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Article

Development of Mini-Conveyor Trainer Kit based on Modbus Protocol

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Abstract: This research focuses on the development of a Mini-Conveyor Trainer Kit designed for automation system education. The prevalent communication protocol in the industry is the Modbus protocol. Therefore, the mini conveyor controller is equipped with an RS485 module to enable communication via the Modbus protocol. The mini conveyor employs a DC motor and is controlled using an 8-bit microcontroller. By utilizing the Modbus protocol, the mini conveyor can be controlled through a PLC, simulating an industrial conveyor system. This approach provides a comprehensive understanding of automation systems to learners. The trainer kit aims to bridge the gap between theoretical knowledge and practical application in automation systems. The integration of the Modbus protocol allows for real-time control and monitoring, which are critical skills in modern industrial settings. Throughout this research, we detail the design and implementation process of the mini conveyor system, including hardware setup, microcontroller programming, and Modbus communication protocol configuration. Additionally, we conduct a series of tests to evaluate the system's performance, reliability, and response time when controlled via a PLC. The results demonstrate that the mini conveyor trainer kit successfully replicates the functionality of industrial conveyor systems, making it an invaluable tool for educational purposes. Learners can gain hands-on experience with industrial communication protocols and control systems, enhancing their understanding and preparedness for careers in automation and manufacturing industries. In conclusion, the development of this Mini-Conveyor Trainer Kit provides an effective educational tool that aligns with industry standards, thereby enriching the learning experience and equipping students with essential skills for the future.

Keywords: conveyor, modbus, PLC

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1. Introduction

In the modern industrial era, automation systems have become a crucial component supporting various production processes across multiple sectors. Automation not only enhances efficiency and accuracy in manufacturing processes but also allows for operational cost reduction and improved workplace safety[1]. One key element in industrial automation systems is the conveyor, which functions to automatically move materials from one point to another. These conveyors are typically controlled by a Programmable Logic Controller (PLC)[2], which employs various communication protocols. One of the most commonly used protocols is Modbus, known for its stability, reliability, and ease of integration into various systems.

To support learning in the field of automation systems and provide a deeper understanding of industrial conveyor technology[3], realistic and representative learning tools are necessary. One solution that can be implemented is the development of a Mini-Conveyor Trainer Kit. This tool is designed to offer practical experience to students on the principles of conveyor operation and control methods using the Modbus protocol, similar to those used in real industrial applications. The Mini-Conveyor Trainer Kit is equipped with various components that allow for the simulation of conveyor operations in an industrial setting. The use of the Modbus protocol in this trainer kit enables reliable communication between the PLC and system components, including the control of on/off functions and conveyor speed regulation. The PLC manages various operational parameters of the conveyor, providing students with the opportunity to learn how to set and control these parameters according to industry standards. To facilitate communication between the controller and the PLC, an RS485 module is used, enabling efficient and stable data exchange[4].

Additionally, to monitor and control the rotation speed of the DC motor used in the conveyor, the system is equipped with a rotary sensor. This sensor provides feedback on the motor's rotation speed, which is then used for more precise control. Thus, students can understand the concept of closed-loop control commonly applied in industrial automation systems. The use of the Mini-Conveyor Trainer Kit with features that reflect real industrial conditions aims to provide comprehensive understanding to students. Through direct interaction with this device, they can develop practical skills in controlling automation systems while gaining insight into the importance of communication protocols like Modbus in system integration. This is expected to enhance students' competencies, preparing them to enter the industrial world with a strong understanding of automation and control technologies.

2. Methods

Conveyors in the industry are mechanical systems that function to transport materials from one point to another automatically and continuously. These systems consist of various components, such as belts or chains, motors, rollers, and supporting structures that work together to move goods or raw materials along a predetermined path[5]. In their applications, conveyors can be tailored to the specific needs of an industry, such as belt conveyors for light products, chain conveyors for heavy loads, or gravity roller conveyors that do not require a power source.

