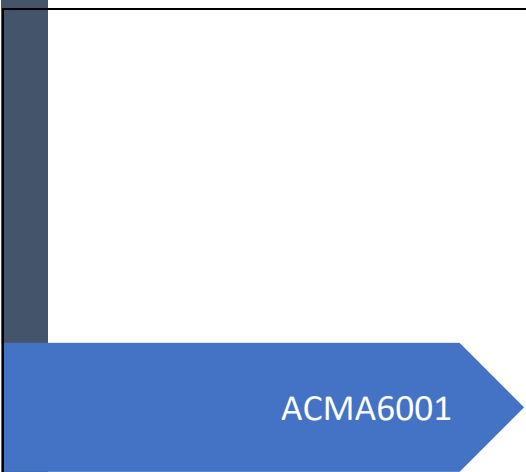
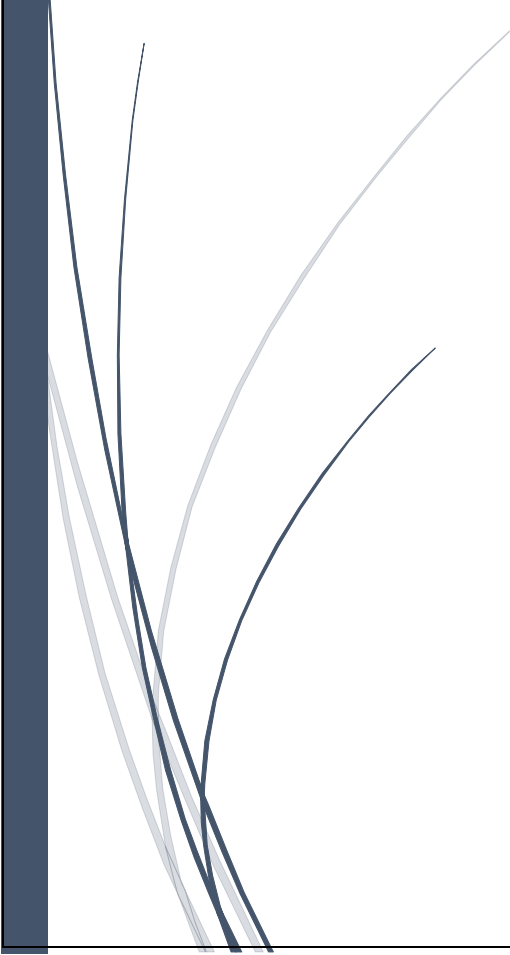




ACMA6001

Factory Control

Module: Control Technology



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Introduction

Factory control is essential to the success of modern-day manufacturing. With a major shift towards automation, manufacturing companies are required to employ a range of different control systems such as PLC's (Programmable Logic Controllers), PAC's (Programmable Automation Controllers) and HMI's (Human-Machine Interfaces) to just name a few (CSD, 2021). According to Nevatio (2021), PLCs are used extensively in manufacturing, not only to automate but control machines and processes. PLC's receive input information from a range of sensors and switches and operate pre-programmed sequences (signalling output devices).

PLCs are used in a range of different industries such as controlling traffic systems, nuclear power plants (controlling and monitoring reactor systems), elevators, and factory assembly lines again only to name a few. The main advantages that PLC's offer over traditional control systems such as banks of electromechanical relay systems is that they are reliable, efficient, and flexible. It is easy to implement any changes by updating the program and quickly uploading it to the PLC. Previously, banks of relays would be required to be re-wired in different configurations to match the changes which was a tedious job (AutomationDirect, 2023) as shown in Figure 1.

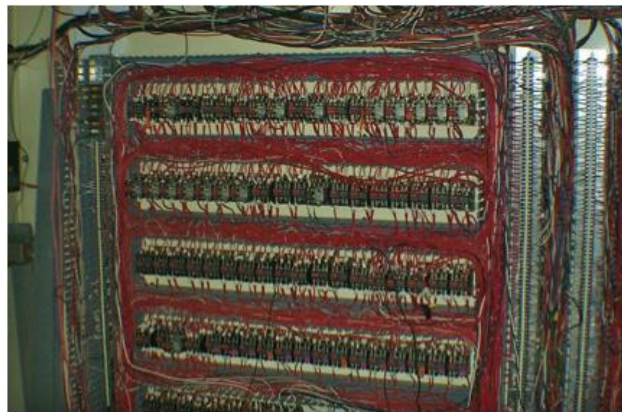


Figure 1 - Relay Bank 1965 (Eschweigert, 2012).

