Green Groom -An Automatic Solar Grass Cutter and Shaper

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***Abstract*—Arduino UNO-based Solar powered Grasscutter designed to cut healthy grass in places like parks, hotels, public places, etc., The Grasscutter is designed through using LIDAR and solar, which is controlled remotely through Bluetooth module. The proposed model consists of hardware components like Arduino UNO, Solar panel, DC motor, motor driver, IR sensors ,rechargeable batteries and Bluetooth module. The designed model is programmed through Arduino IDE to control the operation of the Grasscutter. The control mechanism and movements such as Forward movement, Backward movement, Right movement, Left movement, On mechanism, Off mechanism and Stop function for the Grasscutter prototype. An LIDAR connected to the head of the model avoids the system from colliding with obstacles while in movement.**

Keywords—Arduino UNO, Solar panel, DC motor, motor driver, IR sensors, rechargeable batteries, Bluetooth module, Arduino IDE, Forward movement, Backward movement, Right movement, Left movement, On mechanism, Off mechanism, Stop function, LIDAR, obstacle avoidance, Grasscutter, remote control,

I. INTRODUCTION

In the past, and even in many places today, cutting grass was typically done manually using a cutlass. However, this method is time-consuming and often results in uneven cutting. With the advancement of technology, grass cutting is now achieved through the use of single or multiple blades, which can cut the grass surface to a uniform height. The height of the grass cutting is usually adjusted by the operator using a lever or nut on the machine's wheels. This approach allows for efficient trimming of grass while minimizing the amount of human power required. There are several types of grass cutters available to suit various needs, and the choice of power source also plays a critical role in designing the best tool for the user.

II. EASE OF USE

Modern grass-cutting technologies incorporate energy sources such as petrol, electricity, propane, and more. Solar power grass cutting robots are innovative machines designed to automate lawn care by using solar energy as a power source. These robots are equipped with sensors and intelligent software that allows them to navigate through different terrains, avoid obstacles, and cut grass effectively. The concept of a solar power grass cutting robot emerged as a result of the need to reduce manual labour in lawn maintenance, improve efficiency, and reduce the environmental impact of lawn care activities. These robots have become increasingly popular in recent years, especially in areas where there is a high demand for lawn care service. The primary advantage of a solar power grass cutting robot is its use of solar energy, which is a clean, renewable, and abundant source of power. By harnessing the power of the sun, these robots can operate for extended periods without needing to be recharged, and they emit zero carbon emissions, making them an environmentally friendly alternative to traditional gas-powered lawn mowers. Another significant advantage of solar power grass cutting robots is their autonomous operation. These robots are equipped with advanced sensors and mapping software that enable them to navigate through different terrains and avoid obstacles, such as trees, rocks, and other objects in their path. This makes them ideal for use in large lawns, golf courses, parks, and other outdoor spaces that require frequent maintenance. In addition to their autonomous operation, solar power grass cutting robots are also equipped with cutting-edge technology that allows them to cut grass efficiently and effectively. These robots use advanced algorithms to optimize their cutting patterns and ensure that they cut the grass to the desired height and level of precision. Another benefit of solar power grass cutting robots is their low www.ijcrt.org © 2023 IJCRT | Volume 11, Issue 4 April 2023 | ISSN: 2320-2882 IJCRT2304128 International Journal of Creative Research Thoughts (IJCRT) www.ijcrt.org b24 maintenance requirements. Since they

use solar energy as their primary power source, they do not require frequent oil changes, spark plug replacements, or other maintenance tasks typically associated with traditional gas-powered lawn mowers. This translates into lower maintenance costs and a longer lifespan for the machine. overall, solar power grass cutting robots represent a significant advancement in lawn care technology. They offer a sustainable, efficient, and cost-effective solution to the challenges associated with manual lawn maintenance. As technology continues to evolve, it is likely that we will see further advancements in this field, leading to even more sophisticated and intelligent lawn care machines that can transform the way we manage our outdoor space.

III. LITERATURE SURVEY

Research paper presented by Md. Rawshan Habib, Koushik Ahmed, Naureen Khan, Mahbubur Rahman Kiran, Md. Ahasonul Habib, Md. Tanvir Hasan and Omar Farrok on automatic solar grass cutter titled "PID Controller Based Automatic Solar Power Driven Grass Cutting Machine" and published on International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering (IC4ME2). It .Utilizes a color sensor to detect the position of grass based on a specified green color signal.Uses two-degree-of-freedom PID controllers to control the motor speed.Powered primarily by an 8W, 9V solar panel.Includes rechargeable Li-poly batteries (3.7 V) for energy storage.The research paper titled "PID Controller Based Automatic Solar Power-Driven Grass Cutting Machine" presents an innovative approach to grass cutting using solar power and PID (Proportional-Integral-Derivative) controllers. The system comprises a lightweight, portable device with motor-driven cutting blades and a color sensor for grass detection. However, the paper highlights the need to address challenges such as battery capacity, obstacle detection, maintenance, and market viability. Overall, this research offers a promising solution for eco-friendly grass cutting but underscores the importance of further development and real-world testing.[1]

Research paper presented by M. Manimegalai,V. Mekala,N. Prabhuram,D. Suganthan,Department of ECE titled "Automatic Solar Powered Grass Cutter Incorporated with Alphabet Printing and Pesticide Spray" published on IEEE.When an obstacle is detected by the ultrasonic sensor, the grass cutter avoids it by turning left (first detection) and right (second detection).The system can cut grass in the shape of alphabets and spray pesticides as needed.Solar power eliminates pollution and reduces operational costs.The research paper discusses the development of an Automatic Solar-Powered Grass Cutter that incorporates features like alphabet printing and pesticide spraying. The system aims to reduce human intervention in lawn maintenance, operating on solar power to minimize pollution. I By combining grass cutting, alphabet printing, and pesticide spraying into a single machine, the research aims to reduce space, costs, and manpower required for lawn maintenance. The system utilizes ultrasonic sensors, an Arduino UNO board, and a solar panel for efficient operation.,leaving room for further development and validation.[2]

Research paper presented by Balakrishna K, Rajesh N titled "Design of remote monitored solar powered grasscutter robot with obstacle avoidance using IoT" presented on Global Transitions Proceedings 3.The robot is equipped with a Bluetooth module (HC-05), enabling wireless communication with a mobile device through the Blynk application. Users can remotely control the robot using the app. The robot can perform various control functions, including forward movement, backward movement, right movement, left movement, on/off mechanisms for the grass cutter blade, and a stop function to prevent collisions.Developing a solar-powered grasscutter robot with IoT-enabled obstacle avoidance presents a multifaceted challenge. The project encompasses power management, energy efficiency, reliable obstacle detection, IoT integration, and robust navigation algorithms. Ensuring durability, cost-efficiency, and regulatory compliance are additional hurdles. User experience, data security, and environmental impact considerations further complicate this endeavor. Successfully addressing these challenges demands a holistic approach and iterative design improvements, promising a practical and eco-friendly solution for automated grass cutting.[3]

Research paper presented by Firas B. Ismail, Nizar F.O. Al-Muhsen, Fazreen A. Fuzi, A. Zukipli titled "Design and Development of Smart Solar Grass Cutter", presented on International Journal of Engineering and Advanced Technology (IJEAT). Microcontroller: An Arduino UNO board serves as the main control unit for the grass cutter.Remote Control: The grass cutter can be remotely controlled using a smartphone via a Bluetooth module (HC-05).The Smart Solar Grass Cutter is a renewable energy-powered grass-cutting device designed to reduce air pollution and improve efficiency. It features a 12V, 10W solar panel as the primary energy source and a 12V, 7Ah lithium-ion battery for energy storage. Controlled by an Arduino UNO and a smartphone via Bluetooth, the grass cutter operates for over two hours on a full charge, offering an efficiency of approximately 93.37%. Its mechanical reliability is confirmed through stress-strain analysis, and it presents a promising eco-friendly alternative to traditional grass cutters.[4]

Research paper presented by Kartik R. Khodke, Himanshu Kukreja, Sumit Kotekar, Nital kukade, C. J. Shende , titled "Grass Cutter Machine" presented on International Journal of Emerging Technologies in Engineering Research (IJETER).Developing grass cutting machines with smart features, such as GPS-guided mowing patterns, remote control, or smartphone app integration, could be an area of innovation.The paper titled "Literature Review of Grass Cutter Machine" provides an overview of technological developments in the field of grass cutting machines. It discusses the historical evolution of grass cutting, from manual methods to modern machines. The paper highlights the importance of efficient grass cutting in various applications, including agriculture. It mentions different types of grass cutters powered by solar, electric,

and internal combustion engines available in the market. The authors aim to innovate and fabricate a grass cutting machine tailored for agricultural use, emphasizing the need for improved technology in this domain.[5]

Research paper presented by Praful P. Ulhe Manish D. Inwate Fried D. Wankhede Krushnkumar S. Dhakte titled "Modification of Solar Grass Cutting Machine" presented on International Journal for Innovative Research in Science & Technology.The machine features a spiral cutting blade to efficiently cut grass.The grass cutter can operate in both manual and motor-driven modes. In the motor-driven mode, it can be remotely controlled.The machine includes a collecting box to gather and store the cut grass, preventing it from scattering on the lawn or ground.An RF (Radio Frequency) module is used for remote control operation, allowing for safer and more convenient use.The research paper discusses the modification of a solar-powered grass cutting machine for enhanced efficiency and ease of operation. It introduces the use of spiral cutting blades and RF remote control to improve grass cutting performance. The machine utilizes solar panels to harness renewable energy, minimizing environmental impact. However, the paper lacks specific technical details and empirical data to support its claims effectively. It is crucial to address these shortcomings for a more comprehensive and informative research paper.[6]

Research paper presented by Dhanaraju Athina, D Kiran Kumar, R.B.Kalyani,Kolli Vittal. Titled "Solar Grass Cutter Using Embedded Platform An Experimental Validation" . Presented on IOP Conf. Series: Materials Science and Engineering .The grass cutting robot is equipped with a set of sensors, including GPS, cameras, temperature sensors, and battery level sensors, to collect essential data for monitoring and control.The system seamlessly integrates Internet of Things (IoT) technology, allowing remote monitoring and control of solar grass cutting robots via a cloud-based platform.This research paper explores the design and development of an innovative automatic solar-powered grass cutter, aiming to address environmental concerns and enhance lawn maintenance practices. It presents a comprehensive system architecture integrating solar panels, energy storage, and autonomous navigation technology. The paper emphasizes energy efficiency, obstacle detection, and cutting precision. Field testing results showcase the machine's adaptability and reduced carbon emissions, promising a sustainable and efficient solution. However, potential challenges include optimizing energy storage, ensuring robust obstacle avoidance, and addressing scalability for broader applications.[7]

2.1.11 Research paper presented by Sushant M. More, Ramappa K. Pujari, Shreyas S. Jadhav, Kiran R. Kalli, Digvijay P. Mali. Titled "Fully Automatic Solar Grass Cutter".Presented on International Journal of Research in Engineering, Science and Management .The system includes a voltage regulator to manage and optimize energy consumption. This contributes to the overall energy efficiency of the grass cutter, allowing it to operate with minimal power requirements.This research project introduces a solar-powered automatic grass cutter designed to reduce human effort in lawn maintenance. The system employs solar panels to capture and convert solar energy into electrical power, stored in batteries for continuous operation. Controlled via Bluetooth through an Android application, it combines ultrasonic sensors for obstacle avoidance. While the paper lacks empirical evidence and detailed technical specifications, it presents a promising concept for eco-friendly lawn care. However, addressing security concerns, scalability, and providing cost analysis would strengthen its practicality.[8]

