SMARTWATCH ECG

A THESIS SUBMITTED TO THE GRADUATE
SCHOOL OF APPLIED SCIENCES
OF
NEAR EAST UNIVERSITY

By
MURAT SERTEL

In Partial Fulfillment of the Requirements
for the Degree of Master of Science
in
Biomedical Engineering

NICOSIA,2021

SMARTWATCH ECG

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

**By
MURAT SERTEL**

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Biomedical Engineering

NICOSIA, 2021

Murat SERTEL: SMARTWATCH ECG

Approval of the Director of the Graduate Education Institute

Prof. Dr. K.Hüsnü Can BAŞER

We certify this thesis is satisfactory for the award of the degree of Master of Sciences in Biomedical Engineering

Examming Committee in Charge:

Prof.Dr. Ayşe Günay Kibarer   Supervisor, Head of the Department of Biomedical Engineering, NEU

Yrd. Doç. Dr. Elbrus Imanov   Committee Chairman, Computer Engineering, NEU

Doç. Dr. Sertan Serte   Electrical and Electronic Engineering, NEU

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

.

Name, Last name: Murat Sertel

Signature:

Date:21/01/2021

ACKNOWLEDGMENTS

First of all, I would like to thank Prof. Dr. Ayşe Günay KİBARER who guided and guided us through our project and shared the necessary information with me. I would like to thank Mehmet KESKİNER and Akın ŞENKUL, Biomedical engineer in Near East University Hospital, who helped me with my project thinking and exchanged ideas with us. I would like to thank my dear teacher Dr.Ali IŞIN for their help

Finally, ı would like to thank Mehmet Nuri BOLAT, who helped me a lot in software field in my project.

ABSTRACT

Our project is the wireless connection of a smart watch with an ECG sensor and electrodes placed in the chest area. Purpose of the project; Biological signs are taken from the chest area with the help of electrodes. It is to find the difference of biological signals between electrodes and to transmit the signal wirelessly by amplifying that signal and converting it to digital signals with the help of a microprocessor. To obtain the signal at the frequency we want by filtering this signal with the help of a microprocessor. Our idea of doing this project is that patients who have many heart diseases, heart attack conditions or need to be followed up constantly, can continue their daily life while being monitored instantly without being attached to the hospital. In this way, reducing the manpower needed while increasing the life comfort of the patients. When we bring this device to the level we want, for example, elderly people, people with pacemakers or people with problems in their coronary vessels can be monitored instantly using this device. In emergency situations that even the patients cannot understand, it can be contacted with the patient via remote access and the necessary precautions can be taken and life can be saved. In emergency situations such as a heart attack, the device can directly contact the hospital and an ambulance can be called to the patient's location. Elderly monitoring system can be made with a few sensors that can be added to the device. A pressure sensor can be used for blood pressure measurement, and a motion sensor can be placed in cases where ECG electrodes are disconnected or a pulse cannot be obtained. This sensor may indicate that an emergency situation may also occur if there is no movement for a certain period of time. Older people who are left alone with such things can lead a more secure life. In short, the design of this device is aimed for early diagnosis and treatment by making human life more comfortable. It aims to even provide the opportunity to treat patients regardless of the hospital environment.

Keywords: ECG, LCD, Arduino, ESP32S module, Defibrillator, Sensor

ÖZET

Bizim projemiz göğüs bölgesine yerleştirilen bir EKG sensörü ve elektrodlarla, bir akıllı saatin kablosuz bağlanmasıdır. Projedeki amaç; göğüs bölgesinden elektrotlar yardımıyla biyolojik işaretler alınır. Biyolojik işaretlerin elektrotlar arası farkını bularak, o sinyali yükselterek bir mikroişlemci yardımyla sayısal işaretlere çevirerek kablosuz şekilde sinyali aktarmasıdır. Bu sinyali yine mikroişlemci yardımıyla filtreleyerek istediğimiz frekansta sinyali elde etmek. Bizim bu projeyi yapma düşüncemiz, günümüzde bir çok kalp hastalıkları yaşayan, kalp krizi durumları veya sürekli takip edilmesi gereken hastaların hastaneye bağlı kalmadan anlık takibi yapılırken günlük yaşantısına devam edebilmesi. Bu sayede hastaların yaşam konforunu arttırırken gerek duyulan insan gücünüde azaltmak. Bu cihazı istediğimiz seviyeye getirdiğimiz zaman, örneğin yaşlı insanlar, kalp pili olan insanlar veya kroner damarlarında sıkıntı olan insanlar bu cihazı kullanarak anlık takibi yapılabilecek. Hastaların bile anlayamacağı acil durumlarda uzaktan erişimle hastayla iritibata geçerek gereken önlemlerin alınması sağlanıp hayat kurtarılabilir. Kalp krizi gibi acil durumlarda cihaz direk hastaneyle iletişime geçip hastanın bulunduğu konuma ambulans çağırılabilir. Cihaza eklenebilecek birkaç sensörle yaşlı takip sistemi yapılabilir. Tansiyon ölçümü için bir basınç sensörü, EKG elektrodların çıkma veya nabız alınamadığı durumlarda, bir hareket sensörü konulabilir. Bu sensör belli bir süre hareketsiz kalındığında da acil bir durum olabileceğini belirtebilir. Bu gibi şeylerle yanlız kalan yaşlılar daha güvenilir bir hayat sürebilir. Kısaca bu cihazın tasarımı insan hayatını daha konforlu hale getirerek, erken tanı tedavi için amaçlanmıştır. Hastaları hastane ortamına bağlı kalmadan tedavi edebilme imkanı dahi sağlabilmeyi hedeflemiştir.

Anahtar kelimeler: EKG, LCD, Arduino, ESP32S modül, Defibrilatör, Sensör

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

ECG: Electrocardiogram

EMG: Electromyography

EEG: Electroencephalography

NACL: Table salt or sodium chloride

kg: Kilogram

km: Kilometer

µV: Microvolt

mV: Milivolt

ml/s: Unit of speed in millimeters advancing per second

^{o}C: Centigrade

mmHg: Millimeters of mercury, torr, pressure unit

hz: Hertz

DC: Direct current

LCD: Liquid Crystal Display

GPS: Global Positioning System

CHAPTER 1
INTRODUCTION

1.1 What is the ecg?

ECG is to obtain images of heart movements in order to obtain information and interpret about cardiovascular diseases, that is, suspicious conditions related to the heart and blood vessels, the conditions and functioning of the heart and vessels in the body. At the same time, the short duration of the shots and the easy shooting allow them to be made to every person. Rhythm disturbances in the heart are visible and detectable on ECG. Thanks to the electric potential in the human body, ECG is recorded. The effect of the electrical attraction created by the heart on the body surface and the changes in the heart in this context are recorded with ECG. ECG electrodes are placed on certain parts of the ankle, wrist and chest while shooting. Electrodes cannot be placed in different places according to the head, each region has a situation, function and meaning. (Alpman,2011) After ECG recording, heart rhythm signals are transferred on paper, then interpreted and evaluated by doctors. ECG cables have names according to the region where they are placed. DI cable measures the potential difference between the left wrist and the right wrist. The DII cable measures the potential difference between the right ankle and the left ankle (Eneyli,2014).
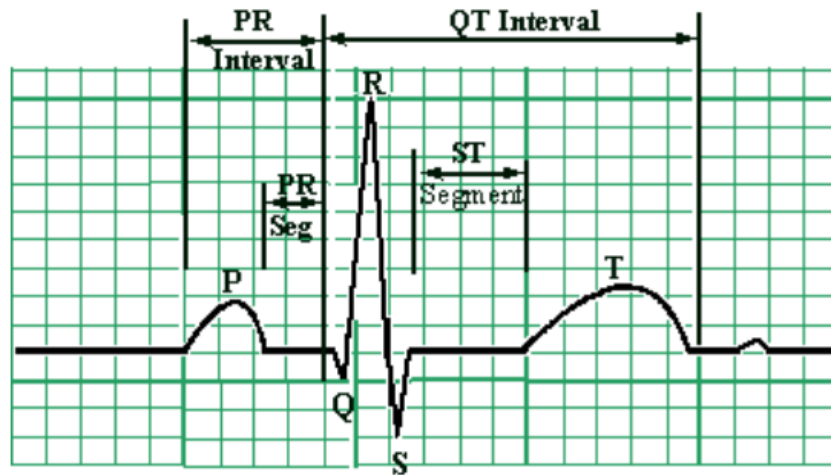
1.1.1 ECG Signal:

Figure 1.1: ECG signal. By looking at the shapes of these waves and the lengths of the intervals, we can examine the electrical events in the heart (Akbulut, 2013).

1.1.2 P Wave:

It shows the positive deviation in the ECG signal. It is also the first wave to occur and this is called deflection. It spreads to the myocardium first during the electrical activation p wave and then to all parts. First, a p wave is formed in the right atrium and then depolarization occurs in the left atrium. If the P wave is not in its normal state, cardiovascular mortality increases and certain disturbances occur when the P wave is absent. In the absence of P waves, nodal rhythm and hyperkalaemia disturbances are seen in ECG recording (Akbulut, 2013).

A P wave should be steep in the aVF portion and in an upside-down position to show heart rhythm as a sinus rhythm in the VR portion. The relationship between P and QRS indicates cardiac arrhythmia. The shape and duration of the P wave provides information about atrial enlargement.

