Journal of Engineering, Technology & Applied Science
p-ISSN: 2721-7949, e-ISSN: 2721-8090

Original Research Paper

PLC Based Speed Control in a Color Sorting System: A Design and Simulation Perspective

Kalyankolo Umaru[1*], Munguleni Marlon[2], Yudaya Nansukusa[3], Salaama Asikuru[1], Nafuna Ritah[3], Kalyankolo Zaina[4]

[1] *Department of Electrical Engineering and Automation, Muni University. Uganda.*
[2] *Department of Electrical and Control Engineering, International University of East Africa. Uganda.*
[3] *Department of Computer and Information Sciences, Muni University. Uganda.*
[4] *Department of Electrical Engineering, Mbarara University of Science and Technology, Uganda.*

Article History
Received:
09.03.2025

Revised:
28.03.2025

Accepted:
09.04.2025

***Corresponding Author:**
Kalyankolo Umaru
Email:
u.kalyankolo@muni.ac.ug

Abstract: For simulation purposes in Factory IO and TIA Portal, the research is tailored to emulate industrial sorting operations. In numerous industrial scenarios, sorting operations play a crucial role, with objects segregated based on various criteria such as dimensions, colors, weight, and material composition. For instance, within Thermal Power Stations, electromagnetic sorting techniques are employed to separate ferromagnetic materials from coal. This research specifically focuses on sorting goods based on color, with adjustable speed parameters to match production rates. The system is equipped with a digital display screen, providing real-time feedback on the count of sorted objects, and receives an analog speed signal from the PLC for precise control. This research is divided into two primary components, i.e. Software and Simulation in Factory IO. The software aspect involves the implementation of ladder logic programming in TIA Portal, enabling systematic control of the entire research process based on the input data sequence, while the simulation in Factory IO is encompasses the virtual representation of conveyors for object transportation and RGB color vision sensors for color detection. The entry conveyor features two branches to load objects onto the respective conveyors, directed by the sorting logic implemented in TIA Portal.

Keywords: Digital Display Screen, Factory IO, Programmable Logic Controller, RGB, TIA Portal.

Journal of Engineering, Technology & Applied Science, vol. 7, no. 1, pp. 37-51, April 2025. **DOI: 10.36079/lamintang.jetas-0701.828**

1. Introduction

The color sorting machine is a sophisticated piece of equipment designed to automate the process of sorting objects based on their color. These machines are commonly used in various industries such as food processing, agriculture, recycling, and manufacturing to improve efficiency, accuracy, and consistency in sorting tasks [1] - [7]. The concept of color sorting dates back to the early 20th century when manual sorting methods were predominant in industries such as agriculture and manufacturing [8] [9]. With the advancement of technology, particularly in optics and computing, automated color-sorting machines began to emerge in the mid-20th century [10] - [12].

Early models were rudimentary and primarily used in specific industries such as food processing and textile manufacturing. Color sorting machines work based on the principles of optical sensing and image processing. A conveyor belt or chute system feeds objects to be sorted into the machine's inspection area. A high-resolution camera captures images of the objects as they pass through. Advanced image processing algorithms analyze the images to identify the color of each object accurately [13] - [16].

Based on predefined criteria, the machine activates pneumatic or mechanical mechanisms to divert objects into appropriate bins or channels. This research therefore, is intended to constitute a real time application which sorts objects by color with a controllable speed using a PLC [1]. The system attains efficient connection between the objects using several sensors [1]. The modules used with PLC for this system are, RGB color vision sensors for color detection, a potentiometer used to vary an analog voltage of 0 to 10V for speed control of the conveyor, a pivot sorter arm for sorting the objects, digital display screen to display the number of sorted goods and analog speed signals, Red and Green stack lights to show the off and on state of the system respectively.

The aim and objectives are:

1) to Programme a color vision sensor and pivot arm sorter in the ladder logic to achieve color sorting.
2) to integrate a module so as to control supply voltage frequency to achieve a variable speed.
3) to Programme a counter in the ladder logic to count the number of sorted goods.

2. Literature Review

The research aims to boost sorting efficiency by implementing speed control mechanisms, adjusting conveyor speeds according to production rates, as mentioned in research papers such as "Design and Development of a PLC Based Automatic Object Sorting" and "Design and Fabrication of Automated Sorting System." Furthermore, it seeks to automate the counting of sorted goods using counters, in line with suggestions from "Image Processing Based Automatic Color Object Sorting Using PLC System" to enhance accuracy and productivity.

Human color perception is trichromatic, based on stimulation of three types of cone cells: short (S), medium (M), and long (L) wavelengths, corresponding to blue, green, and red.

