Comprehensive Development and Integration of Mechatronics Assembly Line Systems Using Siemens PLC Technology

Project Report submitted in the partial fulfilment

of

Bachelor in Technology (BTech)
In
Mechatronics Engineering

By
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(2023-24)

CERTIFICATE

This is to certify that the project entitled "Comprehensive Development and Integration of Mechatronics Assembly Line Systems Using Siemens PLC Technology" has been done by **Mr. Adnan Kanchwala** under my guidance and supervision & has been submitted in partial fulfilment of the degree of Bachelors in Technology of the stream Mechatronics Engineering of MPSTME, SVKM's NMIMS (Deemed-to-be University), Mumbai, India.

Project mentor (Dr. Venkatesh Deshmukh)
(Internal Guide)

Examiner (Name and Signature)

Date

Place: Mumbai

(HoD) (Dr. Venkatesh Deshmukh)

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Sincerely,

Adnan Abbas Kanchwala

ABSTRACT

This report presents the culmination of an internship project focused on the comprehensive understanding, development, and integration of mechatronics assembly line systems using Siemens TIA Portal software and S7-1200/S7-1500 PLCs. The project encompassed a multifaceted approach, including PLC ladder logic development, individual unit testing, system integration, PLC replacement, Input/Output (I/O) segregation, wiring, error resolution, and HMI development. The initial phase involved gaining a deep understanding of the assembly line flow and the specific requirements of each system. This was followed by the development of PLC ladder logic for various systems such as Mixing Tanks, Traffic Lights, and Dispenser Systems, as well as addressing additional problem statements provided by the mentor. Unit testing played a crucial role, with individual systems undergoing rigorous testing on S7-1200 PLCs to ensure functionality and reliability. Proper wiring and matching of I/Os were meticulously executed, and continuity tests were performed to segregate I/Os for each unit. The total count of I/Os after segregation was determined to select the appropriate number of I/O modules.

Furthermore, the project involved the replacement of legacy S7-300 PLCs with modern S7-1500 PLCs, necessitating careful configuration and resolution of errors such as sourcing and sinking problems. Mechanical work, including table assemblies for various systems, was also undertaken to ensure seamless integration with the PLC-controlled processes. The project focused on the development of Human-Machine Interface (HMI) systems for real-time monitoring and control of assembly line operations. HMI interfaces were designed and implemented for various systems, enhancing operational efficiency and providing intuitive user interfaces for operators.

Overall, this internship project demonstrates a comprehensive approach to the development and integration of mechatronics assembly line systems, leveraging Siemens PLC technology and TIA Portal software. Through meticulous planning, execution, and testing, the project successfully delivered robust and efficient solutions to meet the operational requirements of the assembly line.

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Introduction

1.1 BACKGROUND OF THE PROJECT TOPIC

The project topic focuses on the automation of a complex mechatronics assembly line to streamline the process of packaging and storage. Mechatronics, an interdisciplinary field combining mechanical engineering, electronics, computer science, and control engineering, plays a pivotal role in modern manufacturing environments to achieve high efficiency and precision.

The assembly line comprises various interconnected systems, each contributing to different stages of the packaging and storage process. These systems include a Magazine Unit for component storage and retrieval, Conveyor Systems for material transportation between workstations, Handling Units for manipulating components, Pneumatic Presses for assembly operations, and an Automatic Storage and Retrieval System for efficient inventory management. Traditionally, these processes may have been executed manually or through rudimentary automation methods. However, with advancements in technology, particularly in Programmable Logic Controllers (PLCs) and Human-Machine Interfaces (HMIs), there exists a significant opportunity to enhance efficiency, accuracy, and flexibility in assembly line operations.

The adoption of Siemens TIA (Totally Integrated Automation) Portal software, coupled with Siemens PLC technology, offers a robust platform for developing, testing, and integrating automation solutions for complex mechatronics systems. By leveraging TIA Portal's comprehensive development environment, engineers can design intricate PLC ladder logic programs tailored to the specific requirements of each system within the assembly line. Automation of the mechatronics assembly line not only improves productivity but also ensures consistency and quality in the packaging and storage process. By eliminating manual intervention and minimizing human error, manufacturers can achieve higher throughput rates, reduced cycle times, and improved overall equipment effectiveness (OEE). Moreover, the integration of advanced control algorithms, sensor technologies, and real-time monitoring capabilities enables predictive maintenance, fault detection, and optimization of operational parameters, contributing to the overall reliability and performance of the assembly line.

1.2 MOTIVATION AND SCOPE OF THE REPORT

- **Motivation:**

The automation of manufacturing processes has become increasingly vital in modern industrial settings to enhance efficiency, accuracy, and throughput while minimizing operational costs. The integration of mechatronics systems, such as Magazine Units, Conveyor Systems, Handling Units, Pneumatic Presses, and Automatic Storage and Retrieval Systems, plays a pivotal role in achieving seamless automation within assembly lines. The motivation behind this project stems from the necessity to develop a comprehensive understanding of these mechatronics systems and their PLC-based control mechanisms to optimize manufacturing processes.

Automation not only streamlines production but also improves safety, reduces errors, and enables scalability to meet evolving market demands. By leveraging Siemens TIA Portal software and PLC technology, this project aims to harness the power of mechatronics to transform traditional assembly line processes into efficient, automated workflows.

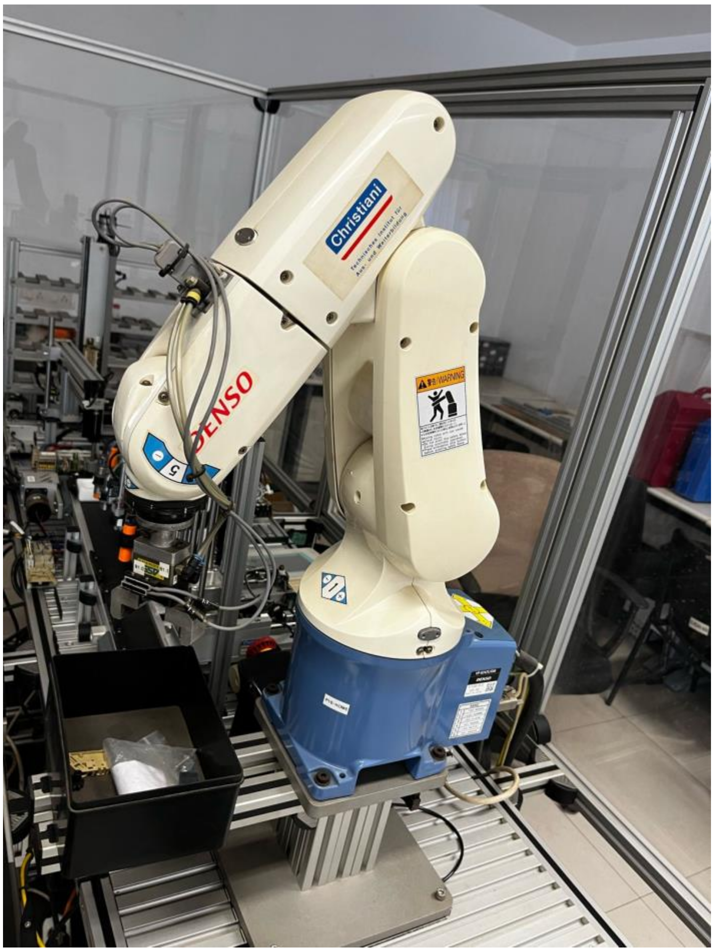


Figure 1: Mechatronics Assembly Line

- **Scope:**

  The scope of this project encompasses a wide range of activities focused on the development and integration of mechatronics assembly line systems using Siemens PLC technology. Specifically, the project will address the following key areas:

- **Understanding and Development of PLC Ladder Logic:**

  Comprehensive development of PLC ladder logic for each mechatronics system, including Magazine Units, Conveyor Systems, Handling Units, Pneumatic Presses, and Automatic Storage and Retrieval Systems. This involves translating the operational requirements of each system into logical control sequences to automate their respective functions.

- **Individual Unit Testing and Integration:**

  Rigorous testing of each mechatronics system on S7-1200 PLCs to ensure functionality and reliability. Subsequent integration of these systems into the larger assembly line framework to create a cohesive and synchronized manufacturing environment.

- **PLC Replacement and Configuration:**

  Replacement of legacy PLCs with modern S7-1500 PLCs to leverage advanced features and enhance performance. Configuration of PLCs to meet the specific requirements of the assembly line systems, including error resolution and optimization of control algorithms.

- **Input/Output Segregation and Wiring:**

  Segregation of input and output signals for each mechatronics unit using continuity tests to ensure proper interfacing with the PLCs. Implementation of structured wiring practices to facilitate seamless communication between the PLCs and peripheral devices.

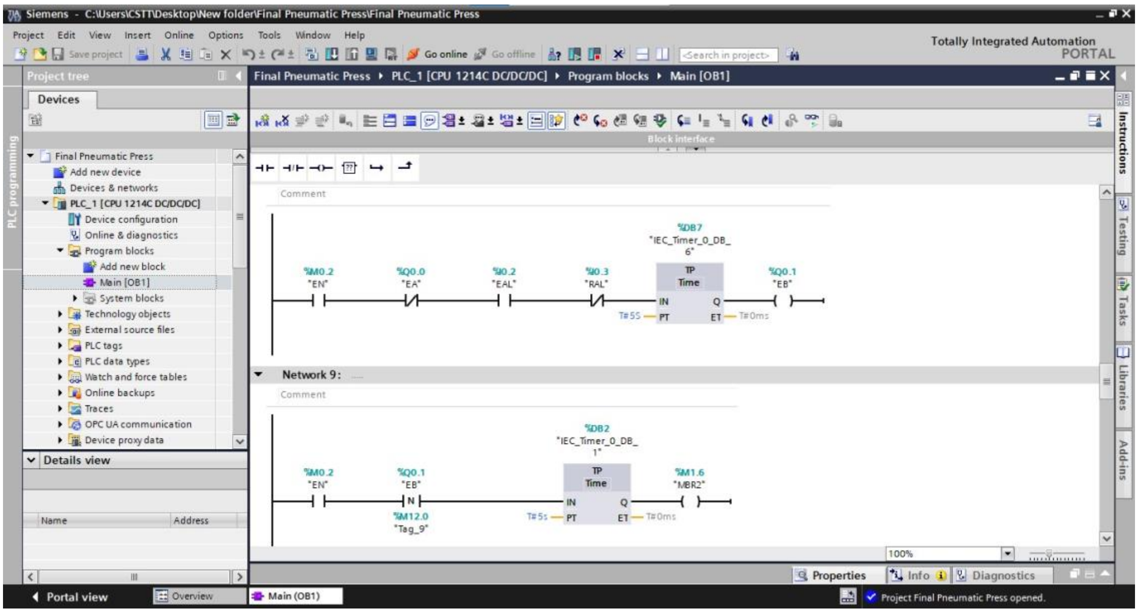
- **Human-Machine Interface (HMI) Development:**

  Design and development of intuitive HMI interfaces for real-time monitoring and control of the assembly line processes. Integration of HMI systems with PLCs to provide operators with comprehensive visibility and control over manufacturing operations.

- **Mechanical Work:**

  Execution of mechanical tasks such as table assemblies and structural modifications to facilitate the integration of mechatronics systems into the assembly line layout.

The integration of mechatronics systems within assembly line processes represents a significant leap forward in the realm of industrial automation. By automating the packaging and storage processes through meticulous development and integration of PLC-based control systems, this project endeavors to revolutionize traditional manufacturing workflows. The envisioned solution not only aims to enhance efficiency by streamlining operations but also prioritizes reliability and scalability to adapt to evolving market demands. Through the seamless coordination of Magazine Units, Conveyor Systems, Handling Units, Pneumatic Presses, and Automatic Storage and Retrieval Systems, the assembly line will become a well-oiled machine, capable of consistently delivering high-quality products at an accelerated pace.



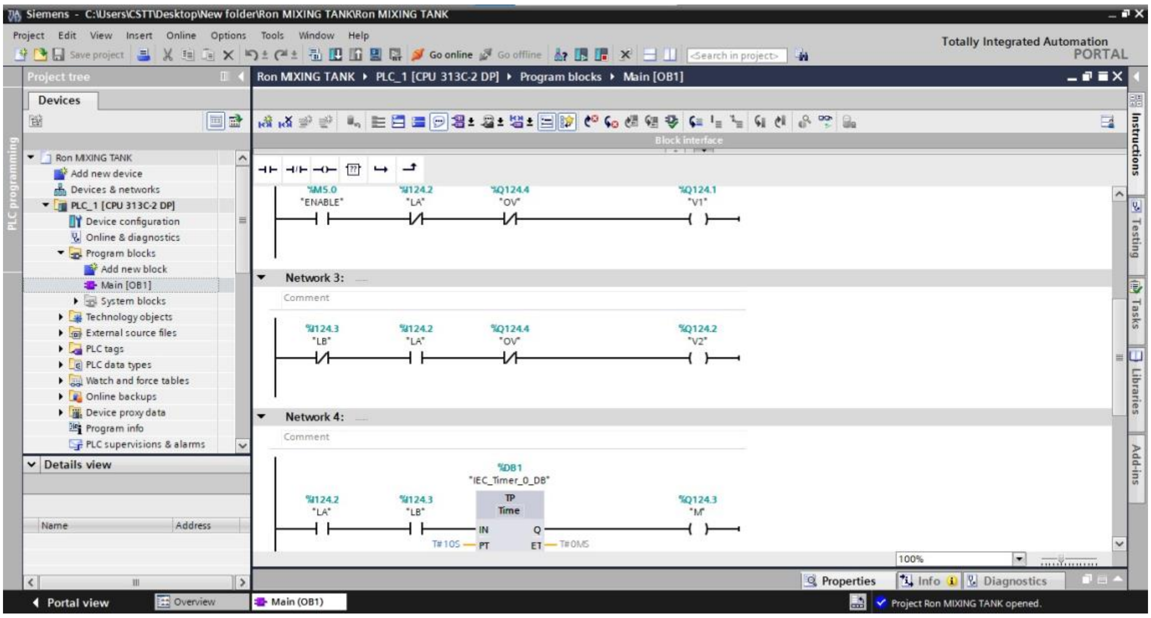


Figure 2: PLC Ladder Logics Implemented

1.3 PROBLEM STATEMENT

The modern manufacturing landscape demands increased efficiency, reliability, and flexibility in assembly line processes. To address these requirements, there is a pressing need to automate and streamline mechatronics assembly systems such as Magazine Units, Conveyor Systems, Handling Units, Pneumatic Presses, and Automatic Storage and Retrieval Systems.

However, the integration and automation of these diverse systems present significant challenges. Current manual processes are prone to errors, inefficiencies, and downtime, leading to increased costs and reduced productivity. Moreover, the lack of a cohesive control system exacerbates these challenges, hindering synchronization and coordination between different assembly line components.

The Primary issues are:

- **Lack of Automation:** Manual operation of mechatronics assembly line systems results in inefficiencies, errors, and suboptimal performance. Without automation, tasks such as material handling, part assembly, and storage are time-consuming and prone to human error. This leads to decreased throughput, increased labor costs, and compromised product quality.
- **Absence of Integrated Control:** The absence of a centralized control system hampers the synchronization and coordination of diverse assembly line components. Each system operates independently, leading to inefficiencies in material flow, suboptimal resource utilization, and difficulty in monitoring and troubleshooting. This fragmented approach limits agility, scalability, and adaptability to changing production demands.

Therefore, the primary objective of this project is to develop and implement a comprehensive solution for integrating and automating mechatronics assembly line systems. By leveraging Siemens TIA Portal and PLC technology, the project aims to achieve the following key outcomes:

- Seamless integration of Magazine Units, Conveyor Systems, Handling Units, Pneumatic Presses, and Automatic Storage and Retrieval Systems into a unified assembly line framework.
- Automation of critical processes such as material handling, part assembly, packaging, and storage to improve efficiency, accuracy, and throughput.

- Development of PLC ladder logic for each system to enable real-time control, monitoring, and coordination.
- Implementation of Human-Machine Interface (HMI) systems for intuitive visualization and control of assembly line operations.
- Optimization of resource utilization, energy efficiency, and overall productivity through systematic analysis and refinement of assembly line processes.

Addressing the challenges outlined and achieving the project objectives will not only revolutionize the efficiency and competitiveness of the mechatronics assembly line but also propel the industry towards a new era of manufacturing automation. By integrating and automating diverse systems such as Magazine Units, Conveyor Systems, Handling Units, Pneumatic Presses, and Automatic Storage and Retrieval Systems, the project will streamline operations, reduce errors, and increase throughput. The development and implementation of PLC ladder logic for each system, along with the integration of Human-Machine Interface (HMI) systems, will provide real-time control and monitoring capabilities, enabling operators to make informed decisions swiftly. Moreover, optimizing resource utilization and energy efficiency through systematic analysis and refinement of assembly line processes will not only drive cost savings but also contribute to sustainability efforts. Ultimately, the success of this project will serve as a catalyst for future advancements in manufacturing automation, fostering innovation and driving industry-wide transformation towards smarter, more efficient production systems.