Main Body

Task 1 – Literature Review

PLC's have many applications which range from simple automation tasks to far more sophisticated systems. Selecting the correct PLC is often a difficult task but it is critical to the success of the application. Different PLC systems vary significantly in both the hardware and software capabilities. This review will cover four popular PLCs used in industry looking at both the positives and negatives of each PLC in terms of software and hardware.

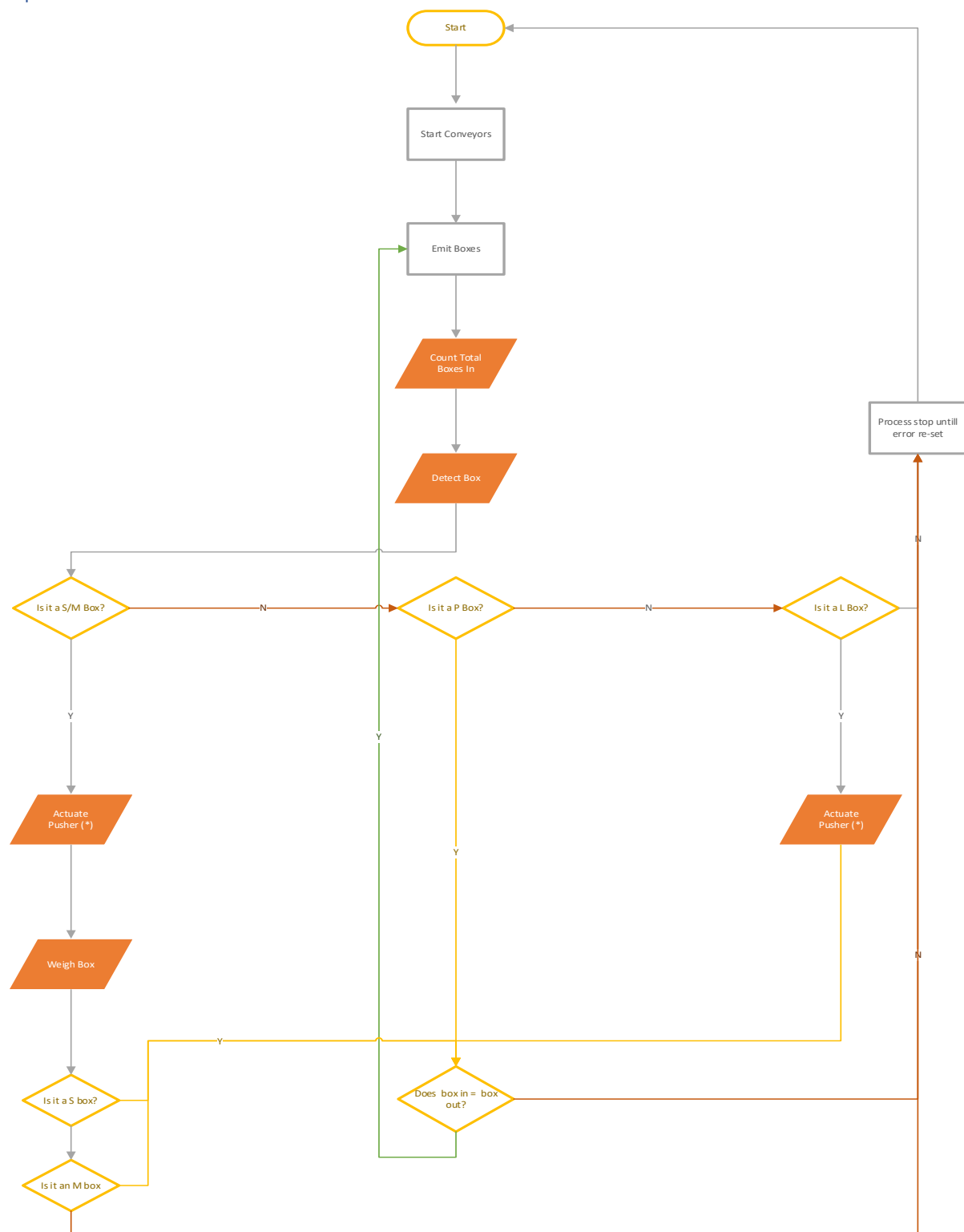
According to Peko Precision (2023), the most popular PLC brands are Siemens with their line of SIMATIC controllers, Allen-Bradley that offer large, small and microcontrollers, Mitsubishi which offer a wide range from their MELSEC line and Schneider Electric with advanced automation solutions with the Modicon master range. Each of these brands have both their positives and negatives which are reviewed in table 1:

