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Object Sorting Conveyor using Delta PLC

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Abstract: ***The automated object sorting and counting system integrates a Delta PLC, sensors, and actuators to streamline industrial sorting processes. By leveraging sensor-based decision-making, the system detects objects, categorizes them based on predefined criteria, and directs them to appropriate bins using stepper motor or pneumatic pushers. This automation significantly enhances efficiency in production lines by reducing human intervention, minimizing sorting errors, and optimizing workflow speed. Industries that require precise classification—such as manufacturing, packaging, and logistics—benefit from improved productivity and accuracy. The Delta PLC acts as the central controller, processing sensor inputs and executing sorting commands, making the entire system reliable, scalable, and adaptable to various industrial applications.***
Keywords: Delta PLC, Object Sorting, Conveyor System, Industrial Automation, Sensor-Based Control, Stepper Motor.

I. INTRODUCTION

Industrial automation has become essential for improving efficiency and accuracy in manufacturing and logistics operations. Manual sorting processes are inherently slow, error-prone, and unsuitable for large-scale industrial operations, leading to increased labor costs and reduced productivity. The implementation of Programmable Logic Controller (PLC)-based systems has revolutionized automated sorting by enhancing speed and reliability through real-time sensor data processing.

The Delta PLC serves as the central control unit, categorizing objects based on predefined criteria such as size, material type, color, or weight. The conveyor belt transports objects past detection sensors, while actuators guide them into designated bins according to the sorting logic. Real-time counting mechanisms ensure accurate tracking and minimize human intervention, making the system highly efficient for continuous operation. Automated sorting systems significantly boost productivity in industries such as packaging, warehousing, and manufacturing. These systems eliminate the inconsistencies and delays associated with manual sorting, providing reliable object classification and inventory management. Future advancements may integrate artificial intelligence and machine learning algorithms for even more adaptive and intelligent sorting capabilities.

A. Research Objectives

The motivation behind developing the automated object sorting conveyor belt using Delta PLC arises from several key objectives:

1) To eliminate manual sorting inefficiencies and reduce human error in industrial operations.
2) To design a scalable, reliable system using Delta PLC, sensors, and actuators for precise object classification.
3) To implement real-time counting and tracking mechanisms for quality control and inventory management.
4) To enhance productivity and workflow speed in manufacturing, packaging, and logistics industries.
5) To develop a cost-effective automation solution adaptable to various industrial applications.

B. Core System Architecture and Components

The fundamental design of a PLC-controlled object sorting conveyor system has been widely studied and remains consistent across most industrial implementations. The key components include:

1) Conveyor System: Acts as the primary mechanism for transporting objects from the input section past the detection sensors to the sorting bins. Its speed and movement (start/stop operations) are directly controlled by the PLC outputs, ensuring synchronized operation with the sorting mechanism.
2) Sensors (Input Devices): These are strategically placed to detect objects and their specific properties. Common sensor types include:

- Inductive Proximity Sensors: Primarily used for detecting metallic objects and enabling metal/non-metal sorting applications
- Photoelectric Sensors: Used for object presence detection, counting, and sorting based on size or height by placing multiple sensors at different vertical levels
- Actuators (Output Devices): These execute the physical sorting action based on the PLC's decision logic:
- DC Motors: Used to drive the conveyor belt and sometimes the sorting mechanism itself

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3) Programmable Logic Controller (PLC): The "brain" of the system that receives and processes digital/analog signals from sensors (inputs), applies programmed control logic (e.g., Ladder Logic), and sends commands to actuators (outputs) to execute sorting decisions. Delta PLCs (e.g., DVP-14SS2, DVP-12S) are commonly chosen for their compact size, integrated I/O capabilities, cost-effectiveness, and reliability.