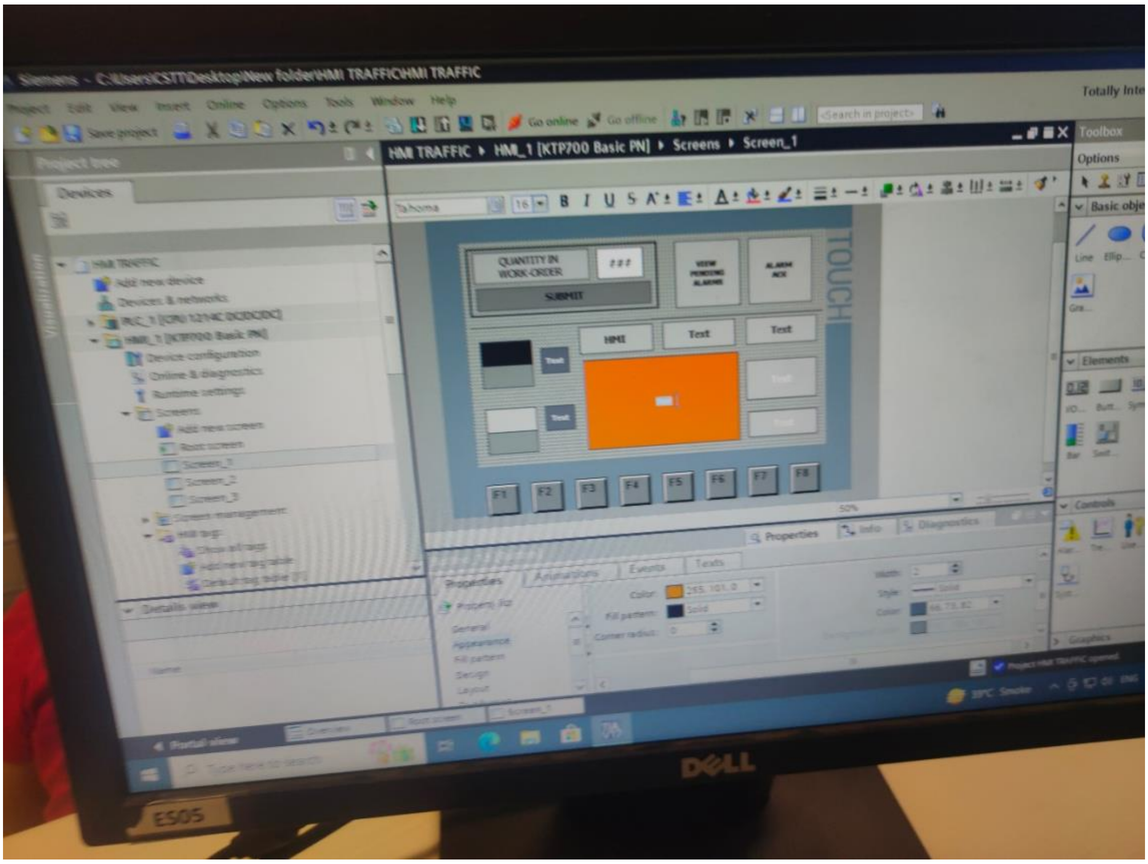


Figure 3: HMI Development for Assembly

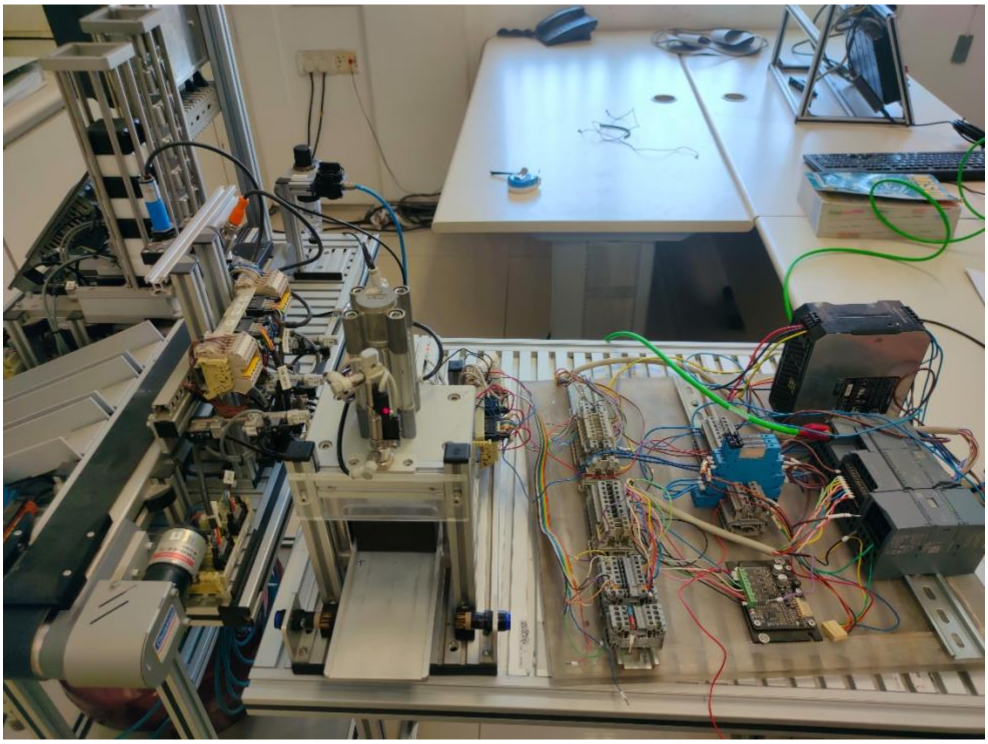


Figure 4: PLC Integration

1.4 SALIENT CONTRIBUTION

One of the primary contributions of the project lies in its holistic approach to the automation of the mechatronics assembly line, encompassing diverse systems including the Magazine Unit, Conveyor System, Handling Unit, Pneumatic Press, and Automatic Storage and Retrieval System. By leveraging Siemens TIA Portal and PLC technology, we achieved seamless integration and coordination among these systems, resulting in enhanced efficiency, accuracy, and reliability throughout the packaging and storage process.

Specifically, our project addressed several key challenges and made notable contributions:

PLC Ladder Logic Development and Testing: We developed robust PLC ladder logic for each system, tailored to their unique functionalities and interdependencies. Through rigorous testing and validation on S7-1200 PLCs, we ensured optimal performance and adherence to operational requirements.

System Integration and Replacement: The successful replacement of legacy S7-300 PLCs with modern S7-1500 PLCs exemplifies our commitment to staying abreast of technological advancements and optimizing system performance. This integration facilitated smoother communication and enhanced functionality across the assembly line.

Input/Output Segregation and Wiring Optimization: By conducting continuity tests and segregating Input/Output (I/O) signals for each unit, we optimized wiring configurations and streamlined communication pathways. This meticulous approach minimized potential errors and maximized system reliability.

Human-Machine Interface Development: The development of intuitive Human-Machine Interface (HMI) systems provided operators with real-time monitoring and control capabilities, enhancing overall system visibility and user experience. By designing user-friendly interfaces, we empowered operators to manage and optimize assembly line operations effectively.

In summary, our project's salient contribution lies in its comprehensive approach to mechatronics assembly line automation, encompassing PLC programming, system integration, mechanical assembly, and HMI development. Through meticulous planning, execution, and testing, we delivered a robust and efficient automation solution tailored to the specific requirements of the packaging and storage process.

Chapter 2

Literature survey

2.1 LITERATURE REVIEW

The final-year internship project focused on the development of PLC ladder logic and HMI for each system of an assembly line, with an emphasis on understanding the systems through in-depth research and study. The literature survey was conducted to gather comprehensive knowledge about mechatronics assembly line systems, PLC programming, and Human-Machine Interface (HMI) design principles. The following sources were consulted:

1. **Christiani Automation Handbooks**: The Christiani Automation handbooks served as fundamental resources for understanding the principles and components of automation systems. These handbooks cover a wide range of topics including PLC programming, industrial sensors, actuators, and control systems. The information obtained from these handbooks provided essential theoretical knowledge and practical insights into the design and operation of mechatronics systems.
2. **Research Papers and Journals**: Various research papers and journals were explored to delve deeper into specific aspects of mechatronics assembly line systems. Key topics included PLC programming techniques, ladder logic design methodologies, HMI development strategies, and case studies on industrial automation projects. By examining peer-reviewed literature, the intern gained valuable insights into emerging trends, best practices, and innovative approaches in the field of mechatronics.
3. **Textbooks on Mechatronics and Automation**: Textbooks on mechatronics, automation, and control systems were consulted to supplement the understanding of core concepts and principles. These textbooks cover topics such as sensor technology, control theory, digital logic, and industrial robotics, providing a comprehensive foundation for designing and implementing automation solutions.
4. **Online Resources and Tutorials**: Online resources such as technical forums, tutorial websites, and video lectures were utilized to access practical guides, troubleshooting tips, and instructional materials related to PLC programming and HMI development. These resources offered valuable support in overcoming challenges encountered during the internship project and enhancing the intern's skills in mechatronics engineering.

2.2 REFERENCE AND CITATIONS

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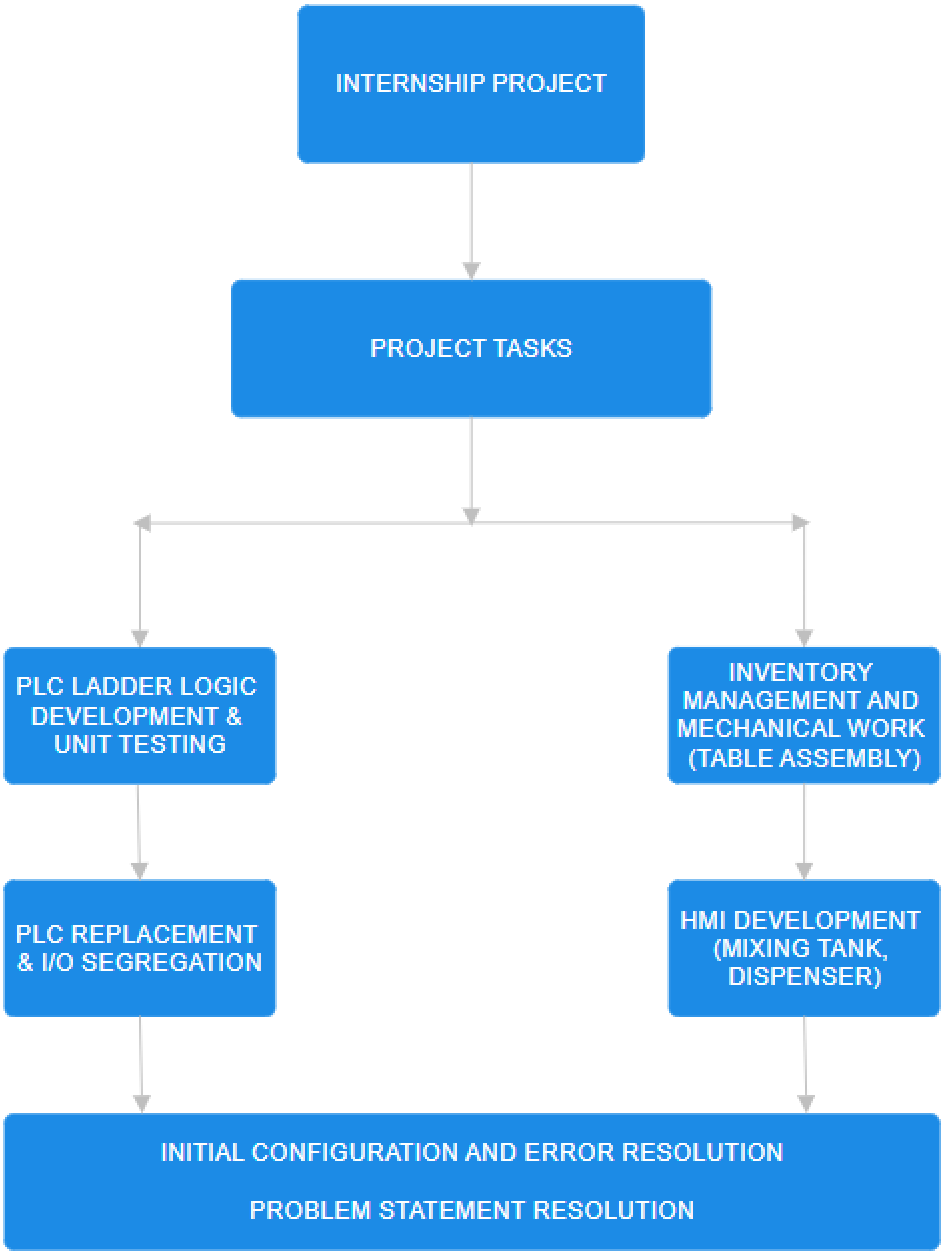
Figure 5: Christiani Automation Hand Books

Chapter 3

Methodology and Implementation

3.1 BLOCK DIAGRAM



3.1.1 UNDERSTANDING THE BLOCK DIAGRAM

- **PLC Ladder Logic Development & Unit Testing:**

Using specialised software like Siemens Tia Portal, we designed and implemented ladder logic programmes in this task. These programmes act as the automation system's brain, controlling how various parts communicate and function. To guarantee the assembly line runs smoothly and effectively, each programme needs to be carefully designed. Subsequently, unit testing is carried out to verify the individual programmes' functionality. Each component in the unit was taken apart and put back together so that all its mechanical components could be fully understood. To comprehend the unit's circuit diagram, the wiring from the reed switches, push buttons, and DCV to the terminal was traced. Using the Siemens TIA Portal, a PLC ladder logic programme was initially written for the S7-300 PLC. Next, unit testing was performed on the S7-1200 PLC.

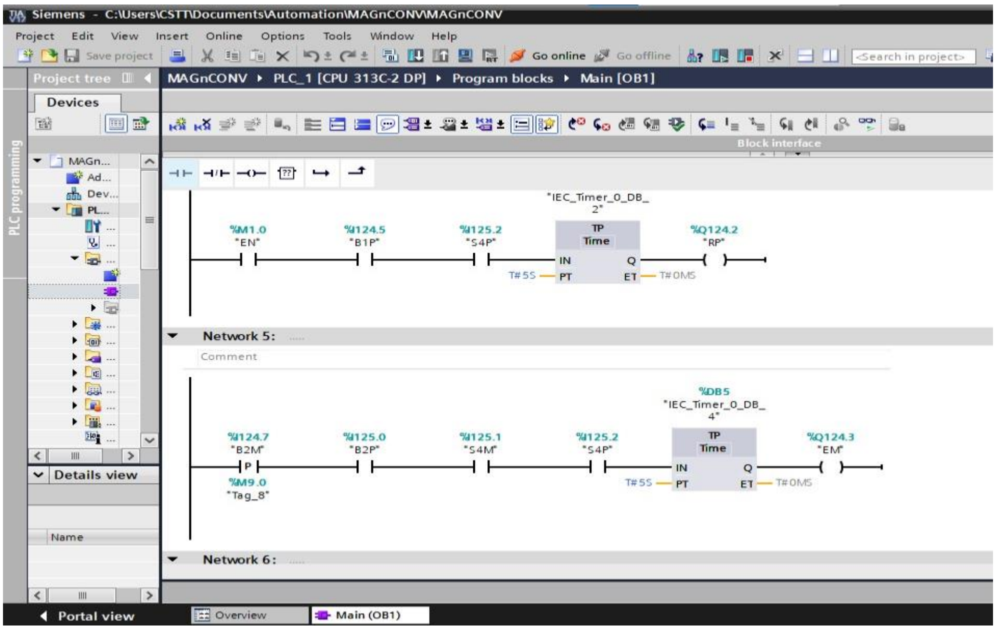


Figure 6: PLC Ladder Logic of the Magazine Unit and Conveyor Unit Together

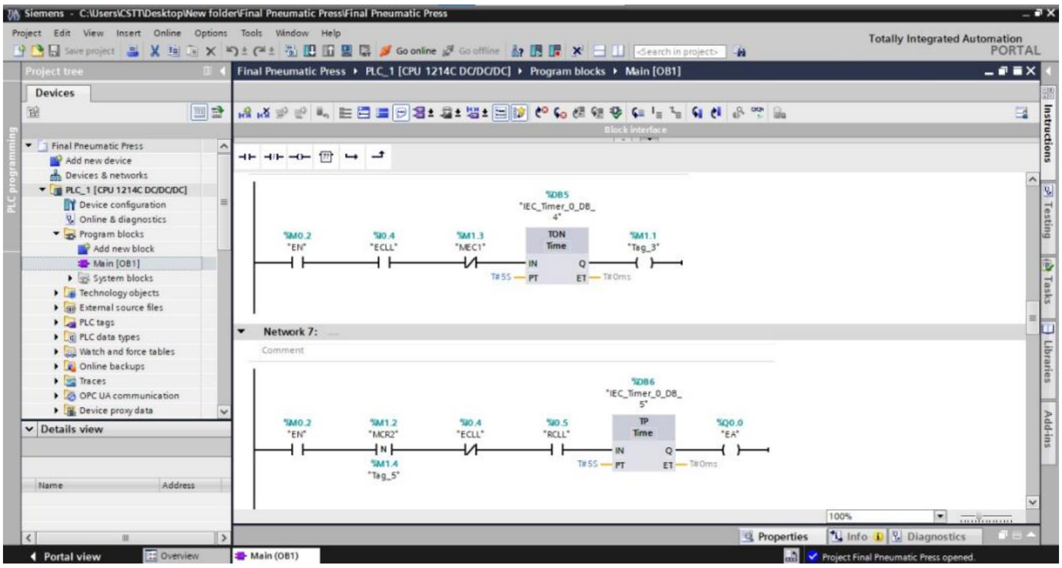


Figure 7: PLC Ladder Logic Program of the Pneumatic Press

The testing procedure for each unit was the same; the Pneumatic Press Unit's testing procedure is as follows:

1. Testing every mechanical component of the pneumatic press i.e. the actuators which is the pneumatic cylinders and push buttons individually, also tested the functionality of the reed switches.
2. Once every component worked individually, moved on making the entire connection of the pneumatic press unit.
3. Developed the PLC Program of the Pneumatic Press for the S7-1200 PLC.
4. Checked for any defects in the pneumatic pipes connecting to the various pneumatic cylinders of the press unit.
5. Manually tested the Directional Control Valve (DCV) to make sure there was proper ait flow happening through each valve.
6. Once everything was found to be working properly, the final test of the overall unit was then
7. To make the process more efficient, the entire units system was made to be in a loop.

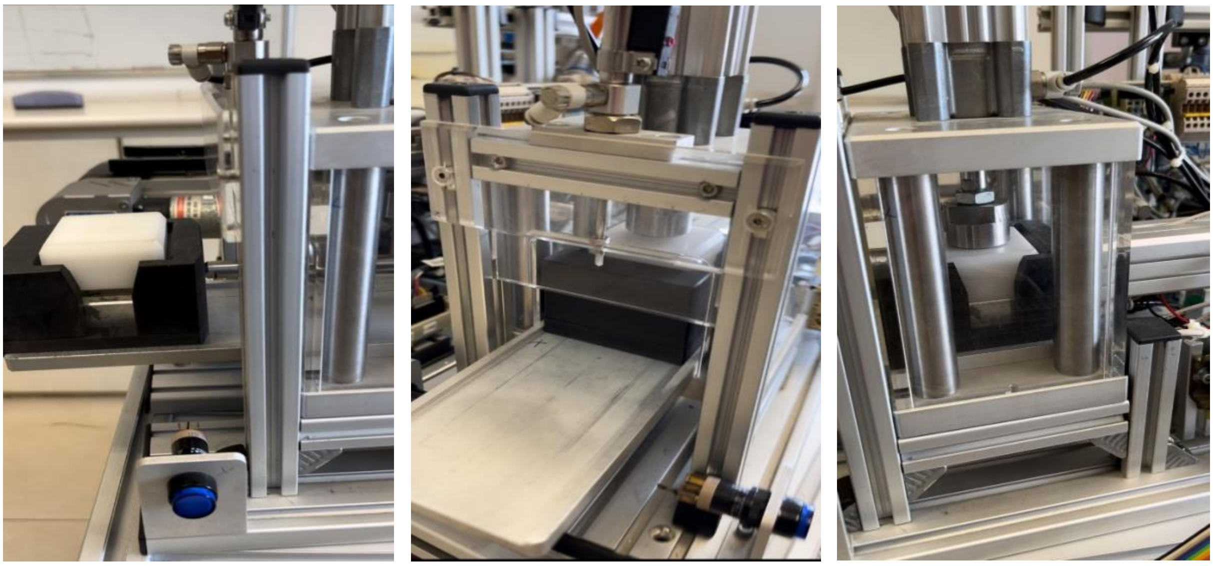


Figure 8: Testing of Pneumatic Press Unit

To ensure that the PLC behaves as expected and is free from errors or unexpected behaviour, this entails simulating various inputs and scenarios.

- **Inventory Management:**

This refers to the process of overseeing and controlling the flow of goods and materials. Multiple Laboratory Tables and frames had to be designed for the S7-1500 PLC and a miniature elevator system.

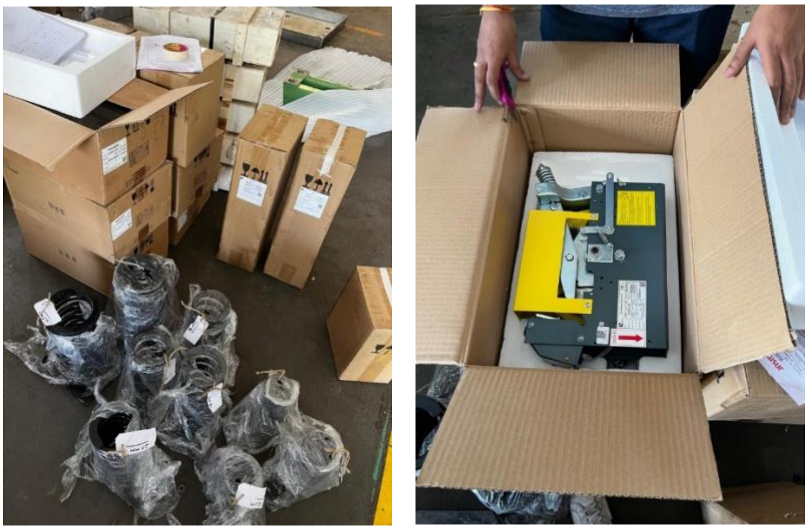


Figure 9: Inventory of Miniature Elevator System

Research was done on the components needed for the elevator system. Accordingly, a Bill of Material (BOM) was created which included the quantity and specifications of the resources required, which were aluminium extrusions and Galvanized Iron Plates for the Tables and Frames and also Oil buffers, Spring Buffers and Overspeed Governors for the miniature elevator model. After the materials were delivered, the order was reviewed again to ensure that the resources we received matched the specifications listed in the Bill of Material.

