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DESIGN OF AN ADVANCED EV BATTERY AND SOC MONITORING SYSTEM

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Abstract - *Design of an advanced ev battery and soc monitoring system designed to enhance the safety and reliability of electric vehicles (EVs). The project incorporates advanced monitoring mechanisms to ensure the optimal functioning of the electric vehicle. Key parameters such as temperature and voltage levels of the Li-ion battery are continuously tracked in real-time. The integration of IoT technology enables remote monitoring and reporting of these crucial metrics, providing valuable insights to both vehicle owners and manufacturers. This system employs a sophisticated fire detection sensor to enhance safety measures. In the event of a fire being detected, the system is programmed to automatically stop the vehicle to prevent further escalation of the situation. This proactive approach significantly reduces the risk of fire-related accidents in EVs. The system also includes a comprehensive dashboard featuring an LCD display and IoT connectivity, allowing users to access real-time data and receive immediate notifications in case of any abnormalities. The incorporation of a buzzer further ensures that users are promptly alerted to address any issues that may arise during the vehicle's operation. The project not only focuses on monitoring critical parameters of the Li-ion battery but also addresses safety concerns by integrating a fire sensor and an automatic shutdown mechanism. The combination of real-time data visualization, IoT connectivity, and immediate response capabilities contributes to a robust and proactive solution for the safe operation of electric vehicles, mitigating potential risks and enhancing overall user confidence in EV technology.*

***Key Words*: Battery Management System (BMS) :** State of Charge (SOC),State of Health (SOH),Lithium-ion Batteries Sensor ,Temperature Sensor,SOC Estimation Algorithms ,BatteryVoltageMonitoring,Current

1. INTRODUCTION

The purpose of our project is IoT-based Avoid Fire Accident in EV Vehicle with Multiple Fault Detection and Li-ion Battery Management is to address critical safety concerns in electric vehicles (EVs) while enhancing their reliability and performance. As the adoption of EVs continues to rise, ensuring the safety of these vehicles becomes paramount. Our project focuses on integrating advanced monitoring mechanisms, IoT technology, and proactive safety measures to mitigate potential risks and provide users with peace of mind during their EV journeys. Implementing such a comprehensive system comes with its own set of challenges. One of the primary implementation problems is ensuring seamless integration of various sensors and monitoring devices within the vehicle architecture without compromising its design and functionality. This requires careful planning and coordination to optimize space utilization and minimize interference with other vehicle components. Another challenge lies in the development of robust algorithms for real-time data analysis and fault detection. The system must be capable of accurately interpreting data from multiple sensors, detecting abnormalities, and initiating appropriate actions to prevent potential hazards. Achieving this level of intelligence and responsiveness demands extensive testing and refinement to ensure reliability under diverse operating conditions. Furthermore, ensuring compatibility and interoperability with existing EV models poses another implementation hurdle. Our system must be adaptable to different vehicle configurations and manufacturers specifications to facilitate widespread adoption across the EV industry. This necessitates collaboration with OEMs and standardization bodies to establish common protocols and interfaces for seamless integration. Despite these implementation challenges, the benefits of our project are significant. By continuously monitoring key parameters such as battery temperature and voltage levels, we can detect potential issues before they escalate, thereby preventing fire accidents and enhancing overall safety. The integration of IoT technology enables remote monitoring and reporting, providing users with real-time insights into their vehicle's health and performance. Moreover, the automatic shutdown mechanism triggered by the fire detection sensor adds an extra layer of protection, minimizing the risk of fire-related accidents and ensuring user safety. This proactive approach not only safeguards lives but also protects investments by preventing costly damages to EVs and their surroundings. Additionally, the comprehensive dashboard and notification system empower users with actionable insights and timely alerts, allowing them to take proactive measures and address any issues promptly. This enhances user confidence in EV technology and promotes wider adoption of electric vehicles, ultimately contributing to a cleaner and more sustainable transportation ecosystem.

