THE UNIVERSITY OF DANANG

UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING

# CAPSTONE PROJECT

MAJOR: MECHATRONIC ENGINEERING

TOPIC:

# RESEARCH, PARAMETER SETTING AND IMPROVEMENT OF VACUUM POTTING MACHINE

Supervisor: DR. HOAI NAM LE

Mentor: ENG. TRONG TAI NGUYEN

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Da Nang, 06/2025

THE UNIVERSITY OF DANANG

UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING

PREMO

# CAPSTONE PROJECT

# PREMO VIETNAM CO.,LTD

# ABSTRACT

Topic: Research, parameter setting and improvement of vacuum potting machine.

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Student ID: 101200239 – 101200356 - 101200350

Class: 20CDT1 – 20CDTCLC2 - 20CDTCLC2

This project was assigned and carried out at Premo Vietnam Co.,Ltd, focusing on analyzing and developing solutions to reduce the adhesive dispensing time for the E245 LF ANTENNA product while maintaining the required output quality. To achieve this goal, the research team implemented several improvement measures for the vacuum potting machine, including redesigning the adhesive dispensing toolset, optimizing operating parameters and the nozzle movement trajectory, as well as programming the PLC system, flow sensors, and HMI to monitor adhesive flow. Upon completion of the improvements, the machine's performance was compared with pre-improvement data to evaluate the effectiveness of the enhancements. The results showed that the total production time per unit was reduced by 2.5 seconds compared to the previous setup. This demonstrates that, although the original configuration of the potting machine ensured quality, the implemented improvements significantly increased productivity. While the time reduction was effectively achieved, broader application in mass production will require further evaluation of the system's long-term stability. In addition, training personnel to adapt to and operate the new system is crucial to sustaining optimal production efficiency.

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# GRADUATION PROJECT ASSIGNMENT

| No. | Student's name | Student ID | Class | Major |
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| 2 | Nhat Huy Nguyen Van | 101200356 | 20CDTCLC2 | Mechatronic Engineering |
| 3 | Van Hau Nguyen Huynh | 101200350 | 20CDTCLC2 | Mechatronic Engineering |

1. *Topic:* Research, parameter setting and improvement of vacuum potting machine
2. *Topics covered by:* ☐ Having signed an intellectual property agreement for the implementation results
3. *Initial figures and data:*
   - Based on the initial operating condition of the machine
   - Cycle time: 10 seconds per product
4. *Contents of explanations and calculations:*

Chapter 1: INTRODUCTION

Chapter 2: MECHANICAL DESIGN IMPROVEMENT

Chapter 3: ELECTRICAL DESIGN IMPROVEMENT

Chapter 4: CONTROL DESIGN IMPROVEMENT & RESEARCH, PARAMETER SETTING

Chapter 5: CONCLUSION

5. *Drawings, graphs (specify types and sizes of drawings):*
   - 2D Detailed drawings: A0
   - Assembly drawing: A0

- PLC input/output & layout drawing: A0
- Flowchart diagram of the PLC control algorithm for the flow sensor: A0

6. *Supervisor:* Dr. Hoai Nam Le - Eng. Trong Tai Nguyen
7. *Project assignment date:* 17/02/2025
8. *Project completion date:* 30/05/2025

*Da Nang, 06/2025*

| | |
|---|---|
| **Head of Department** | **Supervisor** |
| **Mechatronic Engineering** | |

## ACKNOWLEDGMENT

To successfully complete this graduation capstone project, in addition to our own efforts, we have also received encouragement and support from our family, teachers, and friends.

First and foremost, we would like to sincerely thank all the lecturers of the University of Science and Technology – The University of Danang in general, and the faculty members of the Faculty of Mechanical Engineering in particular, for providing us with the necessary knowledge and experience throughout our studies.

Especially, we would like to express our deep gratitude to Dr. Hoai Nam Le and Eng. Trong Tai Nguyen for their dedicated guidance and invaluable feedback, which have helped us overcome challenges in our research and complete this project in the best possible way. At the same time, we extend our heartfelt thanks to the Board of Directors and all employees at Premo Vietnam Co., Ltd. for giving us the opportunity to learn and work in a professional environment, equipping us with essential skills for our future career.

Despite our best efforts, this project may still contain shortcomings. We sincerely hope to receive understanding and constructive feedback from our respected teachers to further improve our work.

We sincerely thank you!

*Executing Students*

**Huu Quan Huynh**

**Nhat Huy Nguyen Van**

**Van Hau Nguyen Huynh**

# DECLARATION

We hereby declare that this graduation capstone project at Premo Vietnam Co.,Ltd is us own research and work, carried out under the guidance of Dr. Hoai Nam Le and Eng. Trong Tai Nguyen, without any plagiarism from other sources.

This report includes references to specific materials cited in the reference section. If any fraud is detected, We take full responsibility for the content of my report.

*Executing Students*

**Huu Quan Huynh**

**Nhat Huy Nguyen Van**

**Van Hau Nguyen Huynh**

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| Abbreviation of symbol | Definition |
|---|---|
| 3DC | Three Dimensions Coil |
| AOI | Automatic Optical Inspection |
| ISO | International Organization for Standardization |
| SMD | Surface-Mount Device |
| RFID | Radio Frequency Identification |
| TRAFO AUTO | Autotransformer |
| CMCF | Common Mode Choke Ferrite |
| AEC-Q200 | Automotive Electronics Council |
| HMI | Human Machine Interface |
| NG | Not good |
| PLC | Programmable Logic Controller |

# Chapter 1: INTRODUCTION


*Figure 1.1 Premo Vietnam Co.Ltd*

## 1.1. Overview and History [1]

Premo Vietnam is a subsidiary of the Premo Group, headquartered in Malaga, Spain. The company specializes in manufacturing electronic components for the automotive, telecommunications, and industrial electronics industries, with numerous offices and research centers across Europe and Asia. As a multinational company, it operates in multiple languages and fosters a professional yet friendly work environment.

Their product portfolio includes RFID antennas (world leading), AR/VR Motion Tracking Sensors, transformers, inductors & inductors, current sensors, EMC filters, and PLC components. In addition to a wide range of standard components, products are available, Premo also designs customs solutions tailored to customer requirements, based on the latest technologies that help the customer's system work efficiently.

In 2015, another factory was opened at Lot 21, Dien Nam, Dien Ngoc Industrial Park, Dien Ban, Quang Nam. There are factories equipped with the most advanced production technology, which meet the quality and quantity standards of customers' customers both domestically and internationally.


*Figure 1.2 Premo was founded in 1962*

In 1962 PREMO, S.A. was founded as a company to develop and manufacture TV sets and the inductive components needed for them. Eight years later however, PREMO abandoned the production of TV sets and specialized steadily into what was going to be the core business of the whole group: export oriented inductive components development and manufacturing. PREMO's first foreign sales office was established in 1982 in France.

**1981,** as from 1981 PREMO was split into various spin-off companies, all specialized in a different segment of the inductive components sector.

**1999,** in 1999 overseas expansion started with the establishment of sales offices in the United States. At this moment the PREMO Group is represented in six states by three commercial organizations.

**2001,** however, it was not until 2001 that the PREMO Group became a true multinational. A long-cherished wish came true with the opening of a new manufacturing plant in Wuxi, a town near Shanghai, China. So far, this is the largest manufacturing plant of PREMO Group, with 300 employees, including 20 R&D engineers. The majority of PREMO products are now made in this factory in China.

Together with the opening of the China plant it was felt that the different companies forming part of the PREMO Group should market and sell their products under and the same brand name, though organically and management wise they would stay independent. By virtue of this desire, a new corporate image was developed with a modern version of the PREMO logo and taking the red from the original PREMO, S.A. colours.

In 2004, the PREMO Group added a new series of products to its product portfolio: PLC products. These include inductors, transformers, control devices, and other devices dedicated to the transmission of data over the public electrical network. This is a very promising business area as telecommunications costs can be significantly reduced, as well as speed up if traditional telecommunications networks are avoided. The development and production of PLC products will be located at the Málaga plant.

In 2006 new manufaturing plant was open in Tanger.

**2008,** PREMO closed first Wuxi Plant and first Tangier Plant to open a new and larger plant in Tangier. PREMO open a new R&D Center in Grenoble (France) and

Bangalore (India). A back office in Tokio was opened. 2012 PREMO signed Toyota TE Japan Partnership.

**2013,** Premo Alwox partnership (Korea). **2014,** Open PREMO Korea. **2015 ,** Foundation of PREMO Vietnam and a opening of a new R&D Center in Málaga. **2017,** foundation of PREMO USA (Yorba Linda, California). Introduction of AR/VR EM Tracking Sensors and Amfitech partnership. **2018,** foundation of New PREMO Tangier Plant. **2019,** foundation of New PREMO Germany Office.

## 1.2. Mission & Vision [1]

### *1.2.1. Mission*

Premo's mission is to drive innovation in electromagnetic components, providing high-quality, cutting-edge solutions that empower industries worldwide.

Premo is dedicated to enhancing connectivity, efficiency, and sustainability through advanced technologies, enabling its customers to thrive in their markets.

Premo's commitment to customer satisfaction, continuous improvement, and responsible practices fuels its passion for creating value and positively impacting society.

### *1.2.2. Vision*

Premo's vision is to be the global leader in innovative electromagnetic technologies that transform industry standards.

Premo aspires to foster a sustainable future through groundbreaking advancements and collaborative partnerships, positioning itself at the forefront of the 4th Industrial Revolution.

By embracing emerging technologies and focusing on customer-driven solutions, Premo aims to shape a world where innovation and efficiency are seamlessly integrated, enhancing lives and driving progress across all sectors.

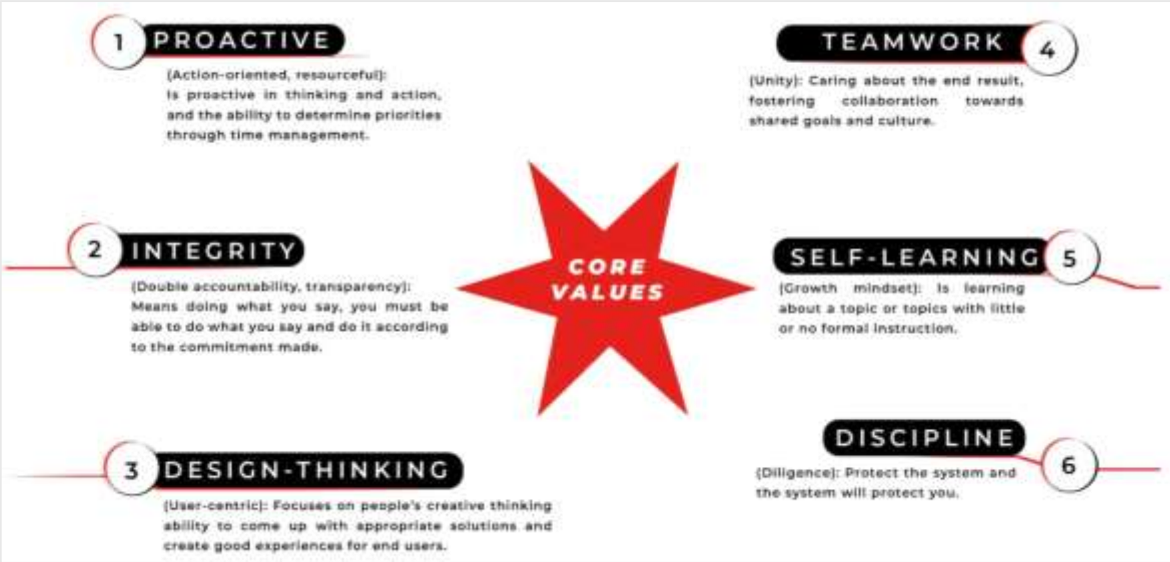



*Figure 1.3 Premo's Core Values*

## 1.3. Company Organizational Structure [1]


*Figure 1.4 Organizational structure chart of Premo Vietnam Co.,Ltd*

Andress Garcia is currently the director of Factory 1 at Premo Vietnam, leading the company's operations. Under his leadership are the main departments including: Finance Department, Human Resources (HR) Department, Purchasing Department, IT Department, Operations Department, Facility Department, Quality Assurance (QA) Department, Research and Development (R&D) Department, Business Development Department.

The Finance Department manages budgets, financial reporting and accounting, tracks cash flow, investments, and expenses, makes financial plans, and analyzes financial performance. The Human Resources Department is in charge of recruitment, training and development of employees, management of remuneration, benefits and policies, as well as building company culture and resolving HR issues. The Purchasing Department searches and selects suppliers, negotiates prices and contract terms, manages inventory, and ensures the supply of supplies. The IT department provides and maintains information technology systems, supports users and handles technical problems, and ensures network security and information security.

The Operations Department manages the production process and daily operations, optimizes performance and minimizes waste, ensuring compliance with regulations and standards. The Facilities Department manages and maintains the company's facilities, ensures safe and efficient working conditions, and plans construction or repair projects. The Quality Assurance Department inspects and ensures the quality of products/services, develops and maintains a quality management system, as well as handles complaints and improves processes. The Research and Development (R&D) department researches and develops new products/services, improves production processes and technologies, and analyzes market trends and customer needs. Finally, the Business Development Department seeks new business opportunities and market development, formulates marketing and product promotion strategies, and maintains relationships with customers and partners.

## 1.4. Introduction and technical specifications of the product under study

*Figure 1.5 E245 Short LF ANTENNA*

### *1.4.1. Structure*

The E245 Short LF ANTENNA consists of five main components, including the Housing, Coil Former, Ferrite Core, Wire, and Terminal. It operates as an inductor when connected to a connector at the connection end.

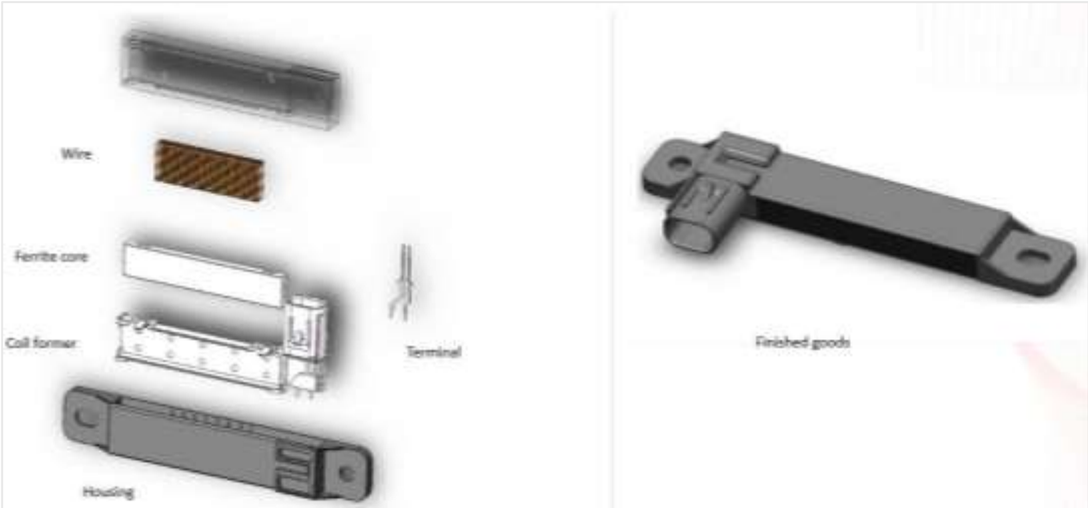



*Figure 1.6 E245 Short LF ANTENNA' s Structure*

Connector Spec: Design according to ENG_CD_1438198_A1 connector drawing. Male connector Tyco 1438198 (Keying option “A”)

Table 1.1 E245 Short LF ANTENNA' s connector

|  | Pin No. | Function definition | Signal type |
|---|---|---|---|
| | 1 | LF+ | Analog |
| | 2 | LF- | Analog |

### *1.4.2. Materials*

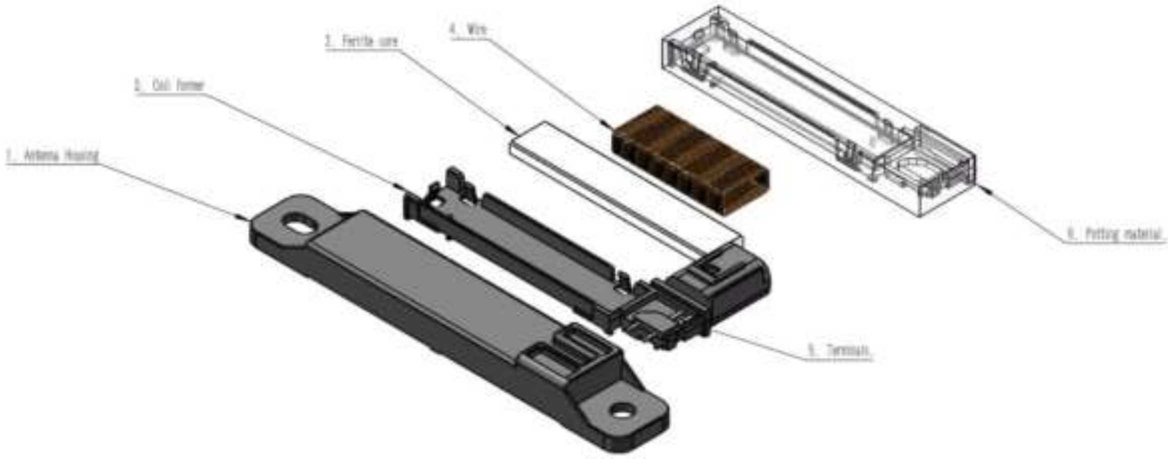


Table 1.2 E245 Short LF ANTENNA' s material structure

| Item | Part name | Descriptions |
|---|---|---|
| 1 | Antenna Housing | Material PBT GF20% |

| | | |
|---|---|---|
| 2 | Coil former | Material PBT GF20% |
| 3 | Ferrite core | Ferrite core MnZn 70×13×4 |
| 4 | Wire | Enamelled Cu wire Ø0.300/UEW/P180/UL |
| 5 | Terminals | – Base material: C–7025–H(TM–03)– Plating: Ni 2um–4um then Tin 4um–8um Bright plating |
| 6 | Potting | Black potting |

### *1.4.3. Electrical diagram*

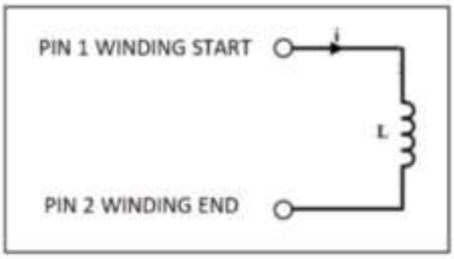



*Figure 1.7 E245 Short LF ANTENNA' s electrical diagram*

### *1.4.4. Technical Drawing of the Product*

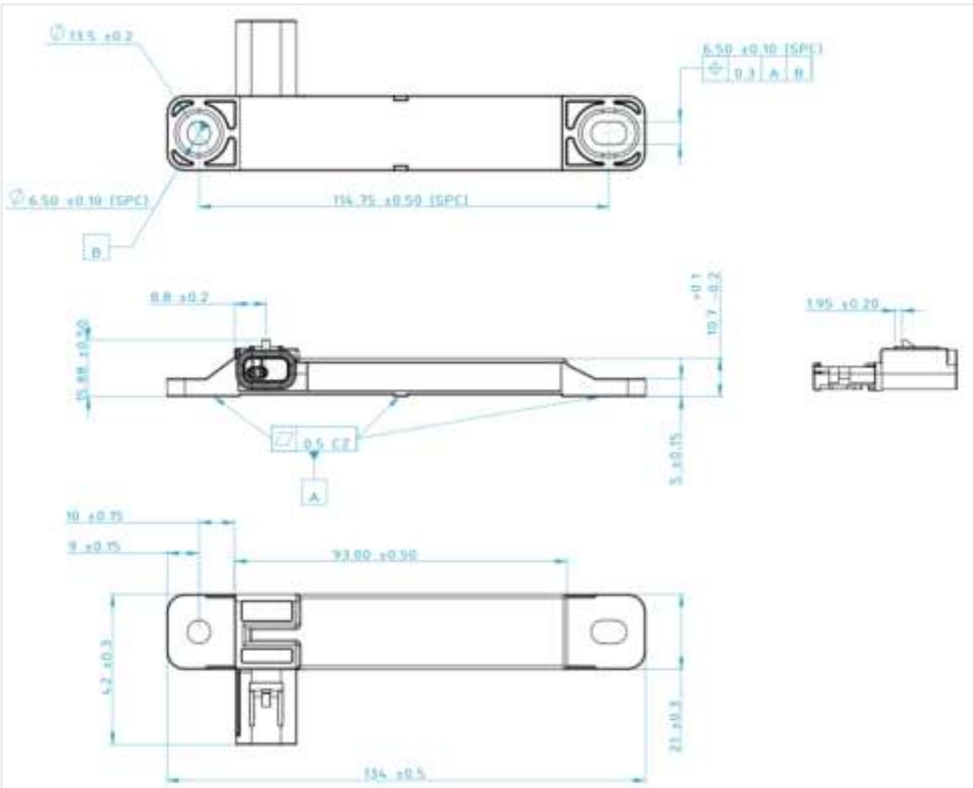


*Figure 1.8 E245 Short LF ANTENNA' s 2D drawing*

### *1.4.5. Technical Specifications*

Table 1.3 E245 Short LF ANTENNA' s technical specifications

| Parameters | Min | Typ. | Max | Symbol | Units | Remarks |
|---|---|---|---|---|---|---|
| **Operating Frequency** | | 125 | | Fo | kHz | |
| **Inductance** | 334.65 | 345 | 355.35 | L | µH | Measured 100% in EOL (ON FREE AIR) |
| **Inductance** | 324.3 | 345 | 365.7 | L | µH | Validation test in qualification |
| **DC Resistance** | | | 12 | Rdc | Ω | Measured 100% in EOL (ON FREE AIR) |
| **DC Resistance** | | | 12 | Rdc | Ω | Validation test in qualification |
| **Quality factor** | 100 | | | Q | | Validation test in qualification |
| **Quality factor** | 100 | | | Q | | |
| **Operating Current** | | | 2 | I | App | |
| **Operating Voltage** | | | 600 | | Vpp | |

### *1.4.6. Requirements*

- Gating, application separation and marks of ejector pins max 0.15 raised
- Burrs and form misalignment max 0.15
- Parts free of silicone, grease, oil
- Use of any mould release agents is not permitted
- Use of recycled material is not allowed
- Every change in process and design must be indicated and released by Continental
- Parts free from Asbestos, lead, PVC, PCB, Cadmium, halogens and heavy metals
- Missing dimensions must be taken from 3D-model
- Missing radii<0.5 unless in 3d-model or otherwise specified

- Material information needs to be entered in IMDS and submitted with PPAP
- Cleanliness requirement: Class 1 = 40mg/1000cm² / max length of metallic particle 1000 µm
- Laser marking

### *1.4.7. Production process*

To produce the E245 Short LF ANTENNA, the manufacturing process consists of nine consecutive stages. The first two stages are carried out separately on molding machines, while the remaining seven stages are performed directly on the ANPOT01 production line to ensure that the final product meets strict quality, dimensional, and technical specifications, the production line must always be maintained in optimal condition, with continuous inspections and maintenance to prevent potential disruptions.


*Figure 1.9 The production process of the E245 Short LF ANTENNA*

Stage 1: Ferrite Core Sintering

In stage 1, workers supervise and operate the molding machine to produce Coil Formers according to the specified dimensions, ensuring precise assembly with the Ferrite core.

*Figure 1.10 Injection Coil former machine*

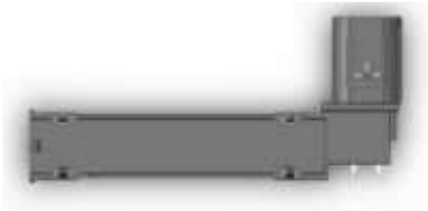


*Figure 1.11 The output product of stage 1*

Stage 2: Housing Molding

*Figure 1.12 Injection housing machine*

In stage 2, workers similarly supervise and operate the molding machine to produce Housings according to the specified dimensions, ensuring proper assembly.

*Figure 1.13 The output product of stage 2*

Stage 3: Assembly Ferrite core and coil former

*Figure 1.14 Assembly  Machine*

In stage 3, workers place the trays of Ferrite cores and Coil Formers in the correct positions for the machine to perform the assembly process, inserting the Ferrite core into the Coil Former. During this stage, the assembly is checked using an infrared sensor to ensure that the Ferrite core fits precisely into the Coil Former.

*Figure 1.15 The output product of stage 3*

Stage 4: Winding

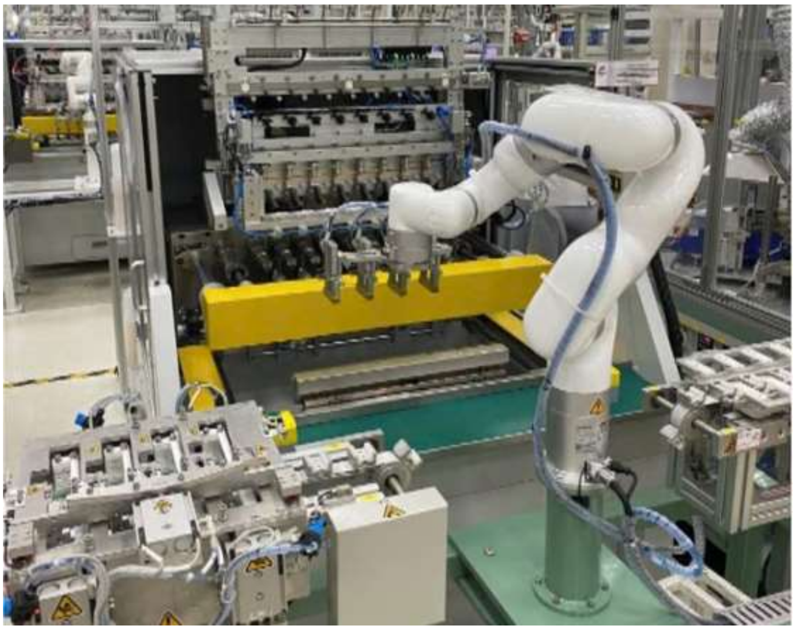


*Figure 1.16 Winding Machine*

In stage 4, the robotic arm sequentially picks up four products and places them into the winding machine cavities to perform wire winding according to the pre-set parameters.

*Figure 1.17 The output product of stage 4*

Stage 5: Soldering

*Figure 1.18 Soldering Machine*

In stage 5, the products are placed into each cavity and sequentially pass through different stations for flux application, soldering, electrical testing, and AI-based solder joint inspection.

*Figure 1.19 The output product of stage 5*

Stage 6: Assembly Ferrite core and Antenna Housing

In stage 6, workers position the housing correctly for assembly with the product from stage 5. After assembly, the product is inspected for the height of the inserted steel core using an infrared sensor and then classified accordingly

*Figure 1.20 Assembly machine*

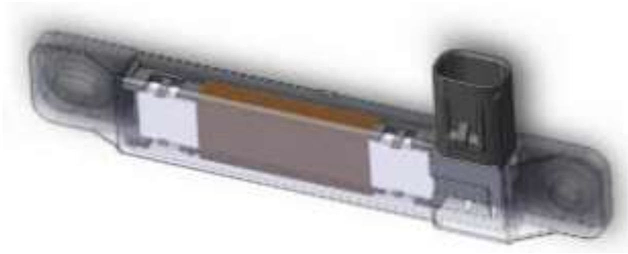


*Figure 1.21 The output product of stage 6*

Stage 7: Potting

*Figure 1.22 Vacuum potting machine*

In stage 7, the product from stage 6 undergoes vacuum processing and adhesive dispensing.

*Figure 1.23 The output product of stage 7*

Stage 8: Curing

*Figure 1.24 Curing Machine*

In stage 8, the drying machine is set with appropriate parameters to cure the adhesive.

*Figure 1.25 The output product of stage 8*

Stage 9: Final test – Packing

In stage 9, the product undergoes a final inspection, including electrical parameters, connector fitting accuracy, and adhesive bonding verification using AI. After passing the inspection, the product is packaged

*Figure 1.26 Final test machine*

*Figure 1.27 The output product of stage 9*

## 1.5. Potting machine – Improvement project

*Figure 1.28 Vacuum Potting Machine*

### *1.5.1. Structure*

The vacuum potting machine consists of the following components: the material feeding conveyor system, the vacuum chamber, the adhesive dispensing and mixing system, the output conveyor, and the three-axis robot for adhesive dispensing.

