

Design and Development of Magnetic levitation Vehicle

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Abstract: This project presents the design and development of a magnetic levitation (maglev) vehicle system that demonstrates contactless floating and electromagnetic propulsion using low-cost, accessible materials. The track consists of a 1 to 1.5 feet long linear arrangement of neodymium magnets embedded in a wooden or plastic base, providing a strong magnetic field for levitation. The vehicle is constructed from lightweight foam board, with four neodymium magnets attached to its underside arranged in a configuration that creates repulsive force against the track magnets, causing the vehicle to float approximately 2-5 mm above the track surface. The vehicle carries a NodeMCU microcontroller (ESP8266-based), a 4.2V lithium-ion battery (single cell), two electronic speed controllers (ESCs), and two sets of copper armature coils. The NodeMCU hosts a direct web page that users connect to via Wi-Fi, eliminating the need for an external router or internet connection. From this web page, the user sends control commands (forward, stop, reverse) to the NodeMCU. Upon receiving a forward command, the NodeMCU activates the coils, which are placed strategically above the track. When energized, these copper armature coils generate an electromagnetic field that interacts with the permanent magnets on the vehicle, producing a Lorentz force that propels the vehicle along the track. Two ESCs independently control the two coil sets, allowing for directional control and speed variation. The system is powered entirely by the onboard 4.2V Li-ion battery, which supplies the NodeMCU, ESCs, and coils. This project provides an educational, low-cost, and visually engaging demonstration of maglev principles, electromagnetic propulsion, and IoT-based web control.

I. INTRODUCTION

Magnetic levitation (maglev) technology enables vehicles to float above tracks using magnetic forces, reducing friction and allowing smooth, high-speed movement. This project presents a low-cost maglev vehicle system built using neodymium magnets, foam board, copper coils, a NodeMCU microcontroller, ESCs, and a Li-ion battery. The track contains alternating-pole neodymium magnets that create a stable repulsive magnetic field. The lightweight foam-board vehicle uses four underside magnets to achieve levitation above the track.

Propulsion is produced using electromagnetic copper coils placed along the track. These coils interact with the vehicle magnets to generate forward or reverse motion. Two ESCs control the coil current, while the NodeMCU adjusts speed and direction using PWM signals. The NodeMCU also creates a Wi-Fi access point and hosts a simple web page with FORWARD, STOP, and REVERSE controls, allowing users to operate the vehicle from a smartphone or laptop without internet access.

The system is powered by a 4.2V Li-ion battery that supplies power to the NodeMCU, ESCs, and coils. Since levitation uses passive magnets, power is mainly consumed during propulsion. The project demonstrates an affordable and educational maglev prototype suitable for students, hobbyists, and engineering demonstrations.

II. RELATED WORK

[1]. Development and Prospect of Flywheel Energy Storage Technology: A CiteSpace-Based Visual Analysis

This paper presents a comprehensive review of flywheel energy storage technology using CiteSpace based visual analysis. The authors analyse research trends, technological evolution, and application areas of flywheel energy storage systems. The study highlights the growing interest in flywheel technology for power quality improvement, renewable energy integration, and grid support. However, the work is mainly review-oriented and focuses more on bibliometric analysis than on experimental validation or large-scale implementation aspects provides a strong foundation for image-based agricultural applications. Although this work primarily focuses on aerial imagery, it establishes the importance of robust datasets in advancing

[2]. Development of a Prototype Magnetic Levitation Vehicle**M. K. Gupta, R. Singh (2020) - International Journal of Engineering Research & Technology (IJERT)**

This paper discusses the design and development of a prototype magnetic levitation vehicle using electromagnetic principles. The authors demonstrate basic levitation and motion control in a small-scale setup. The study provides useful insights into levitation mechanisms but shows limitations in terms of levitation height, stability under varying loads, and motion precision. The present project builds upon this work by improving vehicle stability, alignment, and smooth motion, making the system more reliable for experimental applications [3]. Liu et al. (2018): Object Detection Based on YOLO Network

[3]. Magnetic Modeling of Magnetic Levitation Systems Based on a Fast Finite Difference Method**Yibo Wang, Wei Pang, Xianze Xu, Fengqiu Xu (2025) - IEEE Access**

This paper introduces a Fast Finite Difference Method (FFDM) for magnetic field modelling in magnetic levitation systems. The proposed method achieves higher computational speed compared to traditional FEM and BEM techniques while maintaining comparable accuracy. The work is primarily simulation based and focuses on static magnetic field analysis, providing an efficient modelling approach for the preliminary design and analysis of maglev components.