1.1.3 QRS Wave:

The R wave shows positive bias and the Q wave shows negative bias. With Q wave movement, doctors can diagnose myocardial infarction. The QRS signal process is the ventricular motion measurement process. With the measurement of ventricular depolarization, the QRS duration is obtained with the reflection of negative and positive deviations. Depolarization is divided into three; first stage from left to right, then these directions are equalized, this period may vary depending on the age of the patient (Akbulut, 2013).PR segment depression means atrial lesions or pericardia. The deviation of different morphologies of the P at the ECG tip can give the rhythm of pacemakers such as pacemakers or multifocal atrial tachycardia. The QRS wave is larger than the P wave because it contains more muscle than the ventricular atrium. In addition, with the increasing conduction velocity of the QRS wave, it takes a vertical structure instead of rolling.

1.1.4 T Wave:

It must be positive, it means that it is positive, ECG recording is normal. If negative, it means left ventricular hypertrophy and ischemia disorders.
Normal ST is slightly concave. It gives straight, slightly curved and reduced ST coronary ischemia. ST segment elevation gives heart muscle infarction. Often the T waves are positive but negative in lead aVR is normal. In addition, it is not common to obtain T waves in aVL or aVF. High or tented T signal gives hyperkalaemia(Akbulut, 2013).

1.1.5 U Wave:

This wave is not always visible. It is seen after the T wave. Typically it is small. U wave divergence shows a lower line deflection than the T wave. The U wave is thought to represent the repolarization of the Papillary muscle or Purkinje fibers. The U wave is in the chest area of V2-V3 cables. Abnormalities in U waves are observed in patients with hypokalemia. U wave reversal may mean cardiac muscle ischemia or left ventricular volume overload.

The QT wave varies from person to person. Because it varies according to the structure of women, men, young and old people. We learn the heart rate with PR waves.

Corrected QT can provide a diagnosis of long QT syndrome and short QT syndrome. The QT interval changes depending on the heart rate. The QT interval correction factor for heart rate was developed. This fix is Bazett (Akbulut, 2013).

1.2 Types of ECG:

Three types of ECG are common; ECG, Stress EKG and Holter EKG used in clinics

Figure 1.2: ECG (Google).

1.2.1 Holter ECG:

It is a small portable ECG type that continuously records cardiac activation for 1-2 days without affecting the normal life of the patient.

Figure 1.3: Holter ECG (Google).

1.2.2 Stress ECG:

It is the type of ECG that records the ECG activation of the patient on the treadmill or ergo bike.

ECG devices differ in the direction of the place, purpose and target they were used, and they are all similar in terms of general characteristics.

Figure 1.4: Stress ECG (Google).

1.2.3 ECG Device sections:

<u>Voltmeter:</u> It is the circuit structure that perceives body electro potentials with electrodes placed on the body.

<u>Filter:</u>It is a filter circuit structure that eliminates electrical activity outside of the heart.

<u>Amplifier:</u> The parts of the heart's electrical signals that reach the body surface are sensitive and low, this circuit structure amplifies the signal.

<u>Printer:</u> Thermal printers are generally used in writing the signals on paper. ECG paper is a structure that turns black against the heat. ECG is drawn on the paper, which is easily heated by electric current. It is also used in ECG devices with carbon, ink and optical systems (invention, 2016).

ECG Device display panel keys:
- Power on-off: start, stop
- Start, stop: start, end
- Auto, manual: automatic and manual recording
- Lead: select desired lead while manually
- Speed: recording speed

- Filter: filters alerts from different sources

1.2.4 Other different ECG types:

Multi-channel ECG, automatic or manual ECG, monitored ECG, commented ECG.

Parts of these devices; patient cable, EKG electrode, ECG paper, wireless network card, modem card.

Today, ECG devices are produced with different features with the advancement of technology; There are ECG devices with touch screen, comment chip, electrode non-contact, when the battery is low, when the ECG paper is exhausted, when the cover is open.

1.3 ECG Date:

Summary:

• The first ECG recording was obtained by Dutch physiologist Willem Einthoven (in 1895).

• The first person to apply the Q, P, R, S, T definitions in the ECG signal was again Willem Einthoven (1895).

• Willem Einthoven started to shoot EKG in 1905 in his laboratory, 1.5 km from the hospital. The ECG device was shot in Einthoven's laboratory and the patient was in the hospital 1.5 km away.

• Willem Einthoven first published normal and abnormal ECG recordings in 1906.

• At the same time, ECG recording from the esophagus was first made in 1906.

• Nicolai and Simmons first attempted to make ECG changes during Angina pectoris in 1909.

• Willem Einthoven was awarded the Nobel Prize in 1924 for inventing the EKG.

• Woldemar Mobitz (Mobitz type 1 and type 2) heart block classifications were published in 1924.

• The use of exercise ECG in the diagnosis of coronary artery disease was proposed for the first time by Goldhammer and Scherf in 1932.

• Chest electrodes were used for the first time in 1932 by Charles Wolferth and Francis Wood (Bronzio, 1995).
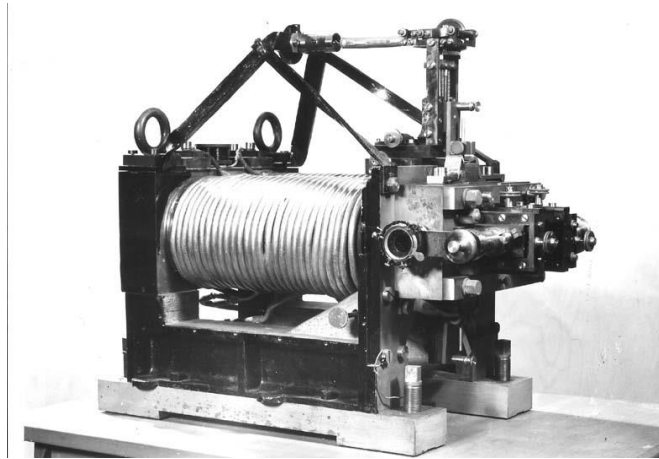
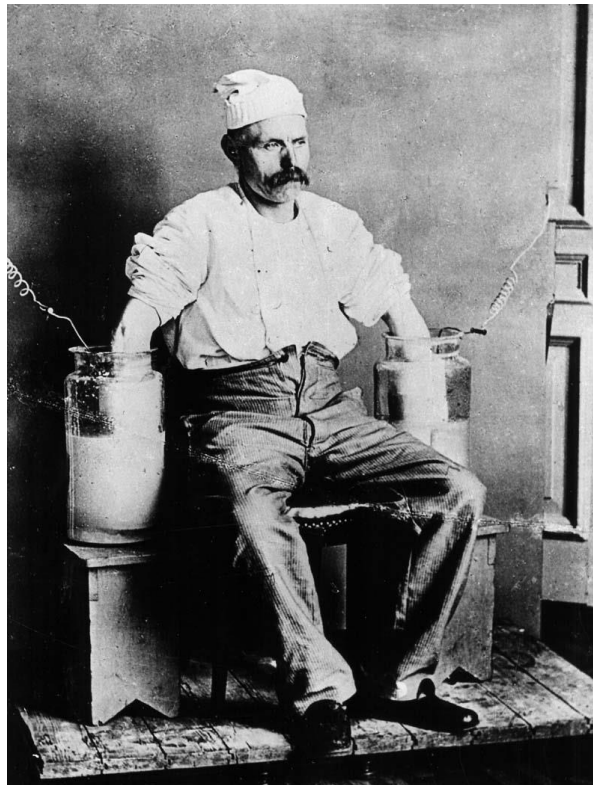**Figure 1.5:** Spring Galvanometer (Bronzio, 1995).

Figure 1.6: Since the first ECG records were not electrodes, measurements were made by immersing hands in NACL solution(Bronzio, 1995).

The ECG device was made by the Dutch physiologist and doctor Willem Einthoven in 1895 at the University of Leiden and was developed in 1903. In 1924, Einthoven was awarded the Nobel Prize in Medicine for the invention of EKG. The Leiden bottle was discovered in 1744. In this way, electricity has entered the field of medicine. Electricity is of great importance in the medical field. W. Gilbert, the doctor of the Queen of England (1st Elizabeth), wrote his book on static electricity in 1600. European doctors experimented with electricity thanks to the discovery of the Leiden flask. When the Italian biologist L. Galvani cut the frog's leg on the metal plate in 1780, the leg suddenly contracted. Another scientist saw the dead frog's leg move with an electrically charged bottle of leiden. L. Galvani thought that electricity is hidden in the leg of a dead frog and became famous for his books called animal electricity. Physics professor A. Volta proved that the movement of the leg is not caused by the dead frog, but because the blade and the metal plate are made of different metals. Volta produced the first electric battery in 1800 by placing cardboard with salt water between zinc and copper. Many people believed that electricity could cure some diseases and bring the dead back to life (Bronzio, 1995).
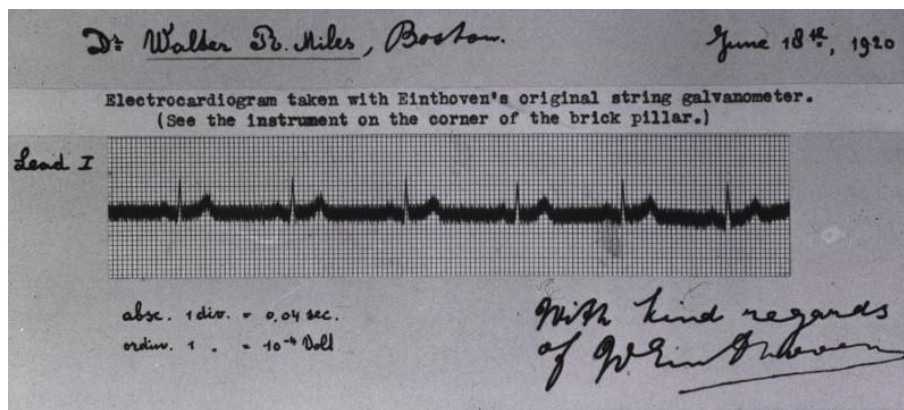

Figure 1.7: The first ECG signal recorded by Einthoven's original Spring Galvanometer (Bronzio, 1995).
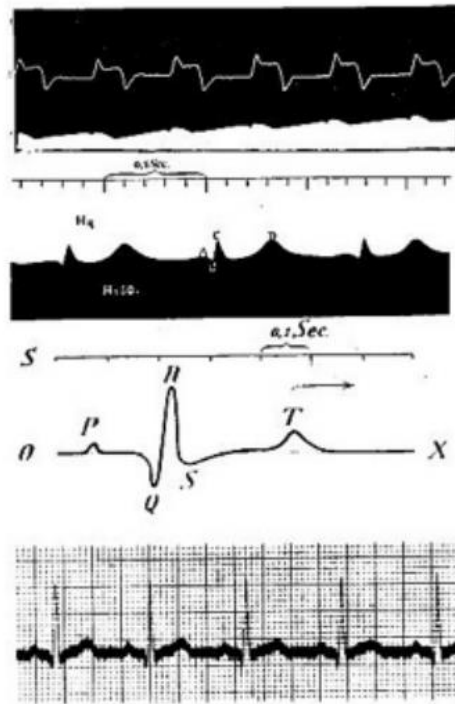
Figure 1.8: Einthoven (1903) (Bronzio, 1995).