1.1 BACKGROUND OF THE WORK

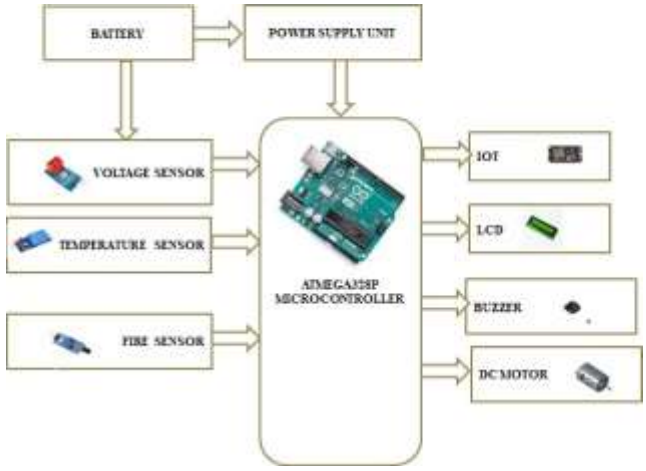
The growing interest in electric vehicles (EVs) as a sustainable alternative to traditional internal combustion engine vehicles has accelerated the development of sophisticated technologies to enhance the performance, safety, and efficiency of electric drivetrains. Central to the performance of EVs is the battery, which serves as the primary source of energy. Proper management of the battery is crucial to ensuring the vehicle's longevity, safety, and operational efficiency.

1.2 MOTIVATION AND SCOPE OF PROPOSED WORK

The transition to electric vehicles (EVs) is at the forefront of global efforts to reduce greenhouse gas emissions and combat climate change. With increasing concerns over air pollution, energy security, and the environmental impact of fossil fuels, EVs are seen as a key technology to replace internal combustion engine (ICE) vehicles. However, the widespread adoption of EVs hinges on the development of more efficient, reliable, and sustainable battery technologies. This is where the role of an advanced Battery Management System (BMS) and State of Charge (SOC) monitoring becomes critical.

2. METHODOLOGY

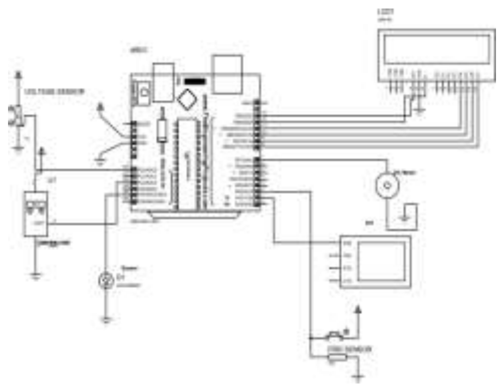
The development of an advanced Battery Management System (BMS) for Electric Vehicles (EVs) requires a multi-disciplinary approach that integrates hardware design, software algorithms, and control systems. The primary goal of this BMS is to ensure the safe, efficient, and reliable operation of the EV's battery pack, optimizing its performance while ensuring longevity. This includes precise monitoring of the State-of-Charge (SOC), State-of-Health (SOH), and the temperature of the cells. Below is a detailed methodology for designing an advanced EV BMS, particularly focused on SOC monitoring:



2.1 BLOCK EXPLANATION

Voltage Sensor: This sensor is responsible for measuring the voltage of the battery. It detects the electrical potential difference between two points in the battery system and sends this data to the IoT platform for monitoring and analysis.
Temperature Sensor: The temperature sensor monitors the temperature of the battery. It provides real-time temperature data to the IoT system. If the temperature exceeds a predefined threshold, indicating a potential overheating issue, the system triggers a buzzer alert and displays a warning message on the LCD screen.
Fire Sensor: This sensor is crucial for safety. It detects the presence of fire or extreme heat near the battery. If a fire is detected, the sensor activates an alarm to alert nearby individuals and initiates appropriate safety protocols.
IoT Platform: The IoT platform serves as the central hub for data collection, processing, and analysis. It receives data from various sensors such as voltage and temperature sensors, processes this data, and provides insights into the battery's health and performance. It also facilitates remote monitoring and control of the battery system.
Buzzer: The buzzer is an audible alarm device that is activated in case of critical events such as overheating or fire detection. It alerts nearby individuals to potential safety hazards associated with the battery.
LCD Display: The LCD display provides a user interface for visualizing important information such as battery voltage, temperature, and alarm notifications. It allows users to quickly assess the status of the battery system without accessing the IoT platform.

2.2 CIRCUIT DIAGRAM



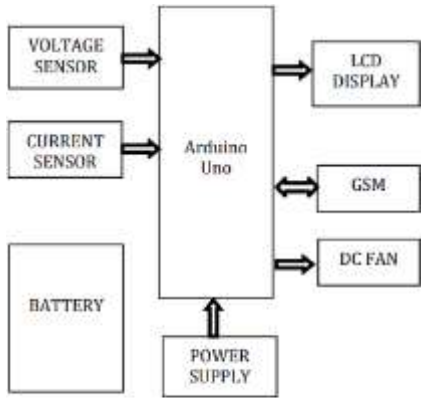
2.3 ADVANTAGE

- Maintain the safety and the reliability of the battery
- Battery state monitoring and evaluation
- It improves the battery performance
- It enhances the lifespan of battery
- It controls the charging, discharging and temperature ranges and keeps them within their range.
- It predicts the batteries capabilities in near future

3. EXISTING SYSTEM

The existing system for electric vehicle battery monitoring using a voltage sensor, current sensor Arduino if temperature high cooling system will be on and message send using GSM is designed to monitor the battery performance of an electric vehicle in real-time. The system uses a voltage sensor and current sensor to measure the battery's voltage and current values respectively. The data is then fed into an Arduino microcontroller, which is programmed to analyze the data and calculate the battery's state of charge and state of health. If the temperature of the battery exceeds a predetermined threshold, a cooling system is activated to prevent damage to the battery.

