

AN INTELLIGENT DEVICE FOR OFFLINE AND ONLINE TELEMEDICINE FOR PATIENTS WITH HEALTH MONITORING AND DIAGNOSIS THROUGH IOT

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Electronics and Communication Engineering

by

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

SCHOOL OF ELECTRICAL AND ELECTRONICS

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL - 2021



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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **GELLI SIVARAJA** (Reg.no.**37130141**) and **GANDRALA AVINASH REDDY** (Reg.no.**37130133**) who carried out the project entitled "AN INTELLIGENT DEVICE FOR OFFLINE AND ONLINE TELEMEDICINE FOR PATIENTS WITH HEALTH MONITORING AND DIAGNOSIS THROUGH IOT" under my supervision from December 2020 to April 2021.

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Submitted for Viva voce Examination held on_____

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DECLARATION

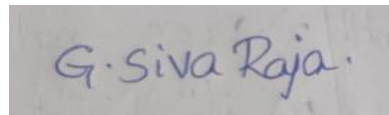
We **GELLI SIVARAJA (Reg.no.37130141)** and **GANDRALA AVINASH REDDY (Reg.No.37130133)** hereby declare that the Project Report entitled “**AN INTELLIGENT DEVICE FOR OFFLINE AND ONLINE TELEMEDICINE FOR PATIENTS WITH HEALTH MONITORING AND DIAGNOSIS THROUGH IOT**” done by us under the guidance of **Ms. R. SAKTHI PRABHA, M.E., (Ph.D.)**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in **ELECTRONICS AND COMMUNICATION ENGINEERING**.

DATE: 17-04-2021

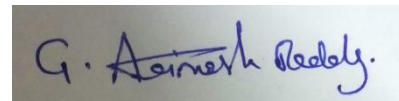
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SIGNATURE OF THE CANDIDATE

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ABSTRACT

Telemedicine is a rapidly expanding area within medical informatics. Defined as using computer and communication technologies to provide medical expertise and services to distant locations with internet connectivity as well as providing on the go Monitoring and diagnostics services. Many people in rural villages and in parts where Hospital or small medical dispensary is not accessible over short period of time, this device can be very useful in the process. As ICU monitoring is costly in today world and patients requiring from continuous monitoring can make use of this device which can send crucial data to the doctor for him to monitor and also make decisions based on the data from the sensors. In this project we are going to develop an intelligent device for monitoring online and offline health using IOT sensors with advance disease prediction (COVID-19 – as of now) through sensor technology. Added to this is an adaptive sensor calibration method coded with performed calculations and advanced prediction. In case of the future interventions in this project we would try using AI and ML models to better simulate patterns and give alerts and alarms in case the patient undergoes any life-threatening situations.

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CHAPTER 1

INTRODUCTION

Telemedicine involves the use of electronic communications and software to provide clinical services to patients without an in-person visit. In this project a telemedicine device is made for patients in rural villages who couldn't afford ICU expenses. This device can monitor as well as send data to the concerned doctor for immediate course of action. Here, a prototype of an MQTT based patient health monitoring system is implemented that can measure patient vital parameters such as Heart beat rate, Body temperature and patient position. The system sends an alert message to care taker mobile using MQTT protocol, if the vital parameters of the patient change to abnormal values, and in case of a fall of an elderly or ill patient. The developed system is helpful for patients at home who need constant or periodical monitoring by the doctor or care taker at any time and anywhere through the internet ease of use

The ECG, Heartbeat, EEG, PI sensors, and Arduino IDE, ESP Controller, LCD Display, Power controlling circuits, Arduino Simulator, Things Board, IoT platform, PSPICE for Simulation. The infrastructure presented in this can also be applied to other healthcare domains. It concludes with extensibilities found for the solution in the healthcare domain.

This system notifies the patient with possible precautionary steps to be practiced by them and it also suggests the patient with medical care and what patient has to do when any critical situation come. This system helps the doctor to monitor his patient from anywhere and anytime and it also helps the patient relatives to view patient health condition remotely.

An efficient management, analysis, and interpretation of big data can change the game by opening new avenues for modern healthcare. That is exactly why various industries, including the healthcare industry, are taking vigorous steps to convert this potential into better services and financial advantages. With a strong integration of biomedical and healthcare data, modern healthcare organizations can possibly revolutionize the medical therapies and personalizemedicine

CHAPTER 2

LITERATURE SURVEY

Kazim Abu Zolani; Rubye Yasmin; presents a wireless biosignal acquisition system-on-a-chip (WBSA-SoC) specialized for electrocardiogram (ECG) monitoring. The proposed system consists of three subsystems, namely, 1) the ECG acquisition node, 2) the protocol for standard IEEE 802.15.4 ZigBee system, and 3) the RF transmitter circuits. The ZigBee protocol is adopted for wireless communication to achieve high integration, applicability, and portability. A fully integrated CMOS RF front end containing a quadrature voltage-controlled oscillator and a 2.4-GHz low-IF (i.e., zero-IF) transmitter is employed to transmit ECG signals through wireless communication. The low-power WBSA-SoC is implemented by the TSMC 0.18- μm standard CMOS process. An ARM-based displayer with FPGA demodulation and an RF receiver with analog-to-digital mixed-mode circuits are constructed as verification platform to demonstrate the wireless ECG acquisition system. Measurement results on the human body show that the proposed SoC can effectively acquire ECG signals.

Kazim Abu Zubair; Md. Radwan Samir; build an Android platform based mobile application for the healthcare domain, which uses the idea of Internet of Things (IoT) and cloud computing. We have built an application called 'ECG Android App' which provides the end user with visualization of their Electro Cardiogram (ECG) waves and data logging functionality in the background. The logged data can be uploaded to the user's private centralized cloud or a specific medical cloud, which keeps a record of all the monitored data and can be retrieved for analysis by the medical personnel. Though the idea of building a medical application using IoT and cloud techniques is not totally new, there is a lack of empirical studies in building such a system. This paper reviews the fundamental concepts of IoT. Further, the paper presents an infrastructure for the healthcare domain, which consists of various technologies: IOIO microcontroller, signal processing, communication protocols, secure and efficient mechanisms for large file transfer, data base management system, and the centralized cloud. The paper emphasizes on the system and software architecture and design which is essential to overall IoT and cloud based medical applications. The infrastructure presented in the paper can also be applied to other healthcare domains. It concludes with extensibilities found for the solution in the

healthcare domain.

Samoa Marijuana villegas-Ceballos presents the Internet of things (IoT) is the emerging paradigm, which contains a vital amount of smart devices and smart objects are connected to the internet for communicating each other. In IoT devices are used in numerous fields which make humans day to day life more comfortable. These smart objects and devices are used to collect information from a sensor like collect temperature, blood pressure, sugar level, which are used in healthcare to evaluate health condition of a patient. This collected information uploaded into the cloud so that doctor will make an accurate decision and notify the caretaker or nurse. In this paper, pulse rate, body temperature. spos.body movement of patient and other parameters are measured and this measured data uploaded to the MQTT server. This system notifies the patient with possible precautionary steps to be practiced by them and it also suggests the patient with medical care and what patient has to do when any critical situation come. This system helps the doctor to monitor his patient from anywhere and anytime and it also helps the patient relatives to view patient health condition remotely.

Ihab kassem; Azzam sleet presents a study aims to develop a community-based electrocardiogram (ECG) monitoring system for cardiac outpatients to wirelessly detect heart rate, provide personalized healthcare, and enhance interactive social contact because of the prevalence of deaths from cardiovascular disease and the growing problem of aging in the world. The system not only strengthens the performance of the ECG monitoring system but also emphasizes the ergonomic design of wearable devices and user interfaces. In addition, it enables medical professionals to diagnose cardiac symptoms remotely and electronically manage medical reports and suggestions. The experimental result shows high performance of the dry electrode, even in dynamic conditions. The comparison result with different ECG healthcare systems shows the essential factors that the system should possess and the capability of the proposed system. Finally, a user survey was conducted based on the unified theory of acceptance and users of technology (UTAUT) model.

Boride Samar Salieri; Amara Presario Pulse oximetry has revolutionized the ability to monitor oxygenation in a continuous, accurate, and non-invasive fashion. Despite its ubiquitous use, it is our impression and supported by studies that many providers do not know the basic

principles behind its mechanism of function. This knowledge is important because it provides the conceptual basis of appreciating its limitations and recognizing when pulse oximeter readings may be erroneous. In this review, we discuss how pulse oximeters are able to distinguish oxygenated hemoglobin from deoxygenated hemoglobin and how they are able to recognize oxygen saturation only from the arterial compartment of blood. Based on these principles, we discuss the various conditions that can cause spurious readings and the mechanisms underlying them.

Ihab Kassem; Azzam sleet A wireless ECG system using dry-contact electrodes is presented. The system consists of a pair of coin sized dry-contact electrodes manufactured on a standard printed circuit board that can operate both on top of the skin and through clothing and can be embedded within comfortable layers of fabric. The wireless main unit assures the transmission of the ECG signal to a computer for storage and processing. The system provides a differential gain of 56dB over a 1-150Hz bandwidth. Signals are digitized with a 10-bit ADC and samples are transferred via ultra-low power ANT+ wireless technology. The preliminary results showed that the proposed wearable system is ideally suited for monitoring patient cardiac activity in real time at home, healthcare or sports facilities. It is highly suitable for integration in wearable ECG chest harness.

Chris Edwards as the Raspberry Pi celebrates its first birthday, designs intended for the hobbyist are getting mainstream attention from developers of 'grown up' applications. Few items of electronic hardware have engendered quite as much enthusiasm as the compact, single-board computer developed by the Raspberry Pi Foundation with the aim of encouraging basic computer science in schools. Had it had been for sale in shops, the queues would probably have outstripped those around Apple stores in the earlier days of the iPhone and iPad. The Pi - and other hardware like it - is reinvigorating the world of electronic design; but the project started out with fairly limited ambitions, with its founders hoping that it would simply fill a gap in education. As the Raspberry Pi celebrates its first birthday - and one million units shipped - there are several indications that its value is being readily exploited by developers of 'grown up' products who see it as a cheap (circa £25) and effective way of getting compute power into a range of commercial-class solutions requirements.

Yusuf Abdullahi Bahamas In this paper, we analyze the working principle of an arduino. These days many people try to use the Arduino because it makes things easier due to the simplified version of C++ and the already made Arduino microcontroller (atmega328 microcontroller [1]) that you can programme, erase and reprogramme at any given time. In this paper we will discuss the hardware components used in the arduino board, the software used to programme it (Arduino board) with the guide on how to write and construct your own projects, and a couple of examples of an Arduino project, This will give you the overall view of an Arduino uno, that after reading this paper you will get the basic concept and use of an Arduino uno.

Ormand, A. The Internet of Things (IoT) relies on physical objects interconnected between each other's, creating a mesh of devices producing information and services. In this context, sensors and actuators are being continuously embedded in everyday objects (e.g., cars, home appliances, and smartphones) thus pervading our living environment. Among the plethora of application contexts, smart Healthcare is gaining momentum. Indeed IoT can revolutionize the healthcare industry by improving operational efficiency and clinical trials' quality of monitoring, and by optimizing healthcare costs. This paper provides an overview of IoT, its applicability in healthcare, some insights about current trends and an outlook on future developments of healthcare systems.

M. El-hajj, M. Chamoun, A. Fathallah and A. Zerhouni, Internet of Things (IoT) is slowly but steadily becoming part of different aspects of our lives, with its applications ranging from smart homes, to wearable devices, to healthcare, etc. This wide spectrum of applications results in shared data containing large amount of users' private information. The security of such information becomes a paramount concern. The IoT security requirements include data confidentiality, data integrity, authentication, access control, privacy, etc. In particular, authentication of IoT devices has a particular importance given the variety of attacks which might result from its breach [1]. This paper provides an analysis of the different authentication schemes proposed in the literature. Through a multi-criteria classification, it compares and analyzes the existing authentication protocols, showing their advantages and disadvantages.

Hafizi, H., Robertson, T. L., Moon, G. D., Au- Yeung, K. Y., Zoellick, M. J., & Savage, G. M. Internet of Things (IoT) is slowly but steadily becoming part of different aspects of our lives, with its applications ranging from smart homes, to wearable devices, to healthcare, etc. This wide spectrum of applications results in shared data containing large amount of users' private information. The security of such information becomes a paramount concern. The IoT security requirements include data confidentiality, data integrity, authentication, access control, privacy, etc. In particular, authentication of IoT devices has a particular importance given the variety of attacks which might result from its breach [1]. This paper provides an analysis of the different authentication schemes proposed in the literature. Through a multi-criteria classification, it compares and analyzes the existing authentication protocols, showing their advantages and disadvantages.