Research paper presented by Varun Upasani,Kaustubh Adhyapak , Mousami Wanjale.Titled "Fully Automated Solar Grass Cutter". presented on Journal of Emerging Technologies and Innovative Research (JETIR).
The system is designed to autonomously cut grass at various lengths without human intervention. It utilizes 12V batteries to power the vehicle motors and the grass cutter motor. Additionally, it incorporates a solar panel for recharging the batteries, eliminating the need for external charging.The Fully Automated Solar Grass Cutter is a solar-powered grass-cutting system that operates without human intervention. It utilizes a 12V/7W solar panel to charge onboard batteries, powering both the vehicle motors and grass cutter motor. Equipped with an ultrasonic sensor for obstacle detection, it can navigate autonomously. Users have the flexibility to control it manually via Bluetooth or enable automatic mode. This eco-friendly solution reduces carbon emissions, offers variable grass cutting lengths, and has the potential for future enhancements.[9]

2.1.14 Research paper presented by Dr. J. G. Chaudhari, Akash S Ingole, Aakash Z Patel, Kunal R Bhagat, Ashwini S Gaurkhede. Titled "Smart Solar Based Grass Cutter".Presented on International Journal of Advanced Research in Science, Communication and Technology (IJARSCT).A 40W solar panel is used to charge the batteries.
Solar panel specifications include maximum power voltage (19.25 V), maximum power current (2.08 A), short circuit current (2.22 A), and open circuit voltage (22.5 V).Four DC gear motors are used for wheel movement with a speed of 30 rpm, 0.5 A load current, 12 V operating voltage, and 2.94 N.m torque.The research paper introduces a "Smart Solar Based Grass Cutter" as an eco-friendly alternative to traditional grass cutting machines. It highlights the environmental issues associated with gas-powered cutters, emphasizing the need for cleaner solutions. The smart cutter is powered by solar energy and controlled by an Arduino Uno microcontroller, making it fully automated and programmable. However, the paper lacks comprehensive testing data and comparative analysis, and it should address safety, scalability, reliability, and cost-benefit aspects for practical implementation. Future research and improvements are also briefly mentioned.[10]

IV. Existing System

The current approach to lawn maintenance predominantly relies on manual labor and traditional fuel-powered lawnmowers. Manual mowing requires significant physical effort and time, as human operators either push or ride the lawnmower across the lawn. Conventional lawnmowers, powered by fossil fuels, contribute to environmental pollution and are dependent on non-renewable energy sources. These systems lack advanced automation features, remote control capabilities, and smart functionalities. Overall, the existing system is characterized by labor-intensive practices and limited technological innovation, with potential environmental drawbacks due to the use of conventional energy sources.

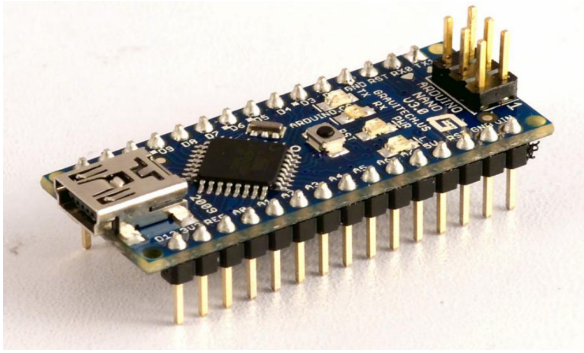
V. Proposed System

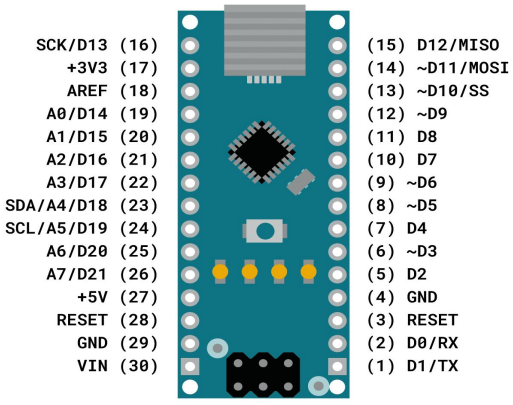
The proposed system introduces a paradigm shift in lawn maintenance with the development of a solar-powered grass-cutting robot incorporating Bluetooth connectivity. Solar panels are integrated into the design to harness renewable energy from the sun, reducing the environmental impact associated with traditional fuel-powered alternatives. Bluetooth technology is employed for wireless communication, allowing users to control and monitor the robot remotely using a smartphone or dedicated control unit. The robot is equipped with automated navigation features, leveraging sensors for obstacle detection and ensuring efficient coverage of the lawn. AI-based cutting algorithms enable precise and adaptive cutting patterns based on grass height and density. The system also prioritizes safety with emergency stop mechanisms and obstacle avoidance, while efficient energy management optimizes the use of solar power. The user-friendly interface, environmental considerations, and potential for future upgrades make the proposed system a more sustainable, efficient, and technologically advanced solution for lawn maintenance.

VI. HARDWARE

*A. **Arduino Nano***

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Nano was designed and is being produced by Gravitech. Arduino Nano 3.0 (ATmega328): schematic, Eagle files. Arduino Nano 2.3 (ATmega168): manual (pdf), Eagle files. Note: since the free version of Eagle does not handle more than 2 layers, and this version of the Nano is 4 layers, it is published here unrouted, so users can open and use it in the free version of Eagle. Microcontroller Atmel ATmega168 or ATmega328 Operating Voltage (logic level) 5 V Input Voltage (recommended) 7-12 V Input Voltage (limits) 6-20 V Digital I/O Pins 14 (of which 6 provide PWM output) Analog Input Pins 8 DC Current per I/O Pin 40 mA Flash Memory 16 KB (ATmega168) or 32 KB (ATmega328) of which 2 KB used by bootloader SRAM 1 KB (ATmega168) or 2 KB (ATmega328) EEPROM 512 bytes (ATmega168) or 1 KB (ATmega328) Clock Speed 16 MHz Dimensions 0.73" x 1.70" The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source. The FTDI FT232RL chip on the Nano is only powered if the board is being powered over USB. As a result, when running on external (non-USB) power, the 3.3V output (which is supplied by the FTDI chip) is not available and the RX and TX LEDs will flicker if digital pins 0 or 1 are high. The ATmega168 has 16 KB of flash memory for storing code (of which 2 KB is used for the bootloader); the ATmega328 has 32 KB, (also with 2 KB used for the bootloader). The ATmega168 has 1 KB of SRAM and 512 bytes of EEPROM (which can be read and written with the EEPROM library); the ATmega328 has 2 KB of SRAM and 1 KB of EEPROM. Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms.





· Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip.

· External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.

· PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.

· SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.

· LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off. The Nano has 8 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the analogReference() function. Additionally, some pins have specialized functionality:

· I2C: 4 (SDA) and 5 (SCL). Support I2 C (TWI) communication using the Wire library (documentation on the Wiring website). There are a couple of other pins on the board:

· AREF. Reference voltage for the analog inputs. Used with analogReference().

· Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board. See also the mapping between Arduino pins and ATmega168 ports. The Arduino Nano has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega168 and ATmega328 provide UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An FTDI FT232RL on the board channels this serial communication over USB and the FTDI drivers (included with the Arduino software) provide a virtual com port to software on the computer. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the FTDI chip and USB connection to the computer (but not for serial communication on pins 0 and 1). A SoftwareSerial library allows for serial communication on any of the Nano's digital pins. The ATmega168 and ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. To use the SPI communication, please see the ATmega168 or ATmega328 datasheet. The Arduino Nano can be programmed with the Arduino software (download). Select "Arduino Diecimila, Duemilanove, or Nano w/ ATmega168" or "Arduino Duemilanove or Nano w/ ATmega328" from the Tools > Board menu (according to the microcontroller on your board). For details, see the reference and tutorials. The ATmega168 or ATmega328 on the Arduino Nano comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files). You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details. Rather then requiring a physical press of the reset button before an upload, the Arduino Nano is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the FT232RL is connected to the reset line of the ATmega168 or ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload. This setup has other implications. When the Nano is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Nano. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software on running on a computer (e.g. Flash, Processing, MaxMSP). Arduino is a cross-platoform program. You'll have to follow different instructions for your personal OS. Check on the Arduino site for the latest instructions. http://arduino.cc/en/Guide/HomePage Once you have downloaded/unzipped the arduino IDE, you'll need to install the FTDI Drivers to let your PC talk to the board. First Plug the Arduino to your PC via USB cable. Now you're actually ready to "burn" your first program on the arduino board. To select "blink led", the physical translation of the well known programming "hello world", select File>Sketchbook> Arduino-0017>Examples> Digital>Blink Once you have your skecth you'll see something very close to the screenshot on the right. In Tools>Board select Arduino NANO and with the AtMEGA you're using (probably 328) Now you have to go to Tools>SerialPort and select the right serial port, the one arduino is attached to.

B. ***Lithimu Ion Battery***

This article is about rechargeable lithium-ion batteries. For disposable primary lithium batteries, see Lithium battery.

Specific energy	100–265 W·h/kg (0.36–0.875 MJ/kg)
Energy density	250–693 W·h/L (0.90–2.43 MJ/L)
Specific power	~250 – ~340 W/kg
Charge/discharge efficiency	80–90%
Energy/consumer-price	6.4 Wh/US$
Self-discharge rate	0.35% to 2.5% per month depending on state of charge
Cycle durability	400–1,200 cycles
Nominal cell voltage	3.6 / 3.7 / 3.8 / 3.85 V, LiFePO4 3.2 V

A lithium-ion battery or Li-ion battery (abbreviated as LIB) is a type of rechargeable battery. Lithium-ion batteries are commonly used for portable electronics and electric vehicles and are growing in popularity for military and aerospace applications.[9] The technology was largely developed by John Goodenough, Stanley Whittingham, Rachid Yazami and Akira Yoshino during the 1970s–1980s,[10][11] and then commercialized by a Sony and Asahi Kasei team led by Yoshio Nishi in 1991.

In the batteries, lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode. The batteries have a high energy density, no memory effect (other than LFP cells)[12] and low self-discharge. They can however be a safety hazard since they contain a flammable electrolyte, and if damaged or incorrectly charged can lead to explosions and fires. Samsung were forced to recall Galaxy Note 7 handsets following lithium-ion fires,[13] and there have been several incidents involving batteries on Boeing 787s.

Chemistry, performance, cost and safety characteristics vary across LIB types. Handheld electronics mostly use lithium polymer batteries (with a polymer gel as electrolyte) with lithium cobalt oxide (LiCoO
2) as cathode material, which offers high energy density, but presents safety risks, especially when damaged. Lithium iron phosphate (LiFePO
4), lithium ion manganese oxide battery (LiMnor LMO), and lithium nickel manganese cobalt oxide (LiNiMnCoO
2 or NMC) offer lower energy density but longer lives and less likelihood of fire or explosion. Such batteries are widely used for electric tools, medical equipment, and other roles. NMC in particular is a leading contender for automotive applications.