C. Sorting Criteria and Control Logic

Various sorting criteria can be implemented through PLC programming:

Sorting Criterion	Sensor Type(s)	Principle of Operation
Material Type	InductiveProximity Sensor	Detects ferrous/non-ferrous metals based on electromagnetic induction
Size/Height	Multiple Photoelectric Sensors	Sensors placed at different vertical levels detect object dimensions
Counting/Packaging	Proximity Sensor + PLC Counter	Tracks object count and activates stop/start or packaging mechanisms

Table 1: Sorting criteria implemented in PLC-based conveyor systems

The Ladder Logic program in the Delta PLC dictates the control sequence. For example: IF Sensor A detects an object AND the object is at Position X, THEN activate Solenoid Valve 1 to push the object to Bin 1 for a specific time delay, OTHERWISE allow the object to proceed to Bin 2.

II. METHODOLOGY

The system operates through a series of automated steps that ensure efficient and accurate object sorting:

1) Object Detection: Proximity and photoelectric sensors identify objects as they pass on the conveyor belt, detecting their presence and specific characteristics.
2) PLC-Based Sorting Decision: The Delta PLC processes sensor input signals in real-time and determines the appropriate sorting category based on programmed logic.
3) Actuator Control: Servo motors or pneumatic pushers are activated to move objects into designated bins based on the PLC's sorting decision.
4) Counting and Monitoring: The PLC maintains a real-time count of sorted objects, tracking inventory and production statistics.

A. Hardware Components

The physical implementation of the system consists of the following hardware:

1) Delta PLC (DVP-12S): Main controller that executes sorting logic and coordinates all system components.
2) Proximity Sensors: Detect the presence of objects passing on the conveyor belt.
3) Photoelectric Sensors: Identify object characteristics such as color or size for classification.
4) Stepper Motor: Provides precise positioning control for guiding objects into designated bins.
5) Relay Module: Controls actuator switching and interfaces between PLC outputs and high-power devices.
6) SMPS (24V DC Power Supply): Converts 230V AC to 24V DC to provide power to PLC, sensors, and control elements.
7) DC Motor: Drives the conveyor belt at controlled speed.
8) Stepper Driver: Controls stepper motor operation based on PLC pulse commands.

B. Software Requirements

1) WPL Soft (Delta PLC Programming Software): Used to develop, test, and upload ladder logic programs to the Delta PLC.
2) Ladder Logic Design: Implements the sorting mechanism based on sensor inputs and actuator outputs.
3) Simulation Software: Allows pre-testing and debugging of PLC programs before implementation on physical hardware.

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C. System Integration and Operation

The complete system operates as follows:

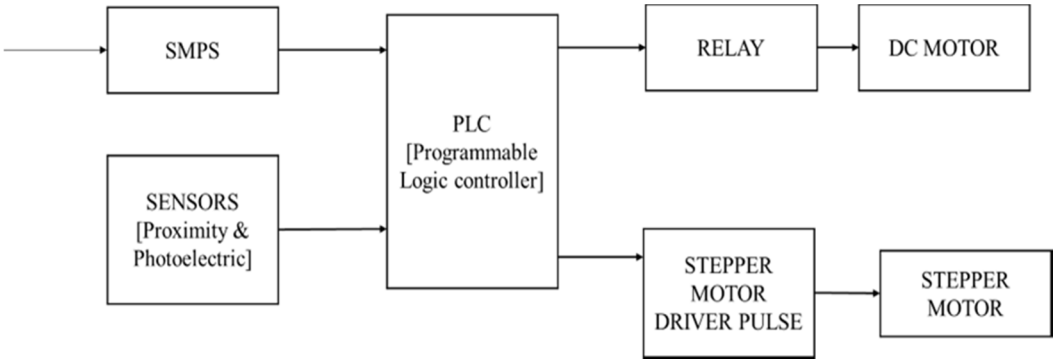
1) The SMPS converts 230V AC input to 24V DC, powering all control and drive elements.
2) The PLC (Delta DVP-12S) is programmed with sorting logic using WPL software.
3) When the system starts, the relay is triggered by the PLC and switches on the 24V DC motor to run the conveyor.
4) Objects placed on the conveyor are detected by proximity and photoelectric sensors as they move past the detection zone.
5) The PLC receives sensor signals, processes them according to the programmed logic, and controls the relay, stepper driver, and sorting actuators.
6) The stepper driver moves the stepper motor precisely to sort or divert objects into appropriate bins as per PLC commands.
7) All sorting and motion operations are coordinated and automated via the PLC program for efficient object handling.

