CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

A modernized healthcare system is one of the challenges for humanity. According to the constitutions of World Health Organization (WHO) the highest attainable standard of health is a fundamental right for an individual. Healthy individuals also reduce pressure overloaded hospitals, clinics, and medical professionals. A smart IoT healthcare system proves an effective solution to achieve this.

Internet of Things (IoT) is a system in which connected physical objects can be accessed through the internet. Using IoT technology, various smart objects can be connected through the internet and can provide efficient data exchange methods for application purposes.

The propounded systems in place for remote health care allow monitoring of patient's health parameters but these systems require the sensors to be placed in such a way that it limits the patient to his bed. Currently, there is no framework in place where constant time to time checking of the patient is accomplished with data security to avoid breaches. The existing systems are non- portable, complex, difficult to operate, energy inefficient which also lacks an emergency rescue mechanism.

The immediate objective and outcome of this project was to develop a more reliable remote patient monitoring system so that the healthcare professionals can monitor their patients, who are either hospitalized or executing their normal daily life activities from anywhere in the world. The patient's medical records are also secured using a unique ID (Identity Document) and password assigned only to authorized doctors. The authorized doctor can also suggest medications to the patient enabling patient monitoring and Tele-medicine integrated into a single system.

The prime purpose was to develop a portable, efficient, easy to operate system to facilitate remote monitoring of patient's health status who cannot afford long term stay at hospitals due to economic restrictions, work etc. even though their health status must be monitored in a real time or short periodic mode. The GSM (Global System for Mobile) Technology and Cloud computing helps in the transfer and access of data between the patient and the medical professional making the system more reliable.

1.2 MOTIVATION

In today's busy world, long term patient stay at hospitals are not feasible due to time constraints, economic restrictions, increasing population demands and limited resources even though their health status must be monitored in real time. The motivation for this project was to reduce the overload at hospitals and demand for medical professionals caused due to increasing population and limited resources. This can be done by acquiring the patient's vital health parameters and transmitting them to a cloud which can be accessed by medical professionals from through any browser residing at any corner of the world with access to internet. The authorized doctor can then prescribe medications or quick aid in case of emergency to the patient/Care taker.

1.3 OBJECTIVE

The objective is to design and implement a system capable of monitoring the health and workout routine recommendations to patients outside of conventional clinical settings (e.g. in the home), which may increase access to care and decrease healthcare delivery costs. This system creates a new revolution in e-healthcare domain. It monitors the vital parameters such as temperature, heartbeat, Echo Cardio Gram (ECG) of patients who are executing their normal everyday activities. These parameters are sent to a prescribed medical professional through the internet and during crucial scenario an emergency rescue mechanism is incorporated by sending alert messages to authorized doctors only. An additional feature to this system is Tele-medicine, where the doctor can provide medication and assistance to the patients.

It allows patients to maintain independence, prevent complications, and minimize personal costs. Remote Patient Monitoring system facilitates these goals by delivering care right to the home. Furthermore, patients and their family members feel comfort knowing that they are being monitored and will be supported if a problem arises. The time saved as a result of this system implementation increases efficiency, and allows healthcare providers to allocate more time to remotely educate and communicate with patients.

1.4 METHODOLOGY

It is inconvenient for most patients to afford long-term hospital stays due to economic restrictions, work etc. even though their health status must be monitored in a real time or short periodic mode such as during post operational days. Here, the sensor unit collects and transmits data from various sensors connected to the body of a patient that measure vital parameters of human body to a central network capable of comprehending, analysing and processing the collected data. It comprises of a Microcontroller, Temperature sensor, Heart rate sensor GSM MODEM, Piezo-Electric buzzer, and Regulated Power Supply. The Microcontroller collects the data from the sensors and sends the data to the cloud and the data is also displayed on the LCD. The user interface html webpage is designed to automatically refresh for every fifteen seconds thereby ensuring constant monitoring of patient by the doctor. The information stored on the cloud can be accessed anytime by the authorized doctor using any browser from end devices such as laptop/mobile. The doctor can login to the webpage using a unique IP address and password assigned to them. When the vital parameters cross the safe threshold, a message is sent to alert the doctor through GSM MODEM and simultaneously the buzzer turns on to alert the caretaker. If there is no response from the prescribed doctor within a stipulated time frame, the message is sent to the mobile of another authorized doctor, making the system more reliable. Doctor can also suggest medications to the patient achieving both telemedicine and remote patient monitoring integrated into a single system.

The proposed system extends healthcare set up from the traditional clinic or hospital setting to the patient's home, enabling Tele-care without the prohibitive costs of retrofitting existing dwellings.

CHAPTER 2

LITERATURE SURVEY

The modern visionary of healthcare industry is to provide better healthcare to people anytime and anywhere in the world in a more economic and patient friendly manner. Therefore for increasing the patient care efficiency, there arises a need to improve the patient monitoring devices and make them more mobile. The existing systems in place for remote healthcare monitoring make use of IoT as the basic platform. Some of the related works related to patient monitoring system are as follows:

Godfrey Winster. S et al. [1] proposed a novel concept of monitoring the patients in a more efficient manner using IoT concept. This system collects the required parameters and evaluates the data from the obtained IoT devices. It also notifies the patient with possible precautionary measures to be practiced by them and suggests the patient with medical care and the preceding step to be followed in case of critical condition. The doctors, caretaker and the patients can view the details using the mobile application or through the web. But the data collected from the IoT devices to the system lasts only for three days in the mobile application.

Prasad Virkar et al.[2] presented a novel simple system using GSM and ZigBee modules which examines the body temperature and heart rate of the patients using appropriate sensors. The data from the sensors is processed by predefined software and will be transmitted to the ZigBee module which is in the vicinity of the patient's room. This data will be received by the receiver ZigBee module present at the doctor's desk. When a critical condition arises, an alert message is sent to all the numbers predefined in the program. It measures only two human health parameters namely body temperature and heart rate sensor lacks continuous monitoring of the patient by the doctor from any remote place at any given time since a short range communication mode such as ZigBee module is used.

Deepta Rajan et.al [3] developed a mobile application called Android Java-DSP (AJDSP) that interfaces with sensors and enables simulation. In this system firstly there is creation of interface between external sensors and on-board device sensors for monitoring the physiological parameters of human being. A small wireless low-power sensor platform called

SHIMMER is used that can record and transmit physiological and kinematic data in real time. But the drawback of this system is that it only monitors those patients who are admitted in the hospital.

Dr. T. Bhuvaneshware et.al [4] designed a system that monitors a patient's health physical or mental through mobile devices and gives extra information like location of user and provides security and reliability. To maintain the security a wireless technology called as NFC (Near Field Communication Technology for Future) which interacts with the electromagnetic radio fields. It is used to access the patient information, and this information is stored in hospital EMR Database. When the patient is discharged all the details will be transferred to the NFC tag from EMR. This system mainly emphasizes on the database security rather than providing service like nearest hospital list and alert to the family members.

S. Sneha et al.[5] came up with a new approach of a system utilizing mobile technologies to enable continuous, wireless ECG (Electro Cardio Gram) monitoring of cardiac patients. The proposed system has the potential to improve patient's quality of life by allowing them to move around freely while undergoing continuous heart monitoring and to reduce healthcare costs associated with prolonged hospitalization, treatment and monitoring. The drawback of this system is that it only measures ECG and no other essential human health parameters.

Prabhakaran R et.al [6] designed a conventional monitoring system which consists of sensor node and centralized node. The sensor node consists of temperature sensor and heartbeat sensor for health parameter for data sensing and monitoring. The sensor node monitors health conditions and sends data wirelessly to a central node using ZigBee. The central node acts as a software defined control centre and it is designed for data storage, data processing and uploading the web server. But this system monitors only two human health parameter which makes it less efficient.

Vandana Milind R Rohokale et.al [7] proposed a novel corporative IoT approach for rural healthcare applications. The distinctiveness of this algorithm is that node location information and high source transmit power for data are not needed. This approach can prove reliable for critical healthcare applications like continuous monitoring and control of health parameters of human beings such as heart beat, blood pressure, blood sugar etc. Energy savings of 57% is achieved in this case is the first step towards green IoT. The outage behaviour is almost same as that of amplify and forward technique. The energy savings achieved at the low threshold value is the added advantage of this system. The drawback of this system is that it does not provide proper authentication of data and authorization of doctors which is a major concern.

CHAPTER 3

SYSTEM DESIGN

“Remote Patient Monitoring with Tele-Medicine based on Internet-Of-Things” basically has five units i.e. the data acquisition unit, data transmission unit, Cloud processing, the GSM unit and telemedicine. The below figure shows the complete block diagram of the system.

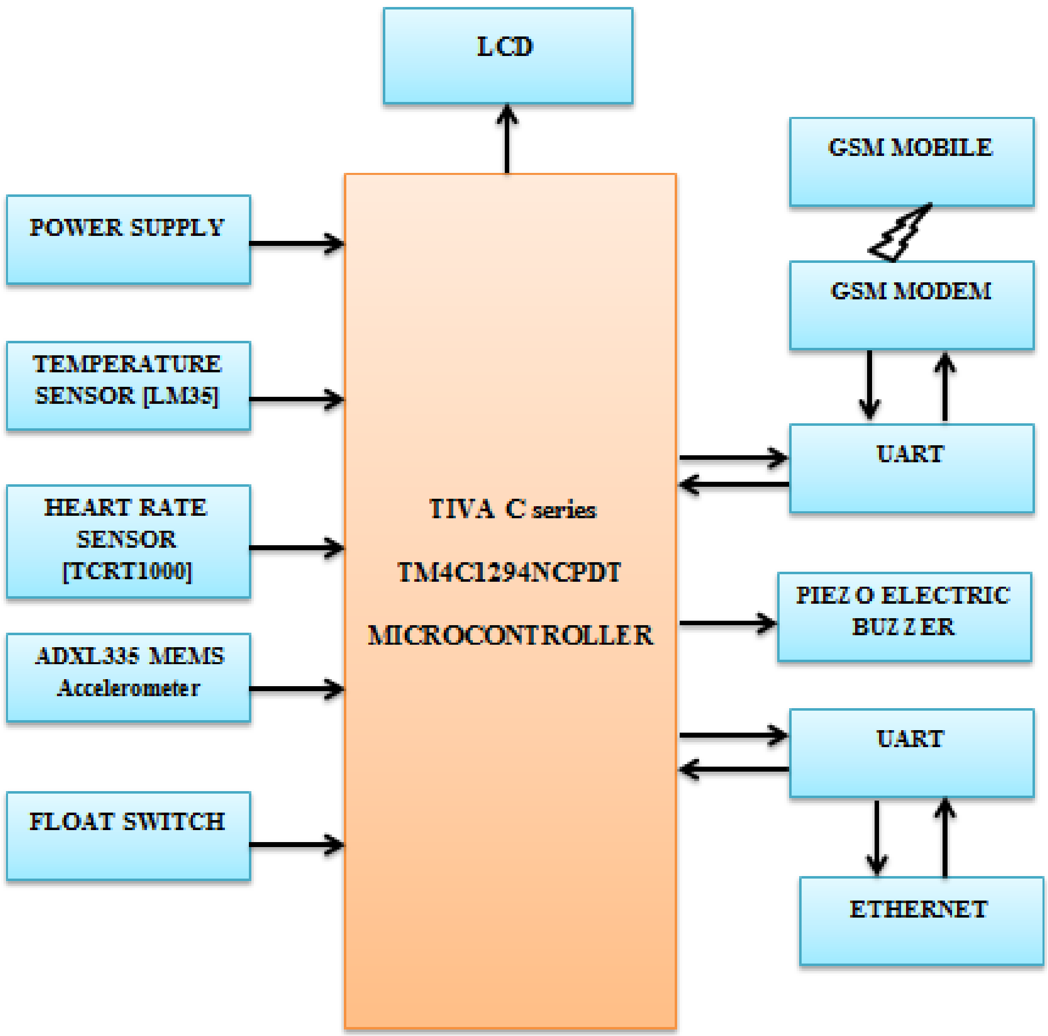


Figure: 3.1: Block Diagram of Proposed System

The data acquisition unit consists of sensors placed at the patient's end which consists of a temperature sensor, heart rate sensor, and an ECG sensor which measures the vital parameters of a patient. These readings are then stored in the cloud and accessed by authorized doctors using a unique ID and password assigned to them.

The Data Transmission components of the system are responsible for conveying recordings of the patient from the patient's house (or any remote location) to the data centre of the Healthcare Organization (HCO) with assured security and privacy, ideally in near real-time. The data acquired is sent to the central unit i.e micro controller. Aggregated data is further relayed to a HCO for long term storage using Internet connectivity on the concentrator, typically via a cellular data connection. Sensors in the data acquisition part form an Internet of Things (IoT)-based architecture as each individual sensor's data can be accessed through the Internet via any browser using a smart phone or Laptop.

Cloud Processing has three distinct components: storage, analytics, and visualization. The system is designed for long term storage of patient's biomedical information as well assisting health professionals with diagnostic information. Analytics that use the sensor data along with e-Health records that are becoming prevalent can help with diagnoses and prognoses for a number of health conditions and diseases. Additionally, Visualization is a key requirement for any such system because it is impractical to ask physicians to pore over the voluminous data or analyses from wearable sensors.

In the GSM unit, an emergency rescue mechanism is incorporated i.e. when the vital parameters cross the safe threshold, to alert the doctor a message is sent to the doctor's cell phone through GSM modem and simultaneously the buzzer turns on to alert the caretaker. If there is no response reception from the prescribed doctor within a stipulated time frame, the message is sent to the mobile of another doctor, making the system more reliable.

Tele-Medicine Unit is the remote delivery of healthcare services, such as health assessments or consultations, over the telecommunications infrastructure. Based on the readings the doctor can provide medication and assistance to the patient which is sent to the patient's mobile and also displayed on the LCD for the caretaker to take notice.

The proposed system has five distinct units i.e.

- The data acquisition unit.
- Data transmission unit.
- Cloud processing.
- The GSM unit.
- Telemedicine.

3.1. THE DATA ACQUISITION UNIT

Data acquisition unit consists of various sensors that measure vital human health parameters like body temperature, heart rate, ECG which is connected to a data aggregator i.e a microcontroller The data accumulator which is typically a microcontroller is used to connect the sensors to the network. The LCD display will act as an output source in this project that will be helpful to display the location name on this display. The RS, R/W. and EN pins are the control pins which are used for controlling purpose. The RS pin is used to select either data mode or command mode. The R/W is used to indicate that the LCD will acts as a either read or write mode. The EN pin is used to enable the data. The system is first initialized for successful connection and then the readings are taken for the respective patient marked by a patient ID. Messages such as “Take Temperature”, “Take Heart Rate” and “Take ECG” are displayed after which the readings are taken on press of “OK” button. In this manner, the data is acquired by the seniors and sent to the micro controller unit for further processing to be sent to the network.

3.2. THE DATA TRANSMISSION UNIT

The data transmission unit consists of a TIVA Series Controller capable of analysing the data and transmitting it to a server. The data on the cloud is accessed by the authorized doctor via any browser using a unique ID and password assigned to them. The UI HTML webpage is automatically designed to refresh for every 15 seconds to update and store the recent readings.

3.3. CLOUD PROCESSING

The data from the micro controller is sent to the cloud i.e. web server by using Ethernet. Long-term storage of patient’s biomedical data is made possible along with facilitating the doctor with diagnostic information. Diagnostics deals with sensor data and e-health records which are important for the prognosis of various health conditions and ailments. Visualization is a prime necessity for any such system as it is inappropriate to depend on the physicians for data from sensors.

The data located in one central location rather than being distributed apart in different places provides higher feasibility and data security. Since, it is an ethical requirement to protect the critical medical data of individual’ bio signals, hence the centralized architectural design pattern was. In our architectural design, the data monitored for all the patients will be stored in one centralized location, which will be separated through a unique identifier to identify the data for different individuals .Since all the data are stored in one place, it will be easy to query the database and perform data analysis out of the combined data.

3.4. THE GSM UNIT

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. During extreme conditions to alert the doctor, a warning message is sent to the doctor’s cell phone through GSM modem connected to the controller. If response is not received by the prescribed doctor within a specified time frame, an alert message is sent to a secondary authorized doctor. Quick provisional medication can be easily done by this system making it efficient with low power consumption capability, easy setup, high performance and time to time response.

3.5. TELEMEDICINE

Telemedicine is part of healthcare that is utilizing telecommunications and information technology in order to eliminate the distance from healthcare provider. The doctor on having access to vital parameters can suggest immediate aid in case of emergency or medication and assistance to the patient via SMS sent to the patient’s mobile phone and also displayed on LCD at the patient’s end.

3.6 FLOWCHART

The initialization of the device indicating successful connection to the internet is performed. Thereafter the vital parameters such as temperature, heartbeat and ECG samples is taken for five seconds and sent to a global server which can be accessed from any browser. If the parameters cross the safe threshold value, a message is sent to the prescribed doctor's phone, else stored in the html data base segregated by dates for access to the doctor. The doctor then can prescribe medications to the patients accordingly.