Advances before the ECG discovery The discovery of the galvanometer was the pathway to the discovery of the EKG device. Before the galvanometer discovery, physics and chemistry professor H. Oersted, while experimenting with electricity in 1820, discovered that the compass next to the cable deviated when the current flows from the magnet to the wire. When the current stopped, ipre came back to its original direction. In this way, it was learned that the magnet deviated by creating a magnetic field while the current flows through the wire. After this idea, the first galvanometer invention took place in Germany by wrapping a wire around the compass. Galvanometry developed rapidly and became the most important device for people doing research on electricity and made their work easier. The galvanometer has been perfected in the UK. It was proved in England in 1875 with a galvanometer that there is an electrical signal in the animal brain. After that, it was proved by connecting caplos to the frog heart and the production of electrical signal by galvanometer. In the early days of ECG, the patient put his hand in salt water and the electrical signals in the heart were measured while the heart was beating. A. D. Waller was the first to take these measurements. Waller took the technician's EKG (1887). One doctor

17

suggested that the signals measured from the heart were two different signals, which was corrected in the following years to Q, R, S, T.
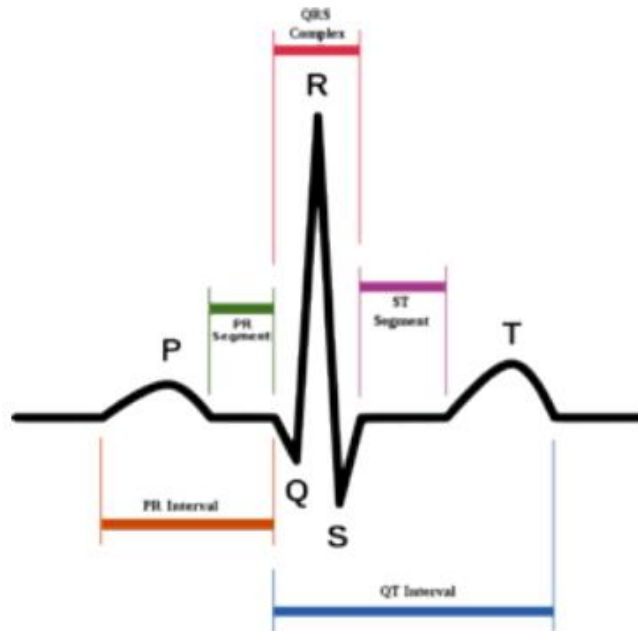

Figure 1.9: P, Q, R, S, T waves and time intervals (Alpman, 2013)

They had trouble understanding these signals, and scientists at Oxford University mathematically simplified these signals. Thanks to this mathematical simplification, the doctors obtained the signals simply and without interference. At the University of Leiden in the Netherlands, W. Einthoven watched the presentation of Waller's ECG trials. He then took ECG images of Einthoven dog. He connected a booster to the galvanometer to amplify the signals. Einthoven used to put people's hands and feet, and his dogs' feet in salt water while shooting EKGs. He used to take ECG of his patients in the hospital from 1.5 km in his laboratory. In order to mathematically eliminate interference in electrical signals, 5 different phases named them P, Q, R, S, T. These letters are also applied today. P atria contraction, QRS ventricles contraction and T ventricles relaxation. Einthoven's ECG device weighed 270 kg. Today, they can be lighter than 1 kg. In 1903, Einthoven simplified his device and made it more advanced over time. He also carried out the mass production and export of the Einthoven EKG device. He received the 1924 Nobel Prize for Medicine for inventing the EKG device. ECG made the diagnosis of heart diseases easy.

For nearly a hundred years, the lives of millions of people have been saved with early diagnosis. With the ECG, both printing and imaging can be done at the same time. It is possible to evaluate and report the information received at the same time (Alpman, 2013).

1.4 Source of biomedical signals:

Bioelectric signs:

The electrical currents created and produced by living things are called bioelectrics. Bioelectric stresses occur as a result of various biological processes. The existence of the bioelectric signal has been learned since ancient times due to the Nile catfish or electric eel. The transmitted stimulus spreads to nerve fibers by an action potential, that is, electrical impulses. Similarly, electrical impulses cause muscle contraction. Cell membrane permeability is temporarily changed by electrochemical stimulation in nerve and muscle cells. Thus, the inner and outer parts of the membrane are emptied to create a potential difference. This current moves along the muscle fibers and the contraction mechanism is activated. Sodium ions must be transported in order to create an action potential (Eneyli, 2014).
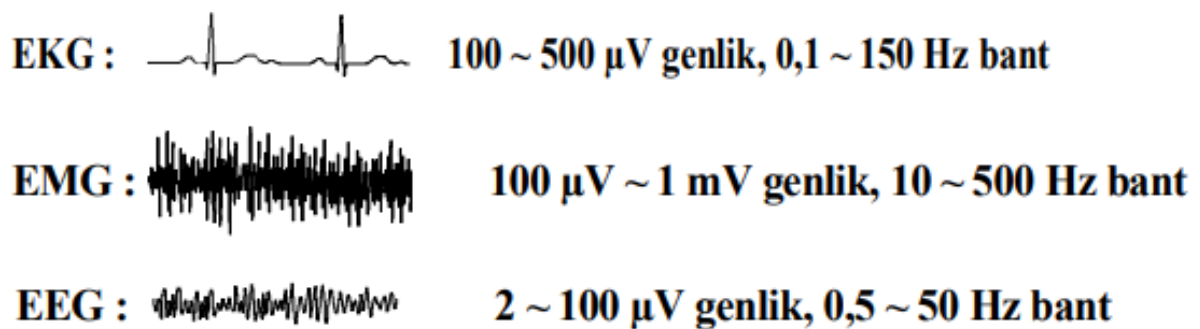
EKG : — 100 ~ 500 µV genlik, 0,1 ~ 150 Hz bant

EMG : 100 µV ~ 1 mV genlik, 10 ~ 500 Hz bant

EEG : 2 ~ 100 µV genlik, 0,5 ~ 50 Hz bant

Figure 1.10: Some electrical biological signs (Alpman, 2013)

Bioelectric signals are specific to biomedical systems and are produced by nerve and muscle cells. Membrane potential whose source is stimulated to generate a specific action potential. The electric field created by many cells scattered around the surface electrodes used creates bioelectric signals. Bioelectric signals are the most important bio signs. The use of excitable cells by biosystems allows the use of biomarkers to study and monitor the function of systems. The electric field spreads to the biological environment and the

potential becomes available at the surface. A converter (transducer) is needed to obtain a bioelectric signal. Because the electrical conduction in the biomedical environment is by ions and the conduction in the measurement system is by electrons. For this reason, bioelectric signal is widely used in biomedical field.
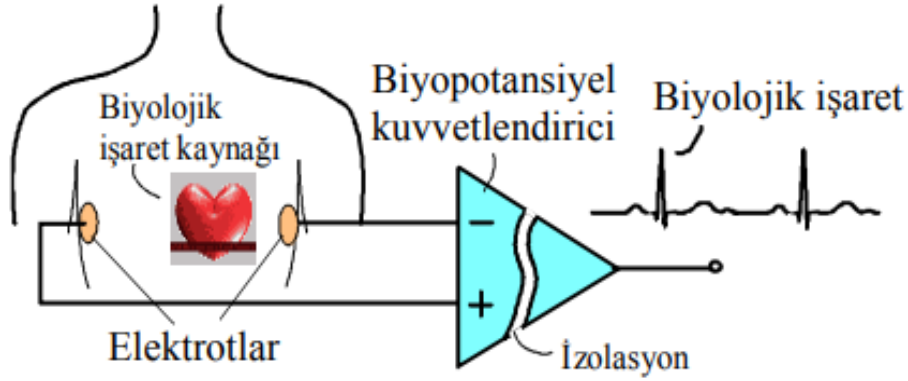

Figure 1.11: Detection of biological markers(Alpman, 2013)

It contains important information about tissue impedance, composition, blood volume, blood distribution, endocrine activity, nervous system activity and more. The frequency range is chosen such that electrode polarization problem is minimal and is chosen to avoid tissue damage due to heating effects. Four electrodes are used in bioimpedance measurements.

Figure 1.12: Some non-electrical biological signs(Alpman, 2013)

20

1.5 ECG current use:

Portable biomedical devices are used extensively in today's modern life. This means that the used battery must be replaced immediately. If the energy source used is rechargeable, it must be able to be charged in a short time. The battery type is selected according to the type of load, the current to be drawn, the operating voltage of the load and the duration of the desired operation. If critical devices such as EKG devices work with batteries regardless of the network, the battery structure must be of good quality and long life. The backup battery must be ready with full charge (İnvention,2016).