Conveyors are used in a wide range of industrial applications, from manufacturing and logistics to mining and construction. In the manufacturing industry, conveyors are often used to transport components, sub-assemblies, or finished products from one workstation to the next, facilitating an efficient production process and increasing productivity[6]. In the logistics sector, conveyors play a crucial role in the sorting and distribution of goods, such as in airports for the handling and transportation of passenger luggage, or in distribution centers for managing and dispatching packages to their destinations.

In the mining industry, conveyors are used to transport mined materials such as coal, metal ores, and other heavy materials from the mining site to processing facilities or for stockpiling. These conveyors can transport large quantities and heavy loads, significantly reducing reliance on manual labor and enhancing operational efficiency[7]. Additionally, conveyors can also be utilized in the construction industry for transporting materials like sand, gravel, or concrete, thereby speeding up the construction process. With the ability to operate continuously and reduce the need for manual labor, conveyors have become a crucial element in various industrial operations, helping companies achieve greater efficiency and productivity[8].

Students in the fields of automation, manufacturing, and mechatronics need to master conveyor technology as part of their understanding of industrial automation systems[9]. This expertise is crucial because conveyors are a key component in various production processes, used to transport goods efficiently and automatically. Mastering conveyor technology enables them to understand how to design, operate, and maintain these material transport systems. Additionally, knowledge of conveyors encompasses technical aspects such as the types of conveyors, their working principles, speed control, and load management, as well as practical aspects like installation, troubleshooting, and integration with other automation systems such as PLCs and sensors. By mastering conveyor technology, students can prepare themselves to contribute to the design and implementation of automation systems in various industrial sectors, thereby enhancing productivity and supporting technological innovation. This knowledge also opens up broader career opportunities in engineering, whether in manufacturing, logistics, or other sectors that utilize automation technology.

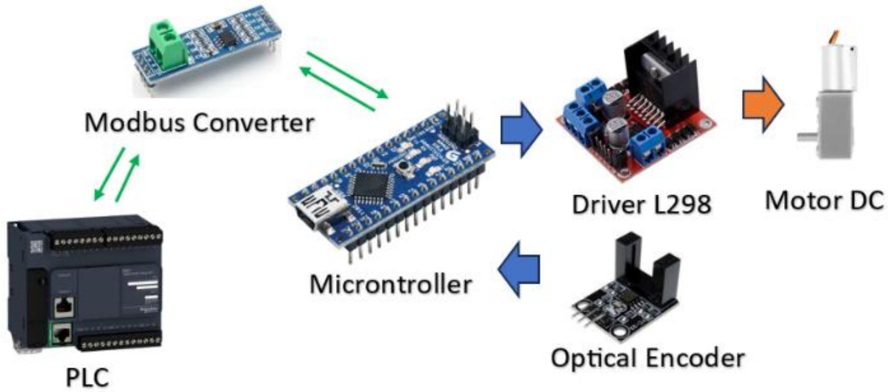


Figure 1. Block Diagrams System

Figure 1 displays a block diagram of a DC motor control system that uses the Modbus interface[10], commonly employed in industrial applications for communication and automation control. At the core of this system is the PLC (Programmable Logic Controller), which acts as the main controller, responsible for executing control logic and making decisions based on input received from various sensors or external commands. The PLC sends and receives data through a Modbus Converter, a device that converts communication signals from the PLC into a format that can be understood by the microcontroller and vice versa, enabling smooth two-way communication using the Modbus protocol, known for its stability and ease of integration[11].

After the signals are converted, the Microcontroller receives commands from the PLC via the Modbus Converter[12]. This microcontroller acts as a local control unit, processing the received commands and transmitting them to the L298 Driver, a motor driver that regulates the flow of electrical current to the DC motor. The L298 Driver allows precise control of the motor's rotation direction and speed, according to the application requirements. The motor can be used to drive various mechanisms, such as conveyor belts, pulleys, or even robotic mechanisms. The DC Motor itself is an actuator responsible for converting electrical signals into mechanical movement, which is crucial in various industrial automation applications. To ensure the system operates with precision, it is equipped with an Optical Encoder, a sensor that detects the speed and position of the motor's rotation. This optical encoder provides vital feedback to the microcontroller, enabling the system to make real-time adjustments to motor operation based on the data collected, such as the actual speed of the motor compared to the desired speed.

