MAHARASHTRASTATEBOARDOFTECHNICALEDUCATION

PROJECTREPORTON

"Smart Robot Vaccum Cleaner"

UNDERTHECOURSE

"CAPSTONEPROJECT-EXECUTION&REPORTWRITING"

SUBMITTEDBY

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Submittedinpartialfulfilmentoftherequirementfortheawardof

DiplomaofEngineeringIn

ELECTRONICSANDCOMMUNICATIONENGINEERING

UnderTheGuidance

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CERTIFICATE

This is to certify that the following students of Diploma in Electronics and Communication Engineering, have completed the project of final year having title **"Smart Robot Vaccum Cleaner"** during theacademicyear2022–23.Theprojectcompletedbyundertheguidanceofthefacultyguide.

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CHAPTER-1

ABSTRACT

This project focuses on the development of a motor control system utilizing an ATmega328 microcontroller, an L293D motor driver, and an HC-05 Bluetooth module. The objective is to enable remote control of two DC motors for movement and an additional motor for a vacuum cleaner application via commands sent from an Android application. The system allows users to control the movement of the motors by sending commands such as forward, backward, left, right, and stop from the Android app. The ATmega328 microcontroller interprets these commands received via Bluetooth and activates the appropriate motor control signals using the L293D motor driver. The Android app establishes a Bluetooth connection with the HC-05 module, providing a user-friendly interface for sending motor control commands wirelessly. Through proper hardware integration, firmware development, and software interface design, this project aims to create a versatile and accessible platform for remote motor control applications, with potential implementations in robotics, home automation, and other fields requiring mobile motor control solutions.

METHODOLOGY

1. **Requirement Analysis**:
   - Identify the specific requirements and functionalities of the motor control system, including the types of motors to be controlled, supported commands, and communication protocol with the Android app.

2. **Hardware Setup**:
   - Gather the necessary hardware components, including the ATmega328 microcontroller, L293D motor driver, DC motors, HC-05 Bluetooth module, and associated peripherals.
   - Design the hardware layout and connections, ensuring proper wiring between the microcontroller, motor driver, motors, and Bluetooth module.

3. **Firmware Development**:
   - Set up the development environment (e.g., Arduino IDE) for programming the ATmega328 microcontroller.
   - Write firmware code to initialize serial communication with the HC-05 module and define the motor control logic based on received commands.
   - Implement functions to interpret incoming commands from the Android app and generate corresponding motor control signals.

4. **Android App Development**:
   - Set up the development environment (e.g., Android Studio) for creating the Android application.
   - Develop the user interface (UI) for the app, including buttons or other controls for sending motor control commands.
   - Implement Bluetooth communication functionality to establish a connection with the HC-05 module and send commands to the microcontroller.

5. **Integration**:
   - Connect the hardware components according to the designed layout, ensuring proper power supply and signal connections.
   - Integrate the firmware developed for the ATmega328 microcontroller with the hardware setup.
   - Test the communication between the Android app and the motor control system to ensure proper data exchange.

6. **Testing and Debugging**:
   - Conduct thorough testing of the complete system, including individual hardware components and software modules.
   - Verify the functionality of motor control commands sent from the Android app and the corresponding response of the motors.
   - Debug any issues encountered during testing, such as communication errors or unexpected motor behavior.

7. **Optimization and Refinement**:
   - Identify areas for optimization, such as improving code efficiency or enhancing user experience in the Android app.
   - Refine the system based on feedback from testing, ensuring reliability, responsiveness, and ease of use.

8. **Documentation and Deployment**:
   - Document the hardware setup, firmware code, and Android app functionality for future reference.
   - Prepare user manuals or guides for operating the motor control system.
   - Deploy the system for practical use, ensuring proper installation and setup in the intended environment.

9. **Maintenance and Support**:
   - Provide ongoing maintenance and support for the motor control system, addressing any issues or updates as needed.
   - Gather feedback from users to identify potential enhancements or new features for future iterations of the system.

By following this methodology, you can systematically develop and deploy a motor control system capable of remote operation via an Android app, meeting the specified requirements and ensuring reliability and usability in practical applications.

PROBLEM STATEMENT

The objective of this project is to design and implement a motor control system capable of remote operation via an Android application. The system should allow users to control the movement of two DC motors and an additional motor for a vacuum cleaner application using commands sent wirelessly from the Android app. The specific tasks include:

1. Designing the hardware setup, including connecting the DC motors to the L293D motor driver and interfacing it with an ATmega328 microcontroller, along with integrating an HC-05 Bluetooth module for wireless communication.

2. Developing firmware for the ATmega328 microcontroller to interpret commands received via Bluetooth from the Android app and control the motors accordingly. This includes logic for forward, backward, left, right, and stop commands.

3. Creating an Android application with Bluetooth capabilities to establish a connection with the HC-05 module and provide a user-friendly interface for sending motor control commands.

4. Integrating the hardware and software components to ensure seamless communication between the Android app and the motor control system, allowing users to remotely control the movement of the motors.

5. Testing the complete system to verify its functionality, reliability, and usability. This includes testing for correct motor response to commands, robust Bluetooth communication, and overall system stability.

The successful completion of this project will result in a versatile motor control system that can be operated remotely from an Android device, with potential applications in robotics, home automation, and other fields requiring mobile motor control solutions.

1. **Hardware Setup:**

- Connect the two DC motors to the L293D motor driver. Ensure proper connections for motor direction control (forward, backward) and motor speed control.
- Connect the L293D motor driver to the ATmega328 microcontroller. Pin 8, 9, 10, and 11 are commonly used for controlling the motor driver inputs (IN1, IN2, IN3, IN4).
- Connect the HC-05 Bluetooth module to the ATmega328 microcontroller. You'll need to connect it to appropriate UART pins (typically TX and RX).

2. **ATmega328 Programming**:
- Write a program in C/C++ using the Arduino IDE or another suitable development environment.
- Initialize serial communication to communicate with the HC-05 module.
- Set up pin modes for motor control pins (8, 9, 10, 11).
- Implement a function to interpret commands received from the Android app through Bluetooth. Based on the received commands (F, B, R, L, S), control the direction and speed of the motors by setting appropriate pins high or low.

3. **Android App Development**:
- Develop an Android app using a platform like Android Studio.
- Implement Bluetooth communication using the HC-05 module. The app should be able to establish a connection with the HC-05 module and send commands based on user input.
- Create a user interface that allows users to send commands to control the motors (forward, backward, left, right, stop).

4. **Integration and Testing:**
- Upload the firmware to the ATmega328 microcontroller.
- Pair the Android device with the HC-05 module.
- Test the system by sending commands from the Android app and verifying that the motors respond accordingly.
- Debug any issues and refine the system as needed.

5. **Safety Considerations**:
- Ensure proper power management to avoid damage to the motors, motor driver,

and microcontroller.

- Implement safety mechanisms to prevent the motors from running uncontrollably or causing harm.
- Consider adding physical barriers or sensors to prevent collisions or other hazards.

CHAPTER-2

WORKING

1. **Hardware Setup**:
   - **DC Motors & L293D Motor Driver**: The L293D motor driver allows bidirectional control of two DC motors. Connect the DC motors to the motor driver's output pins, ensuring proper polarity for forward and backward movement.
   - **ATmega328 Microcontroller**: Connect the motor control pins (IN1, IN2, IN3, IN4) of the L293D motor driver to pins 8, 9, 10, and 11 of the ATmega328 microcontroller.
   - **HC-05 Bluetooth Module**: Connect the HC-05 module to the UART pins (typically TX and RX) of the ATmega328 microcontroller.

2. **ATmega328 Programming**:
   - **Serial Communication**: Initialize serial communication in your code to communicate with the HC-05 Bluetooth module. You'll use the `Serial` library in Arduino to send and receive data.
   - **Motor Control Logic**: Write functions to control the motors based on received commands. For example, if you receive 'F' (forward) command, set IN1 and IN3 pins high and IN2 and IN4 pins low to drive the motors forward. Similar logic applies for other commands.
   - **Bluetooth Communication**: Read incoming data from the Bluetooth module using `Serial.read()`. Interpret the received commands and call the appropriate motor control functions.
   - **Error Handling**: Implement error checking and handling to ensure robust communication and motor control. For instance, you may want to handle invalid commands gracefully.

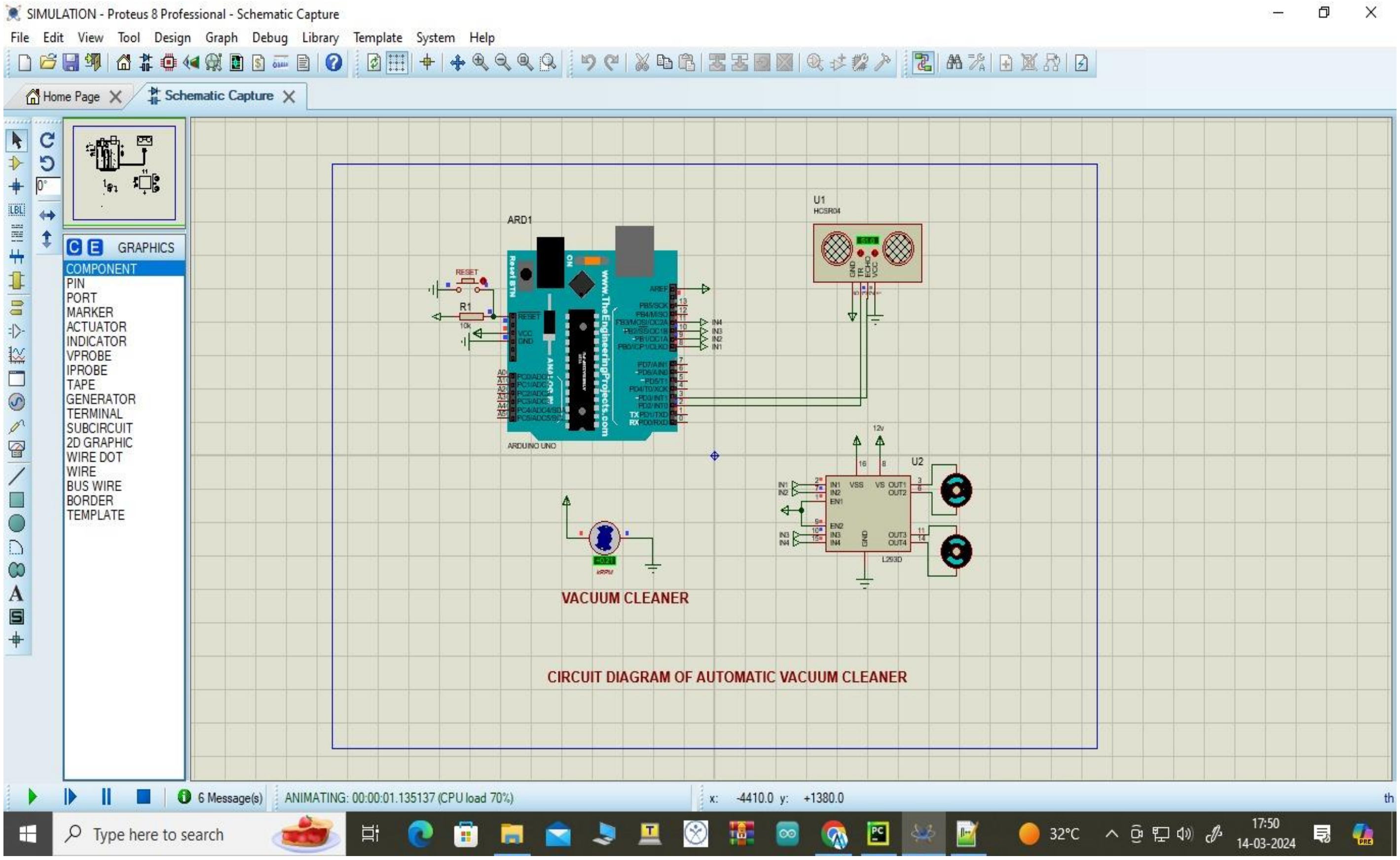
3. **Android App Development**:
   - **Bluetooth Communication**: Develop the Android app to establish a Bluetooth connection with the HC-05 module. Use Android's Bluetooth API to manage the connection and data transmission.
   - **User Interface**: Design a user-friendly interface allowing users to send commands to control the motors. This could be buttons for forward, backward, left, right, and stop commands.
   - **Data Transmission**: When the user interacts with the app, send the corresponding commands ('F', 'B', 'R', 'L', 'S') to the HC-05 module over the Bluetooth connection.

