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PLC-Based Color Sorting With Metal Detection

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Abstract- Traditional manual sorting in industrial settings often suffers from inefficiency, high labor requirements, and error-proneness. This study introduces an automated sorting system utilizing a PLC with integrated metal detection to tackle these issues. The system's core is an S-TRONiX 8 I/O PLC, offering a dependable foundation for effective process management. A LX 101 color sensor is incorporated for product sorting based on color, while a metal detector sensor differentiates between metallic and non-metallic items. This combined sorting approach enhances accuracy in handling diverse materials across production lines.The setup includes three actuators driven by RDS 3115MG servo motors, which accurately direct objects to specific bins. A 30 RPM DC geared motor powers the conveyor system, ensuring steady object transport. An L298N motor drive efficiently controls motor functions, and an SMPS provides consistent power to the system's electrical components. NO/NC push buttons allow for secure manual control of the sorting process.The system follows a structured control protocol: objects on the conveyor are first assessed by the metal sensor. Metallic items are redirected to a dedicated container, while non-metallic objects move on to color detection. The LX 101 sensor identifies object colors, triggering the appropriate actuator to sort products into designated bins. This streamlined approach boosts sorting efficiency, minimizes human involvement, and improves production precision.By integrating metal detection and color sorting into a single framework, the proposed system shows marked improvements over conventional sorting methods. It is particularly suited for industries requiring precise material segregation, such as recycling facilities, food processing plants, and packaging sectors. Future enhancements may incorporate advanced sensorsfor size or weight-based sorting, further expanding the system's adaptability in industrial applications.

Keywords: PLC, Color Sensor, Automation, Servo Motors, Sorting System, Metal

INTRODUCTION

An automatic sorting system is a fast and efficient method for sorting products, particularly in industries where manual sorting is time-consuming and labor-intensive. Industries implement sorting systems to classify products and raw materials based on predefined criteria, enhance accuracy, and minimize human effort. Manual sorting methods are prone to errors and require significant effort, making automated sorting systems a crucial advancement for improving the efficiency of industrial processes.

This project presents a novel PLC-based sorting system integrated with metal detection capabilities. The system utilizes an **S-TRONiX 8 I/O PLC** as the master controller, ensuring accurate and reliable control over sensors, actuators, and the conveyor mechanism. A **LX 101 color sensor** is employed to identify product colors, while a **metal detector sensor** distinguishes between metallic and non-metallic objects.

Various sorting systems have been proposed in previous research. In "Automatic Sorting in Process Industries using PLC," Thirumurugan proposed a sorting system that classifies objects based on height. However, this system was limited to small height variations, making it unsuitable for large-scale industries [1]. Mohd Aleem Uddin developed an “Automatic Industrial Sorting Machine” using different sensors for automation, demonstrating that PLCs can effectively manage a wide range of control

tasks using simple ladder logic. However, this system lacked visual inspection capabilities and offered limited flexibility in dynamic sorting [2].

In "Design of an Object Sorting System Using PLC," a fully automated sorting framework was designed using PLCs and DVD drives. However, DVD drives are costly, occupy more space, and offer limited flexibility compared to modern actuators [3]. Another approach, "Object Sorting and Stacking Automation Using PLC," proposed using infrared sensors for sorting, but infrared sensors are prone to interference from dust, fog, and environmental conditions, reducing their reliability [4].

A low-cost automation system (LAC) was introduced in "PLC Based Object Sorting Automation" to improve repeatability, reduce cycle time, and enhance production speed. While this system demonstrated improved efficiency, it lacked precision in multi-parameter sorting [5]. Saurin Sheth’s "Automatic Sorting Machine Using Machine Vision" introduced a visual inspection system that identifies defective items and directs them to recycling bins. However, the high costs of these vision-based systems make them unsuitable for small-scale industries [6].

In "Automatic Sorting Machine Using Conveyor Belt," a PLC-based system with multiple sensors for detecting shape, height, weight, and color was introduced. While effective, this system was costly and required constant monitoring, limiting its scalability for smaller industries [7]. A similar PLC and HMI-based system was proposed with an automatic conveyor system and in-process sorting mechanism. However, its reliance on proprietary PLC devices added cost and maintenance challenges [8].

