University of Babylon

Faculty of Engineering

Electrical Engineering Department

Reading and Monitoring of ECG sensor signal Based on Arduino

A Project Submitted in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science (B.Sc.) in Electrical Engineering.

By

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Academic year 2022/2021

Certificate

The project entitled:

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Which is being submitted by

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In the fulfillment of requirement for the award of the B.Sc. degree in Electrical Engineering. This has been carried out under my supervision and accepted for presentation & examination.

Signature : ....

Supervisor's name :

Date:……… /……/.2022

The Supervisor**…**

CERTIFICATE

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In the partial fulfillment of requirement for the award of the B.Sc. degree in Electrical Engineering has been discussed by us and all the suggested recommendations during the discussion are carried out.

1st Examiner (The supervisor):	**2nd Examiner**
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Date: / / 2022	**Date: / / 2022**
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Name :	**Name :**
Date: / / 2022	**Date : / / 2022**
5th Examiner	**6th Examiner**
Signature:	**signature:**
Name :	**Name :**
Date: / / 2022	**Date: / / 2022**

بسم الله الرحمن الرحيم

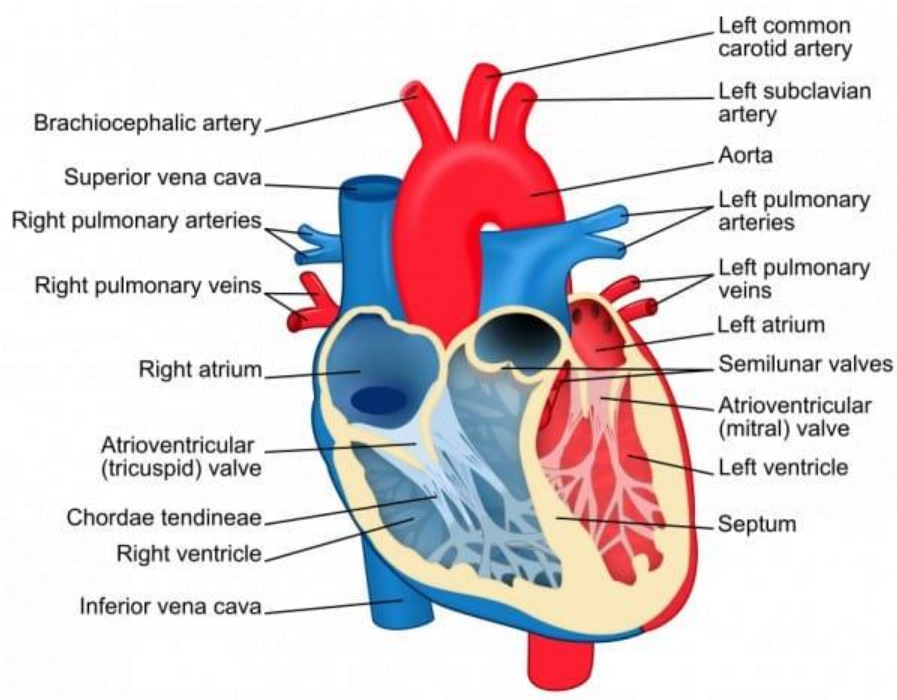
﴿قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَاعَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيم﴾

صدق الله العلي العظيم

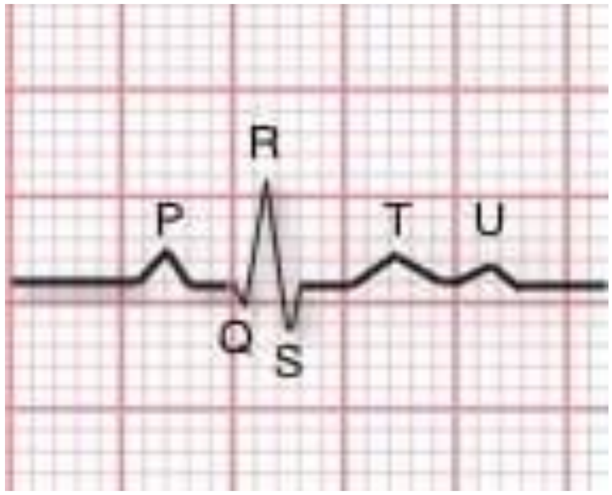
Content

Chapter one

ECG or Electrocardiography



An ECG is a paper or digital recording of the electrical signals in the heart. It is also called an electrocardiogram or an EKG. The ECG is used to determine heart rate, heart rhythm, and other information regarding the heart's condition. ECGs are used to help diagnose heart arrhythmias, heart attacks, pacemaker function, and heart failure. ECG can be analyzed by studying components of the waveform. These waveform components indicate cardiac electrical activity. The first upward of the ECG tracing is the P wave. It indicates atrial contraction. The QRS complex begins with Q, a small downward deflection, followed by a larger upwards deflection, a peak (R); and then a downwards S wave. This QRS complex indicates ventricular depolarization and contraction. Finally, the T wave, which is normally a smaller upwards waveform, representing ventricular re-polarization.



Medical uses of ECG

The overall goal of performing an ECG is to obtain information about the electrical functioning of the heart. Medical uses for this information are varied and often need to be combined with knowledge of the structure of the heart and physical examination signs to be interpreted. Some indications for performing an ECG include the following:

Chest pain or suspected myocardial infarction (heart attack), such as ST elevated myocardial infarction (STEMI) or non-ST elevated myocardial infarction (NSTEMI)

Symptoms such as shortness of breath, murmurs, fainting, seizures, funny turns, or arrhythmias including new onset palpitations or monitoring of known cardiac arrhythmias

Medication monitoring (e.g., drug-induced QT prolongation, Digoxin toxicity) and management of overdose (e.g., tricyclic overdose)

Electrolyte abnormalities, such as hyperkalemia

Perioperative monitoring in which any form of anesthesia is involved (e.g., monitored anesthesia care, general anesthesia). This includes preoperative assessment and intraoperative and postoperative monitoring.

Cardiac stress testing

Computed tomography angiography (CTA) and magnetic resonance angiography (MRA) of the heart (ECG is used to "gate" the scanning so that the anatomical position of the heart is steady)

Clinical cardiac electrophysiology, in which a catheter is inserted through the femoral vein and can have several electrodes along its length to record the direction of electrical activity from within the heart.

