CHAPTER - 1

INTRODUCTION

In today's world there is a severe increase in the use of vehicles, such heavy automobile usage has increased traffic and thus resulting in a rise in road accidents. This takes a toll on the property as well as causes human life loss because of unavailability of immediate safety facilities. Complete accident prevention is unavoidable but at least repercussions can be reduced. Proposed system makes an effort to provide the emergency facilities to the victims in the shortest time possible. In big organizations the drivers make illegal use of the vehicles thus resulting in financial, time loss of the organization. Apart from these purposes the system can be used for tracking of stolen vehicles or travelling luggage, fleet management and vehicular sales etc. The system incorporates a single-board embedded system that contains GPS and GSM modems connected with a microcontroller. The entire set-up is installed in the vehicle. A vibration sensor is used. It measures the vibration at the location it is placed. The signal is then compared with the standard value which further confers the accident of the car, unnecessary shock or vibration produced by machines, tilt of the car with respect to the earth's axis can be identified with the level of acceleration. Global Positioning System (GPS) is used to identify the location of the vehicle.GSM is used to inform the exact vehicular location to the preceded numbers. Message will give longitude and latitude values. From these values location of accident can be determined.GSM modem provides a two way communication by using a sim card. Such a module works the same as a regular phone. The project aims at intelligent security system providing situational awareness and agile safety.

In recent years, the increase in the number of deaths due to accidents has significant increased. Especially, due to the delay in the arrival of ambulance with rescue teams and emergency teams to save the victim who has been injured by the road traffic accident. As per a statistical report, it is stated that every year the lives of approximately 1.35 million people are cut short as a result of a road traffic crash [1]. Also, it is reported that nearly 20 to 50 million peoples suffer due to non-fatal injuries, with many incurring a disability as a result of their injury [1]. Here, Saudi Arabia is not an exception and is estimated that nearly 70% of accident deaths in Saudi Arabia is due to the delay in the arrival of ambulance to rescue the people injured by accident [2], [3]. Accidents happen mainly due to fast driving and overtaking, preventing death and serious injuries from traffic accidents is an increasingly important goal of governments around the world.

There is no modern technology that can completely avoid accidents and you don’t even know where and when an accident might happen. Most of the time, the life of the victim depends on the reactions of those close to them. People may not want to participate in any kind of rescue operation after an accident, resulting in tragic consequences for the victims or the bystander not having enough time to help that victim. All these bottlenecks and others hamper the rapid transportation of the victim to the nearby hospital. As discussed earlier, very worst accident requires immediate medical attention. Under such circumstances, the delays in medical care likely leads to death. Therefore, reducing the time taken since the accident and sending responders is very crucial because it reduces mortality [9]. It is very evident that the most crucial requirement to enhance the survival rates of a victim met with an accident is the time taken by the emergency team to address the victim. Thus, by reducing the time between an accident and the arrival of emergency team to the accident location can positively decrease the death rate by accident to greater percentage. One effective solutions to address this problem is to use automatic accident detection system that can sense the accident and notify the emergency personnel immediately to address the victim.

Many Internet of things (IoT) based solutions are reported in literature [10]. Most of these are either in-vehicle built and not available for old cars or they are smart mobile phone-based apps which require the intervention of the victim to operate after the accident which is not possible in all cases. Thus, there is urgent demand for low-cost solution for automatic accident detection and notification for the current smart city environment as well that can be deployed in old cars.

The emergence of more effective and low-priced machineries for distributed data processing has concreted the way for innovative applications, allowing use of the IoT-centered machine-to-machine paradigm. The internet of things enabled to alleviate few common problems of the urban areas, causing developments in the cities. Recently multitudes of applications have been developed to observe the activities and the atmospheric changes that are taking place in the cities, delivering, the particulars about the events of the people, vehicles, buildings, animals, weather based on the information's acquired from the sensors. A large amount of information's are gathered from the urban areas by engaging the sensor nodes. So the sensors engaged allows one to have the details of the unpredictable disaster that requires immediate response as it causes major economic losses. Hence sorting out an effective ways to regulate the exigent situations in these context are significant.

The sensor technology exploited to create awareness among the people on the disaster situations emphasis only on a particular phenomenon for instance either the flood, fire, rainstorm etc. lacking flexibility or adaptability in observing various scenarios. So this makes one to employ various number of essential system to alert the public or over burden the sensors engaged. So monitoring and reporting an exigent circumstances requires enhancement looking after the progress of such applications. The exigent situations may be categorized based on its severity, and the damages it has created on the affected area as well as its time-based consequence, however the situations is it is necessary to track the direct line between an emergency as will the instance the events has occurred so as to turn on the alarm system.

Although multitudes of ways exist to identify the events and the proposed method utilizes the Coordinates of the Geo-positioning system to identify the criticality of the incident occurred in a particular time instant followed by activating the alarm system. But the extent of the occurrence totally depends on the various installations that are adapted. For instance the detecting a smoke emission could be indicated by the temperature sensor but the intensity of the smoke level is required to activate the alarm system and the level of the alarms activated has to be varied depending on the population in the affected area. So the proposed model in the paper devises an exceedingly configurable, more adaptable and effective exigent-incident alarm frame work that is three layered holding the applications, happenings and the incident alarms in each of its layers. The proposed method engages devices to identify (IU's) the occurrence of the events along with the location and the time instance of occurrence using the geo-positioning system, the computing units to process the information's gathered and the user applications registered.

CHAPTER - 2

LITERATURE SURVEY

Several approaches have been proposed related to this issue in many papers. Of these, some specific papers have been analyzed in the following paragraphs. Vijay Savania el al [4] proposed a system using an alcohol sensor placed in the vehicle along with the ultrasonic sensor used for car accident prevention. The resulting information is transmitted via SMS to the close by acquaintance through the GSM module.

Su et al [1], has elaborated the details of the internet of things applications that has are necessitated in making a city smart Zygiaris, et al [2] has put forth the “Assisting planners to conceptualize the building of smart city innovation ecosystems” Valanarasu et al [3], has proposed the “Smart and Secure Iot and AI Integration Framework for Hospital Environment” Song, et al [4], discloses the “foundations and the principle required in developing a smart city”

Duraipandian et al [5] has put forth a "Cloud based Internet of Things for smart connected objects." Reyes, et al [6] has developed an "Computer-enabled, networked, facility emergency notification, management and alarm system." Tewolde et al [7] has put forth the "Sensor and network technology for intelligent transportation systems." In the development of smart cities.

Gharaibeh et al[8] elaborates the “A survey on data management, security, and enabling technologies for the smart cities” Smys, S., et al [9] discusses the "Introduction to the Special Section on Inventive Systems and Smart Cities." Bhatti et al [10] has put forth the "A novel internet of things-enabled accident detection and reporting system for smart city environments."

Alharbi, N., et al [11] has developed a “the challenges, involvement and the activities of the sensors in the smart cities” Jennifer S. Raj et al [12] has put forth the “Internet of Things and Big Data Analytics for Health Care with Cloud Computing.” More et al [13] proposes the "Smart Goods Transportation system using Internet of Vehicle." Ashwin, Dr M. et al [14] has devised a solution for the challenges faced in the application of smart cities.

Bhatt et al [15] “disclosed the methodology to devise a traffic sign board that is smart for the smart cities” J. Vijitha Ananthi et al [16] proposed an IoT based “ automated greenhouse environment” that monitors the changes in temperature, humidity and the pressure and Stoyanov, et al constructed a novel reference structure that supports the applications of the smart city.

CHAPTER-3

EMBEDDED SYSTEMS

An embedded system can be defined as a computing device that does a specific focused job. Appliances such as the air-conditioner, VCD player, DVD player, printer, fax machine, mobile phone etc. are examples of embedded systems. Each of these appliances will have a processor and special hardware to meet the specific requirement of the application along with the embedded software that is executed by the processor for meeting that specific requirement. The embedded software is also called "firm ware". The desktop/laptop computer is a general purpose computer. You can use it for a variety of applications such as playing games, *word* processing, accounting, software development and so on. In contrast, the software in the embedded systems is always fixed listed below:

Embedded systems do a very specific task, they cannot be programmed to do different things. . Embedded systems have very limited resources, particularly the memory. Generally, they do not have secondary storage devices such as the CDROM or the floppy disk. Embedded systems have to work against some deadlines. A specific job has to be completed within a specific time. In some embedded systems, called real-time systems, the deadlines are stringent. Missing a deadline may cause a catastrophe-loss of life or damage to property. Embedded systems are constrained for power. As many embedded systems operate through a battery, the power consumption has to be very low. Some embedded systems have to operate in extreme environmental conditions such as very high temperatures and humidity.

APPLICATION AREAS

Nearly 99 per cent of the processors manufactured end up in embedded systems. The embedded system market is one of the highest growth areas as these systems are used in very market segment- consumer electronics, office automation, industrial automation, biomedical engineering, wireless communication, data communication, telecommunications, transportation, military and so on.

Consumer appliances: At home we use a number of embedded systems which include digital camera, digital diary, DVD player, electronic toys, microwave oven, remote controls for TV and air-conditioner, VCO player, video game consoles, video recorders etc. Today's high-tech car has about 20 embedded systems for transmission control, engine spark control, air-conditioning, navigation etc. Even wristwatches are now becoming embedded systems. The palmtops are powerful embedded systems using which we can carry out many general-purpose tasks such as playing games and word processing.

Office automation: The office automation products using em embedded systems are copying machine, fax machine, key telephone, modem, printer, scanner etc.

Industrial automation: Today a lot of industries use embedded systems for process control. These include pharmaceutical, cement, sugar, oil exploration, nuclear energy, electricity generation and transmission. The embedded systems for industrial use are designed to carry out specific tasks such as monitoring the temperature, pressure, humidity, voltage, current etc., and then take appropriate action based on the monitored levels to control other devices or to send information to a centralized monitoring station. In hazardous industrial environment, where human presence has to be avoided, robots are used, which are programmed to do specific jobs. The robots are now becoming very powerful and carry out many interesting and complicated tasks such as hardware assembly.

Medical electronics: Almost every medical equipment in the hospital is an embedded system. These equipments include diagnostic aids such as ECG, EEG, blood pressure measuring devices, X-ray scanners; equipment used in blood analysis, radiation, colonscopy, endoscopy etc. Developments in medical electronics have paved way for more accurate diagnosis of diseases.

Computer networking: Computer networking products such as bridges, routers, Integrated Services Digital Networks (ISDN), Asynchronous Transfer Mode (ATM), X.25 and frame relay switches are embedded systems which implement the necessary data communication protocols. For example, a router interconnects two networks. The two networks may be running different protocol stacks. The router's function is to obtain the data packets from incoming pores, analyze the packets and send them towards the destination after doing necessary protocol conversion.

Most networking equipments, other than the end systems (desktop computers) we use to access the networks, are embedded systems

Telecommunications: In the field of telecommunications, the embedded systems can be categorized as subscriber terminals and network equipment. The subscriber terminals such as key telephones, ISDN phones, terminal adapters, web cameras are embedded systems. The network equipment includes multiplexers, multiple access systems, Packet Assemblers Dissemblers (PADs), sate11ite modems etc. IP phone, IP gateway, IP gatekeeper etc. are the latest embedded systems that provide very low-cost voice communication over the Internet.

Wireless technologies: Advances in mobile communications are paving way for many interesting applications using embedded systems. The mobile phone is one of the marvels of the last decade of the 20’h century. It is a very powerful embedded system that provides voice communication while we are on the move. The Personal Digital Assistants and the palmtops can now be used to access multimedia services over the Internet. Mobile communication infrastructure such as base station controllers, mobile switching centers are also powerful embedded systems.

Insemination: Testing and measurement are the fundamental requirements in all scientific and engineering activities. The measuring equipment we use in laboratories to measure parameters such as weight, temperature, pressure, humidity, voltage, current etc. are all embedded systems. Test equipment such as oscilloscope, spectrum analyzer, logic analyzer, protocol analyzer, radio communication test set etc. are embedded systems built around powerful processors. Thank to miniaturization, the test and measuring equipment are now becoming portable facilitating easy testing and measurement in the field by field-personnel.

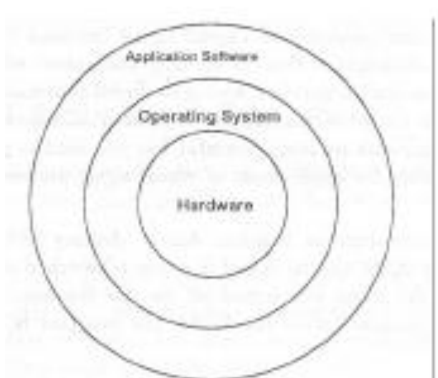
Security: Security of persons and information has always been a major issue. We need to protect our homes and offices; and also the information we transmit and store. Developing embedded systems for security applications is one of the most lucrative businesses nowadays. Security devices at homes, offices, airports etc. for authentication and verification are embedded systems. Encryption devices are nearly 99 per cent of the processors that are manufactured end up in~ embedded systems. Embedded systems find applications in . every industrial segment- consumer electronics, transportation, avionics, biomedical engineering, manufacturing, process control and industrial automation, data communication, telecommunication, defense, security etc. Used to encrypt the data/voice being transmitted on communication links such as telephone lines. Biometric systems using fingerprint and face recognition are now being extensively used for user authentication in banking applications as well as for access control in high security buildings.

Finance: Financial dealing through cash and cheques are now slowly paving way for transactions using smart cards and ATM (Automatic Teller Machine, also expanded as Any Time Money) machines. Smart card, of the size of a credit card, has a small micro-controller and memory; and it interacts with the smart card reader! ATM machine and acts as an electronic wallet. Smart card technology has the capability of ushering in a cashless society. Well, the list goes on. It is no exaggeration to say that eyes wherever you go, you can see, or at least feel, the work of an embedded system!

Overview of Embedded System Architecture

Every embedded system consists of custom-built hardware built around a Central Processing Unit (CPU). This hardware also contains memory chips onto which the software is loaded. The software residing on the memory chip is also called the 'firmware'. The embedded system architecture can be represented as a layered architecture as shown in Fig.

The operating system runs above the hardware, and the application software runs above the operating system. The same architecture is applicable to any computer including a desktop



Layered Architecture of an Embedded Syste computer. However, there are significant differences. It is not compulsory to have an operating system in every embedded system. For small appliances such as remote control units, air conditioners, toys etc., there is no need *for* an operating system and you can write only the software specific to that application. For applications involving complex processing, it is advisable to have an operating system. In such a case, you need to integrate the application software with the operating system and then transfer the entire software on to the memory chip. Once the software is transferred to the memory chip, the software will continue to run *for* a long time you don't need to reload new software.

Now, let us see the details of the various building blocks of the hardware of an embedded system. As shown in Fig. the building blocks are;

· Central Processing Unit (CPU)

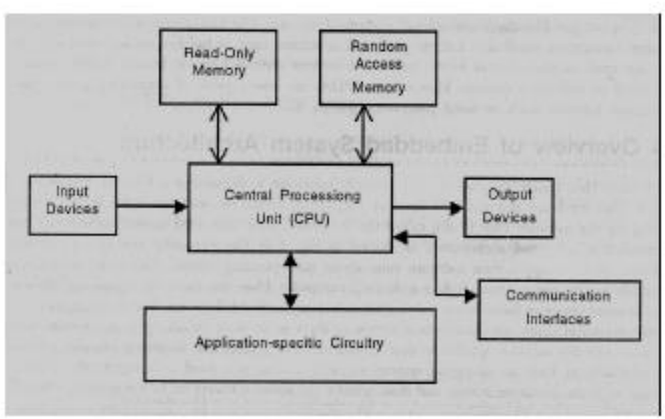
· Memory (Read-only Memory and Random Access Memory)

· Input Devices

· Output devices

· Communication interfaces

· Application-specific circuitry



CENTRAL PROCESSING UNIT (CPU)

The Central Processing Unit (processor, in short) can be any of the following: microcontroller, microprocessor or Digital Signal Processor (DSP). A micro-controller is a low-cost processor. Its main attraction is that on the chip itself, there will be many other components such as memory, serial communication interface, analog-to digital converter etc. So, for small applications, a micro-controller is the best choice as the number of external components required will be very less. On the other hand, microprocessors are more powerful, but you need to use many external components with them. D5P is used mainly for applications in which signal processing is involved such as audio and video processing.

Memory: The memory is categorized as Random Access 11emory (RAM) and Read Only Memory (ROM). The contents of the RAM will be erased if power is switched off to the chip, whereas ROM retains the contents even if the power is switched off. So, the firmware is stored in the ROM. When power is switched on, the processor reads the ROM; the program is program is executed.

Input devices: Unlike the desktops, the input devices to an embedded system have very limited capability. There will be no keyboard or a mouse, and hence interacting with the embedded system is no easy task. Many embedded systems will have a small keypad-you press one key to give a specific command. A keypad may be used to input only the digits. Many embedded systems used in process control do not have any input device *for* user interaction; they take inputs *from* sensors or transducers 1’fnd produce electrical signals that are in turn fed to other systems.

Output devices: The output devices of the embedded systems also have very limited capability. Some embedded systems will have a *few* Light Emitting Diodes (LEDs) *to* indicate the health status of the system modules, or *for* visual indication of alarms. A small Liquid Crystal Display (LCD) may also be used to display *some* important parameters.

Communication interfaces: The embedded systems may need to, interact with other embedded systems at they may have to transmit data to a desktop. To facilitate this, the embedded systems are provided with one or a *few* communication interfaces such as RS232, RS422, RS485, Universal Serial Bus (USB), IEEE 1394, Ethernet etc.

Application-specific circuitry: Sensors, transducers, special processing and control circuitry may be required fat an embedded system, depending on its application. This circuitry interacts with the processor to carry out the necessary work. The entire hardware has to be given power supply either through the 230 volts main supply or through a battery. The hardware has to design in such a way that the power consumption is minimized.

CHAPTER-4

EXISTING METHODS

The block diagram of the existing system is shown in Fig 2. It consists of a switch which is used to start the system. It is analogous to starting the car engine. The MQ-3 alcohol sensor is used to detect the presence of alcohol that crosses the specified threshold value. The value is then sent to the Arduino and if the specified value is surpassed, then it forwards an input to GSM module to send a SMS to the concerned authority. The DC motor is used in order to signify the car ignition system which is cut off in case of alcohol consumption.

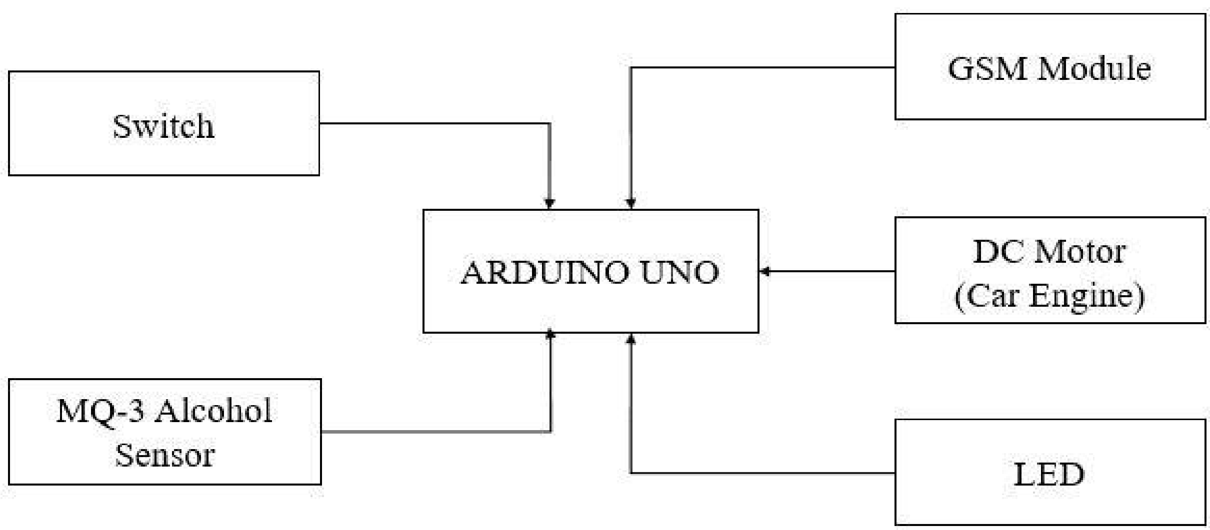


Figure-2: Existing System

CHAPTER-5

PROPOSED SYSTEM

After a critical review of several IoT based architectures in the past literatures, we devised an architecture for the proposed system that can enable to utilize the designed smart belt for car accident and notification to emergency services for timely rescue. The proposed architecture is illustrated in Fig. 3 and consists of four layers namely application layer, service layer, transmission layer and sensing layer. The description about these layers are summarized below for better understanding of the proposed system [11].