Dash, S., Shakya war, S. K., Sharma, M., & Kaushik, S. 'Big data' is massive amounts of information that can work wonders. It has become a topic of special interest for the past two decades because of a great potential that is hidden in it. Various public and private sector industries generate, store, and analyze big data with an aim to improve the services they provide. In the healthcare industry, various sources for big data include hospital records, medical records of patients, results of medical examinations, and devices that are a part of internet of things. Biomedical research also generates a significant portion of big data relevant to public healthcare. This data requires proper management and analysis in order to derive meaningful information. Otherwise, seeking solution by analyzing big data quickly becomes comparable to finding a needle in the haystack. There are various challenges associated with each step of handling big data which can only be surpassed by using high-end computing solutions for big data analysis. That is why, to provide relevant solutions for improving public health, healthcare providers are required to be fully equipped with appropriate infrastructure to systematically generate and analyze big data. An efficient management, analysis, and interpretation of big data can change the game by opening new avenues for modern healthcare. That is exactly why various industries, including the healthcare industry, are taking vigorous steps to convert this potential into better services and financial advantages. With a strong integration of biomedical and healthcare data, modern healthcare organizations can possibly revolutionize the medical therapies and personalized medicine.

CHAPTER 3

REQUIREMENTS

3.1 EXISITING SYSTEM

Internet of Things (IoT) Based Smart Health Care Medical Box for Elderly People. A QoS Benchmark System for Telemedicine Communication Over 5G URLLC and MMTC Scenarios. Low-Cost Multimodal Telemedicine and Telehealth Station. As the concept of the remote monitoring system works on the principle of virtual assistance, both the patient as well as the medical staff is not required to travel. Also, in cases of patients who suffer from chronic diseases or need post-operative care, remote patient monitoring reduces the cost of re-admission for follow-up care as well as for care management [1]. In short, remote health monitoring systems can easily address the problems related to infrastructure and the shortage of medical staff in rural areas.

3.1.1 DRAWBACKS OF THE EXISTING SYSTEM

- Alerts and alarms aren't provided to the doctor in real time.
- Portable device hasn't been power efficiency enough to maintain battery life.
- Risk of uncalibrated values resulting in misdiagnosis of the patient

3.2 PROPOSED SYSTEM

In this Project we are developing a low-cost telemedicine device for offline and online monitoring of health data. Using this device, we can monitor the health condition of the patient in any environment. Immediate alerts and alarms are programmed to reach the doctor / Caretaker for immediate action. Data is stored in the cloud server for more analysis and deep consultation for the patient. Arduino is an open-source hardware and software platform with a single microcontroller board using an Atmel 32-bit ARM processor. Here UNO a variant of Arduino is employed. This platform can be divided into three categories, namely Hardware, software, and expansion shields.

We will be gathering information on the rural villages which lack hospital facility and connectivity for this project future development. Analysis of medical sensors such as ECG, Heartbeat, EEG, PI etc. using Arduino software. Drawing the layouts and dimensions for the enclosure of the Device with component size and measurement.

We will be Testing the medical sensors with the controller and obtain sequence of data and we will verify the data with a doctor for calibration systems. We will use Arduino software. We will design the circuit board using PSPICE and run simulations.

We will bring all components and sensors and embed them into a single / multiple PCB boards and integrate it and we will check for the device performance in the wireless mode. We will initiate the dashboard using Thing speak and monitor the data. We will conduct tests and validate the data points. We will repeatedly check for the sensors and its output. Finalize the output and circuit board integration and verify the output.

3.2.1 ADVANTAGES

- Transportation time and commutable time can be avoided.
- Better access to specialist doctors even from a remote location.
- Data analytics can provide prediction of advanced diseases.
- Advancement in medical science has resulted in increased life expectancy across the globe, which in turn has resulted in the growth of the elderly population.
- According to a report released by HelpAge India, by the year 2021, the population of older citizens in India will reach approximately 143 million.
- Two-thirds of this population live in villages with minimal access to basic health care facilities.
- A shortage of qualified doctors and allied healthcare workers is a major issue facing the Indian healthcare system.
- Around 75% of physicians work in urban areas, making the availability of proper health care even less for those who reside in semi-urban and rural areas.
- These figures clearly show the imbalance in the distribution of health workers, technologies and infrastructure throughout the country

3.3 BLOCK DIAGRAM OF PROPOSED SYSTEM

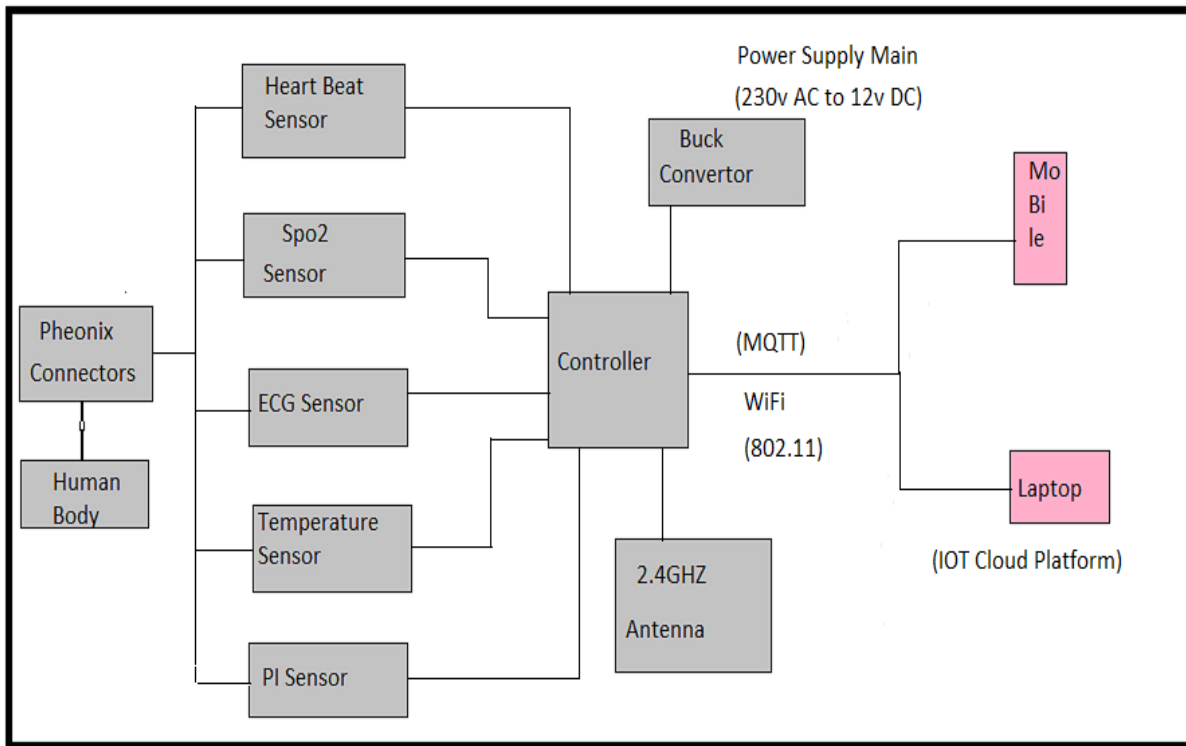


Fig:3.3 Block diagram of proposed system

The flow represents the sensors being connected via the phoenix connectors for data in and various Vcc and Gnd terminals. As from the data in points of the sensors. The various sensors give out pulses both in analog and digital form. The controller interprets the analog values and converts them too digital. Readable value format using the libraried embedded onto the firmware code. On successful connection to the MQTT broker. The value is pushed on to Node server from a remote computer where the data is computed and visualized in a dashboard view.

4.1 ARDUINO

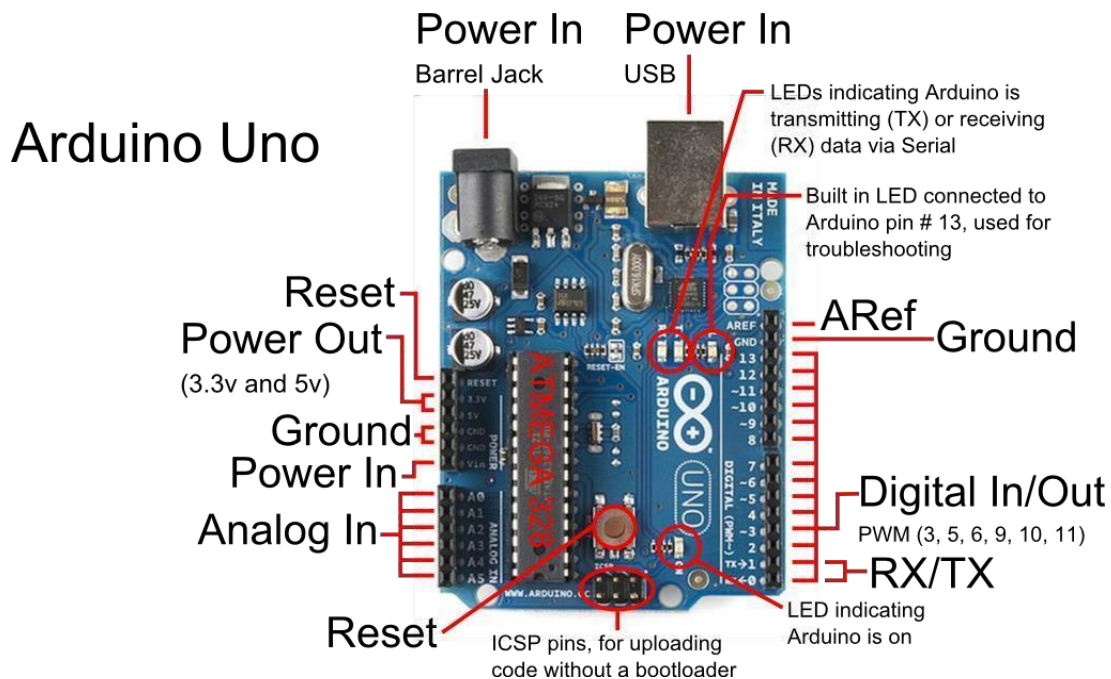


Fig.no:4.1 Arduino

To use the voltage divider as a sensor reading device first you need to know the maximum voltage allowed by the analog inputs you are using to read the signal. On an Arduino this is 5V. So, already we know the maximum value we need for V_{out} . The V_{in} is simply the amount of voltage already present on the circuit before it reaches the first resistor. You should be able to find the maximum voltage your sensor outputs by looking on the Datasheet, this is the maximum amount of voltage your sensor will let through given the voltage in of your circuit. Now we have exactly one variable left, the value of the second resistor. Solve for R_2 and you will have all the components of your voltage divider figured out! We solve for R_1 's highest value because a smaller resistor will simply give us a smaller signal which will be readable by our analog inputs.

Powering an analog Reference is exactly the same as reading a sensor except you have to calculate for the Voltage Out value you want to use as the analog Reference

All of the electrical signals that the Arduino works with are either Analog or Digital. It is extremely important to understand the difference between these two types of signal and how to manipulate the information these signals represent.

4.1.1 DIGITAL

An electronic signal transmitted as binary code that can be either the presence or absence of current, high and low voltages or short pulses at a particular frequency.

Humans perceive the world in analog, but robots, computers and circuits use Digital. A digital signal is a signal that has only two states. These states can vary depending on the signal, but simply defined the states are ON or OFF, never in between.

In the world of Arduino, Digital signals are used for everything with the exception of Analog Input. Depending on the voltage of the Arduino the ON or HIGH of the Digital signal will be equal to the system voltage, while the OFF or LOW signal will always equal 0V. This is a fancy way of saying that on a 5V Arduino the HIGH signals will be a little under 5V and on a 3.3V Arduino the HIGH signals will be a little under 3.3V.

To receive or send Digital signals the Arduino uses Digital pins # 0 - # 13. You may also setup your Analog In pins to act as Digital pins. To set up Analog In pins as Digital pins use the command: `pinMode(pinNumber, value);`

where `pinNumber` is an Analog pin (A0 – A5) and `value` is either INPUT or OUTPUT. To setup Digital pins use the same command but reference a Digital pin for `pinNumber` instead of an Analog In pin. Digital pins default as input, so really you only need to set them to OUTPUT in `pinMode`. To read these pins use the command: `digitalRead(pinNumber)` where `pinNumber` is the Digital pin to which the Digital component is connected. The `digitalRead` command will return either a HIGH or a LOW signal. To send a Digital signal to a pin use the command: `digitalWrite(pinNumber, value);` where `pinNumber` is the number of the pin sending the signal and `value` is either HIGH or LOW.

The Arduino also has the capability to output a Digital signal that acts as an Analog signal, this signal is called Pulse Width Modulation (PWM). Digital Pins # 3, # 5, # 6, # 9, #10 and #11 have PWM capabilities. To output a PWM signal use the command: `analogWrite(pinNumber, value);` where `pinNumber` is a Digital Pin with PWM capabilities and `value` is a number between 0 (0%) and 255 (100%). For more information on PWM see the PWM worksheets or S.I.K. circuit 12.

THINGS TO REMEMBER ABOUT DIGITAL:

- Digital Input/Output uses the Digital pins, but Analog pins can be used as Digital
- To receive a Digital signal use: `digitalRead(pinNumber);`
- To send a Digital signal use: `digitalWrite(pinNumber, value);`
- Digital Input and Output are always either HIGH or LOW

All of the electrical signals that the Arduino works with are either Analog or Digital. It is extremely important to understand the difference between these two types of signal and how to manipulate the information these signals represent.