Today, apart from the style of the battery, it is produced in accordance with the use and preferred features of doctors. According to the doctor's preference;

- According to heart rhythm irregularities (arrhythmia)
- According to heart defects
- According to the problems in the heart valves
- Coronary artery disease, according to the problems of blocked and narrowed vessels in the heart
- In sudden heart attack
- According to previous heart attack situations

Today, 50-100 heart rhythms per minute are sought as a result of ECG measurement. If the heart is slower or faster than these values, this gives doctors a lot of information about heart health.

In addition, the information provided by the ECG today is as follows;

- Gives information about the heart rate
- Gives information about the rhythm of the heart
- Gives information about heart attack
- Provides information about the amount of oxygen and blood delivered to the heart
- Provides information about structural abnormalities in the heart

1.5.1 ECG capture and technique:

The patient does not need to be prepared for an ECG, the procedure is painful and there is no problem for the patient. Shooting can be done anywhere, with the patient lying down.

Electrodes are attached to 2 arms, 2 legs and 6 chest through the cable connected to the ECG. In this way, the electric potentials formed in the heart with electrodes are transferred to the paper and the process time is around 1-2 minutes. But in rhythm problems, it can be recorded for a longer time if necessary. Almost all of today's ECG devices record on thermal papers. Since thermal papers turn black with heat, the printer tip is heated to write like a pen. For this reason, papers should be protected from light and heat. Otherwise, the lines fade and fade over time.

Accordingly, today EKG offers a lot to the health and biomedical sector in terms of diagnosis and treatment.

1.6 Smart watch:

Smart watches contain a processor and computer circuitry. It is put on arm like a normal watch. They can do almost all the action a phone does. Smart watches can be connected to phones using Bluetooth technology. The smart watch needs to be integrated with a phone. Smart watches can also be used without integrating into the phone, but must be connected to a phone in order to benefit from all its features. Smart watches can send and receive messages. They can go to social networks or take pictures. It has features that vary from model to model. Some models provide the opportunity to talk remotely, thanks to their built-in speakers. You can record sound and listen to music with the smart watch. You can send and receive e-mails and take advantage of the calendar and calendar features. In addition to all these, it also has a clock feature. Almost all smart watches have a pedometer and you can keep track of your runs and walks with this feature. Some smartwatches also have a heart rate monitor, but no clock that measures an EKG (Lina,2016).

Figure 1.13: Smart watch (Lina,2016).

1.6.1 History of Smart Watches:

The release date of the smart watches is 2012 and they have emerged with Pebble. After the Pebble brand smart watches, which sold one million units in time, they started to develop and popularize smart watches in other brands.

Figure 1.14: The first smartwatch (Lina,2016).

The most common features found in smart watches are:

Heart rate measurement

- Time and date

- Making a phone conversation

- Measuring sleep quality

- Ability to use various applications (Foursquare, Evernote, Shazam etc.)

- Step counting

- measuring calories

- Alarm clock

- Phone notifications (various app, message notifications, etc.)

- GPS

- Music

Figure 1.15: Smart watch usage areas (Google)

The Most Preferred Smart Watch Brands Today:

1. Apple Watch 2
2. Samsung Gear S3
3. Fossil Q Marshal
4. Pebble Time Round
1. 5.Asus ZenWatch 3
5. Huawei Watch 2
2. 7.Moto 360
3. 8.Apple Watch
4. 9.Huawei Watch
5. 10. Samsung Gear S2

Smart Watch Prices: The prices of smart watches vary according to the model, brand and features of these devices. The more features the smart watch has, the higher its price. Prices in our country vary between 1500tl and 2500tl (Gül, 2013).

CHAPTER 2 : MATERIALS AND METHODS

2.1 Parts Used:

• FM105-Jumper Cable Set

• Single Breadboard

• 128x128 1.5 Inch Oled Graphic Display

• 3.7V 1400mA 1S Lipo Battery

• ESP-32S Module Wifi and Bluetooth

• Gravity Analog Arduino Pulse Sensor- (ECG Sensor)

• Lipo Charger 500mA

• Arduino Nano

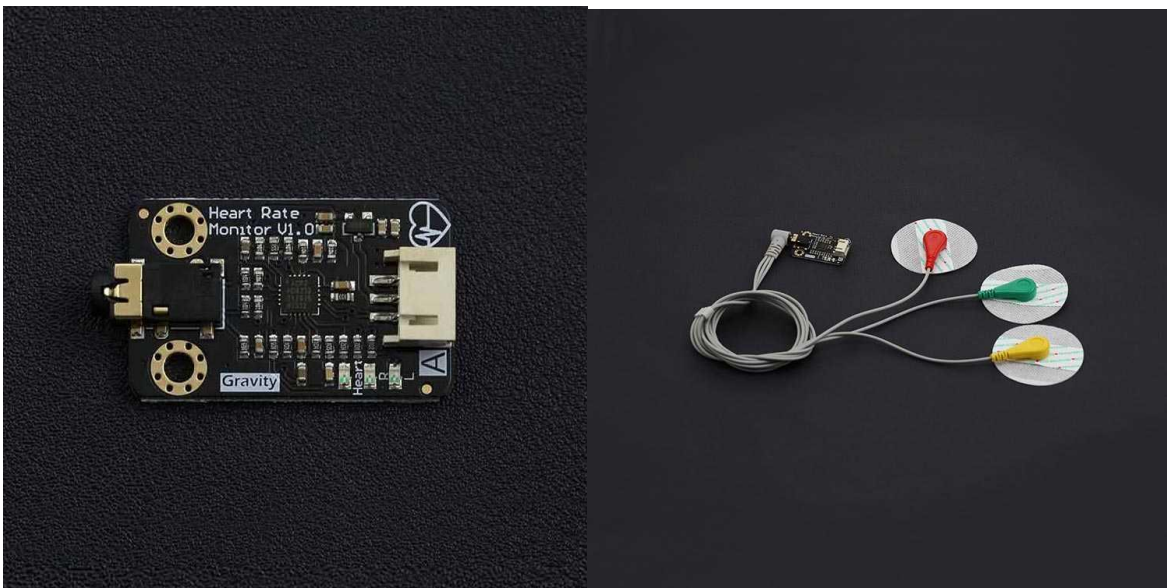**2.1.1 Gravity Analog Arduino Pulse Sensor- (ECG Sensor)**

Figure 2.1: ECG sensor (Google).

Specifications;

• Stackable connector. Up to 6 channels, namely A0-A6 analog inputs can be superimposed with jumper and wired.

• Used to measure the electrical activity of the heart.

• Suitable for electromyography - capable of monitoring and data collection.

- Calibrate signal can be generated with digital output D4 / D9.

- Precisely adjustable potentiometer for calibration and gain. (All shields are fully assembled, tested and calibrated)

- Input connector for standard or active electrodes.

- Works with both 3.3V and 5V Arduino boards.

- Hardware and software can be intervened. Users can access all design documents.

- There are examples for Arduino, Pinguino and Maple.

- ECG / EMG shield can be used for electroencephalography up to one stage. But its design is not suitable.

2.1.2 FM105- Jumper Cable Set
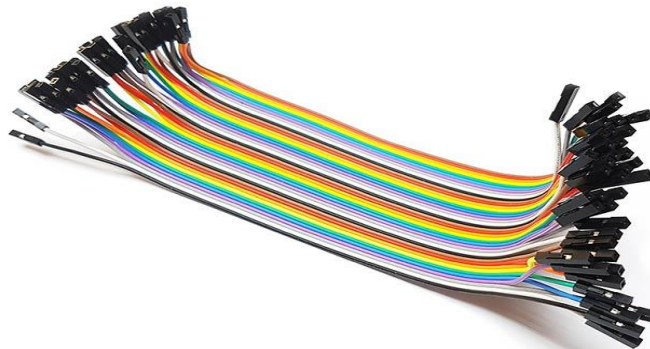
Figure 2.2: Jumper cable(Google).

Specifications;
- Feature of jumper cable set is data transmission.

- Usually used between Ardunio and breadboard.

- Our jumper cable set contains 1 Female-Female Jumper cable, 1 Female-Male Jumper cable, 1 Male-Male jumper cable.

- Generally, we use Male-Male Jumper Cables.

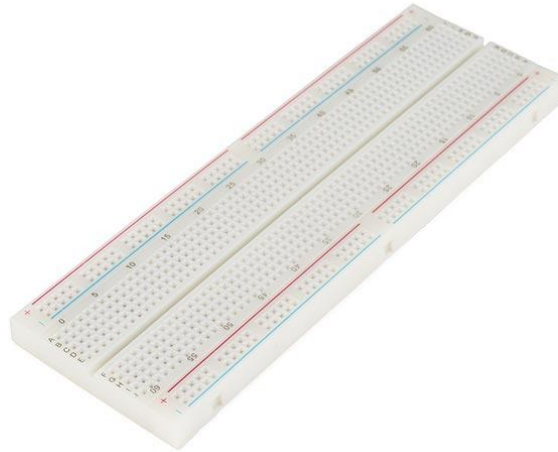**2.1.3 Single Breadboard**

Figure 2.3: Breadboard(Google).

Specifications;

- It is a circuit board used when making projects with Arduino.

- There are parallel lines connected to each other on the circuit board.

- Each hole is designated with the letters A, B, C, D, E, F.