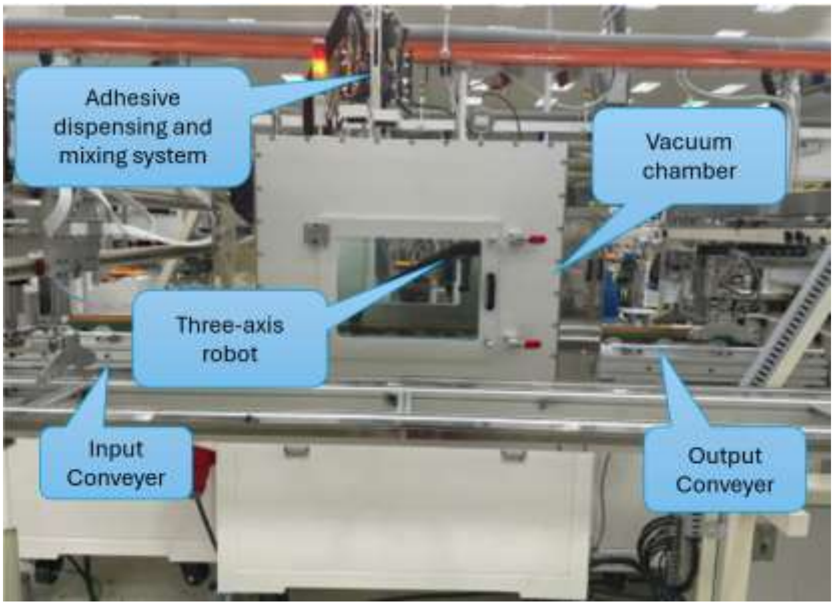



*Figure 1.29 Potting machine's structure*

*Figure 1.30 Input conveyer*

*Figure 1.31 Output conveyer*

*Figure 1.32 Three-axis Robot and vacuum chamber*

*Figure 1.33 Adhesive dispensing and mixing system*

### 1.5.2. Operating principle

After the robot successfully picks up 36 products and places them on the tray in the previous cycle, the vacuum chamber door opens. The input conveyor is activated to transport the product tray into the vacuum chamber. Once the product tray reaches the correct position, the conveyor stops, the vacuum chamber door closes, preparing for the potting process. The vacuum pump starts, removing air from the chamber according to a predefined sequence, the adhesive dispensing valve opens, initiating the potting process. After the adhesive dispensing is complete, the vacuum chamber door opens, the output conveyor is activated to transport the finished product tray to the next stage in the workflow

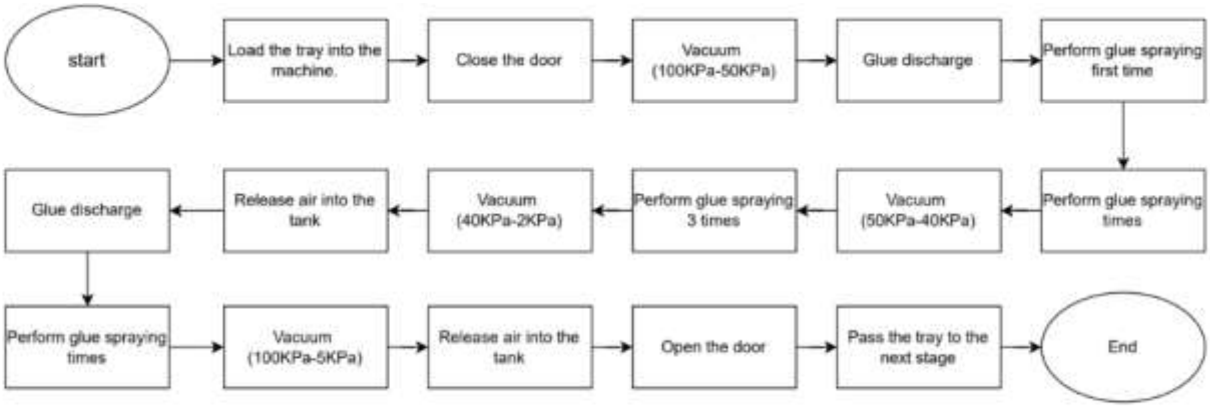



*Figure 1.34 Potting machine's operation workflow*

### *1.5.3. Output Product Requirement*

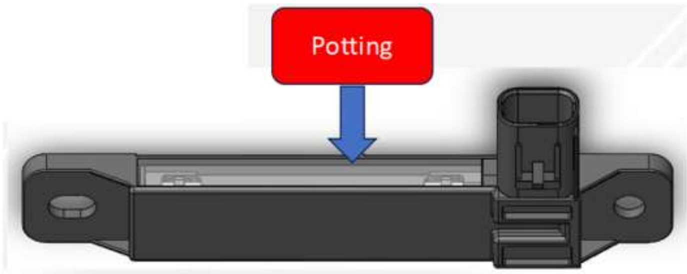



*Figure 1.35 The output product of Potting machine*

The final product must meet the following quality standards:

- The adhesive must be dispensed with an exact mass of $7.2 \pm 0.3$g
- The adhesive must be contained within the assembly area of the casing and ferrite core.
- No deep dents, no rough surface.
- No adhesive should overflow or spread onto the assembly surface, as this could interfere with the product's integration with the customer’s equipment.
- The adhesive must be evenly distributed across the entire product surface.
- The adhesive must be free from air bubbles to ensure product integrity and performance.

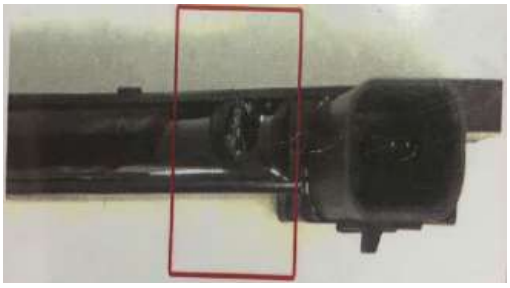
*a) Acceptable product*

- Parts with potting spillage in head and tail of top surface are acceptable

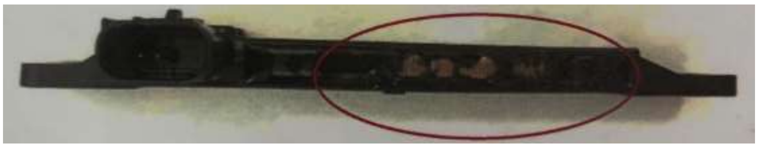
- Parts have bubbles of les than 3 points, each point is less than 1mm, which is acceptable

*b) NG product*

- Potting bubbles on the surface

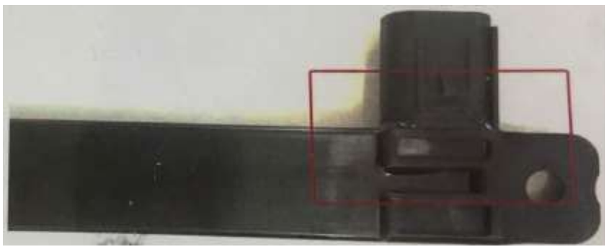


- Missing potting



- The potting surface is rough

- Overflow potting at connector location



- Potting overflow

- Deep concave on potting surface

### *1.5.4. Improvement project*

*a) Current status of the machine*

Currently, the machine operates stably; however, several limitations remain:

- The potting time is approximately 10 seconds per product.
- The A:B adhesive ratio and the actual adhesive flow rate are not accurately monitored in real time.
- The vacuuming process accounts for a significant portion of the total potting time, leading to an overall prolonged potting duration.
- The adhesive dispensing cycle and initial parameter settings are not yet optimized for the machine’s operational efficiency.
- After dispensing, adhesive residue adheres to the tool, making cleaning difficult and resulting in cumulative errors.

*Figure 1.36 Glue sticking on the tool*

*b) Objective of the project*

The objective of this study is to analyze the operational efficiency of the current vacuum potting machine process, identify existing limitations and issues, and develop strategies for improvement.

This includes the integration of advanced industrial equipment and the optimization of the machine's operational capabilities, with the ultimate goal of reducing the adhesive dispensing time from the current 10s/unit to 7.5s/unit.

By optimizing the potting process, the overall efficiency of the production line can be significantly improved, minimizing disruptions to subsequent production stages.

*c) Scope of the Study*

- Target Machine: The Vacuum Potting Machine currently used in the production process.
- Main Function: Dispensing adhesive into the product (including the core and casing) and using a vacuum pump to remove air bubbles, ensuring product quality.
- Research Constraints: The study focuses on improving the machine rather than a complete redesign. Testing is limited to real factory conditions. The system will only use components and technologies compatible with the existing platform.

*d) Improvement method*

Based on the analysis of the current system, the study focuses on improving **three main aspects** of the machine:

(1) Mechanical System Improvement:
- Improve the adhesive pump mechanism to ensure more precise dispensing.
- Optimize the vacuum chamber to enhance air removal efficiency.

(2) Electrical System Improvement:
- Enhance measurement accuracy and improve monitoring processes.
- Integrate a monitoring interface (HMI) for real-time sensor status tracking.

(3) Software and Control System Improvement:
- Increase processing speed, improve accuracy, and optimize process control.
- Improve logic control for the adhesive pump and vacuum system.
- Investigating and establishing input parameters to optimize the machine's operational process

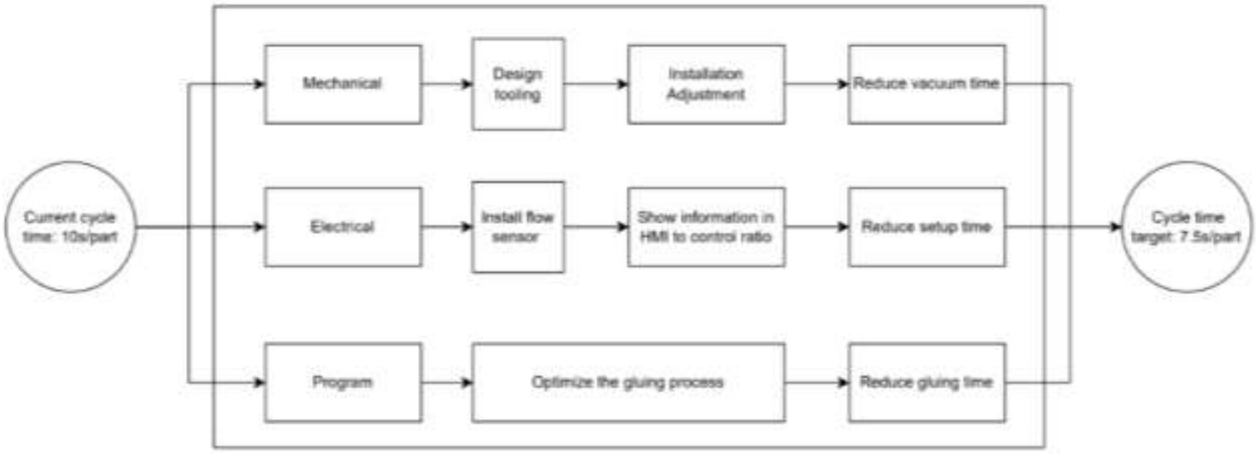



*Figure 1.37 Improvement methods*

# Chapter 2: MECHANICAL DESIGN IMPROVEMENT

## 2.1. Tool Design for Potting Machine

### 2.1.1. Original design

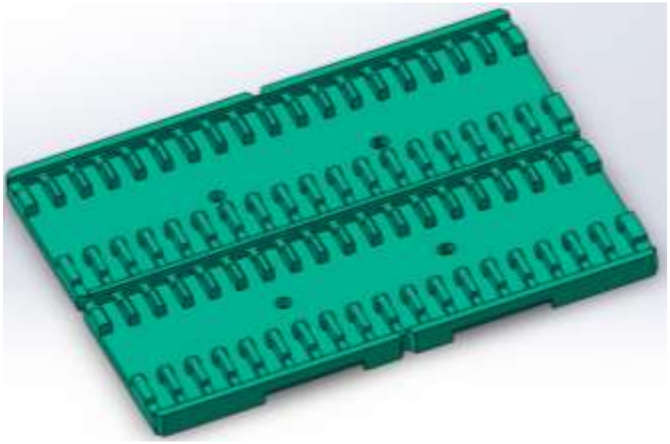


*Figure 2.1 Initial Design Approach*

With the initial design, the potting machine operates relatively stably; however, some issues still occur:

- The design has not yet optimized material usage
- When excess glue overflows, it becomes very difficult to clean the tray
- Errors occur when glue sticks to the tool, causing the robot to misplace and misalign products on the tray.

### *2.1.2. Improved Solution*

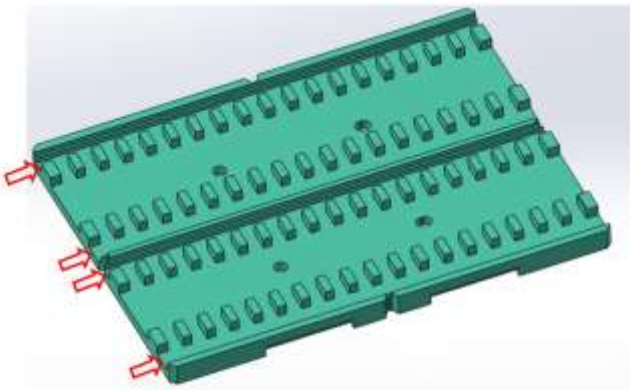


*Figure 2.2 Angle Adjustment Approach*

By milling the positions marked to be flush with the surface, the tool will have fewer corners where glue can accumulate, making the tool simpler and easier to clean. However, removing the raised parts makes it more difficult to determine the correct orientation of the part, which can lead to confusion. Additionally, during the tray movement process, glue may overflow onto the surface, and the excess glue can still stick to the product, affecting its aesthetic quality.

### *2.1.3. Optimal Solution*

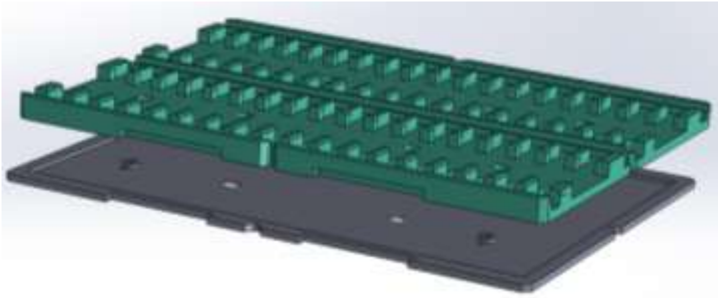


*Figure 2.3 Optimized Approach*

To solve the issue of excess glue sticking to the product and misalignment from the groove, the team proposed milling through-slots on the surface of the tool(*). This solution allows excess glue to flow down without sticking to the product, while also reducing the contact surface with the product's curved sides. As a result, it helps minimize product misalignment during tray transfer.

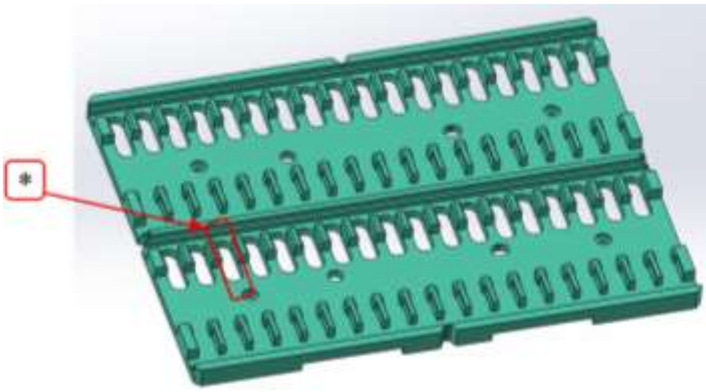



*Figure 2.4 Upper Section of the Tray*

Next, a protective layer is added to prevent the glue from spreading and contacting other surfaces of the machine, making the cleaning process easier. The layer can simply be removed to clean any areas where glue has accumulated.

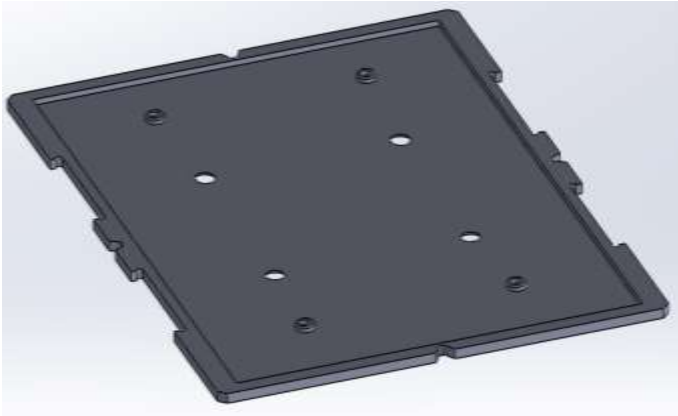


*Figure 2.5 Under Section of the Tray*

This design solution addresses most of the issues related to fixture placement and cleaning. Additionally, it ensures compliance with all size and weight requirements of the tray.

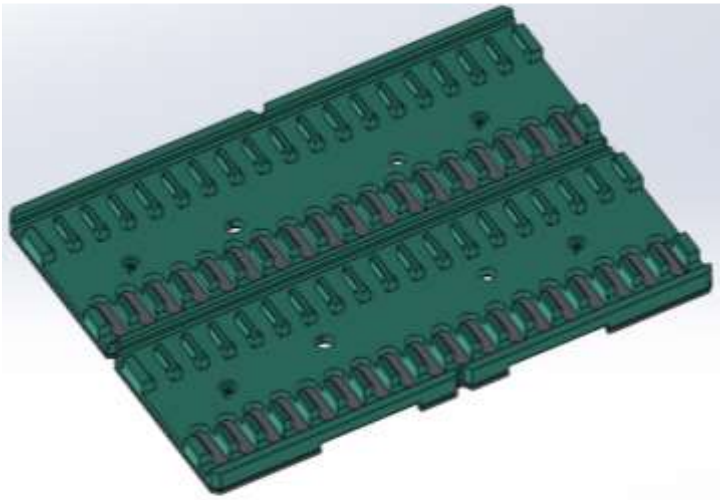


*Figure 2.6  Tray assembly*

## 2.2. Optimization of Vacuum Chamber Volume

### *2.2.1. Calculate Vacuum Chamber Volume*

When using a vacuum pump to reduce the pressure in a chamber, the amount of gas in the chamber changes over time. This process can be described by the gas mass balance equation, based on the ideal gas law and the principle of gas flow out of the chamber.

*a) The ideal gas law applied to the vacuum pumping process.*

The air in the chamber is considered an ideal gas, following the equation of state:

$$PV = nRT \tag{2.1}$$

Where:

- $P$ = Pressure in the chamber (Pa or mbar)
- $V$ = Volume of the chamber ($m^3$)
- $n$ = Number of moles of gas in the chamber (mol)
- $R$ = Ideal gas constant ( $R \approx 8.314$ J/mol·K)
- $T$ = Gas temperature (K)

When the pump extracts gas, the amount of gas in the chamber gradually decreases, reducing the pressure from *P1* to *P2* over a period of time *t*.

*b) Gas suction flow rate of the vacuum pump.*

The vacuum pump has a pumping speed $Q$ ($m^3$/h), which is the volume of gas the pump can remove per unit of time. The flow rate of gas leaving the chamber is expressed as:

$$\frac{dV_g}{dt} = Q \tag{2.2}$$

Where:

- $Vg$ is the volume of gas in the chamber at a given moment.
- $Q$ is the pumping rate ($m^3$/h).

*c) Establish the differential equation describing the pressure change.*

The number of moles of gas in the chamber can be expressed using the ideal gas equation:

$$n = \frac{PV}{RT} \tag{2.3}$$

When gas is pumped out, the amount of gas in the chamber decreases over time:

$$\frac{d(PV)}{dt} = -QP_{atm} \tag{2.4}$$

Since the volume $V$ is constant, we have:

$$V\frac{dP}{dt} = -QP_{atm}$$

Divide both sides by *V:*

$$\frac{dP}{dt} = -\frac{Q}{V} P_{atm} \tag{2.5}$$

This is the differential equation describing the pressure change during the vacuum pumping process.

*d) Solve the equation to find the volume V*

Solve the differential equation:

$$\int_{P1}^{P2} \frac{dP}{P} = -\frac{Q}{V} \int_{0}^{t} dt$$

$$\ln \frac{P_2}{P_1} = -\frac{Q}{V} t$$

Take the absolute value to rearrange in order to find *V*.

$$V = \frac{Q.t}{\ln(\frac{P_1}{P_2})} \tag{2.6}$$

*e) Physical meaning of the equation*

- The volume *V* depends on the pumping rate *Q* and the pumping time ***t*.**
- The logarithmic function represents the nonlinear rate of pressure decrease: as the pressure approaches the limit, the pumping rate slows down because the number of gas molecules left in the chamber decreases.
- The assumption of no leakage: if the chamber is not perfectly sealed, some gas may leak in, affecting the calculation results.

Table 2.1 Calculation results of the vacuum chamber volume

| ***No.*** | ***P1 (kPa)*** | ***P2 (kPa)*** | ***t (s)*** | ***V (l)*** |
|---|---|---|---|---|
| 1 | 55.38 | 34.87 | 2.62 | 393.29 |
| 2 | 43.23 | 1.62 | 18.53 | 391.80 |
| 3 | 101.3 | 46.39 | 4.45 | 395.66 |
| 4 | 54.78 | 35.89 | 2.38 | 390.83 |
| 5 | 44.32 | 1.71 | 18.49 | 394.46 |

| | | | | |
|---|---|---|---|---|
| 6 | 101.3 | 4.88 | 17.07 | 390.82 |
| 7 | 101.3 | 45.19 | 4.61 | 396.57 |
| 8 | 57.62 | 32.72 | 3.21 | 393.90 |
| 9 | 101.3 | 4.79 | 17.35 | 394.81 |
| 10 | 101.3 | 44.68 | 4.67 | 396.16 |
| 11 | 101.3 | 4.09 | 18.17 | 393.12 |
| 12 | 40.07 | 1.65 | 18.1 | 394.02 |
| 13 | 52.4 | 29.36 | 3.32 | 397.98 |
| 14 | 101.3 | 4.67 | 17.54 | 395.84 |
| 15 | 40.16 | 1.63 | 18.21 | 394.63 |
| 16 | 52.85 | 34.37 | 2.44 | 393.78 |
| 17 | 101.3 | 4.06 | 18.31 | 395.24 |
| 18 | 101.3 | 4.24 | 17.9 | 391.67 |
| 19 | 101.3 | 4.09 | 18.3 | 395.93 |
| V_avg*(l)* | | 394.24 | | |

The vacuum pump has a suction capacity of $S$ = 250 $m^3/h$, equivalent to 69.44 liters per second. The atmospheric pressure is 101.3 kPa. The maximum vacuum pressure achieved by the system is $8 \times 10^{-2}$ mbar, which is equal to 8 Pa or $8 \times 10^{-3}$ kPa.Through the process of measurement and calculation, and assuming that the potting machine system is completely sealed with no gas leakage occurring during operation, we obtained the data as presented in the table above. Based on these results, the estimated average volume of the machine chamber is approximately 395 (*l*).

### 2.2.2. Encountered Issues & Solutions

Reducing the vacuum time in the vacuum chamber helps increase product output, so it is necessary to optimize the chamber's volume.

*Figure 2.7 Vacuum Chamber*

Noticing that the vacuum time of the chamber was relatively long, the team proposed adding blocks to reduce the internal volume. This speeds up the vacuum process, reducing vacuum time and ultimately increasing the machine's productivity.

Through inspection, it was found that there were still empty spaces inside the vacuum chamber. The team utilized these spaces by adding fixtures inside to further reduce the volume.

,

*Figure 2.8 Remaining Empty Spaces Inside the Vacuum Chamber*

After a period of direct observation and thorough study of the three-axis robot's movement path inside the Potting machine, the team carried out careful measurements, analysis, and calculations. As a result, the team identified three locations within the machine's working space where there is no interference with the robot's movement or other functional components. These are unused empty spaces that are not affected by the machine's operations.

Based on the survey and calculations, the team concluded that these three empty spaces can be effectively utilized by placing hollow blocks inside them. The purpose of inserting these hollow blocks is to optimize the internal volume of the machine, thereby reducing the total volume required for the chamber. This contributes to shortening the vacuuming time of the machine.

These proposals were made after ensuring that placing the hollow blocks in these positions does not affect the stable, precise, and safe operation of the robot or the entire Potting machine system during its operation.

Two installation solutions were proposed.

- **Solution 1**: The inserted blocks are made of sealed steel plates and are fixed to the chamber walls by screwing them into the machine's inner walls. However, this solution is quite difficult to implement because drilling and tapping into the chamber walls is challenging and may affect the chamber's functionality.
- **Solution 2**: The blocks are made of POM material and are fixed using adhesive. This solution is relatively simple, easy to implement, and does not cause any damage to the machine's interior.

Due to the high cost of using POM material, the team decided to switch to steel and adopt a stamping process to form a hollow block, which is then sealed by welding to prevent air leakage and ensure efficiency during the vacuum process. This solution also helps reduce the internal volume of the potting machine.

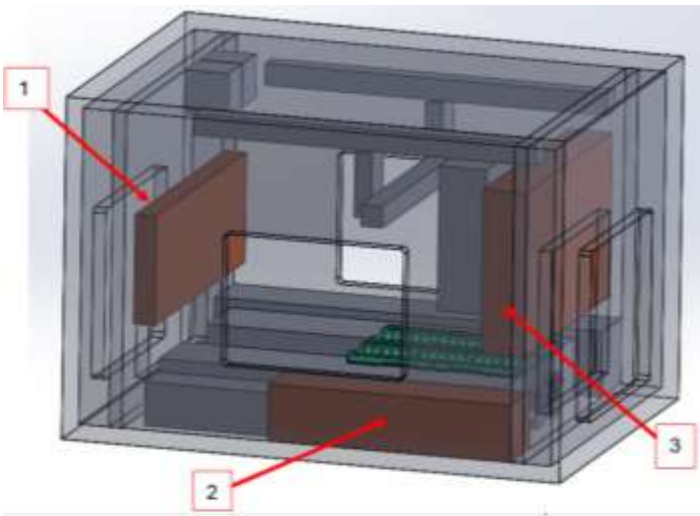



*Figure 2.9 Fixture Installation Approach*

Position (1): The block is placed near the outlet of the welding tool

*Figure 2.10 Block 1 placement position*

Using steel and applying a stamping process to form a hollow block that is hermetically sealed to prevent any air from entering.

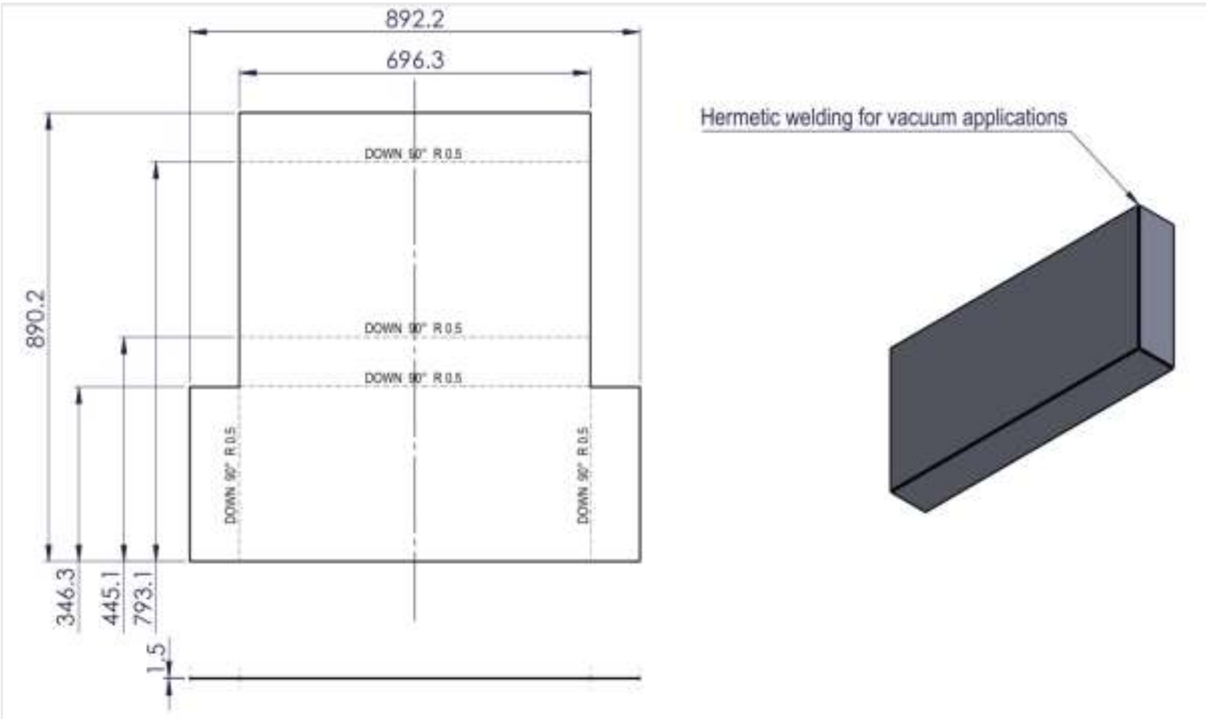



*Figure 2.11 Block 1's Drawing*

Position (2): The empty space underneath the potting machine

*Figure 2.12 Block 2 placement position*

Using steel and applying a stamping process to form a hollow block that is hermetically sealed to prevent any air from entering.