ECGs can be recorded as short intermittent tracings or continuous ECG monitoring. Continuous monitoring is used for critically ill patients, patients undergoing general anesthesia, and patients who have an infrequently occurring cardiac arrhythmia that would unlikely be seen on a conventional ten-second ECG. Continuous monitoring can be conducted by using Holter monitors, internal and external defibrillators and pacemakers, and/or biotelemetry.

Screening

A patient undergoing an ECG

Evidence does not support the use of ECGs among those without symptoms or at low risk of cardiovascular disease as an effort for prevention. This is because an ECG may falsely indicate the existence of a problem, leading to misdiagnosis, the recommendation of invasive procedures, and overtreatment. However, persons employed in certain critical occupations, such as aircraft pilots, may be required to have an ECG as part of their routine health evaluations. Hypertrophic cardiomyopathy screening may also be considered in adolescents as part of a sports physical out of concern for sudden cardiac death.

When an ECG is used

An ECG is often used alongside other tests to help diagnose and monitor conditions affecting the heart.

It can be used to investigate symptoms of a possible heart problem, such as chest pain, palpitations (suddenly noticeable heartbeats), dizziness and shortness of breath.

An ECG can help detect:

- **arrhythmias** – where the heart beats too slowly, too quickly, or irregularly
- **coronary heart disease** – where the heart's blood supply is blocked or interrupted by a build-up of fatty substances
- **heart attacks** – where the supply of blood to the heart is suddenly blocked
- **cardiomyopathy** – where the heart walls become thickened or enlarged

A series of ECGs can also be taken over time to monitor a person already diagnosed with a heart condition or taking medication known to potentially affect the heart.

How an ECG is carried out

There are several different ways an ECG can be carried out. Generally, the test involves attaching a number of small, sticky sensors called electrodes to your arms, legs and chest. These are connected by wires to an ECG recording machine.

You don't need to do anything special to prepare for the test. You can eat and drink as normal beforehand.

Before the electrodes are attached, you'll usually need to remove your upper clothing, and your chest may need to be shaved or cleaned. Once the electrodes are in place, you may be offered a hospital gown to cover yourself.

The test itself usually only lasts a few minutes, and you should be able to go home soon afterwards or return to the ward if you're already staying in hospital.

Types of ECG

There are 3 main types of ECG:

- **a resting ECG** – carried out while you're lying down in a comfortable position
- **a stress or exercise ECG** – carried out while you're using an exercise bike or treadmill
- **an ambulatory ECG (sometimes called a Holter monitor)** – the electrodes are connected to a small portable machine worn at your waist so your heart can be monitored at home for 1 or more days

The type of ECG you have will depend on your symptoms and the heart problem suspected.

For example, an exercise ECG may be recommended if your symptoms are triggered by physical activity, whereas an ambulatory ECG may be more suitable if your symptoms are unpredictable and occur in random, short episodes.

Chapter two

What is Arduino

Arduino is an open-source hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices. Its hardware products are licensed under a CC BY-SA license, while software is licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL),[1] permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially from the official website or through authorized distributors.

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ('shields') or breadboards (for prototyping) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs. The microcontrollers can be programmed using the C and C++ programming languages, using a standard API which is also known as the **Arduino language**, inspired by the Processing language and used with a modified version of the Processing IDE. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) and a command line tool developed in Go.

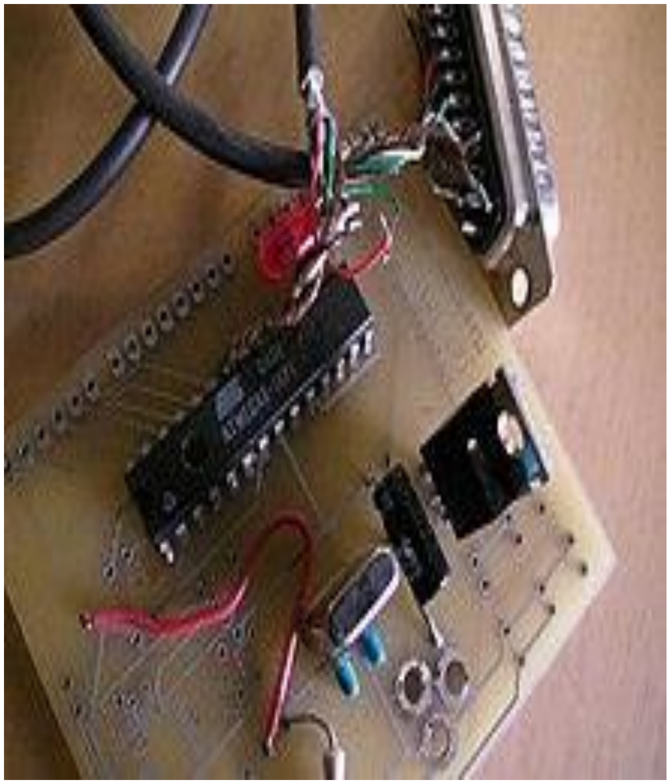
The Arduino project began in 2005 as a tool for students at the Interaction Design Institute Ivrea, Italy,[2] aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples of such devices intended for beginner hobbyists include simple robots, thermostats and motion detectors.

The name *Arduino* comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet. The bar was named after Arduin of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014.

Founding

The first Arduino ever made

The Arduino project was started at the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy. At that time, the students used a BASIC Stamp microcontroller at a cost of $50. In 2003 Hernando Barragán created the development platform *Wiring* as a Master's thesis project at IDII, under the supervision of Massimo Banzi and Casey Reas. Casey Reas is known for co-creating, with Ben Fry, the Processing development platform. The project goal was to create simple, low cost tools for creating digital projects by non-engineers. The Wiring platform consisted of a printed circuit board (PCB) with an ATmega128 microcontroller, an IDE based on Processing and library functions to easily program the microcontroller. In 2005, Massimo Banzi, with David Mellis, another IDII student, and David Cuartielles, extended Wiring by adding support for the cheaper ATmega8 microcontroller. The new project, forked from Wiring, was called *Arduino*.



The initial Arduino core team consisted of Massimo Banzi, David Cuartielles, Tom Igoe, Gianluca Martino, and David Mellis.