The "Development of a Prototype Automated Sorting System for Plastic Recycling" introduced an automated plastic sorting system using AI-based pattern recognition for improved sorting accuracy on high-speed conveyor belts. However, image blur on fast-moving conveyors remained a challenge [9]. In another approach, "A Proposed Hierarchical Control Model for Automated Manufacturing Systems" provided a five-layered control model for managing industrial automation, though frequent system updates and communication issues limited its practicality [10].

Pourdarbani’s "Study on an Automatic Sorting System for Date Fruits" employed machine vision for sorting dates in food packaging industries. However, the system’s accuracy varied when outlier data was present [11].

In this project, the proposed system integrates a **metal detector sensor** and **LX 101 color sensor** to sort both

metallic and non-metallic objects, followed by color-based classification. The conveyor belt system, driven by a **30 RPM DC geared motor**, ensures steady object movement, while **RDS 3115MG servo motors** are employed for accurate positioning of sorted items. An **L298N motor drive** manages motor operation, and an **SMPS** provides stable power delivery. **NO/NC push buttons** ensure safe and reliable manual control of the system. This innovative design minimizes human intervention, enhances sorting accuracy.

METHODOLOGY

The system uses an **S-TRONiX 8 I/O PLC** as the master controller, coordinating sensors, actuators, and the conveyor mechanism. It ensures seamless communication between various components, making the automation process efficient and accurate.

A. Process Flow & Block Diagram

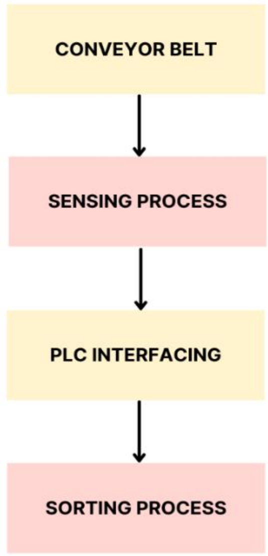


Fig1. Process Flow

A **LX 101 color sensor** identifies product colors, while a **metal detector sensor** distinguishes between metallic and non-metallic objects. This dual-sensor setup enhances sorting capabilities by addressing multiple product characteristics in one integrated system.

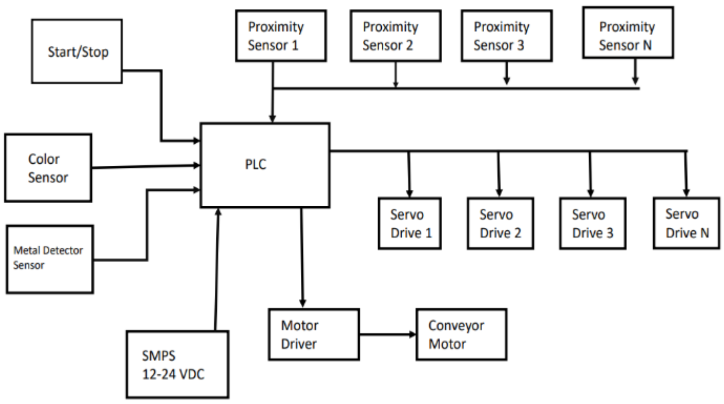


Fig2. Block Diagram

A **LX 101 color sensor** identifies product colors, while a **metal detector sensor** distinguishes between metallic and non-metallic objects. This dual-sensor setup enhances sorting capabilities by addressing multiple product characteristics in one integrated system.

The system uses **RDS 3115MG servo motors** for precise sorting, and a **30 RPM DC geared motor** drives the conveyor. These motors provide accurate positioning of products, ensuring correct placement in the designated bins.