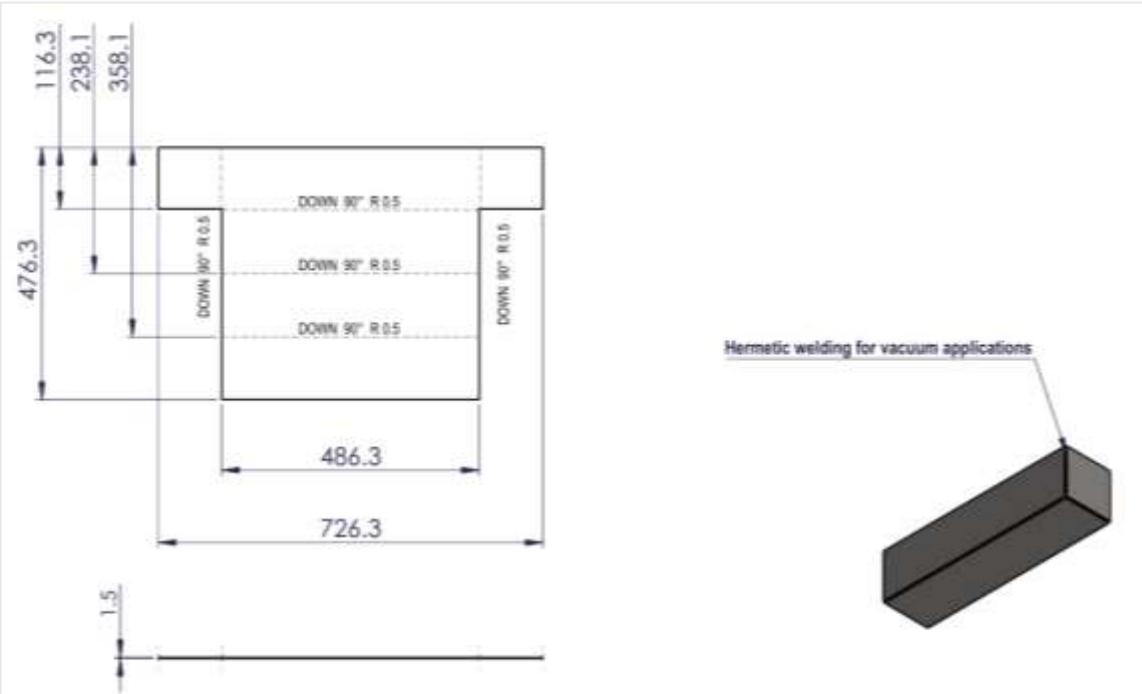



*Figure 2.13 Block 2's Drawing*

Position (3): The inlet position of the potting machine.

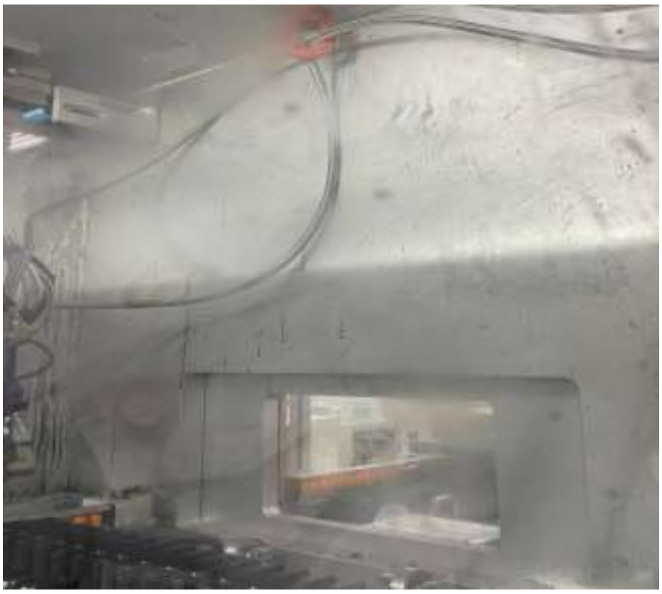


*Figure 2.14 Block 3 placement position*

Using steel and applying a stamping process to form a hollow block that is hermetically sealed to prevent any air from entering.

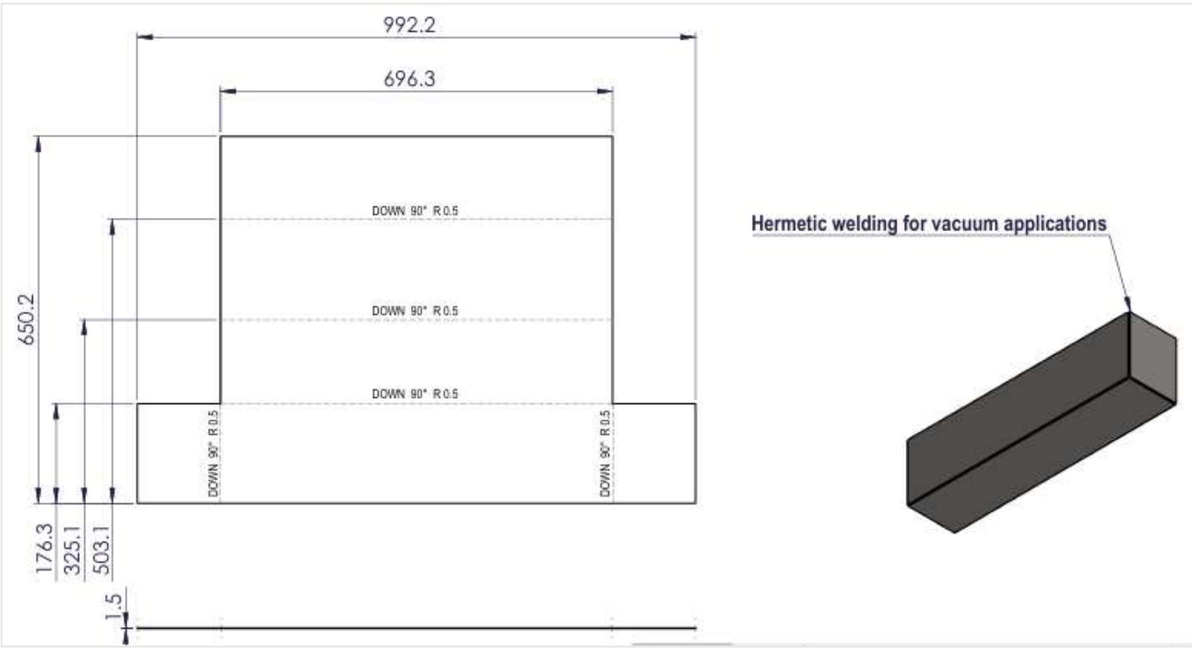



*Figure 2.15 Block 3's Drawing*

### *2.2.3. Analysis Results*

Volume of the objects placed inside the potting machine:

- Block 1: 100mm × 350mm × 700mm = 24.500.000 mm³ = 24,5 *l*
- Block 2: 120mm × 120mm × 490mm = 7.056.000 mm³ = 7,056 *l*
- Block 3: 150mm × 120mm × 700mm = 12.600.000 mm³ = 12,6 *l*

- Total volume occupied by the three blocks:
  Blocks volume = 24,5 + 7,056 + 12,6 = 44,156 *l*
- Initial internal volume of the potting machine: 394,24 *l*
- After placing the blocks inside:
  Remaining volume = 394,24 – 44,156 = 350,084 *l*

**Vacuum time calculation**

At stage 5 of the vacuum process, the initial parameters were recorded as follows:

| No. | *P1* (kPa) | *P2* (kPa) | *t* (s) | *V* (l) |
|---|---|---|---|---|
| 5 | 44.32 | 1.71 | 18.49 | 394.46 |

Applying the formula for determining volume during the vacuum process:

$$V = \frac{S.t}{\ln(\frac{P_1}{P_2})}$$

Which leads to:

$$t = \frac{V.\ln(\frac{P_1}{P_2})}{s} \qquad (2.7)$$

Keeping the vacuum speed S and the pressures $P_1$ = 44.32 kPa, $P_2$ = 1.71 kPa constant, and substituting *V*=350.084 liters, the new vacuum time is calculated as: $t \approx$ 16.44 seconds.

Compared to the initial vacuum time of 18.49 seconds, the time after volume reduction is only 16.44 seconds, which is approximately 2.05 seconds shorter. If we calculate specifically, this time reduction is equivalent to 11,09%.

This indicates that the performance has improved by approximately 11.09% in each cycle compared to the initial state. With the method of reducing the volume inside the potting machine, if the issue of air leakage during vacuum suction can be resolved, the machine's performance will be significantly enhanced. This not only helps reduce the cycle time but also improves stability and accuracy in the production process, thereby contributing to increased overall productivity and reduced energy consumption for the entire system.

### 2.3. Design solution for a three-branch adhesive dispensing tool

*Figure 2.16 Two adhesive dispensing heads inside the potting machine*

Inside the potting machine, two adhesive dispensing heads are installed to distribute glue into the products placed on the tray. Through on-site observations, the team found that during each operation cycle, the two nozzles can only dispense glue into two products simultaneously. This means that in every cycle, the machine can only process a very limited number of items compared to the total number on the tray. As a result, the time required to complete glue dispensing for the entire tray is quite long, negatively affecting the overall efficiency and speed of the production line. This presents a potential bottleneck that should be addressed to optimize productivity and reduce waiting time in the potting process.

*Figure 2.17 Adhesive dispensing nozzle*

Through research and analysis of the current system, the team proposed an improvement to the adhesive dispensing system by splitting each dispensing head from one nozzle into three nozzles. With this enhancement, instead of just two nozzles as in the original setup, the system will have a total of six dispensing nozzles, enabling simultaneous glue application for six products in a single operating cycle. As a result, the dispensing process is significantly accelerated, reducing the time required to complete one tray of products. This not only shortens the operating time of the potting machine but also contributes to improving overall production efficiency.

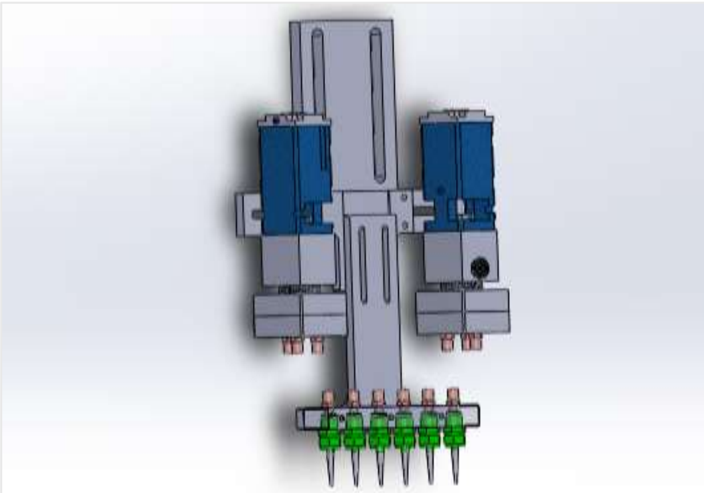


*Figure 2.18 Solution for splitting into six adhesive dispensing nozzles*

Three-way adhesive distributor connected to the pump head.

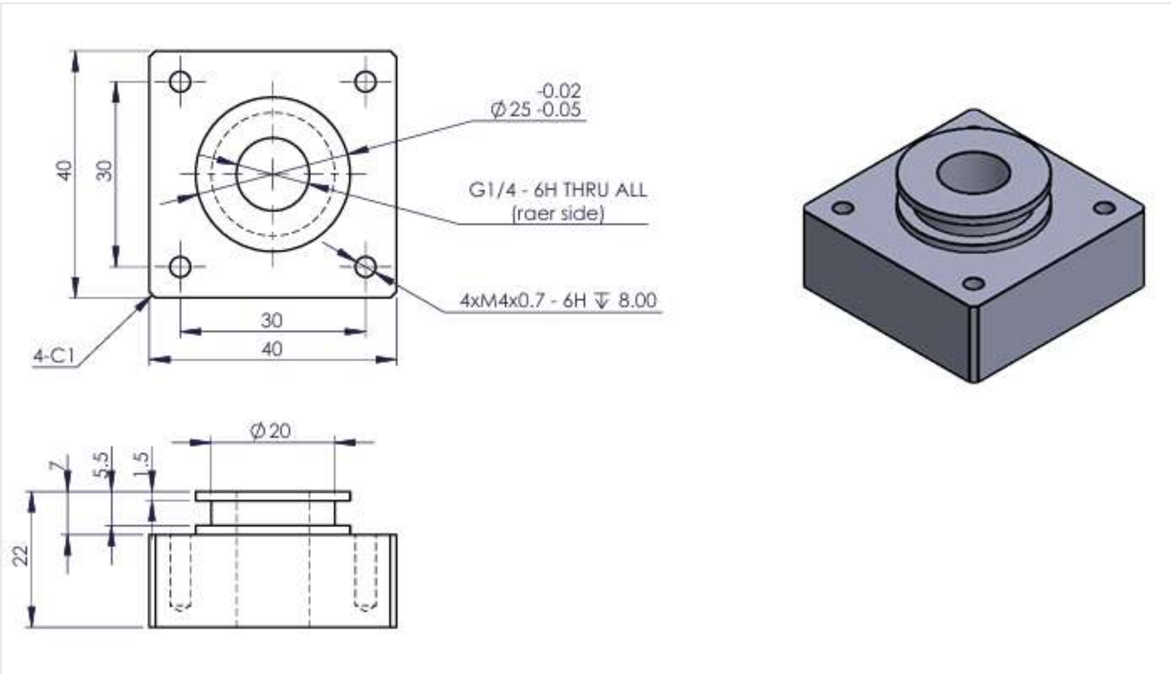



*Figure 2.19 Tool for installing the nozzle splitter 1*

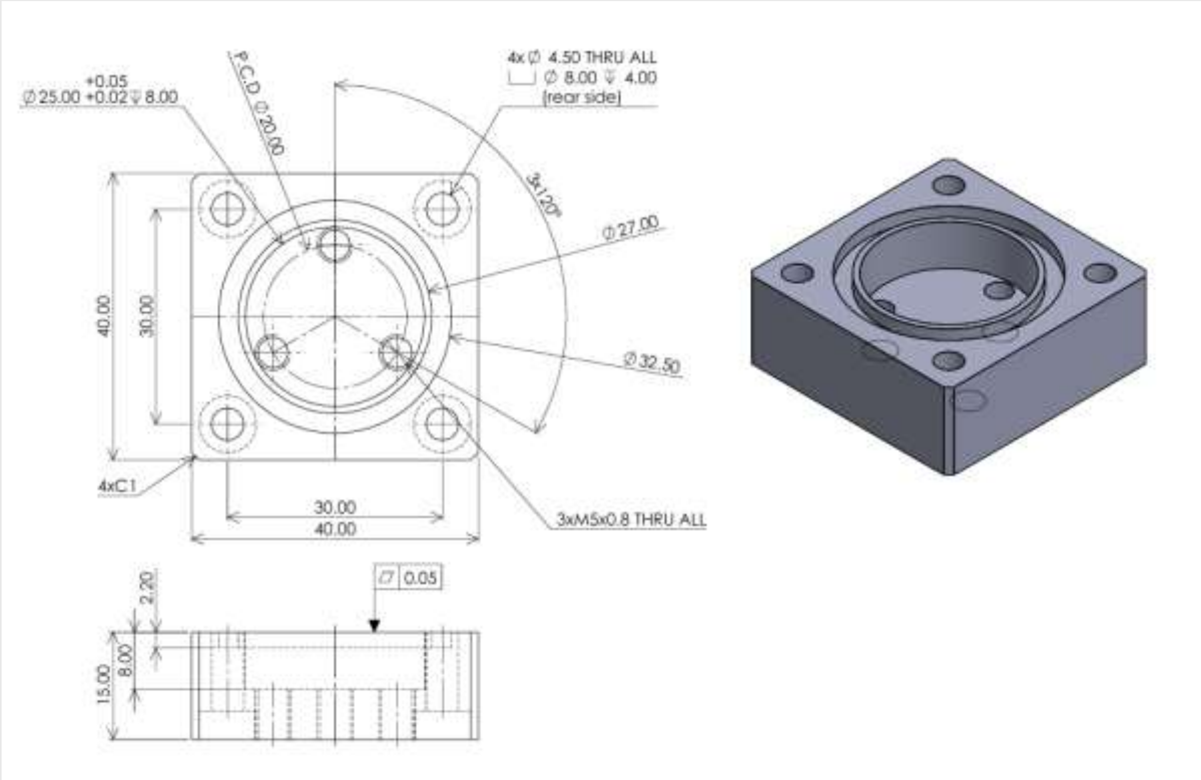



*Figure 2.20 Tool for installing the nozzle splitter 2*

Mounting tool for the dispensing splitter.

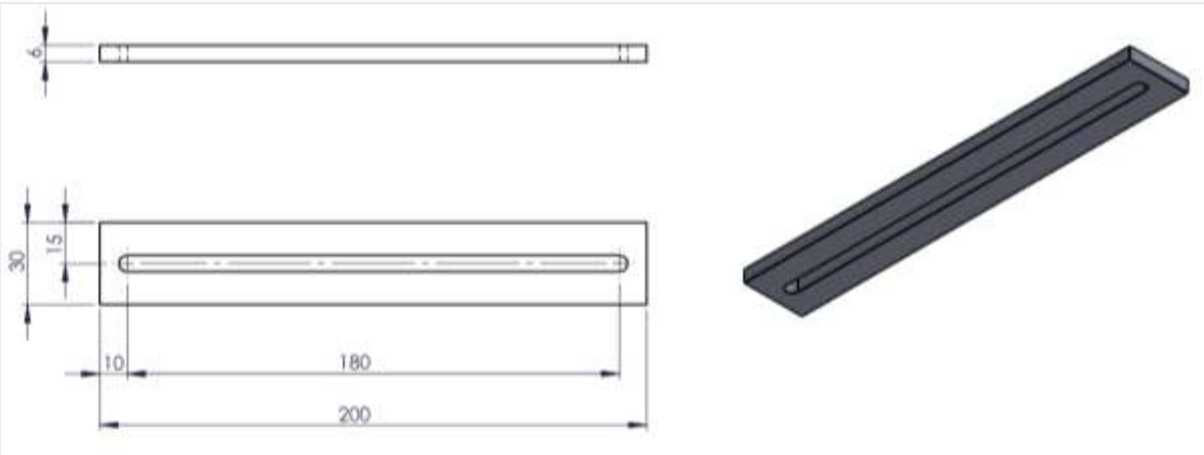



*Figure 2.21 Tool 1*

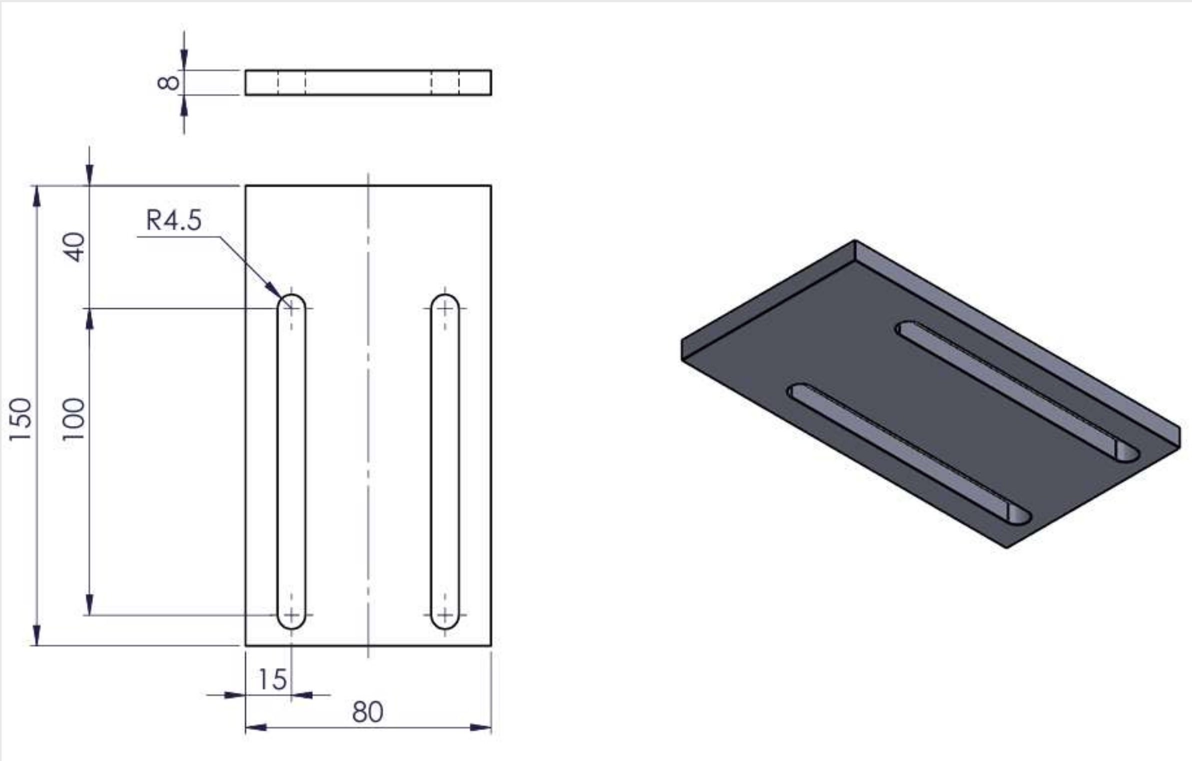



Figure 2.22 Tool 2

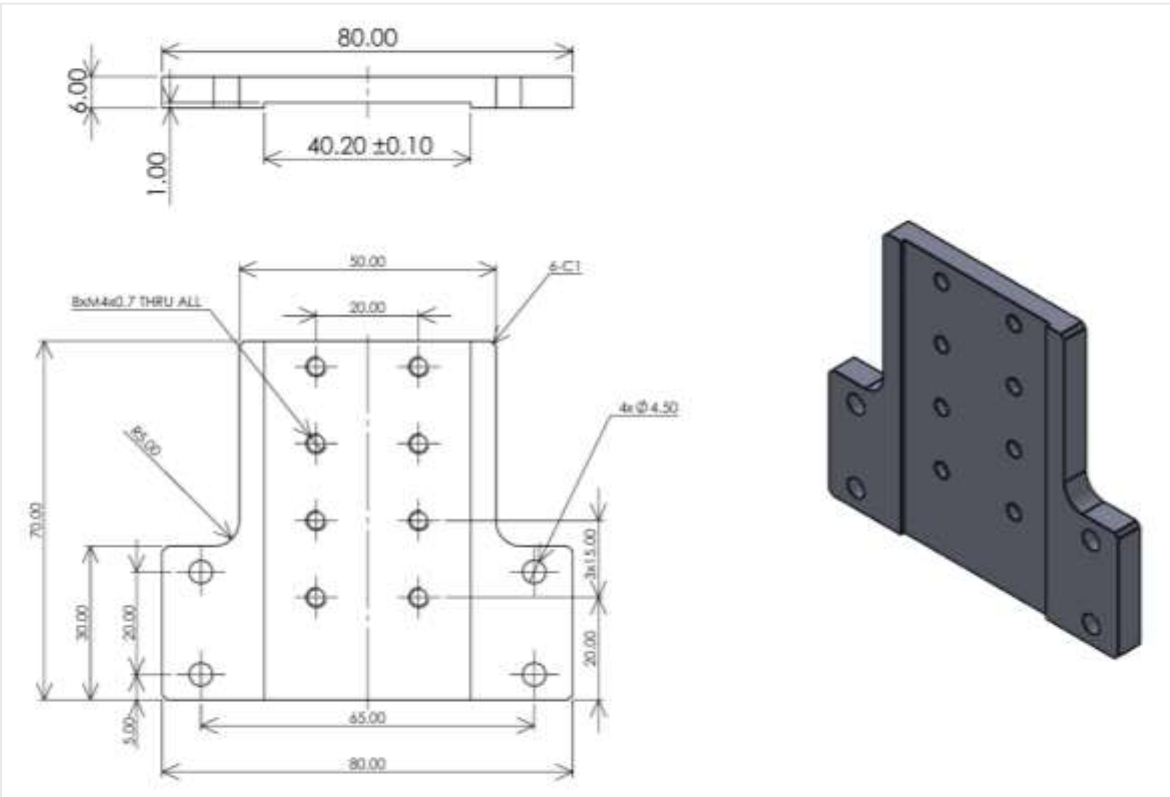



Figure 2.23 Tool 3

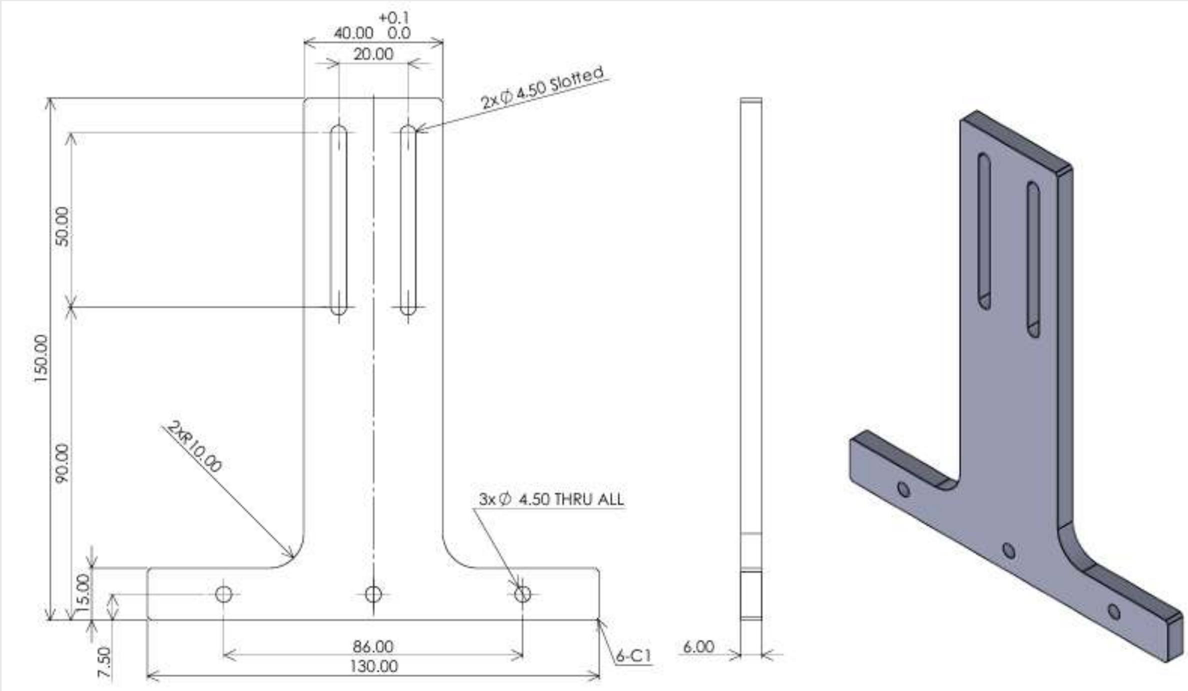



*Figure 2.24 Tool 4*

Mechanical fixtures for the assembly and branching of glue nozzles

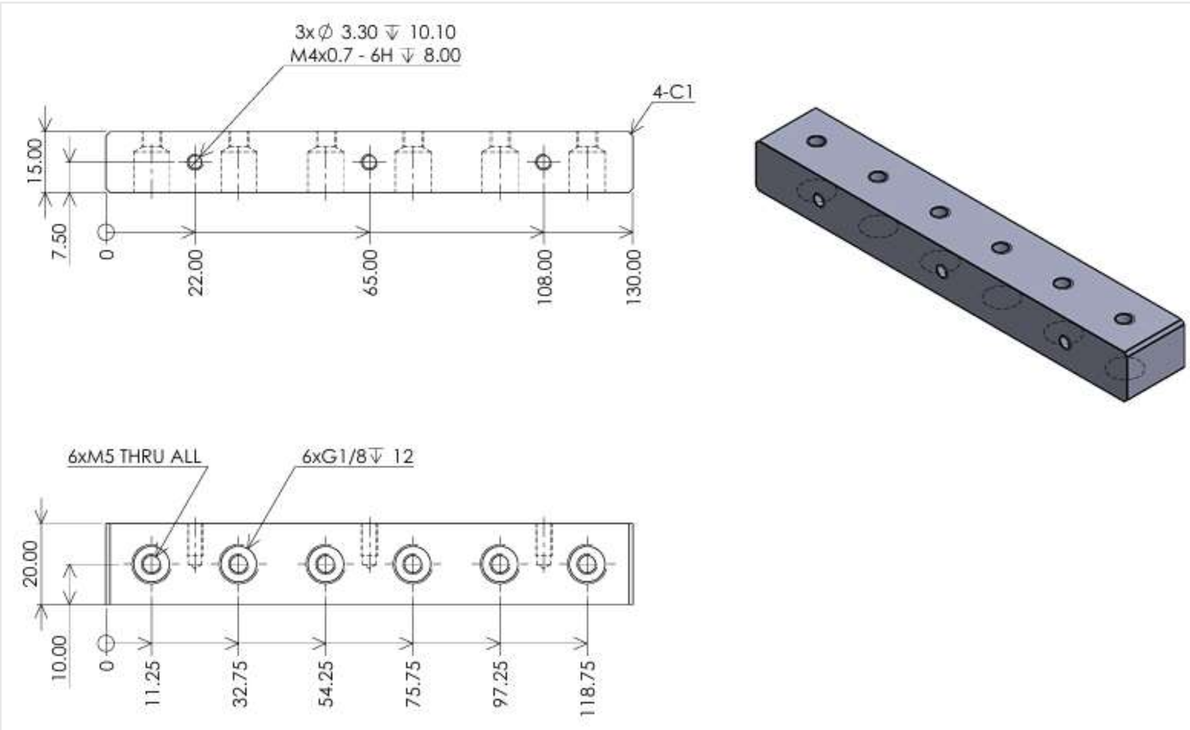



*Figure 2.25 Tool for nozzle connection splitter*

Post-machining installation results into the machine

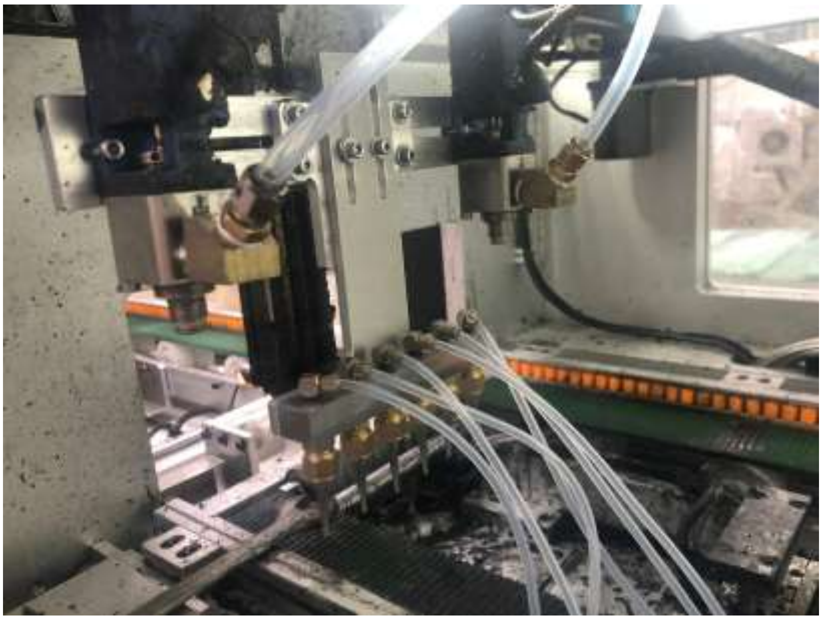


*Figure 2.26 Install the glue splitter*

The initial test results of this solution show relatively high stability:

- The amount of glue is evenly distributed across all 6 dispensing heads, nearly identical.
- The glue is dispensed continuously without any interruptions.
- The glue dispensing process does not affect the movement of the 3-axis robot.
- However, during the vacuum suction process, excess glue dripping occurs and cannot be fully controlled yet.