2.1 BLOCK DIAGRAM

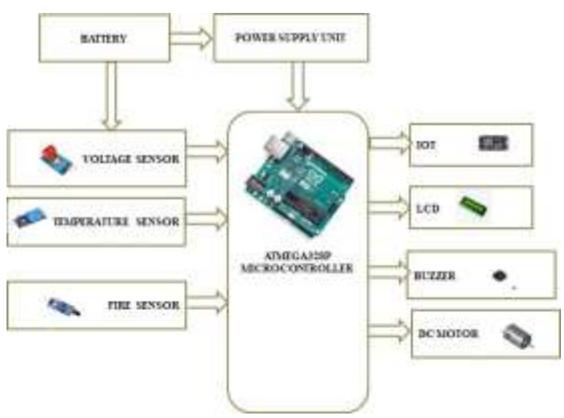


3.2 DISADVANTAGE

- While the system uses GSM for sending messages, the reliability of GSM networks can vary depending on factors such as network coverage and signal strength.
- The system only focuses on voltage, current, and temperature monitoring

4 SYSTEM ARCHITECTURE

The system architecture of an Advanced Electric Vehicle (EV) Battery Management and State-of-Charge (SOC) Monitoring System consists of voltage sensor to detect the voltage and update in IOT.The temperature sensor is used to sense the battery temperature; if there is increase in temperature buzzer alert is given and displayed in LCD.For safety purpose the system is interfaced with fire sensor that detects the fire in the battery and gives alarm.The overvoltage button indicates when the voltage exceeds certain level.The measured parameters are updated in IOT and displayed in LCD display.



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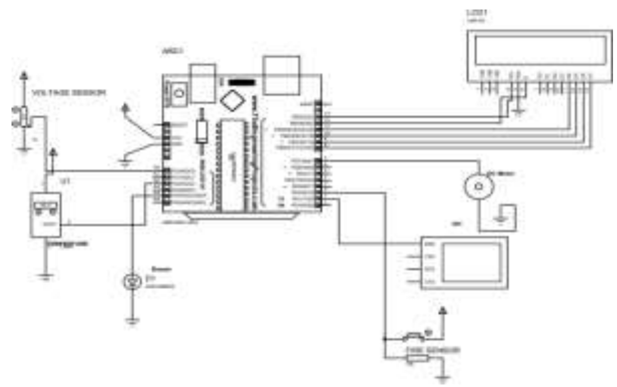
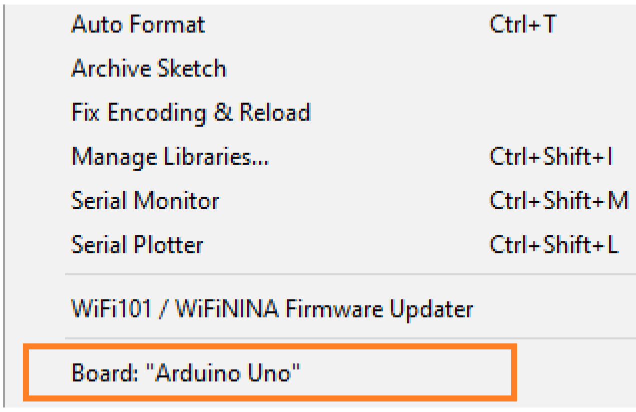


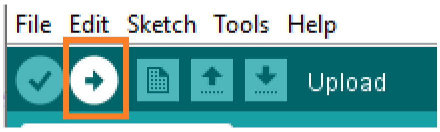
4.1 SOFTWARE IMPLEMENTATION

4.1.1 ARDUINO IDE

The Arduino Integrated Development Environment (IDE) is a software platform used for programming and developing applications for Arduino microcontroller boards. It provides a user-friendly interface that simplifies the process of writing, compiling, and uploading code to Arduino hardware. The IDE is open-source, which means that its source code is freely available for modification and improvement by the community. This collaborative nature has contributed to its widespread popularity among hobbyists, students, educators, and professional developers alike.