4. **Integration and Testing**:
   - **Upload Firmware**: Upload the firmware to the ATmega328 microcontroller using the Arduino IDE or another suitable tool.
   - **Pairing Bluetooth**: Pair your Android device with the HC-05 module.
   - **Testing**: Test the system by sending commands from the Android app and observing the motor's response. Verify that the motors move in the expected directions according to the commands sent from the app.
   - **Debugging**: If you encounter any issues during testing, debug your code and hardware connections to identify and resolve the problem.

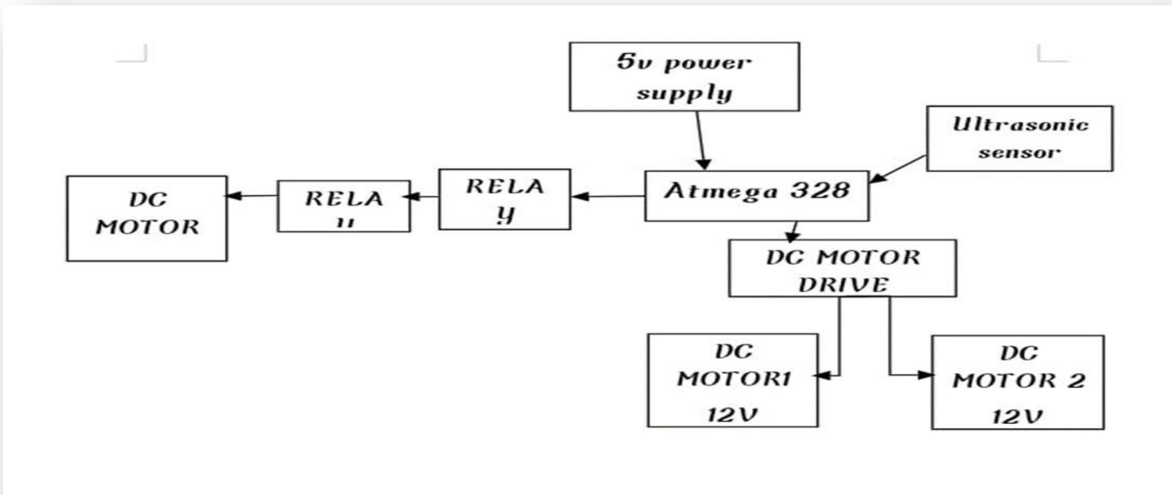
5. **Safety Considerations**:
   - **Power Management**: Ensure proper power supply to the motors, motor driver, and microcontroller to prevent damage.
   - **Safety Mechanisms**: Implement safeguards to prevent unintended motor movement or other hazards. For example, you might include a timeout mechanism to stop the motors if no command is received for a certain period.

By following these steps and ensuring thorough testing, you should be able to develop a functional system for controlling DC motors via Bluetooth commands from an Android app.

SCHEMATIC DIAGRAM



FLOW CHART



5v power supply
Ultrasonic sensor
DC MOTOR
RELA y
RELA y
Atmega 328
DC MOTOR DRIVE
DC MOTOR1 12V
DC MOTOR 2 12V

CHAPTER-3

COMPONENTS

- **AT mega 328 (Arduino)**

The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, 3 flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8 channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and 5 software-selectable power-saving modes. The device operates between 1.8 and 5.5 volts. The device achieves throughput approaching 1 MIPS/MHz.

Application:-
ATmega328 is commonly used in many projects and autonomous systems where a simple, low-powered, low-cost micro-controller is needed. Perhaps the most common implementation of this chip is on the popular Arduino development platform, namely the Arduino Uno, Arduino Pro Mini[4] and Arduino Nano models.

The high-performance Microchip picoPower® 8-bit AVR® RISC-based microcontroller combines 32 KB ISP Flash memory with read-while-write

capabilities, 1024B EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented Two-Wire serial interface, SPI serial port, a 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts.
By executing powerful instructions in a single clock cycle, the device achieves throughputs approaching one MIPS per MHz, balancing power consumption and processing speed.ATmega328P is a high performance yet low power consumption 8-bit AVR microcontroller that's able to achieve the most single clock cycle execution of 131 powerful instructions thanks to its advanced RISC architecture. It can commonly be found as a processor in Arduino boards such as Arduino Fio and Arduino Uno.

- Features:-

High endurance non-volatile memory segments
In system self-programmable flash program memory
Programming Lock for software security

- Peripheral features:-

Two 8-bit Timer/Counter with separate prescaler, compare mode.
One 16-bit Timer/Counter with separate prescaler, compare mode, and capture mode
Temperature measurement
Programmable serial USART and watchdog timer with separate on-chip oscillator

- Unique features compared to other microcontrollers (ARM, 8051, PIC):-

Power-on reset and programmable brown-out detection
Internal calibrated oscillator
External and Internal interrupt sources
Six sleep modes: Idle, ADC noise reduction, power-save, power-down, standby, and extended standby

- Advantages and Disadvantages:

  - Advantages:

Processors are simpler to use, with the usage of 8bit and 16bit instead of 32/64bit which are more complex
Readily usable without additional computing components with 32k bytes of onboard self-programmable flash program memory as well as 23 programmable I/O lines
Code Efficient, all 31 registers are directly connected to the arithmetic logic unit (ALU), making it 10 times faster than conventional CISC microcontrollers
Optimized for AVR enhanced RISC instruction set

- Disadvantages:

Lacks performance compared to higher bit microcontrollers

- Product Applications

The ATmega328P is supported with a full suite of program and system development tools which includes: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits.

The fast PWM mode that provides a high-frequency PWM waveform generation allows for it to be suited for power regulation, rectification, and DAC applications.

- **LM 7805**

The LM7805 is a voltage regulator that outputs +5 volts.

Like most other regulators in the market, it is a three-pin IC; input pin for accepting incoming DC voltage, ground pin for establishing ground for the regulator, and output pin that supplies the positive 5 volts.

- Product Features:

3-Terminal Regulators
Output Current up to 1.5A
Internal Thermal-Overload Protection
High Power-Dissipation Capability
Internal Short-Circuit Current Limiting
Output Transistor SAFE-Area Compensation

Absolute Maximum Input Voltage

- 35V

Recommended Operating Conditions

- Input Voltage: Minimum 7V, Maximum 25V
- Output Current: 1.5A
- Operating Virtual Junction Temperature: Minimum 0, Maximum 125°C

Possible High Temperatures

- If differences between the input and output voltages are not well managed, LM7805 can overheat, which may result in malfunctioning. Solutions Include:
- Limiting input voltage to 2-3 volts above the output regulated voltage
- Placing a heat sink in the circuit to dissipate heat solutions

What are they	Regulators that use linear, non switching techniques for regulation of voltage output from power supply	Regulators that provide high efficiency through rapidly switching series element on and off
Design Flexibility	Buck	Buck, Boost, Buck-Boost
Efficiency	Low to medium-high for low difference between voltages	High
Complexity	Low	Medium to High
Cost	Low, Cheap	Medium to High
Noise Generated	Low	Medium to High
Usage Purpose	Powering low powered devices Applications that has minimal difference between input and output voltages	High effeciency, high power projects Applications that has a higher voltage input range
Examples	LM7805, LM317	LM3671

- Application

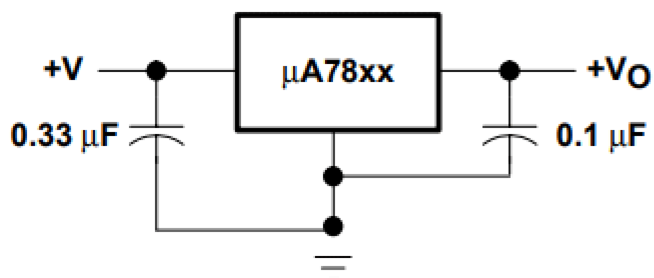
- Fixed-Output Regulator
- Positive Regulator in Negative Configuration
- Adjustable Output Regulator
- Current Regulator
- Regulated Dual-Supply
- Output Polarity-Reversal-Protection Circuit
- Reverse bias projection Circuit

LM7805 can also be used in building circuits for inductance meter, phone chargers, portable CD player, etc.

- Voltage regulators are very common in electronic circuits. They provide a constant output voltage for a varied input voltage. In our case the 7805 IC is an iconic regulator IC that finds its application in most of the projects. The name 7805 signifies two meaning, "78" means that it is a positive voltage regulator and "05" means that it provides 5V as output. So our 7805 will provide a +5V output voltage.

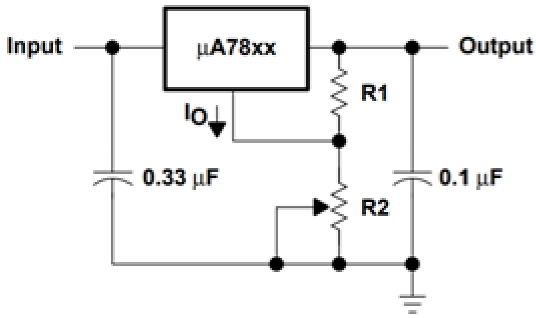
- The output current of this IC can go up to 1.5A. But, the IC suffers from heavy heat loss hence a Heat sink is recommended for projects that consume more current. For example if the input voltage is 12V and you are consuming 1A, then (12-5) * 1 = 7W. This 7 Watts will be dissipated as heat.

- 7805 as +5V Voltage Regulator
- This is a typical application circuit of the 7805 IC. We just need two capacitors of vale 33uf and 0.1uf to get this IC working.



- The input capacitor 0.33uF is a ceramic capacitor that deals with input inductance problem and the output capacitor 0.1uF is also a ceramic capacitor that adds to the stability of the circuit. These capacitors should be placed close to the terminals for them to work effectively. Also they should be of ceramic type, since ceramic capacitors are faster than electrolytic.

- 7805 as adjustable output Regulator
- This IC can also act as an adjustable output voltage regulator, meaning you can also control the output voltage for your desired value using the below circuit.



Here, the input voltage can be anywhere between 9V-25V, and the output voltage can be adjusted using the value of resistance R1 and R2. The value can be calculated using the below formulae.

$$V_O = V_{xx} + \left(\frac{V_{xx}}{R1} + I_Q\right)R2$$

Where, Vxx=5, IQ = 5*10-3

- **<u>Ultrasonic sensor</u>**

The ultrasonic sensor is a non-contact type of sensor used to measure an object's distance and velocity. This sensor operates on sound wave property to measure the velocity and distance of the object (Souri et al., 2020) demonstrates an example of ultrasonic sensor.