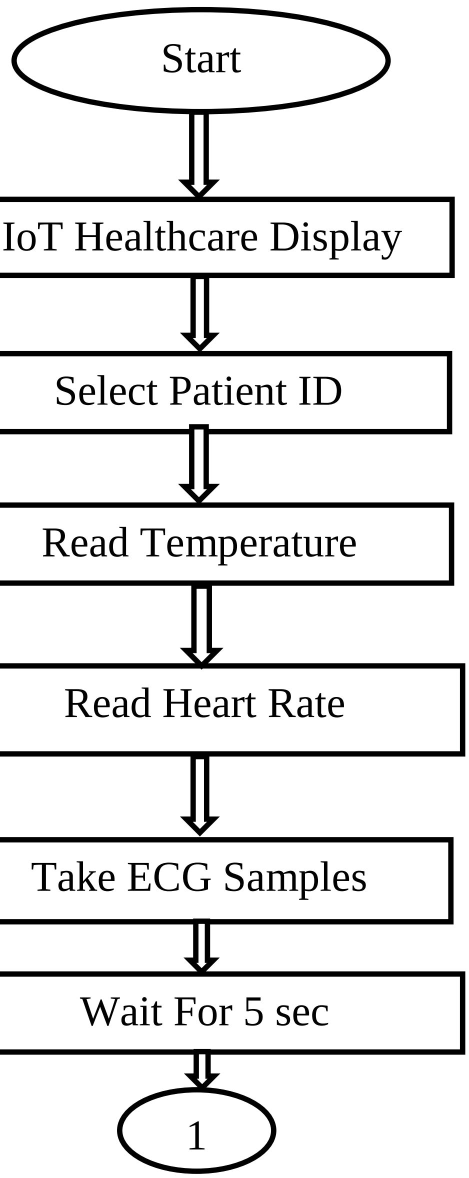
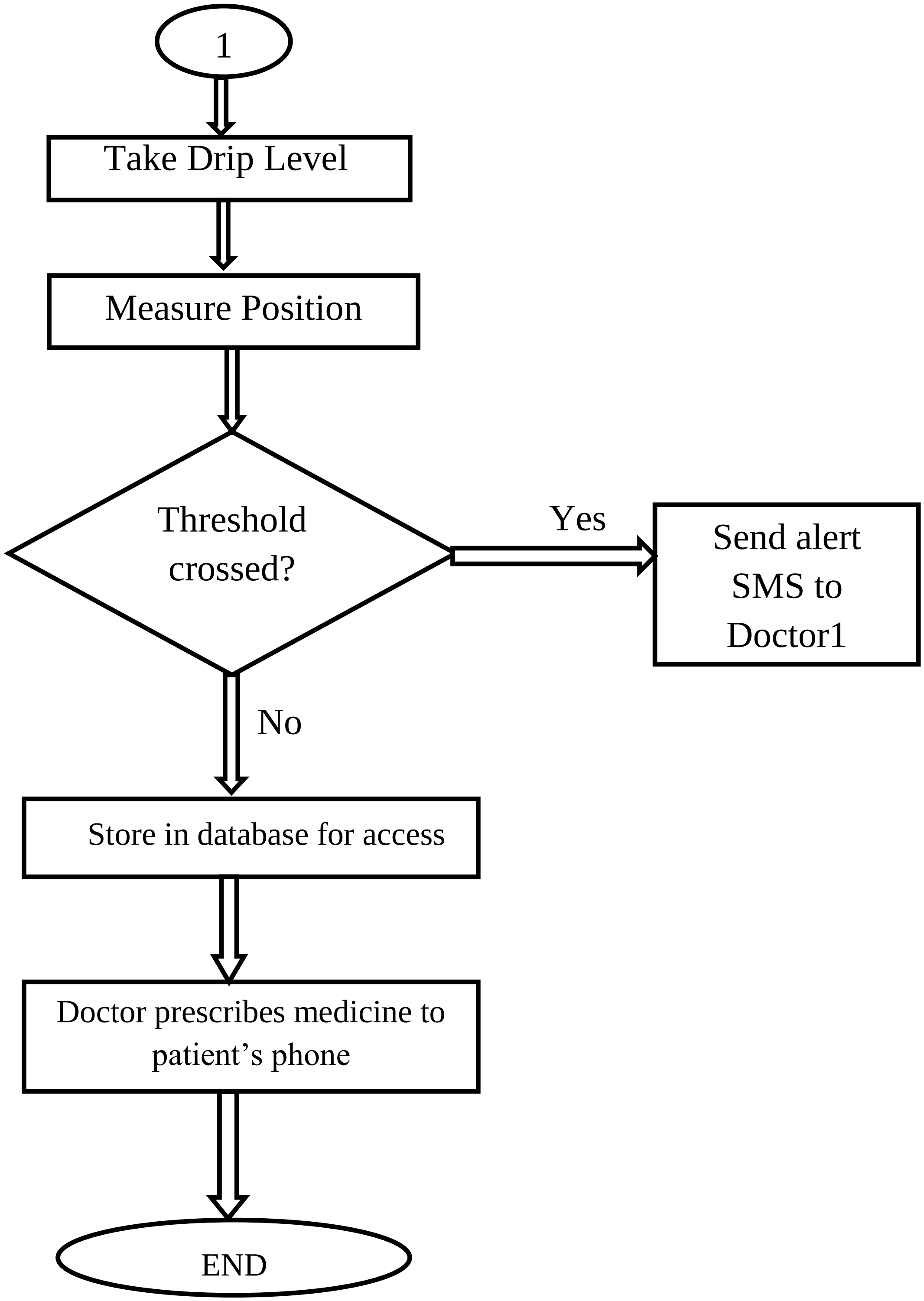


Figure 3.2 Flowchart of proposed system



Continuation of Figure 3.2

CHAPTER 4

DESCRIPTION OF HARDWARE AND SOFTWARE REQUIREMENTS

4.1 HARDWARE REQUIREMENTS

Tiva™ C Series TM4C1294NCPDT Connected LaunchPad Evaluation Kit
Temperature sensor LM35
Heart Rate sensor TCRT1000
ECG sensor AD8232
ADXL335 MEMS Accelerometer
Float Switch
Resistors
Capacitors
Potentiometer
Transformer
Op-amp
LEDs
Voltage regulator
Push buttons
GSM Module
LCD

4.1.1 POWER SUPPLY

Components required for regulated power supply:

Table: 4.1: Components required for regulated power supply

Name of the components	Range/Series of components	Quantity
Semiconductor	7805 Regulator IC1	1
Diode	1N4007 Rectifier Diodes	2
Capacitor	1000 µf/25V	1
Miscellaneous	230V AC Pri,14-0-14 1Amp Sec Transformer	1

4.1.2 CIRCUIT DESCRIPTION OF REGULATED POWER SUPPLY:

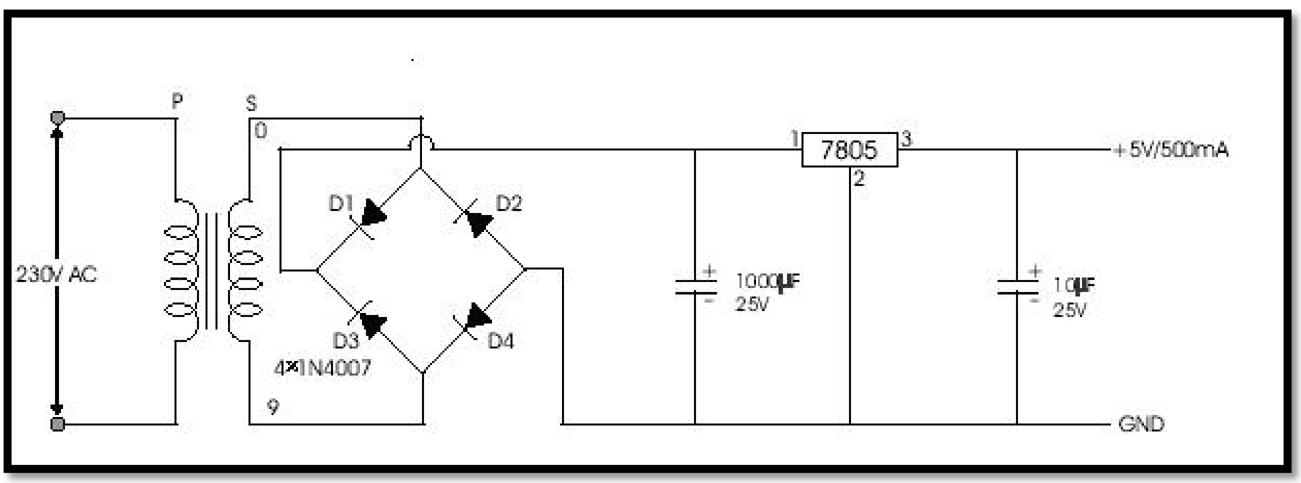


Figure: 4.1: Circuit diagram of +5v full wave regulated power supply

The circuit needs a voltage of +5V to work. The voltage is supplied by this specially designed power supply. The main objective of the 'power supply' is to deliver the required amount of stabilized power to the circuit.

Every typical power supply contains the following sections:

Step-down Transformer: The conventional supply, which is generally available to the user, is 230V AC. It is necessary to step down the mains supply to the desired level. This is achieved by using suitably rated step-down transformer. While designing the power supply, it is necessary to go for little higher rating transformer than the required one for accurate and stabilized output. The transformer rating is 230V AC at Primary and 12-0-12V, 1 Amperes across secondary winding. This transformer has a capability to deliver a current of 1 Ampere, which is more than enough to drive any electronic circuit or varying load. The 12VAC appearing across the secondary is the RMS value of the waveform and the peak value would be 12 x 1.414 = 16.8 volts. This value limits our choice of rectifier diode as 1N4007, which is having PIV rating more than 16Volts.

Rectifier stage: The step-downed Alternating Current is converted into Direct Current. This rectification is achieved by using passive components such as diodes. If the power supply is designed for low voltage/current drawing loads/circuits (say +5V), it is sufficient to employ full-wave bridge rectifier with centre-tap transformer as a power source. While choosing the diodes the PIV (peak inverse voltage) rating is taken into consideration. The two diodes D1 & D2 are connected across the secondary winding of the transformer as a full-wave rectifier. During the positive half-cycle of secondary voltage, the end A of the secondary winding becomes positive and end B negative. This makes the diode D1 forward biased and diode D2 reverse biased. Therefore diode D1 conducts while diode D2 does not. During the negative half-cycle, end A of the secondary winding becomes negative and end B positive. Therefore diode D2 conducts while diode D1 does not.

Voltage Regulation: The filtered DC output is not stable. It varies in accordance with the fluctuations in mains supply or varying load current. This variation of load current is observed due to voltage drop in transformer windings, rectifier and filter circuit. These variations in DC output voltage may cause inaccurate or erratic operation or even malfunctioning of many electronic circuits. For example, the circuit boards which are implanted by CMOS or TTL ICs.

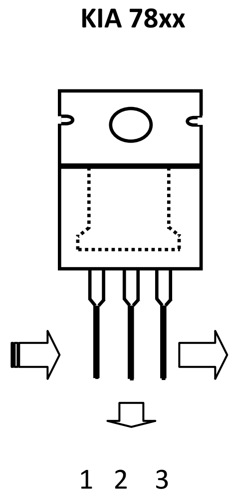


Figure: 4.2: Voltage regulator IC

The stabilization of DC output is achieved by using the three terminal voltage regulator IC. This regulator IC comes in two flavours: 78xx for positive voltage output and 79xx for negative voltage output. For example 7805 gives +5V output and 7905 gives -5V stabilized output. These regulator ICs have in-built short-circuit protection and auto-thermal cut-out provisions. If the load current is very high the IC needs 'heat sink' to dissipate the internally generated power.

A DC power supply which maintains the output voltage constant irrespective of A.C. mains fluctuations or load variations is known as regulated DC power supply. It is also referred as full-wave regulated power supply as it uses four diodes in bridge fashion with the transformer. This laboratory power supply offers excellent line and load regulation and output voltages of +5V & +12 V at output currents up to one amp.

Filter Stage: Here Capacitor C1 is used for filtering purpose and connected across the rectifier output. It filters the AC components present in the rectified DC and gives steady DC voltage. As the rectifier voltage increases, it charges the capacitor and also supplies current to the load. When capacitor is charged to the peak value of the rectifier voltage, rectifier voltage starts to decrease. As the next voltage peak immediately recharges the capacitor, the discharge period is of very small duration. Due to this continuous charge-discharge-recharge cycle very little ripple is observed in the filtered output. Moreover, output voltage is higher as it remains substantially near the peak value of rectifier output voltage. This phenomenon is also explained in other form as the shunt capacitor offers a low reactance path to the AC components of current and open circuit to DC component. During positive half cycle the capacitor stores energy in the form of electrostatic field. During negative half cycle, the filter capacitor releases stored energy to the load.

4.1.3 TIVA™ C SERIES TM4C1294NCPDT

The Tiva™ C Series ARM Cortex-M4 microcontrollers provide top performance and advanced integration. The product family is positioned for cost-effective applications requiring significant control processing and connectivity capabilities. Tiva™ C Series microcontrollers integrate a large variety of rich communication features to enable a new class of highly connected designs with the ability to allow critical, real-time control between performance and power. The microcontrollers feature integrated communication peripherals along with other high-performance analog and digital functions to offer a strong foundation for many different target uses, spanning from human machine interface to networked system management controllers.

In addition, Tiva™ C Series microcontrollers offer the advantages of ARM's widely available development tools and System-on-Chip (SoC) infrastructure. Additionally, these microcontrollers use ARM'sThumb-2 instruction set to reduce memory requirements and, thereby, cost. Finally, the TM4C1294NCPDT microcontroller is code-compatible to all members of the extensive Tiva™ C Series, providing flexibility to fit precise needs. Texas Instruments offers a complete solution to get to market quickly, with evaluation and development boards, white papers and application notes, an easy-to-use peripheral driving library, and a strong support, sales, and distributor network.

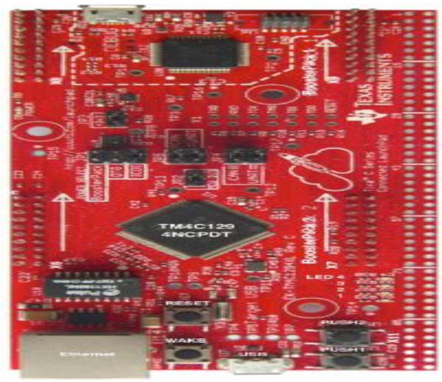


Figure: 4.3: Tiva™ C Series TM4C1294 Microcontroller

The TM4C1294NCPDT microcontroller combines complex integration and high performance with the features as shown in the table below:

Table: 4.2: TM4C1294NCPDT Microcontroller Features

Features	Description
Performance	
Core	ARM Cortex-M4F processor core
Performance	120-MHz operation; 150 DMIPS performance
Flash	1024 KB Flash memory
System SRAM	256 KB single-cycle System SRAM
EEPROM	6KB of EEPROM
Internal ROM	Internal ROM loaded with TivaWare™ for C Series software
External Peripheral Interface (EPI)	8-/16-/32- bit dedicated interface for peripherals and memory
Security	
Cyclical Redundancy Check (CRC) Hardware	16-/32-bit Hash function that supports four CRC forms
Tamper	Support for four tamper inputs and configurable tamper event response

Communication interface	
Universal Asynchronous Receivers/Transmitter (UART)	Eight UARTs
Quad Synchronous Serial Interface (QSSI)	Four SSI modules with Bi-, Quad- and advanced SSI support
Inter-Integrated Circuit (I2C)	Ten I2C modules with four transmission speeds including high-speed mode
Controller Area Network (CAN)	Two CAN 2.0 A/B controllers
Ethernet MAC	10/100 Ethernet MAC
Ethernet PHY	PHY with IEEE 1588 PTP hardware support
Universal Serial Bus (USB)	USB 2.0 OTG/Host/Device with ULPI interface option and Link Power Management (LPM) support
System Integration	
Micro Direct Memory Access (µDMA)	ARM® PrimeCell® 32-channel configurable µDMA controller
General-Purpose Timer (GPTM)	Eight 16/32-bit GPTM blocks
Watchdog Timer (WDT)	Two watchdog timers
Hibernation Module (HIB)	Low-power battery-backed Hibernation module
General-Purpose Input/Output (GPIO)	15 physical GPIO blocks
Advanced Motion Control	
Pulse Width Modulator (PWM)	One PWM module, with four PWM generator blocks and a control block, for a total of 8 PWM outputs.
Quadrature Encoder Interface (QEI)	One QEI module
Analog-to-Digital Converter (ADC)	Two 12-bit ADC modules, each with a maximum sample rate of two million samples/second

Analog Support	
Analog Comparator Controller	Three independent integrated analog comparators
Digital Comparator	16 digital comparators
JTAG and Serial Wire Debug (SWD)	One JTAG module with integrated ARM SWD
Package Information	
Package	128-pin TQFP

- ***ARM Cortex-M4F Processor Core***

  All members of the Tiva™ C Series, including the TM4C1294NCPDT microcontroller, are designed around an ARM Cortex-M processor core. The ARM Cortex-M processor provides the core for a high-performance and low-cost platform that meets the needs of minimal memory implementation, reduced pin count, and low power consumption, while delivering outstanding computational performance and exceptional system response to interrupts. The 32-bit ARM Cortex-M4F architecture is optimized for small footprint embedded applications and has an operation frequency of 120MHz and 150 DMIPS performance. It has an outstanding processing performance combined with fast interrupt handling.

- ***System Timer (Sys Tick)***

  ARM Cortex-M4F includes an integrated system timer, SysTick. SysTick provides a simple, 24-bit, clear-on-write, decrementing, wrap on zero counter with a flexible control mechanism .When enabled, the timer counts down on each clock from the reload value to zero, reloads (wraps) to the value in the STRELOAD register on the next clock edge, then decrements on subsequent clocks. Clearing the STRELOAD register disables the counter on the next wrap. When the counter reaches zero, the COUNT status bit is set. The COUNT bit clears on reads. Writing to the STCURRENT register clears the register and the COUNT status bit. The write does not trigger the SysTick exception logic. On a read, the current value is the value of the register at the time the register is accessed. The SysTick counter runs on the system clock. If this clock signal is stopped for low power mode, the SysTick counter stops. Ensure software uses aligned word accesses to access the SysTick registers.