Following the completion of the platform, lighter and less expensive versions were distributed in the open-source community. It was estimated in mid-2011 that over 300,000 official Arduinos had been commercially produced, and in 2013 that 700,000 official boards were in users' hands.

Trademark dispute

In early 2008, the five co-founders of the Arduino project created a company, Arduino LLC, to hold the trademarks associated with Arduino. The manufacture and sale of the boards was to be done by external companies, and Arduino LLC would get a royalty from them. The founding bylaws of Arduino LLC specified that each of the five founders transfer ownership of the Arduino brand to the newly formed company. At the end of 2008, Gianluca Martino's company, Smart Projects, registered the Arduino trademark in Italy and kept this a secret from the other co-founders for about two years. This was revealed when the Arduino company tried to register the trademark in other areas of the world (they originally registered only in the US), and discovered that it was already registered in Italy. Negotiations with Martino and his firm to bring the trademark under control of the original Arduino company failed. In 2014, Smart Projects began refusing to pay royalties. They then appointed a new CEO, Federico Musto, who renamed the company *Arduino SRL* and created the website *arduino.org*, copying the graphics and layout of the original *arduino.cc*. This resulted in a rift in the Arduino development team. In January 2015, Arduino LLC filed a lawsuit against Arduino SRL. In May 2015, Arduino LLC created the worldwide trademark **Genuino**, used as brand name outside the United States. At the World Maker Faire in New York on 1 October 2016, Arduino LLC co-founder and CEO Massimo Banzi and Arduino SRL CEO Federico Musto announced the merger of the two companies. Around that same time, Massimo Banzi announced that in addition to the company a new Arduino Foundation would be launched as "a new beginning for Arduino", but this decision was withdrawn later. In April 2017, Wired reported that Musto had "fabricated his academic record... On his company's website, personal LinkedIn accounts, and even on Italian business documents, Musto was, until recently, listed as holding a PhD from the Massachusetts Institute of Technology. In some cases, his biography also claimed an MBA from New York University." Wired reported that neither university had any record of Musto's attendance, and Musto later admitted in an interview with Wired that he had never earned those degrees. The controversy surrounding Musto continued when, in July 2017, he reportedly pulled many open source licenses, schematics, and code from the Arduino website, prompting scrutiny and outcry.

By 2017 Arduino AG owned many Arduino trademarks. In July 2017 BCMI, founded by Massimo Banzi, David Cuartielles, David Mellis and Tom Igoe, acquired Arduino AG and all the Arduino trademarks. Fabio Violante is the new CEO replacing Federico Musto, who no longer works for Arduino AG.

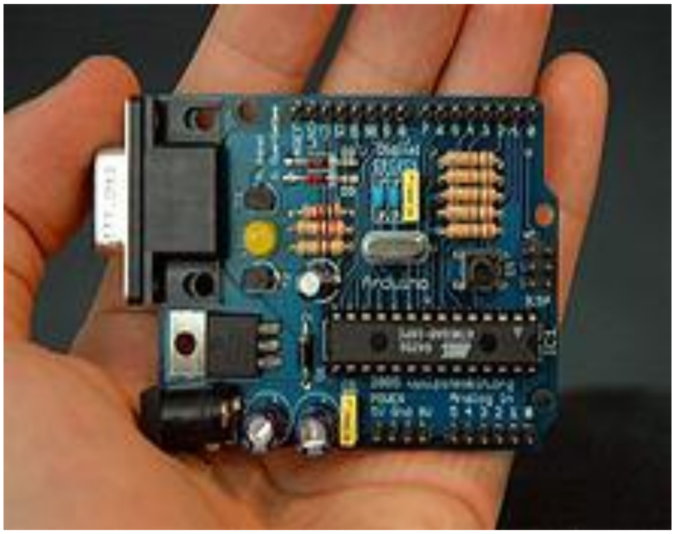
Post-dispute

In October 2017, Arduino announced its partnership with ARM Holdings (ARM). The announcement said, in part, "ARM recognized independence as a core value of Arduino ... without any lock-in with the ARM architecture". Arduino intends to continue to work with all technology vendors and architectures.

Under Violante's guidance, the company started growing again and releasing new designs. The Genuino trademark was dismissed and all products were branded again with the Arduino name. As of February 2020, the Arduino community included about 30 million active users based on the IDE downloads. In August 2018, Arduino announced its new open source command line tool (arduino-cli), which can be used as a replacement of the IDE to program the boards from a shell. In February 2019, Arduino announced its IoT Cloud service as an extension of the Create online environment.

Hardware

Arduino is open-source hardware. The hardware reference designs are distributed under a Creative Commons Attribution Share-Alike 2.5 license and are available on the Arduino website. Layout and production files for some versions of the hardware are also available.



Although the hardware and software designs are freely available under copyleft licenses, the developers have requested the name *Arduino* to be exclusive to the official product and not be used for derived works without permission. The official policy document on use of the Arduino name emphasizes that the project is open to incorporating work by others into the official product. Several Arduino-compatible products commercially released have avoided the project name by using various names ending in -*duino*.

An early Arduino board with an RS-232 serial interface (upper left) and an Atmel ATmega8 microcontroller chip (black, lower right); the 14 digital I/O pins are at the top, the 6 analog input pins at the lower right, and the power connector at the lower left.

Most Arduino boards consist of an Atmel 8-bit AVR microcontroller (ATmega8, ATmega168, ATmega328, ATmega1280, or ATmega2560) with varying amounts of flash memory, pins, and features. The 32-bit Arduino Due, based on the Atmel SAM3X8E was introduced in 2012. The boards use single or double-row pins or female headers that facilitate connections for programming and incorporation into other circuits. These may connect with add-on modules termed *shields*. Multiple and possibly stacked shields may be individually addressable via an I²C serial bus. Most boards include a 5 V linear regulator and a 16 MHz crystal oscillator or ceramic resonator. Some designs, such as the LilyPad, run at 8 MHz and dispense with the onboard voltage regulator due to specific form-factor restrictions.