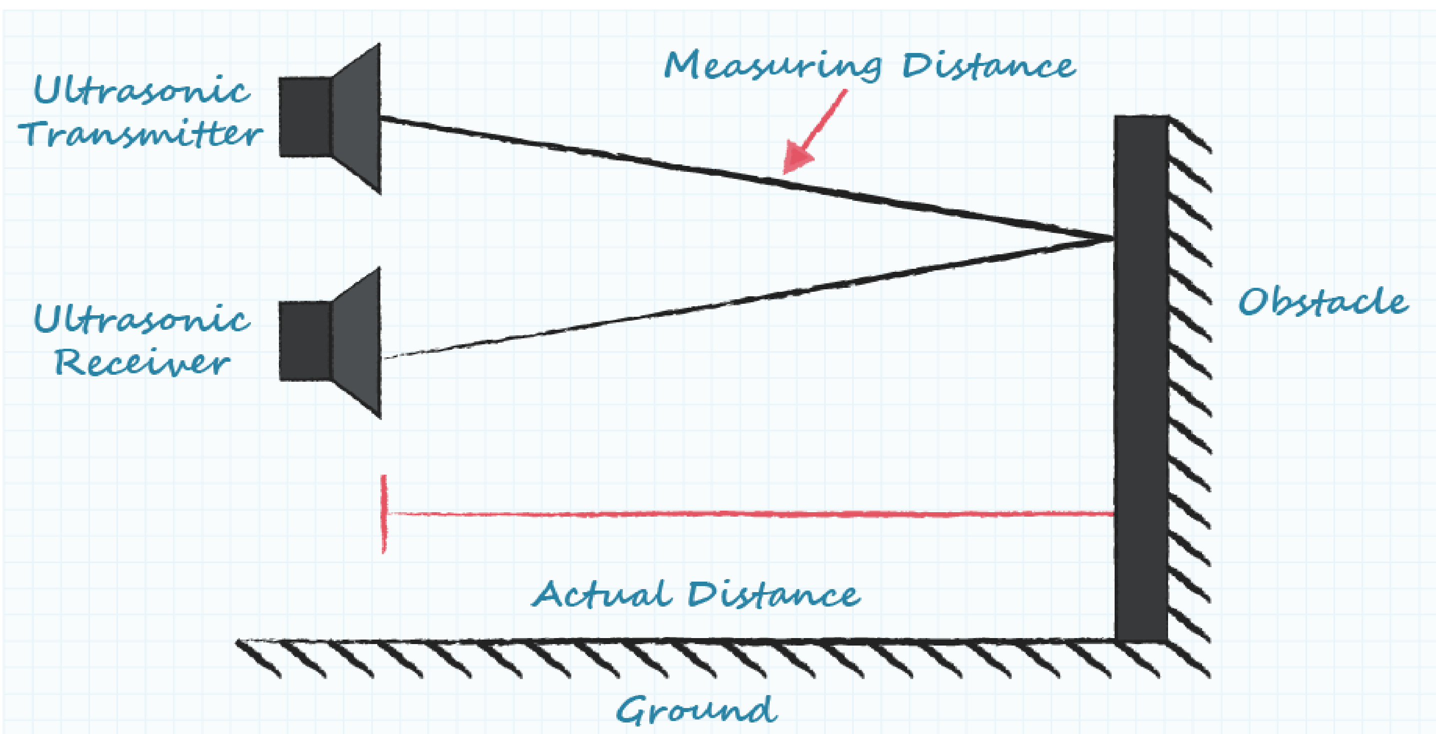
With ultrasonic sensors, all physical properties of the system can be measured, that modify ultrasonic wave propagation across the material (namely, longitudinal and shear wave velocities and reflection coefficients). Therefore, especially two critical stages during the cross-linking process can be detected by ultrasound: gelation and vitrification [50]. Ultrasonic technique as a means of following the cure process of resins (such as epoxy or amino resins or unsaturated polyesters) has been described already many years ago, for instance, by Alig and his coworkers [27,88–93] and others [94–103]. The principal setup [50] and an industrial application example for ultrasonic measurement equipment [104] are depicted schematically 12A–C.

Utrasonic sensors emit a chirp usually between 23 kHz and 40 kHz, much higher than the typical audible range of human hearing at 20 kHz, hence the term ultrasonic. Using this chirp, they measure the amount of time it takes for the sound to bounce off an object. This is based on the same basic principles of echolocation used by bats to find their prey. As the speed of sound in air at room temperature is 343 meters per second, that time can be easily converted to distance, remembering that the ultrasonic chirp travels both to and from the object being sensed.

WORKING OF A ULTRASONIC SENSOR:-
Moving from theory to reality, an ultrasonic sensor requires two parts, both

a transmitter and a receiver. In the most standard configuration, these are placed side-by-side as close together as reasonably possible. With the receiver close to the transmitter, sound travels in a straighter line from the transmitter to the detected object and back to the receiver, yielding smaller errors in the measurements. There are also ultrasonic transceivers where the transmitter and receiver functions are integrated into a single unit, minimizing error as much as physically possible while also significantly reducing the PCB footprint.

he acoustic waves that leave the transmitter are more similar in shape to light leaving a flashlight than a laser, so spread and beam angle must be considered. As the sound waves travel farther from the transmitter, the area of detection grows laterally and vertically. This changing area is why ultrasonic sensors give their coverage specification in either beam width or beam angle instead of a standard detection area. When comparing this beam angle between manufacturers, it is recommended to verify that the beam angle is either the full angle of the beam or the angle of variation from the straight line from a transducer.



A secondary effect of the beam angle is the range of the device. In general, a narrow beam yields a greater detection range as the energy of the ultrasonic pulse is more focused and can go farther before dissipating to unusable levels. Inversely, a wider beam spreads that energy in a wider arc, reducing the expected detection range. Choosing the ideal beam width is highly dependent on the application, with wide beams better at covering larger areas and general detection, while more narrow beams avoid false positives by limiting the detection area.

As with any technology, ultrasonic sensors are best utilized in certain situations or applications over others. A few of their strengths include the following:

- Ultrasonic sensors are unaffected by the color of the objects being detected, including translucent or transparent objects such as water or glass.
- Their minimum and maximum ranges are quite flexible, with most ultrasonic sensors capable of detecting as near as a few centimeters up to approximately five meters. Specifically configured modules can even measure up to nearly 20 meters.
- With decades of use, this mature technology is very reliable and well understood, yielding consistent results.
- Ultrasonic sensors provide relatively precise measurements, within 1% typically and even more precision if desired.
- They can make many measurements per second, yielding quick refresh rates.
- As there are no rare materials needed, they are usually quite inexpensive.
- Ultrasonic sensors are resistant to electrically noisy environments as well as most acoustic noise, particularly when using modules equipped with encoded chirps.

APPLICATIONS:-

The first of the two most common ultrasonic sensor applications is liquid level sensing, as they can detect liquids of any color or opacity yet are also non-contact. The second is general object detection due to their low cost and simplicity. Specific object detection applications include anti-collision detection for vehicles, people detection, presence detection, box sorting, pallet detection with forklifts, bottle counting on drink filling machines, and many more.

An example of a more creative usage for ultrasonic sensors would be to use the one-way functionality of ultrasonic transmitters and receivers separately. While the ultrasonic pulses are outside of human audible ranges, they are within the hearing ranges of various animals. An ultrasonic transmitter could conceivably use its

- **GEAR MOTORS AND WHEELS:-**

- **DC MOTORS:-**

12 volt DC motor is a rotary motor which can convert the direct current into mechanical energy or convert mechanical energy into DC power. It means that the 12 volt DC motor can interconvert electric energy and mechanical energy. When it is operated as a DC motor, electric energy is converted into mechanical energy.

The DC motor is the motor which converts the direct current into the mechanical work. It works on the principle of Lorentz Law, which states that “the current carrying conductor placed in a magnetic and electric field experience a force”. And that force is the Lorentz force.

- **Parts of a DC Motor**

– A DC motor is made up of the following main parts:
– Armature or Rotor
– The armature of a DC Motor is a cylinder of magnetic laminations insulated from one another.
– The armature or rotor is perpendicular to the axis of the cylinder.
– The armature rotates on its axis and is separated from the field coil by an air gap.
– Field Coil or Stator
– A field coil of a DC motor is a non-moving part wherein winding is wound to produce a magnetic field. The electromagnet has a cylindrical cavity in between its poles.
– Commutator and Brushes
– The commutator is a cylindrical structure in a DC Motor that is made up of copper segments that are stacked together but are insulated from each other due to mica.
– The commutator works to supply electrical current to the armature winding.
– Brushes are basically carbon and graphite structures. These brushes conduct electric current from the external field to the rotating commutator.
– Therefore, the commutator and the brush unit are responsible for transmitting power from the static electrical circuit to the mechanically rotating region known as the rotor.

- **Working Principle of DC Motor**

- The working principle of DC Motor is Fleming's Left-hand rule that is when a current-carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move. This is known as **Motoring Action**.
- Working of DC Motor
- When the DC Motor, field coil is energized, a magnetic field is created in the air gap.
- The magnetic field that is created is in the direction of the radii of the armature.
- The magnetic field enters the armature from the side of the North pole of the field coil and exits from the South pole side.
- The conductors located on the other pole get subjected to a force of the same intensity in the opposite direction.
- These two forces create a torque that leads to the motor armature to rotate.
- If the direction of current in the wire is reversed, the direction of rotation also reverses. When magnetic field and electric field interact they produce a mechanical force that tends to rotate the Armature.

- Applications of DC Motor

- The applications of various **types of DC Motors** are given below:
- Shunt DC Motors
- As the shunt DC motors possess a fairly constant speed and medium starting torque, they are used in the following applications:
- Lathe machines
- Centrifugal and reciprocating pumps
- Blowers and fans
- Drilling and milling machines
- Machine tools
- Series DC motors
- On account of the high starting torque and variable speed of series DC motors, they are used in the following applications:
- Conveyors
- Hoists, Elevators
- Cranes
- Electric Locomotives
- Cumulative Compound DC Motors

- Due to the high starting torque of cumulative compound DC motors, they are used in the following applications:
- Shears
- Heavy Planers
- Rolling mills
- Elevators

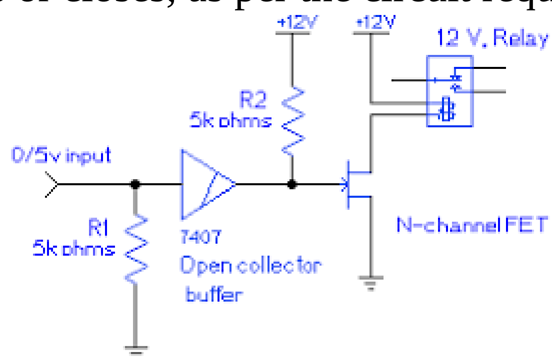
- **Construction of DC Motor**

- There is a stator inside DC Motors which are poles with copper-binding also known as Field binding as **magnetic fields** are attached to it.
- Those permanent magnetic fields are controlled by the on and off switch in DC Motors.
- Then comes the Armature which has binding on it.
- The commutator comes between the two brushes.
- The movement occurs there in DC motors and the **pressure** comes on the shaft

- **RELAY DRIVES**

The Relay Driver is a logic module which provides high level system control functions such as high/low voltage alarms, load control and generator start. The product controls four independent relay driver outputs by reading digital data inputs from Morningstar's TriStar controller or by reading battery voltage when used in systems with other controllers.

