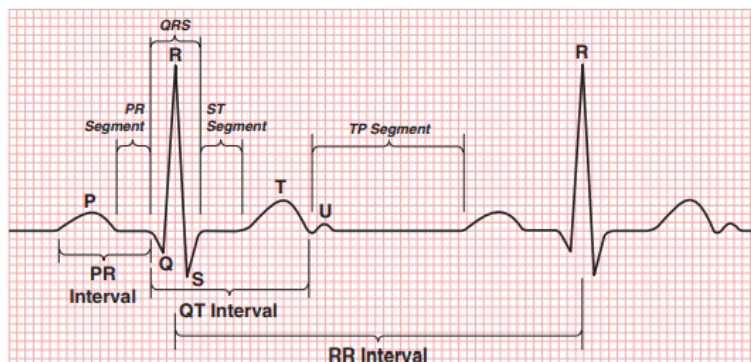


Figure 1.2: R - R Interval

Apart from ECG, it can also be done by measuring heartbeat and pulse. For this,

the count at any arterial crossing point can be used. This method can be expressed as beat per minute (bpm)(Stefanie Passler & Senner, 2019).

1.0.2 The Photoplethysmogram PPG

The terminology firstly introduced by Hertzman at 1938 (Hertzman, 1938). He introduce this as alternative to ECG monitoring. The signal can be measured from various of body parts such as fingers(Boo-Ho Yang & Rhee, 2001) , wrists and arms(Lisa Cadmus-Bertram, 2007). Generally PPG signals has two phases which are anacrotic phase and catacrotic phases. The anacrotic phase is the rising edge of the pulse. The catacrotic phase is the falling edge of pulse figure1.3. The first phase is associated with systole, and the second phase with diastole and wave reflections from the periphery(Integrated, 2019).

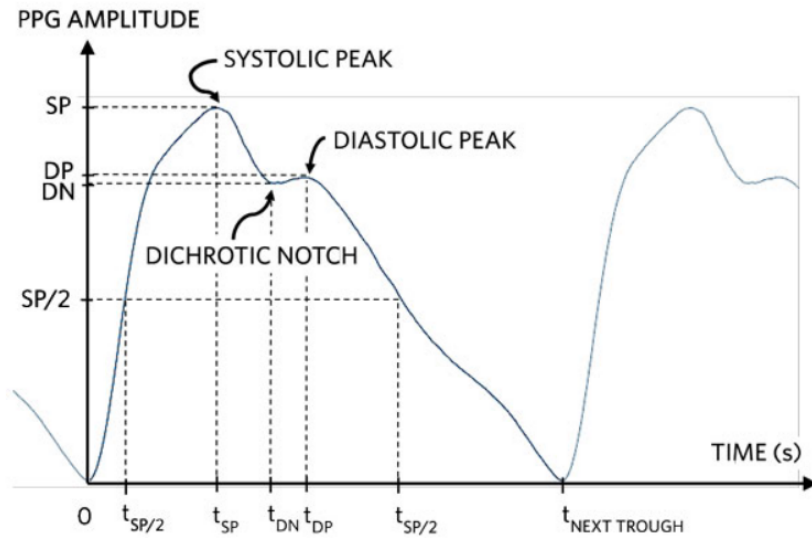


Figure 1.3: PPG characteristic

The shape of PPG described as systolic amplitude, pulse width, pulse area, peak-to-peak interval, pulse interval, and artery stiffness index(Shin & Min, 2017). The typical PPG devices contains a light source and a photo detector. The light reflected on the skin returns and is detected by the photo diode sensor. As like ECG with PPG user can also identify and diagnose diseases(Mohammad Ghamari & Soltanpur, 2018). Basically the reflected light from tissue is always related with blood which helps the identifying diagnoses(ChengWang, 2013).

1.0.3 The Galvanic Skin Response GSR

GSR is a measuring unit of surface resistance skin or conductivity. It can be measured by passing a micro current of electricity through a pair of electrodes located near one another, amplifying and registering current variation (Nilanjan Sarkar, 2021). Many sensor uses GSR and mainly the usage is placing two slots for obtaining bio-signals. The technology commonly used for stress-related problem detection (Alireza Golgouneh & Mobashsher, 2020). The measurement can be obtained various of body part such as waist, wrist or fingers (Matthew S. Goodwin, 2010). Most of the cases derive people to illness caused by stress (Giulia Crifaci, 2014). Beside of this stress is the psychological perception and how people reacts again in different scenarios. The behavior of people changes based on pressure and it effects the measurement of GSR (Bernice Andrews, 2004). GSR sensor measures the electrical resistance of the skin caused by emotional stress in Siemens. When any person gets under stress condition the way of breathing, sweating, shaking are changing accordingly (Jorn Barker, 2011). As stated (Odafe E Jeroh* & Roveda, 2018) people can measure level of stress from fingers or toes. The measurement values can be caused as create anxiety interns of getting arousal. In our approach we follow same principle as stated in (Mahima Sharma, 2016). In the test situation volunteers change their anxiety level based on some overwhelming mind task.

This study involves the iterative design and implementation of a smart wristband device composed of an embedded hardware and software system. Espessically in the hardware we used system on chip tools (Jaume Segura-Garcia & Salvador-Palmer, 2018), thus our processing load is reduced and signaling is strengthened (Marian-Emanuel Ionascu, 2017) The system description is divided into 5 different topics, which are hardware design, embedded code, server code, mobile application code and web site design.

2 LITERATURE REVIEW

This chapter reviews the previous research related to wearable healthcare monitors. The research shows 2 mainstreams based on collected data types: either circulation related data such as heart rate or blood oxygenation or environment sensors such as skin resistance, temperature ,humidity pressure etc. This master thesis envisions to fusion both approaches by collecting and sharing raw data from sensors through multiple platforms.

2.1 Heart Rate Measurement

In early studies, researchers developed systems which have limited hardware and software capabilities for collecting data from users such as heart rate measurement, skin resistance temperature etc. Instead of wireless data transmission they choose to store data inside the microcontroller. Instead of touching on different reference points on the wearable device for measuring EKG, they used 3 leads with electrodes on 3 different part of the body (Mohamed Fezari & Mouldi BeddaDepartment of electronics, 2008)

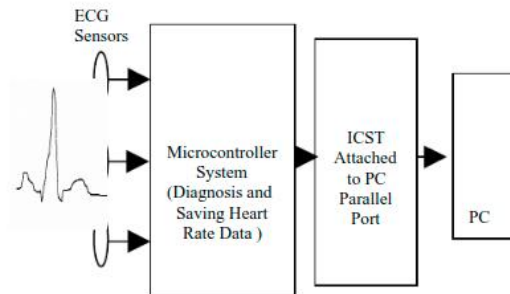


Figure 2.1: Block diagram of (Mohamed Fezari & Mouldi BeddaDepartment of electronics, 2008) ’s base system

Various methods have been used to examine features from heart-related sensors

(Journal, 1996). Naturally, feature extraction and processing is a very difficult procedure. Many signal processing techniques need to be used(J.Lee & Yoo, 2004).

Current research shows that now IOT infrastructure is generally used that enables wireless data transmission and interaction. In order to obtain sensor data the design consists of custom analog to digital converter integrated circuitry where arm, wrist and finger are selected for three data collection points. This eliminated the usage of leads and electrodes from the chest (CHRISTOPHER BEACH, 2019).



Figure 2.2: Heart rate measurement from (CHRISTOPHER BEACH, 2019)

For data transmission, we used Bluetooth, normally as mentioned in (T.K. Kho, 2005). various methods have been tried and it has been seen that the BLE technology is the most optimal considering both data transmission, power consumption and distance (Bin Yu, 2012). The most used method among wearable devices is wireless transmission, the reason for this is basically mobile. Because, although the cable has an increase in data flow speed, it is essential that it restricts mobility and movement capability in transmission(Sunghoon Ivan Lee, 2012).

Our design is similar to this approach with major differences being the sensor variety and quality. Custom circuit design and PCB calculations are extremely painful for adjusting sensor quality, especially when the high frequency or the noise on the board must be considered.

2.2 Galvanic Skin Resistance (GSR) Measurement

In order to check physiological profile of a people, GSR is the mostly used sensor. For example in a study (Dhruv R. Seshadri & Drummond1, 2018) the GSR sensor is used as a biomedical profile calculator. Because of stressful environment or events, people tend to have cardiovascular problems, accidents increased much more frequently. During those moments the body reactions and behaviours changes unexpectedly. These sudden changes can be identified by the use of GSR sensors. Besides GSR , other signals can also be used in order to recognize anomalies. According to (J.P. Pell, 1999), the body temperature is closely affected by a heart attack. Therefore we have decided to use additional sensors to measure parameters such as temperature , humidity and GSR.

The data obtained based on these methods were solved using Java with a mobile app as in (Sunghoon Ivan Lee, 2012). Java was used as in the mobile application while saving the data. This has provided us with great convenience both in writing and in the follow-up phase.

3 SMART WRISTBAND DESIGN

In order to collect data from smart wristband, the system is divided into a hardware and software section. The hardware design is explained in 3 subsections which are component selection , hand made soldering and PCB prototype. The software is described in 4 different subsections which are embedded program , mobile program, server program, web program. All of the design schematic shown on figure 3.1.

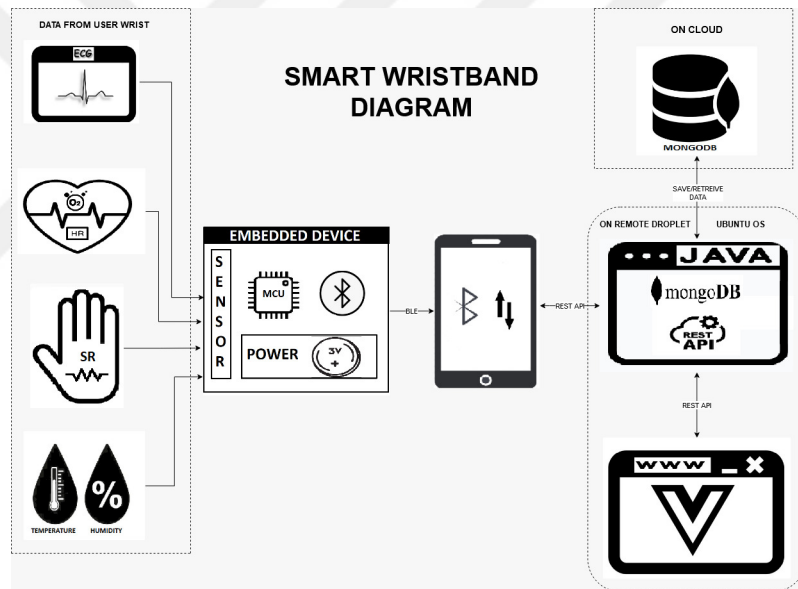


Figure 3.1: Smart Wristband software diagram

3.1 SMART WRISTBAND HARDWARE DESIGN

The aim of the hardware design is to create a small wearable measurement device that can work on battery. The device will acquire data from users via its embedded sensors which are temperature, humidity, skin resistance and heart related data.