Research areas for lithium-ion batteries include life extension, energy density, safety, cost reduction, and charging speed. among others. Research has been under way in the area of non-flammable electrolytes as a pathway to increased safety based on the flammability and volatility of the organic solvents used in the typical electrolyte. Strategies include aqueous lithium-ion batteries, ceramic solid electrolytes, polymer electrolytes, ionic liquids, and heavily fluorinated systems.

WHAT IS BATTERY MANAGEMENT SYSTEM? – BMS BUILDING BLOCKS, WORKING & FUNCTIONS

A Battery Management System AKA BMS ensures the safety of the battery pack by continuously monitoring and regulating parameters like temperature & voltage.With the evolving technology, the need for the batteries is also growing at an astronomical pace. They are found everywhere, nearly in all devices from small earbuds to high-speed electric cars.Researches are going on to make batteries as compact as possible without decreasing the efficiency.

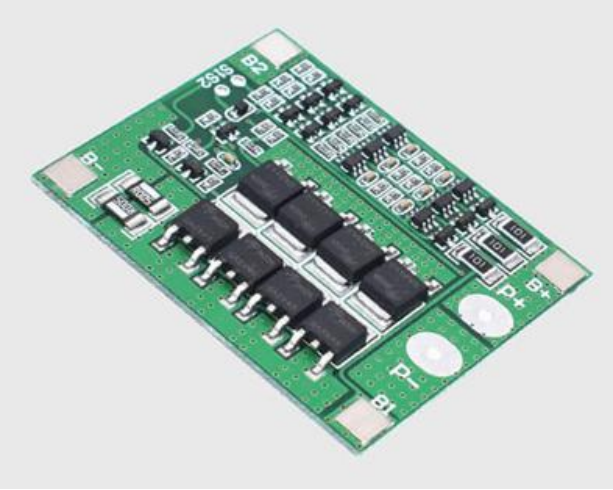
Benefits of using BMS

- Ensure reliable battery operations
- Continuous battery health monitoring to avoid explosion
- Increases the life span of the battery
- Indicates battery level

The Battery Management System (BMS) Technology is so useful. Unfortunately, we have experienced that there is very less information available on the internet, so we have decided to round-up an article on BMS in details.

So stay tuned and read till the end.

What is Battery Management System?

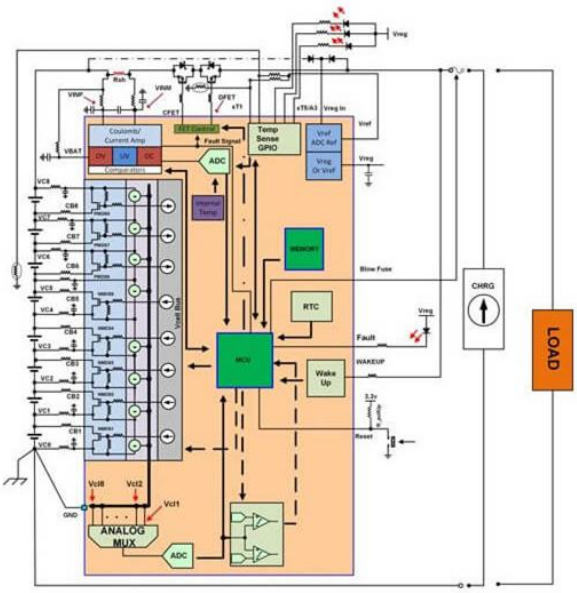


A Battery Management System AKA BMS monitors and regulates internal operational parameters, i.e. temperature, voltage and current during charging and discharging of the battery. In technical terms, the BMS estimates the SoC (State of Charge) and SoH (State of Health) of the battery to improve safety and performance. It avoids over-charging and over-discharging of the battery pack. This way, it maintains charge level within maximum and minimum allowed capacity to prevent sudden accidents [explosion].

Hence a BMS is a highly crucial device to ensure the safety of the battery and user. There are many other benefits of using BMS; we will discuss them later in this article. A BMS is an electronic board consisting of a variety of components and circuitry. After detecting a problem in operational parameters (voltage, temperature etc.) BMS triggers input to the alarm system followed by disconnecting the battery pack from the load or charger.

Building Blocks of Battery Management System

The design of the BMS is board is a bit complicated. To keep this article short and informative, we have briefly defined building blocks of the BMS. If you want in-depth coverage of BMS board construction, refer to this article BMS Tutorial by Renesas.



There are four main functional blocks,

- Cut-off FETs
- Fuel Gauge Monitor
- Cell voltage monitor
- Temperature Monitor

Along with this, there are few more blocks and we will describe them as well.So without any further ado, let's get started.

1. Cut-off FETs

A FET-driver acts as isolation between the battery and the charger. It is used to connect the high-side and low-side of the battery pack.

- High-side – Activates NMOSFET using the charge pump driver
- Low-side – Activates NMOSFET without charge pump driver

This integrated Cut-off FETs reduce the overall cost of the BMS. It is also eliminating the use of high voltage devices that could consume a large die area.

2. Fuel Gauge Monitor

This helps in keeping track of the charge entering and exiting the battery pack. The charge flowing is calculated by multiplying current and time.Although several methods are used to measure the current flow, the most efficient and cost-effective solution is to measure the voltage of sense resistor using a 16-bit ADC with low offset and high common-mode rating. Higher ADC is beneficial to obtain an extensive dynamic range at more speed.

3. Cell Voltage Sensors

Cell voltage monitoring can be called as a standard function of the Battery Management System. It is useful in determining the health of the battery. All cells in a battery should operate at standard voltage levels during charging and discharging for safety and improving the lifecycle. To know how battery packs are formed by connecting battery cells in series and parallel check out this blog Series Parallel Configuration of Lithium Batteries.

4. Temperature Monitoring

As technology is evolving, batteries are made to supply high currents in the meantime keeping the voltage constant. Since a high current flow through batteries can cause sudden temperature rise and force them to explode accidentally. It needs to be avoided. For this reason, the BMS continuously monitor the temperature of the battery and regulate it to the rated value. This feature is handy because if the temperature rises above the rated value, it will inform you to start/stop charging or discharging.

5. Other Building Blocks

Few more of the available blocks are,

- **Battery Authentication** – prevents the connection of BMS electronics to the third-party battery pack.
- **Real-time Clock (RTC)** – used in black-box application
- **Memory** – used in black-box application
- **Daisy Chain** – simplifies the connection between stacked devices

Working of Battery Management System

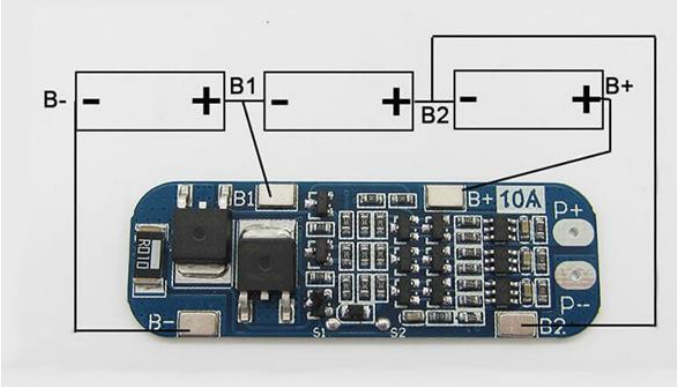
The working of a battery management system is determined by the complexity of the electronic components available on board. Let we discuss the working in details by considering a standard BMS with minimal components for optimum performance. The microcontroller of the BMS measures the cell voltage and current in real-time and based on that it switches the MOSFETs. The BMS uses only one bus for charging and discharging Initially, both charging and

discharging FETs are off so there is no current flow. The microcontroller of the BMS senses the voltage at the input and it turns on the charging MOSFET which again starts charging the battery. If the voltage at input pin is not present then BMS determines the load is connected and it turns on the discharging FET.

Normally two types of cell balancing are used in BMS.

- Passive cell balancing
- Active cell balancing.

In Passive cell balancing, the bypass resistors are used to discharge the excess voltage and equalize with other cells.In the active cell balancing the excess charge of one cell transferred to another cell which has a low charge to equalize them. It uses charge storing capacitors and inductors. To give you the generic idea of the working of the BMS, let's consider a simple circuit as shown below,



The image shows that a 3S BMS is connected with a 3-cell battery pack. Cells are connected in series.

- Storage Mode Voltage – 3.7V
- Full charge voltage – 4.2V

So the charging voltage for the three-cell battery pack is 12.6V.The heavy gauge wires are connected to the power supply. The small wires are used as the cell balancing wires and carry less current. A BMS has rated capacity. It measures the electric charge available and relates to the capacity.As the capacity decreases the count of the electric charge drops.

Functions of BMS

1. Safety

Due to the higher density in lithium-ion battery packs, there is an increased risk of catching fire. So as mentioned earlier, it is essential to operate batteries at rated value.A BMS does this work for you. It avoids over-charging and over-discharging of the battery pack to extend the battery life.It also offers short-circuit protection, charging and discharging over current protection, anti-reverse charging protection etc.

Modern BMS are equipped with Bluetooth and UART communications.

2. Battery Performance Optimization

For a battery to perform at its best, it must operate somewhere between the maximum and minimum rated values, i.e. current, voltage, temperature etc.As we learned earlier, a BMS helps batteries to operate within these critical rated values. In case of the battery packs, it helps in maintaining equal charging and discharging of the cells. This massively improves the performance of the battery pack. Not only performance but an efficient Battery Management System is useful in improving the life of the battery packs.

3. Health Monitoring and Diagnostics

The charge level of a battery determines the charging and discharging time. A BMS is capable of calculating and indicating the charge available in battery. A BMS checks for the oddity in the battery parameter by comparing them with rated values. Also, it is capable of taking corrective actions to increase the health of the battery.

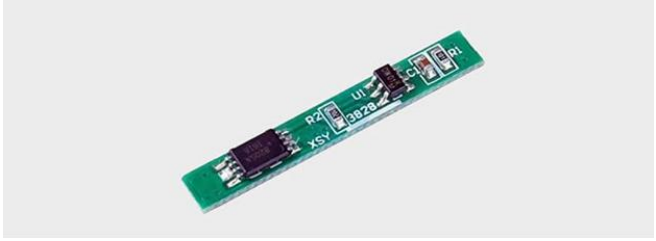
Most Popular BMS Boards

There are a variety of BMS boards available in the market. Also, with the right knowledge of this technology, you can design your own BMS. Yes, of course! It will take lots of time and efforts. Nevertheless it is viable in case of big battery packs. If you have a small lithium-ion battery pack, then we can suggest few BMS that are popular in 2021.

#1 - TP4056 Li-ion BMS

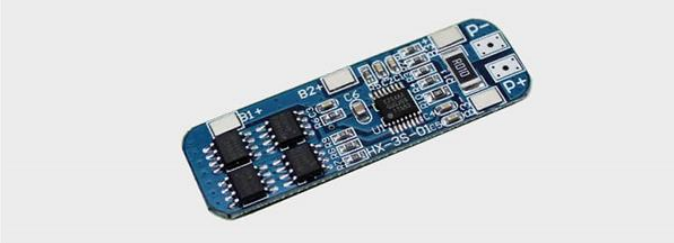
This BMS is perfect for charging a single Li-ion cell. The charge current is 1A and supplied by the TP4056 charger IC and DW01 battery protection IC. It automatically disconnects the battery from the power supply when finished.