Company	Hardware	Software	Positives	Negatives
Siemens	S7-1200	SIMATIC S7 (TIA Portal)	Reliability, Software is easy to use, Program both the HMI and PLC in one application, Scalability.	Siemens is an expensive system compared to other PLC's.
Allen-Bradley	CompactLogix	Studio 5000 Logix Designer	World leading safety, programming capabilities, good support through customer service.	Product range
Mitsubishi	FX3U	GX Developer	High speed processing, reliability, flexibility with IO options, Multiple Communication protocols, Configuration using GX Works.	Cost & Support due to the geography of the product.
Schneider Electric	Modicon M340	EcoStruxure Control Expert	Long-term reliability, expandable system, Wide range of I/O communication, ideal for data acquisition.	Limited supply of spare parts, they are often difficult to obtain.

Table 1 - List of PLC Manufacturers (Pros & Cons)

It's always a difficult task to select the most appropriate PLC for the application, however it is essential that research is undertaken to select a suitable PLC. From table 1, a lot of the manufacturers share the same positives and negatives. Due to this report's nature with emphasis on Factory Control, the author believes that the best two PLC manufacturers to use would be Siemens and Mitsubishi. Siemens has an important role in industrial manufacture. The SIMATIC controller has well designed standard functions that are easily connected through Ethernet and communicated with PROFINET (RT, 2021). Having personal use with the TIA Portal software when writing the factory program, it is easy to program and navigate which is essential in the world of programming.

Operational Flow Chart



This is the top-level operational flow chart for the factory. This was drafted to help aid with the program and ladder structure. The program delves further than this flow chart shows, however, the chart helps to visualise exactly how the program is required to function. University College London (2021) explain that flowcharts “help find less obvious features of the process that can be refined to improve efficiency”. This was useful in understanding the steps required in successfully programming the box sorter.

Alarm & Warning Strategy

An alarm/warning strategy is essential to define how the PLC will react when certain conditions are met. The logic allows the author of the program to capture abnormalities and alert the operator of failure further preventing any damage to the system (Romanov, 2023). The alarms and warnings are often displayed on the HMI or PLC itself as well as triggering visual stack lights and completely stopping the system if required or programmed to do so.

Furthermore, a well-designed alarm/warning strategy should be tailored to the specific process. A critical part of the factory project was to identify some of the conditions that occur during the sorting process, these are listed in table 2 with the operational parameters of each. There are five alarm operational parameters considered, alarm type, alarm severity, alarm trigger conditions, alarm action and alarm reset condition.

Alarm Type	Alarm Severity	Alarm Trigger Conditions	Alarm Action	Alarm Reset Condition
Security door open – Potential for operator to injure themselves on the moving equipment.	Red	If the security door is open, then an alarm will be triggered. This is shown in network 2 of the program within the start up sequence.	Stop the system and output a red stack light indicator.	This alarm will only reset when the door is closed, and the alarm master reset button is pressed in the engineering screen on the HMI. The system will not re-set until this condition is met.
E-Stop pressed – There is something wrong with the system, someone may be injured, or boxes are missing.	Red	If either the E-stop on the control panel or the E-stop on the HMI is pressed, then this will trigger alarm 5. This is also shown in Network 2 of the ladder code.	When alarm 5 is triggered, the system will stop, and the red stack light will illuminate.	The alarm will only re-set when the E-stop is released, and the alarm master is re-set in the engineering screen.
Pallet box warning – Indicates that there are boxes not completing traverse which may be damaged or lost.	Amber	If the counter for pallet boxes exceeds the warning pre-set number for pallet boxes not completing traverse, then warning 0 will trigger to alert the operators that some boxes are not completing the traverse.	When warning 0 is triggered, the amber stack light will illuminate but the system will continue to run.	To re-set the warning, the pallet boxes in and pallet boxes out counter will need to be corrected by an engineer on the HMI to return the system to a green stack light.
Small box warning - Indicates that there are boxes not completing traverse which	Amber	If the counter for small boxes exceeds the warning pre-set number for small boxes not completing traverse, then warning 1 will trigger	When warning 1 is triggered, the amber stack light will illuminate but the system will continue to run.	To re-set the warning, the small boxes in and small boxes out counter will need to be corrected by an engineer on the HMI

