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Applied Programmable Logic Controllers

Module: ACDA6000

Factory Control.

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Abbreviations

- HMI- Human Machine Interface
- PLC- Programable Logic Controller
- TIA- Totally Intergrated Automation Portal
- E-Stop- Emergency Stop
- I/O - Input & Outputs.

Abstract:

Report detailing the design, programming, and operation of the factory system, highlighting the vital role PLCs play in industrial automation. The project demonstrates the practical application of PLC programming to create a scalable and efficient sorting system of packaging boxes. Displaying the key benefits of industrial automation and how it can enhance productivity while ensuring safety and reliability.

Introduction:

PLC's Play a pivotal role in the modern world specifically in industrial automation engineering such as production assembly lines, Process control plants and manufacturing environments. The automation of a system has several positive impacts improving efficiency, productivity, and precision. At the Centre of any automation lies the Programmable Logic Controller (**PLC**). A robust and versatile computing device designed to monitor and control industrial machinery and processes. Often described as the workhorse of PLC's have become a cornerstone of automation due to their reliability, flexibility, and ability to execute real-time control.[1]

A major advantage of the PLC lies in reliability, increasing system performance and stability limiting the need for human operators not only reduces the chance of the human error factor but also can remove a human from a potential hazardous environment which can dramatically improve the health and safety of the workforce.

This Report focuses specifically on Siemens S7-12 PLC and the use of the simulation software Factory I/O to design and program a packaging factory automation system. The project involves creating a system capable of sorting packages based on size and weight, incorporating essential components such as conveyor belts, sensors, pushers, and safety mechanisms. Additionally, the system will integrate a Human-Machine Interface (**HMI**) to facilitate operator interaction, enhancing usability and system control and fault diagnostics.

Components Comparison:

The selection of which components to be used is a crucial step in the project. Understanding the importance of selecting the correct PLC. Table.1 below outlines the strengths and weaknesses of each PLC brand, offering insight into what brand will be most suitable for the Task. Factors such as cost, usability and scalability are considered.

Manufacturer	Siemens [2]	Allen Bradley [3]	Mitsubishi Electric [4]
Cost	Moderate to High (approx. £350 - £1,500)	High (approx. £800 - £3,000)	Low to Moderate (approx. £250 - £1,200) ★
User-Friendly	Pros: TIA Portal integrates PLC & HMI programming. Widely documented.★ Cons: Software requires significant memory and resources.	Pros: Studio 5000 Logix Designer offers powerful debugging tools. Cons: High complex for entry-level use.	- Pros: Compact and straightforward for small-medium systems. Cons: Limited advanced features compared to competitors.
Reliability	Excellent reliability in industrial environments.★	High reliability for complex systems.	Reliable for small and mid-scale applications.
Region Popularity	- Popular in Europe. - Widely used in industries like manufacturing, automotive, and energy.★	- Primary used in North America. - Preferred in oil, gas, and heavy manufacturing.	- Preferred in Japan/Asia. - Common in automotive and electronics industries.
Cost of Ownership	Moderate: Initial cost is high, but maintenance and scalability are cost-effective.	High: Expensive hardware, software, and licensing costs.	Low: Affordable hardware and simple maintenance.★
Scalability	High.★	High.★	Moderate.
Technical Support	Excellent support in Europe.★	Comprehensive support in North America.	Reliable support in Asia.

Table.1

Evaluation

- Siemens ★ ★ ★ ★ ★ ★

- Allen Bradley ★ ★
- Mishibishu ★ ★ ★

After evaluating the three options, the decision was made to proceed with the **Siemens S7-1200 PLC** for this project due to its several key advantages. These include user-friendliness, scalability, long-term cost-effectiveness, and its widespread use and support within Europe.

User-Friendly:

The Siemens S7-1200 is highly regarded for its intuitive programming environment, TIA Portal (Totally Integrated Automation Portal). This integrated software suite simplifies both PLC and Human-Machine Interface (HMI) programming, streamlining the design, implementation, and troubleshooting processes. The TIA Portal makes it easier for both experienced engineers and entry-level users to operate the system, reducing the learning curve and boosting overall efficiency.

Regional Popularity and Support:

Siemens PLCs are widely used across Europe, which ensures comprehensive technical support and access to a vast knowledge base. The availability of resources, both online and from local suppliers, makes Siemens a practical choice for this project.

Cost of Ownership:

Although the **initial cost** of Siemens PLCs is **moderate to high** compared to other brands, the **long-term cost of ownership** is more favorable. The Siemens S7-1200 offers excellent reliability and requires minimal maintenance. Additionally, the modular design of the S7-1200 allows for future scalability without requiring a complete overhaul. For example, the cost of expanding the system with additional modules (such as I/O modules or communication modules) is low, making Siemens PLC an attractive long-term investment.

Price Range: The price of a basic **Siemens S7-1200 PLC** starts around **£350** for a compact CPU, with larger systems or more advanced models reaching up to **£1,500**.

Scalability: The modular design of the S7-1200 supports the addition of extra input/output (I/O) modules, ensuring the system can grow as needed. For example, if additional conveyor belts or sensors are added in the future, the Siemens PLC can easily adapt without requiring a complete overhaul.

The S7-1200 PLC has been successfully deployed in several automotive manufacturing facilities, where it controls the automation of assembly lines using high-speed conveyors and sensors for product tracking. The BMW Group favors Siemens at its

Leipzig plant due to the scalability of the system, as changes in production lines can be easily implemented, allowing the system to be modified and reused for different applications." [12]

Compact and Efficient Design:

The physical size of the Siemens S7-1200 is compact, allowing it to fit seamlessly into standard DIN rail-mounted control panels. Despite its small size, it offers extensive functionality to handle the complex sorting logic required for this project. Figure.1 [5] below depicts the Siemens S7-1200 module.



Figure.1 [5]

Conveyor Selection- The conveyor belt was selected for its suitability in handling boxes and lightweight products, providing smooth and consistent movement along the production line. Roller conveyors are used in areas where heavier items, such as large or bulky products, need to be transported with minimal effort.

Factory Design in Factory I/O:

Factory I/O is a 3D factory simulation software package designed to be user friendly, allowing the user to build a virtual factory using a selection of common industrial parts. It is specifically used for learning automation technologies. [6] This project utilizes Factory I/O to design a package sorting system that integrates with chosen Siemens PLC for real-time control and automation. The system is designed to sort packages based on their size and weight.

Factory Design

Figure.2 below illustrates the complete system of the Package sorting automation line which is a built up of several components such as conveyor belts, sensors, two box pushers, a weight scale with pop up sorter, stack light and sounder. Also included will be two control panels, where the plc would be mounted and an HMI screen fitted.



Figure.2 Conveyor System Design

Control Panel

The control panel houses the PLC and will have several features embedded to allow operator control. Figure.3 below shows the main control panel. It depicts the Stop/ Start manual buttons, stack lights. Light with red (Fault), Amber (warning) and green (normal operation), manual buttons and Siren 0 acts as a sound signal to notify all operators that the system is about to start up.

Emergency stop button.

The most important part of any automated system is the Emergency stop as this provides a safety critical feature allowing the system to immediately stop if pressed and will be unable to restart until released acknowledged and reset in the plc.

According to the Provision and Use of Work Equipment Regulations (PUWER) 1998 which is a legal requirement in the U.K:

PUWER requires that all work equipment, including conveyor systems, must be safe to use and properly maintained.

- Regulation 16 states that machinery must have "suitable controls for starting, stopping, and controlling" equipment, including Emergency Stops where necessary to prevent injury. [7]

Design Requirements are under the British standard *BS EN ISO 13850:2015* [8]

The E-Stop must be:

Easily accessible: Positioned so operators can reach it quickly in an emergency.

Visible: Usually marked in red with a yellow background.

Latching: Remains activated until manually reset. [8]

The system must prevent restarting the machine automatically after the E-Stop is reset. This system successfully complies.



Figure.3 Main Control Panel

The Second control panel illustrated in figure.4 also features a Stack lighting system, emergency stop. Further to this an LCD Display which allows real time visual display of the weight of each measured box from the weighing scale conveyor. Siren 1 is utilized to sound a warning alert if either pusher encounters a problem.

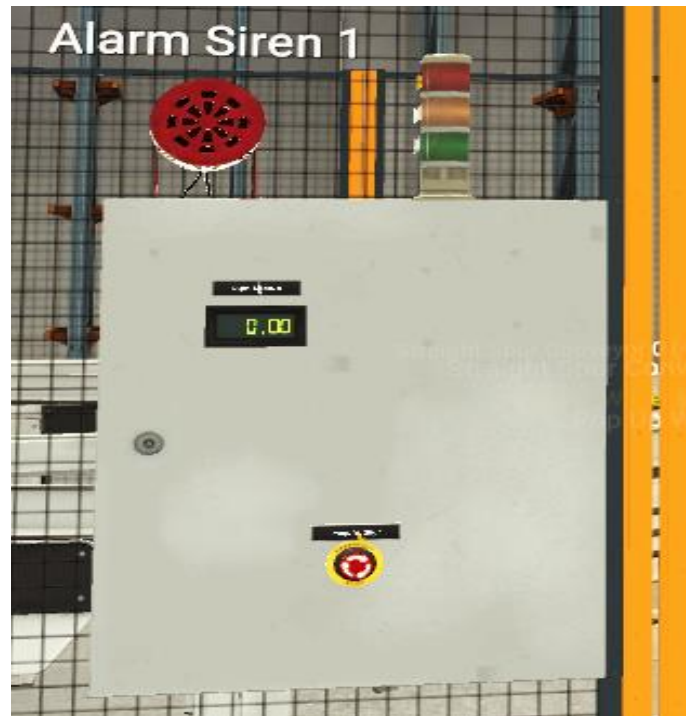


Figure.4 Secondary control panel

Sorting Mechanism

A close-up view of the pushers, scale conveyor, and pop-up sorter is shown, demonstrating how packages are sorted into lanes based on size and weight.

Figure.5 below illustrates this setup. Component **(A)** the pusher, operates based on input from a strategically positioned sensor. This sensor detects medium-sized boxes and sends a delayed output signal to the pusher. Upon activation, the pusher directs the box onto the scale conveyor **(B)**.

On the scale conveyor, the weight of the box is measured, and this value determines how the pop-up sorter **(C)** will turn. The sorter then organizes boxes into designated lanes based on weight. This entire operation is managed by the PLC, which processes I/O signals and executes the programmed logic designed by the software engineer, ensuring accurate and efficient sorting.

