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Design and Implementation of an Automated Production Line Counting System Using Arduino Uno

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Abstract: - In modern industrial production lines, accurate and efficient product counting is critical for maintaining productivity, reducing waste, and ensuring customer satisfaction. Traditional manual counting methods are labor-intensive, error-prone, and inefficient, leading to operational delays and economic losses. To address these challenges, this project proposes the development of an automated production line counting system using the Arduino Uno microcontroller. The system integrates an ultrasonic sensor for object detection, a conveyor belt for product movement, and user interface components such as an LCD display, a 7-segment display, and tactile buttons for user interaction. The system accurately counts products in real-time, displays the count on the user interface, and alerts operators when predefined count limits are reached. By automating the counting process, the system eliminates human error, improves operational efficiency, and reduces costs. This project demonstrates the feasibility of a cost-effective, scalable solution for industrial automation, offering a foundation for future innovations in production line management.

Keywords: Automated Counting System, Industrial Automation, Arduino Uno, Ultrasonic Sensor, Production Line Efficiency.

I. Introduction

In modern industrial production lines, accurate and efficient product counting is essential for maintaining productivity, reducing waste, and ensuring customer satisfaction. Traditional manual counting methods, performed by human operators, are not only time-consuming but also prone to errors due to fatigue, miscounts, and inconsistencies [1], [2]. These labour-intensive and inefficient practices often result in delays in inventory updates and production inefficiencies. Such errors can lead to overstocking, understocking, and incorrect documentation, which negatively impact the overall efficiency of the production process and the economic performance of the business. As businesses continue to prioritize automation to enhance efficiency and accuracy, automated counting systems represent the future of product counting. These innovations empower manufacturers to minimize errors, improve inventory management, and enhance customer satisfaction, ultimately driving competitiveness in a fast-paced, data-driven market. By embracing automated solutions, manufacturers can streamline processes, reduce operational costs, and establish a foundation for continuous improvement, ensuring long-term success in an increasingly competitive landscape.

According to Lauzier, manual data collection in manufacturing is one of the most significant challenges, often resulting in inaccurate data, employee dissatisfaction, and operational inefficiencies [3]. These challenges highlight the need for innovative, automated solutions that can streamline operations and enhance reliability.

To address these issues, this project proposes the development of an automated production line counting system that leverages modern microcontroller technology, specifically the Arduino Uno, to automate the counting process. By integrating an ultrasonic sensor, a conveyor belt, and user interface components such as an LCD display, 7-segment display, and tactile buttons, the system can accurately count products as they move along the production line, display real-time counts, and alert operators when predefined count limits are reached. The system also allows operators to interact with it through a user-friendly interface, enabling them to set count limits, reset counts, and monitor production progress effortlessly.

The primary objectives of this project are to eliminate human error in product counting, improve the efficiency and accuracy of production line operations, provide real-time data and user-friendly interfaces for operators, and reduce operational costs and waste associated with manual counting [1], [2]. Naylor highlights that automated counting systems not only enhance accuracy but also contribute to significant time and cost savings in industrial settings [4]. This paper outlines the design, implementation, and evaluation of the automated counting system, highlighting its technical specifications, engineering design, and the challenges encountered during development. The project represents a significant step toward modernizing industrial production lines and offers a scalable

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solution that can be adapted to various manufacturing environments, paving the way for future innovations in industrial automation.

The rest of this work is organized as follows: Section 2 briefly discusses related work on this subject. The proposed design is presented in Section 3. Section 4 covers the design development and implementation. The design testing and validation are presented in Section 5, and finally, the conclusion is drawn in Section 6.

II. RELATED WORKS

The development and implementation of automated counting systems in industrial production lines have become increasingly vital due to their ability to enhance accuracy, efficiency, and productivity while addressing the significant limitations of traditional manual counting methods. These conventional methods are labour-intensive, prone to errors, and inefficient, which can ultimately hinder the overall performance of production lines. Vision-based counting systems have proven to be a highly effective alternative. For example, the algorithm proposed in [5] for counting rebars on a production line using video analysis demonstrates high precision and adaptability, even in dynamic environments and at high conveyor speeds. This ability to maintain accuracy in challenging conditions represents a significant improvement over manual counting.