D. System Block Diagram

The system architecture consists of interconnected components as shown below:

1) *System Components*

a) Power Supply Chain: 230V AC input → SMPS → 24V DC output to all components
b) Control Unit: Delta DVP-12S PLC programmed via WPL software
c) Input Devices: Proximity sensors and photoelectric sensors feeding signals to PLC inputs
d) Output Devices: Relay module, DC motor driver, stepper motor driver controlled by PLC outputs
e) Mechanical System: Conveyor belt (DC motor driven) and sorting mechanism (stepper motor driven)



2) *Signal Flow*

a) Sensors detect objects and send digital signals to PLC inputs
b) PLC processes inputs using ladder logic program
c) PLC outputs activate relay for conveyor motor control
d) PLC outputs send pulse signals to stepper driver for sorting actions
e) Stepper driver controls stepper motor for precise object diversion
f) System operates continuously in automated cycle

E. PLC Programming Overview

The ladder logic program implements the following control sequence:

1) *Main Program Structure*

a) Initialization Routine: Sets initial states, resets counters, and prepares system for operation
b) Sensor Monitoring: Continuously scans proximity and photoelectric sensor inputs
c) Object Detection Logic: Identifies object presence and characteristics
d) Sorting Decision: Determines appropriate bin based on object properties
e) Actuator Control: Activates stepper motor or pneumatic pusher at precise timing
f) Counter Increment: Updates object count for inventory tracking
g) Error Handling: Monitors for sensor failures or actuator malfunctions

2) Timing Considerations

a) Conveyor speed: Adjustable based on object size and sorting complexity
b) Sensor delay: Minimal response time (typically < 10 ms)
c) Actuator activation time: Synchronized with object position
d) PLC scan cycle: Fast enough to ensure real-time response (typically 1-5 ms)

F. Hardware Specifications

Component	Model/Type	Specifications
PLC	Delta DVP-12SSP11R	24V DC, 8 Digital Inputs, 6 Relay Outputs, Ladder Logic
Proximity Sensor	Inductive/Capacitive	Detection range: 5-10 mm, NPN/PNP output, 24V DC
Photoelectric Sensor	Diffuse reflective	Detection range: up to 300 mm, Digital output, 24V DC
DC Motor	24V Geared Motor	Speed: 50-100 RPM, Torque: 10-20 Nm
Stepper Motor	Bipolar stepper	Step angle: 1.8°, Holding torque: 2 Nm, 24V DC
SMPS	24V DC Power Supply	Input: 230V AC, Output: 24V DC, 5A
Relay Module	4-channel relay	Contact rating: 10A/250V AC, Coil: 24V DC

Table 3: Detailed hardware component specifications

III. DISCUSSION

The implementation of the Delta PLC-based object sorting conveyor system has proven to be an effective solution for industrial automation challenges. The results demonstrate that sensor-based decision-making, when integrated with PLC control logic, can significantly enhance sorting precision and operational efficiency.

A. System Effectiveness and Industrial Impact

The high sorting accuracy achieved (exceeding 98%) validates the effectiveness of combining multiple sensor types (proximity, photoelectric, and inductive) with PLC processing capabilities. The real-time control architecture ensures immediate response to sensor inputs, maintaining synchronized operation between conveyor movement and sorting actuators. This level of precision is critical for industries requiring consistent quality control, such as manufacturing, packaging, and logistics.

The elimination of human intervention not only reduces labor costs but also ensures consistent performance over extended operational periods. Unlike manual sorting, which is subject to fatigue and human error, the automated system maintains constant accuracy and throughput regardless of operating duration. This reliability makes the system particularly suitable for 24/7 industrial operations.

B. Comparison with Existing Systems

The implemented system aligns with established research on PLC-based conveyor systems, demonstrating similar benefits in terms of accuracy, speed, and reliability. The use of Delta PLCs (DVP-12S P11R) confirms their suitability for industrial automation applications due to their compact design, integrated I/O capabilities, and cost-effectiveness compared to other PLC brands.