*Figure 2.27 Overall view of the adhesive dispensing head tool system after installation*

# Chapter 3: ELECTRICAL DESIGN IMPROVEMENT

## 3.1. Proposed Electrical System Improvements

As evaluated in section 1.5.4, the current electrical system of the machine is operating stably; however, the monitoring of adhesive flow rate, volume, and the A/B mixing ratio has not yet been practically controlled or supervised. Therefore, a dedicated sensor system is proposed, consisting of the following devices:

Table 3.1 List of Electrical devices and modules

| No. | Device Name - Quantity | Model | Specifications | Function |
|---|---|---|---|---|
| 1 | Main PLC Controller (1) | Siemens S7 – 1200 | CPU 1212C DC/DC/DC, Ethernet support, expandable I/O | Controls the entire automated process |
| 2 | Analog Input Expansion Module (1) | Siemens SM 1231 AI 16 BIT (6ES7 231-5ND32-0XB0) | 4 channels, input range: ±10VDC/4–20mA | Receives analog signals from sensors |
| 3 | Digital Input Expansion Module (1) | Siemens SM 1221 DI 16 x 24VDC (6ES7 221-1BH32-0XB0) | Input voltage: 24VDC | Receiving I/O communication signals |
| 4 | Human Machine Interface (HMI) (1) | Weintek MT8071iP | 7-inch TFT LCD, 800x480, Ethernet, RS232/RS485, USB host | Displays system status, allows user input & recipe settings |
| 5 | Power Supply (1) | Omron S8FS C10024 - 305 | Input: 200 - 240VAC, Output: 24VDC/4.5A | Provides power to sensors and control modules |
| 6 | Flow sensor (4) | Keyence FD-SS2A | Non-contact, detects flow rate in pipes (liquid only) | Monitors flow rate of adhesive during potting |

| | | | | |
|---|---|---|---|---|
| 7 | Solenoid Valve 5/2 (4) | Airtac 4V210 – 08 | Pressure: 0.15 – 0.8 MPa | Control Pneumatic Ball Valve |
| 8 | Pneumatic Ball Valve (4) | Q11F | Pneumatic Pressure: 3 ~ 8Bar | Control the Adhesive Flow Through Sensors |
| 9 | Multi-channel relay module (1) | G6B-4BND Omron | | Receiving output signals from the PLC to control four 5/2 solenoid valves |
| 10 | 8-pin Interposing Relay (1) | Omron MY2N-J 24VDC | 5A, 250VAC / 30VDC | Receiving output signals from the PLC to control a warning light with buzzer |
| 11 | Tower Light | ST45B-BZ-1 | QLIGHT ST45B-BZ-1 | Trigger a fault warning signal |

### *3.1.1. PLC S7 1200 (1212 C DC/DC/DC) [2]*


*Figure 3.1 PLC S7 – 1200 & some expansion modules*

The **Siemens S7-1200 1212C DC/DC/DC** is a compact programmable logic controller (PLC) belonging to the S7-1200 family, designed for automation tasks requiring high reliability, efficient communication, and scalable I/O capabilities. This integrated device combines the CPU, digital inputs, digital transistor outputs, and a communication interface into a single housing, significantly reducing wiring complexity and panel size.

It operates entirely on 24 VDC for power supply, input signals, and transistor-type output switching. The controller is programmed using Siemens' **TIA Portal**, offering support for standard IEC 61131-3 programming languages such as **LAD**, **FBD**, **SCL**, **STL**, and **Graph**. With its fast processing speed, modular expansion options, and built-in PROFINET communication, the S7-1200C is well-suited for compact automation systems, including those involving pneumatic actuation and flow-based material control.

Key features:

- **Integrated design**: CPU, I/O, and communication port in one device.
- **High-speed processing**: Bit instructions executed in approximately 0.08 µs.
- **PROFINET-enabled**: Built-in Ethernet for communication with HMIs and networked devices.
- **Expandable**: Supports analog I/O modules, communication modules (e.g., RS485/RS232), high-speed counters (HSC), and pulse-width modulation (PWM).
- **Suitable for hybrid control systems**: Can handle electrical, pneumatic, and fluid flow control elements simultaneously.

Table 3.2 Technical Specifications of Siemens S7-1200 1212C DC/DC/DC

| Parameter | Specification |
|---|---|
| Model Example | S7-1200 CPU 1211C DC/DC/DC (e.g., 6ES7211-1BD34-0XB0) |
| Power Supply Voltage | 20.4 – 28.8 V DC (Nominal: 24 V DC) |
| Number of Digital Inputs (DI) | 8 |
| Digital Input Voltage Range | 24 V DC, sink or source |
| Number of Digital Outputs (DO) | 6 |
| Digital Output Type | Transistor (DC switching) |
| Output Current per Channel | Max. 0.5 A per channel |
| Built-in Communication Port | 1 × PROFINET/Ethernet (10/100 Mbps) |

| | |
|---|---|
| Programming Software | TIA Portal |
| Supported Languages | LAD, FBD, SCL, STL, GRAPH |
| Execution Time (Bit Instruction) | Approx. 0.08 µs |
| Execution Time (Word Instruction) | Approx. 1 µs |
| Program/Data Memory | 50 KB program memory, 2 MB load memory |
| Retentive Memory | 10 KB |
| Expandable I/O Modules | Yes – Supports SM (Signal Module) and CM (Communication Module) |
| Real-Time Clock | Integrated |
| Dimensions (W × H × D) | Approx. 90 × 100 × 75 mm (varies by specific model) |
| Mounting Type | DIN rail mounting |
| Protection Class | IP20 |
| Operating Temperature Range | 0°C to +55°C |

### *3.1.2. HMI Weintek*


*Figure 3.2 HMI Weintek MT8071iP v2*

The Weintek MT8071iP v2 is a cost-effective Human-Machine Interface (HMI) featuring a 7-inch widescreen display. It provides a user-friendly graphical interface between operators and automation systems. With its rich communication capabilities and compatibility with various PLC protocols, this HMI is ideal for industrial control systems requiring stable performance and intuitive interaction.

**Technical Specifications:**

- 7-inch TFT LCD display, 800×480 resolution, 16.7M colors, resistive touch.

- 32-bit RISC processor (1 GHz), 256 MB RAM, 256 MB Flash memory.
- Supports Ethernet, RS-232, RS-485, and USB Host for communication.
- Input voltage: 24 VDC (range 10.5–28 VDC), power consumption approx. 350 mA, 24 VDC.
- Configured using EasyBuilder Pro; compatible with MODBUS, Siemens S7, Omron, etc.
- Panel-mounted, IP65-rated front panel, operating temperature 0°C to 50°C.
- Dimensions: 200.1 × 146.5 × 34.2 mm; weight approx. 0.52 kg.

### *3.1.3. Flow sensor - FD - S series Type A [3]*


*Figure 3.3 Flow sensor - FD - S series Type A*

FD-S Series is using a Coriolis method as flow detection principle. Flow is detected by vibrating the internal detection pipe with approximately 400 Hz (350 to 500 Hz), and detecting the phase shift of the mass flow against that basic vibration.

A double U-shape pipe is used for the detection pipe, and effect of external vibration is reduced by adopting the unique small balanced center coil layout. It is designed so the balance of the double U-shape pipe is to be optimal when it is filled with the fluid for this method. Due to the above principle /design, there are unique precaution for handling.

- It is necessary for the detection pipe to be filled with fluid (there is no standing bubble)
- It is necessary not to apply equipment vibration around 400 Hz (350 to 500 Hz) that can affect the equipment (anti-vibration measure might be necessary when mounting the main unit and the piping)
- Detection pipe (Ø1.0 to 5.0) should not clog.

**Technical Specifications:**

- Power supply voltage: 24VDC ± 10%
- Analog output: 4 to 20 mA, maximum load resistance 260 Ω. Analog output voltage can be set arbitrary
- Operating pressure: 5Mpa
- Maximum pressure: 10Mpa
- Fluid flow rate: 0 – 2000mL/min

**I/O cable**

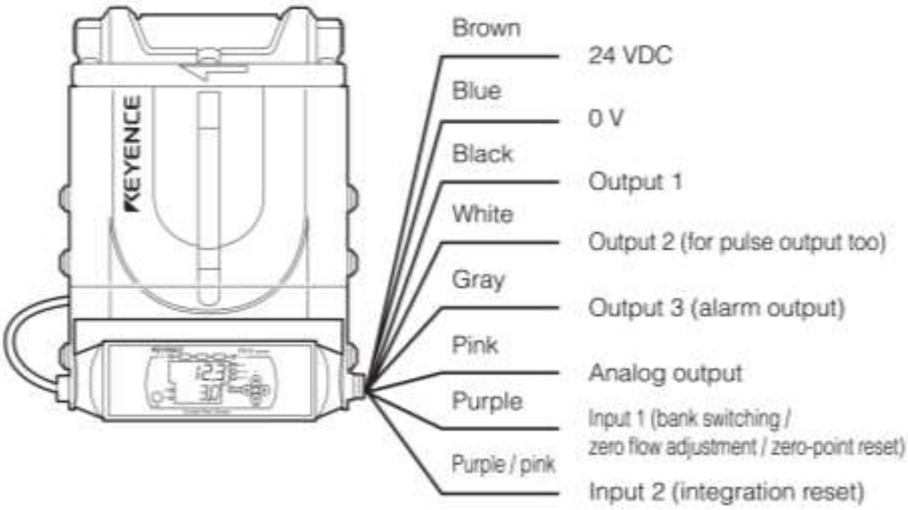



*Figure 3.4 Flow sensor I/O Cable*

**Display unit and Setup**

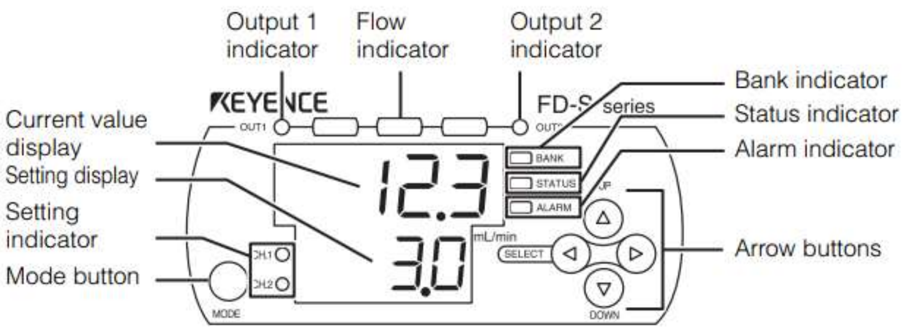



*Figure 3.5 Display unit and Setup*

- Arrow buttons, mode button:  This is used to change the settings and display.
- Output indicator 1/2:  This will light red when the control output is ON.
- Bank indicator:  This will light red when external input is ON using the bank switch function. For more details.
- Alarm indicator:  The alarm indicator illuminates in the following cases.

(1) Measurement pipe is not filled with fluid or there is a bubble

(2) Overcurrent is flowing in the control output

(3) Reverse flow of fluid is detected

(4) There is an access error in the internal memory.

(5) Temperature alarm (out of range in set lower limit or upper limit) is detected.

### *3.1.4. Multi-channel relay module*

*Figure 3.6 OMRON G6B-4BND DC24*

The OMRON G6B-4BND DC24 is a 4-channel intermediate relay module commonly used in automated control systems for signal amplification, electrical isolation between the power and control circuits, and protection of electronic devices such as PLCs. This device operates with a 24VDC control voltage, making it compatible with digital outputs of PLCs, and is capable of switching both AC and DC loads at the output.

In this project, the module is utilized as an intermediary to control the on/off operation of four 5/2 solenoid valves

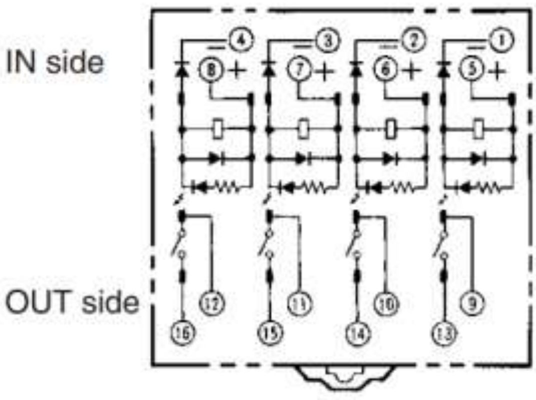



*Figure 3.7 OMRON G6B-4BND DC24 internal connections*

### *3.1.5. Solenoid Valve 5/2 [4]*

The 5/2 solenoid valve has a relatively simple structure for easy and convenient installation and use. Valves rely mainly on electromagnetic suction coils, which activate and control the valve to operate. When the electromagnetic suction coil is energized, a magnetic field is generated and acts directly on the piston of the valve body causing the piston to move, depending on the design of the valve, the piston will close or open and when the power supply to the electromagnetic suction coil is stopped, the piston will return to its original state.

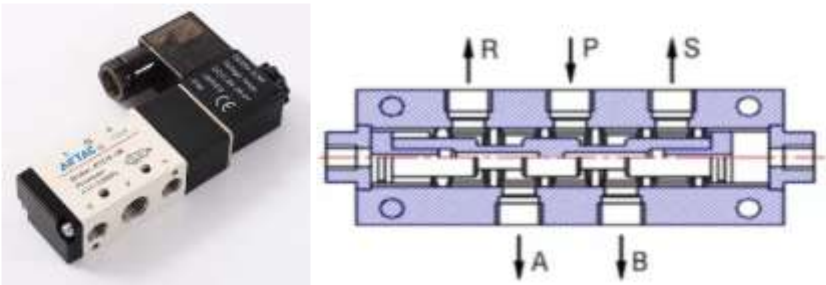



*Figure 3.8 Solenoid Valve 5/2*

**Working Principles:**

For the normally closed type, when this device is used in conjunction with pneumatic cylinders or pneumatic control components, supplying air to the solenoid valve does not change the initial state of the pneumatic devices:

- When the valve is in its **non-activated state**, compressed air enters the solenoid valve through **port P** and flows toward **port A**, delivering air to the pneumatic actuators. The **exhaust air** from the actuators is pushed back through **port B** and discharged via **port S**.
- When the valve is **electrically activated**, the air flow direction is **reversed**. Air moves from **port P to port B**, while the exhaust air from the actuator flows from **port A** and is released through **port R**.

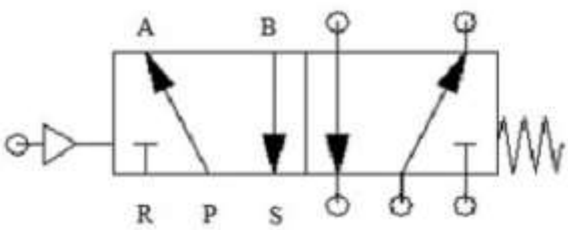



*Figure 3.9 Normally Closed 5/2 Valve Diagram*

For the **normally open** type, it operates **in reverse** compared to the normally closed type. It is also installed together with other pneumatic components such as cylinders and pneumatic actuators:

- When the valve is in its **non-activated state**, compressed air flows from **port P to port B**, supplying air to the downstream pneumatic devices. The incoming air pushes the existing air inside the device out through **port A**, which functions as the **exhaust port**, discharging air via **port R**.
- When the valve is **electrically activated**, the flow direction is **reversed**. Compressed air is then directed from **port P to port A**, and the exhaust air is released from **port B** through **port S**.

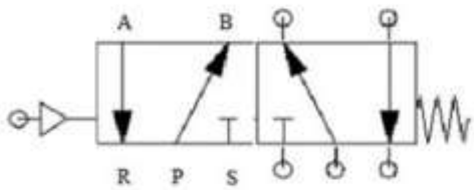



*Figure 3.10 Normally Opened 5/2 Valve Diagram*

### *3.1.6. Pneumatic Ball Valve*

*Figure 3.11 Pneumatic Ball Valve Q11F*

The Q11F pneumatic ball valve is an automatic flow control device operated by compressed air. It is commonly used in industrial systems to regulate and control the flow of liquids, gases, or steam. The valve features a simple structure and performs open/close functions via a pneumatic actuator, optimizing efficiency and minimizing manual intervention.

**Technical Specifications:**

- Size range: DN15 – DN300
- Working pressure: 1.6 MPa (~16 bar)
- Operating temperature range: Up to 120°C
- Body material: Carbon steel, stainless steel (SUS304/SUS316)
- Ball material: Stainless steel SUS304/SUS316

**Advantages:**

- Helps save time and increase work productivity
- Fast valve opening and closing speed, typically within 1–2 seconds
- Available in various compact sizes
- Easy to install, even in confined spaces, elevated areas, or deep locations
- Suitable for various environments, ideal for systems or projects requiring multiple valves operating simultaneously
- Durable, withstanding high temperatures and pressures
- Ensures safety during operation, with no risk of electrical short circuits or explosions

Based on the equipment used in the system as presented in the previous section, an overview diagram of the proposed interconnection between devices is shown below. In this system, the PLC functions as the central processing unit, receiving analog data from the flow sensor and processing it for display on the HMI screen. The PLC's output is connected to intermediate relays to control actuators, including solenoid valves and warning lights. The switching power supply provides electrical power for the entire system.

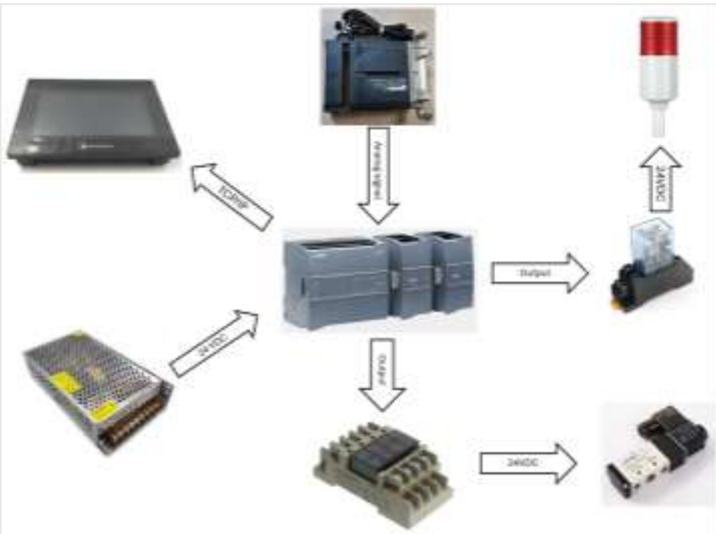



*Figure 3.12 Overview Diagram of PLC Signal Connections*

## 3.2. Design and Implementation

### *3.2.1. Hardware designing*

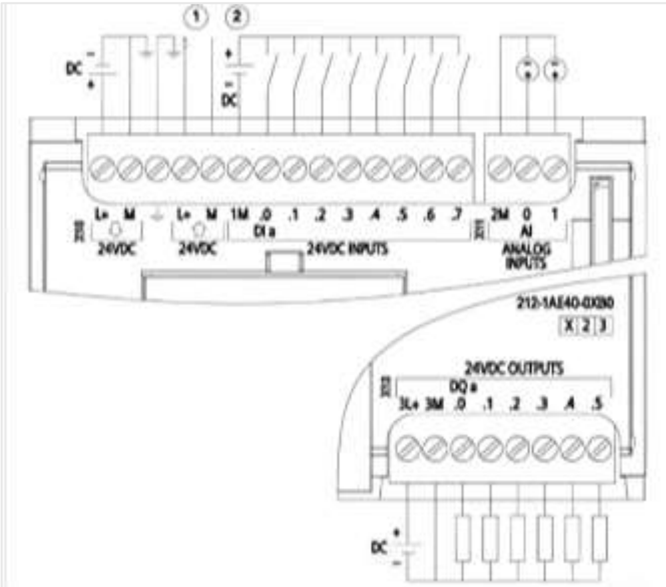


*Figure 3.13 PLC s7 1200 1212C DC/DC/DC wiring diagram*

Based on the wiring diagram of the terminals and the power supply of the PLC, the electrical wiring is implemented as follows:

- **Power supply for the PLC**: L+ is connected to the positive terminal of the 24VDC power source, and M is connected to the negative terminal (GND) of the 24VDC source.
- **Digital Inputs (DI)**: The M and L+ terminals are used as common references for the input signals. Terminals I0.x are connected to signals from sensors, push buttons, etc.
- **Analog Inputs (AI)**: Consist of two input channels, AI0 and AI1; terminal 2M serves as the common ground (GND) for analog input signals.
- **Digital Outputs (DO)**: Power is supplied through terminals 3L+ (positive 24VDC) and 3M (GND). The Qx.x output terminals are connected to the load, with the other end of the load connected to terminal 3M

Drawing from the analysis of the PLC wiring diagram along with the Diagram of Signal Connections between the PLC and Peripheral Devices, the overall wiring diagram of the PLC was designed using EPLAN Electric P8 software as follows:

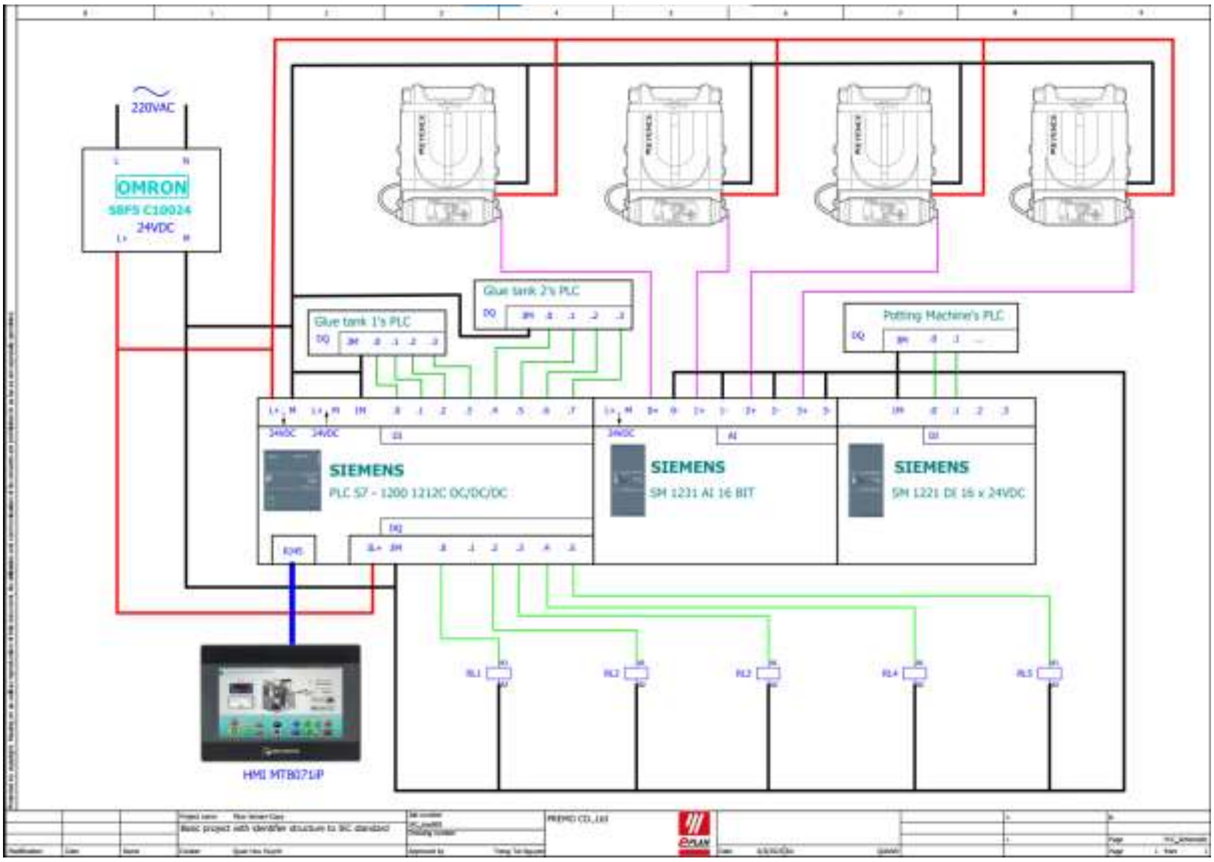



*Figure 3.14 Overall wiring diagram of the PLC system*

In this diagram, each flow sensor has 7 wires, but only 3 are utilized: 2 for power supply and 1 for the analog signal. The analog signal wire is connected to the AI (Analog Input) port of the expansion module.