- Although circuit boards have different sizes, their basic feature is the same. Different types of circuit boards are available in the market according to your needs and the size of the circuits you want to install.
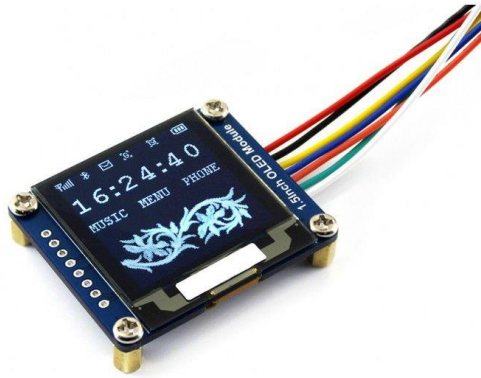
2.1.4 128x128 1.5 Inch OLED Graphic Display
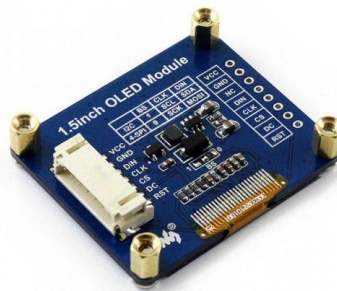
Figure 2.4: OLED Display(Google).

Specifications;

- 128x128 screen resolution
- 16-bit color pixels
- 1.5 inch TFT LCD
- Compatible with 3.3 / 5V operating voltage level,

- Compatible with UTFT library,

- SD card socket,

- PCB dimensions: 68.6mm X 53.3mm X 1.6mm,

- Provides operating voltage via Arduino,

- RoHS standard is available,

- Thanks to the jumper on the pcb to which the screen is connected, it can operate smoothly at 3.3V or 5V voltages.

- Electrical Properties

- If we look at the electrical features of this screen, it works with an average of 5V.

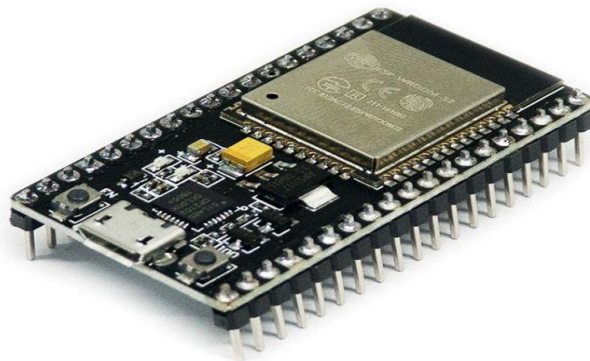**2.1.5 ESP-32S Module Wifi and Bluetooth**

Figure 2.5: Bluetooth module(Google).

Specifications;
- Consists of ESP32, integrated antenna and RF balun, power amplifier, low noise amplifiers, filters.
- Used in data communication.
  - Small volume, easily embedded in other products

- It has powerful function that supports LWIP protocol.
- Supporting three modes: AP, STA and AP + STA
- To support the Lua program is to develop easily.
- It has high performance.
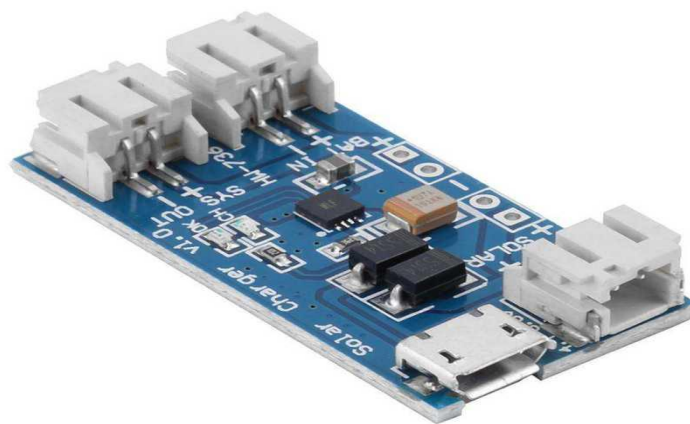
2.1.6 Lipo Charger Module 500mA

Figure 2.6: Charging module(Google).

Specifications;

- It allows you to charge your 1S, single cell lipo batteries with solar energy through the solar panel.
- By connecting a solar panel of maximum 6V and minimum 4.4V to the solar input and connecting a 1S lipo battery to the battery output, you can easily charge it.
- The circuit gives a maximum of 500mA.
- Interface: It is a 2-pin JST connector.
- It has short circuit protection.
- USB charging support.
- Product size: 40mm * 20mm * 7mm.
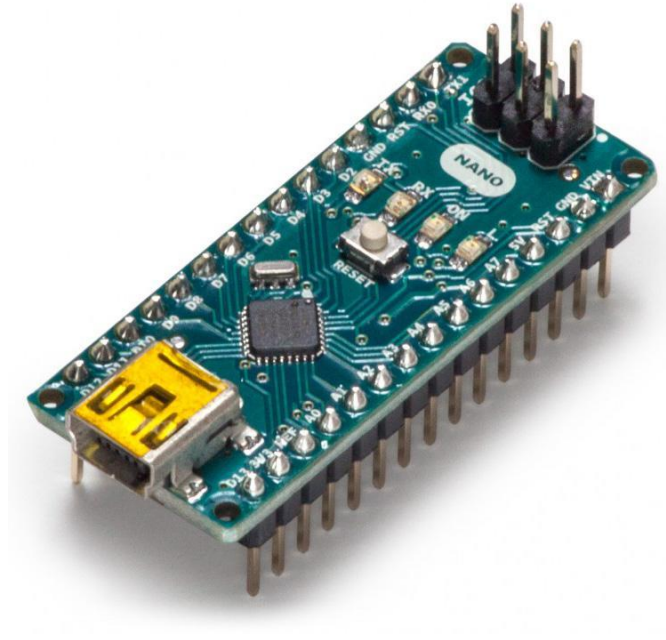
2.1.7 Arduino Nano Module

Figure 2.7: Arduino Nano(Google).

Specifications;

- Dimensions: 18.5mm x 43.2mm
- Input Voltage: DC 7V ~ 12V
- Digital Input Output: 14 pin holes
- Analog Input Output: 8 pin holes
- DC Current Input Output Pins: 40mA
- Input Voltage: 6V-20V
- Flash Memory: 32KB
- Working Frequency: 16MHz

2.2 Working principle of the device:

Measurement of the ECG signal can be vital in diagnosing heart diseases. ECG signals are biopotential signals that are generated as a result of the electrical activity of the heart and can be measured with an electrode from the skin. The amplitude, duration and repetition

frequency of the signals can provide information about the physiology of the heart. These signals can be amplified with instrumentation amplifiers and converted into processable signals. The ECG device is a device that can detect the small-amplitude electrical signal that occurs on the skin surface or in the body and convert it into a graph, so we get information about the rhythm disorders in the heart and vascular occlusions in the heart. In our project, we have designed an EKG that displays an image on the clock. Later, we placed 3 electrodes in the RA, RL, LA positions that we placed in our chest area. By determining one electrode as neutral, we found the biopotential between the other two electrodes and we obtained an ECG signal by processing it in our chest section. Our signal was a little noisy, which was due to insufficient filtering. Then we formed the circuit consisting of ESP 32S, Arduino Nano and Heart rate sensor to receive the signal. With the Oled screen we bought, we created the circuit of the other Wifi module and coded these mechanisms. In the part that creates the ECG signal, the sensor takes the biopotential difference and amplifies it and sends the data to the Arduino nano. Here, the signal passes through certain filtering and goes to the wifi module. Finally, with the connection between two wifi modules, the signal is transferred wirelessly to the second module and reflected on the screen. We used 3.7v Lipo batteries for the power supply of the screen. We did not encounter any problems on our OLED screen. The device is not exactly at the level we want because the sensor is not at the optimum level. Many factors can cause signal noise.

Connection between ESP 32S - Arduino nano - Heart rate monitor in accordance with the current code:

Connection between Arduino nano and ECG sensor;

- 3.3V to Red wire
- A1 to Blue wire
- Gnd to Black Cable

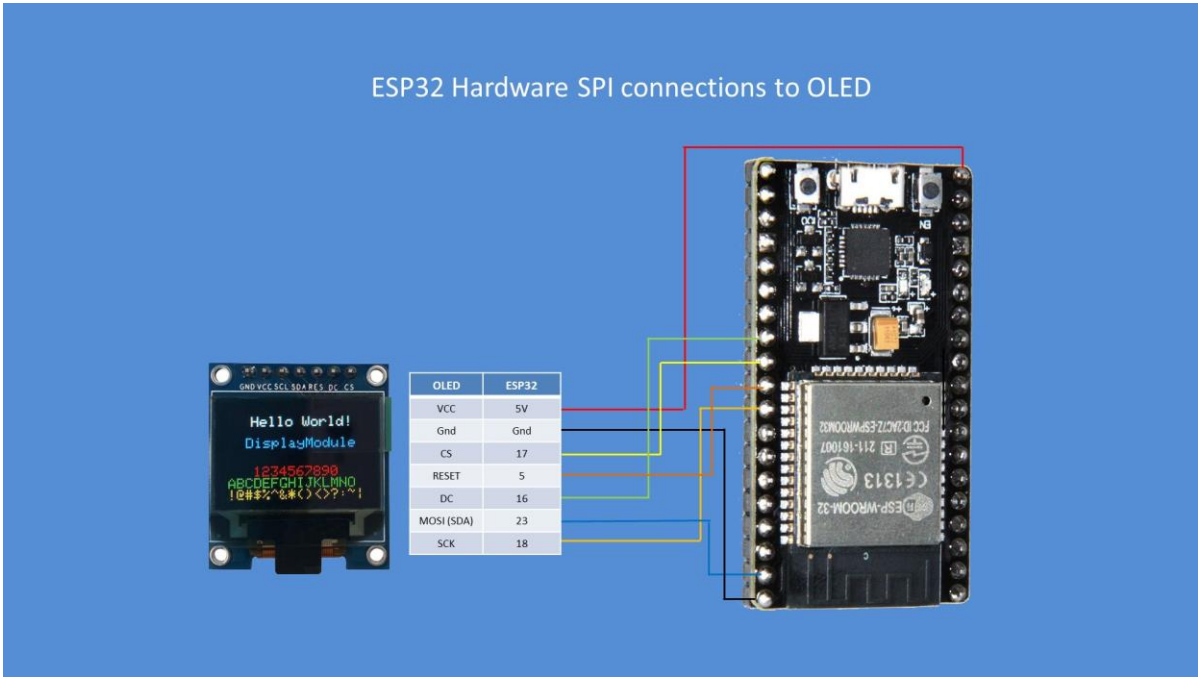Connection between Arduino nano and ESP32S module;

- pin 5 to Analog pin 32

Figure 2.8: LCD screen and ESP 32S module connection diagram(Google).