#2 - 1S 18650 Li-ion BMS



It is one more popular BMS for single-cell lithium-ion batteries. It comes with short circuit protection, over-current protection, over-charge and over-discharge protection.

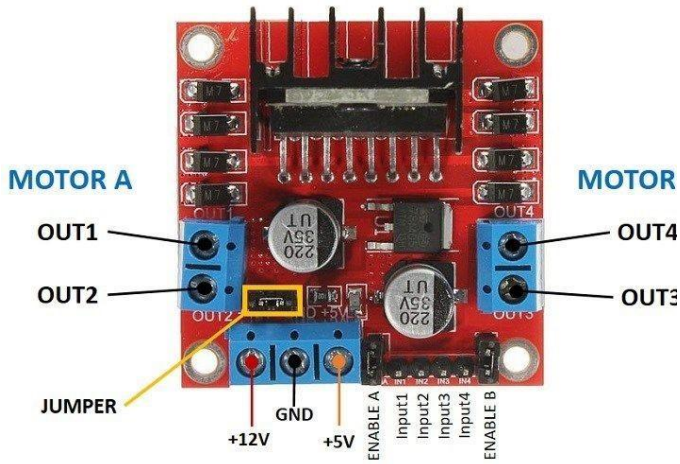
#3 - 3S 10A 18650 Li-Ion BMS



In contrast to the above BMS boards, this board is used for 3-cell li-ion battery. You can connect this BMS with a battery of 11.1V (storage mode voltage) or 12.6 (full-charge voltage). It offers over-charge and over-current protection.

C. ***Interface L298N DC Motor Driver Module***

If you are planning on assembling your new robot friend, you will eventually want to learn about controlling DC motors. One of the easiest and inexpensive way to control DC motors is to interface L298N Motor Driver with Arduino. It can control both speed and spinning direction of two DC motors. And as a bonus, it can even control a bipolar stepper motor like NEMA 17. Control Stepper Motor with L298N Motor Driver & Arduino One of the easiest and inexpensive way to control stepper motors is to interface L298N Motor Driver with Arduino. It can control both speed and...



Controlling a DC Motor

In order to have a complete control over DC motor, we have to control its speed and rotation direction. This can be achieved by combining these two techniques.

- PWM – For controlling speed
- H-Bridge – For controlling rotation direction

PWM – For controlling speed

The speed of a DC motor can be controlled by varying its input voltage. A common technique for doing this is to use PWM (Pulse Width Modulation).PWM is a technique where average value of the input voltage is adjusted by sending a series of ON-OFF pulses..The average voltage is proportional to the width of the pulses known as Duty Cycle. The higher the duty cycle, the greater the average voltage being applied to the dc motor(High Speed) and the lower the duty cycle, the less the average voltage being applied to the dc motor(Low Speed).

Below image illustrates PWM technique with various duty cycles andaverage voltages. Pulse Width Modulation(PWM) Technique

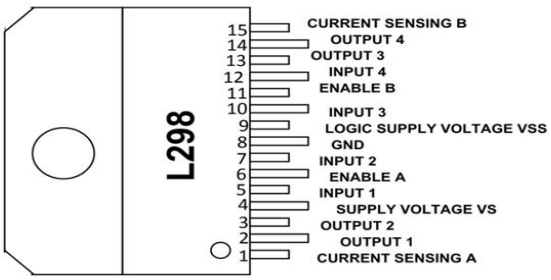
H-Bridge – For controlling rotation direction

The DC motor's spinning direction can be controlled by changing polarity of its input voltage. A common technique for doing this is to use an H-Bridge. An H-Bridge circuit contains four switches with the motor at the center forming an H-like arrangement. Closing two particular switches at the same time reverses the polarity of the voltage applied to the motor. This causes change in spinning direction of the motor.

Below animation illustrates H-Bridge circuit working.

Working of H-Bridge

L298N Motor Driver IC



At the heart of the module is the big, black chip with chunky heat sink is an L298N. The L298N is a dual-channel H-Bridge motor driver capable of driving a pair of DC motors. That means it can individually drive up to two motors making it ideal for building two-wheel robot platforms.

Power Supply

The L298N motor driver module is powered through 3-pin 3.5mm-pitch screw terminals. It consists of pins for motor power supply(Vs), ground and 5V logic power supply(Vss). The L298N motor driver IC actually has two input power pins viz. 'Vss' and 'Vs'. From Vs pin the H-Bridge gets its power for driving the motors which can be 5 to 35V. Vss is used for driving the logic circuitry which can be 5 to 7V. And they both sink to a common ground named 'GND'.

The module has an on-board 78M05 5V regulator from STMicroelectronics. It can be enabled or disabled through a jumper. When this jumper is in place, the 5V regulator is enabled, supplying logic power supply(Vss) from the motor power supply(Vs). In this case, 5V input terminal acts as an output pin and delivers 5V 0.5A. You can use it to power up the Arduino or other circuitry that requires 5V power supply.When the jumper is removed, the 5V regulator gets disabled and we have to supply 5 Volts separately through 5 Volt input terminal.

Warning:

You can put the jumper in place, if the motor power supply is below 12V. If it is greater than 12V, you should remove the jumper to avoid the onboard 5V regulator from getting damaged. Also DO NOT supply power to both the motor power supply input and 5V power supply input when jumper is in place.

Voltage Drop of L298N

The voltage drop of the L298N motor driver is about 2V. This is due to the internal voltage drop in the switching transistors in the H-Bridge circuit. So, if we connect 12V to the motor power supply terminal, the motors will receive voltage around 10V. This means that a 12V DC motor will never spin at its maximum speed. To get maximum speed out of motor, the motor power supply should be bit higher voltage(2V) than motor's actual voltage requirement. Considering the voltage drop of 2V, if you are using 5V motors you'll need to provide 7V at motor power supply terminal. If you have 12V motors then your motor supply voltage should be 14V.

Output Pins

The L298N motor driver's output channels for the motor A and B are broken out to the edge of the module with two 3.5mm-pitch screw terminals. You can connect two DC motors having voltages between 5 to 35V to these terminals. Each channel on the module can deliver up to 2A to the DC motor. However, the amount of current supplied to the motor depends on system's power supply.

Control Pins

For each of the L298N's channels, there are two types of control pins which allow us to control speed and spinning direction of the DC motors at the same time viz. Direction control pins & Speed control pins.

Direction Control Pins

Using the direction control pins, we can control whether the motor spins forward or backward. These pins actually control the switches of the H-Bridge circuit inside L298N IC.

The module has two direction control pins for each channel. The IN1 and IN2 pins control the spinning direction of the motor A while IN3 and IN4 control motor B. The spinning direction of a motor can be controlled by applying either a logic HIGH(5 Volts) or logic LOW(Ground) to these inputs. The below chart illustrates how this is done.

Input1	Input2	Spinning Direction
Low(0)	Low(0)	Motor OFF
High(1)	Low(0)	Forward
Low(0)	High(1)	Backward
High(1)	High(1)	Motor OFF

Speed Control Pins

The speed control pins viz. ENA and ENB are used to turn the motors ON, OFF and control its speed. Pulling these pins HIGH will make the motors spin, pulling it LOW will make them stop. But, with Pulse Width Modulation (PWM), we can actually control the speed of the motors.

The module usually comes with a jumper on these pins. When this jumper is in place, the motor is enabled and spins at maximum speed. If you want to control the speed of motors programmatically, you need to remove the jumpers and connect them to PWM-enabled pins on Arduino.

L298N Motor Driver Module Pinout

Before diving into hookup and example code, let's first take a look at its Pinout. VCC pin supplies power for the motor. It can be anywhere between 5 to 35V. Remember, if the 5V-EN jumper is in place, you need to supply 2 extra volts than motor's actual voltage requirement, in order to get maximum speed out of your motor.

GND is a common ground pin.

5V pin supplies power for the switching logic circuitry inside L298N IC. If the 5V-EN jumper is in place, this pin acts as an output and can be used to power up your Arduino. If the 5V-EN jumper is removed, you need to connect it to the 5V pin on Arduino. ENA pins are used to control speed of Motor A. Pulling this pin HIGH(Keeping the jumper in place) will make the Motor A spin, pulling it LOW will make the motor stop. Removing the jumper and connecting this pin to PWM input will let us control the speed of Motor A. IN1 & IN2 pins are used to control spinning direction of Motor A. When one of them is HIGH and other is LOW, the Motor A will spin. If both the inputs are either HIGH or LOW the Motor A will stop. IN3 & IN4 pins are used to control spinning direction of Motor B. When one of them is HIGH and other is LOW, the Motor B will spin. If both the inputs are either HIGH or LOW the Motor B will stop. ENB pins are used to control speed of Motor B. Pulling this pin HIGH(Keeping the jumper in place) will make the Motor B spin, pulling it LOW will make the motor stop. Removing the jumper and connecting this pin to PWM input will let us control the speed of Motor B.

OUT1 & OUT2 pins are connected to Motor A.

OUT3 & OUT4 pins are connected to Motor B.

Wiring L298N motor driver module with Arduino UNO

Now that we know everything about the module, we can begin hooking it up to our Arduino!

Start by connecting power supply to the motors. In our experiment we are using DC Gearbox Motors(also known as 'TT' motors) that are usually found in two-wheel-drive robots. They are rated for 3 to 12V. So, we will connect external 12V power supply to the VCC terminal. Considering internal voltage drop of L298N IC, the motors will receive 10V and will spin at slightly lower RPM. But, that's OK. Next, we need to supply 5 Volts for the L298N's logic circuitry. We will make use of the on-board 5V regulator and derive the 5 volts from the motor power supply so, keep the 5V-EN jumper in place. Now, the input and enable pins(ENA, IN1, IN2, IN3, IN4 and ENB) of the L298N module are connected to six Arduino digital output pins(9, 8, 7, 5, 4 and 3). Note that the Arduino output pins 9 and 3 are both PWM-enabled.Finally, connect one motor to terminal A(OUT1 & OUT2) and the other motor to terminal B(OUT3 & OUT4). You can interchange your motor's connections, technically, there is no right or wrong way.

D.DC motor

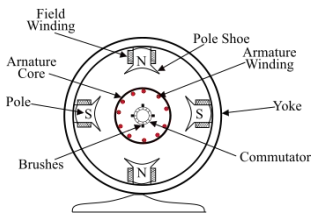
A DC motor is an electromechanical energy conversion device, which converts electrical energy input into the mechanical energy output. The operation of the DC motor is based on the principle that when a current carrying conductor is placed in a magnetic field, a mechanical force acts on the conductor. The magnitude of the force is given by,

F=BIlNewtonsF=BIlNewtons

The direction of this is given by the Fleming's left hand rule.

C. Construction of a DC Motor

Here is the schematic diagram of a DC Motor



A DC motor consists of six main parts, which are as follows

1) Yoke

The outer frame of a DC motor is a hollow cylinder made up of cast steel or rolled steel is known as yoke. The yoke serves following two purposes

- It supports the field pole core and acts as a protecting cover to the machine.
- It provides a path for the magnetic flux produced by the field winding.

2) Magnetic Field System

The magnetic field system of a DC motor is the stationary part of the machine. It produces the main magnetic flux in the motor. It consists of an even number of pole cores bolted to the yoke and field winding wound around the pole core. The field system of DC motor has salient poles i.e. the poles project inwards and each pole core has a pole shoe having a curved surface. The pole shoe serves two purposes

- It provides support to the field coils.
- It reduces the reluctance of magnetic circuit by increasing the cross-sectional area of it.