Thus, this diagram overall illustrates a comprehensive control system where all components work together to ensure accurate and efficient operation. The integration between the PLC, microcontroller, motor driver, and feedback sensor, through the Modbus communication protoco[13]l, creates a flexible and reliable control system, suitable for various industrial applications, such as factory automation, process control, and material handling. This system allows for centralized control and monitoring and provides ease in setting and adjusting operational parameters according to the specific needs of diverse industrial applications.

Conveyors work by converting motor rotation into translational motion on the belt. To convert the rotational speed of the motor shaft into the translational speed of a conveyor belt, we use the relationship between the rotational motion of the motor and the linear motion of the belt. The formula involves the radius of the driving pulley (or drum) that is attached to the motor and the rotational speed of the motor shaft. Equation 1 is the formula to calculate the translational speed v of the conveyor.

$$v = \omega \times r \tag{1}$$

Where,

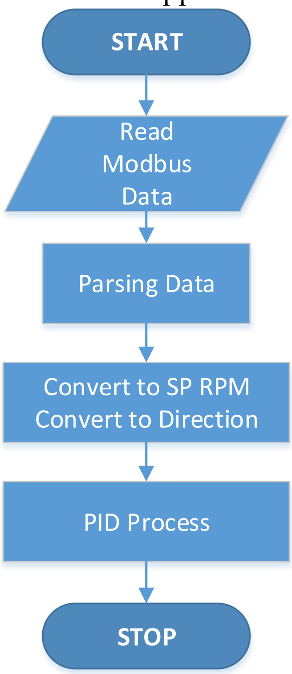
- v is the translational speed of the conveyor belt (typically in meters per second, m/s).
- ω is the angular velocity of the motor shaft (in radians per second, rad/s).
- r is the radius of the driving pulley or drum (in meters, m).

To find the angular velocity ω from the rotational speed N in revolutions per minute (RPM), equation 2 is used.

$$v = \left(\frac{2\pi N}{60}\right) \times r \tag{2}$$

Where,

- N is the rotational speed of the motor shaft (in RPM).
- π is a mathematical constant approximately equal to 3.14159.



- **Figure 2**. Flowchart system for microcontroller.

The system workflow begins with the PLC sending commands through the Modbus Converter to the microcontroller. The microcontroller then instructs the motor driver to drive the DC motor according to the received commands. The Optical Encoder provides real-time information about the motor's speed and position, which is used by the microcontroller to adjust and optimize the overall system performance. Figure 2 is diagram illustrates how each component works together in the conveyor control system to achieve precise and efficient control.

3. Results and Discussion

The learning kit is made using a belt conveyor type with a 12v DC motor drive. Figure 3 is a conveyor device used in this study. The DC motor is controlled by a microcontroller. The microcontroller will receive commands from the PLC regarding the RPM set point and the direction of motor rotation via modbus communication. For RS485 communication, the microcontroller uses serial software. Table 1 is a mapping of the pins used in the conveyor system.