CHAPTER 3: OBTAINED RESULTS

3.1Result

We made the connections of the device, but we encountered some problems in the software. We had to use the Arduino program to program the ESP 32S module, which is inside our materials. We had difficulty introducing the ESP 32S module to the Arduino program. We introduced it to the program somehow, but the codes did not match with the module. The project is not completely finished.
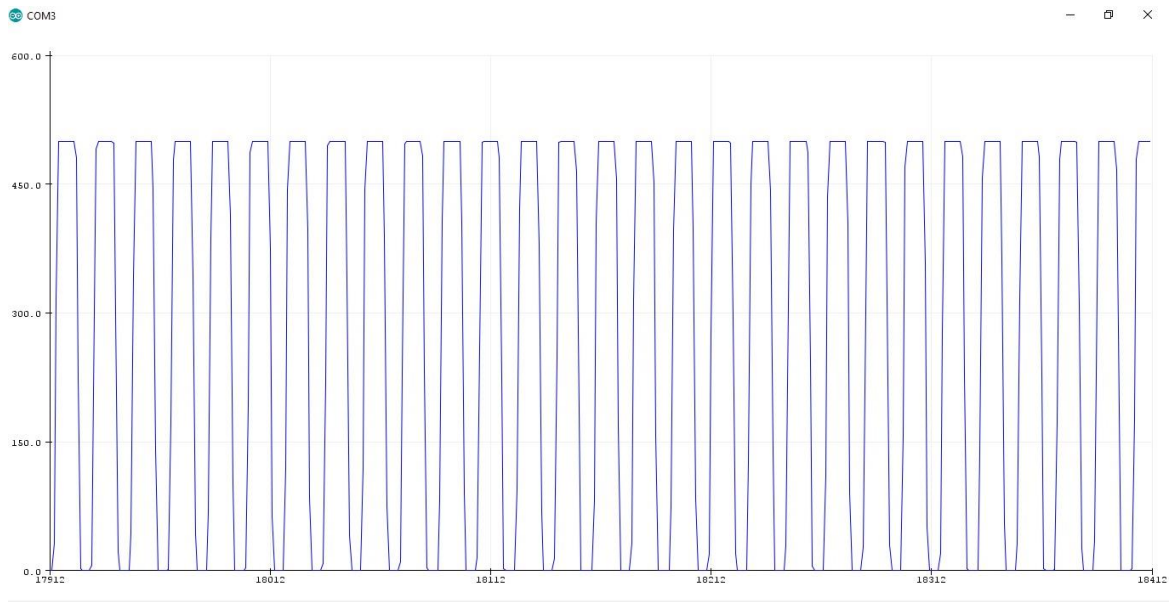

Figure 3.1: Unfiltered signal obtained

As a result of testing the device, we obtained sials. The filtering of the signals was insufficient and we could not provide communication between ESP 32S modules due to the software problem in the program. We connected our screen to the module and we were able to reflect the signal.
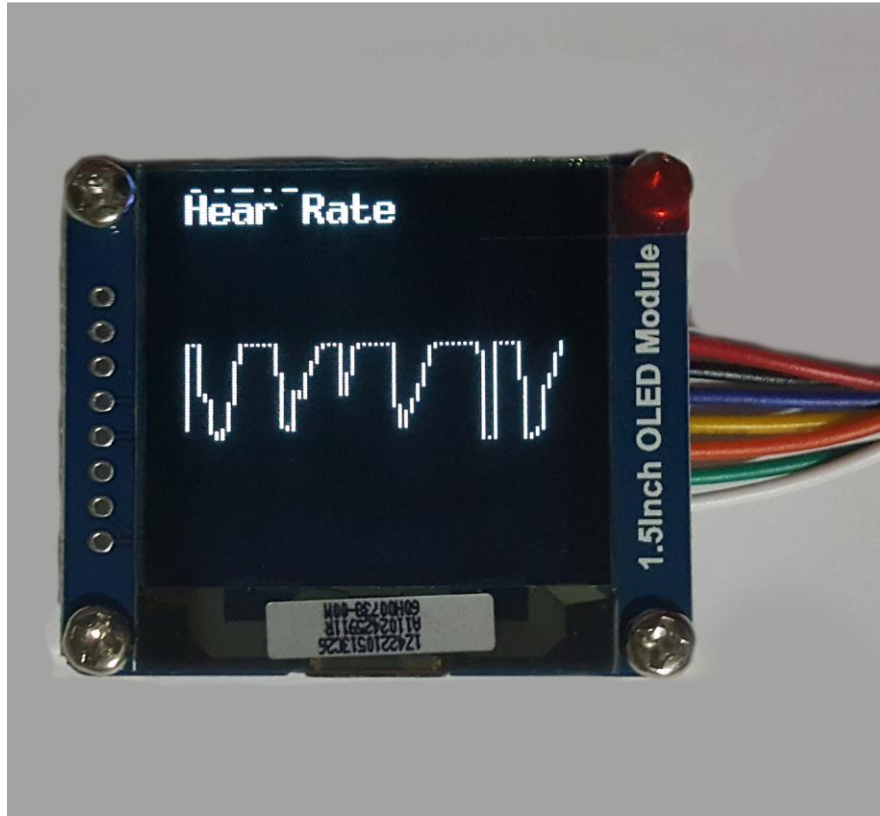
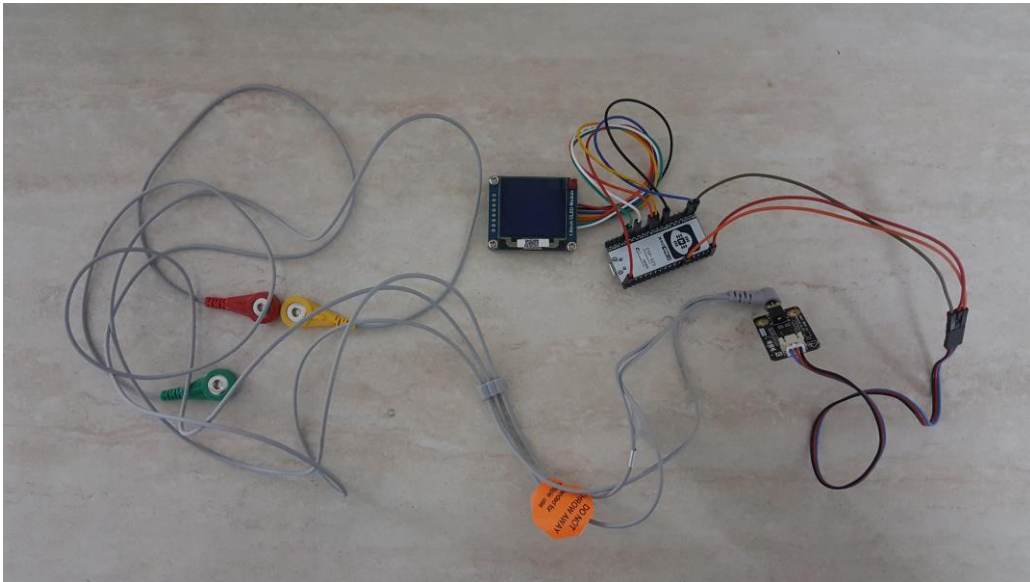**Figure 3.2:** The signal we reflect on the Oled screen.

Figure 3.3: Designed ECG Device

As the second phase of the project; We made changes in the plans we made in the first stage in order to develop our project. In the first stage, we were getting a loud ECG signal in the device we made. In the device we designed, we first aimed to filter the ECG signal. In the device we first installed, we filtered the ECG signal with filtering codes and obtained it with small noises on the principle of a normal ECG device. As a result, we have obtained an ECG signal that can be considered successful, even if the device is not enough to be used in health institutions. The main thing to do was to connect the ESP32S modules. Since there are many models of the ESP32S module, we had trouble connecting with the arduino library, since the correct version was not available in the library. We tried to connect two ESP32S modules by trying different versions, but with no success. Then we purchased the arduino nano, which is compatible with the arduino library. The important thing in this kind of project was that the ECG signal could be affected by interference or noise from anything. After a few tries, we established the connection with the arduino nano.
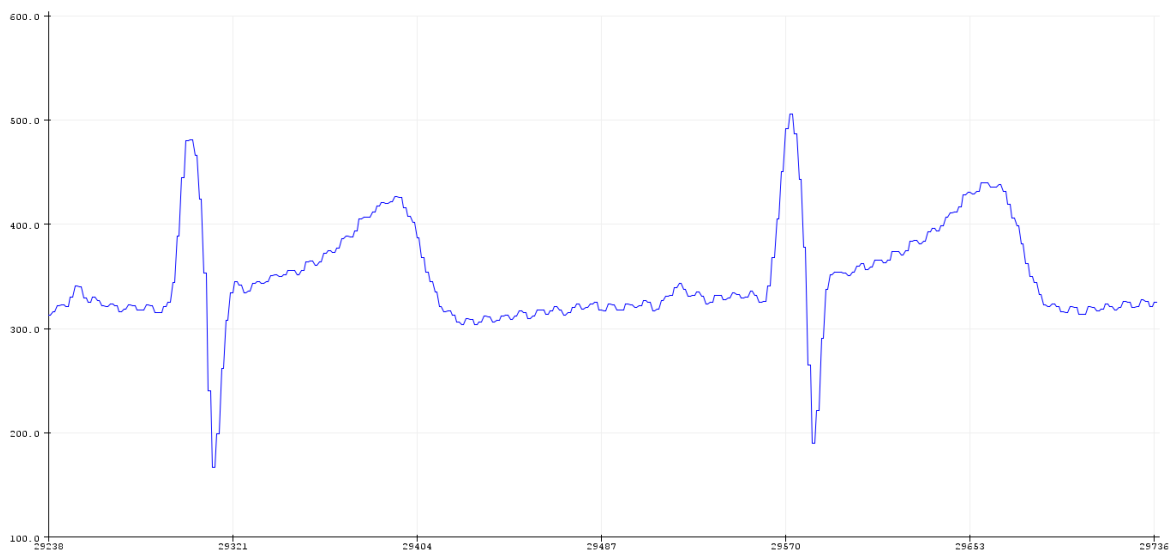