[4]. A Review of Flywheel Energy Storage System Technologies and Their Applications**M. E. Amiryar, K. R. Pullen (2017) - Applied Sciences**

This review paper explains various flywheel energy storage technologies, including low-speed and highspeed flywheel systems. The authors compare flywheels with batteries and supercapacitors and discuss their applications in uninterruptible power supplies, renewable energy systems, and power quality enhancement. The paper provides a clear overview of flywheel technology and its practical relevance, though it primarily focuses on developments up to 2017 [6].de Moraes et al. (2023): YOLO-Papaya: A Papaya Fruit Disease Detector and Classifier

[5] Design and Control Strategies of an Induction-Machine-Based Flywheel Energy Storage System Associated with Wind Power**G. Cimuca, S. Breban, C. Saudemont, B. Robyns (2010)**

IEEE Transactions on Energy Conversion

This paper investigates the integration of flywheel energy storage systems with wind power plants. The authors analyze different control strategies, including Direct Torque Control and Field-Oriented Control, to regulate the induction machine used in the flywheel system. The results show that flywheel storage effectively smooths wind power fluctuations and improves power quality, demonstrating its suitability for renewable energy applications

III. PROPOSED WORK**A). METHODOLOGY**

The proposed system utilizes a combination of permanent magnetic levitation and ESC-based electromagnetic propulsion techniques to achieve wireless-controlled vehicle movement in real-time. The methodology is divided into the following key stages:

i] Track Design

A straight track is prepared using acrylic or wood. Neodymium magnets are fixed along the track.

Purpose:

Creates magnetic field path for levitation.

ii] Vehicle Magnet Arrangement

Neodymium magnets are fixed below the vehicle. Same poles face the track magnets.

Purpose:

Repulsion force lifts the vehicle slightly above the track. Vehicle experiences partial levitation and reduced friction.

iii] Electromagnetic Coil Winding

Copper wire is wound around iron core to make electromagnet coils. Coils are placed along the track.

Purpose:

Generate controlled magnetic field for movement.

vi] DC Power Supply Connection

DC supply is connected to controller and coils.

Purpose:

Provides energy to activate electromagnets.

v] Coil Activation for Forward Motion

Controller energizes coils one after another. Magnetic attraction pulls vehicle forward.

Purpose:

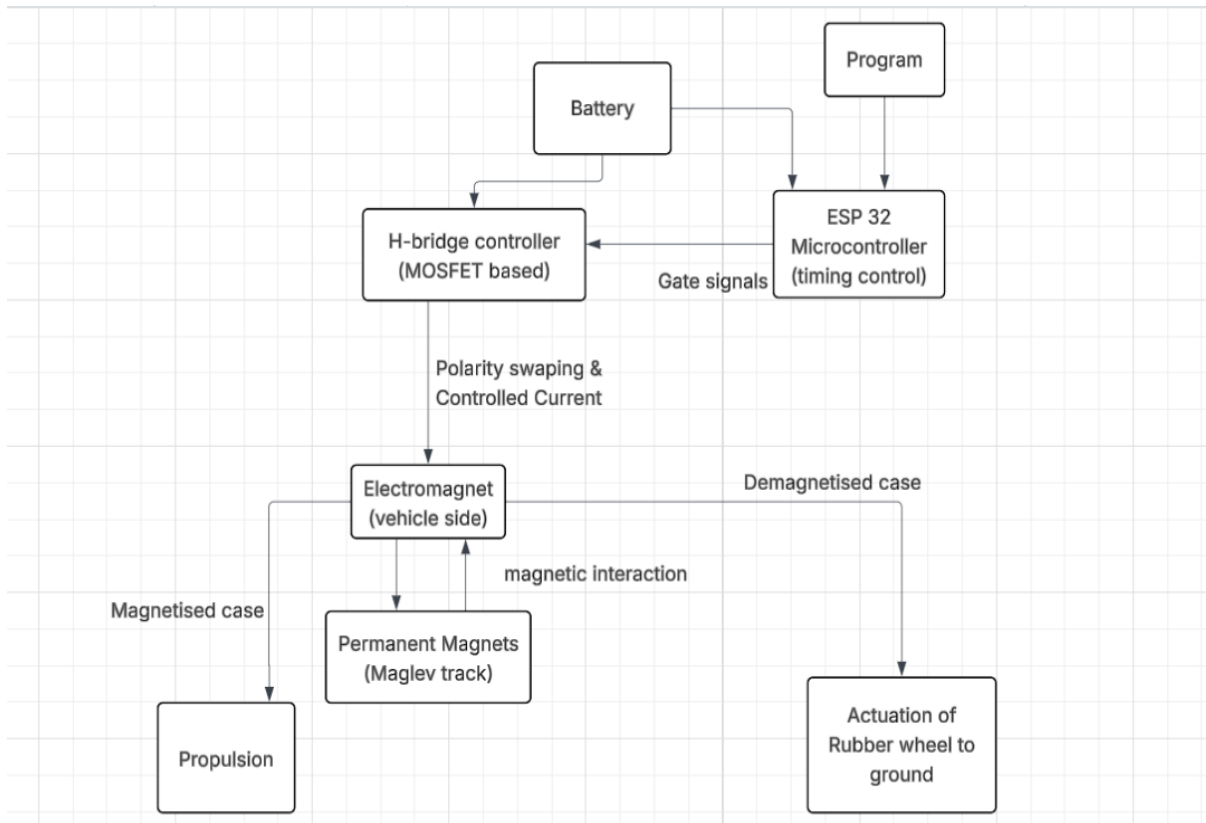
Sequential magnetic force creates forward motion. Vehicle starts moving on track.