As Stephanie [10] mentioned, a color model is a method that uses three primary colors to generate a larger range of colors. There are several types of color models used for several aims, and each has a slightly different range of colors they can create. The whole range of colors that a definite type of color model creates is called a color space [1]. All color results from how our eye procedures light waves, but reliant on the type of media, creating that color comes from several methods.

T

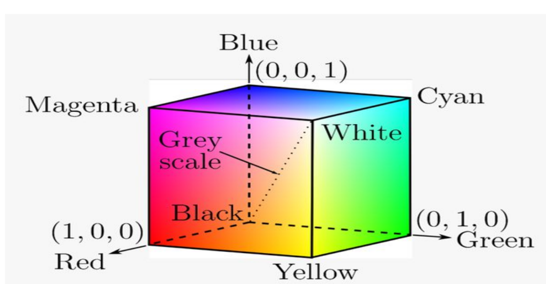


Figure 1. RGB Color Model Stephanie [10]

Two primary color models exist, with the most prevalent being the Red/Green/Blue (RGB) model utilized in digital media, harnessing light to produce color. RGB, also known as an additive color model, generates white when its three primary colors are displayed at equal intensity, and black when all lights are off. In an RGB image, each primary color (red, green, blue) comprises an independent image plane, with specific colors determined by the volume of each primary component [1] [10]. This model employs additive mixing of red, green, and blue to create secondary colors like yellow (red + green), cyan (blue + green), magenta (red + blue), and white (red + green + blue)

3. Methodology

The methodological steps involved in the research execution are as follows:

(1) The Research Architecture

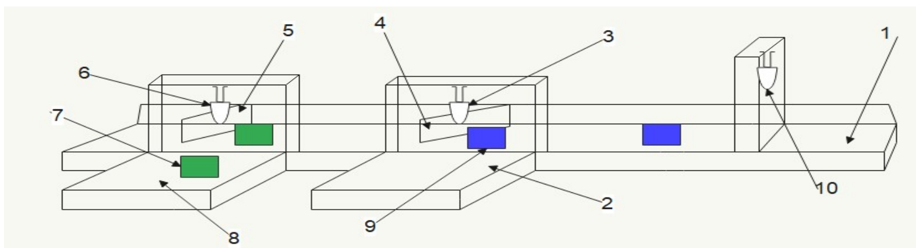


Figure 2. Research Architecture

- *Entry belt conveyor (6meters) labelled 1*: The production line, this facilitates the movement of the objects.
- *Two pivot arm sorters labelled 4 and 5:* Their purpose is to push the objects for sorting.
- *Two (2meter) conveyors labelled 2 and 8:* conveys the sorted objects to their destination.
- *Color Vision sensor labelled 10:* This sensor is programmed to detect both blue and green object. It's responsible for the operation of pivot sorter arms 4 and 5 depending on the color detected.
- *The exit color vision sensor labelled 3:* This sensor is specifically programmed to detect a blue colored object, its purpose is to reset the pivot arm sorter labelled 4 and also the plc.'s memory for the color vision sensor labelled 10 for blue detection.
- *The exit color vision sensor labelled 6:* This sensor serves the same purpose to that of 3, it's only programmed to sense a green colored object, and its purpose is to reset
- The pivot arm sorter labelled 5 and also the plc.'s memory for the color vision sensor labelled 10 for green detection.

(2) The Research Flow Chart for Sorting

To operate the system, it begins with initialization steps where all components are initialized, including the central color vision sensor, pivot arm sorters, and potentiometer signal. Once initialized, the system enters a main loop where it continuously monitors the central color vision sensor and other components.

Within the main loop, the system checks the value of the central color vision sensor. If the value is 4, indicating the presence of blue color, the system activates pivot arm sorter 1. Similarly, if the value is 1, indicating the presence of green color, the system activates pivot arm sorter 2.

Alongside sorting based on color, the system also adjusts the speed of the sorting system based on the potentiometer signal to ensure efficient operation. This cycle is continuous and the flow chart is shown in the Figure 3.

(3) The Programmable Logic Controller

A programmable logic controller (PLC) is an electronic system that can be programmed to control various machines or processes. It stores user-created instructions in its memory, allowing it to perform

Journal of Engineering, Technology & Applied Science, vol. 7, no. 1, pp. 37-51, April 2025. **DOI: 10.36079/lamintang.jetas-0701.828**

tasks like logic operations, sequencing, timing, counting, and arithmetic. PLCs can handle both digital and analog inputs and outputs.

Unlike older relay-based systems, PLCs offer more flexibility and advanced logic capabilities, making them versatile tools in industrial automation. SIEMENS is a notable brand known for producing high-performance automation devices, including PLCs, widely used across different industries for their reliability and adaptability.