Briefly, a relay is a switch with an electric operation. A relay driver circuit is a circuit type that runs a relay, therefore, contributing to an appropriate circuit function. In turn, the relay switch opens or closes, as per the circuit requirement and functioning.



Example of a relay driver circuit

- Working principle

A relay structure comprises a spring-loaded contact and coil that move undisturbed across a pivoted axis.
The central pole ensures that as the relay coil receives voltage, it joins the N/C contact (Normally Closed). The connection happens because the relay coil has an electromagnetic pull that attracts the pole iron.
Later, when you switch OFF the relay coil, the central pole disconnects from the Normally Open (N/O) terminal. It then joins the N/C switch contact terminal hence being in a default contact position.
Generally, the switch OFF and switch ON operations in a relay drive alternately switches N/C to N/O. And it majorly depends on the state of the relay coil.

ADVANTAGES:-

- First, it uses inexpensive NPN drive transistors that are also commonly available.

– It has fewer components.
– Further, you can easily interface it to a low voltage logic circuitry and a relay economy feature.
– Also, its manufacture has an industry-standard technique.
– In addition, it has several interface options, such as the ULN2003 driver.
– Lastly, you can source the relay power by a higher, unregulated voltage. In that way, there’s load reduction on the voltage regulator.

Applications include:

– Heaters,
– Motors, and
– Lamps.

- **BLUETOOTH**

The HC-05 is a class 2 Bluetooth module designed for transparent wireless serial communication. It is pre-configured as a slave Bluetooth device. Once it is paired to a master Bluetooth device such as PC, smart phones and tablet, its operation becomes transparent to the user. All data received through the serial input is immediately transmitted over the air. When the module receives wireless data, it is sent out through the serial interface exactly at it is received. No user code specific to the Bluetooth module is needed at all in the user microcontroller program.
The HC-05 supports two work modes: Command and Data mode. The work mode of the HC-05 can be switched by the onboard push button. The HC-05 is put in Command mode if the push button is activated. In Command mode, user can change the system parameters (e.g. pin code, baud rate, etc) using host controller itself of a PC running terminal software using a serial to TTL converter. Any changes made to system parameters will be retained even after power is removed. Power cycle the HC-05 will set it back to Data Mode. Transparent UART data transfer with a connected remote device occurs only while in Data Mode.
The HC-05 can be re-configured by the user to work as a master Bluetooth device using a set of AT commands. Once configured as master, it can automatically pair with a HC-05 in its default slave configuaration or a HC-06 module, allowing an point to point serial communications.
The HC-05 will work with supply voltage of 3.6VDC to 6VDC, however, the logic level of RXD pin is 3.3V and is not 5V tolerant. A Logic Level Converter is recommended to protect the sensor if connect it to a 5V device (e.g Arduino Uno and Mega). The power to the HC-05 will cut off if the "EN" pin is pulled to logic 0.

Features:
Bluetooth v2.0+EDR
2.4GHz ISM band frequency
Supported baud rate: 9600 (default), 19200,38400, 57600, 115200, 230400, 460800.
Speed: Asynchronous: 2.1Mbps(Max) / 160 kbps, Synchronous: 1Mbps/1Mbps
Power supply: 3.6V to 6V DC
Passkey: 1234

- Bluetooth Module HC-05 is used to communicate between Arduino and other devices. HC-05 is used for a transparent wireless serial connection setup. It is simple to use Bluetooth SPP (Serial Port Protocol) module.

- HC-05 can be used in a Master or Slave configuration, making it a great solution for wireless communication.
- This device is used to send data to Arduino and different types of devices for controlling things or communicate.
- For example, Bluetooth Module is used in Home Automation using Arduino to control appliance using Bluetooth. You can see our article on Home Automation using Arduino and Bluetooth
- This Bluetooth module is based on Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with a complete 2.4GHz radio transceiver and baseband.
- The Bluetooth module HC-05 is a MASTER/SLAVE module. By default the factory setting is SLAVE. To change the role of the module (Master or Slave) can be configured only by AT COMMANDS.

- **HC 05 Pin Configuration**

– This Bluetooth module has 6 pins whose description is are as follow:-

– Key/EN: If we want to bring Bluetooth module in command mode then we have to HIGH the enable pin. Otherwise, the Bluetooth module is in data mode by default. The HC-05 has a default baud rate in data mode is 9600bps and baud rate in command mode is 38400bps. The following are the two modes of the HC-05 module.

– Data mode: For exchanging the data between two devices Data mode is used.

– Command mode: To change the settings like password, name, etc of HC-05 modules we use command mode. In this mode, we send AT commands to HC-05 by serial monitor.

– VCC: To give power or current to the module, this pin will be connected to a 5V or 3.3V pin.

– GND: Ground pin.

– TXD: Transmit Serial data. It is used to wirelessly received data by the Bluetooth module transmitted out serially on the TXD pin.

– RXD: Receive data serially. When the Bluetooth module transmit data, RXD pin is used to receive that data.

– State: It tells whether the module is connected or not.

- HC-05 Module Information

– HC-05 has a red LED which indicates connection status, whether the Bluetooth is connected or not. Before connecting to the 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 3.3 V. We can connect the 5V supply voltage as well since the module has on board 5 to 3.3 V regulator.

– As the HC-05 Bluetooth module has a 3.3 V level for RX/TX and the microcontroller can detect 3.3 V level, so no need to shift the transmit level of the HC-05 module. But we need to shift the transmit voltage level from the microcontroller to RX of the HC-05 module.

- **BUZZER**

An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren.

The pin configuration of the buzzer is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal. This terminal is powered through 6Volts whereas the negative terminal is represented with the '-'symbol or short terminal and it is connected to the GND terminal.

- Electromechanical

– This buzzer was launched in the year 1831 by an American Scientist namely Joseph Henry but, this was used in doorbells until they were eliminated in 1930 in support of musical bells, which had a smooth tone.

– Piezoelectric

– These buzzers were invented by manufacturers of Japanese & fixed into a broad range of devices during the period of 1970s – 1980s. So, this development primarily came due to cooperative efforts through the manufacturing companies of Japanese. In the year 1951, they recognized the Application Research Committee of Barium

Titanate that allows the corporations to be cooperative competitively & bring about numerous piezoelectric creations.

- Specifications
- – The specifications of the buzzer include the following.
- – Color is black
- – The frequency range is 3,300Hz
- – Operating Temperature ranges from – 20° C to +60°C
- – Operating voltage ranges from 3V to 24V DC
- – The sound pressure level is 85dBA or 10cm
- – The supply current is below 15Ma

- Types of Buzzer
  - A buzzer is available in different types which include the following.
  - Piezoelectric
  - Electromagnetic
  - Mechanical
  - Electromechanical
  - Magnetic

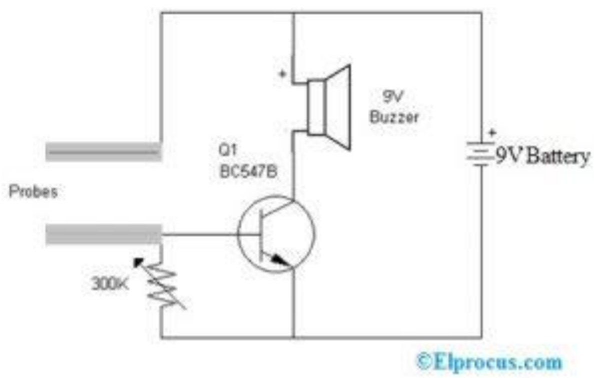
- Piezoelectric
  - As the name suggests, the piezoelectric type uses the piezoelectric ceramic's piezoelectric effect & pulse current to make the metal plate vibrate & generate sound. This kind of buzzer is made with a resonance box, multi resonator, piezoelectric plate, housing, impedance matcher, etc. Some of the buzzers are also designed with LEDs.
  - The multi resonator of this mainly includes ICs and transistors. Once the supply is given to this resonator, it will oscillate and generates an audio signal with 1.5 to 2.kHz. The impedance matcher will force the piezoelectric plate to produce sound.

- Electromagnetic

– This type of buzzer is made with a magnet, solenoid coil, oscillator, housing, vibration diaphragm, and magnet. Once the power supply is given, the oscillator which produces the audio signal current will supply throughout the solenoid coil to generate a magnetic field.

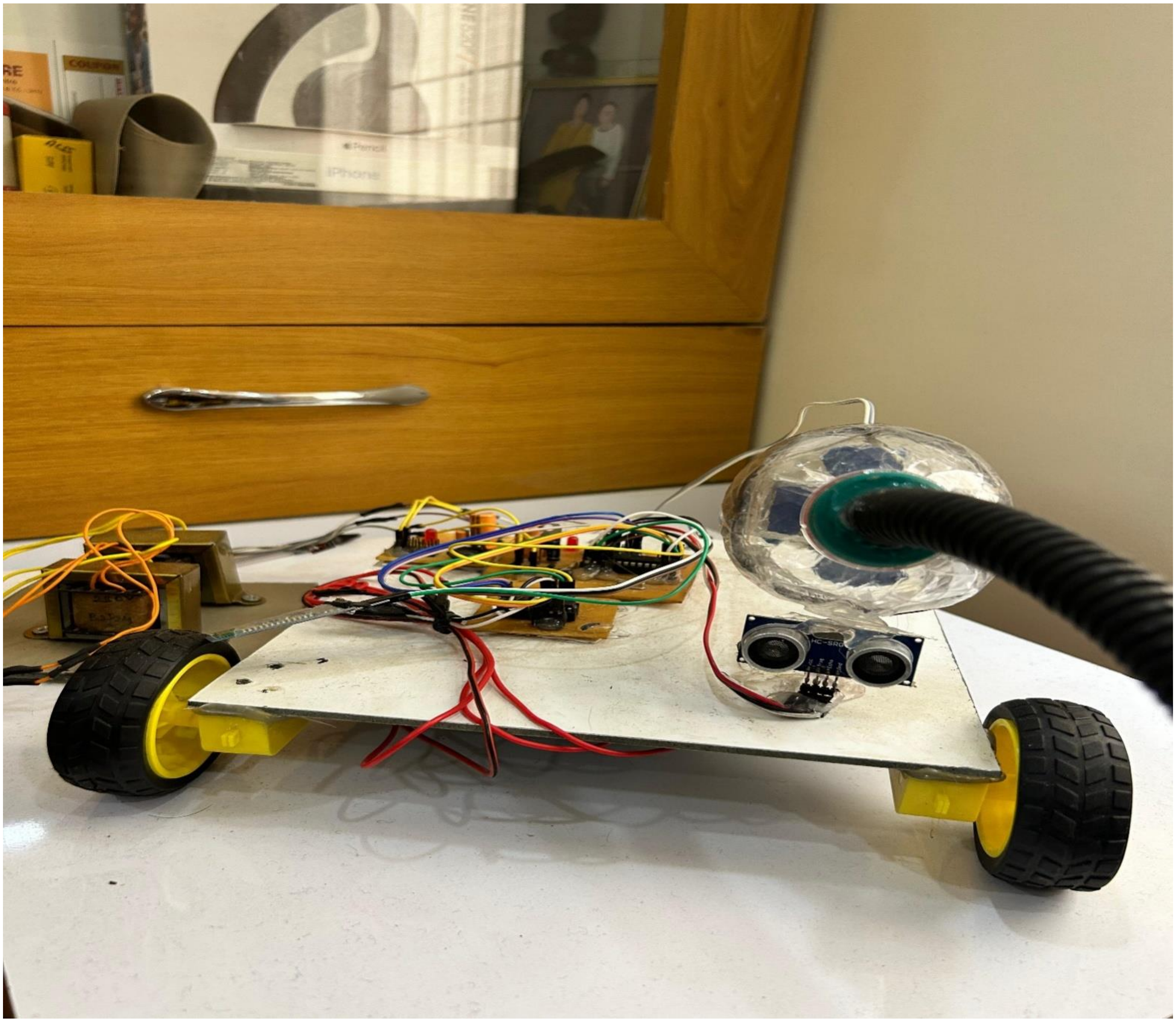
– Sometimes, the vibration diaphragm will vibrate & generates sound under the magnet & solenoid coil
– interaction. The frequency range of this ranges from 2 kHz to 4kHz.