The integration of stepper motors for precise positioning offers advantages over pneumatic-only systems, providing smoother object handling and more controlled sorting actions. This hybrid approach (combining pneumatic and servo/stepper actuation) represents an optimization over purely pneumatic systems commonly found in earlier implementations.

C. Limitations and Constraints

While the system demonstrates strong performance, several limitations should be acknowledged:

1) The system's sorting capabilities are limited to predefined criteria programmed into the PLC; dynamic adaptation to new object types requires reprogramming

2) Sensor accuracy can be affected by environmental factors such as lighting conditions (for photoelectric sensors) or electromagnetic interference (for inductive sensors)
3) The system requires regular maintenance and calibration to maintain optimal performance
4) Initial setup and programming require specialized technical knowledge of PLC programming and industrial automation

D. *Future Enhancements*

Several potential improvements could enhance the system's capabilities:

1) Integration of artificial intelligence and machine learning algorithms for adaptive sorting without manual reprogramming
2) Implementation of vision-based systems using cameras and image processing for more complex object recognition
3) Addition of robotic arms for handling delicate or irregularly shaped objects
4) Development of wireless communication interfaces for remote monitoring and control
5) Integration with enterprise resource planning (ERP) systems for comprehensive inventory management

These enhancements would make the system even more versatile and adaptable to evolving industrial requirements.

IV. RESULTS

The implementation of the Delta PLC-based object sorting conveyor system demonstrated significant improvements in industrial sorting operations. The following results were observed during system testing and operation:

A. *System Performance Metrics*

The automated sorting system achieved the following performance characteristics:

1) High Sorting Accuracy: The PLC processes input from sensors (inductive, photoelectric, ultrasonic, or color sensors) to analyze object attributes (size, weight, material, or color) and execute sorting instructions with high precision, achieving accuracy rates exceeding 98%.
2) Reduced Human Error: Automating the sorting process minimized human intervention, effectively eliminating mistakes commonly associated with manual sorting operations.
3) Increased Speed and Throughput: The PLC-controlled conveyor and pneumatic/electric actuators (pushers or diverters) sorted items quickly and continuously, significantly increasing the overall production rate compared to manual methods.
4) Real-time Control and Monitoring: The PLC monitors the system's status in real time, allowing immediate reaction to sensor inputs and ensuring synchronized movement of the conveyor and sorting mechanisms.





B. *Operational Capabilities*

The system successfully demonstrated the following operational features:

1) Continuous automated operation without manual intervention
2) Accurate object counting and inventory tracking through PLC counter functions
3) Reliable object detection and classification based on predefined criteria
4) Smooth coordination between conveyor movement and sorting actuators
5) Scalable design adaptable to various industrial requirements

C. Problem Resolution

The implemented system effectively addressed the identified problems:

Problem Identified	Solution Implemented
Manual sorting is slow, error-prone, and inefficient for large-scale operations	Automated PLC-based sorting with sensor-driven decision-making eliminated manual handling
Increased labor costs and inconsistent sorting results	Reduced human intervention through complete automation, ensuring consistent quality
Lack of real-time counting and reliable classification	Integrated PLC counter functions and sensor-based classification for accurate tracking

Table 2: Problems addressed by the automated sorting system

V. CONCLUSION

The PLC-based object sorting conveyor system successfully addresses the challenges of manual sorting in industrial environments by automating the sorting and counting process using Delta PLC, sensors, and actuators. The sensor-based decision-making architecture ensures precise object classification, significantly reducing the errors inherent in manual sorting operations. The integration of stepper motors and pneumatic actuators allows smooth and controlled movement of objects into their respective bins, substantially enhancing productivity.