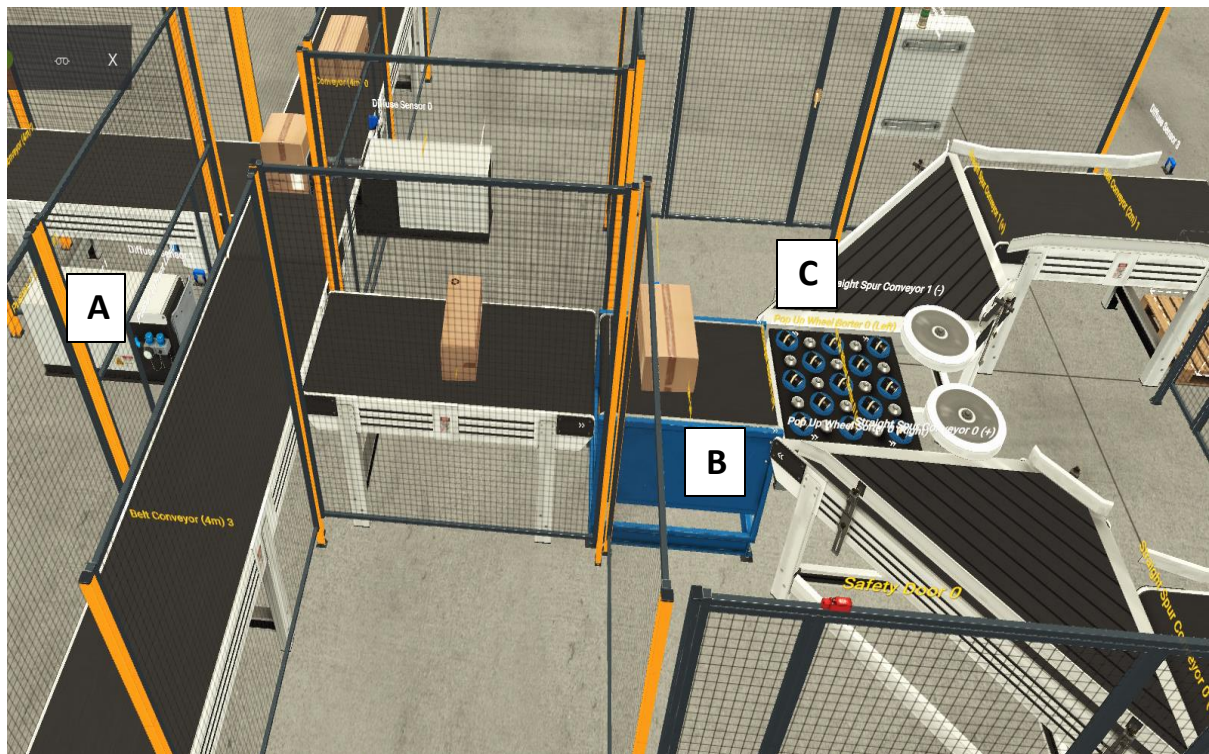


Figure.5 *Medium box sorting process*

The Factory I/O driver in figure.6 highlights all connected inputs and outputs, illustrating a real-world automation setup.

Start Button 1	%I16.0	%Q16.0	Belt Conveyor (4m) 0
Stop Button 0	%I16.1	%Q16.1	Belt Conveyor (4m) 1
Emergency Stop 0	%I16.2	%Q16.2	Belt Conveyor (4m) 2
Emergency Stop 1	%I16.3	%Q16.3	Belt Conveyor (4m) 3
	%I16.4	%Q16.4	Belt Conveyor (2m) 0
	%I16.5	%Q16.5	Belt Conveyor (2m) 1
	%I16.6	%Q16.6	Belt Conveyor (2m) 2
	%I16.7	%Q16.7	Alarm Siren 1
Diffuse Sensor 0	%I17.0	%Q17.0	Alarm Siren 0
Diffuse Sensor 1	%I17.1	%Q17.1	Pusher 0
Diffuse Sensor 2	%I17.2	%Q17.2	Pusher 1
Diffuse Sensor 3	%I17.3	%Q17.3	Warning Light 0
Diffuse Sensor 4	%I17.4	%Q17.4	Conveyor Scale 0 (+)
Diffuse Sensor 5	%I17.5	%Q17.5	Pop Up Wheel Sorter 0 (+)
Diffuse Sensor 6	%I17.6	%Q17.6	Pop Up Wheel Sorter 0 (Left)
	%I17.7	%Q17.7	Pop Up Wheel Sorter 0 (Right)
Pusher 0 (Front Limit)	%I18.0	%Q18.0	Straight Spur Conveyor 0 (-)
Pusher 1 (Front Limit)	%I18.1	%Q18.1	Straight Spur Conveyor 1 (+)
	%I18.2	%Q18.2	Stack Light 0 (Red)
	%I18.3	%Q18.3	Stack Light 0 (Yellow)
	%I18.4	%Q18.4	Stack Light 0 (Green)
	%I18.5	%Q18.5	Stack Light 1 (Red)
Safety Door 1	%I18.6	%Q18.6	Stack Light 1 (Yellow)
	%I18.7	%Q18.7	Stack Light 1 (Green)
Conveyor Scale 0 Weight (V)	%ID30 (REAL)	(REAL) %QD30	Digital Display 0
	%ID34	%QD34	
	%ID38	%QD38	
	%ID42	%QD42	
	%ID46	%QD46	
	%ID50	%QD50	
	%ID54	%QD54	
	%ID58	%QD58	

Figure.6 *Driver in factory IO*

Flow Chart:

To ensuring the success of any project with multiple tasks and sequences can be difficult to understand and interpret through text alone. Visual displays such as Flowcharts allow for easy user-friendly understanding of the step-by-step procedure to be broken down into smaller tasks to help with understanding and any fault finding in the testing and commissioning stage. [9]

A flowchart has been created illustrating the system's operation is provided below in Figure.7. The Flow Chart replicates what is trying to be achieved in the Factory control system. By Implemented the Questions such as Is any alarm Active before system commences allows the software engineer to understand all alarms need to be acknowledge and cleared before system operational start up. This can be written into the ladder logic of the plc program and demonstrated on the HMI screen for the operators to understand. Once Cleared the system can start up and begins to run through the process of sorting boxes based on their size and weight. Further Questions are asked to determine what outputs are active.

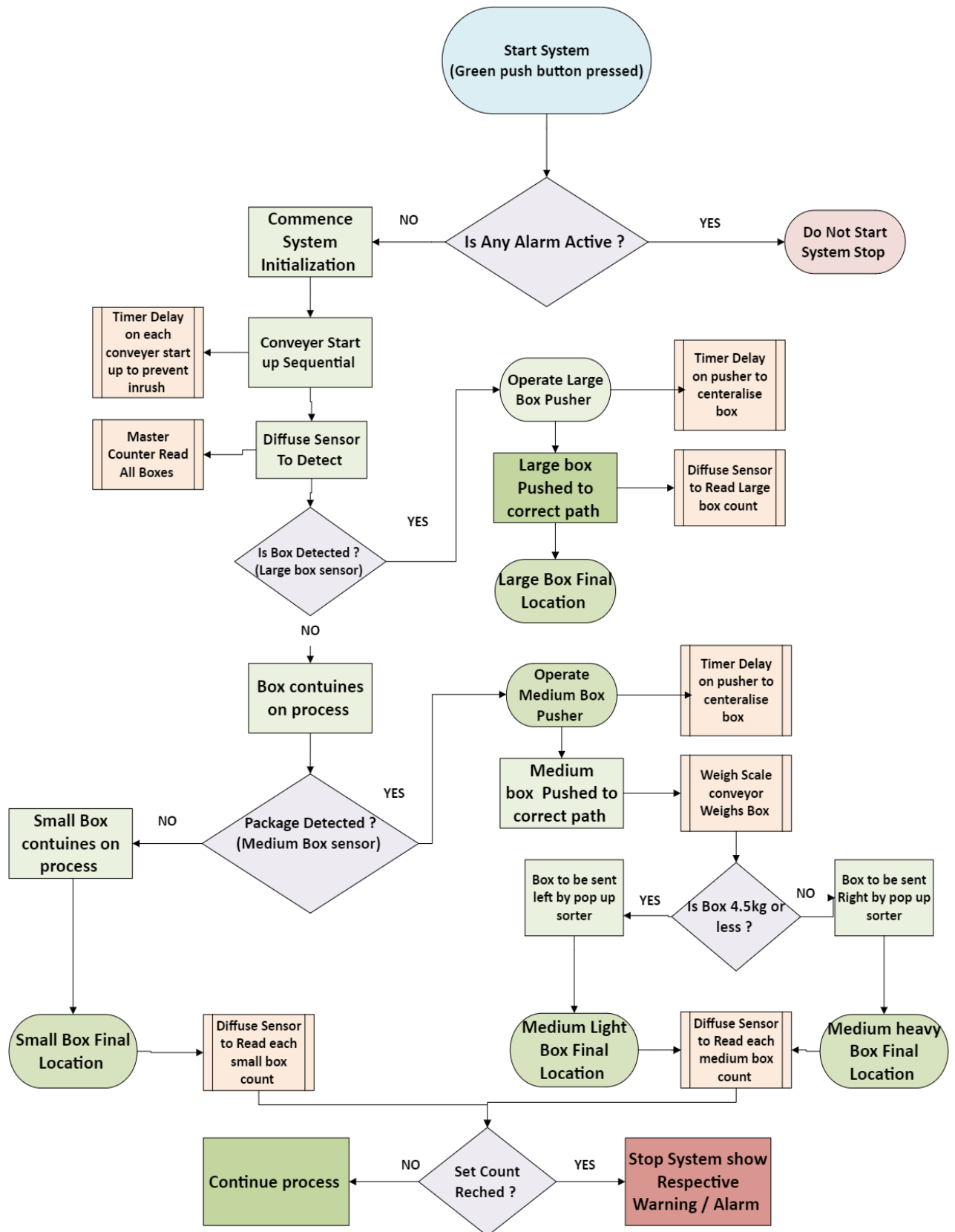


Figure.7

Figure.7 flowchart mirrors the sequence of operations implemented in the ladder logic, providing a clear critical path for system behavior.

Ladder Logic:

The ladder logic for the automated sorting system was developed using Siemens TIA Portal software with detailed Purpose & Function of each network. [10]

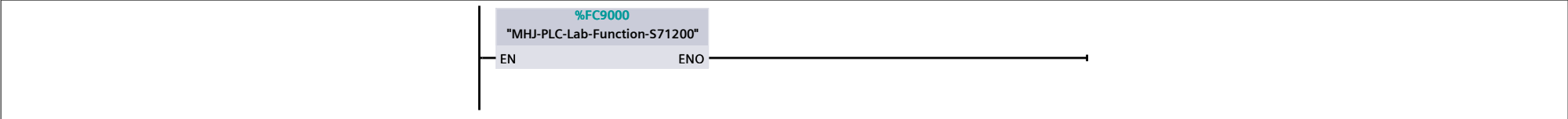
Project 1.4 / PLC_1 [CPU 1214C DC/DC/DC] / Program blocks

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			
Constant			

Network 1: Main Function



Network 2: Start / Stop System

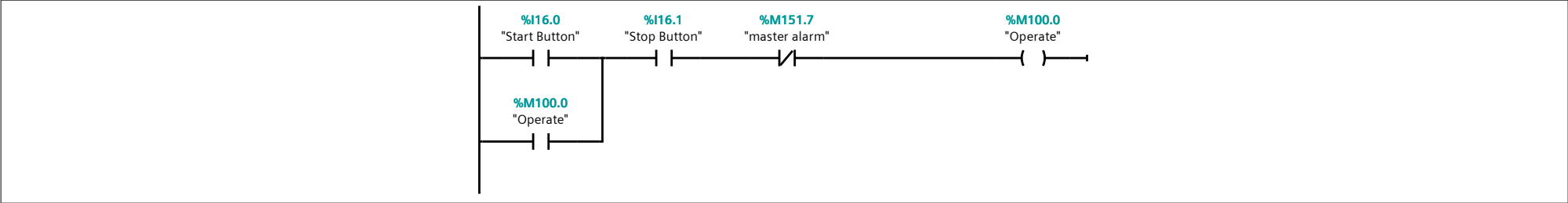
Purpose: Provides manual control, allowing the operator to start and stop the system using the control panel buttons or the HMI screen. The system will operate only if no alarms are active.

Function:

I6.0- Start button pressed operates memory bit M100.0 to set.

I6.1- Stop button pressed operates memory bit M100.0 to re-set this will stop all operations including all conveyor, pushers and any other active components.

M151.7- Master Alarm act as safe interlock to the system preventing starting the system under any active alarm. The system will not start unless all alarms have been cleared.