Time scheduling and management is a massive struggle in hardware design. For this

The time schedule of PCB design from start to end takes approximately 1 to 2 months. Because of that a handmade soldered hardware is implemented after finishing the PCB prototype design. The aim of the handmade design is continuing development while PCB process is completing. Thanks to that a simultaneous process has been achieved.

3.1.1 Component Selection

In this section, we will explain how we choose component or circuit element. For the components to be placed on the smart bracelet, research was conducted for 6 basic attributes that we thought to collect from the users.

- Skin Resistance - LM324PW

In order to receive galvanic skin response we needed 2 filter and one amplifying circuit. For doing this the optimum way is using one low pass one high pass and one amplifier circuit with op-amps. In our research to achieve this, we found that the most suitable circuit is the circuit diagram known as the groove galvanic skin resistance. As can be seen in the circuit in the figure 3.2 , the point that touches the skin is considered as a resistance point. The measurements get effected due to the change in resistance because of the movement of user. As seen in the figure

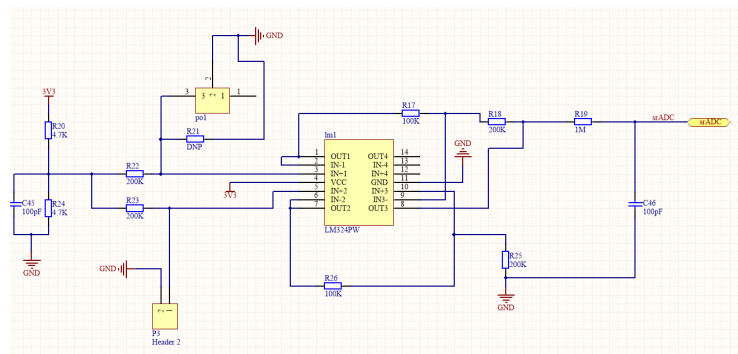


Figure 3.2: Gsr pcb schematic

3.2, the values measured on the skin are passed through a high-pass filter and the signal noises obtained from low-specification noises are eliminated. The signal is then smoothed by passing it through a low-pass filter. Finally obtained signal is integrated into an amplifying circuit and converted to analog voltage that can be read by micro controllers. For doing all of this in one circuit we used LM324PW. The reason we chose this IC is that it can accommodate the 3 op-amp circuits we need on a single IC. It contains 4 separate op-amp circuits inside. In this way, we were able to actively use 3 of the 4 circuits on the integrated circuit. Apart from that, the power consumption of the integrated is very low. As can be seen in the figure 3.3, the average power consumption at the voltage level we use is 10-20 mA. Since our system works with batteries, this consumption is essential for us. In order

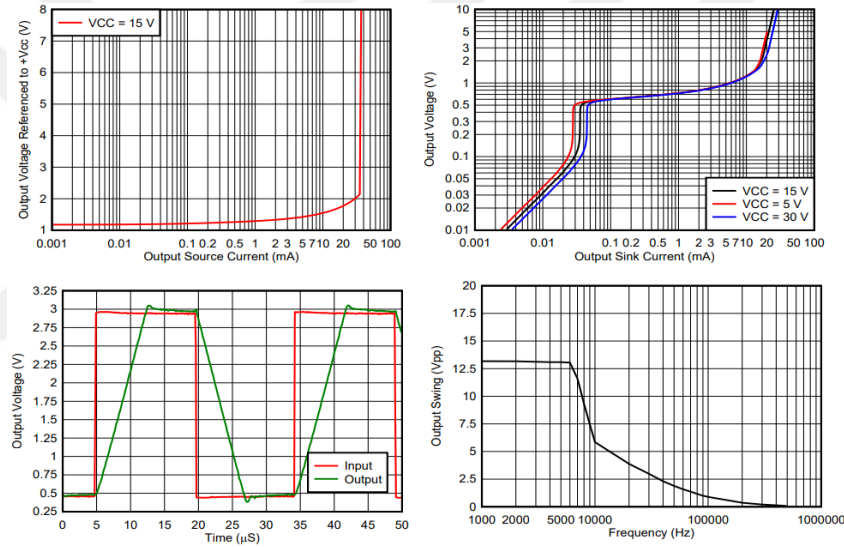


Figure 3.3: Op-amp sensor specs

to measure skin resistance, besides power consumption, another important factor for us is sampling frequency. As can be seen in the figure 3.3, in our operating voltage range (0-3.3), the circuit can produce output at the level of 10 microseconds(t_i, 2015) which is fairly sufficient for our design.

There are no sudden changes for this sensor so we take a snapshot every 100ms.

• Temperature And Humidity Sensor - Si7021

For measurement of temperature and humidity we used Si7021 sensor from Silicon Labs firm. We used this because we considered its sensitivity, measurement specs and current consumption for measurements.

The small and compact structure of the sensor and the use of i2c communication protocol were effective in this selection. As can be seen in the figure 3.4, the sensor has only 2 pins for communication.

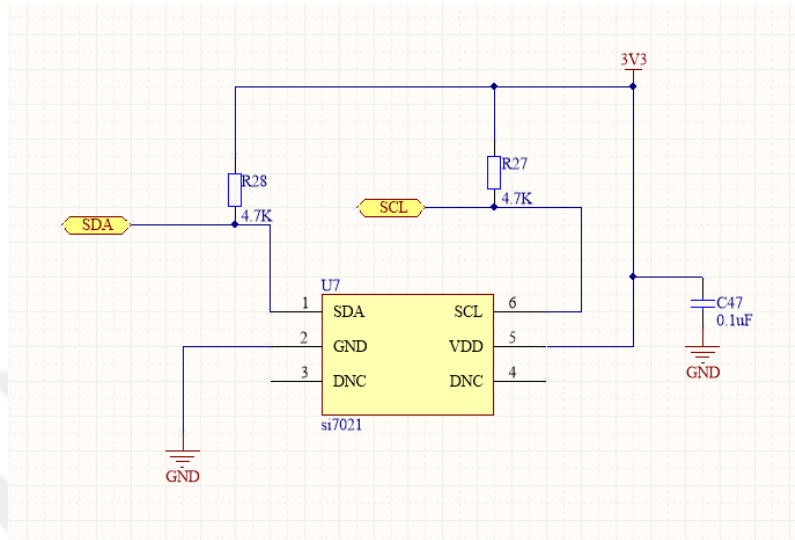


Figure 3.4: Si7021 Schematic

The Si7021 sensor contains 2 sensors together as seen in the figure 3.5. These sensors convert the data they obtain into data that can be processed by the processor with the help of an adc. It measures humidity with 12-bit precision and temperature with 14-bit precision. After receiving data for each type of sensor user need to handle

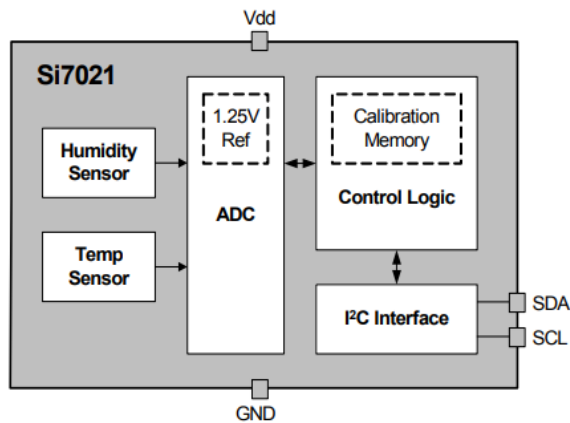


Figure 3.5: Si7021 Diagram

a specific calculation in order to receive real data, for humidity we apply following formula on raw data.

$$\%RH = \left(\frac{125 * RH_Code}{65536} \right) - 6$$

Where %RH is the measured relative humidity value in %RH RH_Code is the 16-bit word returned by the Si7021. Same logic applied for temperature as well, the formulation of temperature is

$$Temperature(^{\circ}C) = \left(\frac{175.72 * Temp_Code}{65536} \right) - 46.85$$

Where Temperature ($^{\circ}C$) is the measured temperature value in $^{\circ}C$ Temp_Code is the 16-bit word returned by the Si7021(sl:, 2016).

There are no sudden changes for this sensor so we take a snapshot every 100ms.

• High-Sensitivity Pulse Oximeter and Heart-Rate Sensor - Max30102

The Max30102 is a sensor that contains the heart rate and blood oxygen values which required for our design. The reasons for choosing this sensor is that it's compact size, uses i2c as a communication protocol, can give both oxygen and pulse in the blood, and has wide calibration options that can adapt to different conditions.

