A

MAJOR PROJECT REPORT

ON

A SMART AIR POLLUTANTS MONITORING SYSTEM USING IOT TECHNOLOGIES

Submitted in partial fulfilment of the requirement for the award of degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

SUBMITTED BY

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UGC AUTONOMOUS

(Approved by AICTE, Affiliated to JNTU Hyderabad, Accredited by NBA)
Kandlakoya(V), Medchal(M), Telangana – 501401

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CERTIFICATE

This is to certify that the major-project work entitled **"A SMART AIR POLLUTANTS MONITORING SYSTEM USING IOT TECHNOLOGIES"** is being submitted by **S. VISHNU VARDHAN** bearing Roll No **228R5A0425, T. ANIL KUMAR** bearing Roll No **228R5A0426, V. SAI TEJA** bearing Roll No **228R5A0427, V. SONY** bearing Roll No **228R5A0428** in B.Tech IV-II semester, Electronics and Communication Engineering is a record Bonafide work carried out during the academic year 2024-25. The results embodied in this report have not been submitted to any other University for the award of any degree.

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DECLARATION

We hereby declare that the major project entitled **"A SMART AIR POLLUTANTS MONITORING SYSTEM USING IOT TECHNOLOGIES"** is the work done by us in campus at **CMR ENGINEERING COLLEGE,** Kandlakoya during the academic year 2024-2025 and is submitted as major project in partial fulfilment of the requirements for the award of degree of **BACHELOR OF TECHNOLOGY** in **ELECTRONICS AND COMMUNICATION ENGINEERING FROM JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY, HYDERABAD.**

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ABSTRACT

Floods cause significant damage to life and property, necessitating efficient early warning systems. This project presents a Flood Monitoring and Warning System using the NRF (Nordic Radio Frequency) module for wireless communication. The system consists of multiple sensor nodes placed near water bodies to measure parameters like water level, flow rate, and rainfall intensity. These sensors communicate wirelessly through NRF modules to a central control unit, which processes real-time data and determines flood risk levels.

In a country like India, air pollution is increasing day by day at the alarming rate. The main reason for increasing of pollution level are crop's remaining burning, emission from the motor vehicle, open defecation of smoke in atmosphere from the industries and burning of garbage openly. Internet of Things (IOT) based pollution system is used to detect the current level of hazardous gases in the atmosphere. In our daily lives the quality of air determines the most because every human being needs fresh air to live. The IOT based pollution system will help us to fetch the data from any location where device is installed. On international basis, one in all our century's essential problems is air pollutants

A graphical user interface can be created on the IOT web server side. The graph visualizes the sensor data in a convenient way. By virtue of this IOT based pollution monitoring system project, air and pollution levels can be constantly monitored from a remote location. This remote location can be anywhere in the world. We can then take steps in order to reduce pollution levels.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF THE PROJECT

This project focuses on developing a smart air pollutants monitoring system using IoT technologies to provide real-time data on air quality and environmental conditions. By integrating various gas and particulate matter sensors, a display, GSM module for data communication, and a centralized database (BAZAAR), the system monitors and reports key air pollutants and weather conditions to enhance public awareness and safety. The gas sensors include the MQ-131 for ozone, MQ-2 for smoke and flammable gases, MQ-7 for carbon monoxide, MQ-6 for LPG and butane, MQ-4 for methane, MQ-135 for harmful gases like ammonia and benzene, MICS-2714 for high-sensitivity ozone detection, and MICS-5524 for carbon monoxide and volatile organic compounds.[1]

The PMS5003 particulate matter sensor measures PM2.5 and PM10 levels, essential for assessing air quality. A DHT22 sensor collects temperature and humidity data to give context to the pollutant data. The Air Quality Index (AQI), calculated from sensor readings, provides a standardized measure of air quality, displayed on the display module for easy access. A GSM module transmits data to remote servers or databases, such as BAZAAR, supporting real-time data logging and monitoring.[5]

BAZAAR stores and processes data for historical access, trend analysis, and integration with other systems. A reliable power supply powers all components to ensure continuous operation. The project aims to provide real-time monitoring, remote data communication, AQI calculation, data analysis, and an intuitive user interface, helping users make informed health decisions and supporting urban planning and environmental policies. This project provides a user-friendly interface and delivers valuable air quality data to aid in public health decisions and supports environmental policy and urban planning by tracking pollution trends and patterns. The system calculates an Air Quality Index (AQI), a standardized score that helps users easily interpret the air quality and understand associated health risks. This AQI and the pollutant data are displayed on an on-site module, allowing users to view current conditions instantly. Through the GSM module, the system sends this data to a remote, centralized database (BAZAAR), enabling continuous data logging, historical data access, and real-time monitoring from any location.[3]

1.2 OBJECTIVE OF THE PROJECT

The objective of this project is to design and implement a smart air pollutants monitoring system that provides real-time insights into air quality by detecting various pollutants and environmental conditions. The system aims to collect accurate data on key air pollutants, including ozone, carbon monoxide, methane, volatile organic compounds (VOCs), and particulate matter (PM2.5 and PM10), alongside temperature and humidity. By calculating the Air Quality Index (AQI) from these measurements, the system delivers a clear, standardized indicator of air quality. Through the GSM module, data will be transmitted to a centralized database (BAZAAR) for remote access, historical analysis, and integration with other systems. This project intends to support public awareness of air pollution levels, guide informed health and lifestyle decisions, and potentially contribute to environmental policy and urban planning efforts by offering a scalable, cost-effective solution for real-time air quality monitoring and data-driven analysis

This project is to develop an advanced IoT-based air pollutants monitoring system that facilitates real-time detection and analysis of various air pollutants to support health and safety. By using a comprehensive range of sensors—covering gases like ozone, carbon monoxide, methane, LPG, and other volatile organic compounds (VOCs), as well as particulate matter (PM2.5 and PM10)—the system captures a holistic view of environmental air quality. The integration of a DHT22 sensor for temperature and humidity measurement enhances the data accuracy by providing context for air pollutant readings

1.3 ORGANIZATION OF THE PROJECT

The Air Pollutants Monitoring System project is organized around key components that work together to detect, analyze, and communicate air quality data. The gas sensors, including the MQ-2 for smoke and flammable gases, MQ-7 for carbon monoxide, MQ-6 for LPG and butane, MQ-4 for methane, MQ-135 for gases like ammonia and benzene, MICS-2714 for high-sensitivity ozone detection, and MICS-5524 for carbon monoxide and VOCs, each contribute to a detailed assessment of air pollutants.[2]

The PMS5003 sensor measures particulate matter (PM2.5 and PM10), crucial for determining overall air quality, while the DHT22 sensor monitors temperature and humidity to provide environmental context. An Air Quality Index (AQI) is calculated from these sensor readings to offer a clear measure of pollution levels, displayed on a local interface for immediate user access. The GSM module transmits this data to BAZAAR, a centralized database where it

is stored for remote monitoring, trend analysis, and integration with other applications. A reliable power supply ensures that all components function continuously, enabling the system to provide consistent, real-time air quality monitoring that supports both public health and environmental insights.

The Air Pollutants Monitoring System project is meticulously organized to ensure comprehensive, real-time monitoring of air quality by utilizing IoT-enabled components for precise pollutant detection, data processing, and communication. Gas sensors like the MQ-2, MQ-7, MQ-6, MQ-4, and MQ-135, along with the MICS-2714 and MICS-5524, work in tandem to detect a variety of pollutants, including smoke, carbon monoxide, methane, LPG, butane, ammonia, and volatile organic compounds (VOCs). These sensors capture granular data about specific pollutants, contributing to a multi-faceted view of air quality. [7]

The PMS5003 sensor adds another layer of analysis by monitoring particulate matter (PM2.5 and PM10), which is critical for assessing the potential health impact of airborne particles, while the DHT22 sensor captures environmental factors like temperature and humidity to enhance data accuracy by contextualizing pollutant readings.

CHAPTER 2

LITERATURE SURVEY

2.1 EXISTING SYSTEM

An The existing system typically refers to traditional air quality monitoring approaches and initial IoT-based solutions. Here's an overview of these systems:

1. **Traditional Air Quality Monitoring Systems**:

Fixed Monitoring Stations: Conventional air quality monitoring usually relies on fixed stations managed by government or environmental agencies. These stations measure pollutants at specific locations, often in urban areas, using large, expensive, and complex instruments.

High Cost and Maintenance These stations require significant setup, operation, and maintenance costs. They also demand high power, professional supervision, and frequent calibration.

Limited Coverage Traditional systems provide limited spatial coverage because they cannot be placed everywhere. Monitoring at a city or regional level can be inefficient, as pollution varies greatly by area and real-time data is sparse.

2. **Initial IoT-Based Monitoring Systems:**

Basic IoT Sensors: Some initial IoT-based air quality solutions introduced low-cost, portable sensors connected via the internet. These sensors can measure basic pollutants like CO_2, PM2.5, CO, and VOCs. These systems began to bridge the gap, offering more granular data.

Limited Data Precision and Accuracy Low-cost IoT sensors, though accessible and easy to deploy, often lack the precision and accuracy of traditional instruments. They are sensitive to environmental factors and may not provide reliable data without recalibration.

Scalability Challenges Early IoT systems often faced connectivity, battery life, and data transmission challenges, especially in remote or densely populated urban areas.

These existing systems represent the foundation on which more advanced IoT-based air quality monitoring solutions are being developed, aiming to improve data accuracy, real-time monitoring, scalability, and cost efficiency.

2.2 PROPOSED SYSTEM

The proposed system aims to offer a more advanced and comprehensive solution for air quality monitoring compared to existing systems by integrating a wider range of sensors, improved data transmission, and real-time reporting, all while enhancing user-friendliness and reliability. Unlike traditional air quality monitoring systems that often rely on a limited number of sensors and static setups, this IoT-based system incorporates multiple sensors, real-time data communication, and cloud-based data storage to create a robust and scalable solution.

Sensor Integration: The system will utilize a broader array of sensors to detect various pollutants, offering more detailed and accurate monitoring than current systems. The sensors integrated into the proposed system include:

- **MQ-2**: Detects smoke, LPG, and other combustible gases, enhancing air quality detection for residential, industrial, and urban environments.
- **MQ-7**: Measures carbon monoxide (CO) levels, an important parameter for assessing air pollution and its effects on human health.
- **MQ-6**: Monitors LPG and butane, providing detection for household and industrial gas leaks.
- **MQ-4**: Focuses on methane detection, contributing to the identification of specific air contaminants related to industrial emissions or natural sources.
- **MQ-135**: Measures harmful gases like ammonia, benzene, and alcohols, further improving the detection of pollutants commonly found in urban environments.
- **DHT22**: Monitors temperature and humidity, offering contextual data that enhances the accuracy of pollutant readings and helps better understand environmental conditions.

This combination of sensors provides a significantly broader scope of air quality detection than existing systems, which often utilize fewer sensors that are limited to detecting just one or two types of pollutants.

Real-Time Data Communication and Cloud Integration

- **Display Module**: The system will feature a user-friendly display module that shows real-time data on air quality, pollutant levels, and the calculated AQI. This immediate feedback

helps users make informed decisions about their health and safety.

- **GSM Module**: The GSM module is employed to send the collected data to a centralized cloud-based system for remote monitoring and storage. This ensures that the system operates efficiently even in areas without stable internet access, offering real-time data transmission through cellular networks.
- **BAZAAR Database**: Data transmitted via GSM will be uploaded to **BAZAAR**, the centralized cloud database. BAZAAR serves as the central repository for all collected data, offering easy access for long-term analysis, historical tracking, and trend identification. This cloud-based approach enables users to access data from any location and ensures continuous data collection and storage.
- This combination of sensors provides a significantly broader scope of air quality detection than existing systems, which often utilize fewer sensors that are limited to detecting just one or two types of pollutants.

Improved System Capabilities

The proposed system offers several advantages over existing systems:

- **Comprehensive Pollutant Detection**: With more sensors deployed, the system provides a much broader range of pollutant detection (including gases, particulates, temperature, and humidity), significantly improving the accuracy and reliability of the air quality data.
- This combination of sensors provides a significantly broader scope of air quality detection than existing systems, which often utilize fewer sensors that are limited to detecting just one or two types of pollutants.
- **Real-Time Monitoring**: The system's integration of GSM communication allows for real-time reporting of air quality conditions to remote servers, unlike traditional systems that may offer delayed data or only monitor a fixed set of locations.
- **Remote Accessibility**: By using the BAZAAR cloud-based storage solution, the system allows for easy access to historical data, real-time monitoring, and trend analysis, giving users better insight into air quality patterns and pollution hotspots.
- **Scalability**: The system is designed to be scalable, allowing additional sensors or components to be easily integrated for further expansion, making it suitable for deployment in both urban and rural areas.

2.3 EMBEDDED INTRODUCTION

An embedded system is a combination of computer hardware and software designed for a specific function or functions within a larger system. The systems can be programmable or with fixed functionality. Industrial machines, consumer electronics, agricultural and process industry devices, automobiles, medical equipment, cameras, household appliances, airplanes, vending machines and toys, as well as mobile devices, are possible locations for an embedded system.

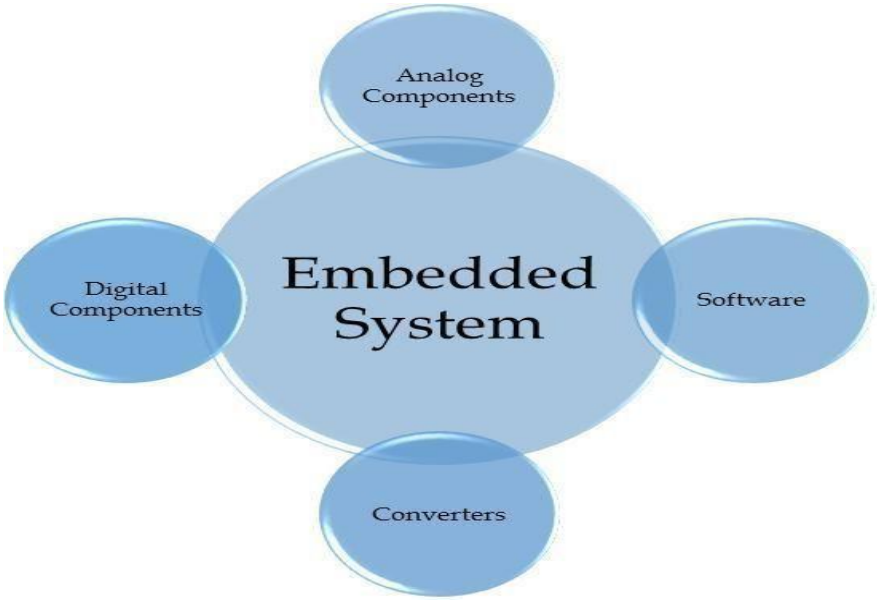

Fig:2.1 EMBEDDED SYSTEM RELATED TO SOFTWARE AND DIGITAL COMPONENTS

While embedded systems are computing systems, they can range from having no user interface (UI) -- for example, on devices in which the system is designed to perform a single task -- to complex graphical user interfaces (GUIs), such as in mobile devices. User interfaces can include buttons, LEDs and touchscreen sensing. Some systems use remote user interfaces as well.

History of embedded systems

Embedded systems date back to the 1960s. Charles Stark Draper developed an integrated circuit (IC) in 1961 to reduce the size and weight of the Apollo Guidance Computer, the digital system installed on the Apollo Command Module and Lunar Module. The first computer to use ICs, it helped astronauts collect real-time flight data.

In 1965, Autonoetic, now a part of Boeing, developed the D-17B, the computer used in the Minuteman I missile guidance system. It is widely recognized as the first mass-produced embedded system.

When the Minuteman II went into production in 1966, the D-17B was replaced with the NS-17 missile guidance system, known for its high-volume use of integrated circuits.In 1968, the first embedded system for a vehicle was released; the Volkswagen 1600 used a microprocessor to control its electronic fuel injection system.

By the late 1960s and early 1970s, the price of integrated circuits dropped, and usage surged. The first microcontroller was developed by Texas Instruments in 1971. The TMS 1000 series, which became commercially available in 1974, contained a 4-bit processor, read-only memory (ROM) and random-access memory (RAM), and cost around $2 apiece in bulk orders.

Also, in 1971, Intel released what is widely recognized as the first commercially available processor, the 4004. The 4-bit microprocessor was designed for use in calculators and small electronics, though it required eternal memory and support chips. The 8-bit Intel 8008, released in 1972, had 16 KB of memory; the Intel 8080 followed in 1974 with 64 KB of memory. The 8080's successor, x86 series, was released in 1978 and is still largely in use today.