The Arduino IDE is its simplicity and ease of use. It employs a simplified version of the C++ programming language, making it accessible to individuals with various levels of programming experience. This makes it an excellent tool for beginners who are just starting to learn about microcontrollers and embedded systems. The IDE includes a set of pre-defined functions and libraries that abstract the complexities of low-level hardware interaction, allowing users to focus on writing code for their specific projects.



Furthermore, the Arduino IDE is cross-platform compatible, meaning it can run on different operating systems like Windows, macOS, and Linux. This versatility ensures that users can develop their projects on the platform that they are most comfortable with. Additionally, the IDE provides a comprehensive set of tools for code editing, including syntax highlighting, auto-completion, and error checking, which significantly aids in the development process. These features streamline the coding experience, allowing users to write and debug their programs efficiently.

The Arduino IDE also facilitates seamless integration with a wide range of sensors, actuators, and other electronic components commonly used in embedded systems. It includes a vast library repository that provides pre-written code modules for interfacing with various devices. This extensive library support drastically simplifies the process of working with sensors, displays, motors, communication modules, and more, enabling users to quickly prototype and develop their projects.

The Arduino IDE stands as a pivotal tool in the world of microcontroller development. Its user-friendly interface, cross-platform compatibility, and extensive library support make it an ideal choice for hobbyists, students, and professionals looking to create innovative electronic projects. With its active community and continuous development, the Arduino IDE remains at the forefront of embedded systems programming, driving innovation in the field of electronics and automation.

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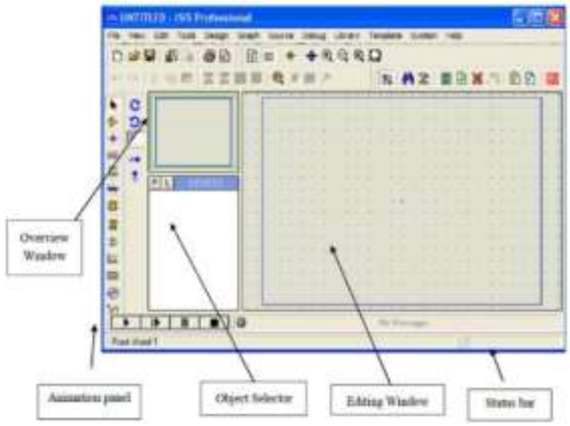
4.1.2 PROTEUS

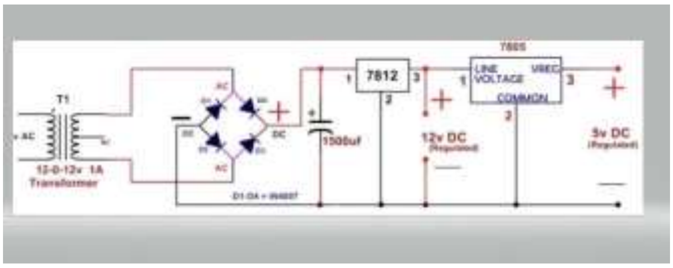
Proteus is a simulation and design software tool for electrical and electronic circuit design created by Labcenter Electronics. It also has a 2D CAD drawing capability. The tagline "From concept to completion" is appropriate. It is a software package that includes schematic, simulation, and PCB design. The ISIS program is used to create schematics and model circuits in real time. The simulation enables for human interaction during run time, resulting in real-time simulation. ARES is used to design PCBs. It provides the capability of seeing output in 3D perspective of the created PCB as well as components. The product's designer can also create 2D drawings.

ARES provides surface mount and through-hole PCB design with up to 14 inner layers. It contains the imprints of several types of discrete components, including ICs, transistors, headers, connections, and others. The PCB Designer has access to both automatic and manual routing methods. It is possible to convert the ISIS schematic straight to ARES.

The software runs on a microcontroller and any analogue or digital devices connected to it. The schematic displays the microcontroller model along with the other elements of your product design. It simulates the way a real chip would execute your object code (machine code).The logic levels in the circuit vary in accordance with what your program code sends to a port, and your program code will detect, exactly as in real life, if the circuit modifies the state of the processor's pins. All I/O ports, interrupts, timers, USARTs, and other peripherals present on each supported chip are entirely emulated by the VSM CPU models. It is not just a simple software simulator since the complete system is emulated and the interaction of all these peripherals with the external circuit is meticulously detailed down to the waveform level. With more than 750 supported microprocessor types, hundreds of embedded SPICE models, and one of the largest libraries of embedded simulation peripherals in the world, Proteus VSM continues to be the ideal option for embedded simulation.