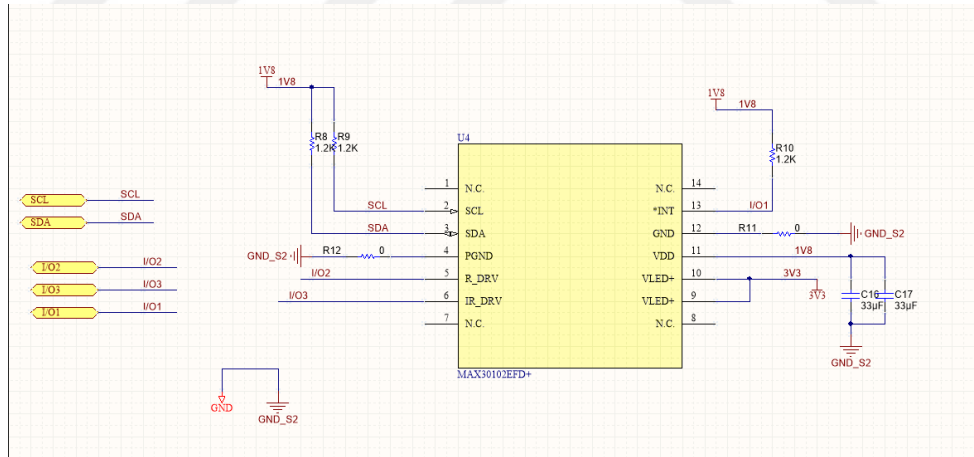


Figure 3.6: Max30102 Schematic

The Max30102 sensor is the component that requires the most power consumption in our system after OLED display. When the sensor is active, it consumes about 0.7mA. As can be seen in the figure 3.7, when the sensor is in the passive position, the power consumption becomes suitable for long battery use. Beside of this other specs here in the sensor selection influenced our decision. As stated in the sensor data sheet, there is no specific specification area of body for data collection (max, 2018) Since our design is a wristband, the contact point of the sensor is between hand

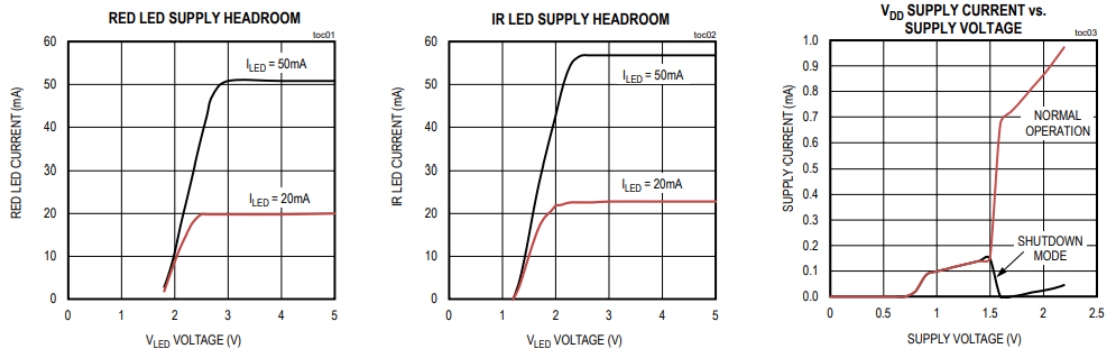


Figure 3.7: Max30102 power consumption

and wrist. For this reason, the contact distance is calculated to be approximately 3-4 mm. For this reason, the threshold values are based on the graph in the figure 3.8 and the values below the threshold are accepted as 0, the values above the threshold are used for the measurements.

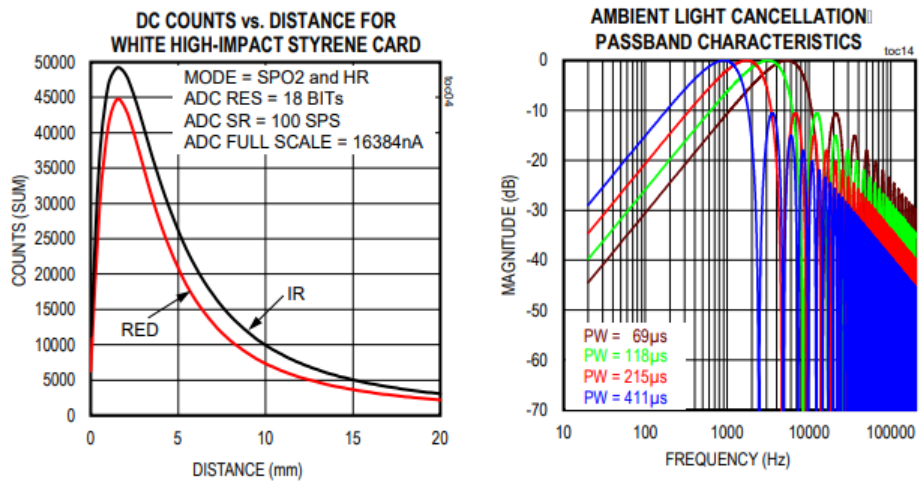


Figure 3.8: Max30102 power consumption

In our system, we set this sensor to approximately 110 sps. Each data transmission is expressed with 4 characters. From data reading to transmission, the system keeps $5 * 4 = 20$ data in a queue structure in the system, so that no data hijacking occurs.

• Ultra-Low Power, Single-Channel Integrated Biopotential (ECG, R-to-R Detection) AFE - Max30003

The most essential of the physiological data measurements obtained by our system is to measure the heart electrocardiogram. Considering the stable operation of the system, the sampling frequency of the data here necessitated finding a component with very low power consumption, compact and high measuring range. In our research, the most applicable module in this segment is the Max30003 coded integration of Analog Device company. The sensor has 15.5 Bit resolution(an:, 2021).

The sensor has low power consumption and high communication rate. In order to communicate with sensor we used SPI commutation as seen in the figure 3.9 sensor works with 1.8 volt therefore we converted 3.3v to 1.8v. Since sensor has high communication rate we need an external crystal which has with 32.768 Hz vibration rate.

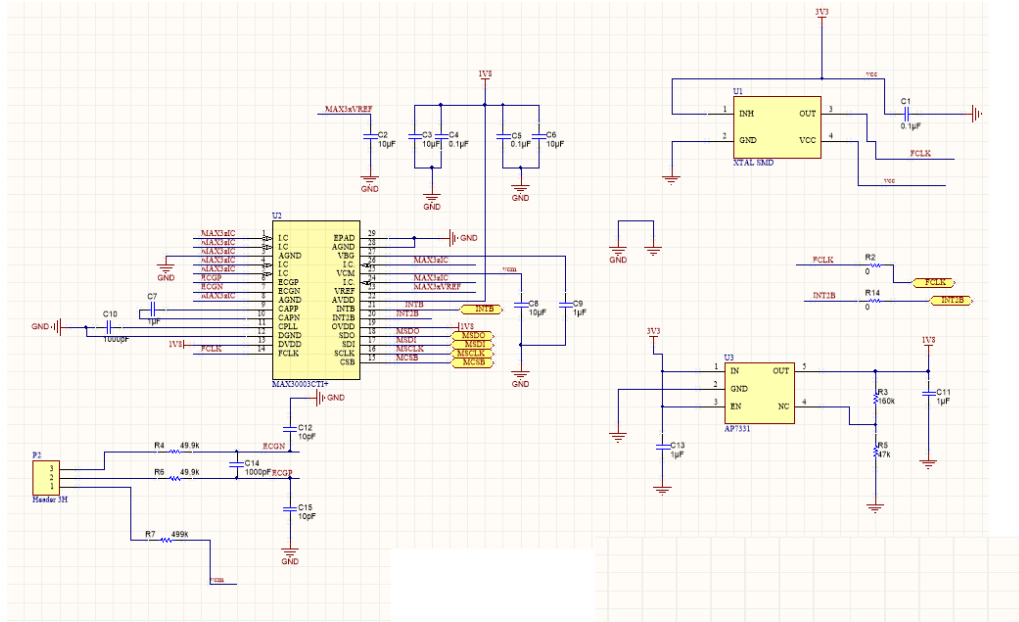


Figure 3.9: Max30003 schematic

The Max30003 sensor offers users a wide choice of filters and noises during ECG measurements. The desired graphic is determined using the configurations provided by the sensor. In our system, selections were made based on the graphics in the figure 3.10 . In our analysis of the graphics, we determined the configurations to be 160 for gain and 40Hz for low-pass filter in order to obtain sharp and low-noise graphics.

In our system, we set this sensor to 128 sps. Each data transmission is expressed with 32 short characters. From data reading to transmission, the system keeps $5 * 32 * 2 = 320$ data in a queue structure in the system, so that no data hijacking occurs. The data from the sensor is transmitted to the system as a kV unit with 15bit data. The data from here provides users with a timeline, an ecg chart and also raw data.

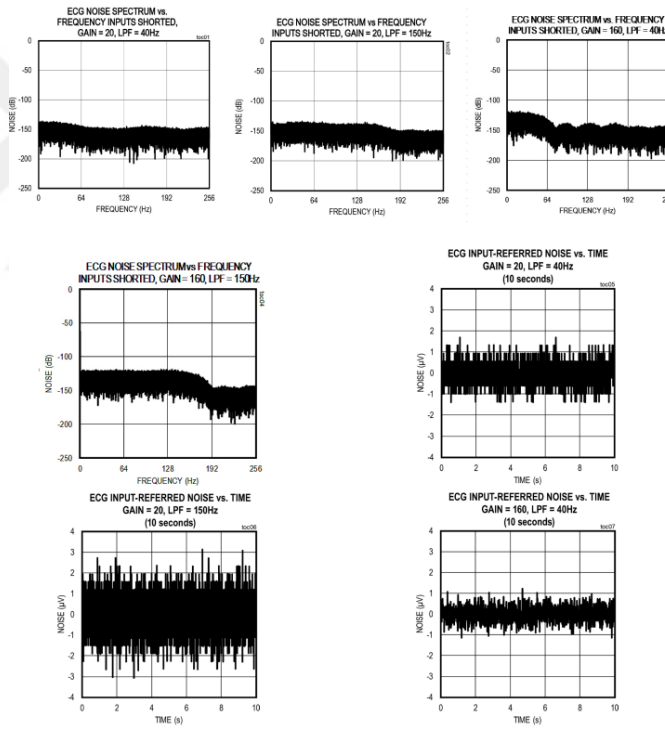


Figure 3.10: Max30003 noise values

• Power Design

Two different ways can be used for the powering the system. One of them is supplying power via the debug port using a micro usb cable, The other one is using battery. For battery we used Lithium Metal. Cr2016 3V Lithium battery is supplying power demand of device. The battery of system is currently non

chargeable, since its not a closed system in case of battery consumption user can easily replace the battery with new one. For powering device with cable, we provide the power supply of the system with the micro USB cable witch's circuit shown in the figure 3.11. In this figure the 5 volt converted to 3.3 volt via LDP39050PU33R circuit to feed the cards power source.