Sensors Layer

This layer is also called perception layer in general IoT architecture. Data collection is key function of this layer and is regarded as the crucial and fundamental task for the subsequent operations in the proposed system architecture of accident detection. Also, several literatures in this field of interest clearly defines that collecting data from various sensors is a challenging task. This is mainly due to heterogeneity among various sensors involved in data collection. From Fig. 2, it can be observed that the sensing layer in the proposed system consists of fingerprint sensor, vibration sensor, GPS module and heart beat pulse sensor. These sensors are mounted inside the driver seat belt of the vehicle and are used to capture data required for car accident detection. For example, fingerprint sensor scans and provides the driver fingerprint information that can be used in authenticating his driver license and allowing to ignite the car. Likewise, heart beat sensor reads and provides the driver heart beat information for detecting whether its normal or not. Vibration sensor is used to read and provide the car vibration information which can be combined with heart-beat information to determine whether car accident has occurred or not.

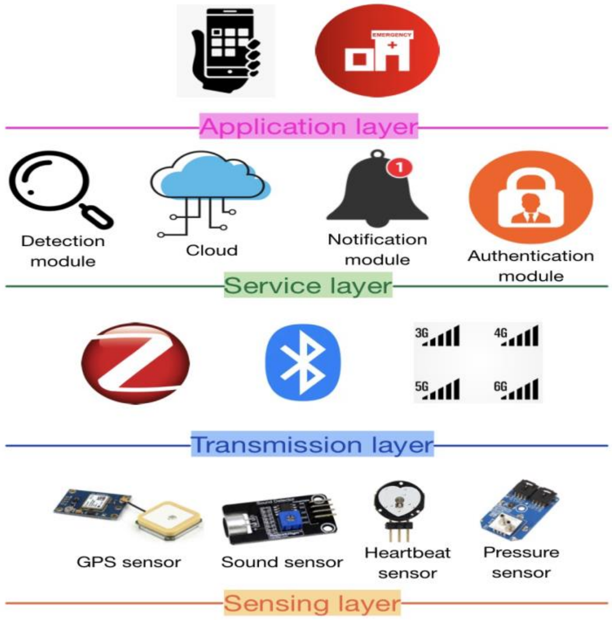


Fig. 3. Proposed System Architecture for car accident detection

Transmission Layer

Transmission layer is on top of perception layer and is considered as backbone of general IoT architecture. The key function of this layer is to transfer the data securely from sensing layer to the processing layer. Depending on the network coverage ability, the transmission layer can include two types of transmission namely, access and network. The access transmission involves near-field communication, Zigbee, Bluetooth, etc. These technologies are capable of providing short area coverage. On other hand, 3G/4G/5G/wifi/LTE that are capable of providing wider range of network coverage are called as network transmission. As shown in Fig. 3, it is advisable to choose the best data transmission technology based on the sensing device deployed in the sensing layer. Therein, the proposed system involves Bluetooth for short area coverage and 3G/4G/5G for wider area coverage to transfer the data captured by the sensors to the processing layer.

Service Layer

This layer is also known as data management layer in general IoT architecture. It acts as the brain for the proposed system residing between the application and sensing layer. The key function of this layer is service management involving different types of operations related to the data management such as storing, preprocessing, analyzing and decision making. The efficiency of this layer is very essential and decides the success of the proposed system since the timely and accurate delivery of alert notification to the emergency service can avoid and reduce the life mortality rate due to accident. This layer communicates with each sensor in perception layer via transmission layer to receive the captured information and stores it in cloud for future use if required. For example, the fingerprint information is collected during the new user registration is stored in the cloud that can be used later for authentication purpose. Also, this layer is responsible for information processing. It uses accident detection module to utilize effectively the information collected from all the sensors and decide accurately whether the accident has occurred or not. Based on the decision, notification module is utilized to send alert message with the required accident details such as location information from the GPS sensor.

Application Layer

This layer is the top most layer in the general IoT architecture. The performance of this layer vitally impacts the users' satisfaction and acceptability of the proposed system. The users are mainly concerned with efficiency of the proposed system in delivering the notification about the accident timely and accurately to the emergency service unit. In this work, the proposed system consists of two client applications namely, the driver mobile application and emergency service application. The driver mobile application allows the driver to register with his personal details. Also, this app allows the driver to login and start the tracking process before each driving trip. Notably, after accident is detected, the mobile app receives notification first and waits for the driver response to cancel the notification in case if the accident detection is wrong. If no response from driver for particular time period then the notification is sent to the nearest emergency service with location details of the accident.

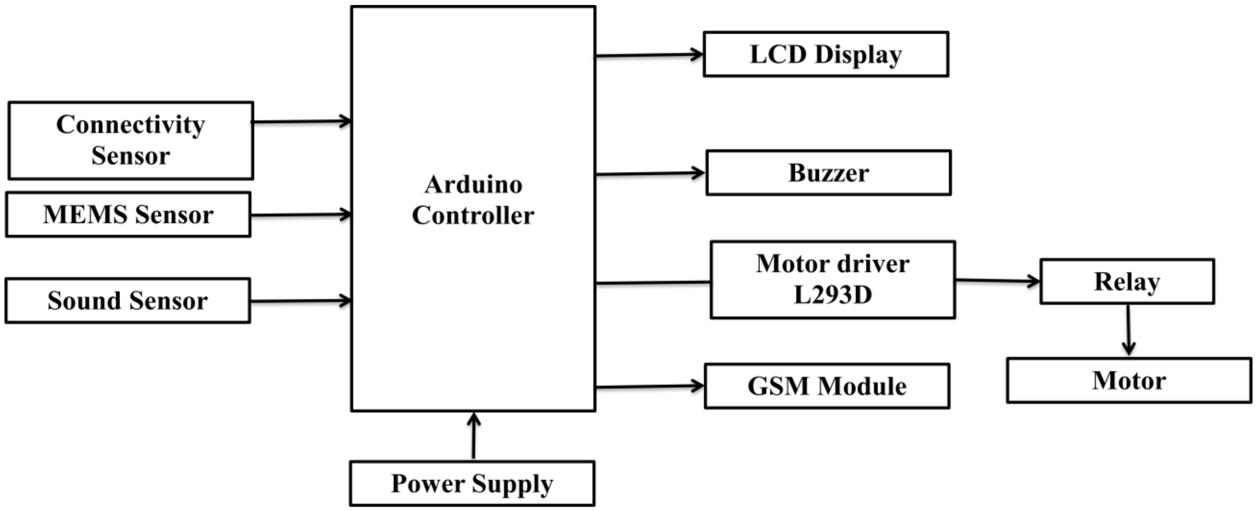


Figure-4: Proposed Block diagram

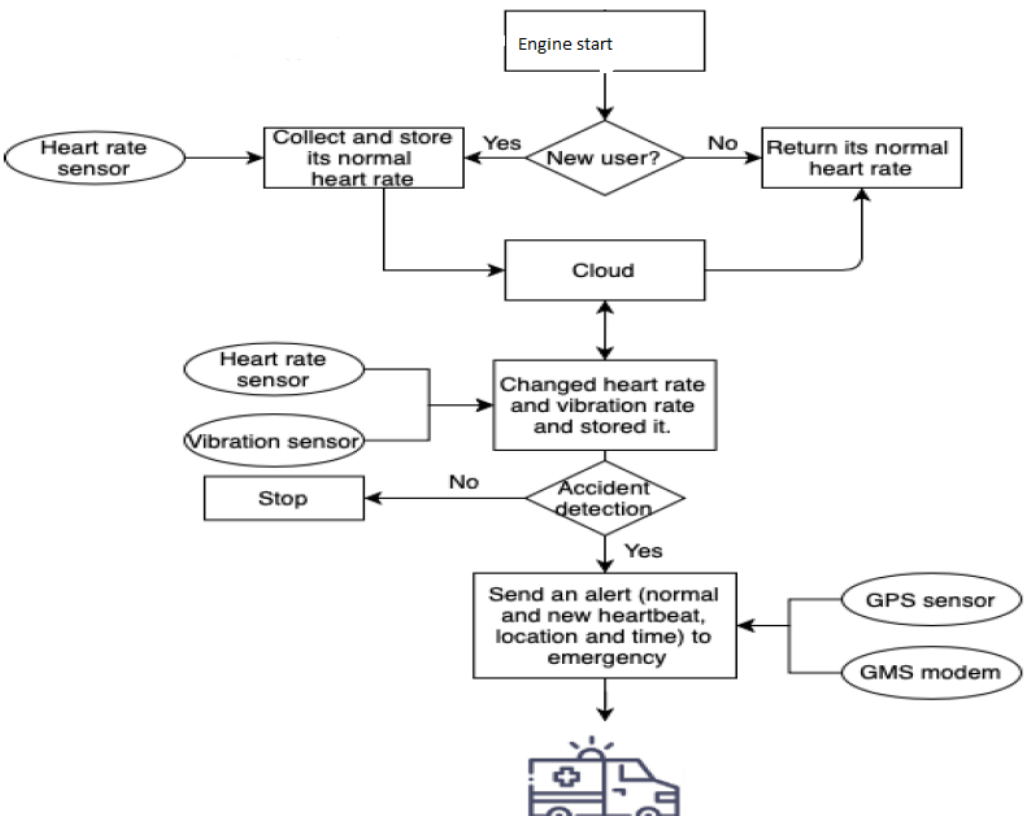


Figure: Flow chart

CHAPTER-6

DESCRIPTION OF HARDWARE COMPONENTS

This chapter briefly explains about the Hardware Implementation of the project. It discusses the design and working of the design with the help of block diagram and circuit diagram and explanation of circuit diagram in detail. It explains the features, timer programming, serial communication, interrupts of **ATmega328P** microcontroller. It also explains the various modules used in this project.

Power Supply

Power supply is a reference to a source of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit or PSU. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others. This power supply section is required to convert AC signal to DC signal and also to reduce the amplitude of the signal.

The available voltage signal from the mains is 230V/50Hz which is an AC voltage, but the required is DC voltage (no frequency) with the amplitude of +5V and +12V for various applications. In this section we have Transformer, Bridge rectifier, are connected serially and voltage regulators for +5V and +12V (7805 and 7812) via a capacitor (1000µF) in parallel are connected parallel as shown in the circuit diagram below. Each voltage regulator output is again is connected to the capacitors of values (100µF, 10µF, 1 µF, 0.1 µF) are connected parallel through which the corresponding output (+5V or +12V) are taken into consideration.

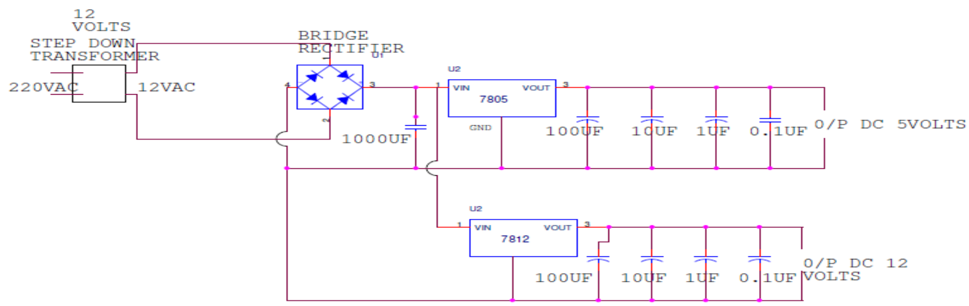


Figure: Power supply Diagram

Circuit Explanation

Transformer

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled electrical conductors. A changing current in the first circuit (the primary) creates a changing magnetic field; in turn, this magnetic field induces a changing voltage in the second circuit (the secondary). By adding a load to the secondary circuit, one can make current flow in the transformer, thus transferring energy from one circuit to the other.

The secondary induced voltage V_S, of an ideal transformer, is scaled from the primary V_P by a factor equal to the ratio of the number of turns of wire in their respective windings:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

Basic principle

The transformer is based on two principles: firstly, that an electric current can produce a magnetic field (electromagnetism) and secondly that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction). By changing the current in the primary coil, it changes the strength of its magnetic field; since the changing magnetic field extends into the secondary coil, a voltage is induced across the secondary.

A simplified transformer design is shown below. A current passing through the primary coil creates a magnetic field. The primary and secondary coils are wrapped around a core of very high magnetic permeability, such as iron; this ensures that most of the magnetic field lines produced by the primary current are within the iron and pass through the secondary coil as well as the primary coil.

Induction law

The voltage induced across the secondary coil may be calculated from Faraday's law of induction, which states that:

$$V_S = N_S \frac{\mathrm{d}\Phi}{\mathrm{d}t}$$

Where V_S is the instantaneous voltage, N_S is the number of turns in the secondary coil and Φ equals the magnetic flux through one turn of the coil. If the turns of the coil are oriented perpendicular to the magnetic field lines, the flux is the product of the magnetic field strength B and the area A through which it cuts. The area is constant, being equal to the cross-sectional area of the transformer core, whereas the magnetic field varies with time according to the excitation of the primary. Since the same magnetic flux passes through both the primary and secondary coils in an ideal transformer, the instantaneous voltage across the primary winding equals

$$V_P = N_P \frac{\mathrm{d}\Phi}{\mathrm{d}t}$$

Taking the ratio of the two equations for V_S and V_P gives the basic equation for stepping up or stepping down the voltage

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

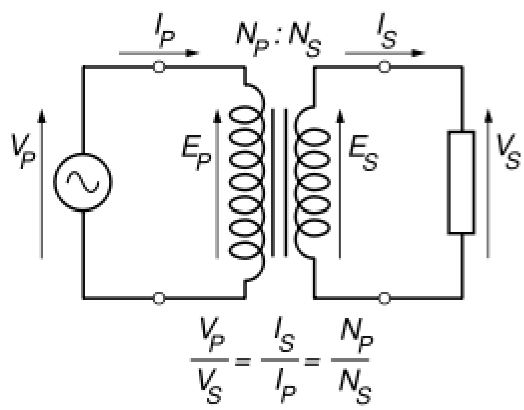
Ideal power equation

If the secondary coil is attached to a load that allows current to flow, electrical power is transmitted from the primary circuit to the secondary circuit. Ideally, the transformer is perfectly efficient; all the incoming energy is transformed from the primary circuit to the magnetic field and into the secondary circuit. If this condition is met, the incoming electric power must equal the outgoing power.

$$P_{incoming} = I_P V_P = P_{outgoing} = I_S V_S$$

Giving the ideal transformer equation

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$$



$$P_{in\text{-}coming} = I_P V_P = P_{out\text{-}going} = I_S V_S$$

giving the ideal transformer equation

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$$

If the voltage is increased (stepped up) ($V_S > V_P$), then the current is decreased (stepped down) ($I_S < I_P$) by the same factor. Transformers are efficient so this formula is a reasonable approximation.

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The impedance in one circuit is transformed by the *square* of the turns ratio. For example, if an impedance Z_S is attached across the terminals of the secondary coil, it appears to the primary circuit to have an impedance of

$$Z_S\left(\frac{N_P}{N_S}\right)^2$$

This relationship is reciprocal, so that the impedance Z_P of the primary circuit appears to the secondary to be

$$Z_P\left(\frac{N_S}{N_P}\right)^2$$

Detailed operation

The simplified description above neglects several practical factors, in particular the primary current required to establish a magnetic field in the core, and the contribution to the field due to current in the secondary circuit.

Models of an ideal transformer typically assume a core of negligible reluctance with two windings of zero resistance. When a voltage is applied to the primary winding, a small current flows, driving flux around the magnetic circuit of the core. The current required to create the flux is termed the magnetizing current; since the ideal core has been assumed to have near-zero reluctance, the magnetizing current is negligible, although still required to create the magnetic field.

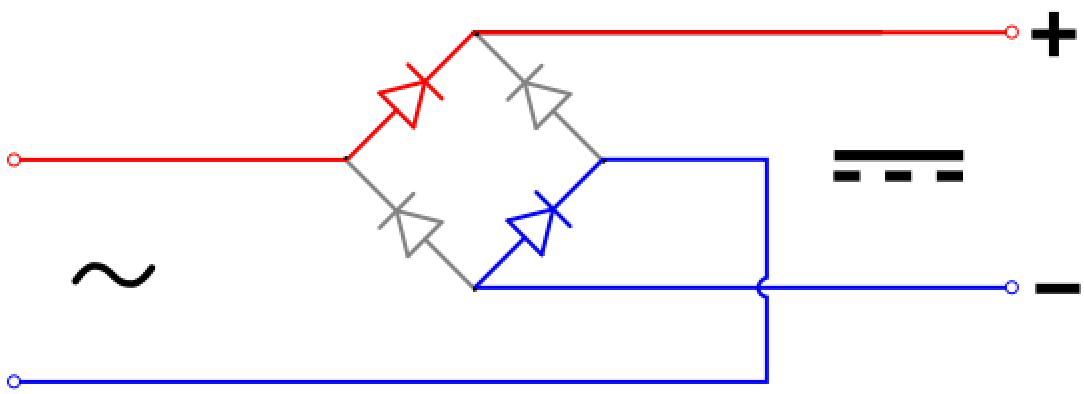
The changing magnetic field induces an electromotive force (EMF) across each winding. Since the ideal windings have no impedance, they have no associated voltage drop, and so the voltages V_P and V_S measured at the terminals of the transformer, are equal to the corresponding EMFs. The primary EMF, acting as it does in opposition to the primary voltage, is sometimes termed the "back EMF". This is due to Lenz's law which states that the induction of EMF would always be such that it will oppose development of any such change in magnetic field.

Bridge Rectifier

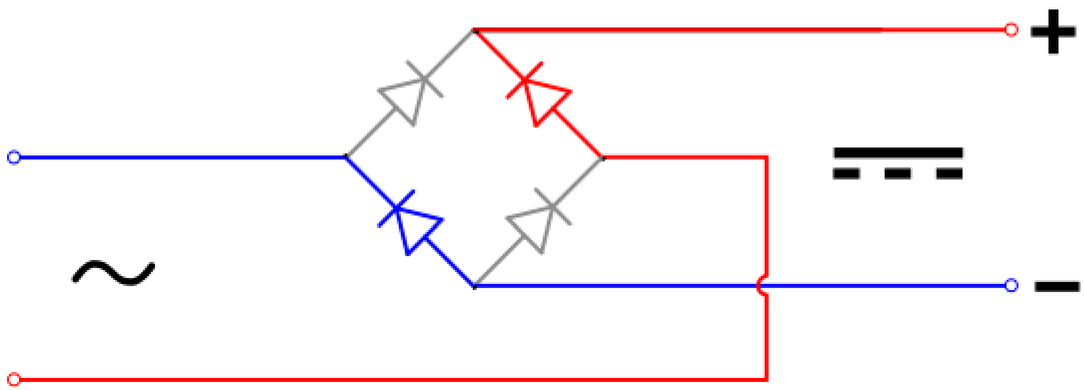
A diode bridge or bridge rectifier is an arrangement of four diodes in a bridge configuration that provides the same polarity of output voltage for any polarity of input voltage. When used in its most common application, for conversion of alternating current (AC) input into direct current (DC) output, it is known as a bridge rectifier. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a center-tapped transformer design, but has two diode drops rather than one, thus exhibiting reduced efficiency over a center-tapped design for the same output voltage.

Basic Operation

When the input connected at the left corner of the diamond is positive with respect to the one connected at the right hand corner, current flows to the right along the upper colored path to the output, and returns to the input supply via the lower one.



When the right hand corner is positive relative to the left hand corner, current flows along the upper colored path and returns to the supply via the lower colored path.



In each case, the upper right output remains positive with respect to the lower right one. Since this is true whether the input is AC or DC, this circuit not only produces DC power when supplied with AC power: it also can provide what is sometimes called "reverse polarity protection". That is, it permits normal functioning when batteries are installed backwards or DC input-power supply wiring "has its wires crossed" (and protects the circuitry it powers against damage that might occur without this circuit in place).

Prior to availability of integrated electronics, such a bridge rectifier was always constructed from discrete components. Since about 1950, a single four-terminal component containing the four diodes connected in the bridge configuration became a standard commercial component and is now available with various voltage and current ratings.