may be damaged or lost.		to alert the operators that some boxes are not completing the traverse.		to return the system to a green stack light.
Medium box warning – Indicates that there are boxes not completing traverse which may be damaged or lost.	Amber	If the counter for medium boxes exceeds the warning pre-set number for medium boxes not completing traverse, then warning 2 will trigger to alert the operators that some boxes are not completing the traverse.	When warning 2 is triggered, the amber stack light will illuminate but the system will continue to run.	To re-set the warning, the medium boxes in and medium boxes out counter will need to be corrected by an engineer on the HMI to return the system to a green stack light.
Large box warning – Indicates that there are boxes not completing traverse which may be damaged or lost.	Amber	If the counter for large boxes exceeds the warning pre-set number for large boxes not completing traverse, then warning 3 will trigger to alert the operators that some boxes are not completing the traverse.	When warning 3 is triggered, the amber stack light will illuminate but the system will continue to run.	To re-set the warning, the large boxes in and large boxes out counter will need to be corrected by an engineer on the HMI to return the system to a green stack light.
Pallet box alarm - Indicates that there are boxes not completing traverse which may be damaged or lost.	Red	If the counter for pallet boxes exceeds the alarm pre-set number for pallet boxes not completing traverse, then alarm 0 will trigger.	When alarm 0 is triggered, the system will stop, and a red stack light will appear. On the HMI the alarm will light up on the error screen indicating that there is an issue with palletising boxes not completing traverse.	To reset the system, either the counters will need to be manually adjusted by the engineer or reset all counters. The alarm master will also need to be reset and then the system restarted.
Small box alarm – Indicates that there are boxes not completing traverse which may be damaged or lost.	Red	If the counter for small boxes exceeds the alarm pre-set number for small boxes not completing traverse, then alarm 1 will trigger.	When alarm 1 is triggered, the system will stop, and a red stack light will appear. On the HMI the alarm will light up on the error screen indicating that there is an issue	To reset the system, either the counters will need to be manually adjusted by the engineer or reset all counters. The alarm master will also need to be reset and then the system restarted.