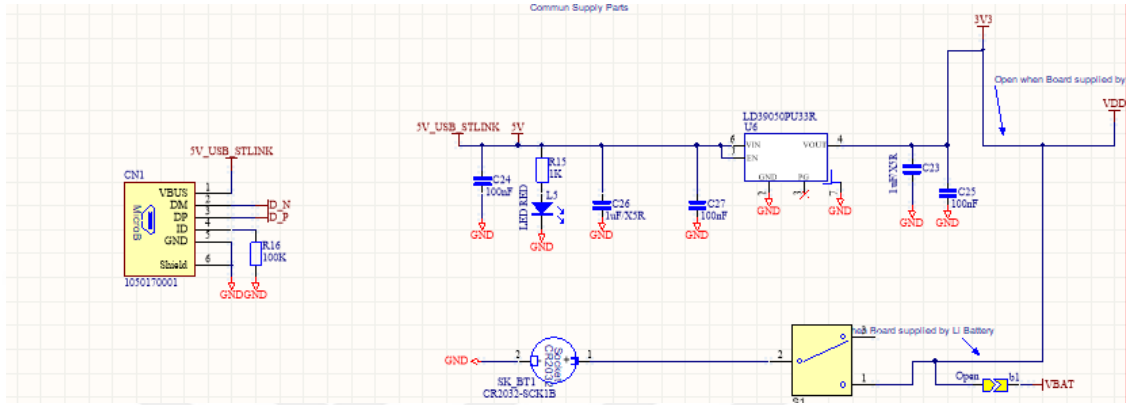


Figure 3.11: Power schematics

3.1.2 Hand Made Soldered Hardware

For handmade soldered hardware design, several components are selected. These include the evaluation boards which are used in the final PCB design. The components are briefly;

- **OLED I2C Screen**

The OLED I2C screen is an OLED screen which controlled by i2c protocol. The screen size is 128x128. The device is used to reflect the status of the embedded device and the connection of BLE also with the acquisition of data.

- **AD8232**

AD8232 is an integrated module for biopotential data collection that is used in our design for the heart electrical activity. In the PCB phase it is substituted with Maxim Electronics medical device sensor (MAX30003CTI bio sensing sensor) which has more accuracy and capability in order to collect data from user.

- **Grove GSR Sensor**

In the design a GSR module is used. The design is made by [Groove/seed](#). It is used to measure galvanic skin resistance of a person. GSR (Galvanic Skin Response), is a method of measuring the electrical conductance of the skin. Strong emotions affect the sympathetic nervous system. Grove - GSR allows you to spot such strong emotions by simple attaching two electrodes to two fingers on one hand. It can also be used as a sleep quality monitor. This device requires two probes which need to touch the skin. We placed the probes directly on the smart wristband to avoid cable attachment.

- **TSL2561 Lux Sensor**

TSL2561 is a sensor which is able to measure the luminance of light. The sensor has wide range of input. We are communicating this sensor via I2C protocol to collect the luminance data.

- **SI7021 Humidity and Temperature sensor**

TSI7021 is a humidity and temperature sensor. It has two main capabilities, first it can give you the data of humidity in terms of 0-100 percentage, with 3 decimal floating point precision. It also yields the temperature of environment between -10 to 85 Celsius degrees with 3 decimal floating point precision. The device communicate with I2C protocol and is used in the design to measure the temperature of users.

- **STM32WB55 Nucleo Board**

This board is used temporarily in our pre-soldered design. In the PCB the main MCU (STM32WB55) which has 32 bit, 64 MHz, 1Mb Flash, 128Kb Ram, BLE5.0 support ,64 pin 7x7mm size is used. The MCU is the core part of the embedded design. This MCU has capability of collecting data from sensors and thanks to its dual core it can acquire and send the data via Bluetooth low energy. The device provide data every 100ms and it's able to send 500 byte data in each sequence.

3.1.2.1 Soldering/Mounting

The components are shown in figure 3.12. Since the PCB design is a highly delicate process, any mistake may result in a delay in development and waste of money. To overcome this issue we soldered the components and we made homemade wiring as shown in figure 3.13.

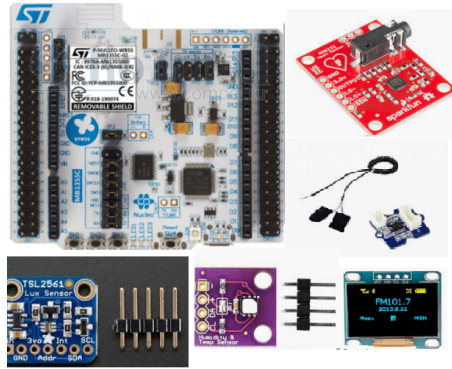


Figure 3.12: Component List

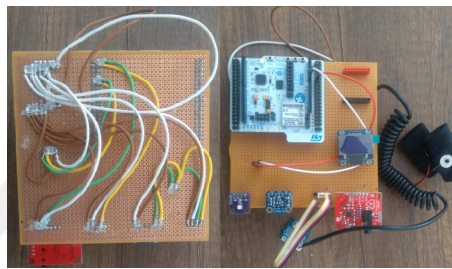


Figure 3.13: Home Soldered PCB

3.1.3 Prototype PCB Design

In this stage 3 PCB component are designed. In each PCB layer FR-4TG130 base material is used. For surface HASL material used. The explanation of PCB layers are explained as top layer bottom layer and middle layer in the following section;

- **Top Layer**

The first layer is crucial in PCB design because almost all integrated chips are located on this layer. In this PCB layer several components are used:

- **MCU**

For micro controller STM32WB series 68 pin Bluetooth-low-energy embedded chip is selected since it has dual core inside and it supports Bluetooth-low-energy features without extra component requirements.

- **Wire Communication/Debug**

In order to communicate through wire for debugging purposes, a Micro USB socket is inserted in the design. For connection a USB to TTL sensor (Silicon Lab/CP2102N) is used.

- Temperature and Humidity sensor

We used the same sensor which is explained in the previous section 3.1.2

- GSR

The design uses two reference points for data collection. The output is redirected to the input of an analog digital converter (0 - 3.3V).

- ECG sensor

For making this process more precise, a different approach from the previous design is selected. In PCB prototype Maxim Electronics/ MAX30003 sensor is used. The sensor is chosen because of its advanced features such as (ECG, RR), low power consumption and high communication rate (SPI/15bit range).

All of these components are mounted on a 6x4 cm sized PCB as can be seen in figure 3.14.

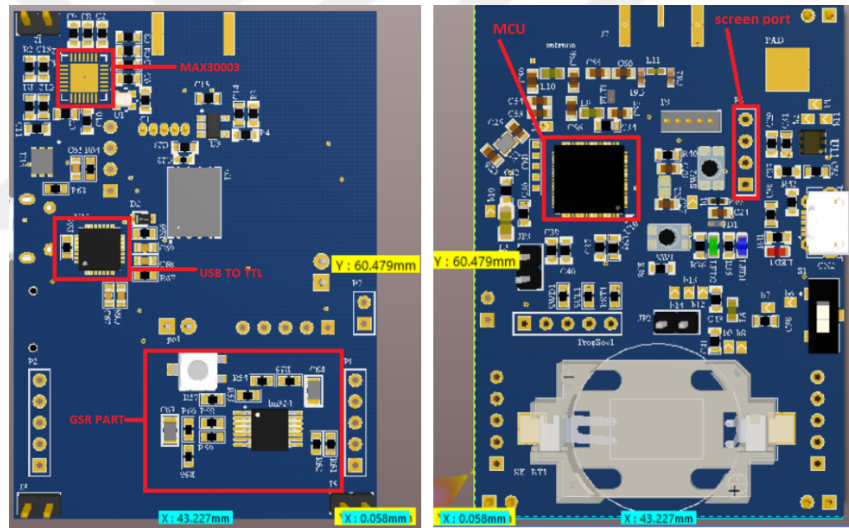


Figure 3.14: PCB top layer

- **Middle Layer**

Based on PCB prototype design, this part is soldered under the bottom layer PCB. In this layer a high sensitivity pulse oximeter and heart rate sensor (Maxim electronics MAX30102 sensor) is placed for measuring the heart rate of users. The size of this layer is fit on 2x1.5 cm PCB which can be seen in figure 3.15.

- **Bottom Layer**

In this layer no component is used. This layer has two functions. The first function is conductance. In order to achieve this, all bottom layer is covered with metal

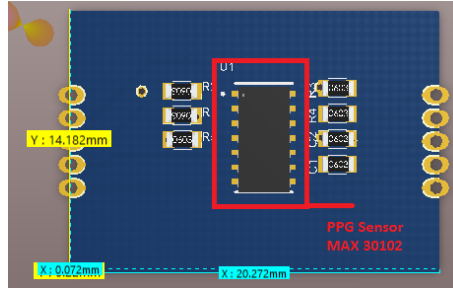


Figure 3.15: PCB middle layer

surface. This plane is used for transmitting ECG signals. Second function is to become a hub for housing the PPG sensor. To do so a hole is created on bottom of the device inside in which the middle layer sensor is able to analyse the skin and send data through header pins. figure 3.16.

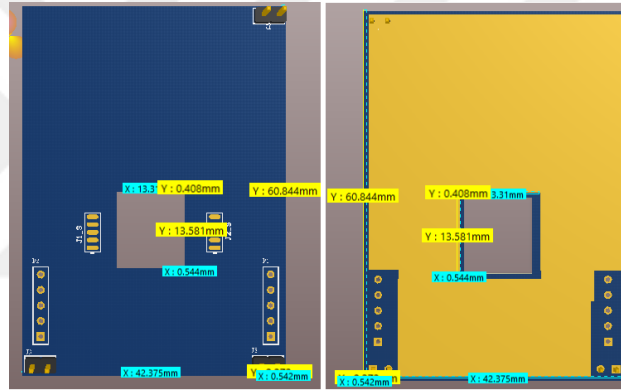


Figure 3.16: PCB bottom layer

3.1.4 Major PCB Design

This PCB prototype design guided us in the design of the ultimate PCB. This major design flow is basically this;

- **Volume Implementation Problems**

In the initial design two separate pieces of PCB are considered. We planned to connect these two shells via connection headers. We planned to use a case to make the device mobile. After soldering PCB parts we realize that the device volume becomes huge for a wearable unit. It became 6x4x3 cm rectangular prism as shown

in figure 3.17. For this PCB a 3D designed case is printed. The aim of the design