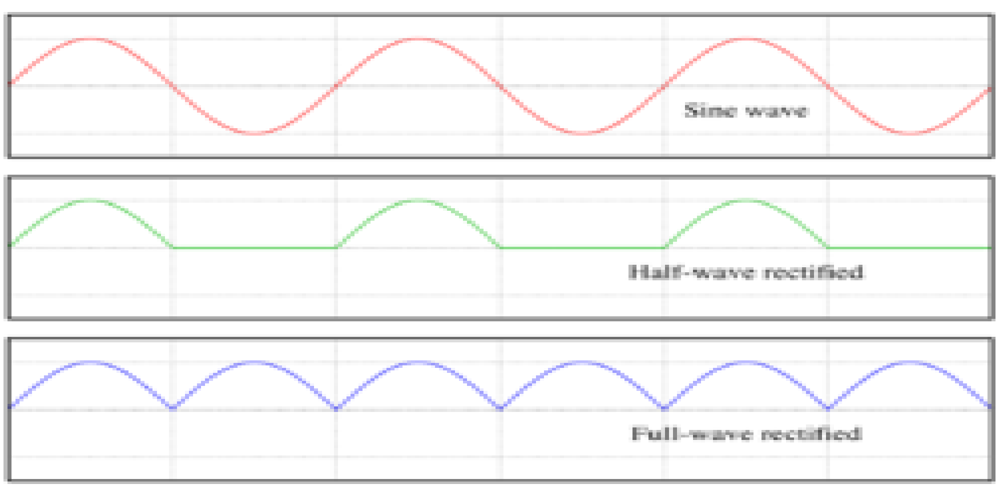
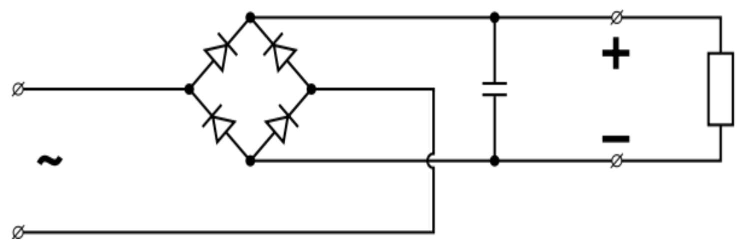


Figure: Output smoothing (Using Capacitor)

For many applications, especially with single phase AC where the full-wave bridge serves to convert an AC input into a DC output, the addition of a capacitor may be important because the bridge alone supplies an output voltage of fixed polarity but pulsating magnitude (see diagram above).



The function of this capacitor, known as a reservoir capacitor (aka smoothing capacitor) is to lessen the variation in (or 'smooth') the rectified AC output voltage waveform from the bridge. One explanation of 'smoothing' is that the capacitor provides a low impedance path to the AC component of the output, reducing the AC voltage across, and AC current through, the resistive load. In less technical terms, any drop in the output voltage and current of the bridge tends to be cancelled by loss of charge in the capacitor.

This charge flows out as additional current through the load. Thus the change of load current and voltage is reduced relative to what would occur without the capacitor. Increases of voltage correspondingly store excess charge in the capacitor, thus moderating the change in output voltage / current. Also see rectifier output smoothing.

The simplified circuit shown has a well deserved reputation for being dangerous, because, in some applications, the capacitor can retain a *lethal* charge after the AC power source is removed. If supplying a dangerous voltage, a practical circuit should include a reliable way to safely discharge the capacitor. If the normal load can not be guaranteed to perform this function, perhaps because it can be disconnected, the circuit should include a bleeder resistor connected as close as practical across the capacitor. This resistor should consume a current large enough to discharge the capacitor in a reasonable time, but small enough to avoid unnecessary power waste.

Because a bleeder sets a minimum current drain, the regulation of the circuit, defined as percentage voltage change from minimum to maximum load, is improved. However in many cases the improvement is of insignificant magnitude.

The capacitor and the load resistance have a typical time constant $\tau = RC$ where C and R are the capacitance and load resistance respectively. As long as the load resistor is large enough so that this time constant is much longer than the time of one ripple cycle, the above configuration will produce a smoothed DC voltage across the load.

In some designs, a series resistor at the load side of the capacitor is added. The smoothing can then be improved by adding additional stages of capacitor–resistor pairs, often done only for sub-supplies to critical high-gain circuits that tend to be sensitive to supply voltage noise.

The idealized waveforms shown above are seen for both voltage and current when the load on the bridge is resistive. When the load includes a smoothing capacitor, both the voltage and the current waveforms will be greatly changed. While the voltage is smoothed, as described above, current will flow through the bridge only during the time when the input voltage is greater than the capacitor voltage. For example, if the load draws an average current of n Amps, and the diodes conduct for 10% of the time, the average diode current during conduction must be 10n Amps. This non-sinusoidal current leads to harmonic distortion and a poor power factor in the AC supply.

In a practical circuit, when a capacitor is directly connected to the output of a bridge, the bridge diodes must be sized to withstand the current surge that occurs when the power is turned on at the peak of the AC voltage and the capacitor is fully discharged. Sometimes a small series resistor is included before the capacitor to limit this current, though in most applications the power supply transformer's resistance is already sufficient.

Output can also be smoothed using a choke and second capacitor. The choke tends to keep the current (rather than the voltage) more constant. Due to the relatively high cost of an effective choke compared to a resistor and capacitor this is not employed in modern equipment.

Some early console radios created the speaker's constant field with the current from the high voltage ("B +") power supply, which was then routed to the consuming circuits, (permanent magnets were considered too weak for good performance) to create the speaker's constant magnetic field. The speaker field coil thus performed 2 jobs in one: it acted as a choke, filtering the power supply, and it produced the magnetic field to operate the speaker.

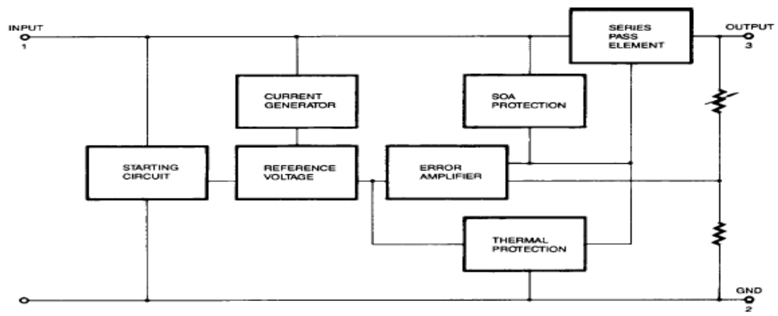
Voltage Regulator

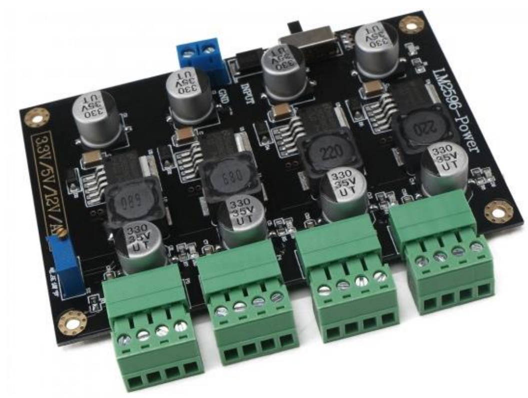
A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level.

The 78xx (also sometimes known as LM78xx) series of devices is a family of self-contained fixed linear voltage regulator integrated circuits. The 78xx family is a very popular choice for many electronic circuits which require a regulated power supply, due to their ease of use and relative cheapness. When specifying individual ICs within this family, the xx is replaced with a two-digit number, which indicates the output voltage the particular device is designed to provide (for example, the 7805 has a 5 volt output, while the 7812 produces 12 volts). The 78xx line is positive voltage regulators, meaning that they are designed to produce a voltage that is positive relative to a common ground. There is a related line of 79xx devices which are complementary negative voltage regulators. 78xx and 79xx ICs can be used in combination to provide both positive and negative supply voltages in the same circuit, if necessary.

78xx ICs have three terminals and are most commonly found in the TO220 form factor, although smaller surface-mount and larger TrO3 packages are also available from some manufacturers. These devices typically support an input voltage which can be anywhere from a couple of volts over the intended output voltage, up to a maximum of 35 or 40 volts, and can typically provide up to around 1 or 1.5 amps of current (though smaller or larger packages may have a lower or higher current rating).

Internal Block Digram

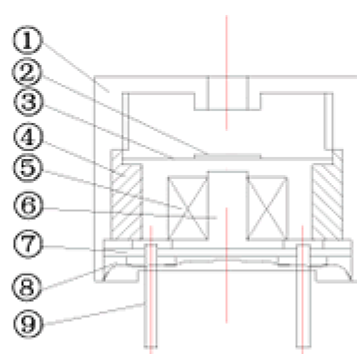




Buzzer

Magnetic Transducer

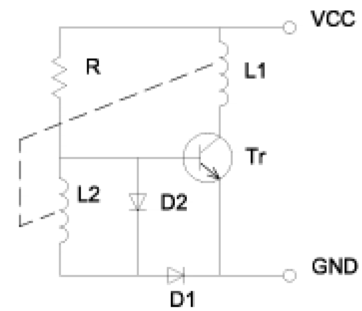
Magnetic transducers contain a magnetic circuit consisting of a iron core with a wound coil and a yoke plate, a permanent magnet and a vibrating diaphragm with a movable iron piece. The diaphragm is slightly pulled towards the top of the core by the magnet's magnetic field. When a positive AC signal is applied, the current flowing through the excitation coil produces a fluctuating

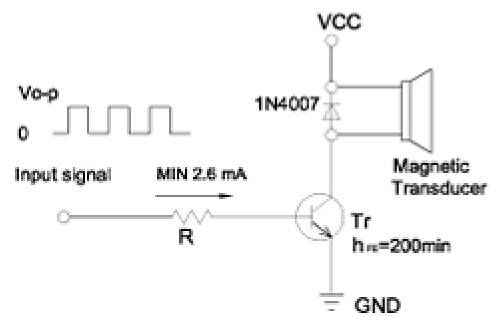


magnetic field, which causes the diaphragm to vibrate up and down, thus vibrating air. Resonance amplifies vibration through resonator consisting of sound hole(s) and cavity and produces a loud sound.

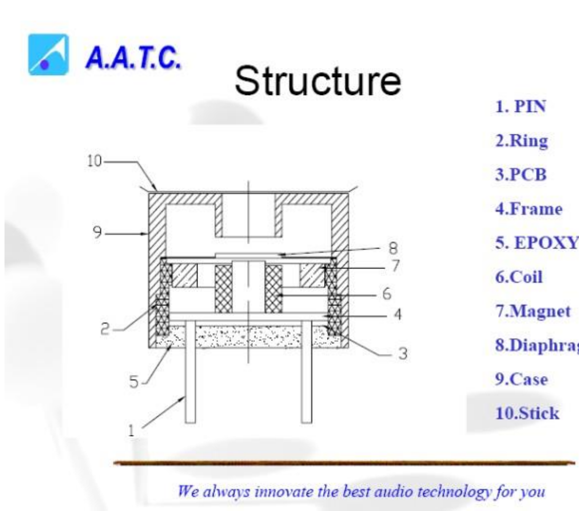
Magnetic Buzzer (Sounder)

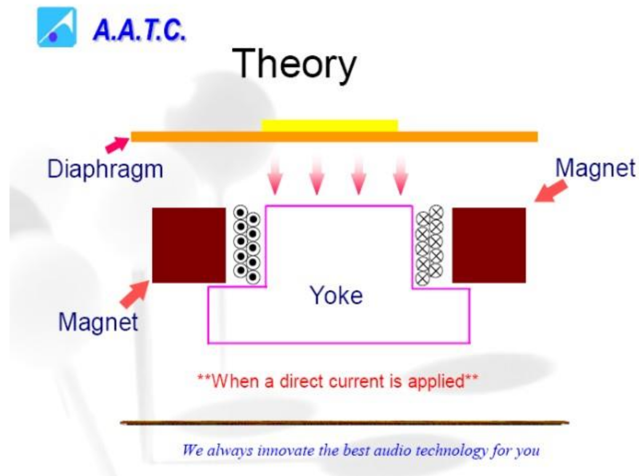
Buzzers like the TMB-series are magnetic audible signal devices with built-in oscillating circuits. The construction combines an oscillation circuit unit with a detection coil, a drive coil and a magnetic transducer. Transistors, resistors, diodes and other small devices act as circuit devices for driving sound generators. With the application of voltage, current flows to the drive coil on primary side and to the detection coil on the secondary side. The amplification circuit, including the transistor and the feedback circuit, causes vibration. The oscillation current excites the coil and the unit generates an AC magnetic field corresponding to an oscillation frequency. This AC magnetic field magnetizes the yoke comprising the magnetic circuit. The oscillation from the intermittent magnetization prompts the vibration diaphragm to vibrate up and down, generating buzzer sounds through the resonator.



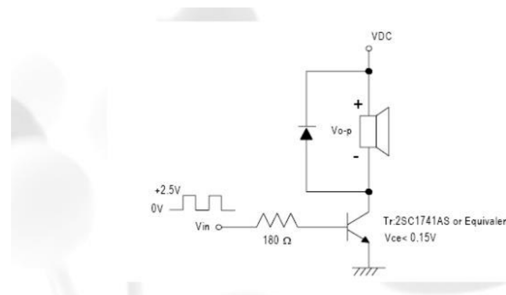


Recommended Driving Circuit for Magnetic Transducer Introduction of Magnetic Buzzer (Transducer)





Specifications:



Rated Voltage: A magnetic buzzer is driven by 1/2 square waves (V o-p).

Operating Voltage: For normal operating. But it is not guaranteed to make the minimum Sound Pressure Level (SPL) under the rated voltage.

Consumption Current: The current is stably consumed under the regular operation. However, it normally takes three times of current at the moment of starting to work.

Direct Current Resistance: The direct current resistance is measured by ammeter directly.

Sound Output: The sound output is measured by decibel meter. Applying rated voltage and 1/2 square waves, and the distance of 10 cm.

Rated Frequency: A buzzer can make sound on any frequencies, but we suggest that the highest and the most stable SPL comes from the rated frequency.

Operating Temp. : Keep working well between -30℃ and +70℃.

How to choose:

Driving methods: AX series with built drive circuit will be the best choice when we cannot provide frequency signal to a buzzer, it only needs direct current.

Dimension: Dimension affects frequency, small size result in high frequency.

Voltage: Depend on V o-p (1/2 square waves)

Fixed methods: From the highest cost to the lowest- DIP, wires/ connector, SMD.
Soldering methods: AS series is soldered by hand, the frequency is lower because of the holes on the bottom. On the other hand, we suggest AC series for the reflow soldering, the reliability is better.

How to choose a buzzer

There are many different kinds of buzzer to choose, first we need to know a few parameters, such as voltage, current, drive method, dimension, mounting type, and the most important thing is how much SPL and frequency we want.

Operating voltage: Normally, the operating voltage for a magnetic buzzer is from 1.5V to 24V, for a piezo buzzer is from 3V to 220V. However, in order to get enough SPL, we suggest giving at least 9V to drive a piezo buzzer.

Consumption current: According to the different voltage, the consumption current of a magnetic buzzer is from dozens to hundreds of mill amperes; oppositely, the piezo type saves much more electricity, only needs a few mill amperes, and consumes three times current when the buzzer start to work.

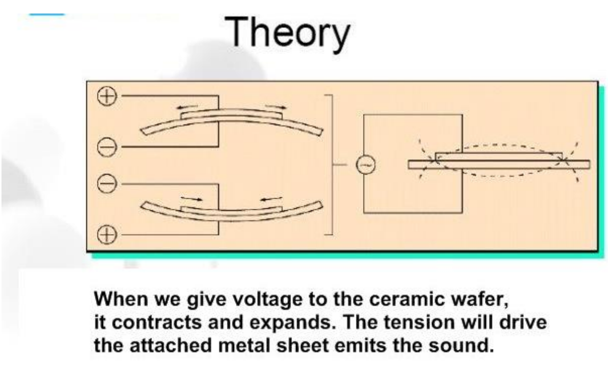
Driving method: Both magnetic and piezo buzzer have self drive type to choose. Because of the internal set drive circuit, the self drive buzzer can emit sound as long as connecting with the direct current. Due to the different work principle, the magnetic buzzer need to be driven by 1/2 square waves, and the piezo buzzer need square waves to get better sound output.

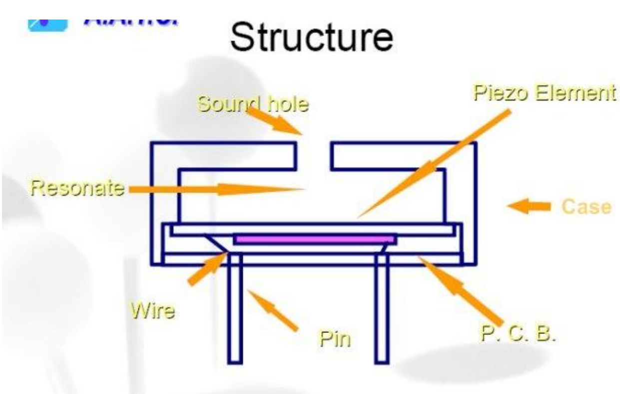
Dimension: The dimension of the buzzer affects its SPL and the frequency, the dimension of the magnetic buzzer is from 7 mm to 25 mm; the piezo buzzer is from 12 mm to 50 mm, or even bigger.

Connecting way: Dip type, Wire type, SMD type, and screwed type for big piezo buzzer are usuallyseen.

Sound Pressure Level (SPL): Buzzer is usually tested the SPL at the distance of 10 cm, if distance double, the SPL will decay about 6 dB; oppositely, the SPL will increase 6 dB when the distance is shortened by one time. The SPL of the magnetic buzzer can reach to around 85 dB/ 10 cm; the piezo buzzer can be designed to emit very loud sound, for example, the common siren, are mostly made of piezo buzzer.

Introduction of Piezo Buzzer





Specifications:

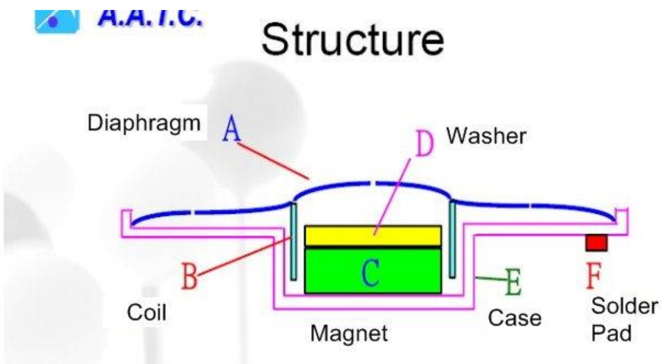
Rated Voltage: A piezo buzzer is driven by square waves (V p-p).
Operating Voltage: For normal operating. But it is not guaranteed to make the minimum SPL under the rated voltage.
Consumption Current: The current is stably consumed under the regular operation. However, it normally takes three times of current at the moment of starting to work.
Capacitance: A piezo buzzer can make higher SPL with higher capacitance, but it consumes more electricity.
Sound Output: The sound output is measured by decibel meter. Applying rated voltage and square waves, and the distance of 10 cm.
Rated Frequency: A buzzer can make sound on any frequencies, but we suggest that the highest and the most stable SPL comes from the rated frequency.

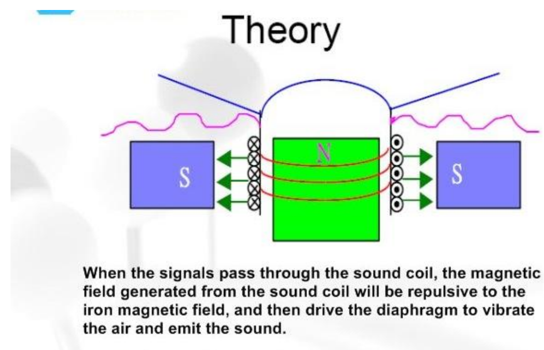
Operating Temp.: Keep working well between -30℃ and +70℃.

How to choose:

Driving methods: AZ-x S-x series with built drive circuit will be the best choice when we cannot provide frequency signal to a buzzer, it only needs direct current. Besides, there are different tone nature for you to choose, such as continuous, fast pulse, and slow pulse.
Dimension: Dimension affects frequency, small size result in high frequency.
Voltage: Driven by square waves (V p-p), the higher voltage results in the higher SPL.
Pin Pitch: The numerous spec. for the piezo buzzers lead to the difficulty in finding a spec. in facsimile, therefore we suggest that you can firstly choose a spec. with the same pitch and similar frequency.

Introduction of Micro Speaker





How to choose:

The factors which affect the SPL: the square measure of diaphragm, the amplitude of vibration, magnetic field intensity, power, impedance, resonant chamber, the pattern and the thickness of diaphragm, and the holes.
Power vs. SPL: Suppose all the conditions are the same, increasing the power dose not mean the SPL will increase as well. We need to revise the diaphragm and the sound coil to load the higher power, but it leads to lower SPL instead.
Dimension vs. SPL: A larger speaker can vibrate more air, therefore it provides higher SPL. In addition, the thicker speaker can give wider amplitude of vibration which also leads to higher SPL.
Acoustics: What we request most is how much SPL a micro speaker can output.
Matching: It will be better to provide the power slight higher than the rated power for the enlarged circuit.

