

Applied Programmable Logic Controllers

ACDA6000

Stefan-Cristian Daitoiu 2317310

1. Introduction	3
2. Abstract	4
What are PLCs?	4
Different PLC types used in industry	4
3. System Design and Implementation	6
Overview of the developed system	6
Physical layout and System Architecture	6
Weight Measurement and Processing	7
Sorting Logic and Decision Making	8
Programming	9
Conveyor Operation and Sequential Control	9
Counters and Signal Conditioning	9
Flowchart Description Of System Operation	10
Ladder Logic Implementation Overview	12
System Evaluation and Limitations	12
4. Conclusion	13

1. Introduction

This project involves the design and implementation of an automated factory sorting system using a programmable logic controller (PLC) and the Factory I/O simulation environment. [1]. The system is required to sort four different types of packages based on weight, demonstrating core principles of industrial automation including sensing, actuation, sequencing, and control logic.

The system is designed using Siemens TIA Portal, which provides an integrated environment for PLC programming. The simulated factory process is implemented and tested using Factory I/O, allowing realistic modelling of conveyors, sensors, and actuators in an industrial setting.

The system incorporates multiple industrial components including conveyor belts, pushers, sensors, a conveyor scale, stack lights, warning indicators, and an emergency stop system. These components are controlled through PLC logic to ensure correct sorting of packages, safe operation of machinery, and efficient system performance.

Overall, this project demonstrates the application of PLC-based automation in a realistic industrial scenario, combining control logic, system design, and operator interface development to replicate a modern automated manufacturing process.

2. Abstract

What are PLCs?

Programmable logic controllers (PLCs) are industrial computers that are specialised for the usage of automation and control machinery, production lines and process systems.

Furthermore, they are designed to provide flexible and reconfigurable control for industrial automation systems. One of their key advantages is that system behaviour can be modified through software programming rather than physical rewiring. This allows control logic to be updated quickly in response to changing production requirements, reducing downtime and improving system adaptability. [2]

PLCs are also more compact and reliable than relay systems due to the reduced number of mechanical components. This leads to lower maintenance requirements and improved operational reliability. In addition, PLCs can be expanded easily through modular input/output units, allowing systems to scale without major redesign. [3]

When compared to general-purpose computers, PLCs are specifically engineered for industrial environments. Furthermore, PLCs are designed to withstand vibration, temperature fluctuation, humidity, and electrical noise, making them more robust than standard computer systems. They also include built-in input/output interfaces and are optimised for real-time control tasks rather than complex data processing. [4]

Overall, PLCs provide an effective balance between flexibility, robustness, and ease of programming, making them a fundamental component of modern industrial automation systems.

Different PLC types used in industry

Programmable logic controllers are manufactured by several major companies, each offering different strengths depending on cost, application and regional industrial standards. The most commonly used PLC brands in industry include Siemens, Allen Bradley and Mitsubishi. Each brand has developed its own ecosystem and programming environment meaning the choice of PLC is often influenced by the continent it's used on location and the scope of requirements. [5]

Siemens PLC systems, such as the S7-1200 and S7-1500 series, are widely used across European industrial automation. These systems are programmed using Siemens TIA Portal, which provides an integrated environment for PLC programming, HMI design, and system diagnostics. Siemens PLCs are commonly found in automotive manufacturing, process control, and general factory automation due to their scalability and strong integration capabilities. A key advantage of Siemens systems is their ability to combine PLC control, HMI interfaces, and industrial communication within a single engineering platform. They also offer strong diagnostic tools and are widely supported in industrial environments. However,

they can have a steeper learning curve compared to simpler systems, particularly for beginners. [6]

Allen-Bradley PLCs, developed by Rockwell Automation, are primarily used in North American industries and are particularly common in large-scale manufacturing sectors such as oil and gas, automotive production, and heavy industry. These systems are known for their robustness and reliability in demanding industrial environments. They are supported by a well-developed software ecosystem, including Studio 5000 and FactoryTalk, which are widely used in industrial control applications. Despite their strengths, Allen-Bradley systems are generally expensive and operate within a closed ecosystem, which can limit flexibility when integrating with third-party systems or alternative platforms. [7]

Mitsubishi Electric PLCs are commonly used in Asia and are often selected for small to medium-scale automation applications such as packaging lines and assembly systems. They are considered a cost-effective alternative to Siemens and Allen-Bradley systems, offering reliable performance in compact industrial environments. Mitsubishi PLCs are relatively easy to implement and are suitable for straightforward automation tasks. However, they are less commonly used in the UK and European industries, and their software ecosystem is not as widely integrated or unified as Siemens TIA Portal, which can limit their flexibility in more complex systems. [8] [9] [10]

Overall, PLC brands differ significantly in terms of cost, performance, and regional adoption. Siemens is widely used in European industrial automation due to its strong integration capabilities and compatibility with engineering environments such as Siemens TIA Portal. Allen-Bradley dominates in North American heavy industry, while Mitsubishi is more commonly used in cost-sensitive or specialised automation applications. For this project, Siemens is the most suitable choice due to its strong integration with simulation tools such as Factory I/O, making it ideal for designing and testing automated control systems.