Figure 3.4: ECG signal obtained

Figure 3.5: Device prototype

Figure 3.6: ECG signal obtained

CHAPTER 4: CONCLUSION AND SUGGESTIONS

4.1 Conclusıon And Suggestıons

While we were setting up this device, in our first stage, we used the ESP32S, EKG arduino kit and the LED screen to connect them with the pins we coded with jumper cables. We created our code as a result of long efforts so that we can receive the signal and we aimed to operate these parts in an integrated way with each other. As a result, we obtained a noisy signal, and this ECG signal was encoded on the LED screen and displayed on the screen. But as our first stage, this signal was a little bit loud. The reason is the missing filters. As a continuation of the project, we have completed the filtering of the ECG sensor. During the construction phase, we had problems in the connection of the ESP 32S module with the Hearth rate sensor due to the libraries. As a solution, we added Arduino nano to act as a bridge between the wifi module and the ECG sensor. We tried to connect the ESP 32S modules via bluetooth, but it would be slow in transmitting the ECG signal, so we decided to send the signal via wifi. We defined the part where the heart rhythm sensor is located as the server and the clock part is defined as the slave that connects to the server called the slave. We provided the wireless connection, but we still haven't optimized this setup and we are facing problems. Wireless connection causes disturbances in the signal and can cause problems in matching. In the clock section, the ESP module is connected to the server as a microprocessor and reflects the ECG signal to the Oled screen.

REFERENCES

Ahmet Alpman, (2011), Electrocardiogram (ECG), Access date 2021, from http:/ www.ahmetalpman.com/konuoku_tam.asp?id=227

Assist. Prof. Dr. Müge Günalp Eneyli, (2014), ECG, Access date 2021, from http://aciltip.medicine.ankara.edu.tr/files/2014/11/d5_ekg.p

Ezgi Gül, (2013), Smart Watches and Features, Access date 2021, from https://www.myfikirler.org/akilli-saatler-ve-ozellikleri.html

Funda Lina, (2016), What is Smart Clock ?, Access date 2021, from https://www.fundalina.com/akilli-saatlerin-tarihcesi/

Invention, (2016), Who Invented the EKG Device, Access date 2021, from http://www.ilkkimbıldı.com/kalp-elektrosu-ekg-kim-bulur/

J.D.Bronzio, (1995), The Biomedical Engineering Handbook, Access date 2021, from http://www.metealpaslan.com/link1.htm

n.a, (2015), What is Smart Clock ?, Life is easy, Access date 2021, from http://www.hayatkolay.com/hayat/akilli-saat-nedir/

n.a, (n.a), Formation and Properties of Biological Signals, Access date 2021, from https://web.itu.edu.tr/~dokur/EMG_Giris/EMG_07.pdf

n.a, (n.a), Short History of the ECG, Access date 2021, from http://www.metealpaslan.com/link1.htm

n.a, (2011), ECG (Electrocardiography), T.R. Ministry of National Education, Access date 2021, fromhttp: //megep.meb.gov.tr/mte_program_modul/moduller_pdf/Ekg%20 (electrocardiography) .pdf

Ural Akbulut, (2013), Electrocardiography developed in the Netherlands, Access date 2021, fromhttp: //www.uralakbulut.com.tr/wp-content/uploads/2013/01/ekg.pdf

APPENDİX 1: Codes

1.1 ECG part codes consisting of ESP 32S - Arduino Nano - Heart rate sensor:

```
#include <esp_now.h>
#include <WiFi.h>

// Global copy of slave
#define NUMSLAVES 2
esp_now_peer_info_t slaves[NUMSLAVES] = {};
int SlaveCnt = 0;
#define ANALOG_PIN_0 32

#define CHANNEL 3
#define PRINTSCANRESULTS 0

// Init ESP Now with fallback
void InitESPNow() {
  WiFi.disconnect();
  if (esp_now_init() == ESP_OK) {
    Serial.println("ESPNow Init Success");
  }
  else {
    Serial.println("ESPNow Init Failed");
    // Retry InitESPNow, add a counte and then restart?
    // InitESPNow();
    // or Simply Restart
    ESP.restart();
  }
}

// Scan for slaves in AP mode
```

```
void ScanForSlave() {
 int8_t scanResults = WiFi.scanNetworks();
 //reset slaves
 memset(slaves, 0, sizeof(slaves));
 SlaveCnt = 0;
 Serial.println("");
 if (scanResults == 0) {
   Serial.println("No WiFi devices in AP Mode found");
 } else {
   Serial.print("Found "); Serial.print(scanResults); Serial.println(" devices ");
   for (int i = 0; i < scanResults; ++i) {
     // Print SSID and RSSI for each device found
     String SSID = WiFi.SSID(i);
     int32_t RSSI = WiFi.RSSI(i);
     String BSSIDstr = WiFi.BSSIDstr(i);

     if (PRINTSCANRESULTS) {
       Serial.print(i + 1); Serial.print(": "); Serial.print(SSID); Serial.print(" [");
Serial.print(BSSIDstr); Serial.print("]"); Serial.print(" ("); Serial.print(RSSI);
Serial.print(")"); Serial.println("");
     }
     delay(10);
     // Check if the current device starts with `Slave`
     if (SSID.indexOf("Slave") == 0) {
       // SSID of interest
       Serial.print(i + 1); Serial.print(": "); Serial.print(SSID); Serial.print(" [");
Serial.print(BSSIDstr); Serial.print("]"); Serial.print(" ("); Serial.print(RSSI);
Serial.print(")"); Serial.println("");
       // Get BSSID => Mac Address of the Slave
       int mac[6];

       if ( 6 == sscanf(BSSIDstr.c_str(), "%x:%x:%x:%x:%x:%x%c", &mac[0], &mac[1],
```

```
                            &mac[2], &mac[3], &mac[4], &mac[5] ) ) {
        for (int ii = 0; ii < 6; ++ii ) {
          slaves[SlaveCnt].peer_addr[ii] = (uint8_t) mac[ii];
        }
      }
      slaves[SlaveCnt].channel = CHANNEL; // pick a channel
      slaves[SlaveCnt].encrypt = 0; // no encryption
      SlaveCnt++;
    }
  }
}


  if (SlaveCnt > 0) {
   //Serial.print(SlaveCnt); Serial.println(" Slave(s) found, processing..");
  } else {
   Serial.println("No Slave Found, trying again.");
  }


  // clean up ram
  WiFi.scanDelete();
}


// Check if the slave is already paired with the master.
// If not, pair the slave with master
void manageSlave() {
  if (SlaveCnt > 0) {
    for (int i = 0; i < SlaveCnt; i++) {
      const esp_now_peer_info_t *peer = &slaves[i];
      const uint8_t *peer_addr = slaves[i].peer_addr;
      Serial.print("Processing: ");
      for (int ii = 0; ii < 6; ++ii ) {
        Serial.print((uint8_t) slaves[i].peer_addr[ii], HEX);
```

```
    if (ii != 5) Serial.print(":");
  }
  Serial.print(" Status: ");
  // check if the peer exists
  bool exists = esp_now_is_peer_exist(peer_addr);
  if (exists) {
    // Slave already paired.
    Serial.println("Already Paired");
  } else {
    // Slave not paired, attempt pair
    esp_err_t addStatus = esp_now_add_peer(peer);
    if (addStatus == ESP_OK) {
      // Pair success
      Serial.println("Pair success");
    } else if (addStatus == ESP_ERR_ESPNOW_NOT_INIT) {
      // How did we get so far!!
      Serial.println("ESPNOW Not Init");
    } else if (addStatus == ESP_ERR_ESPNOW_ARG) {
      Serial.println("Add Peer - Invalid Argument");
    } else if (addStatus == ESP_ERR_ESPNOW_FULL) {
      Serial.println("Peer list full");
    } else if (addStatus == ESP_ERR_ESPNOW_NO_MEM) {
      Serial.println("Out of memory");
    } else if (addStatus == ESP_ERR_ESPNOW_EXIST) {
      Serial.println("Peer Exists");
    } else {
      Serial.println("Not sure what happened");
    }
  // delay(100);
  }
 }
} else {
```

```
    // No slave found to process
    Serial.println("No Slave found to process");
  }
}
uint8_t data = 0;
// send data
void sendData() {
  data=analogRead(ANALOG_PIN_0);
  for (int i = 0; i < SlaveCnt; i++) {
    const uint8_t *peer_addr = slaves[i].peer_addr;
    if (i == 0) { // print only for first slave
      Serial.print("Sending: ");
      Serial.println(data);
    }
    esp_err_t result = esp_now_send(peer_addr, &data, sizeof(data));
    Serial.print("Send Status: ");
    if (result == ESP_OK) {
     // Serial.println("Success");
    } else if (result == ESP_ERR_ESPNOW_NOT_INIT) {
      // How did we get so far!!
      Serial.println("ESPNOW not Init.");
    } else if (result == ESP_ERR_ESPNOW_ARG) {
      Serial.println("Invalid Argument");
    } else if (result == ESP_ERR_ESPNOW_INTERNAL) {
      Serial.println("Internal Error");
    } else if (result == ESP_ERR_ESPNOW_NO_MEM) {
      Serial.println("ESP_ERR_ESPNOW_NO_MEM");
    } else if (result == ESP_ERR_ESPNOW_NOT_FOUND) {
      Serial.println("Peer not found.");
    } else {
      Serial.println("Not sure what happened");
    }
```

```
    //delay(100);
  }
}


// callback when data is sent from Master to Slave
void OnDataSent(const uint8_t *mac_addr, esp_now_send_status_t status) {
  char macStr[18];
  snprintf(macStr, sizeof(macStr), "%02x:%02x:%02x:%02x:%02x:%02x",
        mac_addr[0], mac_addr[1], mac_addr[2], mac_addr[3], mac_addr[4], mac_addr[5]);
  Serial.print("Last Packet Sent to: "); Serial.println(macStr);
  Serial.print("Last Packet Send Status: "); Serial.println(status ==
ESP_NOW_SEND_SUCCESS ? "Delivery Success" : "Delivery Fail");
}
void setup() {
  Serial.begin(115200);
  //Set device in STA mode to begin with
  WiFi.mode(WIFI_STA);
  Serial.println("ESPNow/Multi-Slave/Master Example");
  // This is the mac address of the Master in Station Mode
  Serial.print("STA MAC: "); Serial.println(WiFi.macAddress());
  // Init ESPNow with a fallback logic
  InitESPNow();
  // Once ESPNow is successfully Init, we will register for Send CB to
  // get the status of Trasnmitted packet
  esp_now_register_send_cb(OnDataSent);
}
void loop() {
  // In the loop we scan for slave
  if (SlaveCnt < 1) {
  ScanForSlave();
  }
  // If Slave is found, it would be populate in `slave` variable
```

```
  // We will check if `slave` is defined and then we proceed further
  if (SlaveCnt > 0) { // check if slave channel is defined
    // `slave` is defined
    // Add slave as peer if it has not been added already
    manageSlave();
    // pair success or already paired
    // Send data to device
    sendData();
  } else {
    // No slave found to process
  }
  // wait for 3seconds to run the logic again
  //delay(1000);
}
```