The pole cores are made of thin laminations of sheet steel which are insulated from each other to reduce the eddy current loss. The field coils are connected in series with one another such that when the current flows through the coils, alternate north and south poles are produced.

3) Armature Core

The armature core of DC motor is mounted on the shaft and rotates between the field poles. It has slots on its outer surface and the armature conductors are put in these slots. The armature core is a made up of soft steel laminations which are insulated from each other and tightly clamped together. In small machines, the laminations are keyed directly to the shaft, whereas in large machines, they are mounted on a spider. The laminated armature core is used to reduce the eddy current loss.

4) Armature Winding

The insulated conductors are put into the slots of the armature core. The conductors are suitably connected. This connected arrangement of conductors is known as armature winding. There are two types of armature windings are used – wave winding and lap winding.

5) Commutator

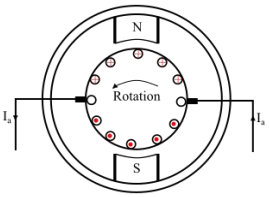
A commutator is a mechanical rectifier which converts the direct current input to the motor from the DC source into alternating current in the armature winding. The commutator is made of wedge-shaped copper segments insulated from each other and from the shaft by mica sheets. Each segment of commutator is connected to the ends of the armature coils.

6) Brushes

The brushes are mounted on the commutator and are used to inject the current from the DC source into the armature windings. The brushes are made of carbon and is supported by a metal box called brush holder. The pressure exerted by the brushes on the commutator is adjusted and maintained at constant value by means of springs. The current flows from the external DC source to the armature winding through the carbon brushes and commutator.

D. Working of DC Motor

Consider a two pole DC motor as shown in the figure. When the DC motor is connected to an external source of DC supply, the field coils are excited developing alternate N and S poles and a current flows through the armature windings.



All the armature conductors under N pole carry current in one direction (say into the plane of the paper), whereas all the conductors under S pole carry current in the opposite direction (say out of the plane of the paper). As each conductor carrying a current and is placed in a magnetic field, hence a mechanical force acts on it.

By applying Fleming's left hand rule, it can be seen that the force on each conductor is tending to move the armature in anticlockwise direction. The force on all the conductors add together to exert a torque which make the armature rotating. When the conductor moves from one side of a brush to the other, the current in the conductor is reversed and at the same time it comes under the influence of next pole of opposite polarity. As a result of this, the direction of force on the conductor remains the same. Therefore, the motor being rotating in the same direction.

D. Liquid Crystal Display (LCD)

Character LCD Display:

Character LCDs are designed for displaying characters and are commonly used in various electronic projects. The tutorial specifically mentions an HD44780-based character LCD display.

Internal Pixel Grid Structure:

The character LCD's display consists of a grid structure, and each character is made up of a 5x8 pixel matrix. The tutorial provides a visual representation of the internal pixel grid structure.

Custom Characters:

The tutorial introduces the concept of creating and displaying custom characters on the LCD. It includes a custom character generator tool for designing characters and provides examples of creating custom characters using arrays.

Hardware Overview:

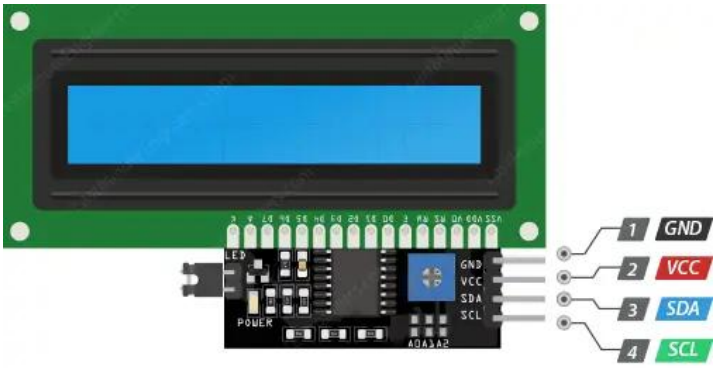
I2C LCD Adapter:

An I2C LCD display typically includes an HD44780-based character LCD and an I2C LCD adapter. The I2C adapter utilizes an 8-bit I/O expander chip, such as PCF8574, to convert I2C data from the Arduino into parallel data required for the LCD display. The adapter also features a trimpot for adjusting the display's contrast and a jumper for controlling the backlight intensity.

I2C Address Configuration:

The I2C LCD adapter allows the configuration of its I2C address to avoid conflicts with other devices on the same I2C bus. The tutorial explains the use of solder jumpers (A0, A1, and A2) for setting the I2C address based on the chip manufacturer (TI or NXP).

Working Pin Description:



I2C LCD Display Pinout:

GND (Ground): Connected to the ground pin.

VCC (Power Supply): Connected to the 5V output of the Arduino or an external 5V power supply.

SDA (I2C Data Pin): Connected to the Arduino's SDA (data line) or A4 pin.

SCL (I2C Clock Pin): Connected to the Arduino's SCL (clock line) or A5 pin.

Adjusting LCD Contrast:

The tutorial explains the process of adjusting the LCD contrast using a potentiometer on the I2C adapter.

Library Installation and Programming:

Library:

The LiquidCrystal_I2C library is used for controlling I2C displays and is installed through the Arduino IDE Library Manager.

Determining I2C Address:

The tutorial provides an I2C scanner sketch to determine the I2C address of the LCD display.

Basic Arduino Sketch:

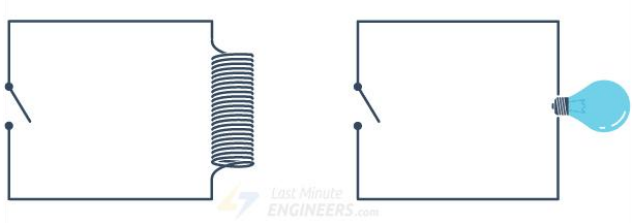
A basic Arduino sketch is provided for a "Hello World" program, demonstrating how to initialize the LCD, print messages, and use the library functions.

Custom Character Example:

An example sketch is given for displaying custom characters on the LCD, with explanations for creating and using custom characters.

E. How Do Relays Work?

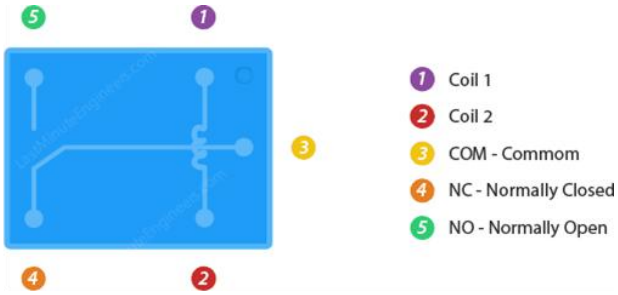
A relay is an electromagnetic switch operated by a relatively small current that can control much larger current .Here's a simple animation illustrating how the relay uses one circuit to switch on another circuit.



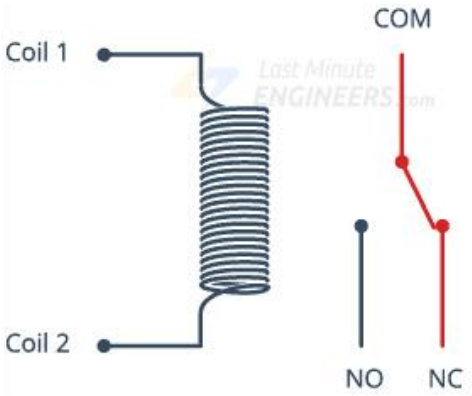
Initially the first circuit is switched off and no current flows through it until something (either a sensor or switch closing) turns it on. The second circuit is also switched off. When a small current flows through the first circuit, it activates the electromagnet, which generates a magnetic field all around it. The energized electromagnet attracts a contact in the second circuit toward it, closing the switch and allowing a much bigger current to flow through the second circuit. When the current stops flowing, the contact goes back up to its original position, switching the second circuit off again.

Relay Basics

Typically the relay has 5 pins, three of them are high voltage terminals (NC, COM, and NO) that connect to the device you want to control.



The mains electricity enters the relay at the common (COM) terminal. While use of NC & NO terminals depends upon whether you want to turn the device ON or OFF. Between the remaining two pins (coil1 and coil2), there is a coil that acts like an electromagnet.



When current flows through the coil, the electromagnet becomes charged and moves the internal contacts of the switch. At that time the normally open (NO) terminal connects to the common (COM), and the normally closed (NC) terminal becomes disconnected. When current stops flowing through the coil, the internal contact returns to its initial state i.e. the normally closed (NC) terminal connects to the common (COM), and the normally open (NO) terminal reopens.

This is known as a single pole, double throw switch (SPDT).

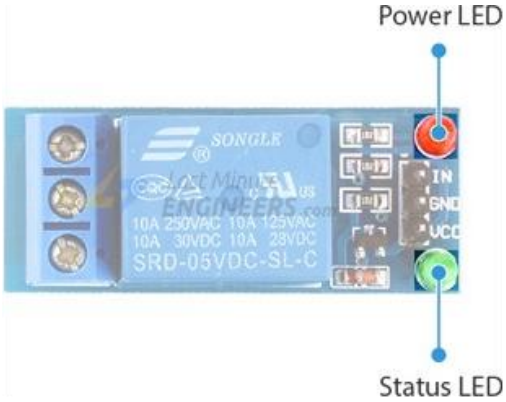
One Channel Relay Module

For this tutorial, we are going to use one channel relay module. However there are other modules with two, four and eight channels. You can choose the one that best suits your needs.

This module is designed for switching only a single high powered device from your Arduino. It has a relay rated up to 10A per channel at 250VAC or 30VDC.

LEDs

There are two LEDs on the relay module indicating the position of the relay.



The Power LED will light up when the module is powered. The Status LED will light up when the relay is activated.

Output Terminal Block

We have three channels of the relay broken out to blue screw pin terminals. The channels are labeled for their function: common (COM), normally closed (NC), and normally open (NO) The names explain the state of the channel with relation to the switch at rest.

COM (Common): This is the pin you should connect to the signal (mains electricity in our case) you are planning to switch.

NC (Normally Closed): A normally closed configuration is used when you want to turn off the relay by default. In this configuration the relay is always closed and remains closed until you send a signal from the Arduino to the relay module to open the circuit.

NO (Normally Open): A normally open configuration works the other way in which the relay is always open until you send a signal from the Arduino to the relay module to close the circuit.

Control Pins

On the other side of the module, there are three pins – a Ground pin and a VCC pin to power the module and an input pin IN to control the relay.

The input pin is active low, meaning the relay will be activated when you pull the pin LOW and it will become inactive when you pull the pin HIGH.

Control Pins:

IN pin is used to control the relay. It is an active low pin, meaning the relay will be activated when you pull the pin LOW and it will become inactive when you pull the pin HIGH.
GND is the ground connection.
VCC pin supplies power to the module.

Output Terminal:

COM pin is connected to the signal you are planning to switch. NC pin is connected to the COM pin by default, unless you send a signal from the Arduino to the relay module to break the connection. NO pin is open by default, unless you send a signal from the Arduino to the relay module to make the connection.