Network 3: Stack Light Operation

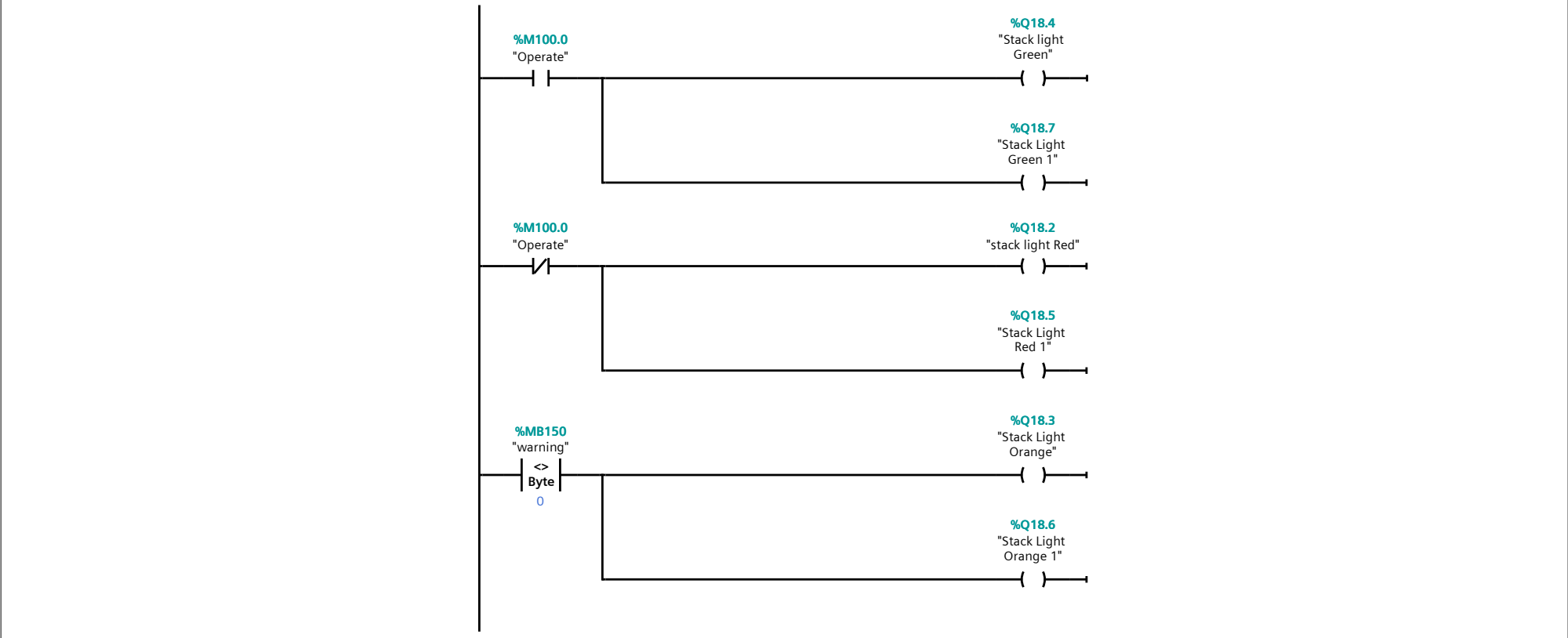
Purpose: Purpose: Displays the operational status of the system using a stack light. The stack light serves as an additional safety feature, providing visual signals to the operator.

Function:

Q18.4 & Q18.7 Stack light green normal operation (running) with no warnings or alarms the memory bit is M100.0 as previously stated for operate.

Q18.2 & Q18.5 Stack light Red. System Stopped as M100.0 is closed. Additionally Stopped under Alarm which will activate if memory M151 is triggered. M151 is the byte for all 8 alarms.

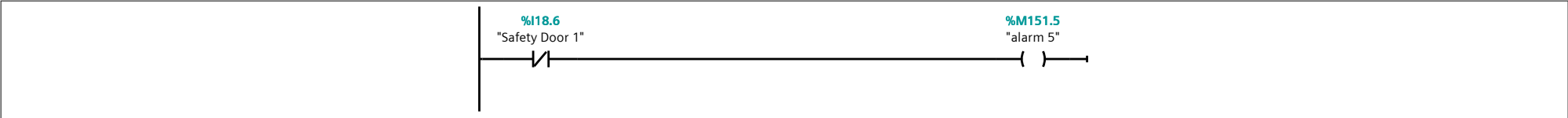
Q18.3 & Q18.6 Stack light Orange. System warning this will operate if any of the warnings are triggered from memory M150 the byte for all the warnings. However the system will still run under warning allowing the operators to acknowledge and rectify the warning accordingly.



Network 4: Safety door

Purpose:Ensures operator and maintenance personnel are safe when entering the hazardous area by stopping the system while the door is open.

Function:
I8.6 input is open will trigger Alarm 5. Stopping the system. Disables system untill door is securely closed.

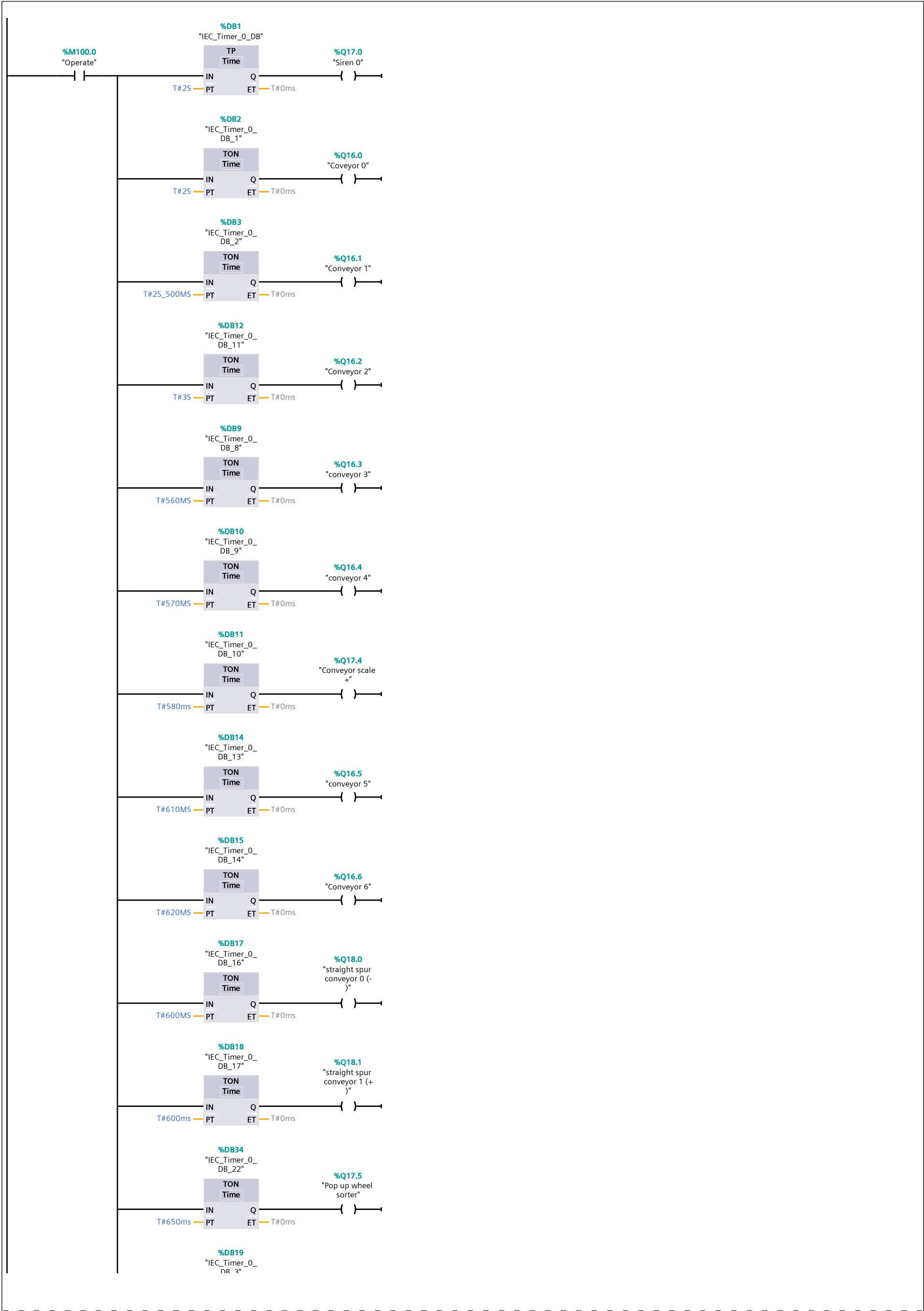


Network 5: System Initialization

Purpose: Handles system startup sequence and ensures that conveyors start in a staggered manner to limit initial inrush current & additional safety features of a sound and light signal.
Function:
Sequentially energizes conveyor motors with time delays.

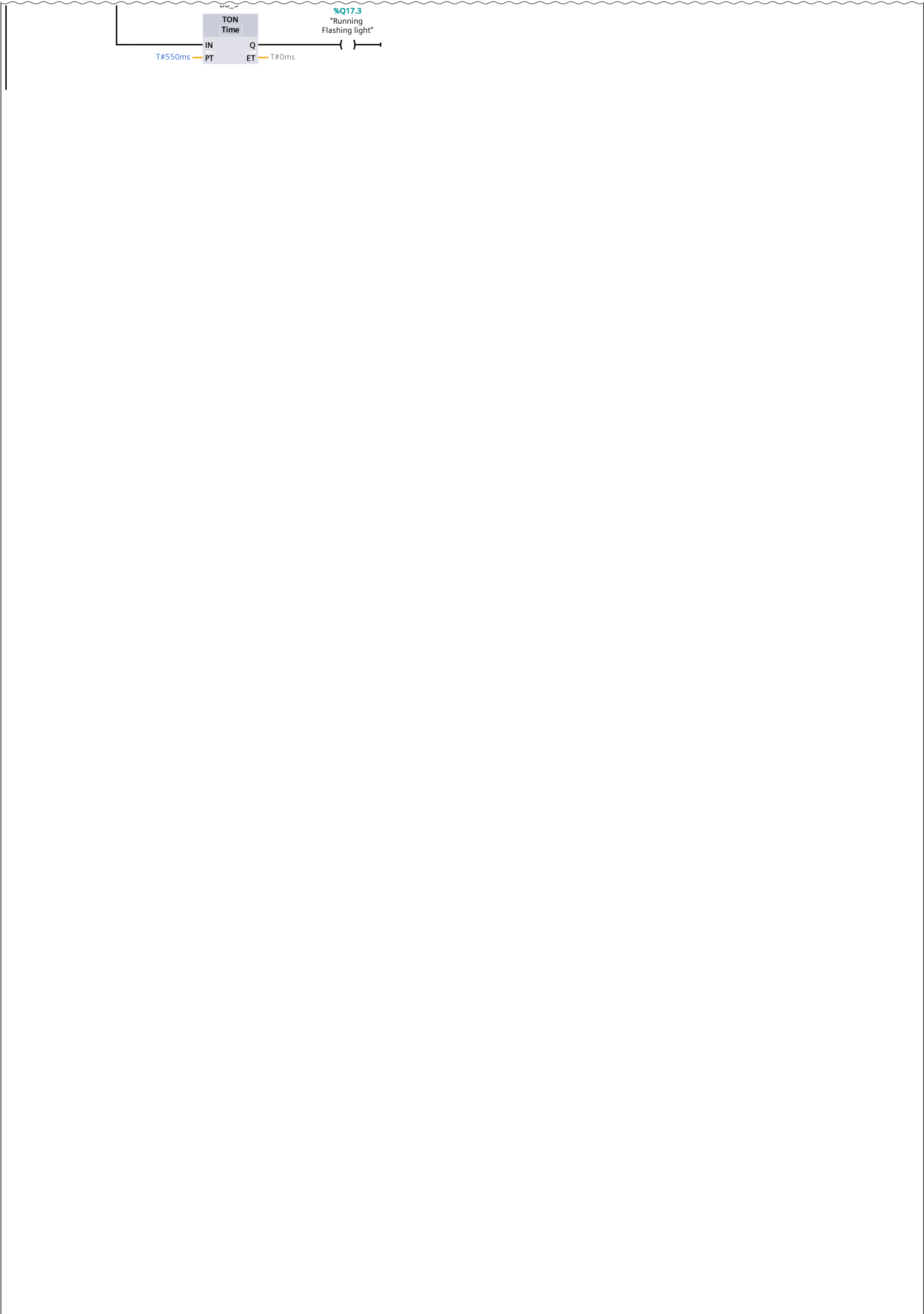
Checks that the system is ready all necessary inputs are in the correct state before starting sequence. The TON Blocks Are used to stagger the conveyor motor start up procedure the timer delay will minimize the in rush current draw.
Additionally a sound and visual signal are added by using a Siren & Flashing light beacon output from the if true operate setting.