- **Mechanical Work:**

This aspect of the project involves assembling mechanical components and structures necessary for the assembly line's operation. This includes constructing tables or platforms to support the machinery and systems. Various Mechanical tools and machines such as the drilling machine and mechanical processes such as tapping had to be done on many aluminium extrusions to be able to make the necessary structures.

Figure 10: Few Mechanical Tools

- **PLC Replacement & Input/Output Segregation:**

Modernising the assembly line and improving its dependability and performance require upgrading the PLC hardware. To complete this task, older PLC model like the Siemens S7-300 had to be replaced with more recent models, like the Siemens S7-1500, which have more features and capabilities. In the assembly line, we also had to separate input and output devices according to their roles. We had to follow each wire from the Assembly back to its corresponding terminal to connect it to the PLC. We then used a multimeter to make sure the wire was still connected. By doing this, we were able to identify which wire belongs to which assembly unit as well as to the input or the output. A wiring as a result, the overall performance of the system is optimised through effective communication and coordination between PLCs and peripheral devices like switches, actuators, and sensors.

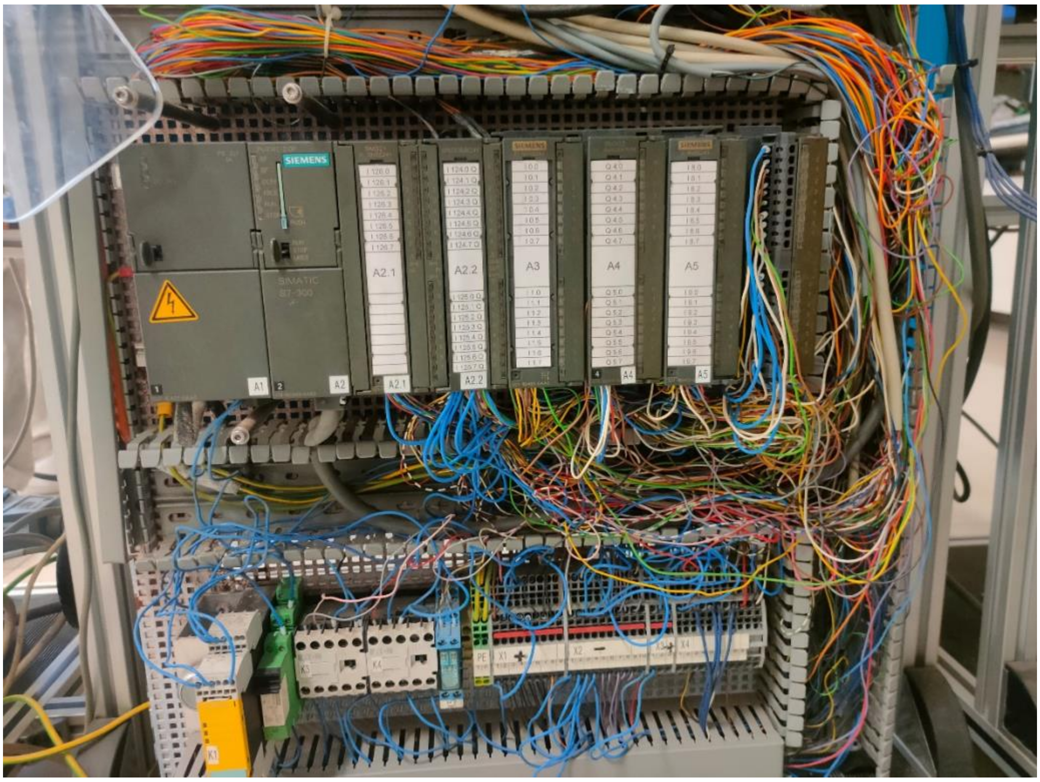


Figure 11: PLC Wire Tracing and Segregation

- **HMI Development:**

The goal of human-machine interface (HMI) development is to provide operator interfaces that are simple to use and intuitive. This entails creating graphical user interfaces that present status indicators, control options, and real-time data in an understandable and structured way. To create HMIs, we utilised software tools like Siemens WinCC and Siemens PLC Simulator. Every HMI has a PLC Ladder Logic base to it. We developed multiple HMIs for various real-life problem statements such as The Mixing Tank and Dispenser System. The Ladder Logic was made on the Siemens TIA Portal and the interface was designed on it as well with the help of Siemens WinCC.

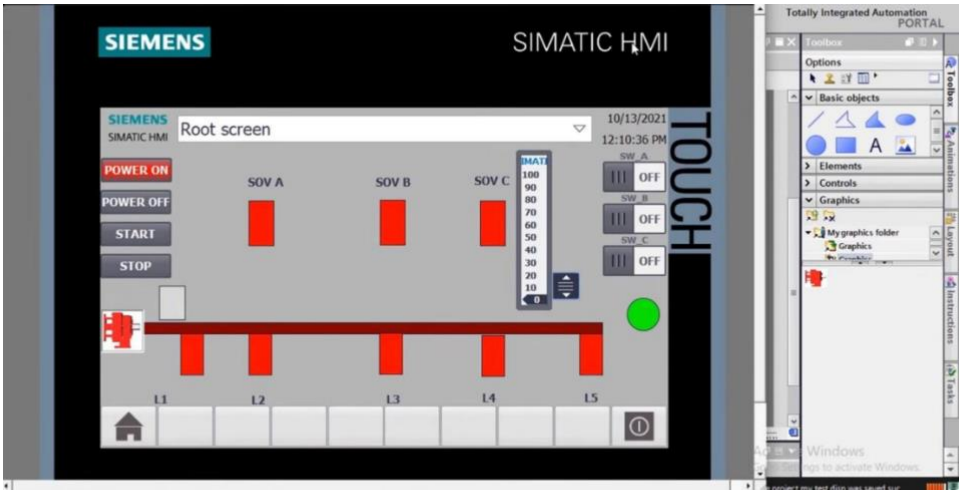


Figure 12: HMI Development of the Dispenser System

The various components in the interface such as the start, stop buttons, the sensors, the sliders all depended on the addresses given to every input and output in the PLC Ladder Logic Program. The HMI was simulated on Siemens PLC Simulator. If any errors are found in the operation or in the HMI, changes can be made in the Siemens TIA Portal Usability, accessibility, and ergonomic design principles are taken into consideration to make sure that operators can efficiently oversee and manage the production process.

- **Initial Configuration & Error Resolution:**

One of the most important steps in making sure the automation system operates correctly is configuring PLCs. To create smooth communication between PLCs and peripheral devices, we had to configure hardware parameters, address schemes, and communication protocols. We often ran into mistakes or problems during this process, like sourcing or sinking issues, which needed to be quickly found and fixed. During the initial configuration phase of the S7-1500 PLC to replace the existing S7-300 PLC, several errors were encountered, each requiring careful troubleshooting and resolution. These errors included:

1. I/P Address Error:

The initial challenge was assigning IP addresses, as incorrect or conflicting ones can cause communication issues and hinder data exchange. Resolving this error involved reviewing and configuring IP addresses for all network devices.

2. Hardware-Software Configuration:

Another common issue faced during the configuration process was mismatched hardware and software configurations. Ensuring that the hardware components of the S7-1500 PLC were correctly configured to align with the software settings is crucial for optimal performance and functionality. This required careful inspection and adjustment of hardware parameters to match the software requirements.

3. Potential Group Problems:

Incorrect wiring or configuration settings can cause issues with the potential group of the base model, which defines the electrical isolation between modules and devices connected to the PLC. Discrepancies in potential group assignments can lead to system malfunction. Resolving this error involves reviewing potential group assignments and ensuring proper isolation between modules.

4. Sourcing and Sinking Base Module Placement Problems:

Sourcing and sinking refer to the electrical characteristics of input and output signals in a PLC system. Incorrect placement of base modules or mismatched sourcing/sinking configurations can result in signal inconsistencies and errors in data processing. Addressing this issue required reevaluating the placement of base modules within the PLC rack and verifying the sourcing/sinking configurations to ensure compatibility with connected devices.

The team used a systematic approach to identify and resolve errors in the S7-300 to S7-1500 PLC, involving thorough inspection, diagnosis, and configuration adjustments. Collaboration and technical documentation from Siemens Tia Portal were crucial in resolving these challenges, ensuring the smooth operation of the mechatronics assembly line during the initial configuration phase. PLCs underwent extensive testing after configuration to ensure stability and dependability.

3.2 HARDWARE DESCRIPTION

- **Siemens S7-300 PLC**

It is a strong and adaptable automation system made to satisfy the needs of industrial applications that need a high level of performance, dependability, and flexibility. The S7-300 PLC, which is a part of the Siemens Simatic S7 family, has long been a mainstay of industrial automation, providing engineers and technicians all over the world with a wealth of features and capabilities.

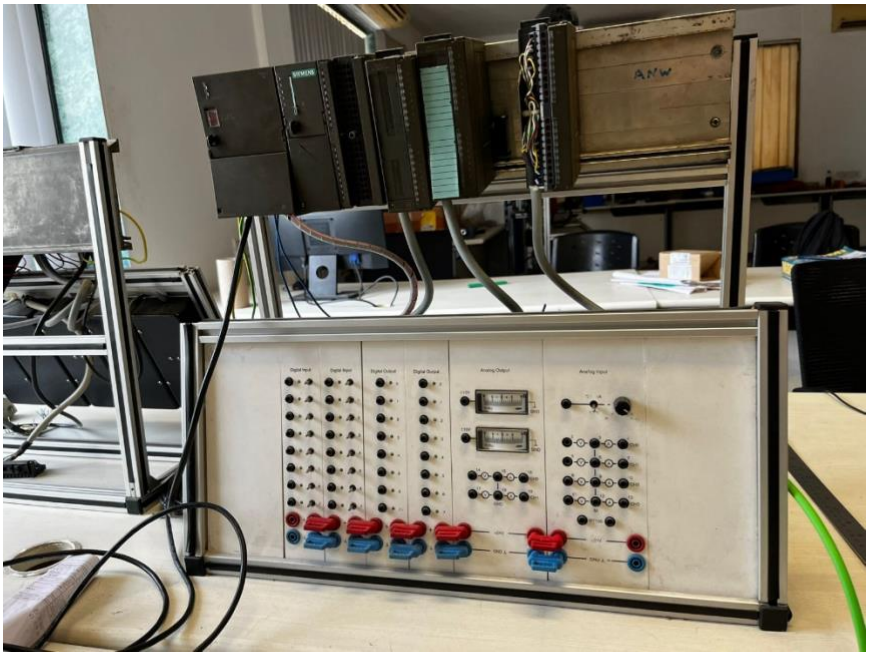


Figure 13: Siemens S7-300 PLC

The S7-300 PLC's modular design, which enables users to tailor the system to their unique application requirements, is one of its main advantages. A variety of modules, such as CPU, input/output (I/O), communication, and special function modules, are supported by the PLC rack. Whether a user wants a small standalone control system or a sophisticated distributed control architecture, the PLC system's modularity allows them to customise it to meet their needs. With its strong processing capabilities, quick cycle times, and large memory capacity, the S7-300 PLC can effectively manage demanding control tasks. Users can choose the right CPU module model for their application by choosing from a variety of models that differ in processing speeds and memory capacities. The PLC also allows for multitasking and multilingual programming, which gives users the ability to create complex logic sequences and control algorithms.

- **Siemens S7-1200 PLC**

The S7-1500 PLC's modular and scalable design, which enables smooth expansion and customization to satisfy changing application requirements, is one of its primary features. A central processing unit (CPU) module, several input/output (I/O) modules, communication modules, and additional accessories make up the PLC system. Users can set up the PLC system to suit their needs, be they small standalone machines or large-scale production lines, thanks to its modular architecture.

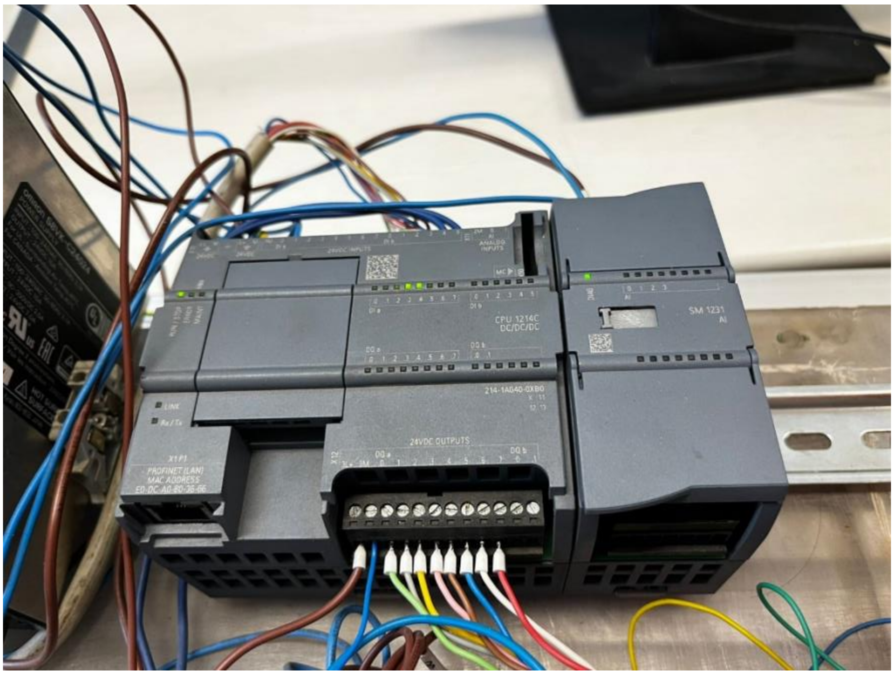


Figure 14: Siemens S7-1200 PLC

The Siemens S7-1200 PLC's compact design is one of its primary characteristics, making it ideal for installations with limited space. The S7-1200 has a compact form factor but powerful performance capabilities that enable it to perform a wide range of automation tasks accurately and effectively. A wide variety of digital and analogue input/output (I/O) modules are available for the S7-1200 PLC, giving the controller flexibility in configuration to match the demands of applications. These modules facilitate the smooth integration of sensors, actuators, and other devices into automation systems by allowing their connection.

The Siemens S7-1200 PLC's intuitive programming environment makes it simple to programme. Siemens' TIA (Totally Integrated Automation) Portal software, which provides a full suite of programming tools and libraries for creating ladder logic, function block diagrams, and structured text programmes, can be used to programme the controller.

- **Siemens S7-1500 PLC**

Renowned for its remarkable performance, scalability, and versatility, the Siemens S7-1500 Programmable Logic Controller (PLC) is a state-of-the-art development in industrial automation technology. With a wide range of industrial applications in mind, the S7-1500 PLC offers a comprehensive suite of features and capabilities that are specifically tailored to meet the demanding requirements of modern manufacturing environments.

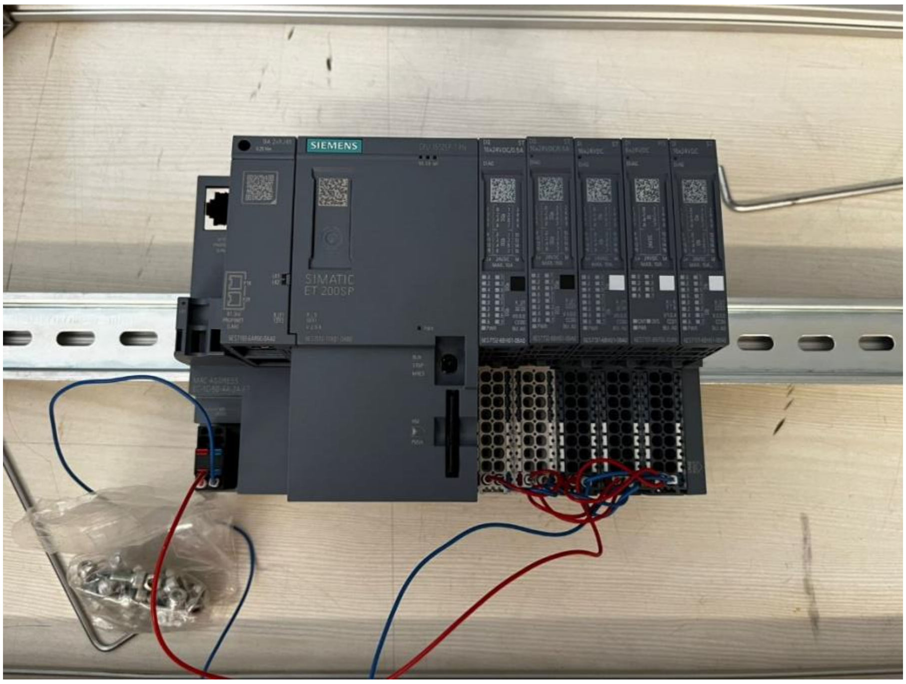


Figure 15: Siemens S7-1500 PLC

Its robust multi-core processor architecture, which offers unmatched processing speed and efficiency, is its central component. Because of this, the S7-1500 can reliably and precisely handle complex automation tasks, even in high-speed, high-volume production environments. The multi-core architecture permits the simultaneous execution of several tasks and functions while guaranteeing optimal performance. The S7-1500 PLC's modular and scalable design, which enables smooth expansion and customization to satisfy changing application requirements, is one of its primary features. A central processing unit (CPU) module, several input/output (I/O) modules, communication modules, and additional accessories make up the PLC system. Users can set up the PLC system to suit their needs, be they small standalone machines or large-scale production lines, thanks to its modular architecture.

- **Pneumatic Cylinders**

These are crucial parts of a lot of manufacturing and industrial applications because they provide linear motion by transferring compressed air energy into mechanical force. These gadgets are composed of a cylindrical chamber that a piston travels back and forth; the chamber is usually constructed of metal or sturdy plastic. The piston is forced to move in the desired direction by compressed air that is injected into one end of the cylinder. In industrial machinery and automation systems, the piston's movement is then utilised to carry out a variety of operations, including lifting, pushing, pulling, and clamping objects.

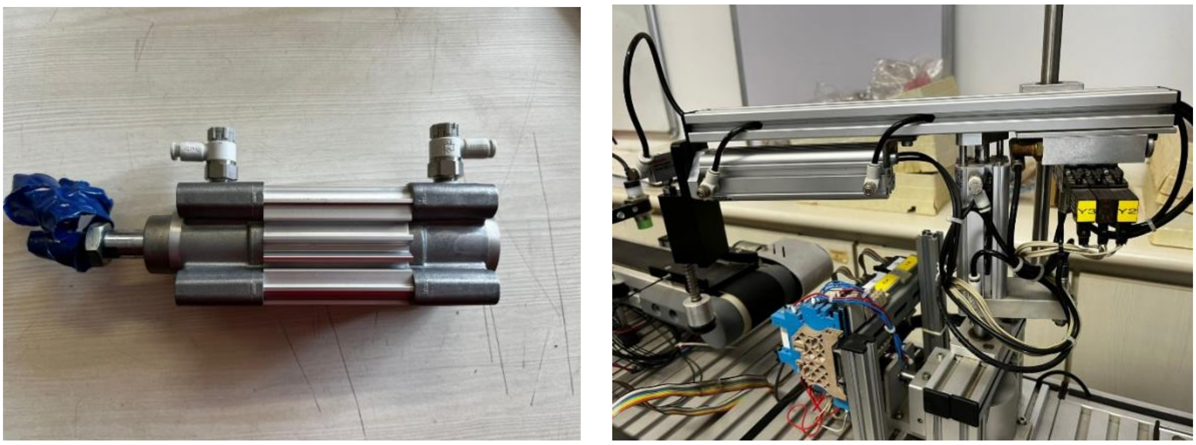


Figure 16: Pneumatic Cylinders used in the Mechatronics Assembly

The ease of use and dependability of pneumatic cylinders is one of their main benefits. Pneumatic cylinders use compressed air instead of hydraulic systems, which use fluid pressure to create motion. Compressed air is easier to handle and is commonly available in industrial settings. Pneumatic cylinders are perfect for applications requiring quick actuation and exact control because they are also reasonably lightweight, reasonably priced, and able to deliver high forces over short distances.