Similarly, the system introduced in [6] for counting rebars in two-stage conveying systems achieves remarkable accuracy rates—over 99.85% for rebars with diameters ranging from 8-12mm and over 99.96% for larger diameters. This highlights the potential of image processing technologies in overcoming challenges such as rebar sticking and sliding. In the context of harsh industrial environments like steel manufacturing, 3D visions systems, such as the one presented in [7], have been developed to count reinforcing bars in hot rolling mills. These systems provide high accuracy under variable lighting conditions, effectively addressing the limitations of mechanical counting methods, which are prone to inaccuracies in such demanding settings.

The integration of artificial intelligence (AI) and machine learning has further advanced the capabilities of automated counting systems. For instance, [1] introduces "Perfect Count" by Sciotex, a system that utilizes computer vision and AI algorithms to deliver real-time data updates with high accuracy and scalability, making it adaptable to diverse manufacturing environments. This development highlights how AI can optimize the counting process, making it faster and more reliable while reducing human error. Additionally, [8] explores the use of sound-based counters for production tracking, employing the Kolmogorov-Smirnov test to achieve 92% accuracy in noisy manufacturing environments, outperforming traditional methods. This innovative approach demonstrates the versatility of automated counting systems in dealing with various production challenges.

The transition to Industry 4.0 has also been a significant driving force behind the development of smart counting machines. As described in [9], these machines enhance legacy hardware components through unsupervised learning methods and OPC UA communication protocols, enabling the reuse of control setups and strategies. This flexibility supports the adaptation of production lines to evolving market conditions and helps address the challenges posed by market volatility, further underscoring the growing importance of automation in manufacturing.

Recent research has focused on improving the adaptability of counting systems. For example, [10] proposes a method for counting both circular and rectangular steel bars using image processing techniques that are robust to variations in camera angles and lighting intensity. This adaptability makes it possible to maintain high accuracy across a wide range of operating conditions. Additionally, [11] introduces an intelligent counting method for steel materials that leverages an enhanced YOLOv4 detector, achieving a maximum average precision of 91.41%. This system is implemented in a mobile application that has already garnered over 28,000 registered users, further illustrating the growing integration of counting systems into mobile platforms for real-time accessibility and management.

These advancements emphasize the critical role that automated counting systems play in improving operational efficiency, streamlining inventory management, and supporting data-driven decision-making. As industries seek to modernize production lines, these systems have become indispensable tools for driving productivity and achieving sustainable growth in an increasingly competitive global market. However, an analysis of current research and proposed methods reveals two major challenges: the complexity of implementation and the high costs associated with many existing solutions. Most proposed systems, while highly effective, require significant financial investment and technical expertise to deploy, making them inaccessible for smaller businesses or those with limited resources [12], [13], [14].

In light of these challenges, the present work aims to fill the gap by proposing a cost-effective, automated counting system for industrial production lines. The goal is to develop a solution that maintains the high accuracy and efficiency seen in more complex systems while being accessible to businesses of various sizes. By offering a more affordable and straightforward approach to automated counting, this system aims to democratize access to the benefits of automation, helping businesses optimize their operations without the burden of excessive costs or complicated implementation processes.

III. Proposed Design

The block diagram of the proposed design is presented in Fig. 1.