Network 5: System Initialization (1.1 / 2.1)



Network 5: System Initialization (2.1 / 2.1)

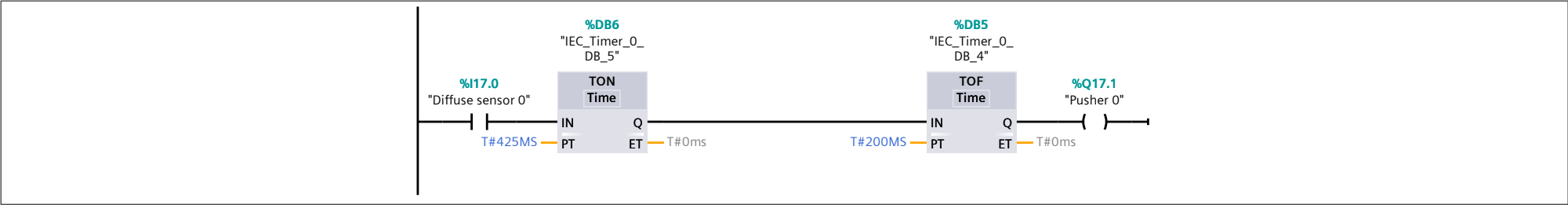
1.1 (Page1 - 3)



Network 6: Large Box Pusher Logic

Purpose: Send Large boxes to the appropriate sorting path by the use of a pusher.

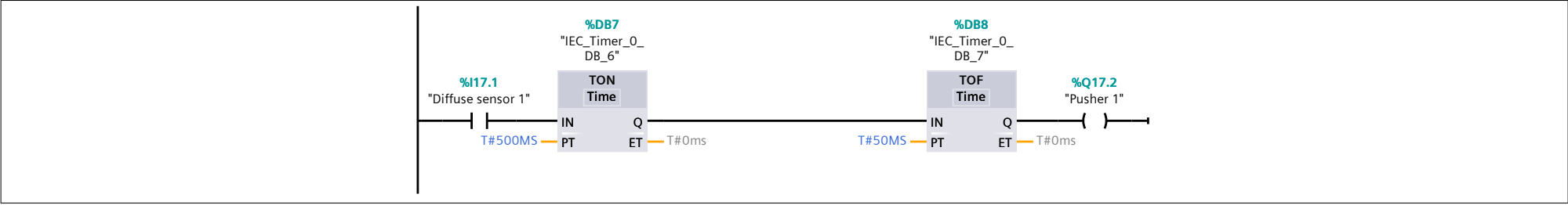
Function:
If the Diffuse Sensor (I17.0) is activated, it sends an input to the TON Timer, delaying by 425ms to allow the pusher to centralize the box into the correct sorting path. The TOF will bring the pusher back to its orginal closed position after 200ms of operation ensuring no boxes behind are jammed or sent the wrong way.



Network 7: Medium Box Pusher Logic

Purpose: Send Medium boxes to the appropriate sorting path by the use of a pusher.

Function: If the Diffuse sensor (I17.1) is activated it will send an input to the TON Timer which is delayed by 500ms to allow for the pusher to push the box centrally into the correct sorting path. The TOF will bring the pusher back to its orginal closed position after 500ms of operation ensuring no boxes behind are jammed or sent the wrong way.



Network 8: Pusher Fault Warning

Purpose: Detects if either pusher fails to operate as expected and triggers a warning which is displayed on the HMI aswell as activating the stack light orange & Siren 1 will sound.

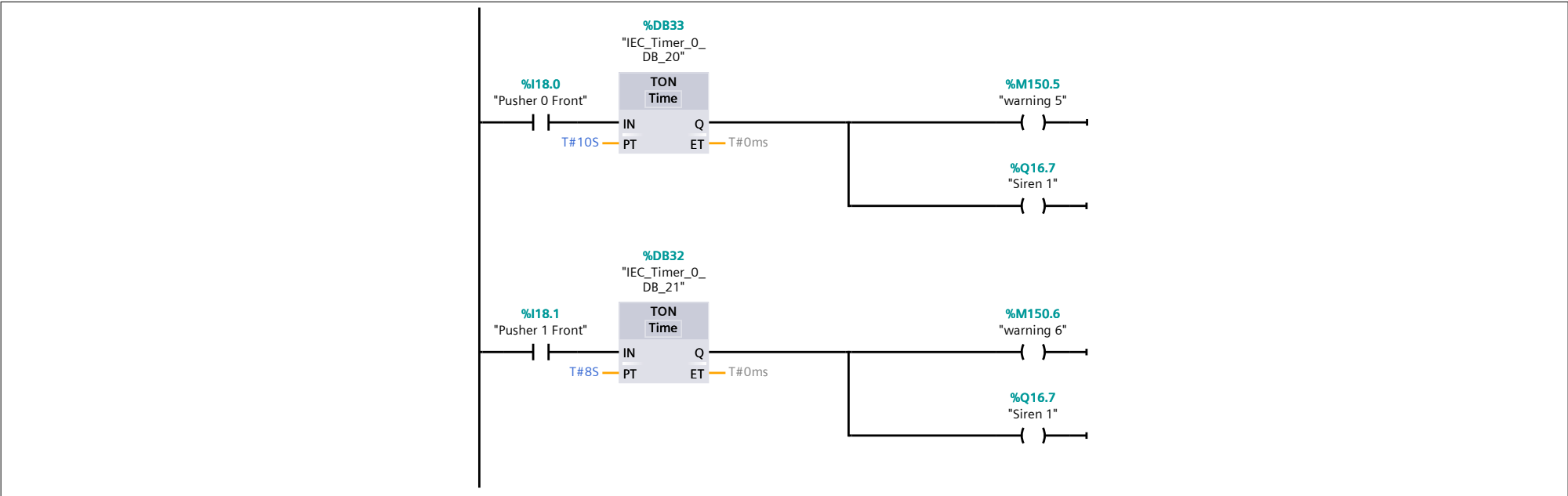
Function:

I18.0: Pusher 0 fault detected and triggers a TON timer (%DB33) set for 10s. If unresolved, Warning 5 (%M150.5) is activated.

I18.1: Pusher 1 fault detected and triggers a TON timer (%DB32) set for 8s. If unresolved, Warning 6 (%M150.6) is activated.

Q16.7: Siren 1 activates to alert operators.

The Warning will activate the Orange Stack light from memory and also the HMI Warnings lights.



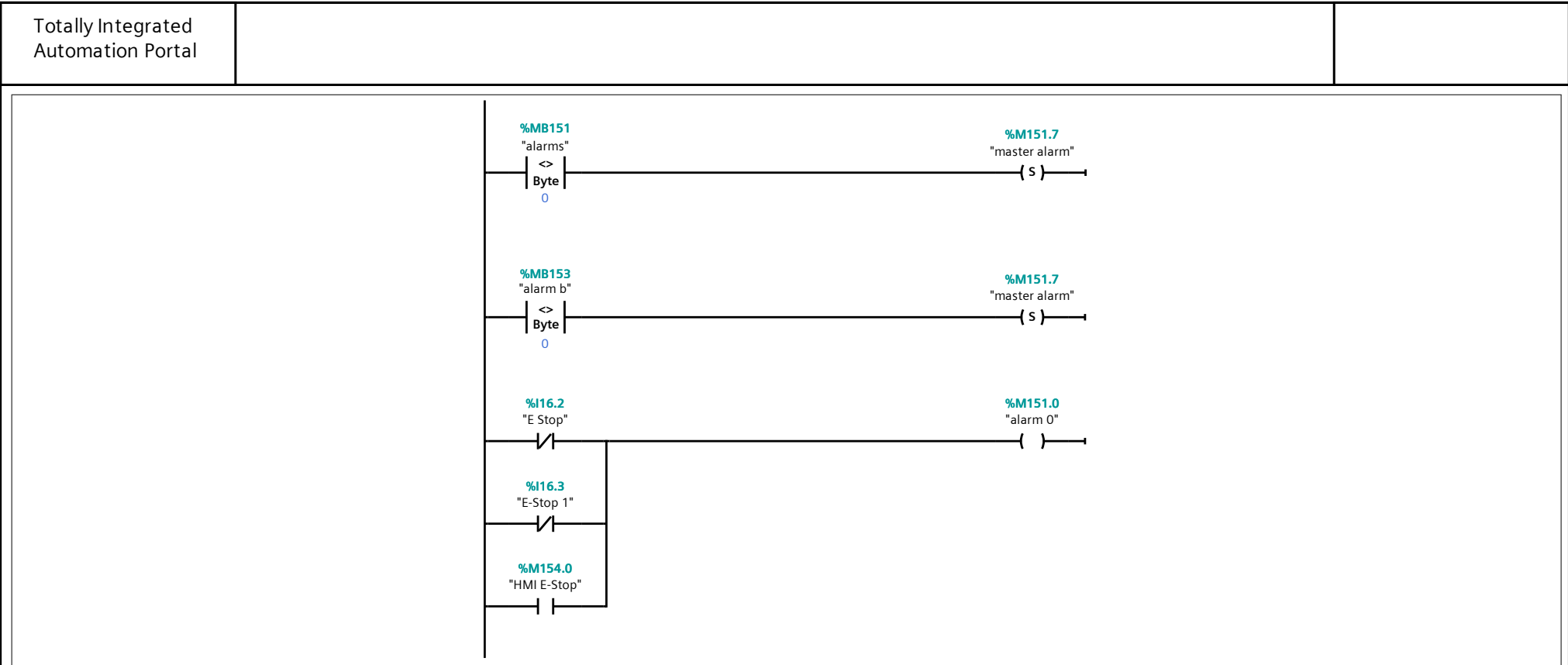
Network 9: Alarm Activate Master Alarm Display & E-Stop system

Purpose: Activates the master alarm and displays individual alarms on the HMI for Operator to see the cause.

Function:
-Monitors all alarm conditions (%MB151 and %MB153 bytes).

M151.7 Master alarm flag is set when any individual alarm is active.
- HMI displays the root cause of the alarm.

M151.0 (alarm 0) is the first alarm of the system. It act as the E-stop Alarm two field alarms I16.2 / I16.3 and one programed to the HMI Screen. These can be hit in emergency to shut the operation down imeadiatly the system will not reset untill the E-Stop has been reset.



Network 10: Master Counter

Purpose: Counts the total number of packages sorted and triggers an alarm or warning when preset threshold is exceeded.

Will only reset if the master counter button is pressed on.