4.1.2 ANALOG

Humans perceive the world in analog. Everything we see and hear is a continuous transmission of information to our senses. The temperatures we perceive are never 100% hot or 100% cold, they are constantly changing between our ranges of acceptable temperatures. (And if they are out of our range of acceptable temperatures then what are we doing there?) This continuous stream is what defines analog data. Digital information, the complementary concept to Analog, estimates analog data using only ones and zeros.

In the world of Arduino an Analog signal is simply a signal that can be HIGH (on), LOW (off) or anything in between these two states. This means an Analog signal has a voltage value that can be anything between 0V and 5V (unless you mess with the Analog Reference pin). Analog allows you to send output or receive input about devices that run at percentages as well as on and off. The Arduino does this by sampling the voltage signal sent to these pins and comparing it to a voltage reference signal (5V). Depending on the voltage of the Analog signal when compared to the Analog Reference signal the Arduino then assigns a numerical value to the signal somewhere between 0 (0%) and 1023 (100%). The digital system of the Arduino can then use this number in calculations and sketches.

To receive Analog Input the Arduino uses Analog pins # 0 - # 5. These pins are designed for use with components that output Analog information and can be used for Analog Input. There is no setup necessary, and to read them use the command: `analogRead(pinNumber);` where `pinNumber` is the Analog In pin to which the Analog component is connected. The `analogRead` command will return a number including or between 0 and 1023.

The Arduino also has the capability to output a digital signal that acts as an Analog signal, this signal is called Pulse Width Modulation (PWM). Digital Pins # 3, # 5, # 6, # 9, #10 and #11 have PWM capabilities. To output a PWM signal use the command: `analogWrite(pinNumber, value);` where `pinNumber` is a Digital Pin with PWM capabilities and `value` is a number between 0 (0%) and 255 (100%). On the Arduino UNO PWM pins are signified by a ~ sign. For more information on PWM see the PWM worksheets or S.I.K. circuit 12.

THINGS TO REMEMBER ABOUT ANALOG:

- Analog Input uses the Analog In pins, Analog Output uses the PWM pins
- To receive an Analog signal use: `analogRead(pinNumber);`
- To send a PWM signal use: `analogWrite(pinNumber, value);`
- Analog Input values range from 0 to 1023 (1024 values because it uses 10 bits, 2^{10})
- PWM Output values range from 0 to 255 (256 values because it uses 8 bits, 2^8)

All of the electrical signals that the Arduino works with are either input or output. It is extremely important to understand the difference between these two types of signal and how to manipulate the information these signals represent.

4.1.3 OUTPUT SIGNALS

Output to the Arduino pins is always Digital, however there are two different types of Digital Output; regular Digital Output and Pulse Width Modulation Output (PWM). Output is only possible with Digital pins # 0 - # 13.

The Digital pins are preset as Output pins, so unless the pin was used as an Input in the same sketch, there is no reason to use the `pinMode` command to set the pin as an Output. Should a situation arise where it is necessary to reset a Digital pin to Output from Input use the command: `pinMode (pinNumber, OUTPUT);` where `pinNumber` is the Digital pin number set as Output. To send a Digital Output signal use the command: `digitalWrite (pinNumber, value);` where `pinNumber` is the Digital pin that is outputting the signal and `value` is the signal. When outputting a Digital signal value can be either HIGH (On) or LOW (Off). `analogWrite (pinNumber, value);` where `pinNumber` is a Digital Pin with PWM capabilities and `value` is a number between 0 (0%) and 255 (100%). For more information on PWM see the PWM worksheets or S.I.K. circuit 12.

Output can be sent to many different devices, but it is up to the user to figure out

which kind of Output signal is needed, hook up the hardware and then type the correct code to properly use these signals

All of the electrical signals that the Arduino works with are either input or output. It is extremely important to understand the difference between these two types of signal and how to manipulate the information these signals represent.

4.1.4 INPUT SIGNALS

Analog Input enters your Arduino through the Analog In pins # 0 - # 5. These signals originate from analog sensors and interface devices. These analog sensors and devices use voltage levels to communicate their information instead of a simple yes (HIGH) or no (LOW). For this reason, you cannot use a digital pin as an input pin for these devices. Analog Input pins are used only for receiving Analog signals. It is only possible to read the Analog Input pins so there is no command necessary in the setup () function to prepare these pins for input. To read the Analog Input pins use the command: `analogRead(pinNumber)`; where `pinNumber` is the Analog Input pin number. This function will return an Analog Input reading between 0 and 1023. A reading of zero corresponds to 0 Volts and a reading of 1023 corresponds to 5 Volts. These voltage values are emitted by the analog sensors and interfaces. If you have an Analog Input that could exceed $V_{cc} + 5V$ you may change the voltage that 1023 corresponds to by using the Aref pin. This pin sets the maximum voltage parameter your Analog Input pins can read. The Aref pin's preset value is 5V.

Digital Input can enter your Arduino through any of the Digital Pins # 0 - # 13. Digital Input signals are either HIGH (On, 5V) or LOW (Off, 0V). Because the Digital pins can be

possible to alternatively connect external power using 9v. pin or 5v. pin. (see POWER PINOUT).

ICSP:

2x3 pin header Used to program At mega with bootloader. The number 1 on both sides of the board indicates cable pin1 position. Used to upload sketches on At mega ICs without bootloader (available only in Arduino IDE versions 0011 and 0012).

JP0:

3 pins jumper when in position 2-3, this jumper enables serial connection (through X1 connector) to/from computer/devices. Use this as default position. When in position 1- 2, it disables serial communication, and enables external pull-down resistors on pin0 (RX) and pin1 (TX). Use this only to prevent noise on RX (that seems incoming data to At mega), that sometimes makes sketch not starting. When removing this jumper, serial communication is disabled, and pin0 and pin1 work as a normal (floating) digital pin. Useful when more digital pins are needed, but only when serial communication is not necessary. External pull- down/pull-up resistor is required.

JP4:

2 pins jumper when in position 1-2, this jumper enables auto reset feature, useful when uploading a sketch to Arduino, resetting At mega automatically. It makes unnecessary to press reset button (S1) when uploading sketches. Be sure that computer COM Port speed is set to 19200bps otherwise auto reset will not work properly. If removed, disables auto reset feature. Very useful to prevent undesired At mega reset when using sketches that needs serial communication. Auto reset works with DTR pulse on serial pin4. Sometimes Arduino senses a DTR pulse when connecting X1 (serial connector) and some software's sends a DTR pulse when it starts or when it closes, that makes At mega reset when not desired.

S1:

Tactile button This button resets At mega, to restart uploaded sketch or to prepare Arduino to receive a sketch through serial connector (when auto reset is not active).

LEDS:

Indicative led POWER led Turns on when Arduino is powered through DC1, +9v. pin or +5v. pin. RX led Blinks when receiving data from computer/device through serial connection. TX led Blinks when sending data to computer/device through serial connection. L led This led is connected to digital pin13 with a current limiter resistor (that doesn't affect pin13). Useful to test sketches. It is normal to blink when boot loading too.

POWER PINOUT:

6 pin header RST pin:

Makes Atmega reset when connected to GND. Useful for Shield Boards, or to connect external reset.

NC pin:

This pin is not connected in Arduino Uno. Arduino Uno has a 3.3 volts pin in the same position.

+9v pin:

When Arduino DC1 is powered (with battery or DC adaptor), this pin is used as Vout, with the same voltage supplied on DC1 (see DC1), minus 0,7 volts. The total supplied current depends on external power source capacity. When Arduino DC1 is not powered, +9v. pin can be used as Vin, connecting it to external regulated power source (+7 to +20 volts) and connecting 0v. pin to external power source GND. In this case,

+5v pin:

Can be used as Vout, supplying +5 volts. +5v pin. When Arduino DC1 is powered (with battery or DC adaptor), +5v. pin supplies +5 volts as a Vout pin. The total supplied current depends on Voltage Regulator (7805 supplies up to 1A). This applies only to

+5v pin:

Atmega in/out pins only supplies max. 40mA on each pin. When Arduino DC1 is not powered, this pin can be used as Vin, connecting it to a regulated +5v. and connecting 0v. pin to power source GND. In this case, +9v. pin is inactive. 0v. pin (GND) Two 0v. pins between +5v. and +9v.

0v pin:

Beside AREF pin. When Arduino DC1 is powered, 0v. pin supplies 0 volts reference (GND) for +5v. pin and +9v. pin. When DC1 is not powered, and Arduino is powered through +5v. pin or +9v. pin, 0v. pin must be used as GND reference, connecting it to the external power source GND.

GND pin:

See 0v pin (GND).

AREF pin:

The AREF can be set to AVcc (default), internal 2.56 volts (Atmega8), internal 1.1 volts (Atmega168), or external AREF. In case of AVcc or internal AREF, AREF pin can be used to attach an external capacitor to decouple the signal, for better noise performance. In case

of external AREF, AREF pin is used to attach the external reference voltage. Remember that it is necessary to change de fuses (wiring.c file), and re-upload sketch, before connecting external voltage to AREF.

4.1.5 SOFTWARE TIPS

When boot loading an Atmega8 chip with Arduino 0010, there is a command (-i800) that makes bootloader delay 10 minutes. So, if you need to use bootloader, use command line instead of IDE, removing “-i800” command and adding “-F” command, or use Arduino 0007 IDE. To upload sketches Arduino 0010 works fine.

ARDUINO S3v3 NEW FEATURES

- Full compatible with Shield Boards (Version 2 is the only Arduino Board not compatible with Shield Boards because of ICSP header wrong position, and tall components);
- A Vcc LP filter to reduce noise level on ADC;
- Auto reset feature;
- Auto reset enable/disable jumper, to avoid not desired reseating;
- Arduino Diecimila compatible reset pin;
- Pin13 onboard led, with current limiter resistor;
- TX and RX onboard lids;
- Power led with appropriate current limiter resistor (less 20mA of consumption);
- Jumper to disable serial communication and to enable RX external pulldown resistor, to avoid “RX floating error”. This feature allows to use digital pin0 and pin1 as a normal pin, when serial communication is not needed;
- All similar components (diodes, transistors, lids, capacitors) has the same board orientation (to makes easier to mount with less mistakes);
- No wires between pads, more space between wires, larger wires, larger pads (better for etching, soldering and drilling, with no short circuits, soldering bridges or open wires in corrosion);
- Only 3 wire bridges;
- Electrolytic capacitor (in serial to TTL circuit) changed to bipolar type (to avoid inverted voltage problem when serial cable is not connected);

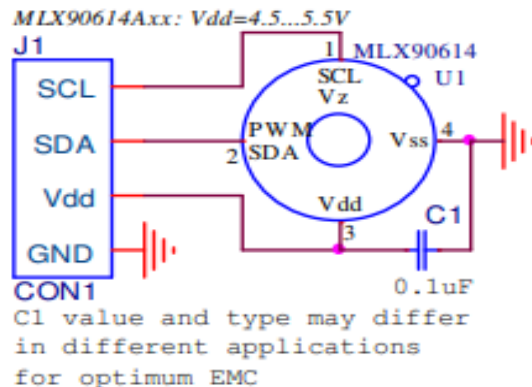
- All jumpers are right angle type, to allow Shield Boards use.

4.2 MLX90614 (Digital plug & play infrared thermometer in a TO-can)

4.2.1 Features and Benefits

- Small size, low cost
- Easy to integrate
- Factory calibrated in wide temperature range: $-40^{\circ}\text{C} \dots +125^{\circ}\text{C}$ for sensor temperature and $-70^{\circ}\text{C} \dots +380^{\circ}\text{C}$ for object temperature.
- High accuracy of 0.5°C in a wide temperature range ($0^{\circ}\text{C} \dots +50^{\circ}\text{C}$ for both T_a and T_o)
- High (medical) accuracy calibration
- Measurement resolution of 0.02°C
- Single and dual zone versions
- SMBus compatible digital interface
- Customizable PWM output for continuous reading
- Available in 3V and 5V versions
- Simple adaptation for 8V...16V applications
- Sleep mode for reduced power consumption
- Different package options for applications and measurements versatility
- Automotive grade

4.2.2 Functional diagram



MLX90614 connection to SMBus

4.2.3 General Description

The MLX90614 is an Infra-Red thermometer for noncontact temperature measurements. Both the IR sensitive thermopile detector chip and the signal conditioning ASSP are integrated in the same TO-39 can. Thanks to its low noise amplifier, 17-bit ADC and powerful DSP unit, a high accuracy and resolution of the thermometer is achieved.

The thermometer comes factory calibrated with a digital PWM and SMBus (System Management Bus) output. As a standard, the 10-bit PWM is configured to continuously transmit the measured temperature in range of $-20...120^{\circ}\text{C}$, with an output resolution of 0.14°C . The factory default POR setting is SMBus.

The MLX90614 is built from 2 chips developed and manufactured by Melexis:

- The Infra-Red thermopile detector MLX81101
- The signal conditioning ASSP MLX90302, specially designed to process the output of IR sensor.