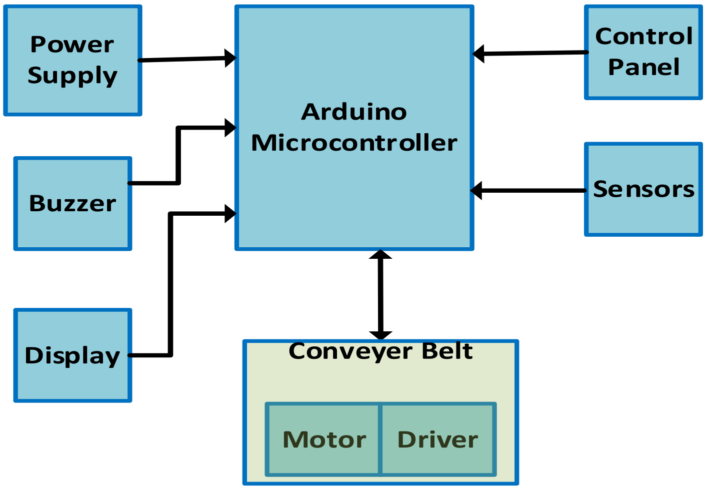

Fig. 1. Block diagram of the proposed system

This figure consists of several components working together to achieve the desired goal. The operation is as follows: the control panel is used to select the desired counting mode (either counting until a certain number or continuous counting). The Ultrasonic Sensor (HC-SR04) detects items and sends signals to the Arduino Uno, which processes the data, increments the count, and updates both the LCD Display (20x4 I2C) and the 7-Segment Display (TM1638). Simultaneously, the Arduino controls the Motor Driver (L298N) to regulate the geared DC motor, ensuring smooth operation of the production line. This seamless integration of components enables accurate counting, real-time monitoring, and efficient production. At the end of each programmed counting session, the buzzer is activated, emitting a loud sound to alert the user. A brief overview of all the main components is provided in the following paragraphs.

Fig. 2. Arduino Uno

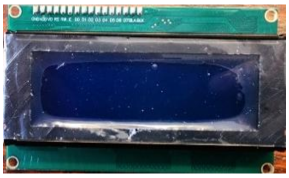

Fig. 3. I2C LCD display

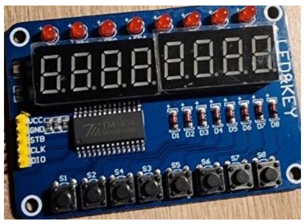

Fig. 4. 7-segment display module

A. Arduino Uno

Fig. 2 shows an Arduino Uno which forms part of the Arduino family [15]. The Arduino Uno serves as the central microcontroller in the production line counting system, acting as the brain of the circuit. It processes input data from sensors like the HC-SR04 Ultrasonic Sensor, calculates item counts, and updates the displays (LCD and 7-segment) with real-time information. Additionally, it controls the L298N Motor Driver to manage the movement of the production line via the geared DC motor, ensuring smooth operation. The Arduino also handles system logic, such as triggering alarms or stopping the line in case of errors, making it the core component for coordination and control.

B. LCD Display

Fig. 3 show the 20x4 I2C LCD Display which provides a detailed user interface for the production line counting system, showing real-time information such as total item counts, production rates, and system status [16]. Its I2C interface simplifies wiring by reducing the number of connections to the Arduino, making the circuit cleaner and easier to manage. The display ensures operators can monitor the system's performance immediately, offering clear and comprehensive feedback on the production process.

C. 7-Segment Display Module

Fig. 3 show the TM1638 8-Digit 7-Segment Display Module is used to display numerical data, such as item counts or time elapsed, in a clear and easily readable format [17]. Its bright LED segments make it ideal for environments where quick and accurate reading of data is essential. The module can also include additional features like LED indicators or buttons for user input, adding versatility to the system while maintaining a simple and effective way to convey critical information.

Fig. 5. Geared DC Motor drives

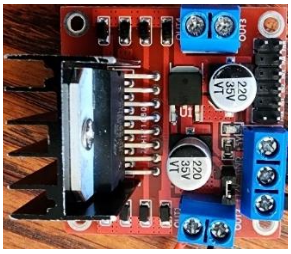

Fig. 6. Motor Driver Module

Fig. 7. Ultrasonic Sensor

D. Geared DC Motor

Fig. 5 show the Geared DC Motor which drives the mechanical components of the production line, such as conveyor belts, to move items along the system. Its gear reduction mechanism provides higher torque, allowing it to handle heavier loads at controlled speeds [18]. Working in tandem with the L298N Motor Driver, the motor ensures consistent and reliable movement of the production line, making it an essential component for automating the transportation of items in the counting system.

E. Motor Driver Module

Fig. 6 show the L298N Motor Driver Module which acts as an interface between the Arduino and the geared DC motor, enabling the Arduino to control the motor's speed and direction [19]. It provides the necessary current and voltage to drive the motor, ensuring smooth and precise movement of the production line. The module can also control two motors simultaneously, making it suitable for systems with multiple moving parts, and plays a critical role in maintaining the operational flow of the production line.