Function:

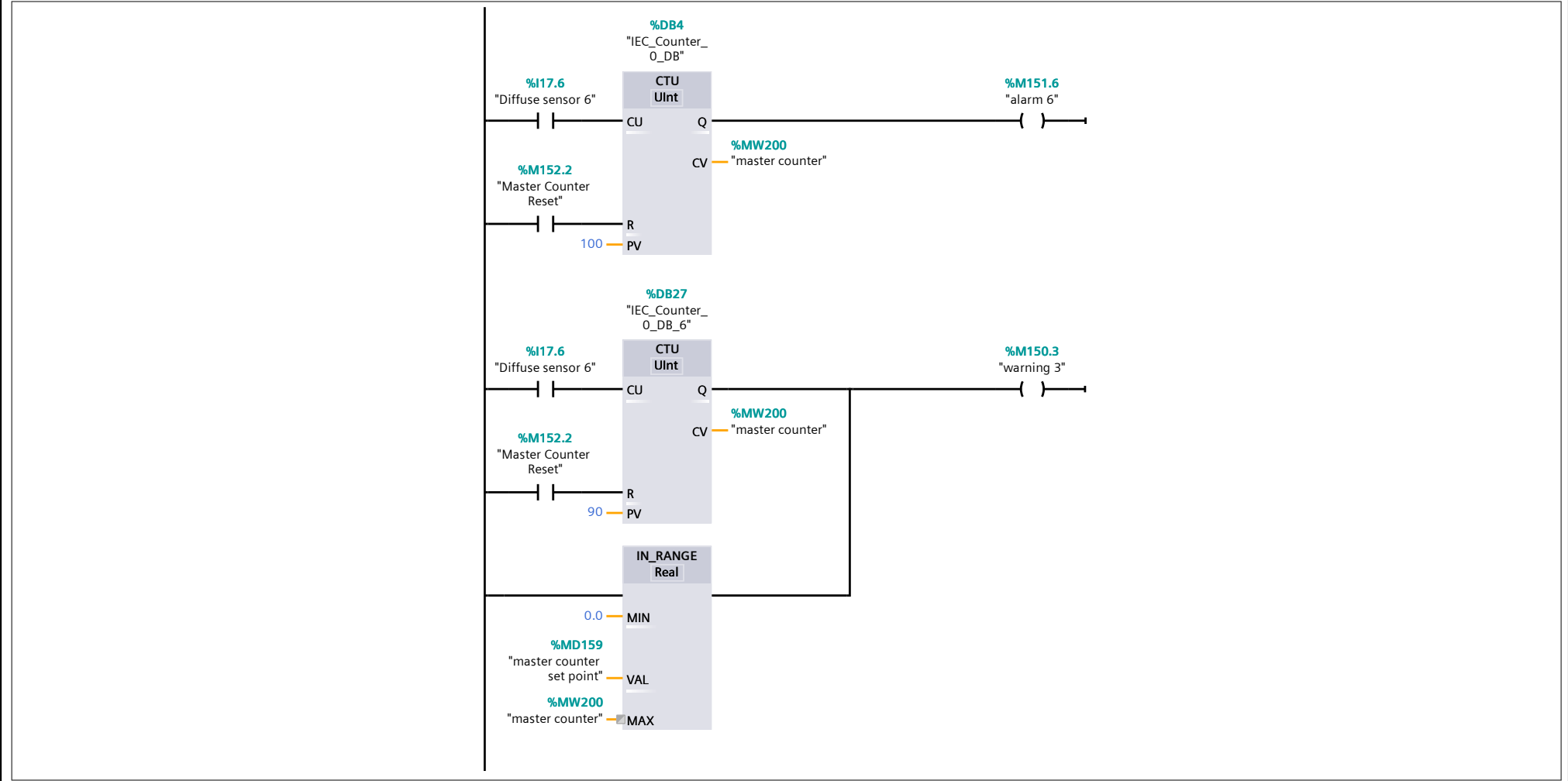
%MW200 Master counter tracks the total sorted packages.
Diffuse sensor 6 I17.6 is used to send the input each time the sensor reads. The system logs the count in memory.

M151.6: Alarm 6 is triggered if the master counter exceeds its preset value of 100 boxes.

M150.3: Warning 3 Is triggered if the master counter goes to 90 giving the operator time to acknowledge.

HMI provides an option to reset the counter (%M152.2) on the engineers screen this allows the operator to clear individual boxes whilst still keeping count of the total batch order.

MD159: Allows the engineer to Change to Preset value to desired value as per package order within the MAX - Min value programed into the memory If Pre set input value is exceeded the warning will appear for the order.



Network 11: Large box count

Purpose: Tracks the count of large boxes and triggers warning / alarm if thresholds are reached.

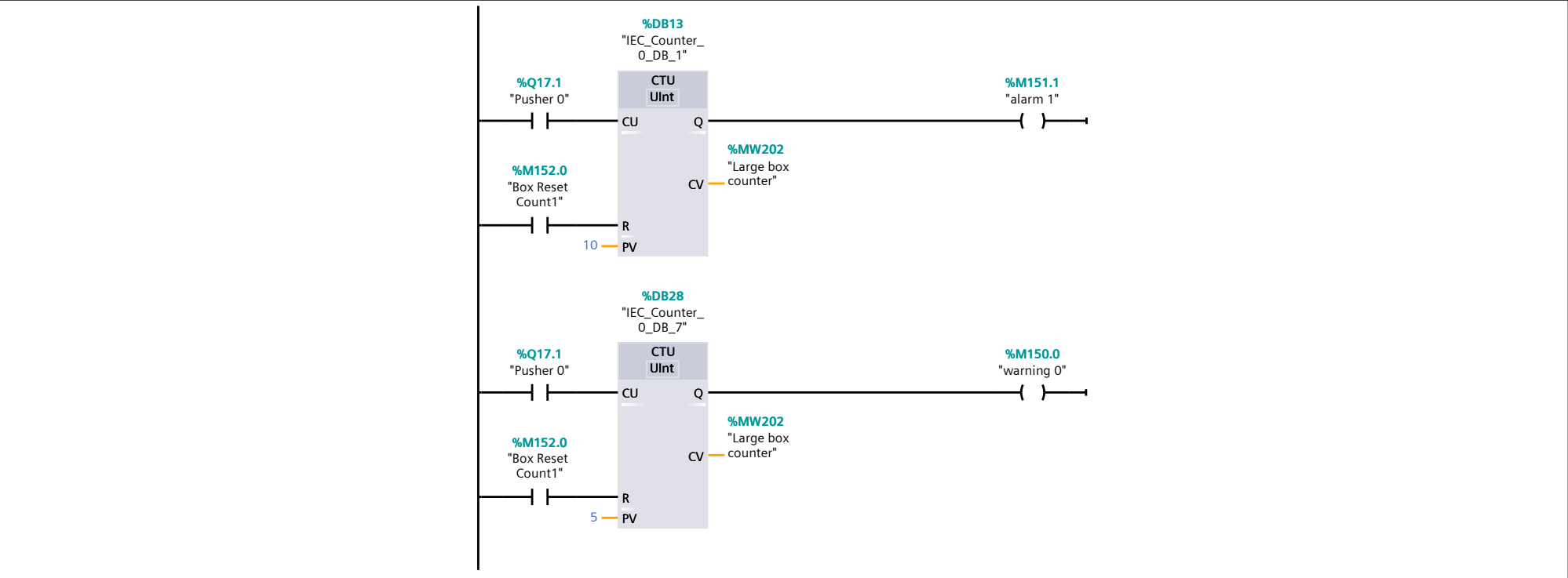
Function:

MW202: Counter tracks the number of large boxes sorted.By Utalizing the Pusher 0 Output.

M150.0: Warning 0 is triggered at the pre-warning threshold set at 5 the system will still operate but this will bring in the warning stack light also indication lights on HMI.

M151.1: Alarm 1 is triggered if the counter exceeds the alarm threshold set at 10. which will stop operation.

M152.0: Box Reset Count Allows the operator to acknowledge the number and reset all boxes apart from the master count which can only be reset by the authorized engineer.



Network 12: Medium Heavy Box Count

Purpose: Tracks the count of Medium Heavy box and triggers warning / alarm if thresholds are reached.

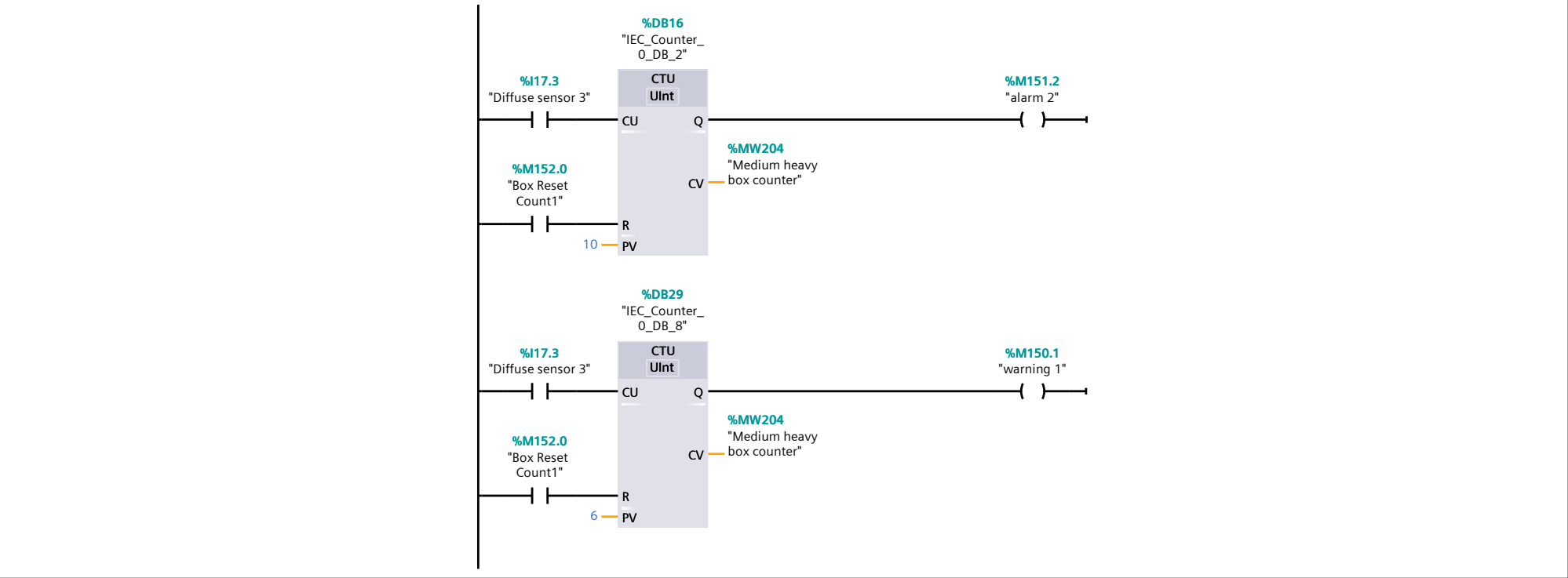
Function:

MW204: Counter tracks the number of medium heavy boxes sorted.By Utalizing input I17.3 Diffuse sensor 3 .

M150.1: Warning 1 is triggered at the pre-warning threshold set at 6 the system will still operate but this will bring in the warning stack light also indication lights on HMI.

M151.2: Alarm 2 is triggered if the counter exceeds the alarm threshold set at 10 which will stop operation.

M152.0: Box Reset Count Allows the operator to acknowledge the number and reset all boxes apart from the master count which can only be reset by the authorized engineer.



Network 13: Medium Light Box Count

Purpose: Tracks the count of Medium light box and triggers warning / alarm if thresholds are reached.