B. Circuit Diagram

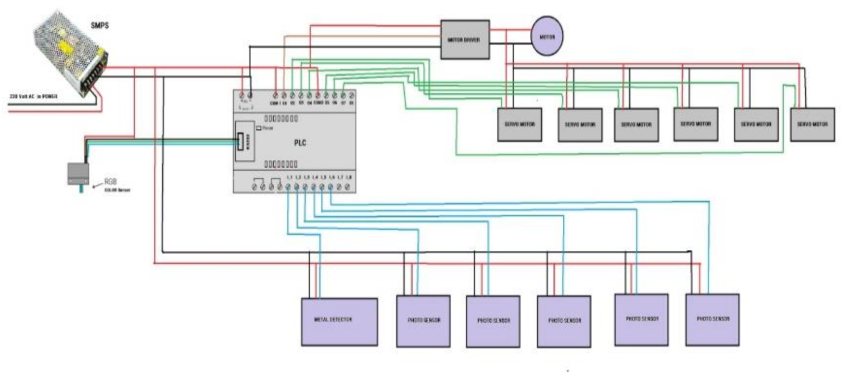
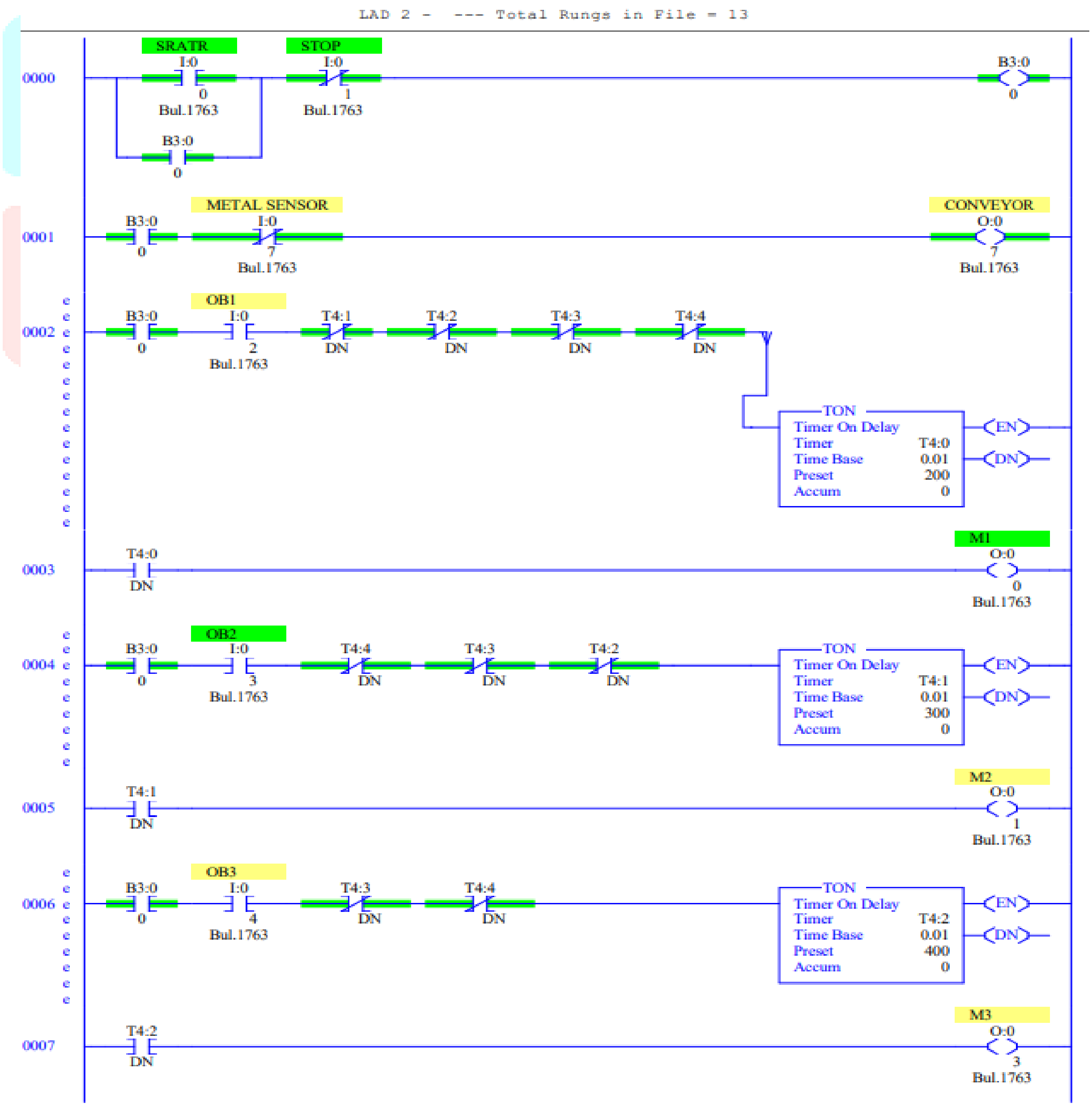


Fig3. Circuit Diagram

An **L298N motor drive** regulates motor control, and an **SMPS** ensures stable power delivery. **NO/NC push buttons** provide manual control for operational flexibility, allowing the system to be paused or adjusted as required.