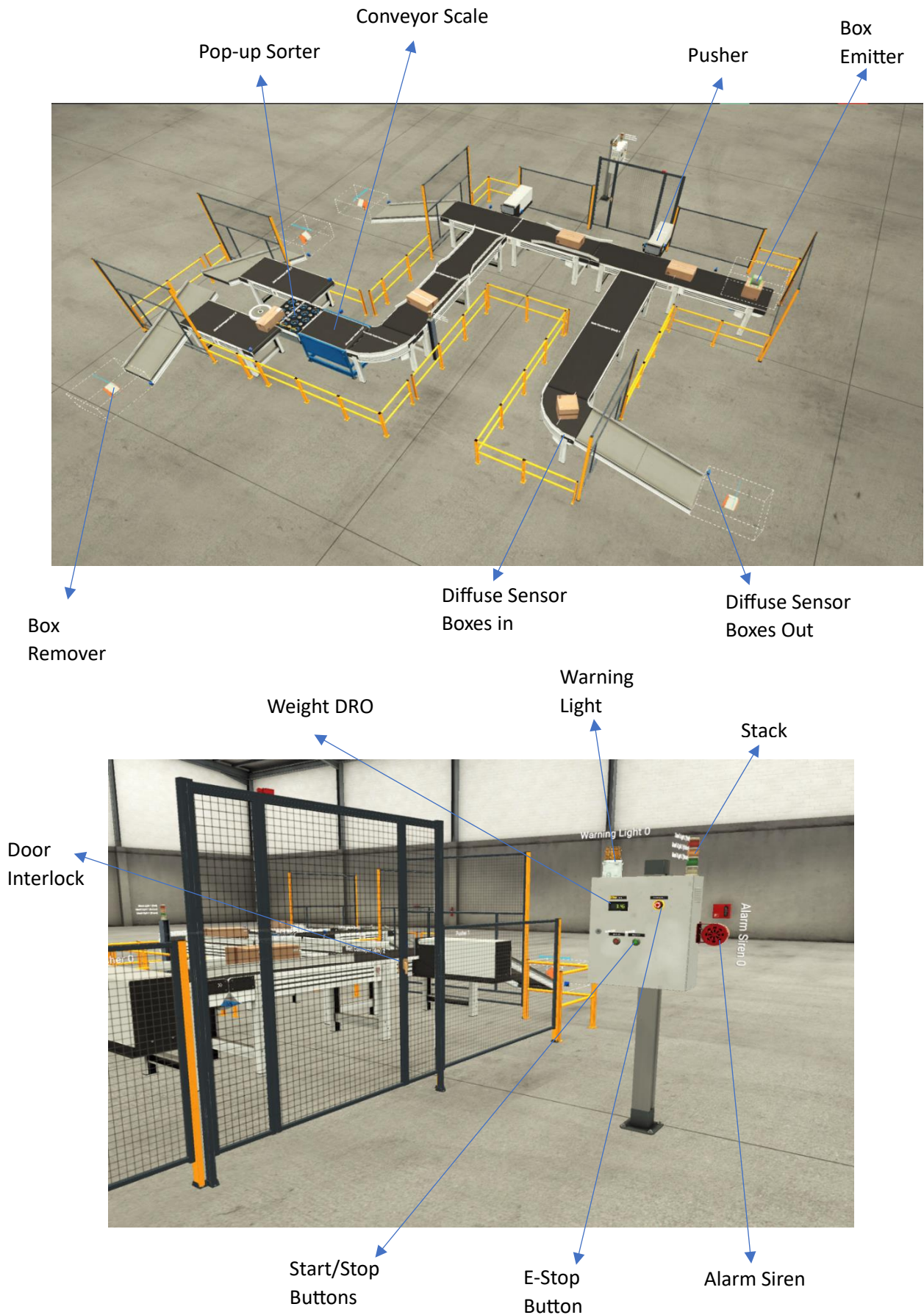
			with small boxes not completing traverse.	
Medium box alarm – Indicates that there are boxes not completing traverse which may be damaged or lost.	Red	If the counter for medium boxes exceeds the alarm pre-set number for medium boxes not completing traverse, then alarm 2 will trigger.	When alarm 2 is triggered, the system will stop, and a red stack light will appear. On the HMI the alarm will light up on the error screen indicating that there is an issue with medium boxes not completing traverse.	To reset the system, either the counters will need to be manually adjusted by the engineer or reset all counters. The alarm master will also need to be reset and then the system restarted.
Large box alarm – Indicates that there are boxes not completing traverse which may be damaged or lost.	Red	If the counter for large boxes exceeds the alarm pre-set number for large boxes not completing traverse, then alarm 3 will trigger.	When alarm 3 is triggered, the system will stop, and a red stack light will appear. On the HMI the alarm will light up on the error screen indicating that there is an issue with large boxes not completing traverse.	To reset the system, either the counters will need to be manually adjusted by the engineer or reset all counters. The alarm master will also need to be reset and then the system restarted.

Table 2 - Alarm & Warning Strategy for the Box Sorter

Task 2 – Factory

The Factory IO file is attached within the zipped file along with the TIA Portal Project Folder.