- **Reed switches**

These are essential to pneumatic systems because they act as dependable sensors to determine where moving parts, such as pneumatic actuators, are located. The two thin, magnetizable metal reeds in these switches are housed inside a glass tube that is filled with inert gas. The reeds attract one another when a magnetic field is applied, usually produced by an electromagnet or permanent magnet, completing an electrical circuit. They are frequently used in pneumatic systems to identify whether the piston or rod of a pneumatic cylinder is present or absent. A magnet attached to the piston or rod triggers the reed switch when the cylinder reaches a predetermined position, like fully extended or fully retracted, alerting the controller to begin the subsequent stage of the operation. Pneumatic actuators inside the system are precisely controlled and synchronised thanks to this feedback mechanism, which maximises efficiency and performance.

Figure 17: Reed Switches

The intrinsic simplicity and dependability of reed switches is one of their main benefits in pneumatic systems. Reed switches offer consistent performance and long-term durability in demanding industrial environments because they do not have any mechanical parts that can break down or wear out over time. They are ideal for spaces-constrained applications, like pneumatic cylinders or valves, because of their small size and simplicity of integration.

- **Directional Control Valves (DCV)**

By controlling the direction of airflow to manage the motion of pneumatic actuators and other pneumatic components, directional control valves, or DCVs, play a crucial part in pneumatic systems. These valves are crucial for controlling the precise movement of machine parts in a variety of industrial applications by directing compressed air to pneumatic cylinders, motors, or other devices. Controlling the direction of airflow is one of DCVs' main duties in pneumatic systems. Multiple ports and internal passageways enable compressed air to enter and exit the valve body of a DCV. DCVs determine the path of airflow through the system and direct it to the desired pneumatic actuators to achieve the desired motion by selectively opening and closing these passages.

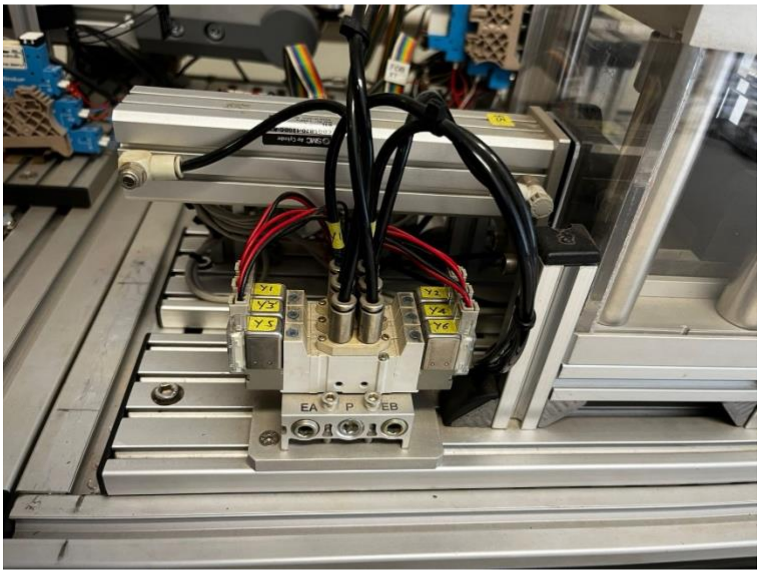


Figure 18: DCV used in the Pneumatic Press Unit

There are many different configurations for DCVs, such as 2-way, 3-way, 4-way, and even more intricate designs. Three-way valves add a third port for exhaust air to escape, while two-way valves regulate the flow of air between two ports. Commonly found in pneumatic systems, four-way valves have two ports for air intake, one port for exhaust, and one port for connecting to the pneumatic actuator. These valves allow for exact control over various forms of linear and rotary motion, including the extension and retraction of pneumatic cylinders. DCVs frequently include extra features in addition to airflow direction control to improve their functionality and adaptability in pneumatic systems. These features could include electrical or pneumatic pilot operation for remote or automated control, position feedback for remotely monitoring valve position, and manual overrides for manual operation during emergencies or maintenance.

- **Limit Switches**

Limit switches are crucial parts of industrial automation and control systems. They define the limits of motion inside a machine or system, detect the presence or absence of an object, and locate moving parts. By giving feedback to the control system and initiating the proper actions based on the detected conditions, these switches are essential to guaranteeing safe and dependable operation.

- **Sensors**

Sensors are essential parts of automation and control systems because they give the system the information it needs to monitor, analyze, and make decisions about the outside world. Two popular types of sensors that are used in many different industries are capacitive and optical sensors. Each has specific applications and principles of operation. The capacity of a system to store an electric charge is known as capacitance, and capacitive sensors work by monitoring variations in this property. Optical sensors use light to measure different physical properties or determine whether an object is present or absent.

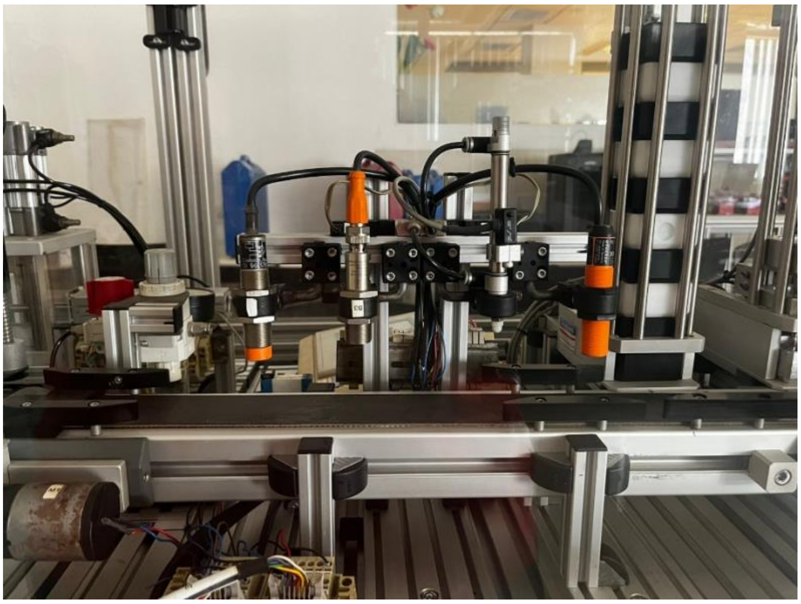


Figure 19: Sensors used in the Conveyor Unit

3.3 SOFTWARE DESCRIPTION

- **Siemens TIA Portal**

Siemens AG created the robust engineering framework known as the Siemens Totally Integrated Automation (TIA) Portal, which is used for automation system configuration, programming, and diagnostics. In order to streamline the development process and increase productivity, it acts as a centralised platform for integrating different automation tasks, such as drive configuration, HMI (Human-Machine Interface) design, and PLC (Programmable Logic Controller) programming, into a single environment.

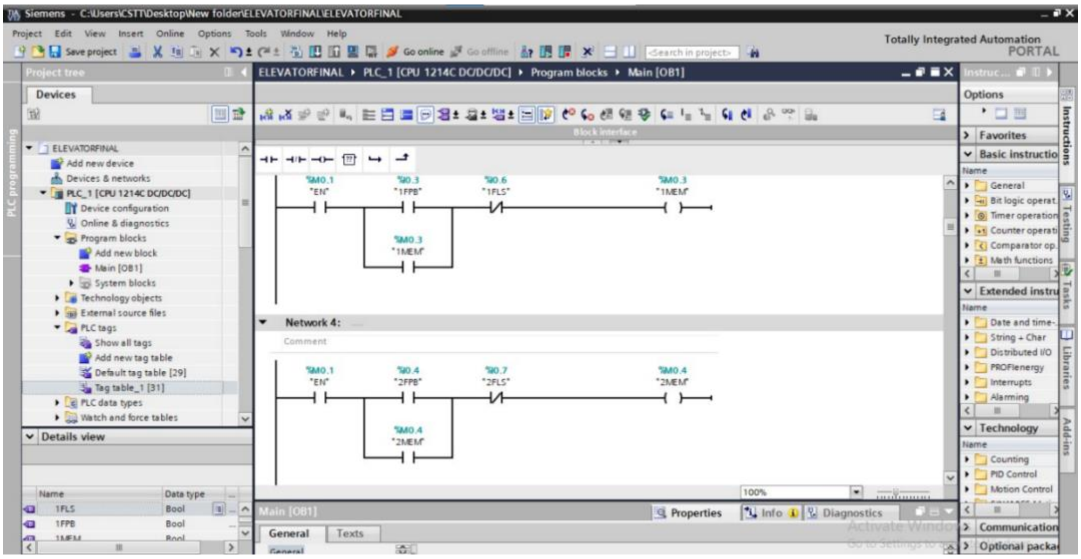


Figure 20: Siemens TIA Portal Interface for PLC Ladder Logic Programming

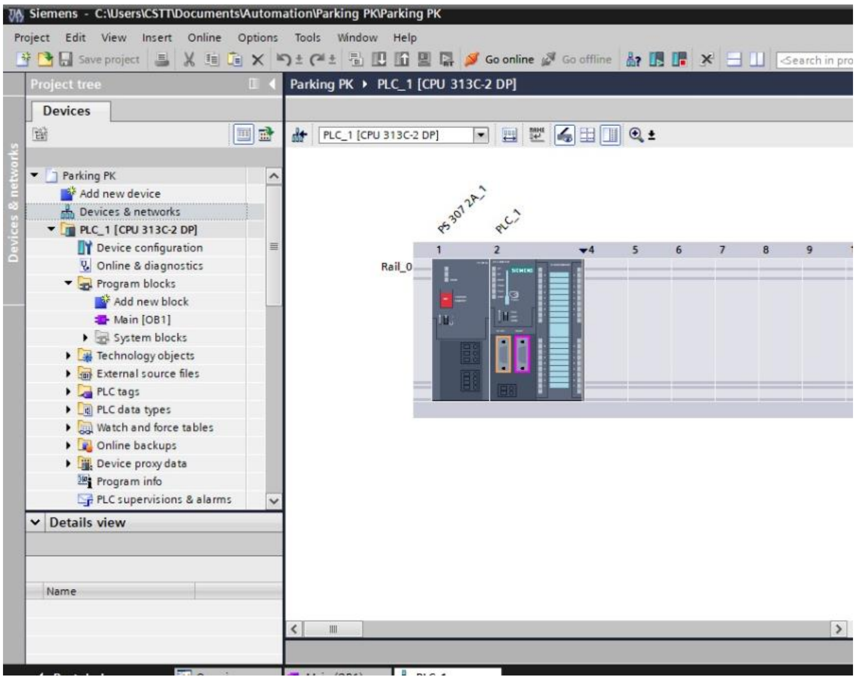


Figure 21: Interface of Device and Network in Siemens TIA Portal

The TIA Portal's user-friendly and intuitive interface, which is intended to streamline complicated automation tasks and cut down on engineering time, is its fundamental component. Using a common set of tools and workflows, the portal offers engineers a unified workspace where they can easily switch between various engineering disciplines, such as motion control, HMI configuration, and PLC programming.

Its smooth interaction with Siemens' automation hardware, such as PLCs, HMIs, and drives, is one of its primary features. Siemens PLCs, like the S7-1200 and S7-1500 series, are simple to configure and programme using a range of programming languages, such as ladder logic, function block diagram (FBD), and structured text (ST). Before deploying PLC programmes, engineers can verify their logic by simulating and testing them on the portal.

- **Siemens PLC Simulator**

It is an effective tool made to replicate Siemens PLC behaviour in a virtual setting. Without requiring actual hardware, it is an invaluable tool for PLC programmers, engineers, and students to create, test, and debug PLC programmes. With the TIA PLC Simulator, users can mimic ladder logic programmes, watch PLC inputs and outputs, and examine system behaviour in real time. The simulator mimics the functionality of Siemens PLCs. The TIA PLC Simulator's intuitive interface, which closely mimics the Siemens PLC programming environment in real life, is one of its primary features. It is simple to switch between simulation and real PLC programming when users can create and edit ladder logic programmes using well-known programming languages.

HMI Simulation on Siemens PLC Simulator

Users can simulate different input conditions and see the corresponding output behaviour by using the simulator, which offers a virtual representation of PLC inputs and outputs. This makes it possible to thoroughly test and validate PLC programmes in various contexts, which aids in locating any potential problems or anomalies prior to implementing the programme on actual hardware.

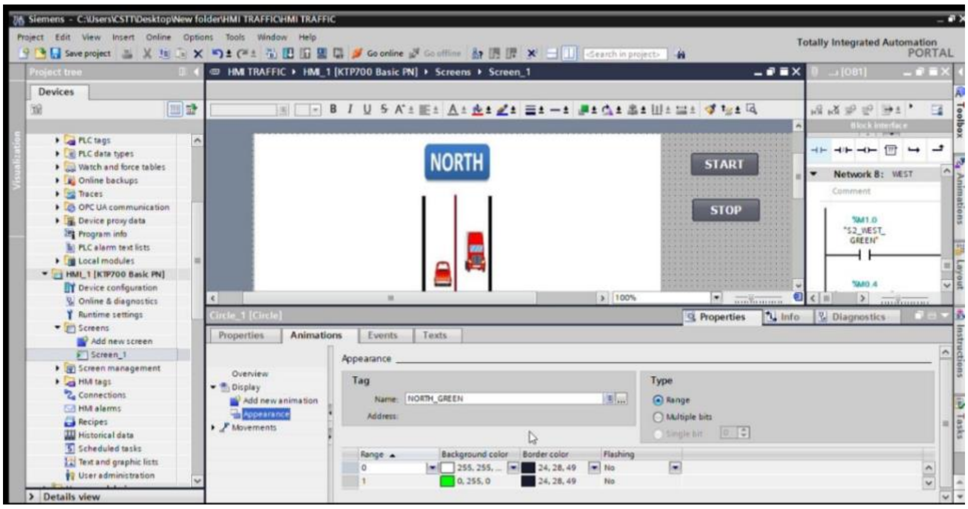


Figure 22: Traffic Light System Simulation

- **AutoCAD**

It is a software that is extensively used across many industries to create accurate 2D and 3D models, drawings, and designs. It gives drafters, designers, engineers, and architects strong tools to effectively create, visualize, and record their concepts and projects. AutoCAD's ability to support both 2D and 3D design workflows is one of its key features. Users can produce intricate blueprints and drawings in 2D mode for a variety of projects, including mechanical, electrical, and architectural ones. AutoCAD's 3D mode lets users make lifelike three-dimensional models of mechanical parts, buildings, and other objects. To create intricate 3D geometry, users can loft, rotate, and extrude 2D sketches. Materials, textures, and lighting effects can then be added to improve visual realism.

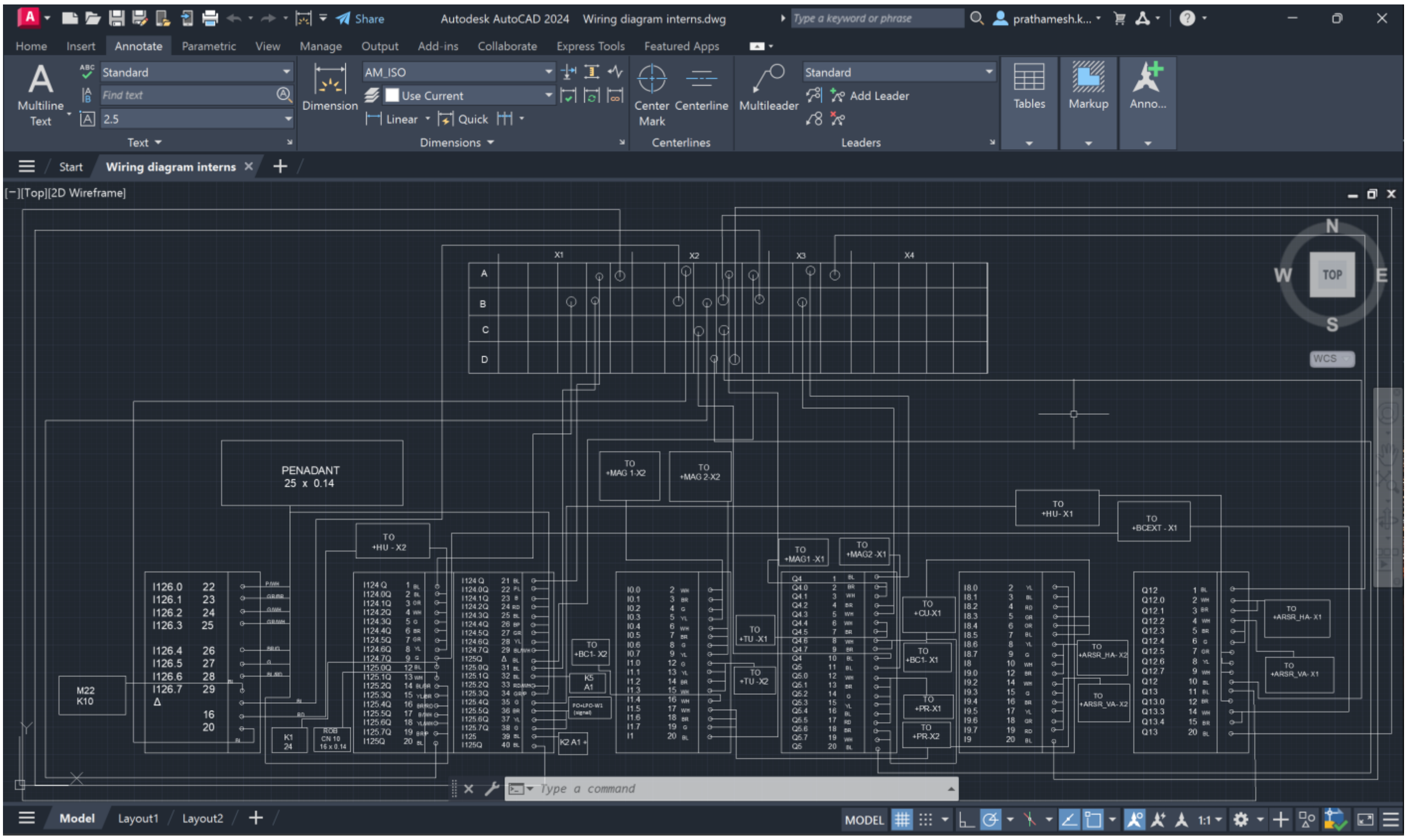


Figure 23: Wiring Diagram Designed on AutoCAD

Chapter 4

Results and Analysis

4.1 DERIVED OUTCOMES AND ITS ANALYSIS

- **Functional Systems:** All systems within the mechatronics assembly line underwent successful development and rigorous testing. This process aimed to ensure that each component functioned as intended and could seamlessly interact with other systems. The demonstrated functionality and interoperability signify the successful implementation of PLC ladder logic and HMI interfaces across the entire assembly line.

