
DESIGN AND DEVELOPMENT OF A COST-EFFECTIVE AUTOMATIC BOTTLE

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ABSTRACT

The Automatic Bottle Labeling Machine is designed to automate the labeling process using an Arduino Nano microcontroller as the main control unit. The system integrates a stepper motor for precise label dispensing and a DC gear motor for conveyor movement, ensuring synchronized and accurate operation. A 16×2 LCD display is incorporated to show the total number of bottles labeled, enabling real-time production monitoring. The bottle detection is carried out using sensors, which trigger the labeling mechanism when a bottle reaches the labeling position. The stepper motor ensures accurate rotation of the label roll, allowing precise label placement without misalignment. The DC gear motor drives the conveyor system, maintaining steady bottle movement. The Arduino Nano processes sensor inputs and controls both motors efficiently to maintain synchronization between bottle positioning and label application. The counter system continuously updates the LCD display to show the total labeled bottles, improving production tracking and operational transparency. This system reduces manual labor, increases labeling speed, and improves consistency in industrial packaging processes. The design is cost-effective and suitable for small and medium-scale industries. Overall, the developed prototype demonstrates reliable performance, accurate label placement, and efficient automation using embedded system technology.

KEYWORDS: Bottle labeling machine, Packaging automation, Semiautomatic system, PLC control, SMEs

1. INTRODUCTION

The Automatic Bottle Labeling Machine is an important automation system used in packaging industries to improve efficiency and accuracy in labeling operations. In modern industries such as food, beverage, pharmaceutical, and cosmetics, proper labeling is essential for product identification, branding, and regulatory compliance. Manual labeling methods are slow, inconsistent, and prone to human error, which affects overall productivity and product quality.

To overcome these limitations, an automated labeling system has been developed using the Arduino Nano microcontroller as the central control unit. The Arduino Nano is compact, cost-effective, and suitable for embedded automation applications. In this project, it controls the entire labeling process by coordinating sensors, motors, and display modules.

The system uses a DC gear motor to drive the conveyor mechanism that moves the bottles to the labeling position. A stepper motor is used to control the label dispensing mechanism because it provides precise rotational control, which ensures accurate label placement. This synchronization between the conveyor and labeling unit is critical for proper alignment.

A sensor is used to detect the presence of a bottle at the labeling station. Once detected, the Arduino Nano activates the stepper motor to release a label and apply it to the bottle surface. After successful labeling, the system increments the bottle count and displays it on a 16×2 LCD screen. This feature allows real-time monitoring of production output.

The integration of mechanical components with electronic control makes the system reliable and efficient. The use of a digital counter display improves operational tracking and reduces the need for manual supervision. The design focuses on low cost, easy maintenance, and scalability for small and medium-scale industries.

Overall, this project demonstrates how embedded systems and motor control technologies can be effectively used to automate industrial processes. The Automatic Bottle Labeling Machine enhances speed, accuracy, and productivity while reducing labor dependency and operational errors.

2. Literature Review

1. Design of PLC Based Automatic Flat Bottle Label Adjuster

Great intellectual designs of Labelling machines are widely in use for packaging product in manufacturing industries. Hands-on experience on varieties of these designs had spun the idea on which the improvement discussed in this article is designed. For every labelling machine, we have the labelling head and a Gap sensor, these two components

are universal and common to all labelling machines. The vertical movement (aided by a hand wheel) of the labelling head is often used in adjusting the upward -downward position of labels on bottles while horizontal movement of the Gap sensor adjusts the right-left movement of labels on bottles. In this article, electronic means is designed to automatically do label adjustment on bottles, eliminating the crude mechanical hand wheel and hand adjusting been employed by most labelling machines available industries today. This article aims to eliminate human interference when proper label positioning on bottles is required. The design, though simple but yet efficient, employed the use of Photo -sensors, Relays, Programmable Logic Controllers and Servo Drives and Motors, to archive its goal. Flat bottle labelling is considered for this design. Product packaging and identification is a paramount and vital stage before processed goods can be termed finished goods. There are various forms of product identification adopted all over the world by manufacturers when packaging their processed goods. It could be direct print of ink on product packaging, pasting adhesive labels, or heat shrink-wrapped sleeves. In this article, adhesive label method is examined, improved upon and discussed. Many work s and designs are presently in use in various manufacturing industries, but this work is intended to improve on a part of these designs. Adhesive labels require a Pressure Sensitive.

Labelling Machine. A Pressure Sensitive Labelling Machine applies pre-glued labels that are supplied on a reel of release paper or film. Pressure sensitive labels undergo multiple manufacturing steps to have the label temporarily adhere to a web or roll but will permanently adhere to the package. There are multiple types of applicators but they all share the capability to peel the label away from the web or backing and transfer it to a package. After the preglued label is peeled from the web, there are several ways to apply the label. The simplest way is to wipe the leading edge onto to the package. The other is to transfer the label to an applicator drum which holds on to the label by vacuum or other mechanical means before transfer to the package. Typical speeds are 0.5m/s but higher speeds are possible.