This automated system improves sorting accuracy and minimizes manual intervention, making it ideal for industries requiring efficient material handling. The system's reliability and flexibility make it suitable for sectors like recycling, food processing, and manufacturing.

C. Ladder Logic



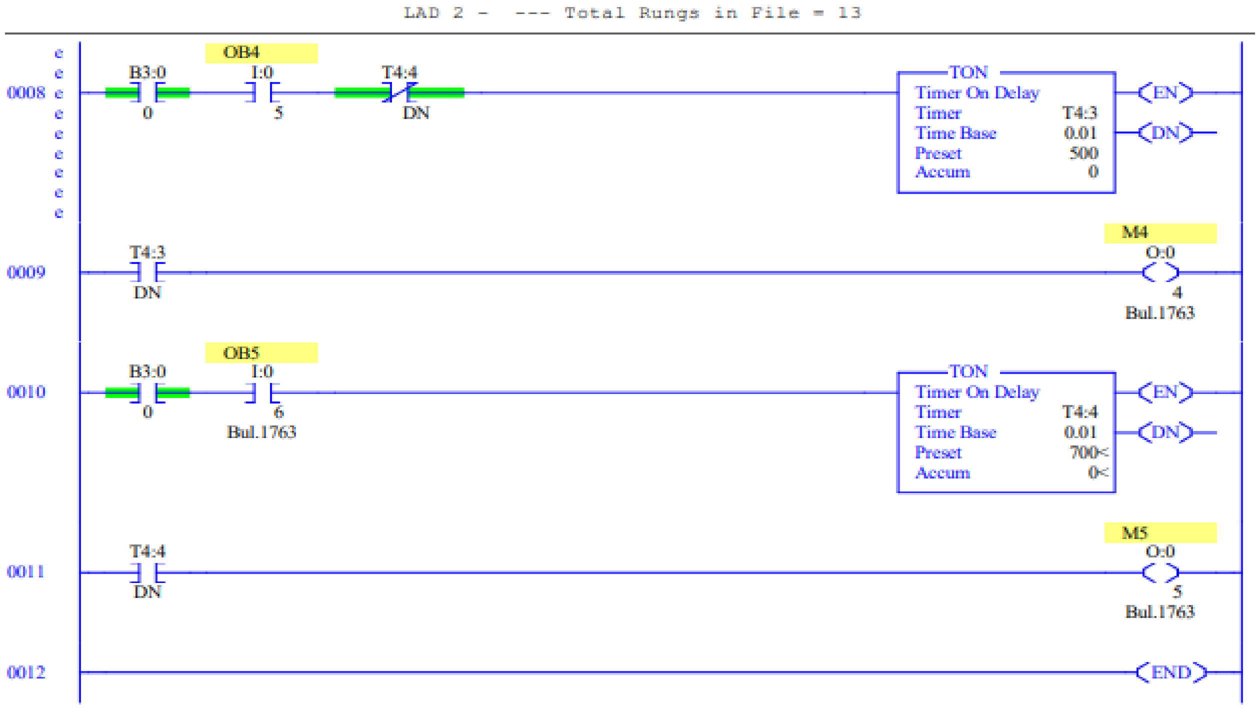


Fig4. Ladder Logic

1. Start and Stop Controls (Rung 0000)

- **Inputs:** SRATR (Start Button), STOP (Stop Button)
- **Output:** B3:0/0 (Internal Memory Bit)
- When the **Start** button is pressed, B3:0/0 is set, enabling the system.
- The **Stop** button deactivates B3:0/0, stopping the system.

2. Metal Sensor Activation (Rung 0001)

- **Inputs:** Metal Sensor (I:0/1), B3:0/0 (System Enabled)
- **Output:** Conveyor (O:0/0)
- If an object is detected by the **Metal Sensor**, the conveyor keeps running.

3. Object 1 (OB1) Detection and Timer Activation (Rung 0002)

- **Inputs:** OB1 Sensor (I:0/2), System Enabled (B3:0/0)
- **Outputs:**
- T4:0 (Timer with a 200 ms delay)
- M1 (O:0/1) is activated when the timer completes.
- If an object is detected by **OB1**, the system delays for **200 ms** before activating M1.