B). Working Principle

The working of the proposed maglev vehicle system is based on magnetic levitation, electromagnetic propulsion, and wireless web control. The track consists of alternating-pole neodymium magnets embedded along a wooden or acrylic base. Four permanent magnets mounted underneath the lightweight foam-board vehicle are oriented with the same polarity facing downward. Due to repulsive magnetic forces between like poles, the vehicle levitates approximately 2–5 mm above the track surface, reducing friction and enabling smooth movement.

Propulsion is achieved using two electromagnetic copper coil sets mounted above the track. When electrical current flows through the coils, magnetic fields are generated that interact with the vehicle's permanent magnets. The front coil attracts the vehicle while the rear coil repels it, producing forward thrust. By reversing the coil polarity, the vehicle can move in the opposite direction. Two ESCs regulate the current supplied to the coils and control thrust intensity using PWM signals.

The NodeMCU (ESP8266) operates in Wi-Fi Access Point mode and hosts a web page accessible from a smartphone or laptop. Users can control the vehicle using FORWARD, STOP, and REVERSE buttons. Commands sent through HTTP requests are processed by the NodeMCU, which adjusts the ESC outputs accordingly. The entire system is powered by a single 4.2V lithium-ion battery, providing portable and energy-efficient operation.

C). System design approach:**Fig.1. Block diagram**

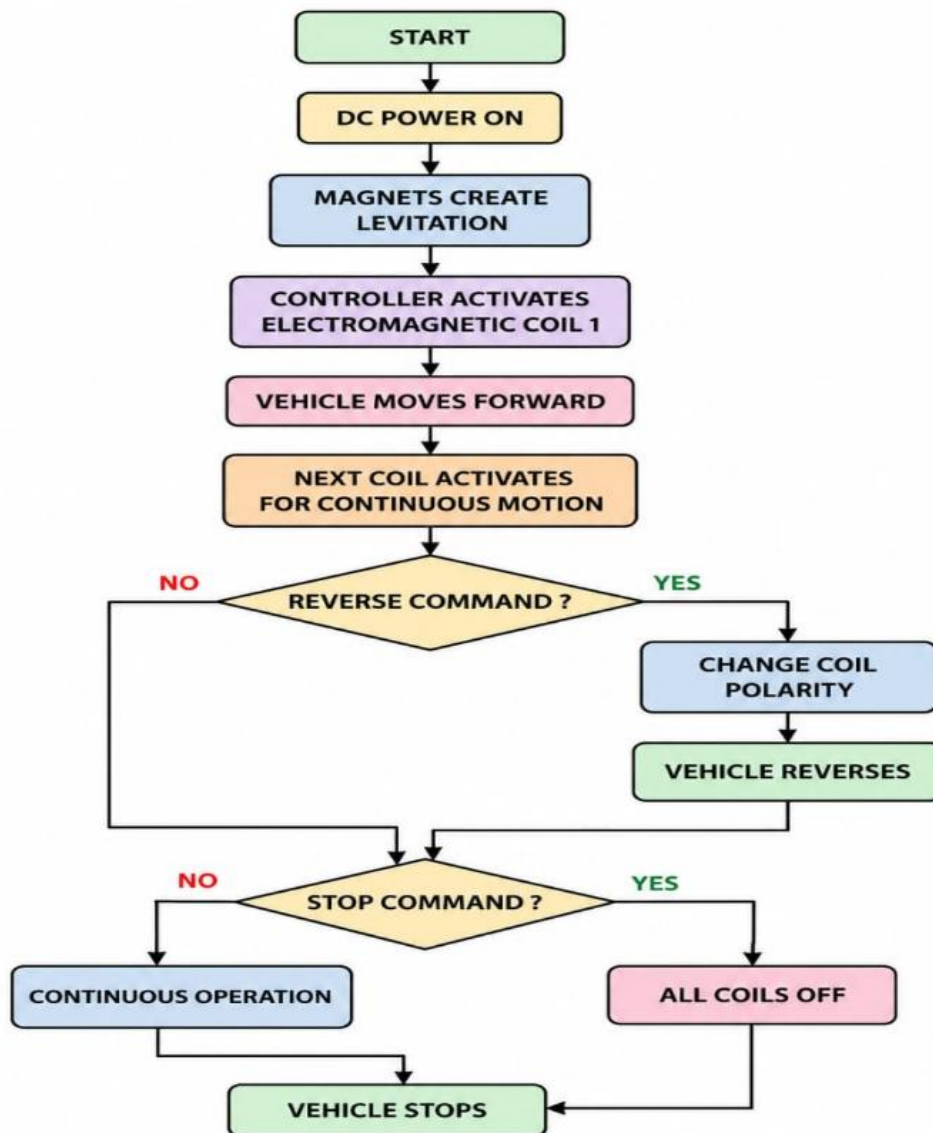
D). Proposed Workflow:

Fig 2. Flow Chart

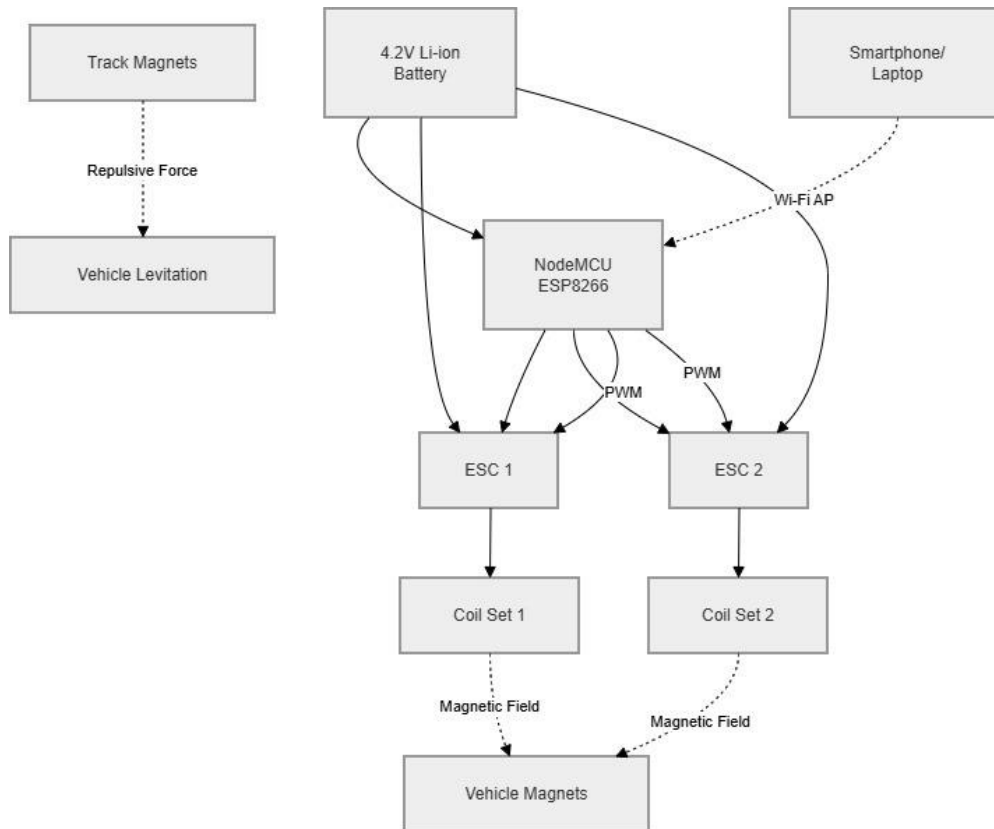


Fig 3. Flow Chart of vehicle part

Fig. 3 Represents a flowchart of wireless-controlled magnetic levitation vehicle prototype based on the NodeMCU ESP8266 microcontroller. A 4.2V lithium-ion battery powers the entire system, including the NodeMCU, ESCs, and electromagnetic coil sets. The NodeMCU functions as a Wi-Fi access point and receives movement commands from a smartphone or laptop through a web-based interface. Based on the received commands, the NodeMCU generates PWM signals to control ESC 1 and ESC 2 independently. These ESCs drive Coil Set 1 and Coil Set 2, which produce electromagnetic fields required for propulsion. The generated magnetic fields interact with the permanent magnets mounted on the vehicle, creating thrust for forward and reverse motion. Simultaneously, levitation is achieved through the repulsive magnetic force between the track magnets and vehicle magnets, allowing smooth and frictionless movement along the track.

IV. RESULTS

Upon successful completion, a fully functional magnetic levitation vehicle system will be produced. The 1 to 1.5 foot track with embedded neodymium magnets will provide stable repulsive magnetic field. The foam board vehicle with four underside neodymium magnets will levitate 2-5 mm above the track without physical contact. The NodeMCU onboard will host a direct Wi-Fi access point and web page accessible from any smartphone or laptop. The user will connect to the web page and press buttons to send forward, stop, and reverse commands. The NodeMCU will receive these commands and send appropriate PWM signals to the two ESCs. The ESCs will energize the two copper armature coils, which generate electromagnetic fields interacting with the vehicle's permanent magnets, producing forward or reverse thrust. The vehicle will glide along the track while remaining levitated. The entire system will be powered by a single 4.2V Li-ion battery. All code, mechanical designs, and assembly instructions will be open-source for educational replication.