F. Ultrasonic Sensor

Fig. 7 show the HC-SR04 Ultrasonic Sensor which detects the presence of items on the production line by emitting ultrasonic waves and measuring the time taken for the waves to bounce back after hitting an object [20]. This allows it to calculate the distance to the object, ensuring accurate counting by triggering a count increment only when an item is within a specific range. Its reliability and precision make it a key component for automating the counting process in the production line system.

IV. Design Development and Implementation

A. Schematic and Simulation

The proposed design circuit is presented in Fig. 8 and 9. The circuitry was simulated using Tinkercad and Wokwi to provide an idea of the outcome of the system. The software also allows for code to be uploaded to simulate the functionality of the code with the components. Not all components of the project are supported by this software such as the motor driver module, motor and the 8-digit 7-segment display but most of the user interfacing components were able to be simulated.

The circuit was compiled with all the components that were bought. The system was built around an Arduino as the microcontroller of the whole system. Code was written to bring life to the circuitry. This code interfaced all the components of the production line counting system. An LCD display and 8-digit 7-segment display were used to display the user interface. Buttons were used to for user input. For the alarm a buzzer and an LED was used to indicate the product count was reached. The sensor used to sense items on the production line was an ultrasonic sensor. A motor driver module and DC motor was used to move the belt of a conveyor. Two 6V batteries were connected in series to create a 12V supply for the motor and a 5V supply to the Arduino. The system was tested and tweaked to better the outcome of the system. The code would be tweaked if the outputs weren't correct on the system or didn't happen at the right time and the circuitry was tweaked accordingly to the code if it was needed.