Question for mechanism:

The volume of the resonant chamber: The general problem of the consuming products is that the resonant chambers are not big enough. We can only try to find space to enlarge the volume of the resonant chamber.

Sound Hole: Must be more than 1/8 of the diaphragm’s area at least.

Airtight: The front and back sound fields of the speaker should be separated to avoid neutralization.

Shock absorber: When a speaker works the vibration will also happen at the same time. In order to reduce interference, it will do good to have some material between speaker and case to absorb the shock.

Mounting: The speakers are usually fixed on the case. Firmly fixed is important especially for the iron housing or the large size to avoid separating in the drop test.

How to choose the speaker

Dimension: To the micro speaker, size has decisive influence on its volume. 5mm difference of diameter might result in double or half area of diaphragm, therefore the SPL is quite different. Besides, the thicker speaker has more space to vibrate the air, and usually has bigger magnet, so it will be more powerful to push the air and emit louder sound.

Power: Mainly refer to how much power can a speaker bear, there is no direct relation to the SPL. The speaker with larger power needs to use thicker diaphragm and sound coil to bear larger power, which will lead to lower efficiency (SPL). Therefore, according to the mechanical design, try to select a larger speaker which matches the outputting power from the amplified circuit, then the best SPL would be emitted.

Impedance: Higher impedance can save more electricity, however, the SPL and the loaded power will go down. The reason is that we have to use thinner wire or to coil more, the front makes the power lower, and the after leads to heaviness and low efficiency.

The material of diaphragm: Most speakers (diameter less than 50mm) use mylar diaphragms, which are easily finished, cheaper and waterproof. However, mylar diaphragm is not good at heatproof and the sound is stiff.

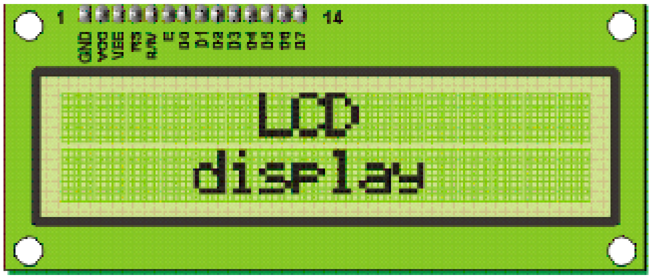
The patterns of diaphragm: The speaker with concentric circles diaphragm is good for the speech sounds. Generally, the SPL is good at the frequency before 5-6 KHz, but will dramatically decrease after 6 KHz. On the other hand, the speaker with radiate diaphragm has average frequency response. Supposing other conditions are all the same, the SPL of radiate diaphragm will lower than the concentric circles one at the frequency before 6 KHz.

LIQUID CRYSTAL DISPLAY:

LCD stands for **L**iquid **C**rystal **D**isplay. LCD is finding wide spread use replacing LEDs (seven segment LEDs or other multi segment LEDs) because of the following reasons:

1. The declining prices of LCDs.
2. The ability to display numbers, characters and graphics. This is in contrast to LEDs, which are limited to numbers and a few characters.
3. Incorporation of a refreshing controller into the LCD, thereby relieving the CPU of the task of refreshing the LCD. In contrast, the LED must be refreshed by the CPU to keep displaying the data.
4. Ease of programming for characters and graphics.

These components are “specialized” for being used with the microcontrollers, which means that they cannot be activated by standard IC circuits. They are used for writing different messages on a miniature LCD.



A model described here is for its low price and great possibilities most frequently used in practice. It is based on the HD44780 microcontroller (*Hitachi*) and can display messages in two lines with 16 characters each. It displays all the alphabets, Greek letters, punctuation marks, mathematical symbols etc. In addition, it is possible to display symbols that user makes up on its own.

Automatic shifting message on display (shift left and right), appearance of the pointer, backlight etc. are considered as useful characteristics.

Pins Functions

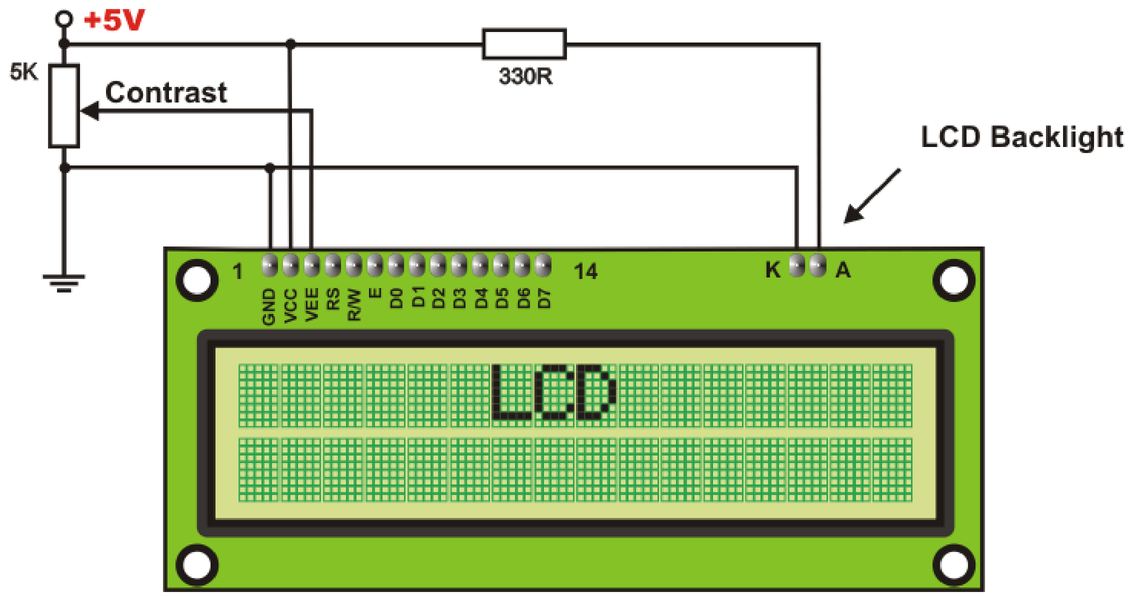
There are pins along one side of the small printed board used for connection to the microcontroller. There are total of 14 pins marked with numbers (16 in case the background light is built in). Their function is described in the table below:

Function	**Pin Number**	**Name**	**Logic State**	**Description**
Ground	1	Vss	-	0V
Power supply	2	Vdd	-	+5V
Contrast	3	Vee	-	0 – Vdd
Control of operating	4	RS	0 1	D0 – D7 are interpreted as commands D0 – D7 are interpreted as data
Control of operating	4	RS	0 1	D0 – D7 are interpreted as commands D0 – D7 are interpreted as data
	5	R/W	0	Write data (from controller to

			1	LCD) Read data (from LCD to controller)
	6	E	0 1 From 1 to 0	Access to LCD disabled Normal operating Data/commands are transferred to LCD
Data / commands	7	D0	0/1	Bit 0 LSB
	8	D1	0/1	Bit 1
	9	D2	0/1	Bit 2
	10	D3	0/1	Bit 3
	11	D4	0/1	Bit 4
	12	D5	0/1	Bit 5
	13	D6	0/1	Bit 6
	14	D7	0/1	Bit 7 MSB

LCD screen:

LCD screen consists of two lines with 16 characters each. Each character consists of 5x7 dot matrix. Contrast on display depends on the power supply voltage and whether messages are displayed in one or two lines. For that reason, variable voltage 0-Vdd is applied on pin marked as Vee. Trimmer potentiometer is usually used for that purpose. Some versions of displays have built in backlight (blue or green diodes). When used during operating, a resistor for current limitation should be used (like with any LE diode).



LCD Basic Commands

All data transferred to LCD through outputs D0-D7 will be interpreted as commands or as data, which depends on logic state on pin RS:

RS = 1 - Bits D0 - D7 are addresses of characters that should be displayed. Built in processor addresses built in "map of characters" and displays corresponding symbols. Displaying position is determined by DDRAM address. This address is either previously defined or the address of previously transferred character is automatically incremented.

RS = 0 - Bits D0 - D7 are commands which determine display mode. List of commands which LCD recognizes are given in the table below**:**

Command	**RS**	**RW**	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**	**Execution Time**
Clear display	0	0	0	0	0	0	0	0	0	1	1.64Ms
Cursor home	0	0	0	0	0	0	0	0	1	x	1.64mS

Entry mode set	0	0	0	0	0	0	0	1	I/D	S	40uS
Display on/off control	0	0	0	0	0	0	1	D	U	B	40uS
Cursor/Display Shift	0	0	0	0	0	1	D/C	R/L	x	x	40uS
Function set	0	0	0	0	1	DL	N	F	x	x	40uS
Set CGRAM address	0	0	0	1	CGRAM address						40uS
Set DDRAM address	0	0	1	DDRAM address							40uS
Read “BUSY” flag (BF)	0	1	BF	DDRAM address							-
Write to CGRAM or DDRAM	1	0	D7	D6	D5	D4	D3	D2	D1	D0	40uS
Read from CGRAM or DDRAM	1	1	D7	D6	D5	D4	D3	D2	D1	D0	40uS

I/D 1 = Increment (by 1)

0 = Decrement (by 1)

S 1 = Display shift on

0 = Display shift off

D 1 = Display on

0 = Display off

U 1 = Cursor on

0 = Cursor off

B 1 = Cursor blink on

R/L 1 = Shift right

0 = Shift left

DL 1 = 8-bit interface

0 = 4-bit interface

N 1 = Display in two lines

0 = Display in one line

F 1 = Character format 5x10 dots

0 = Character format 5x7 dots

D/C 1 = Display shift

0 = Cursor blink off 0 = Cursor shift

LCD Connection

Depending on how many lines are used for connection to the microcontroller, there are 8-bit and 4-bit LCD modes. The appropriate mode is determined at the beginning of the process in a phase called “initialization”. In the first case, the data are transferred through outputs D0-D7 as it has been already explained. In case of 4-bit LED mode, for the sake of saving valuable I/O pins of the microcontroller, there are only 4 higher bits (D4-D7) used for communication, while other may be left unconnected.

Consequently, each data is sent to LCD in two steps: four higher bits are sent first (that normally would be sent through lines D4-D7), four lower bits are sent afterwards. With the help of initialization, LCD will correctly connect and interpret each data received. Besides, with regards to the fact that data are rarely read from LCD (data mainly are transferred from microcontroller to LCD) one more I/O pin may be saved by simple connecting R/W pin to the Ground. Such saving has its price.

Even though message displaying will be normally performed, it will not be possible to read from busy flag since it is not possible to read from display.

LCD Initialization

Once the power supply is turned on, LCD is automatically cleared. This process lasts for approximately 15mS. After that, display is ready to operate. The mode of operating is set by default. This means that:

1. Display is cleared

2. Mode

DL = 1 Communication through 8-bit interface

N = 0 Messages are displayed in one line

F = 0 Character font 5 x 8 dots

3. Display/Cursor on/off

D = 0 Display off

U = 0 Cursor off

B = 0 Cursor blink off

4. Character entry

ID = 1 Addresses on display are automatically incremented by 1

S = 0 Display shift off

Automatic reset is mainly performed without any problems. If for any reason power supply voltage does not reach full value in the course of 10mS, display will start perform completely un predictably.

If voltage supply unit cannot meet this condition or if it is needed to provide completely safe operating, the process of initialization by which a new reset enabling display to operate normally must be applied.

Algorithm according to the initialization is being performed depends on whether connection to the microcontroller is through 4- or 8-bit interface. All left over to be done after that is to give basic commands and of course- to display messages.

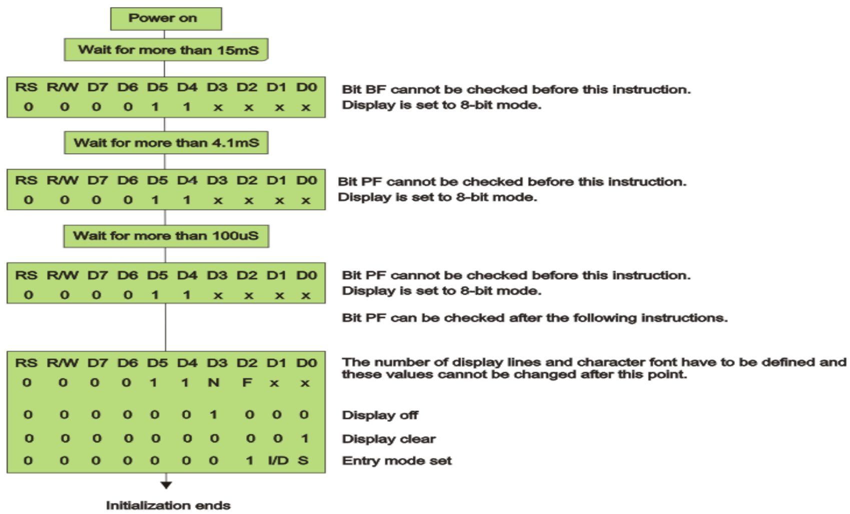
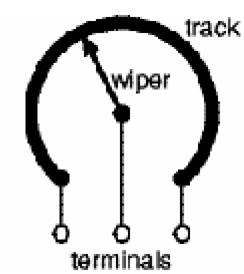


Fig: Procedure on 8-bit initialization

Contrast control:

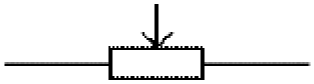
To have a clear view of the characters on the LCD, contrast should be adjusted. To adjust the contrast, the voltage should be varied. For this, a preset is used which can behave like a variable voltage device. As the voltage of this preset is varied, the contrast of the LCD can be adjusted.



Variable resistor

Potentiometer

Variable resistors used as potentiometers have all **three terminals** connected. This arrangement is normally used to **vary voltage**, for example to set the switching point of a circuit with a sensor, or control the volume (loudness) in an amplifier circuit. If the terminals at the ends of the track are connected across the power supply, then the wiper terminal will provide a voltage which can be varied from zero up to the maximum of the supply.



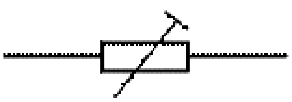
Potentiometer Symbol

Presets

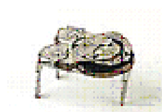
These are miniature versions of the standard variable resistor. They are designed to be mounted directly onto the circuit board and adjusted only when the circuit is built. For example, to set the frequency of an alarm tone or the sensitivity of a light-sensitive circuit, a small screwdriver or similar tool is required to adjust presets.

Presets are much cheaper than standard variable resistors so they are sometimes used in projects where a standard variable resistor would normally be used.

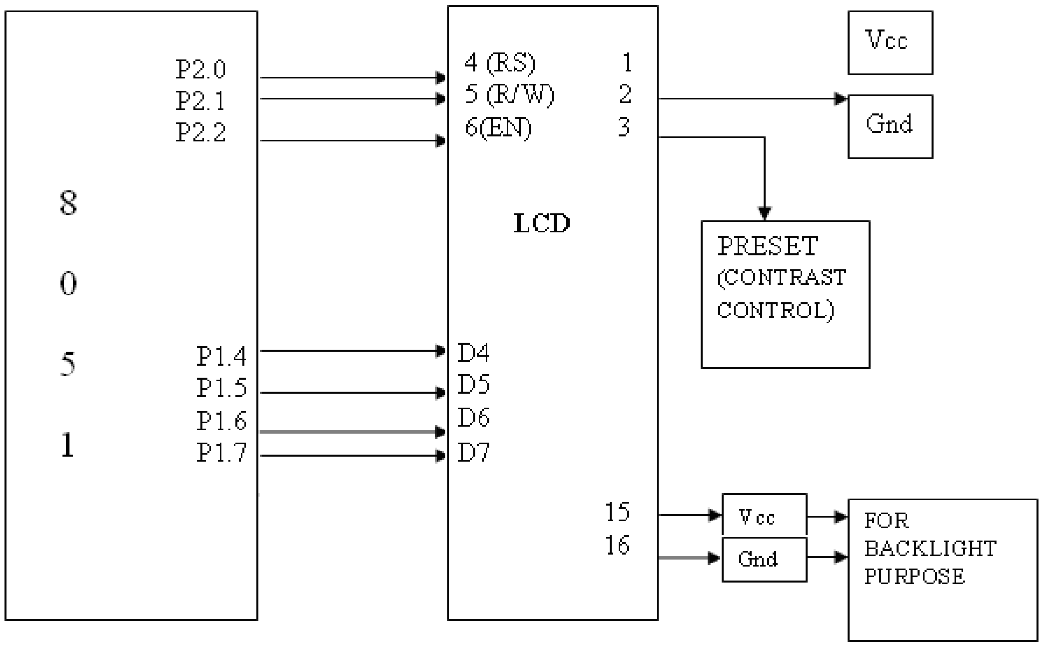
Multiturn presets are used where very precise adjustments must be made. The screw must be turned many times (10+) to move the slider from one end of the track to the other, giving very fine control.



Preset Symbol



LCD interface with the microcontroller (4-bit mode):



MEMS

Introduction to MEMS

Micro electro mechanical systems (MEMS) are small integrated devices or systems that combine electrical and mechanical components. Their size range from the sub micrometer (or sub micron) level to the millimeter level and there can be any number, from a few to millions, in a particular system. MEMS extend the fabrication techniques developed for the integrated circuit industry to add mechanical elements such as beams, gears, diaphragms, and springs to devices. Examples of MEMS device applications include inkjet-printer cartridges, accelerometers, miniature robots, microengines, locks, inertial sensors, micro transmissions, micromirrors, micro actuators, optical scanners, fluid pumps, transducers and chemical, pressure and flow sensors. Many new applications are emerging as the existing technology is applied to the miniaturization and integration of conventional devices.

These systems can sense, control and activate mechanical processes on the micro scale and function individually or in arrays to generate effects on the macro scale. The micro fabrication technology enables fabrication of large arrays of devices, which individually perform simple tasks, but in combination can accomplish complicated functions.

MEMS are not about any one application or device, or they are not defined by a single fabrication process or limited to a few materials. They are a fabrication approach that conveys the advantages of miniaturization, multiple components and microelectronics to the design and construction of integrated electromechanical systems. MEMS are not only about miniaturization of mechanical systems but they are also a new pattern for designing mechanical devices and systems.

Fabrication Technologies

The three characteristic features of MEMS fabrication technologies are miniaturization, multiplicity, and microelectronics. Miniaturization enables the production of compact, quick response devices. Multiplicity refers to the batch fabrication inherent in semiconductor processing, which allows thousands or millions of components to be easily and concurrently fabricated. Microelectronics provides the intelligence to MEMS and allows the monolithic merger of sensors, actuators, and logic to build closed-loop feedback components and systems.

The successful miniaturization and multiplicity of traditional electronics systems would not have been possible without IC fabrication technology. Therefore, IC fabrication technology, or microfabrication, has so far been the primary enabling technology for the development of MEMS. Microfabrication provides a powerful tool for batch processing and miniaturization of mechanical systems into a dimensional domain not accessible by conventional (machining) techniques. Furthermore, microfabrication provides an opportunity for integration of mechanical systems with electronics to develop high-performance closed-loop-controlled MEMS.

Advances in IC technology in the last decade have brought about corresponding progress in MEMS fabrication processes. Manufacturing processes allow for the monolithic integration of microelectromechanical structures with driving, controlling, and signal-processing electronics. This integration promises to improve the performance of micromechanical devices as well as reduce the cost of manufacturing, packaging and instrumenting these devices.

A. IC Fabrication

Any discussion of MEMS requires a basic understanding of IC fabrication technology, or microfabrication, the primary enabling technology for the development of MEMS. The major steps in IC fabrication technology are film growth, doping, lithography, etching, dicing, and packaging.

Film growth: Usually, a polished Si wafer is used as the substrate, on which a thin film is grown. The film, which may be epitaxial Si, $SiO2$, silicon nitride ($Si3N4$), polycrystalline Si (polysilicon), or metal, is used to build both active or passive components and interconnections between circuits.

Doping: To modulate the properties of the device layer, a low and controllable level of an atomic impurity may be introduced into the layer by thermal diffusion or ion implantation.

Lithography: A pattern on a mask is then transferred to the film by means of a photosensitive (i.e., light sensitive) chemical known as a photoresist. The process of pattern generation and transfer is called photolithography. A typical mask consists of a glass plate coated with a patterned chromium (Cr) film.