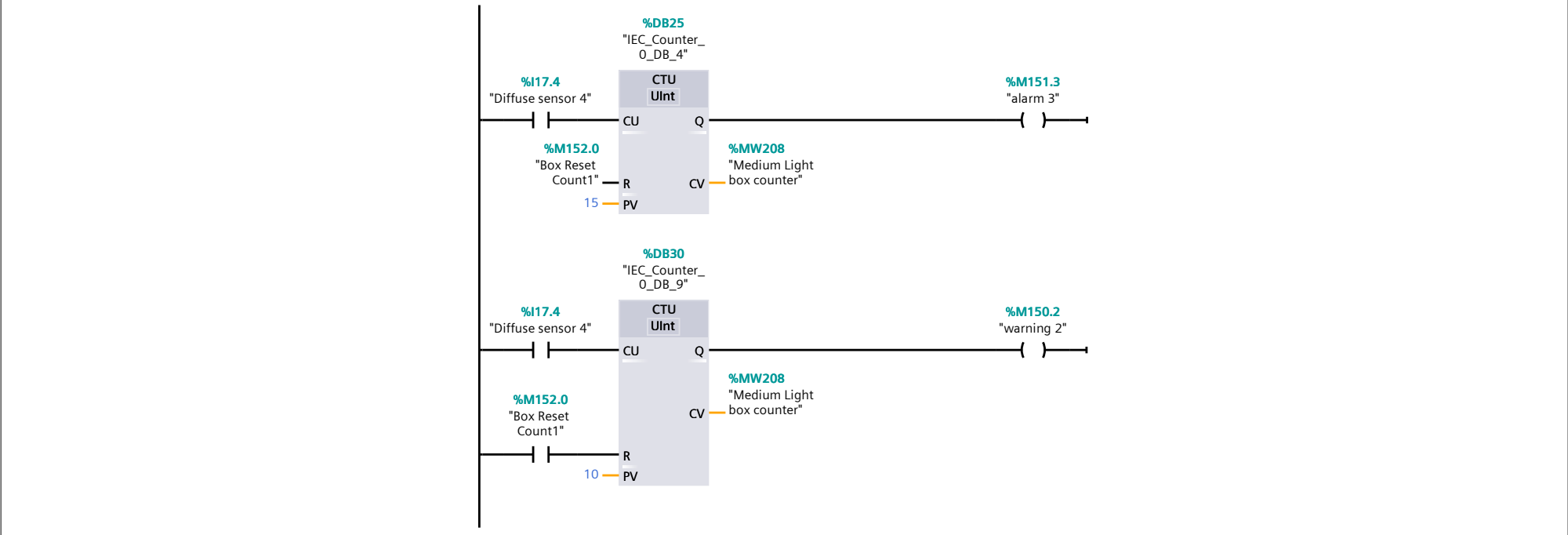
Function:

MW208: Counter tracks the number of medium light boxes sorted.By Utalizing input I17.4 Diffuse sensor 4.

M150.2: Warning 2 is triggered at the pre-warning threshold set at 10 the system will still operate but this will bring in the warning stack light also indication lights on HMI.

M151.3: Alarm 3 is triggered if the counter exceeds the alarm threshold set at 15 which will stop operation.

M152.0: Box Reset Count Allows the operator to acknowledge the number and reset all boxes apart from the master count which can only be reset by the authorized engineer.



Network 14: Small box Counter

Purpose: Tracks the count of small box and triggers warning / alarm if thresholds are reached.

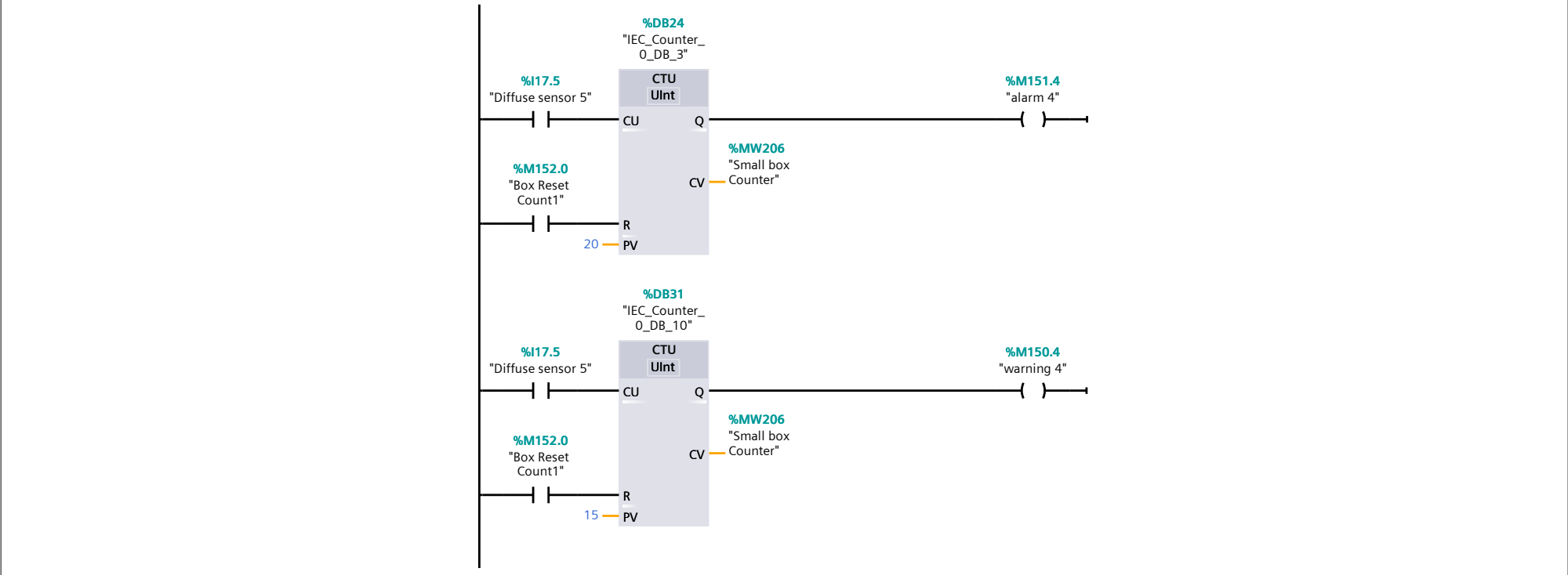
Function:

MW206: Counter tracks the number of medium heavy boxes sorted.By Utilizing input I17.5 Diffuse sensor 5 .

M150.1: Warning 4 is triggered at the pre-warning threshold set at 15 the system will still operate but this will bring in the warning stack light also indication lights on HMI.

M151.4: Alarm 4 is triggered if the counter exceeds the alarm threshold set at 20 which will stop operation.

M152.0: Box Reset Count Allows the operator to acknowledge the number and reset all boxes apart from the master count which can only be reset by the authorized engineer.



Network 15: Scale Control to conveyor

Purpose: Controls the operation of the conveyor associated with the scale, ensuring accurate package positioning for weighing and efficient movement during sorting.

Function:

M100.0: Operate memory bit enables system operation.

M100.1: Scale control memory bit triggers the conveyor scale to position packages accurately for weighing set with a small pause to allow the the time to see the package accuratley .

Q17.4: Conveyor scale output powers the conveyor motor, moving packages into and out of the scale area as needed.



Network 16: Medium Box Weight timer

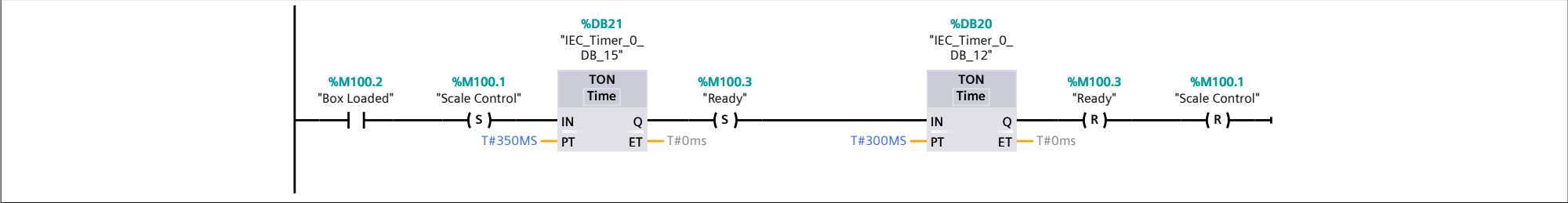
Purpose: Times the operation of the conveyor scale for medium boxes to ensure accurate sorting.

Function:

M100.1 Scale control set
TON Timer (DB21): Delays by 350ms after a medium box is detected.

M100.3: Ready memory bit signals that the scale operation is complete.

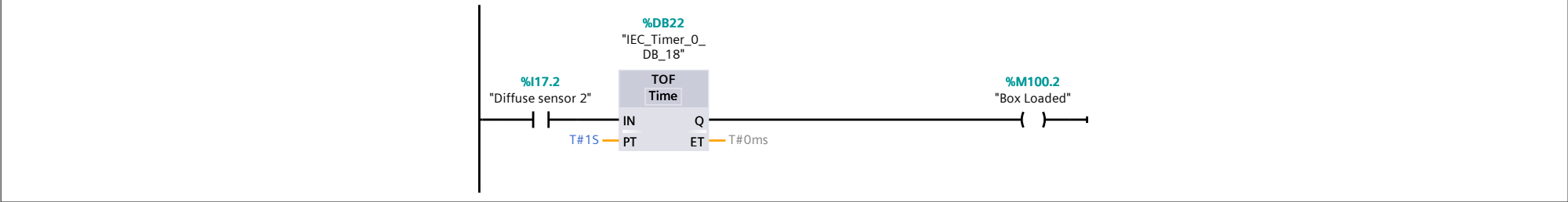
The 'Ready' bit synchronizes scale operation with sorting logic, preventing overlap in package processing.



Network 17: Sensor timer to box acknowledge for weight sorter

Purpose: Ensure correct timing between the detection of a box by the sensor and its acknowledgment by the weight sorting system 1 second set.

Function:
I7.2 Diffuse sensor 2 used to detect box present.
TOF (OFF Delay Timer) Delays the box acknowledgment M100.2 by 1 second to ensure synchronization with the weight sorter.
This will reduce the chance of overlapping boxing and limit errors.



Network 18: Medium Box Sorter

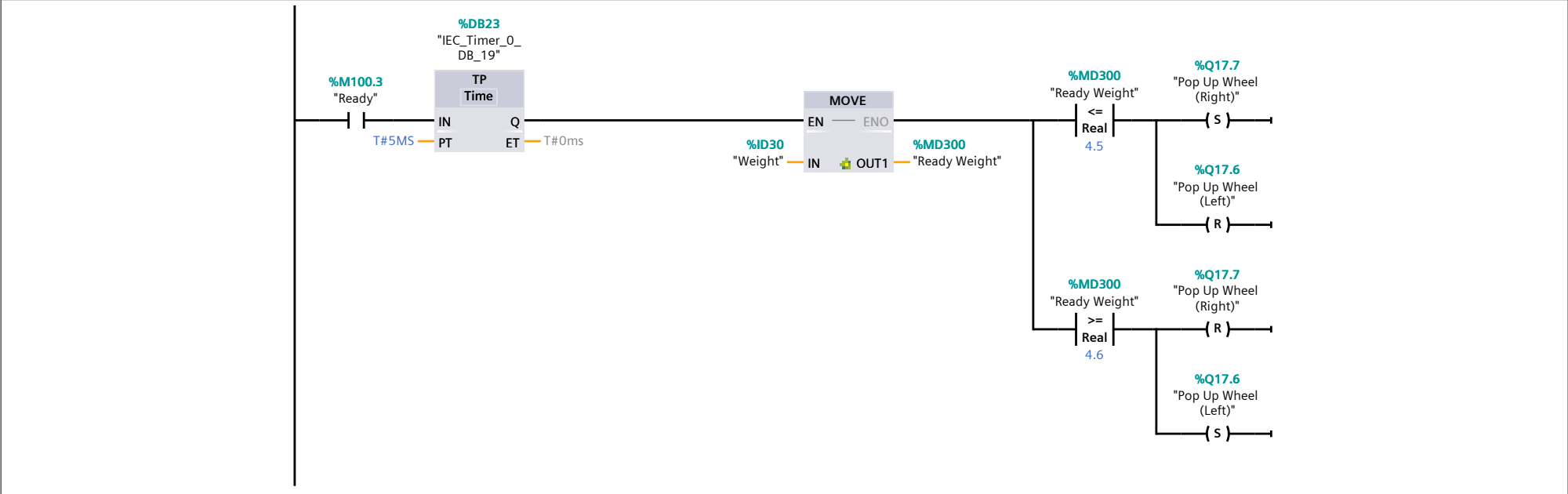
Purpose: Sort medium boxes by using weight values to determine the correct sorting direction Left or Right.