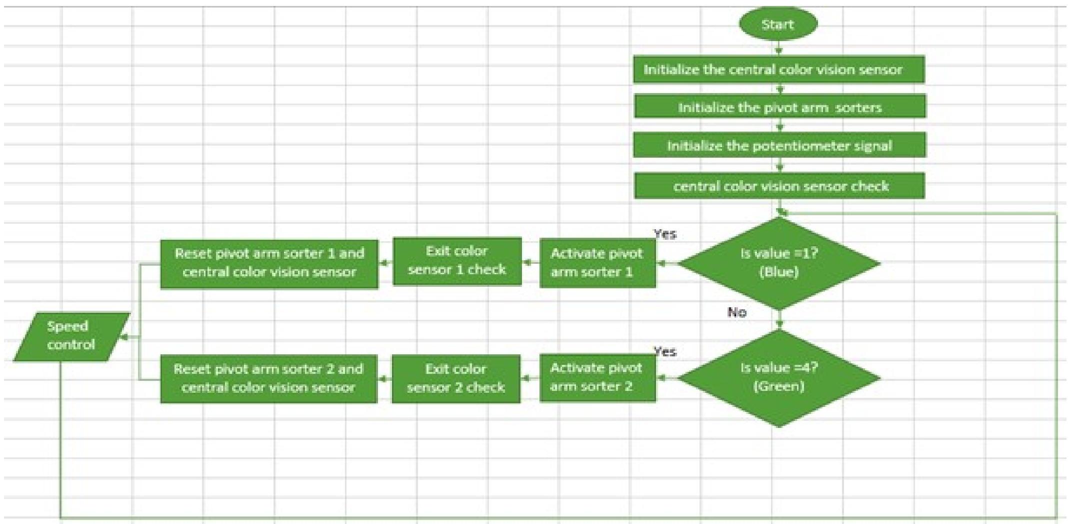


Figure 3. Sorting Flow Chart

(4) Programming in PLC

In this research, the PLC utilizes the Siemens Tia portal (Totally Integrated Automation Software) for programming purposes. This software provides a platform for users to input programs into the PLC. Before the PLC can execute any control tasks, it needs to be programmed accordingly.

Siemens Tia portal supports multiple programming languages, including:

- Ladder Language (LD): This language uses graphical symbols resembling ladder rungs to represent logic functions. It's commonly used in PLC programming due to its ease of understanding, especially for those familiar with electrical schematics.
- Function Block Diagram: This language employs graphical blocks to represent functions and their interconnections. It's useful for creating modular and reusable code, particularly for complex systems.
- Sequential Flow Chart (SFC): SFC is a graphical language that represents the sequence of steps in a process. It's beneficial for visualizing and designing sequential control logic.
- Structured Text Language (STL): This text-based language resembles traditional programming languages like C or Pascal. It's suitable for implementing complex algorithms and mathematical operations.

(5) Ladder Logic

Indeed, ladder logic is extensively utilized in PLC programming, especially in scenarios necessitating sequential control of processes or manufacturing operations. It is a graphical programming language that mirrors relay diagrams, making it well-suited for translating traditional relay-based control systems into PLC logic. Ladder logic is particularly effective for combinational processing.

The language employs fundamental graphic symbols such as contacts, coils, and blocks to represent various components and operations within a control system. Contacts symbolize inputs or conditions, while coils represent outputs or actions. Blocks, on the other hand, encapsulate sets of instructions or logic operations.

Ladder logic allows for the execution of specific calculations and operations within these blocks, enabling complex control tasks to be implemented efficiently. Furthermore, any necessary modifications or adjustments to the control tasks can be made by simply altering the program, providing flexibility and ease of maintenance.

Overall, ladder logic's intuitive graphical representation, its ability to handle sequential control tasks, and its suitability for combinational processing make it a preferred choice for PLC programming in a wide range of industrial applications.

3.1. PLC System Architecture

The system is comprised of several functional units essential for industrial automation, including color vision sensors, exit color vision sensors 1 and 2, conveyor belts, pivot arm sorters, stack lights, digital displays, and potentiometers. At the core of this system is the PLC (Programmable Logic Controller), which serves as its central control unit.