Key Features

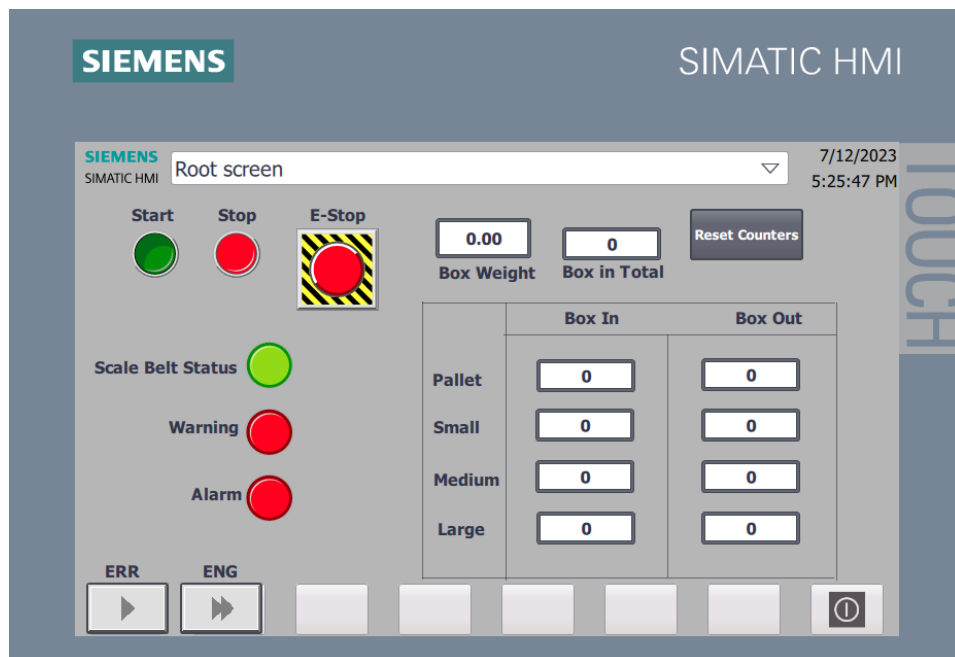


Task 3 – Ladder Logic Program

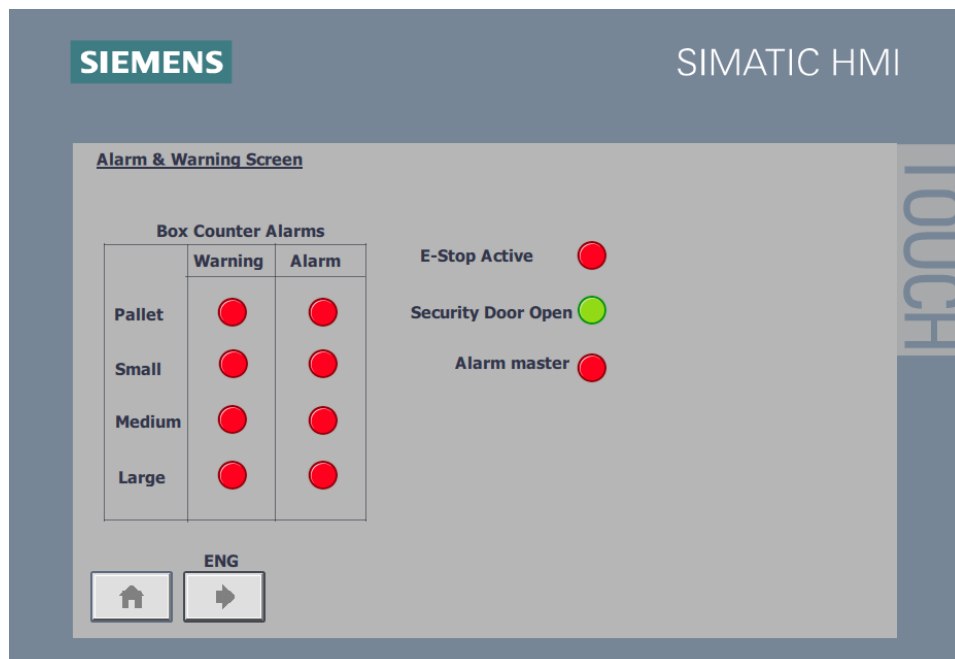
Please refer to the appendix for the printed report copy of the ladder logic program used to control the factory. This is again attached as a zip file in the TIA Portal Project Folder.