3. System Design and Implementation

Overview of the developed system

The purpose of this system is to demonstrate the application of PLC-based control in an industrial context, specifically focusing on sorting packages based on measured weight.

The developed system consists of a conveyor-driven process in which packages are introduced via an emitter and transported through a series of stages including detection, measurement, classification, and sorting. The design prioritises simplicity and clarity while still demonstrating key automation principles such as real-time decision making, signal processing, and actuator control.

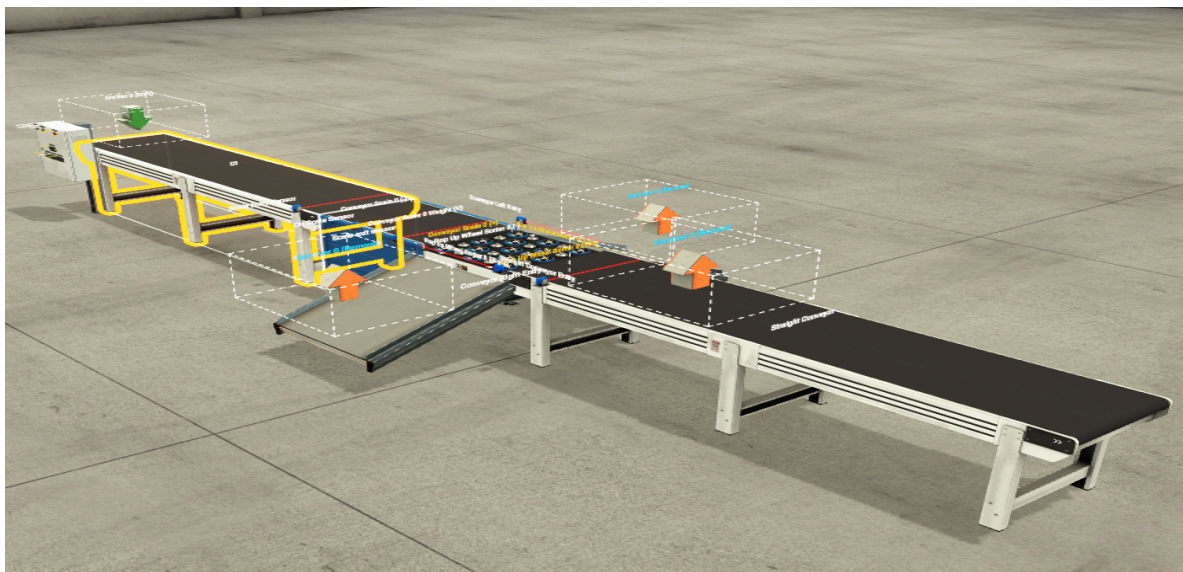


Figure 1: Overall System

Physical layout and System Architecture

The system layout was designed to provide a clear and logical flow of materials through each stage of the process. Packages are initially placed onto a primary conveyor, which transports them towards a sensing and measurement stage. A diffuse sensor is positioned before the weighing system to detect the presence of an incoming package and initiate the measurement sequence.

The weighing process is carried out using a conveyor scale, which forms a dedicated section of the conveyor system. This ensures that each package is stable during measurement, improving the accuracy and reliability of the recorded weight. Once the package has been weighed, it is then transferred onto the pop-up wheel sorter.