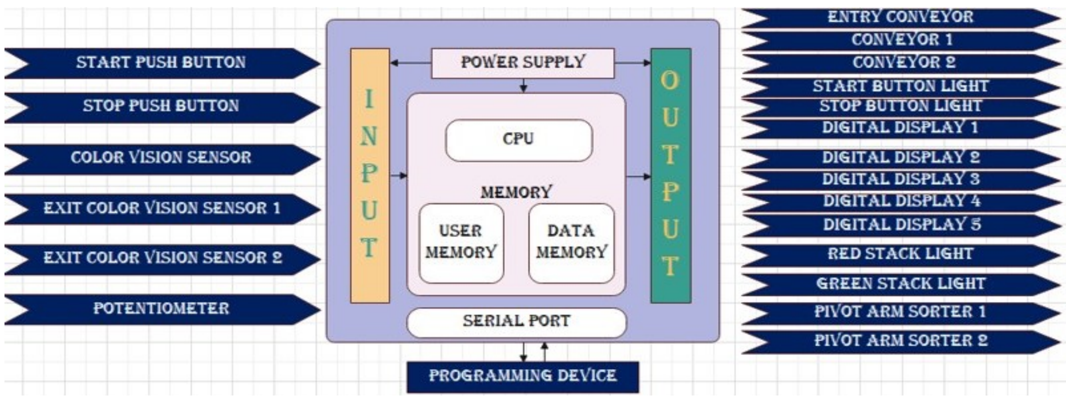


Figure 4. PLC Architecture

3.1.1. Description of the Proposed System

The project involves designing and simulating a PLC-based speed-controlled automatic color sorting system, which is divided into six cycles or modules. Speed control module, object counting module, system state indicators (Red and Green stack lights), object detection, object placement on conveyor belt and conveyor starting, sensory detection, and sorting mechanism.

By incorporating controllable speed adjustment and automated object counting into the sorting machine, the project aims to enhance efficiency, accuracy, and ease of operation. These features not only improve the sorting process but also streamline record-keeping, reducing manual effort and potential errors.

3.1.2. Object placing module

The object placing module (emitter) serves as the mechanism responsible for moving objects between workstations within the sorting machine. In real world scenario, emitter emulates the robotic arm for object placement onto a conveyor. Its function is to transfer objects from one station to another based on predefined criteria, such as material type or other properties. In the context of Factory I/O simulation, the emitter module is simulated to release objects onto the conveyor belt or another transport mechanism, ensuring they are directed to the appropriate workstation for further processing or sorting.

3.1.3. PLC Module

The PLC module (Siemen's PLCSIM) consists of the following;

- Simatic S7-1200
- 24v DC power module
- Digital input modules
- Digital output modules
- 4 Analog inputs
- 8 Analog out puts.

Figure 5 Siemen's PLC Simulator

The Siemens S7-1200 is a popular PLC (Programmable Logic Controller) used in industrial automation applications. Overall, the Siemens S7-1200 PLCs offer a combination of performance, flexibility, and scalability, making them well-suited for a wide range of industrial automation applications. In my project, its virtual form was used as the controller.

3.1.4. Conveyor Belt Module

The project comprises an entry belt conveyor that transports objects to pivot arm sorters for separation and simultaneous sensing. The objects are sorted during this process. A conveyor named "blue belt conveyor" is designated for transporting blue sorted objects to their respective destination, while a conveyor named "a green belt conveyor" is allocated for carrying green sorted objects to their final destination.

3.1.5. Object Pushing Module

In this module, the pivot arm sorter receives sorting signals from the color vision sensor based on the detected color. For instance, when a blue object is detected, pivot arm sorter 1, programmed for blue objects, and is activated. Similarly, when a green object is detected, pivot arm sorter 2 is activated.

3.1.6. Sensor Module

In this project, three color vision sensors were employed: the central color vision sensor, exit color vision sensor 1, and exit color vision sensor 2. The central vision sensor is configured to detect blue and green colored objects, thereby enabling it to activate the respective pivot sorter arms.

3.2. Project Design

The project progressed through five stages during its design and simulation. The Factory IO software served as the virtual platform for 3D design, while Siemens' Totally Integrated Automation software was utilized for developing ladder logic.

3.2.1. Stage One of the Project Design

The outset of the project was characterized by the initial phase of design and simulation. Here, the key focus was to facilitate the activation and deactivation of the entry conveyor using push buttons, alongside implementing stack lights to signify system states. A green stack light illuminated to indicate the system was operational, while a red stack light indicated it was inactive. Furthermore, a green button light denoted the running state, while the stop button light indicated the off state.

3.2.2. The Stage One of The Project Design Components

The components used are:

- Electric Switch Board
  In Factory I/O, an electric switchboard simulates power distribution and control, incorporating safety features and fault simulation for training in industrial automation and electrical engineering.
- Stack Lights
  In Factory I/O, stack lights simulate visual status indicators for machines, signaling normal operation, warnings, or faults.

Journal of Engineering, Technology & Applied Science, vol. 7, no. 1, pp. 37-51, April 2025. **DOI: 10.36079/lamintang.jetas-0701.828**

- Column
  In Factory I/O, columns are structural elements that provide vertical support to the virtual factory environment.
- Start Push Button
  A start push button is a manual control device in industrial settings used to initiate machine operations. When pressed, it sends a signal to start the intended process, ensuring safe and controlled operation.
- Stop Push Button
  A stop push button in industrial contexts is a manual control device used for emergency halting of machine operations. When pressed, it swiftly interrupts power to machinery, ensuring safety by providing a rapid means to stop operations.