In 1987, the first embedded operating system, the real-time VxWorks, was released by Wind River, followed by Microsoft's Windows Embedded CE in 1996. By the late 1990s, the first embedded Linux products began to appear. Today, Linux is used in almost all embedded devices.

Characteristics of embedded systems

The main characteristic of embedded systems is that they are task specific. They perform a single task within a larger system. For example, a mobile phone is not an embedded system, it is a combination of embedded systems that together allow it to perform a variety of general-purpose tasks. In 1987, the first embedded operating system, the real-time VxWorks, was released by Wind River, followed by Microsoft's Windows Embedded CE in 1996. By the late 1990s, the first embedded Linux products began to appear. Today, Linux is used in almost all embedded devices. in 1971, Intel released what is widely recognized as the first commercially available processor, the 4004. The 4-bit microprocessor was designed for use in calculators and small electronics, though it required eternal memory and support chips. The 8-bit Intel 8008, released in 1972

The embedded systems within it perform specialized functions. For example, the GUI performs the singular function of allowing the user to interface with the device. In short, they are programmable computers, but designed for specific purposes, not general ones.

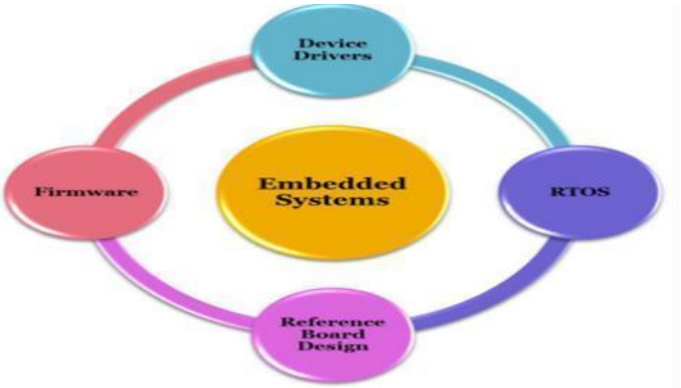

Fig:2.2 CHARACTERISTICS OF EMBEDDED SYSTEMS

Additionally, embedded systems can include the following characteristics:

- comprised of hardware, software and firmware;

- embedded in a larger system to perform a specific function as they are built for specialized tasks within the system, not various tasks;
- either microprocessor-based or microcontroller-based -- both are integrated circuits that give the system compute power;
- often used for sensing and real-time computing in internet of things (IoT) devices -- devices
  that are internet-connected and do not require a user to operate;
- vary in complexity and in function, which affects the type of software, firmware and hardware they use; and
- often required to perform their function under a time constraint to keep the larger system functioning properly.

  Embedded systems vary in complexity, but generally consist of three main elements:
- vary in complexity and in function, which affects the type of software, firmware and hardware they use; and

  embedded in a larger system to perform a specific function as they are built for specialized tasks within the system, not various tasks

- **Hardware.** The hardware of embedded systems is based around microprocessors and microcontrollers. Microprocessors are very similar to microcontrollers, and generally refer to a CPU that is integrated with other basic computing components such as memory chips and digital signal processors (DSP). Microcontrollers have those components built into one chip.

- **Software.** Software for embedded systems can vary in complexity. However, industrial grade microcontrollers and embedded IoT systems generally run very simple software that requires little memory.

Fig:2.3 BLOCKS OF EMBEDDED SYSTEMS

- **Firmware**. Embedded firmware is usually used in more complex embedded systems to connect the software to the hardware. Firmware is the software that interfaces directly with the hardware. A simpler system may just have software directly in the chip, but more complicated systems need firmware under more complex software applications and operating systems.

2.4 WHY EMBEDDED?

An embedded system is a computer system with a particular defined function within a larger mechanical or electrical system. They control many devices in common use. They consume low power, are of a small size and their cost is low per-unit.

Modern embedded systems are often based on micro-controllers. A micro-controller is a small computer on a single integrated circuit which contains a processor core, memory, and programmable input and output peripherals. As Embedded system is dedicated to perform specific tasks therefore, they can be optimized to reduce the size and cost of the product and increase the reliability and performance.

Almost every Electronic Gadget around us is an Embedded System, digital watches, MP3 players, Washing Machine, Security System, scanner, printer, a cellular phone, Elevators, ATM, Vendor Machines, GPS, traffic lights, Remote Control, Microwave Oven and many more. Software for embedded systems can vary in complexity. However, industrial grade microcontrollers and embedded IoT systems generally run very simple software that requires little memory. The uses of embedded systems are virtually limitless because every day new products are introduced to the market which utilize embedded computers in a number of ways.

Embedded Systems has brought about a revolution in science. It is also a part of an Internet of Things (IoT) – a technology in which objects, animals or people are provided with unique identifiers and the ability to transfer data over a network without requiring human-to- human or human-to-computer interaction.

Fig:2.4 EMBEDDED SYSTEMS HARDWARE

Let's make it easy for you. For Example – You are sitting in a train headed to your destination and you are already fifty miles away from your home and suddenly you realise that you forgot to switch of the fan. Not to worry, you can switch it off just by clicking a button on your cell phone using this technology – The Internet of Things.

Well, this is just one good thing about IoT. We can monitor Pollution Levels, we can control the intensity of street lights as per the season and weather requirements, IoT can also provide the parents with real-time information about their baby's breathing, skin temperature, body position, and activity level on their smartphones and many other applications which can make our life easy.

2.4 DESIGN APPROACHES

A system designed with the embedding of hardware and software together for a specific function with a larger area is embedded system design. In embedded system design, a microcontroller plays a vital role. Micro-controller is based on Harvard architecture, it is an important component of an embedded system. External processor, internal memory and i/o components are interfaced with the microcontroller. It occupies less area, less power consumption. The application of microcontrollers is MP3, washing machines.

Critical Embedded Systems (CES) are systems in which failures are potentially catastrophic and, therefore, hard constraints are imposed on them. Not to worry, you can switch it off just by clicking a button on your cell phone using this technology. In the last years the amount of software accommodated within CES has considerably changed.

For example, in smart cars the amount of software has grown about 100 times compared to previous years. This change means that software design for these systems is also bounded to hard constraints (e.g., high security and performance). Along the evolution of CES, the approaches for designing them are also changing rapidly, so as to fit the specialized needs of CES. Thus, a broad understanding of such approaches is missing.

Steps in the Embedded System Design Process

The different steps in the embedded system design flow/flow diagram include the following:

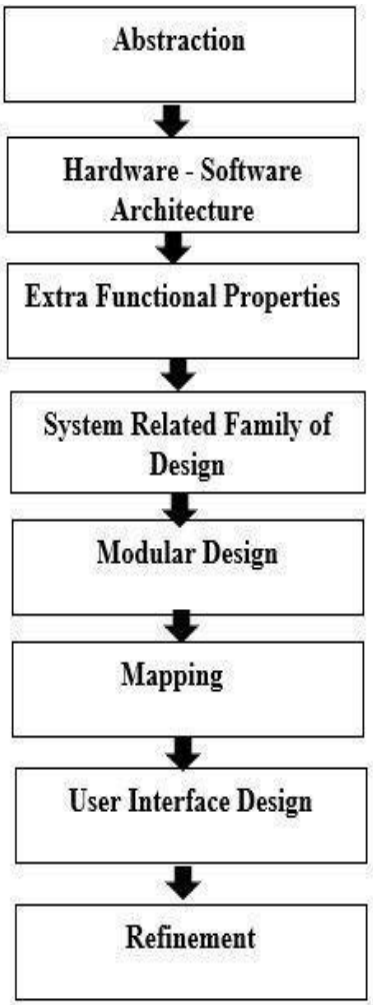

Fig:2.5 EMBEDDED DESIGN-PROCESS-STEPS

Abstraction

In this stage the problem related to the system is abstracted.

Hardware – Software Architecture

Proper knowledge of hardware and software to be known before starting any design process.

Extra Functional Properties

Extra functions to be implemented are to be understood completely from the main design.

System Related Family of Design

When designing a system, one should refer to a previous system-related family of design.

Modular Design

Separate module designs must be made so that they can be used later on when required.

Mapping

Based on software mapping is done. For example, data flow and program flow are mapped into one.

User Interface Design

In user interface design it depends on user requirements, environment analysis and function of the system. For example, on a mobile phone if we want to reduce the power consumption of mobile phones, we take care of other parameters, so that power consumption can be reduced.

Refinement

Every component and module must be refined appropriately so that the software team can understand.

Architectural description language is used to describe the software design.

- Control Hierarchy
- Partition of structure
- Data structure and hierarchy
- Software Procedure.

In user interface design it depends on user requirements, environment analysis and function of the system. For example, on a mobile phone if we want to reduce the power consumption of mobile phones, we take care of other parameters, so that power consumption can be reduced. To help countries and health-care facilities to achieve system change and adopt alcohol-based hand rubs as the gold standard for hand hygiene in health care, WHO has identified formulations for their local preparation. Logistic, economic, safety, and cultural.

Table:2.1 DESIGN PARAMETERS OF AN EMBEDDED SYSTEM

Design Parameters of an Embedded System	**Function**
Power Dissipation	Always maintained low
Performance	Should be high
Process Deadlines	The process/task should be completed within a specified time.
Manufacturing Cost	Should be maintained.
Engineering Cost	It is the cost for the edit-test-debug of hardware and software.
Size	Size is defined in terms of memory RAM/ROM/Flash Memory/Physical Memory.
Prototype	It is the total time taken for developing a system and testing it.
Safety	System safety should be taken like phone locking, user safety like engine breaks down safety measure must be taken.
Maintenance	Proper maintenance of the system must be taken, in order to avoid system failure.
Time to market	It is the time taken for the product /system developed to be launched into the market.

2.4.1 SPECIFICATION

During this part of the design process, the informal requirements of the analysis are transformed to formal specification using SDL.

2.4.2 SYSTEM-SYNTHESIS

For performing an automatic HW/SW partitioning, the system synthesis step translates the SDL specification to an internal system model switch contains problem graph& architecture graph. After system synthesis, the resulting system model is translated back to SDL.

2.4.3 IMPLEMENTATION-SYNTHESIS

On a prototyping platform, the implementation of the system under development is executed with the software parts running on multiprocessor unit and the hardware part running on a FPGA board known as phoenix, prototype hardware for Embedded Network Interconnect Accelerators

2.4.4 APPLICATIONS

Embedded systems are finding their way into robotic toys and electronic pets, intelligent cars and remote controllable home appliances. All the major toy makers across the world have been coming out with advanced interactive toys that can become our friends for life. 'Furby' and 'AIBO' are good examples at this kind. Furbies have a distinct life cycle just like human beings, starting from being a baby and growing to an adult one. In AIBO first two letters stand for Artificial Intelligence. Next two letters represent robot.

The AIBO is robotic dog. Embedded systems in cars also known as Telematic Systems are used to provide navigational security communication &entertainment services using GPS, satellite. Home appliances are going the embedded way. LG electronics digital DIOS refrigerator can be used for surfing the net, checking e-mail, making video phone calls and watching TV.IBM is developing an air conditioner that we can control over the net. Embedded systems cover such a broad range of products that generalization is difficult. Here are some broad categories.

In the automobile sector, embedded systems, often referred to as Telematic Systems, are essential for navigation, safety, entertainment, and autonomous driving. Modern cars feature GPS-based navigation, collision detection, adaptive cruise control, and parking assistance, all powered by real-time data processing and AI algorithms.

Companies like Tesla use advanced embedded systems and LIDAR sensors to enable self-driving capabilities, improving road safety and driving efficiency.

- **Aerospace and defence electronics**: Fire control, radar, robotics/sensors, sonar.
- **Automotive**: Autobody electronics, auto power train, auto safety, car information systems.
- **Broadcast & entertainment**: Analog and digital sound products, camaras, DVDs, Set top boxes, virtual reality systems, graphic products.
- **Consumer/internet appliances**: Business handheld computers, business network computers/terminals, electronic books, internet smart handheld devices, PDAs.
- **Data communications:** Analog modems, ATM switches, cable modems, XDSL modems, Ethernet switches, concentrators.
- **Digital imaging**: Copiers, digital still cameras, Fax machines, printers, scanners.

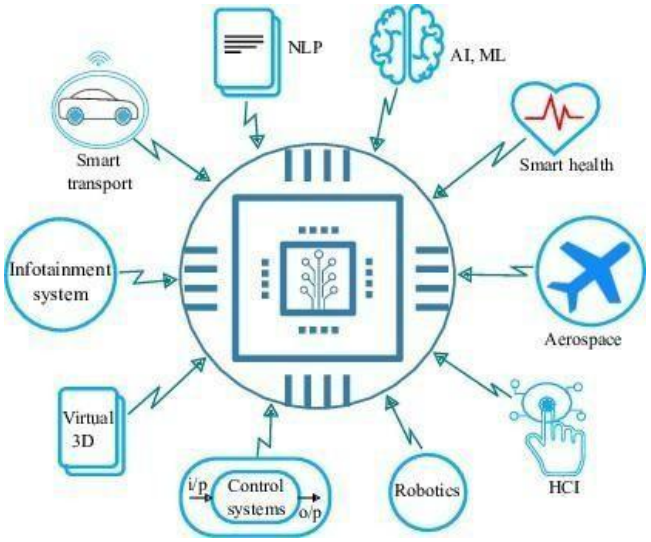

Fig:2.6 APPLICATIONS OF EMBEDDED SYSTEMS

- **Healthcare:** Automated insulin pumps, ECG monitors & heart rate sensors, MRI & CT scanners, Smart prosthetics, Wireless patient monitoring
- **Industrial measurement and control:** Hydro electric utility research & management traffic management systems, train marine vessel management systems.
- **Medical electronics:** Diagnostic devices, real time medical imaging systems, surgical devices, critical care systems.
- **Server I/O:** Embedded servers, enterprise PC servers, PCI LAN/NIC controllers, RAID devices, SCSI devices.
-

- **Telecommunications**: ATM communication products, base stations, networking switches, SONET/SDH cross connect, multiplexer.
- **Networking devices**: Routers, modems, and IoT gateways enable seamless internet connectivity, data transmission, and smart device communication in embedded systems.
- **Virtual Reality (VR) & Augmented Reality (AR):** Virtual Reality (VR) immerses users in a fully digital environment, while Augmented Reality (AR) overlays digital elements onto the real world, enhancing the user's perception of their surroundings.

2.4.5 FEATURES

Embedded systems are specialized computing devices designed for dedicated tasks with reliability and efficiency. They operate under real-time constraints, using minimal memory and low power consumption to ensure stable performance. Their task-specific design emphasizes fault tolerance, low cost, and minimal interface requirements.

By focusing on optimized functionality, embedded systems deliver high efficiency in processing and managing data. They are widely used in automotive, healthcare, industrial automation, and IoT applications. With compact designs and user-friendly operation, these systems ensure high stability and consistent performance, meeting strict timing requirements and enabling seamless, reliable operation in diverse environments. They continuously excel in efficiency.

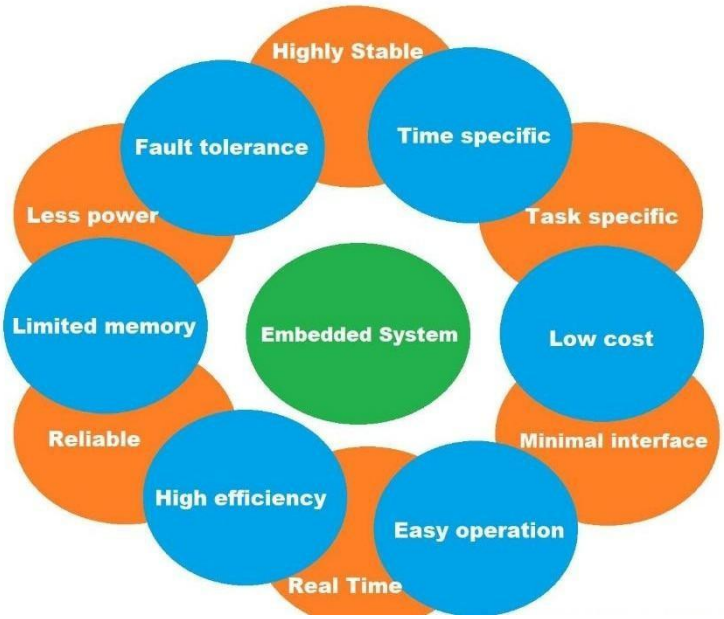

Fig: 2.7 FEATURES OF EMBEDDED SYSTEM

- **Highly Stable** – Ensures reliable performance over long periods.
- **Time-Specific** – Operates within strict time constraints.
- **Task-Specific** – Designed for a dedicated function.
- **Low Cost** – Cost-effective due to optimized hardware and software.
- **Minimal Interface** – Requires simple user interaction.
- **Easy Operation** – User-friendly and automated functionality.
- **Real-Time Processing** – Responds quickly to inputs for real-time applications.
- **High Efficiency** – Optimized for maximum performance with limited resources.
- **Reliable** – Functions consistently without frequent failures.
- **Limited Memory** – Operates with minimal RAM and storage.
- **Less Power Consumption** – Designed to use minimal energy.
- **Fault Tolerance** – Can handle errors and failures effectively.