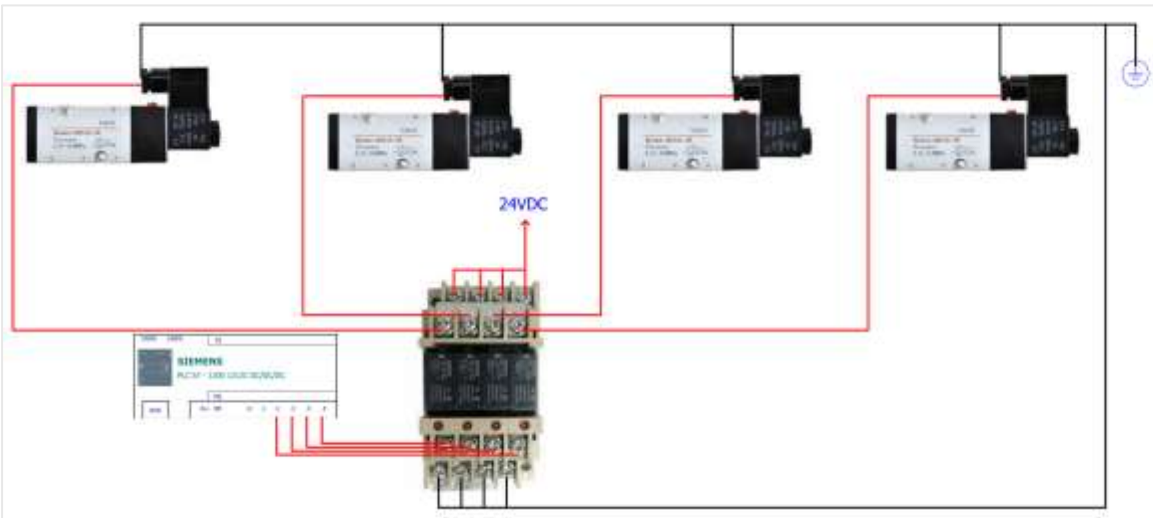



*Figure 3.15 Wiring diagram of the relay and 5/2 solenoid valve*

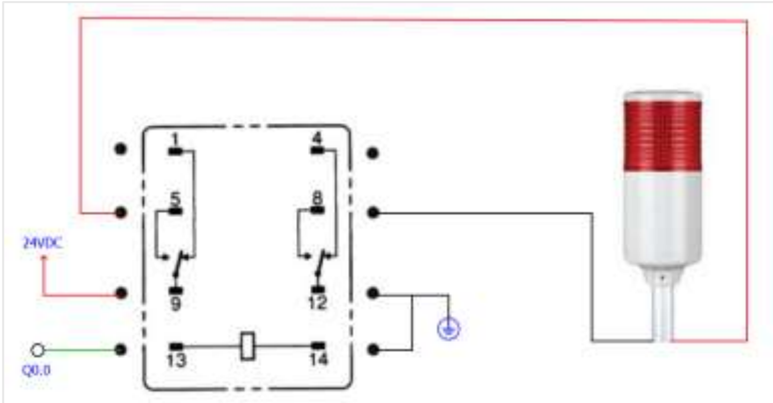
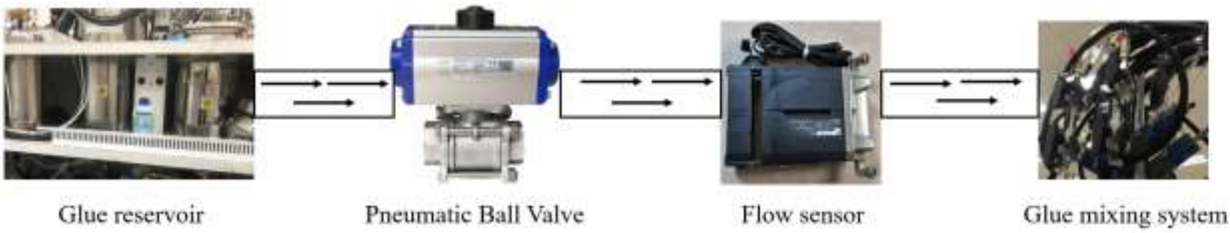



*Figure 3.16 Wiring diagram of the intermediate relay and warning light*

**Piping and Instrumentation Diagram (P&ID)**




In the diagram above, the adhesive reservoir serves as the supply source for the entire system. A ball valve is installed before the inlet of the flow sensor to control the adhesive flow, allowing it to pass through the sensor only during the potting machine's operation. Additionally, the valve helps prevent adhesive leakage and air bubble accumulation, which could cause measurement errors in the sensor. The outlet of the flow sensor is connected to the adhesive mixer, which facilitates the dispensing of adhesive into the product during the potting process.

### *3.2.2. HMI designing & programming*

*a) HMI designing*

To design the monitoring interface for the sensors on the Weintek HMI, we utilized the **EasyBuilder Pro** software, which offers outstanding features, user-friendly access, and seamless connectivity. The interface consists of three screens:

- Main screen – displays information about the project topic and includes navigation buttons.

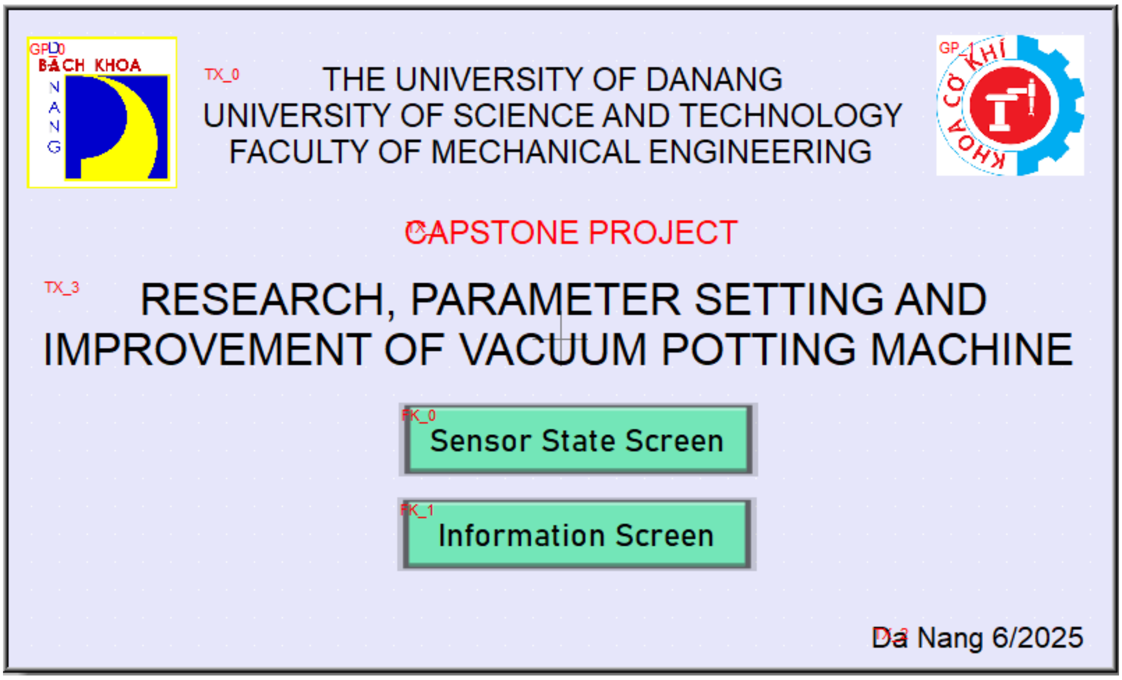



*Figure 3.17 Main screen*

- Monitoring screen – presents 2 real-time charts based on actual sensor data, along with adhesive ratio calculations for each dispensing head.

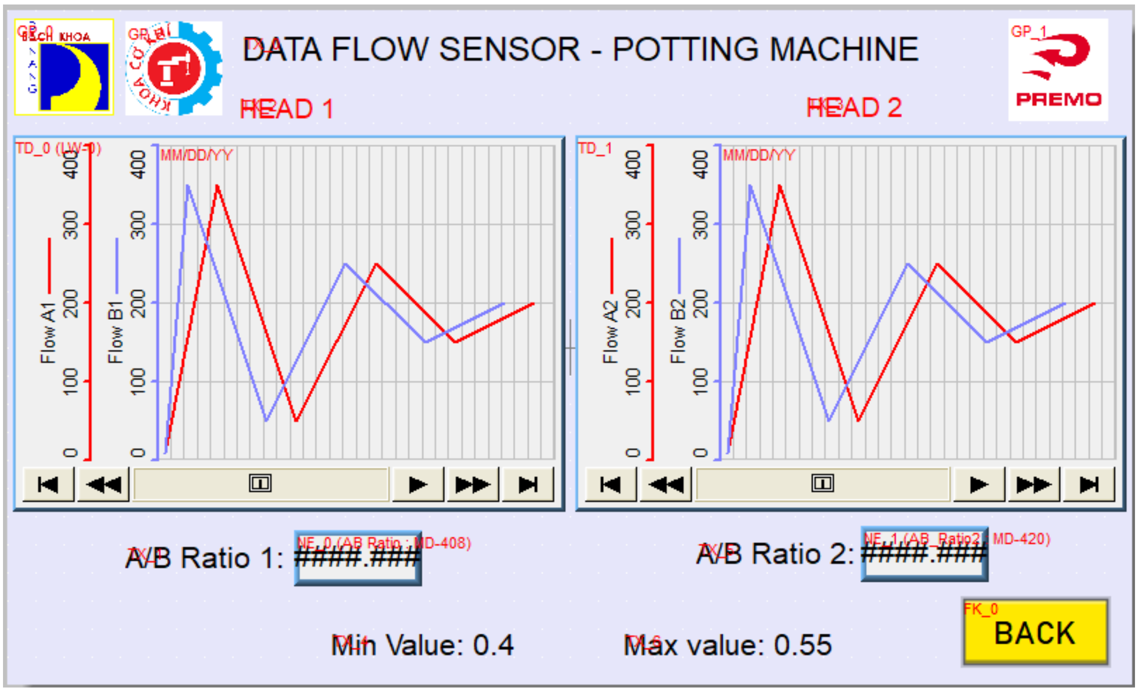



*Figure 3.18 Sensor state screen*

- Information screen – contains details related to the authors.

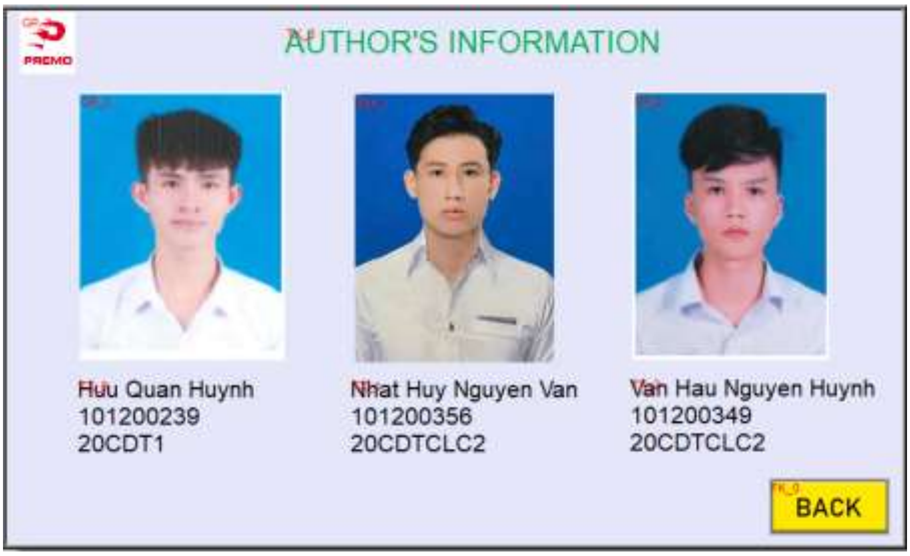
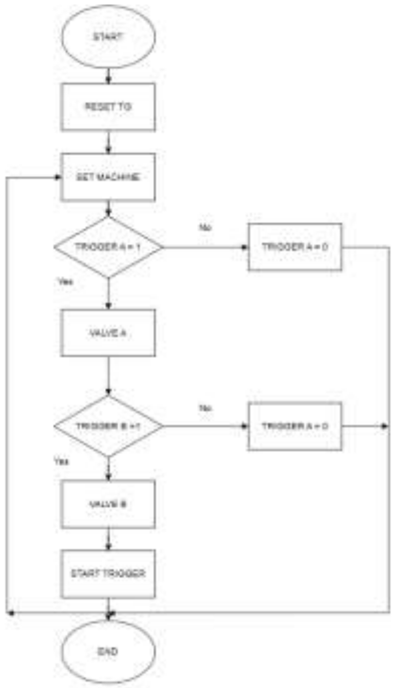
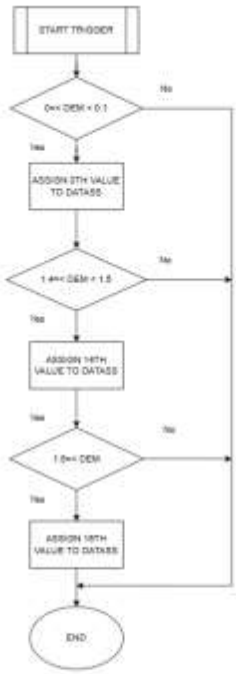


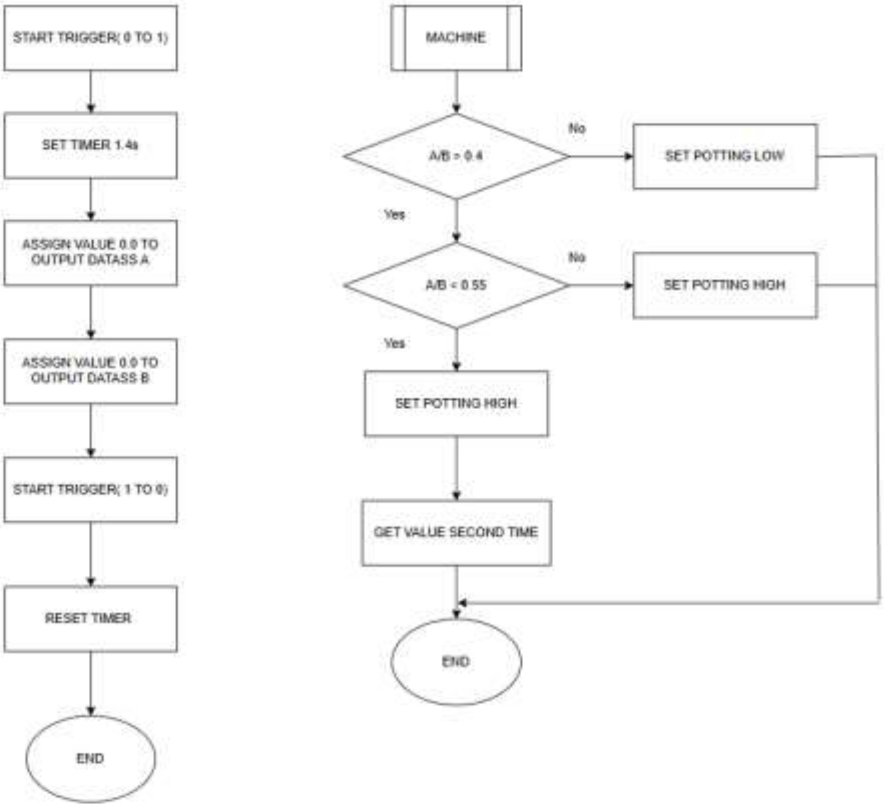

*Figure 3.19 Author information screen*

*b) Programming - Control Algorithm Flowchart*

The PLC control algorithm is developed as follows: The adhesive dispensing process is carried out using two reservoirs, each containing two types of adhesive: A1/B1 and A2/B2 respectively. The PLC reads data from four flow sensors, calculates the quantity and mixing ratio of the adhesive. The data is logged over time within a 1.5-second cycle, during which the maximum adhesive volume is identified. The system then controls the valves accordingly, and the mechanism is reset at the end of each cycle. Each cycle is illustrated in the flowcharts below.






### *3.2.3. Sensor functions setting*

The sequence of steps for configuring the sensor parameters is based on the Instruction Manual provided by Keyence. The configuration parameters are determined as follows:

- Flow unit: L (mL/min)
- Flow direction: Same direction as the arrow on the sensor unit
- Selection of analog output: Free range analog ouput mode (Pink wire)

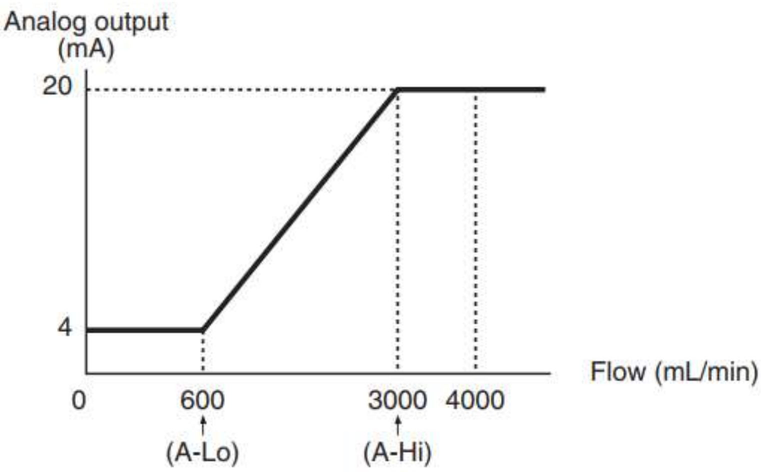



*Figure 3.20 Free range analog ouput mode*

- Setting of the minimum flow rate: 0

### *3.2.4. System Installation implementation*

*a) Sensor Installation*

**Installation considerations:**

- Avoid surrounding of the electrical equipment (motor, transformer, radio equipment, electrolysis tank, others that will generate electromagnetic induction disturbance or electrostatic induction disturbance) that can cause disturbance to the measurement.
- Avoid location with large vibration.
- Avoid location with direct sunlight as much as possible. Place a shading or similar when there is a direct sunlight.
- Avoid using in the environment with corrosive environment, high humidity, or high temperature with condensation.
- Avoid high or narrow location, and select a location easy to operate.
- Design the piping so the measuring fluid will be full in the measuring pipe whether the fluid is flowing or stopped.
- Install so the plastic part of the casing will not physically touch the walls or the piping. Accuracy will drop when there is excessive stress on the casing.


*Figure 3.21 Proposed installation method for pneumatic ball valves and flow sensors*

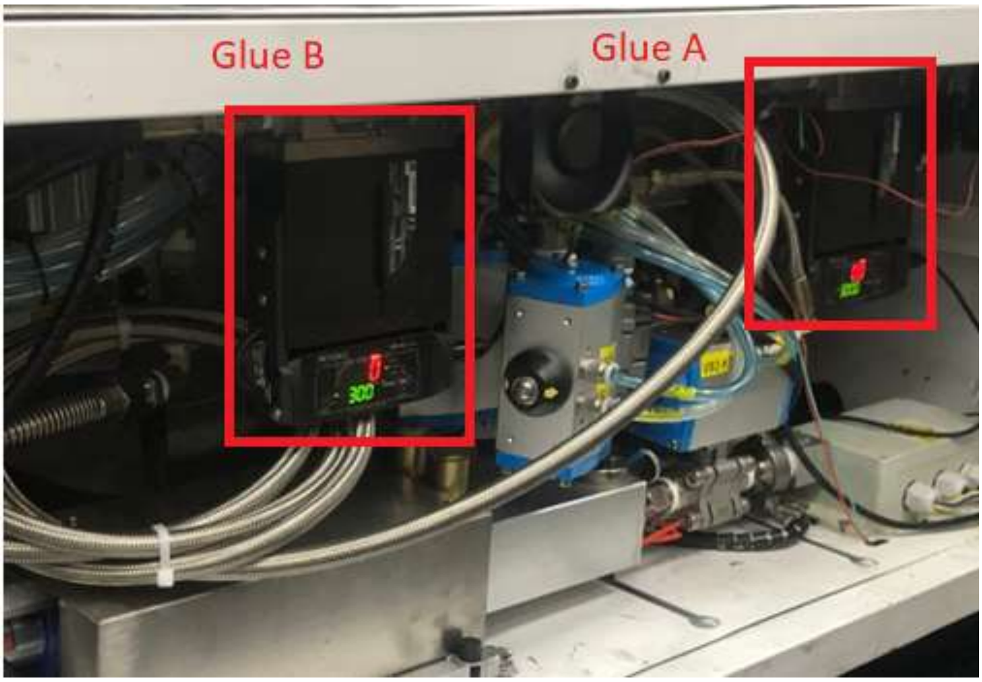



*Figure 3.22 Installation of Sensor System and Pneumatic Ball Valves*

*b) HMI Installation*


*Figure 3.23 Installation of the HMI Screen, Warning Light*

# Chapter 4: CONTROL DESIGN IMPROVEMENT & RESEARCH, PARAMETER SETTING

## 4.1. Optimizing Machine Operating Parameters

**Calculate the potting speed of two-component adhesive:**

$$T_{lt} = \sum_{i=1}^{4} t_i = L(\frac{1}{v_1} + \frac{1}{v_2} + \frac{1}{v_3} + \frac{1}{v_4}) + T_{Delay} = 55.(\frac{3}{v_1} + \frac{1}{v_4}) + 1,2 \quad (4.1)$$

$$\rightarrow v_4 = 1 : (\frac{T_{tt} - 1,2}{55} - \frac{3}{v_1})$$

$$M = (A+B).T_{tt} = (A+B).\sum_{i=1}^{4} t_i = (A+B).(55(\frac{1}{v_1} + \frac{1}{v_2} + \frac{1}{v_3} + \frac{1}{v_4}) + 1,2) \quad (4.2)$$

**Case 1:**

| | |
|---|---|
| *M* (g) | 7,2 |
| *A:B* | 0,4 – 0,55 |
| *A* (g/5s) | 3,35 |
| *B* (g/5s) | 7 |
| *A:B* | 0,47 |
| *A+B* (g/5s) | 10,35 |
| *A+B* (g/s) | 2,07 |
| *T (lt)* | 3,48 |
| *T (tt)* | 3,98 |

| | | | |
|---|---|---|---|
| $v_1 = v_2 = v_3$ (mm/s) | 80 | 85 | 90 |
| $v_4$ (mm/s) | 104 | 84 | 72 |

Actual weight after calculation:

| $M_{ct}$ (g) | $M_{ct}$ (g) | $M_{ct}$ (g) |
|---|---|---|
| 7,84 | 7.,85 | 7,86 |

**Case 2:**

| | |
|---|---|
| *M* (g) | 7,2 |
| *A:B* | 0,4 – 0,55 |
| *A* (g/5s) | 3,76 |
| *B* (g/5s) | 8 |
| A:B | 0,47 |
| *A+B* (g/5s) | 11,76 |
| *A+B* (g/s) | 2,352 |
| *T (lt)* | 3,06 |
| *T (tt)* | 3,56 |

| | | | |
|---|---|---|---|
| $v_1 = v_2 = v_3$ (mm/s) | 100 | 105 | 110 |
| $v_4$ (mm/s) | 113 | 97 | 86 |

Actual weight after calculation:

| $M_{ct}$ (g) | $M_{ct}$ (g) | $M_{ct}$ (g) |
|---|---|---|
| 7,84 | 7,85 | 7,85 |

**Case 3:**

| $M$ (g) | 7,2 |
|---|---|
| $A:B$ | 0,4 – 0,55 |
| $A$ (g/5s) | 4 |
| $B$ (g/5s) | 8,5 |
| $A:B$ | 0,47 |
| $A+B$ (g/5s) | 12,5 |
| $A+B$ (g/s) | 2,5 |
| $T$ (lt) | 2,88 |
| $T$(tt) | 3,38 |

| $v_1 = v_2 = v_3$ (mm/s) | 110 | 115 | 120 |
|---|---|---|---|
| $v_4$ (mm/s) | 125 | 109 | 97 |

Actual weight after calculation:

| $M_{ct}$ (g) | $M_{ct}$ (g) | $M_{ct}$ (g) |
|---|---|---|
| 7,85 | 7,84 | 7,85 |

**Case 4:**

| $M$ (g) | 7,2 |
|---|---|
| $A:B$ | 0,4 – 0,55 |
| $A$ (g/5s) | 2,9 |
| $B$ (g/5s) | 6,1 |
| $A:B$ | 0,475 |
| $A+B$ (g/5s) | 9 |
| $A+B$ (g/s) | 1,8 |
| $T$ (lt) | 4 |
| $T$ (tt) | 4,5 |

| $v_1 = v_2 = v_3$ (mm/s) | 60 |
|---|---|
| $v_4$ (mm/s) | 135 |

Actual weight after calculation:

| $M_{ct}$ (g) |
|---|
| 7,84 |

In which:

$M$: Total desired adhesive weight

$A,B$: Flow rate of two-component adhesive A and B

$T_{lt}$: Total calculated time

$T_{tt}$: Calculated time including an error of 0.5 seconds

$M_{ct}$: Total adhesive weight after dispensing

$L$: Length of the adhesive path on the item

$T_{Delay}$: Total delay time after 4 speed changes

$v_{1\to4}$: Moving speed during the 4 dispensing stages ($v_{1\to4} < 200$mm/s)

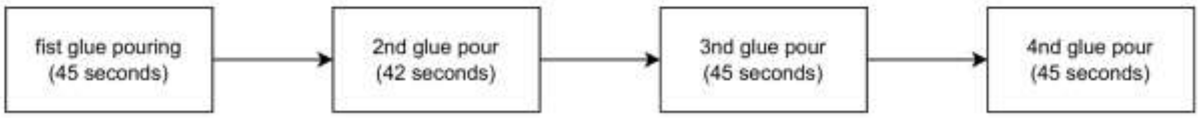
When potting the glue onto the product, a total of four potting stages are performed to ensure that the glue is evenly distributed and free of air bubbles. The flow rate and speed in the first three stages are set the same to achieve the lowest possible speed, while in the final stage, a thinner layer of glue is poured onto the surface to enhance the aesthetics. The speed of the fourth potting stage is calculated accordingly.

After selecting the speed parameters to calculate and the calculated amount of glue is 7,84 grams, which is quite different from the required amount of glue because during pumping, the amount of glue is lost inside a part of the pump tube. With the moving speed of the potting head set up respectively as: $v_1 = v_2 = v_3$ 60mm/s, $v_4$ =135mm/s.

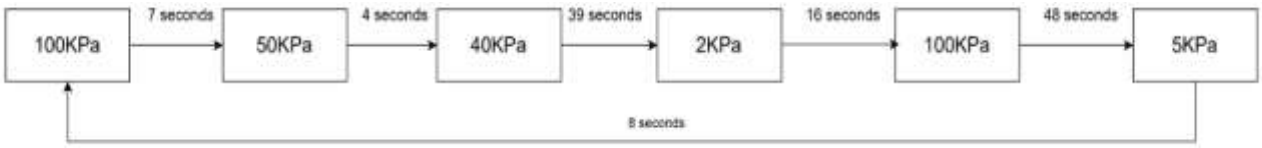
## 4.2. Optimizing the adhesive potting cycle

### *4.2.1. Potting time*

To pour glue and 1 row, we pour a total of 4 times with a total time of 177 seconds.




### *4.2.2. Optimize the vacuum process*




During operation, the pressure inside the chamber is initially balanced with atmospheric pressure at 100 kPa. The vacuum process begins with the first stage, reducing the pressure to 50 kPa within 7 seconds, followed by the first glue dispensing cycle, which lasts 45 seconds.

After completing the first dispensing cycle, the second glue dispensing cycle begins, lasting 42 seconds. Meanwhile, the vacuum pressure is further reduced to 40 kPa over 4 seconds. The third glue dispensing cycle then takes place, lasting 45 seconds.

For the third vacuum stage, the pressure decreases from 40 kPa to 2 kPa within 39 seconds. Once this is achieved, the air valve opens, allowing air to enter the chamber and restore the pressure to 100 kPa over 17 seconds.

Next, the fourth glue dispensing cycle is carried out for 45 seconds. The fifth vacuum stage then reduces the pressure from 100 kPa to 5 kPa in 49 seconds, followed by another air intake phase, restoring the chamber to 100 kPa within 7 seconds.

**Problem:** The total vacuum time is 119 seconds, which is quite large, so we considered optimizing this process.

**Solution:** Optimize by vacuuming and potting glue into the product at the same time. To reduce vacuuming time.

**Efficiency:** After reviewing the plan and observing the machine running, potting glue while vacuuming leads to a situation where the suction while vacuuming causes the glue to splash onto the goods due to the boiling phenomenon of the liquid while potting. Therefore, this plan cannot be applied.

### *4.2.3. Optimizing the adhesive dispensing trajectory*

**Problem:** A tray contains 36 products. The current total time for the machine to complete gluing one tray is 360 seconds. The goal is to design an optimal gluing trajectory so that the total gluing time for 36 products is 330 seconds.