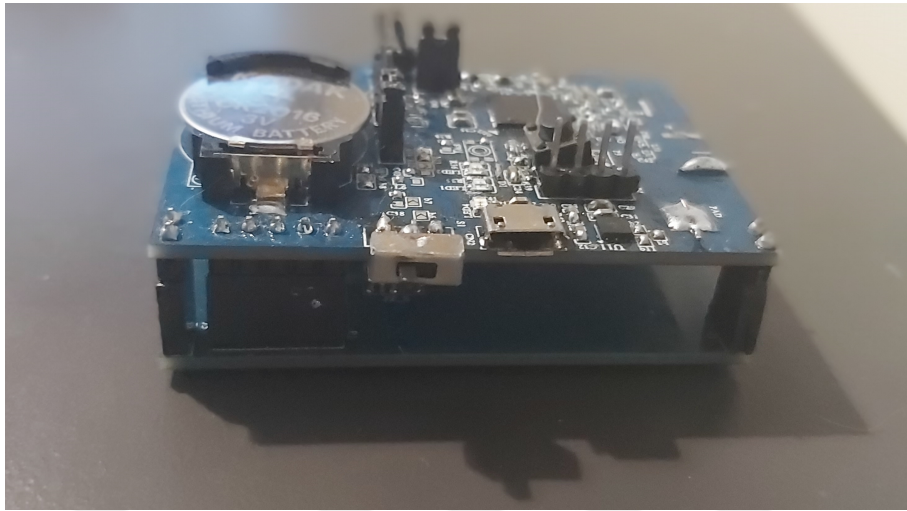


Figure 3.17: Two Layer PCB soldered

was making device portable and acquiring data from users via conductive cloth. By nature design requires 4 touching points. 2 points are required for skin resistance measurement and 2 points are needed for ECG measurement. We planned to cover 3d printed case via conductive cloths for this measurement part . Four of the conductive cloth pieces are placed on bottom of case and the conductive plate is placed on top of case for ECG measurement in both hand. The implementation can be seen in figure 3.18.

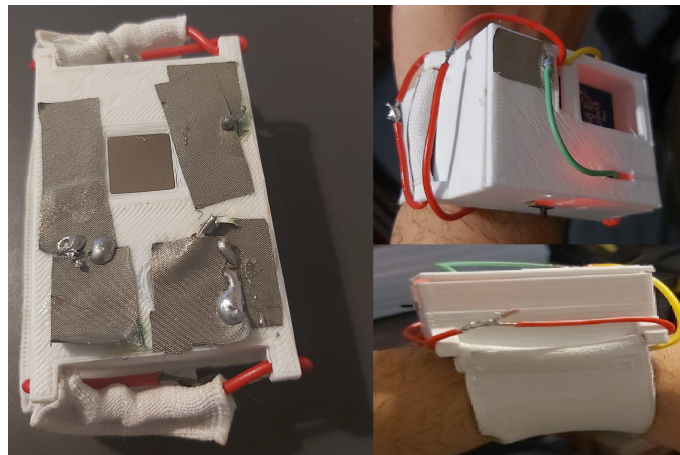


Figure 3.18: Two Layer PCB soldered

As seen in figure the PCB and the printed case required a huge volume. Because of the volume the device is not able to measure sensor features effectively.

• Precision Problems

When the designed prototype is placed in the case, more deviations than expected values were observed in the measurements. It was thought that the reason for these measurement errors was the inability of the conductive cloth to touch the skin sufficiently and the conductivity problems caused by the bulkiness of the case. Apart from these reasons, the headers used for transmission between the cards, which are 2 pieces, have an antenna effect and create noise on sensor values. This led us to a single card design. In the new design, it was decided to include the design in a synthetic leather cloth instead of a box.

3.1.5 PCB Bracelet Implementation

It was decided that a new design should be made based on the previous design and the handmade circuit. For doing this, the test points for the previous circuit were removed, the layout of the design was made more regular and the whole circuit was fit into a single board. The processor, USB to TTL chip and power circuit were placed on the front of the card as can be seen in figure 3.19. On the back of the

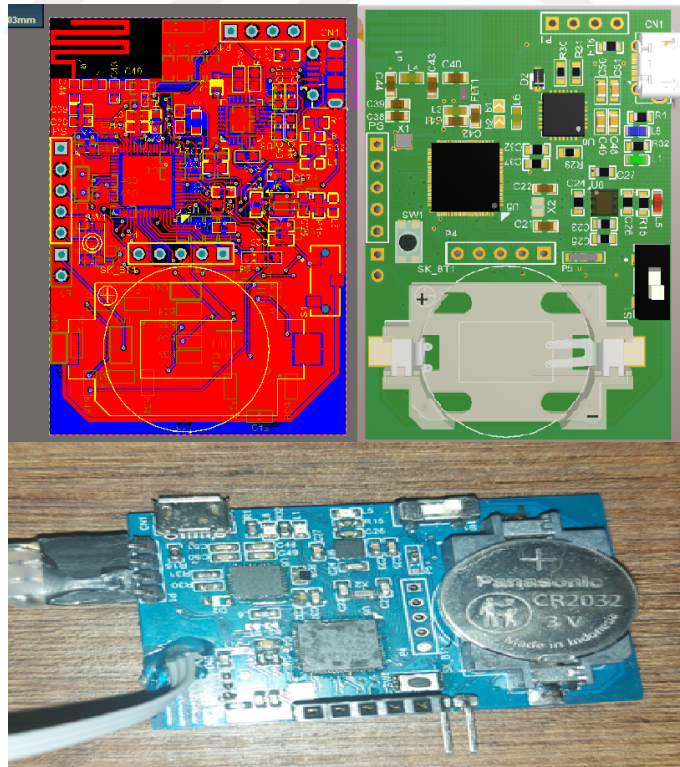


Figure 3.19: Single Layer PCB front end.

card, the GSR sensor, the sensor that measures the heartbeat and SPO2 value in

the blood, the sensor that receives the ECG data and finally the temperature sensor are placed. Apart from these sensors, one display socket was placed on the board. It is designed to be used to convey the video card data and the communicate the status of the card to the users. The bottom layer can be seen in figure 3.20.

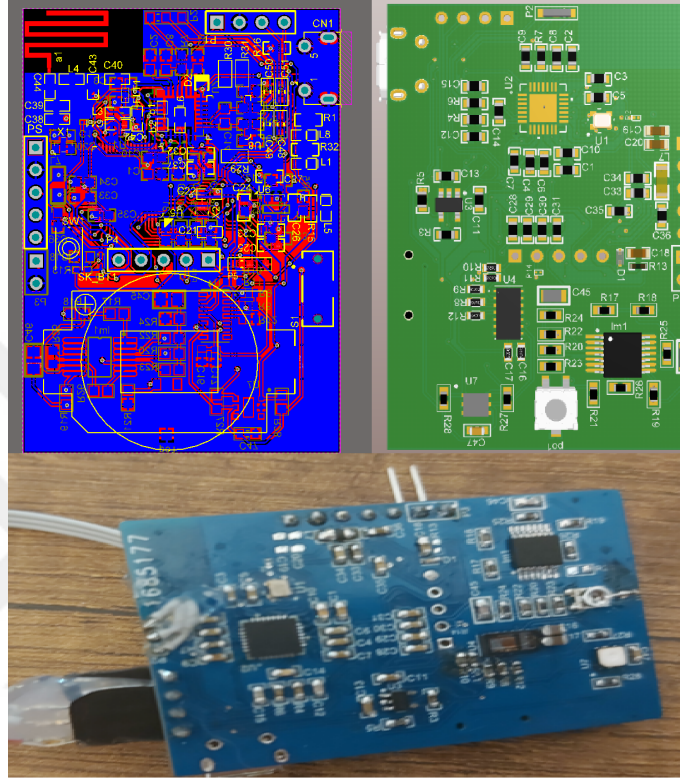


Figure 3.20: Two Layer PCB soldered

After the layout of the design, it was decided that the most suitable way for the design would be a bracelet to be created with synthetic leather. For this the bracelet shown in the figure 3.21 was designed with the help of a tailor.

The features of the designed bracelet are as follows. 4 metal plates were placed on the lower surface of the design. With these plates, skin contact was provided, almost like a metal button. Cable was pulled from the inner surface of each plate for communication with the corresponding sensor. A hole was drilled for the temperature sensor and the heartbeat SPO2 sensor. On the upper surface of the design, a metal plate and a screen cell were placed. The metal plate was placed for use of two separate arms during ECG measurements. The screen pocket is placed for users to monitor the status of their embedded device. The result of the bracelet can be observed in the figure 3.22.



Figure 3.21: Two Layer PCB soldered

3.2 SMART WRISTBAND EMBEDDED CODE DESIGN

To develop the embedded code , C language is used. The micro-controllers officially supported IDE (Atollic True Studio) is selected.

All the codes reside in the projects GitHub page [link](#) . In the code design we are using two main process which are;

A BLE Related:

For wireless communication Bluetooth low energy 5.0 is used. The selected MCU has wide range in terms of communication distance. The MCU stores BLE stack inside its dual core. One core is dedicated for ble applications and the other core is for peripherals. Each bluetooth service and character are stored in internal memory of MCU.

When MCU powers up it displays “WSMART” message. The program advertise for 3 minutes, if no client connects the server the device moves to sleep mode.

If a client connects to the device, user gets BLE GAT characteristics and services in their apps. For the embedded part user can see the message “CONNECTED”



Figure 3.22: Two Layer PCB soldered

on the screen.

The embedded code has one primary service which has the UID “94538aee-dd71-11e0-8a34-2a2ae2dbcce4”. The screen and service name are shown in figure 3.24.

Inside this service we store five characteristics. Four characteristics are for four different sensor data and one for collecting all data from sensors for mobile application. The four characteristics are explained below.