CHAPTER 3

HARDWARE REQUIREMENTS

3.1 HARDWARE

Embedded system hardware

Embedded system hardware can be microprocessor- or microcontroller-based. In either case, an integrated circuit is at the heart of the product that is generally designed to carry out real time computing. Microprocessors are visually indistinguishable from microcontrollers. However, the microprocessor only implements a central processing unit (CPU) and, thus, requires the addition of other components such as memory chips. Conversely, microcontrollers are designed as self-contained systems. Microcontrollers include not only a CPU, but also memory and peripherals such as flash memory, RAM or serial communication ports.

Because microcontrollers tend to implement full (if relatively low computer power) systems, they are frequently used on more complex tasks. For example, microcontrollers are used in the operations of vehicles, robots, medical devices and home appliances. At the higher end of microcontroller capability, the term System on a chip (SOC) is often used, although there's no exact delineation in terms of RAM, clock speed, power consumption and so on. It is one of the characteristics of embedded and cyber-physical systems that both hardware and software must be taken into account.

The reuse of available hard- and software components is at the heart of the platform-based design methodology. Consistent with the need to consider available hardware components and with the design information flow, we are now going to describe some of the essentials of embedded system hardware.

Hardware for embedded systems is much less standardized than hardware for personal computers. Due to the huge variety of embedded system hardware, it is impossible to provide a comprehensive overview of all types of hardware components. Nevertheless, we will try to provide a survey of some of the essential components which can be found in most systems.

The choice of components for the WHO-recommended hand rub formulations takes into account cost constraints and microbicidal activity. Hardware for embedded systems is much less standardized than hardware for personal computers. Consistent with the need to consider available hardware components and with the design information flow, we are now going to describe some of the essentials of embedded system hardware both hardware and software.

The following two formulations are recommended for local production with a maximum of 50 litres per lot to ensure safety in production and storage.

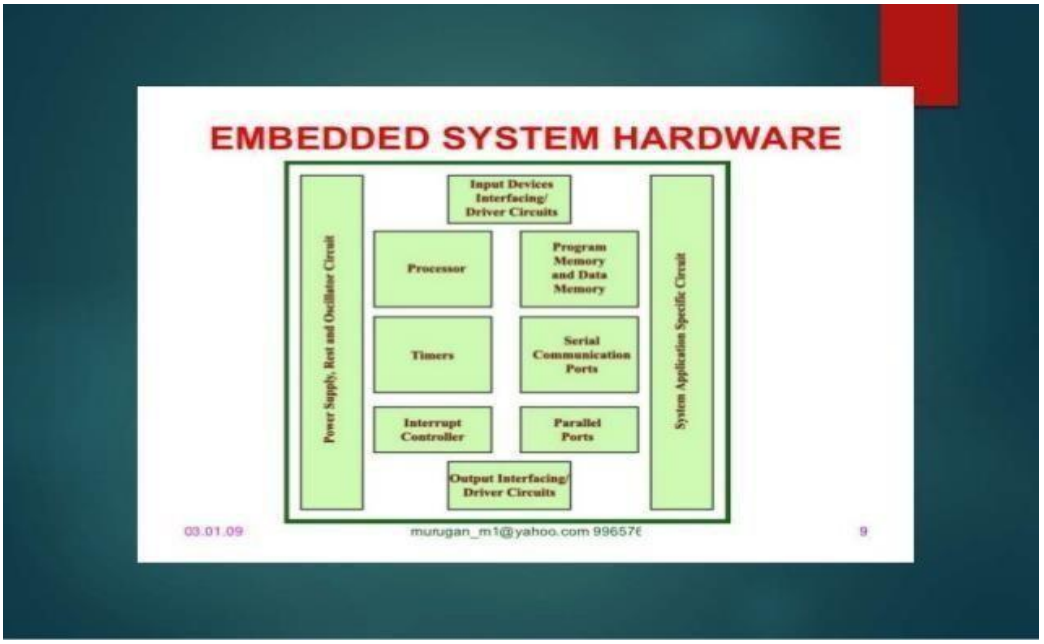

Fig:3.1EMBEDDED SYSTEMS HARDWARE BLOCK DIAGRAM

Markets and Markets, a business to business (B2B) research firm, predicts that the embedded market will be worth $116.2 billion by 2025. Chip manufacturers for embedded systems include many well-known technology companies, such as Apple, IBM, Intel and Texas Instruments, as well as numerous other companies less familiar to those outside the field.

To be used efficiently, all computer software needs certain hardware components or other software resources to be present on a computer.[1] These prerequisites are known as (computer) system requirements and are often used as a guideline as opposed to an absolute rule.

Most software defines two sets of system requirements: minimum and recommended. With increasing demand for higher processing power and resources in newer versions of software, system requirements tend to increase over time. Industry analysts suggest that this trend plays a bigger part in driving upgrades to existing computer systems than technological advancements. A second meaning of the term of system requirements, is a generalisation of this first definition, giving the requirements to be met in the design of a system or subsystem.

Often manufacturers of games will provide the consumer with a set of requirements that are different from those that are needed to run a software. These requirements are usually called the recommended requirements. These requirements are almost always of a significantly higher level than the minimum requirements, and represent the ideal situation in which to run software.

Architecture

All computer operating systems are designed for a particular computer architecture. Most software applications are limited to particular operating systems running on particular architectures. Although architecture-independent operating systems and applications exist, most need to be recompiled to run on a new architecture. See also a list of common operating systems and their supporting architectures.

Processing power

The power of the central processing unit (CPU) is a fundamental system requirement for any software. Most software running on x86 architecture define processing power as the model and the clock speed of the CPU. Many other features of a CPU that influence its speed and power, like bus speed, cache, and MIPS are often ignored. This definition of power is often erroneous, as AMD Athlon and Intel Pentium CPUs at similar clock speed often have different throughput speeds. Intel Pentium CPUs have enjoyed a considerable degree of popularity, and are often mentioned in this category.

Memory

All software, when run, resides in the random access memory (RAM) of a computer. Memory requirements are defined after considering demands of the application, operating system, supporting software and files, and other running processes. Optimal performance of other unrelated software running on a multi-tasking computer system is also considered when defining this requirement.

Secondary storage

Data storage device requirements vary, depending on the size of software installation, temporary files created and maintained while installing or running the software, and possible use of swap space (if RAM is insufficient).

Display adapter

Software requiring a better than average computer graphics display, like graphics editors and high-end games, often define high-end display adapters in the system requirements CPUs at similar clock speed often have different throughput speeds. Intel Pentium CPUs have enjoyed a considerable degree of popularity, and are often mentioned in this category.

Peripherals

Some software applications need to make extensive and/or special use of some peripherals, demanding the higher performance or functionality of such peripherals. Such peripherals include CD-ROM drives, keyboards, pointing devices, network devices, etc.

Basic Structure of an Embedded System

The following illustration shows the basic structure of an embedded system:

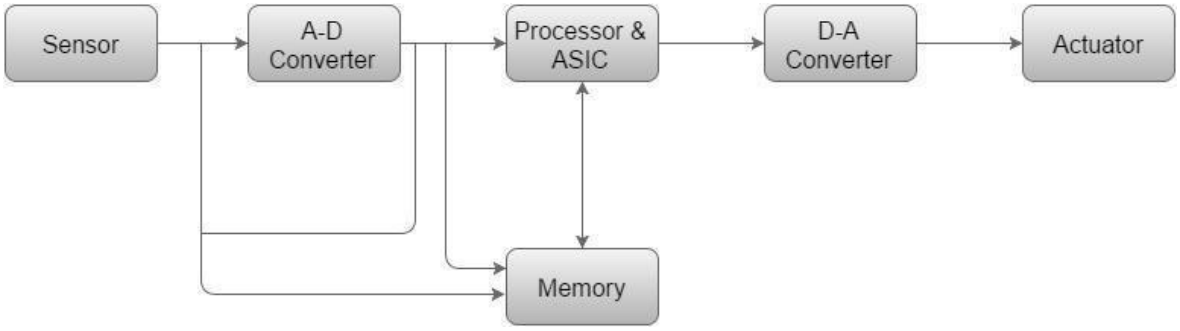

Fig:3.2 BASIC EMBEDDED STRUCTURE

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- **Sensor** − It measures the physical quantity and converts it to an electrical signal which can be read by an observer or by any electronic instrument like an A2D converter. A sensor stores the measured quantity to the memory.
- **A-D Converter** − As the name implies, the purpose of the analog-to-digital converter (ADC) is to convert the signal from its analog form to a digital data representation. Due to the physics of converter circuitry, most ADCs require inputs of at least several volts for their full range input. Two of the most important characteristics of an ADC are the conversion rate and the resolution. The conversion rate defines how fast the ADC can convert an analog value to a digital value. The resolution defines how close the digital number is to the actual analog value. The output of the ADC is a binary number that can be manipulated mathematically.
- **Processor & ASICs** − Processors process the data to measure the output and store it to the memory.
- **D-A Converter** − A Digital to Analog Converter (DAC) converts a digital input signal into an analog output signal. The digital signal is represented with a binary code, which is a combination of bits 0 and 1.
- **Actuator** − An actuator compares the output given by the D-A Converter to the actual (expected) output stored in it and stores the approved output.

In this loop, information about the physical environment is made available through sensors. Typically, sensors generate continuous sequences of analog values. In this book, we will restrict ourselves to information processing where digital computers process discrete sequences of values. Appropriate conversions are performed by two kinds of circuits: sample-and-hold-circuits and analog-to-digital (A/D) converters. After such conversion, information can be processed digitally. Generated results can be displayed and also be used to control the physical environment through actuators. Since most actuators are analog actuators, conversion from digital to analog signals is also needed. This model is obviously appropriate for control applications. For other applications, it can be employed as a first order approximation. In the following, we will describe essential hardware components of cyber-physical systems following the loop structure.

They aren't a lot different to the requirements for working with non-embedded systems. A lot depends on the purpose of the embedded system. You need to understand:

- Requirement set
- Environmental context
- Regulator requirements
- Interface specifications, including choice of hardware, and how to drive that hardware
- Criticality of what you are building, including hazards, and any defined mitigation to those hazards. For instance, is there a safe state to fail to if anything goes wrong.
- Real time constraints, such as cycle times, and time allowable for response. This should also include hysteresis, response of mechanical components, and backlash.
- Real time response from the combination of code, operating system, and hardware you are working with.
- Architecture, including any need for redundancy, diversity, fail safety, voting systems, comparators.
- Platform limitations. Cross compilers, linkers, auto-code generators, etc.
- Choice of operating environment, such as bare metal minimal kernel, real time operating system, or regular operating system.
- Whether you can rely on your tools. In particular, you need to understand how your tools can fail, and how you'd know if something went wrong.
- Communications protocols. Synchronous, and asynchronous communications. Error checking. Error correcting.

- Timing issues, clock rates. Anything that might stop you meeting your real time response targets, or impact the firing of timers.
- Exception handling.
- Interrupts. How to handle them. How long they take. What the impact is upon respondingto real time response targets.
- How to test on the platform you are working with.

CHAPTER 4

SOFTWARE REQUIREMENTS

4.1 SOFTWARE TOOLS

A typical industrial microcontroller is unsophisticated compared to the typical enterprise desktop computer and generally depends on a simpler, less-memory-intensive program environment. The simplest devices run on bare meta land are programmed directly using the chip CPU's machine code language.

Often, embedded systems use operating systems or language platforms tailored to embedded use, particularly where real-time operating environments must be served. At higher levels of chip capability, such as those found in SoCs, designers have increasingly decided the systems are generally fast enough and the tasks tolerant of slight variations in reaction time that near-real-time approaches are suitable. In these instances, stripped-down versions of the Linux operating system are commonly deployed, although other operating systems have been pared down to run on embedded systems, including Embedded Java and Windows IoT (formerly Windows Embedded).
Generally, storage of programs and operating systems on embedded devices make use of either flash or rewritable flash memory.
These activities include:

- Setting up a cloud service provider such as Amazon Web Services, Google Cloud, etc
- Set up private and public keys along with a device certificate.
- Write a device policy for devices connecting to the cloud service
- Connect an embedded system to the cloud service
- Transmit and receive information to the cloud
- Build a basic dashboard to examine data in the cloud and control the device

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If developers are able to do these things, they will have built a good foundation from which to master cloud connectivity for their embedded systems.

Software requirements

Software requirements deal with defining software resource requirements and prerequisites that need to be installed on a computer to provide optimal functioning of an application. These requirements or prerequisites are generally not included in the software installation package and need to be installed separately before the software is installed.

Platform

A computing platform describes some sort of framework, either in hardware or software, which allows software to run. Typical platforms include a computer's architecture, operating system, or programming languages and their run time libraries. Operating system is one of the requirements mentioned when defining system requirements (software). Software may not be compatible with different versions of same line of operating systems, although some measure of backward compatibility is often maintained. For example, most software designed for Microsoft Windows XP does not run on Microsoft Windows 98, although the converse is not always true. Similarly, software designed using newer features of Linux Kernelv2.6 generally does not run or compile properly (or at all) on Linux distributions using Kernel v2.2 or v

APIs and drivers

Software making extensive use of special hardware devices, like high-end display adapters, needs special API or newer device drivers. A good example is DirectX, which is a collection of APIs for handling tasks related to multimedia, especially game programming, on Microsoft platforms.

Web browser

Most web applications and software depend heavily on web technologies to make use of the default browser installed on the system. Microsoft Internet Explorer is a frequent choice of software running on Microsoft Windows, which makes use of Active X controls, despite their

- It is easily available for operating systems like MAC, Windows, Linux and runs on the Java, python Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing and compiling the code in the environment.

- The Raspberry Pi is a very cheap computer that runs Linux, but it also provides a set of GPIO

(general purpose input/output) pins, allowing you to control electronic components for physical computing and explore the Internet of Things (IoT).

- Each of them contains amicrocontrolleron the board that is actually programmed and accepts the information in the form of code.

The Raspberry Pi is a low-cost, credit-card-sized single-board computer that has become immensely popular for education, DIY projects, prototyping, and hobbyist electronics. Developed by the Raspberry Pi Foundation.

Programming Languages: The Raspberry Pi supports a variety of programming languages, including Python, C, C++, Java, and many others. Python is particularly popular for educational purposes.

4.2 RESEARCH

The embedded systems industry was born with the invention of microcontrollers and since then it has evolved into various forms, from primarily being designed for machine control applications to various other new verticals with the convergence of communications. Today it spans right form small metering devices to the multi-functional smartphones. I will cover the areas that are currently focused for development in embedded systems and state what are the ongoing research opportunities in that particular area.

Security

Security remains a great challenge even today. Ongoing Research is to sustain physical tampering, mechanisms to trust the software, authenticate the data and securely communicate over internet. With the advent of IoT/IoE, not only the number devices will continue to increase but also will the **number of possible attack vectors**. Many challenges remain ahead to get the connected devices on a billion scale.

Connectivity

Wi-Fi, BLE, ZigBee, Thread, ANT, etc have been adapted by embedded system experts from considerable time. Head-on competition between these groups is in progress to determine as to who will emerge as the best solution provider to this huge estimated market of IoT/IoE. **4G/5G** on low power devices is the ongoing experimentation which will make embedded systems easily and robustly connect to the internet. Communication using GSM/LTE in licensed/unlicensed communication bands with the cloud can change the ball game of IoE all

Memory

Various type of volatile/non-volatile memories with variable sizes and speeds are widely available today. Research is more towards **organizing** them in best possible architecture to reach closer to the design goal of optimal power-performance-cost.