Arduino microcontrollers are pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory. The default bootloader of the Arduino Uno is the Optiboot bootloader. Boards are loaded with program code via a serial connection to another computer. Some serial Arduino boards contain a level shifter circuit to convert between RS-232 logic levels and transistor–transistor logic (TTL) level signals. Current Arduino boards are programmed via Universal Serial Bus (USB), implemented using USB-to-serial adapter chips such as the FTDI FT232. Some boards, such as later-model Uno boards, substitute the FTDI chip with a separate AVR chip containing USB-to-serial firmware, which is reprogrammable via its own ICSP header. Other variants, such as the Arduino Mini and the unofficial Boarduino, use a detachable USB-to-serial adapter board or cable, Bluetooth or other methods. When used with traditional microcontroller tools, instead of the Arduino IDE, standard AVR in-system programming (ISP) programming is used.

An official Arduino Uno R2 with descriptions of the I/O locations

The Arduino board exposes most of the microcontroller's I/O pins for use by other circuits. The *Diecimila*, *Duemilanove*, and current *Uno* provide 14 digital I/O pins, six of which can produce pulse-width modulated signals, and six analog inputs, which can also be used as six digital I/O pins. These pins are on the top of the board, via female 0.1-inch (2.54 mm) headers. Several plug-in application shields are also commercially available. The Arduino Nano, and Arduino-compatible Bare Bones Board and Boarduino boards may provide male header pins on the underside of the board that can plug into solderless breadboards.

Many Arduino-compatible and Arduino-derived boards exist. Some are functionally equivalent to an Arduino and can be used interchangeably. Many enhance the basic Arduino by adding output drivers, often for use in school-level education, to simplify making buggies and small robots. Others are electrically equivalent, but change the form factor, sometimes retaining compatibility with shields, sometimes not. Some variants use different processors, of varying compatibility.

Software

A program for Arduino hardware may be written in any programming language with compilers that produce binary machine code for the target processor. Atmel provides a development environment for their 8-bit AVR and 32-bit ARM Cortex-M based microcontrollers: AVR Studio (older) and Atmel Studio (newer).

IDE

The Arduino integrated development environment (IDE) is a cross-platform application (for Microsoft Windows, macOS, and Linux) that is written in the Java programming language. It originated from the IDE for the languages *Processing* and *Wiring*. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple *one-click* mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. The source code for the IDE is released under the GNU General Public License, version 2.

The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub *main()* into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program *avrdude* to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

IDE 2.0

On October 18, 2019, Arduino Pro IDE (alpha preview) was released. Later, on March 1, 2021, the beta preview was released, renamed IDE 2.0. The system still uses Arduino CLI (Command Line Interface), but improvements include a more professional development environment, autocompletion support, and Git integration. The application frontend is based on the Eclipse Theia Open Source IDE. The main features available in the new release are:

- Modern, fully featured development environment
- Dual Mode, Classic Mode (identical to the Classic Arduino IDE) and Pro Mode (File System view)
- New Board Manager
- New Library Manager
- Board List
- Basic Auto-Completion (Arm targets only)
- Git Integration
- Serial Monitor
- Dark Mode

Sketch

A *sketch* is a program written with the Arduino IDE. Sketches are saved on the development computer as text files with the file extension **.ino**. Arduino Software (IDE) pre-1.0 saved sketches with the extension **.pde**.

A minimal Arduino C/C++ program consists of only two functions:

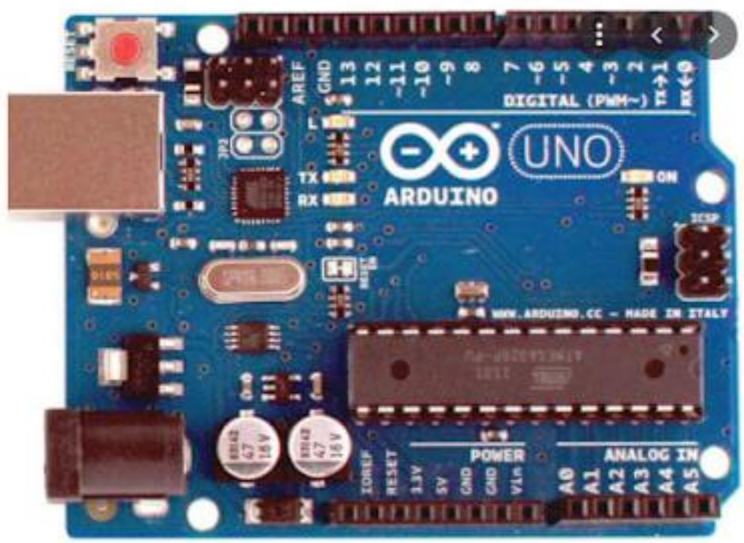
- `setup()`: This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch. It is analogous to the function `main()`.
- `loop()`: After `setup()` function exits (ends), the `loop()` function is executed repeatedly in the main program. It controls the board until the board is powered off or is reset. It is analogous to the function `while(1)`.

Bill of Materials

S.N.	COMPONENTS NAME	DESCRIPTION	QUANTITY
1	Arduino Board	Arduino UNO R3 Development Board	1
2	ECG Sensor	AD8232 ECG Sensor Kit	1
3	Connecting Wires	Jumper Wires	20
4	Breadboard	-	1
	Heart rate sensor	Max30100	1

Arduino Uno

Arduino UNO is a low-cost, flexible, and easy-to-use programmable open-source microcontroller board that can be integrated into a variety of electronic projects. This board can be interfaced with other Arduino boards, Arduino shields, Raspberry Pi boards and can control relays, LEDs, servos, and motors as an output. Arduino UNO features AVR microcontroller Atmega328, 6 analogue input pins, and 14 digital I/O pins out of which 6 are used as PWM output.



Arduino UNO

This board contains a USB interface i.e. USB cable is used to connect the board with the computer and Arduino IDE (Integrated Development Environment) software is used to program the board.

The unit comes with 32KB flash memory that is used to store the number of instructions while the SRAM is 2KB and EEPROM is 1KB.

The operating voltage of the unit is 5V which projects the microcontroller on the board and its associated circuitry operates at 5V while the input voltage ranges between 6V to 20V and the recommended input voltage ranges from 7V to 12V.

Arduino UNO Components

The Arduino UNO board contains the following components and specifications:

ATmega328: This is the brain of the board in which the program is stored.