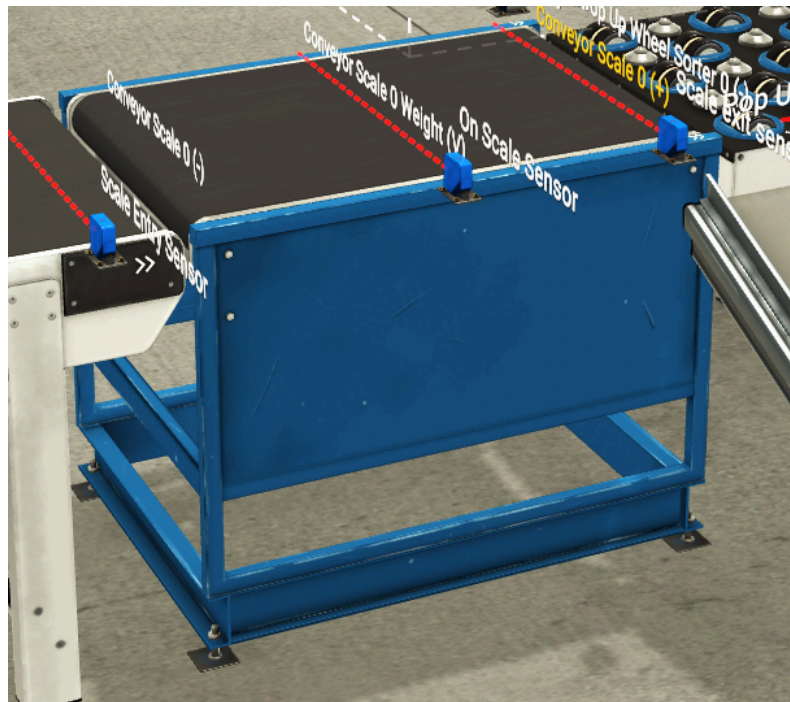


Figure 2: Scale

The pop-up wheel sorter is used as the primary actuation device for directing packages into different output paths. Depending on the classification result, the sorter diverts packages either to the left or right, while allowing others to continue straight ahead. This creates three distinct output paths corresponding to different weight categories. (Left for light packages, right for medium packages and straight on for large packages).

This structured approach ensures that sensing, measurement, and actuation are clearly separated, which simplifies both the control logic and the overall system design.

Weight Measurement and Processing

The conveyor scale provides an analogue signal representing the weight of each package. Within Siemens TIA Portal, this signal is interpreted as a continuous numerical value. Unlike digital inputs, which operate in binary states, the analogue value allows for precise measurement and classification. To ensure consistency in the sorting process, the weight is not continuously evaluated. Instead, the value is captured and stored at the moment the package is detected on the scale. This prevents fluctuations caused by movement or vibration from affecting the classification outcome. The stored weight value is then used for all subsequent decision-making processes. This approach reflects real industrial practice, where signal stabilisation and data integrity are critical for reliable system operation.

Sorting Logic and Decision Making

The sorting process is based on comparing the stored weight value against predefined thresholds. These thresholds divide the packages into three categories: small, medium, and large. Each category corresponds to a specific output path controlled by the pop-up wheel sorter.

Small packages are diverted to the left, medium packages are directed to the right, and large packages continue along the main conveyor path. This classification method provides a clear and efficient sorting mechanism while minimising the complexity of the physical system. The decision-making process is implemented within the PLC using comparison operations and logical conditions. This demonstrates the use of PLCs for real-time control and automated decision making in industrial environments.