- ***Nested Vectored Interrupt Controller (NVIC)***

  The TM4C1294NCPDT controller includes the ARM Nested Vectored Interrupt Controller (NVIC). The NVIC and Cortex-M4F prioritize and handle all exceptions in Handler Mode. The processor state is automatically stored to the stack on an exception and automatically restored from the stack at the end of the Interrupt Service Routine (ISR). The interrupt vector is fetched in parallel to the state saving, enabling efficient interrupt entry. The processor supports tail-chaining, meaning that back-to-back interrupts can be performed without the overhead of state saving and restoration. Software can set eight priority levels on seven exceptions (system handlers) and 106 interrupts .External non-maskable interrupt signal (NMI) is available for immediate execution of NMI handler for safety critical applications.

- ***Floating-Point Unit (FPU)***

  The FPU fully supports single-precision add, subtract, multiply, divide, multiply and accumulate, and square root operations. It also provides conversions between fixed-point and floating-point data formats, and floating-point constant instructions. There are 32-bit instructions for single-precision (C float) data-processing operations and combined multiply and accumulate instructions for increased precision. Hardware support for conversion, addition, subtraction, multiplication with optional accumulate, division, and square-root is available.

- ***System Control Block (SCB)***

  The SCB provides system implementation information and system control, including configuration, control, and reporting of system exceptions.

- ***Memory Protection Unit (MPU)***

  The MPU divides the memory map into a number of regions and defines the location, size, access permissions, and memory attributes of each region. The MPU supports independent attribute settings for each region, overlapping regions, and export of memory attributes to the system. The memory attributes affect the behaviour of memory accesses to the region. The Cortex-M4 MPU defines eight separate memory regions, 0-7, and a background region. When memory regions overlap, a memory access is affected by the attributes of the region with the highest number. The background region has the same memory access attributes as the default memory map, but is accessible from privileged software only. The Cortex-M4 MPU memory map is unified, meaning that instruction accesses and data accesses have the same region settings. If a program accesses a memory location that is prohibited by the MPU, the processor generates a memory management fault, causing a fault exception and possibly causing termination of the process in an OS environment. In an OS environment, the kernel can update the MPU region setting dynamically based on the process to be executed. Typically, an embedded OS uses the MPU for memory protection.

- ***SRAM***

  The TM4C1294NCPDT microcontroller provides 256 KB of single-cycle on-chip SRAM. The internal SRAM of the device is located at offset 0x2000.0000 of the device memory map. The SRAM is implemented using four 32-bit wide interleaving SRAM banks (separate SRAM arrays) which allow for increased speed between memory accesses. The SRAM memory provides nearly 2 GB/s memory bandwidth at a 120 MHz clock frequency. Because read-modify-write (RMW) operations are very time consuming, ARM has introduced bit-banding technology in the Cortex-M4F processor. With a bit-band-enabled processor, certain regions in the memory map (SRAM and peripheral space) can use address aliases to access individual bits in a single, atomic operation.

- ***Flash Memory***

  The TM4C1294NCPDT microcontroller provides 1024 KB of on-chip Flash memory. The Flash memory is configured as four banks of 16K x 128 bits which are two-way interleaved. Memory blocks can be marked as read-only or execute-only, providing different levels of code protection. Read-only blocks cannot be erased or programmed, protecting the contents of those blocks from being modified. Execute-only blocks cannot be erased or programmed, and can only be read by the controller instruction fetch mechanism, protecting the contents of those blocks from being read by either the controller or by a debugger. The

TM4C1294NCPDT microcontroller provides enhanced performance and power savings by implementation of two sets of instruction pre-fetch buffers. Each pre-fetch buffer is 2 x 256 bits and can be combined as a 4 x 256-bit pre-fetch buffer.

- ***EEPROM***

The TM4C1294NCPDT microcontroller includes an EEPROM with the following features:

■ 6Kbytes of memory accessible as 1536 32-bit words.

■ 96 blocks of 16 words (64 bytes) each.

■ Built-in wear levelling.

■ Access protection per block.

■ Lock protection option for the whole peripheral as well as per block using 32-bit to 96-bit unlock codes.

■ Interrupt support for write completion to avoid polling.

■ Endurance of 500K writes.

- ***Ethernet Connectivity***

The microcontroller contains a fully integrated Ethernet MAC and PHY. This integration creates a simple, elegant and cost-saving Ethernet circuit design. The embedded Ethernet on this device can be programmed to act as an HTTP server, client or both. The design and integration of the circuit and microcontroller also enable users to synchronize events over the network using the IEEE1588 precision time protocol. The TM4C1294NCPDT Ethernet Controller consists of a fully integrated media access controller (MAC) and network physical (PHY) interface. It supports multiple addressing modes with four MAC address filters providing promiscuous mode support. It is highly configurable and supports Magic Packet and wakeup frames. Efficient transfers using integrated Direct Memory Access (DMA) are also possible. The Ethernet controller supports 10/100 Mbps data transmission rates and supports full-duplex and half-duplex operation. The Ethernet Controller Module and Integrated PHY receive two clock inputs; a gated system clock acts as the clock source to the Control and Status registers (CSR) of the Ethernet MAC. The SYSCLK frequency for Run, Sleep and Deep Sleep mode is programmed in the System Control module and the PHY receives the main oscillator (MOSC) which must be 25 MHz ± 50 ppm for proper operation.

- ***Controller Area Network (CAN)***

  Controller Area Network (CAN) is a multicast shared serial-bus standard for connecting electronic control units (ECUs). CAN was specifically designed to be robust in electromagnetically noisy environments and can utilize a differential balanced line like RS-485 or twisted-pair wire. Originally created for automotive purposes, it is now used in many embedded control applications. Bit rates up to 1 Mbps are possible at network lengths below 40 meters. Decreased bit rates allow longer network distances. A transmitter sends a message to all CAN nodes (broadcasting). Each node decides on the basis of the identifier received whether it should process the message. The identifier also determines the priority that the message enjoys in competition for bus access. Each CAN message can transmit from 0 to 8 bytes of user information.

- ***Universal Serial Bus (USB)***

  Universal Serial Bus (USB) is a serial bus standard designed to allow peripherals to be connected and disconnected using a standardized interface without rebooting the system. The TM4C1294NCPDT microcontroller has one USB controller that supports high and full speed multi-point communications and complies with the USB 2.0 standard for high-speed function. The USB controller can have three configurations namely USB Device, USB Host, and USB On-The-Go (negotiated on-the-go as host or device when connected to other USB-enabled systems). Support for full-speed communication is provided by using the integrated USB PHY or optionally, a high-speed ULPI interface can communicate to an external PHY.

- ***UART***

  A Universal Asynchronous Receiver/Transmitter (UART) is an integrated circuit used for RS-232C serial communications, containing a transmitter (parallel-to-serial converter) and a receiver (serial-to-parallel converter), each clocked separately. The TM4C1294NCPDT microcontroller includes eight fully programmable 16C550-type UARTs. Although the functionality is similar to a 16C550 UART, this UART design is not register compatible. The UART can generate individually masked interrupts from the receiver, transmitter, modem flow control, modem status, and error conditions. The module generates a single combined interrupt when any of the interrupts are asserted and are unmasked.

- ***Inter-Integrated Circuit (I^2C) Interface***

  The Inter-Integrated Circuit (I2C) bus provides bi-directional data transfer through a two-wire design (a serial data line SDA and a serial clock line SCL), and interfaces to external I2C devices such as serial memory (RAMs and ROMs), networking devices, LCDs, tone generators, and so on. The I2C bus may also be used for system testing and diagnostic purposes in product development and manufacturing. The TM4C1294NCPDT microcontroller provides the ability to communicate with other I^2C devices. Devices on the I2C bus can be designated as either master or slave.

- ***Direct Memory Access***

  The TM4C1294NCPDT microcontroller includes a Direct Memory Access (DMA) controller, known as micro-DMA (μDMA). The μDMA controller provides a way to offload data transfer tasks from the Cortex-M4F processor, allowing for more efficient use of the processor and the available bus bandwidth. The μDMA controller can perform transfers between memory and peripherals. It has dedicated channels for each supported on-chip module and can be programmed to automatically perform transfers between peripherals and memory as the peripheral is ready to transfer more data.

- ***System Control and Clocks***

  System control determines the overall operation of the device. It provides information about the device, controls power-saving features, controls the clocking of the device and individual peripherals, and handles reset detection and reporting. The TM4C1294NCPDT microcontroller is clocked by the system clock (SYSCLK) that is distributed to the processor and integrated peripherals after clock gating. The SYSCLK frequency is based on the frequency of the clock source and a divisor factor. A PLL (Phase Lock Loop) is provided for the generation of system clock frequencies in excess of the reference clock provided. The reference clocks for the PLL are the PIOSC and the main crystal oscillator.

- ***Programmable Timers***

  Programmable timers can be used to count or time external events that drive the Timer input pins. Each 16/32-bit GPTM (General Purpose Timer Module) block provides two 16-bit timers/counters that can be configured to operate independently as timers or event counters, or configured to operate as one 32-bit timer or one 32-bit Real-Time Clock (RTC). Timers can also be used to trigger analog-to-digital (ADC) conversions and DMA transfers.

- ***Watchdog Timers***

  A watchdog timer is used to regain control when a system has failed due to a software error or to the failure of an external device to respond in the expected way. The TM4C1294NCPDT Watchdog Timer can generate an interrupt, a non-maskable interrupt, or a reset when a time-out value is reached. In addition, the Watchdog Timer is ARM FIRM-compliant and can be configured to generate an interrupt to the microcontroller on its first time-out, and to generate a reset signal on its second timeout. Once the Watchdog Timer has been configured, the lock register can be written to prevent the timer configuration from being inadvertently altered.

- ***Analog to Digital Converter (ADC)***

  An analog-to-digital converter (ADC) is a peripheral that converts a continuous analog voltage to a discrete digital number. The TM4C1294NCPDT ADC module features 12-bit conversion resolution and supports 20 input channels plus an internal temperature sensor. Four buffered sample sequencers allow rapid sampling of up to 20 analog input sources without controller intervention. Each sample sequencer provides flexible programming with fully configurable input source, trigger events, interrupt generation, and sequencer priority. Each ADC module has a digital comparator function that allows the conversion value to be diverted to a comparison unit that provides eight digital comparators.

- ***Analog Comparators***

  An analog comparator is a peripheral that compares two analog voltages and provides a logical output that signals the comparison result. The TM4C1294NCPDT microcontroller provides three independent integrated analog comparators that can be configured to drive an output or generate an interrupt or ADC event. The comparator can provide its output to a device pin, acting as a replacement for an analog comparator on the board, or it can be used to signal the application via interrupts or triggers to the ADC to cause it to start capturing a sample sequence. The interrupt generation and ADC triggering logic is separate. This means, for example, that an interrupt can be generated on a rising edge and the ADC triggered on a falling edge.

4.1.4 LM35 (Temperature Sensor)

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air.

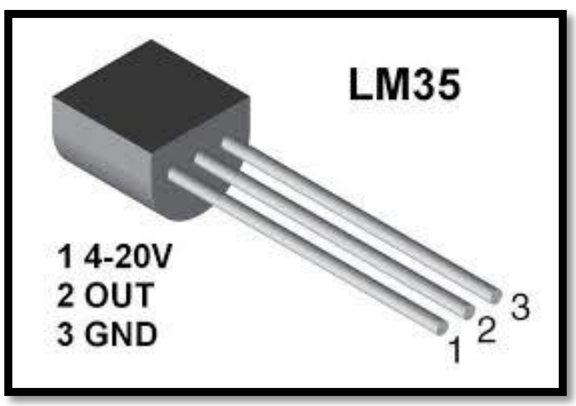


Figure: 4.4: LM35 Temperature Sensor

The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor package. The LM35D device is available in an 8-lead surface-mount small-outline package and a plastic TO-220 package. The temperature-sensing element is then buffered by an amplifier and provided to the VOUT pin.

The amplifier has a simple class A output stage with typical 0.5-Ω output impedance as shown in the Functional Block Diagram in Fig 3.6. Therefore the LM35 can only source current and its sinking capability is limited to 1 µA.

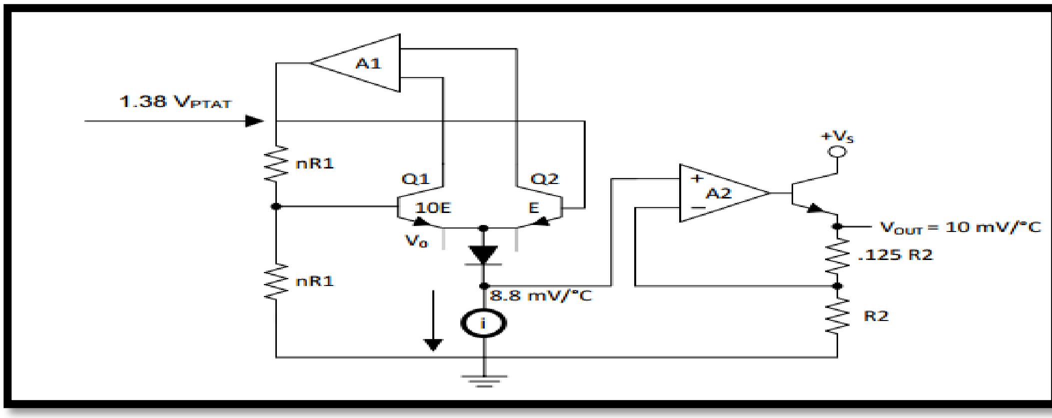


Figure: 4.5: Functional Block Diagram of LM35

The accuracy specifications of the LM35 are given with respect to a simple linear transfer function:

$$VOUT = 10\ mV/°C \times T \qquad (3.1)$$

where VOUT is the LM35 output voltage and T is the temperature in °C.

The only functional mode of the LM35 is that it has an analog output directly proportional to temperature.

- ***Capacitive Drive Capability***

  Like most micro power circuits, the LM35 device has a limited ability to drive heavy capacitive loads. Alone, the LM35 device is able to drive 50 pF without special precautions. If heavier loads are anticipated, isolating or decoupling the load with a resistor is easy as shown in Fig 4.6.

  The tolerance of capacitance can be improved with a series R-C damper from output to ground as shown in Fig 4.7.

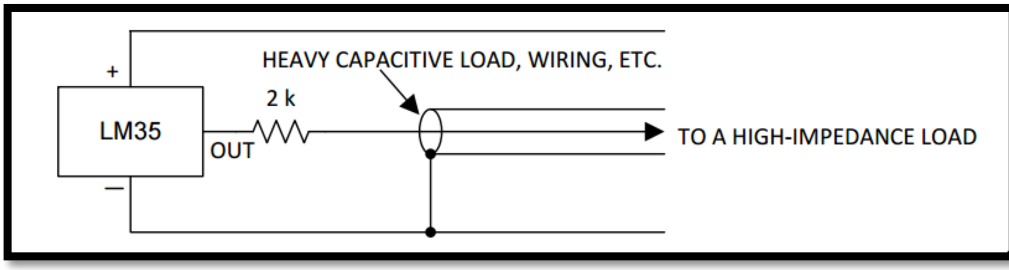


Figure: 4.6: LM35 with decoupling from Capacitive Load

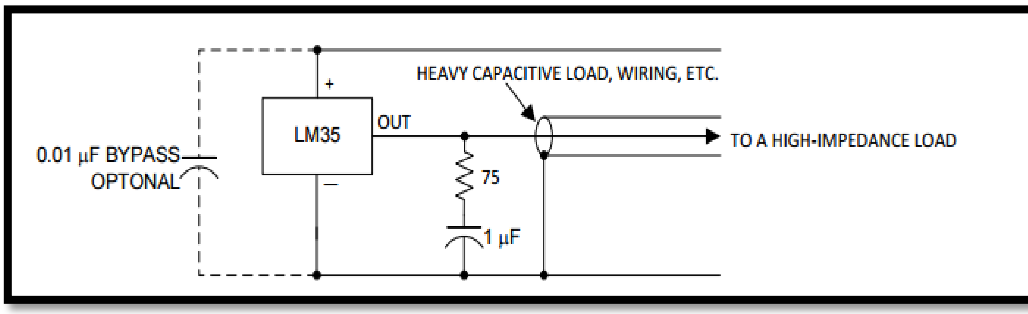


Figure: 4.7: LM35 with R-C Damper

When the LM35 device is applied with a 200-Ω load resistor as shown in Fig 4.8 and Fig 4.9 the device is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input and not on the output. However, as with any linear circuit connected to wires in a hostile environment, performance is affected adversely by intense electromagnetic sources (such as relays, radio transmitters, motors with arcing brushes, and SCR transients), because the wiring acts as a receiving antenna and the internal junctions act as rectifiers. For best results in such cases, a bypass capacitor from VIN to ground and a series R-C damper, such as 75 Ω in series with 0.2 or 1 µF from output to ground are often useful.

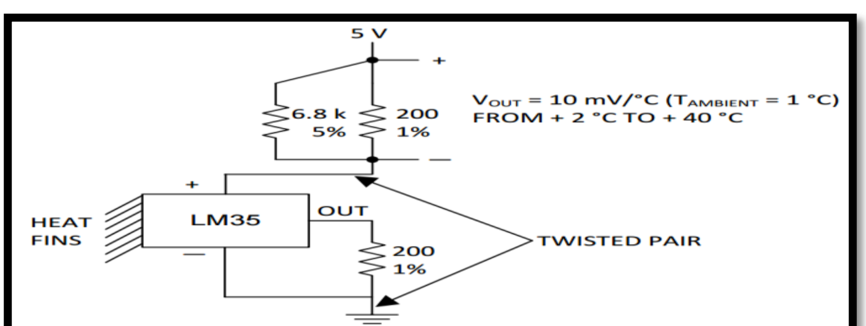


Figure: 4.8: Two-wire remote Temperature Sensor (Grounded Sensor)

The LM35 device has a very wide 4-V to 30-V power supply voltage range, which makes it ideal for many applications. In noisy environments, TI recommends adding a 0.1 µF from V+ to GND to bypass the power supply voltage. Larger capacitances maybe required and are dependent on the power-supply noise.