Ground Pin: there are several ground pins incorporated on the board.

PWM: the board contains 6 PWM pins. PWM stands for Pulse Width Modulation, using this process we can control the speed of the servo motor, DC motor, and brightness of the LED.

Digital I/O Pins: there are 14 digital (0-13) I/O pins available on the board that can be connected with external electronic components.

Analogue Pins: there are 6 analogue pins integrated on the board. These pins can read the analogue sensor and can convert it into a digital signal.

AREF: It is an Analog Reference Pin used to set an external reference voltage.

Reset Button: This button will reset the code loaded into the board. This button is useful when the board hangs up, pressing this button will take the entire board into an initial state.

USB Interface: This interface is used to connect the board with the computer and to upload the Arduino sketches (Arduino Program is called a Sketch)

DC Power Jack: This is used to power up the board with a power supply.

Power LED: This is a power LED that lights up when the board is connected with the power source.

Micro SD Card: The UNO board supports a micro SD card that allows the board to store more information.

3.3V: This pin is used to supply 3.3V power to your projects.

5V: This pin is used to supply 5V power to your projects.

VIN: It is the input voltage applied to the UNO board.

Voltage Regulator: The voltage regulator controls the voltage that goes into the board.

SPI: The SPI stands for Serial Peripheral Interface. Four Pins 10(SS), 11(MOSI), 12(MISO), 13(SCK) are used for this communication.

TX/RX: Pins TX and RX are used for serial communication. The TX is a transmit pin used to transmit the serial data while RX is a receive pin used to receive serial data.

Arduino UNO Pinout

There is a range of Arduino boards available in the market but the Arduino UNO is the most common board used in the electronic industry. The following figure shows the Arduino UNO Pinout for better understanding:

How to Program Arduino UNO

Arduino UNO is easy to program and a person with little or no technical knowledge can get hands-on experience with this board. The Arduino UNO board is programmed using Arduino IDE software which is an official software introduced by Arduino.cc to program the board. The Arduino program is called a sketch which you need to unload into the board. The sketch is nothing but a set of instructions that allow the board to perform certain functions as per your requirements.

Each Arduino sketch comes with two main parts:

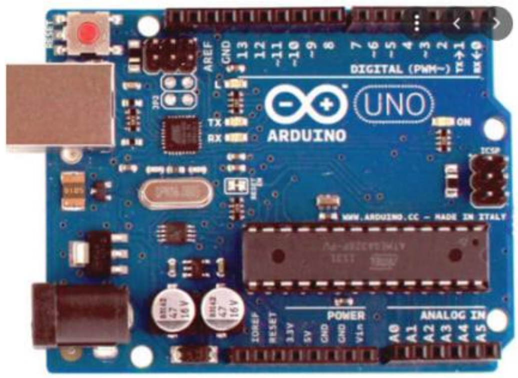
void setup() – this sets up the things that need to be done once and they don’t happen again in the running program.

void loop() – this part comes with the instructions that get repeated again and again until the board is turned off.

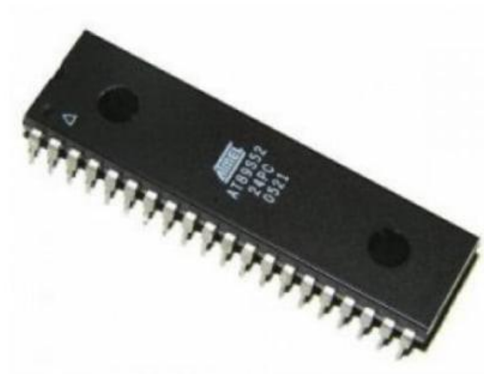
Difference between Arduino Board and Microcontroller:

Arduino boards can perform some functions that a single microcontroller is capable of doing. But hobbyists and experts still prefer the Arduino board over the microcontroller. Why? Because Arduino boards are easy to use and you don’t require a lot of expertise to run these units. Simply plug the board into the computer and start playing with it.

Moreover, while using Arduino boards, you don’t require extra peripherals and components to run the boards. Arduino is the complete board that comes with GPIO pins, analogue pins, and a microcontroller as the heart of the board. A microcontroller, on the other hand, is a chip where all the necessary parts like microprocessor, ram, and flash memory are incorporated into a single chip.



Arduino Board



Microcontroller

So we can say every Arduino board is a microcontroller but not every microcontroller is an Arduino board.

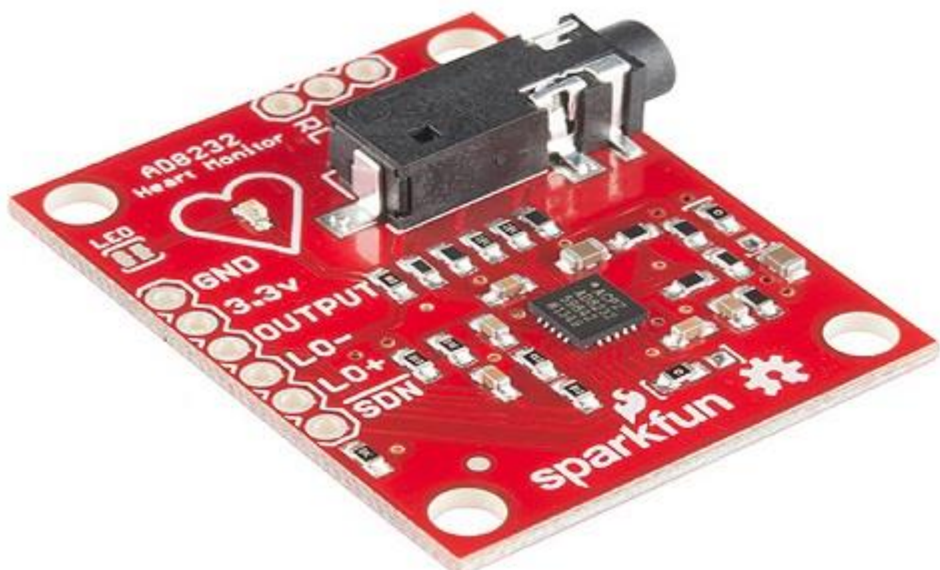
Arduino UNO Applications

The Arduino boards can work as a stand-alone project and can be interfaced with other Arduino boards or Raspberry Pi boards. Arduino UNO board is used in the following applications.