4. Timer 1 Completion Check (Rung 0003)

- **Input:** T4:0/DN (Timer Done Bit)
- **Output:** M1 (O:0/1)
- When the **timer completes**, M1 remains activated.

5. Object 2 (OB2) Detection and Timer Activation (Rung 0004)

- **Inputs:** OB2 Sensor (I:0/3), System Enabled (B3:0/0)
- **Outputs:**
- T4:1 (Timer with a 300 ms delay)
- M2 (O:0/2) is activated when the timer completes.
- When OB2 detects an object, the system waits for **300 ms** before triggering M2.

6. Timer 2 Completion Check (Rung 0005)

- **Input:** T4:1/DN (Timer Done Bit)
- **Output:** M2 (O:0/2)
- When the **timer completes**, M2 remains activated.

7. Object 3 (OB3) Detection and Timer Activation (Rung 0006)

- **Inputs:** OB3 Sensor (I:0/4), System Enabled (B3:0/0)
- **Outputs:**
- T4:2 (Timer with a 400 ms delay)
- M3 (O:0/3) is activated when the timer completes.
- When OB3 detects an object, the system waits for **400 ms** before triggering M3.

8. Timer 3 Completion Check (Rung 0007)

- **Input:** T4:2/DN (Timer Done Bit)
- **Output:** M3 (O:0/3)
- When the **timer completes**, M3 remains activated.

9. Object 4 (OB4) Detection and Timer Activation (Rung 0008)

- **Inputs:** OB4 Sensor (I:0/5), System Enabled (B3:0/0)
- **Outputs:**
- T4:3 (Timer with a 500 ms delay)
- M4 (O:0/4) is activated when the timer completes.
- When OB4 detects an object, the system waits for **500 ms** before triggering M4.

10. Timer 4 Completion Check (Rung 0009)

- **Input:** T4:3/DN (Timer Done Bit)
- **Output:** M4 (O:0/4)
- When the **timer completes**, M4 remains activated.

11. Object 5 (OB5) Detection and Timer Activation (Rung 0010)

- **Inputs:** OB5 Sensor (I:0/6), System Enabled (B3:0/0)
- **Outputs:**
- T4:4 (Timer with a 700 ms delay)
- M5 (O:0/5) is activated when the timer completes.
- When OB5 detects an object, the system waits for **700 ms** before triggering M5.

12. Timer 5 Completion Check (Rung 0011)

- **Input:** T4:4/DN (Timer Done Bit)
- **Output:** M5 (O:0/5)
- When the **timer completes**, M5 remains activated.

Summary of Operation

- **System starts** when the START button is pressed.
- The **conveyor runs continuously** as long as the system is active.
- Objects are detected by **sensors OB1 to OB5**, each triggering a **specific delay timer** before sorting the item.
- The **delays allow precise activation** of different actuators (M1 to M5) for sorting based on color or metal presence.

SYSTEM HARDWARE

1. PLC (S-TRONiX – 8 I/O)

The PLC (Programmable Logic Controller) is the central processing unit that controls and automates system operations.

Types & Function:
- 8 I/O ports – Supports multiple input and output connections for automation.
- Processes sensor data and controls actuators based on programmed logic.

Project Integration:
- Interfaces with sensors and motors for coordinated operation.
- Programmed using ladder logic for efficient automation.

2. Colour Sensor (LX 101)

The colour sensor detects and differentiates colours in objects based on reflected light.

Types & Function:
- LX 101 – Recognizes various colours using an optical sensing method.
- Used for object sorting and quality control applications.

Project Integration:
- Placed at the inspection point to detect object colours.
- Sends colour data to the PLC for decision-making.

3. Servo Motors (RDS 3115MG)

Servo motors provide precise angular movement for controlled motion.

Types & Function:
- RDS 3115MG – High-torque metal gear servo motor.
- Used for positioning and actuation tasks.

Project Integration:
- Controlled via PWM signals from the PLC.
- Used for mechanisms requiring accurate rotational movement.

4. Motor Drive (L298N)

The motor drive controls the speed and direction of DC motors.

Types & Function:
- L298N – Dual H-bridge motor driver for bidirectional control.
- Allows speed variation and forward/reverse control of motors.

Project Integration:
- Connected between the PLC and DC geared motors.
- Enables automated movement control in the system.

5. DC Geared Motor (30 RPM)

A geared motor provides controlled rotational movement at a fixed speed.