The MLX90614 is factory calibrated in wide temperature ranges: $-40^{\circ}\text{C}...125^{\circ}\text{C}$ for the ambient temperature and $-70^{\circ}\text{C}...380^{\circ}\text{C}$ for the object temperature.

The measured value is the average temperature of all objects in the Field of View of the sensor. The MLX90614 offers a standard accuracy of $\pm 0.5^{\circ}\text{C}$ around room temperatures. A special version for medical applications exists offering an accuracy of $\pm 0.2^{\circ}\text{C}$ in a limited temperature range around the human body temperature.

It is very important for the application designer to understand that these accuracies are only guaranteed and achievable when the sensor is in thermal equilibrium and under isothermal conditions (there are no temperature differences across the sensor package). The accuracy of the thermometer can be influenced by temperature differences in the package induced by causes like (among others): Hot electronics behind the sensor, heaters/coolers behind or beside the sensor or by a hot/cold object very close to the sensor that not only heats the sensing element in the thermometer but also the thermometer package.

This effect is especially relevant for thermometers with a small FOV like the xxC and xxF as the energy received by the sensor from the object is reduced. Therefore, Melexis has

introduced the xCx version of the MLX90614. In these MLX90614xCx, the thermal gradients are measured internally and the measured temperature is compensated for them. In this way, the xCx version of the MLX90614 is much less sensitive to thermal gradients, but the effect is not totally eliminated. It is therefore important to avoid the causes of thermal gradients as much as possible or to shield the sensor from them.

The PWM pin can also be configured to act as a thermal relay (input is To), thus allowing for an easy and cost-effective implementation in thermostats or temperature (freezing / boiling) alert applications. The temperature threshold is user programmable. In a SMBus system this feature can act as a processor interrupt that can trigger reading all slaves on the bus and to determine the precise condition.

The thermometer is available in 2 supply voltage options: 5V compatible or 3V (battery) compatible. The 5V can be easily adopted to operate from a higher supply voltage (8...16V, for example) by use of few external components (refer to “Applications information” section for details).

An optical filter (long-wave pass) that cuts off the visible and near infra-red radiant flux is integrated in the package to provide ambient and sunlight immunity. The wavelength pass band of this optical filter is from 5.5...14µm (except for xCH and xCI type of devices which incorporate uncoated silicon lens).

4.2.4 Glossary of terms

PTAT	Proportional To Absolute Temperature sensor (package temperature)
POR	Power On Reset
HFO	High Frequency Oscillator (RC type)
DSP	Digital Signal Processing
FIR	Finite Impulse Response. Digital filter
IIR	Infinite Impulse Response. Digital filter
IR	Infra-Red
PWM	Pulse With Modulation
DC	Duty Cycle (of the PWM) ; Direct Current (for settled conditions specifications)
FOV	Field Of View
SDA,SCL	Serial DAta, Serial CLock – SMBus compatible communication pins
Ta	Ambient Temperature measured from the chip – (the package temperature)
To	Object Temperature, ‘seen’ from IR sensor
ESD	Electro-Static Discharge
EMC	Electro-Magnetic Compatibility
ASSP	Application Specific Standard Product
TBD	To Be Defined

4.2.5 Maximum Rating

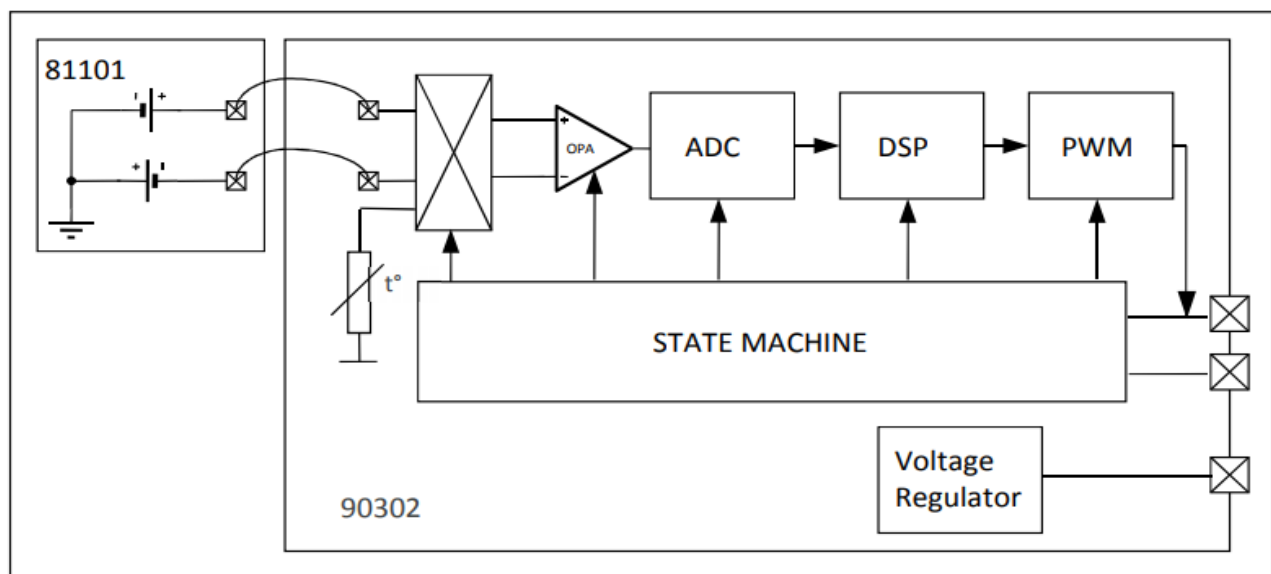
Parameter	MLX90614ESF-Axx	MLX90614ESF-Bxx MLX90614ESF-Dxx	MLX90614KSF-Axx
Supply Voltage, V_{DD} (over voltage)	7V	5V	7V
Supply Voltage, V_{DD} (operating)	5.5 V	3.6V	5.5V
Reverse Voltage	0.4 V		
Operating Temperature Range, T_A	-40°C...+85°C		-40°C...+125°C
Storage Temperature Range, T_S	-40°C...+125°C		-40°C...+125°C
ESD Sensitivity (AEC Q100 002)	2kV		
DC current into SCL / Vz (Vz mode)	2 mA		
DC sink current, SDA / PWM pin	25 mA		
DC source current, SDA / PWM pin	25 mA		
DC clamp current, SDA / PWM pin	25 mA		
DC clamp current, SCL pin	25 mA		

4.2.6 Electrical Specification

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supplies						
External supply	V_{DD}		4.5	5	5.5	V
Supply current	I_{DD}	No load		1.3	2	mA
Supply current (programming)	I_{DDpr}	No load, erase/write EEPROM operations		1.5	2.5	mA
Zener voltage	V_Z	$I_Z = 75 \dots 1000 \mu A$ ($T_a = \text{room}$)	5.5	5.7	5.9	V
Zener voltage	$V_Z(T_a)$	$I_Z = 70 \dots 1000 \mu A$, full temperature range	5.15	5.7	6.24	V
Power On Reset						
POR level	V_{POR_up}	Power-up (full temp range)	1.4	1.75	1.95	V
POR level	V_{POR_down}	Power –down (full temp range)	1.3	1.7	1.9	V
POR hysteresis	V_{POR_hys}	Full temp range	0.08	0.1	1.15	V
V_{DD} rise time (10% to 90% of specified supply voltage)	T_{POR}	Ensure POR signal			20	ms
Output valid (result in RAM)	T_{valid}	After POR		0.25		s
Pulse width modulation ¹						
PWM resolution	PWM_{res}	Data band		10		bit
PWM output period	$PWM_{T,def}$	Factory default, internal oscillator factory calibrated		1.024		ms
PWM period stability	$dPWM_T$	Internal oscillator factory calibrated, over the entire operation range and supply voltage	-10		+10	%
Output high Level	PWM_{HI}	$I_{source} = 2 \text{ mA}$	$V_{DD}-0.2$			V
Output low Level	PWM_{LO}	$I_{sink} = 2 \text{ mA}$			$V_{SS}+0.2$	V
Output drive current	I_{drive_PWM}	$V_{out,H} = V_{DD} - 0.8V$		7		mA
Output sink current	I_{sink_PWM}	$V_{out,L} = 0.8V$		13.5		mA

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
SMBus compatible 2-wire interface ²						
Input high voltage	$V_{IH}(Ta, V)$	Over temperature and supply	3			V
Input low voltage	$V_{IL}(Ta, V)$	Over temperature and supply			0.6	V
Output low voltage	V_{OL}	Over temperature and supply, $I_{sink} = 2mA$			0.2	V
SCL leakage	$I_{SCL, leak}$	$V_{SCL}=4V, Ta=+85^{\circ}C$			30	μA
SDA leakage	$I_{SDA, leak}$	$V_{SDA}=4V, Ta=+85^{\circ}C$			0.3	μA
SCL capacitance	C_{SCL}				10	pF
SDA capacitance	C_{SDA}				10	pF
Slave address	SA	Factory default		5A		hex
Wake up request	t_{wake}	SDA low	33			ms
SMBus Request	t_{REQ}	SCL low	1.44			ms
Timeout, low	$T_{imeout,L}$	SCL low	27		33	ms
Timeout, high	$T_{imeout,H}$	SCL high	45		55	μs
Acknowledge setup time	$T_{suac}(MD)$	8-th SCL falling edge, Master			1.5	μs
Acknowledge hold time	$T_{hdac}(MD)$	9-th SCL falling edge, Master			1.5	μs
Acknowledge setup time	$T_{suac}(SD)$	8-th SCL falling edge, Slave			2.5	μs
Acknowledge hold time	$T_{hdac}(SD)$	9-th SCL falling edge, Slave			1.5	μs
EEPROM						
Data retention		$Ta = +85^{\circ}C$	10			years
Erase/write cycles		$Ta = +25^{\circ}C$	100,000			Times
Erase/write cycles		$Ta = +125^{\circ}C$	10,000			Times
Erase cell time	T_{erase}			5		ms
Write cell time	T_{write}			5		ms

4.2.7 Block Diagram



4.2.8 Signal Processing Principle

The operation of the MLX90614 is controlled by an internal state machine, which controls the measurements and calculations of the object and ambient temperatures and does the post-processing of the temperatures to output them through the PWM output or the SMBus compatible interface.

The ASSP supports 2 IR sensors (second one not implemented in the MLX90614xAx). The output of the IR sensors is amplified by a low noise low offset chopper amplifier with programmable gain, converted by a Sigma Delta modulator to a single bit stream and fed to a powerful DSP for further processing. The signal is treated by programmable (by means of EEPROM content) FIR and IIR low pass filters for further reduction of the band width of the input signal to achieve the desired noise performance and refresh rate. The output of the IIR filter is the measurement result and is available in the internal RAM. 3 different cells are available: One for the on-board temperature sensor and 2 for the IR sensors.

Based on results of the above measurements, the corresponding ambient temperature T_a and object temperatures T_o are calculated. Both calculated temperatures have a resolution of 0.01°C . The data for T_a and T_o can be read in two ways: Reading RAM cells dedicated for this purpose via the 2-wire interface (0.02°C resolution, fixed ranges), or through the PWM digital output (10-bit resolution, configurable range).

In the last step of the measurement cycle, the measured T_a and T_o are rescaled to the desired output resolution of the PWM) and the recalculated data is loaded in the registers of the PWM state machine, which creates a constant frequency with a duty cycle representing the measured data.

4.2.8.1 Amplifier

A low noise, low offset amplifier with programmable gain is used for amplifying the IR sensor voltage. By carefully designing the input modulator and balanced input impedance, the max offset of the system is $0.5\mu\text{V}$.

4.2.8.2 Supply regulator and POR

The module can operate from 3 different supplies:

VDD = 5V -> MLX90614Axx

VDD = 3V -> MLX90614Bxx (battery or regulated supply)

VDD = 8V...16V -> MLX90614Axx few external components are necessary please refer to “Applications information”

section for information about adopting higher voltage supplies.

The Power on Reset (POR) is connected to Vdd supply. The on-chip POR circuit provides an active (high) level of the POR signal when the Vdd voltage rises above approximately 0.5V and holds the entire MLX90614 in reset until the Vdd is higher than the specified POR threshold VPOR. During the time POR is active, the POR signal is available as an open drain at the PWM/SDA pin. After the MLX90614 exits the POR condition, the function programmed in EEPROM takes precedence for that pin.

4.2.8.3 SMBus compatible 2-wire protocol wire protocol

The chip supports a 2 wires serial protocol, build with pins PWM / SDA and SCL. SCL – digital input only, used as the clock for SMBus compatible communication. This pin has the auxiliary function for building an external voltage regulator. When the external voltage regulator is used, the 2-wire protocol is available only if the power supply regulator is overdriven.

PWM/SDA – Digital input / output, used for both the PWM output of the measured object temperature(s) or the digital input / output for the SMBus. In PWM mode the pin can be programmed in EEPROM to operate as Push / Pull or open drain NMOS (open drain NMOS is factory default). In SMBus mode SDA is forced to open drain NMOS I/O, push-pull selection bit defines PWM / Thermal relay operation.