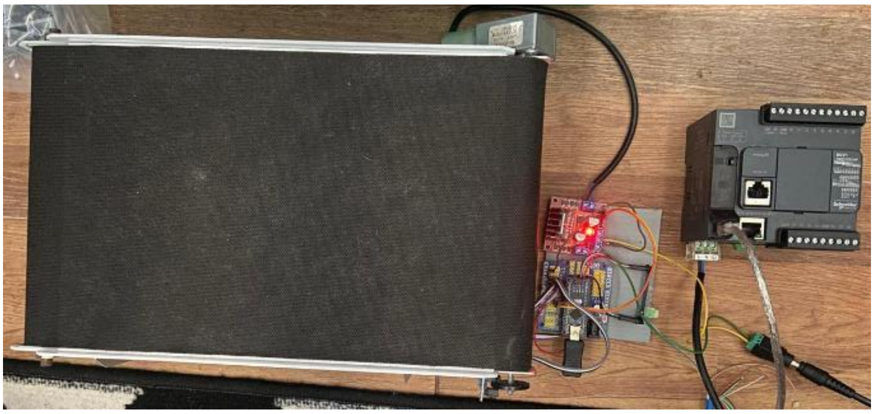


Figure 3. Conveyor and controller devices

Table 1. Pin Mapping

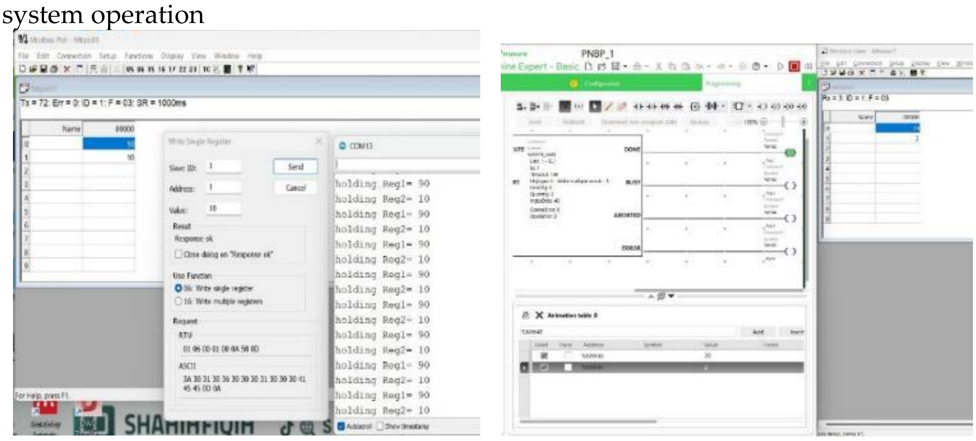
No	Microcontroller Pin	Connection
1	5	RX RS485
2	6	TX RS485
3	7	Enable Dir RS485
4	8	PWM L298
5	9	Direction L298
6	3	Rotary

Testing is a crucial aspect of any engineering project, particularly in the development and implementation of conveyor systems. The primary reason for conducting tests is to ensure that the system operates as intended and meets the required specifications. By performing thorough testing, engineers can identify and rectify any design flaws, operational inefficiencies, or potential safety hazards before the system is deployed in a real-world environment. Testing is essential to validate the design, ensure reliable operation, optimize performance, and guarantee safety. It provides the assurance that the conveyor system will function as required, delivering consistent and safe performance in its intended application.

3.1 Basic function testing

Basic Function Testing is performed to ensure that every component in the conveyor system operates according to its design and function. This testing includes verifying that all elements, such as the PLC, microcontroller, motor driver, DC motor, and optical encoder, work correctly. It involves checking whether the motor can be turned on and off according to commands, whether the motor can rotate in the correct direction, and whether the system can adjust the motor speed according to the instructions given. Basic function testing also ensures that all input and output signals are processed correctly by the system.

In the system created, PLC acts as a modbus master, while the microcontroller acts as a modbus slave. For connection testing, data communication testing is carried out through the modbus monitor application. Figure 4a is a test of sending data from the PLC to the modbus monitor. Figure 4b is a test of receiving data by the microcontroller from the modbus monitor. From the basic testing, the communication system was successful.This testing ensures that data and commands can be sent and received accurately and timely. It includes checking whether every message or command sent by the PLC can be correctly interpreted by the microcontroller and whether the microcontroller can send status data or feedback back to the PLC. This testing is crucial to ensure there are no interruptions or errors in communication that could affect the overall system operation

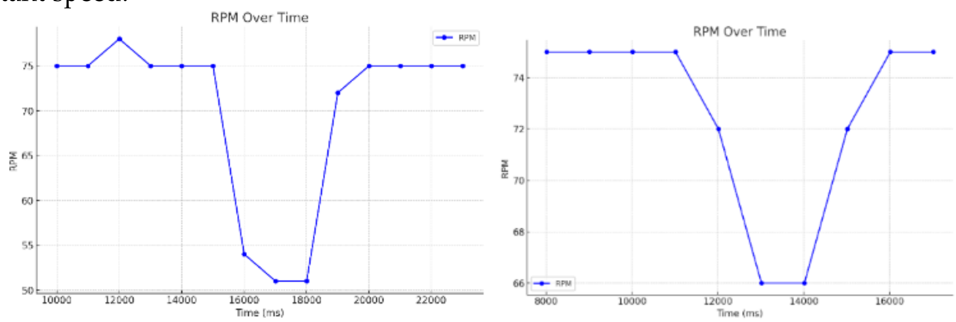


a) b)