F. DHT11 Vs DHT22/AM2302

We have two versions of the DHTxx sensor series. They look a bit similar and have the same pinout, but have different characteristics. Here are the details:

The DHT22 is the more expensive version which obviously has better specifications. Its temperature measuring range is from -40°C to +125°C with +-0.5 degrees accuracy, while the DHT11 temperature range is from 0°C to 50°C with +-2 degrees accuracy. Also the DHT22 sensor has better humidity measuring range, from 0 to 100% with 2-5% accuracy, while the DHT11 humidity range is from 20 to 80% with 5% accuracy.

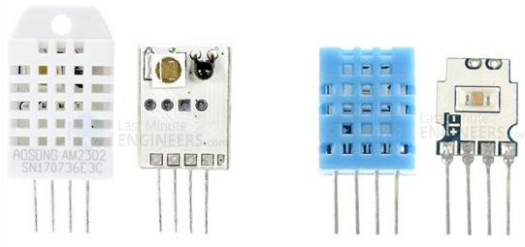
Though DHT22 is more precise, more accurate and works in a bigger range of temperature & humidity; there are three things where the DHT11 beats the hell out of DHT22. It's less expensive, smaller in size and has higher sampling rate. The sampling rate of the DHT11 is 1Hz i.e. one reading every second, while the sampling rate of DHT22 is 0.5Hz i.e. one reading every two seconds.

However, the operating voltage of both sensors is from 3 to 5 volts, while the max current used during conversion (while requesting data) is 2.5mA. And the best thing is that DHT11 and DHT22 sensors are 'swappable' – meaning, if you build your project with one you can just unplug it and use another. Your code may have to adjust a little but at least the wiring is the same!

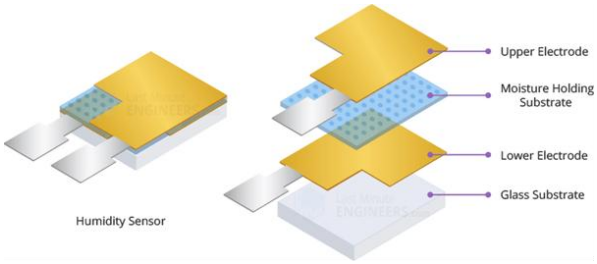
Hardware Overview

Now let's move on to the interesting stuff. Let's teardown both the DHT11 and DHT22 sensors and see what's inside. The casing is in two parts so to get inside it is just a matter of getting a sharp knife and splitting the case apart. Inside the case, on the sensing side, there is a humidity sensing

component along with a NTC temperature sensor (or thermistor)

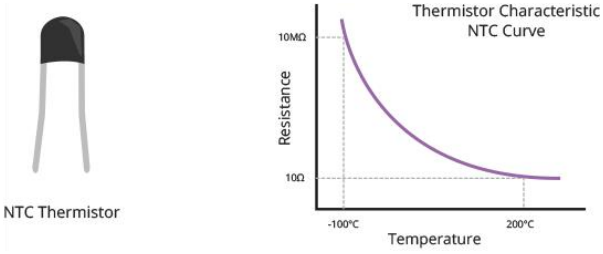


Humidity sensing component is used, of course to measure humidity, which has two electrodes with moisture holding substrate (usually a salt or conductive plastic polymer) sandwiched between them. The ions are released by the substrate as water vapor is absorbed by it, which in turn increases the conductivity between the electrodes. The change in resistance between the two electrodes is proportional to the relative humidity. Higher relative humidity decreases the resistance between the electrodes, while lower relative humidity increases the resistance between the electrodes.



Internal Structure of Humidity Sensor

Besides,they consist of a NTC temperature sensor/Thermistor to measure temperature. A thermistor is a thermal resistor – a resistor that changes its resistance with temperature. Technically, all resistors are thermistors – their resistance changes slightly with temperature – but the change is usually very very small and difficult to measure. Thermistors are made so that the resistance changes drastically with temperature so that it can be 100 ohms or more of change per degree! The term "NTC" means "Negative Temperature Coefficient", which means that the resistance decreases with increase of the temperature.

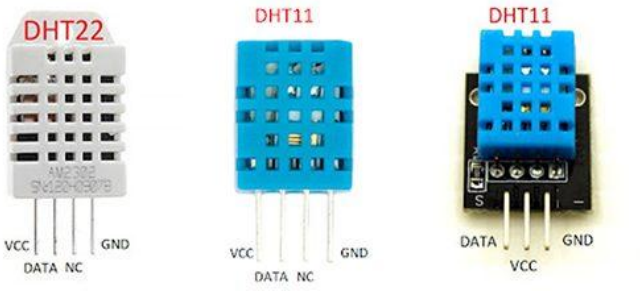


NTC Thermistor with Characteristic Curve

On the other side, there is a small PCB with an 8-bit SOIC-14 packaged IC. This IC measures and processes the analog signal with stored calibration coefficients, does analog to digital conversion and spits out a digital signal with the temperature and humidity.

DHT11 and DHT22 Pinout

The DHT11 and DHT22 sensors are fairly easy to connect. They have four pins:



VCC pin supplies power for the sensor. Although supply voltage ranges from 3.3V to 5.5V, 5V supply is recommended. In case of 5V power supply, you can keep the sensor as long as 20 meters. However, with 3.3V supply voltage, cable length shall not be greater than 1 meter. Otherwise, the line voltage drop will lead to errors in measurement.When you hear the term 'smart garden', one of the things that comes to your mind is a system that measures soil moisture and irrigates your plants automatically. With this type of system, you can water your plants only when needed and avoid over-watering or under-watering.

G. IR SENSOR

IR technology is used in daily life and also in industries for different purposes. For example, TVs use an IR sensor to understand the signals which are transmitted from a remote control. The main benefits of IR sensors are low power usage, their simple design & their convenient features. IR signals are not noticeable by the human eye. The IR radiation in the electromagnetic spectrum can be found in the regions of the visible & microwave. Usually, the wavelengths of these waves range from 0.7 µm 5 to 1000µm. The IR spectrum can be divided into three regions like near-infrared, mid, and far-infrared. The near IR region's wavelength ranges from 0.75 – 3µm, the mid-infrared region's wavelength ranges from 3 to 6µm & the far IR region's infrared radiation's wavelength is higher than 6µm.

What is an IR Sensor/Infrared Sensor?

An infrared sensor is an electronic device that emits in order to sense some aspects of the surroundings. An IR sensor can measure the heat of an object as well as detecting the motion. These types of sensors measure only infrared radiation, rather than emitting it that is called a passive IR sensor. Usually, in the infrared spectrum, all the objects radiate some form of thermal radiation.

Infrared Sensor

These types of radiation are invisible to our eyes, which can be detected by an infrared sensor. The emitter is simply an IR LED (Light Emitting Diode) and the detector is simply an IR photodiode that is sensitive to IR light of the same wavelength as that emitted by the IR LED. When IR light falls on the photodiode, the resistances and the output voltages will change in proportion to the magnitude of the IR light received.

Working Principle

The working principle of an infrared sensor is similar to the object detection sensor. This sensor includes an IR LED & an IR Photodiode, so by combining these two can be formed as a photo-coupler otherwise optocoupler. The physics laws used in this sensor are planks radiation, Stephan Boltzmann & weins displacement. IR LED is one kind of transmitter that emits IR radiation. This LED looks similar to a standard LED and the radiation which is generated by this is not visible to the human eye. Infrared receivers mainly detect the radiation using an infrared transmitter. These infrared receivers are available in photodiodes form. IR Photodiodes are dissimilar as compared with usual photodiodes because they detect simply IR radiation. Different kinds of infrared receivers mainly exist depending on the voltage, wavelength, package, etc. Once it is used as the combination of an IR transmitter & receiver, then the receiver's wavelength must equal the transmitter. Here, the transmitter is IR LED whereas the receiver is IR photodiode. The infrared photodiode is responsive to the infrared light that is generated through an infrared LED. The resistance of photodiode & the change in output voltage is in proportion to the infrared light obtained. This is the IR sensor's fundamental working principle. Once the infrared transmitter generates emission, then it arrives at the object & some of the emission will reflect toward the infrared receiver. The sensor output can be decided by the IR receiver depending on the intensity of the response.

Types of Infrared Sensor

Infrared sensors are classified into two types like active IR sensor and passive IR sensor.

Active IR Sensor

This active infrared sensor includes both the transmitter as well as the receiver. In most of the applications, the light-emitting diode is used as a source. LED is used as a non-imaging infrared sensor whereas the laser diode is used as an imaging infrared sensor. These sensors work through energy radiation, received & detected through radiation. Further, it can be processed by using the signal processor to fetch the necessary information. The best examples of this active infrared sensor are reflectance and break beam sensor.

Passive IR Sensor

The passive infrared sensor includes detectors only but they don't include a transmitter. These sensors use an object like a transmitter or IR source. This object emits energy and detects through infrared receivers. After that, a signal processor is used to understand the signal to obtain the required information. The best examples of this sensor are pyroelectric detector, bolometer, thermocouple-thermopile, etc. These sensors are classified into two types like thermal IR sensor and quantum IR sensor. The thermal IR sensor doesn't depend on wavelength. The energy source used by these sensors is heated. Thermal detectors are slow with their response and detection time. The quantum IR sensor depends on the wavelength and these sensors include high response and detection time. These sensors need regular cooling for specific measurements.

IR Sensor Circuit Diagram

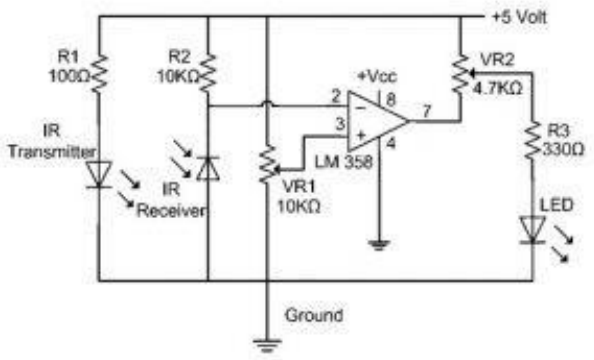
An infrared sensor circuit is one of the basic and popular sensor modules in an electronic device. This sensor is analogous to human's visionary senses, which can be used to detect obstacles and it is one of the common applications in real-time. This circuit comprises the following components

LM358 IC 2 IR transmitter and receiver pair

Resistors of the range of kilo-ohms.

Variable resistors.

LED (Light Emitting Diode).



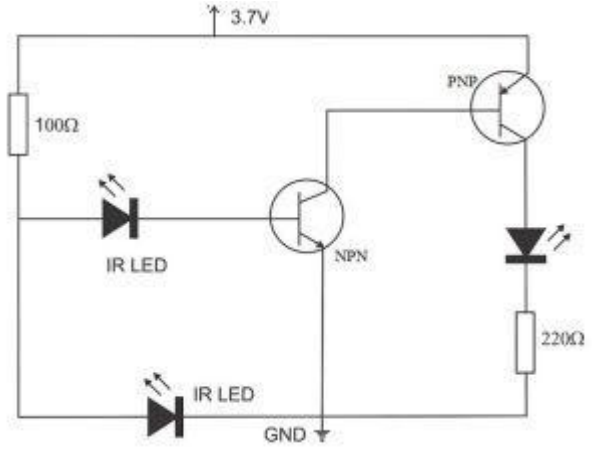
Infrared Sensor Circuit Diagram

In this project, the transmitter section includes an IR sensor, which transmits continuous IR rays to be received by an IR

receiver module. An IR output terminal of the receiver varies depending upon its receiving of IR rays. Since this variation cannot be analyzed as such, therefore this output can be fed to a comparator circuit. Here an operational amplifier (op-amp) of LM 339 is used as a comparator circuit. When the IR receiver does not receive a signal, the potential at the inverting input goes higher than that non-inverting input of the comparator IC (LM339). Thus the output of the comparator goes low, but the LED does not glow. When the IR receiver module receives a signal to the potential at the inverting input goes low. Thus the output of the comparator (LM 339) goes high and the LED starts glowing. Resistor R1 (100), R2 (10k), and R3 (330) are used to ensure that a minimum of 10 mA current passes through the IR LED Devices like Photodiode and normal LEDs respectively. Resistor VR2 (preset=5k) is used to adjust the output terminals. Resistor VR1 (preset=10k) is used to set the sensitivity of the circuit Diagram. Read more about IR sensors.