  Analysis: The successful development and testing of all systems within the mechatronics assembly line indicate a thorough understanding of PLC ladder logic and system integration. This achievement reflects the team's proficiency in translating conceptual designs into functional solutions.
- **Improved Performance**: The transition from S7-300 to S7-1500 PLC brought about notable improvements in performance, reliability, and scalability. The upgraded PLC hardware offered enhanced processing power and advanced features, contributing to the overall efficiency of the assembly line. This upgrade lays a solid foundation for future expansions and optimizations, aligning the system with evolving industrial standards and requirements.

  Analysis: The replacement from S7-300 to S7-1500 PLC signifies a strategic decision to leverage advanced hardware capabilities for improved performance, reliability, and scalability. This upgrade demonstrates a proactive approach to adapting to technological advancements in industrial automation.
- **Efficient I/O Management:** The segregation of I/O modules played a crucial role in streamlining the management of inputs and outputs within the assembly line. By organizing I/O modules based on functional units and conducting continuity tests to ensure accurate wiring, the project optimized the layout and facilitated swift troubleshooting processes. This efficient I/O management minimizes complexity and enhances maintainability, ultimately improving the overall robustness of the system.

Analysis: The segregation of I/O modules using continuity test and optimization of wiring layout indicate meticulous planning and attention to detail in system architecture design. This approach streamlines maintenance and troubleshooting processes, reducing downtime and enhancing operational efficiency.

- **Error Resolution:** The project prioritized the timely resolution of PLC errors to uphold the uninterrupted operation of the assembly line. By promptly identifying and addressing issues such as sourcing and sinking problems, the team mitigated potential disruptions and minimized downtime. This proactive approach to error resolution underscores the project's commitment to maintaining high levels of productivity and reliability in industrial environments.

  Analysis: The prompt resolution of PLC errors highlights a proactive approach to risk management and system maintenance. By addressing issues such as sourcing and sinking problems in a timely manner, the project mitigates potential disruptions and ensures continuous operation of the assembly line.

- **User-Friendly Interfaces:** The development of intuitive HMI interfaces represents a significant milestone in enhancing operator control and monitoring capabilities. These interfaces provide operators with real-time insights into system performance, enabling them to make informed decisions and swiftly address any anomalies. By prioritizing user-friendliness and functionality, the project empowers operators to navigate complex systems with ease, thereby increasing operational efficiency and reducing the likelihood of errors.

  Analysis: The development of intuitive HMI interfaces reflects a user-centered design approach, prioritizing operator convenience and system usability. These interfaces empower operators to monitor and control the assembly line effectively, facilitating informed decision-making and rapid response to changing conditions.

- **Successful Integration:** The successful integration of mechanical and electrical components highlights the interdisciplinary nature of mechatronics engineering. By ensuring seamless communication and interaction between different subsystems, the project underscores the importance of collaboration and synergy in achieving optimal system performance. This successful integration not only validates the effectiveness of the developed PLC ladder logic and HMI interfaces but also underscores the project's commitment to delivering comprehensive solutions in mechatronics assembly line design and automation.

  Analysis: The successful integration of mechanical and electrical components demonstrates interdisciplinary collaboration and effective communication among team members. It validates the compatibility and interoperability of different subsystems, ensuring seamless operation and optimal performance of the assembly line.

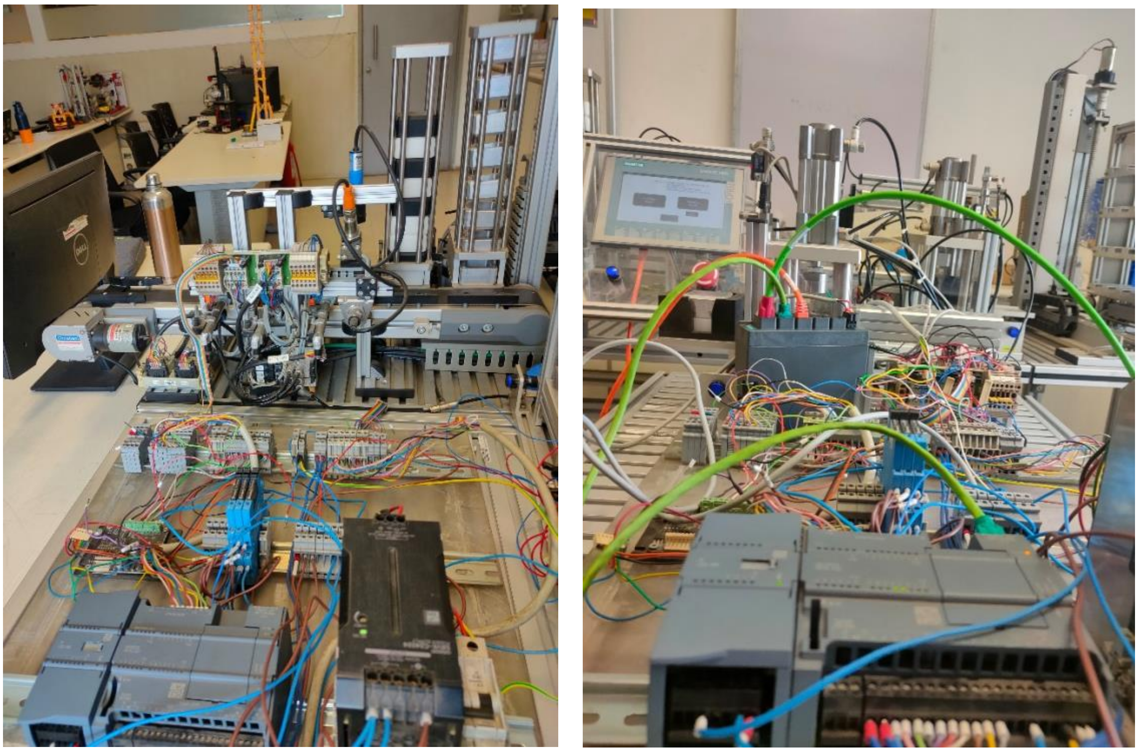


Figure 24: PLC and HMI Working

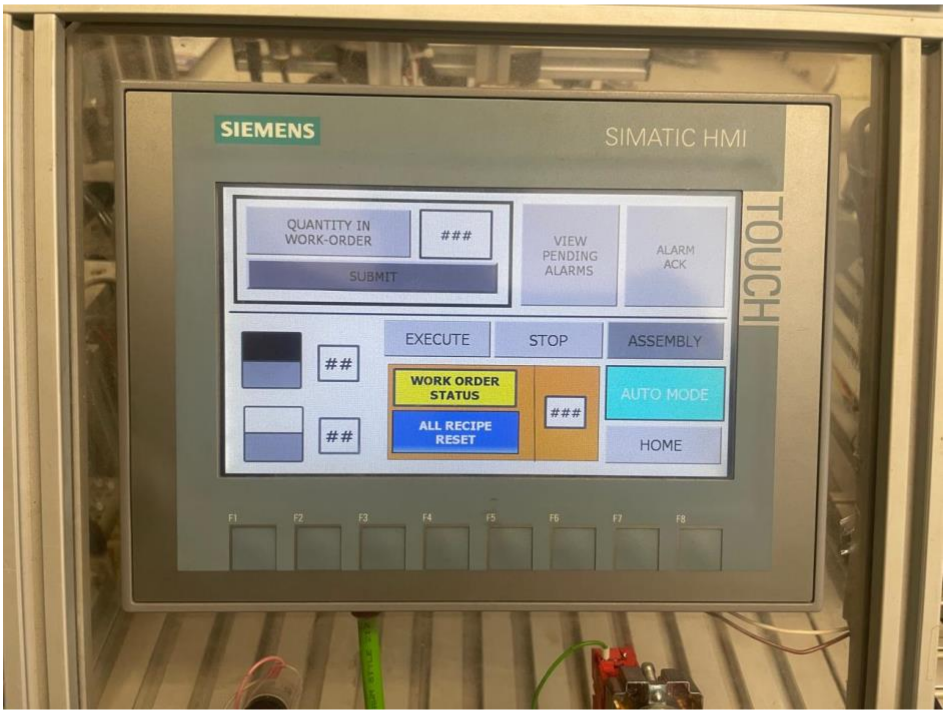


Figure 25: HMI

Chapter 5 Advantages, Limitations and Applications

5.1 PLC PROGRAMMING

PLC programming has many benefits for automating industrial processes and managing intricate systems, but there are drawbacks and difficulties that must be resolved. Notwithstanding these drawbacks, PLC programming's dependability, flexibility, and capacity for real-time control make it a flexible and extensively used technology across a range of industries. Below are some of its Advantages, Limitations and Applications:

Advantages:

1. Flexibility:
   Control logic can be readily adjusted and modified with PLC programming, negating the need for significant hardware or rewiring modifications. Because of its adaptability, producers can quickly reorganise production lines to account for modifications to product specifications, output levels, or workflows. PLC programming, for instance, enables engineers to update the control logic quickly and minimize downtime and production disruptions when a manufacturer needs to introduce a new product variant or alter an established production process.

2. Dependability:
   PLCs are made to function dependably in challenging industrial settings that include vibration, humidity, temperature swings, and electromagnetic interference. Because PLC hardware is ruggedized and designed to endure these circumstances, it can operate continuously even in harsh settings. Furthermore, PLC software has built-in fault detection and error handling mechanisms that reduce the chance of system failures, making it extremely robust and stable. System reliability is further improved by redundancy options, such as dual-redundant CPUs and I/O modules, which offer backup components in the event of a hardware failure.

3. Scalability:

   Because PLC systems are so scalable, manufacturers can update or expand their automation systems to meet changing needs for production or plant expansion. It is simple to incorporate new I/O modules, communication interfaces, or processing units into PLC systems that are already in place without causing a major disruption to business operations. Manufacturers can adjust their automation systems to changing business requirements and production demands thanks to this scalability, which guarantees long-term profitability and protects investment.

4. Real-time Control:

   PLCs enable accurate machine movement coordination, production sequence synchronization, and quick reaction to process deviations by offering real-time control over industrial processes. Control actions are carried out in milliseconds or microseconds thanks to PLCs' deterministic and fast processing of control logic. For high-speed manufacturing applications to maintain tight tolerances, reduce cycle times, and maximise throughput, real-time control is essential.

5. Diagnostic Capabilities:

   Advanced diagnostic features provided by PLCs make industrial system maintenance and troubleshooting easier. Engineers can swiftly locate and fix errors or malfunctions in PLC hardware or software thanks to built-in diagnostics, which include self-testing procedures, error logging, and alarm notifications. Remote monitoring capabilities allow maintenance personnel to access PLC systems from anywhere via network connections, enabling proactive maintenance and minimizing unplanned downtime.

Limitations:

1. Complexity:

   Programming a PLC can be challenging, particularly when dealing with large, complex systems that have numerous interdependencies and intricate control logic. It takes specific knowledge and proficiency in electrical engineering, control theory, and industrial automation to develop and debug PLC programmes. Furthermore, advanced knowledge and expertise may be needed for troubleshooting and diagnosing problems with PLC systems, especially when handling intricate interactions between hardware and software components.

2. Cost:

   The initial cost of PLC hardware, software licences, and programming tools can be high, especially for high-performance systems or large-scale automation projects. Moreover, continuous expenses like upkeep, assistance, and instruction could raise the overall cost of ownership for the PLC system throughout its lifespan. In small and medium-sized businesses with tight budgets, PLC automation might be too expensive up front, forcing them to turn to other options or manual control techniques.

Applications:

1. Manufacturing Automation:

   Applications including assembly lines, material handling systems, packaging machines, and robotic cells all use PLC programming. PLCs regulate the order, timing, and synchronisation of machinery functions to maximise output yield and product excellence. In manufacturing plants, for instance, PLCs manage robotic arms, palletizing systems, and conveyor belts to assemble products and fill containers.

2. Process Control:

   Applications for PLC programming is used in the chemical processing, oil and gas, power generation, and water treatment industries. To maintain ideal process conditions and guarantee the safe and effective operation of industrial processes, PLCs regulate parameters like temperature, pressure, flow rate, and level. To control flow rates, temperatures, and pressures in chemical reactors, distillation columns, and heat exchangers, for instance, PLCs operate valves, pumps, and actuators.

3. Building Automation:
   In both commercial and residential buildings, building automation systems use PLC programming to control lighting, security, HVAC (heating, ventilation and air conditioning), and access control. To increase comfort, effectiveness, and safety, PLCs monitor the surrounding environment, modify equipment settings, and put energy management plans into practice. PLCs, for instance, regulate air handlers, boilers, and chillers to maintain desired

5.2 MECHATRONICS ASSEMBLY LINE

A wide range of industries rely heavily on mechatronic assembly lines due to their many benefits in terms of accuracy, efficiency, and adaptability. But in order to fully realise the advantages and guarantee successful results of mechatronic assembly line implementation, manufacturers must also be cognizant of the constraints and difficulties involved. Some of their advantages, limitations and applications are as follows:

Advantages:

1. Enhanced Productivity:
   Mechatronics assembly lines combine computer, electrical, and mechanical systems, which streamlines workflows and boosts output effectiveness. Automation speeds up cycle times, minimizes human error, and maximizes resource use. Mechatronic assembly lines, as opposed to manual assembly methods, can dramatically reduce assembly time, and improve throughput in the automotive manufacturing industry, for instance.

2. Enhanced Precision:
   Mechatronics systems enable precise control over assembly processes, ensuring accurate positioning, alignment, and manipulation of components. This results in higher product quality and consistency. In electronics manufacturing, mechatronics assembly lines ensure precise placement of components on PCBs, minimizing defects and ensuring product reliability.

3. Flexibility and Adaptability:

   Changes in production needs or product designs can be readily accommodated by reconfiguring or reprogramming mechatronic assembly lines. Because of this adaptability, producers can react swiftly to changes in the market and in consumer preferences. Mechatronic assembly lines, for instance, can quickly adjust to changes in product formulations or packaging formats in the food and beverage industry.

4. Cost Reduction:

   Mechatronics assembly lines help cut labour expenses, material waste, and production downtime by automating repetitive tasks and optimising resource usage. This raises manufacturing operations' overall cost-effectiveness. Mechatronic assembly lines, for example, can lower costs in the pharmaceutical sector by increasing productivity and reducing the need for manual labour.

5. Increased Safety:

   To safeguard personnel and equipment from mishaps and dangers, mechatronic systems are equipped with safety features like sensors, interlocks, and emergency stop mechanisms. By eliminating the need for manual intervention in potentially hazardous tasks, automated processes lower the risk of injuries and increase workplace safety. Mechatronics assembly lines help to improve safety in sectors like aerospace and automotive manufacturing that use heavy machinery and equipment by limiting the amount of risk that workers face.

Limitations:

1. Initial Investment:

   A substantial upfront investment in hardware, software, and training is necessary for the implementation of mechatronic assembly lines. This upfront expense may be prohibitive for startups or businesses with tight budgets. Nonetheless, the initial investment is frequently justified by the long-term advantages of higher productivity and efficiency.

2. Maintenance and Downtime:

   Because mechatronic assembly lines depend on complex hardware and software, they may need periodic calibration and maintenance to operate at peak efficiency. Production halts and lost productivity can result from malfunctioning machinery or software. Robust maintenance procedures are imperative for manufacturers in order to minimise downtime and guarantee the dependability of mechatronic assembly lines.

Applications:

1. Automotive Industry:

   A lot of vehicle assembly, including chassis assembly, engine installation, and interior fitting, is done on mechatronic assembly lines. In the automotive sector, automation lowers costs while enhancing production efficiency, quality, and safety.

2. Electronics Manufacturing:

   In the electronics manufacturing industry, mechatronic assembly lines automate tasks like soldering, component placement, and PCB assembly. In order to meet the demand for mass production while maintaining product quality and reliability, electronics manufacturing uses high-speed and precise automation.

3. Aerospace Industry:

   Aircraft components, such as fuselage assembly and wing installation, are assembled using mechatronic assembly lines. In the aerospace sector, automation guarantees accuracy, reliability, and adherence to strict safety regulations.

4. Medical Device

   Manufacturing: Surgical instrument assembly and packaging are among the tasks in medical device production that mechatronic assembly lines automate. In order to guarantee product safety and regulatory compliance, the medical device industry needs to use high-quality, sterile manufacturing processes.

Chapter 6

Conclusion and Future Scope

6.1 CONCLUSION

The project's successful completion implies a significant milestone in the domain of automation engineering. This endeavor was characterized by a methodical approach encompassing meticulous planning, rigorous development, and exhaustive testing, all of which were aimed at enhancing the efficiency and reliability of the mechatronics assembly line. Central to the project's success was the thorough analysis and automation of the core systems constituting the mechatronics assembly line and understanding the flow of assembly line. These included the Magazine Unit, Conveyor System, Handling Unit, Pneumatic Press, and Automatic Storage and Retrieval System. Each system was subjected to a detailed examination to discern its specific functionalities, operational intricacies, and integration requirements.

Utilizing Siemens PLC technology as the cornerstone of automation, the project team embarked on the development of PLC ladder logic tailored to the unique characteristics of each system. This process involved translating conceptual designs into executable code, ensuring precise control and coordination of system components. By customizing the PLC logic to match the distinct requirements of each subsystem, the project aimed to facilitate seamless integration and operation within the overarching assembly line workflow. Furthermore, the project placed a strong emphasis on ensuring the compatibility and interoperability of the automated systems. Extensive testing and validation procedures were conducted to verify the seamless integration of the Magazine Unit, Conveyor System, Handling Unit, Pneumatic Press, and Automatic Storage and Retrieval System within the assembly line environment. By rigorously testing the interconnectedness of these systems, the project sought to mitigate the risk of integration challenges and ensure smooth and uninterrupted operation during real-world deployment.

In summary, the successful culmination of the project underscores the transformative potential of Siemens PLC technology in revolutionizing industrial automation. By leveraging meticulous planning, rigorous development, and comprehensive testing, the project has not only enhanced the efficiency and reliability of the mechatronics assembly line but has also paved the way for future advancements in automation engineering.

6.2 FUTURE SCOPE

As the project draws to a close, it serves not as an endpoint but rather as a springboard for future innovation and advancement. Several avenues beckon, each offering tantalizing prospects for further refinement and expansion:

- **Harnessing Advanced Technologies:** The convergence of advanced control algorithms, machine learning, and artificial intelligence holds immense promise for unlocking new frontiers of efficiency and adaptability. By leveraging these cutting-edge technologies, the assembly line can transcend its current limitations and chart a course towards unprecedented levels of performance.
- **Embracing the Internet of Things (IoT):** The integration of IoT technology promises to revolutionize the assembly line landscape, ushering in an era of unparalleled connectivity and insight. Real-time monitoring, predictive maintenance, and data-driven decision-making are but a few of the transformative capabilities poised to reshape the manufacturing paradigm.
- **Empowering Remote Operations:** In an increasingly interconnected world, the ability to monitor and control assembly line operations remotely represents a tantalizing opportunity. By embracing remote monitoring and control capabilities, organizations can transcend geographical boundaries and unlock newfound flexibility and responsiveness.
- **Cultivating a Culture of Continuous Improvement:** The pursuit of excellence is a never-ending journey, and the assembly line is no exception. By instituting a culture of continuous improvement, organizations can systematically identify inefficiencies, address bottlenecks, and seize opportunities for optimization, ensuring that the assembly line remains at the vanguard of innovation.
- **Energy Efficiency and Sustainability:** Investigate strategies for improving energy efficiency and reducing environmental impact across the assembly line systems. This may include the adoption of energy-efficient components, the implementation of smart energy management systems, and the integration of renewable energy sources such as solar or wind power.