*Figure 4.1 Initial adhesive potting trajectory*

The initial glue dispensing trajectory moves as shown in the image above. This results in a relatively long travel distance between two products on the tray, consuming a significant amount of time to complete one tray.

**Solution:** Optimize the moving trajectory as Figure 4.2

*Figure 4.2 Improved Movement Trajectory*

**Efficiency:** Adjusting the trajectory as shown in the Figure 4.2 above helps reduce the travel time between two consecutive glue dispensing operations for adjacent products.

### *4.2.4. Setting Up Machine Operating Parameter*

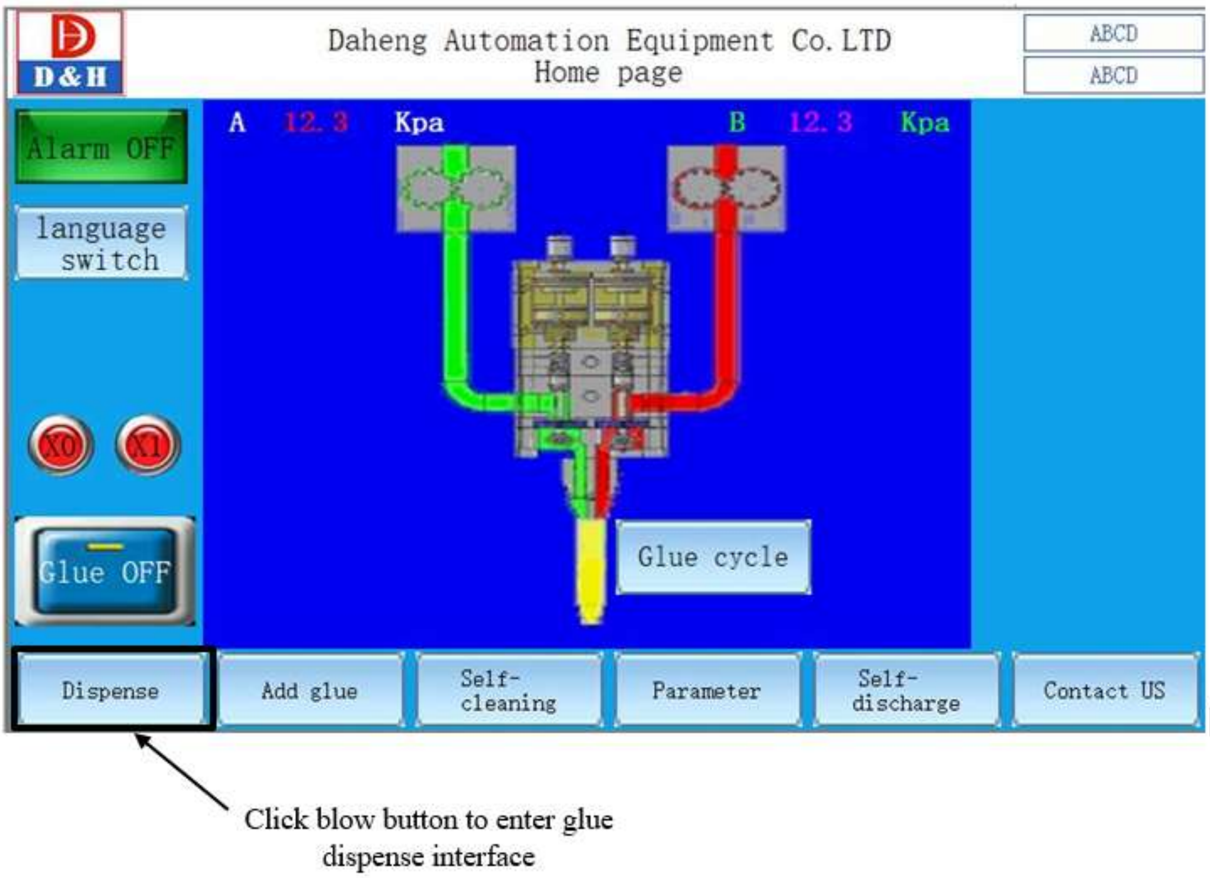



*Figure 4.3 Interface screen of the glue potting*

After calculating and selecting the flow rate for the two-component adhesive, open the mixer interface screen and begin configuring the parameters. Press <**Dispense**> to start.

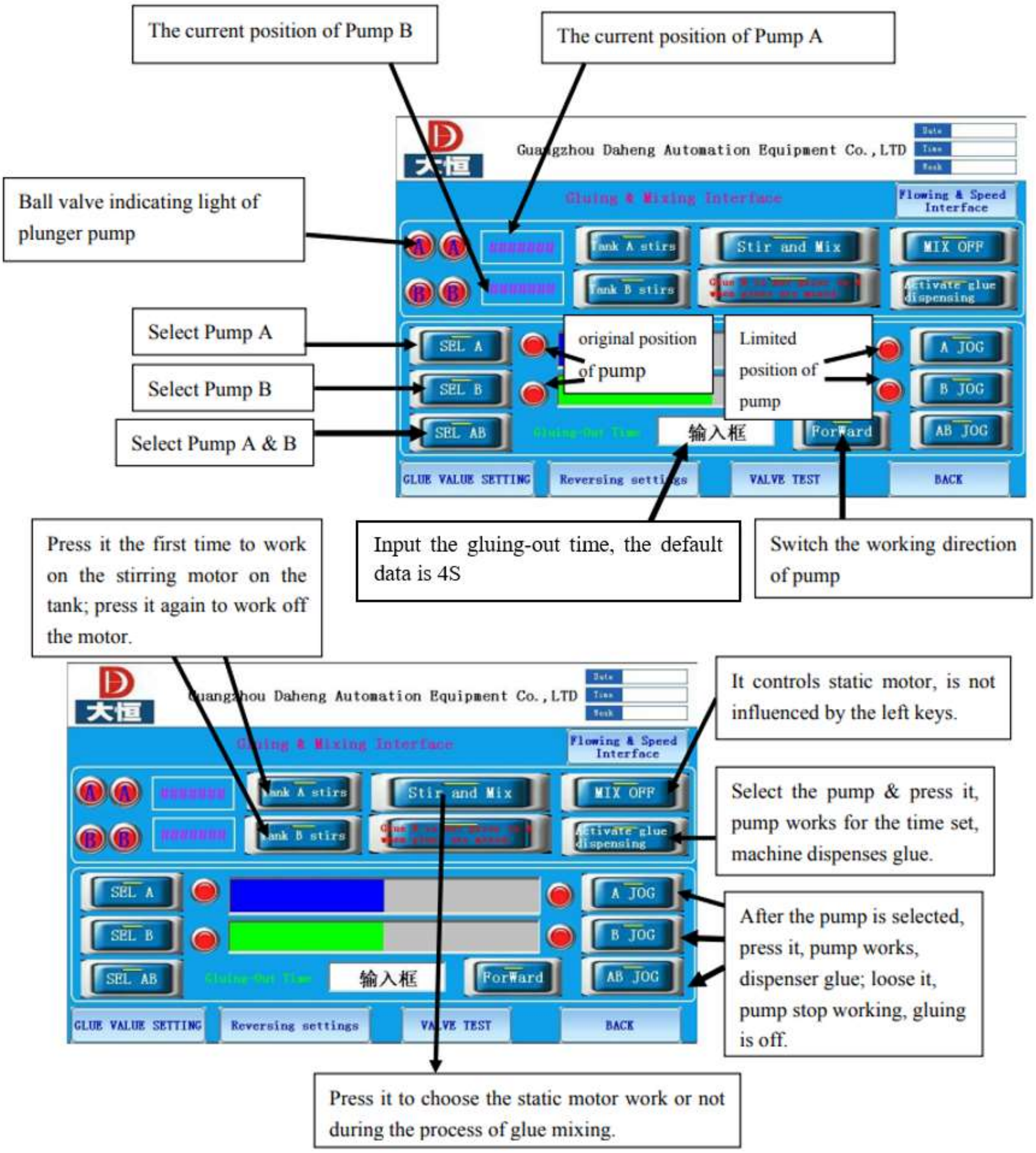



*Figure 4.4 Function keys of the glue potting*

Begin setting the flow rate by pressing the <**Glue value Setting**> buttons after calculating the required value to input into the machine. Select the appropriate time for the machine to dispense the correct amount of glue for one product unit.


*Figure 4.5 Flow rate setting and actual flow rate inspection*

After setting the parameters for the machine to operate for 4 seconds, re-weigh the glue with an error of no more than 0.05 grams compared to the calculated value. This is to ensure that the amount of glue poured in is accurate, avoiding the phenomenon of glue overflow when vacuuming (because the liquid will expand in a vacuum environment) or lack of glue leading to the phenomenon of the coil inside being exposed, affecting the aesthetics of the product.

### *4.2.5. Set the adhesive dispensing trajectory*

*a) Create a trajectory from the points:*

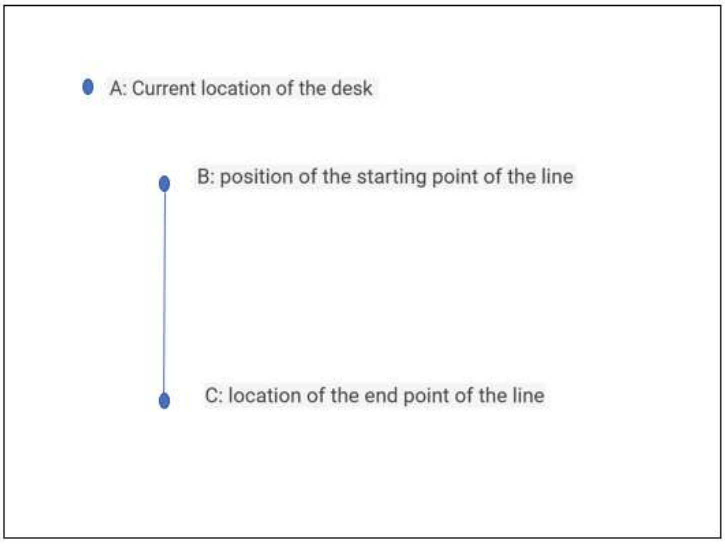



*Figure 4.6 Setting the motion trajectory using multiple points*

- Insert a straight-line graphic; this marks the starting point of the line.

- Move the workbench from point A to point B.
- Press <**Ente**r> to record (or confirm) the starting point of the line.
- The system will automatically insert the end point of the line as instructed.
- Move the workbench to point C and press to confirm.

To create a desired movement trajectory, proceed by generating a series of consecutive straight-line segments.

*b) Set the parameters*


*Figure 4.7 Creating a new motion trajectory file*


*Figure 4.8. Setting the parameters of the glue dispensing nozzle*

- Define the X, Y, Z coordinates for each point.
- <**Process speed**> sets the calculated speed.
- <**Empty speed**> Movement speed without glue.
- <**Off glue distance**> distance before the end of the glue path of the row
- Set the delay time for each move to the next point.

- Configure the <**Elevate Height**> to raise the dispensing head to a safe position after dispensing adhesive.
- <**Glue**> setting determines whether adhesive is dispensed at each point.

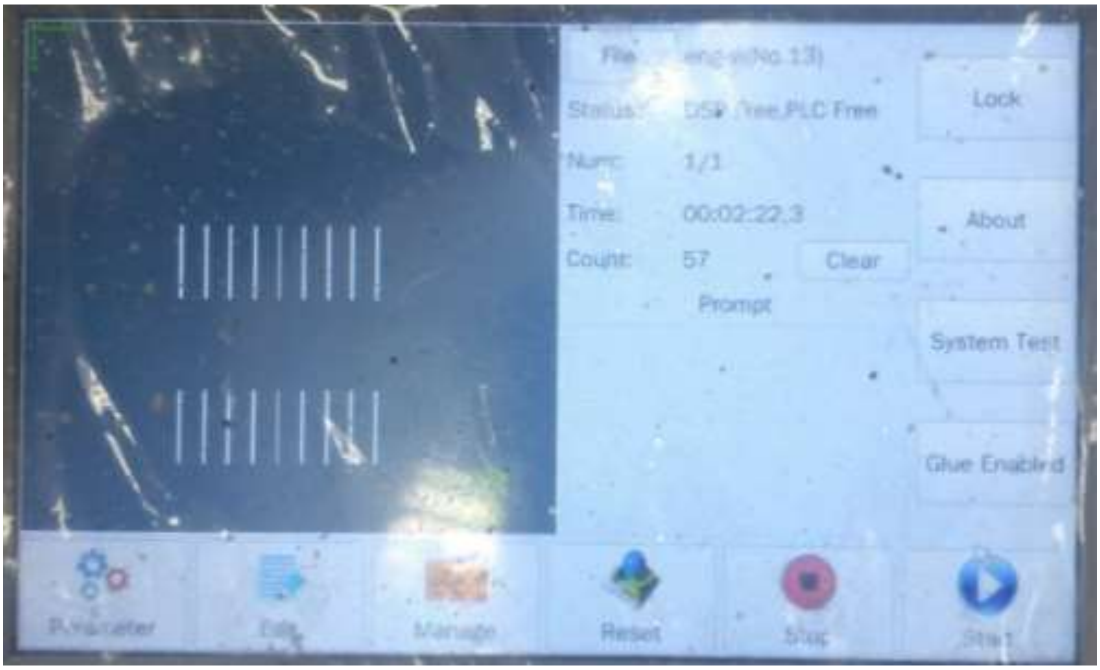



*Figure 4.9 Trajectory after configuration*

After completing the parameter settings, the desired motion trajectory will be generated. Press <**Start**> to run a test and verify the setup.

# Chapter 5: OPERATION RESULT AND CONCLUSION

## 5.1. Operation result

### *5.1.1. Operating time*

*a) Total shortened time of the moving trajectory*

Table 5.1 Movement trajectory time with 2 glue dispensing heads

| Process | Time(s) | |
|---|---|---|
| Tray enters | 0-6 | 6 |
| Door closes | 6-10 | 4 |
| Vacuum suction (100 kPa – 50 kPa) | 10-17 | 7 |
| Glue discharge | 17-20 | 3 |
| First potting | 20-1'05 | 45 |
| Second potting | 1'05-1'47 | 42 |
| Vacuum suction (50 kPa – 40 kPa) | 1'47-1'50 | 3 |
| Third potting | 1'50-2'35 | 45 |
| Vacuum suction (40 kPa – 2 kPa) | 2'35-3'12 | 37 |
| Air release (2 kPa – 100 kPa) | 3'12-3'29 | 17 |
| Glue discharge | 3'29-3'34 | 5 |
| Fourth potting | 3'34-4'19 | 45 |
| Vacuum suction (100 kPa – 5 kPa) | 4'19-5'08 | 49 |
| Air release (5 kPa – 100 kPa) | 5'08-5'15 | 7 |
| Door opens | 5'15-5'19 | 4 |
| Clamp product tray | 5'19-5'30 | 11 |
| Total | 330 | |

Based on the collected data table, the total time to process one product tray containing 36 units using 2 glue dispensing heads is approximately 330 seconds. With the glue dispensing tool unchanged and still using 2 dispensing heads, the process time can be reduced by 30 seconds compared to the original machine operation time with the initial setup parameters.

*b) Total shortened process time with 6 glue dispensing heads*

Table 5.2 Time with 6 glue dispensing heads

| **Process** | **Time(s)** | |
|---|---|---|
| Tray enters | 0-6 | 6 |
| Door closes | 6-10 | 4 |
| Vacuum suction (100 kPa – 50 kPa) | 10-17 | 7 |
| Glue discharge | 17-20 | 3 |
| First potting | 20-46 | 26 |
| Second potting | 46-1’17 | 31 |
| Vacuum suction (50 kPa – 40 kPa) | 1’17-1’20 | 3 |
| Third potting | 1’20-1’46 | 26 |
| Vacuum suction (40 kPa – 2 kPa) | 1’46-2’23 | 37 |
| Air release (2 kPa – 100 kPa) | 2’23-2’40 | 17 |
| Glue discharge | 2’40-2’45 | 5 |
| Fourth potting | 2’45-3’09 | 24 |
| Vacuum suction (100 kPa – 5 kPa) | 3’09-3’58 | 49 |
| Air release (5 kPa – 100 kPa) | 3’58-4’05 | 7 |
| Door opens | 4’05-4’09 | 4 |
| Clamp product tray | 4’09-4’20 | 11 |
| Total | 254 | |

Based on the collected data, the total time to process one product tray containing 36 units using 6 glue dispensing heads is approximately 254 seconds. This represents a significant time reduction (from 330 seconds to 254 seconds). With this shortened duration, the improvement successfully meets the target time of 270 seconds.

### *5.1.2. Adhesive volume compliance*

The glue dispensing tool is designed with 2 distribution valves and 6 dispensing heads. Each distribution valve supplies 3 dispensing heads, so we conducted

Table 5.3 Actual glue weight measurement

| Number of trials | 3 glue dispensing heads | Housing(g) | Housing + Glue(g) | Glue(g) |
|---|---|---|---|---|
| 1st | 1 | 11,96 | 19,26 | 7,30 |
| | 2 | 11,96 | 19,32 | 7,36 |
| | 3 | 11,96 | 19,57 | 7,61 |
| 2nd | 1 | 11,96 | 19,31 | 7,35 |
| | 2 | 12,04 | 19,40 | 7,36 |
| | 3 | 12,04 | 19,59 | 7,55 |
| 3rd | 1 | 12,04 | 19,31 | 7,27 |
| | 2 | 12 | 19,31 | 7,31 |
| | 3 | 12,1 | 19,65 | 7,55 |
| 4th | 1 | 12,1 | 19,34 | 7,24 |
| | 2 | 11,99 | 19,35 | 7,36 |
| | 3 | 11,99 | 19,52 | 7,53 |
| 5th | 1 | 12 | 19,31 | 7,31 |
| | 2 | 11,98 | 19,32 | 7,34 |
| | 3 | 12 | 19,60 | 7,36 |

With a total of 5 measurements, the resulting weight ranged from approximately 7.24 grams to 7.61 grams, with a measurement error of 0.4 grams. This error is significantly higher than the target tolerance of 0.05 grams.

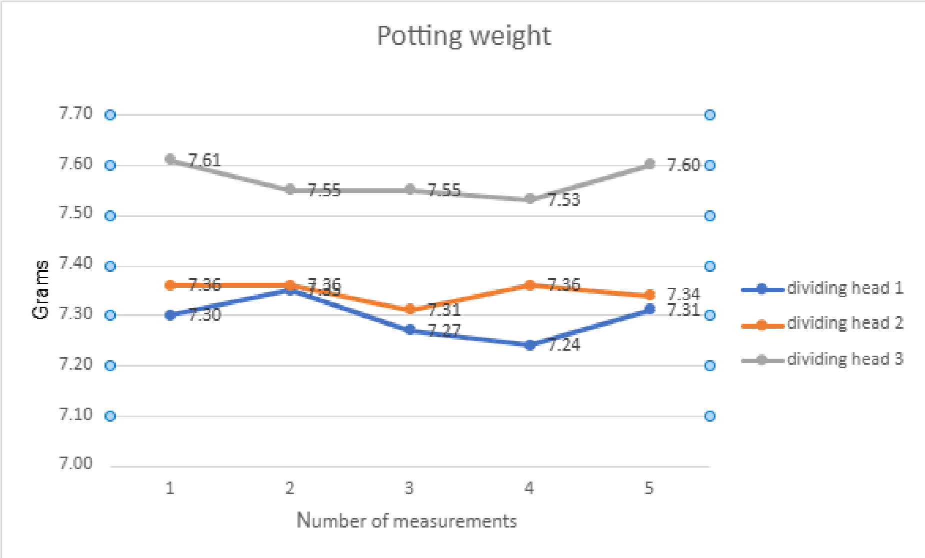



*Figure 5.1 Graph showing the glue volume of the 3 dispensing heads*

From the graph, it can be seen that the glue volumes dispensed by the three heads are not equal. Therefore, the result does not meet the specified requirements.

### *5.1.3. Operation of the adhesive flow monitoring system*


*Figure 5.2 HMI screen displaying adhesive flow rate*

By implementing the adhesive flow monitoring system, factory workers and engineers are now able to visually and accurately track the amount of adhesive dispensed during each potting cycle. The system demonstrates a high and precise response speed compared to real-time conditions, with an error margin of only a few millimeters per second. Additionally, the system provides error warnings and enables machine operators to identify fault conditions promptly and accurately, facilitating timely and appropriate corrective actions.

## 5.2. Conclusion

However, this improvement cannot be applied yet due to some technical limitations arising during operation. Specifically, during the vacuum suction process, it is very difficult to precisely control the amount of glue dispensed. This inconsistency in glue volume results in non-uniform product weights, which may distort the product design. Excess glue causes the glue to boil during vacuum suction, leading to overflow outside the product and compromising its appearance. This directly affects the final product quality, causing the product to fail to meet the required standards.

To overcome the above issue, one proposed solution is to increase the waiting time to allow the glue sufficient time to stabilize and prevent overflow. However, extending the waiting time negatively impacts the system's working efficiency, increasing the total cycle time. This results in no significant improvement in production efficiency, making it nearly equivalent to the option using only 2 glue dispensing heads.

Based on the above analysis, it can be seen that this approach still has many limitations and cannot be widely implemented in practice. To ensure production efficiency and product quality, further research is needed to explore more suitable solutions or make additional improvements to better control the glue amount during the vacuum suction process.

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# APPENDIX 1

**PLC I/O tags**

| No. | Name | Data Type | Logical Address | Comment |
|---|---|---|---|---|
| 1 | Trigger_pottingA1 | Bool | %I0.0 | Adhesive Pump A1 Status |
| 2 | Trigger_pottingB1 | Bool | %I0.1 | Adhesive Pump B1 Status |
| 3 | Trigger_reflowA1 | Bool | %I0.2 | Reverse Flow Signal from Adhesive Sensor A1 |
| 4 | Trigger_reflowB1 | Bool | %I0.3 | Reverse Flow Signal from Adhesive Sensor B1 |
| 5 | Trigger_pottingA2 | Bool | %I0.4 | Adhesive Pump A2 Status |
| 6 | Trigger_pottingB2 | Bool | %I0.5 | Adhesive Pump B2 Status |
| 7 | Trigger_reflowA2 | Bool | %I0.6 | Reverse Flow Signal from Adhesive Sensor A2 |
| 8 | Trigger_reflowB2 | Bool | %I0.7 | Reverse Flow Signal from Adhesive Sensor B2 |
| 9 | Trigger_Potting machine | Bool | %I1.0 | Potting machine's operating status |
| 10 | Flow_Sensor_A2 | Int | %IW100 | Sensor_A1's data |
| 11 | Flow_Sensor_B2 | Int | %IW102 | Sensor_A2's data |
| 12 | Flow_Sensor_A1 | Int | %IW96 | Sensor_B1's data |
| 13 | Flow_Sensor_B1 | Int | %IW98 | Sensor_B2's data |
| 14 | Alarm | Bool | %Q0.0 | Error alarm |
| 15 | Valve_A1 | Bool | %Q0.2 | Activate the 5/2 solenoid valve to control the adhesive on/off valve A1 |
| 16 | Valve_B1 | Bool | %Q0.3 | Activate the 5/2 solenoid valve to control the adhesive on/off valve B1 |

| | | | | |
|---|---|---|---|---|
| 17 | Valve_A2 | Bool | %Q0.4 | Activate the 5/2 solenoid valve to control the adhesive on/off valve A2 |
| 18 | Valve_B2 | Bool | %Q0.5 | Activate the 5/2 solenoid valve to control the adhesive on/off valve B2 |

**PLC Memory tags**

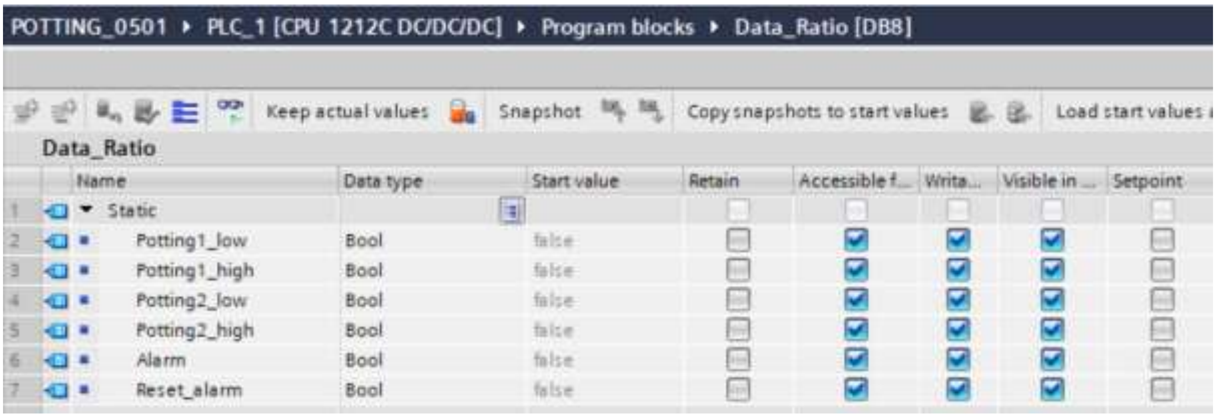
| No. | Name | Data Type | Logical Address | Comment |
|---|---|---|---|---|
| 1 | Amount_A1 | Real | %MD400 | Adhesive Flow Rate Value of A1 |
| 2 | Amount_A2 | Real | %MD412 | Adhesive Flow Rate Value of A2 |
| 3 | Amount_B1 | Real | %MD404 | Adhesive Flow Rate Value of B1 |
| 4 | Amount_B2 | Real | %MD416 | Adhesive Flow Rate Value of B2 |
| 5 | Amount_GlueA1 | Real | %MD22 | Adhesive Mass Value of A1 |
| 6 | Amount_GlueA2 | Real | %MD600 | Adhesive Mass Value of A2 |
| 7 | Amount_GlueB1 | Real | %MD26 | Adhesive Mass Value of B1 |
| 8 | Amount_GlueB2 | Real | %MD604 | Adhesive Mass Value of B2 |
| 9 | GT_SSB1 | Real | %MD204 | |
| 10 | MACHINE | Bool | %M0.5 | |
| 11 | Potting1_high | Bool | %M30.1 | High Adhesive Ratio Error at Head 1 |
| 12 | Potting1_low | Bool | %M30.0 | Low Adhesive Ratio Error at Head 1 |
| 13 | Potting2_high | Bool | %M30.3 | High Adhesive Ratio Error at Head 2 |
| 14 | Potting2_low | Bool | %M30.2 | Low Adhesive Ratio Error at Head 2 |
| 15 | Ratio_1 | Real | %MD408 | Adhesive Mixing Ratio Value at Head 1 |

| | | | | |
|---|---|---|---|---|
| 16 | Ratio_2 | Real | %MD420 | Adhesive Mixing Ratio Value at Head 2 |
| 17 | Tag_100 | Bool | %M14.4 | |
| 18 | Tag_101 | Bool | %M14.6 | Delay Time Variable for Alarm Buzzer |
| 19 | Tag_103 | Bool | %M15.2 | Error Status Variable for Ratio Fault |
| 20 | Tag_105 | Bool | %M16.0 | |
| 21 | Tag_106 | Bool | %M16.1 | |
| 22 | Tag_107 | Bool | %M16.2 | |
| 23 | Tag_108 | Bool | %M16.3 | |
| 24 | Tag_11 | Bool | %M0.6 | |
| 25 | Tag_15 | Real | %MD200 | |
| 26 | Tag_2 | Bool | %M3.4 | |
| 27 | Tag_23 | Real | %MD220 | |
| 28 | Tag_5 | Real | %MD202 | Offset value |
| 29 | Tag_60 | Real | %MD206 | |
| 30 | Tag_63 | Real | %MD212 | |
| 31 | Tag_8 | Bool | %M14.3 | |
| 32 | Tag_9 | Bool | %M3.6 | |
| 33 | Tag_92 | Bool | %M3.7 | |
| 34 | Tag_93 | Bool | %M4.0 | |
| 35 | Tag_94 | Real | %MD208 | |
| 36 | Tag_95 | Real | %MD210 | |
| 37 | Tag_96 | Real | %MD214 | |
| 38 | Tag_97 | Real | %MD216 | |