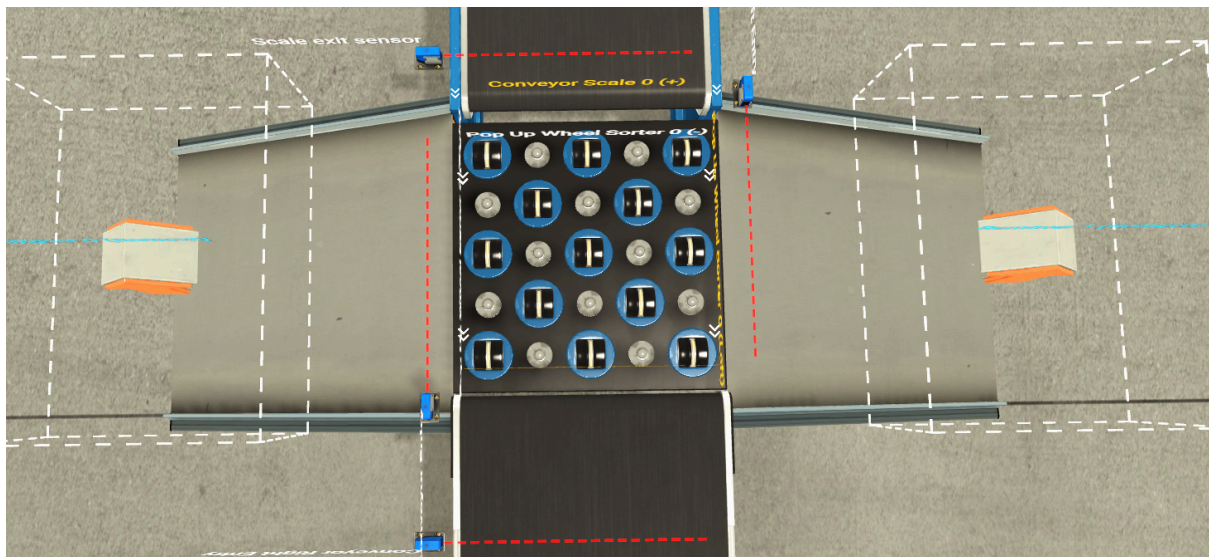


Figure 3: Weight sort

Programming

The programming is implemented using ladder logic within Siemens TIA Portal. There are different network rungs that perform different steps of the sequence, all within the “Logic” function block. This approach was used due to the small program size; splitting the logic over multiple function blocks would’ve made troubleshooting and visibility worse.

Conveyor Operation and Sequential Control

The conveyor system is designed to operate in a controlled and coordinated manner. Rather than starting all conveyors simultaneously, a sequential startup strategy is implemented. This involves introducing timed delays between the activation of each conveyor. This approach reduces the potential for high inrush currents and reflects real-world industrial practices where motor loads are staggered to protect electrical systems. Additionally, all conveyors are operated at a consistent speed to ensure predictable package movement and accurate positioning during the sorting process.



Figure 4: Push buttons

Counters and Signal Conditioning

To monitor the performance of the system, counters are implemented to track the number of packages sorted into each category.

During system testing, it was observed that prolonged sensor activation could result in multiple counts for a single package. To address this issue, a delay of approximately 100 milliseconds was introduced into the counting logic. This effectively prevents repeated triggering and ensures that each package is counted only once.

Furthermore, it was observed that having multiple instances of the same output being activated would create a race condition for the pop up wheel sorter which would cause it to not work at all. To fix this, multiple branches were connected to a singular “+” contact for the pop up wheel sorter so it would remove the race condition, thus allowing predictable behaviour to occur. This implementation highlights the importance of signal conditioning and timing control in PLC-based systems, particularly when dealing with real-time sensor inputs.

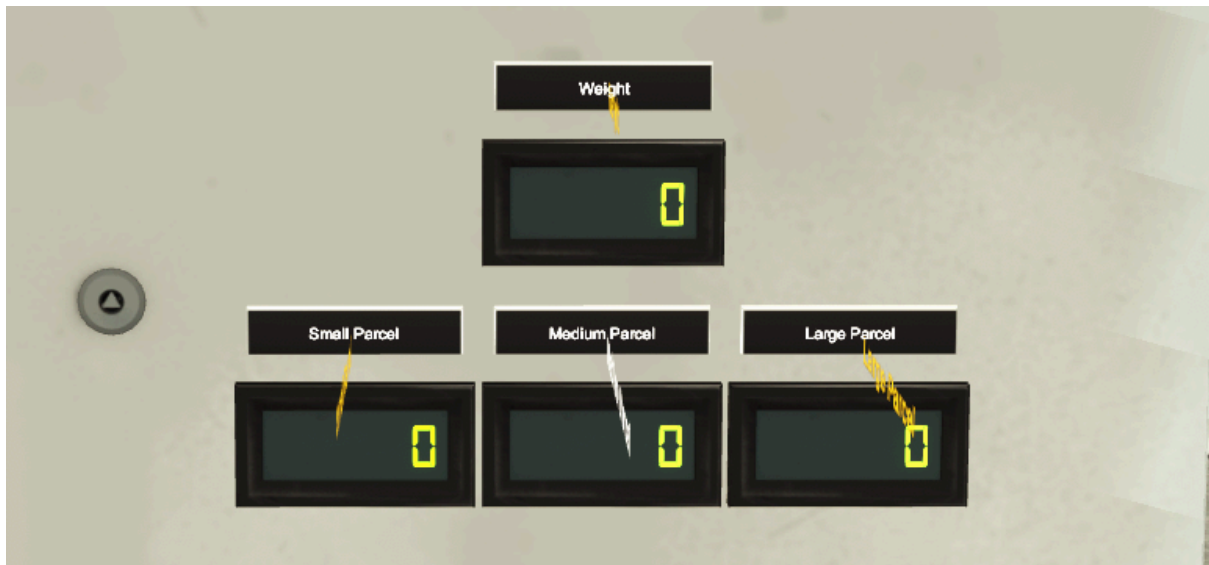


Figure 5: Displays

Flowchart Description Of System Operation

The overall system operation can be represented using a flowchart, beginning with system startup and proceeding through detection, measurement, classification, and sorting stages.