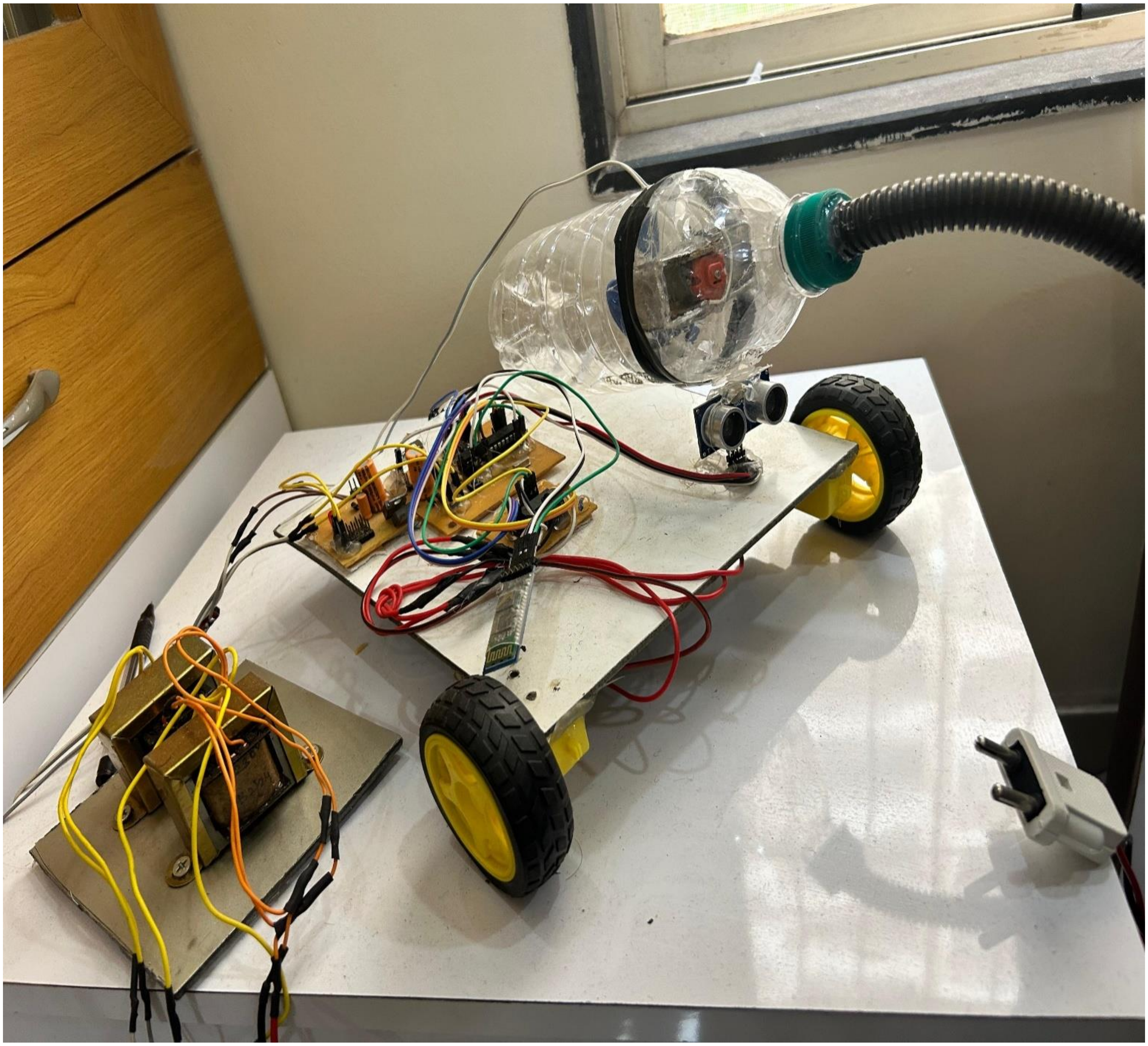
The **circuit diagram of the water level indicator using the buzzer** is shown below. This circuit is used to sense or detect the water level within the tank or washing machine or pool, etc. This circuit is very simple to design using few components such as a transistor, buzzer, 300K variable resistor, and power supply or 9V battery.



Once the two probes of the circuit are placed in the tank, it detects the level of water. Once the water level exceeds the fixed level, then it generates a beep sound through a buzzer connected to the circuit. This circuit uses a BC547B NPN transistor however we can also use any general-purpose transistor instead of using 2N3904/2N2222. This water level sensor circuit working is very simple and the transistor used within the circuit works as a switch. Once the two probes notice the water level within the tank, then the transistor turns ON & the voltage begins flowing throughout the transistor to trigger the buzzer.

PHOTOS





CHAPTER-4

EPRESS PCB

Overview

There are two parts to ExpressPCB, our CAD software and our board manufacturing service. Our CAD software includes ExpressSCH for drawing schematics and ExpressPCB for designing circuit boards. After you complete your PC board design, we provide a low cost, high quality and fast source for having your boards made. Here is how it works:

1. We recommend that you begin your project by drawing a schematic using ExpressSCH. Drawing a schematic is not required, but it will save you time when designing your board and reduce the possibility of wiring errors.

2. Next, use the ExpressPCB program to layout your PC board. If you link your schematic to ExpressPCB, the program will guide you through the wiring process by highlighting how the components should be connected.

3. When your layout is complete, you can determine the exact cost of having your boards made with the Compute Board Cost command.

4. To order the boards, simply enter your name, address and billing information into ExpressPCB and press the Send button within the Order Boards Via The Internet dialog box.

In a few business days (typically 2 or 3) an overnight courier will deliver your PC boards.

Understanding the Layers of a PCB

ExpressPCB manufactures double-sided boards (with 2 copper layers) and 4 layer boards (with 4 copper layers). Double-sided boards work well for most simple applications. They are somewhat less expensive and take fewer days to manufacture than four-layer boards. But four-layer boards offer advantages. They are better at controlling electrical noise and four-layer boards can be smaller with components closely spaced together. Also these boards are easier to lay out.

Depending on the options you choose, your boards can have as few as two layers, or as many as seven. The layers from top to bottom are:

1. Silkscreen
2. Top Solder Mask
3. Top Copper
4. Inner Copper Ground Plane
5. Inner Copper Power Plane
6. Bottom Copper
7. Bottom Solder Mask

- All boards have a Top copper and Bottom copper layer. The Top copper layer is on the component side of the board and is displayed in red by the ExpressPCB layout program. The Bottom copper layer is on the solder side of the PCB and is shown in green.

- The optional Solder masks layers are green coatings that cover the top and bottom of the board. The coating is applied everywhere except over the pads where components are soldered. These masks make soldering easier by helping to prevent solder bridges from forming between adjacent pads and traces.

- Boards with solder masks also include a Silkscreen layer. The Silkscreen layer is used to show the outlines of components, and text identifying each part. The outlines and text are printed on the top of the board in white ink.

- Four-layer boards have two additional copper layers that are not included with Double-sided boards. Sandwiched inside these PCBs are two inner layers, a Ground Plane and a Power Plane. Any through-hole pad on a four-layer board can be connected to or isolated from either of these planes. Because the inner layers are completely filled copper planes, they greatly improve the noise immunity of your circuit.

- Our Standard Service and Standard MiniBoard Service manufacturing options deliver boards without a silkscreen or the two solder mask layers. It is not necessary to consider these layers when designing your board. However, even though the silkscreen layer is not printed on the final PCB, we still recommend that you create it to document the placement of each component in your circuit.

- Our Production Service, ProtoPro Service, and MiniBoardPro Service manufacturing options include the silkscreen layer and the two solder masks layers. These layers give the board a more professional appearance.

- The solder mask layers are displayed in reverse. Solder mask is applied everywhere on the board, except where something is drawn on the layer. The ExpressPCB layout program automatically blocks the solder mask from pads and components from our library. However, if you want to expose other copper areas, do so by drawing on the solder mask layers. For example, if you create edge connector fingers using trace segments, you will want to place large rectangles on the solder mask layers to prevent the entire edge connector from being covered with mask.

Atmega microcontroller

Overview

The ATmega48PA/88PA/168PA/328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega48PA/88PA/168PA/328P achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed

- Features
– High Performance, Low Power AVR® 8-Bit Microcontroller
– Advanced RISC Architecture
– 131 Powerful Instructions
– Most Single Clock Cycle Execution
– 32 x 8 General Purpose Working Registers
– Fully Static Operation
– Up to 20 MIPS Throughput at 20 MHz
– On-chip 2-cycle Multiplier

- High Endurance Non
– volatile Memory Segments
– 4/8/16/32K Bytes of In
– -System Self-Programmable Flash progam memory (ATmega48PA/88PA/168PA/328P)
– 256/512/512/1K Bytes EEPROM (ATmega48PA/88PA/168PA/328P)
– 512/1K/1K/2K Bytes Internal SRAM (ATmega48PA/88PA/168PA/328P)
– Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
– Data retention: 20 years at 85°C/100 years at 25°C(1)
– Optional Boot Code Section with Independent Lock Bits In

– -System Programming by On
– -chip Boot Program True Read
– -While-Write Operation
– Programming Lock for Software Security

- Peripheral Features

– Two 8-bit Timer/Counters with Separate Prescaler and Compare Mode
– One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
– Real Time Counter with Separate Oscillator
– Six PWM Channels
– 8-channel 10-bit ADC in TQFP and QFN/MLF package Temperature Measurement
– 6-channel 10-bit ADC in PDIP Package Temperature Measurement
– Programmable Serial USART
– Master/Slave SPI Serial Interface
– Byte-oriented 2-wire Serial Interface (Philips I2 C compatible)
– Programmable Watchdog Timer with Separate On-chip Oscillator
– On-chip Analog Comparator
– Interrupt and Wake-up on Pin Change

- Special Microcontroller Features

– Power-on Reset and Programmable Brown-out Detection
– Internal Calibrated Oscillator
– External and Internal Interrupt Sources
– Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby, and Extended Standby • I/O and Packages
– 23 Programmable I/O Lines
– 28-pin PDIP, 32-lead TQFP, 28-pad QFN/MLF and 32-pad QFN/MLF

- Operating Voltage:

– 1.8 - 5.5V for ATmega48PA/88PA/168PA/328P

- Temperature Range:

– -40°C to 85°C

- Speed Grade:

– 0 - 20 MHz @ 1.8 - 5.5V

- Low Power Consumption at 1 MHz, 1.8V, 25°C for ATmega48PA/88PA/168PA/328P: – Active Mode: 0.2 mA – Power-down Mode: 0.1 µA – Power-save Mode: 0.75 µA (Including 32 kHz RTC

L293D

PUSH-PULL FOUR CHANNEL DRIVER WITH DIODES 600mA OUTPUT CURRENT CAPABILITY PER CHANNEL 1.2A PEAK OUTPUT CURRENT (non repetitive) PER CHANNEL ENABLE FACILITY OVERTEMPERATURE PROTECTION LOGICAL ”0” INPUT VOLTAGE UP TO 1.5 V (HIGH NOISE IMMUNITY) INTERNAL CLAMP DIODES DESCRIPTION

- The Device is a monolithic integrated high voltage, high current four channel driver designed to accept standard DTL or TTL logic levels and drive inductive loads (such as relays solenoides, DC and stepping motors) and switching power transistors. To simplify use as two bridges each pair of channels is equipped with an enable input. A separate supply input is provided for the logic, allowing operation at a lower voltage and internal clamp diodes are included. This device is suitable for use in switching applications at frequencies up to 5 kHz.