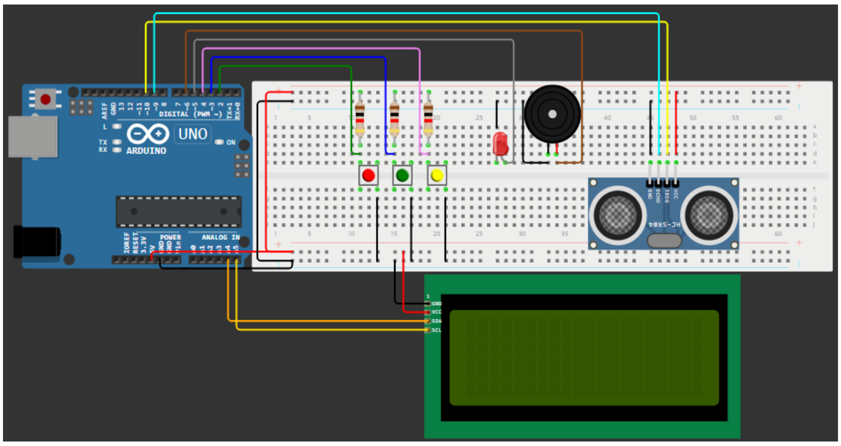

Fig.8. Project schematic

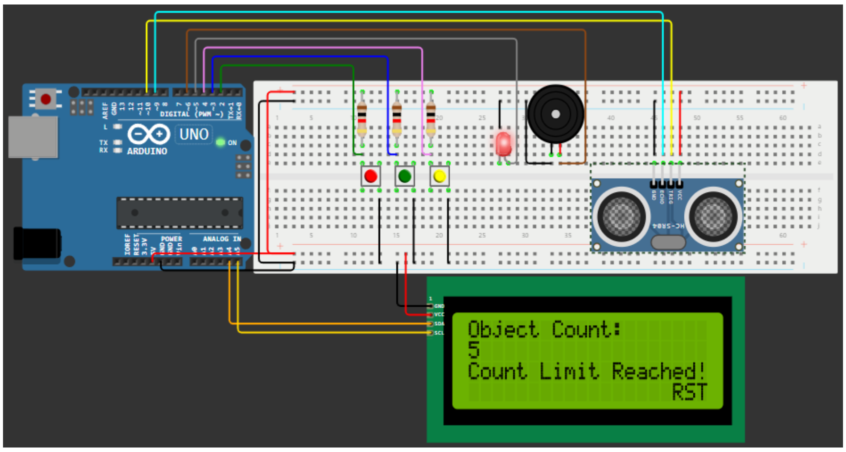

Fig.9. Simulation of project

B. Conveyor Belt

The design of the conveyor belt was determined with the help of the concept from the proposal. The dimensions were determined by drawing the conveyor in AutoCAD and then the components were bought to start implementing the design. Wood and aluminium flat bar was cut to the correct dimensions to make the base of the conveyor. Holes were drilled to make space for the driver and idler shaft, where machine screws were used. The rollers of the conveyor were made from conduit pipe and bearings were used to make a near frictionless contact between the rollers and the shaft.

Figure.10. Conveyor schematic

The motor was coupled with the driver roller to allow for rotation of the driver roller. A belt was made from a fake leather material by cutting a strip then stitching each side together and placing it over both rollers. Then all electrical components were attached to the conveyor's side to create the production line counting system. The user interfacing components were soldered to a protoboard and then attached to the side of the conveyor.

The ultrasonic sensor was set facing the side of the conveyor to sense when items cross it. The motor driver module and Arduino were fixed to the base of the conveyor to allow for connections to the motor of the conveyor and everything else to the Arduino.

C. Conveyor Belt

The final product after all components were soldered, and the Veroboard and other components were secure to the conveyor is presented in Fig. 11. The system was tested to check if everything interfaced with each other correctly. Code was adjusted to account for the sensor to sense the items on the production line correctly. The motor speed was changed to get the conveyor belt running at the correct speed and the direction of the motor was changed to get the belt moving in the direction that was intended.

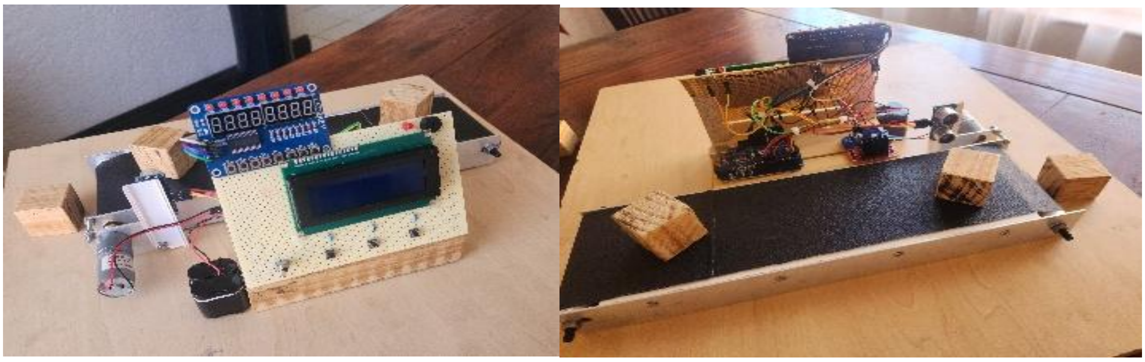

Fig. 11. The final product.

V. DESIGN TEST AND VALIDATION

The test and validation of the developed system was performed in three steps. The step one was the switching on, the step two was the setting of the count limit and step three was the running of the system in order to assess its responses. These three steps test and validation are illustrated with Fig.12 to 14.

