International Journal of Creative and Open Research in Engineering and Management
ISSN: **3108-1754 (Online)**
Volume 02 Issue 05 May-2026 | Impact Factor: 3.5

Electromagnetic Launch Module

Samir Sayyad[1], Vivek Kharche[2], Arshad Maniyar[3]

[1] Electronics & Telecommunication, Shatabdi Institute of Engineering, Nashik, Maharashtra, India
[2] Electronics & Telecommunication, Shatabdi Institute of Engineering, Nashik, Maharashtra, India
[3] Electronics & Telecommunication, Shatabdi Institute of Engineering, Nashik, Maharashtra, India
Corresponding Author Email: samirsayyad2024@gmail.com

How to Cite this Article:

Sayyad, S., Kharche, V. & Maniyar, A. (2026). Electromagnetic Launch Module. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(05). https://doi.org/10.55041/ijcope.v2i5.327

https://doi.org/10.55041/ijcope.v2i5.327

Abstract—

The Electromagnetic Launch Module (ELM) is a compact electromagnetic acceleration system developed to demonstrate the practical implementation of electromagnetism, automation, and embedded control systems. The system is designed to accelerate an iron ball along a circular track using sequentially activated electromagnetic coils controlled through sensor-based switching mechanisms. The primary objective of this project is to achieve controlled electromagnetic motion, speed measurement, and automated operation in a compact and cost-effective setup.

The proposed system consists of electromagnetic coils (L1, L2, L3, and L4)**,** MOSFET switching circuits (IRF540N)**,** BC557 transistors**,** Infrared (IR) sensors, an Arduino Nano**,** a servo motor-based gate mechanism, and an LCD display for real-time speed monitoring. A 24V DC power supply is used to energize the coils, generating magnetic fields that accelerate the iron ball through electromagnetic attraction. The IR sensors continuously detect the position of the ball and provide signals for synchronized coil activation.

The Arduino Nano performs speed measurement by processing sensor timing data and displays the calculated speed on the LCD display. Additionally, a servo motor is integrated to control the gate mechanism, which opens automatically only when the ball reaches a predefined constant speed, ensuring stable and controlled operation. The mechanical structure of the system is designed using Maya and fabricated through 3D printing using Bambu Studio, improving structural accuracy and system compactness.

Experimental results demonstrated successful electromagnetic acceleration, reliable speed measurement, and synchronized system operation. The developed prototype effectively serves as an educational and experimental model for understanding electromagnetism, automation, and motion control while providing a low-cost and practical engineering solution.

Experimental testing of the Electromagnetic Launch Module demonstrates successful particle acceleration, synchronized coil operation, accurate speed measurement, and reliable gate automation. The system effectively validates the use of electromagnetic force for motion control while maintaining compact size and low implementation cost. Although minor challenges such as heat generation and synchronization delay were observed, the system provides a strong platform for future improvements in electromagnetic launch technology.

Keywords— Electromagnetic Launch Module (ELM), Electromagnetic Coils, Arduino Nano, IR Sensors, Speed Measurement, Servo Motor, Electromagnetic Acceleration, 3D Printing.

I. INTRODUCTION

The Electromagnetic Launch Module (ELM) is a compact electromagnetic acceleration system designed to demonstrate the practical application of electromagnetism, embedded systems, and automation. The system uses electromagnetic coils (L1, L2, L3, and L4) to generate magnetic fields that accelerate an iron ball along a circular path through sequential coil activation [1], [2]. The operation of the system is controlled using MOSFET switching circuits, BC557 transistors, and Infrared (IR) sensors, which ensure proper synchronization of coil activation [3].

An Arduino Nano is used to measure the speed of the ball and control the gate mechanism through a servo motor. The measured speed is displayed on an LCD display for real-time monitoring [4]. The ring structure of the system is designed using Autodesk Maya and fabricated through 3D printing using Bambu Studio, providing a compact and precise structure [5].

The Electromagnetic Launch Module serves as an educational and experimental platform for understanding electromagnetic acceleration, control systems, and automation while demonstrating a cost-effective and compact implementation of electromagnetic motion [6].

II. LITERATURE REVIEW

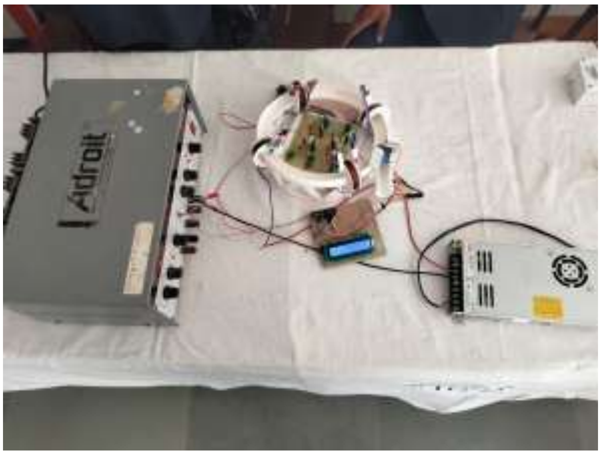
Electromagnetic acceleration systems have been widely studied for their applications in particle motion, transportation, and launching mechanisms. Research on electromagnetic launch technology explains how magnetic fields generated by electromagnetic coils can be used to accelerate objects without physical contact, improving efficiency and reducing mechanical wear [7]. The principles of electromagnetic acceleration are commonly used in systems such as railguns, maglev transportation, and particle accelerators [8].