- The L293D is assembled in a 16 lead plastic packaage which has 4 center pins connected together and used for heatsinking The L293DD is assembled in a 20 lead surface mount which has 8 center pins connected together and used for heatsinking.

- June 1996 BLOCK DIAGRAM SO(12+4+4) Powerdip (12+2+2) ORDERING NUMBERS: L293DD L293D 1/7 ABSOLUTE MAXIMUM RATINGS Symbol Parameter Value Unit VS Supply Voltage 36 V VSS Logic Supply Voltage 36 V Vi Input Voltage 7 V Ven Enable Voltage 7 V Io Peak Output Current (100 µs non repetitive) 1.2 A Ptot Total Power Dissipation at Tpins = 90 °C 4W Tstg, Tj Storage and Junction Temperature – 40 to 150 °C THERMAL DATA Symbol Decription DIP SO Unit Rth j-pins Thermal Resistance Junction-pins max. – 14 °C/W Rth j-amb Thermal Resistance junction-ambient max. 80 50 (*) °C/W Rth j-case Thermal Resistance Junction-case max. 14 –

- Ultrasonic Distance Sensor – Serial Out Its compact size, higher range and easy usability make it a handy sensor for distance measurement and mapping. Features · Minimum range 10 centimeters · Maximum range 400 centimeters (4 Meters) · Accuracy of +-1 cm · Resolution 1 cm · 5V DC Supply voltage · Compact sized SMD design · Modulated at 40 kHz · Serial data of 9600 bps TTL level output for easy interface with any microcontroller

HC-05

- Bluetooth to Serial Port Module

- Overview

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup.

Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04-External single chip Bluetooth system with CMOS technology and with AFH(Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mmx27mm. Hope it will simplify your overall design/development cycle.

- Specifications

– Hardware features
– Typical -80dBm sensitivity
– Up to +4dBm RF transmit power
– Low Power 1.8V Operation ,1.8 to 3.6V I/O λ PIO control
– UART interface with programmable baud rate
– With integrated antenna
– With edge connector

- Software features

– Default Baud rate: 38400, Data bits:8, Stop bit:1,Parity:No parity, Data control:

has. Supported baud rate: 9600,19200,38400,57600,115200,230400,460800.

- Given a rising pulse in PIO0, device will be disconnected.
- Status instruction port PIO1: low-disconnected, high-connected;
- PIO10 and PIO11 can be connected to red and blue led separately. When master and slave are paired, red and blue led blinks 1time/2s in interval, while disconnected only blue led blinks 2times/s.
- Auto-connect to the last device on power as default.
- Permit pairing device to connect as default.
- Auto-pairing PINCODE:”0000” as default
- Auto-reconnect in 30 min when disconnected as a result of beyond the range of connection

CHAPTER-5

CODE FOR THE VACCUM CLEANER

```
#define TRIGGER_PIN 2
#define ECHO_PIN 3

#define MOTOR1_PIN1 8
#define MOTOR1_PIN2 9
#define MOTOR2_PIN1 10
#define MOTOR2_PIN2 11


void setup() {
  Serial.begin(115200);
  delay(2000);
  Serial.print("AT+CIPMUX=1\r\n");
  delay(1000);
  Serial.print("AT+CIPSERVER=1,80\r\n");
  delay(1000);
  pinMode(TRIGGER_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(MOTOR1_PIN1, OUTPUT);
  pinMode(MOTOR1_PIN2, OUTPUT);
  pinMode(MOTOR2_PIN1, OUTPUT);
  pinMode(MOTOR2_PIN2, OUTPUT);
```

```
}
long duration, distance;
void Ultrasonic_Read(){
  digitalWrite(TRIGGER_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIGGER_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIGGER_PIN, LOW);

  // Measure the duration of the echo signal
duration = pulseIn(ECHO_PIN, HIGH);

  // Calculate the distance in cm
  distance = duration * 0.034 / 2;

}

void loop() {

  // Send a 10us pulse to trigger the ultrasonic sensor

  // Print the distance to the serial monitor
  Ultrasonic_Read();
  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");

  while(distance>50)
    {
      Ultrasonic_Read();
      moveForward();
      delay(100);

    }

    {
      stopMotors();
```

```
    turnRight();
    delay(2150);

    stopMotors();
    delay(1000);

    moveForward();
    delay(1000);

    stopMotors();
    delay(1000);

    turnRight();
    delay(2150);

    stopMotors();
    delay(1000);
    moveForward();
     }

   Ultrasonic_Read();
while(distance>50)
  {
    Ultrasonic_Read();
    moveForward();
    delay(100);
  }

  {
    stopMotors();
    turnLeft();
    delay(2150);

    stopMotors();
    delay(1000);

    moveForward();
```

```
    delay(1000);

    stopMotors();
    delay(1000);

    turnLeft();
    delay(2100);

    stopMotors();
    delay(1000);
    moveForward();
     }




  delay(1000); // Adjust the delay as needed for your application


}



void moveForward() {
  digitalWrite(MOTOR1_PIN1, HIGH);
  digitalWrite(MOTOR1_PIN2, LOW);
  digitalWrite(MOTOR2_PIN1, HIGH);
  digitalWrite(MOTOR2_PIN2, LOW);
}

void moveBackward() {
  digitalWrite(MOTOR1_PIN1, LOW);
  digitalWrite(MOTOR1_PIN2, HIGH);
  digitalWrite(MOTOR2_PIN1, LOW);
  digitalWrite(MOTOR2_PIN2, HIGH);
}
```

```
void turnLeft() {
  digitalWrite(MOTOR1_PIN1, LOW);
  digitalWrite(MOTOR1_PIN2, HIGH);
  digitalWrite(MOTOR2_PIN1, HIGH);
  digitalWrite(MOTOR2_PIN2, LOW);
}

void turnRight() {
  digitalWrite(MOTOR1_PIN1, HIGH);
  digitalWrite(MOTOR1_PIN2, LOW);
  digitalWrite(MOTOR2_PIN1, LOW);
  digitalWrite(MOTOR2_PIN2, HIGH);
}

void stopMotors() {
  digitalWrite(MOTOR1_PIN1, LOW);
  digitalWrite(MOTOR1_PIN2, LOW);
  digitalWrite(MOTOR2_PIN1, LOW);
  digitalWrite(MOTOR2_PIN2, LOW);
}
```

CHAPTER-6

HISTORY AND EVOLUTION

Early Developments: Robotic vacuum cleaners originated in the late 1990s with models like the Electrolux Trilobite.
Evolution: Over the years, advancements in sensor technology, artificial intelligence, and battery life have led to
Significant improvement in performance and functionality.

The genesis of smart robotic vacuum cleaners traces back to the late 1990s, when the concept of autonomous cleaning devices first began to take shape. While early iterations were rudimentary compared to today's sophisticated models, they laid the groundwork for a revolutionary transformation in the realm of home cleaning. Let us embark on a journey through time to uncover the fascinating history and evolution of smart robotic vacuum cleaners.

1. Early Developments (Late 1990s - Early 2000s):
- The dawn of smart robotic vacuum cleaners can be traced to the late 1990s, with pioneering models such as the Electrolux Trilobite and the first-generation Roomba by iRobot.
- These early devices, though rudimentary by today's standards, marked a significant milestone in the development of autonomous cleaning technology. They were equipped with basic sensors and navigation systems that enabled them to navigate through rooms and avoid obstacles.

2. Advancements in Sensor Technology (Mid-2000s):
- The mid-2000s witnessed significant advancements in sensor technology, paving the way for more intelligent and efficient robotic vacuum cleaners.
- Manufacturers began incorporating infrared sensors, bump sensors, and cliff sensors, allowing robots to detect obstacles, navigate around furniture, and avoid falls down stairs.

3. Emergence of Mapping and Navigation Systems (Late 2000s - Early 2010s):
- By the late 2000s and early 2010s, robotic vacuum cleaners began to incorporate more sophisticated mapping and navigation systems.
- Laser sensors (LIDAR) and simultaneous localization and mapping (SLAM)

algorithms enabled robots to create maps of their cleaning environment, navigate in straighter paths, and adapt their cleaning patterns to different floor surfaces.

4. Integration of Artificial Intelligence and Connectivity (Mid-2010s - Present):
- The mid-2010s marked a watershed moment in the evolution of smart robotic vacuum cleaners, with the integration of artificial intelligence (AI) and connectivity features.
- AI algorithms allowed robots to learn and adapt to their surroundings, optimizing cleaning routes and improving efficiency over time.
- Connectivity features, such as Wi-Fi and smartphone apps, enabled users to remotely control and monitor their robotic vacuum cleaners, schedule cleaning sessions, and receive notifications.

5. *Allergy Relief:*
- Many smart robotic vacuum cleaners feature HEPA filters, which are highly effective at capturing dust, allergens, pet dander, and other airborne particles. By trapping these particles, robotic vacuum cleaners help improve indoor air quality and provide relief to allergy sufferers, creating a healthier living environment.

6. *Energy Efficiency:*
- Robotic vacuum cleaners are designed to be energy-efficient, consuming less power than traditional vacuum cleaners. Additionally, their ability to operate autonomously and return to their charging dock when the battery is low helps conserve energy and reduce electricity costs.

7. *Remote Control and Monitoring:*
- With connectivity features such as Wi-Fi and smartphone apps, users can remotely control and monitor their robotic vacuum cleaners from anywhere. They can start, stop, or schedule cleaning sessions, adjust cleaning settings, and receive notifications about cleaning progress or issues that require attention, providing peace of mind and flexibility.

8. *Reduced Physical Strain:*
- Using a smart robotic vacuum cleaner eliminates the need for manual pushing,

pulling, and bending associated with traditional vacuuming methods. This can help reduce physical strain and discomfort, particularly for individuals with mobility issues or physical limitations.

9. *Customization and Personalization:*
   - Smart robotic vacuum cleaners offer customization options to suit individual preferences and cleaning needs. Users can adjust cleaning modes, suction power, and scheduling settings to optimize cleaning performance and efficiency based on their specific requirements and lifestyle.

10. *Integration with Smart Home Ecosystems:*
    - Many smart robotic vacuum cleaners integrate seamlessly with smart home ecosystems, allowing users to control and automate various aspects of their home environment. They can be synchronized with other smart devices and virtual assistants, enhancing overall home automation and convenience.

These benefits collectively make smart robotic vacuum cleaners indispensable tools for modern households, offering efficiency, convenience, and improved quality of life to users worldwide.

NEED OF A VACCUM CLEANER

In today's fast-paced world, where time is a precious commodity and convenience is king, the need for smart robotic vacuum cleaners has never been more pronounced. As urbanization and hectic lifestyles become the norm, individuals seek innovative solutions to simplify everyday tasks, including the tedious chore of cleaning floors. Let's delve into the multifaceted reasons driving the demand for these intelligent cleaning devices. innovation and market growth in the years to come.
The purpose of smart robotic vacuum cleaners transcends mere convenience—it epitomizes a fundamental shift towards a more streamlined, efficient approach to home cleaning. At its core, the purpose of these intelligent devices is twofold: to alleviate the burden of manual labor associated with traditional vacuuming methods and to deliver consistently superior cleaning results.