B Sensor Related

There are five sensors in the smart wristband system. One of these sensors is the GSR sensor, which measures skin resistance. This sensor converts the

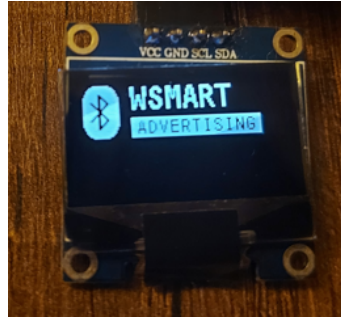


Figure 3.23: Oled Advertising Mode

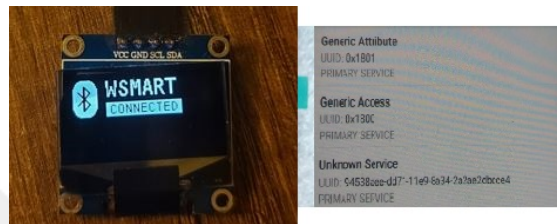


Figure 3.24: Oled Connected Mode And Primary Service

signals coming from the user to analog voltage and transmits it to the micro controller as analog voltage. The energy consumed is around 220uA on average. Another sensor is the one that outputs ECG data. The name of the sensor is Max30003. This sensor works with low power consumption. The average power consumption of the sensor is around 100uA. This sensor receives data from three probes touching the skin and transmit these data to the micro controller with the SPI protocol and stores in the FIFO. On average, it transmits 15-30 shorts of data to the micro controller in each reading. Another sensor (SI7021) is the one that transmits temperature and humidity data. This sensor gives both humidity and temperature data using the i2C protocol. The average power consumption of the sensor is around 150uA. MAX30102 sensor, which gives the heart rate and the amount of oxygen in the blood using the I2C protocol. This sensor gives LED light to the skin of the users and measures the reflection. It measures the average amount of oxygen in the blood through the incoming reflection and determines whether there is a pulse. The average power consumption of the sensor is around 600-800uA. Apart from these sensors, there is an OLED screen in the system. This screen communicates using i2c and thanks to this screen, users can see the status of the system and the value of the sensor data. This screen is the most power consuming element of the system, on average it figures a power consumption of around 26.1mA.

The embedded system screen contains six screen types according to the messages coming from the mobile application. These screens and the work they do in the background, respectively, are explained below.

- **Off screen**

It is desirable to run wearable systems on batteries. The battery used in our design is not rechargeable due to volume constraints. For this reason, it is essential to control the power consumption. Among other components, Oled displays are the most power-consuming. These displays are paired with a radio button in the user interface to turn them off so that they consume less power for long-term measurements. Although the measurements continue when the command comes, the screen is turned off and the data flow is secured. The screenshot can be observed in the figure 3.25.

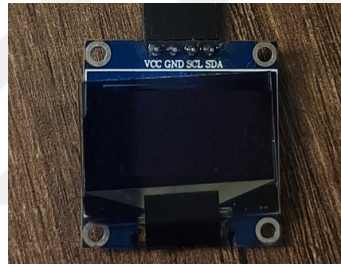


Figure 3.25: Oled off screen

- **ECG Screen**

When users press the ECG radio button on the mobile application, the embedded system runs the ECG screen. For this, values are read from the sensor FIFO, with the interrupt flag being set. The values read are expressed with 15-30 short data. These data are measured on the screen by means of an array and printed graphically. In addition to these data, the RR value provided by the sensor and the approximate measured BPM values are printed on the screen. When this screen is active, an image appears as in figure 3.26.

- **GSR Screen**



Figure 3.26: Oled ECG and RR values

When users press the GSR radio button on the mobile application, the embedded system runs the GSR screen. For this, the processor's ADC value is used. Since the signals to be received from the human skin are very weak, an amplifier circuit has been created by using cooperators. This circuit is obtained from the reverse engineered circuit diagram of the Grove sensor sold in the market. The obtained data is kept in the processor ram as 1 short value. These data are measured on the screen by means of an array and printed graphically. In addition to these data, the GSR value provided by the sensor and the approximate measured value are printed on the screen. When this screen is active, an image appears as in figure 3.27.



Figure 3.27: Oled GSR values

- **PPM and SPO2 Screen**

sensor data is read and printed on the screen. If a pulse is detected from the user, the heart icon on the screen will flash with each pulse beat, so that users can understand the data from the sensor. In addition, the average of the collected data is taken to calculate the oxygen value in the blood and the heartbeat. These values are kept in the processor memory as one byte PPM value, one byte SPO2 value and four byte led and infrared LED values of each. The data which measured on the screen by means of an array

and printed graphically. In addition to these data, the infrared LED value provided by the sensor is printed on the screen. When this screen is active, an image appears as in figure 3.28.

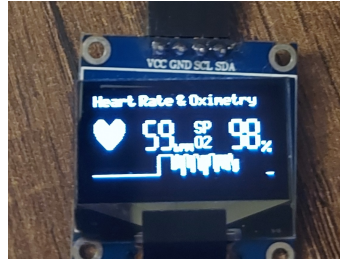


Figure 3.28: Oled Hr and SPO2 values

- **Temperature And Humidity Screen**

When users press the temperature and humidity radio button on the mobile application, the embedded system activates the temperature and humidity screen. For this, the sensor located on the bottom surface of the card is used. This sensor receives temperature and humidity information from the area on the contact surface. The pooling method is used when receiving this data. The sensor specifies the attribute it wants to read in each cycle to the sensor and checks it until the data is received. When the data is ready, it reads the relevant data and sets the next attribute. For example, firstly, temperature data is requested from the sensor, when the temperature data is ready, this value is read and humidity data is requested from the sensor. Since the speed of this process is faster than the sending speed of Bluetooth, both humidity and temperature data are displayed to users at the same time. A float value is assigned for both data in the processor memory. When this screen is active, an image appears as in figure 3.29.



Figure 3.29: Oled Humidity And Temperature

- **Data Collect**

When users press the data collect radio button on the mobile application, it runs the embedded data collect screen. In order to show the data flow to the users, a loader is placed on the screen and the data flow is shown. When this screen is active, an image appears as in figure 3.30.



Figure 3.30: Oled Data Collect and Characteristics

The embedded system combines all sensor data while sending data. After the system is connected to a mobile device, it sends data every 100 ms. Although a wide data band is used when packaging data, there is a risk of data loss in some sensors. For example, the measurement sensitivity range of the data in the temperature sensor, GSR sensor and SPO2 sensor does not exceed 100 ms, so it was sufficient to allocate a space equal to a data requirement for each. For the ECG sensor, the data flow is critical. The ECG data is kept in a queue structure within the system so that the graph to be formed is read correctly and no data is missed. This queue is designed for a maximum of 5 readings. When the system will broadcast the data, it sends the number of queue lengths and data and resets the queues. Thanks to this method, there is no disruption in the data flow and transmission is ensured.

3.3 SMART WRISTBAND SERVER CODE DESIGN

To collect store and show data to user a Java back end program is written. The code and the scripts can be found at this [link](#).

A How To Use Program

To operate the program user needs handle followings. The program runs on Ubuntu 18.04 operating system. In order to start program user need to download Java1.8 to their operating system. The program requires MongoDB database. The java program connects database via a url which provided by MongoDB. For each type of sensor an entity classes created. This entity classes stores retrieved data from sensors.

In order to start program user need to create a base directory. Various file directories must be created in the created directory including bin , conf, scrip and logs.

Inside in the script directory user need to place “run.sh” and “kill.sh” these two scripts for starting and stopping the “ble smart watch server” program. In “run.sh” which is located at this [path](#). For each user the path of script must be adjusted.

```
#!/bin/bash

BASE_PATH = /home/localFolder/smart_watch_server
BIN_BASE_PATH = $BASE_PATH/bin
CONF_PATH = $BASE_PATH/conf
JAR_NAME =smart_watch_server.jar
NOHUP_OUT_PATH =./logs/nohup.out
echo "INFO: Base path:['$BASE_PATH'] bin path:['$BIN_PATH'] conf
path:['$CONF_PATH']"
if ps -ef | grep "$JAR_NAME" | grep -v "grep" >/dev/null
then
    echo "Process $JAR_NAME is already running!"
else
    nohup java -Dfile.encoding=UTF-8 -jar $BIN_PATH/$JAR_NAME
$CONF_PATH/log4j.xml $CONF_PATH/ 2>&1 >> $NOHUP_OUT_PATH&
fi
```

Figure 3.31: Start Script

The program looks for the jar and “conf” files which stated above. After that it check the program is active (to avoid to create multiple process) and starts the program. In “kill.sh” which is located at this [path](#). For using this script user

```
#!/bin/bash

JAR_NAME=smart_watch_server.jar
out=`ps -ef | grep java | grep $JAR_NAME | grep -v grep | awk '{print $2}'`
processes=`ps -ef | grep java | grep $JAR_NAME | grep -v grep | awk '{print
$2}' | wc -l`
if [[ $processes -gt 0 ]]
Then
    echo Killing $JAR_NAME process: $out
    kill $out
else
    echo No $JAR_NAME processes found...
fi
```

Figure 3.32: Stop Script

need to specify the jar name. The script search the jar name and if its found

the jar it terminates the process. Otherwise it warns users. Inside in “conf” directory program search for 3 files which are “application.properties”, “log4j.dtd”, “lo4j.xml”. The “application.properties” is for specifying the parameters for database, controller and email sender information adjustment to run program user need to specify on application properties file.

B The Explanation of Program

The program is written in Java 1.8 language. For framework spring boot, smtp-mail, mongodb, log4j, restfull-web services, java-excel are used.

The connections between frameworks handled by spring boot default services. The program able to connect via restful web service. The program able to handle multiple connection in same time.

For real time stream a queue system implemented on back-end server. For 4 type of sensor chip 4 different separate thread safe queue added on back-end server. If online data stream activated the mobile device feed the queue within 1 second interval. Thanks to that logic smart wristband website can dequeue data via provided endpoint of rest API.

3.4 SMART WRISTBAND MOBIL APPLICATION CODE DESIGN

In order to communicate with embedded design, an android application is created. When application is up it searches a device which has “WSMART” as Bluetooth name. After that it start to follow this procedure which shown in figure 3.33

As seen in the diagram, the application first searches for the Bluetooth device named "WSMART". When the device is found, the application opens the main screen to show the sensor data to the users and process the sensor data.

The embedded device sends a total of 485 bytes of data to the mobile device via Bluetooth, normally Bluetooth low energy sends 20 bytes of data. Thanks to this number of transmissions, energy savings are achieved. When the application provides a connection, the mobile device sends an MTU request to the embedded system, increasing this number to the maximum number of 517. In this way, the embedded system combines the sensor data and sends it at once.