4.2 HARDWARE IMPLEMENTATION



A Power Supply Unit (PSU) is an essential component in most electronic devices, including computers, consumer electronics, and various other electrical appliances. Its primary function is to convert electrical energy from a source (usually the electrical grid or a battery) into a form suitable for powering the internal components of the device it serves. Below is a brief explanation of a typical PSU and its main components: The PSU takes electrical energy from an input source, which can be the standard alternating current (AC) from a wall outlet or direct current (DC) from a battery. The input voltage varies depending on the region;

This component filters out any unwanted electrical noise or interference from the input power source to provide clean and stable power to the PSU.

In the case of an AC input, the rectifier converts the AC voltage into DC voltage. A rectifier typically uses diodes to ensure that the current flows in one direction.

The PSU ensures that the output voltage (5V, 12V) is stable and within the specified range. This is crucial to prevent damage to sensitive electronic components. Voltage regulation is achieved using components like voltage regulators.

The PSU provides various connectors and cables that deliver power to the different components of the device, such as the motherboard, hard drives, graphics cards, and other peripherals.

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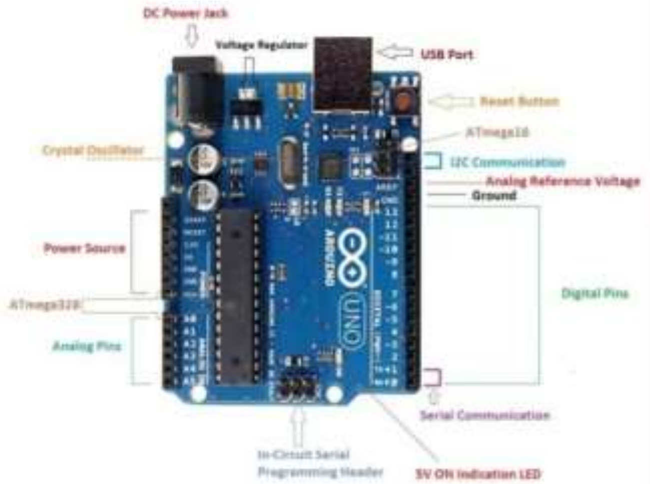
4.3 ARDUINO UNO

In order to link with external electronic circuits, the Arduino Uno is equipped with a USB interface, six analog input pins, and fourteen I/O digital ports. Six of the 14 I/O ports are available for PWM output. In the actual world, it enables the designers to sense and control external electronic components.
The 8-bit ATmega328P microprocessor is the foundation of the Uno microcontroller board. To support the ATmega328P microprocessor, it also includes additional parts such as a voltage regulator, crystal oscillator, serial communication, etc.

4.3.1. FEATURES

- More frequency and number of instructions per cycle: An Atmega328 microcontroller is installed on the board, which includes a number of functions like as timers, counters, interrupts, PWM, CPU, I/O pins, and is based on a 16MHz clock, allowing for a higher frequency and number of instructions per cycle.
- Built-in regulation: When connected to an external device, this board has a built-in regulation mechanism that maintains the voltage under control.
- Flexibility and ease of use: The board incorporates 14 I/O digital and 6 analog pins that allow external connection with any circuit with the board. These pins provide external devices that can be attached to them with flexibility and convenience of usage.
- Configurable pins: The six analog pins have a resolution of 10 bits and are identified by the letters A0 through A5. These pins have a measurement range of 0 to 5V, but the AREF pin and the analog Reference() function allow them to be set to a higher voltage.
- Increased Flash Memory: The amount of code-based instructions is stored in 13KB of flash memory.
- Minimal Voltage: The board just needs 5 V to switch on, which may be done directly with a USB port or an external adapter. Nevertheless, it can accept external power sources up to 12 V, which can be controlled to only 5 V or 3.3 V depending on the project's requirements.
- Plug and Play: There is no need for a hard and fast interface to connect the devices to the board. Simply plug the external device onto the board's pins, which are arranged out in the shape of a header.
- USB interface: The Arduino Uno includes a USB interface, which is a USB port on the board that allows for serial communication with a computer.
- Alternative power sources: In addition to USB, a battery or an AC to DC adapter can be used to power the board.