4.2.9 Functional Description

The SMBus interface is a 2-wire protocol, allowing communication between the Master Device (MD) and one or more Slave Devices (SD). In the system only one master can be presented at any given time [1]. The MLX90614 can only be used as a slave device.

Generally, the MD initiates the start of data transfer by selecting a SD through the Slave Address (SA). The MD has read access to the RAM and EEPROM and write access to 9 EEPROM cells (at addresses 0x00, 0x01, 0x02, 0x03, 0x04, 0x05*, 0x0E, 0x0F, 0x19). If the access to the MLX90614 is a read operation it will respond with 16 data bits and 8-bit PEC only if its own slave address, programmed in internal EEPROM, is equal to the SA, sent by the master. The SA feature allows connecting up to 127 devices (SA=0x00...0x07F) with only 2

wires. In order to provide access to any device or to assign an address to a SD before it is connected to the bus system, the communication must start with zero SA followed by low R/W[−] bit. When this command is sent from the MD, the MLX90614 will always respond and will ignore the internal chip code information.

4.3 ESP32

4.3.1 Featured Solutions

4.3.1.1 Ultra-Low power solution

ESP32 is designed for mobile, wearable electronics, and Internet-of-Things (IoT) applications. It features all the state-of-the-art characteristics of low-power chips, including fine-grained clock gating, multiple power modes, and dynamic power scaling. For instance, in a low-power IoT sensor hub application scenario, ESP32 is woken up periodically and only when a specified condition is detected. Low-duty cycle is used to minimize the amount of energy that the chip expends. The output of the power amplifier is also adjustable, thus contributing to an optimal trade-off between communication range, data rate and power consumption.

4.3.1.2 Wi-Fi Key Features

- 802.11 b/g/n
- 802.11 n (2.4 GHz), up to 150 Mbps
- WMM
- TX/RX A-MPDU, RX A-MSDU
- Immediate Block ACK
- Defragmentation
- Automatic Beacon monitoring (hardware TSF)
- 4 × virtual Wi-Fi interfaces
- Simultaneous support for Infrastructure Station, SoftAP, and Promiscuous modes Note that when ESP32 is in Station mode, performing a scan, the SoftAP channel will be changed.
- Antenna diversity

4.3.1.2 BT Key Features

- Compliant with Bluetooth v4.2 BR/EDR and BLE specifications

- Class-1, class-2 and class-3 transmitter without external power amplifier
- Enhanced Power Control
- +12 dBm transmitting power
- NZIF receiver with –94 dBm BLE sensitivity • Adaptive Frequency Hopping (AFH)
- Standard HCI based on SDIO/SPI/UART • High-speed UART HCI, up to 4 Mbps
- Bluetooth 4.2 BR/EDR BLE dual mode controller
- Synchronous Connection-Oriented/Extended (SCO/eSCO)
- CVSD and SBC for audio codec
- Bluetooth Piconet and Scatter net
- Multi-connections in Classic BT and BLE
- Simultaneous advertising and scanning

4.3.2 Power Scheme

ESP32's digital pins are divided into three different power domains:

- VDD3P3_RTC
- VDD3P3_CPU
- VDD_SDIO VDD3P3_RTC is also the input power supply for RTC and CPU.

VDD3P3_CPU is also the input power supply for CPU. VDD_SDIO connects to the output of an internal LDO whose input is VDD3P3_RTC. When VDD_SDIO is connected to the same PCB net together with VDD3P3_RTC, the internal LDO is disabled automatically. The power scheme diagram is shown below:

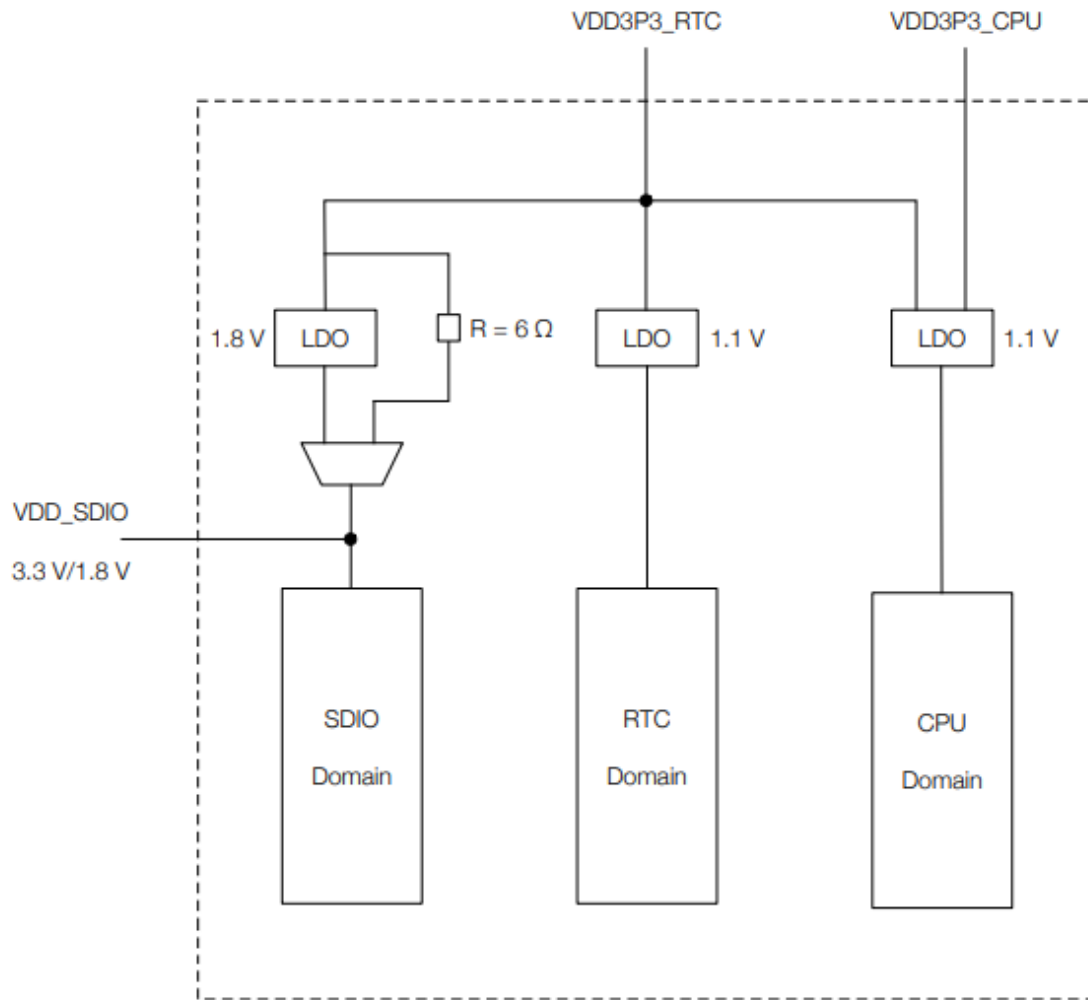


Fig.no. 4.3.2 Power Scheme

The internal LDO can be configured as having 1.8 V, or the same voltage as VDD3P3_RTC. It can be powered off via software to minimize the current of flash/SRAM during the Deep-sleep mode.

4.3.3 Functional Description

This chapter describes the functions integrated in ESP32.

4.3.3.1 CPU

ESP32 contains one or two low-power Xtensa® 32-bit LX6 microprocessor(s) with the following features:

- 7-stage pipeline to support the clock frequency of up to 240 MHz (160 MHz for ESP32-S0WD, ESP32-D2WD, and ESP32-U4WDH)

- 16/24-bit Instruction Set provides high code-density
- Support for Floating Point Unit
- Support for DSP instructions, such as a 32-bit multiplier, a 32-bit divider, and a 40-bit MAC
- Support for 32 interrupt vectors from about 70 interrupt sources

The single-/dual-CPU interfaces include:

- Xtensa RAM/ROM Interface for instructions and data
- Xtensa Local Memory Interface for fast peripheral register access
- External and internal interrupt sources
- JTAG for debugging

4.3.3.2 Internal Memory

ESP32's internal memory includes:

- 448 KB of ROM for booting and core functions
- 520 KB of on-chip SRAM for data and instructions
- 8 KB of SRAM in RTC, which is called RTC FAST Memory and can be used for data storage; it is accessed by the main CPU during RTC Boot from the Deep-sleep mode.
- 8 KB of SRAM in RTC, which is called RTC SLOW Memory and can be accessed by the co-processor during the Deep-sleep mode.
- 1 Kbit of eFuse: 256 bits are used for the system (MAC address and chip configuration) and the remaining 768 bits are reserved for customer applications, including flash-encryption and chip-ID.
- Embedded flash

4.3.3.3 External Flash Or SRAM

ESP32 supports multiple external QSPI flash and SRAM chips. More details can be found in Chapter SPI in the ESP32 Technical Reference Manual. ESP32 also supports hardware encryption/decryption based on AES to protect developers' programs and data in flash.

ESP32 can access the external QSPI flash and SRAM through high-speed caches.

- Up to 16 MB of external flash can be mapped into CPU instruction memory space and read-only memory space simultaneously.
- When external flash is mapped into CPU instruction memory space, up to 11 MB + 248 KB can be mapped at a time. Note that if more than 3 MB + 248 KB are mapped, cache

performance will be reduced due to speculative reads by the CPU.

- When external flash is mapped into read-only data memory space, up to 4 MB can be mapped at a time. 8-bit, 16-bit and 32-bit reads are supported.
- External SRAM can be mapped into CPU data memory space. SRAM up to 8 MB is supported and up to 4 MB can be mapped at a time. 8-bit, 16-bit and 32-bit reads and writes are supported.

4.3.4 Timers and Watchdogs

4.3.4.1 64-bit Timers

There are four general-purpose timers embedded in the chip. They are all 64-bit generic timers which are based on 16-bit prescalers and 64-bit auto-reload-capable up/down-timers.

The timer's feature:

- A 16-bit clock prescaler, from 2 to 65536
- A 64-bit timer
- Configurable up/down timer: incrementing or decrementing
- Halt and resume of time-base counter
- Auto-reload at alarming
- Software-controlled instant reload
- Level and edge interrupt generation

4.3.4.2 Watchdog Timers

The chip has three watchdog timers: one in each of the two timer modules (called the Main Watchdog Timer, or MWDT) and one in the RTC module (called the RTC Watchdog Timer, or RWDT). These watchdog timers are intended to recover from an unforeseen fault causing the application program to abandon its normal sequence. A watchdog timer has four stages. Each stage may trigger one of three or four possible actions upon the expiry of its programmed time period, unless the watchdog is fed or disabled. The actions are: interrupt, CPU reset, core reset, and system reset. Only the RWDT can trigger the system reset, and is able to reset the entire chip, including the RTC itself. A timeout value can be set for each stage individually.

During flash boot the RWDT and the first MWDT start automatically in order to detect, and recover from, booting problems. The watchdogs have the following features:

- Four stages, each of which can be configured or disabled separately

- A programmable time period for each stage
- One of three or four possible actions (interrupt, CPU reset, core reset, and system reset) upon the expiry of each stage
- 32-bit expiry counter
- Write protection that prevents the RWDT and MWDT configuration from being inadvertently altered
- SPI flash boot protection If the boot process from an SPI flash does not complete within a predetermined time period, the watchdog will reboot the entire system.

4.4 AD8232

4.4.1 FEATURES

Fully integrated single-lead ECG front end

Low supply current: 170 μ A (typical)

Common-mode rejection ratio: 80 dB (dc to 60 Hz)

Two or three electrode configurations

High signal gain ($G = 100$) with dc blocking capabilities

2-pole adjustable high-pass filter Accepts up to ± 300 mV of half-cell potential

Fast restore feature improves filter settling

Uncommitted op amp

3-pole adjustable low-pass filter with adjustable gain

Leads off detection: ac or dc options

Integrated right leg drive (RLD) amplifier

Single-supply operation: 2.0 V to 3.5 V

Integrated reference buffer generates virtual ground

Rail-to-rail output

Internal RFI filter

8kV HBM ESD rating

Shutdown pin

20-lead, 4 mm $\times$ 4 mm LFCSP and LFCSP_SS package

Qualified for automotive applications

4.4.2 APPLICATIONS

Fitness and activity heart rate monitors

Portable ECG

Remote health monitors

Gaming peripherals

Biopotential signal acquisition

4.4.3 General Description

The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications. It is designed to extract, amplify, and filter small biopotential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement. This design allows for an ultralow power analog-to-digital converter (ADC) or an embedded microcontroller to acquire the output signal easily.

The AD8232 can implement a two-pole high-pass filter for eliminating motion artifacts and the electrode half-cell potential. This filter is tightly coupled with the instrumentation architecture of the amplifier to allow both large gain and high-pass filtering in a single stage, thereby saving space and cost.