Figure 4. a) Modbus Poll monitoring, b) Modbus Slave monitoring

3.4 Performance Testing

Load and Speed Testing is conducted to evaluate the system's capability to handle various load conditions and operating speeds. Load testing involves adding weight to the conveyor to ensure that the motor and related components can handle the given load without failure or performance degradation. Additionally, speed testing ensures that the conveyor can reach and maintain the desired speed according to specifications. This testing also includes verifying that the optical encoder can provide accurate feedback on the motor speed, allowing the microcontroller to adjust motor settings to maintain a constant speed.



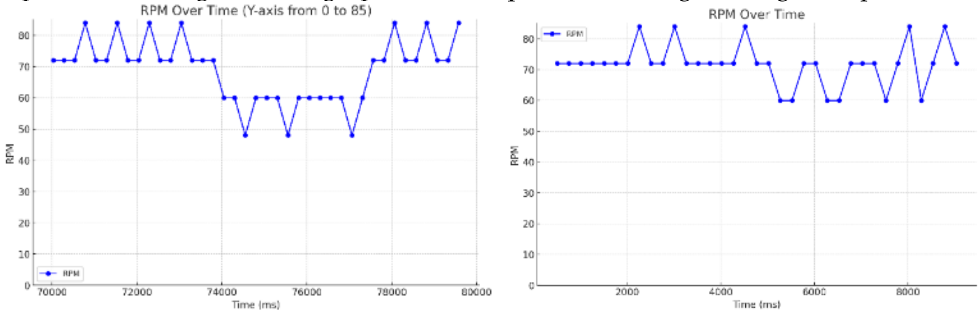
a) b)

Figure 5. Motor RPM with load a) 30gr, b) 60gr

Table 2. Load Testing

No	PWM	Load (gr)	Average RPM
1	128	0	75
2	128	30	45
3	128	60	65

Performance Testing is an overall evaluation of the efficiency and effectiveness of the conveyor system. This testing involves measuring various performance parameters such as operating speed, energy consumption, drive efficiency, and material handling capacity. The goal is to ensure that the system operates according to design specifications and meets the desired operational needs. Performance testing also includes assessing the system's stability in long-term operation and its ability to operate efficiently under various environmental conditions. The results of this testing provide a comprehensive overview of the system's performance and help identify areas that need improvement or optimization. Figure 6 is a graph of motor performance against a given speed reference.



a) b)

Figure 6. Motor RPM (Proportional Control) with load a) 30gr, b) 60gr

4. Conclusions

The development of the Mini-Conveyor Trainer Kit based on the Modbus protocol provides a practical educational tool for students to understand and experience industrial automation systems. The integration of the RS485 communication module with the Modbus protocol enables efficient and reliable control of the conveyor via a PLC, simulating real-world industrial operations. The system's performance, including its response to different loads and speeds, was tested and demonstrated to function effectively, making it an invaluable asset for learning automation and control technologies. The proportional control shows a good response in maintaining RPM with various load variations. By bridging theoretical knowledge with hands-on practice, this tool equips students with critical skills required in the industrial sector, preparing them for future careers in automation, manufacturing, and related fields.

Supplementary Materials: -

Author Contributions: "Conceptualization, 1st. and 2nd; methodology, 3rd; software, 4th; validation, 3rd and 6th; formal analysis, 5th; investigation, 4th; resources, 7th; data curation, 6th; writing—original draft preparation, 3rd; writing—review and editing, 4th; visualization, 4th; supervision, 5th; project administration, 2nd; funding acquisition, 1st"

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