Function:
M100.3 when system is ready the weight of the box is compared to the predefined setpoint.

<=4.5 Pop up wheel will go left Q17.6. this will direct the medium light boxes to the LHS as expected as the weight is 4.5 or below.

>=4.6 Pop up wheel will go right Q17.7 this will direct the medium heavy boxes to the RHS as expected as the weight is 4.6 or above.

DB19 Acts as a pulse timer ensuring the pop up wheel runs smooth for each direction change.



Network 19: Weight LCD Display

Purpose: Display Ready weight on LCD Display on panel.

Function:
MD300 Ready weight is used to show the real time weight of the box on the LCD Display on control panel allowing for the operator to visually compare the readings.



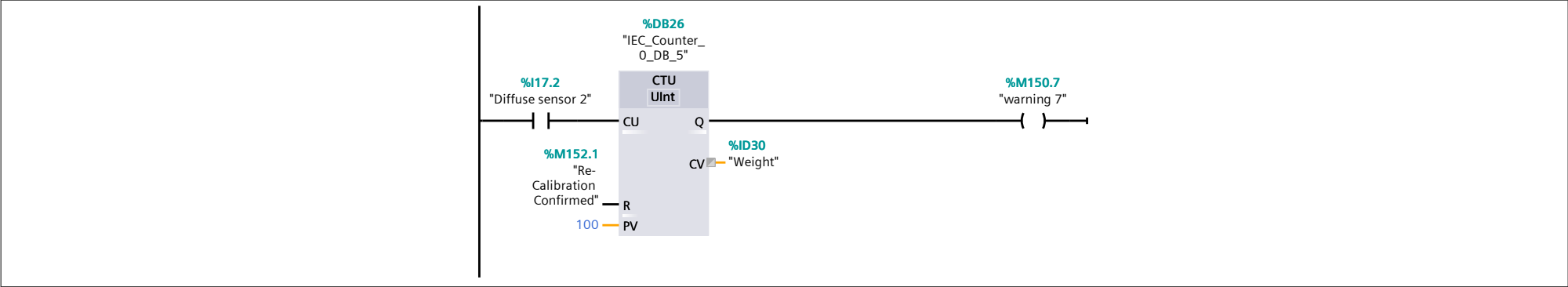
Network 20: Re- Calibration of weight scale warning

Purpose: Notifies operators when the weight scale requires recalibration after a set number of operations (100) by a predefined warning.

Function:

I17.2 Diffuse sensor is used to count all boxes that come onto the conveyor belt through the DB26 Counter memory. Once the pre set value is exceded the counter output will activate warning 7 M150.7 causing a notification on HMI Screen.

M152.1 is set as the reset button to confirm the Scale has had its calibration ensuring accuracy of the system. This can only be reset on the engineers screen.



Human Machine Interface (HMI):

HMI's Play a crucial role in industrial automation serving as the main interaction point for operators and engineers. They Enable real time control, monitoring with user friendly displays. Troubleshooting is another important feature of an HMI with features that can show fault codes and pre-warnings along with alarms.

Root (Home) Screen:

The Root Screen, illustrated in Figure.8 serves as the main interface for the operator. It includes essential functional buttons such as Stop, Start, and Emergency Stop (E-Stop). Additionally, it provides critical information, such as the count of each box size and scale weight of medium boxes allowing operators to monitor production in real time. There are several indication lights on the screen such as alarms, warnings, and a stack light representation to show the current state in which the conveyer is in. This is a replication of the control panel.

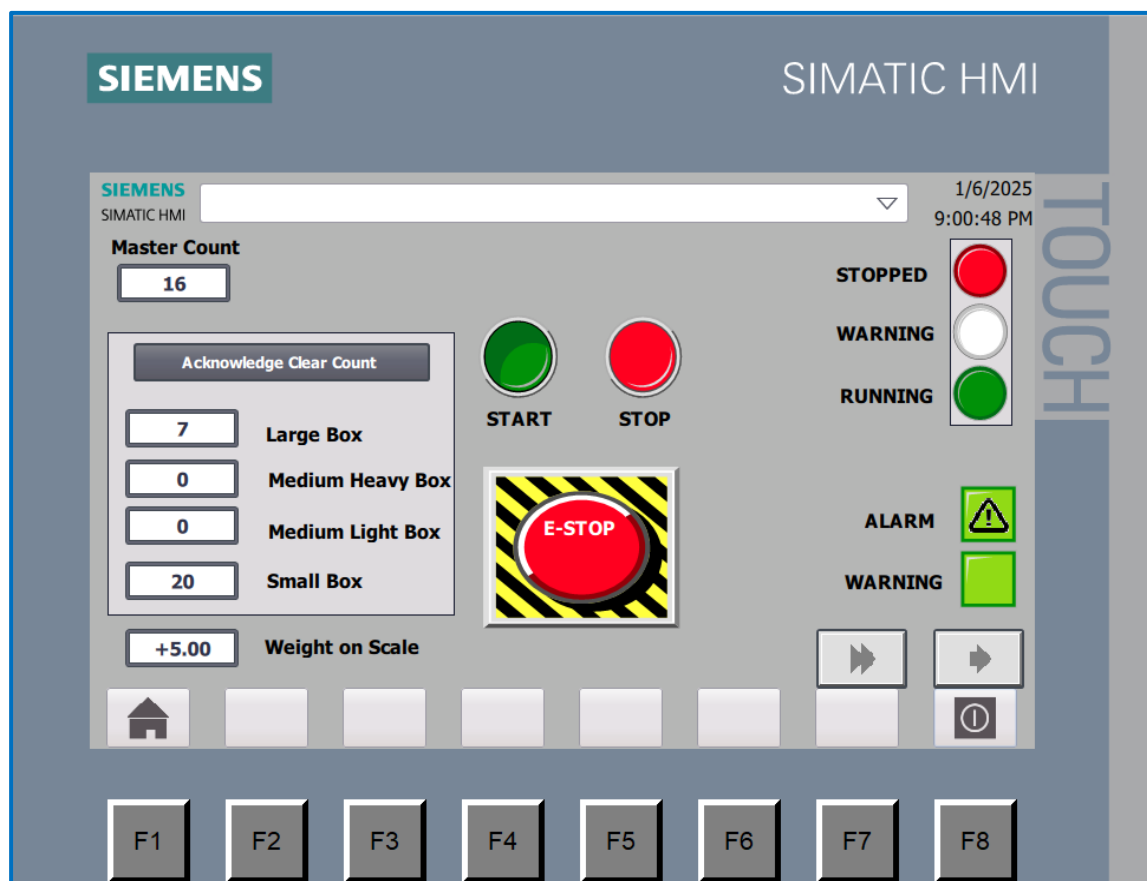


Figure.8 Root Screen HMI

Error Screen:

Shown in Figure.9 Error Screen displays all programmed warnings and alarms. This screen is crucial for identifying the root cause of potential issues. By highlighting warnings, it enables operators to address problems proactively, often before they escalate into critical system failures.

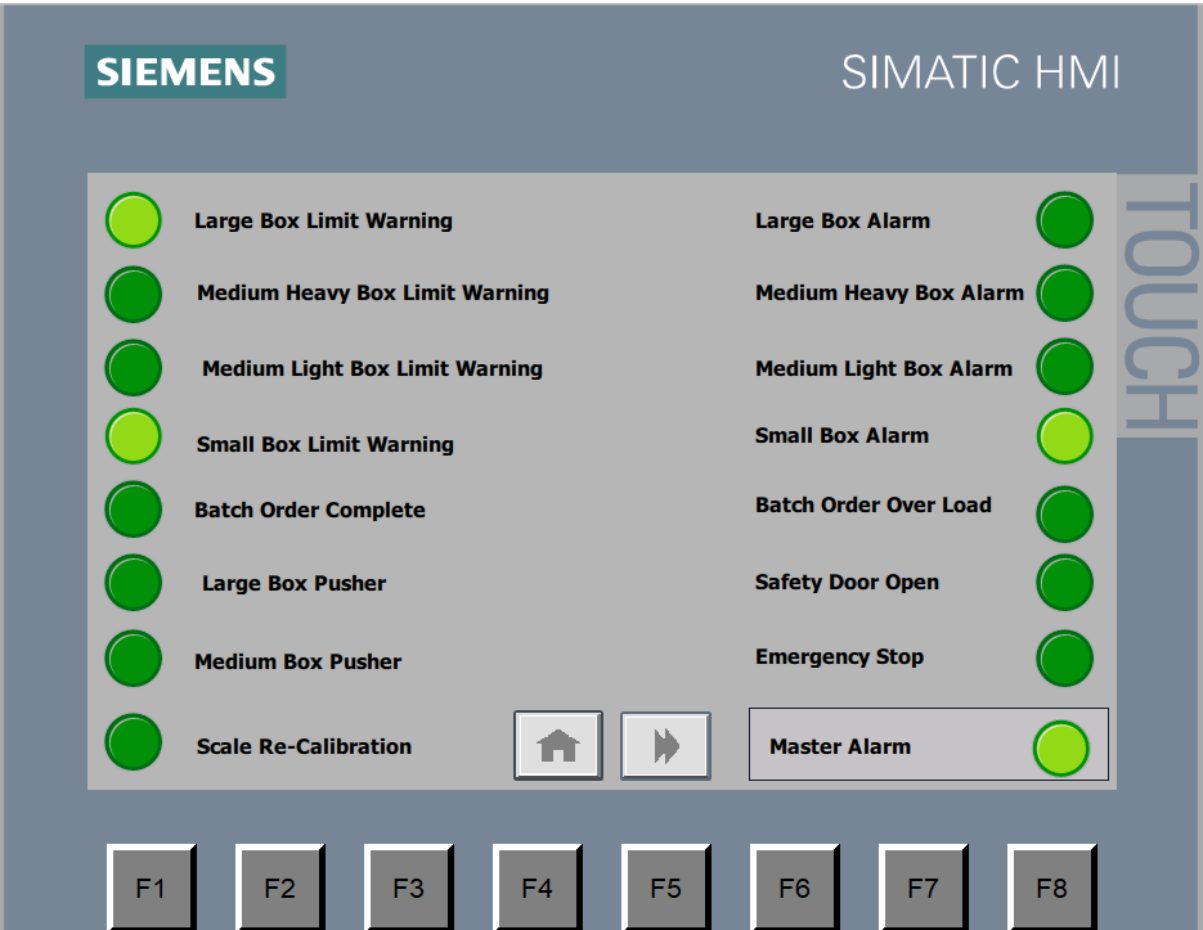


Figure.9 Error Screen

Table.2 Shows all the warnings and alarms alongside the set point values for each indication these are pre-set in the ladder logic and can only be changed through the software except for the batch order which has a range from 0-100 and can be pre-set by the engineer on the engineer's screen shown in figure.10.