Several studies on particle accelerator physics explain the use of electromagnetic fields for controlled motion and acceleration of particles. These studies provide the theoretical foundation for electromagnetic propulsion and magnetic force generation used in compact experimental systems [9], [10]. However, conventional acceleration systems are generally expensive, large in size, and require complex infrastructure, making them unsuitable for educational demonstrations and small-scale experiments [11].

Research in power electronics and switching systems highlights the importance of MOSFET-based control circuits for efficient activation of electromagnetic coils. High-speed switching devices such as MOSFETs improve coil synchronization and reduce power losses in electromagnetic systems [12]. Additionally, flyback diode protection techniques are widely used to protect switching components from back electromotive force (EMF) generated by inductive loads [13].

Sensor-based control methods using Infrared (IR) sensors have also been extensively studied for object detection and automation. IR sensors provide accurate real-time position detection and are widely used in automated control systems due to their fast response and reliability [14]. Similarly, microcontroller platforms such as the Arduino Nano have become popular for automation, speed measurement, and sensor integration because of their compact size and programmable features [15].

Figure 1. Simulation and Modeling



Based on the reviewed literature, it is observed that integrating electromagnetic coils, sensor feedback, microcontroller control, and automated switching can create an efficient and compact electromagnetic launch system. Therefore, the proposed Electromagnetic Launch Module (ELM) is developed as a low-cost educational prototype to demonstrate electromagnetic acceleration, speed measurement, and automated gate control [16].

III. SYSTEM DEVELOPMENT

1. System Architecture

The Electromagnetic Launch Module (ELM) is designed as an integrated electromagnetic acceleration system consisting of mechanical, electrical, and embedded subsystems. The main architecture includes a 24V DC power supply, electromagnetic coils (L1–L4), MOSFET switching circuits (IRF540N), BC557 transistors, Infrared (IR) sensors, Arduino Nano, servo motor, and LCD display. The power supply energizes the coils, while the Arduino Nano processes sensor data, calculates ball speed, controls the gate mechanism, and displays speed on the LCD screen. The entire structure is mounted on a 3D printed circular ring platform for smooth ball movement.

2. Working Principle

The working principle of the Electromagnetic Launch Module is based on electromagnetic attraction. When electric current flows through an electromagnetic coil, a magnetic field is generated that attracts the iron ball toward the energized coil. Multiple coils are arranged around the circular ring and activated sequentially to maintain continuous motion. The IR sensors detect the ball position and send signals to the control system. Based on these signals, the switching circuit activates the corresponding coil to accelerate the ball. The process repeats continuously to achieve smooth electromagnetic motion.

3. Circuit Design

The circuit of the Electromagnetic Launch Module consists of MOSFETs (IRF540N) used for switching the electromagnetic coils. The MOSFETs receive control signals and energize the required coils at the appropriate time. BC557 transistors assist in signal amplification and switching control. 1N5822 diodes are connected across the coils to protect MOSFETs from reverse voltage spikes generated by back electromotive force (EMF). Resistors are used for current limiting and signal stabilization, while LED indicators provide visual feedback of system operation.

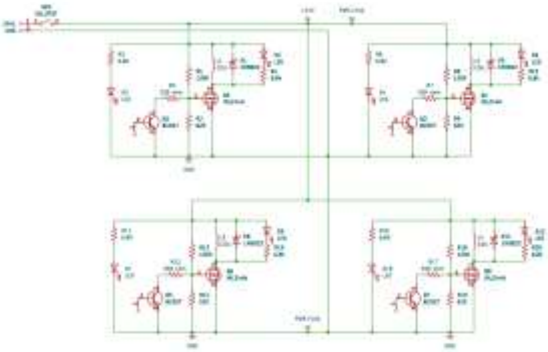


Figure 2. Circuit Diagram of Electromagnetic Launch Module

4. Components Used

The system includes several hardware and software components for proper functioning. The major hardware components include electromagnetic coils, IRF540N MOSFETs, BC557 transistors, IR sensors, Arduino Nano, servo motor, LCD display, diodes, resistors, and a 24V DC power supply. The ring structure is fabricated using PLA material through 3D printing. Software tools such as Maya are used for 3D modeling, Bambu Studio for slicing and printing, and Arduino IDE for programming and system control.