An uncommitted operational amplifier enables the AD8232 to create a three-pole low-pass filter to remove additional noise. The user can select the frequency cutoff of all filters to suit different types of applications

4.4.4 Specifications

$V_S = 3\text{ V}$, $V_{REF} = 1.5\text{ V}$, $V_{CM} = 1.5\text{ V}$, $T_A = 25^\circ\text{C}$, operating temperature (TOPR) = -40°C to $+105^\circ\text{C}$ for the W grade, FR = low, SDN = high, and AC/DC = low, unless otherwise noted.

Table 1.

Parameter	Symbol	Test Conditions/ Comments	A Grade			W Grade			Unit
			Min	Typ	Max	Min	Typ	Max	
INSTRUMENTATION AMPLIFIER									
Common-Mode Rejection Ratio, DC to 60 Hz	CMRR	$V_{CM} = 0.35 \text{ V to } 2.85 \text{ V}$, $V_{DIFF} = 0 \text{ V}$	80	86					dB
		T_{OPR}				80			dB
		$V_{CM} = 0.35 \text{ V to } 2.85 \text{ V}$, $V_{DIFF} = \pm 0.3 \text{ V}$		80			80		dB
Power Supply Rejection Ratio	PSRR	$V_S = 2.0 \text{ V to } 3.5 \text{ V}$	76	90					dB
		T_{OPR}				76	90		dB
Offset Voltage (RTI)	V_{OS}								
Instrumentation Amplifier Inputs			3	8					mV
		T_{OPR}					3	8	mV
DC Blocking Input ¹				5	50		5	50	μV
Average Offset Drift									
Instrumentation Amplifier Inputs				10					$\mu\text{V}/^{\circ}\text{C}$
		T_{OPR}					10		$\mu\text{V}/^{\circ}\text{C}$
DC Blocking Input ¹				0.05			0.05		$\mu\text{V}/^{\circ}\text{C}$
Input Bias Current	I_B			50	200		50	200	pA
		$T_A = 0^{\circ}\text{C to } 70^{\circ}\text{C}$		1					nA
Input Offset Current	I_{OS}	T_{OPR}						3.75	nA
			25	100		25	100		pA
		$T_A = 0^{\circ}\text{C to } 70^{\circ}\text{C}$		1					nA
		T_{OPR}						1	nA
Input Impedance									
Differential				10 7.5			10 7.5		$\text{G}\Omega \text{pF}$
Common Mode				5 15			5 15		$\text{G}\Omega \text{pF}$
Input Voltage Noise (RTI)									
Spectral Noise Density		$f = 1 \text{ kHz}$		100			100		$\text{nV}/\sqrt{\text{Hz}}$
Peak-to-Peak Voltage Noise		$f = 0.1 \text{ Hz to } 10 \text{ Hz}$		12			12		$\mu\text{V p-p}$
		$f = 0.5 \text{ Hz to } 40 \text{ Hz}$		14			14		$\mu\text{V p-p}$
Input Voltage Range		$T_A = 0^{\circ}\text{C to } 70^{\circ}\text{C}$	0.2		$+V_S$				V
		T_{OPR}				0.2		$+V_S$	V
DC Differential Input Range	V_{DIFF}		-300		+300				mV
		T_{OPR}				-300		+300	mV
Output									
Output Swing		$R_L = 50 \text{ k}\Omega$	0.1		$+V_S - 0.1$				V
		T_{OPR}				0.1		$+V_S - 0.1$	V
Short-Circuit Current	I_{OUT}			6.3			6.3		mA
Gain	A_V			100			100		V/V
Gain Error		$V_{DIFF} = 0 \text{ V}$		0.4			0.4		%
		$V_{DIFF} = -300 \text{ mV to } +300 \text{ mV}$		1	3.5			3.5	%
		T_{OPR}						7.9	%
Average Gain Drift			$T_A = 0^{\circ}\text{C to } 70^{\circ}\text{C}$		12				$\text{ppm}/^{\circ}\text{C}$
		T_{OPR}					12	$\text{ppm}/^{\circ}\text{C}$	
Bandwidth	BW			2			2		kHz
RFI Filter Cutoff (Each Input)				1			1		MHz

Parameter	Symbol	Test Conditions/ Comments	A Grade			W Grade			Unit
			Min	Typ	Max	Min	Typ	Max	
OPERATIONAL AMPLIFIER (A1)									
Offset Voltage	V_{OS}		1	5					mV
		T_{OPR}				1	5		mV
Average TC		$T_A = 0^{\circ}\text{C to } 70^{\circ}\text{C}$	5						$\mu\text{V}/^{\circ}\text{C}$
		T_{OPR}				5			$\mu\text{V}/^{\circ}\text{C}$
Input Bias Current	I_B		100			100			pA
		$T_A = 0^{\circ}\text{C to } 70^{\circ}\text{C}$	1						nA
		T_{OPR}				2.5			nA
Input Offset Current	I_{OS}		100			100			pA
		$T_A = 0^{\circ}\text{C to } 70^{\circ}\text{C}$	1						nA
		T_{OPR}				1			nA
Input Voltage Range			0.1		$+V_S - 0.1$	0.1		$+V_S - 0.1$	V
Common-Mode Rejection Ratio	CMRR	$V_{CM} = 0.5 \text{ V to } 2.5 \text{ V}$		100			100		dB
Power Supply Rejection Ratio	PSRR			100			100		dB
Large Signal Voltage Gain	A_{VO}			110			110		dB
Output Voltage Range		$R_L = 50 \text{ k}\Omega$	0.1		$+V_S - 0.1$				V
		T_{OPR}				0.1		$+V_S - 0.1$	V
Short-Circuit Current Limit	I_{OUT}			12			12		mA
Gain Bandwidth Product	GBP			100			100		kHz
Slew Rate	SR			0.02			0.02		V/ μs
Voltage Noise Density (RTI)	e_n	$f = 1 \text{ kHz}$		60			60		nV/ $\sqrt{\text{Hz}}$
Peak-to-Peak Voltage Noise (RTI)	$e_{n \text{ p-p}}$	$f = 0.1 \text{ Hz to } 10 \text{ Hz}$		6			6		$\mu\text{V p-p}$
		$f = 0.5 \text{ Hz to } 40 \text{ Hz}$		8			8		$\mu\text{V p-p}$
RIGHT LEG DRIVE AMPLIFIER (A2)									
Output Swing		$R_L = 50 \text{ k}\Omega$	0.1		$+V_S - 0.1$	0.1		$+V_S - 0.1$	V
Short-Circuit Current	I_{OUT}			11			11		mA
Integrator Input Resistor			120	150	180	120	150	180	k Ω
Gain Bandwidth Product	GDP			100			100		kHz
REFERENCE BUFFER (A3)									
Offset Error	V_{OS}	$R_L > 50 \text{ k}\Omega$		1			1		mV
Input Bias Current	I_B			100			100		pA
Short-Circuit Current Limit	I_{OUT}			12			12		mA
Voltage Range		$R_L = 50 \text{ k}\Omega$	0.1		$+V_S - 0.7$				V
		T_{OPR}				0.1		$+V_S - 0.7$	V
DC LEADS OFF COMPARATORS									
Threshold Voltage				$+V_S - 0.5$			$+V_S - 0.5$		V
Hysteresis				60			60		mV
Propagation Delay				0.5			0.5		μs
AC LEADS OFF DETECTOR									
Square Wave Frequency	f_{AC}		50	100	175	50	100	175	kHz
Square Wave Amplitude	I_{AC}			200			200		nA p-p
Impedance Threshold		Between +IN and -IN	10	20		10	20		M Ω
Detection Delay				110			110		μs
FAST RESTORE CIRCUIT									
Switches		S1 and S2							
On Resistance	R_{ON}		8	10	12	8	10	12	k Ω
Off Leakage				100			100		pA
Window Comparator									
Threshold Voltage		From either rail		50			50		mV
Propagation Delay				2			2		μs
Switch Timing Characteristics									
Feedback Recovery Switch On Time	t_{SW1}			110			110		ms
Filter Recovery Switch On Time	t_{SW2}			55			55		ms
Fast Restore Reset	t_{RST}			2			2		μs

4.4.5 Absolute Maximum Rating

Parameter	Rating
Supply Voltage	3.6 V
Output Short-Circuit Current Duration	Indefinite
Maximum Voltage, Any Terminal ¹	+V _S + 0.3 V
Minimum Voltage, Any Terminal ¹	−0.3 V
Storage Temperature Range	−65°C to +125°C
Operating Temperature Range	
AD8232ACPZ	−40°C to +85°C
AD8232WACSZ	−40°C to +105°C
Maximum Junction Temperature	140°C
θ _{JA} Thermal Impedance ²	48°C/W
θ _{JC} Thermal Impedance	4.4°C/W
ESD Rating	
Human Body Model (HBM)	8 kV
Charged Device Model (FICDM)	1.25 kV
Machine Model (MM)	200 V

4.4.6 PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

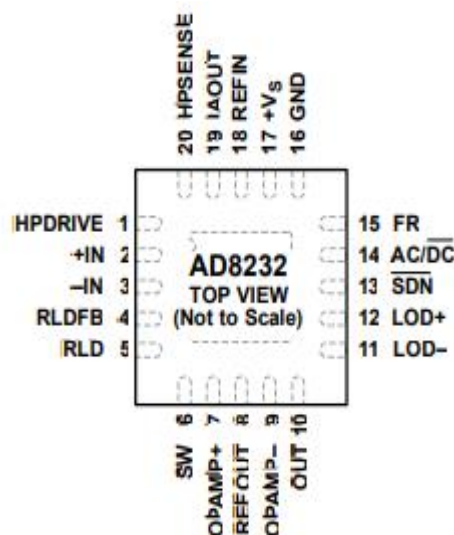


Fig.no:4.4.6 Pin Configuration

Pin No.	Mnemonic	Description
1	HPDRIVE	High-Pass Driver Output. Connect HPDRIVE to the capacitor in the first high-pass filter. The AD8232 drives this pin to keep HPSENSE at the same level as the reference voltage.
2	+IN	Instrumentation Amplifier Positive Input. +IN is typically connected to the left arm (LA) electrode.
3	–IN	Instrumentation Amplifier Negative Input. –IN is typically connected to the right arm (RA) electrode.
4	RLDFB	Right Leg Drive Feedback Input. RLDFB is the feedback terminal for the right leg drive circuit.
5	RLD	Right Leg Drive Output. Connect the driven electrode (typically, right leg) to the RLD pin.
6	SW	Fast Restore Switch Terminal. Connect this terminal to the output of the second high-pass filter.
7	OPAMP+	Operational Amplifier Noninverting Input.
8	REFOUT	Reference Buffer Output. The instrumentation amplifier output is referenced to this potential. Use REFOUT as a virtual ground for any point in the circuit that needs a signal reference.
9	OPAMP–	Operational Amplifier Inverting Input.
10	OUT	Operational Amplifier Output. The fully conditioned heart rate signal is present at this output. OUT can be connected to the input of an ADC.
11	LOD–	Leads Off Comparator Output. In dc leads off detection mode, LOD– is high when the electrode to –IN is disconnected, and it is low when connected. In ac leads off detection mode, LOD– is always low.
12	LOD+	Leads Off Comparator Output. In dc leads off detection mode, LOD+ is high when the +IN electrode is disconnected, and it is low when connected. In ac leads off detection mode, LOD+ is high when either the –IN or +IN electrode is disconnected, and it is low when both electrodes are connected.
13	$\overline{\text{SDN}}$	Shutdown Control Input. Drive $\overline{\text{SDN}}$ low to enter the low power shutdown mode.
14	AC/ $\overline{\text{DC}}$	Leads Off Mode Control Input. Drive the AC/ $\overline{\text{DC}}$ pin low for dc leads off mode. Drive the AC/ $\overline{\text{DC}}$ pin high for ac leads off mode.
15	FR	Fast Restore Control Input. Drive FR high to enable fast recovery mode; otherwise, drive it low.
16	GND	Power Supply Ground.
17	+Vs	Power Supply Terminal.
18	REFIN	Reference Buffer Input. Use REFIN, a high impedance input terminal, to set the level of the reference buffer.
19	IAOUT	Instrumentation Amplifier Output Terminal.
20	HPSENSE	High-Pass Sense Input for Instrumentation Amplifier. Connect HPSENSE to the junction of R and C that sets the corner frequency of the dc blocking circuit.
	EP	Exposed Pad. Connect the exposed pad to GND or leave it unconnected.

4.5 MAX30102

(High-Sensitivity Pulse Oximeter and Heart-Rate Sensor for Wearable Health)

4.5.1 General Description

The MAX30102 is an integrated pulse oximetry and heart-rate monitor module. It includes internal LEDs, photodetectors, optical elements, and low-noise electronics with ambient light rejection. The MAX30102 provides a complete system solution to ease the design-in process for mobile and wearable devices.