(a) (b) (c) (d) (e)

Figure 6. Components Used
(a) Electric Switch Board
(b) Stack Lights
(c) Column
(d) Start Push Button
(e) Stop Push Button

The entry belt conveyor (6 meters) is the initial component responsible for transporting items into the sorting process.

Figure 7. Entry Belt Conveyor

Assembling all the aforementioned components, the initial phase of the design was successfully completed, as illustrated in Figure 8.

Figure 8. First Design Phase

Journal of Engineering, Technology & Applied Science, vol. 7, no. 1, pp. 37-51, April 2025. **DOI: 10.36079/lamintang.jetas-0701.828**

3.3. Stage Two of The Project Design Components

In this stage of the design, all the tools utilized in the initial phase are retained, supplemented by the inclusion of the object placing module, which essentially corresponds to the emitter in Factory IO. A representative image of the emitter is provided in Figure 9

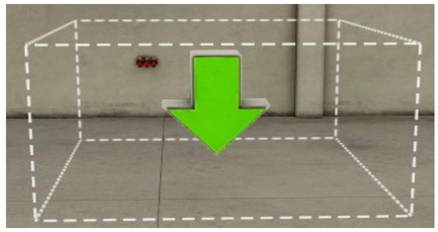


Figure 9. Emitter

The emitter serves as a fundamental component in Factory I/O, generating items within the virtual environment to simulate production processes.

3.4. Stage Three of The Project Design Components

In this phase of the design, we maintain all the tools utilized in the initial phases, while also introducing two additional 2-meter belt conveyors specifically designed to transport blue and green sorted objects to their respective destinations. Additionally, including two chute conveyors to facilitate the transfer of sorted objects from their corresponding belt conveyors. Below is a representative image of the two meter belt conveyor.

Figure 10. Integration of Two 2 Meter Belt Conveyors Into Third Phase of Design

Figure 11. Depicts the Inclusion of Chute Conveyors Designed to Transfer Sorted Objects From Their Respective Belt Conveyors

Journal of Engineering, Technology & Applied Science, vol. 7, no. 1, pp. 37-51, April 2025. **DOI: 10.36079/lamintang.jetas-0701.828**

Combining all the aforementioned components, the third phase of the project design has been effectively executed, as demonstrated in Figure 12

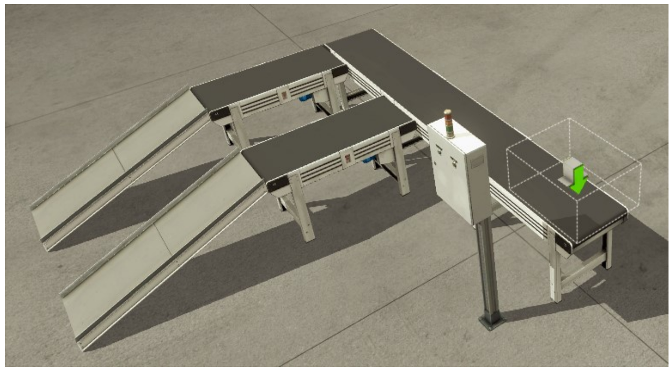
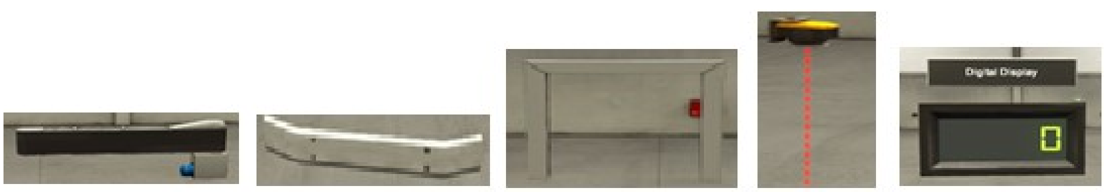


Figure 12. A Complete Stage Three Project Design

3.5. Stage Four of The Project Design

In the advanced phase of the project, the fourth stage sees significant enhancements to the existing components from the third stage. These upgrades primarily involve the integration of two pivot arm sorters and the addition of a central color vision sensor, accompanied by two exit color vision sensors, each named according to their specific spatial orientations within the system. Furthermore, six aligners are introduced to ensure precise positioning of the sorted objects, complemented by the inclusion of three brackets strategically placed to securely mount and position the color vision sensors. Detailed representations of all these tools are provided in the figures on the subsequent page, with each tool represented singularly for ease of comprehension. Moreover, two digital displays are introduced to furnish real-time feedback, presenting the ongoing count of sorted objects classified as either green or blue.