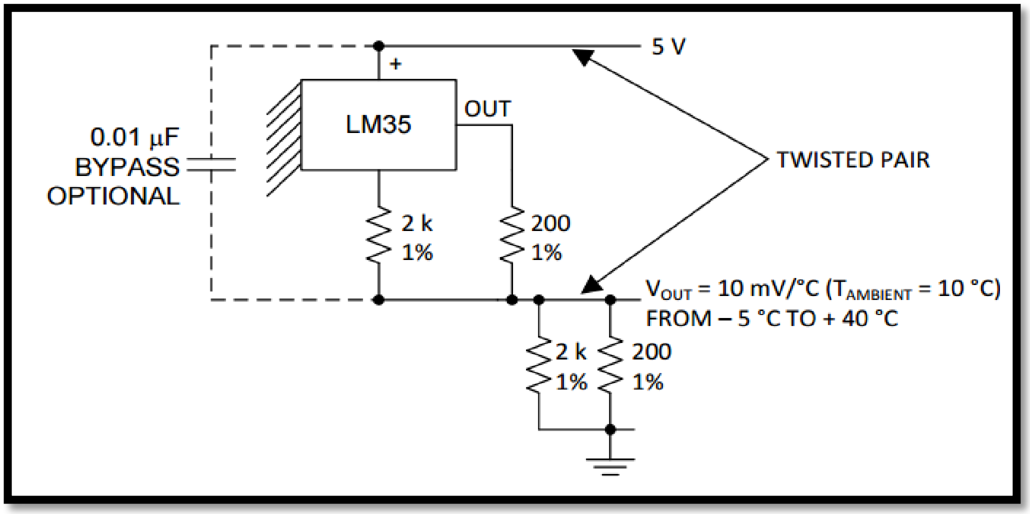


Figure: 4.9: Two-wire remote Temperature Sensor (Output referred to Ground)

Because the LM35 device is a simple temperature sensor that provides an analog output, design requirements related to layout are more important than electrical requirement.

- ***Layout Guidelines***

The LM35 is easily applied in the same way as other integrated-circuit temperature sensors. Glue or cement the device to a surface and the temperature should be within about 0.01°C of the surface temperature. The 0.01°C proximity presumes that the ambient air temperature is almost the same as the surface temperature. If the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature; this is especially true for the TO-92 plastic package. The copper leads in the TO-92 package are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature. Ensure that the wiring leaving the LM35 device is held at the same temperature as the surface of interest to minimize the temperature problem. The easiest fix is to cover up these wires with a bead of epoxy. The epoxy bead will ensure that the leads and wires are all at the same temperature as the surface, and that the temperature of the LM35 die is not affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V− terminal of the circuit will be grounded to that metal. Alternatively, mount the LM35 inside a sealed end metal tube, and then dip into a bath or screw into a threaded hole in a tank. As with any IC, the LM35 device and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as a conformal coating and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 device or its connections. These devices are sometimes soldered to a small light-weight heat fin to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

4.1.5 AD8232 (ECG Sensor)

The AD8232 is an integrated signal conditioning block for ECG and other bio-potential measurement applications. It is designed to extract, amplify, and filter small bio-potential 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 is available in a 4 mm × 4 mm, 20-lead LFCSP package. Performance is specified from 0°C to 70°C and is operational from −40°C to +85°C.

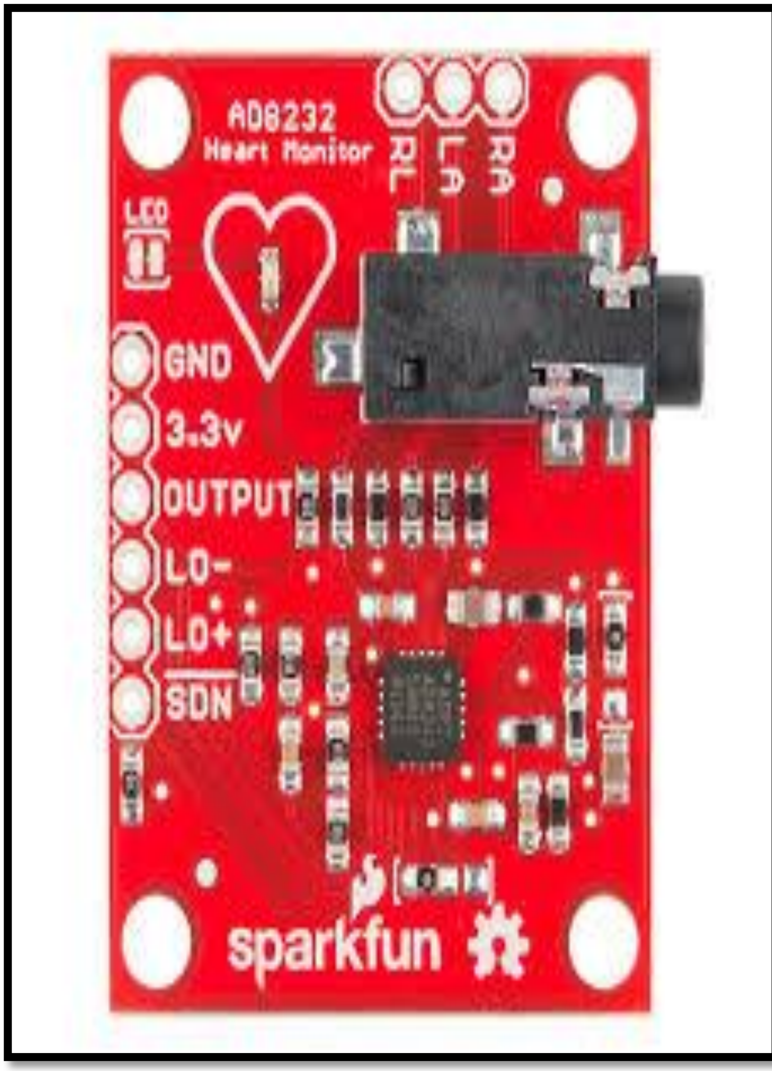


Figure: 4.10: AD8232 (ECG Sensor)

4.1.5 PIN CONFIGURATION OF AD8232

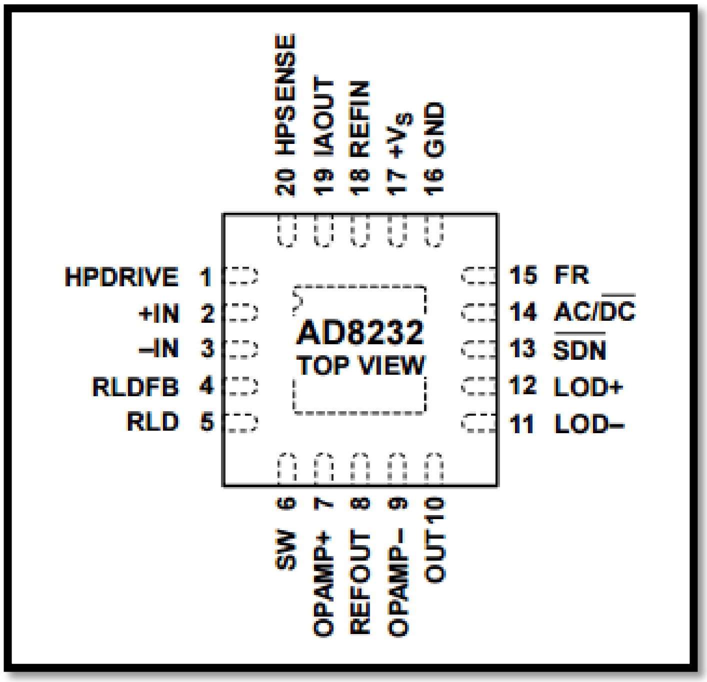


Figure: 4.11: Pin Diagram of AD8232

Table 4.3shows the pin function descriptions of AD8232 ECG sensor in a detailed manner.

Table: 4.3: Pin Function Description

Pin No.	Mnemonic	Description
1	HPDRIVE	High-Pass Driver Output. 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.

6	SW	Fast Restore Switch Terminal
7	OPAMP+	Operational Amplifier Non-inverting Input.
8	REFOUT	Reference Buffer Output. The instrumentation amplifier output is referenced to this potential.
9	OPAMP-	Operational Amplifier Inverting Input.
10	OUT	Operational Amplifier Output. The fully conditioned heart rate signal is present at this output.
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	SDN	Shutdown Control Input.
14	AC/DC	Leads Off Mode Control Input.
15	FR	Fast Restore Control Input.
16	GND	Power Supply Ground.
17	$+V_S$	Power Supply Terminal.
18	REFIN	Reference Buffer Input.
19	IAOUT	Instrumentation Amplifier Output Terminal.
20	HPSENSE EP	High-Pass Sense Input for Instrumentation Amplifier. Exposed Pad.

4.1.6 Functional Block Diagram of AD8232

The AD8232 can implement a two-pole high-pass filter for eliminating motion artefacts 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. The functional block diagram of the AD8232 is shown in Fig 4.12 indicating that the chip includes four amplifiers; an in-amplifier (IA), an operational amplifier (op-amp) A1, a Right Leg Drive (RLD) A2, and a buffer amplifier A3.An uncommitted operational amplifier enables the AD8232 to create a three-pole low-pass filter to remove additional noise.

To improve common-mode rejection of the line frequencies in the system and other undesired interferences, the AD8232 includes an amplifier for driven lead applications, such as right leg drive (RLD).The user can select the frequency cut-off of all filters to suit different types of applications. The AD8232 includes a fast restore function that reduces the duration of otherwise long settling tails of the high-pass filters. After an abrupt signal change that rails the amplifier (such as a leads off condition), the AD8232 automatically adjusts to a higher filter cut-off. This feature allows the AD8232 to recover quickly, and therefore, to take valid measurements soon after connecting the electrodes to the human being.

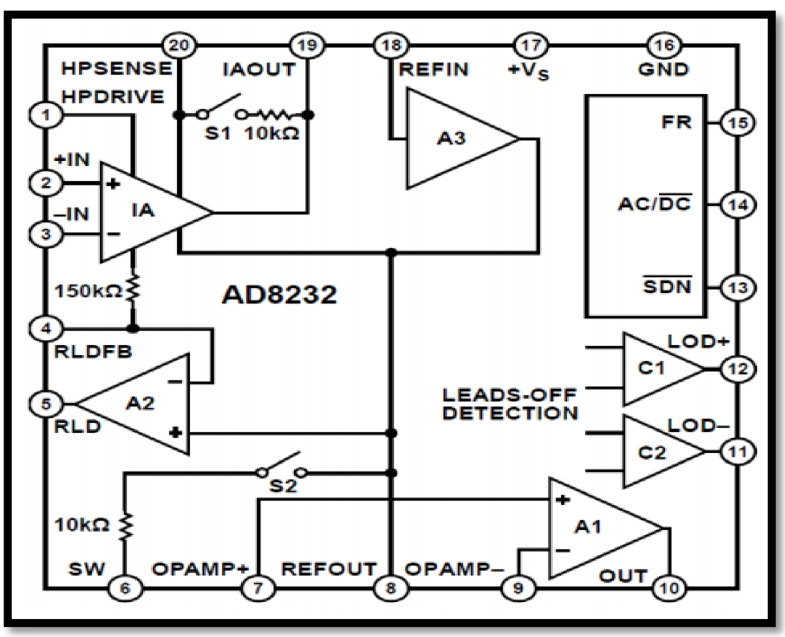


Figure: 4.12: Functional Block Diagram of AD8232

Input

Two-electrode and three-electrode configurations are possible using the AD8232. In the three-electrode configuration, the Right Leg Drive (RLD) can be used as the reference lead. The Right Leg Drive amplifier is employed for rejecting the Common-Mode voltage of the system at the input of the instrumentation amplifier (CMRR = 86dB). The terminals of the AD8232 are protected against electrostatic discharge (ESD). External resistors can be utilized to avoid overload conditions at the input.

Gain and Signal Conditioning

The AD8232 includes an in-amplifier with a fixed gain of 100. It also features an op-amp for creating low pass filter with selectable cut-off frequency for additional noise removal. To avoid Radio Frequency Interference (RFI) and as a result DC offset at the output, a low pass filter with cut-off frequency of 1.1MHz is implemented at each input pins of the AD8232.

Additional Features

The reference buffer is used to create a virtual ground (reference voltage) between the actual ground and the supply. This reference voltage can be driven from REFIN pin using a voltage divider and an external voltage source. The virtual ground is available at REFOUT for use in the circuitry. The AD8232 provides AC and DC leads off detection. The three electrode configuration uses DC lead off detection in which each input terminal is checked for connection. In this case if the IN+ electrode is disconnected the LOD+ pin is set and if the IN- is disconnected the LOD- pin set. AC lead off detection is used for two-electrode configuration. This is done by injecting a small current into the input terminals. This feature informs the user with disconnection of either electrodes but it does not specify which electrode is disconnected.

Power Consumption

The AD8232 operates on a single supply such as CR2032 cell batteries or rechargeable lithium ion batteries. To reduce the power consumption, the chip provides a shutdown mode with the current draw of less than 200nA.

4.1.7 Monitoring ECG - Electrode Location and Waveform Quality

ECG system has two or more electrodes used to monitor voltage across one or more leads. Clinical standard uses a 12-lead ECG that would each provide a view of the heart's electrical activity from different views. Each lead corresponds to a vector of ECG electrical potential. The electrodes are typically placed in a setup known as the Einthoven's triangle, which is formed by the right arm (RA), left arm (LA) and left leg (LL) sensing electrodes as shown in Fig 4.13 below. These are the basis for the frontal axis.

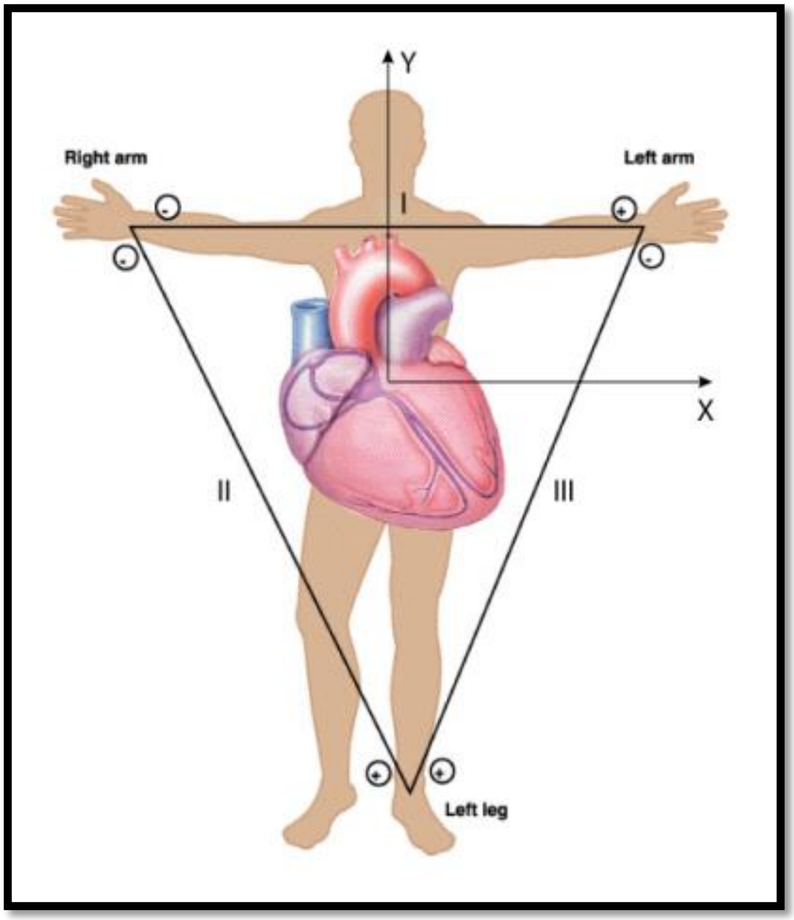


Figure: 4.13: Einthoven's Triangle

Different lead location corresponds to different ECG signal as shown in Fig 4.14 below. Lead II is commonly used as it provides largest positive R-wave that is important to measure heart rate.

