

AUTOMATIC BOTTLE CAPPING MACHINE**Ketan Dinesh Patil^{*a}, Om Anil Atram^b, Yash Yogesh Naik^c, Prof. Shahu A. Zalate^d***A,b,c Student, Mechanical Department, Sandip Foundation's Sandip Polytechnic,
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Article Received: 29 January 2026, Article Revised: 17 February 2026, Published on: 09 March 2026

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DOI: <https://doi-doi.org/101555/ijarp.6329>**ABSTRACT:**

Automation has become a fundamental requirement in modern industrial manufacturing due to increasing demand for high production rates, consistent product quality, and reduced operational costs. The packaging industry, especially in beverage, pharmaceutical, cosmetic, and chemical sectors, relies heavily on efficient sealing systems to ensure product safety and prevent contamination or leakage. Bottle capping is a crucial stage in packaging lines, as improper sealing can lead to product wastage, spoilage, and customer dissatisfaction. Traditionally, bottle capping operations were performed manually or using semi-automatic systems, which often resulted in inconsistent torque application, reduced production speed, and higher labor dependency. This research paper presents the design and development of an Automatic Bottle Capping Machine using the Arduino Uno as the main control unit. The proposed system integrates mechanical components such as a conveyor mechanism, cap feeder, and rotating capping head along with electronic components including infrared sensors, motor drivers, and DC motors. The Arduino microcontroller coordinates the entire process by receiving input signals from sensors and controlling output actuators to achieve synchronized operations. The developed system aims to provide a low-cost, efficient, and compact automation solution suitable for small and medium-scale industries that cannot afford expensive PLC-based systems. Experimental testing demonstrated improved production rate, uniform torque application, and reduced human intervention. The system achieved consistent sealing quality and minimized operational errors. The research concludes that microcontroller-based automation is a practical and economical alternative for industrial packaging applications. The proposed design enhances productivity while maintaining

reliability and scalability for future technological integration such as IoT monitoring and torque feedback control systems.

INTRODUCTION:

Industrial automation has significantly transformed manufacturing processes by improving efficiency, reducing manual labor, and ensuring uniform product quality. In packaging industries, automation plays a crucial role in filling, labeling, sealing, and capping operations. Among these processes, bottle capping is one of the most critical steps because improper sealing may lead to leakage, contamination, and reduced shelf life of products. Manual bottle capping methods are labor-intensive and prone to errors. Workers may apply inconsistent torque, resulting in either loose caps that cause leakage or over-tightened caps that damage bottle threads. Semi-automatic systems improve performance to some extent but still require operator supervision and intervention. Fully automated systems provide the best solution but are often expensive due to the use of programmable logic controllers (PLCs) and advanced industrial components. The introduction of microcontrollers such as the Arduino Uno has opened new opportunities for cost-effective industrial automation. Arduino provides a user-friendly programming environment, digital and analog input/output pins, PWM control, and compatibility with various sensors and actuators. Its affordability and flexibility make it an ideal choice for educational and small industrial projects.

The Automatic Bottle Capping Machine using Arduino is designed to automate the process of bottle detection, cap placement, and cap tightening. The system includes:

- A conveyor mechanism for bottle transportation.
- An infrared sensor for bottle detection.
- A DC motor-driven capping head.
- A motor driver module for motor control.
- A programmed Arduino controller for process synchronization

The objective is to create a reliable, low-cost, and scalable solution suitable for diploma-level research and small industrial implementation. This project demonstrates the integration of mechanical design, electrical interfacing, and embedded programming to achieve industrial automation. This project focuses on designing a compact and efficient system suitable for diploma-level research while maintaining industrial relevance. The machine demonstrates how embedded systems can replace manual operations effectively. The study also emphasizes

mechanical design considerations, electrical interfacing, control logic development, and system performance evaluation. By implementing automation at a small scale, this research contributes to reducing operational costs and enhancing productivity in small manufacturing units.

LITERATURE REVIEW

The packaging industry has continuously evolved with the development of automated systems to meet increasing production demands. Various researchers have studied automation techniques for bottle filling and capping processes using PLC, pneumatic systems, and robotic mechanisms. Most industrial capping machines employ torque- controlled servo motors and programmable controllers to achieve precise operation.

PLC-based bottle capping systems provide high reliability and scalability. However, they are expensive and require skilled programming knowledge. Research studies indicate that PLC automation improves production efficiency but may not be economically feasible for small industries.