Initially, the system waits for the start button to be pressed on the control panel.. Once activated, the conveyors are started in sequence. Packages are then introduced into the system and detected by the first sensor. Upon detection, the system initiates the weighing process and captures the weight value.

The captured value is compared against predefined thresholds to determine the package category. Based on this classification, the appropriate output is activated to direct the package to its designated path. The corresponding counter is incremented, and the system returns to a waiting state for the next package.



Figure 6: Flowchart

Ladder Logic Implementation Overview

The ladder logic program is structured to reflect the sequential and conditional nature of the system. The main program includes networks for system start/stop control, conveyor sequencing, weight processing, sorting logic, counter management, and alarm handling.

Timers are used extensively to manage delays, including conveyor startup sequencing and counter debounce functionality. Comparison instructions are used to classify weight values, while logical operations control the activation of the sorting mechanism.

Each rung of the program is designed to perform a specific function, contributing to the overall operation of the system. This structured approach ensures clarity and aligns with industrial best practices.

System Evaluation and Limitations

The implemented system successfully demonstrates the fundamental principles of industrial automation, including sensing, data processing, decision-making, and actuation. The use of a conveyor scale and pop-up sorter provides a practical method for classifying packages based on weight.

However, it is important to recognise that this system is implemented within a simulation environment. As such, certain real-world considerations, such as mechanical wear, electrical noise, and advanced safety systems, are not fully represented. In a real industrial setting, additional features such as physical guarding, interlocked safety gates, and compliance with safety standards would be required. Despite these limitations, the system provides an effective demonstration of PLC-based control and automation.

4. Conclusion

This project has demonstrated the successful design and implementation of an automated sorting system using PLC technology. By integrating sensing, processing, and actuation within a structured control system, the project highlights the practical application of industrial automation principles.

The use of Siemens TIA Portal and Factory I/O enabled the development and testing of a realistic system, providing valuable insight into modern industrial control systems. The inclusion of features such as analogue measurement further enhances the system's relevance to real-world applications.

Overall, the project demonstrates how PLC-based systems can be used to create flexible, reliable, and efficient automated processes, forming a strong foundation for further study and application in industrial engineering.

Bibliography

- [1]R. Games, "Setting up S7-PLCSIM V13-19 - FACTORY I/O," *Factoryio.com*, 2026. <https://docs.factoryio.com/tutorials/siemens/setting-up-s7-plcsim-v13/#setting-up-s7-plcsim-with-tia-portal>
- [2]W. Bolton, "Programmable Logic Controllers," Jonathan Simpson, 2015. Available: <https://www.iqytechnicalcollege.com/Programmable%20Logic%20Controllers%20Sixth%20Edition.pdf>
- [3]StantonDaniel, "Relay Control vs. PLC Control Key Differences You Should Know," *Rabwellplc*. <https://rabwellplc.com/blogs/news/understanding-relay-vs-plc>
- [4]"AC500-XC | ABB," *ABB Group*, 2026. <https://www.abb.com/global/en/areas/motion/plc/programmable-logic-controllers/ac500-xc>
- [5]"Global PLC Market Share: Allen-Bradley vs Siemens vs Mitsubishi," *LEADTIME*, 2026. <https://leadtime.ca/blogs/learning-center/global-plc-market-share-allen-bradley-vs-siemens-vs-mitsubishi>
- [6]"Naksh Technology Solutions LLP," *Nakshtechology.com*, 2026. <https://www.nakshtechology.com/why-siemens-plc-s7-1200-is-the-best-choice-for-compact-automation-system/>
- [7]B. Hellman, "Allen Bradley vs Siemens: Comprehensive PLC Comparison," *Industrial Automation Co.*, Jan. 10, 2025. <https://www.industrialautomationco.com/blogs/news/allen-bradley-vs-siemens-comprehensive-plc-comparison>
- [8]K. Cheng, "Most Common Used PLC's in Industrialized Countries," *MRO Electric Blog*, Sep. 10, 2024. <https://www.mroelectric.com/blog/most-common-used-plcs-in-industrialized-countries/>
- [9]"MITSUBISHI ELECTRIC Global website," *MITSUBISHI ELECTRIC Global Website*, 2019. <https://www.mitsubishielectric.com/fa/products/cnt/plc/index.html>
- [10]*Eeworld.com.cn*, 2026. <https://en.eeworld.com.cn/news/qrs/eic693809.html>