4.3.2. PIN CONFIGURATION

LED - Arduino Uno comes with built-in LED which is connected through pin 13. Providing HIGH value to the pin will turn it ON. Providing LOW will turn it OFF.
VIN - It is the input voltage provided to the Arduino Board. This pin is used to supply voltage. It is different from 5 V supplied through a USB port. If a voltage is provided through the power jack, it can be accessed through this pin.
5V - This board comes with the ability to provide voltage regulation. A 5V pin is used to provide output regulated voltage. The board is powered up using three ways i.e. USB, Vin pin of the board or DC power jack. USB supports voltage around 5V while Vin and Power Jack support a voltage range between 7V to 20V.
GND - These are ground pins. There are more than one ground pins provided on the board. They can be used as per requirement.
Reset -This pin is incorporated on the board which resets the program running on the board. Instead of physical reset on the board, IDE comes with a feature of resetting the board through programming.
IOREF -It is the abbreviation of Input Output Voltage Reference. This pin is very useful for providing voltage reference to the board. A shield is used to read the voltage across this pin which then selects the proper power source.

PWM – Pulse Width Modulation is provided by 3, 5, 6, 9, 10, 11 pins. These pins are configured to provide 8-bit output PWM.
SPI - It is an abbreviation of Serial Peripheral Interface. Four pins 10(SS), 11(MOSI), 12(MISO), 13(SCK) provide SPI communication with the help of SPI library.
AREF - It is called Analog Reference. This pin is used for providing a reference voltage to the analog inputs.
Serial Communication - Serial communication is carried out through two pins called Pin 0 (Rx) and Pin 1 (Tx). Rx. &Tx. - Rx (Receiver) pin is used to receive data while Tx (Transmitter) pin is used to transmit data.
External Interrupts - Pin 2 and 3 are used for providing external interrupts. An interrupt is called by providing LOW or changing value.

4.4 VOLTAGE SENSOR

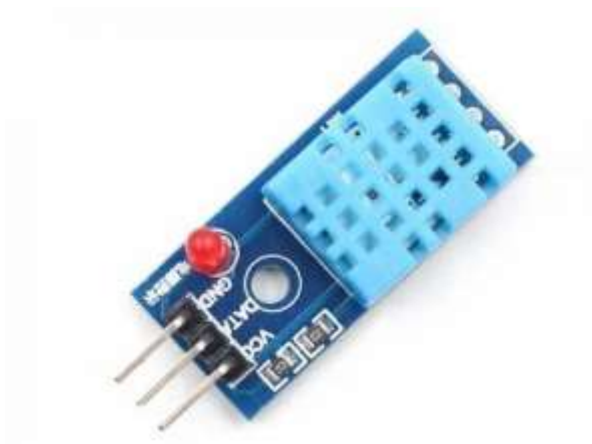
A voltage sensor is an electronic device that measures the voltage level of an electrical circuit. It provides information about the potential difference between two points in the circuit, helping to monitor and control electrical systems. Voltage sensors are essential components in various applications, from power distribution and renewable energy systems to electronic devices and automotive systems.
PIN CONFIGURATIONS
Vcc (Power Supply): This pin is responsible for providing the required power to the voltage sensor. It is usually connected to the positive terminal of the power source. The voltage level supplied to this pin depends on the specifications of the sensor, and it is essential to ensure that the voltage falls within the specified operating range to avoid damaging the sensor.
GND (Ground): The ground pin serves as the reference point for the electrical circuit. It is connected to the negative terminal of the power source. The ground pin completes the electrical path, allowing current to flow through the sensor.
Output: The output pin provides a signal that represents the measured voltage level. This can be in the form of an analog voltage, a digital signal, or a communication protocol. The voltage level or signal provided at this pin is proportional to the voltage being measured by the sensor.

4.4.4 FEATURES

Voltage sensors are designed to provide precise measurements of voltage levels, ensuring reliable and accurate data.
They are capable of measuring a wide range of voltage values, from low millivolt levels to high kilovolt levels, depending on the specific sensor's capabilities.
Many voltage sensors incorporate isolation techniques to protect sensitive electronics from potential electrical hazards. This isolation helps prevent damage to the measurement circuitry.
Voltage sensors typically have fast response times, allowing them to quickly detect changes in voltage levels.
They are designed to consume minimal power, making them suitable for battery-powered or energy-efficient applications.

TEMPERATURE SENSOR

4.5 DH11



The DHT11 sensor is a widely used digital temperature and humidity sensor. It is a cost-effective and easy-to-use component known for its accuracy and simplicity in measuring environmental conditions.

4.5.1 APPLICATIONS

- The DHT11 sensor is used in a wide range of applications, including:
- It is employed in DIY weather monitoring stations to measure temperature and humidity levels.
- Integrated into systems that regulate temperature and humidity in environments like homes, offices, and greenhouses.
- Used in smart home applications for controlling HVAC (Heating, Ventilation, and Air Conditioning) systems.
- Deployed in environments where maintaining specific temperature and humidity levels is critical, such as in laboratories or storage **facilities.**
- Integrated into Internet of Things (IoT) devices for remote monitoring of environmental conditions.
- Employed in automotive applications where monitoring cabin conditions is necessary.
- Integrated into devices like thermostats, dehumidifiers, and air purifiers.