The additional components included are shown in Figure 13.



(a) (b) (c) (d) (e)

Figure 14. Stage Four of The Project Design Components
(a) Pivot Arm Sorter
(b) Aligner
(c) Bracket
(d) Color Vision Sensor
(e) Digital Display

The assembly of various equipment shown in the above figures culminated in the successful completion of the fourth phase of the project design. Figure 15 provides a visual representation of the entire design completion process.

3.6. The Color Vision Sensor In Factory IO

In Factory IO, the color vision sensor returns a value of 4 when a green object is detected and a value of 1 when a blue object is detected. This technique can be utilized in ladder logic to trigger sorting signals based on the detected colors, as shown in Figure 16. By incorporating these sensor values into ladder logic programming, specific actions can be programmed to sort objects accordingly based on their detected colors.

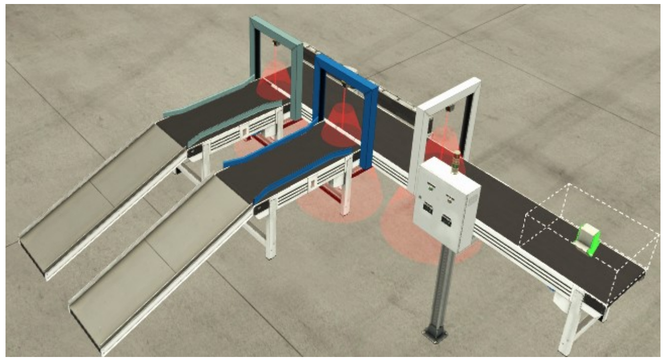


Figure 15. A Complete Stage Four of The Design

Figure 16. Sensor Returns Value 4 for Green And 1 For Blue Objects

3.7. Stage five of the project design

In the final project phase, most components from the advanced stage four are utilized, with the addition of speed control integration into the sorting system. A potentiometer sends 0 to 10 volts to the belt conveyors, which is interpreted by the Variable Frequency Drive (VFD) as a 0 to 50Hz frequency range. By using a mathematical equation (given below) involving the supply voltage frequency and the number of machine poles, synchronous speed is controlled.

$$N_s = 120\, f / P \qquad (1)$$

Where *Ns stands for synchronous speed, f for the supply frequency, P for the number of poles of the induction motor*.

The additional components used are shown in Figure 17.

(a) (b)

Figure 17. Stage Five of the Project Design Components
(a) Potentiometer
(b) Digital Display

Journal of Engineering, Technology & Applied Science, vol. 7, no. 1, pp. 37-51, April 2025. **DOI: 10.36079/lamintang.jetas-0701.828**

The complete 3D design of the last phase of the project is shown in Figure 18.

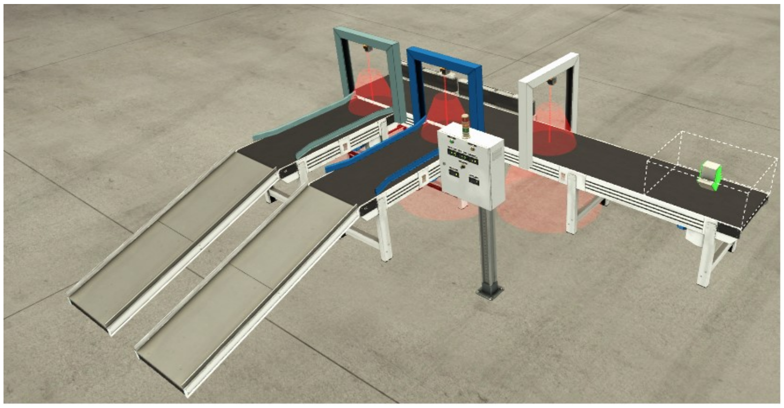


Figure 18. A Complete Stage Five of The Project Design

In phase five of the project design, the input terminal numbers for the start and stop push buttons, as well as the central color vision sensor 1, remain unchanged. Specifically, the potentiometer is connected to analog input ID34.