Warning	Set Point	Alarm	Set Point
Large Box Limit	5	Large Box	10
Medium Heavy Box Limit	6	Medium Heavy Box	10
Medium Light Box Limit	10	Medium Light Box	15
Small Box Limit	15	Small Box	20
Batch Order Limit	Engineer set value 0-100 range	Batch Order Overload	100
Large Box Pusher	10 Seconds in out position	Audio Alarm Siren 1 system will	Continue
Medium Box Pusher	8 Seconds in out position	Audio Alarm Siren 1 system will	Continue
Scale Recalibration	100	NO Alarm system will continue	(Advisory)
		Safety Critical ALARMS	
		Safety Door Open	Open Contact
		Emergency Stop	Any E-stop open Contact
		Master Alarm	Any alarm initiate

Table.2

Warnings

Detailed list of each warning their function and how to acknowledge reset on HMI Screen.

All box limits

Function:

1. Initiates Warning Indication on HMI and specified indication light on warning screen.
2. Activates Stack Light Orange if preset limit is reached.

Clear/ Reset: To Reset Operator must acknowledge and clear box count on the HMI root screen this will clear count of boxes but will maintain the total master count of the batch order.

Batch Order Complete

Function:

1. Initiates Warning Indication on HMI and specified indication light on warning screen activates Stack Light Orange if preset limit is reached.
2. Pre-Set Limit can be changed per batch on Engineers screen up to maximum overload limit of 100.

Clear/ Reset: To Reset Engineer must acknowledge the batch order number and select Master Counter Reset button on the HMI Engineer Screen this will reset the master count ready for next batch order.

Pushers Fault

Function:

1. Initiates Warning Indication on HMI and specified indication light on warning screen activates
2. Stack Light Orange if pusher is stuck in position.
3. Siren 1 will sound to alert operators of fault.

Reset/ Clear: Only Reset when the pusher has gone back into its original in position this will clear the warning and siren without use of HMI. (**Clear stuck box**).

Scale Re-Calibration

Function:

1. Initiates Warning Indication on HMI and activates Stack Light Orange.
2. Pre-Set re call value of 100 after this the warning will stay on until recalibration has been confirmed by Engineer Screen.

Reset/ Clear: Reset from HMI When Engineer selects Re-calibration confirmed button on the Engineer screen.

Alarms

Description on each Alarm function and how to acknowledge clear & reset on HMI Screen.

All box limits

Function:

1. Initiates Specified Alarm Stops Conveyor system.
2. Indication on HMI and specified indication light on alarm screen activates.
3. Stack Light RED if preset limit is reached. Master Alarm will Activate.

Clear/ Reset: To Reset Operator must acknowledge and clear box count on the HMI root screen this will clear count of boxes.

System will maintain the total master count of the batch order.

Clear Master Alarm on Engineer screen and start system.

Batch Order Complete

Function:

1. Initiates Alarm Stops Conveyor System
2. Indication on HMI and specified indication light on Alarm Screen
3. Stack light RED and Master Alarm will activate.

(The order overload max limit is set in the software to 100).

Clear/ Reset: To Reset Engineer must acknowledge the batch order number and select Master Counter Reset button on the HMI Engineer Screen this will reset the master count ready for next batch order.

Safety Door

Function:

1. Initiates Alarm Stops Conveyor System
2. Indication on HMI and specified indication light on Alarm Screen
3. Stack light RED and Master Alarm will activate.

Clear/ Reset: Only Reset if safety door is closed back to original position. Clear Master alarm on HMI to proceed.

Emergency Stop

Function: Initiates Alarm Stops Conveyor System

Clear/ Reset: Only Reset if all E-stops are back to original position (2 field or HMI screen e-stop). Clear Master alarm to proceed.

Master Alarm

Function: Initiates When any of the alarms are activated.

Clear/ Reset: Reset from HMI Engineer screen Master Clear Alarm will only clear if all Alarms are deactivated.

Engineering Screen:

The Engineering Screen, depicted in Figure.11 serves as a secured, maintenance-focused interface. Usually accessible only through password protection, it is used for tasks like system maintenance or troubleshooting. This screen includes a master clear alarm function, ensuring all alarms are acknowledged and resolved before allowing the system to return to normal operation. This feature ensures the system's safety and reliability during maintenance activities.

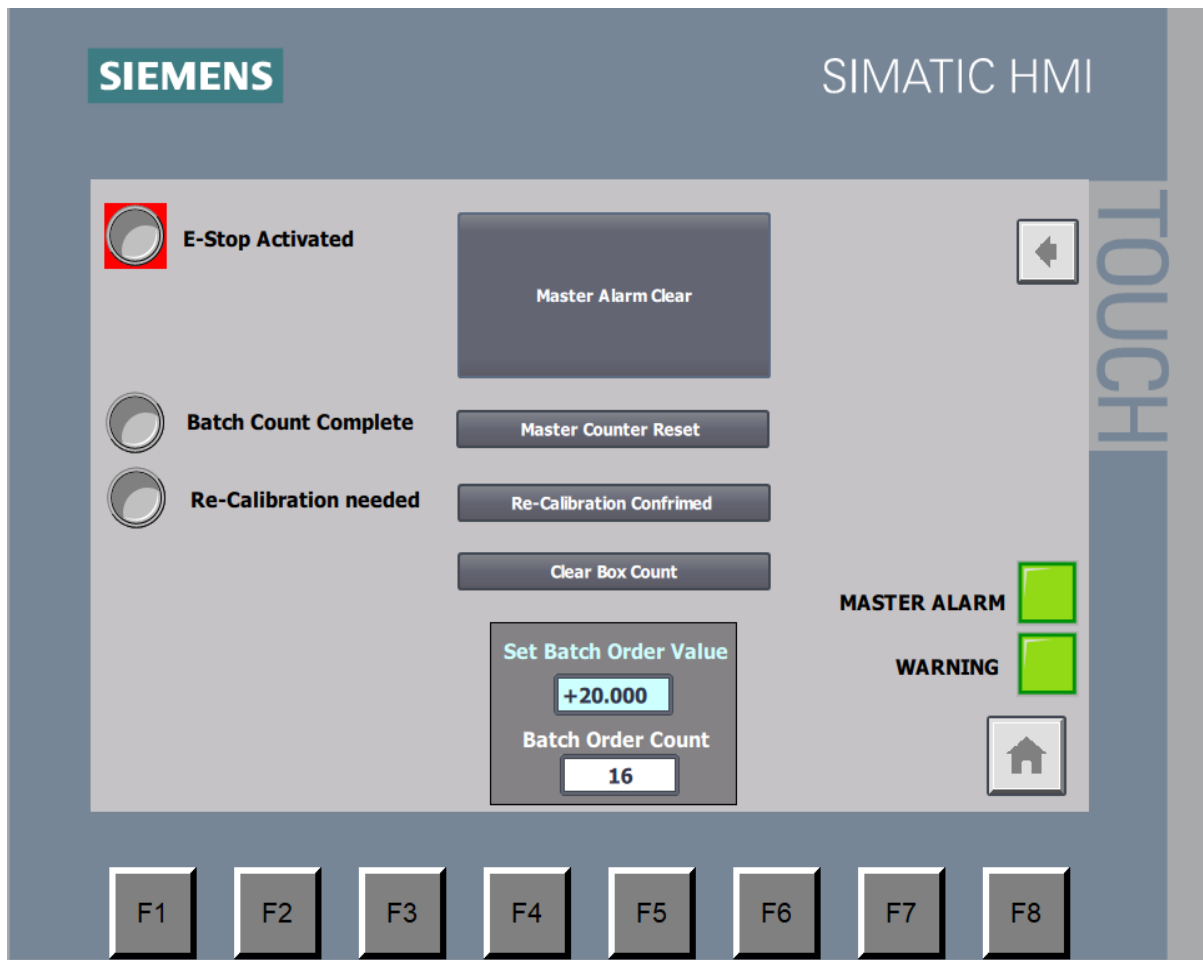


Figure.10

There are several instructions and functions on this screen as it provides the engineer with vital information to maintain the system at a high standard.

1. **Master count reset:** function that allows the engineer to clear the total box count from the system.
2. **Re-Calibration:** warning which acts as an indication that the weighing scale is due a calibration this can be cleared by the engineer once re-calibration has been confirmed.

3. **Clear Box Count:** additional button that is also replicated from the operator screen by repeating this button allows the engineer to remain on one screen to restart the system, saving time.
4. **Set Batch Order Value:** this can be preset from the HMI and will allow the engineer to set the order Quantity to any figure between 0-100 if this is exceeded the warning Batch Order Complete will appear.

Testing:

Testing of any project is a critical stage to not only document all findings but to be able to identify and address any potential issues at the early stage whilst using the simulation software. This can save time and cost of any project. Table.3 shown below illustrates the commissioning testing procedure used to follow the various tasks of the project to ensure each part has been successfully completed.

	Output Required	Result	Pass/Fail	Comments
Large Box	Conveyor runs	YES	Pass	Expectation achieved
	Diff Sensor ack correct size box	YES	Pass	Expectation achieved
	Count Correct	YES	Pass	Expectation achieved
	Warning Count Correct	YES	Pass	Expectation achieved
	Alarm Function Correct	STOP	Pass	Expectation achieved
Medium Box	Conveyor runs	YES	Pass	Expectation achieved
	Diff Sensor ack correct size box	YES	Pass	Expectation achieved
	Count Correct	YES	Pass	Expectation achieved
	Warning Count Correct	YES	Pass	Expectation achieved
	Alarm Function Correct	STOP	Pass	Expectation achieved
Small box	Conveyor runs	YES	Pass	Expectation achieved
	Diff Sensor ack correct size box	YES	Pass	Expectation achieved
	Count Correct	YES	Pass	Expectation achieved
	Warning Count Correct	YES	Pass	Expectation achieved
	Alarm Function Correct	STOP	Pass	Expectation achieved
Weigh Scale / pop Up sorter	Diff sensors count correct	YES	Pass	Expectation achieved
	Delay in Scale Conveyor correct	YES	Pass	Expectation achieved
	Scale Reads correct value?	YES	Pass	Expectation achieved
	Pop Up sort Position, correct?	YES	Pass	Expectation achieved
	Safety Door System operates?	STOP	Pass	Expectation achieved
HMI	Navigation Buttons Functional	YES	Pass	Expectation achieved
	Stop/ Start operation	YES	Pass	Expectation achieved
	E-Stop operate	STOP	Pass	Expectation achieved
	Count display correct	YES	Pass	Expectation achieved
	Warnings/ Alarms displayed	YES	Pass	Expectation achieved
	All Master Resets functional	YES	Pass	Expectation achieved

Table.3

Conclusion:

The project has successfully demonstrated the design and implementation of a factory automation system using the Siemens S7-1200 PLC and Factory I/O simulation software. Integrating conveyor belts, sensors, pushers, and a scale conveyor, the system efficiently sorts packages based on size and weight while ensuring safety.

The integration with Siemens PLC and HMI enhances functionality by providing real-time monitoring and Control.

The selection of the Siemens S7-1200 PLC was pivotal in the design due to its user-friendly programming environment and widespread industry adoption, which provides robust technical support. The system's flexibility and scalability enable future expansions, such as adding additional conveyors or enhancing sorting mechanisms, ensuring it meets evolving industrial demands.

Future improvements that could enhance the system include:

Automated Diagnostics: Enabling proactive fault detection to minimize downtime with a trend screen.

Remote Monitoring: Allowing off-site oversight and adjustments for greater operational efficiency and enhancing safety by limiting time within a potential hazardous environment.

Energy Efficiency Improvements: Implementing variable-speed drives to reduce energy consumption and save costs.

RFID Integration: Incorporating RFID technology for precise package tracking and improved sorting accuracy.

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