4.6 FIRE SENSOR

A fire detector is a device that senses fire, typically as an indicator of fire. Commercial security devices issue a signal to a fire alarm control panel as part of a fire alarm system,

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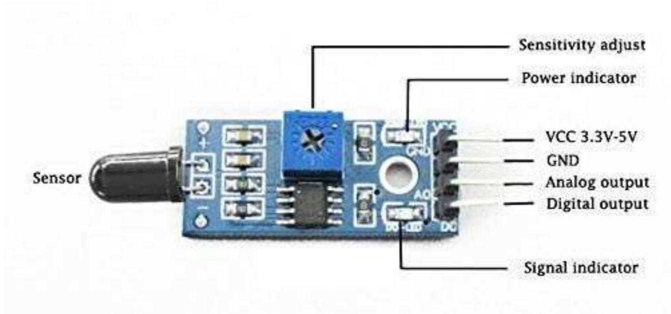
while household fire detectors, also known as fire alarms, generally issue a local audible or visual alarm from the detector itself or several detectors if there are multiple fire detectors interlinked.
Fire detectors are housed in plastic enclosures, typically shaped like a disk or square about 150 millimetres (6 in) in diameter and 25 millimetres (1 in) thick, but shape and size vary. Fire can be detected either optically (photoelectric) or by physical process (ionization); detectors may use either, or both, methods.
Sensitive alarms can be used to detect, and thus deter, smoking in areas where it is banned. Fire detectors in large commercial, industrial, and residential buildings are usually powered by a central fire alarm system, which is powered by the building power with a battery backup. Domestic fire detectors range from individual battery-powered units, to several interlinked mains-powered units with battery backup; with these interlinked units, if any unit detects smoke, all trigger even if household power has gone out.



This is a very easy to use low cost semiconductor Gas sensor Module with analog and digital output. This module uses MQ2 Fire & Flammable gas sensor as a gas sensing element. It requires no external components just plug in Vcc& ground pins and you are ready to go.For Digital output the threshold value can be easily set by an on-board potentiometer. Using this module you can easily interface MQ2 Fire & Combustible gas Sensor to any Microcontroller, Arduino or even Raspberry Pi.Since this Gas Sensor module is sensitive to fire it can be used in for fire detection. MQ2 Gas Sensor is also sensitive to flammable/combustible gasses like LPG, Propane & Hydrogen.

4.6.1 SPECIFICATION

- Power Supply: 5 Volts
- Interface Type: Analog & Digital
- High Sensitivity to Fire & combustible gasses like Hydrogen, LPG & Propane.
- Low Cost.
- Stable & Long Life.
- On board Power indication.

4.7 LCD

A 16x2 LCD display is often used with microcontrollers and other electronic devices for displaying information such as sensor readings, messages, or status updates. These displays are commonly used in DIY projects, embedded systems, and many consumer electronics.

LCDs are a common type of display technology used in various electronic devices, from digital clocks to calculators to more advanced devices like industrial control panels and microcontroller projects. They are known for their low power consumption and the ability to display text or simple graphics.
This indicates the size of the LCD display in terms of character cells. A 16x2 LCD has 16 columns and 2 rows of characters, meaning it can display 16 characters in a row and 2 rows of characters. Each character cell can typically display a single alphanumeric character or symbol.
4.8.1.PIN CONFIGURATION

- VSS (Ground): Connected to the ground (0V) of your power supply.
- VDD (Supply Voltage): Connected to the positive supply voltage (usually +5V).
- VO (Contrast Adjustment): This pin is used for contrast adjustment. It is connected to a potentiometer to control the contrast of the characters on the display.
- RS (Register Select): This pin is used to select between data (RS=1) and command (RS=0) modes.
- RW (Read/Write): This pin is used to read (RW=1) or write (RW=0) data to the LCD.
- E (Enable): The enable pin is used to trigger the read or write operation. A high-to-low transition on this pin latches the data or command.
- D0 to D7 (Data Pins): These pins (D0 to D7) are used for transferring data to/from the LCD in 8-bit mode. In many cases, D0 to D3 may not be connected or left unconnected when using the LCD in 4-bit mode.

4.8 NODEMCU

NodeMCU is an open source Lua based firmware for the ESP8266 Wi-Fi SOC from Espressif and uses an on-module flash-based SPIFFS file system. NodeMCU is implemented in C and is layered on the Espressif NON-OS SDK.
The firmware was initially developed as is a companion project to the popular ESP8266-based NodeMCU development modules, but the project is now

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community-supported, and the firmware can now be run on *any* ESP module.