1. *Time Constraints:* With busy work schedules, social commitments, and family responsibilities, many individuals find themselves struggling to allocate time for household chores. Traditional vacuuming methods require manual operation, consuming valuable time and energy. Smart robotic vacuum cleaners offer a time-saving solution by automating the cleaning process, allowing users to reclaim precious hours for more meaningful pursuits.

2. *Convenience and Efficiency:* The allure of smart robotic vacuum cleaners lies in their ability to deliver hassle-free, hands-off cleaning. Unlike traditional vacuum cleaners that require constant supervision and physical exertion, robotic vacuums can be programmed to clean autonomously, navigating through rooms, around furniture, and under obstacles with ease. This level of convenience not only reduces the burden of manual labor but also ensures consistent and thorough cleaning results.

3. *Accessibility to Hard-to-Reach Areas:* One of the inherent challenges of traditional vacuuming is reaching tight spaces and under furniture where dust and debris tend to accumulate. Smart robotic vacuum cleaners are equipped with slim profiles and maneuverability features that enable them to access areas that are difficult for humans to reach. By effectively cleaning these neglected spaces, robotic vacuums contribute to a more comprehensive and hygienic cleaning routine.

4. *Allergy Relief and Indoor Air Quality:* Indoor air pollution poses a significant health risk, particularly for individuals with respiratory conditions or allergies. Traditional vacuum cleaners often stir up dust and allergens, exacerbating symptoms and compromising indoor air quality. Many smart robotic vacuum cleaners are equipped with high-efficiency particulate air (HEPA) filters, which effectively capture dust, pet dander, pollen, and other allergens, thereby improving indoor air quality and providing relief to allergy sufferers.

5. *Smart Home Integration:* The proliferation of smart home technology has transformed the way we interact with our living spaces. Smart robotic vacuum cleaners seamlessly integrate with existing smart home ecosystems, allowing users to control and monitor cleaning activities remotely via smartphone apps or voice commands. This level of connectivity enhances user convenience and enables greater customization and automation of cleaning routines.

6. *Environmental Sustainability:* As environmental consciousness continues to grow, consumers are increasingly seeking eco-friendly alternatives to conventional cleaning methods. Smart robotic vacuum cleaners are designed with energy-efficient motors and rechargeable batteries, minimizing environmental impact while maximizing cleaning efficiency. Additionally, by maintaining cleaner indoor environments, these devices contribute to overall sustainability efforts by reducing the need for harsh chemical cleaning agents and prolonging the lifespan of flooring surfaces.

7.*Efficiency:* Smart robotic vacuum cleaners are designed with efficiency in mind, offering users a hassle-free cleaning experience that requires minimal time and effort. By automating the cleaning process and leveraging advanced navigation algorithms, these devices can efficiently traverse through rooms, adapt to various floor surfaces, and navigate around obstacles with precision. The result is a thorough and comprehensive cleaning routine that ensures every nook and cranny is meticulously cleaned—without the need for constant supervision.

8. *Convenience:* Convenience lies at the heart of the appeal of smart robotic vacuum cleaners. With the ability to schedule cleaning sessions, monitor cleaning progress remotely, and customize cleaning settings via smartphone apps or voice commands, users gain unprecedented control and flexibility over their cleaning routines. Whether juggling work commitments, caring for family members, or simply enjoying leisure time, users can rest assured that their floors will remain spotless with minimal intervention.

In essence, the purpose of smart robotic vacuum cleaners is to redefine the concept of home cleaning, transcending the constraints of traditional methods to deliver a seamless, efficient, and hassle-free experience. By harnessing the power of technology to automate mundane tasks, these intelligent devices empower users to lead more balanced, fulfilling lives—one clean floor at a time.

In conclusion, the need for smart robotic vacuum cleaners stems from a confluence of factors, including time constraints, convenience, accessibility, health considerations, technological advancements, and environmental sustainability. By addressing these needs, these intelligent cleaning devices not only streamline household cleaning routines but also enhance overall quality of life for users. As technology continues to evolve and consumer expectations evolve, the demand for smart robotic vacuum cleaners is expected to remain strong, driving further innovation and market growth in the years to come.

KEY FEATURES

Navigation Systems: Smart robotic vacuums utilize various navigation methods such as cameras, laser sensors, gyroscopes, and infrared sensors to map and navigate the cleaning area. The purpose of smart robotic vacuum cleaners transcends mere convenience—it epitomizes a fundamental shift towards a more streamlined, efficient approach to home cleaning. At its core, the purpose of these intelligent devices is twofold: to alleviate the burden of manual labor associated with traditional vacuuming methods and to deliver consistently superior cleaning results.

- Cleaning Modes: These devices offer multiple cleaning modes, including auto-clean, spot clean, edge clean, and scheduled cleaning.
- Connectivity: Most smart robotic vacuum cleaners can be controlled remotely via smartphone apps and are compatible with virtual assistants like Amazon Alexa and Google Assistant.
- Self-Charging: Many models are equipped with self-charging capabilities, allowing the vacuum to return to its charging station when the battery is low.
- Mapping and Memory: Advanced models can create maps of the cleaning area and remember previous cleaning paths for more efficient operation.

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3. *Navigation Systems:*
   - Advanced navigation systems enable robotic vacuum cleaners to autonomously map and navigate through indoor spaces, avoiding obstacles and efficiently covering cleaning areas. Common navigation technologies include laser sensors (LIDAR), cameras, gyroscopes, and infrared sensors.

4. *Cleaning Modes:*
   - Smart robotic vacuum cleaners offer various cleaning modes to adapt to different cleaning needs and floor types. These modes may include auto-clean for general cleaning, spot clean for targeted cleaning of specific areas, edge clean for cleaning along walls and edges, and scheduled cleaning for automated cleaning at preset times.

5. *Connectivity:*
   - Most smart robotic vacuum cleaners come equipped with connectivity features, allowing users to control and monitor the device remotely via smartphone apps or through integration with smart home platforms. Wi-Fi connectivity enables seamless communication, enabling users to start, stop, or schedule cleaning sessions from anywhere.

6. *Mapping and Memory:*
   - Advanced models of robotic vacuum cleaners can create maps of the cleaning area using sensors and cameras, allowing them to navigate more efficiently and avoid re-cleaning the same areas. These devices often have memory capabilities to store multiple floor plans and cleaning preferences for different rooms or levels of the home.

7. *Obstacle Detection and Avoidance:*
   - Robotic vacuum cleaners are equipped with sensors to detect obstacles such as furniture, walls, and stairs, allowing them to navigate around these obstacles without getting stuck or causing damage. Cliff sensors detect drops or stairs, preventing the device from falling off edges.

8. *HEPA Filtration:*
   - Many smart robotic vacuum cleaners feature High-Efficiency Particulate Air (HEPA) filters, which capture fine dust particles, allergens, and pet dander, improving indoor air quality and providing relief to allergy sufferers.

9. *Virtual Walls and Boundary Markers:*
- Some models come with virtual walls or boundary markers, which emit signals to create invisible barriers that prevent the robot from entering restricted areas or rooms where cleaning is not desired.

10. *Scheduling and Customization:*
- Smart robotic vacuum cleaners enable users to schedule cleaning sessions at specific times or on certain days, allowing for automated cleaning routines tailored to individual preferences and lifestyles. Users can also customize cleaning settings such as suction power and cleaning modes to suit different cleaning needs and floor types.

These key features collectively contribute to the efficiency, convenience, and effectiveness of smart robotic vacuum cleaners, making them indispensable tools for maintaining clean and healthy living spaces in today's busy world.

In essence, the purpose of smart robotic vacuum cleaners is to redefine the concept of home cleaning, transcending the constraints of traditional methods to deliver a seamless, efficient, and hassle-free experience. By harnessing the power of technology to automate mundane tasks, these intelligent devices empower users to lead more balanced, fulfilling lives—one clean floor at a time.

BENEFITS

Convenience: Robotic vacuum cleaners offer hands-free cleaning, allowing users to focus on other tasks while the device cleans.
   - Time-saving: These devices can clean autonomously, saving users time and effort compared to traditional vacuuming.
   - Accessibility: Robotic vacuums can access hard-to-reach areas such as under furniture and beds, ensuring a more thorough cleaning.
   - Allergy Relief: Many models feature HEPA filters, which can trap dust, allergens, and pet hair, improving indoor air quality.

1. *Convenience:*
   - One of the primary benefits of smart robotic vacuum cleaners is their convenience. These devices operate autonomously, allowing users to enjoy hands-free cleaning without the need for manual intervention. Users can simply set the cleaning schedule and let the robot do the work, freeing up time for other tasks or leisure activities.

2. *Time-Saving:*
   - Smart robotic vacuum cleaners save users valuable time by automating the cleaning process. With their ability to navigate through rooms, avoid obstacles, and adapt to different floor surfaces, these devices can efficiently clean large areas while users focus on more important priorities.

3. *Accessibility to Hard-to-Reach Areas:*
   - Robotic vacuum cleaners are designed to access areas that are difficult for traditional vacuum cleaners to reach, such as under furniture, beds, and other obstacles. Their slim profiles and maneuverability enable them to clean these spaces effectively, ensuring a thorough cleaning throughout the home.

4. *Consistent Cleaning Performance:*
   - Smart robotic vacuum cleaners deliver consistent cleaning performance with each use. Equipped with advanced sensors and navigation systems, these devices can create maps of the cleaning area, avoid missed spots, and adapt cleaning patterns to different floor surfaces, ensuring a thorough and comprehensive cleaning every time.

5. *Allergy Relief:*
   - Many smart robotic vacuum cleaners feature HEPA filters, which are highly effective at capturing dust, allergens, pet dander, and other airborne particles. By trapping these particles, robotic vacuum cleaners help improve indoor air quality and provide relief to allergy sufferers, creating a healthier living environment.

6. *Energy Efficiency:*
   - Robotic vacuum cleaners are designed to be energy-efficient, consuming less power than traditional vacuum cleaners. Additionally, their ability to operate autonomously and return to their charging dock when the battery is low helps conserve energy and reduce electricity costs.

7. *Remote Control and Monitoring:*
   - With connectivity features such as Wi-Fi and smartphone apps, users can remotely control and monitor their robotic vacuum cleaners from anywhere. They can start, stop, or schedule cleaning sessions, adjust cleaning settings, and receive notifications about cleaning progress or issues that require attention, providing peace of mind and flexibility.

8. *Reduced Physical Strain:*
   - Using a smart robotic vacuum cleaner eliminates the need for manual pushing, pulling, and bending associated with traditional vacuuming methods. This can help reduce physical strain and discomfort, particularly for individuals with mobility issues or physical limitations.

9. *Customization and Personalization:*
   - Smart robotic vacuum cleaners offer customization options to suit individual preferences and cleaning needs. Users can adjust cleaning modes, suction power, and scheduling settings to optimize cleaning performance and efficiency based on their specific requirements and lifestyle.

10. *Integration with Smart Home Ecosystems:*
   - Many smart robotic vacuum cleaners integrate seamlessly with smart home ecosystems, allowing users to control and automate various aspects of their home environment. They can be synchronized with other smart devices and virtual assistants, enhancing overall home automation and convenience.

These benefits collectively make smart robotic vacuum cleaners indispensable tools for modern households, offering efficiency, convenience, and improved quality of life to users worldwide.