IR Sensor Circuit using Transistor

The circuit diagram of the IR sensor using transistors namely obstacle detection using two transistors is shown below. This circuit is mainly used for obstacle detection using an IR LED. So, this circuit can be built with two transistors like NPN and PNP. For NPN, BC547 transistor is used whereas, for PNP, BC557 transistor is used. The pinout of these transistors is the same.



Infrared Sensor Circuit using Transistors

In the above circuit, one infrared LED is always switched on whereas the other infrared LED is allied to the PNP transistor's base terminal because this IR LED acts as the detector. The required components of this IR sensor circuit include resistors 100 ohms & 200 ohms, BC547 & BC557 transistors, LED, IR LEDs-2. The step by step procedure of **how to make the IR sensor circuit** includes the following steps.

Connect the components as per the circuit diagram using required components

Connect one infrared LED to the BC547 transistor's base terminal

Connect an infrared LED to the base terminal of the same transistor.

Connect the 100Ω resistor toward the residual pins of the infrared LEDs.

Connect the base terminal of the PNP transistor toward the collector terminal of the NPN transistor.

Connect the LED & 220Ω resistor as per the connection in the circuit diagram.

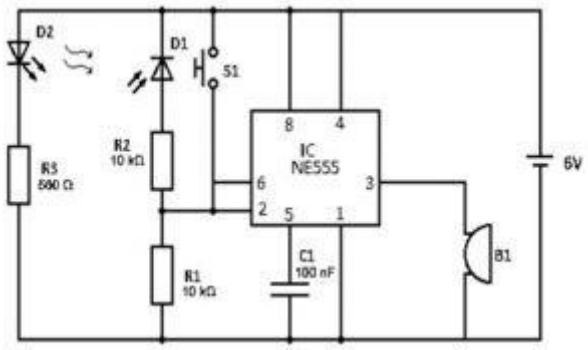
Once the connection of the circuit is done then gives the power supply to the circuit for testing.

Circuit Working

Once the infrared LED is detected, then the reflected light from the thing will activate a small current that will supply throughout the IR LED detector. This will activate the NPN transistor & the PNP; therefore the LED will switch ON. This circuit is applicable for making different projects like automatic lamps to activate once a person approaches close to the light.

Burglar Alarm Circuit using IR Sensor

This IR burglar alarm circuit is used at entries, doors, etc. This circuit gives a buzzer sound to alert the concerned person whenever someone crosses throughout the IR ray. When the IR rays are not visible to humans, then this circuit works as a hidden safety device.



Burglar Alarm Circuit using IR Sensor

The required components of this circuit mainly includes NE555IC, resistors R1 & R2 = 10k & 560, D1 (IR photodiode), D2 (IR LED), C1 Capacitor (100nF), S1 (push switch), B1 (Buzzer) & 6v DC Supply.
This circuit can be connected by arranging the infrared LED as well as the infrared sensors on the door opposite each other. So that IR ray can fall on the sensor properly. Under normal conditions, the infrared ray drops always over the infrared diode & the output condition at pin-3 will stay in the low condition.

This ray will be interrupted once a solid object crosses the ray. When the IR ray smashes, the circuit will activate & the output turns to ON condition. The output condition remains till it retunes by shutting the switch that means, when the interrupt of the ray is detached then an alarm remains ON.

To avoid others from deactivating the alarm, the circuit or reset switch must be located distant or out of sight from the infrared sensor. In this circuit, a 'B1' buzzer is connected to produce sound with an inbuilt sound and this inbuilt sound can be replaced with an alternative bells otherwise loud siren based on the requirement.

Advantages

- The **advantages of IR sensor** include the following
- It uses less power
- The detection of motion is possible in the presence or absence of light approximately with equal reliability.
- They do not need contact with the object for detection
- There is no data leakage because of the ray direction
- These sensors are not affected by oxidation & corrosion
- Noise immunity is very strong

Disadvantages

- The **disadvantages of IR sensor** include the following
- Line of sight is required
- Range is limited
- These can be affected by fog, rain, dust, etc
- Less data transmission rate

IR Sensor Applications

IR sensors are classified into different types depending on the applications. Some of the typical applications of different types of sensors. The speed sensor is used for synchronizing the speed of multiple motors. The temperature sensor is used for industrial temperature control. PIR sensor is used for an automatic door opening system and the Ultrasonic sensor is used for distance measurement. IR sensors are used in various Sensor based projects and also in various electronic devices which measure the temperature that is discussed below.

Radiation Thermometers

IR sensors are used in radiation thermometers to measure the temperature depend upon the temperature and the material of the object and these thermometers have some of the following features.

Measurement without direct contact with the object

Faster response

Easy pattern measurements

Flame Monitors

These types of devices are used for detecting the light emitted from the flames and to monitor how the flames are burning. The Light emitted from flames extend from UV to IR region types. PBS, PbSe, Two-color detector, pyroelectric detector are some of the commonly employed detectors used in flame monitors.

Moisture Analyzers

Moisture analyzers use wavelengths that are absorbed by the moisture in the IR region. Objects are irradiated with light having these wavelengths(1.1 μm, 1.4 μm, 1.9 μm, and 2.7μm) and also with reference wavelengths. The Lights reflected from the objects depend upon the moisture content and are detected by the analyzer to measure moisture (ratio of reflected light at these wavelengths to the reflected light at reference wavelength). In GaAs PIN photodiodes, Pbs photoconductive detectors are employed in moisture analyzer circuits.

Gas Analyzers

IR sensors are used in gas analyzers that use the absorption characteristics of gases in the IR region. Two types of methods are used to measure the density of gas such as dispersive and nondispersive.

Dispersive: An Emitted light is spectroscopically divided and their absorption characteristics are used to analyze the gas ingredients and the sample quantity.

Nondispersive: It is the most commonly used method and it uses absorption characteristics without dividing the emitted light. Nondispersive types use discrete optical bandpass filters, similar to sunglasses that are used for eye protection to filter out unwanted UV radiation.

This type of configuration is commonly referred to as nondispersive infrared (NDIR) technology. This type of analyzer is used for carbonated drinks, whereas a nondispersive analyzer is used in most of the commercial IR instruments, for automobile exhaust gas fuel leakages.

IR Imaging Devices

IR image device is one of the major applications of IR waves, primarily by virtue of its property that is not visible. It is used for thermal imagers, night vision devices, etc.

For example, Water, rocks, soil, vegetation, and atmosphere, and human tissue all feature emit IR radiation. The Thermal infrared detectors measure these radiations in the IR range and map the spatial temperature distributions of the object/area on an image. Thermal imagers are usually composed of an Sb (indium antimonite), Gd Hg (mercury-doped germanium), Hg Cd Te (mercury-cadmium-telluride) sensors.

An electronic detector is cooled to low temperatures using liquid helium or liquid nitrogen. Then the Cooling the detectors ensure that the radiant energy (photons) recorded by the detectors comes from the terrain and not from the

ambient temperature of objects within the scanner itself and IR imaging electronic devices.

The key applications of the infrared sensors mainly include the following.

Meteorology

Climatology

Photo-bio modulation

Analysis of Water

Gas detectors

Testing of Anesthesiology

Exploration of Petroleum

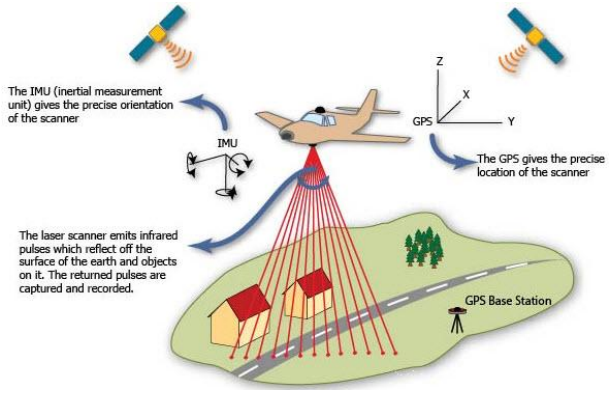
Safety of Rail

G. How Does LIDAR Work?

The working principle of Light Detection and Ranging system is really quite simple. A LIDAR sensor mounted on an aircraft or helicopter. It generates Laser pulse train, which sent to the surface/target to measure the time and it takes to return to its source. The actual calculation for measuring how far a returning light photon has traveled to and from an object is calculated by

Distance = (Speed of Light x Time of Flight) / 2

Accurate distances are then calculated to the points on the ground and elevations can be determined along with the ground surface buildings, roads, and vegetation can be recorded. These elevations are combined with digital aerial photography to produce a digital elevation model of the earth.



The laser instrument fires rapid pulses of laser light at a surface, some at up to 150,000 pulses per second. A sensor on the instrument measures the amount of time takes for each pulse to reflect back. Light moves at a constant and known speed so the LIDAR instrument can calculate the distance between itself and the target with high accuracy. By repeating this in quick progression the instrument builds up a complex 'map' of the surface it is measuring.With **airborne Light Detection and Ranging**, other data must be collected to ensure accuracy. As the sensor is moving height, location and orientation of the instrument must be included to determine the position of the laser pulse at the time of sending and the time of return. This extra information is crucial to the data's integrity. With **ground-based Light Detection and Ranging** a single GPS location can be added at each location where the instrument is set up.

LIDAR System Types

Based on the Platform

Ground-based LIDAR
Airborne LIDAR
Spaceborne LIDAR

TF-Luna is a single-point ranging LiDAR, based on the TOF principle. With unique optical and electrical design, it can achieve **stable, accurate, and highly sensitive range measurement**. The product is built with algorithms adapted to various application environments and adopts multiple adjustable configurations and parameters so as to offer excellent distance measurement performances in complex application fields and scenarios.

The TF Luna is suitable for its technical specifications and its ultra-compact size perfect for identification applications of all kinds. This includes, for example, **level measurements, lift systems, or applications in intrusion detection**. Due to its easy installation and integration, you can use the LiDAR from Benewake also used in numerous other projects.

Product Characteristics

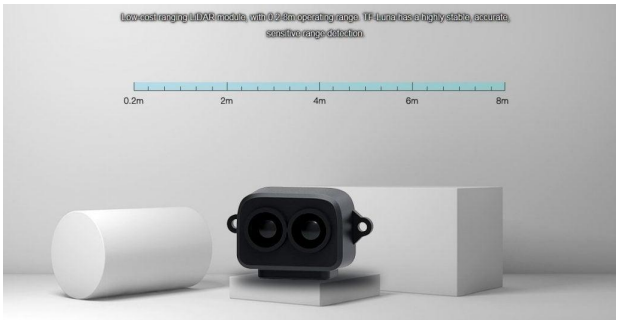
The product is built with algorithms adapted to various application environments and adopts multiple adjustable configurations and parameters so as to offer excellent distance measurement performances in complex application fields and scenarios.