In summation, the successful culmination of the project serves as a testament to the transformative power of automation and the boundless potential of human ingenuity. By exploring these future directions, the mechatronics assembly line project can continue to evolve and innovate, driving improvements in productivity, quality, and sustainability while remaining at the forefront of manufacturing technology.

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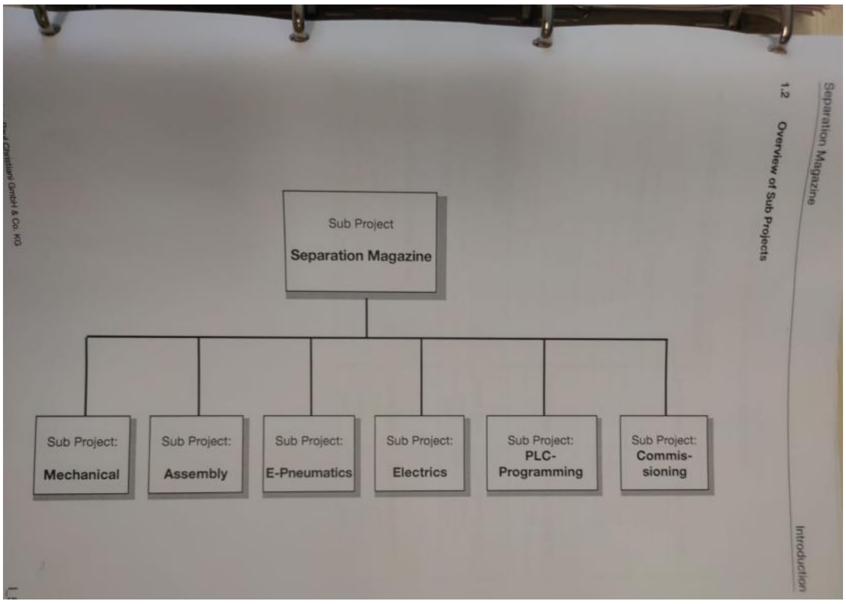
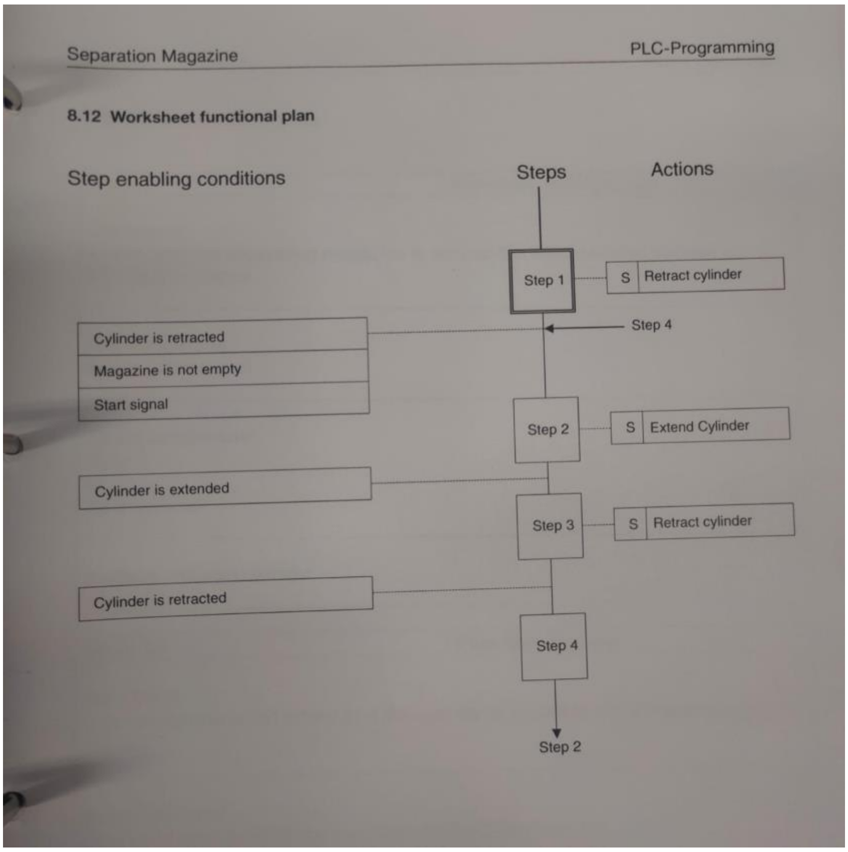
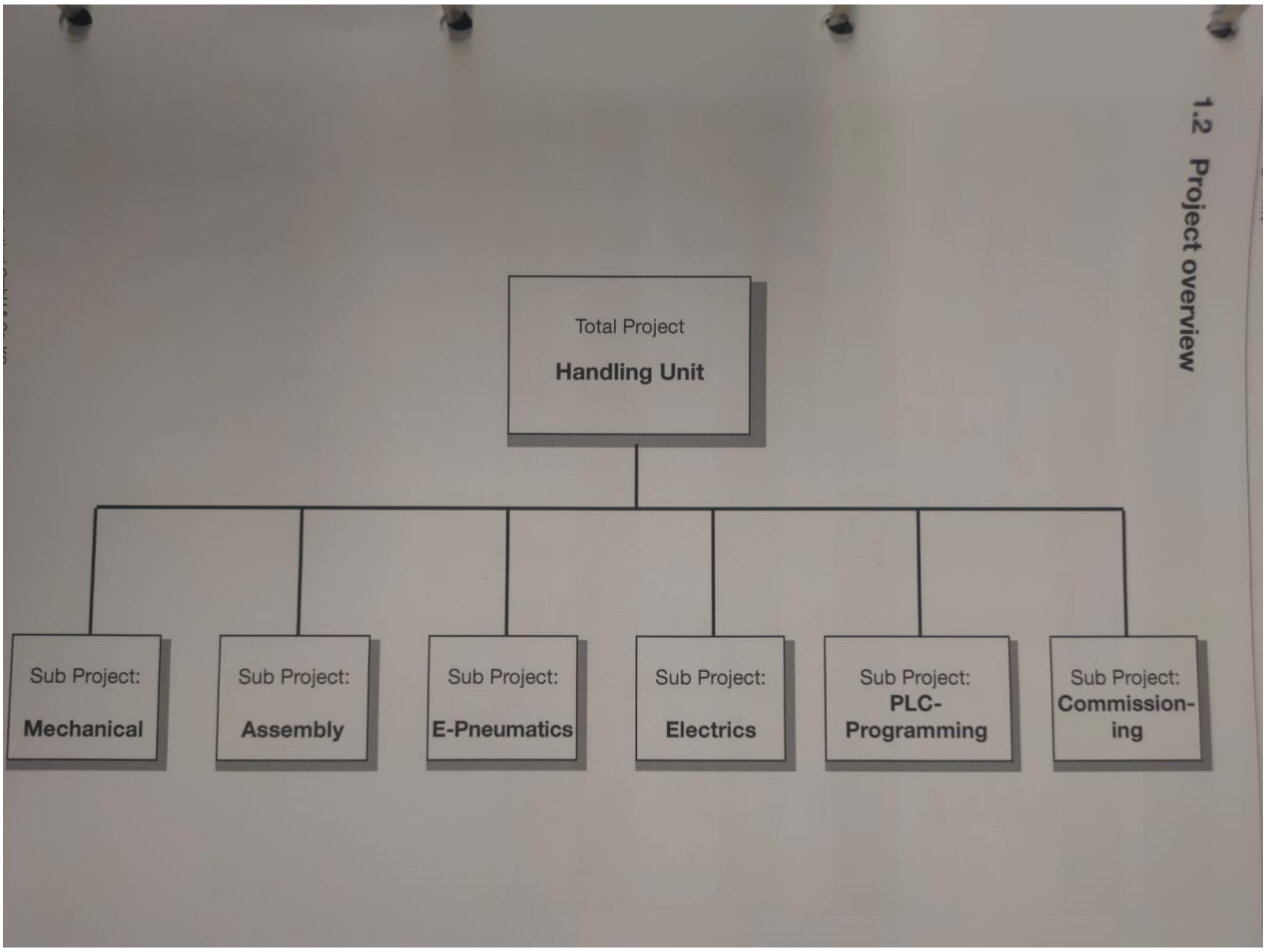
Appendix A: Soft Code Flowcharts

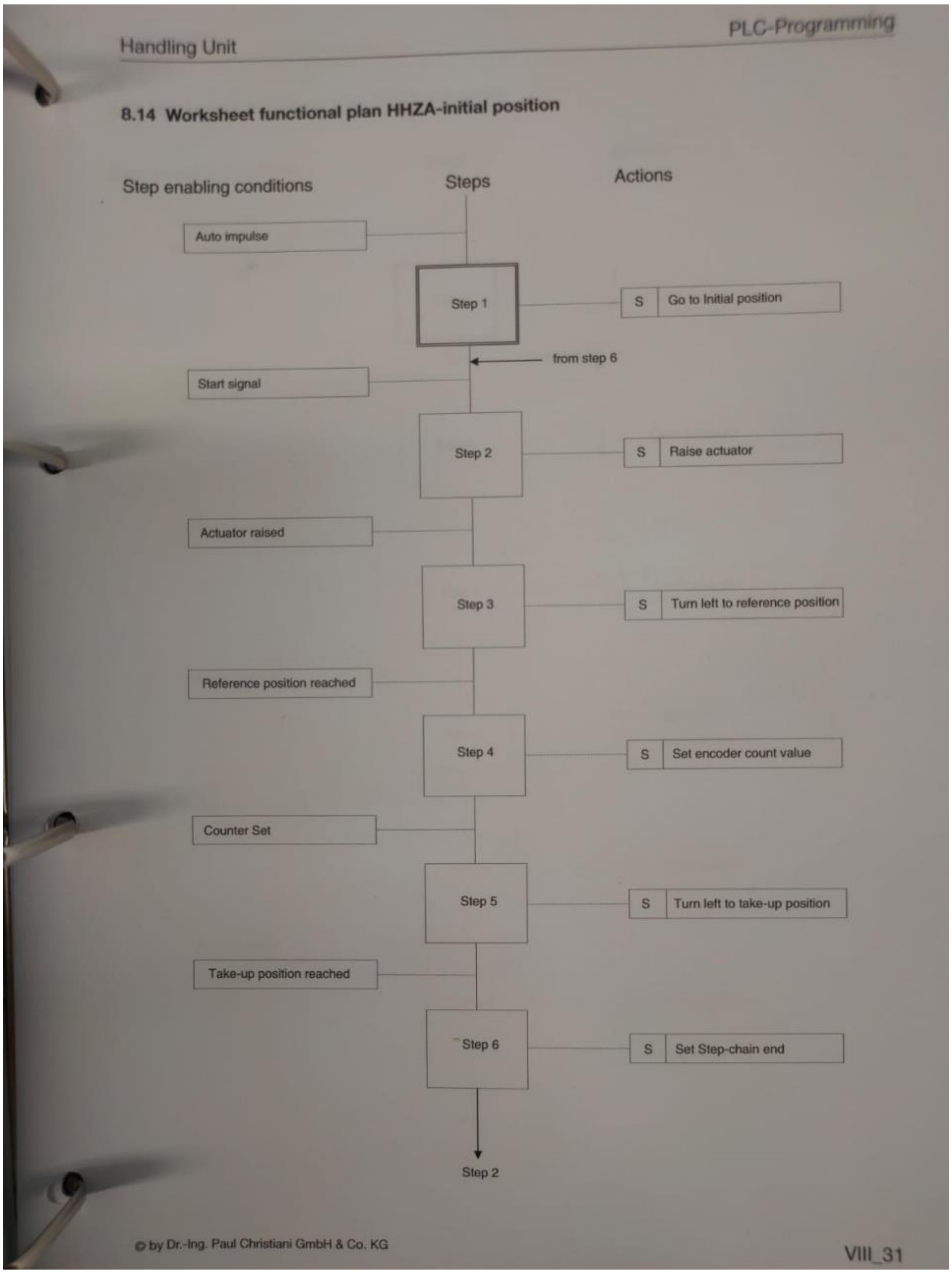
Magazine Unit Block Diagram and Flow Chart





Handling Unit Block Diagram and Flow Chart




Handling Unit PLC-Programming

8.14 Worksheet functional plan HHZA-initial position

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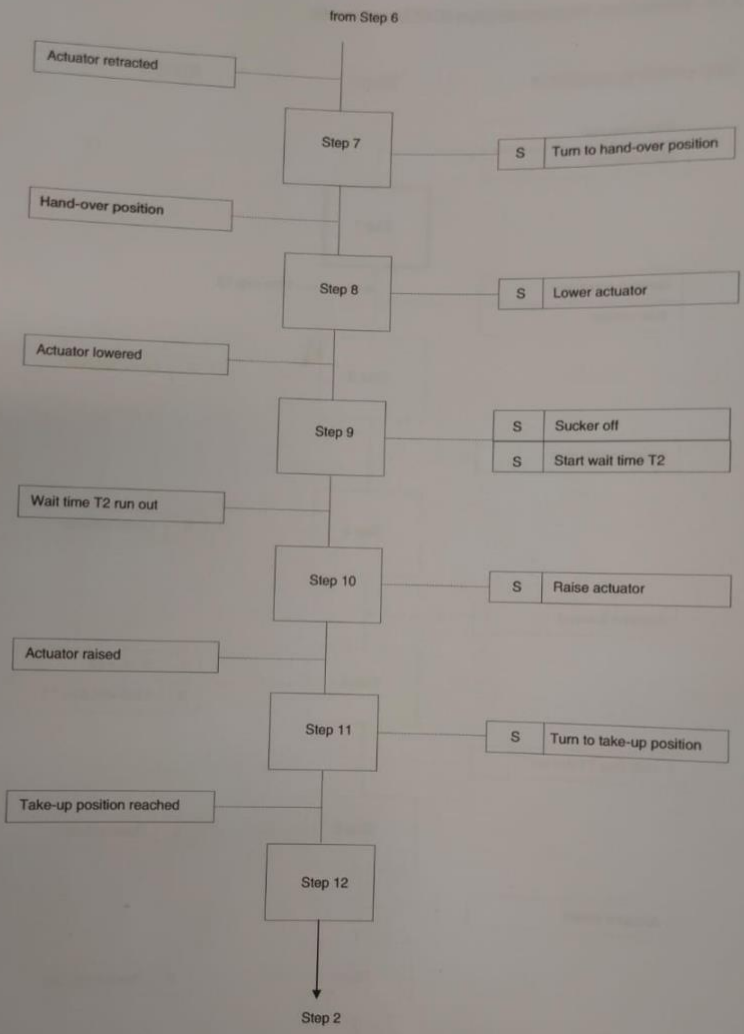
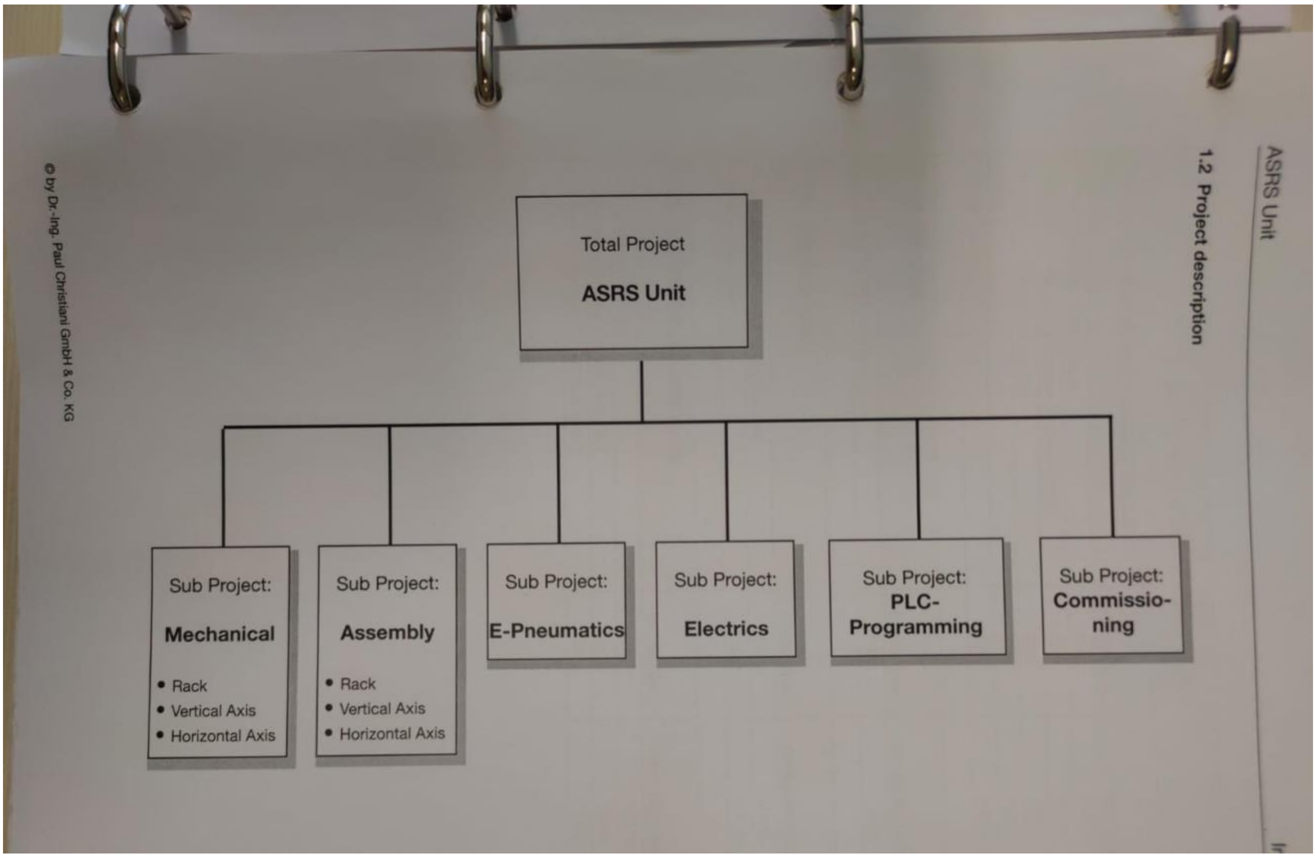
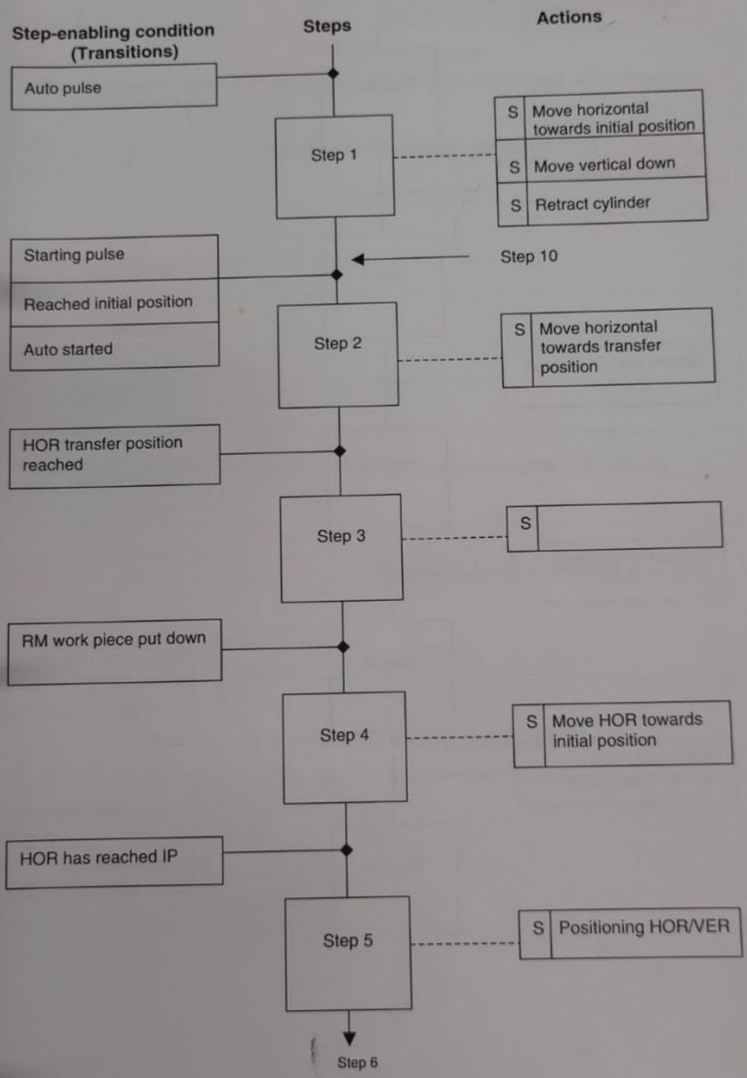
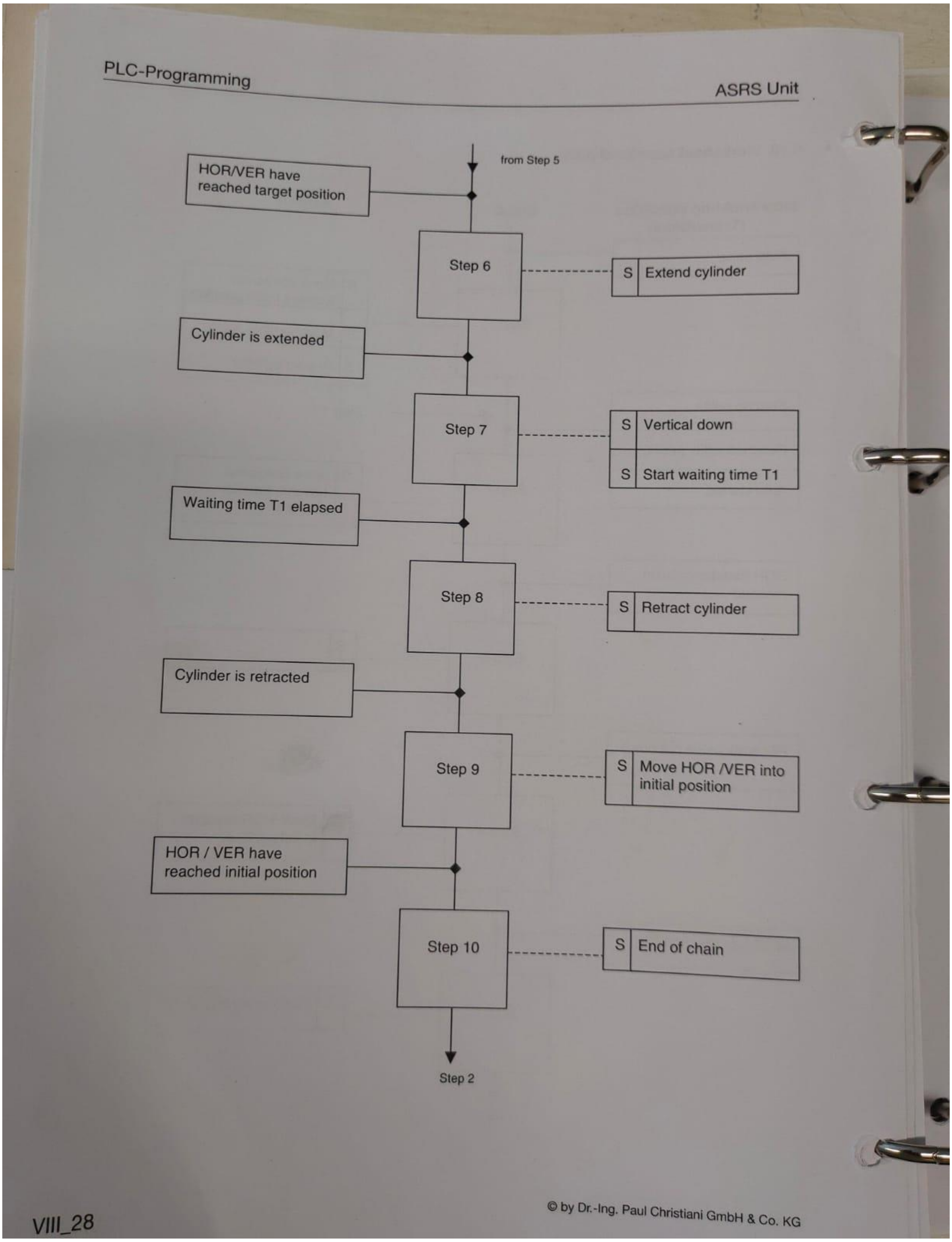