4.9.1 Features:

· Open-source
· Interactive
· Programmable
· Low cost
· Simple
· Smart
· WI-FI enabled

4.9.2 Specification:

The Development Kit based on ESP8266, integates GPIO, PWM, IIC, 1-Wire and ADC all in one board.

Power your developement in the fastest way combinating with NodeMCU Firmware!

· USB-TTL included, plug&play
· 10 GPIO, every GPIO can be PWM, I2C, 1-wire
· FCC CERTIFIED WI-FI module (Coming soon)
· PCB antenna

4.9 BUZZER

A buzzer is an electrical device designed to produce audible sound signals. It is a compact and straightforward component that, when activated, emits a continuous or intermittent buzzing or beeping sound. Buzzer mechanisms typically consist of an electromagnet that, when energized, causes a diaphragm or a vibrating element to create sound waves. Buzzer devices are commonly used for various purposes, such as alarms, notifications, and indicators in electronic devices, household appliances, automobiles, and industrial machinery. They serve as effective means of drawing attention to specific events, warnings, or status changes. The simplicity and reliability of buzzers make them indispensable in situations where auditory alerts or signals are needed, providing a cost-effective solution for communication through sound.

4.10 DC MOTOR

Direct current (DC) motors are a fundamental part of modern technology, converting electrical energy into mechanical motion. They operate on the principle of Lorentz force, where a magnetic field interacts with current-carrying conductors to generate rotational motion. At their core, DC motors consist of two main parts: the stator and the rotor. The stator is the stationary part of the motor and contains coils of wire, typically wrapped around a core, creating a magnetic field when electricity flows through them. The rotor, usually attached to an output shaft, comprises a set of conductors or coils that interact with the stator's magnetic field. When electric current flows through the coils in the stator, it generates a magnetic field. This field interacts with the magnetic field produced by the rotor, causing the rotor to experience a force and start rotating. The direction of the current flow through the coils determines the direction of the magnetic field and subsequently the rotation direction of the motor. DC motors are classified into two main types: brushed and brushless. Brushed DC motors employ brushes and a commutator to switch the direction of current flow in the rotor, allowing it to continuously rotate. However, these brushes can wear out over time, requiring maintenance. On the other hand, brushless DC motors use electronic controllers to switch the currents in the stator windings, eliminating the need for physical brushes and resulting in more efficient and durable operation. These motors find widespread use in various applications due to their simplicity, controllability, and ability to deliver high torque at low speeds. From powering electric vehicles and industrial machinery to being integral parts of household appliances

and robotics, DC motors play a pivotal role in countless devices and systems across industries. Their versatility allows for precise control of speed and direction using methods like pulse-width modulation (PWM) or by varying the voltage supplied to the motor. Additionally, advancements in motor design and control technologies continue to improve their efficiency, reliability, and performance, making DC motors indispensable components in modern engineering and technology.

5. CONCLUSIONS

This system represents a significant advancement in ensuring the safety and efficiency of battery operations. By integrating sensors for voltage, temperature, and fire detection, along with manual input controls like the overvoltage button, the system provides comprehensive monitoring capabilities. Real-time data collection and analysis facilitated by the IoT platform enable proactive management of battery health, allowing for timely interventions in case of abnormalities such as overheating or voltage fluctuations. The incorporation of visual and audible alerts through the LCD display and buzzer enhances user awareness and facilitates quick response to critical situations, ultimately contributing to the reliability and longevity of electric vehicle batteries while prioritizing safety. Furthermore, the system's ability to update measured parameters to the IoT platform ensures accessibility to crucial information remotely, enabling stakeholders to make informed decisions regarding battery maintenance and operation. As electric vehicles continue to gain traction as a sustainable transportation solution, the importance of robust battery management systems cannot be overstated. The proposed system not only addresses immediate safety concerns but also lays the groundwork for future advancements in battery technology and management, ultimately contributing to the widespread adoption and viability of electric vehicles in the global automotive landscape.

6. SUGGESTION FOR FUTURE WORK

- Explore the use of blockchain technology for secure and transparent data logging and authentication, enhancing data integrity and trustworthiness in the system.
- Investigate the incorporation of energy harvesting technologies, such as regenerative braking or solar panels, to supplement the vehicle's power supply and extend battery range.
- Integrate the battery management system with other vehicle systems, such as the propulsion system and onboard diagnostics, for comprehensive vehicle health monitoring and diagnostics.

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