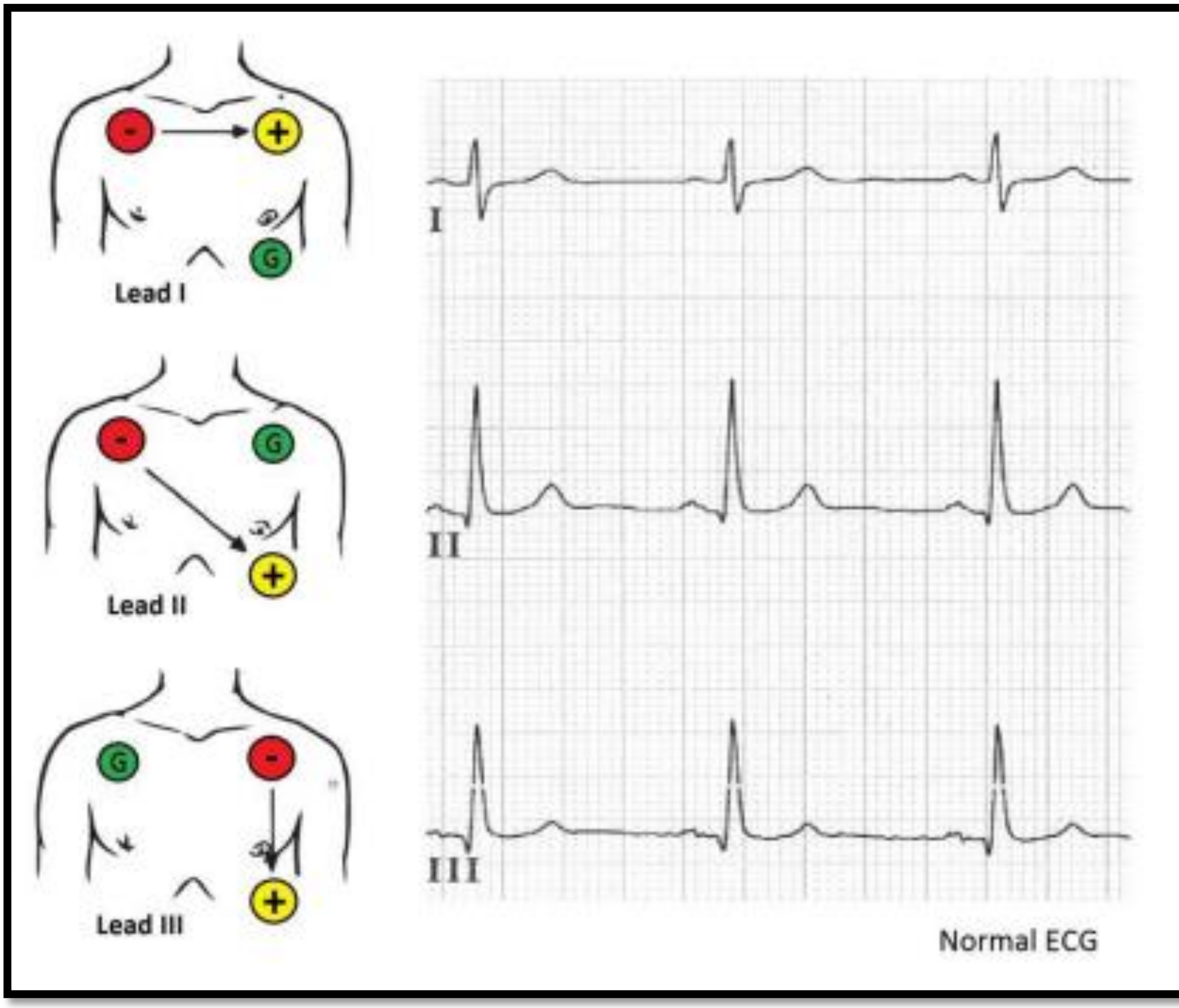


Figure: 4.14: Lead location and ECG output

Two-Electrode Configuration

In this configuration, only one lead is possible. To obtain a Lead II vector, the configuration is shown in Fig 4.15 for option one. Another alternative setup, option two, is also possible but it only has a good view of Lead I. This setup is desired since it is easier for patient.

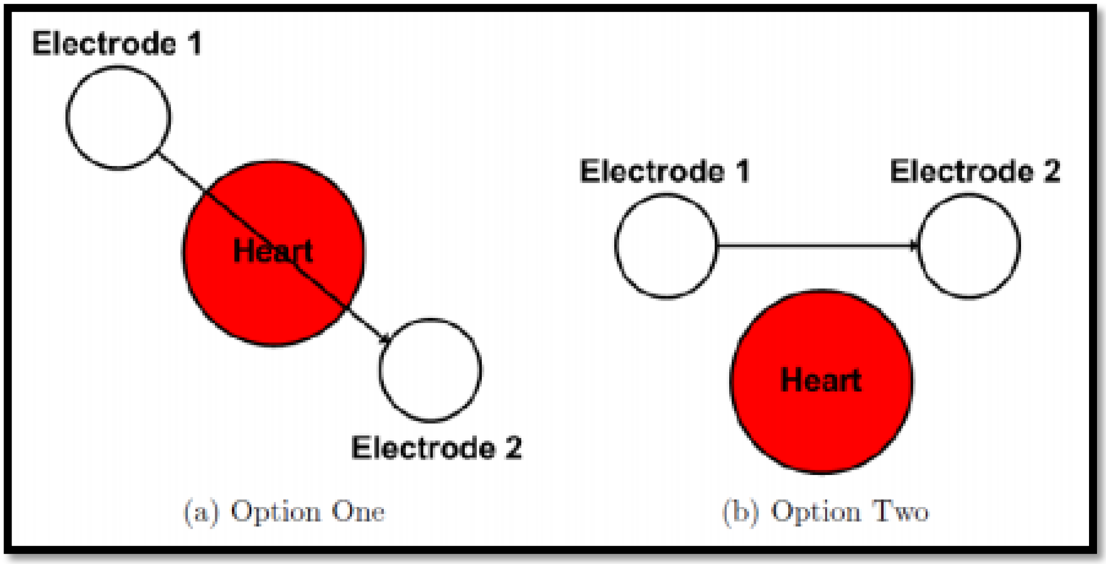


Figure: 4.15: Two-electrode location options

In this case, an ideal setup is shown in Fig 4.16. This would provide better view of Lead I. One disadvantage is that a smaller amplitude of the signal compared to Lead II in three-electrode configuration.

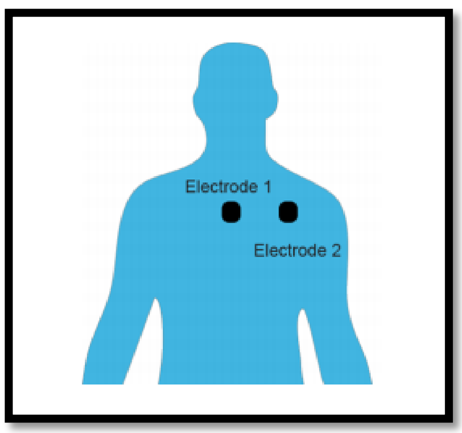


Figure: 4.16: Two-electrode best setup

Three-Electrode Configuration

This configuration would allow a Lead I, Lead II or Lead III to be selected. The two electrodes are used to form a vector while the third electrode is the reference. For three electrodes, it is possible to have up to three unique vectors. This implementation has the advantage having less noise and more lead selection options. The first option would require three electrodes located around the heart. It has views of Lead I, II and III. One disadvantage is the ease of use as it might have to cross over pectoral muscles and breast tissue. Another alternative aims to provide better comfort for the patient. The trade-off would limit lead view as it only has a good view of Lead II.

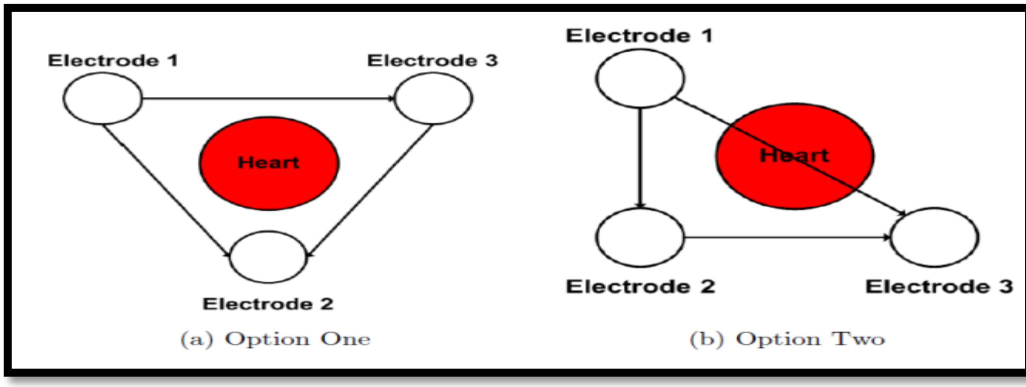


Figure: 4.17: Three-Electrode Location Options

In this case, a desired setup is shown in Fig 4.18. This would provide better view of Lead II. The right-leg drive (RLD) electrode (usually a third electrode) is used to bias the patient to a set DC operating point in order to ensure that the input at the same potential as the monitoring system.

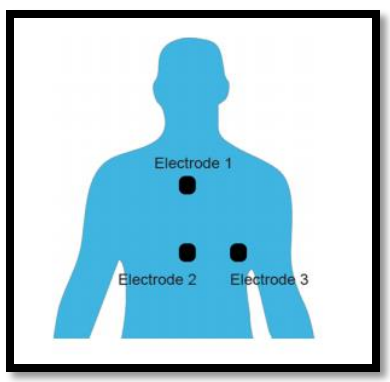


Figure: 4.18: Three-electrode best setup

The signal extraction is critical in the presence of noisy conditions and various interferences. The designed system is preferred to have the capability to use both two and three-electrode configurations. In ECG measurements, skin electrode contact counts as a source of interference producing an offset of ±200 – 300Mv. Two type of signals are available at the input, the Common-Mode (same potential) and Differential-Mode (different potential) signals. For ECG signal monitoring applications, the Common-Mode signal is highly undesirable. The potential between the electrodes and ground can create a Common-Mode component of up to 1.5V. The Common-Mode gain is defined as the ratio of change in output voltage to change in Common-Mode input voltage. The Common-Mode Rejection Ratio (CMRR) is the ratio of the differential gain to the Common-Mode gain.

The system must have a CMRR of 80dB to 120dB over the input frequencies that need to be rejected. In order to achieve gain as well as Common-Mode rejection, instrumentation amplifier (in-amplifier) can be employed. An instrumentation amplifier has a differential input and single ended output with respect to a reference voltage. The in-amp gain is determined by external resistors that are connected between inverting input and the output.

4.1.8 TCRT1000 Heart Rate Sensor

The TCRT1000 is a reflective sensor which includes an infrared emitter and phototransistor in a leaded package which blocks visible light. It is based on the principle of Photoplethysmography (PPG) which is a non-invasive method of measuring the variation in blood volume in tissues using a light source and a detector. Since the change in blood volume is synchronous to the heartbeat, this technique can be used to calculate the heart rate. Transmittance and reflectance are two basic types of Photoplethysmography. For the transmittance PPG, a light source is emitted in to the tissue and a light detector is placed in the opposite side of the tissue to measure the resultant light. Because of the limited penetration depth of the light through organ tissue, the transmittance PPG is applicable to a restricted body part, such as the finger or the ear lobe.

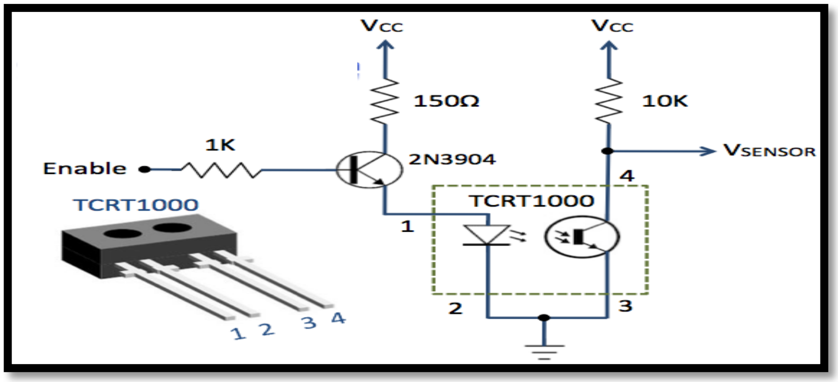


Figure: 4.19: TCRT1000 Heart rate sensor pin diagram and internal circuitry.

However, in the reflectance PPG, the light source and the light detector are both placed on the same side of a body part. The light is emitted into the tissue and the reflected light is measured by the detector. As the light doesn't have to penetrate the body, the reflectance PPG can be applied to any parts of human body. In either case, the detected light reflected from or transmitted through the body part will fluctuate according to the pulsatile blood flow caused by the beating of the heart. A subject's finger is illuminated by an infrared light-emitting diode. More or less light is absorbed, depending on the tissue blood volume. Consequently, the reflected light intensity varies with the pulsing of the blood with heart beat. The output from the sensor is a periodic physiological waveform attributed to small variations in the reflected IR light which is caused by the pulsatile tissue blood volume inside the finger. The waveform is, therefore, synchronous with the heartbeat.

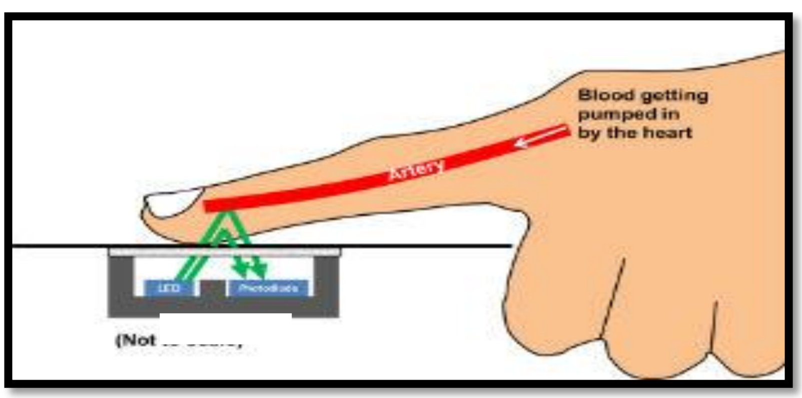


Figure: 4.20: Mechanism of heart rate measurement

The circuit diagram shown in Fig 4.21 below describes the first stage of the signal conditioning which will suppress the large DC component and boost the weak pulsatile AC component, which carries the required information.

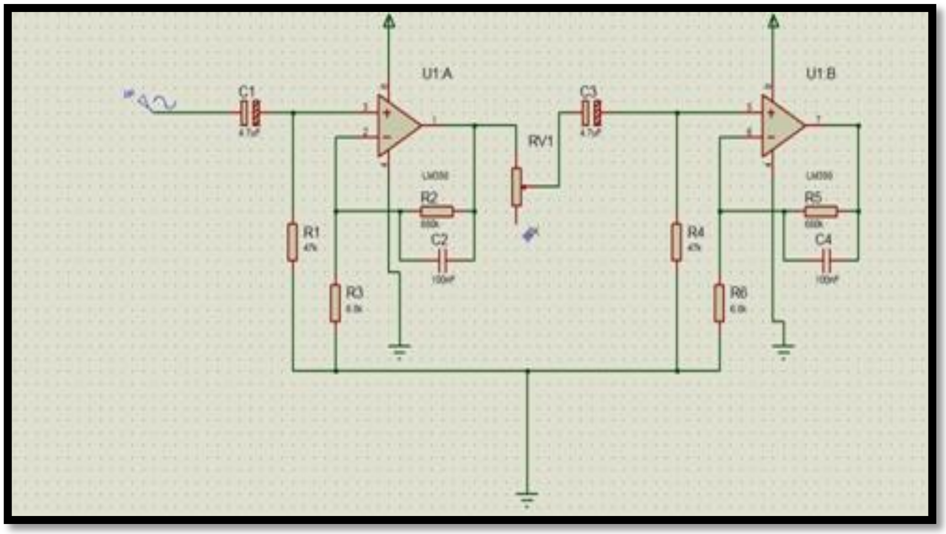


Figure: 4.21: First stage of signal conditioning

The sensor output is first passed through a RC high-pass filter (HPF) to get rid of the DC component. The cut-off frequency of the HPF is set to 0.7 Hz. Next stage is an active low-pass filter (LPF) that is made of an Op-Amp circuit. The gain and the cut-off frequency of the LPF are set to 101 and 2.34 Hz, respectively. Thus the combination of the HPF and LPF helps to remove unwanted DC signal and high frequency noise including 60 Hz (50 Hz in some countries) mains interference, while amplifying the low amplitude pulse signal (AC component) 101 times. The output from the first signal conditioning stage goes to a similar HPF/LPF combination for further filtering and amplification (shown below). So, the total voltage gain achieved from the two cascaded stages is 101*101 = 10201. The two stages of filtering and amplification converts the input PPG signals to near TTL pulses and they are synchronous with the heartbeat. The frequency (f) of these pulses is related to the heart rate (BPM) as,

Beats per minute (BPM) = 60*f ....(3.2)

A 5K potentiometer is placed at the output of the first signal conditioning stage in case the total gain of the two stages is required to be less than 10201. An LED connected to the output of the second stage of signal conditioning will blink when a heartbeat is detected. The final stage of the instrumentation constitutes a simple non-inverting buffer to lower the output impedance. This is helpful if an ADC channel of a microcontroller is used to read the amplified PPG signal.

4.1.9 LCD MODULE (16 X 2)

LCDs can add a lot to any application in terms of providing a useful interface for the user, debugging an application or just giving it a "professional" look. Using this interface is often not attempted by inexperienced designers and programmers because it is difficult to find good documentation on the interface, initializing the interface can be a problem and the displays themselves are expensive. The most common connector used for the 44780 based LCDs is 14 pins in a row, with pin centres 0.100" apart.