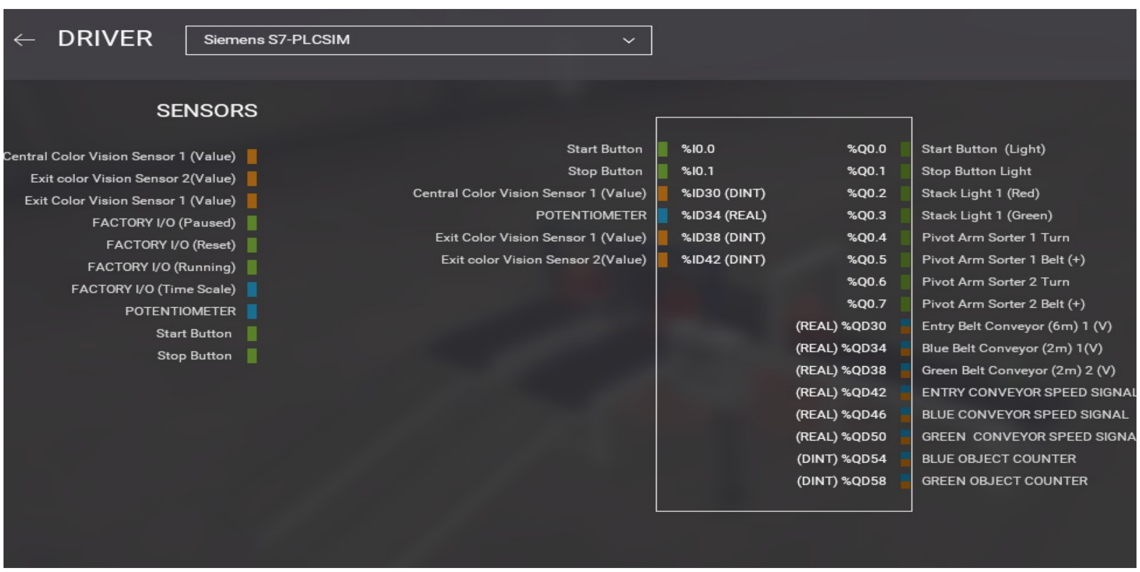


Figure 19. Connection of Field Devices to the I/O Modules of PLCSIM

The wiring configuration for various components is as follows:

- *The start button light is connected to digital output terminal Q0.0 of the PLC.*
- *The stop button light is connected to digital output terminal Q0.1 of the PLC.*
- *The stack lights (red and green) are connected to digital output terminals Q0.2 and Q0.3 respectively.*
- *Pivot arm sorter 1 turn and its belt are connected to digital outputs Q0.4 and Q0.5 respectively.*
- *Exit color vision sensor 1 and 2 are connected to the analog input terminal numbers ID38 and ID42 respectively.*

- *Pivot arm sorter 2 turn and its belt are connected to digital output terminals Q0.6 and Q0.7 respectively.*
- *The entry belt conveyor is connected to the analog output terminal QD30.*
- *The blue belt conveyor is connected to analog output terminal QD34.*
- *The green belt conveyor is connected to analog output terminal QD38.*
- *The entry conveyor speed signal display is connected to the analog output terminal QD42.*

4. Finding and Discussion

(1) System Overview

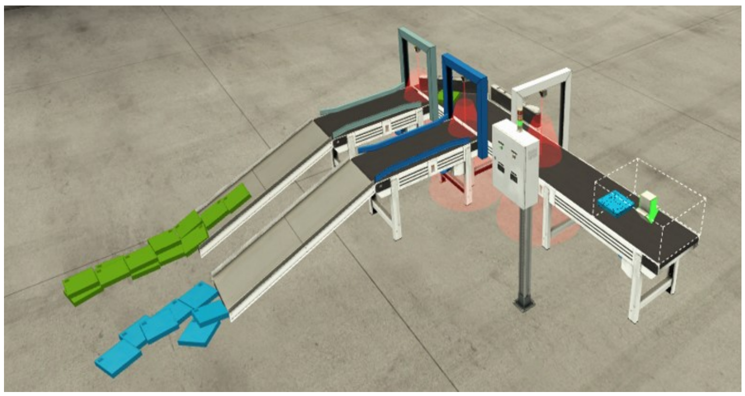


Figure 20. System Overview

(2) Counting the Number Of Sorted Objects

Figure 21 illustrates the counting process for the sorted objects. From the visual representation, it's evident that a total of eleven blue objects have been counted, with three green objects as well.

Figure 21. Counting Process for The Sorted Objects

(3) Speed Control Analog Signal 0f (5.7 Volts) Simulation

Figure 22 shows the analog speed signal for the control of the conveyor belts.

Figure 22. Analog Speed Signal of 5.7 Volts

(4) Speed Control Analog Signal of (10 Volts) Simulation

An analog speed signal of 10 volts shown for each of the three conveyors on their respective display screens.

Figure 22. Analog Speed Signal of 10 Volts

4.2. Discussion

In the simulation of the PLC-based speed-controlled color sorting system, integration of TIA Portal and Factory IO was seamlessly achieved, enabling a comprehensive simulation environment. The PLC logic was effectively programmed to interpret the voltage signal from the potentiometer, ranging from 0 to 10 volts, which was utilized to control the speed of the conveyor belt. This integration provided dynamic control over the system's speed, enhancing its adaptability and functionality.