Energy

Power/Battery management has been under focus for some time. Usage of **renewable resources** to power device's lifetime is currently the challenge that is tried to address; especially for wearables. Optimal power usage to get **Longer Battery Life** with new Hardware/Software architectural designs will continue for some time.

System

Multicore (Symmetric/Asymmetric) architectures are experimented since long. Addition of **GPUs** to systems for VR/Gaming/Machine learning is addressed currently.

Programmable SOCs **(PSOCs) -** (Configurable Hardware Capability) have been there for a long time now, but some has not yet gained momentum. Application-specific computer architectures is also in the pipeline in order to optimize the design matrix of power- performance-cost.

Performance

Real-time on-board Image/Video/Audio processing, feature enabled cameras, on board machinelearning are all currently experimented with varied approaches. Commercialization of these technologies has already started but there is still some time to get the best out of these technologies and there is lot of scope to make them more userfriendly.

Other than this, hardening of modular software functionalities (Yes lot of architectures are coming up with hardware performing redundant software functionalities). Ongoing research is to analyse the performance and determine the applications where this strategy can be fruitful.

Networking

Wireless Sensor Networks, Machine to Machine Communication/Interaction, Human Computer Interaction, Security Gateway protocols are still being improved. Light weight algorithms with optimal security will be targeted for embedded systems. Real-time on-board Image/Video/Audio processing, feature enabled cameras, on board machinelearning are all currently experimented with varied approaches. The embedded systems industry was born with the invention of microcontrollers and since then it has evolved into various forms, from primarily being designed for machine control applications to various other new verticals with the convergence of communications. Today it spans right form small metering devices to the multi-functional smartphones.

Real Time Operating Systems (RTOS)

Many companies are backing at least one Real Time Open-Source Operating System and there are many out there. Challenge is to cover the wide span of devices, there functionalities and variety of applications.

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.

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 4.1: 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. Many companies are backing at least one Real Time Open-Source Operating System and there are many out there. Challenge is to cover the wide span of devices, there functionalities and variety of applications.

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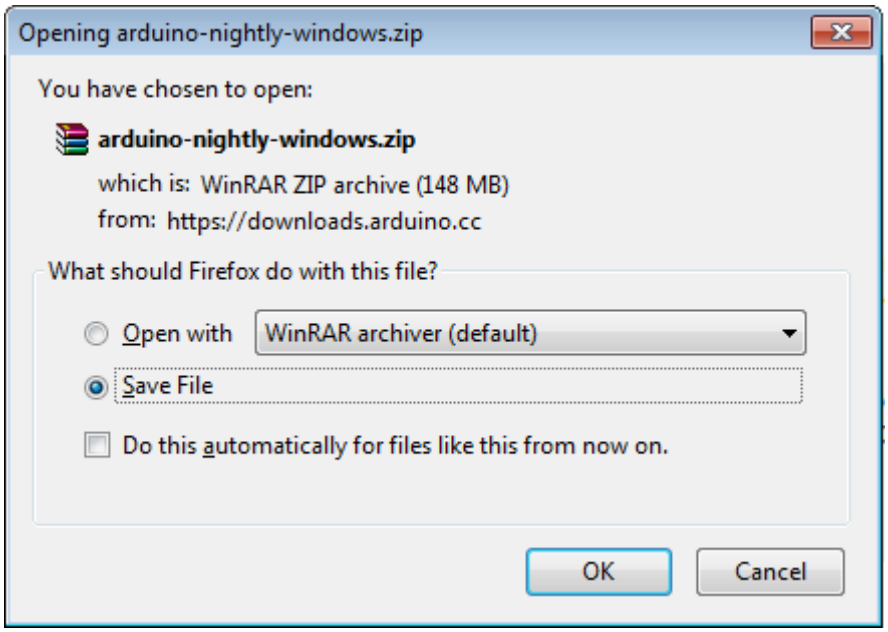
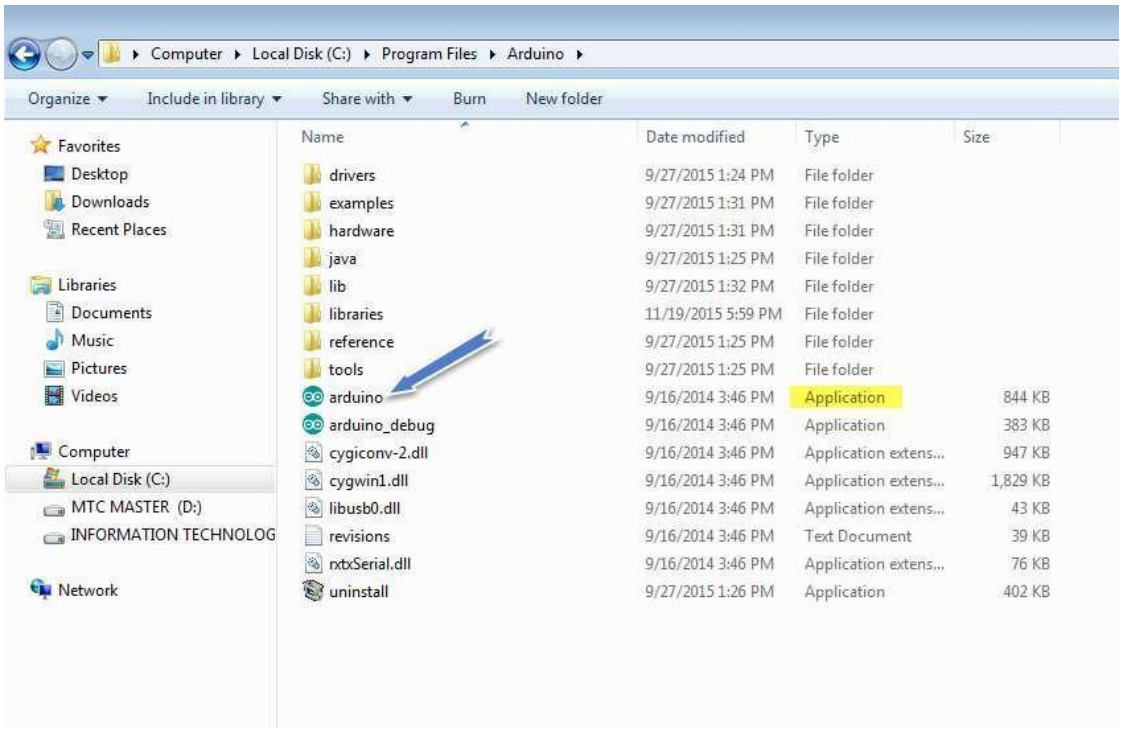


Step 3: Power up your board.

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

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).

Double click the icon to start the IDE. If you are using an Arduino Diecimila, you have to make sure that the board is configured to draw power from the USB connection.

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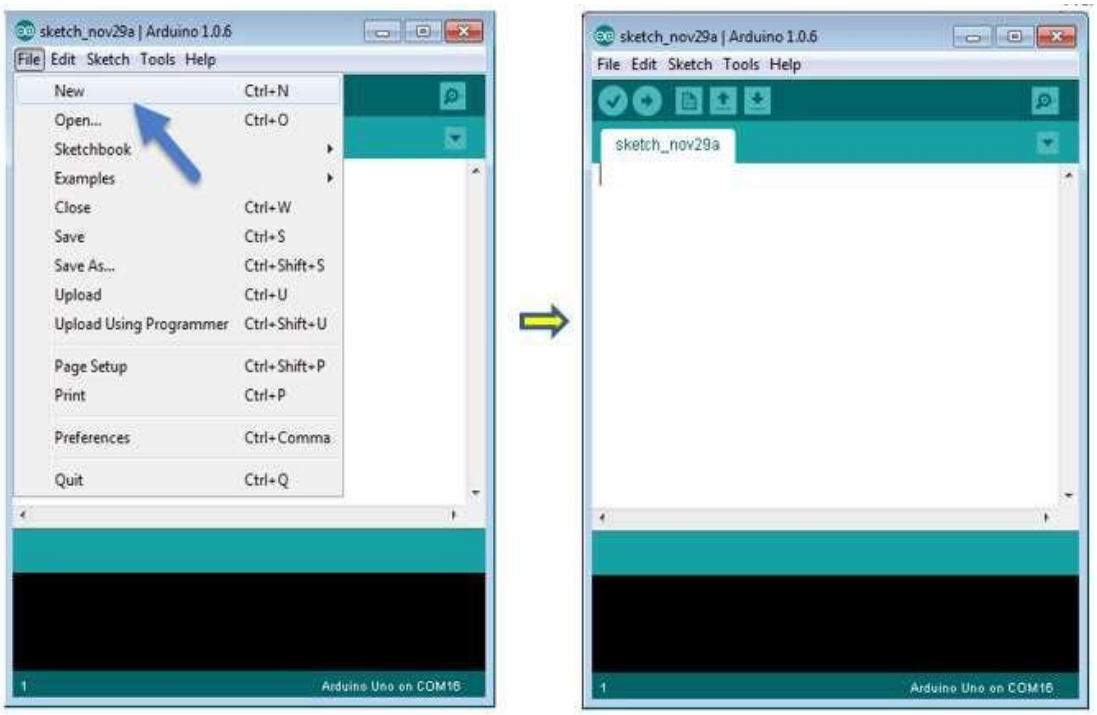
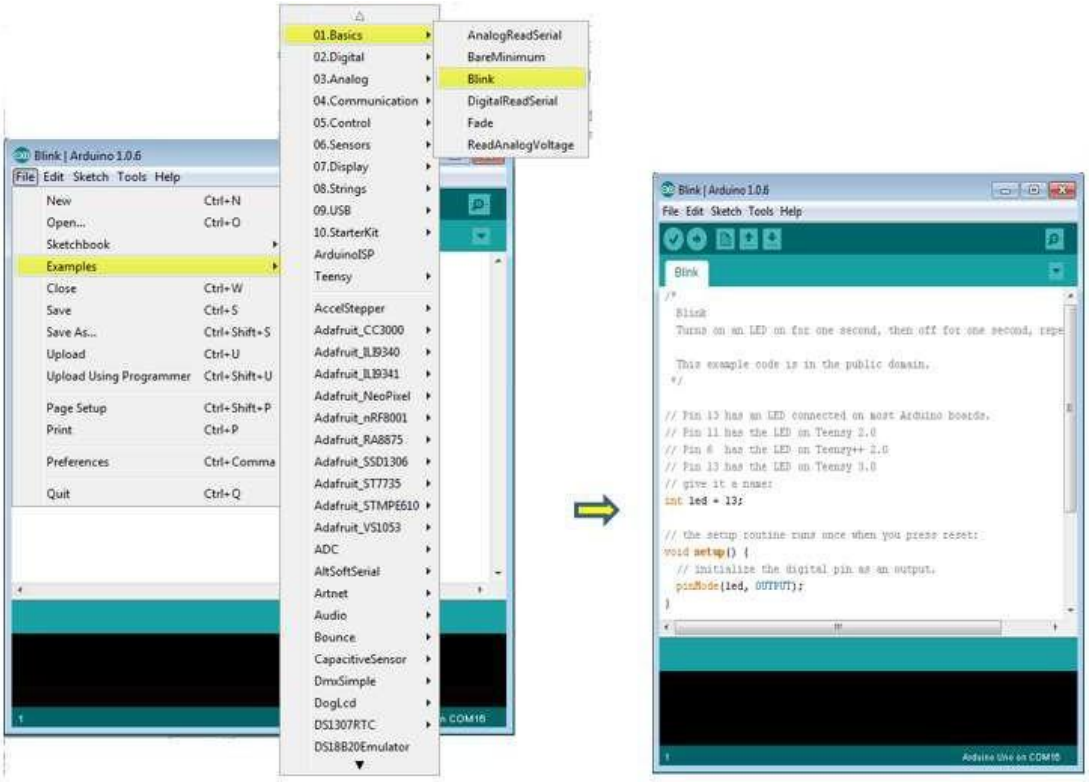


To open an existing project example, select File -> Example -> Basics -> Blink.

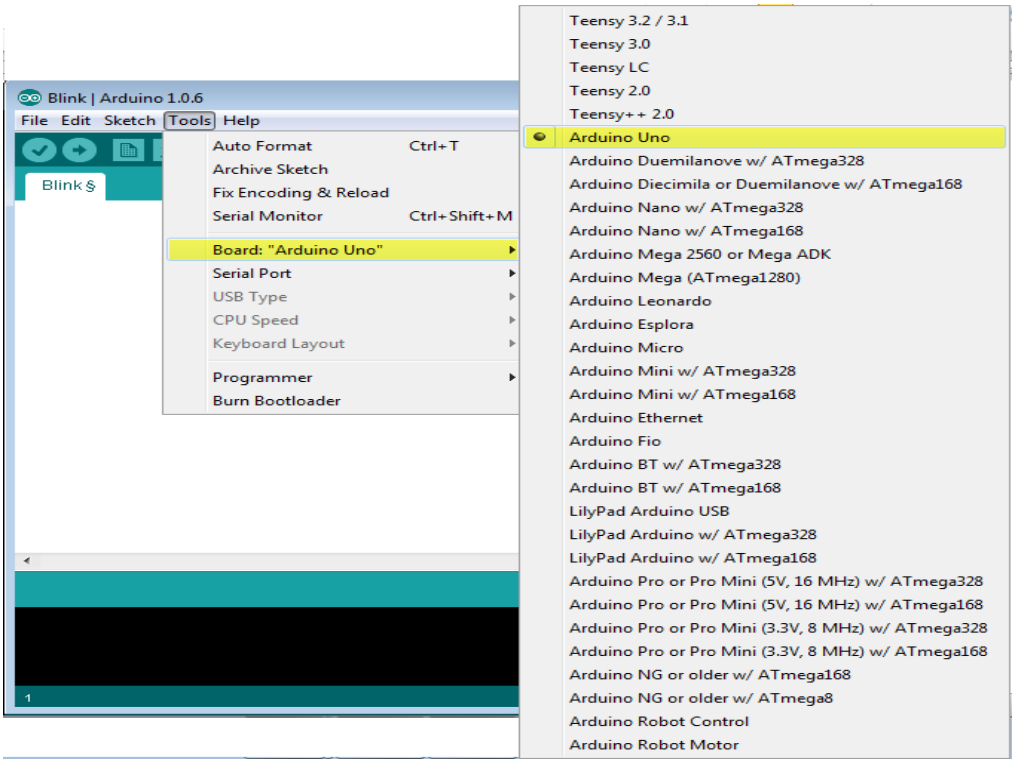


Here, we are selecting just one of the examples with the name **Blink**. It turns the LED on and off with some time delay. You can select any other example from the list.

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.