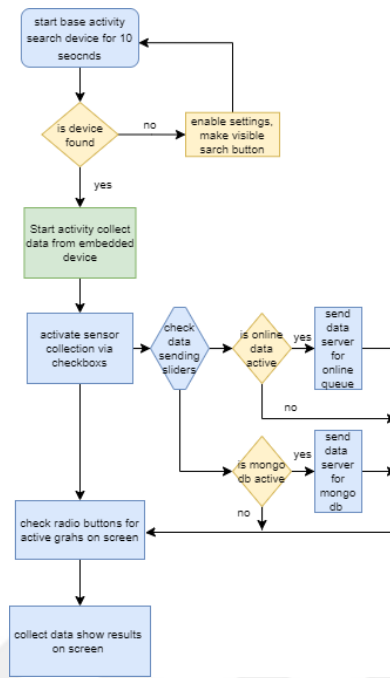


Figure 3.33: Android App Schema

After the mobile application receives the data, it maps each data to an object embedded in the code. As soon as the application starts to receive data from the sensor, it decides which data to process from the embedded system with the help of the check boxes inside. As seen in the figure 3.34, all check boxes are active by default. Users can obtain the data they do not want to see or send to the server by closing the relevant checkbox.

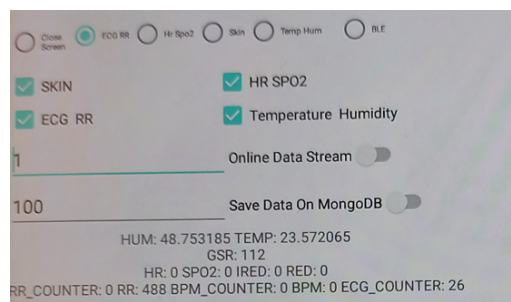


Figure 3.34: Android App Default Scheme

There are 2 sliders on the application. These sliders decide how to communicate with the backend java application running on the server. As communication, mobile application and backend java application communicate over the internet thanks to REST API. If online data stream is active, the application formats a certain amount of data as composite bytes and sends it to the live data queue in backend java via

rest api. If save data on MongoDB is active, the application packs and sends a certain amount of data to be saved to the MongoDB server.

There are 6 radio buttons on the application. These buttons have 2 functions. The 1st task of the selected radio button sends one byte of data to the embedded system. In the sent byte, information is given which sensor should appear on the screen of the embedded system. The second task is to show which sensor's data will be plotted on the application. In the figure 3.35 shown in the example, the radio button showing the person's ECG data is selected and its graphic is seen.

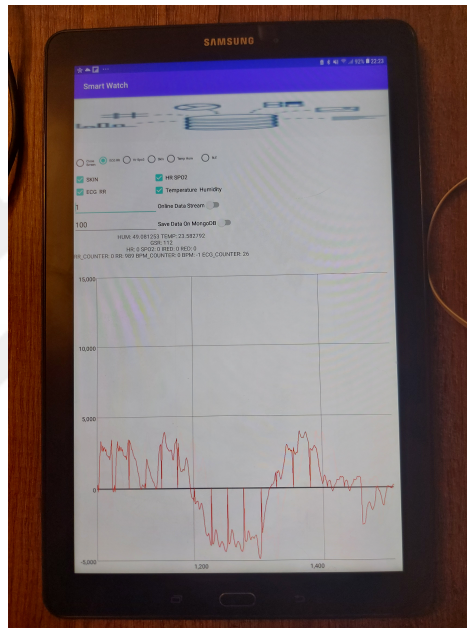


Figure 3.35: Android App ECG Graphs

3.5 SMART WRISTBAND WEBSITE DESIGN

The aim of the website design is showing users the information of wristband embedded system data. In the database the data stored as raw data which has feature of on time/date, user information(name, surname, age, height, weight). Our web designs work is caching the database data and show the data to user with a graphical user interface.

The algorithm communicates with back-end java server code by REST API and it

shows the results on users via a public URL. The user can observe all the raw data which collected from our embedded design.

3.6 Technical Details of Web Site

To design of web site adjusted based on our researches. We decided that the best option is using a very well-known front-end language which is JavaScript.

JavaScript is dominating the web area, thus it is easy to find documentations and tutorials. To handle website more creatively we select a framework which has named VueJS.

VueJs is one of major JavaScript framework for building user interfaces. Thanks to VueJs user makes interactive User interfaces. Beside of that designs in VueJs has simple views for each state in your application, and VueJs will efficiently update and render just the right components when your data changes.

When program loads on DOM, user need to decide whether observe real time data or data from server. The general view of website can be seen in following figure 3.36 if real time selected user need to select which sensor data should print DOM screen.



Figure 3.36: Main Page Smart Watch Website

The selected data received directly from embedded system via queuing logic. The

queuing logic receives data from embedded device to back-end code. The server code queue the data. Then when website request the data from server one of the queued data send to website with a decided interval which can selected via slider on website. figure 3.37



Figure 3.37: Real time data selection

As long as data streams are live on internet user able to see the real sensor data on a ongoing graph data. The embedded device combines data en every 100 ms on mobile phone and the mobile transmit the data to server in ever 1 second as combined data concatenated. The front-end application basically call the rest API based on the time which come from slider such as 500 ms call interval if slider shows 500. After receiving data packet front end API decode the message and concatenate the data on a array to show user as sliding graph figure 3.38

If user would like to check stored/downloaded data they need to select a time from date picker, make sure that online data stream is closed and press the relative button which can responsible for either retrieve and showing data to user or downloading the relative data as an excel sheet.

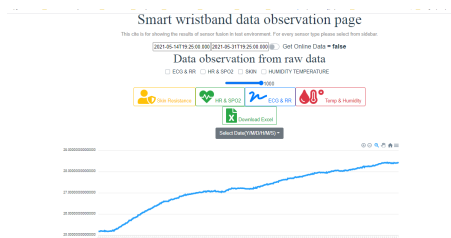


Figure 3.38: Data from server

When user presses the relative button such as, HR and SPO2 the program collects all data from server between the time interval. The collected data stored on a array list in order to give user chance to select which period showed on graph thanks to

Select Date drop down shown in figure 3.39 For further works and machine learning

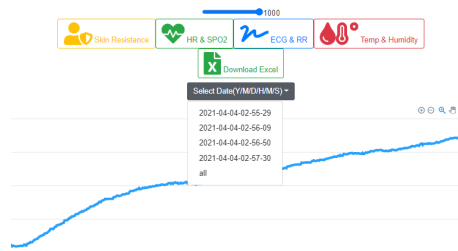


Figure 3.39: Data interval selection

user can get data with an excel sheet for selected interval. Depends on the checkbox user able determine the sensor type and download relative data into local machine.

4 EXPERIMENTS AND RESULTS

We started our tests with the handmade bracelet that we have. We first transmitted the test data from the embedded system to the mobile device with the help of Bluetooth 5.0. 485 bytes of data transmission was provided in each transmission. The reason for the difference here is the difference between the propagation speed of Bluetooth and the data reading of the sensors. Since the embedded system obtained more than one data until each transmission, we added the data from the sensors one on top of the other and transmitted them to the mobile device. During our tests, we noticed that there were some delays as wireless communication was used during data transmission. In order to solve this, we parse each incoming data packet on the mobile side and assign each of the sensor objects we use to a queue. Thus, we prevented irregular time shifts between the producer side and the consumer side of the queue. The figure test beginning of test show us how we started to collect data.



Figure 4.1: Beginning of test sequence

We used mongoDB which provided by google as the intermediary platform to save

the data. The mobile device formatted the data which received from the embedded system in json format and sent it to mongoDB servers on the cloud. We used the graphic drawing features provided by the server to examine the data recorded data.

During data collection, we conducted two-stage tests, The first scenario was carried out by 4 volunteers repeating a specific scenario and taking measurements, the second scenario was performed by taking data from a person by repeating movements in different positions.

4.0.1 First Scenario

We had 4 voluntary participants on the first scenario, 3 men and 1 woman. The physical characteristics of the participants are given in the table 4.1.

Volunteers Information				
Person Gender	Person Age	Person Weight	Person Height	Person Major
Male	30	85	172	Electrical Engineer
Male	31	94	174	Computer Engineer
Male	44	75	176	Doctor
Female	30	85	160	Kindergarten Teacher

Table 4.1: Volunteers Information.

In order to compare the measurements, each participant was asked to do the same task. The test was basically designed to make people relax first and then take actions that will increase their stress level. For this, they were asked to relax for 2 minutes, relax and stay away from stress. After the relaxation phase, participants were asked to subtract backwards, for example counting from 200 by subtracting 19 backwards. This subtraction was continued for 45 seconds. In the third stage, a task was chosen to challenge the verbal abilities of the users rather than their numerical abilities, for example, a sample word was given to the users, and they

were asked to derive a word from the last letter of the word and repeat this process for 45 seconds. In the last phase, users were asked to multiply by complementary numbers. For example, multiplying by counting back to one hundred would be ninety-nine times one, ninety-eight times two, ninety-seven times 3, and so on. This process was repeated for 45 seconds. Each participant repeated the same tests twice, the first of which was measured and recorded by the skin resistance sensor, and the other was measured and recorded by the ECG sensor. In the measurements made, it was observed that the people exhibited a balanced and stable resistance during the resting phases, and the reactions of the bodies in the stress processes changed according to the occupational background. For example as seen in the figure 4.2, fluctuations in the graphs were observed in our volunteers with a mathematical background, who tried to carefully perform the mathematical operations we wanted after listening. These changes occur depending on the difficulties and dealings of people in transactions. In verbal word-oriented tasks, the graphs fluctuated in our doctor and teacher candidates, who communicate in daily life and have a heavy verbal aspect. This has shown us that the change in the attention of people according to their interests and occupations, and therefore the change in their stress, triggers the change in the graphics. In our second set of tests in the figure 4.3, the graphics



Figure 4.2: The result of GSR stress testing.

of the users were generally similar. The difference between the graphs manifested itself in the form of a fluctuation in each state change, for example, a momentary fluctuation during the transition from the resting stage to the mathematical or verbal processing, then in the form of a steady state. In our opinion, long data should be collected and machine learning should be applied in order to observe the situation change with Ecg.



Figure 4.3: The result of ECG stress testing.

4.0.2 Second Scenario

We collected data in 3 different situations , these are sitting, standing, and standing and running.

For this, we made our investigations based on sensor graphics. First, we examined the temperature and humidity sensor. Based on the data from the sensor, as can be seen in the figure 4.4 , the temperature of the person increased and the humidity of the environment decreased with the increase in movement.