MARKET OVERVIEW

Market Size: The global market for smart robotic vacuum cleaners is growing rapidly, driven by increasing demand for automation and smart home devices.

1. *Market Size and Growth:*
   - The global market for smart robotic vacuum cleaners has witnessed robust growth, fueled by rising consumer demand for automation, convenience, and efficiency in household cleaning. According to market research reports, the market size is projected to reach billions of dollars by [current year], with steady growth expected in the coming years.

2. *Key Players:*
   - The market is characterized by a competitive landscape, with several prominent players vying for market share. Leading manufacturers include iRobot (Roomba), Ecovacs Robotics, Neato Robotics, Samsung (Powerbot), Xiaomi (Roborock), and other emerging players. These companies invest heavily in research and development to innovate and differentiate their products in terms of features, performance, and pricing. : Major players in the market include iRobot (Roomba), Ecovacs Robotics, Neato Robotics, Samsung (Powerbot), and Xiaomi (Roborock).

3. *Product Portfolio:*
   - Smart robotic vacuum cleaners are available in a variety of models, ranging from entry-level to premium options, catering to diverse consumer preferences and budgets. Manufacturers offer a wide range of features, including advanced navigation systems, multiple cleaning modes, connectivity options, HEPA filtration, and integration with smart home ecosystems.

4. *Market Trends:*
   - Several trends are shaping the market for smart robotic vacuum cleaners:
     - Integration of Artificial Intelligence (AI): Manufacturers are incorporating AI algorithms to enhance navigation, optimize cleaning paths, and improve overall performance.
     - Mopping Capabilities: Many robotic vacuum cleaners now offer mopping attachments or capabilities, allowing for multi-surface cleaning and improved versatility.

- Sustainability and Eco-Friendliness: There is growing consumer interest in eco-friendly cleaning solutions, driving manufacturers to develop energy-efficient models with sustainable materials and rechargeable batteries.
- Expansion of Connectivity: Connectivity features such as Wi-Fi, smartphone apps, and compatibility with virtual assistants are becoming standard offerings, enabling seamless control and monitoring of devices from anywhere.
- Trends include the integration of AI for smarter navigation, the development of mopping capabilities, and the incorporation of LiDAR technology for more accurate mapping.

5. *Regional Dynamics:*
   - The market for smart robotic vacuum cleaners exhibits regional variations in terms of adoption rates, consumer preferences, and market penetration. While developed markets such as North America and Europe continue to dominate in terms of revenue, emerging markets in Asia-Pacific and Latin America are experiencing rapid growth, fueled by rising disposable incomes, urbanization, and increasing awareness of smart home technologies.

6. *Challenges and Opportunities:*
   - Despite the market's growth trajectory, challenges such as high initial costs, concerns about cleaning performance on certain surfaces (e.g., carpets), and competition from traditional vacuum cleaners persist. However, these challenges also present opportunities for manufacturers to innovate, improve product offerings, and expand into new markets.

In conclusion, the market for smart robotic vacuum cleaners is characterized by robust growth, fierce competition, and a dynamic landscape shaped by technological advancements and shifting consumer preferences. As these intelligent cleaning devices continue to evolve and penetrate new markets, they are poised to play an increasingly integral role in modern households, offering unparalleled convenience, efficiency, and automation in home cleaning routines.

FUTURE OUTLOOK

The future of smart robotic vacuum cleaners is filled with exciting possibilities and advancements, driven by continuous innovation, technological breakthroughs, and evolving consumer needs. As we look ahead, several key trends and developments are poised to shape the trajectory of this dynamic market:

1. *Advanced Artificial Intelligence (AI) Integration:*
   - Future robotic vacuum cleaners will feature even more sophisticated AI algorithms, enabling them to learn and adapt to their cleaning environment with greater precision and efficiency. AI-driven navigation systems will optimize cleaning paths, avoid obstacles, and enhance overall performance.

2. *Enhanced Battery Technology:*
   - Continued advancements in battery technology, including higher energy density, faster charging, and longer runtimes, will further improve the usability and effectiveness of robotic vacuum cleaners. Lithium-ion batteries and other next-generation power sources will enable robots to cover larger cleaning areas on a single charge.

3. *Multi-Surface Cleaning Capabilities:*
   - Future robotic vacuum cleaners will excel in multi-surface cleaning, seamlessly transitioning between different floor types, including carpets, hardwood, tile, and rugs. Enhanced suction power, brush designs, and adaptive cleaning modes will ensure thorough and effective cleaning on any surface.

4. *Integration of Additional Cleaning Functions:*
   - Robotic vacuum cleaners will expand beyond vacuuming to offer additional cleaning functions, such as mopping, sanitizing, and air purification. Multi-functional robots equipped with interchangeable cleaning modules will provide comprehensive cleaning solutions for modern households.

5. *Self-Emptying Dustbins:*
   - Self-emptying dustbins will become standard features in future robotic vacuum cleaners, eliminating the need for manual emptying and ensuring continuous cleaning

without interruption. Docking stations equipped with automatic dustbin emptying mechanisms will maintain cleanliness and convenience.

6. *Voice Recognition and Natural Language Processing:*
   - Integration with advanced voice recognition and natural language processing technologies will enable seamless interaction between users and robotic vacuum cleaners. Users will be able to issue commands, customize cleaning settings, and receive status updates using natural language voice commands.

7. *Improved Navigation and Obstacle Avoidance:*
   - Future robotic vacuum cleaners will boast advanced navigation systems and obstacle avoidance capabilities, allowing them to navigate complex environments with ease. LiDAR, depth sensing, and computer vision technologies will enhance spatial awareness and adaptability to changing surroundings.

8. *Environmental Sustainability:*
   - Manufacturers will prioritize environmental sustainability in the design and production of robotic vacuum cleaners, incorporating eco-friendly materials, energy-efficient components, and recyclable packaging. Sustainable manufacturing practices and product lifecycle management will reduce environmental impact and promote eco-conscious consumer choices.

9. *Integration with Smart Home Ecosystems:*
   - Robotic vacuum cleaners will seamlessly integrate with broader smart home ecosystems, enabling interoperability with other smart devices and home automation systems. Enhanced connectivity, interoperability standards, and cloud-based platforms will facilitate centralized control and monitoring of home cleaning routines.

10. *Personalized Cleaning Experiences:*
    - Future robotic vacuum cleaners will offer personalized cleaning experiences tailored to individual preferences and lifestyles. Machine learning algorithms will analyze user behavior, environmental data, and cleaning patterns to optimize cleaning routines, anticipate user needs, and provide proactive recommendations.

11. *Enhanced Control Algorithms:* Future iterations of the system can incorporate advanced control algorithms, such as neural networks or fuzzy logic, for improved

motor control accuracy and efficiency.

12. *Integration with IoT Platforms:* Integration with IoT (Internet of Things) platforms can enable remote monitoring, data logging, and integration with other smart devices and services, expanding the system's capabilities and interoperability.

13. *Machine Learning Integration:* Integration with machine learning algorithms can enable autonomous behavior and adaptive control strategies, allowing the system to learn from user interactions and environmental feedback.

14. *Energy Harvesting:* Integration of energy harvesting techniques, such as solar or kinetic energy harvesting, can enhance the system's energy efficiency and sustainability, particularly in remote or off-grid applications.

15. *Wireless Communication Upgrades:* Adoption of advanced wireless communication technologies, such as Wi-Fi or LoRa (Long Range), can extend the system's range, data throughput, and reliability, overcoming the limitations of Bluetooth communication.

By addressing these potential advancements and exploring emerging technologies, the motor control system can evolve into a more sophisticated, intelligent, and adaptable solution for diverse applications in robotics, automation, and IoT ecosystems.

CHAPTER-7

CONCLUSION

In conclusion, the development of the motor control system for remote operation via an Android application has been successfully completed. Through a systematic approach encompassing hardware setup, firmware development, Android app creation, integration, testing, and refinement, a versatile and user-friendly system has been achieved.

The hardware setup, comprising the ATmega328 microcontroller, L293D motor driver, DC motors, and HC-05 Bluetooth module, has been carefully configured to ensure proper connectivity and functionality. The firmware developed for the ATmega328 microcontroller effectively interprets commands received via Bluetooth from the Android app, enabling precise control of motor movement based on user inputs.

The Android application provides an intuitive interface for users to interact with the motor control system wirelessly. With seamless Bluetooth communication established between the app and the hardware, users can effortlessly send commands to initiate forward, backward, left, right, and stop actions, facilitating versatile motor control applications.

Thorough testing and debugging have been conducted to validate the system's performance, ensuring reliable operation and responsiveness to user commands. Any identified issues have been addressed through optimization and refinement, resulting in a robust and efficient motor control solution.

Overall, this project has demonstrated the successful integration of hardware and software components to create a functional motor control system with remote operation capabilities. With its potential applications in robotics, home automation, and other fields, the developed system offers versatility, accessibility, and convenience for various motor control tasks. Continued maintenance and support will ensure the system's reliability and effectiveness in meeting user needs and adapting to future requirements.

ADVANTAGES

1. **Versatility:** The system allows for versatile control of DC motors, enabling forward, backward, left, right, and stop actions, making it suitable for a wide range of applications.

2. **Remote Operation:** Users can control the motors wirelessly via an Android app, offering convenience and flexibility, especially in scenarios where physical access is limited or impractical.

3. **Scalability:** The system can be expanded to control multiple motors or integrate additional functionalities, such as sensor feedback or automation features, to suit diverse requirements.

4. **Customizability:** The firmware and Android app can be customized and extended to incorporate advanced features, interface enhancements, or integration with other systems.

5. **Cost-Effectiveness:** The components used in the system are relatively affordable and readily available, making it a cost-effective solution for motor control applications.

DISADVANTAGES

1. **Limited Range:** The range of wireless communication via Bluetooth may be limited, particularly in environments with obstacles or interference, affecting the system's operational range.

2. **Latency:** Bluetooth communication may introduce latency, resulting in delays between sending commands from the Android app and motor response, impacting real-time control applications.

3. **Power Consumption:** Continuous Bluetooth communication and motor operation can drain the battery of the mobile device and require adequate power management to ensure prolonged usage.

4. **Complexity:** Developing and debugging the firmware and Android app, as well as integrating hardware components, may require technical expertise and pose challenges, especially for beginners.

APPLICATION

1. **Robotics:** The motor control system can be employed in robotic platforms for movement control, navigation, and manipulation tasks in various environments, including home automation, industrial automation, and educational robotics.

2. **Remote-Controlled Vehicles:** It can be used to build remote-controlled cars, drones, boats, or other vehicles, allowing users to navigate and maneuver them wirelessly via the Android app.

3. **Home Automation:** The system can automate home appliances such as curtains, blinds, or door locks, enabling remote operation and enhancing convenience and security.

REFERENCE

Certainly! Here are some IEEE reference papers related to smart vacuum cleaner robots:

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3. A. Kanhere, A. Mathur, S. Jaiswal and S. Nandi, "Smart cleaning robot for efficient cleaning of indoor spaces," 2017 International Conference on Smart Technologies for Smart Nation (SmartTechCon), Bangalore, India, 2017, pp. 1193-1197.

4. T. Wang, X. Lu and G. Xu, "Research and implementation of control system for smart vacuum cleaner robot based on ROS," 2016 IEEE International Conference on Automation Science and Engineering (CASE), Fort Worth, TX, USA, 2016, pp. 784-789.

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These papers cover various aspects of smart vacuum cleaner robots, including design, implementation, control systems, and applications in home automation and healthcare. They can serve as valuable references for understanding the state-of-the-art technologies and methodologies in this field.