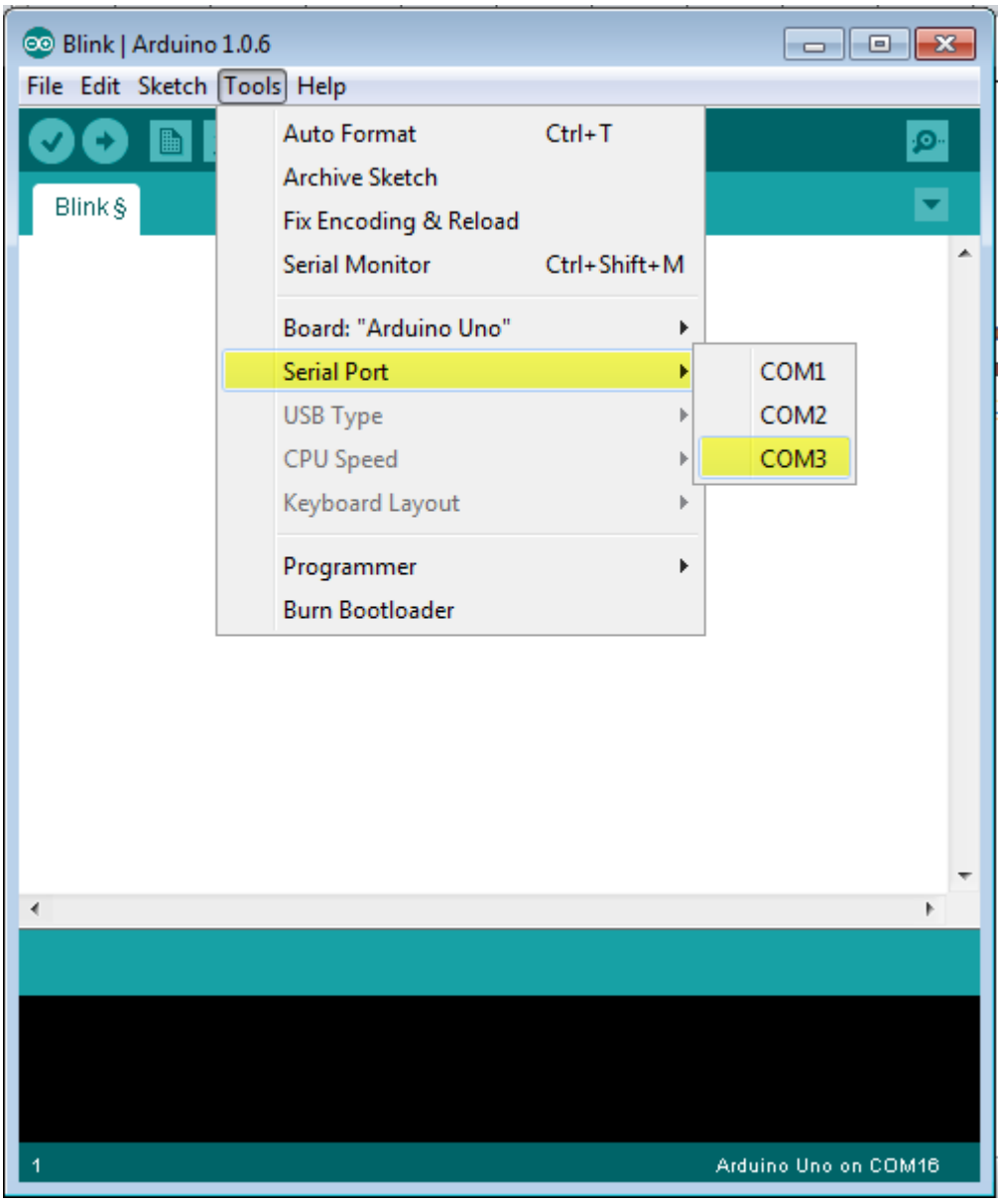
Go to Tools -> Board and select your board



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

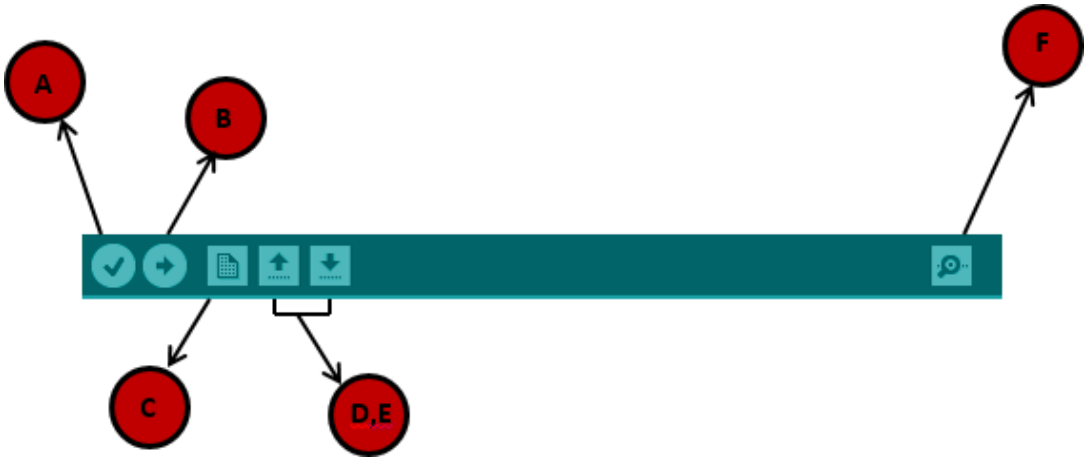
Step 7: Select your serial port.

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 stracture

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.

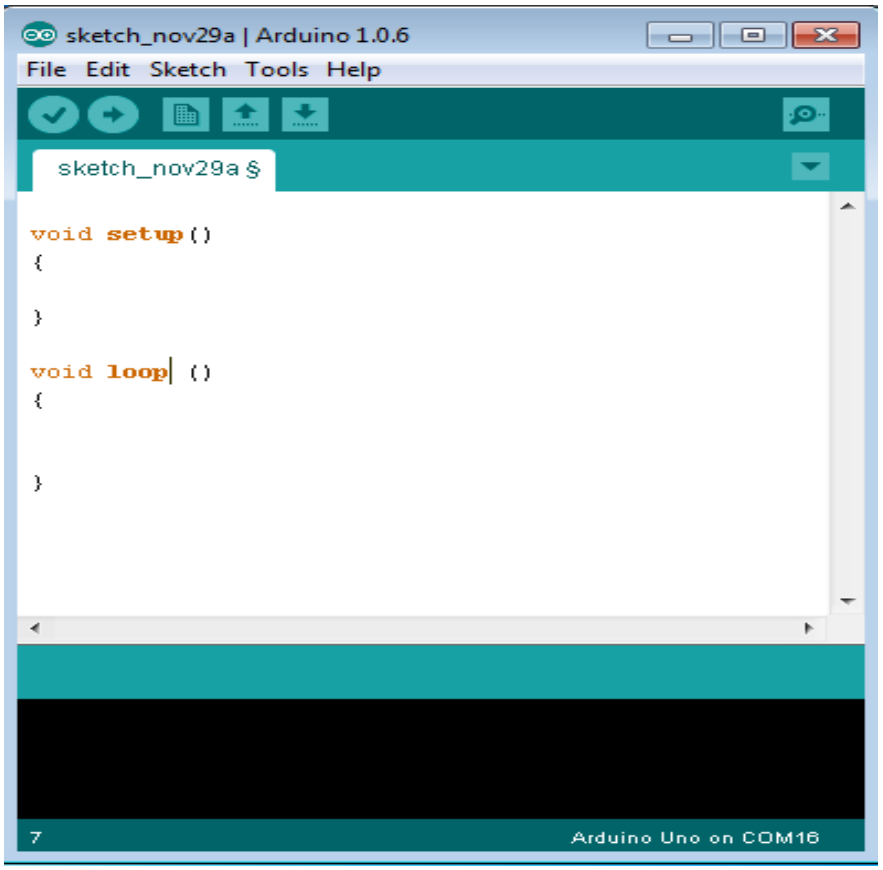
Sketch: The first new terminology is the Arduino program called "**sketch**".

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

CHAPTER 5

WORKING MODEL AND COMPONENTS

5.1 BLOCK DIAGRAM

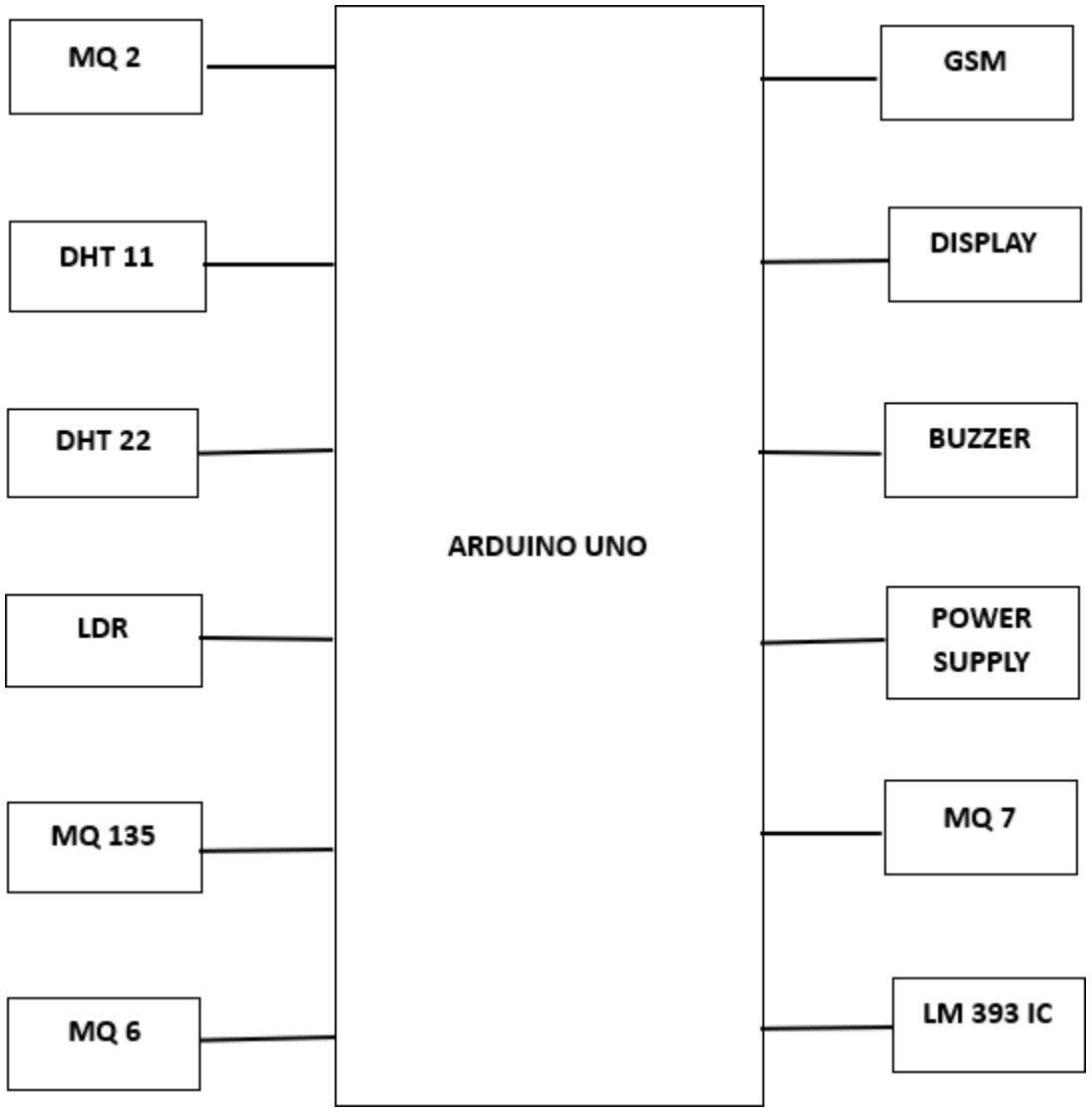


FIG: 5.1 BLOCK DIAGRAM

5.2 WORKING

The Smart Air Pollutants Monitoring System is a comprehensive solution designed to provide real-time air quality monitoring using advanced IoT technologies. The system incorporates a variety of sensors to detect multiple types of air pollutants, such as the MQ-2, MQ-7, MQ-6, MQ-4, MQ-135, MICS-2714, and MICS-5524, which measure gases like smoke, carbon monoxide, methane, LPG, volatile organic compounds (VOCs), and ozone.

Additionally, the PMS5003 sensor measures particulate matter (PM2.5 and PM10), which is crucial for assessing the fine dust in the air. The DHT22 sensor provides real-time data on temperature and humidity, offering a more complete understanding of environmental conditions that influence air quality.

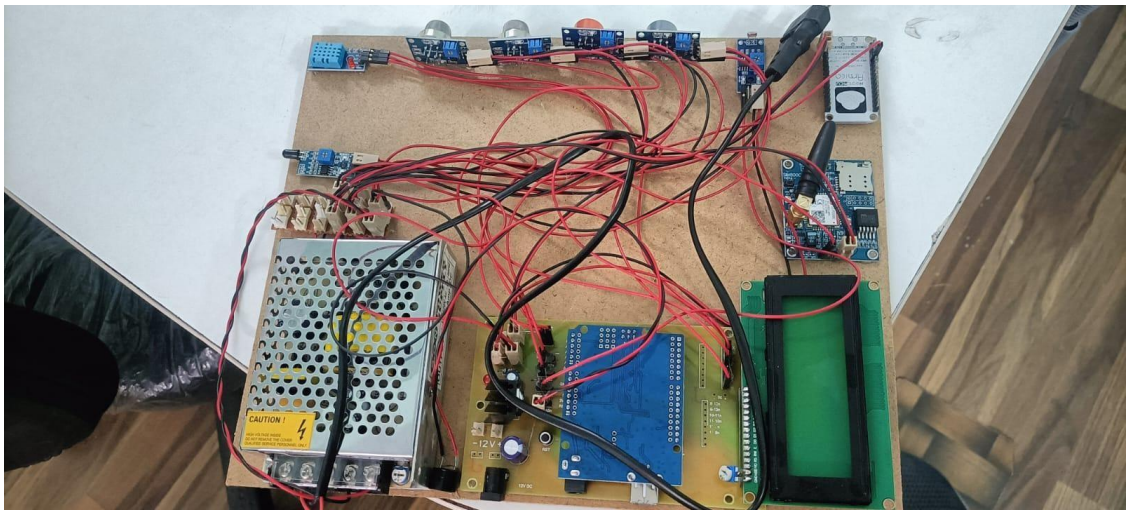


Fig :5.2 Circuit connections

The microcontroller (e.g., Arduino or ESP32) processes the sensor data and calculates the Air Quality Index (AQI**)** based on predefined thresholds and algorithms. This AQI is then displayed on a local screen, such as an LCD or OLED display, allowing users to view the current air quality in real time.

In parallel, the system uses a GSM module (e.g., SIM900) to transmit the data to a remote cloud-based platform, BAZAAR, which serves as the centralized database for storing and analyzing the collected data. This cloud connection allows for remote monitoring, enabling users to access real-time information and historical trends from anywhere through a web interface or mobile app.

1. **Sensors**: The system uses multiple sensors (e.g., MQ series, DHT22) to detect pollutants like gases (e.g., carbon monoxide, methane, ozone) and particulate matter (PM2.5, PM10),

along with environmental data such as temperature and humidity. Monitors environmental factors like temperature, humidity, wind, and atmospheric pressure, helping in predictive analysis

2. **Microcontroller & AQI Calculation**: A microcontroller processes the data from these sensors and calculates the **Air Quality Index (AQI)**, which is a standardized way of reporting air quality. Arduino: Acts as the central controller, collecting data from all sensors. It processes this data to detect anomalies, such as excessive rainfall or rising water levels. It also integrates signals from the weather sensor for comprehensive flood risk analysis
3. **Local Display**: The AQI and sensor data are displayed on a screen for immediate access, providing users with real-time information on air quality. : Facilitates wireless communication between multiple sensor nodes placed at different locations. It ensures data from remote areas reaches the central Arduino system
4. **Remote Monitoring (GSM + Cloud)**: The system transmits the collected data via a **GSM module** to a cloud-based platform (called **BAZAAR**), where the data can be stored and accessed remotely for analysis and monitoring.
5. **Power Supply**: The system is powered by a reliable power source to ensure it operates continuously. Triggers a local audible alarm when thresholds are exceeded, warning nearby residents or workers of impending danger. Sends SMS or calls to designated phone numbers with real-time updates on the flood status
6. **Purpose and Benefits**: The goal of the system is to provide real-time monitoring, raise public awareness about air pollution policies.
7. The microcontroller (e.g., Arduino or ESP32) processes the sensor data and calculates the Air Quality Index (AQI**)** based on predefined thresholds and algorithms. This AQI is then displayed on a local screen, such as an LCD or OLED display, allowing users to view the current air quality in real time.
8. In parallel, the system uses a GSM module (e.g., SIM900) to transmit the data to a remote cloud-based platform, BAZAAR, which serves as the centralized database for storing and analyzing the collected data. This cloud connection allows for remote monitoring, enabling users to access real-time information and historical trends from anywhere through a web interface or mobile app.
9. Additionally, the PMS5003 sensor measures particulate matter (PM2.5 and PM10), which is crucial for assessing the fine dust in the air. The DHT22 sensor provides real-time data on temperature and humidity, offering a more complete understanding of environmental conditions that influence air quality.

5.2.1 ARDUINO UNO MICROCONTROLLER

The Electronics being one of the fastest growing industry in the world, we can see many new ideas, innovations, new projects are coming up in people's mind. And to get started with your projects is no more difficult task.. The open source platforms like Arduino has rewarded the people by supporting them to create new and innovative products. And hence, with the changing technology, Arduino always come up with new interesting features in order to meet your creativity! As an example we can see the emerging of ARDUINO.

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.