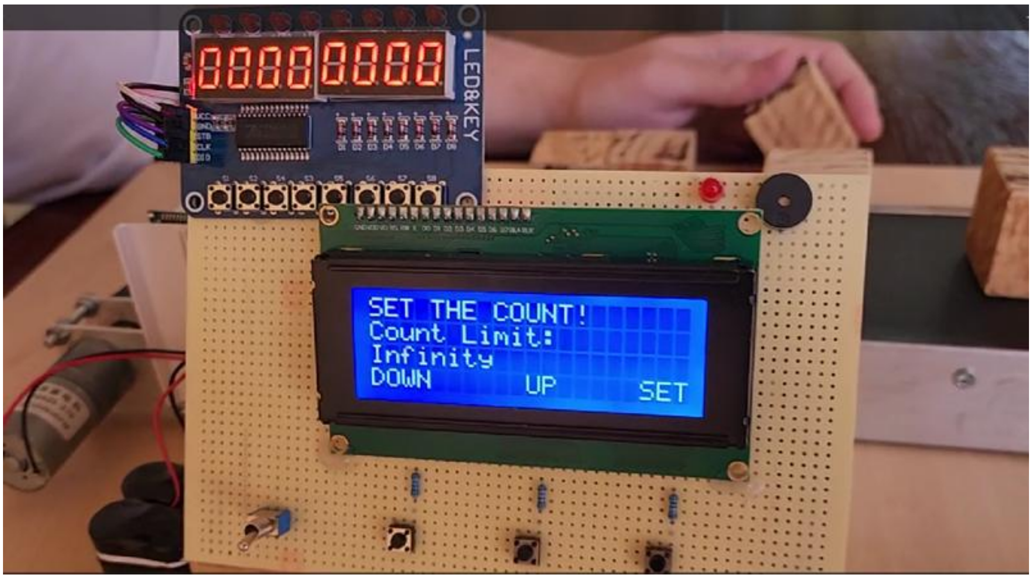

Fig. 12. Switching ON of the system.

1. Starting Sequence of the System Test

- Flip the lever switch to the "On" position.

- Observe that the LCD lights up, briefly displays the project name, the buzzer activates, and then the LCD shows the last saved count from before the system was turned off.
- The user is then prompted to set a count limit, with the prompt displayed on the LCD. In this case the count limit was set to 3.

Results:

The system powers on, indicated by the “ON” LED on the Arduino and motor driver module illuminating. The LCD backlight turns on and displays the project name, confirming that power is supplied to all components and the code has been successfully uploaded.

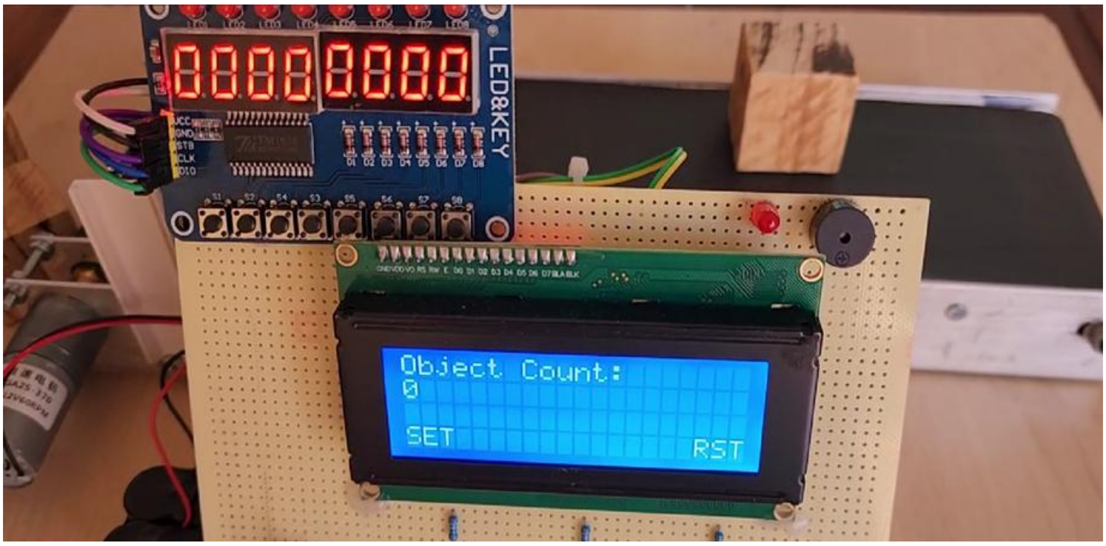

Fig. 12. Setting of the system.

2. Setting of the System Test

- The user can increase or decrease the count limit using the left and middle buttons, respectively.
- Press the right button to confirm and set the chosen count limit.
- Setting the count limit to zero will set the count limit to infinity. In this case the count limit was set to 3 and the object was not yet detected hence the object count was still at 0.

Results:

The count limit is adjusted correctly using the buttons. The LCD displays the updated count limit as the buttons are pressed, showing “infinity” instead of zero when the limit is set to zero. Each button press is accompanied by a buzzer tone, providing audible feedback for the user’s actions.