The pins are wired as:

Table: 4.4: Pin Descriptions of LCD Module

Pins	Descriptions
1	Ground
2	Vcc
3	Contrast Voltage
4	“R/S” Instruction/Register select
5	“R/W” Read/Write LCD Register
6	“E” clock
7	Data I/O Pins

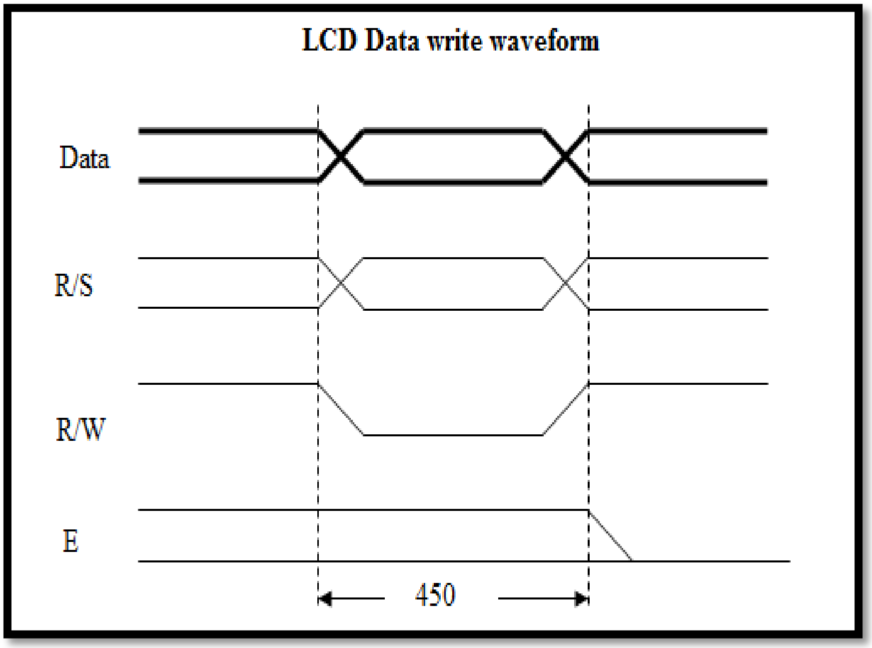


Figure: 4.22: Data Write Waveform of LCD

The interface is a parallel bus, allowing simple and fast reading/writing of data to and from the LCD. The LCD Data Write Waveform will write an ASCII Byte out to the LCD's screen. The ASCII code to be displayed is eight bits long and is sent to the LCD either four or eight bits at a time. If four bit mode is used, two "nibbles" of data are sent to make up a full eight bit transfer. The "E" Clock is used to initiate the data transfer within the LCD. Sending parallel data as either four or eight bits are the two primary modes of operation. While there are secondary considerations and modes, deciding how to send the data to the LCD is most critical decision to be made for an LCD interface application.

4.1.10 GSM

GSM, which stands for Global System for Mobile communications, reigns as the world's most widely used cell phone technology. Cell phones use a cell phone service carrier's GSM network by searching for cell phone towers in the nearby area. The origins of GSM can be traced back to 1982 when the Group Special Mobile (GSM) was created by the European Conference of Postal and Telecommunications Administrations (CEPT) for the purpose of designing a pan-European mobile technology. It is approximated that 80 percent of the world uses GSM technology when placing wireless calls, according to the GSM Association (GSMA), which represents the interests of the worldwide mobile communications industry. This amounts to nearly 3 billion global people. Cell phone carriers T-Mobile and AT&T use GSM for their cell phone networks. GSM carriers have roaming contracts with other GSM carriers and typically cover rural areas more than CDMA carriers (and often without roaming charges, too). GSM also has the advantage of using SIM (*S*ubscriber *I*dentity *M*odule) cards in the U.S.

Functional Sections - GSM system is composed of three key sections:

Mobile Stations (MS) - A device that converts media to and from GSM radio signals.

Base Station Subsystem (BSS) - Assemblies that convert digital signals to radio signals that can be sent to mobile devices and receive radio signals that can be converted back to their digital form. The BSS is divided into base station BS parts that are located at the cell site and base station controllers BSC that coordinate the distribution and reception of communication connections.

Network and Switching System (NSS) - The NSS performs the interconnection between the base station parts and other networks such as the public switched telephone network PSTN and public internet**.** The NSS is composed of circuit data and packet data switches, databases, and administrative control services.

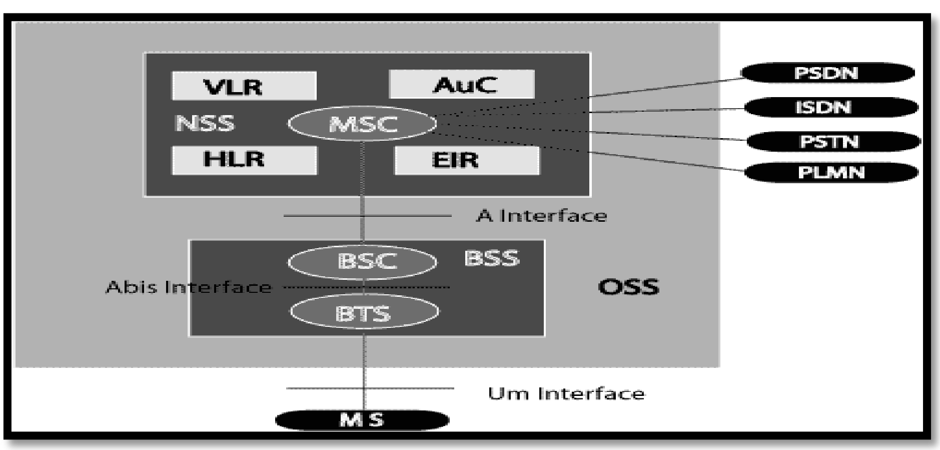


Figure: 4.23: The diagram of GSM Network along with added elements

The GSM network can be divided into following broad parts.

- The Mobile Station (MS)
- The Base Station Subsystem (BSS)
- The Network Switching Subsystem (NSS)
- The Operation Support Subsystem (OSS)

The added components of the GSM architecture include the functions of the databases and messaging systems:

- Home Location Register (HLR)
- Visitor Location Register (VLR)
- Equipment Identity Register (EIR)
- Authentication Centre (AuC)
- SMS Serving Centre (SMS SC)
- Gateway MSC (GMSC)
- Chargeback Centre (CBC)
- Transcoder and Adaptation Unit (TRAU)

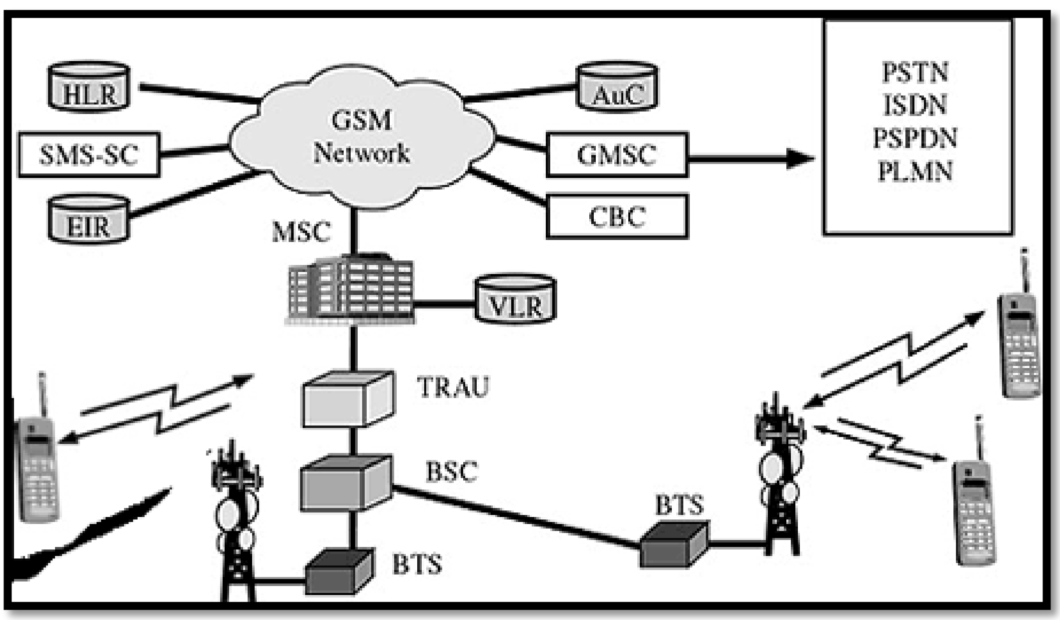


Figure: 4.24: GSM network

4.1.11 LED

A light-emitting diode (LED) is a semiconductor device that emits visible light when an electric current passes through it. The light is not particularly bright, but in most LEDs it is monochromatic, occurring at a single wavelength. The output from an LED can range from red (at a wavelength of approximately 700 nanometres) to blue-violet (about 400 nanometres). Some LEDs emit infrared (IR) energy (830 nanometres or longer); such a device is known as an *infrared-emitting diode* (IRED).Some of the applications are low power requirement, high efficiency, long life, indicator lights, LCD panel backlighting, fibre optic data transmission and remote control.

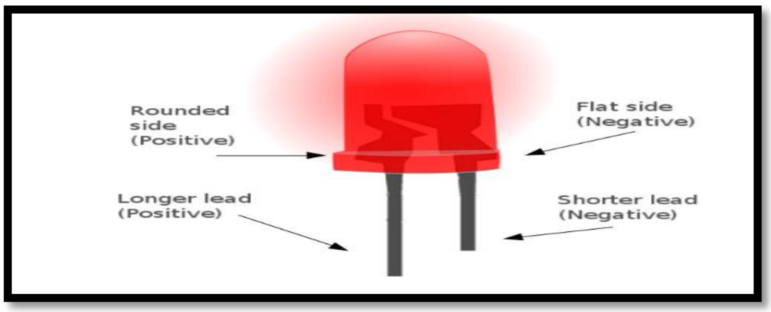


Figure: 4.25: Diagram of LED

4.1.12 ADXL335 MEMS Accelerometer

The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis. The ADXL335 is available in a small, low profile, 4 mm × 4 mm × 1.45 mm, 16-lead, plastic lead frame chip scale package (LFCSP_LQ).

4.1.13 THEORY OF OPERATION

The ADXL335 is a complete 3-axis acceleration measurement system. It contains a polysilicon surface-micro-machined sensor and signal conditioning circuitry to implement an open loop acceleration measurement architecture. The output signals are analog voltages that are proportional to acceleration. The accelerator can measure static acceleration of gravity in tilt sensing applications as well as dynamic acceleration resulting from motion, shock or vibration. The sensor is a polysilicon surface-micro machine structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of wafer and provide a resistance against acceleration forces. Reflection of a structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180 degree out of phase square waves. Acceleration deflects moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Phase sensitive demodulation techniques are then used to determine the magnitude and direction of acceleration. The demodulator output is amplified and brought off-chip through a 32 kilo-ohm resistor. The user then sets the signal bandwidth of the device by adding a capacitor. This filtering improves measurement resolution and helps prevent aliasing.

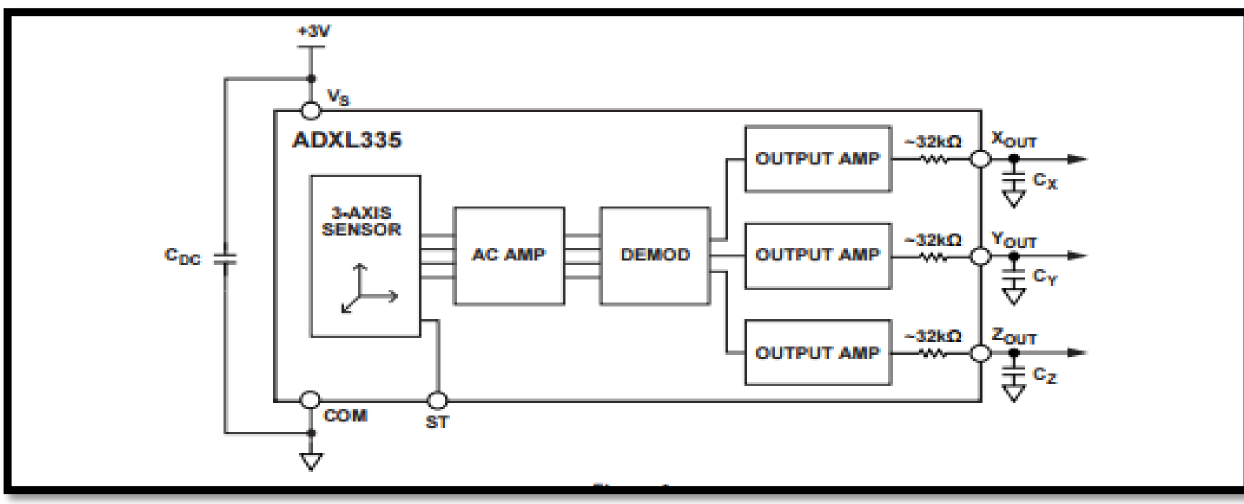


Figure: 4.26: Functional Block Diagram of ADXL335

4.1.14 Pin configuration and Function Descriptions of ADXL335

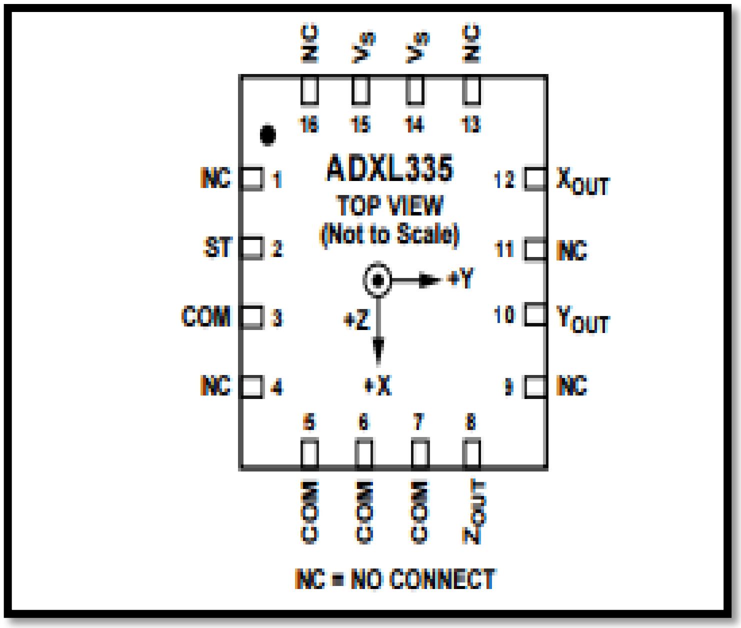


Figure: 4.27: Pin Diagram of ADXL335

Below Table 3.6 specifies the pin description

Table: 4.5: Pin function description of ADXL335

Pin No.	Mnemonic	Description
1	NC	No Connect[1].
2	ST	Self-Test.
3	COM	Common.
4	NC	No Connect[1].
5	COM	Common.
6	COM	Common.
7	COM	Common.
8	Z_{OUT}	Z Channel Output.
9	NC	No Connect[1].
10	Y_{OUT}	Y Channel Output.
11	NC	No Connect[1].
12	X_{OUT}	X Channel Output.
13	NC	No Connect[1].
14	V_S	Supply Voltage (1.8 V to 3.6 V).
15	V_S	Supply Voltage (1.8 V to 3.6 V).
16	NC	No Connect[1].
EP	Exposed Pad	Not internally connected. Solder for mechanical integrity.

4.1.15 Specifications of ADXL335

4.1.16 Analog vs Digital:

- Number of axis (1-3)
- Maximum swing
    1. Tilt +/- 1.5g
    2. Motion of car ,plane or robot +/-2g
    3. Sudden starts or stops +/- 5g
- Sensitivity
- Bandwidth
- Impedance or buffering issues

4.1.17 Common Accelerometer types:

- Resistive
- Capacitive
- Fibre optics
- Servo or force balance
- Vibrating quartz
- Piezoelectric

Here a capacitive accelerometer sensor (Cas) is used.

4.1.18 Typical Characteristics of Resistive/Capacitive:

- Measure down to zero hertz (DC response)
- Limited dynamic range (<80 db=10000:1)
- Limited high frequency range (<10kHz)
- Often a damped frequency response (0.7% of critical)
- Sensitivity may vary with input (m V/g/V)
- Traditionally fragile (limited shock protection)
- Operates multi-conductor cable (at least 3 wires)
- Micro-machined versions are small and light weight.

4.1.19 Features of ADXL335:

- 3-axis sensing.
- Small, low profile package4 mm X 4 mm X 1.45 mm LFCSP.
- Low power: 350 micro amp (typical).
- Single support operation: 1.8V to 3.6 V .
- 10,000g shock survival.
- Excellent temperature stability.
- BW adjustment with a single capacitor per axis.
- RoHS/WEEE lead-free complaint.

4.1.20 Accelerometer Application

- Cost sensitive, low power, motion-sensing and tilt-sensing application
- Mobile devices and gaming systems
- Disk drive protection
- Image stabilization
- Sports and health device
- Automotive: monitor vehicle’s tilt, roll, skid, impact, vibration, etc. to deploy safety devices and to ensure comfortable ride (active suspension)
- Aerospace: inertial navigation, smart munitions, unmanned vehicle.
- Sports/gaming: monitor athlete performance and injury, joystick, tilt
- Personal electronics: cell phones, digital devices
- Security: motion and vibration detection
- Industrial: machinery health monitoring
- Robotics: self-balancing.

4.1.21 FLOAT SWITCH

A float switch is a device used to detect the level of liquid within a tank. The switch may be used in a pump, an indicator, an alarm, or other devices. Float switches range from small to large and may be as simple as a mercury switch inside a hinged float or as complex as a series of optical or conductance sensors producing discrete outputs as the liquid reaches many different levels within the tank. Perhaps the most common type of float switch is simply a float raising a rod that actuates a micro switch.

A very common application is in sump pump and condensate pumps where the switch detects the rising level of liquid in the sump or tank and energizes an electrical pump which then pumps liquid out until the level of the liquid has been substantially reduced, at which point the pump is switched off again. Float switches are often adjustable and can include substantial hysteresis. That is, the switch's "turn on" point may be much higher than the "shut off" point. This minimizes the on-off cycling of the associated pump.

Some float switches contain a two-stage switch. As liquid rises to the trigger point of the first stage, the associated pump is activated. If the liquid continues to rise (perhaps because the pump has failed or its discharge is blocked), the second stage will be triggered. This stage may switch off the source of the liquid being pumped, trigger an alarm, or both.