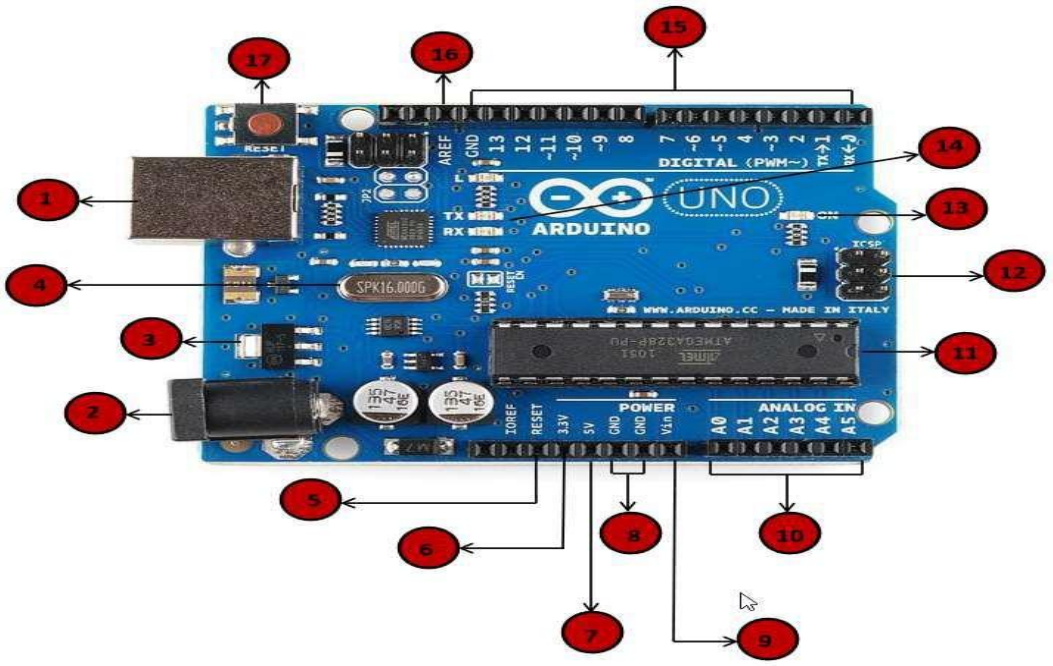


Figure 5.3: Arduino uno board

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. 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.

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.

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 5.1: 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. **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. 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.

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.

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

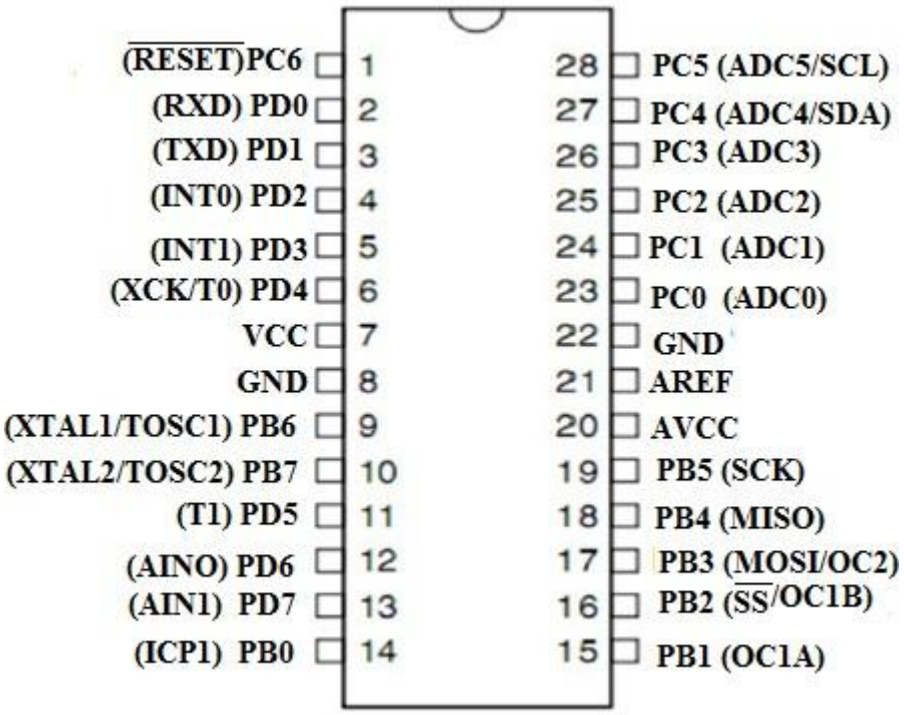


Figure 5.4: Pin diagram

5.1.3.2 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) 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.

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 pinsworking. 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.

5.2.2 INTRODUCTION TO MQ SENSORS

The "MQ" in MQ sensors stands for "Metal Oxide". The sensors are based on a metal oxide semiconductor (MOS) technology, where the sensing element consists of a metal oxide layer that reacts with specific gases. When these gases come into contact with the sensor, they cause a change in the resistance of the metal oxide layer, which can be measured to determine the concentration of the target gas.

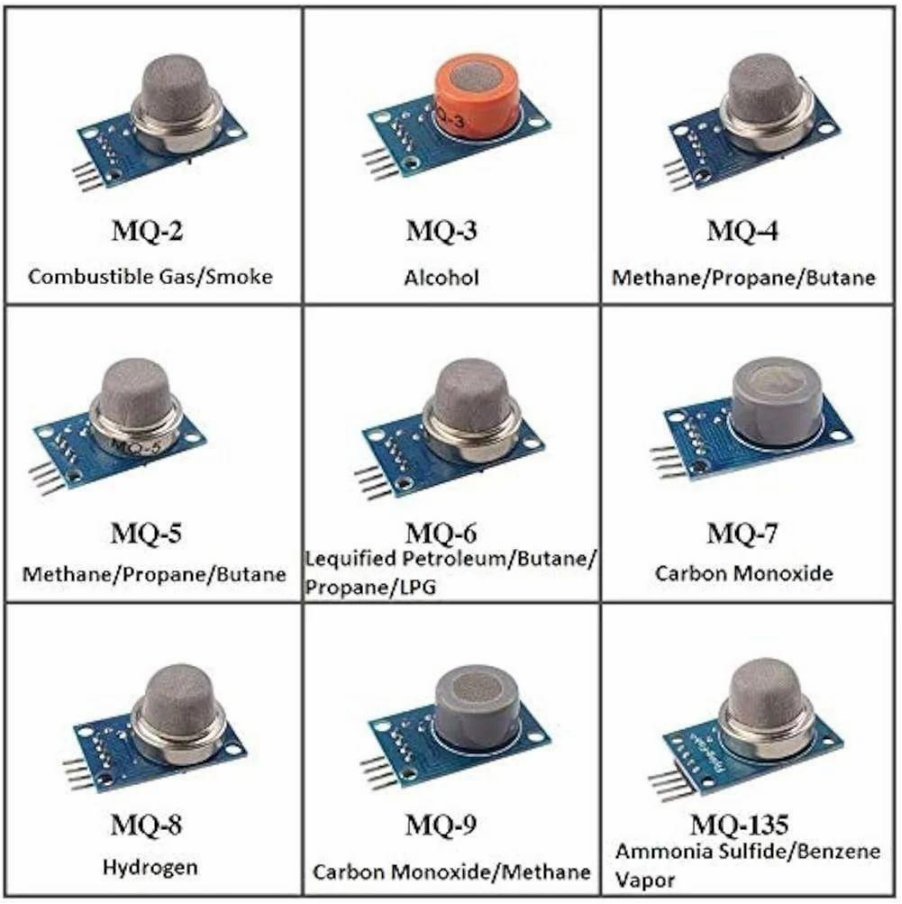


FIG: 5.5 MQ SENSORS

The MQ-131 is an ozone (O_3) gas sensor that detects ozone levels by measuring changes in the resistance of its metal oxide semiconductor material. It is commonly used in air quality monitoring systems, especially for detecting ozone in industrial or urban environments. It operates by using a metal oxide semiconductor (MOS) that changes resistance when exposed to ozone, allowing the concentration of the gas to be measured. This sensor is often used in environmental monitoring and safety applications.

The MQ-2 is a versatile sensor that detects a variety of gases including smoke, LPG, methane, butane, and carbon monoxide, with its resistance varying based on exposure to these

gases. This sensor is often used in smoke alarms, gas leak detectors, and air quality monitoring. Its resistance changes when exposed to these gases, making it suitable for applications such as smoke alarms, gas leakage detection in homes and industries, and air quality monitoring in urban areas. Its broad sensitivity to different gases makes it very versatile for general gas detection purposes.

The MQ-7 is specifically designed to detect carbon monoxide (CO), utilizing a sensitive film that reacts to CO, causing resistance changes which help determine its concentration. It is widely used in carbon monoxide detection systems, particularly in homes and vehicles. It operates by detecting the chemical changes that occur when the sensor's metal oxide surface interacts with CO molecules, resulting in a measurable change in resistance. The MQ-7 is primarily used in carbon monoxide detectors, especially in residential and automotive applications, where CO is a significant concern.

The MQ-6 is sensitive to combustible gases like LPG, butane, and propane, detecting them through resistance changes when exposed to these gases. It is commonly applied in gas leak detection in kitchens and industrial settings. It works by sensing changes in the resistance of its metal oxide material when exposed to these gases. This sensor is commonly used in domestic and industrial gas leak detection systems, including in kitchens, gas pipelines, and even in industrial plants that handle flammable gases, where safety is a priority.

Finally, the MQ-4 is designed for detecting methane (CH_4) gas, with its resistance changing in response to the presence of methane. This sensor is typically used in gas leak detection systems in areas such as natural gas pipelines and industrial plants. The MQ-4 sensor works similarly to other MQ sensors by detecting changes in resistance when exposed to methane. It is widely used in gas leak detection systems, particularly in natural gas pipelines, industrial plants, and areas where methane is used or stored.

These sensors are essential components for a wide range of safety and environmental applications. Their ability to detect hazardous gases in real-time helps protect human health, prevent accidents, and maintain air quality standards. The MQ-6 is sensitive to combustible gases like LPG, butane, and propane, detecting them through resistance changes when exposed to these gases. It is commonly applied in gas leak detection in kitchens and industrial settings. It works by sensing changes in the resistance of its metal oxide material when exposed to these gases. This sensor is commonly used in domestic and industrial gas leak detection systems, including in kitchens, gas pipelines, and even in industrial plants that handle flammable gases, where safety is a priority. The MQ series of sensors are widely used in smart home systems, industrial safety setups, environmental monitoring stations, and any application where air quality and gas safety are a priority.

5.2.3 INTRODUCTION TO DHT11

The DHT11 is a widely used, low-cost digital temperature and humidity sensor, designed for environmental monitoring, weather stations, and IoT-based applications. It integrates a capacitive humidity sensor and a thermistor to measure relative humidity (RH) and temperature, providing real-time data with a simple one-wire communication protocol.

The DHT11 operates on a 3.3V to 5V power supply, making it compatible with microcontrollers like Arduino, Raspberry Pi, ESP8266, and STM32. It has a humidity measurement range of 20% to 90% RH with an accuracy of ±5%, and a temperature range of 0°C to 50°C with an accuracy of ±2°C. Although it has a sampling rate of 1Hz (one reading per second), which is slower compared to some advanced sensors, it remains energy-efficient and is ideal for low-power applications. The sensor provides output in a digital signal format, eliminating the need for additional analog-to-digital conversion, simplifying integration into embedded systems. The four-pin package includes VCC, GND, Data, and a pull-up resistor, ensuring easy wiring and setup. One of the key advantages of the DHT11 is its built-in calibration, allowing it to deliver accurate readings without the need for complex configuration.

Fig 5.6 DHT11 SENSOR

While it is less precise and has a smaller measurement range compared to the DHT22 (AM2302), the DHT11 is still a preferred choice for basic applications due to its affordability, ease of use, and reliability. It is commonly used in automated greenhouses, smart home automation, HVAC (Heating, Ventilation, and Air Conditioning) systems, weather monitoring devices, and industrial environmental tracking. The sensor's low power consumption, coupled with its ability to provide stable and consistent readings, makes it an efficient choice for long-term use in embedded systems.

With strong community support, extensive documentation, and simple interfacing, the DHT11 remains one of the most accessible and practical sensors for temperature and humidity monitoring in DIY projects, academic research, and industrial applications.

INTRODUCTION TO DHT22 SENSOR

A Voice recognition, also known as speech recognition, is a computer technology that analyzes and converts spoken words or commands into editable text or executable actions. It enables individuals to interact with computers or devices through speech, eliminating the need for traditional input methods like keyboards or mice. Voice recognition technology has found applications in various areas, including voice assistants, smart homes, voice search, and voice-controlled notebooks.

The DHT22(also known as the AM2302) is a popular digital sensor that measures temperature and humidity. It is widely used in DIY projects, environmental monitoring, and home automation due to its affordability and reasonable accuracy. The sensor can measure temperatures ranging from -40°C to 80°C with an accuracy of ±0.5°C, and it can measure humidity levels from 0% to 100% with an accuracy of ±2-5% RH.

It provides a digital output, simplifying integration with microcontrollers like Arduino or Raspberry Pi. The DHT22 operates on a 3.3V to 6V power supply and consumes low power, making it ideal for battery-operated systems. It typically provides readings every 2 seconds, which makes it suitable for real-time monitoring. It is commonly used in weather stations, HVAC systems, agriculture for greenhouse monitoring, and air quality monitoring systems. The DHT22 is appreciated for its ease of use, low cost, and reliability in a wide range of applications where temperature and humidity need to be tracked.

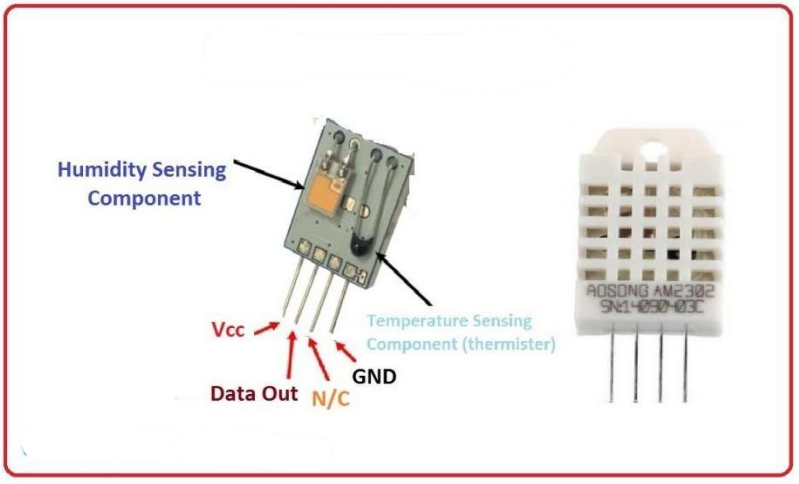


FIG: 5.7 DHT22 SENSOR

5.2.4 INTRODUCTION TO MOINITORING DISPLAY

A monitoring display for air pollution is an interface or system that visually presents data collected from various sensors tracking air quality. These displays show real-time readings of pollutants like PM2.5, PM10, NO_2, CO, O_3, and other harmful substances in the air, often using graphs, numerical values, and color-coded indicators. The main purpose is to give immediate feedback to users about the current air quality, allowing them to take timely actions if pollution levels exceed safe thresholds. This can be critical for public health, especially in urban environments or areas with high industrial activity

FIG:5.8 DISPLAY

These displays typically use Air Quality Index (AQI) values to simplify complex data into an easy-to-understand scale. The AQI is divided into categories, from "Good" to "Hazardous," each associated with a color (green to maroon), providing a quick visual cue for users to assess the air quality. The display might also show individual pollutant concentrations, trend graphs, and alerts for high pollutant levels. Advanced systems often feature touchscreens, interactive interfaces, and real-time updates from remote sensors, offering users the ability to interact with the data and explore detailed information about air pollution sources and effects.

For public air quality monitoring systems, displays are usually installed in high-traffic areas like parks, schools, government buildings, or transportation hubs. These systems serve the dual purpose of informing the public about local air quality and encouraging healthier behaviors, such as reducing outdoor activities when air pollution is high. In more advanced or commercial settings, these displays may be integrated into broader environmental monitoring systems, providing data analytics, predictions.