from Step 6
Actuator retracted
Step 7
S
Turn to hand-over position
Hand-over position
Step 8
S
Lower actuator
Actuator lowered
Step 9
S
Sucker off
S
Start wait time T2
Wait time T2 run out
Step 10
S
Raise actuator
Actuator raised
Step 11
S
Turn to take-up position
Take-up position reached
Step 12
Step 2

ASRS Unit Block Diagram and Flow Chart



8.13 Worksheet functional plan




PLC-Programming
ASRS Unit
from Step 5
HOR/VER have reached target position
Step 6
S Extend cylinder
Cylinder is extended
Step 7
S Vertical down
S Start waiting time T1
Waiting time T1 elapsed
Step 8
S Retract cylinder
Cylinder is retracted
Step 9
S Move HOR /VER into initial position
HOR / VER have reached initial position
Step 10
S End of chain
Step 2
VIII_28
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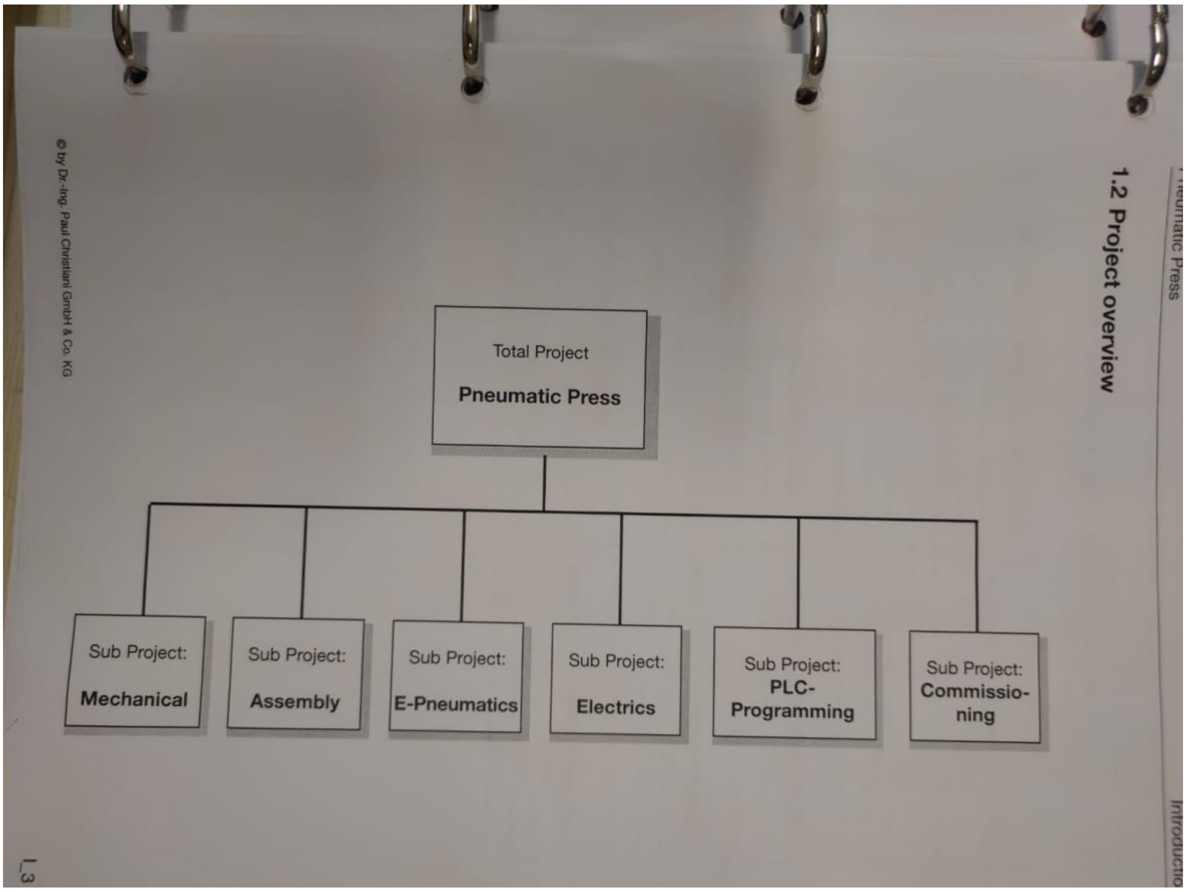
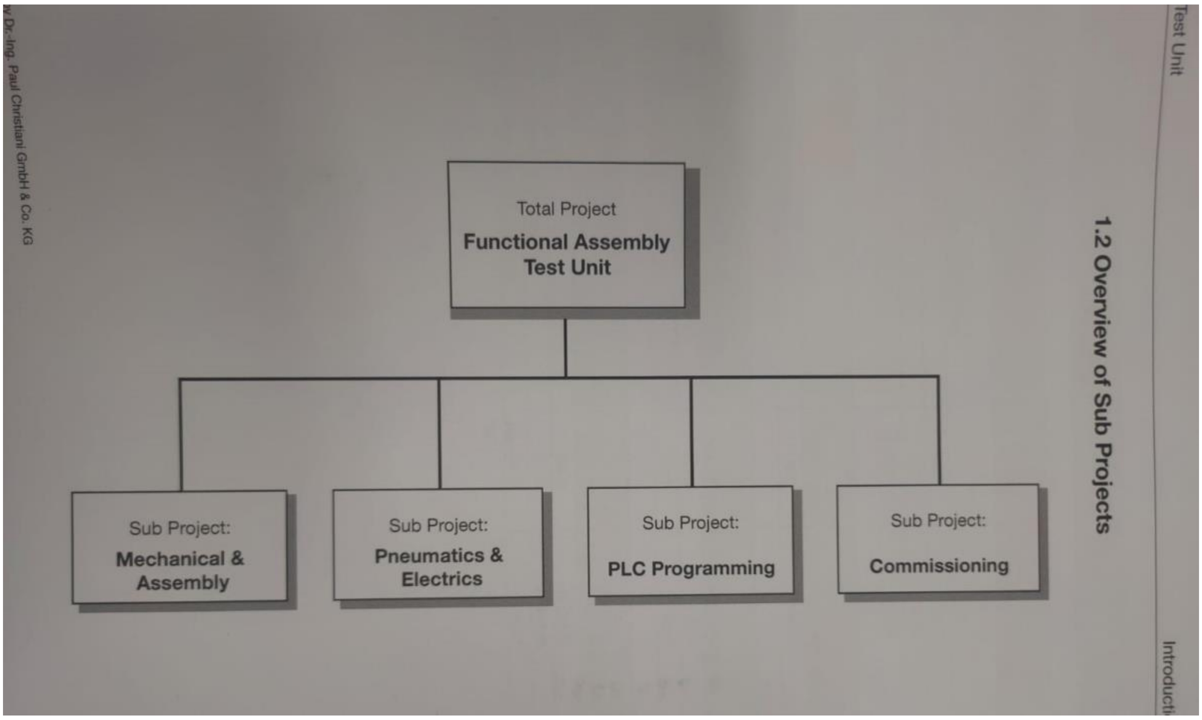
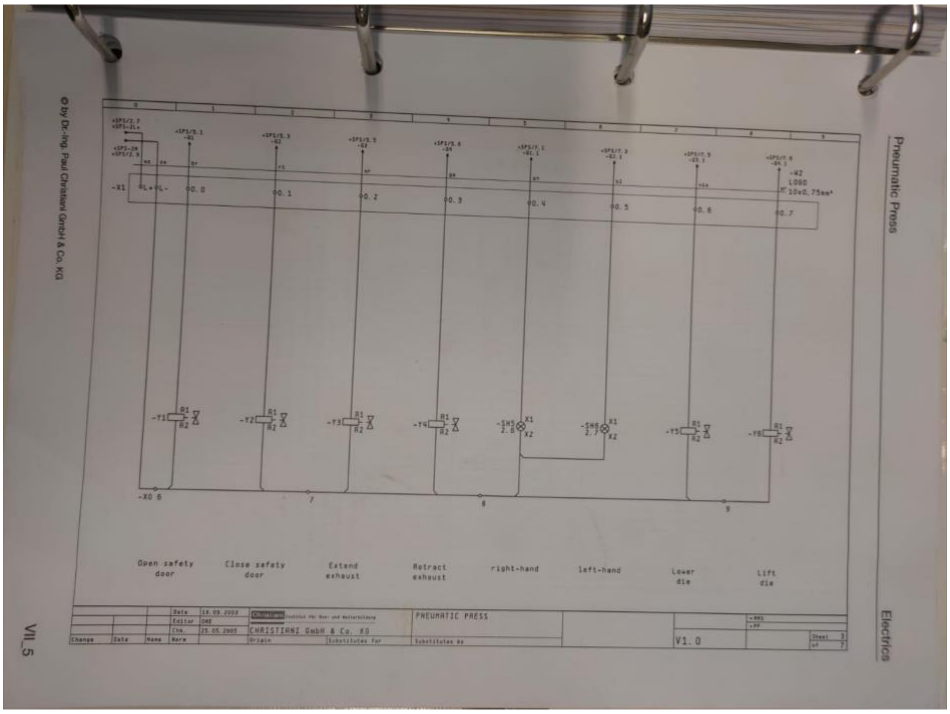
Pneumatic Press and Testing Unit Block Diagram

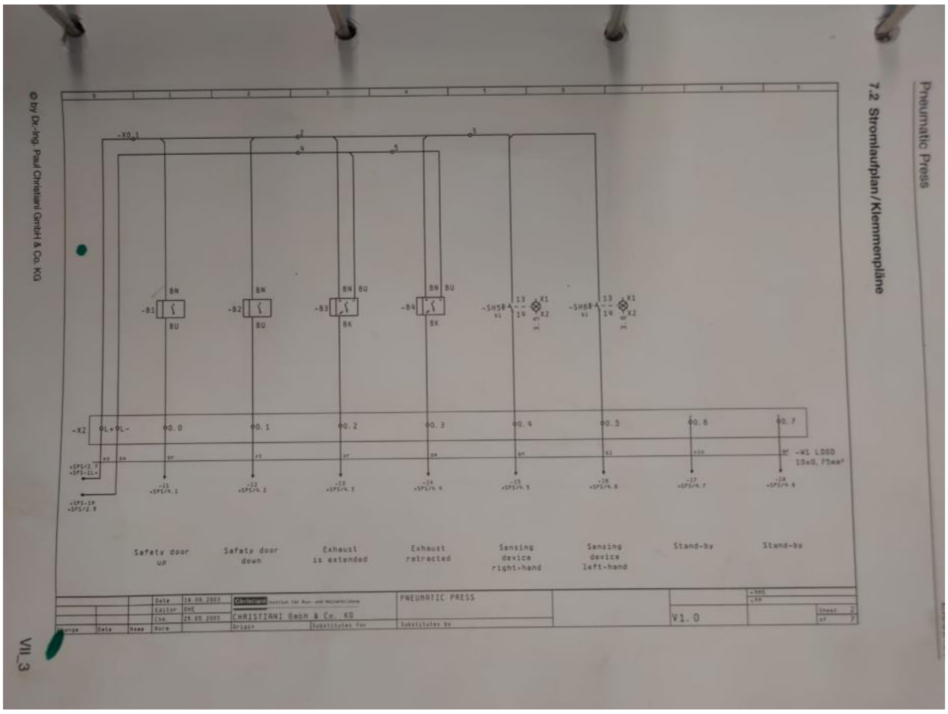



1.2 Overview of Sub Projects
Total Project
Functional Assembly Test Unit
Sub Project:
Mechanical & Assembly
Sub Project:
Pneumatics & Electrics
Sub Project:
PLC Programming
Sub Project:
Commissioning
Test Unit
Dr.-Ing. Paul Christiani GmbH & Co. KG