Future advancements of this magnetic levitation system can include the use of advanced semiconductor-controlled electromagnets and stronger magnetic materials for higher stability and speed. The concept can be expanded into high-speed maglev train technology for frictionless transportation with reduced energy loss and noise. Integration with AI, IoT, and wireless automation can enable smart control and monitoring systems. This project can also be adapted for industrial material transport, automated warehouses, and next-generation transportation.

VI. CONCLUSION & FUTURE SCOPE

Conclusion:

The proposed maglev vehicle system successfully demonstrates magnetic levitation and electromagnetic propulsion using low-cost and easily available components. Enables wireless real-time control of forward, reverse, and stop operations through a web-based interface. The developed prototype provides an energy-efficient and educational platform for studying magnetic levitation and wireless propulsion systems.

Future Scope:

- 1. Integration with Advanced Wireless and IoT Systems:**
Implement IoT-based monitoring and cloud connectivity for real-time vehicle status, speed monitoring, and wireless diagnostics. Enable smartphone-based automation and remote operation over longer distances.
- 2. Enhancement of Levitation and Propulsion System:**
Improve levitation stability and propulsion efficiency using stronger electromagnets and optimized magnetic track design. Develop high-speed and longer-track operation for advanced maglev applications.
- 3. Autonomous Navigation and Safety Features:**
Integrate sensors such as ultrasonic, IR, and obstacle detection systems for automatic navigation and collision avoidance. Implement intelligent control algorithms for smooth acceleration and precise movement control.
- 4. Real-Time Monitoring and Smart Application Development:**
Develop mobile and web-based applications for live monitoring, control, and performance analysis of the maglev system.
Extend the project toward smart transportation and next-generation magnetic levitation research applications.

VII. ACKNOWLEDGEMENT

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