- Weighing Machines
- Traffic Light Count Down Timer
- Parking Lot Counter
- Embedded systems
- Home Automation
- Industrial Automation
- Medical Instrument
- Emergency Light for Railways

AD8232 ECG Sensor

The AD8232 ECG sensor is a commercial board used to calculate the electrical movement of the human heart. This action can be chart like an Electrocardiogram and the output of this is an analog reading. Electrocardiograms can be very noisy, so to reduce the noise the AD8232 chip can be used. The **working principle of the ECG sensor** is like an operational amplifier to help in getting a clear signal from the intervals simply.



AD8232-ECG-sensor

The AD8232 sensor is used for signal conditioning in ECG as well as other measurement applications of biopotential. The main purpose of this chip is to amplify, extract as well as filter biopotential signals which are small in the noisy conditions like those formed through the replacement of remote electrode as well as motion.

AD8232 Pin Configuration

The heart rate monitoring sensor like AD8232 includes the pins like SDN pin, LO+ pin, LO- pin, OUTPUT pin, 3.3V pin, and GND pin. So that we can connect this IC to development boards like Arduino by soldering pins.

Additionally, this board includes pins like the right arm (RA), left arm (LA) & right leg (RL) pins to connect custom sensors. An LED indicator in this board is used to indicate the heartbeat rhythm of humans.

The AD8232 sensor comprises a function like quick restore, used to decrease the length of long resolving tails of the HPFs. This sensor is accessible in a 4 mm × 4 mm size, and the package of this sensor is 20-lead LFCSP. It operates from −40°C -to- +85°C but the performance is specified from 0°C -to- 70°C.

Features and Specifications

The features of this sensor mainly include the following.

- Operation of single supply ranges from 2V to 3.5V
- The front end is integrated fully with only lead ECG
- The virtual ground can be generated through integrated reference
- RFI filter is used internally
- The current supply is low like 170 µA
- The output is rail to rail
- Shutdown pin
- CMRR is 80 dB

- Incorporated RLD amplifier (right leg drive
- Electrode configurations are 2 or 3
- The operational amplifier is uncommitted
- It accepts half cell potential up to ±300 mV
- Three-pole adaptable LPF with adaptable gain
- The signal gain is high using DC blocking capacity
- Filter settling can be improved by quick restore
- Two-pole adaptable HPF
- 4 mm × 4 mm and 20-lead LFCSP package

Applications of AD8232 ECG Sensor

The applications of the AD8232 ECG sensor include the following.

- Monitoring of heart and fitness activity
- Handy ECG
- Monitoring of remote health
- Used in gaming devices
- Acquisition of biopotential signal
- Biometrics
- Physiology studies
- Prototyping of biomedical instruments
- Variability of heart rate
- Interaction of human-computer
- Psychophysiology

MAX30100

MAX30100 is an integrated pulse oximeter and heart-rate monitor sensor solution. It's an optical sensor that derives its readings from emitting two wavelengths of light from two LEDs – a red and an infrared one – then measuring the absorbance of pulsing blood through a photodetector. This particular LED colour combination is optimized for reading the data through the tip of one's finger. It is fully configurable through software registers and the digital output data is stored in a 16-deep FIFO within the device.It has an I2C digital interface to communicate with a host microcontroller.

The pulse oximetry subsystem in MAX30100 consists of ambient light cancellation (ALC), 16-bit sigma delta ADC, and proprietary discrete time filter. It has an ultra-low-power operation which makes it ideal for battery operated systems. MAX30100 operates on a supply in the range of 1.8 to 3.3V.It can be used in wearable devices, fitness assistant devices, medical monitoring devices, etc.The MAX30100 operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.

Pin Configuration of MAX30100 Pulse Oximeter Heart Rate Sensor Module:

SN	PINS	DEFINITION OF PINS
1	VIN	Input voltage (1.8V to 5.5V)
2	SCL	IIC-SCL
3	SDA	IIC-SDA
4	INT	MAX30100INT
5	IRD	MAX30100 IR_DRV
6	RD	MAX30100 R_DRV
7	GND	Ground

Specifications and Features of MAX30100 Pulse Oximeter Heart Rate Sensor Module:

- It is an integrated pulse oximetry and heart rate monitor sensor solution.
- Integrated LEDs, Photo Sensor, and High-Performance Analog Front -End
- Complete Pulse Oximeter and Heart-Rate Sensor Solution Simplifies Design
- Measures absorbance of pulsing blood
- I2C interface plus INT pin
- Tiny 5.6mm x 2.8mm x 1.2mm 14-Pin Optically Enhanced System-in-Package
- Ultra-Low-Power Operation Increases Battery Life for Wearable Devices
- Programmable Sample Rate and LED Current for Power Savings
- Ultra-Low Shutdown Current (0.7µA, typ)
- Advanced Functionality Improves Measurement Performance
- High SNR Provides Robust Motion Artifact Resilience
- Integrated Ambient Light Cancellation
- High Sample Rate Capability
- Fast Data Output Capability