Etching: Next is the selective removal of unwanted regions of a film or substrate for pattern delineation. Wet chemical etching or dry etching may be used. Etch-mask materials are used at various stages in the removal process to selectively prevent those portions of the material from being etched. These materials include SiO_2, Si_3N_4, and hard-baked photoresist.

Dicing: The finished wafer is sawed or machined into small squares, or dice, from which electronic components can be made.

Packaging: The individual sections are then packaged, a process that involves physically locating, connecting, and protecting a device or component. MEMS design is strongly coupled to the packaging requirements, which in turn are dictated by the application environment.

B. Bulk Micromachining and Wafer Bonding

Bulk micromachining is an extension of IC technology for the fabrication of 3D structures. Bulk micromachining of Si uses wet- and dry-etching techniques in conjunction with etch masks and etch stops to sculpt micromechanical devices from the Si substrate. The two key capabilities that make bulk micromachining a viable technology are:

1) Anisotropic etchants of Si, such as ethylene-diamine and pyrocatechol (EDP), potassium hydroxide (KOH), and hydrazine (N_2H_4). These preferentially etch single crystal Si along given crystal planes.

2) Etch masks and etch-stop techniques that can be used with Si anisotropic etchants to selectively prevent regions of Si from being etched. Good etch masks are provided by SiO_2 and Si_3N_4, and some metallic thin films such as Cr and Au (gold).

A drawback of wet anisotropic etching is that the microstructure geometry is defined by the internal crystalline structure of the substrate. Consequently, fabricating multiple, interconnected micromechanical structures of free-form geometry is often difficult or impossible. Two additional processing techniques have extended the range of traditional bulk micromachining technology: deep anisotropic dry etching and wafer bonding. Reactive gas plasmas can perform deep anisotropic dry etching of Si wafers, up to a depth of a few hundred microns, while maintaining smooth vertical sidewall profiles. The other technology, wafer bonding, permits a Si substrate to be attached to another substrate, typically Si or glass. Used in combination, anisotropic etching and wafer bonding techniques can construct 3D complex microstructures such as microvalves and micropumps.

C. Surface Micromachining

Surface micromachining enables the fabrication of complex multicomponent integrated micromechanical structures that would not be possible with traditional bulk micromachining. This technique encases specific structural parts of a device in layers of a sacrificial material during the fabrication process. The substrate wafer is used primarily as a mechanical support on which multiple alternating layers of structural and sacrificial material are deposited and patterned to realize micromechanical structures. The sacrificial material is then dissolved in a chemical etchant that does not attack the structural parts. The most widely used surface micromachining technique, polysilicon surface micromachining, uses SiO2 as the sacrificial material and polysilicon as the structural material.

At the University of Wisconsin at Madison, polysilicon surface micromachining research started in the early 1980s in an effort to create high-precision micro pressure sensors. The control of the internal stresses of a thin film is important for the fabrication of microelectromechanical structures. The microelectronic fabrication industry typically grows polysilicon, silicon nitride, and silicon dioxide films using recipes that minimize time. Unfortunately, a deposition process that is optimized to speed does not always create a low internal stress film. In fact, most of these films have internal stresses that are highly compressive (tending to contract). A freestanding plate of highly compressive polysilicon that is held at all its edges will buckle (i.e., collapse or give way). This is highly undesirable. The solution is to modify the film deposition process to control the internal stress by making it stress-free or slightly tensile.

One way to do this is to dope the film with boron, phosphorus, or arsenic. However, a doped polysilicon film is conductive, and this property may interfere with the mechanical devices incorporated electronics. Another problem with doped polysilicon is that it is roughened by hydrofluoric acid (HF), which is commonly used to free sections of the final mechanical device from the substrate. Rough polysilicon has different mechanical properties than smooth polysilicon. Therefore, the amount of roughening must be taken into account when designing the mechanical parts of the micro device.

A better way to control the stress in polysilicon is through post annealing, which involves the deposition of pure, fine-grained, compressive (i.e., can be compressed) polysilicon. Annealing the polysilicon after deposition at elevated temperatures can change the film to be stress-free or tensile. The annealing temperature sets the film's final stress. After this, electronics can then be incorporated into polysilicon films through selective doping, and hydrofluoric acid will not change the mechanical properties of the material.

Deposition temperature and the film's silicon to nitride ratio can control the stress of a silicon nitride (Si_3N_4) film. The films can be deposited in compression, stress-free, or in tension. Deposition temperature and post annealing can control silicon dioxide (SiO_2) film stress. Because it is difficult to control the stress of SiO_2 accurately, SiO_2 is typically not used as a mechanical material by itself, but as electronic isolation or as a sacrificial layer under polysilicon.

D. Micromolding

In the micromolding process, microstructures are fabricated using molds to define the deposition of the structural layer. The structural material is deposited only in those areas constituting the microdevice structure, in contrast to bulk and surface micromachining, which feature blanket deposition of the structural material followed by etching to realize the final device geometry.

After the structural layer deposition, the mold is dissolved in a chemical etchant that does not attack the structural material. One of the most prominent micromolding processes is the LIGA process. LIGA is a German acronym standing for lithography, galvanoformung and abformung (lithography, electroplating and molding). This process can be used for the manufacture of high aspect ratio 3D microstructures in a wide variety of materials, such as metals, polymers, ceramics, and glasses. Photosensitive polyimides are also used for fabricating plating molds. The photolithography process is similar to conventional photolithography, except that polyimide works as a negative resist.

IV. Applications of MEMS

Here are some examples of MEMS technology:

A. Pressure Sensors

MEMS pressure micro sensors typically have a flexible diaphragm that deforms in the presence of a pressure difference. The deformation is converted to an electrical signal appearing at the sensor output. A pressure sensor can be used to sense the absolute air pressure within the intake manifold of an automobile engine, so that the amount of fuel required for each engine cylinder can be computed. In this example, piezo resistors are patterned across the edges of a region where a silicon diaphragm will be micro machined. The substrate is etched to create the diaphragm. The sensor die is then bonded to a glass substrate, creating a sealed vacuum cavity under the diaphragm. The die is mounted on a package, where the topside of the diaphragm is exposed to the environment. The change in ambient pressure forces the downward deformation of the diaphragm, resulting in a change of resistance of the piezo resistors. On-chip electronics measure the resistance change, which causes a corresponding voltage signal to appear at the output pin of the sensor package.

B. Accelerometers

Accelerometers are acceleration sensors. An inertial mass suspended by springs is acted upon by acceleration forces that cause the mass to be deflected from its initial position. This deflection is converted to an electrical signal, which appears at the sensor output. The application of MEMS technology to accelerometers is a relatively new development.

One such accelerometer design is discussed by DeVoe and Pisano (2001). It is a surface micromachined piezoelectric accelerometer employing a zinc oxide (ZnO) active piezoelectric film. The design is a simple cantilever structure, in which the cantilever beam serves simultaneously as proof mass and sensing element. One of the fabrication approaches developed is a sacrificial oxide process based on polysilicon surface micromachining, with the addition of a piezoelectric layer atop the polysilicon film.

In the sacrificial oxide process, a passivation layer of silicon dioxide and low-stress silicon nitride is deposited on a bare silicon wafer, followed by 0.5 micron of liquid phase chemical vapor deposited (LPCVD) phosphorous-doped polysilicon. Then, a 2.0-micron layer of phosphosilicate glass (PSG) is deposited by LPCVD and patterned to define regions where the accelerometer structure will be anchored to the substrate. The PSG film acts as a sacrificial layer that is selectively etched at the end to free the mechanical structures. A second layer of 2.0-micron-thick phosphorus-doped polysilicon is deposited via LPCVD on top of the PSG, and patterned by plasma etching to define the mechanical accelerometer structure. This layer also acts as the lower electrode for the sensing film.

A thin layer of silicon nitride is next deposited by LPCVD, and acts as a stress-compensation layer for balancing the highly compressive residual stresses in the ZnO film. By varying the thickness of the Si3N4 layer, the accelerometer structure may be tuned to control bending effects resulting from the stress gradient through the device thickness. A ZnO layer is then deposited on the order of 0.5 micron, followed by sputtering of a 0.2-micron layer of platinum (Pt) deposited to form the upper electrode. A rapid thermal anneal is performed to reduce residual stresses in the sensing film. Afterwards, the Pt, Si3N4, and ZnO layers are patterned in a single ion milling etch step, and the devices are then released by passivating the ZnO film with photoresist, and immersing the wafer in buffered hydrofluoric acid, which removes the sacrificial PSG layer [8].

C. Inertial Sensors

Inertial sensors are a type of accelerometer and are one of the principal commercial products that utilize surface micromachining. They are used as airbag-deployment sensors in automobiles, and as tilt or shock sensors. The application of these accelerometers to inertial measurement units (IMUs) is limited by the need to manually align and assemble them into three-axis systems, and by the resulting alignment tolerances, their lack of in-chip analog-to-digital conversion circuitry, and their lower limit of sensitivity. A three-axis force-balanced accelerometer has been designed at the University of California, Berkeley, to overcome some of these limitations. The accelerometer was designed for the integrated MEMS/CMOS technology. This technology involves a manufacturing technique where a single-level (plus a second electrical interconnect level) poly silicon micromachining process is integrated with 1.25-micron CMOS.

D. Micro engines

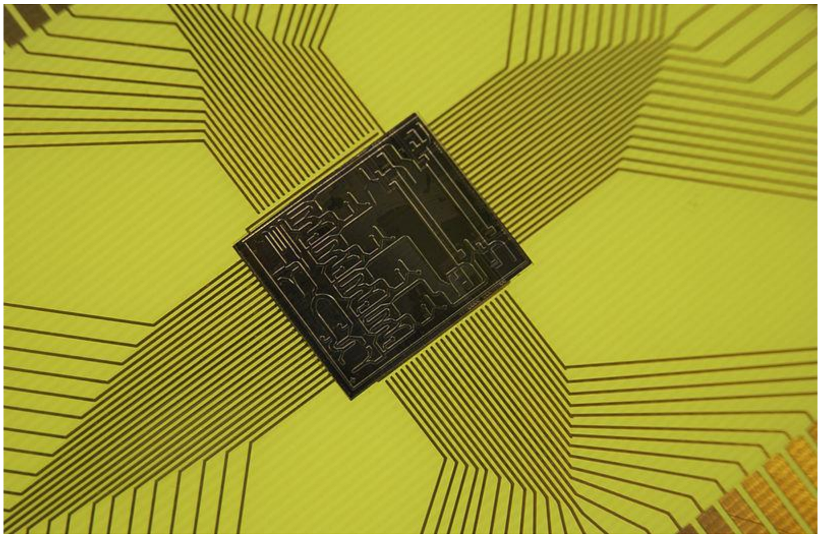
A three-level poly silicon micromachining process has enabled the fabrication of devices with increased degrees of complexity. The process includes three movable levels of poly silicon, each separated by a sacrificial oxide layer, plus a stationary level. Operation of the small gears at rotational speeds greater than 300,000 rpm has been demonstrated. Micro engines can be used to drive the wheels of micro combination locks. They can also be used in combination with a micro transmission to drive a pop-up mirror out of a plane. This device is known as a micro mirror.

As a final example, MEMS technology has been used in fabricating vaporization micro chambers for vaporizing liquid micro thrusters for Nano satellites. The chamber is part of a micro channel with a height of 2-10 microns, made using silicon and glass substrates. The nozzle is fabricated in the silicon substrate just above a thin-film indium tin oxide heater deposited on glass.

V. The Future

MEMS technology has the potential to change our daily lives as much as the computer has. However, the material needs of the MEMS field are at a preliminary stage. A thorough understanding of the properties of existing MEMS materials is just as important as the development of new MEMS materials.

Future MEMS applications will be driven by processes enabling greater functionality through higher levels of electronic-mechanical integration and greater numbers of mechanical components working alone or together to enable a complex action. Future MEMS products will demand higher levels of electrical-mechanical integration and more intimate interaction with the physical world. The high up-front investment costs for large-volume commercialization of MEMS will likely limit the initial involvement to larger companies in the IC industry. Advancing from their success as sensors, MEMS products will be embedded in larger non-MEMS systems, such as printers, automobiles, and biomedical diagnostic equipment, and will enable new and improved systems.

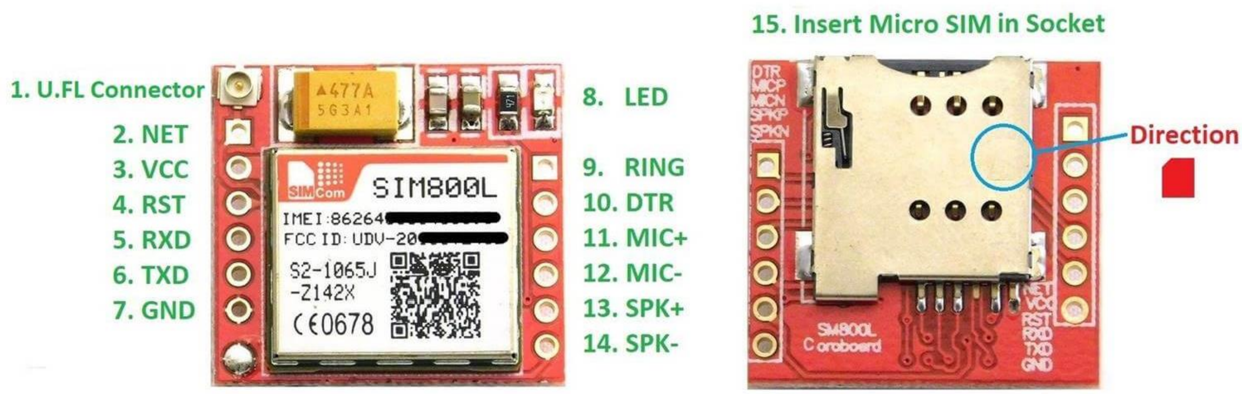


GSM MODULE

Definition of GSM:

GSM (Global System for Mobile communications) is an open, digital cellular technology used for transmitting mobile voice and data services.

GSM (Global System for Mobile communication) is a digital mobile telephone system that is widely used in Europe and other parts of the world. GSM uses a variation of Time Division Multiple Access (TDMA) and is the most widely used of the three digital wireless telephone technologies (TDMA, GSM, and CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1,800 MHz frequency band. It supports voice calls and data transfer speeds of up to 9.6 kbit/s, together with the transmission of SMS (Short Message Service).



History

In 1982, the European Conference of Postal and Telecommunications Administrations (CEPT) created the Group Special Mobile (GSM) to develop a standard for a mobile telephone system that could be used across Europe. In 1987, a memorandum of understanding was signed by 13 countries to develop a common cellular telephone system across Europe. Finally the system created by SINTEF lead by Torleiv Maseng was selected.

In 1989, GSM responsibility was transferred to the European Telecommunications Standards Institute (ETSI) and phase I of the GSM specifications were published in 1990. The first GSM network was launched in 1991 by Radiolinja in Finland with joint technical infrastructure maintenance from Ericsson.

By the end of 1993, over a million subscribers were using GSM phone networks being operated by 70 carriers across 48 countries. As of the end of 1997, GSM service was available in more than 100 countries and has become the *de facto* standard in Europe and Asia.

GSM Frequencies

GSM networks operate in a number of different frequency ranges (separated into GSM frequency ranges for 2G and UMTS frequency bands for 3G). Most 2G GSM networks operate in the 900 MHz or 1800 MHz bands. Some countries in the Americas (including Canada and the United States) use the 850 MHz and 1900 MHz bands because the 900 and 1800 MHz frequency bands were already allocated. Most 3G GSM networks in Europe operate in the 2100 MHz frequency band. The rarer 400 and 450 MHz frequency bands are assigned in some countries where these frequencies were previously used for first-generation systems.

GSM-900 uses 890–915 MHz to send information from the mobile station to the base station (uplink) and 935–960 MHz for the other direction (downlink), providing 124 RF channels (channel numbers 1 to 124) spaced at 200 kHz. Duplex spacing of 45 MHz is used. In some countries the GSM-900 band has been extended to cover a larger frequency range. This 'extended GSM', E-GSM, uses 880–915 MHz (uplink) and 925–960 MHz (downlink), adding 50 channels (channel numbers 975 to 1023 and 0) to the original GSM-900 band.

Time division multiplexing is used to allow eight full-rate or sixteen half-rate speech channels per radio frequency channel. There are eight radio timeslots (giving eight burst periods) grouped into what is called a TDMA frame. Half rate channels use alternate frames in the same timeslot. The channel data rate for all 8 channels is 270.833 Kbit/s, and the frame duration is 4.615 ms.

The transmission power in the handset is limited to a maximum of 2 watts in GSM850/900 and 1 watt in GSM1800/1900. GSM operates in the 900MHz and 1.8GHz bands in Europe and the 1.9GHz and 850MHz bands in the US. The 850MHz band is also used for GSM and 3G in Australia, Canada and many South American countries. By having harmonized spectrum across most of the globe, GSM’s international roaming capability allows users to access the same services when travelling abroad as at home. This gives consumers seamless and same number connectivity in more than 218 countries.

Terrestrial GSM networks now cover more than 80% of the world’s population. GSM satellite roaming has also extended service access to areas where terrestrial coverage is not available.

Mobile Telephony Standards

Standard	Generation	Frequency band	Throughput	
GSM	2G	Allows transfer of voice or low-volume digital data.	9.6 kbps	9.6 kbps
GPRS	2.5G	Allows transfer of voice or moderate-volume digital data.	21.4-171.2 kbps	48 kbps
EDGE	2.75G	Allows simultaneous transfer of voice and digital data.	43.2-345.6 kbps	171 kbps
UMTS	3G	Allows simultaneous transfer of voice and high-speed digital data.	0.144-2 Mbps	384 kbps

1G

The first generation of mobile telephony (written **1G**) operated using analogue communications and portable devices that were relatively large. It used primarily the following standards:

- **AMPS** (Advanced Mobile Phone System), which appeared in 1976 in the United States, was the first cellular network standard. It was used primarily in the Americas, Russia and Asia. This first-generation analogue network had weak security mechanisms which allowed hacking of telephones lines.
- **TACS** (Total Access Communication System) is the European version of the AMPS model. Using the 900 MHz frequency band, this system was largely used in England and then in Asia (Hong-Kong and Japan).
- **ETACS** (Extended Total Access Communication System) is an improved version of the TACS standard developed in the United Kingdom that uses a larger number of communication channels.

The first-generation cellular networks were made obsolete by the appearance of an entirely digital second generation.

Second Generation of Mobile Networks (2G)

The second generation of mobile networks marked a break with the first generation of cellular telephones by switching from analogue to digital. The main 2G mobile telephony standards are:

- GSM (*Global System for Mobile communications*) is the most commonly used standard in Europe at the end of the 20th century and supported in the United States. This standard uses the 900 MHz and 1800 MHz frequency bands in Europe. In the United States, however, the frequency band used is the 1900 MHz band. Portable telephones that are able to operate in Europe and the United States are therefore called **tri-band**.

- **CDMA** (*Code Division Multiple Access*) uses a spread spectrum technique that allows a radio signal to be broadcast over a large frequency range.

- **TDMA** (*Time Division Multiple Access*) uses a technique of time division of communication channels to increase the volume of data transmitted simultaneously. TDMA technology is primarily used on the American continent, in New Zealand and in the Asia-Pacific region.

With the 2G networks, it is possible to transmit voice and low volume digital data, for example text messages (**SMS**, for *Short Message Service*) or multimedia messages (**MMS**, for *Multimedia Message Service*). The GSM standard allows a maximum data rate of 9.6 kbps.

Extensions have been made to the GSM standard to improve throughput. One of these is the **GPRS** (*General Packet Radio System*) service which allows theoretical data rates on the order of 114 Kbit/s but with throughput closer to 40 Kbit/s in practice. As this technology does not fit within the "3G" category, it is often referred to as **2.5G**

The **EDGE** (*Enhanced Data Rates for Global Evolution*) standard, billed as **2.75G**, quadruples the throughput improvements of GPRS with its theoretical data rate of 384 Kbps, thereby allowing the access for multimedia applications. In reality, the EDGE standard allows maximum theoretical data rates of 473 Kbit/s, but it has been limited in order to comply with the IMT-2000 (*International Mobile Telecommunications-2000*) specifications from the ITU (*International Telecommunications Union*).

3G

The IMT-2000 (*International Mobile Telecommunications for the year 2000*) specifications from the International Telecommunications Union (ITU) defined the characteristics of **3G** (third generation of mobile telephony). The most important of these characteristics are:

1. High transmission data rate.
2. 144 Kbps with total coverage for mobile use.
3. 384 Kbps with medium coverage for pedestrian use.
4. 2 Mbps with reduced coverage area for stationary use.
5. World compatibility.
6. Compatibility of 3rd generation mobile services with second generation networks.