Extreme Cost Performance

Low-cost ranging LiDAR module, with 0.2-8m operating range. TF-Luna has a highly stable, accurate, sensitive range detection.

Slim Figure Yet Big Skill

The product is built with algorithms adapted to various application environments and adopts multiple adjustable configurations and parameters so as to offer excellent distance measurement performances in complex application fields and scenarios. The TF-Luna adopts serial communication protocol so that it can connect to any control board supporting serial port communication like Arduino, Raspberry Pi, etc.



Features:

1. The range is up to 8 meters
2. Low power consumption
3. Wide range of temperature adaptation and voltage input.
4. It has high accuracy and frequency.
5. Small size
6. Lightweight

Applications:

7. Auxiliary focus
8. Elevator projection
9. Intrusion detection
10. Level measurement
11. UAV/UAS Robots

H.Solar panel working

1. Photovoltaic Effect:

Solar panels operate on the principle of the photovoltaic effect, where certain materials generate an electric current when exposed to sunlight.

The most common material used is silicon, which releases electrons when photons (light particles) strike its surface.

2. Components of a Solar Panel:

Solar Cells: Individual units within a solar panel that generate electricity. They are typically made of semiconductor materials like crystalline silicon.

Frame: Provides structural support and protection for the solar cells.

Glass Cover: Protects the solar cells from environmental factors while allowing sunlight to pass through.

Backsheet: The back layer that shields the solar cells from moisture and enhances the overall durability of the panel.

Working Principle:

1. Sunlight Absorption:

Solar panels are positioned to capture sunlight, which contains photons. Photons with sufficient energy strike the semiconductor material (usually silicon) in the solar cells.

2. Electron Excitation:

When photons hit the semiconductor, they transfer their energy to electrons in the material. This energy excites the electrons, causing them to move, creating an electric current.

3. Generation of Direct Current (DC):

The movement of electrons generates direct current (DC) electricity within the solar cells.

4. Inverter Conversion:

Solar panels produce DC electricity, but most household appliances and the grid use alternating current (AC). An inverter is used to convert DC electricity into AC electricity, making it compatible with standard electrical systems.

5. Power Distribution:

The generated AC electricity can be used immediately to power devices or fed into the electrical grid for distribution.

Types of Solar Panels:

1. Monocrystalline Solar Panels:

Made from a single crystal structure, typically silicon. High efficiency and a sleek black appearance. More expensive to manufacture.

2. Polycrystalline Solar Panels:

Composed of multiple silicon crystals. Slightly less efficient than monocrystalline panels. More cost-effective to produce.

3. Thin-Film Solar Panels:

Made from thin layers of semiconductor materials like amorphous silicon, cadmium telluride, or copper indium gallium selenide (CIGS). Flexible, lightweight, and suitable for certain applications. Generally less efficient than crystalline panels.

Key Considerations:

1. Efficiency:

The efficiency of a solar panel refers to its ability to convert sunlight into electricity. Higher efficiency panels are generally more expensive but can generate more power in limited space.

2. Location and Orientation:

Solar panels are most effective when exposed to direct sunlight. Proper orientation and tilt maximize sunlight exposure, with south-facing angles often recommended in the northern hemisphere.

3. Maintenance:

Solar panels require minimal maintenance, mainly cleaning to remove dirt and debris that may reduce efficiency. Regular inspections ensure optimal performance.

4. Lifespan:

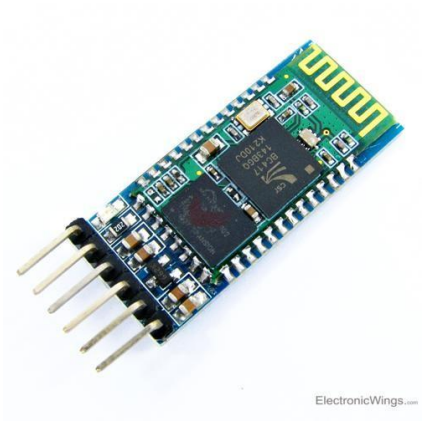
Solar panels have a long lifespan, typically around 25-30 years or more. Manufacturers often provide warranties for durability and performance.

5. Environmental Impact:

Solar energy is a clean and renewable resource, producing no greenhouse gas emissions during operation. Consideration of the environmental impact includes manufacturing processes and end-of-life disposal.

I .HC-05 BLUETOOTH MODULE

- HC-05 is a Bluetooth module which is designed for wireless communication. This module can be used in a master or slave configuration.



HC-05 Bluetooth Module

HC-05 BLUETOOTH MODULE PIN DIAGRAM

HC-05 Bluetooth Module Pin Diagram

Bluetooth serial modules allow all serial enabled devices to communicate with each other using Bluetooth.

It has 6 pins,

1. **Key/EN:** It is used to bring Bluetooth module in AT commands mode. If Key/EN pin is set to high, then this module will work in command mode. Otherwise by default it is in data mode. The default baud rate of HC-05 in command mode is 38400bps and 9600 in data mode.

HC-05 module has two modes,

1. **Data mode:** Exchange of data between devices.
2. **Command mode:** It uses AT commands which are used to change setting of HC-05. To send these commands to module serial (USART) port is used.

2. **VCC:** Connect 5 V or 3.3 V to this Pin.

3. **GND:** Ground Pin of module.

4. **TXD:** Transmit Serial data (wirelessly received data by Bluetooth module transmitted out serially on TXD pin)

5. **RXD:** Receive data serially (received data will be transmitted wirelessly by Bluetooth module).

6. **State:** It tells whether module is connected or not.

HC-05 module Information

- HC-05 has **red LED** which indicates **connection status**, whether the Bluetooth is connected or not.

Before connecting to HC-05 module this red LED blinks continuously in a periodic manner. When it gets connected to any other Bluetooth device, its blinking slows down to two seconds.

- This module **works on 3.3V**. We can connect 5V supply voltage as well since the module has on board 5 to 3.3 V regulator.
- As HC-05 Bluetooth module has **3.3V level for RX/TX** and microcontroller can detect 3.3 V level, so, no need to shift transmit level of HC-05 module. But we need to shift the transmit voltage level from microcontroller to RX of HC-05 module.
- The data transfer rate of HC-05 module can vary up to **1Mbps** is in the **range of 10 meters**.

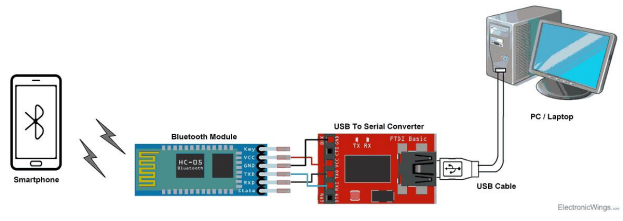
Specification of HC-05 Bluetooth Module

- Bluetooth version: 2.0 + EDR (Enhanced Data Rate)
- Frequency: 2.4 GHz ISM band
- Modulation: GFSK (Gaussian Frequency Shift Keying)
- Transmit power: Class 2 (up to 4 dBm)
- Sensitivity: -80 dBm typical
- Range: approximately 10 meters (or 33 feet) in open air
- Profiles supported: SPP (Serial Port Profile), HID (Human Interface Device) and others
- Operating voltage: 3.3V to 5V DC
- Operating current: less than 50mA
- Standby current: less than 2.5mA
- Sleep current: less than 1mA
- Interface: UART (Universal Asynchronous Receiver/Transmitter)
- Baud rates: 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200, 230400, and 460800
- Operating temperature: -20°C to 75°C (-4°F to 167°F)

Bluetooth communication between Devices

E.g. Send data from Smartphone terminal to HC-05 Bluetooth module and see this data on PC serial terminal and vice versa.

To communicate smartphone with HC-05 Bluetooth module, smartphone requires Bluetooth terminal application for transmitting and receiving data. You can find Bluetooth terminal applications for android and windows in respective app. store.



Bluetooth Module Serial Interface

So, when we want to communicate through smartphone with HC-05 Bluetooth module, connect this HC-05 module to the PC via serial to USB converter.

Before establishing communication between two Bluetooth devices, 1st we need to pair HC-05 module to smartphone for communication.

Pair HC-05 and smartphone:

1. Search for new Bluetooth device from your phone. You will find Bluetooth device with "HC-05" name.
2. Click on connect/pair device option; default pin for HC-05 is 1234 or 0000.

After pairing two Bluetooth devices, open terminal software (e.g. Teraterm, Realterm etc.) in PC, and select the port where we have connected USB to serial module. Also select default baud rate of 9600 bps.

In smart phone, open Bluetooth terminal application and connect to paired device HC-05.

It is simple to communicate, we just have to type in the Bluetooth terminal application of smartphone. Characters will get sent wirelessly to Bluetooth module HC-05. HC-05 will automatically transmit it serially to the PC, which will appear on terminal. Same way we can send data from PC to smartphone.

Command Mode

- When we want to change settings of HC-05 Bluetooth module like change password for connection, baud rate, Bluetooth device's name etc.
- To do this, HC-05 has AT commands.
- To use HC-05 Bluetooth module in AT command mode, connect "Key" pin to High (VCC).
- Default Baud rate of HC-05 in command mode is 38400bps.
- Following are some AT command generally used to change setting of Bluetooth module.
- To send these commands, we have to connect HC-05 Bluetooth module to the PC via serial to USB converter and transmit these command through serial terminal of PC.

Alternate options for HC-05 Bluetooth Module

3. **HC-06 Bluetooth module**: This is a similar module to the HC-05, but it is limited to a slave role only. It has a smaller form factor and is generally cheaper than the HC-05. However, it does not support some of the advanced features of the HC-05, such as the ability to enter AT mode to configure the module.
4. **HM-10 Bluetooth module**: This is a more advanced Bluetooth module that supports Bluetooth 4.0 (BLE) and can act as both a master and slave device. It also supports a wider range of AT commands for configuring the module, and has a longer range than the HC-05. However, it is generally more expensive than the HC-05.
5. **RN-42 Bluetooth module**: This is another Bluetooth module that supports both the SPP and

HID profiles, similar to the HC-05. It has a longer range than the HC-05 and supports faster data rates. However, it is also more expensive and may require additional configuration to work properly.

6. **ESP32 Bluetooth module**: This is a powerful Wi-Fi and Bluetooth module that includes a dual-core processor and support for both Bluetooth Classic and BLE. It is more expensive than the HC-05, but offers more advanced features and capabilities.
7. **nRF24L01+ Wireless module**: This is a wireless module that operates at 2.4GHz and uses a different protocol than Bluetooth. It is generally cheaper than Bluetooth modules and can be used for applications where a shorter range and lower data rate are acceptable.

VII. CONCLUSION AND FUTURE SCOPE

In this paper, an eco-friendly solution for lawn mowing is proposed. Based on observations, it can be concluded that the system is more efficient compared to earlier designs as it eliminates the need for manpower and is pollution-free. The system works very well on flat surface lawns. However, in the case of uneven surfaces, the obstacle detection stage may fail to detect objects near the system.The ability to cut grass in uneven surfaces , with the help of image processing and open C.V training the robot to cut the grass in desired shape.

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