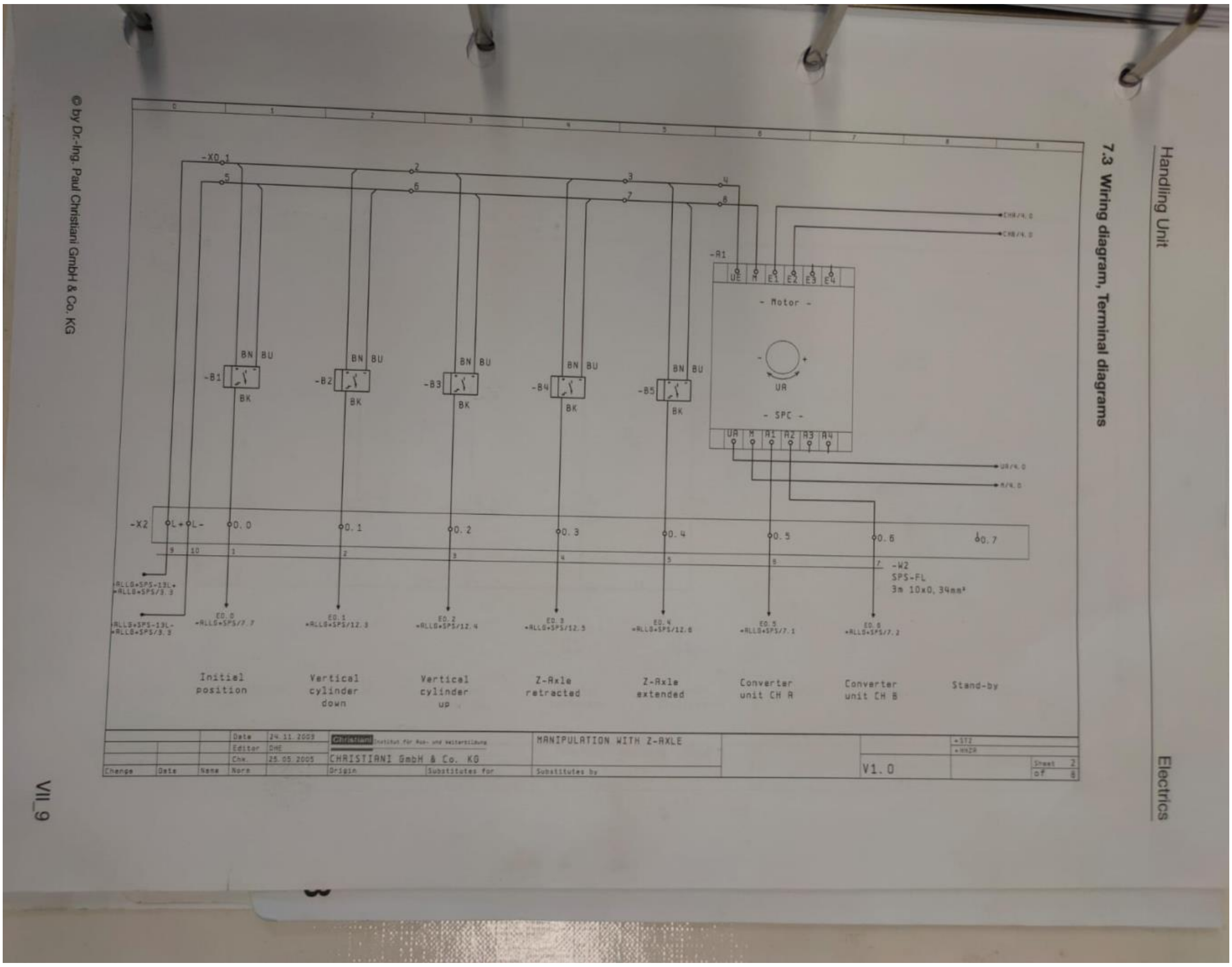
Appendix B: Data Sheets

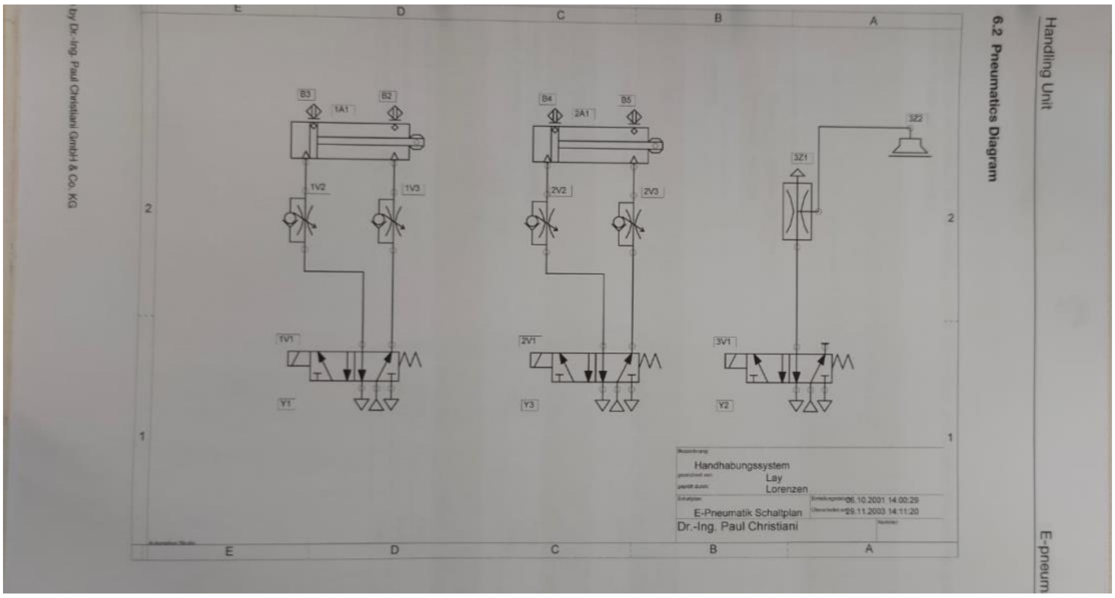
Pneumatic Press Wiring data sheet



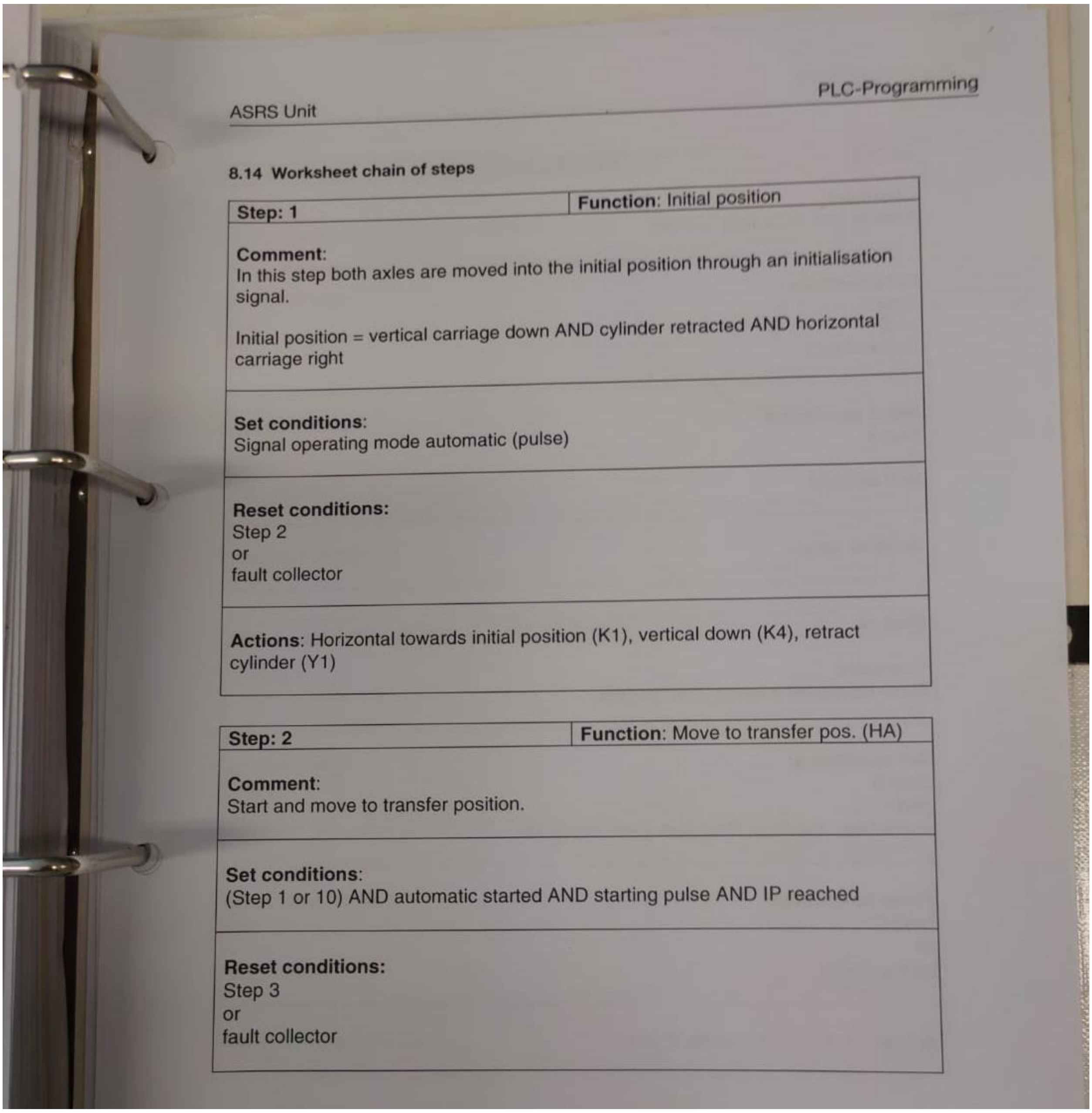


Handling Unit Wiring and Pneumatic data sheet





Automatic Storage and Retrieval System Operational Data Sheet



8.14 Worksheet chain of steps

Step: 1	**Function**: Initial position
Comment: In this step both axles are moved into the initial position through an initialisation signal. Initial position = vertical carriage down AND cylinder retracted AND horizontal carriage right	
Set conditions: Signal operating mode automatic (pulse)	
Reset conditions: Step 2 or fault collector	
Actions: Horizontal towards initial position (K1), vertical down (K4), retract cylinder (Y1)	

Step: 2	**Function**: Move to transfer pos. (HA)
Comment: Start and move to transfer position.	
Set conditions: (Step 1 or 10) AND automatic started AND starting pulse AND IP reached	
Reset conditions: Step 3 or fault collector	

Step: 3	Function: Wait until work piece is transferred
Comment: Waiting step in transfer position	
Set conditions: Step 2 AND B10 and B15	
Reset conditions: Step 4 or fault collector	
Actions: none	

Step: 4	Function: Move to initial position (HA)
Comment: Move horizontal towards initial position	
Set conditions: Step 3 AND signal from interface: "RM work piece put down"	
Reset conditions: Step 5 or fault collector	
Actions: Horizontal towards IP (K1)	

Step: 5	**Function**: Start positioning
Comment: Initial position reached, start positioning	
Set conditions: Step 4 AND S 13	
Reset conditions: Step 6 or fault collector	
Actions: Positioning	

Step: 6	**Function**: Extend cylinder
Comment: Extend cylinder	
Set conditions: Step 5 AND signal HA_Ziel_erreicht AND VA_Ziel_erreicht	
Reset conditions: Step 7 or fault collector	
Actions: Extend cylinder	

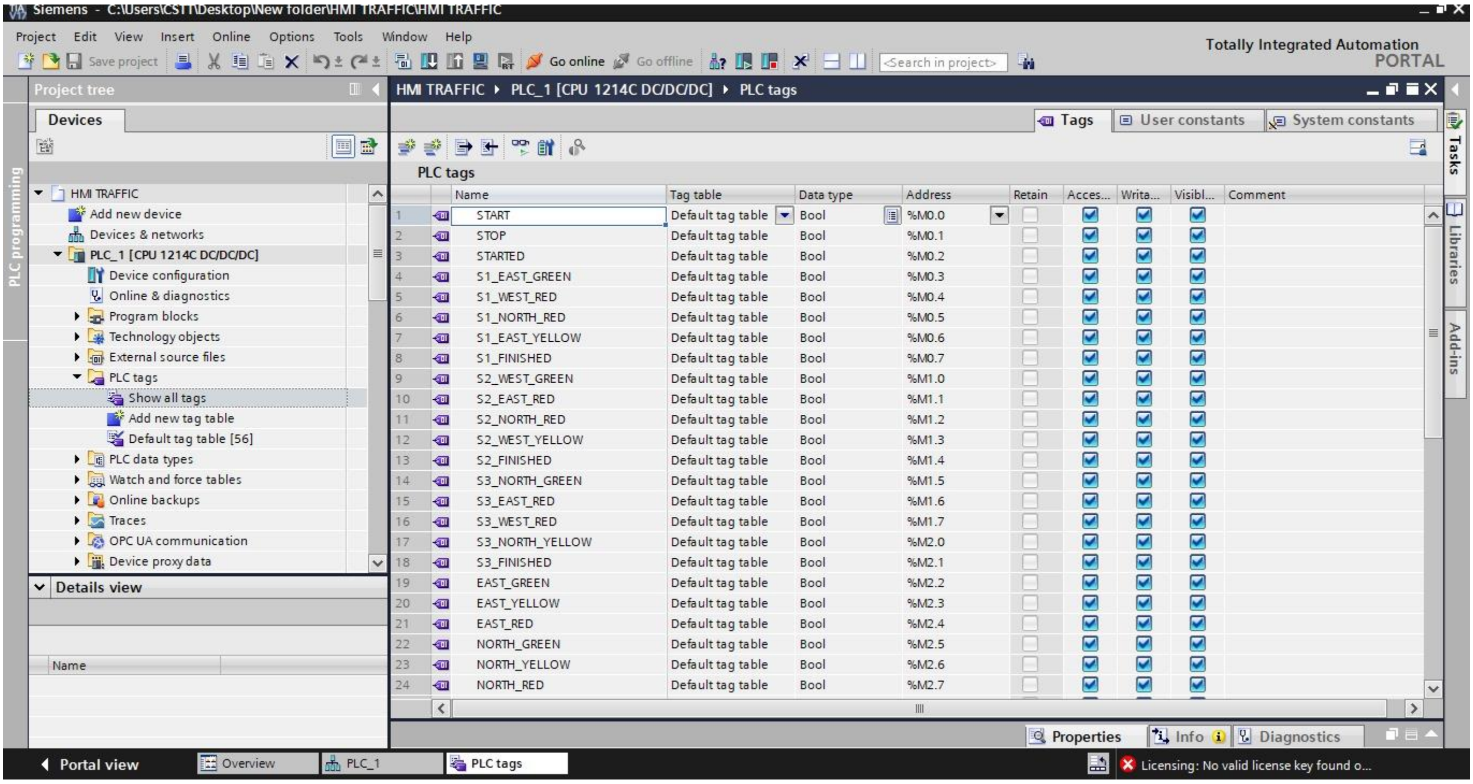
Step: 7	Function: Lower cylinder
Comment: Lowering of the work piece through lowering of the vertical carriage by T1	
Set conditions: Step 6 AND B6	
Reset conditions: Step 8 or fault collector	
Actions: Vertical down (K4), start waiting time T1	

Step: 8	Function: Retract cylinder
Comment: Retract cylinder	
Set conditions: Step 7 AND T1 elapsed	
Reset conditions: Step 9 or fault collector	
Actions: Retract cylinder	

Step: 9	**Function**: Move to initial position (HOR and VER)
Comment: Move to IP, HA/VA	
Set conditions: Step 8 AND B7	
Reset conditions: Step 10 or fault collector	
Actions: Horizontal towards IP (K1), vertical down (K4)	

Step: 10	**Function**: End of chain
Comment: This step becomes active, when the IP is reached. No action is executed.	
Set conditions: Step 9 AND S2 AND S13	
Reset conditions: Step 2 or fault collector	
Actions: none	

PLC Tag Data List



	Name	Tag table	Data type	Address
1	START	Default tag table	Bool	%M0.0
2	STOP	Default tag table	Bool	%M0.1
3	STARTED	Default tag table	Bool	%M0.2
4	S1_EAST_GREEN	Default tag table	Bool	%M0.3
5	S1_WEST_RED	Default tag table	Bool	%M0.4
6	S1_NORTH_RED	Default tag table	Bool	%M0.5
7	S1_EAST_YELLOW	Default tag table	Bool	%M0.6
8	S1_FINISHED	Default tag table	Bool	%M0.7
9	S2_WEST_GREEN	Default tag table	Bool	%M1.0
10	S2_EAST_RED	Default tag table	Bool	%M1.1
11	S2_NORTH_RED	Default tag table	Bool	%M1.2
12	S2_WEST_YELLOW	Default tag table	Bool	%M1.3
13	S2_FINISHED	Default tag table	Bool	%M1.4
14	S3_NORTH_GREEN	Default tag table	Bool	%M1.5
15	S3_EAST_RED	Default tag table	Bool	%M1.6
16	S3_WEST_RED	Default tag table	Bool	%M1.7
17	S3_NORTH_YELLOW	Default tag table	Bool	%M2.0
18	S3_FINISHED	Default tag table	Bool	%M2.1
19	EAST_GREEN	Default tag table	Bool	%M2.2
20	EAST_YELLOW	Default tag table	Bool	%M2.3
21	EAST_RED	Default tag table	Bool	%M2.4
22	NORTH_GREEN	Default tag table	Bool	%M2.5
23	NORTH_YELLOW	Default tag table	Bool	%M2.6
24	NORTH_RED	Default tag table	Bool	%M2.7

Table 1a

Appendix C: List of Components

During the course of our internship project at Christiani Automation, a variety of components and tools were utilized to facilitate our tasks. Below is a comprehensive list of components and tools employed:

Tools Used in Mechatronics Lab:

1. Allen keys
2. Wrench
3. Screwdriver set
4. Star Allen key set
5. Drilling machine
6. Tapping tool
7. Clamps
8. Hammer
9. Polishing tool
10. Turning tool
11. Buffing tool
12. Blower
13. Multimeter
14. Electric Solder
15. Tester

Components Comprised in the Mechatronics Assembly Line Kit:

A. Pneumatic press assembly line
B. Handling unit
C. ASRS (Automated Storage and Retrieval System) unit
D. Mag (Magnetic) unit
E. Testing unit

The Mechatronics Assembly Line Kit provided a comprehensive set of components essential for simulating real-world industrial automation processes. Each unit within the kit served a specific function in the assembly line, enabling us to gain hands-on experience in mechatronics and automation technologies.

A. Pneumatic press sub-assembly

The Pneumatic unit is designed for assembling or attaching workpieces. After inserting the workpieces, the workpiece holder transports the parts to be processed to the workspace. Then, the safety door closes, and the joining cylinder begins extending. After the assembly of the cube halves, the safety door opens. The joint workpieces are pushed out of the workspace and are ready for further transport. Due to the safety door, the Assembly Unit ha fully enclosed workspace during processing. However, the safety walls made of plexiglass makes it possible to observe the joining procedure. The operating pressure is 4 bar. The operating voltage is 24 VDC.

- **Technical Details**
  Operating pressure: 4 bar
  Operating voltage: 24 VDC

  Components:
  - 7 x cylinder switch
  - 3 x 5/2 way valves
  - 3 x double-acting pneumatic cylinder

Requirements for the PLC:
- 7 digital PLC inputs
- 6 digital PLC outputs

B. Handling Unit

The handling unit implements what are called pick-and-place applications, in which workpieces are picked up from one location and placed at another one. The three-axis Handling Unit covers a work area of 270°. In this work area, any position can be approached. The drive uses a DC motor with integrated rotary encoder. Both the vertical and the horizontal axis are driven by distortion-safe pneumatic cylinders. In order to hold the workpieces, the manipulator is equipped with a vacuum suction device. Combined with other mechatronic Functional Units, the Handling Unit can, for example, do the following:

- Pick up workpieces from a belt conveyor and feed them to a press / an Assembly Unit for further processing
- Pick up workpieces from a belt conveyor and transfer them to an ASRS for storage

- **Technical Data**

  Operating pressure: 4 bar

  Operating voltage: 24 VDC

  Components:

  - 4 x cylinder switch
  - 1 x inductive sensor
  - 1 x pressure switch
  - 3 x 5/2 way valve
  - 2 x double-acting pneumatic cylinder
  - 1 x 24 V direct current gear motor
  - Encoder on motor
  - 1Q Speed controller

- **Requirements for the PLC:**
  - 8 digital PLC inputs of which 2 fast counters
  - 8 digital PLC outputs
  - 1 analog PLC output

C. Automatic Storage and Retrieval System(ASRS) unit

The ASRS consists of a rack and the associated ASRS operating device, which are mounted together on two assembly platforms. The workpieces to be stored are supplied - for instance by a manipulator - and transferred to the ASRS operating device and stored in the rack. The workpieces can also be removed from storage in the opposite order. In total, there are 28 available storage spaces. For storing the workpieces and for removing them from storage, a double-acting pneumatic cylinder is available. The operating pressure is 4 bar.

- **Technical Data**

  Operating pressure: 4 bar

  Operating voltage: 24 VDC

  Components:

  - 2x fork light barrier
  - 1 x gear motor 70 rpm
  - 1 x gear motor 230 rpm
  - 4 x microswitches
  - 1 x 5/2 way valve
  - 1 x double-acting pneumatic cylinder
  - 2 x cylinder switch
  - 1 x diffuse sensor

- **Requirements for the PLC:**
  - 9 digital PLC inputs
  - 6 digital PLC outputs

D. Mag unit

The function of the separating magazine is to separate workpieces such as cube halves. In the storage of the separating magazine type 2 there is room for up to eight stacked workpieces. In contrast to the separating magazine 1, it can hold the cube halves including inserted connecting pins. In connection with magazine type 1, it is thus possible to alternately separate cube halves with pins and without pins. The operating pressure is 4 bar, the operating voltage 24 VDC.

- **Technical Data**

  Operating pressure: 4 bar

  Operating voltage: 24 VDC

  Components:

  - 2x cylinder switch
  - 1 x diffuse sensor
  - 2 x microswitches
  - 1 x 5/2 way valve
  - 1 x double-acting pneumatic cylinder

- **Requirements for the PLC:**
    - digital PLC inputs
    - 2 digital PLC outputs

E. Conveyer and Testing unit

The functional assembly conveyor belt consists of a 700 mm long and 50 mm wide belt section. A sensor is mounted at the end of the conveyor belt section. The conveyor belt is equipped with a DC motor including integrated speed controller. This allows infinitely variable speed control as well as a change of direction of rotation. Other belt lengths are available on request in increments of 100 mm

- **Technical Data**

  Operating voltage: 24 VDC

  Components:
    - Direct current motor incl. integrated speed controller
    - Fibre optic sensor
- **Requirements for the PLC:**
    - digital PLC inputs
    - 3 digital PLC outputs
    - 1 analog PLC output