5. Arduino Nano Working

The Arduino Nano acts as the central control unit of the Electromagnetic Launch Module. It receives signals from the IR sensors and calculates the speed of the iron ball based on sensor timing data. The Arduino processes these inputs and controls the servo motor mechanism according to predefined conditions. The measured speed value is transmitted to the LCD display for real-time monitoring. The Arduino Nano is programmed using the Arduino IDE for accurate timing, automation, and synchronization.

6. Servo Motor Gate Mechanism

A servo motor is used to control the gate mechanism of the Electromagnetic Launch Module. The gate remains closed during normal operation and opens automatically only when the ball reaches a predefined constant speed. The Arduino Nano sends a control signal to the servo motor after verifying the speed condition. This mechanism ensures controlled motion, prevents unstable launching, and improves overall system safety and automation.

7. LCD Speed Display

The 16×2 LCD display is used to display the real-time speed of the moving iron ball. The Arduino Nano continuously calculates the speed using sensor timing data and sends the measured value to the LCD. This display enables users to monitor the system performance, observe experimental results, and analyze the effectiveness of electromagnetic acceleration during operation.

8. 3D Modeling and Printing

The circular launch ring and structural components of the Electromagnetic Launch Module were designed using Maya software to achieve accurate dimensions and proper component alignment. After completing the design, the model was processed using Bambu Studio for slicing and preparing the file for 3D printing. The components were printed using PLA material, which provided sufficient strength, durability, and precision for experimental operation. The use of 3D printing improved system compactness and enabled easy modification of the structure.

IV. RESULTS AND DISCUSSION

The developed Electromagnetic Launch Module (ELM) was successfully designed, fabricated, and tested to demonstrate electromagnetic acceleration using sequential coil activation. The experimental setup showed effective movement of the iron ball along the circular launch ring through the magnetic force generated by the electromagnetic coils. The system operated according to the intended design, validating the concept of electromagnetic motion control. During testing, the electromagnetic coils (L1, L2, L3, and L4) generated sufficient magnetic fields to attract and accelerate the iron ball along the track. The MOSFET switching circuit successfully controlled the ON/OFF operation of the coils, ensuring sequential activation and smooth movement of the particle. Proper synchronization between the coils improved the acceleration process and maintained continuous motion.

The Infrared (IR) sensors accurately detected the position of the iron ball and transmitted signals to the control system. Based on the sensor inputs, the Arduino Nano calculated the speed of the ball and displayed the measured value on the LCD display in real time. The displayed speed values were consistent during repeated experiments, indicating reliable system performance and accurate measurement. The servo motor-based gate mechanism functioned effectively by opening automatically only when the iron ball reached the predefined constant speed. This feature improved operational safety and ensured controlled movement within the system. The automation of the gate mechanism minimized manual intervention and enhanced the reliability of the launch process. The ring structure modeled using Maya and fabricated using Bambu Studio through 3D printing provided proper alignment for the coils, sensors, and particle pathway. The structural design contributed to stable operation and smooth movement of the iron ball throughout experimentation.

However, certain limitations were observed during continuous operation. Minor heat generation occurred in the electromagnetic coils due to high current flow, and slight timing variations were observed in sensor-coil synchronization during prolonged testing. These issues can be minimized through better cooling systems and improved control optimization.

Parameter	**Observation**
Coil Activation	Sequential switching achieved successfully
IR Sensor Detection	Accurate ball detection
Speed Measurement	Real-time speed displayed on LCD
Servo Motor Operation	Gate opened at predefined speed
Power Supply Performance	Stable 24V operation
Heat Generation	Minor heating observed in coils
Overall Performance	Successful electromagnetic acceleration

Table I: Performance Observation

V. CONCLUSION

The Electromagnetic Launch Module (ELM) was successfully designed, developed, and implemented to demonstrate the practical application of electromagnetic acceleration, embedded systems, and automation. The project effectively utilized electromagnetic coils, MOSFET switching circuits, IR sensors, an Arduino Nano, a servo motor, and an

LCD display to achieve controlled motion and real-time monitoring of the iron ball.

The system successfully demonstrated the principle of electromagnetic force by accelerating the iron ball through sequential activation of coils around the circular track. The IR sensors accurately detected the ball position, while the Arduino Nano effectively measured the ball speed and displayed the results on the LCD screen. The servo motor-controlled gate mechanism operated successfully by opening automatically when the ball reached a predefined constant speed, improving system automation and operational control.

The use of Maya for 3D modeling and Bambu Studio for 3D printing enabled accurate fabrication of the ring structure and component placement, contributing to smooth system operation and structural stability. Experimental testing confirmed reliable coil synchronization, effective speed measurement, and stable electromagnetic acceleration.Although minor challenges such as coil heating and slight synchronization delays were observed during continuous operation, the overall performance of the system was successful. These limitations can be improved in future work through better cooling methods, optimized control systems, and enhanced sensor accuracy.