5.2.5 INTRODUCTION TO LIGHT DEPENDENT RESISTOR:

A water Light Dependent Resistors are astoundingly significant especially in light/dull sensor circuits. Typically the protection of a LDR is high, once in a while as high as 1,000,000 ohms, however when they are lit up with light, the protection drops significantly. . Along these lines in this endeavor, LDR expect a basic part in trading on the lights in light of the power of light i.e., if the power of light is all the more (amid daytime) the lights will be in off condition. What's more, if the power of light is less (amid evenings), the lights will be exchanged on. The yield of the LDR is given to ADC which changes over the simple power an incentive into relating advanced information and presents this information as the contribution to the microcontroller

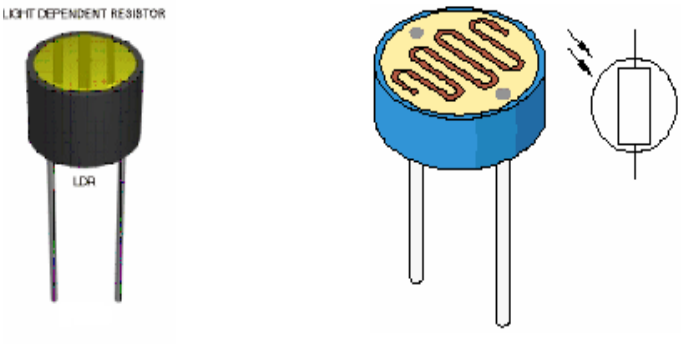


FIG :5.9 LDR

A Light Dependent Resistor (LDR), also known as a photoresistor, is a type of resistor that changes its resistance based on the intensity of light falling on it. Made from semiconductor materials like cadmium sulfide, LDRs exhibit high resistance in darkness and low resistance in bright light. This property makes them useful in various applications, such as automatic lighting systems, solar street lamps, and light-sensing circuits. When exposed to light, the number of charge carriers in the material increases, allowing more current to flow through the resistor and reducing its resistance.

LDRs are widely used in devices that require light sensitivity, such as night lamps, alarm systems, and photography exposure meters. Their response time varies depending on the intensity of light, and they are often used in conjunction with other electronic components to control circuits automatically. It is widely used in DIY projects, environmental monitoring, and home automation due to its affordability and reasonable accuracy. The sensor can measure temperatures ranging from -40°C to 80°C with an accuracy of ±0.5°C, and it can measure humidity levels from 0% to 100% with an accuracy of ±2-5% RH. While LDRs are simple and cost-effective, they have limitations, such as slow response times and sensitivity to temperature changes. Despite these drawbacks, they remain a popular choice for applications requiring light detection without complex electronic setups**.**

The accuracy of the sensor depends on the quality of the conductive traces and the electronic components used, with some advanced versions incorporating capacitive or ultrasonic sensing for higher precision. In the context of flood monitoring systems, integrating a water level sensor with a wireless communication module enables early warning mechanisms that help mitigate disaster risks, safeguard human lives, and protect infrastructure from water- related damages. With the increasing focus on smart automation and environmental safety, water level sensors have become an essential component in modern IoT-based monitoring and alert systems, playing a crucial role in efficient water resource management and disaster prevention..

5.2.6 INTRODUCTION TO BUZZER SENSOR

A buzzer is an electronic component used to produce sound in response to an electrical signal, making it an essential device for alerts, alarms, and notifications in various applications. It operates by converting electrical energy into mechanical vibrations, which generate sound waves. while passive buzzers require an external oscillating signal, such as a PWM (Pulse Width Modulation) signal, to produce sound of varying frequencies. Due to their small size, low power consumption, and ease of use, buzzers are widely employed in devices like alarms, timers, security systems, household appliances, and embedded systems.

Buzzers are commonly classified into two types: piezoelectric buzzers and electromagnetic buzzers. Piezoelectric buzzers use a piezoelectric crystal that deforms when an electric voltage is applied, creating sound through rapid oscillations, while electromagnetic buzzers rely on a coil and a diaphragm that vibrate to produce audible tones.

Buzzers can be either active or passive, where active buzzers generate a sound when powered, while passive buzzers require an external oscillating signal, such as a PWM (Pulse Width Modulation) signal, to produce sound of varying frequencies. Due to their small size, low power consumption, and ease of use, buzzers are widely employed in devices like alarms, timers, security systems, household appliances, and embedded systems.

In applications like flood monitoring, fire alarms, and intruder alert systems, buzzers serve as an effective means of immediate audio warning, allowing users to take quick action. In automotive systems, they are used for seatbelt reminders, reverse parking assistance, and turn signal notifications. It is widely used in DIY projects, environmental monitoring, and home automation due to its affordability and reasonable accuracy. The sensor can measure temperatures ranging from -40°C to 80°C with an accuracy of ±0.5°C, and it can measure humidity levels from 0% to 100% with an accuracy of ±2-5% RH. Additionally, in industrial settings, buzzers provide alerts for machinery faults, ensuring workplace safety.

The frequency and duration of the buzzer sound can be adjusted to convey different alerts, such as continuous beeping for emergencies and intermittent beeps for warnings. Some advanced buzzers allow tone variation, enabling multi-tone alarm systems for different scenarios. With its reliability, durability, and responsiveness, the buzzer remains a fundamental component in modern electronic warning systems, enhancing safety and situational awareness across various domains.

FIG:5.10 BUZZER SENSOR

5.2.7 INTRODUCTION TO GSM

A GSM (Global System for Mobile Communications) module is a device that enables communication between systems, devices, or applications and a GSM network, allowing for voice calls, SMS, and data transmission. These modules are widely used in embedded systems and IoT applications to provide wireless connectivity.

A GSM module typically includes a SIM card slot and uses a SIM card to connect to a mobile network, functioning like a mini mobile phone without a display or keypad. It operates on GSM bands (850 MHz, 900 MHz, 1800 MHz, and 1900 MHz), making it compatible with networks worldwide.

The module interfaces with microcontrollers or microprocessors through standard communication protocols like UART, SPI, or I2C, allowing it to send and receive commands for operations such as making calls, sending SMS, or connecting to the internet via GPRS. Popular GSM modules like SIM800, SIM900, and SIM7000 are compact, power-efficient, and support a range of functionalities, including voice recognition, location tracking via GPS integration, and internet-of-things (IoT) applications. They are widely used in fields like home automation, vehicle tracking, industrial monitoring, and health care systems.

GSM modules have become a cornerstone for real-time communication and automation, especially in remote areas where wired internet access is limited.

With advancements in technology, modern GSM modules now integrate 4G and even 5G capabilities, offering faster and more reliable communication, making them essential for modern connectivity-driven solutions.

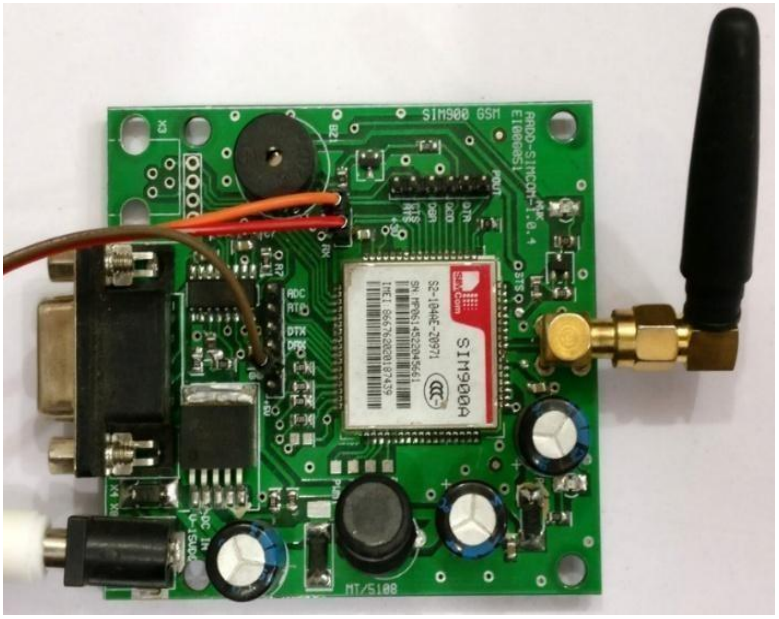


FIG:5.11 GSM MODULE

GSM provides recommendations, not requirements. The GSM specifications define the functions and interface requirements in detail but do not address the hardware. The GSM network is divided into three major systems: the switching system (SS), the base station system (BSS), and the operation and support system (OSS).

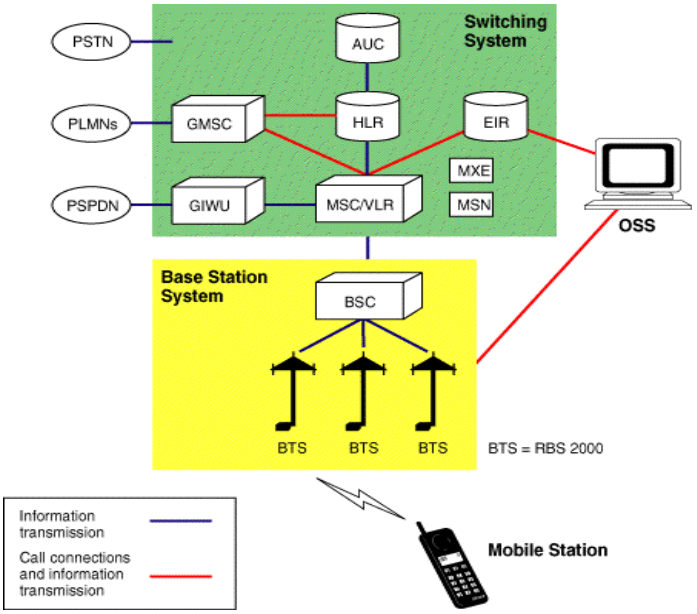


Fig: 5.12 GSM NETWORK

5.2.8 INTRODUCTION TO 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. while passive buzzers require an external oscillating signal, such as a PWM (Pulse Width Modulation) signal, to produce sound of varying frequencies. Due to their small size, low power consumption, and ease of use, buzzers are widely employed in devices like alarms, timers, security systems, household appliances, and embedded systems.

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.

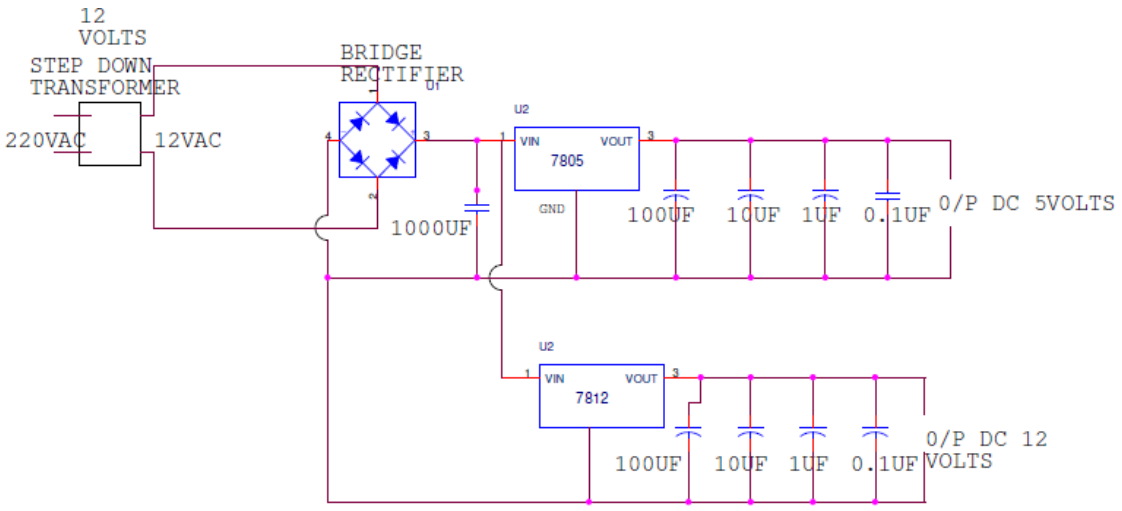


FIG: 5.13 POWER SUPPLY

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).

CHAPTER 6

RESULTS

The implementation of the Smart Air Pollutants Monitoring System using IoT has yielded promising results in detecting and monitoring various environmental parameters. The system successfully collected and transmitted real-time data on gas concentrations, temperature, humidity, light intensity, and fire hazards. The MQ-series gas sensors effectively detected pollutants such as CO, CO2, LPG, and NH3, providing accurate readings under controlled conditions. The DHT11 and DHT22 sensors offered reliable temperature and humidity data, ensuring a comprehensive environmental assessment. The GSM module efficiently sent alerts and notifications whenever pollution levels exceeded predefined thresholds, demonstrating the practicality of remote monitoring

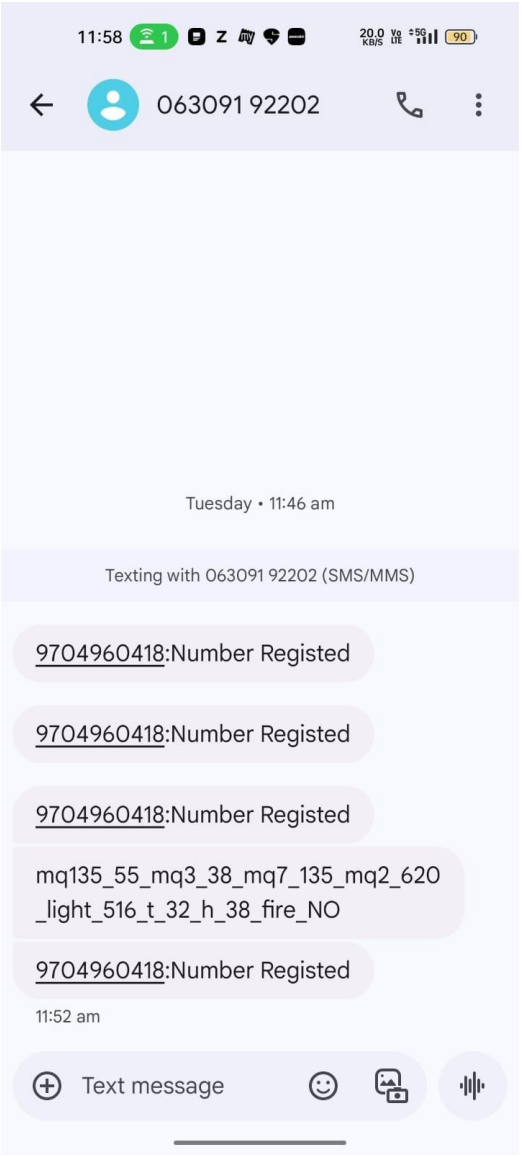
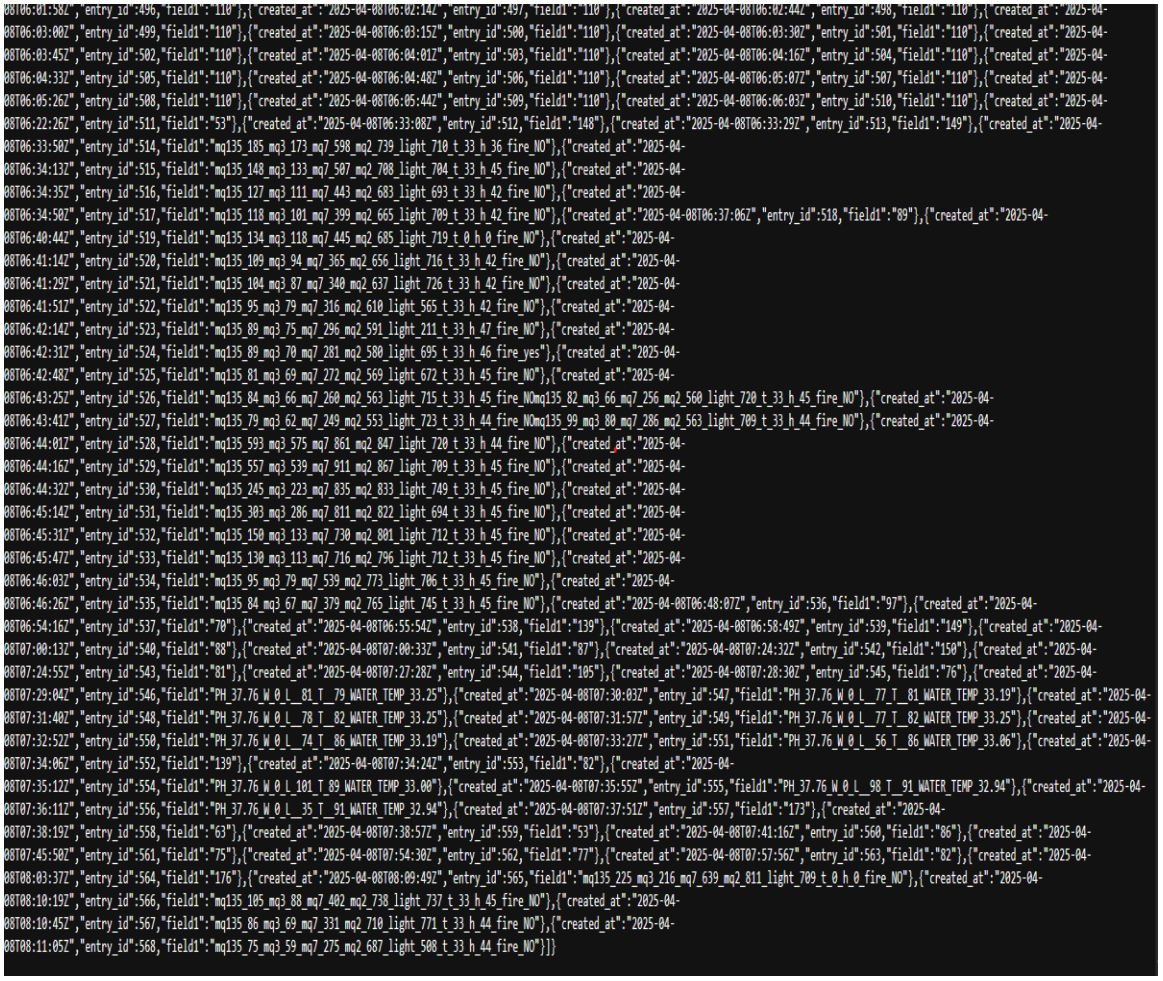


FIG:6.1 MESSAGE

The data collected from the system provided insights into pollution trends, allowing for timely intervention and necessary actions to be taken. Overall, the system proved to be a viable solution for air quality monitoring, highlighting its potential for large-scale deployment in urban and industrial environments. Although some sensor fluctuations and calibration challenges were observed, the results affirm the effectiveness of the system in contributing to a healthier and safer environment. To further validate the system's efficiency, tests were conducted in different environments, including residential areas, industrial zones, and urban locations.