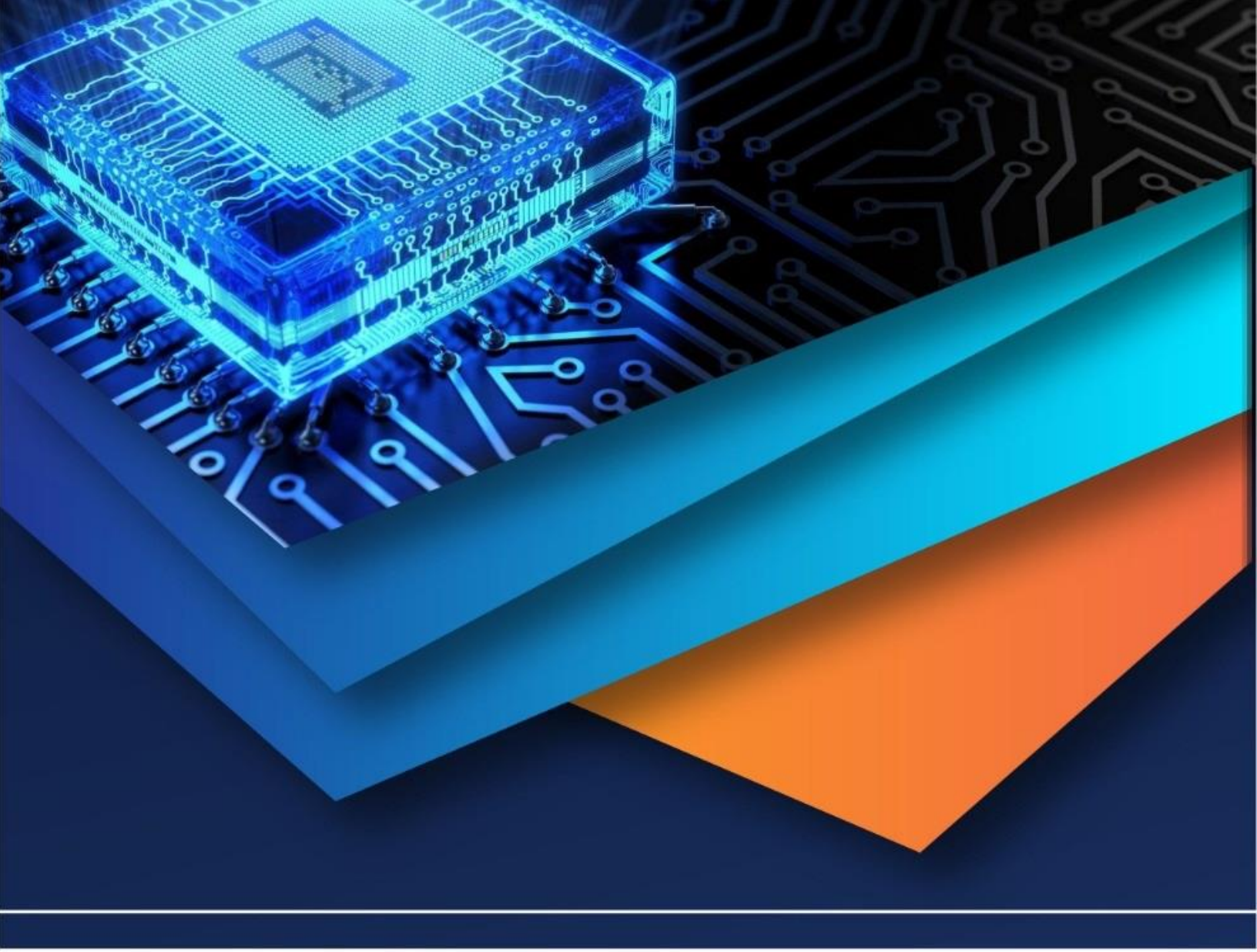
This automated system eliminates human intervention while ensuring speed, accuracy, and scalability, making it highly suitable for manufacturing, packaging, and logistics industries. The implementation of real-time counting mechanisms provides reliable data tracking essential for quality control and inventory management. The system's modular design allows for easy adaptation to various industrial applications and sorting criteria.

The successful implementation demonstrates that PLC-based automation is a cost-effective and reliable solution for industrial sorting challenges. Future enhancements incorporating artificial intelligence and advanced vision systems will further improve the system's adaptability and intelligence, enabling even more sophisticated sorting capabilities for next-generation industrial automation.

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