3. System Design and WORKING

The Automatic Bottle Labeling Machine works based on coordination between the input sensors, Arduino Nano microcontroller, and motor driving mechanisms as shown in the block diagram.

1. System Initialization

When power is supplied, the Arduino Nano initializes all input and output components such as the E18D80 sensor, start button, 16×2 LCD display, DC gear motor, and stepper motor driver. The LCD displays a welcome message and the initial bottle count (0).

2. Start Button Operation

When the start button is pressed, the Arduino activates the DC gear motor. The DC gear motor drives the conveyor mechanism, which moves the bottles toward the labeling position.

3. Bottle Detection

The E18D80 proximity sensor continuously monitors the presence of a bottle. When a bottle reaches the labeling station, the sensor detects it and sends a signal to the Arduino Nano.

4. Conveyor Stop Mechanism

Upon receiving the detection signal, the Arduino temporarily stops the DC gear motor to hold the bottle in the correct labeling position. This ensures accurate label placement.

5. Label Dispensing Process

The Arduino sends control signals to the stepper driver module. The stepper driver then rotates the stepper motor by a predefined number of steps.

The stepper motor pulls the label paper roll forward with high precision, dispensing exactly one label.

6. Label Application

As the label is dispensed, it is applied to the bottle surface through a pressing roller mechanism. The precise control of the stepper motor ensures proper alignment and avoids label overlapping or misplacement.

7. Bottle Counting and Display

After successful labeling, the Arduino increments the bottle counter by one. The updated count is displayed on the 16×2 LCD screen, allowing real-time monitoring of the total labeled bottles.

8. Conveyor Restart

Once labeling is complete, the Arduino restarts the DC gear motor, allowing the labeled bottle to move forward and the next bottle to enter the detection zone.

9. Continuous Operation

The system continues this cycle automatically for each bottle until the machine is stopped manually.

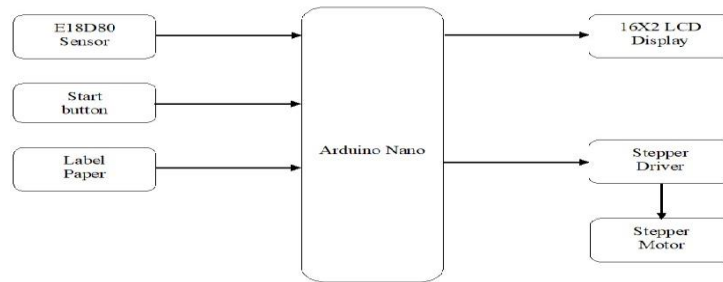


Figure 1. Block Diagram of Semi-Automatic Bottle Labeling Machine

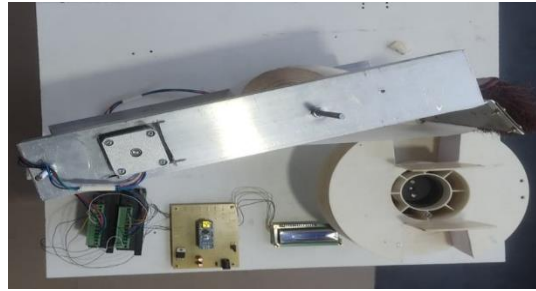


Fig No:01-Bottol Labelling Machine

4. RESULTS AND DISCUSSION

Testing showed the machine labeling 22-25 bottles per minute, far exceeding the manual rate of 6-8. Label placement averaged $\pm 1.5\text{mm}$ accuracy and over 96% were defectfree. Performance was best with cylindrical bottles and depended heavily on label adhesive quality and peel plate alignment.

□ Future upgrades could add LoT sensors for monitoring a vision system for quality inspection and full automation with bottle feeders. This affordable solution can significantly boost SME productivity, improve working conditions, and enhance local manufacturing competitiveness.

Table 1. Comparison of Manual and Semi-Automatic Labeling

Method	Speed (BPM)	Accuracy	Labor Required
Manual	10–15	Low	High
Proposed	30–40	High	Low

5. Applications

APPLICATIONS

- Beverage industry
- Pharmaceutical industry
- Cosmetic industry
- Chemical packaging industry

6. CONCLUSION

The Automatic Bottle Labeling Machine successfully demonstrates the implementation of an efficient and cost-effective labeling system using the Arduino Nano microcontroller. The integration of the E18D80 sensor ensures accurate bottle detection, enabling precise label placement. The use of a stepper motor provides controlled and accurate label dispensing, while the DC gear motor ensures smooth conveyor movement.

The 16×2 LCD display allows real-time monitoring of the total number of bottles labeled, improving production tracking and transparency. The synchronization between sensors and motors enhances system reliability and reduces labeling errors.

This project reduces manual effort, increases operational speed, and improves consistency in labeling applications. The design is suitable for small and medium-scale industries due to its affordability and simplicity. Overall, the system proves that embedded automation can significantly enhance industrial packaging processes.

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