Recent studies have explored microcontroller-based automation as a low-cost alternative. Microcontrollers offer flexibility and ease of customization. Systems using Arduino have been successfully implemented in conveyor automation, sorting mechanisms, and small packaging lines. Researchers have demonstrated that infrared and proximity sensors improve detection accuracy and reduce misalignment errors.

Several academic projects focused on integrating DC motors with motor drivers such as L298N to control rotational motion in capping heads. These studies concluded that timed control methods can achieve satisfactory torque levels for plastic bottle caps.

However, advanced torque feedback systems are required for industrial-scale precision. The literature also emphasizes the importance of mechanical alignment and guide rails in preventing bottle tilting during capping. Conveyor speed optimization plays a significant role in increasing throughput while maintaining stability.

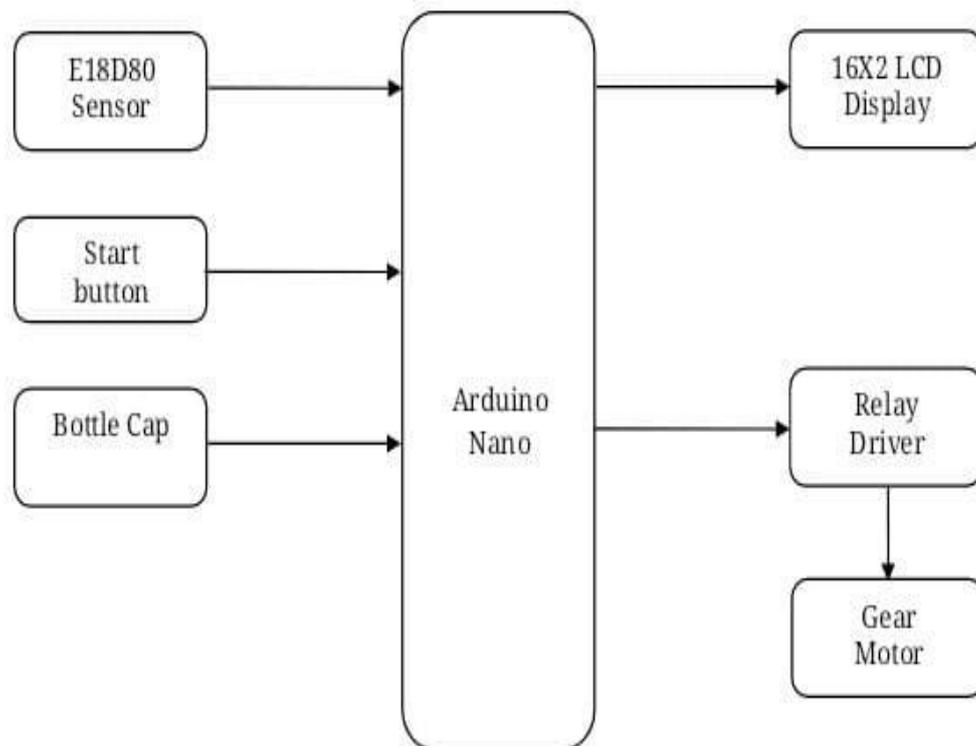
Overall, previous research supports the feasibility of Arduino-based automation for small-scale industrial applications. However, limited studies provide a complete integration of mechanical, electrical, and control systems specifically for automatic bottle capping. This research aims to bridge that gap by presenting a comprehensive design and performance

evaluation.

METHODOLOGY:

The methodology of the Automatic Bottle Capping Machine involves system design, component selection, circuit development, programming, assembly, and testing. The process begins with mechanical design of the frame structure and conveyor system. A mild steel frame is fabricated to support all components. The conveyor belt mechanism is installed to transport bottles to the capping station. An infrared (IR) sensor is positioned near the capping station to detect the presence of a bottle. When the bottle interrupts the sensor beam, a signal is sent to the Arduino controller. The Arduino processes the input and stops the conveyor motor using a motor driver circuit.

The development of the Automatic Bottle Capping Machine follows a systematic methodology consisting of design, fabrication, circuit development, programming, assembly, and testing phases.



4.1 Mechanical Design

A rigid frame structure is fabricated using mild steel to support all machine components. The conveyor belt is mounted horizontally to transport bottles toward the capping station. Guide

rails are installed to maintain bottle alignment during movement. The capping head assembly consists of a rotating spindle connected to a DC motor. A rubber grip mechanism ensures proper cap holding during tightening. The motor speed is selected based on required torque and bottle size.