The MAX30102 operates on a single 1.8V power supply and a separate 3.3V power supply for the internal LEDs. Communication is through a standard I2C-compatible interface. The module can be shut down through software with zero standby current, allowing the power rails to remain powered at all times

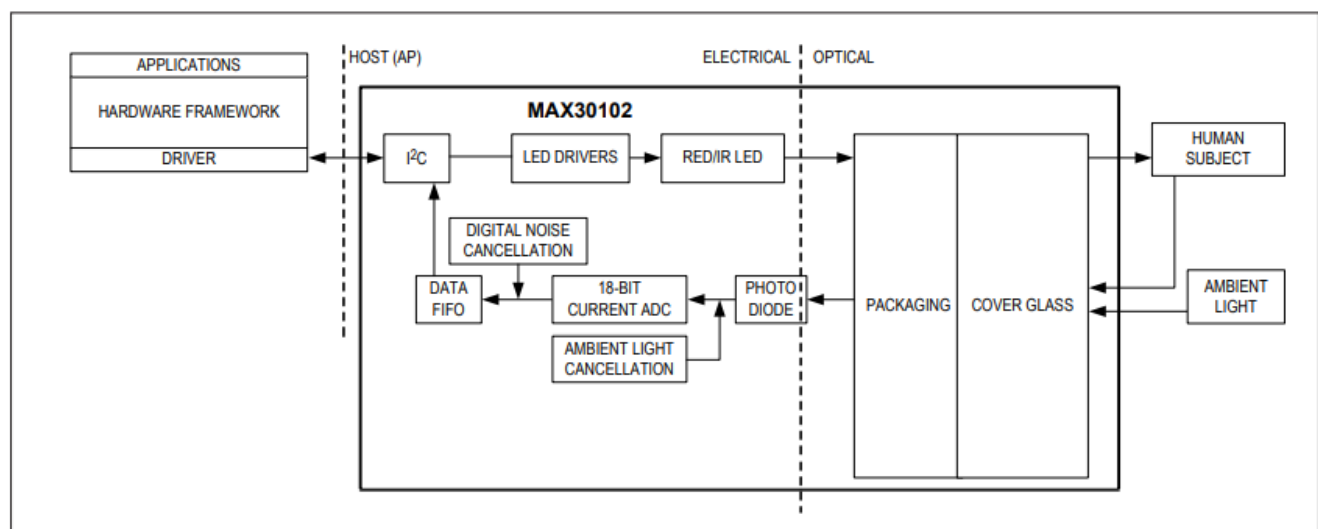
4.5.2 Benefits and Features

- Heart-Rate Monitor and Pulse Oximeter Sensor in LED Reflective Solution
- Tiny 5.6mm x 3.3mm x 1.55mm 14-Pin Optical Module
- Integrated Cover Glass for Optimal, Robust Performance
- Ultra-Low Power Operation for Mobile Devices • Programmable Sample Rate and LED Current for Power Savings
- Low-Power Heart-Rate Monitor (< 1mW)
- Ultra-Low Shutdown Current (0.7μA, typ)
- Fast Data Output Capability
- High Sample Rates
- Robust Motion Artifact Resilience
- High SNR
- -40°C to +85°C Operating Temperature Range

4.5.3 Applications

- Wearable Devices
- Fitness Assistant Devices
- Smartphones
- Tablets

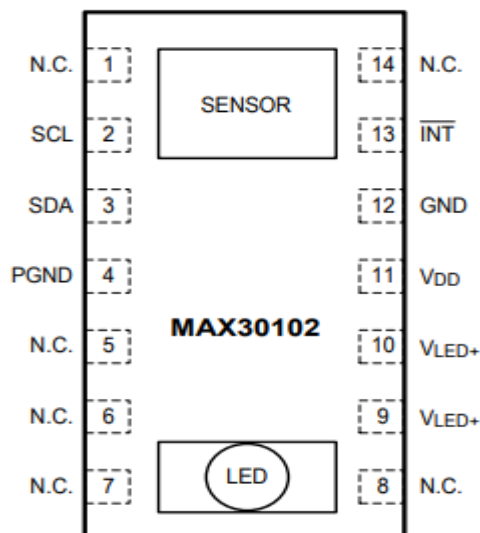
4.5.4 System Diagram



4.5.5 Absolute Maximum Rating

VDD to GND	-0.3V to +2.2V
GND to PGND.....	-0.3V to +0.3V
VLED+ to PGND.....	-0.3V to +6.0V
All Other Pins to GND	-0.3V to +6.0V
Output Short-Circuit Current Duration.....	Continuous
Continuous Input Current into Any Terminal	±20mA
ESD, Human Body Model (HBM).....	2.5kV
Latch up Immunity	±250mA

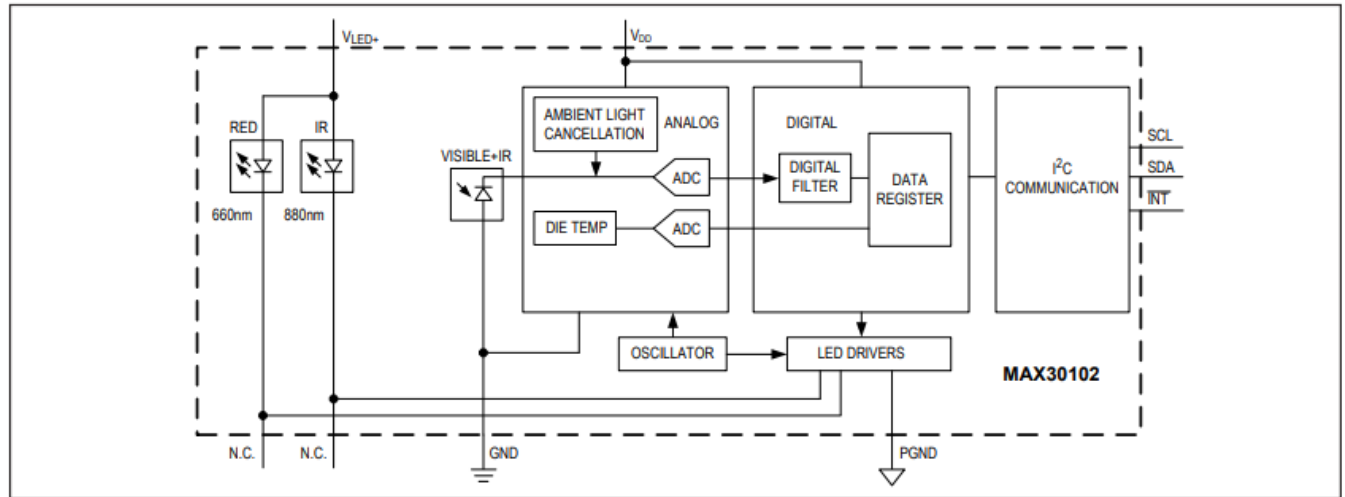
4.5.6 Pin Configuration



4.5.6.1 Pin Configuration

PIN	NAME	FUNCTION
1, 5, 6, 7, 8, 14	N.C.	No Connection. Connect to PCB pad for mechanical stability.
2	SCL	I ² C Clock Input
3	SDA	I ² C Data, Bidirectional (Open-Drain)
4	PGND	Power Ground of the LED Driver Blocks
9	V _{LED+}	LED Power Supply (anode connection). Use a bypass capacitor to PGND for best performance.
10	V _{LED+}	
11	V _{DD}	Analog Power Supply Input. Use a bypass capacitor to GND for best performance.
12	GND	Analog Ground
13	INT	Active-Low Interrupt (Open-Drain). Connect to an external voltage with a pullup resistor.

4.5.7 Functional Diagram



The MAX30102 is a complete pulse oximetry and heart-rate sensor system solution module designed for the demanding requirements of wearable devices. The device maintains a very small solution size without sacrificing optical or electrical performance. Minimal external hardware components are required for integration into a wearable system.

The MAX30102 is fully adjustable through software registers, and the digital output data can be stored in a 32-deep FIFO within the IC. The FIFO allows the MAX30102 to be connected to a microcontroller or processor on a shared bus, where the data is not being read continuously from the MAX30102's registers.

4.5.7.1 SpO₂ Subsystem

The SpO₂ subsystem of the MAX30102 contains ambient light cancellation (ALC), a continuous-time sigma-delta ADC, and a proprietary discrete time filter. The ALC has an internal Track/Hold circuit to cancel ambient light and increase the effective dynamic range. The SpO₂ ADC has programmable full-scale ranges from 2 μ A to 16 μ A. The ALC can cancel up to 200 μ A of ambient current.

The internal ADC is a continuous time oversampling sigma-delta converter with 18-bit resolution. The ADC sampling rate is 10.24MHz. The ADC output data rate can be programmed from 50sps (samples per second) to 3200sps.

4.5.7.2 Temperature Sensor

The MAX30102 has an on-chip temperature sensor for calibrating the temperature dependence of the SpO₂ subsystem. The temperature sensor has an inherent resolution of 0.0625°C.

The device output data is relatively insensitive to the wavelength of the IR LED, where the Red LED's wavelength is critical to correct interpretation of the data. An SpO₂ algorithm used with the MAX30102 output signal can compensate for the associated SpO₂ error with ambient temperature changes.

4.5.7.3 LED Driver

The MAX30102 integrates Red and IR LED drivers to modulate LED pulses for SpO₂ and HR measurements. The LED current can be programmed from 0 to 50mA with proper supply voltage. The LED pulse width can be programmed from 69µs to 411µs to allow the algorithm to optimize SpO₂ and HR accuracy and power consumption based on use cases.

4.6 BUCK CONVERTERS

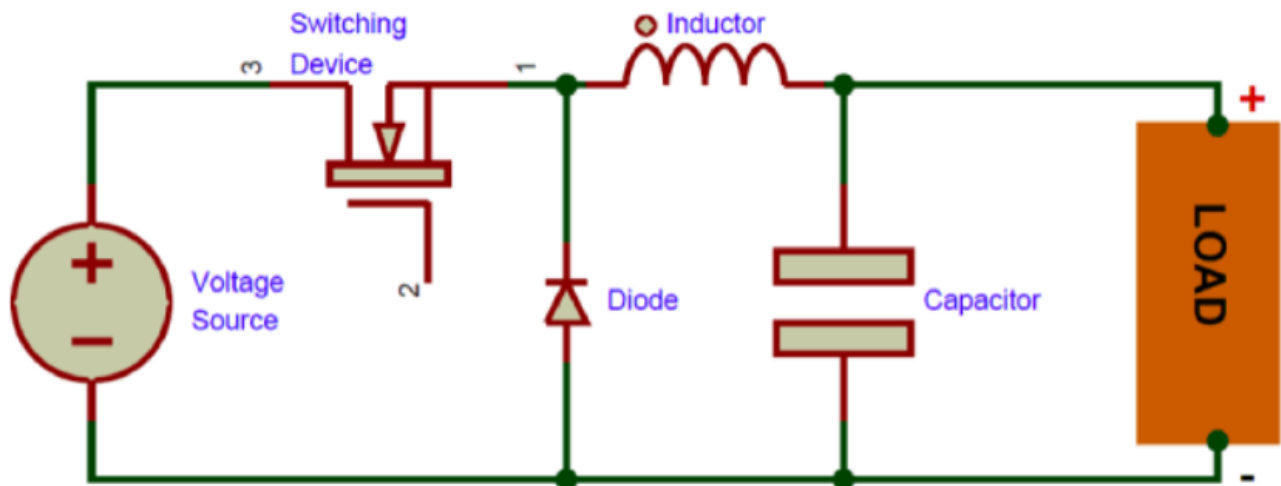


Fig.no:4.6 Buck Converter

Many a times in the electronics world we find the need to reduce one DC voltage to a lower one. For example, we may need to power a 3.3V microcontroller from a 12V supply rail. The solution is simple, we just add a 3.3V linear regulator IC like LD1117 with the 12V rail and it regulates the voltage down to 3.3V. We have already learnt the working of Voltage regulators in our previous article.

Now, suppose we have to power an LED strip from the same 3.3V rail. LEDs easily consume around 20mA each, so a long strip would easily eat up an amp or so. If we calculate the power dissipated by the regulator:

$$P = (V_{in} - V_{out}) * I_{out}$$

The power dissipated comes out to be around 8.7 Watts! Now this is a LOT of power for a little linear regulator to dissipate. If we calculate the efficiency, which is just output power divided by the input power, it comes out to be a pathetic 38%! Normally Linear voltage regulators has very low efficiency compared with switching regulators.

Now we feel the pressing need to find something that can step DC voltages down and do it efficiently!

4.6.1 Introduction to Buck Converter

Luckily such a device already exists, and it's called a buck converter or step-**down** voltage regulators. It's a type of DC-DC converter, so it accomplishes the task using a few transistor switches and an inductor. A typical buck converter circuit is shown in the above image.

It's quite similar to a [boost converter](#), but the placement of the inductor and transistor are switched. The switch shown in the above circuit will normally be a power electronics switch like MOSFET, IGBT or BJT. The switch will be switched (turned on and off) by using a PWM signal.

The working of Buck converter is slightly similar to that of PWM 'dimming'. We've all heard of lights being dimmed by a PWM signal. A small duty cycle means that the average voltage seen by the load is small and when the duty cycle is high the average voltage is high too.

But average voltage is not what we need – a raw PWM signal oscillates between high voltage level and ground, something no delicate load (like the microcontroller) would like. Of course, connecting an RC filter to a square wave source renders the output clean. The voltage level of the filter depends on the duty cycle of the PWM signal – the higher the duty cycles the higher the output voltage.