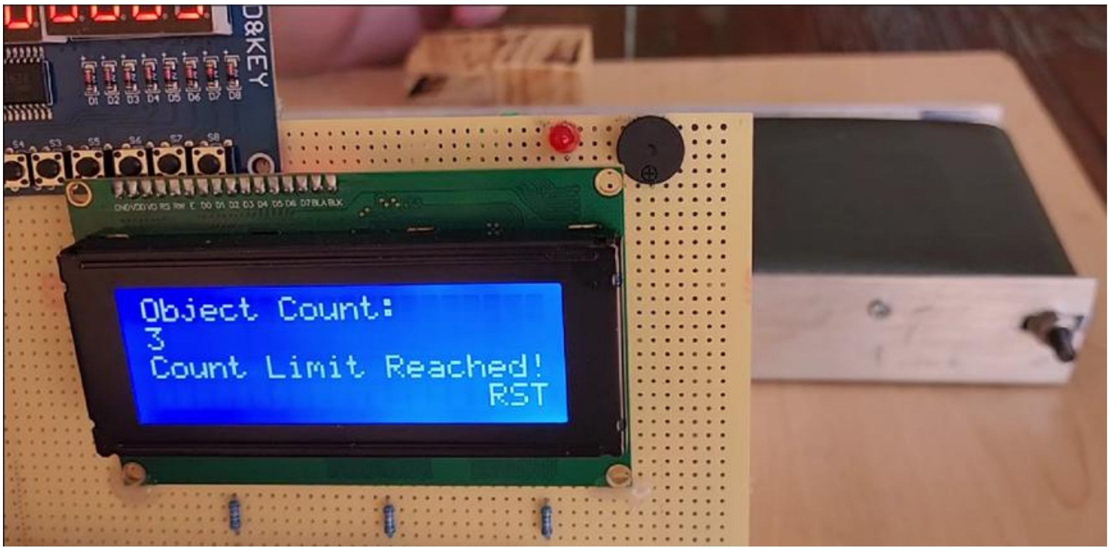

Fig. 12. Running of the system.

3. Running of the System Test

- The conveyor should start, and the screen should show the running count as the items pass the ultrasonic sensor.
- There should be a buzzer beep for each object detected.
- The reset button should take the running object count back to zero, and the set button should allow the user to change the set count limit.
- When the count limit is reached (in this case, the count limit was set to 3), the count and conveyor should stop, the buzzer should beep, and the LED should blink.

Results:

The ultrasonic sensor accurately detects objects as the items pass by and the running count updates on the LCD. The conveyor motor stops, and the system reacts as expected when the count limit is reached. The motor also stops when the set button and the LCD displays the set count limit screen. When the count limit is set to infinity, the count continuously increases until the count limit is changed.

Overall, the project successfully demonstrated the feasibility of automating the counting process, with the system accurately detecting and counting products as they moved along the conveyor. This project represents a significant advancement in industrial automation, offering a scalable and adaptable solution that can be tailored to various manufacturing environments. By reducing reliance on manual counting methods, the system not only improves operational efficiency but also contributes to cost savings and enhanced customer satisfaction. The successful implementation of this automated counting system paves the way for further innovations in industrial production line management.

VI. Conclusion

The development and implementation of the automated production line counting system have successfully demonstrated the potential of modern microcontroller technology in addressing the inefficiencies of manual counting methods. By leveraging the Arduino Uno, ultrasonic sensor, and user-friendly interface components, the system achieves accurate, real-time product counting while providing operators with intuitive controls and feedback. Testing validated the system's ability to detect objects, update counts, and respond to user inputs, such as setting count limits and resetting counts. The system's design ensures scalability and adaptability, making it suitable for various manufacturing environments. This project highlights the importance of automation in enhancing operational efficiency, reducing costs, and improving inventory management. By eliminating human error and streamlining production processes, the system represents a significant step toward modernizing industrial production lines.

Future work could explore integrating advanced technologies such as machine learning or IoT connectivity to further enhance the system's capabilities, paving the way for smarter, more efficient manufacturing systems.

VII. Acknowledgment

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