3G offers data rates of more than 144 Kbit/s, thereby allowing the access to multimedia uses such as video transmission, video-conferencing or high-speed internet access. 3G networks use different frequency bands than the previous networks: 1885-2025 MHz and 2110-2200 MHz.

The main 3G standard used in Europe is called **UMTS** (*Universal Mobile Telecommunications System*) and uses **WCDMA** (*Wideband Code Division Multiple Access*) encoding. UMTS technology uses 5 MHz bands for transferring voice and data, with data rates that can range from 384 Kbps to 2 Mbps. **HSDPA** (*High Speed Downlink Packet Access*) is a third generation mobile telephony protocol, (considered as "3.5G"), which is able to reach data rates on the order of 8 to 10 Mbps. HSDPA technology uses the 5 GHz frequency band and uses WCDMA encoding.

Introduction to the GSM Standard

The **GSM** (*Global System for Mobile communications*) network is at the start of the 21st century, the most commonly used mobile telephony standard in Europe. It is called as Second Generation (2G) standard because communications occur in an entirely digital mode, unlike the first generation of portable telephones. When it was first standardized in 1982, it was called as **Group Special Mobile** and later, it became an international standard called **"Global System for Mobile communications"** in 1991.

In Europe, the GSM standard uses the 900 MHz and 1800 MHz frequency bands. In the United States, however, the frequency band used is the 1900 MHz band. For this reason, portable telephones that are able to operate in both Europe and the United States are called **tri-band** while those that operate only in Europe are called **bi-band**.

The GSM standard allows a maximum throughput of 9.6 kbps which allows transmission of voice and low-volume digital data like text messages (**SMS**, for *Short Message Service*) or multimedia messages (**MMS**, for *Multimedia Message Service*).

GSM Standards:

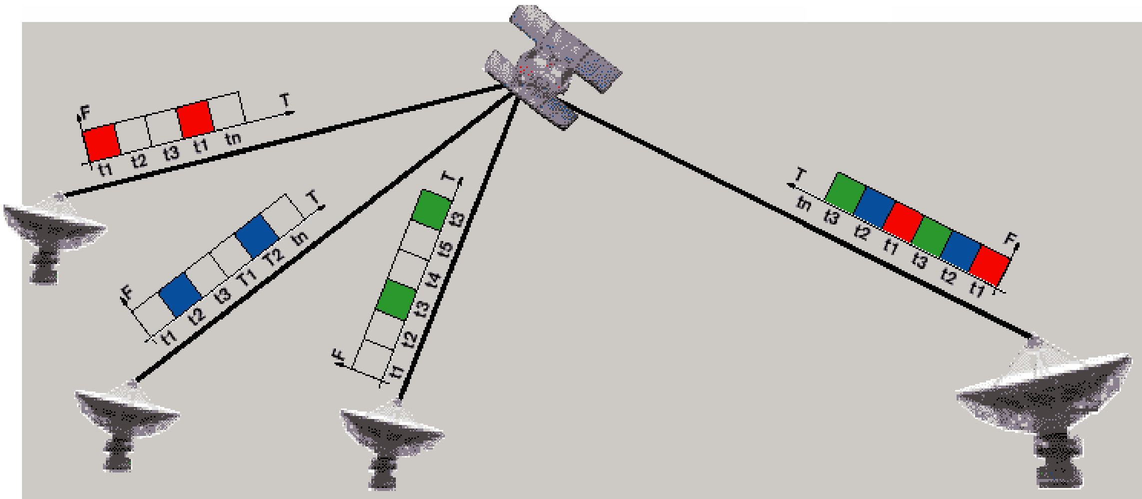
GSM uses narrowband TDMA, which allows eight simultaneous calls on the same radio frequency. There are three basic principles in multiple access, FDMA (Frequency Division Multiple Access), TDMA (Time Division Multiple Access), and CDMA (Code Division Multiple Access). All three principles allow multiple users to share the same physical channel. But the two competing technologies differ in the way user sharing the common resource.

TDMA allows the users to share the same frequency channel by dividing the signal into different time slots. Each user takes turn in a round robin fashion for transmitting and receiving over the channel. Here, users can only transmit in their respective time slot.

CDMA uses a spread spectrum technology that is it spreads the information contained in a particular signal of interest over a much greater bandwidth than the original signal. Unlike TDMA, in CDMA several users can transmit over the channel at the same time.

TDMA in brief:

In late1980's, as a search to convert the existing analog network to digital as a means to improve capacity, the cellular telecommunications industry association chose TDMA over FDMA. Time Division Multiplex Access is a type of multiplexing where two or more channels of information are transmitted over the same link by allocating a different time interval for the transmission of each channel. The most complex implementation using TDMA principle is of GSM's (Global System for Mobile communication). To reduce the effect of co-channel interference, fading and multipath, the GSM technology can use frequency hopping, where a call jumps from one channel to another channel in a short interval.



Time Division Multiple Access

TDMA systems still rely on switch to determine when to perform a handoff. Handoff occurs when a call is switched from one cell site to another while travelling. The TDMA handset constantly monitors the signals coming from other sites and reports it to the switch without caller's awareness. The switch then uses this information for making better choices for handoff at appropriate times. TDMA handset performs hard handoff, i.e., whenever the user moves from one site to another, it breaks the connection and then provides a new connection with the new site.

Advantages of TDMA:

There are lots of advantages of TDMA in cellular technologies.

1. It can easily adapt to transmission of data as well as voice communication.
2. It has an ability to carry 64 kbps to 120 Mbps of data rates. This allows the operator to do services like fax, voice band data and SMS as well as bandwidth intensive application such as multimedia and video conferencing.

3. Since TDMA technology separates users according to time, it ensures that there will be no interference from simultaneous transmissions.

4. It provides users with an extended battery life, since it transmits only portion of the time during conversations. Since the cell size grows smaller, it proves to save base station equipment, space and maintenance.

TDMA is the most cost effective technology to convert an analog system to digital.

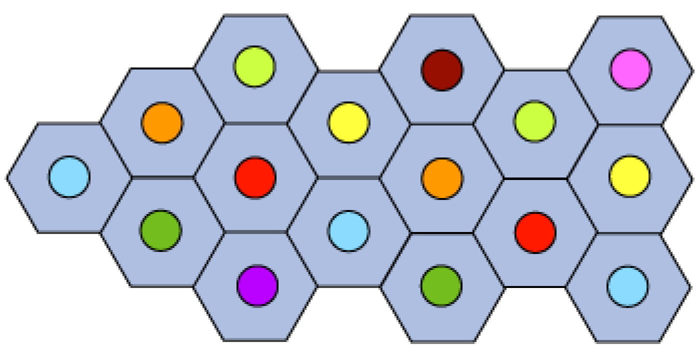
Disadvantages of TDMA:

One major disadvantage using TDMA technology is that the users has a predefined time slot. When moving from one cell site to other, if all the time slots in this cell are full the user might be disconnected. Likewise, if all the time slots in the cell in which the user is currently in are already occupied, the user will not receive a dial tone.

The second problem in TDMA is that it is subjected to multipath distortion. To overcome this distortion, a time limit can be used on the system. Once the time limit is expired, the signal is ignored.

The concept of cellular network

Mobile telephone networks are based on the concept of **cells**, circular zones that overlap to cover a geographical area.



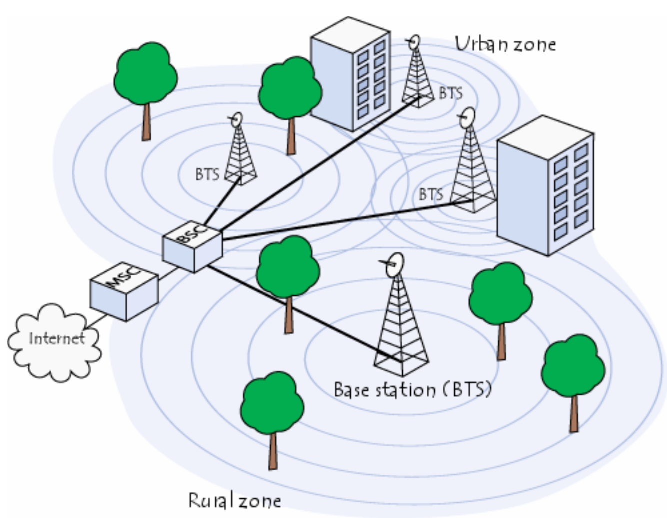
Cellular networks are based on the use of a central transmitter-receiver in each cell, called a "**base station**" (or *Base Transceiver Station*, written **BTS**). The smaller the radius of a cell, the higher is the available bandwidth. So, in highly populated urban areas, there are cells with a radius of a few hundred meters, while huge cells of up to 30 kilometers provide coverage in rural areas.

In a cellular network, each cell is surrounded by 6 neighbouring cells (thus a cell is generally drawn as a hexagon). To avoid interference, adjacent cells cannot use the same frequency. In practice, two cells using the same frequency range must be separated by a distance of two to three times the diameter of the cell.

Architecture of the GSM Network

In a GSM network, the user terminal is called a **mobile station**. A mobile station is made up of a **SIM** (*Subscriber Identity Module*) card allowing the user to be uniquely identified and a mobile terminal. The terminals (devices) are identified by a unique 15-digit identification number called **IMEI** (*International Mobile Equipment Identity*). Each SIM card also has a unique (and secret) identification number called **IMSI** (*International Mobile Subscriber Identity*). This code can be protected using a 4-digit key called a *PIN code*.

The SIM card therefore allows each user to be identified independently of the terminal used during communication with a base station. Communications occur through a radio link (air interface) between a mobile station and a base station.



All the base stations of a cellular network are connected to a **base station controller** (**BSC**) which is responsible for managing distribution of the resources. The system consisting of the base station controller and its connected base stations is called the **Base Station Subsystem** (**BSS**).

Finally, the base station controllers are themselves physically connected to the **Mobile Switching Centre** (**MSC**), managed by the telephone network operator, which connects them to the public telephone network and the Internet. The MSC belongs to a **Network Station Subsystem** (**NSS**), which is responsible for managing user identities, their location and establishment of communications with other subscribers. The MSC is generally connected to databases that provide additional functions:

1. The **Home Location Register** (**HLR**) is a database containing information (geographic position, administrative information etc.) of the subscribers registered in the area of the switch (MSC).

2. The **Visitor Location Register** (**VLR**) is a database containing information of users other than the local subscribers. The VLR retrieves the data of a new user from the HLR of the user's subscriber zone. The data is maintained as long as the user is in the zone and is deleted when the user leaves or after a long period of inactivity (terminal off).

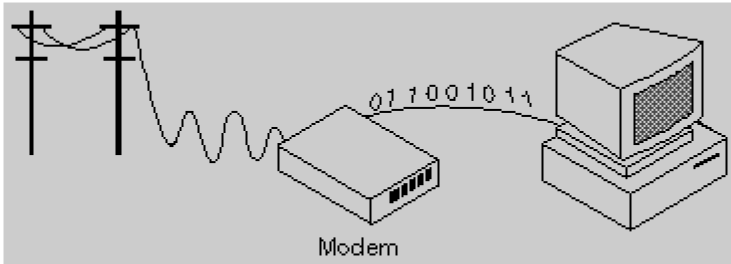
3. The **Equipment Identify Register** (**EIR**) is a database listing the mobile terminals.

4. The **Authentication Centre** (**AUC**) is responsible for verifying user identities.

5. The cellular network formed in this way is designed to support mobility via management of *handovers* (movements from one cell to another).

Finally, GSM networks support the concept of **roaming** i.e., movement from one operator network to another.

Introduction to Modem:



Modem stands for *modulator-demodulator.*

A modem is a device or program that enables a computer to transmit data over telephone or cable lines. Computer information is stored digitally, whereas information transmitted over telephone lines is transmitted in the form of analog waves. A modem converts between these two forms.

Fortunately, there is one standard interface for connecting external modems to computers called *RS-232*. Consequently, any external modem can be attached to any computer that has an RS-232 port, which almost all personal computers have. There are also modems that come as an expansion board that can be inserted into a vacant expansion slot. These are sometimes called *onboard* or *internal modems*.

While the modem interfaces are standardized, a number of different protocols for formatting data to be transmitted over telephone lines exist. Some, like CCITT V.34 are official standards, while others have been developed by private companies. Most modems have built-in support for the more common protocols at slow data transmission speeds at least, most modems can communicate with each other. At high transmission speeds, however, the protocols are less standardized.

Apart from the transmission protocols that they support, the following characteristics distinguish one modem from another:

- **Bps:** How fast the modem can transmit and receive data. At slow rates, modems are measured in terms of baud rates. The slowest rate is 300 baud (about 25 cps). At higher speeds, modems are measured in terms of bits per second (bps). The fastest modems run at 57,600 bps, although they can achieve even higher data transfer rates by compressing the data. Obviously, the faster the transmission rate, the faster the data can be sent and received. It should be noted that the data cannot be received at a faster rate than it is being sent.

- **Voice/data:** Many modems support a switch to change between voice and data modes. In data mode, the modem acts like a regular modem. In voice mode, the modem acts like a regular telephone. Modems that support a voice/data switch have a built-in loudspeaker and microphone for voice communication.

- **Auto-answer:** An auto-answer modem enables the computer to receive calls in the absence of the operator.

- **Data compression:** Some modems perform data compression, which enables them to send data at faster rates. However, the modem at the receiving end must be able to decompress the data using the same compression technique.

- **Flash memory:** Some modems come with *flash memory* rather than conventional ROM which means that the communications protocols can be easily updated if necessary.

- **Fax capability:** Most modern modems are fax modems, which mean that they can send and receive faxes.

GSM Modem:

A GSM modem is a wireless modem that works with a GSM wireless network. A wireless modem behaves like a dial-up modem. The main difference between them is that a dial-up modem sends and receives data through a fixed telephone line while a wireless modem sends and receives data through radio waves.

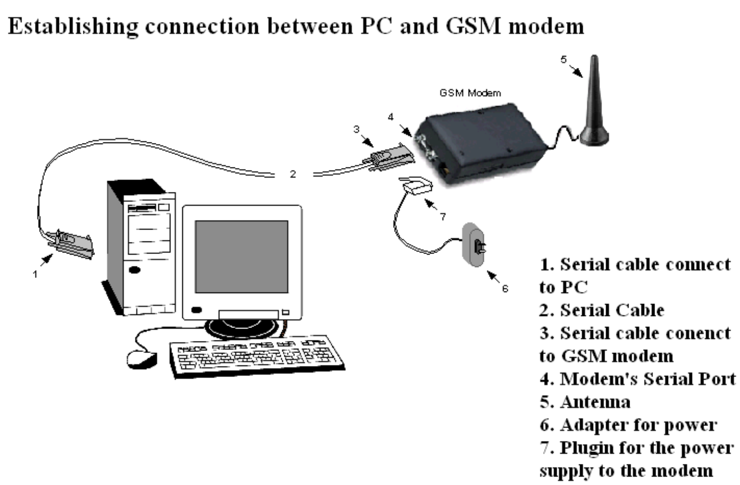
A GSM modem can be an external device or a PC Card / PCMCIA Card. Typically, an external GSM modem is connected to a computer through a serial cable or a USB cable. A GSM modem in the form of a PC Card / PCMCIA Card is designed for use with a laptop computer. It should be inserted into one of the PC Card / PCMCIA Card slots of a laptop computer. Like a GSM mobile phone, a GSM modem requires a SIM card from a wireless carrier in order to operate.

A SIM card contains the following information:

- Subscriber telephone number (MSISDN)
- International subscriber number (**IMSI, International Mobile Subscriber Identity)**
- State of the SIM card
- Service code (operator)
- Authentication key
- PIN (***Personal Identification Code***)
- PUK (***Personal Unlock Code***)

Computers use AT commands to control modems. Both GSM modems and dial-up modems support a common set of standard AT commands. In addition to the standard AT commands, GSM modems support an extended set of AT commands. These extended AT commands are defined in the GSM standards. With the extended AT commands, the following operations can be performed:

- Reading, writing and deleting SMS messages.
- Sending SMS messages.
- Monitoring the signal strength.
- Monitoring the charging status and charge level of the battery.
- Reading, writing and searching phone book entries.



The number of SMS messages that can be processed by a GSM modem per minute is very low i.e., about 6 to 10 SMS messages per minute.

Introduction to AT Commands

AT commands are instructions used to control a modem. AT is the abbreviation of ATtention. Every command line starts with "AT" or "at". That's the reason, modem commands are called AT commands. Many of the commands that are used to control wired dial-up modems, such as ATD (Dial), ATA (Answer), ATH (Hook control) and ATO (Return to online data state) are also supported by GSM modems and mobile phones.

Besides this common AT command set, GSM modems and mobile phones support an AT command set that is specific to the GSM technology, which includes SMS-related commands like AT+CMGS (Send SMS message), AT+CMSS (Send SMS message from storage), AT+CMGL (List SMS messages) and AT+CMGR (Read SMS messages).

It should be noted that the starting "AT" is the prefix that informs the modem about the start of a command line. It is not part of the AT command name. For example, D is the actual AT command name in ATD and +CMGS is the actual AT command name in AT+CMGS.

Some of the tasks that can be done using AT commands with a GSM modem or mobile phone are listed below:

- Get basic information about the mobile phone or GSM modem. For example, name of manufacturer (AT+CGMI), model number (AT+CGMM), IMEI number (International Mobile Equipment Identity) (AT+CGSN) and software version (AT+CGMR).
- Get basic information about the subscriber. For example, MSISDN (AT+CNUM) and IMSI number (International Mobile Subscriber Identity) (AT+CIMI).
- Get the current status of the mobile phone or GSM/GPRS modem. For example, mobile phone activity status (AT+CPAS), mobile network registration status (AT+CREG), radio signal strength (AT+CSQ), battery charge level and battery charging status (AT+CBC).
- Establish a data connection or voice connection to a remote modem (ATD, ATA, etc).
- Send and receive fax (ATD, ATA, AT+F*).

- Send (AT+CMGS, AT+CMSS), read (AT+CMGR, AT+CMGL), write (AT+CMGW) or delete (AT+CMGD) SMS messages and obtain notifications of newly received SMS messages (AT+CNMI).

- Read (AT+CPBR), write (AT+CPBW) or search (AT+CPBF) phonebook entries.

- Perform security-related tasks, such as opening or closing facility locks (AT+CLCK), checking whether a facility is locked (AT+CLCK) and changing passwords(AT+CPWD). (Facility lock examples: SIM lock [a password must be given to the SIM card every time the mobile phone is switched on] and PH-SIM lock [a certain SIM card is associated with the mobile phone. To use other SIM cards with the mobile phone, a password must be entered.])

- Control the presentation of result codes / error messages of AT commands. For example, the user can control whether to enable certain error messages (AT+CMEE) and whether error messages should be displayed in numeric format or verbose format (AT+CMEE=1 or AT+CMEE=2).

- Get or change the configurations of the mobile phone or GSM/GPRS modem. For example, change the GSM network (AT+COPS), bearer service type (AT+CBST), radio link protocol parameters (AT+CRLP), SMS center address (AT+CSCA) and storage of SMS messages (AT+CPMS).

- Save and restore configurations of the mobile phone or GSM/GPRS modem. For example, save (AT+CSAS) and restore (AT+CRES) settings related to SMS messaging such as the SMS center address.

It should be noted that the mobile phone manufacturers usually do not implement all AT commands, command parameters and parameter values in their mobile phones. Also, the behavior of the implemented AT commands may be different from that defined in the standard. In general, GSM modems, designed for wireless applications, have better support of AT commands than ordinary mobile phones.

Basic concepts of SMS technology

1. Validity Period of an SMS Message

An SMS message is stored temporarily in the SMS center if the recipient mobile phone is offline. It is possible to specify the period after which the SMS message will be deleted from the SMS center so that the SMS message will not be forwarded to the recipient mobile phone when it becomes online. This period is called the validity period. A mobile phone should have a menu option that can be used to set the validity period. After setting it, the mobile phone will include the validity period in the outbound SMS messages automatically.

2. Message Status Reports

Sometimes the user may want to know whether an SMS message has reached the recipient mobile phone successfully. To get this information, you need to set a flag in the SMS message to notify the SMS center that a status report is required about the delivery of this SMS message. The status report is sent to the user mobile in the form of an SMS message.

A mobile phone should have a menu option that can be used to set whether the status report feature is on or off. After setting it, the mobile phone will set the corresponding flag in the outbound SMS messages for you automatically. The status report feature is turned off by default on most mobile phones and GSM modems.