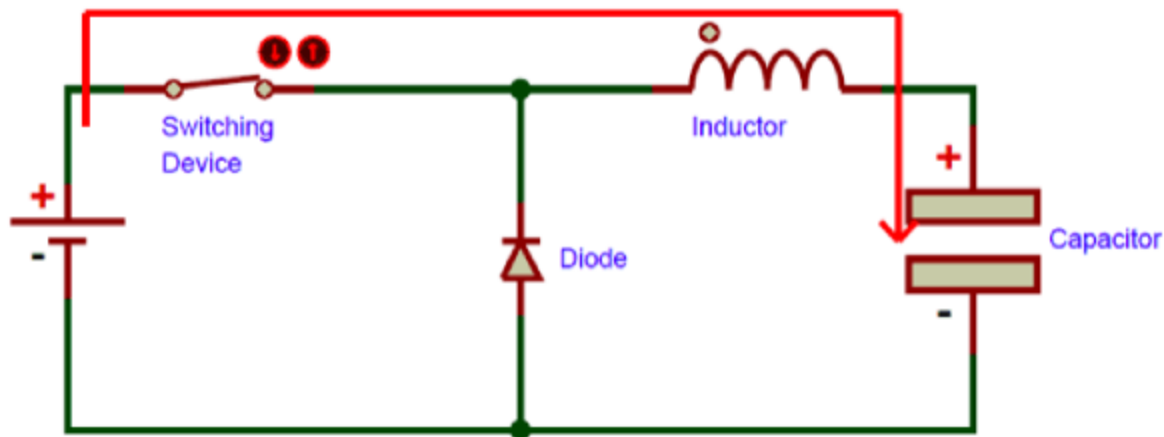
So now we have a clean output voltage. The below graph shows the raw PWM signal in blue colour and the filtered outputs in red and violet colour.

4.6.2 Working of a Buck Converter

The working of a buck converter can be broken down into a few steps.

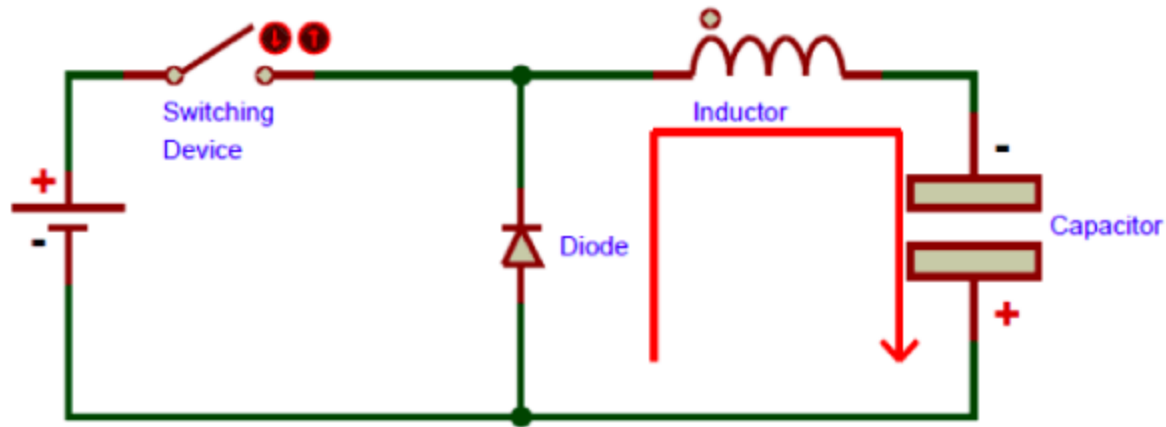
STEP – 1:

The switch turns on and lets current flow to the output capacitor, charging it up. Since the voltage across the capacitor cannot rise instantly, and since the inductor limits the charging current, the voltage across the cap during the switching cycle is not the full voltage of the power source.



STEP – 2:

The switch now turns off. Since the current in an inductor cannot change suddenly, the inductor creates a voltage across it. This voltage is allowed to charge the capacitor and power the load through the diode when the switch is turned off, maintaining current output current throughout the switching cycle.



These two steps keep repeating many thousands of times a second, resulting in continuous output.

4.6.3 Designing a Buck Converter

STEP – 1

Determine the input voltage and the output voltage and current.

The duty cycle of the converter is given by:

$$DC = V_{out}/V_{in}$$

STEP – 2

Determine the output power, that is, the product of the output voltage and current. This is also the input power, by the law of conservation of energy (though not exactly so – nothing is a hundred percent efficient!).

STEP - 3

Now divide the output power by the selected switching frequency in order to get the power transferred per pulse.

Since it is easier to talk about inductors in terms of energy, we can assume now that the output power is simply the output energy per second. So, if the output of our converter is 30 Watts, then we can say that the output energy is thirty Joules every second.

STEP - 4

Now that we have the energy per pulse, we can calculate the inductance using the input current and the energy:

$$L = 2E/I^2$$

Where E is the energy transferred per pulse and I is the square of the input current.

Using the values of the inductance, frequency and duty cycle, we can now get to work building a simple boost converter.

4.6.4 Choice of Parts

4.6.4.1 MOSFET

Since the switch is on the high side, using an N channel MOSFET or an NPN bipolar wouldn't work, unless we have a bootstrapped gate driver. Though this is possible, it is quite complicated.

Using a P channel device in these circumstances would be recommended, they greatly simplify driving requirements, but remember that they turn on when the gate is low, so an inverted signal would be necessary. One can use the IRF5210, it has a decent on resistance of $60\text{m}\Omega$ and a V_{DS} of -100V , which should be plenty for most applications. However, there are many better devices available, the choice is entirely up to the designer based on the specific application.

Remember to use a gate driver to reduce switching losses!

4.6.4.2 DIODE

Since this diode does not have to handle very high voltages, rather high currents, it would be a good design choice to use a Schottky diode with a low forward voltage drop to keep things efficient.

4.6.4.3 CAPACITOR

The capacitor value depends on the output voltage ripple and can be calculated using the capacitor equation, but generally a value between $100\mu\text{F}$ to $680\mu\text{F}$ for low current applications should suffice.

CHAPTER 5

RESULT



Fig.no.5.1: ECG OUTPUT

The recording of an ECG from the above picture allows the time taken for the various phases of electrical depolarization to be measured, usually in milliseconds. There is a recognized normal range for such 'intervals': PR interval (measured from the beginning of the P wave to the first deflection of the QRS complex). Normal range 120 – 200 MS (3 – 5 small squares on ECG paper). QRS duration (measured from first deflection of QRS complex to end of QRS complex at isoelectric line). Normal range up to 120 MS (3 small squares on ECG paper). QT interval (measured from first deflection of QRS complex to end of T wave at isoelectric line). Normal range up to 440 MS (though varies with heart rate and may be slightly longer in females)

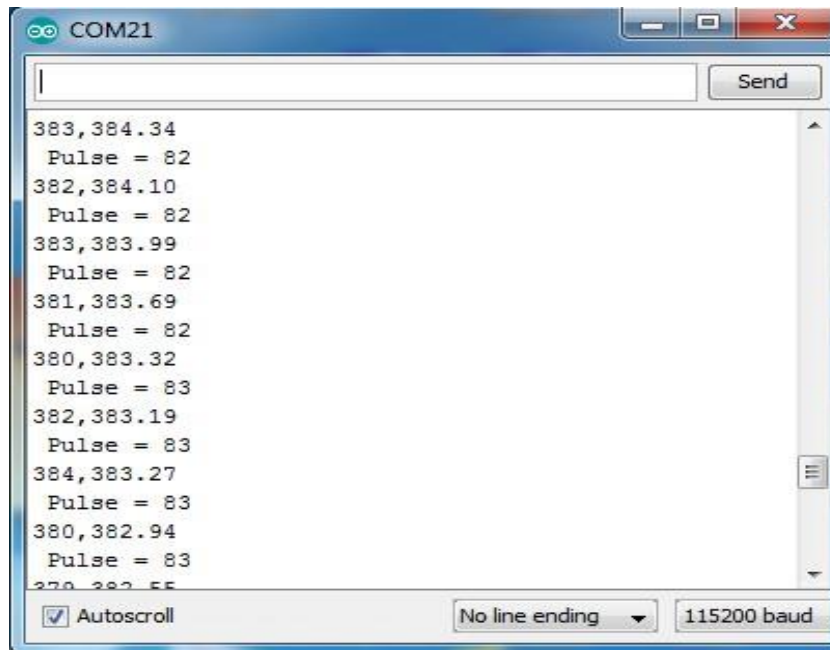


Fig.no.5.2: Heart Beat Count

The above figure depicts the measurement of heart rate by the sensor. As pulse signals are obtained via the IR proximity range and various calculations are undertaken in calculating the heart rate in BPM

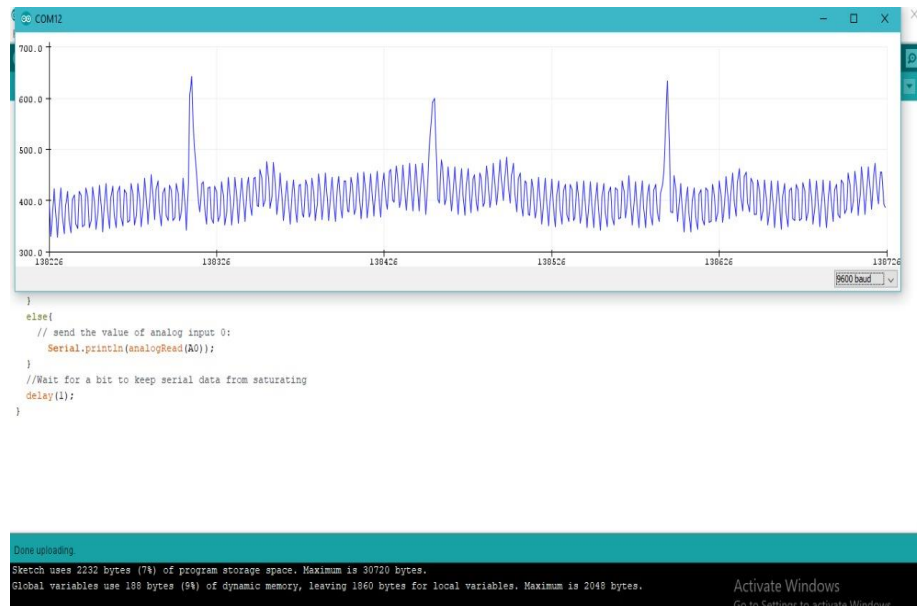


Fig.no: 5.3 ECG With Heart Beat

The above figure describes the graphical view of heart rate progression towards the end. The length between the two amplitudes in the wave clearly show the time taken for the heart to relax and beat. Sharp points are observed towards the end where amplitude slightly changes as

a result of lowering of heart beat.

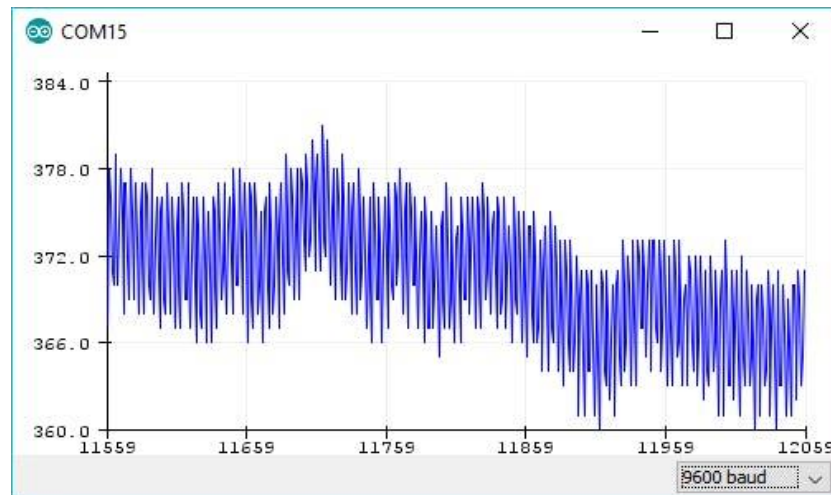


Fig.no.5.4: Pulsated Rythmic Outic

The above pic represents the Depolarization of the ventricles results in usually the largest part of the ECG signal (because of the greater muscle mass in the ventricles) and this is known as the QRS complex.

The Q wave is the first initial downward or 'negative' deflection

The R wave is then the next upward deflection (provided it crosses the isoelectric line and becomes 'positive')

The S wave is then the next deflection downwards, provided it crosses the isoelectric line to become briefly negative before returning to the isoelectric baseline.

CHAPTER 6

CONCLUSION

In this paper it demonstrated an MQTT based patient health monitoring system, which is continuously monitor the patient's heart beat, body temperature, position and other critical parameters. This system has potential to offer a wide range of benefits to patients, early detection of abnormal conditions, continuous patient monitoring and potential knowledge discovery through data mining of all gathered information.

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