1.2 OLED Display - Codes of the clock section consisting of the ESP 32S Module

```
#include <Adafruit_SSD1306.h>
#include <splash.h>


#include <Arduino.h>
#include <U8g2lib.h>


#ifdef U8X8_HAVE_HW_SPI
#include <SPI.h>
#endif
#ifdef U8X8_HAVE_HW_I2C
#include <Wire.h>
#endif


#include <esp_now.h>
#include <WiFi.h>
```

```
#define CHANNEL 1

U8G2_SSD1327_MIDAS_128X128_F_4W_SW_SPI u8g2(U8G2_R0, /* clock=*/ 18, /*
data=*/ 23, /* cs=*/ 5, /* dc=*/ 2, /* reset=*/ 4);

// End of constructor list

typedef u8g2_uint_t u8g_uint_t;

#define SECONDS 10
uint8_t flip_color = 0;
uint8_t draw_color = 1;

void draw_set_screen(void) {
  // graphic commands to redraw the complete screen should be placed here
  u8g2.setColorIndex(flip_color);
  u8g2.drawBox( 0, 0, u8g2.getWidth(), u8g2.getHeight() );
}
int deger;
int t = 0;
int x1 = 0;
int y11 = u8g2.getHeight() * 2 / 3;
void draw_line(void) {
  u8g2.setColorIndex(draw_color);
  // while(t<u8g2.getWidth()+1){
   //deger = *data;
   //delay(1);

//Serial.print("++++++++++++");
deger=map(deger,0,255,50,100);
  Serial.println(deger);
  u8g2.drawLine(x1, y11, t, deger );
```

```c
    delay(1);
   y11 = deger;
   x1 = t;


   t += 2;
}
uint16_t execute_with_fps(void (*draw_fn)(void)) {
  uint16_t FPS10 = 0;
  uint32_t time;


  time = millis() + SECONDS * 1000;


  // picture loop
  do {
    //u8g2.clearBuffer();
    draw_fn();
    u8g2.sendBuffer();
    FPS10++;
    flip_color = flip_color ^ 1;
  } while ( millis() < time );
  return FPS10;
}
const char *convert_FPS(uint16_t fps) {
  static char buf[6];
  strcpy(buf, u8g2_u8toa( (uint8_t)(fps / 10), 3));
  buf[3] =  '.';
  buf[4] = (fps % 10) + '0';
  buf[5] = '\0';
  return buf;
}
void show_result(const char *s, uint16_t fps) {
  // assign default color value
```

```
    u8g2.setColorIndex(draw_color);

    u8g2.setFont(u8g2_font_8x13B_tf);

    //  u8g2.firstPage();

    // do {

    u8g2.drawStr(0, 12, s);

    u8g2.drawStr(0, 1, convert_FPS(fps));

    //} while( u8g2.nextPage() );

}

// Init ESP Now with fallback

void InitESPNow() {

  WiFi.disconnect();

  if (esp_now_init() == ESP_OK) {

    Serial.println("ESPNow Init Success");

  }

  else {

    Serial.println("ESPNow Init Failed");

    // Retry InitESPNow, add a counte and then restart?

    // InitESPNow();

    // or Simply Restart

    ESP.restart();

  }

}

// config AP SSID

void configDeviceAP() {

  String Prefix = "Slave:";

  String Mac = WiFi.macAddress();

  String SSID = Prefix + Mac;

  String Password = "123456789";

  bool result = WiFi.softAP(SSID.c_str(), Password.c_str(), CHANNEL, 0);

  if (!result) {

    Serial.println("AP Config failed.");

  } else {
```

```
    Serial.println("AP Config Success. Broadcasting with AP: " + String(SSID));
  }
}

void setup(void) {
  Serial.begin(115200);
  Serial.println("ESPNow/Basic/Slave Example");
  //Set device in AP mode to begin with
  WiFi.mode(WIFI_AP);
  // configure device AP mode
  configDeviceAP();
  // This is the mac address of the Slave in AP Mode
  Serial.print("AP MAC: "); Serial.println(WiFi.softAPmacAddress());
  // Init ESPNow with a fallback logic
  InitESPNow();
  // Once ESPNow is successfully Init, we will register for recv CB to
  // get recv packer info.
  esp_now_register_recv_cb(OnDataRecv);
  u8g2.begin();
  draw_color = 1;
}
// callback when data is recv from Master
void OnDataRecv(const uint8_t *mac_addr, const uint8_t *data, int data_len) {
  char macStr[18];
  snprintf(macStr, sizeof(macStr), "%02x:%02x:%02x:%02x:%02x:%02x",
         mac_addr[0], mac_addr[1], mac_addr[2], mac_addr[3], mac_addr[4], mac_addr[5]);
  //Serial.print("Last Packet Recv from: "); Serial.println(macStr);
  // Serial.print("Last Packet Recv Data: ");
  Serial.println(*data);
  //Serial.println("");
  deger = *data;
  delay(1);
```

```
}
void loop(void) {
 uint16_t fps;
 fps = execute_with_fps(draw_line);
 show_result("Hear Rate", fps);
 delay(10);
 if (t > u8g2.getWidth()) {
  t = 0;
  x1 = 0;
  u8g2.firstPage();
 }
}
```

APPENDİX 2: Ethical Approval letter

ETHICAL APPROVAL DOCUMENT

Date:20/01/2021

TotheGraduate School of AppliedSciences

Forthethesisprojectentitled as "Smartwatch ECG" theresearchersdeclarethattheydid not collectanydatafromhuman/animaloranyothersubjects. Therefore, thisprojectdoes not needtogothroughtheethicscommitteeevaluation.

Title: PROF. DR.
Name Surname: AYŞE GÜNAY KİBARER

Signature:

Role in theResearch Project: Supervisor

APPENDIX 3: Similarity Report -TURNITIN (Consultant Signed)

turnitin
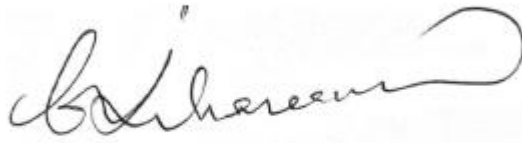
	AUTHOR	TITLE	SIMILARITY	GRADE	RESPONSE	FILE	PAPER ID
☐	Murat Sertel	ABSTRACT	0%	--	--		1491530990
☐	Murat Sertel	CHAPTER-1 INTRODUCTION	6%	--	--		1491532340
☐	Murat Sertel	CHAPTER-2	12%	--	--		1491533151
☐	Murat Sertel	CHAPTER-3 RESULTS AND DISCUSSION	0%	--	--		1491534286
☐	Murat Sertel	CHAPTER-4 CONCLUSION	0%	--	--		1491543423
☐	Murat Sertel	MASTER THESIS ALL CHAPTERS	6%	--	--		1491544534

Prof. Dr. Ayşe Günay Kibarer

Head of the Department