3. Message Submission Reports

After leaving the mobile phone, an SMS message goes to the SMS center. When it reaches the SMS center, the SMS center will send back a message submission report to the mobile phone to inform whether there are any errors or failures (e.g. incorrect SMS message format, busy SMS center, etc). If there is no error or failure, the SMS center sends back a positive submission report to the mobile phone. Otherwise it sends back a negative submission report to the mobile phone. The mobile phone may then notify the user that the message submission was failed and what caused the failure.

If the mobile phone does not receive the message submission report after a period of time, it concludes that the message submission report has been lost. The mobile phone may then send the SMS message again to the SMS center. A flag will be set in the new SMS message to inform the SMS center that this SMS message has been sent before. If the previous message submission was successful, the SMS center will ignore the new SMS message but send back a message submission report to the mobile phone. This mechanism prevents the sending of the same SMS message to the recipient multiple times.

Sometimes the message submission report mechanism is not used and the acknowledgement of message submission is done in a lower layer.

4 .Message Delivery Reports

After receiving an SMS message, the recipient mobile phone will send back a message delivery report to the SMS center to inform whether there are any errors or failures (example causes: unsupported SMS message format, not enough storage space, etc). This process is transparent to the mobile user. If there is no error or failure, the recipient mobile phone sends back a positive delivery report to the SMS center. Otherwise it sends back a negative delivery report to the SMS center.

If the sender requested a status report earlier, the SMS center sends a status report to the sender when it receives the message delivery report from the recipient. If the SMS center does not receive the message delivery report after a period of time, it concludes that the message delivery report has been lost. The SMS center then ends the SMS message to the recipient for the second time.

Sometimes the message delivery report mechanism is not used and the acknowledgement of message delivery is done in a lower layer.

THING SPEAK CLOUD

It is an IoT platform that is designed to enable meaningful connections between people and things. It features real-time data collection, data analysis, data processing, data visualization using a connected Social Networking Service (SNS) via an open source API to support various platforms. It helps to easily transfer data from embedded devices such as Arduino, Raspberry PI, NodeMCU, etc. Also, it supports various languages and environments. Our proposed system reads and sends sensor data using ThingSpeak. The main objective is to design and implement an automated system and to visualize sensed information as charts. The data obtained can be seen globally anywhere, anytime.

Microcontroller:

Introduction:

Microcontroller as the name suggest, a small controller. They are like single chip computersthat are often embedded into other systems to function as processing/controlling unit. Forexample, the control you are using probably has microcontrollers inside that do decoding andother controlling functions. They are also used in automobiles, washing machines, microwavesovens, toys….etc, where automation is needed.

Arduino Uno Microcontroller:

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digitalinput/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "Uno" means "One" in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

The Arduino Uno can be powered via the USB connection or with an external power supply. The powersource is selected automatically.External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adaptercan be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from abattery can be inserted in the Gnd and Vin pin headers of the POWER connector.The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5Vpin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts

The power pins are as follows:·

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to5 volts from the USB connection or other regulated power source). You can supply voltage throughthis pin, or, if supplying voltage via the power jack, access it through this pin.·
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3.3V.**A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory:

The Atmega328 has 32 KB of flash memory for storing code (of which 0,5 KB is used for the bootloader); Ithas also 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output:

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA andhas an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins havespecialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip .
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, arising or falling edge, or a change in value. See the attach Interrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication, which although provided by the underlying hardware, is not currently included in the Arduino language.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED ison, when the pin is LOW, it's off.

The Uno has 6 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). Bydefault they measure from ground to 5 volts, though is it possible to change the upper end of their rangeusing the AREF pin and the analogReference() function. Additionally, some pins have specialized

functionality:

- **I2C: 4 (SDA) and 5 (SCL).** Support I2C (TWI) communication using the Wire library.
  There are a couple of other pins on the board:
- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button toshields which block the one on the board.

Communication:

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '8U2 firmware uses the standard USBCOM drivers, and no external driver is needed. However, on Windows, an *.inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-toserial chip and USB connection to the computer (but not for serial communication on pins 0 and 1). A SoftwareSerial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus

ARDUINO UNO BOARD:

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

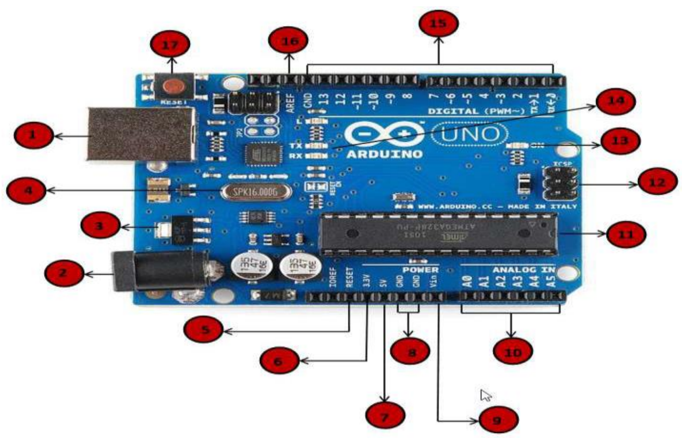


Figure: Arduino uno board

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converters.

Technical Specifications:

FEATURE	SPECIFICATION
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Table: Arduino uno specifications

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

1.USB Interface:

Arduino board can be powered by using the USB cable from your computer. All you need to do is connect the USB cable to the USB connection

2.External power supply:

Arduino boards can be powered directly from the AC mains power supply by connecting it to the power supply (Barrel Jack)

3.Voltage Regulator:

The function of the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements.

4.Crystal Oscillator:

The crystal oscillator helps Arduino in dealing with time issues. How does Arduino calculate time? The answer is, by using the crystal oscillator. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz.

5,17.Arduino Reset:

It can reset your Arduino board, i.e., start your program from the beginning. It can reset the UNO board in two ways. First, by using the reset button (17) on the board. Second, you can connect an external reset button to the Arduino pin labelled RESET (5).

6-9.Pins (3.3, 5, GND, Vin):

- 3.3V (6): Supply 3.3 output volt
- 5V (7): Supply 5 output volt
- Most of the components used with Arduino board works fine with 3.3 volt and 5 volt.
- GND (8)(Ground): There are several GND pins on the Arduino, any of which can be used to ground your circuit.
- Vin (9): This pin also can be used to power the Arduino board from an external power source, like AC mains power supply.

10.Analog pins:

The Arduino UNO board has five analog input pins A0 through A5. These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.

11.Main microcontroller:

Each Arduino board has its own microcontroller (11). You can assume it as the brain of your board. The main IC (integrated circuit) on the Ardsuino is slightly different from board to board. The microcontrollers are usually of the ATMEL Company. You must know what IC your board has before loading up a new program from the Arduino IDE. This information is available on the top of the IC. For more details about the IC construction and functions, you can refer to the data sheet.

Tthe Atmega8U2 programmed as a USB-to-serial converter. "Uno" means "One" in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards

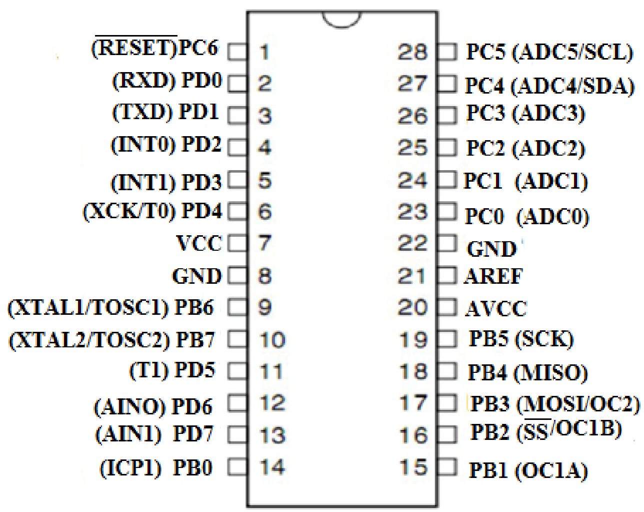


Figure: Pin diagram

Pin Description:

VCC: Digital supply voltage.

GND: Ground.

Port B (PB[7:0]) XTAL1/XTAL2/TOSC1/TOSC2:

Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Depending on the clock selection fuse settings, PB6 can be used as input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

Depending on the clock selection fuse settings, PB7 can be used as output from the inverting Oscillator amplifier.

If the Internal Calibrated RC Oscillator is used as chip clock source, PB[7:6] is used as TOSC[2:1] input for the Asynchronous Timer/Counter2 if the AS2 bit in ASSR is set.

Port C (PC[5:0]):

Port C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC[5:0] output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs,

Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running.

PC6/RESET:

If the RSTDISBL Fuse is programmed, PC6 is used as an I/O pin. Note that the electrical characteristics of PC6 differ from those of the other pins of Port C.

If the RSTDISBL Fuse is unprogrammed, PC6 is used as a Reset input. A low level on this pin for longer than the minimum pulse length will generate a Reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a Reset.

Port D (PD[7:0]):

Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

AVCC: AVCC is the supply voltage pin for the A/D Converter, PC[3:0], and PE[3:2]. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter. Note that PC[6:4] use digital supply voltage, VCC.

AREF: AREF is the analog reference pin for the A/D Converter.

ADC [7:6] (TQFP and VFQFN Package Only): In the TQFP and VFQFN package, ADC[7:6] serve as analog inputs to the A/D converter. These pins are powered from the analog supply and serve as 10-bit ADC channels.

12. ICSP pin: Mostly, ICSP (12) is an AVR, a tiny programming header for the Arduino consisting of MOSI, MISO, SCK, RESET, VCC, and GND. It is often referred to as an SPI (Serial Peripheral Interface), which could be considered as an "expansion" of the output. Actually, you are slaving the output device to the master of the SPI bus.

13. Power LED indicator: This LED should light up when you plug your Arduino into a power source to indicate that your board is powered up correctly. If this light does not turn on, then there is something wrong with the connection.

14. TX and RX LEDs: On your board, you will find two labels: TX (transmit) and RX (receive). They appear in two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TX and RX led (13). The TX led flashes with different speed while sending the serial data. The speed of flashing depends on the baud rate used by the board. RX flashes during the receiving process.

15. Digital I / O: The Arduino UNO board has 14 digital I/O pins (15) (of which 6 provide PWM (Pulse Width Modulation) output. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled “~” can be used to generate PWM.

16. AREF:AREF stands for Analog Reference. It is sometimes, used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins working.

CHAPTER-7

SOFTWARE AND CODING

Introduction to Arduino IDE

Arduino is a prototype platform (open-source) based on an easy-to-use hardware and software. It consists of a circuit board, which can be programmed (referred to as a microcontroller) and a ready-made software called Arduino IDE (Integrated Development Environment), which is used to write and upload the computer code to the physical board.

The key features are:

- Arduino boards are able to read analog or digital input signals from different sensors and turn it into an output such as activating a motor, turning LED on/off, connect to the cloud and many other actions.
- You can control your board functions by sending a set of instructions to the microcontroller on the board via Arduino IDE (referred to as uploading software).
- Unlike most previous programmable circuit boards, Arduino does not need an extra piece of hardware (called a programmer) in order to load a new code onto the board. You can simply use a USB cable.
- Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program.
- Finally, Arduino provides a standard form factor that breaks the functions of the micro-controller into a more accessible package.

After learning about the main parts of the Arduino UNO board, we are ready to learn howto set up the Arduino IDE. Once we learn this, we will be ready to upload our program onthe Arduino board.

Arduino data types: Data types in C refers to an extensive system used for declaring variables or functions of different types. The type of a variable determines how much space it occupies in the storage and how the bit pattern stored is interpreted.

The following table provides all the data types that you will use during Arduino programming.

Void:

The void keyword is used only in function declarations. It indicates that the function is expected to return no information to the function from which it was called.

Example:

```
Void Loop ( )

{

// rest of the code

}
```

Boolean:

A Boolean holds one of two values, true or false. Each Boolean variable occupies one byte of memory.

Example:

Boolean state= false ; // declaration of variable with type boolean and initialize it with false.

Boolean state = true ; // declaration of variable with type boolean and initialize it with false.

Char:A data type that takes up one byte of memory that stores a character value. Character literals are written in single quotes like this: 'A' and for multiple characters, strings use double quotes: "ABC".

However, characters are stored as numbers. You can see the specific encoding in the ASCII chart. This means that it is possible to do arithmetic operations on characters, in whichthe

ASCII value of the character is used. For example, 'A' + 1 has the value 66, since theASCII value of the capital letter A is 65.

Example:

Char chr_a = ‘a’ ;//declaration of variable with type char and initialize it with character a.

Char chr_c = 97 ;//declaration of variable with type char and initialize it with character 97

Unsigned char:

Unsigned char is an unsigned data type that occupies one byte of memory. The unsigned char data type encodes numbers from 0 to 255.

Example:

Unsigned Char chr_y = 121 ; // declaration of variable with type Unsigned char and initialize it with character y

Byte:

A byte stores an 8-bit unsigned number, from 0 to 255.

Example:

byte m = 25 ;//declaration of variable with type byte and initialize it with 25

int:

Integers are the primary data-type for number storage. **int** stores a 16-bit (2-byte) value. This yields a range of -32,768 to 32,767 (minimum value of -2^15 and a maximum value of (2^15) - 1).

The **int** size varies from board to board. On the Arduino Due, for example, an **int** stores a 32-bit (4-byte) value. This yields a range of -2,147,483,648 to 2,147,483,647 (minimum value of -2^31 and a maximum value of (2^31) - 1).

Example:

int counter = 32 ;// declaration of variable with type int and initialize it with 32.

Unsigned int:

Unsigned ints (unsigned integers) are the same as int in the way that they store a 2 byte value. Instead of storing negative numbers, however, they only store positive values, yielding a useful range of 0 to 65,535 (2^16) - 1). The Due stores a 4 byte (32-bit) value, ranging from 0 to 4,294,967,295 (2^32 - 1).

Example:

Unsigned int counter= 60 ; // declaration of variable with type unsigned int and initialize it with 60.

Word:

On the Uno and other ATMEGA based boards, a word stores a 16-bit unsigned number. On the Due and Zero, it stores a 32-bit unsigned number.

Example

word w = 1000 ;//declaration of variable with type word and initialize it with 1000.

Long:

Long variables are extended size variables for number storage, and store 32 bits (4 bytes), from 2,147,483,648 to 2,147,483,647.

Example:

Long velocity= 102346 ;//declaration of variable with type Long and initialize it with 102346

Unsigned long: Unsigned long variables are extended size variables for number storage and store 32 bits (4 bytes). Unlike standard longs, unsigned longs will not store negative numbers, making their range from 0 to 4,294,967,295 (2^32 - 1).

Example:

Unsigned Long velocity = 101006 ;// declaration of variable with type Unsigned Long and initialize it with 101006.

Short:

A short is a 16-bit data-type. On all Arduinos (ATMega and ARM based), a short stores a 16-bit (2-byte) value. This yields a range of -32,768 to 32,767 (minimum value of -2^15 and a maximum value of (2^15) - 1).

Example:

short val= 13 ;//declaration of variable with type short and initialize it with 13

Float:

Data type for floating-point number is a number that has a decimal point. Floating-point numbers are often used to approximate the analog and continuous values because they have greater resolution than integers.

Floating-point numbers can be as large as 3.4028235E+38 and as low as 3.4028235E+38. They are stored as 32 bits (4 bytes) of information.

Example:

float num = 1.352;//declaration of variable with type float and initialize it with 1.352.

Double:

On the Uno and other ATMEGA based boards, Double precision floating-point number occupies four bytes. That is, the double implementation is exactly the same as the float, with no gain in precision. On the Arduino Due, doubles have 8-byte (64 bit) precision.

Example:

double num = 45.352 ;// declaration of variable with type double and initialize it with 45.352.

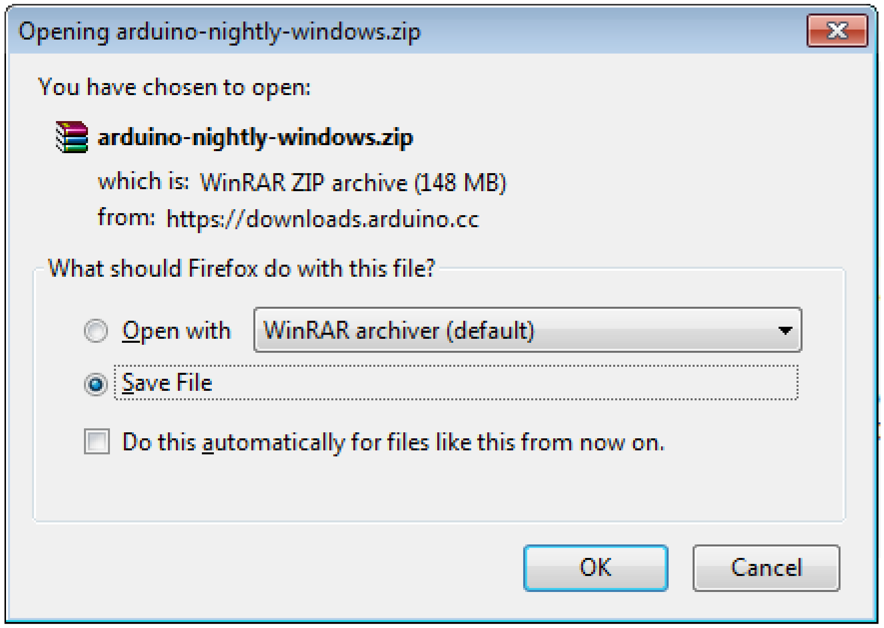
In this section, we will learn in easy steps, how to set up the Arduino IDE on our computerand prepare the board to receive the program via USB cable.

Step 1: First you must have your Arduino board (you can choose your favorite board) anda USB cable. In case you use Arduino UNO, Arduino Duemilanove, Nano, Arduino Mega2560, or Diecimila, you will need a standard USB cable (A plug to B plug), the kind youwould connect to a USB printer as shown in the following image.

Figure: USB Cable

Step 2: Download Arduino IDE Software.

You can get different versions of Arduino IDE from the Download page on the Arduino Official website. You must select your software, which is compatible with your operating system (Windows, IOS, or Linux). After your file download is complete, unzip the file.

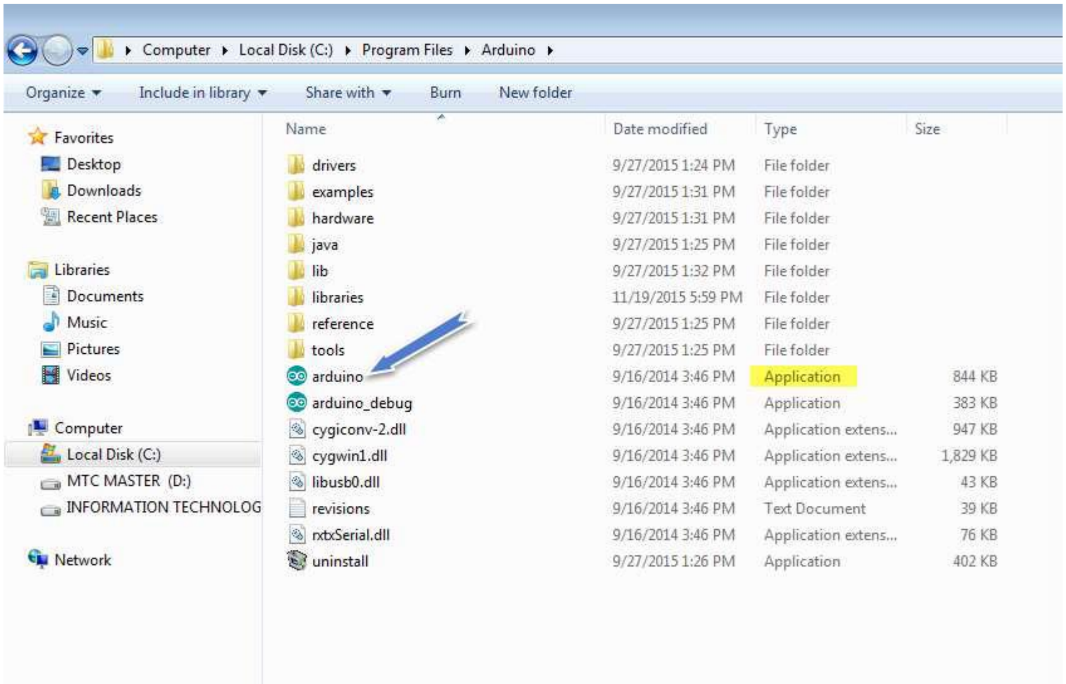


Step 3: Power up your board.