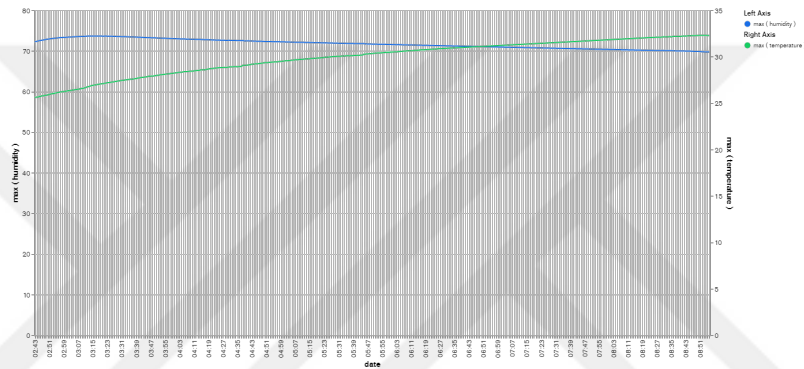


Figure 4.4: Testing of temperature and humidity.

The second sensor we examined is the skin resistance sensor. There have been observable changes in the sensor graphics depending on the person's movement. When the test is started, the person is in a sitting position, and data is taken at the level of approximately 80-85 mV by the graph. Here, as the movement increased, certain breaks occurred in the resistance level of the person. Since the person stood up, the data read by the sensor decreased. This decrease regressed to 0 level with the transition to the running phase. Here the sensor reads 8 bits of data. In order to increase the sensitivity in further tests, it is necessary to increase this data reading set to 10 or 12 bits.

As seen in the figure 4.5 we calculated the mean of data in definite period.

Another sensor we use on the system is the sensor that gives the amount of oxygen in the blood and the heart rate values. In our tests this sensor, we have seen that in order to measure oxygen, it is sufficient for the sensor to touch the skin however, for

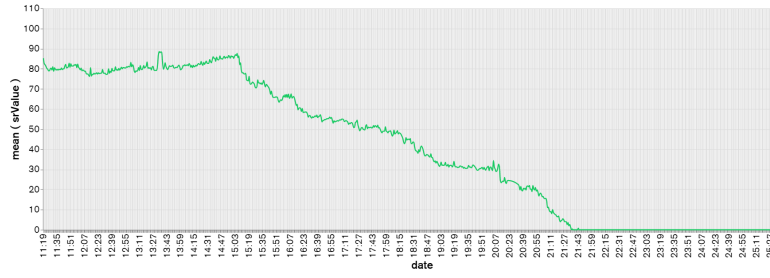


Figure 4.5: Testing of skin resistance.

measuring heartbeat value , a certain pressure must be applied to the skin. Since we can receive data from the wrist here, we can provide skin contact here, but we cannot obtain enough pressure at the moment. For this, we calculated and graphed the oxygen value we obtained from the system as a percentage which can be seen in figure 4.6, but instead of heartbeat, we tried to extract the attribute by passing the raw data from the sensors through various filters. As seen in the data the saturation

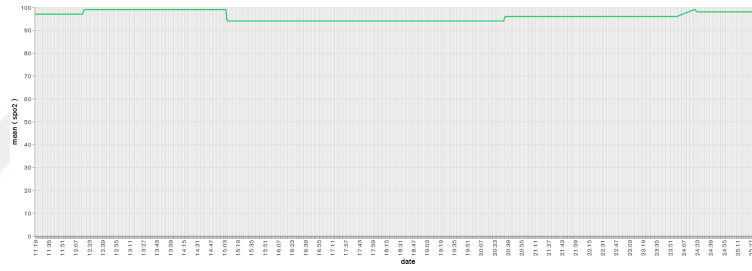


Figure 4.6: Testing of oxygen measurement.

level is standing until person change movement position sting to standing. After a certain degree in oxygen level when person start to running level increased to same amount.

For heartbeat the studies carried out that the relations of the data with each other are suitable to extract features from raw data. In order to find the feature from raw data , we examined the ir, and r values, that is, the sent and return signals from the sensor. Here we looked at both the max and min values as well as the standard deviations and variance of the estimated heart rate calculated from embedded system. It was observed that the projections of the graphs changed according to movement relatively.

The last sensor we tested is the max3003 sensor, which provides us with the ECG and RR values. When we analyzed the data of this sensor via MongoDB server, the

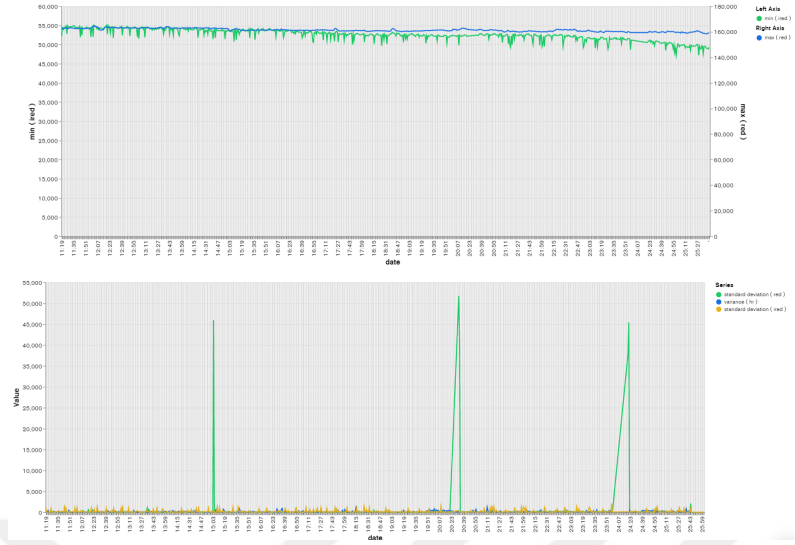


Figure 4.7: The result of feature extraction.

graphics we obtained unfortunately did not come as we wanted. This is because our sensor currently produces 128 sps of data and the server can display the data on the screen in a minimum of seconds. In order to give an approach, we got mean of the data we obtained from device. We showed the graph of the data form server and mobile device which obtained with millisecond level. For stable results We will need to collect large-scale data so that we can examine the data on the server.

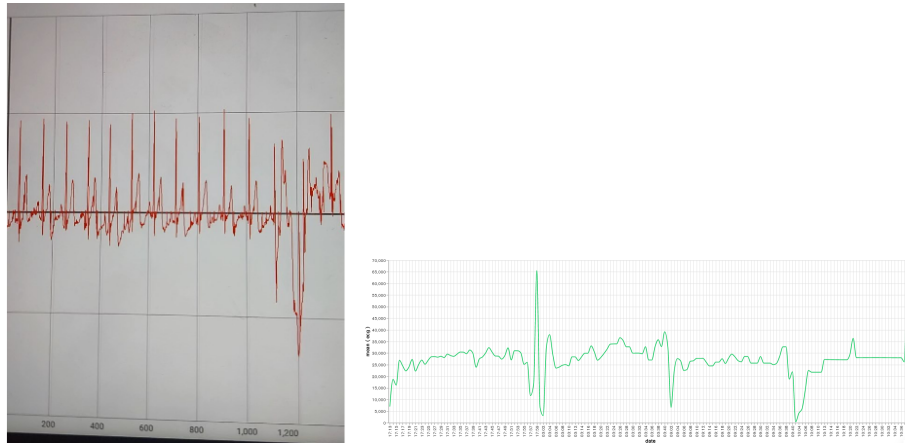


Figure 4.8: The result ecg sensor on mobile and server.

Thanks to Bluetooth low energy the device, we can collect data 3-4 days without any interrupt. The communication range of data is tested between 3-5 meter. Because of this we are able to feed any kind of machine learning algorithm with raw data.

5 CONCLUSION

In summary, the work reported here illustrates that the implementation of a physiological data collector on an wearable device. The resulting quality show us this system can measure high quality data in terms of feature extraction. The wearable device offers enhanced hardware options thus with developing of sensor technology the devices capabilities can be increased. The smart wristband based on a fusion of several sensor data which are HR, SPO2 , ECG ,RR, Temperature, Humidity, Galvanic Skin Response. Beside of that the implementation of Bluetooth low-energy made the device a IOT device thus the mobility of usage widely increased. The design and implementation made because we want to collect data and extract features from users in their daily life activities. In our early implementation we partially achieve our goals for testing.

Since the hardware and software handled by us this device can be implemented several outfit for different cases such as divers or climbers etc. Based on implementation the wristband could be change and implement any part of wearable devices. Based on wearable requirements the software and hardware could be altered easily. For further use and development all the project blueprints and software published on GitHub account.

One of the benefit of design is data security, in this decade one of the most important thing is data. Currently all monitoring systems handled by big corporate firms. As users we don't know how they store and how they use this user physiological data features. In our system all the data stored in securely in our servers since the embedded code and mobile code is published online user will know the data flow from embedded device to server.

The wristbands currently on the market have one main problem. Companies have to make their size as small as possible in order to make a watch with style. In our

design, the aim is to collect the data of individuals. For this reason, there is no restriction on size and hence battery space. Since the battery area is large, there is no measurement constraint to collect data in the design. Because of that we can take the sampling frequency and measurement on sensors to a larger scale data collection. For example, inside in Apples watch the ECG sensors sampling rate provided by the Apple [company](#) has been stated as approximately 238 sps, in our design we can go up to 512 samples because our limits are wide interms of power consumption.

In this work in order to collaborate with further research we made all the resource available on public GitHub address, any user can be access our codes and design from this [link](#).

Exploring these options, integrating precision of measurements and wireless data transmission capabilities into the smart-wristband represents promising directions for future research. Such technology would build on advances in bio-tracking, emotional states and ubiquitous healthcare.

6 FUTURE WORKS

Currently the developed system can handle data uploads in 100 millisecond data intervals. We are able to share all sensor information in each cycles with wireless transmission. In this interval we are able to propagate all the sensor data however, we cannot store data inside in our design. In the future we are planing to store the data inside in device for long term data collection. Thanks to that we can achieve a big data more rapidly and we can feed the data for machine learning algorithms

In our tests, we had the opportunity to examine the data of people, and we want to do this with more people and big data, so we think that we can do a more precise situation analysis.

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BIOGRAPHICAL SKETCH

Cagri CANDAN completed his bachelor degree as an Electrical and Electronics Engineer in 2015. He specialized in embedded PCB design, embedded software, and back-end software development. Cagri CANDAN has been in software development since 2015.