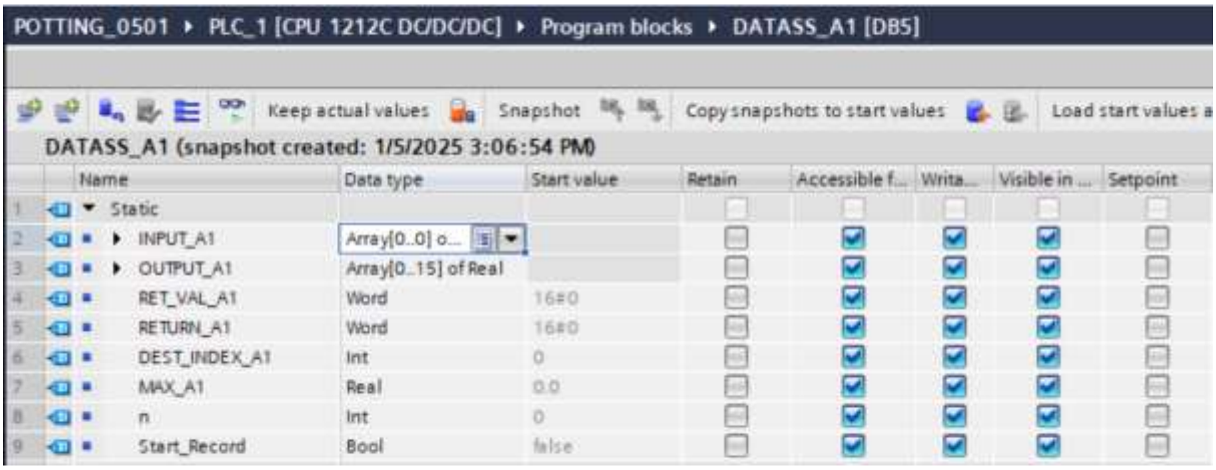
| | | | | |
|---|---|---|---|---|
| 39 | Tag_98 | Real | %MD218 | |
| 40 | Tag_99 | Real | %MD222 | |
| 41 | TG | Bool | %M10.0 | |
| 42 | Timer_Reset | Bool | %M3.5 | |
| 43 | Trigger_Reset | Bool | %M14.2 | |
| 44 | Trigger_Start1 | Bool | %M3.3 | Memory Variable for Glue Pump Start Status of Machine 1 |
| 45 | Trigger_Start2 | Bool | %M14.1 | Memory Variable for Glue Pump Start Status of Machine 2 |

**Datablock configuration (DB)**

- Data_ratio




- Data_SS_A1




- Data_SS_A2

| | Name | Data type | Start value | Retain | Accessible f... | Writa... | Visible in ... | Setpoint |
|---|---|---|---|---|---|---|---|---|
| | **DATASS_A2 (snapshot created: 1/5/2025 3:06:54 PM)** | | | | | | | |
| 1 | ▼ Static | | | | | | | |
| 2 | ▸ INPUT_A2 | Array[0..0] o... | | ☐ | ☑ | ☑ | ☑ | ☐ |
| 3 | INPUT_A2[0] | Real | 0.0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 4 | ▸ OUTPUT_A2 | Array[0..15] of Real | | ☐ | ☑ | ☑ | ☑ | ☐ |
| 5 | RET_VAL_A2 | Word | 16#0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 6 | RETURN_A2 | Word | 16#0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 7 | DEST_INDEX_A2 | Int | 0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 8 | MAX_A2 | Real | 0.0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 9 | n | Int | 0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 10 | Start_Record | Bool | false | ☐ | ☑ | ☑ | ☑ | ☐ |

- Data_SS_B1

| | Name | Data type | Start value | Retain | Accessible f... | Writa... | Visible in ... | Setpoint |
|---|---|---|---|---|---|---|---|---|
| | **DATASS_B1 (snapshot created: 1/5/2025 3:06:54 PM)** | | | | | | | |
| 1 | ▼ Static | | | | | | | |
| 2 | ▸ INPUT_B1 | Array[0..0] o... | | ☐ | ☑ | ☑ | ☑ | ☐ |
| 3 | ▸ OUTPUT_B1 | Array[0..15] of Real | | ☐ | ☑ | ☑ | ☑ | ☐ |
| 4 | RET_VAL_B1 | Word | 16#0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 5 | RETURN_B1 | Word | 16#0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 6 | DEST_INDEX_B1 | Int | 0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 7 | MAX_B1 | Real | 0.0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 8 | MAX_B1_offset | Real | 0.0 | ☐ | ☑ | ☑ | ☑ | ☐ |

- Data_SS_B2

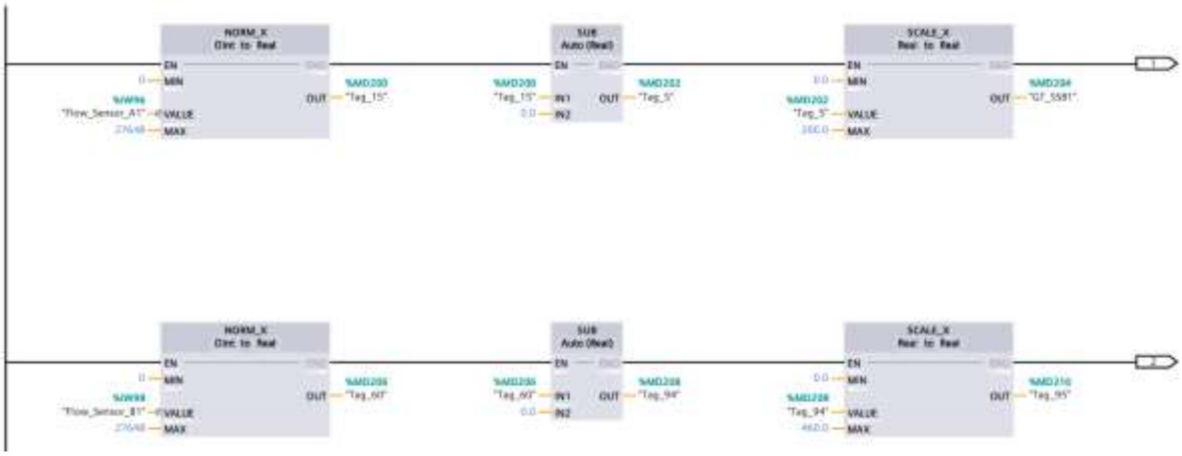
| | Name | Data type | Start value | Retain | Accessible f... | Writa... | Visible in ... | Setpoint |
|---|---|---|---|---|---|---|---|---|
| | **DATASS_B2 (snapshot created: 1/5/2025 3:06:54 PM)** | | | | | | | |
| 1 | ▼ Static | | | | | | | |
| 2 | ▸ INPUT_B2 | Array[0..0] o... | | ☐ | ☑ | ☑ | ☑ | ☐ |
| 3 | ▸ OUTPUT_B2 | Array[0..15] of Real | | ☐ | ☑ | ☑ | ☑ | ☐ |
| 4 | RET_VAL_B2 | Word | 16#0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 5 | RETURN_B2 | Word | 16#0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 6 | DEST_INDEX_B2 | Int | 0 | ☐ | ☑ | ☑ | ☑ | ☐ |
| 7 | MAX_B2 | Real | 0.0 | ☐ | ☑ | ☑ | ☑ | ☐ |

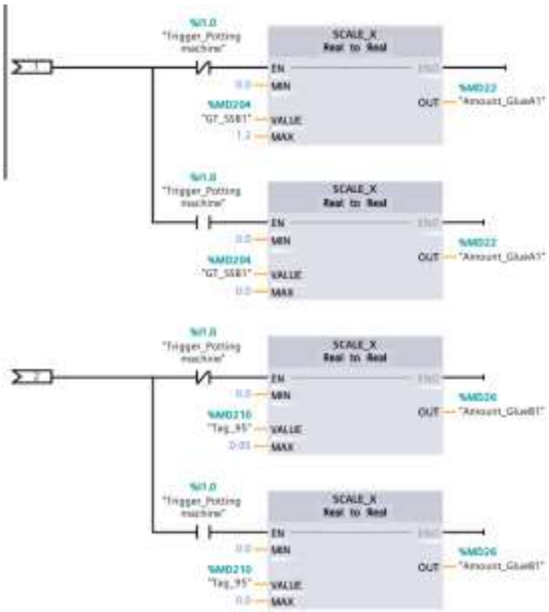
## PLC Program - Main [OB1]

| Main Properties | | | | | | | |
|---|---|---|---|---|---|---|---|
| **General** | | | | | | | |
| Name | Main | Number | 1 | Type | OB | Language | LAD |
| Numbering | Automatic | | | | | | |
| **Information** | | | | | | | |
| Title | "Main Program Sweep (Cycle)" | Author | | Comment | | Family | |
| Version | 0.1 | User-defined ID | | | | | |

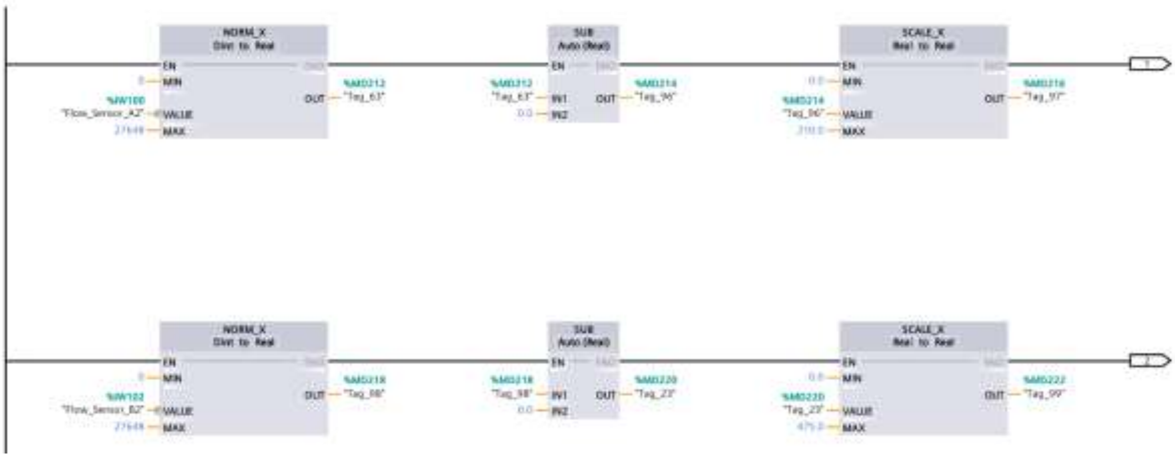
| Main | | | |
|---|---|---|---|
| **Name** | **Data type** | **Default value** | **Comment** |
| ▼ Input | | | |
| Initial_Call | Bool | | Initial call of this OB |
| Remanence | Bool | | =True, if remanent data are available |
| ▼ Temp | | | |
| Test | Bool | | |
| Constant | | | |

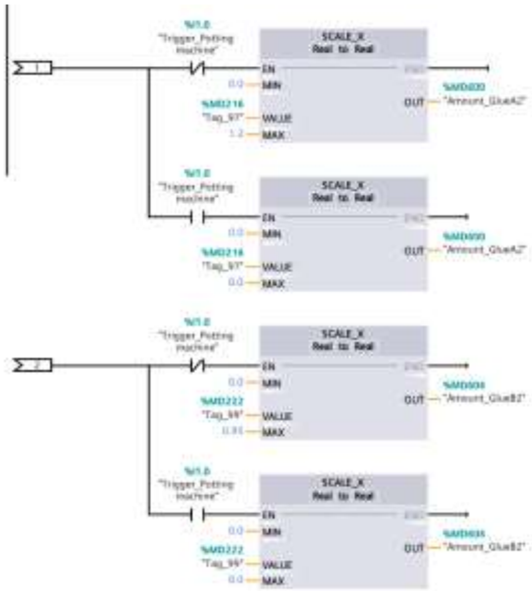
- Network 1: Data_Processing1



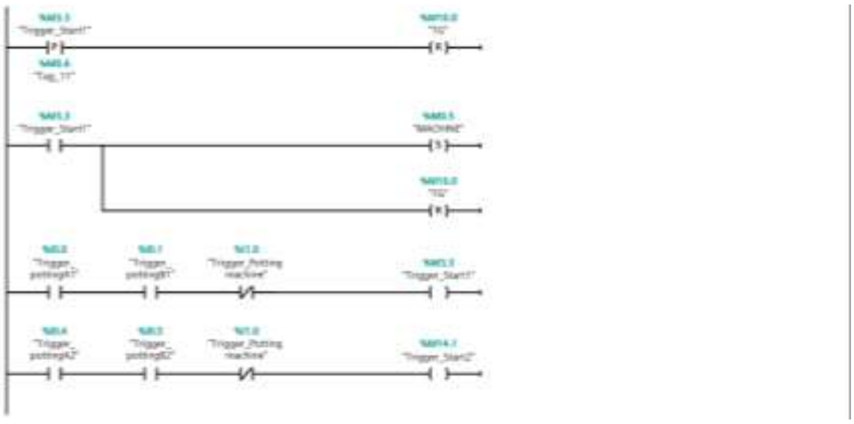


- Network 2: Data_Processing2

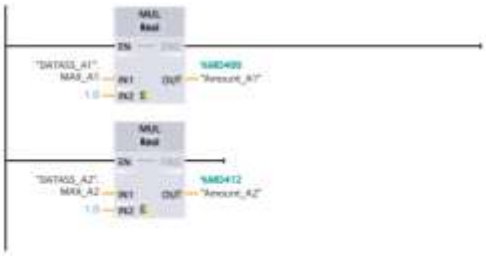




- Network 3: Start activation

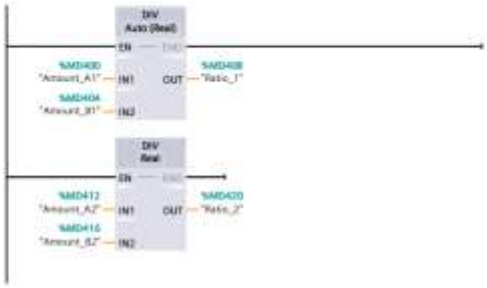


- Network 4: Mass of glue A

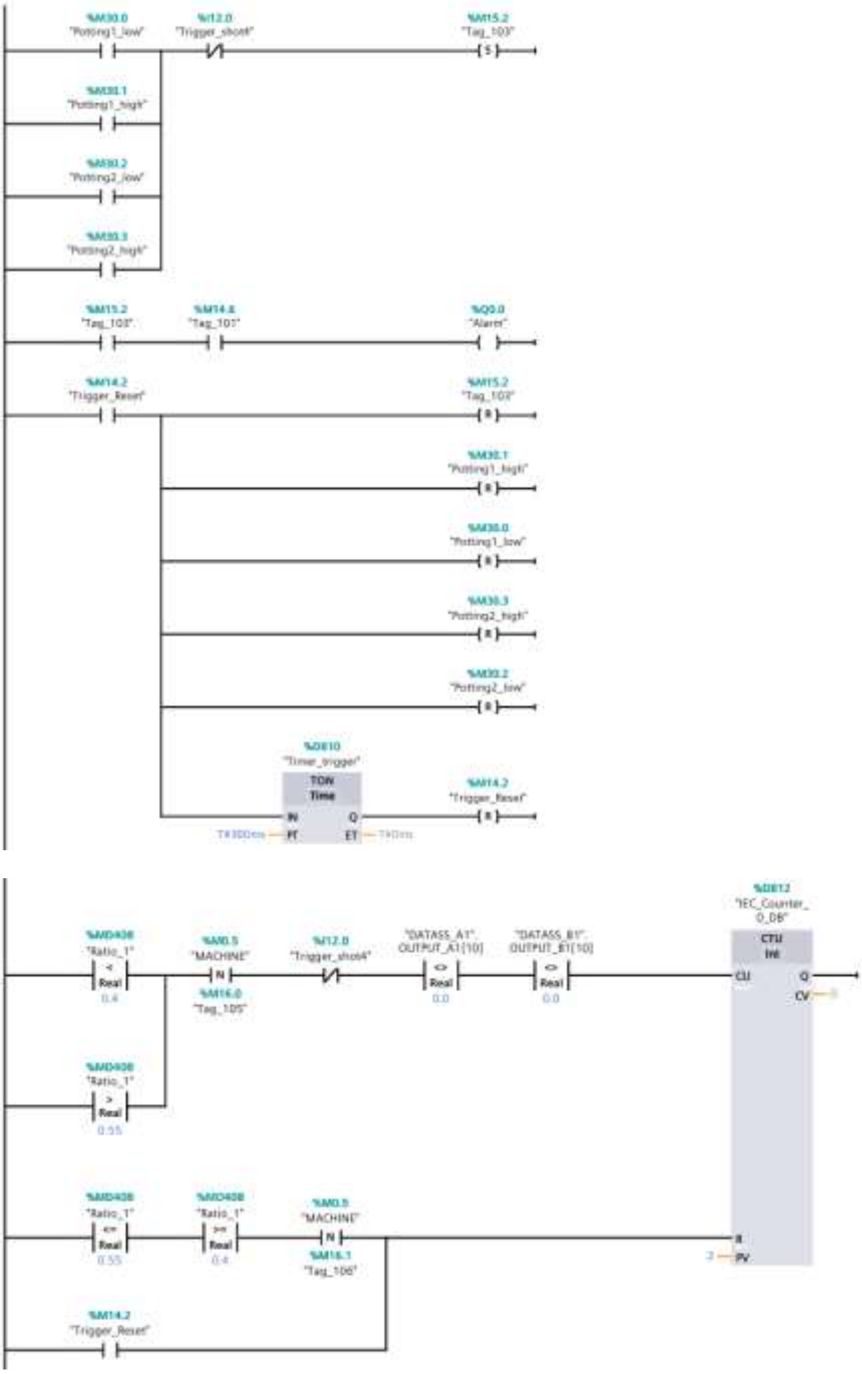


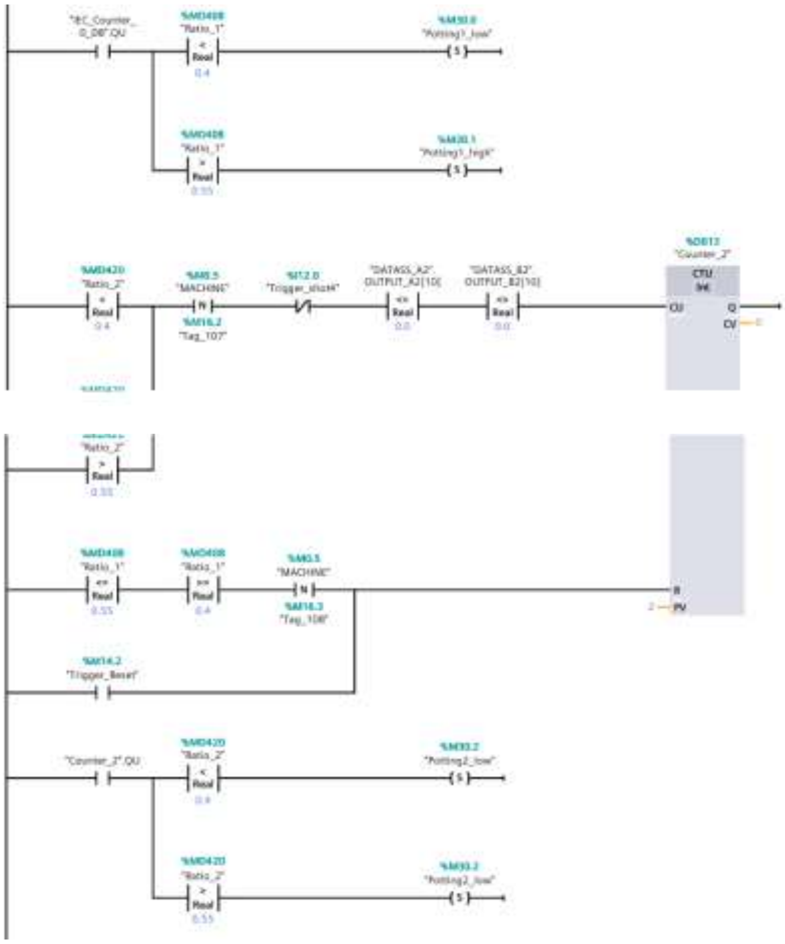
- Network 5: Mass of glue B

- Network 6: A,B ratio




- Network 7: Error handling

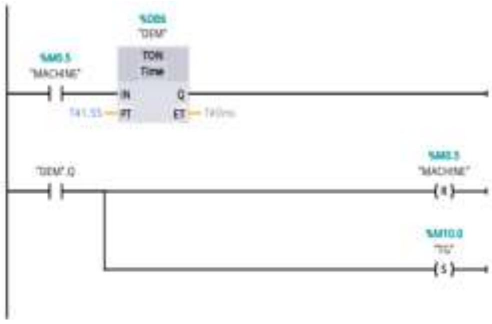




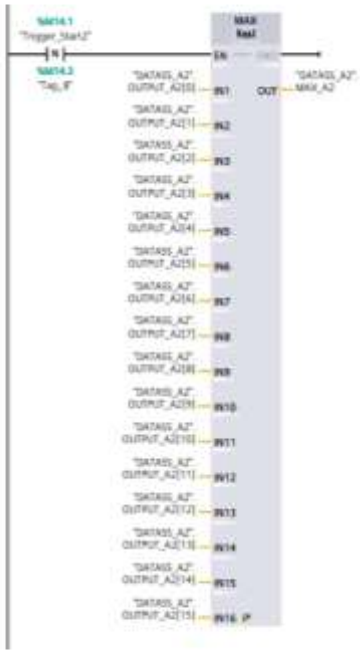
- Network 8: Data Storage A


- Network 9: Data processing A

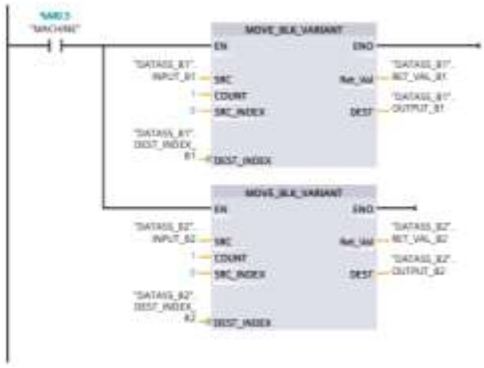

- Network 10: Reset cycle




- Network 11: Data processing A

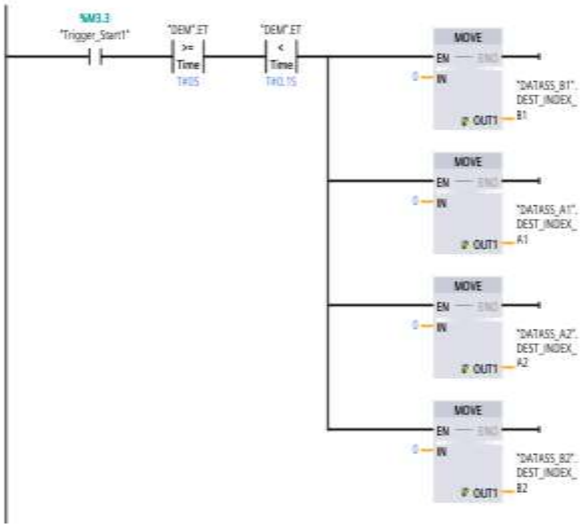



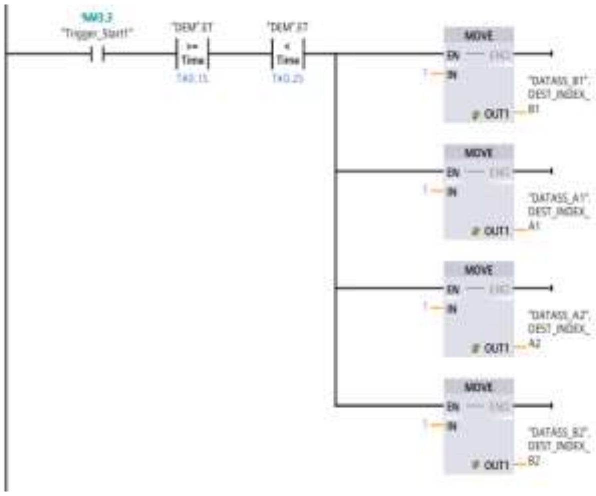

- Network 12: Data Storage B

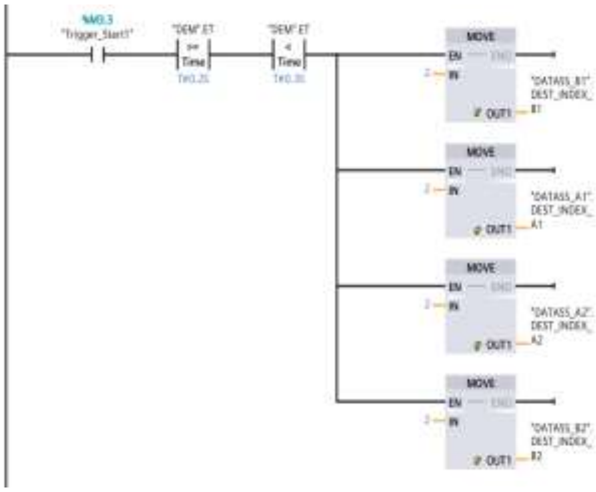


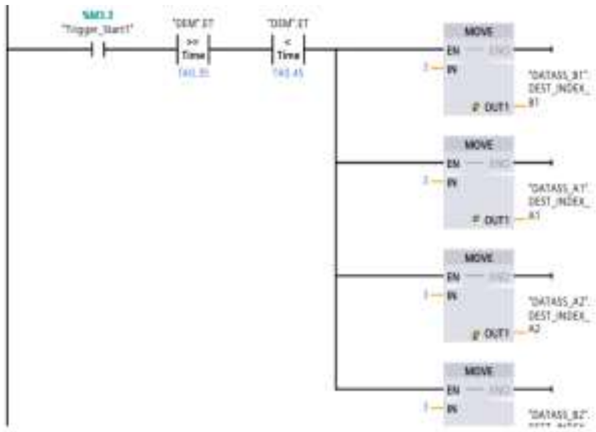

- Network 13: B

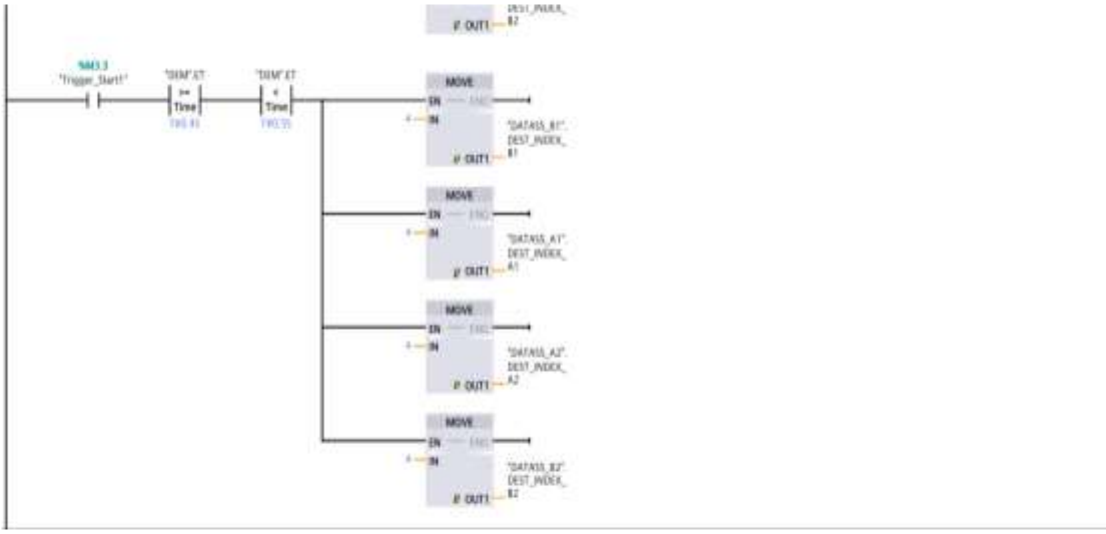

- Network 14: Define array indices




%M3.2
"Trigger_Start1"
"DEM".ET
>=
Time
T#0.1S
"DEM".ET
<
Time
T#0.2S
MOVE
EN
ENO
IN
OUT1
"DATASS_B1".DEST_INDEX_B1
"DATASS_A1".DEST_INDEX_A1
"DATASS_A2".DEST_INDEX_A2
"DATASS_B2".DEST_INDEX_B2


%M3.2
"Trigger_Start1"
"DEM".ET
>=
Time
T#0.2S
"DEM".ET
<
Time
T#0.3S
MOVE
EN
ENO
IN
OUT1
"DATASS_B1".DEST_INDEX_B1
"DATASS_A1".DEST_INDEX_A1
"DATASS_A2".DEST_INDEX_A2
"DATASS_B2".DEST_INDEX_B2