The Arduino Uno, Mega, Duemilanove and Arduino Nano automatically draw power from either, the USB connection to the computer or an external power supply. If you are using an Arduino Diecimila, you have to make sure that the board is configured to draw power from the USB connection. The power source is selected with a jumper, a small piece of plastic that fits onto two of the three pins between the USB and power jacks. Check that it is on the two pins closest to the USB port. Connect the Arduino board to your computer using the USB cable. The green power LED (labeled PWR) should glow.

Step 4: Launch Arduino IDE.

After your Arduino IDE software is downloaded, you need to unzip the folder. Inside the folder, you can find the application icon with an infinity label (application.exe). Doubleclick the icon to start the IDE.

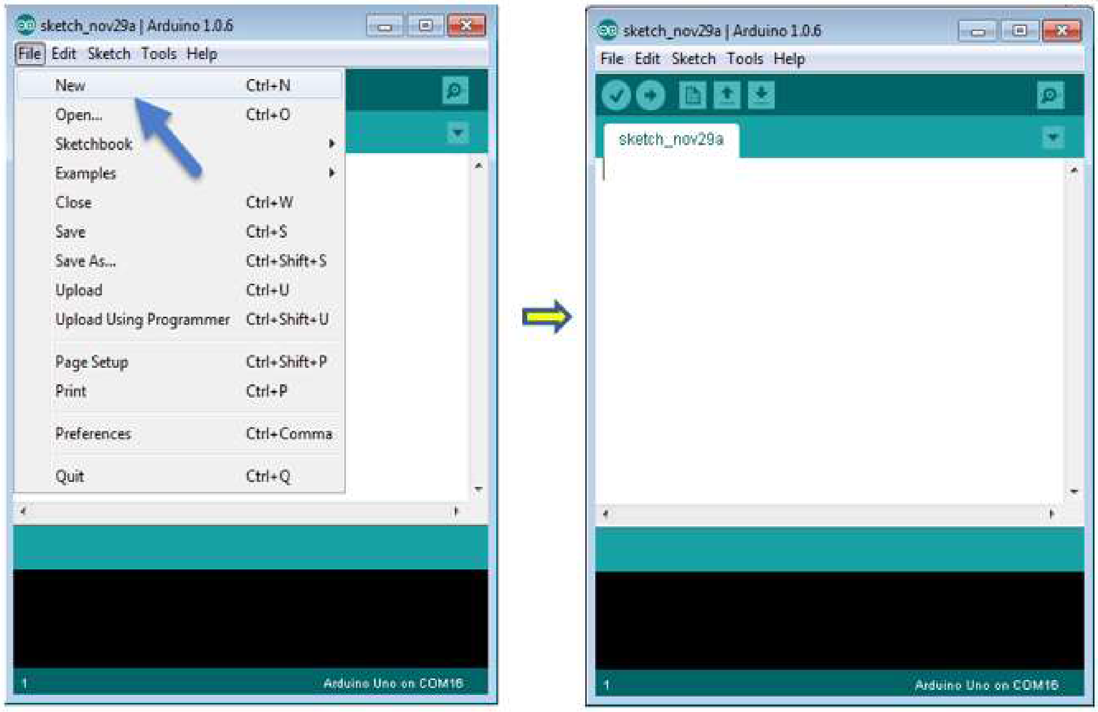


Step 5: Open your first project.

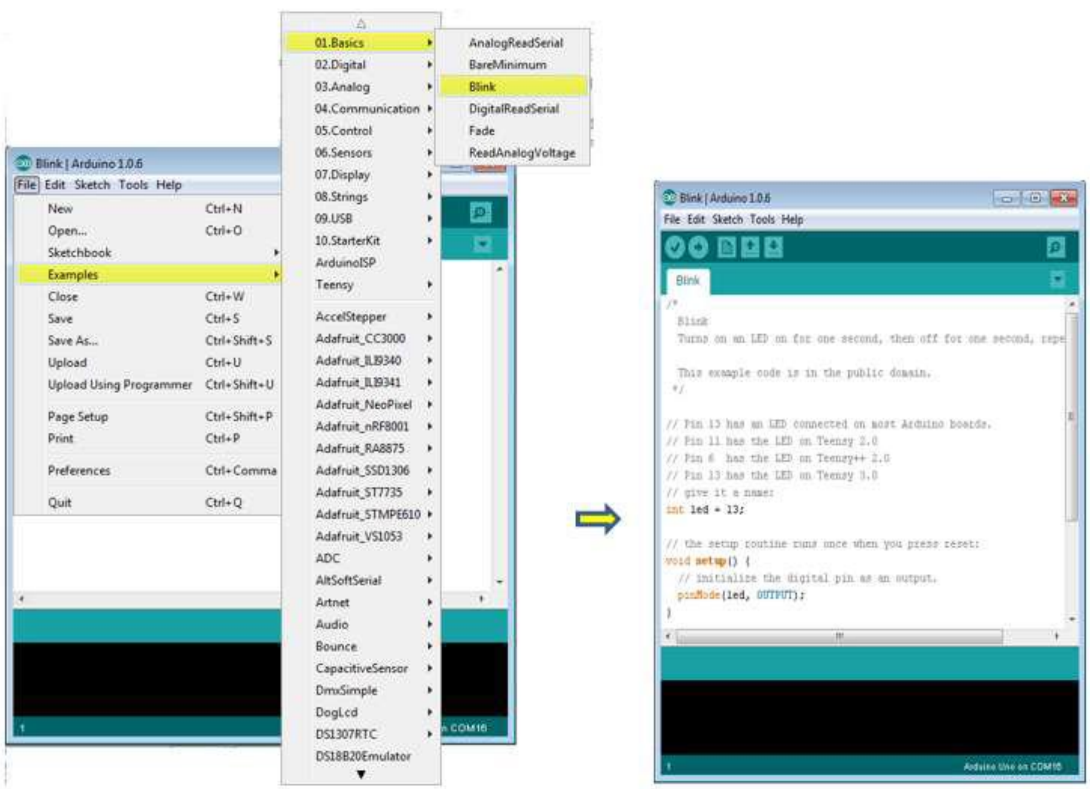
Once the software starts, you have two options:

- Create a new project.
- Open an existing project example.

To create a new project, select File --> New.To open



To open an existing project example, select File -> Example -> Basics -> Blink.

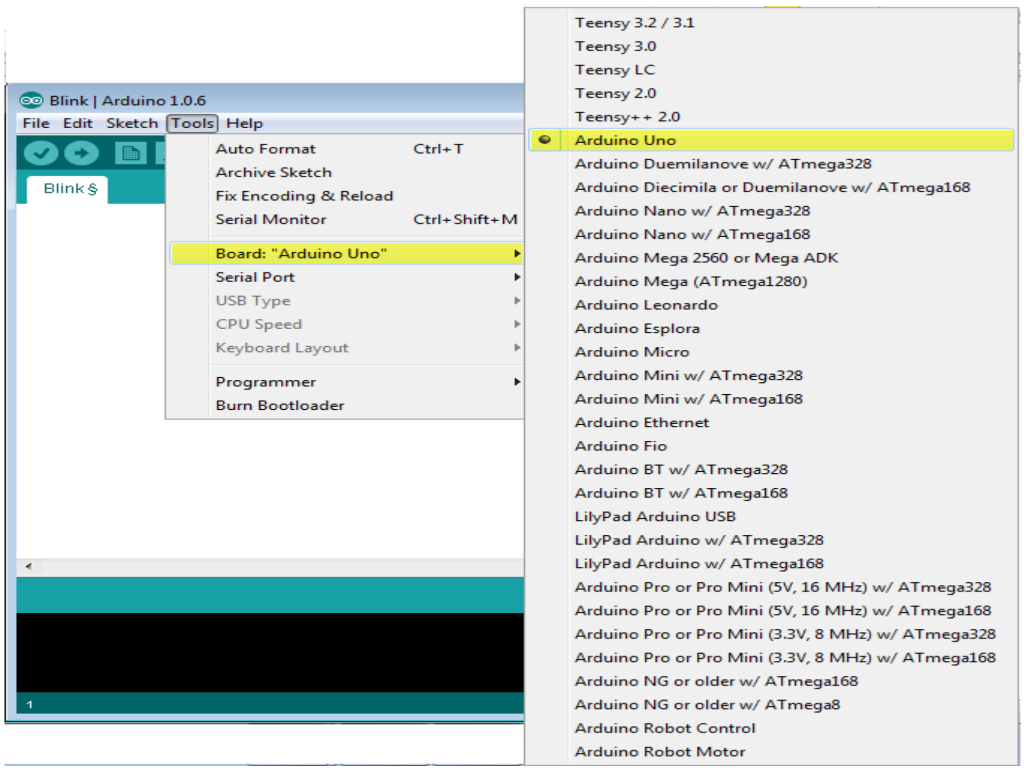


Here, we are selecting just one of the examples with the name **Blink**. It turns the LED on and off with some time delay. You can select any other example from the list.

Step 6: Select your Arduino board.

To avoid any error while uploading your program to the board, you must select the correct Arduino board name, which matches with the board connected to your computer.

Go to Tools -> Board and select your board

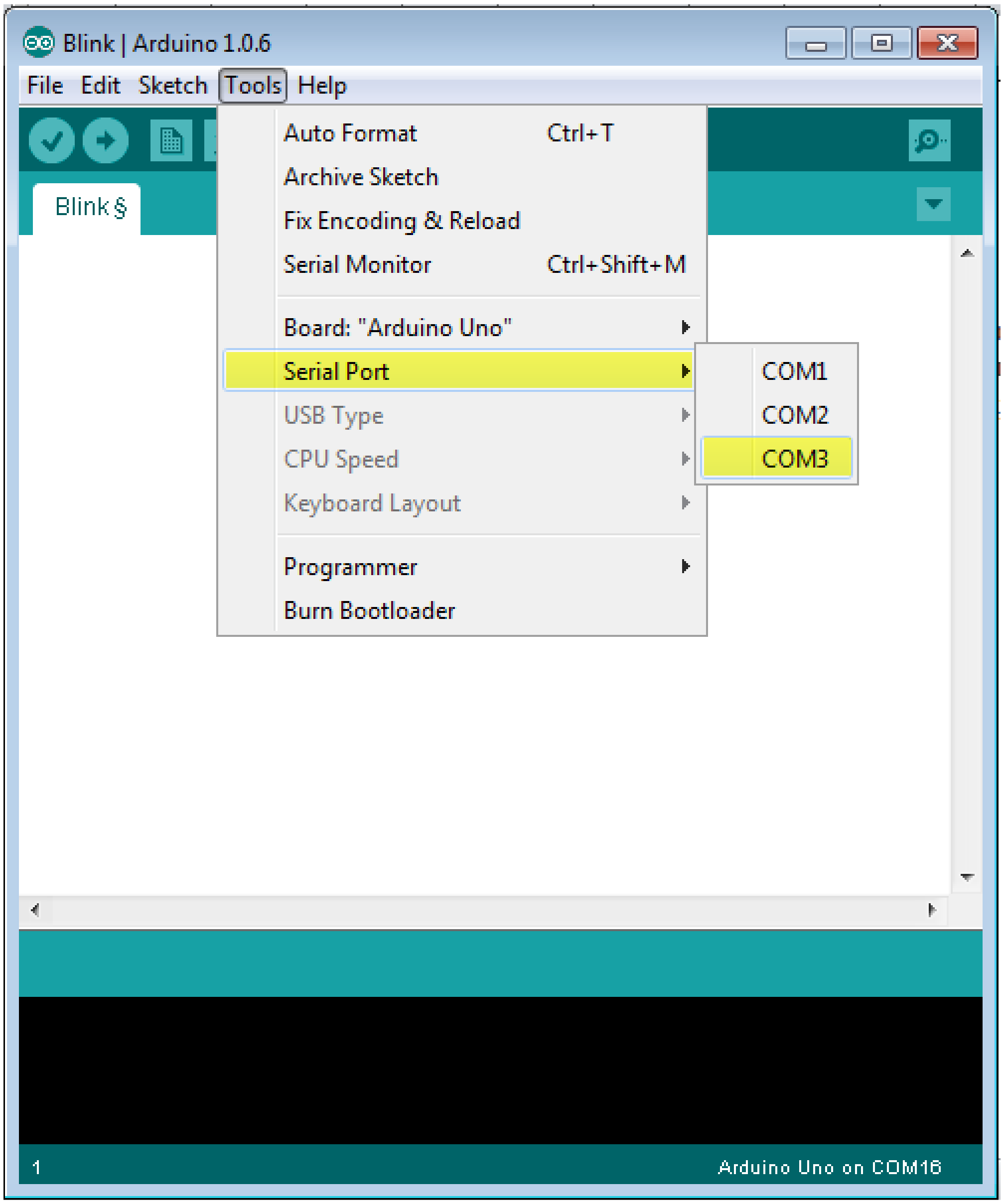


Here, we have selected Arduino Uno board according to our tutorial, but you must select the name matching the board that you are using

Step 7: Select your serial port.

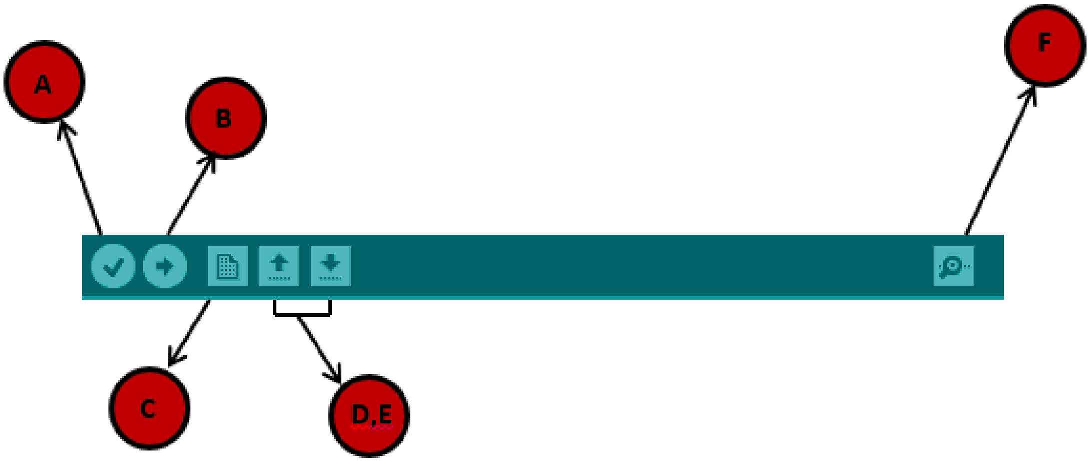
Select the serial device of the Arduino board. Go to **Tools** ->**Serial Port** menu. This is likely to be COM3 or higher (COM1 and COM2 are usually reserved for hardware serial ports).

To find out, you can disconnect your Arduino board and re-open the menu, the entry that disappears should be of the Arduino board. Reconnect the board and select that serial port.



Step 8: Upload the program to your board.

Before explaining how we can upload our program to the board, we must demonstrate the function of each symbol appearing in the Arduino IDE toolbar.



A- Used to check if there is any compilation error.

B- Used to upload a program to the Arduino board.

C- Shortcut used to create a new sketch.

D- Used to directly open one of the example sketch.

E- Used to save your sketch.

F- Serial monitor used to receive serial data from the board and send the serial data to the board.

Now, simply click the "Upload" button in the environment. Wait a few seconds; you will see the RX and TX LEDs on the board, flashing. If the upload is successful, the message "Done uploading" will appear in the status bar.

Note: If you have an Arduino Mini, NG, or other board, you need to press the reset button physically on the board, immediately before clicking the upload button on the Arduino Software.

Arduino programming structure

In this chapter, we will study in depth, the Arduino program structure and we will learn more new terminologies used in the Arduino world. The Arduino software is open-source. The source code for the Java environment is released under the GPL and the C/C++ microcontroller libraries are under the LGPL.

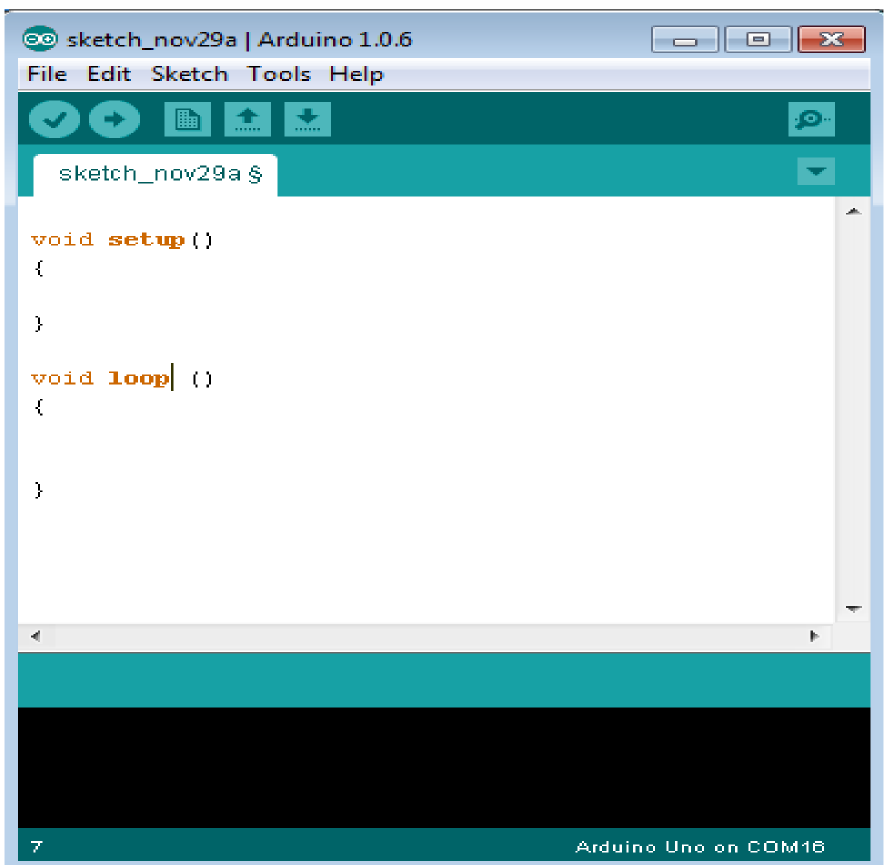
Sketch: The first new terminology is the Arduino program called "**sketch**".

Structure

Arduino programs can be divided in three main parts: **Structure**, **Values** (variables and constants), and **Functions**. In this tutorial, we will learn about the Arduino software program, step by step, and how we can write the program without any syntax or compilation error.

Let us start with the **Structure**. Software structure consist of two main functions:

- Setup( ) function
- Loop( ) function



Void setup ( )

{

}

PURPOSE:

The **setup()** function is called when a sketch starts. Use it to initialize the variables, pin modes, start using libraries, etc. The setup function will only run once, after each power up or reset of the Arduino board.

INPUT

OUTPUT

RETURN

Void Loop ( )

{

}

PURPOSE:

After creating a **setup ()** function, which initializes and sets the initial values, the **loop()** function does precisely what its name suggests, and loops seductively, allowing your program to change and respond. Use it to actively control the Arduino board.

INPUT

OUTPUT

RETURN

CHAPTER-8

RESULTS

Assemble the circuit on the bread board and general board. After assembling the circuits on the boards check it for proper connections before switching on the power supply.

The implementation of "**MENTION YOUR TITLE**" is done successfully. The communication is properly done without any interference between different modules in the design. Design is done to meet all the specifications and requirements.

It can be concluded that the design implemented in the present work provide portability, flexibility and the data transmission is also done with low power consumption.

ADD YOUR PROJECT IMAGES

Conclusion

In recent years, with the increase in population, the volume of vehicles has also increased dramatically. This increase in number of vehicle has increased the road traffic and has become one of main cause for road accident. From earlier literature, it is obvious that the driving by unlicensed people cause greater risk to legitimate drivers as their over speed results in severe accidents. Though numerous systems are proposed in the past to detect accident and notify emergency services, yet the mortality rate due to road accident is high across the globe. Therefore, this work aims to design an IoT based smart car seat belt that can be used to detect accident and notify emergency team timely and accurately. Importantly, to avoid unlicensed people from driving, the proposed system avails fingerprint recognition based biometric system for driver authentication and car ignition. Later, the system uses the information collected by sensor mounted inside the seat belt to detect whether accident has occurred. If accident is detected, then the driver heart beat rate is captured using pulse sensor to conform the accident. The proposed system demonstrated to reduce the number of false rate in accident detection. Nevertheless, the system is limited in functionality as the notification task of the system requires internet connectivity for successful communication. In future, the system limitation will be addressed by leveraging the benefits of edge computing to enhance its security and reduce the latency time.

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