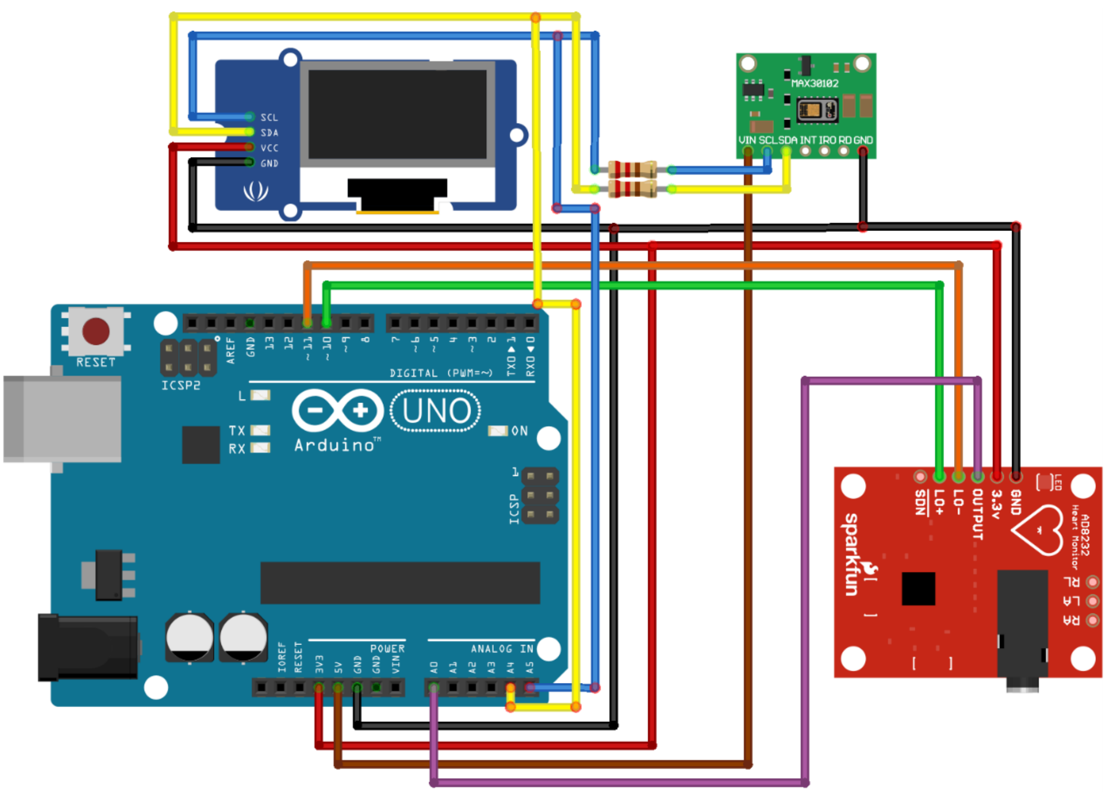
Applications of MAX30100 Pulse Oximeter Heart Rate Sensor Module:

- Fitness Assistant Devices
- Medical Monitoring Devices
- Wearable Devices

Thus, the AD8232 ECG sensor is a precise small chip used for measuring the electrical movement of the heart that can be charted like an Electrocardiogram (ECG). It is used for assisting in diagnosing a variety of heart conditions?

Experiment setup

The AD8232 Heart Rate Monitor breaks out nine connections from the IC. We traditionally call these connections "pins" because they come from the pins on the IC, but they are actually holes that you can solder wires or header pins to.



We'll connect five of the nine pins on the board to Arduino. The five pins you need are labeled GND, 3.3v, OUTPUT, LO-, and LO+.

Board Label	Pin Function	Arduino Connection
GND	Ground	**GND**
3.3v	3.3v Power Supply	**3.3v**
OUTPUT	Output Signal	**A0**
LO-	Leads-off Detect -	**11**
LO+	Leads-off Detect +	**10**
SDN	Shutdown	**Not used**

Then we connect the MAX30100 sensor's pins GND, SCL, SDA

GND	GND
SCL	A5
SDA	A4

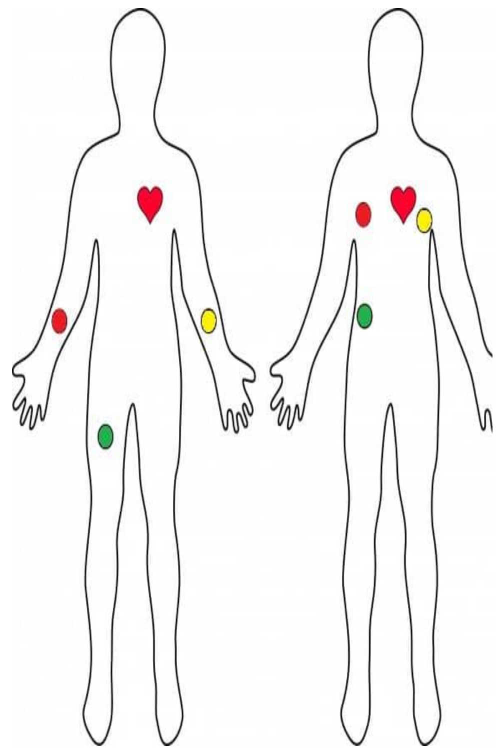
AD8232 ECG Sensor Placement on Body

It is recommended to snap the sensor pads on the leads before application to the body. The closer to the heart the pads are, the better the measurement. The cables are color-coded to help identify proper placement.

Red: RA (Right Arm)

Yellow: LA (Left Arm)

Green: RL (Right Leg)



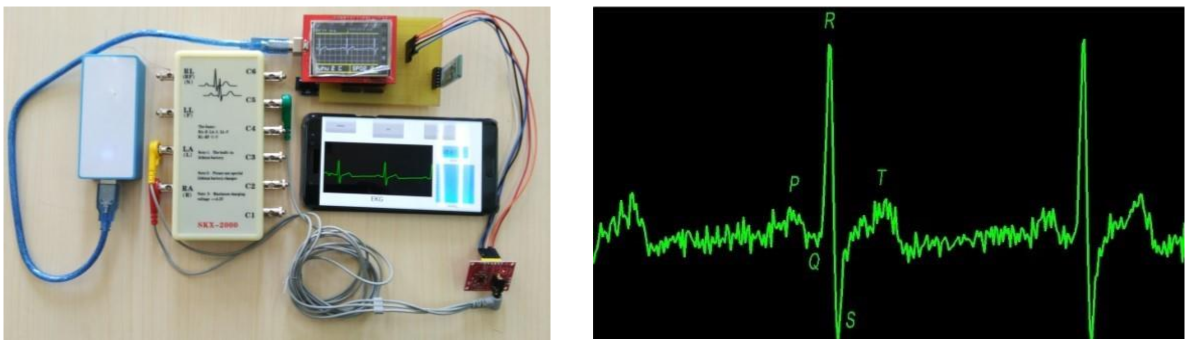
Arduino Source Code/Program

```
void setup() {
// initialize the serial communication:
Serial.begin(9600);
pinMode(10, INPUT); // Setup for leads off detection LO +
pinMode(11, INPUT); // Setup for leads off detection LO -

}

void loop() {

if((digitalRead(10) == 1)||(digitalRead(11) == 1)){
Serial.println('!');
}
else{
// send the value of analog input 0:
Serial.println(analogRead(A0));
}
//Wait for a bit to keep serial data from saturating
delay(1);
}
```

RESULT AND DISCUSSION

ECG Simulator

The Figure shows a trial with ECG Simulator as the reference data, showing a healthy heart wave (Normal Sinus Rhythm). Figure (a) shows a full assembly of Portable ECG with Bluetooth feature acquiring data from ECG Simulator. While figure (b) is a close-up look on one cycle of a PQRST wave, which was produced by a simulator acting as a healthy heart.