Fig: 4.28: Float Switch

4.1.22 PIEZO-ELECTRIC BUZZER

Piezo buzzer is an electronic device commonly used to produce sound. Light weight, simple construction and low price make it usable in various applications like car/truck reversing indicator, computers, call bells etc. Piezo buzzer is based on the inverse principle of piezo electricity discovered in 1880 by Jacques and Pierre Curie. It is the phenomena of generating electricity when mechanical pressure is applied to certain materials and the vice versa is also true. Such materials are called piezo electric materials. Piezo electric materials are either naturally available or manmade. Piezo-ceramic is class of manmade material, which poses piezo electric effect and is widely used to make disc, the heart of piezo buzzer. When subjected to an alternating electric field they stretch or compress, in accordance with the frequency of the signal thereby producing sound.

Figure: 4.29: Piezo-Electric Buzzer

The above figure shows a very commonly used piezo buzzer also called piezo transducer operating at DC voltage. Encapsulated in a cylindrical plastic coating, it has a hole on the top face for sound to propagate. A yellow metallic disc which plays an important role in the producing sound can be seen through the hole.

4.1.23 INTERNAL CIRCUIT DIAGRAM OF PIEZO-ELECTRIC BUZZER

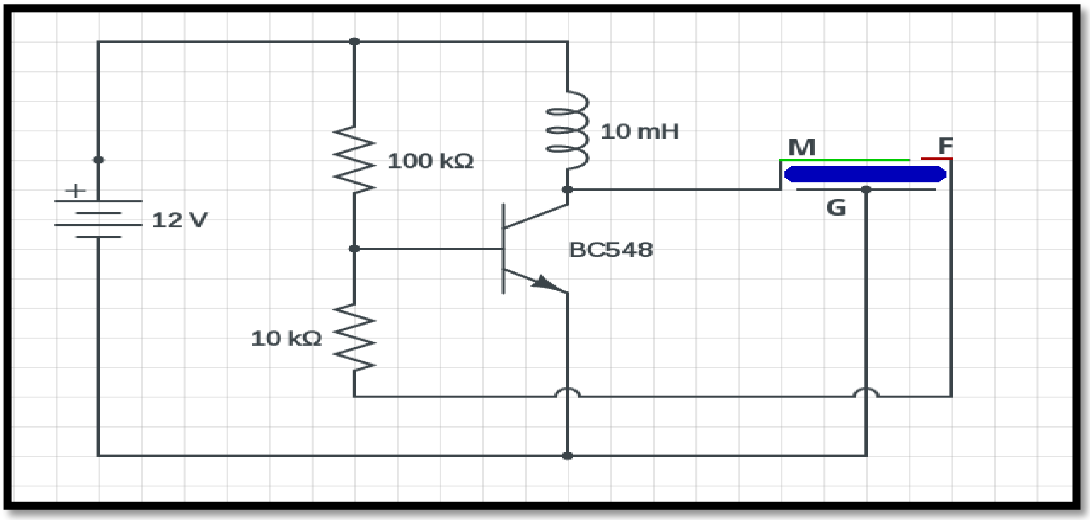


Figure: 4.30: Circuit Diagram of Piezo-Electric Buzzer.

In the Figure.3.30 the piezoelectric element's pin out, M is the main terminal, F is the feedback terminal and G is the ground plate. When a small DC voltage is applied to the input pins, it is first converted to an oscillating signal using the combination of resistor and transistor. These oscillating signals are amplified using the inductor coil. When high voltage alternating signals are applied to the piezo ceramic disc, it causes mechanical expansion and contraction in radial direction. This causes the metal plate to bend in opposite direction. When metal plate bends and shrinks in opposite direction continuously it produces sound waves in the air.

4.1.24 SOFTWARE REQUIREMENTS

Platform: Energia IDE

Energia is an open-source electronics prototyping platform started by Robert Wessels in January of 2012 with the goal to bring the Wiring and Arduino framework to the Texas Instruments MSP430 based Launchpad. The Energia IDE is cross platform and supported on Mac OS, Windows, and Linux. Energia includes an integrated development environment (IDE) that is based on Processing. Energia is also a portable framework/abstraction layer that can be used in other popular IDEs. The cores included in the board manager are: MSP430, MSP432 (MT, TI-RTOS based multitasking), CC3200 and Tiva C.

Energia started out to bring the wiring and Arduino framework to Texas Instruments MSP430 Launchpad. The LaunchPad is low-cost microcontroller board that is made by Texas Instruments together with Energia Launchpad can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors and other physical outputs. Launchpad projects can be stand-alone or they can communicate with software running on your computer. It is also possible to add wireless modules to enable communication over various types of RF including Wi-Fi, NFC, Bluetooth, Zigbee, cellular and more.

Figure: 4.31: Energia software.

Languages Used :

Embedded C

Embedded C is a set of language extensions for the C programming language by the C Standards Committee to address commonality issues that exist between C extensions for different embedded systems. Historically, embedded C programming requires nonstandard extensions to the C language in order to support exotic features such as fixed-point arithmetic, multiple distinct memory banks, and basic I/O operations.

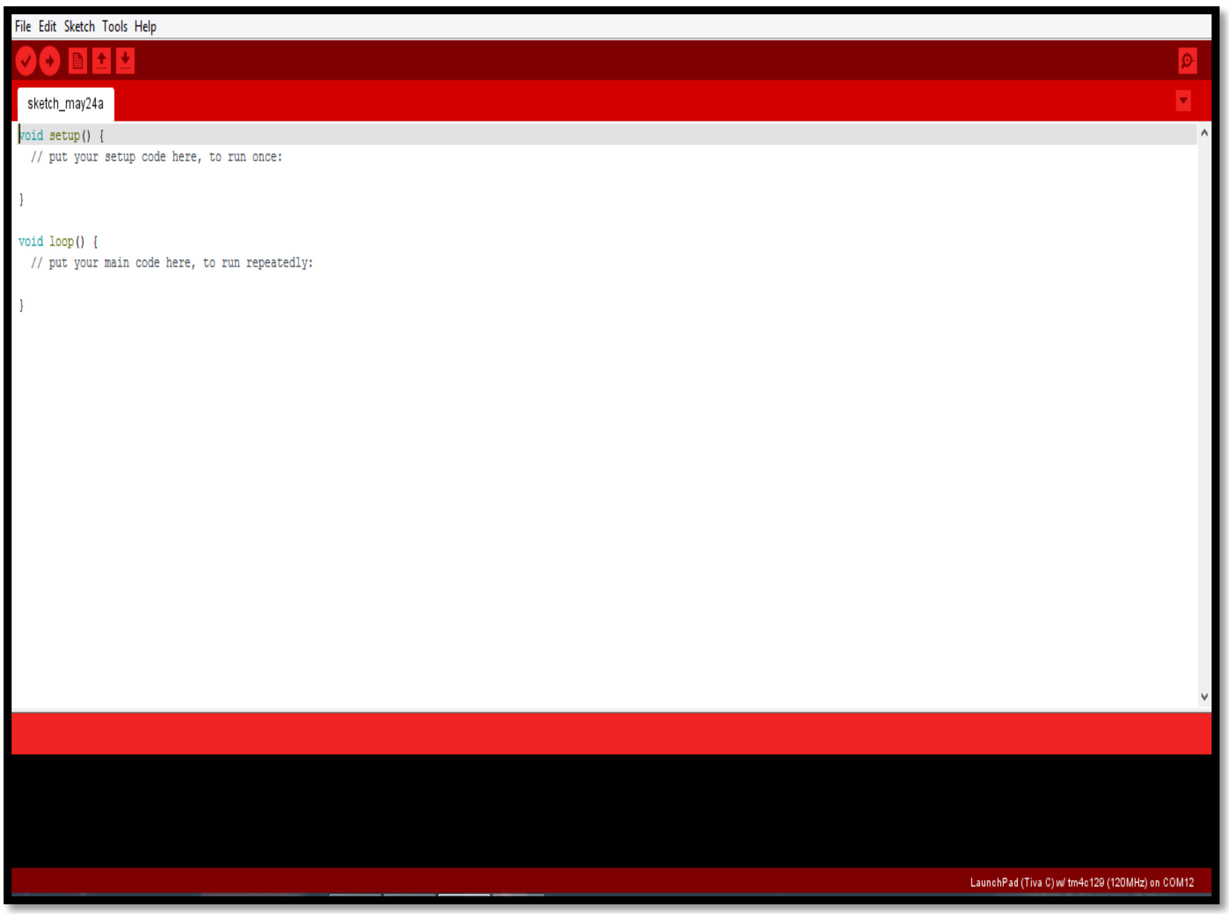


Figure: 4.1: Energia IDE version 1.6

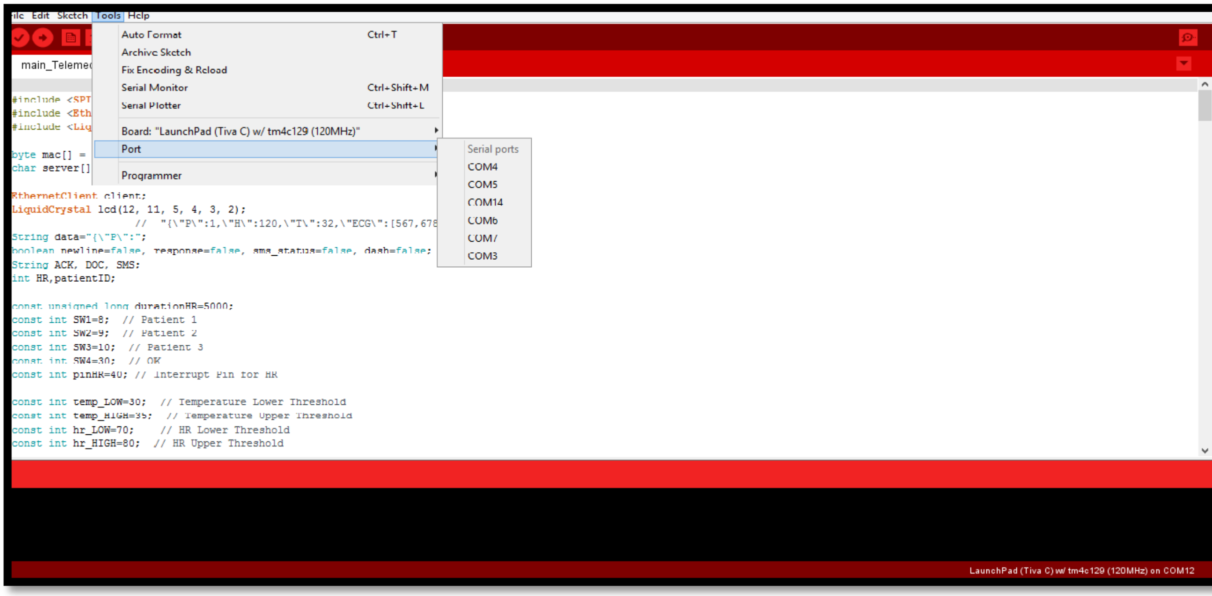


Figure: 4.2: Selecting the serial port

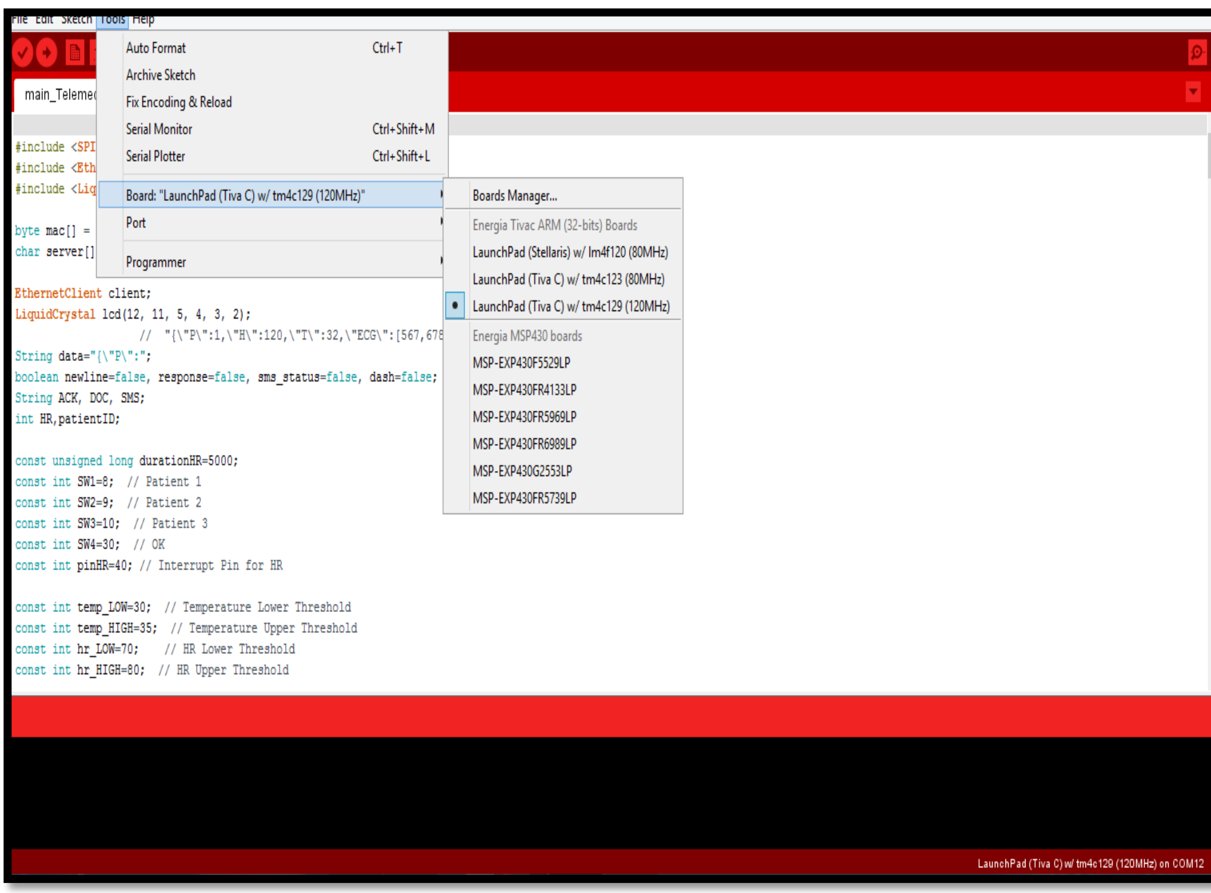


Figure: 4.3: Selecting the board

CSS

Cascading Style Sheets (CSS) is a style sheet language used for describing the presentation of a document written in a mark-up language. Although most often used to set the visual style of web pages and user interfaces written in HTML and XHTML, the language can be applied to any XML document, including plain XML, SVG and XUL, and is applicable to rendering in speech, or on other media. Along with HTML and JavaScript, CSS is a cornerstone technology used by most websites to create visually engaging web pages, user interfaces for web applications, and user interfaces for many mobile applications.

JAVA SCRIPT

JavaScript, often abbreviated as "JS", is a high-level, dynamic, un-typed, and interpreted run-time language. Alongside HTML and CSS, JavaScript is one of the three core technologies of World Wide Web content production; the majority of websites employ it, and all modern Web browsers support it without the need for plug-ins. JavaScript is prototype-based with first-class functions, making it a multi-paradigm language, supporting object-oriented, imperative, and functional programming styles. It has an API for working with text, arrays, dates and regular expressions, but does not include any I/O, such as networking, storage, or graphics facilities, relying for these upon the host environment in which it is embedded.

MySQL

MySQL is an open-source relational database management system (RDBMS). Its name is a combination of "My", the name of co-founder Michael Wideniusdaughter, and "SQL", the abbreviation for Structured Query Language. The MySQL development project has made its source code available under the terms of the GNU General Public License, as well as under a variety of proprietary agreements. MySQL was owned and sponsored by a single for-profit firm, the Swedish company MySQL AB, now owned by Oracle Corporation. For proprietary use, several paid editions are available, and offer additional functionality.