Types & Function:
- 30 RPM – Low-speed, high-torque motor for precise motion.
- Used in conveyor or robotic arm applications. **Project Integration:**
- Driven by L298N motor driver for speed and direction control.
- Moves objects or components as per PLC instructions.

6. SMPS (Switched Mode Power Supply)

The SMPS provides a stable power supply to all system components.

Types & Function:
- Converts AC to regulated DC power.
- Supplies appropriate voltage and current for components.

Project Integration:
- Powers PLC, sensors, motors, and other electronics.
- Ensures reliable operation with stable voltage output.

7. IR Proximity Sensor

The IR proximity sensor detects objects based on infrared reflection.

Types & Function:
- Non-contact sensing – Identifies objects within a fixed range.
- Used for obstacle detection and positioning applications.

Project Integration:
- Sends signals to the PLC upon object detection.
- Triggers actions such as stopping a motor or activating another mechanism.

8. Metal Detector Sensor

The metal detector sensor identifies metallic objects in its detection range.

Types & Function:
- Detects ferrous and non-ferrous metals.
- Used in security, sorting, or industrial applications.

Project Integration:
- Sends metal detection signals to the PLC.
- Activates sorting mechanisms based on detection results.

9. Push Buttons (NO/NC Type)

Push buttons serve as manual control inputs for system operation

.Types & Function:
- NO (Normally Open) – Activates when pressed.
- NC (Normally Closed) – Deactivates when pressed.

Project Integration:
- Connected to the PLC for manual control of functions.
- Used for start/stop operations and emergency control.

ADVANTAGES

1. **Increased Efficiency** – Automated sorting significantly reduces time and labor compared to manual processes.
2. **Enhanced Accuracy** – PLC-controlled actuators ensure precise object placement in designated bins.
3. **Flexible Integration** – The system's modular design allows easy integration of additional sensors for improved sorting capabilities.
4. **Improved Safety** – Reduces the need for manual handling, minimizing risks for operators.
5. **Reduced Operational Costs** – Automated sorting lowers labor costs and enhances productivity.
6. **High Reliability** – The use of dedicated power supply and regulated motor control ensures stable performance.
7. **Adaptability** – The system can efficiently handle a variety of objects, making it suitable for multiple industries.

APPLICATION

1. **Recycling Industry** – Efficiently separates metallic and non-metallic waste, improving recycling processes.
2. **Food Processing Plants** – Ensures accurate sorting of packaged goods based on color and material.
3. **Pharmaceutical Industry** – Automates the sorting of tablets, capsules, or medical devices based on size, color, or material.
4. **Automotive Sector** – Used to classify and sort metal and plastic components during assembly.
5. **Textile Industry** – Efficiently separates fabrics based on color variations for improved product management.
6. **Mining Industry** – Identifies and separates valuable metals from raw material streams.

7. **Electronics Industry** – Assists in segregating electronic components for recycling or reuse.

CONCLUSION

This research presents the development of a **PLC-based Color Sorting System with Metal Detection**, designed to enhance industrial automation by providing a precise, efficient, and automated sorting solution. By utilizing an **S-TRONiX 8 I/O PLC**, along with a **LX 101 color sensor** and a metal detector sensor, the system ensures accurate identification and segregation of products based on material type and color. This dual-sensor integration addresses key limitations in conventional sorting methods, offering improved reliability and performance.

The study involved comprehensive research into industrial requirements, analysis of sorting system constraints, and a detailed evaluation of sensor capabilities. The designed system employs RDS 3115MG servo motors for precise object positioning and a 30 RPM DC geared motor to ensure smooth conveyor movement. An L298N motor drive provides efficient motor control, while an SMPS ensures stable power delivery, enhancing system consistency. NO/NC push buttons are included to offer manual control for added operational flexibility.

This research contributes to the field of industrial automation by delivering a scalable, cost-effective, and practical solution for material segregation. The system's modular design allows for seamless expansion, making it adaptable to additional sensors or process modifications. Future advancements may include integrating AI-driven sorting algorithms, IoT-enabled monitoring systems, and enhanced sensor technologies to further improve sorting accuracy and system responsiveness.

The findings of this study provide a foundation for further innovations in automated sorting technology, reinforcing the importance of advanced control systems in improving industrial productivity, operational safety, and process efficiency.

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