(a) (b)

Reading results of Portable ECG with ECG Simulator. (a) Actual experimental setup. (b) Smartphone's screenshot of data

Figure (b) explains the result of a healthy heart. Two main values were extracted from the data, one in the form or morphology of the PQRST wave, and the second one was the heart's BPM. Figure 7(b) is an example of an ECG wave caught on the smartphone screen. An ECG wave could be split into three sections, which are P-wave, QRS complex, and T-wave. P-wave was the recording result of the SA Node which was the heart's pacemaker. The QRS complex was the combination of deflection and contraction of the ventricle's muscle. T-wave was the recording when the ventricle's muscle repolarized to be ready for the next heartbeat.

The second value was BPM (Beats per Minute), which was the frequency of heartbeats inside 60 seconds time period. A healthy heart rate is 60 - 100 BPM while in a resting state. When exercising, it will increase to around 110150 BPM. And while sleeping, the heartbeats will be around 40-60BPM. In making data acquisition on a patient's heart, the said patient must be set on a resting state. If a patient has a heart rate value outside the range of 60 - 100 BPM, then the patient is afflicted by Bradycardia if his heart rate below 60 BPM or tachycardia if it's over 100 BPM.

Data Acquisition Trial on Human Body with ECG

Next, Portable ECG with Bluetooth feature was tested on a real human body that has an unhealthy heart condition. The results which were displayed in figure then interpreted using medical reasonings and a conclusion.

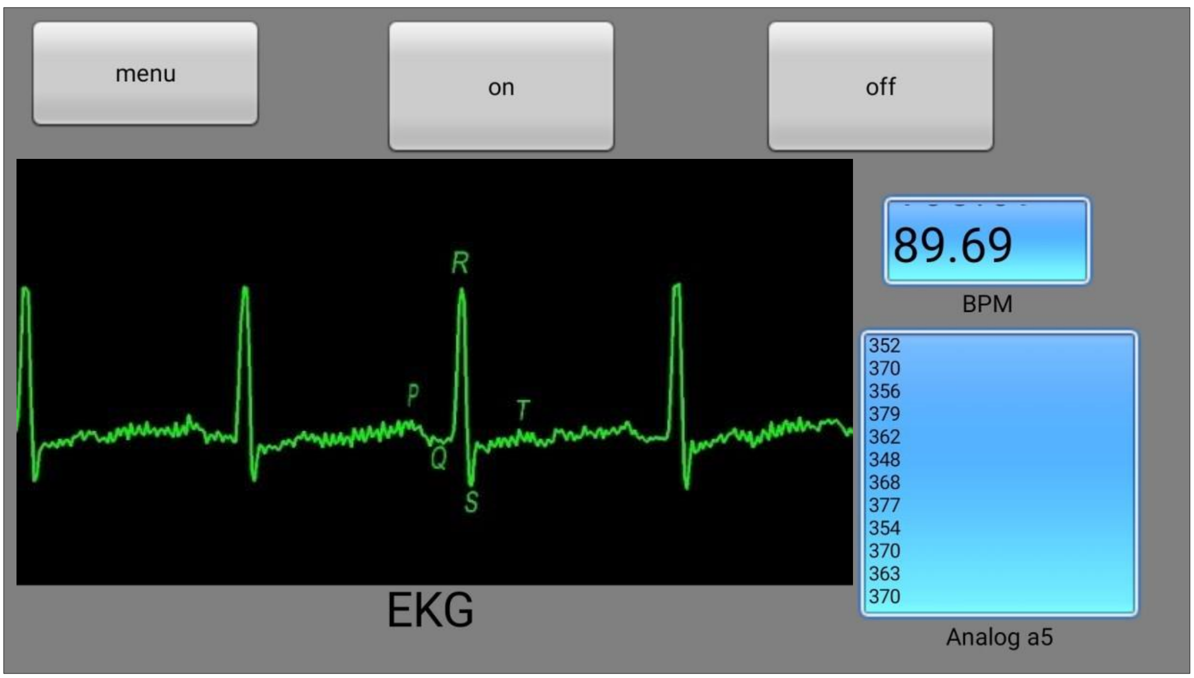


FIGURE. ECG's reading results in the human body (smartphone screenshot).

In Figure, it can be interpreted that the distance between each of the R wave is similar to others. This result showed that the heart has a normal heart rhythm. The value of Heartrate was 89 BPM, which told that its Heartrate was normal because it was still inside the range value of 60-100 BPM. Seen from the morphology of the ECG waves, we could observe that there were differences between ECG Simulator and Patient's ECG wave. First is that the ECG wave on the patient is not as smooth as ECG Simulator. This caused by “noise” from the patient’s muscle movement and the imperfect noises from the place of data acquisition. The P-wave of the patient was a bit less visible compared to ECG Simulator yet still has normal morphology. The QRS complex also had the same shape as the simulator. The T- wave had a very small amplitude, showing signs that there was partial clotting inside the patient’s coronary artery.

It could be concluded that the patient was afflicted by Myocardial Ischemia (Coronary disease).

CONCLUSION

This ECG hardware has worked with a desirable result. The smartphone display was not only able to record the electrical activity of the heart using the AD8232 sensor and MAX30100 sensor but also able to plot analog data in the form of a graph on the screen.

ECG used the HC-05 Bluetooth module. It can be saved in the JPG file from which it can be inserted into this report

and also, in an MP4 file to see the real-time process of data acquisition directly.

Chapter four

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جامعـــة بابــل

كليـــة الهندســـــة

قسم الهندسـة الكهربائيــة

قراءة ومراقبة إشارة كهربية القلب باستخدام الأردوينو

قــدم هــذا المشروع لاستكمال جزء من متطلبات الحصول على درجــة البكالوريوس في الهندسة الكهربائية

من قبل:

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