%M3.2
"Trigger_Start1"
"DEM".ET
>=
Time
T#0.3S
"DEM".ET
<
Time
T#0.4S
MOVE
EN
ENO
IN
OUT1
"DATASS_B1".DEST_INDEX_B1
"DATASS_A1".DEST_INDEX_A1
"DATASS_A2".DEST_INDEX_A2
"DATASS_B2".DEST_INDEX_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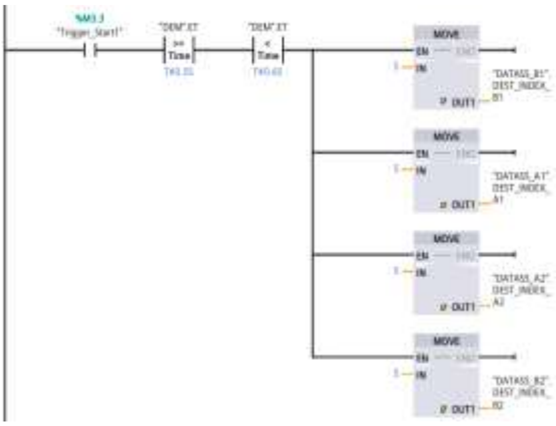
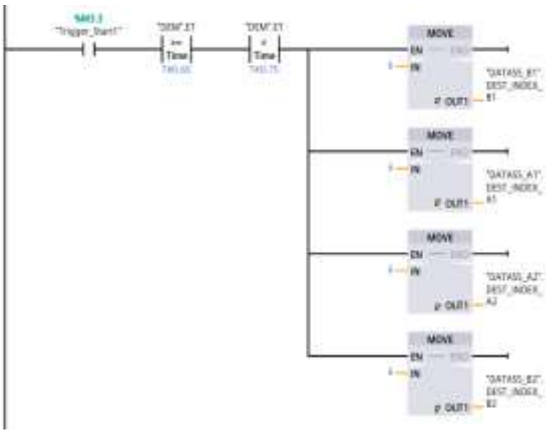
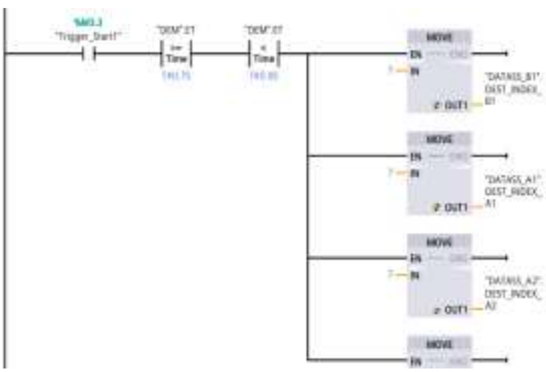
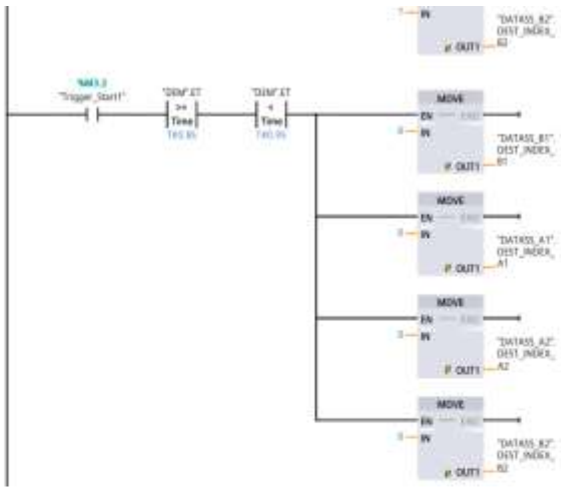
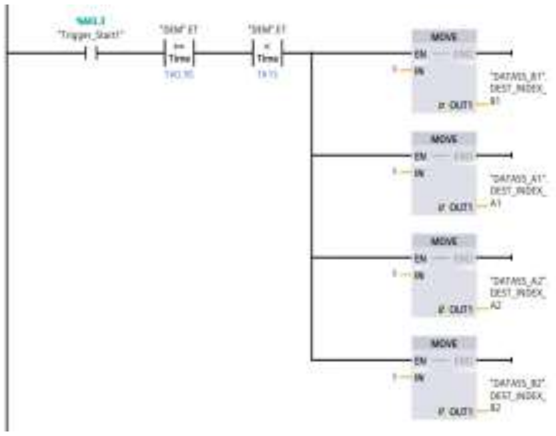
EN
IN
OUT1
Time

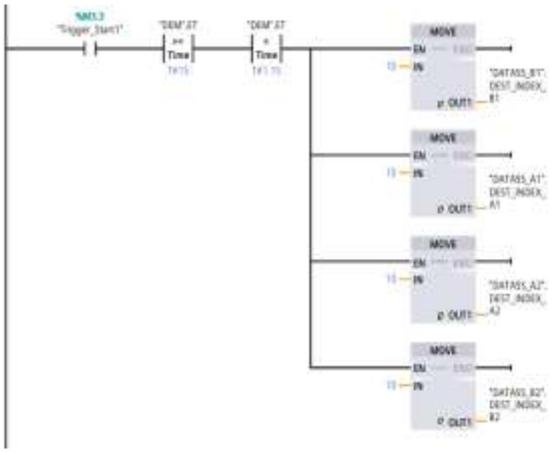

MOVE
EN
IN
OUT1
Time

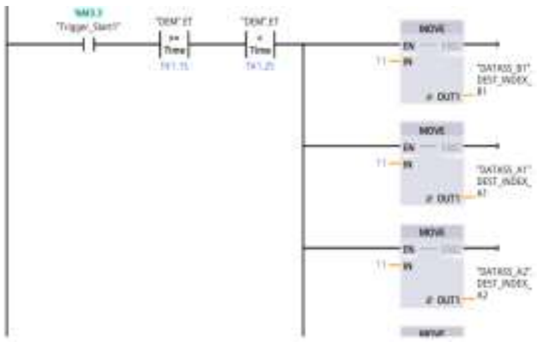

MOVE
EN
IN
OUT1
Time

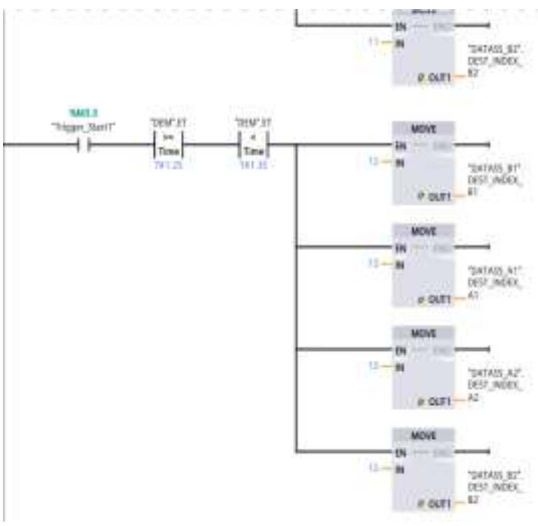

MOVE
EN
IN
OUT1
Time


MOVE
EN
IN
OUT1
Time

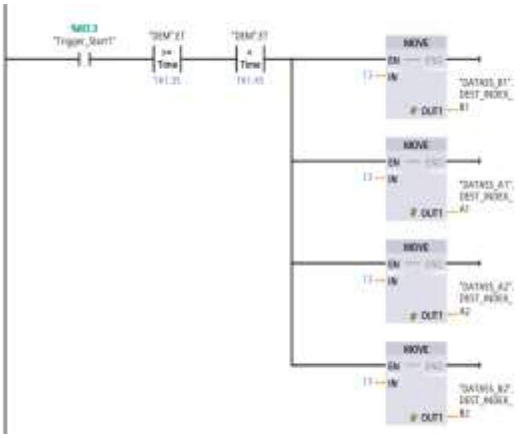

MOVE
EN
IN
OUT1
Time


MOVE
EN
IN
OUT1
Time

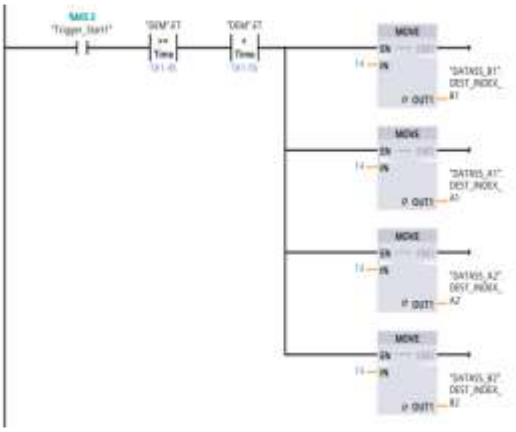

MOVE
EN
IN
OUT1
Time



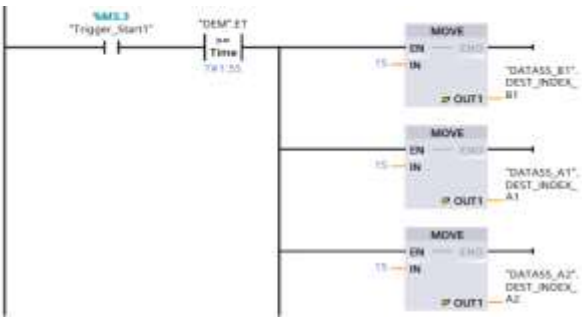
MOVE
EN
IN
OUT1
"Trigger_Start1"
"DEM".ET
Time

MOVE
EN
IN
OUT1
"Trigger_Start1"
"DEM".ET
Time

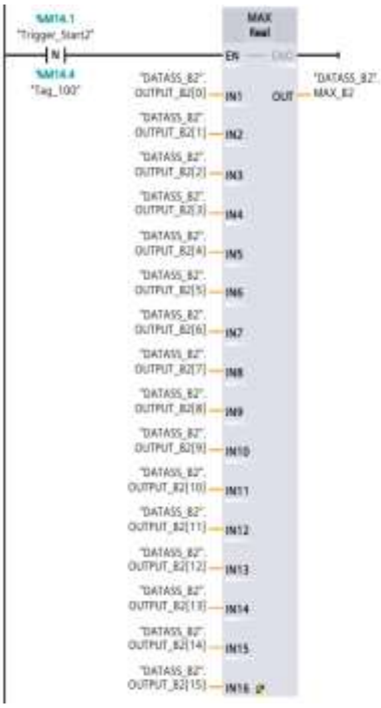



MOVE
EN
IN
OUT1
"Trigger_Start1"
"DEM".ET
Time

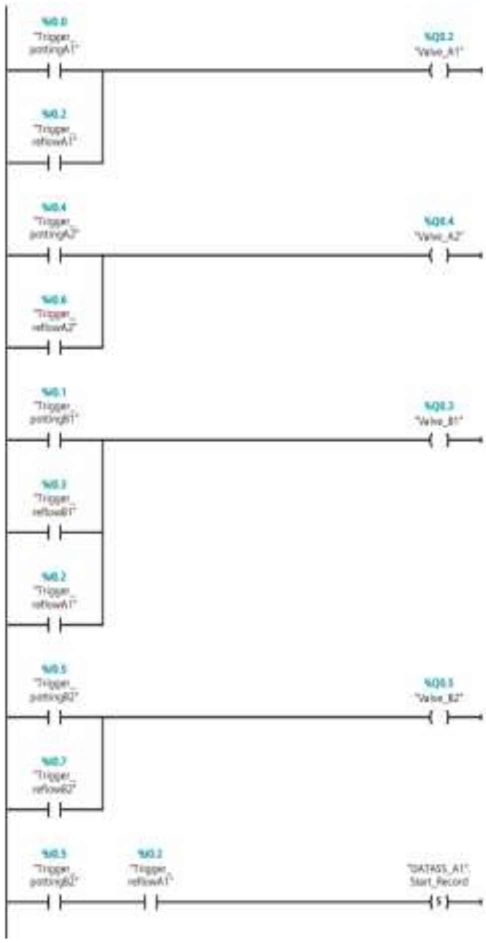



"Trigger_Start1"
"DEM".ET
>=
Time
MOVE
EN
IN
OUT1
"DATASS_B1".
DEST_INDEX_
B1
MOVE
EN
IN
OUT1
"DATASS_A1".
DEST_INDEX_
A1
MOVE
EN
IN
OUT1
"DATASS_A2".
DEST_INDEX_
A2

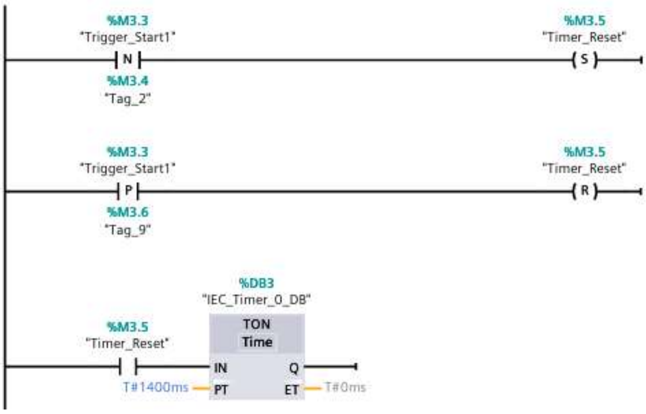

- Network 15: Data processing B

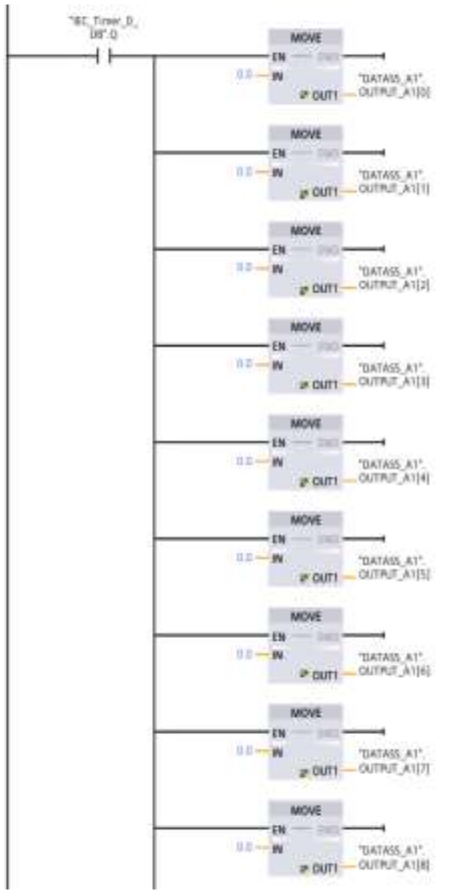



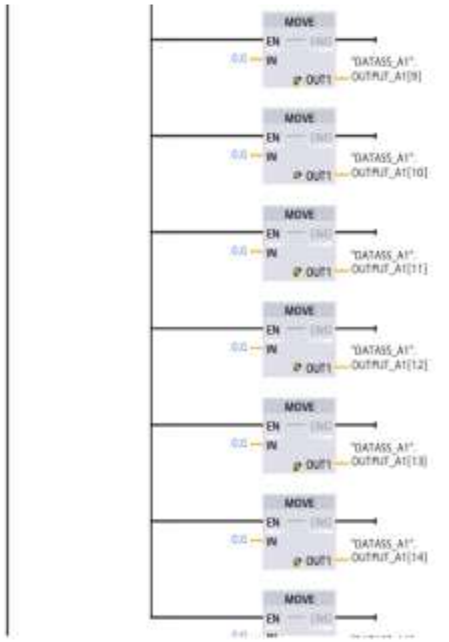

- Network 16: Trigger Valve

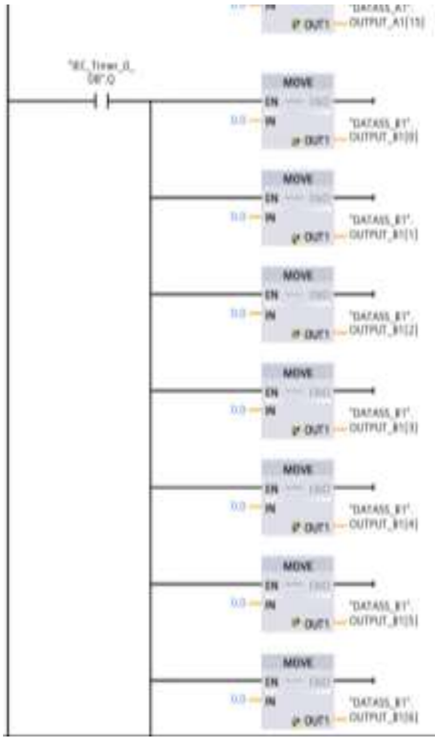


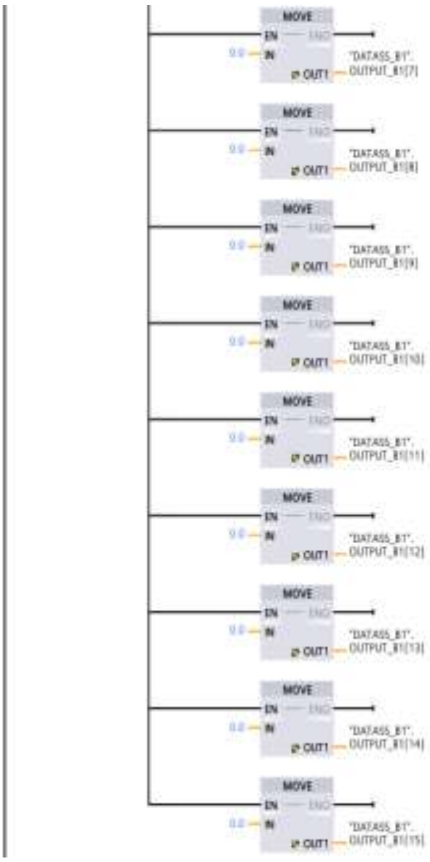
- Network 17: Reset data

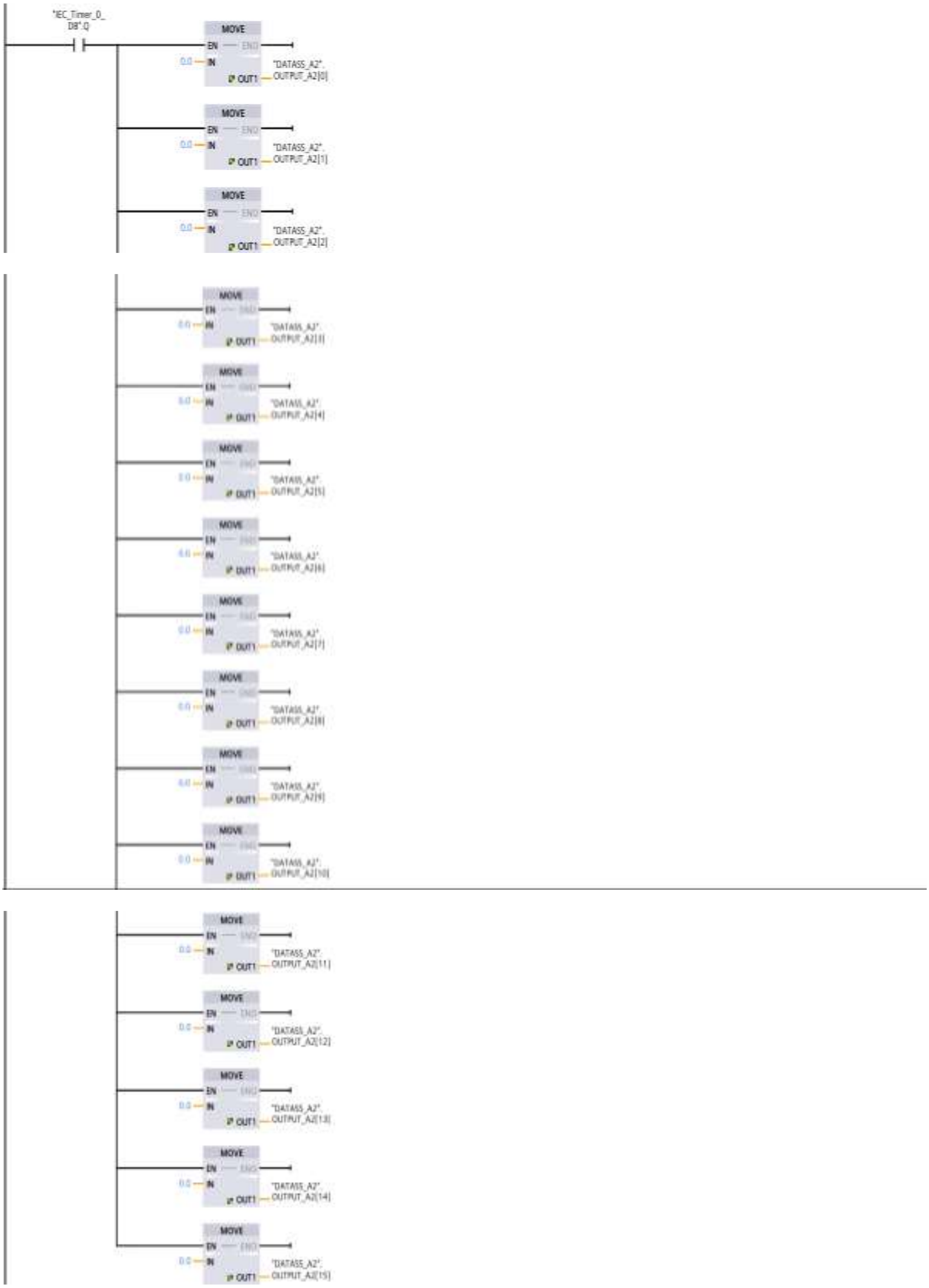


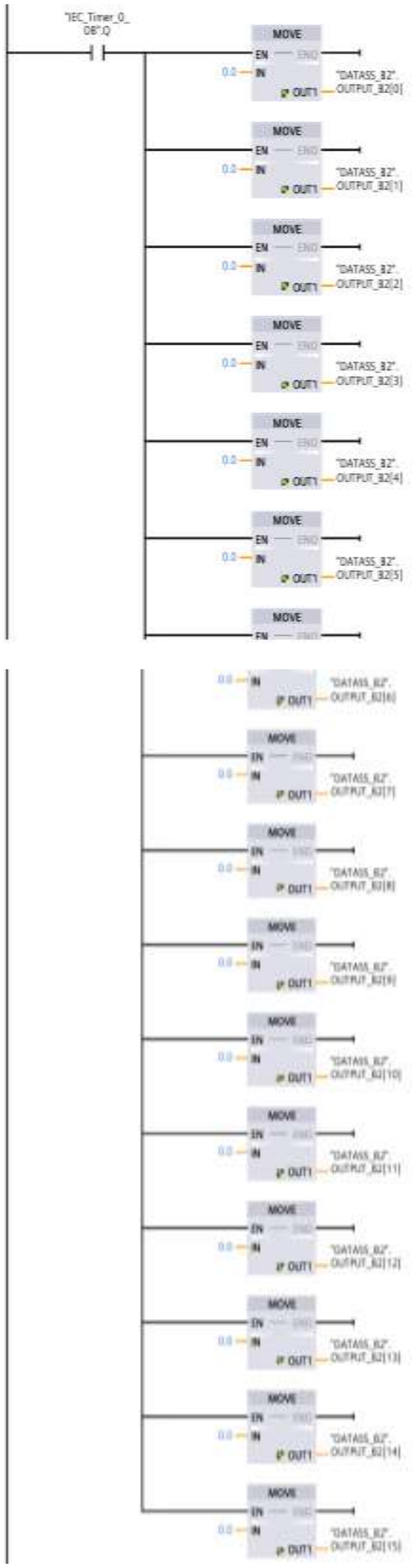

MOVE
EN
IN
OUT1
0.0
"DATASS_A1".
OUTPUT_A1[0]
"DATASS_A1".
OUTPUT_A1[1]
"DATASS_A1".
OUTPUT_A1[2]
"DATASS_A1".
OUTPUT_A1[3]
"DATASS_A1".
OUTPUT_A1[4]
"DATASS_A1".
OUTPUT_A1[5]
"DATASS_A1".
OUTPUT_A1[6]
"DATASS_A1".
OUTPUT_A1[7]
"DATASS_A1".
OUTPUT_A1[8]


MOVE
EN
IN
OUT1
0.0
"DATASS_A1".
OUTPUT_A1[9]
"DATASS_A1".
OUTPUT_A1[10]
"DATASS_A1".
OUTPUT_A1[11]
"DATASS_A1".
OUTPUT_A1[12]
"DATASS_A1".
OUTPUT_A1[13]
"DATASS_A1".
OUTPUT_A1[14]

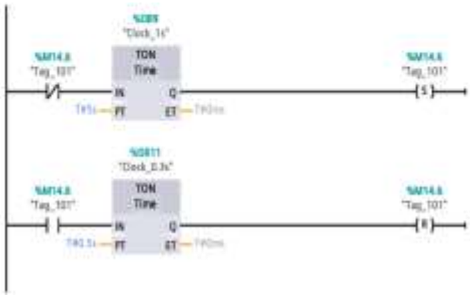

"DATASS_A1".OUTPUT_A1[15]
"IEC_Timer_0_DB".Q
MOVE
EN
ENO
IN
OUT1
"DATASS_B1".OUTPUT_B1[0]
"DATASS_B1".OUTPUT_B1[1]
"DATASS_B1".OUTPUT_B1[2]
"DATASS_B1".OUTPUT_B1[3]
"DATASS_B1".OUTPUT_B1[4]
"DATASS_B1".OUTPUT_B1[5]
"DATASS_B1".OUTPUT_B1[6]


MOVE
EN
ENO
IN
OUT1
"DATASS_B1".OUTPUT_B1[7]
"DATASS_B1".OUTPUT_B1[8]
"DATASS_B1".OUTPUT_B1[9]
"DATASS_B1".OUTPUT_B1[10]
"DATASS_B1".OUTPUT_B1[11]
"DATASS_B1".OUTPUT_B1[12]
"DATASS_B1".OUTPUT_B1[13]
"DATASS_B1".OUTPUT_B1[14]
"DATASS_B1".OUTPUT_B1[15]


"IEC_Timer_0_DB".Q
MOVE
EN
ENO
IN
OUT1
0.0
"DATASS_A2".OUTPUT_A2[0]
"DATASS_A2".OUTPUT_A2[1]
"DATASS_A2".OUTPUT_A2[2]
"DATASS_A2".OUTPUT_A2[3]
"DATASS_A2".OUTPUT_A2[4]
"DATASS_A2".OUTPUT_A2[5]
"DATASS_A2".OUTPUT_A2[6]
"DATASS_A2".OUTPUT_A2[7]
"DATASS_A2".OUTPUT_A2[8]
"DATASS_A2".OUTPUT_A2[9]
"DATASS_A2".OUTPUT_A2[10]
"DATASS_A2".OUTPUT_A2[11]
"DATASS_A2".OUTPUT_A2[12]
"DATASS_A2".OUTPUT_A2[13]
"DATASS_A2".OUTPUT_A2[14]
"DATASS_A2".OUTPUT_A2[15]




- Network 18: Delay_time


"Clock_1s"
TON
Time
"Tag_101"
IN
Q
PT
ET
"Tag_101"
TON
Time
"Tag_101"
IN
Q
PT
ET
"Tag_101"

# APPENDIX 2

**Task assignment table**

| No. | Full name | Student ID | Main Responsibilities | Remarks |
|---|---|---|---|---|
| **1** | Huu Quan Huynh | 101200239 | Research and evaluate the machine's condition and develop improvement strategies. | Team leader |
| | | | Developing a method for calculating the volume of the vacuum chamber and evaluating the results. | |
| | | | Proposal for electrical system enhancement with integrated flow sensor. | |
| | | | Design of I/O diagrams, PLC control algorithm flowcharts, and system layout drawings. | |
| | | | Implement and install the entire improved electrical system: PLC programming, sensor configuration, HMI setup, etc | |
| | | | Collecting data and preparing a report to evaluate the effectiveness of the improvements. | |
| **2** | Nhat Huy Nguyen Van | 100200356 | Design and prepare manufacturing drawings for the improved adhesive pump tool | |
| | | | Assemble and test the improved tools | |
| | | | Inspect and collect data on the adhesive volume | |

| | | | | |
|---|---|---|---|---|
| | | | dispensed by the pumps after improvements | |
| | | | Measure the cycle time and calculate the vacuum chamber volume | |
| | | | Conduct experiments and plot charts illustrating the adhesive volume from the improved pumps | |
| **3** | Van Hau Nguyen Huynh | 101200350 | Calculate and determine the required velocity and the amount of adhesive to be dispensed for each product | |
| | | | Set up and program the adhesive dispensing head's movement trajectory | |
| | | | Design of product-holding tool for the machine | |
| | | | Design the layout for component placement on the production line | |
| | | | Develop a flowchart for the operational process | |