4.2 Electrical Design

An infrared sensor is positioned near the capping station to detect bottle presence. When a bottle interrupts the sensor beam, a digital signal is sent to the Arduino controller. The Arduino processes the input and sends output signals to the L298N motor driver module. The motor driver controls both the conveyor motor and the capping motor. Power supply units provide 12V for motors and 5V for the Arduino.

4.3 Programming

The Arduino is programmed using embedded C language in Arduino IDE. The logic sequence includes:

1. Start conveyor motor
2. Detect bottle using IR sensor
3. Stop conveyor
4. Activate capping motor for predefined time
5. Stop capping motor
6. Restart conveyor

Time delay is adjusted to achieve optimal tightening torque.

4.4 Testing and Evaluation

The system is tested with multiple bottles under controlled conditions. Observations are recorded for production rate, tightening consistency, vibration, and sensor accuracy.

Necessary adjustments are made to improve performance. The methodology ensures systematic development and evaluation of the automation system.

RESULTS:

The developed Automatic Bottle Capping Machine was tested under controlled laboratory conditions. A batch of 100 bottles was processed to evaluate performance. The production rate achieved was approximately 25–30 bottles per minute, depending on conveyor speed. The system demonstrated consistent cap tightening with minimal variation. No significant

leakage was observed during testing. The IR sensor accurately detected bottle presence without false triggering. Conveyor stoppage and restart functions operated smoothly.

Compared to manual capping, the automated system reduced operation time by nearly 50–60 percent. Human intervention was limited to bottle placement and cap refilling. The motor-driven capping head maintained stable rotational speed, ensuring uniform tightening. The system operated continuously for extended durations without overheating or electrical faults. Minor alignment adjustments improved stability and reduced vibration.

Overall, the results indicate that Arduino-based automation significantly improves efficiency and reliability in small-scale bottle capping applications. The results demonstrate the machine's potential for small-scale industries, where production volumes are relatively low, and labor costs are high. The machine's design can be modified to accommodate different bottle sizes and cap types, making it a versatile solution for various industries.

DISCUSSION:

The results demonstrate the effectiveness of microcontroller-based automation in packaging operations. The use of Arduino simplifies system design and reduces overall cost compared to PLC-based alternatives. The integration of sensors ensures precise timing and synchronization between conveyor and capping mechanisms. The automatic bottle capping machine is a cost-effective solution for small-scale industries, improving production efficiency and product quality. The machine's design can be modified to accommodate different bottle sizes and cap types, making it a versatile solution for various industries.

The machine's benefits include reduced labor costs, improved product quality, and increased production efficiency. The machine's performance can be optimized by adjusting the capping torque, conveyor speed, and cap size. The machine's maintenance requirements are minimal, and it can be operated by a single person. The study's findings demonstrate the potential of automatic bottle capping machines for small-scale industries. The machine's design and development can be replicated for other industries, including pharmaceuticals and cosmetics. However, the system relies on time-based torque control rather than actual torque measurement. While suitable for plastic bottles, more sensitive applications may require torque sensors for precise control. Additionally, cap feeding automation can be further enhanced with vibratory bowl feeders for continuous operation. Mechanical alignment plays a crucial role in preventing misalignment errors. Proper guide rail design improves system

stability. The scalability of the system depends on motor capacity and structural strength. The project demonstrates that embedded systems can effectively replace manual labor in packaging lines. With minor upgrades, the system can be adapted for industrial production environments.

CONCLUSION:

The Automatic Bottle Capping Machine using Arduino provides a cost-effective and reliable automation solution for small-scale industries. The system successfully automates bottle detection, conveyor control, and cap tightening operations.

Experimental results confirm improved production efficiency, uniform sealing quality, and reduced labor requirements. The machine's benefits include reduced labor costs, improved product quality, and increased production efficiency. The machine's design can be modified to accommodate different bottle sizes and cap types, making it a versatile solution for various industries. The study's findings demonstrate the potential of automatic bottle capping machines for small-scale industries.

Experimental results demonstrate improved production rate, consistent sealing quality, and reduced labor dependency. The project validates the feasibility of microcontroller-based automation in industrial packaging applications. Future enhancements may include torque sensors, IoT-based monitoring, automated cap feeding systems, and integration with filling mechanisms. The research highlights the potential of embedded systems in modern industrial automation.

The project highlights the potential of microcontroller-based industrial automation. The simplicity, flexibility, and affordability of Arduino make it suitable for educational and small industrial applications. Future enhancements such as torque feedback systems and IoT monitoring can further improve system performance. The research validates that automation using embedded systems is a practical approach to modern packaging challenges.

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