Overall, the developed Electromagnetic Launch Module proved to be an efficient educational and experimental prototype for understanding electromagnetism, motion control, sensor integration, and automation. The project successfully achieved its objectives and demonstrated the feasibility of compact electromagnetic acceleration systems for engineering applications.

ACKNOWLEDGMENT

We express our sincere gratitude to the faculty members and staff of Shatabdi Institute of Engineering & Research, affiliated with Savitribai Phule Pune University, for their valuable guidance, encouragement, and support throughout the development of the Electromagnetic Launch Module (ELM) project. We would also like to thank our project guide and all contributors for providing technical assistance, resources, and motivation during the successful completion of this project. Finally, we express our gratitude to our family and friends for their continuous support and encouragement.

REFERENCES

[1] T. P. Wangler, *RF Linear Accelerators*. New York, NY, USA: Wiley, 2008.

[2] S. Humphries, *Principles of Charged Particle Acceleration*. New York, NY, USA: Wiley, 1999.

[3] I. R. McNab, “Electromagnetic launch technology,” *IEEE Transactions on Magnetics*, vol. 39, no. 1, pp. 295–304, Jan. 2003.

[4] M. H. Rashid, *Power Electronics: Circuits, Devices and Applications*, 4th ed. Noida, India: Pearson, 2014.

[5] H. D. Fair, “Electromagnetic launch science and technology,” *IEEE Transactions on Magnetics*, vol. 43, no. 1, pp. 93–98, Jan. 2007.

[6] H. Wiedemann, *Particle Accelerator Physics*, 4th ed. Cham, Switzerland: Springer, 2015.

[7] M. Reiser, *Theory and Design of Charged Particle Beams*. New York, NY, USA: Wiley, 2008.

[8] P. Horowitz and W. Hill, *the Art of Electronics*, 3rd ed. Cambridge, U.K.: Cambridge Univ. Press, 2015.

[9] S. Monk, *Arduino Projects for Beginners*. New York, NY, USA: McGraw-Hill, 2014.

[10] S. Y. Lee, *Accelerator Physics*, 3rd ed. Singapore: World Scientific, 2012.

[11] J. Boxall, *Arduino Workshop: A Hands-On Introduction with 65 Projects*. San Francisco, CA, USA: No Starch Press, 2013.

[12] A. Malvino and D. Bates, *Electronic Principles*, 8th Ed. New York, NY, USA: McGraw-Hill, 2015.

[13] R. Boylestad and L. Nashelsky, *Electronic Devices and Circuit Theory*, 11th Ed. New Delhi, India: Pearson, 2013.

[14] N. Mohan, T. Undeland, and W. Robbins, *Power Electronics: Converters, Applications, and Design*, 3rd ed. Hoboken, NJ, USA: Wiley, 2003.

[15] S. Franco, *Design with Operational Amplifiers and Analog Integrated Circuits*, 4th Ed. New York, NY, USA: McGraw-Hill, 2014.

[16] D. A. Bell, *Electronic Devices and Circuits*, 5th Ed. New Delhi, India: Oxford Univ. Press, 2008.

[17] M. H. Rashid, *Power Electronics: Circuits, Devices and Applications*, 4th ed. Noida, India: Pearson, 2014.

[18] D. A. Bell, *Electronic Devices and Circuits*, 5th Ed. New Delhi, India: Oxford Univ. Press, 2008.

[19] I. R. McNab, “Electromagnetic launch technology,” *IEEE Transactions on Magnetics*, vol. 39, no. 1, pp. 295–304, Jan. 2003.

[20] H. D. Fair, “Electromagnetic launch science and technology,” *IEEE Transactions on Magnetics*, vol. 43, no. 1, pp. 93–98, Jan. 2007.

[21] P. Horowitz and W. Hill, *the Art of Electronics*, 3rd ed. Cambridge, U.K.: Cambridge Univ. Press, 2015.

[22] R. Boylestad and L. Nashelsky, *Electronic Devices and Circuit Theory*, 11th Ed. New Delhi, India: Pearson, 2013.

[23] Autodesk Maya Documentation.

[24] Bambu Studio Documentation.

[25] J. Boxall, *Arduino Workshop: A Hands-On Introduction with 65 Projects*. San Francisco, CA, USA: No Starch Press, 2013.

[26] Arduino IDE Documentation.

[27] A. Malvino and D. Bates, *Electronic Principles*, 8th Ed. New York, NY, USA: McGraw-Hill, 2015.

[28] S. Monk, *Arduino Projects for Beginners*. New York, NY, USA: McGraw-Hill, 2014.

[29] Autodesk Maya Documentation.

[30] Bambu Studio Documentation.