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Overall, the project has demonstrated the feasibility of low-cost IoT-based air pollution monitoring, paving the way for future developments in smart environmental solutions. The results suggest that with proper enhancements, this system can become a crucial tool for policymakers, industries, and individuals aiming to reduce pollution exposure and improve air quality management.

ADVANTAGES

The Air Monitoring & Warning System provides numerous advantages, making it a highly effective, cost-efficient, and scalable solution for flood risk management. Below are its key advantages:

1. Real Time Monitoring

Provides continuous, real-time monitoring of air quality and environmental conditions. Continuously tracks air pollution levels. Can be programmed to send immediate alerts if pollution exceeds safe limits. The system also prevents property damage by allowing people to take timely protective actions, such as moving valuables or reinforcing flood barriers. Additionally, it assists emergency responders by providing accurate flood risk data, enabling better resource allocation and disaster management.

2. Cost Effective

Uses affordable sensors and microcontrollers like Arduino Uno, making it budget-friendly. Uses affordable components like Arduino and MQ gas sensors.Cheaper than industrial-grade air quality monitoring systems. Its wireless setup eliminates the need for expensive infrastructure, reducing installation costs and making deployment easier. The system is portable and lightweight, allowing it to be easily installed in remote and rural areas where flood risks are high. while passive buzzers require an external oscillating signal, such as a PWM (Pulse Width Modulation) signal, to produce sound of varying frequencies. Due to their small size, low power consumption, and ease of use, buzzers are widely employed in devices like alarms, timers, security systems, household appliances, and embedded systems.

3. Remote Data Access

GSM module enables wireless data transmission and remote access via SMS or cloud.
Uses a GSM module to send real-time alerts and updates via SMS.Can be expanded to connect with a cloud-based platform for mobile app integration. Additionally, the GSM module sends SMS alerts, ensuring notifications even in areas with no internet access, enhancing reliability in remote locations. while passive buzzers require an external oscillating signal, such as a PWM (Pulse Width Modulation) signal, to produce sound of varying frequencies. Due to their small size, low power consumption, and ease of use, buzzers are widely employed in devices like alarms, timers, security systems, household appliances, and embedded systems. MQ gas sensors.Cheaper than industrial-grade air quality monitoring systems. Its wireless setup eliminates the need for expensive infrastructure, reducing installation costs and making deployment easier. The system is portable and lightweight, allowing.

4. Multi- pollutant Detection

Detects multiple pollutants like CO, CO2, LPG, smoke, temperature, humidity, light intensity, etc.

- Gas Sensors: MQ-2 (smoke, LPG), MQ-6 (LPG, butane), MQ-7 (carbon monoxide), MQ-135 (CO2, NH3, benzene).
- Temperature & Humidity: DHT11 & DHT22 measure environmental conditions.
- Light Intensity Sensor (LDR): Helps detect day/night conditions.
- Fire Sensor: Detects flame presence and prevents hazardous situations.

5. Early Warning System

Fire sensor and gas sensors act as an early warning system for fire and gas leak hazards. Alerts in case of gas leaks, high CO levels, or fire hazards. Can be integrated with an automatic ventilation system or alarms. The system utilizes error correction algorithms to maintain stable and accurate data transmission, even in challenging environments. Powered by solar energy, it operates continuously, even during power outages, providing uninterrupted flood monitoring. Once deployed, the system is self-sufficient, requiring no manual intervention, making it an efficient and low-maintenance solution for flood detection and early warning.

6. Simple Integration

Easy to integrate additional sensors if required due to modular design. More sensors (e.g., PM2.5, PM10) can be added to enhance functionality. Can be extended with WiFi or LoRa modules for better connectivity. It can be customized for both small-scale communities and large-scale government projects, providing flexibility in deployment.

The system is effective for temporary flood risks, such as flash floods, as well as long-term monitoring of flood-prone regions. Additionally, it plays a crucial role in water resource management by helping control dam and reservoir levels, preventing overflow disasters. With further modifications, it can also be used for marine and river flood detection applications, making it a valuable tool for diverse environments. Fire sensor and gas sensors act as an early warning system for fire and gas leak hazards. Alerts in case of gas leaks, high CO levels, or fire hazards. Can be integrated with an automatic ventilation system or alarms. The system utilizes error correction algorithms to maintain stable and accurate data transmission.

APPLICATIONS

The Air Monitoring and Warning System has a wide range of applications across various sectors. It plays a crucial role in disaster management, urban planning, agriculture, and infrastructure protection. Below are the key applications:

1. Indoor Air Quality Mointoring

The Helps maintain air quality in homes, offices, and hospitals. Can trigger air purifiers when pollution exceeds a threshold.

2. Industrial Safety & Pollution Control

Used in factories to detect harmful gas leaks and fire risks. Helps prevent workplace accidents and ensures compliance with pollution norms.

3. Smart Cities & Urban Pollution Control

Helps municipalities monitor city-wide air quality. Can be used for data-driven pollution control policies.

4. Agriculture & Greenhouse Monitoring

Monitors gases like CO2 and ammonia in poultry farms and greenhouses. Helps regulate ventilation for better crop and livestock health

5. Schools, Hospitals, and Public Spaces

Ensures a safe and healthy environment for children, elderly, and patients. Alerts authorities in case of high pollution levels.

Through continuous data collection and analysis, this project demonstrates the potential of IoT in providing real-time solutions for air quality management. The results of this project highlight the effectiveness of using low-cost sensors to monitor pollution and the feasibility of deploying such a system in homes, industries, and public spaces. Fire sensor and gas sensors act as an early warning system for fire and gas leak hazards.

Alerts in case of gas leaks, high CO levels, or fire hazards. Can be integrated with an automatic ventilation system or alarms. The system utilizes error correction algorithms to maintain stable and accurate data transmission, even in challenging environments. Powered by solar energy, it operates continuously, even during power outages, providing uninterrupted flood monitoring. Overall, the project has demonstrated the feasibility of low-cost IoT-based air pollution monitoring, paving the way for future developments in smart environmental solutions. The results suggest that with proper enhancements, this system can become a crucial tool for policymakers, industries, and individuals aiming to reduce pollution exposure and improve air quality management.

CONCLUSION

The Smart Air Pollutants Monitoring System using IoT Technologies is a cost-effective and efficient solution for real-time air quality monitoring. By integrating multiple sensors such as MQ-2, MQ-6, MQ-7, MQ-135, DHT11, DHT22, LDR, and a fire sensor, this system effectively detects hazardous gases, temperature, humidity, and light intensity.

The implementation of a GSM module allows remote communication, ensuring that alerts and notifications are sent to relevant authorities or users in case of environmental hazards. This system plays a crucial role in monitoring air pollution levels, which is essential for human health and environmental safety.

Through continuous data collection and analysis, this project demonstrates the potential of IoT in providing real-time solutions for air quality management. The results of this project highlight the effectiveness of using low-cost sensors to monitor pollution and the feasibility of deploying such a system in homes, industries, and public spaces.

However, calibration and maintenance of sensors remain a challenge for long-term sustainability. Overall, this project lays a strong foundation for scalable and advanced air quality monitoring systems that can contribute to cleaner and healthier environments. In addition to its immediate benefits, the system's ability to provide real-time alerts allows quick decision-making to prevent potential health risks caused by exposure to toxic gases.

Air pollution has been linked to various respiratory and cardiovascular diseases, making real-time monitoring a crucial component of public health initiatives. The integration of IoT in environmental monitoring is an innovative approach that ensures continuous assessment and helps formulate policies for better pollution control.

Additionally, this project has applications in research and academic settings, enabling students and researchers to explore the impact of pollution on different environments. By utilizing Arduino-based technology, this system serves as an educational tool for understanding IoT, sensor integration, and data analytics. Despite its benefits, the system requires further optimization for higher accuracy and stability. External factors such as humidity, temperature variations, and sensor aging can influence data accuracy.

Overall, the project has demonstrated the feasibility of low-cost IoT-based air pollution monitoring, paving the way for future developments in smart environmental solutions. The results suggest that with proper enhancements, this system can become a crucial tool for policymakers, industries, and individuals aiming to reduce pollution exposure and improve air quality management.

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FUTURE SCOPE

The Smart Air Pollutants Monitoring System has significant potential for future enhancements and wider applications. One of the key improvements is the integration of cloud-based data storage and visualization platforms, allowing users to access air quality data through mobile applications or web interfaces. Additionally, incorporating machine learning algorithms can help predict pollution trends and identify sources of contamination. Enhancing the system with GPS functionality would enable real-time geo-tagging of pollution levels, making it useful for city-wide air quality mapping.

To improve energy efficiency, solar-powered sensors can be deployed for long-term environmental monitoring. Moreover, the inclusion of advanced sensors such as PM2.5 and PM10 detectors would enhance the system's capability to detect particulate matter pollution. Another possible extension is the implementation of automatic mitigation mechanisms, such as triggering air purifiers or ventilation systems when pollution levels exceed a predefined threshold. By integrating IoT with government monitoring agencies, this system can serve as a valuable tool for environmental policymakers, industries, and smart city initiatives, making air quality monitoring more accessible and actionable on a larger scale.

Another promising future application is integrating blockchain technology to ensure the security and transparency of air quality data. By storing pollution data on a decentralized ledger, authorities and researchers can access tamper-proof information, leading to more reliable environmental policies. Additionally, public participation can be encouraged by allowing citizens to access real-time pollution data and report environmental hazards through mobile apps. Crowdsourced air quality monitoring would enable a more comprehensive and localized understanding of pollution trends.

Furthermore, the development of edge computing capabilities can allow real-time data processing at the sensor level, reducing latency and improving responsiveness. This would be particularly beneficial in industrial areas where immediate action is required in case of gas leaks or hazardous air quality conditions. The system can also be expanded to include wearable sensors for personal air quality monitoring, helping individuals make informed decisions about their exposure to pollutants. With the continuous advancement of IoT, AI, and data analytics, the Smart Air Pollutants Monitoring System has the potential to become an integral part of urban infrastructure.

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APPENDIX

```
#include<SoftwareSerial.h>
SoftwareSerial gps(6,7);

#include <SimpleDHT.h>
int pinDHT11 = 2;
SimpleDHT11 dht11(pinDHT11);

#include <LiquidCrystal.h>
const int rs = 13, en = 12, d4 = 11, d5 = 10, d6 = 9, d7 = 8;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

int fire=3;
int buzzer=A0;
int temp1=0;
void setup()
{
  pinMode(buzzer,OUTPUT);digitalWrite(buzzer,HIGH);
  Serial.begin(9600);delay(10);gps.begin(9600);
  pinMode(fire,INPUT);
  lcd.begin(20, 4);
  lcd.clear();lcd.print("Smart-Air-Pollutants");
lcd.setCursor(0,1);lcd.print("Monitoring-System");
lcd.setCursor(0,2);lcd.print("Using-IOT Technologies");delay(1000);
lcd.clear();lcd.print("AT");Serial.print("AT\r\n");delay(1000);
lcd.clear();lcd.print("ATE0");Serial.print("ATE0\r\n");delay(1000);
lcd.clear();lcd.print("AT+CMGF=1");Serial.print("AT+CMGF=1\r\n");delay(1000);
lcd.clear();lcd.print("AT+CNMI=1,2,0,0");
Serial.print("AT+CNMI=1,2,0,0\r\n");delay(1000)  ;
lcd.setCursor(0,1);lcd.print("Sending sms... ");
Serial.print("AT+CMGS=");
Serial.print("");
Serial.print("9704960418");
Serial.print("");
Serial.print("\r\n");delay(1000);
Serial.print("9704960418");Serial.print(":Number Registed");delay(100);
Serial.write(0x1A);delay(10000);

}
void loop()
{
   byte temperature = 0;
  byte humidity = 0;
  int err = SimpleDHTErrSuccess;
  if ((err = dht11.read(&temperature, &humidity, NULL)) != SimpleDHTErrSuccess)
  {
   // Serial.print("Read DHT11 failed, err="); Serial.print(SimpleDHTErrCode(err));
   // Serial.print(","); Serial.println(SimpleDHTErrDuration(err)); delay(1000);
    return;
  }
```

```
  int temp=((int)temperature);
  int hum=((int)humidity);delay(150);
lcd.clear();
          lcd.print("TEMP:");lcd.print(temp);
          lcd.print("  HUM:");lcd.print(hum);delay(100);
if(temp>40)
{
digitalWrite(buzzer,LOW);delay(1000);digitalWrite(buzzer,HIGH);
}
int mq135=analogRead(A5);delay(100);
int mq3=analogRead(A4);delay(100);mq3=mq3-17;

lcd.setCursor(0,1);lcd.print("Mq135:");lcd.print(mq135);delay(100);
                lcd.print(" Mq3:");lcd.print(mq3);delay(100);

int mq7=analogRead(A3);delay(100);
int mq2=analogRead(A2);delay(100);

lcd.setCursor(0,2);lcd.print("Mq7:");lcd.print(mq7);delay(100);
lcd.print(" Mq2:");lcd.print(mq2);delay(100);

int light=analogRead(A1);delay(100);light=1024-light;
lcd.setCursor(0,3);lcd.print("light:");lcd.print(light);delay(100);

String
iot="mq135_"+String(mq135)+"mq3"+String(mq3)+"mq7"+String(mq7)+
"mq2"+String(mq2)+"light"+String(light)+"t"+String(temp)+"h"+String(hum);

int fireval=digitalRead(fire);delay(100);
if(fireval==LOW)
{
lcd.print(" Fire:");lcd.print("YES");delay(100);
iot=iot+"_fire_yes";delay(1000);
digitalWrite(buzzer,LOW);delay(1000);digitalWrite(buzzer,HIGH);
}
if(fireval==HIGH)
{
lcd.print(" Fire:");lcd.print("NO");delay(100);
iot=iot+"_fire_NO";delay(1000);
}
gps.print(iot);delay(1000);
delay(1000);

temp1=temp1+1;delay(1000);
lcd.print(" ");lcd.print(temp1);delay(2000);
if(temp1>=20)
{
 lcd.clear();lcd.print("AT");Serial.print("AT\r\n");delay(1000);
lcd.clear();lcd.print("ATE0");Serial.print("ATE0\r\n");delay(1000);
lcd.clear();lcd.print("AT+CMGF=1");Serial.print("AT+CMGF=1\r\n");delay(1000);
lcd.clear();lcd.print("AT+CNMI=1,2,0,0");
Serial.print("AT+CNMI=1,2,0,0\r\n");delay(1000);
```

```
lcd.setCursor(0,1);lcd.print("Sending sms... ");
Serial.print("AT+CMGS=");
Serial.print("");
Serial.print("9704960418");
Serial.print("");
Serial.print("\r\n");delay(1000);
Serial.print(iot);delay(100);
Serial.write(0x1A);delay(10000);
temp1=0;

}
}
```