HTML

Hypertext Mark-up Language (HTML) is the standard mark-up language for creating web pages and web applications. With Cascading Style Sheets (CSS) and JavaScript it forms a triad of cornerstone technologies for the World Wide Web. Web browsers receive HTML documents from a webserver or from local storage and render them into multimedia web pages. HTML describes the structure of a web page semantically and originally included cues for the appearance of the document.HTML elements are the building blocks of HTML pages. With HTML constructs, images and other objects, such as interactive for, may be embedded into the rendered page. It provides a means to create structured documents by denoting structural semantics for text such as headings, paragraphs, lists, links, quotes and other items.HTML elements are delineated by *tags*, written using angle brackets. Browsers do not display the HTML tags, but use them to interpret the content of the page. HTML can embed programs written in a scripting language such as JavaScript which affect the behaviour and content of web pages. Inclusion of CSS defines the look and layout of content. The World Wide Web Consortium (W3C), maintainer of both the HTML and the CSS standards, has encouraged the use of CSS over explicit presentational HTML since 1997.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1. OBTAINED OUTCOME:

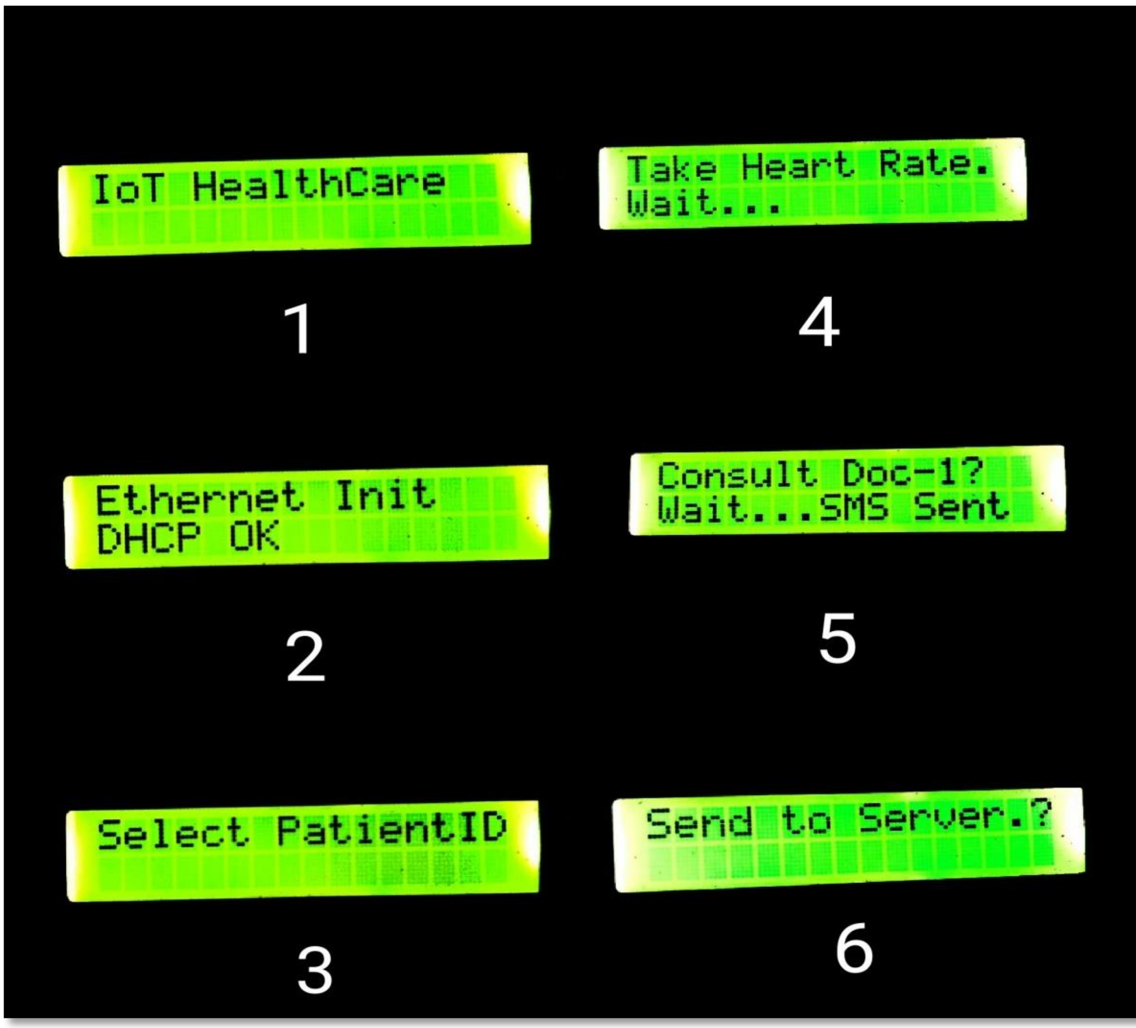


Figure: 5.1: Display on LCD

5.2. WEB PAGE DESIGN

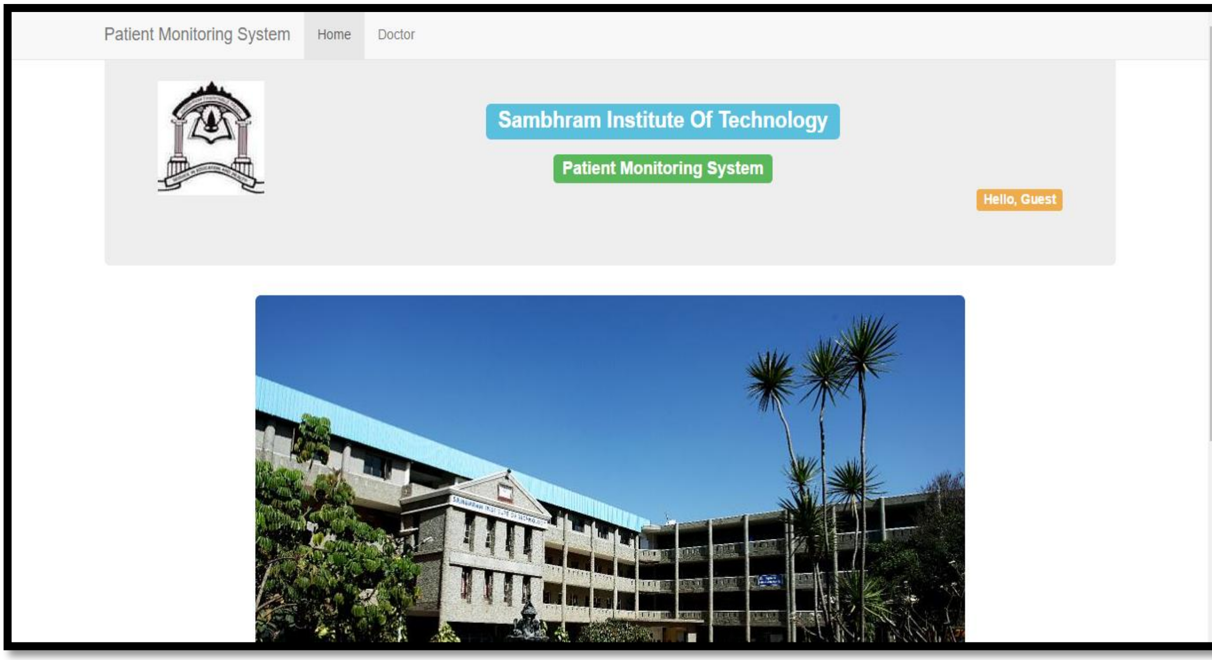


Figure: 5.2.1: Home Page

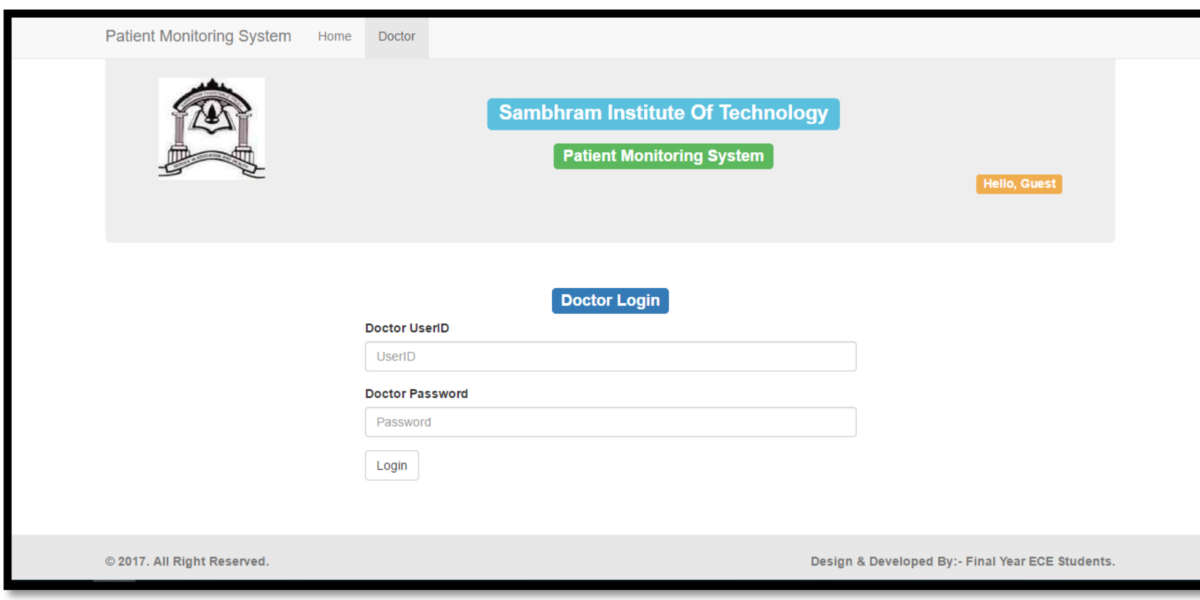


Figure: 5.2.2: Doctor Login Page

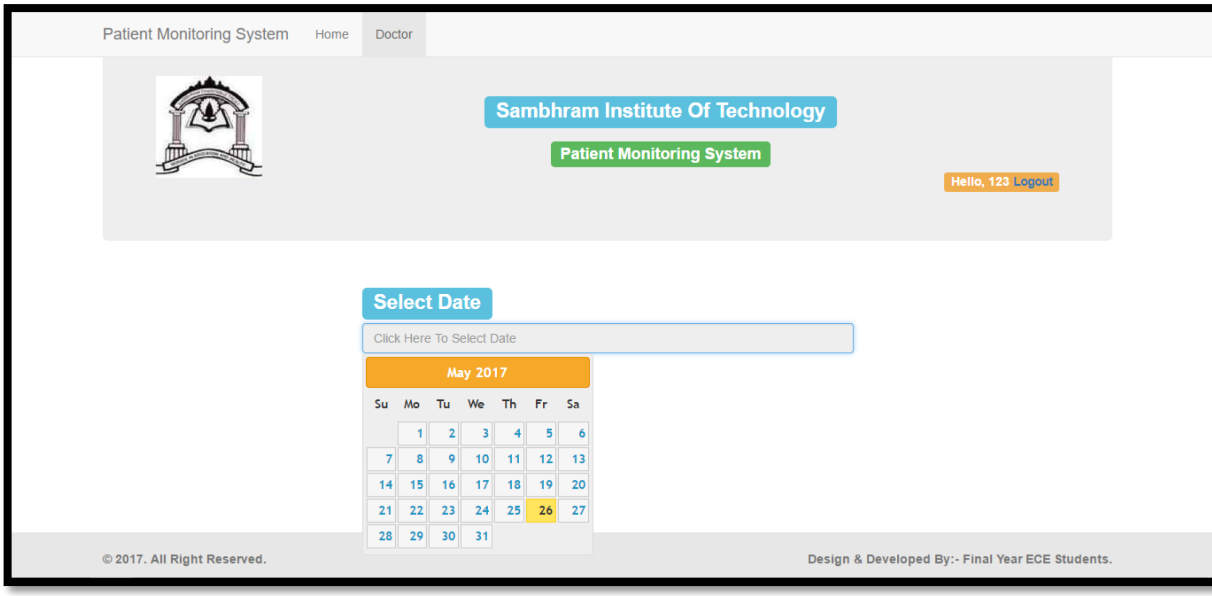


Figure: 5.2.3: Selection of date to view patient details

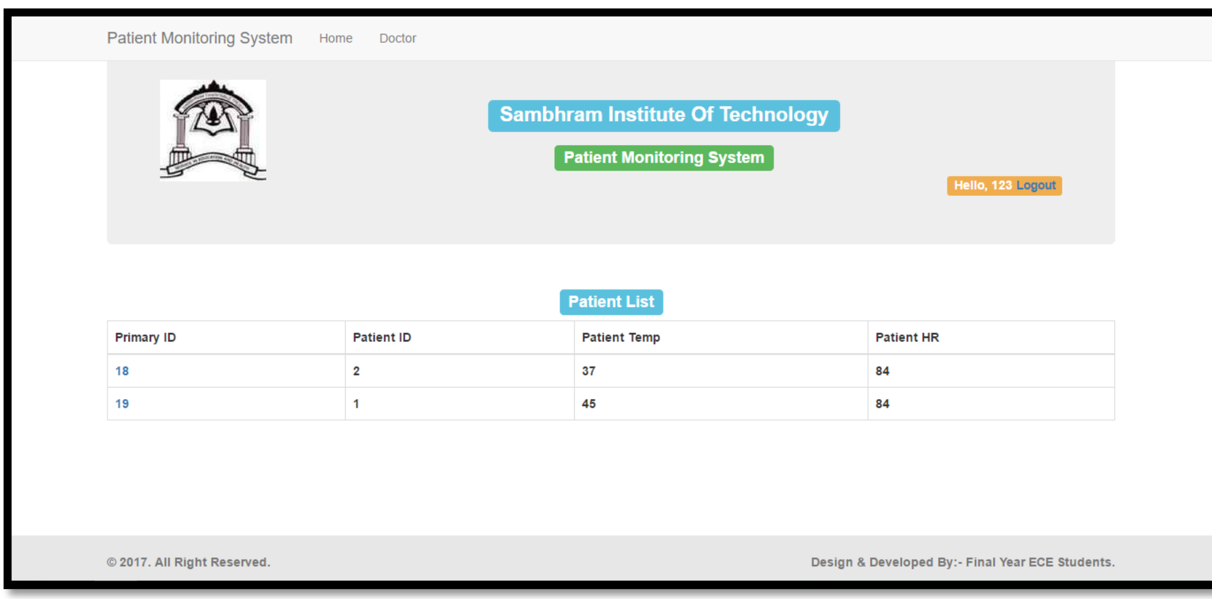


Figure: 5.2.4: Display of patient's vital parameters

Figure: 5.2.5: Display of ECG waveform

5.3. COMPLETE MODEL

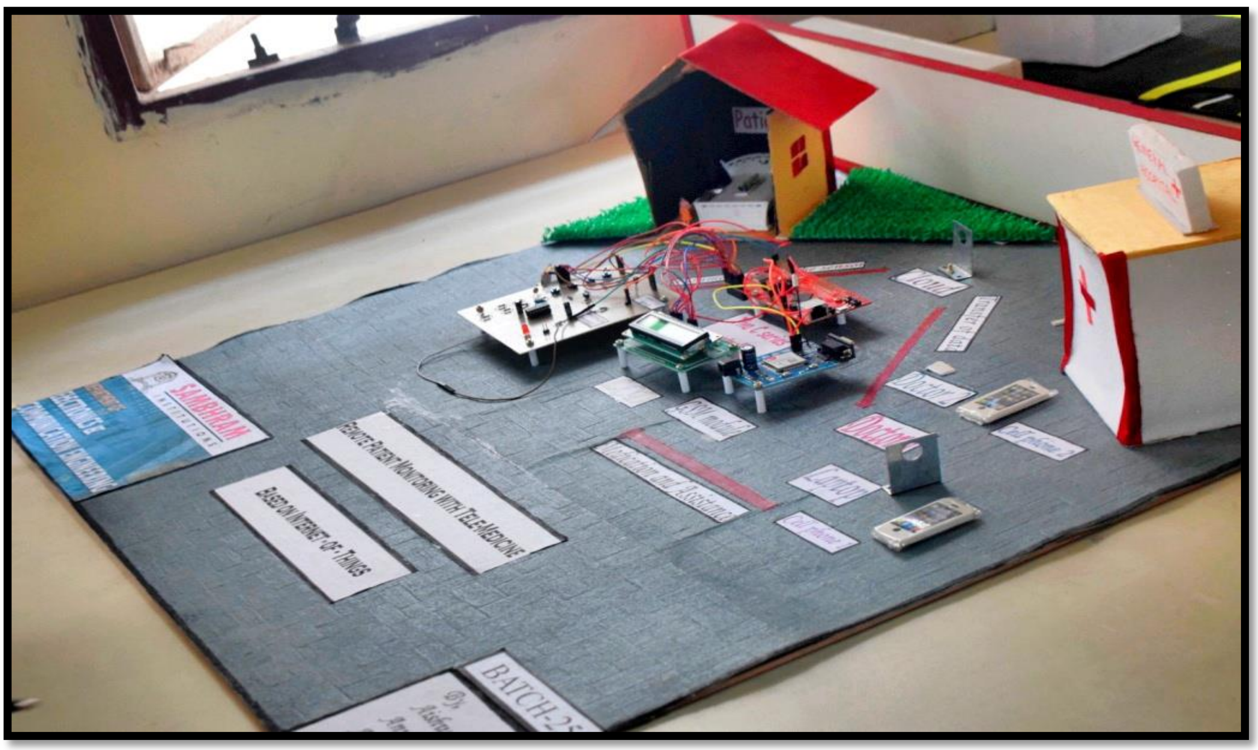


Figure: 5.3.1: Complete model

CHAPTER 6

ADVANTAGES AND DISADVANTAGES

Advantages:

- Increases the capacity for physicians to treat more patients by reason of not being limited to the confines of the traditional healthcare clinic or facility.
- Reduced healthcare delivery costs.
- Enables early detection of deterioration.
- Enhanced diagnosis and prescriptions.
- Saves time and reduces strains on the available facilities.
- Simplifies complex tasks since they are largely automate.

Disadvantages:

- Highly dependent on a reliable internet connection.
- Initial set up cost is high.

CHAPTER 7

CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

In this project ,the current problems in healthcare system has been analysed and a productive remote patient monitoring system is put forward which communicates through the internet to provide more desirable healthcare facilities. The system is user friendly and in case of an emergency a warning message can be sent to the physician's phone. At the same instant, the buzzer turns on to alert the caretaker. The doctors can view the patient's parameters by logging to the web page with a unique ID and password. The page refreshes after every update in order to acquire ceaseless data reception. The encryption facility provided for the patient's data will be an added advantage. The doctor can also suggest medications or assistance in the time of emergency based on the readings. Thus such a system will indeed be a boon for both doctors as well as patients.

7.2 FUTURE SCOPE

There is always chance to improve any system as research & development is an endless process. The proposed system is no exception to this phenomenon. The following developments can be done in future for this project. In future we can use this project in several applications by adding additional components to it.

- Integration with existing medical practices and technology
- Miniature wearable sensors
- Assistance to the elderly and chronic patients.
- Patient tracking module can be included in the system using GPS
- A network on a diabetic patient could auto inject insulin though a pump, as soon as his insulin level declines, thus making the patient 'doctor-free' and virtually healthy.

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