During real-time simulation within the Factory IO environment, the color detection and sorting process operated smoothly. Objects were accurately sorted based on predefined color criteria, demonstrating the reliability of the system. Performance analysis revealed satisfactory results in terms of speed accuracy, color detection reliability, and overall sorting efficiency.

In discussions regarding the efficiency of PLC programming, the implemented logic for interpreting the potentiometer signal and controlling conveyor belt speed was evaluated. The simplicity and robustness of the programming logic were considered, along with potential areas for improvement or optimization.

Additionally, the accuracy of color detection algorithms and sensors was assessed. Challenges encountered in accurately identifying different colors were discussed, along with possible enhancements to improve detection accuracy.

Evaluation of the conveyor belt speed control mechanism highlighted its effectiveness in adapting to varying color detection scenarios.

Seamless integration between TIA Portal and Factory IO was a notable aspect of the project. The ease of simulation setup and data exchange between the software platforms facilitated a cohesive and realistic simulation environment.

Looking to the future, opportunities for improvement include refining color detection algorithms, optimizing PLC logic for enhanced speed control, and exploring alternative simulation software to leverage advanced features and capabilities. These enhancements aim to further optimize the system for real-world implementation, ensuring its effectiveness and reliability in industrial automation scenarios.

5. Conclusion

The simulation of the PLC-based speed-controlled color sorting system, integrating the potentiometer speed signal and stack lights to indicate system states, along with the use of counters in ladder logic to tally sorted objects, exemplifies the feasibility and efficacy of leveraging TIA Portal and Factory IO in industrial automation applications.

The system's dynamic control over conveyor belt speed, combined with robust color detection and sorting capabilities, highlights its promise for practical deployment in real-world scenarios.

The findings and discussions offer invaluable insights for ongoing refinement and optimization efforts, laying the groundwork for heightened performance and expanded functionality in industrial automation systems.

There are several improvements that can be made to the system to boost production rates and refine its overall model. These enhancements involve both adjustments to the program and upgrades to the components. For instance;

- We can implement the simulation into the real world.
- We can add a load cell for measurement and control of the product's weight.
- The system can be used as a quality controller by adding more sensors.
- The sensor can be changed according to the type of the product.

References

[1] K. Sasidhar, S. F. Hussain, S. A. Safdar, and M. A. Uddin, "Design and development of a PLC based automatic object sorting," unpublished.

[2] K. Sasidhar, S. F. Hussain, S. A. Safdar, and M. A. Uddin, "Image processing based automatic color object sorting using PLC system," unpublished.

[3] R. Maske, S. Dhawangale, and S. Badwaik, "Design and fabrication of automated sorting system," 2023.

[4] N. Shaukat, "PLC based automatic object sorting machine," in *Multi Topic Conference*, 2002, IEEE Publications.

[5] F. D. Petron Ella, *Programmable Logic Controllers*, Tata McGraw Hill Education, 2010.

[6] R. Selvakumaran, T. Kumaar, and M. Amarnath, "Color based product sorting machine: A systematic literature review," *Department of Mechatronics, Sathyabama Institute of Science and Technology*, Chennai, India, unpublished.

[7] A. Kassab, D. Al Nabhani, P. Mohanty, C. Pannier, and G. Y. Ayoub, "Advancing plastic recycling: Challenges and opportunities in the integration of 3D printing and distributed recycling for a circular economy," *Polymers*, vol. 15, no. 19, pp. 3881, 2023.

[8] L. Hou, Z. Liu, J. You, Y. Liu, J. Xiang, J. Zhou, and Y. Pan, "Tomato Sorting System Based on Machine Vision," *Electronics*, vol. 13, no. 11, pp. 2114, 2024.

[9] J. A. Rehgss and G. J. Satori, *Programmable Logic Controllers*, Pearson Prentice Hall, 2009.
[10] S. Przybylek, "What is a color model? - Uses & definition," *Study-Academy-Lesson*, 2018.
[11] J. Smith, *History of Industrial Sorting Machines*, Industrial Processing Press, 2010.
[12] R. Johnson, "Advancement in sorting technology," 2005.
[13] X. Li *et al.*, "Development of an RGB sensor-based color sorting system for agricultural products," *Journal of Agricultural Engineering*, 2018.
[14] Y. Chen *et al.*, "Enhancing color sorting accuracy with machine learning," *International Journal of Recycling Technologies*, 2019.
[15] K. Gupta and S. Bansal, "Industrial application of RGB sensors in sorting manufactured components," *Journal of Manufacturing Processes*, 2020.
[16] A. Kumar and J. Verma, "Challenges and solutions in RGB sensor-based color sorting systems," *Journal of Automation and Control Engineering*, 2021.