Task 4 & 5 – HMI

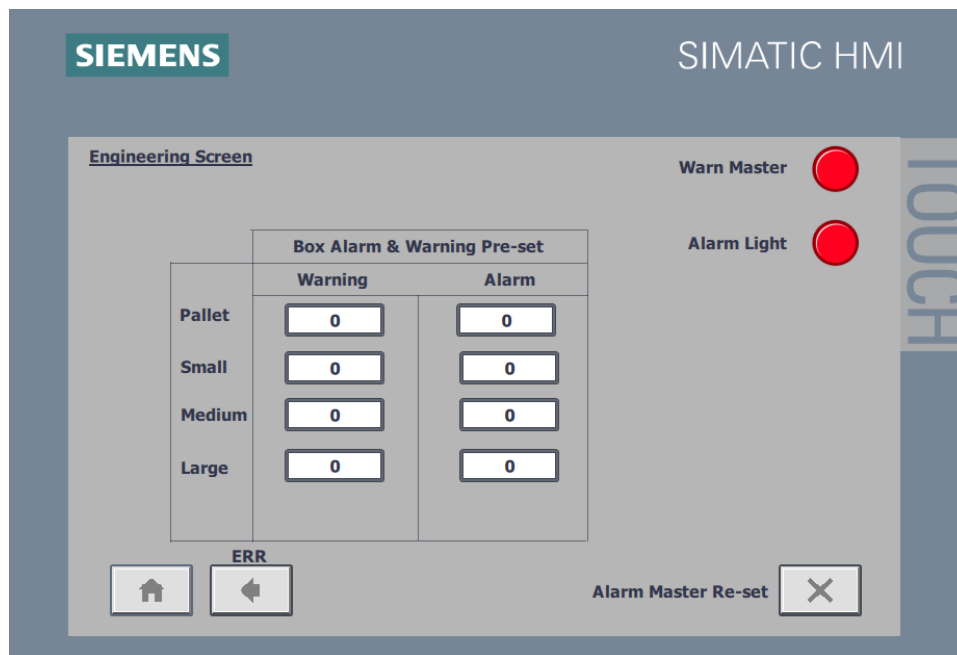
The HMI screens are pictured below, the full HMI is attached within the zipped folder within TIA Portal Project Folder also accessible in the factory programme.



This is the root screen that will appear upon start up, the screen starts in error mode. These errors need to be cleared. The root screen features the counters for each of the box sizes in and out of the system, start and stop button, E-Stop button, an alarm and warning lamp, the box weight from the scale conveyor and a button to re-set all the counters when required.



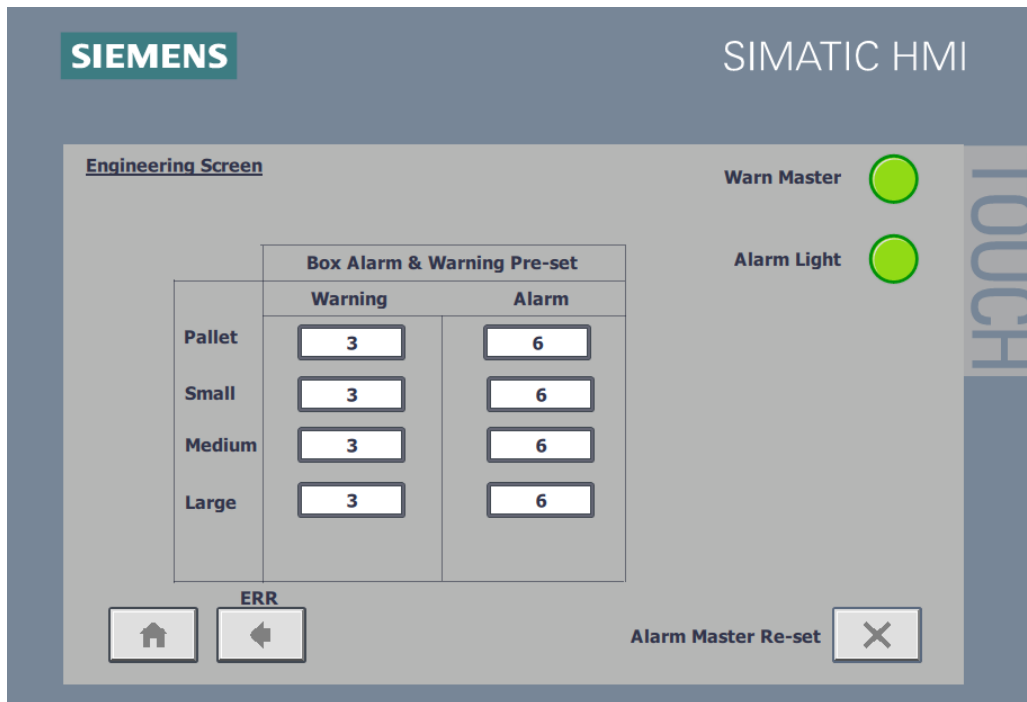
This is the error screen that can be navigated from the root screen. All box sizes are in alarm state along with both the E-Stop and alarm master.



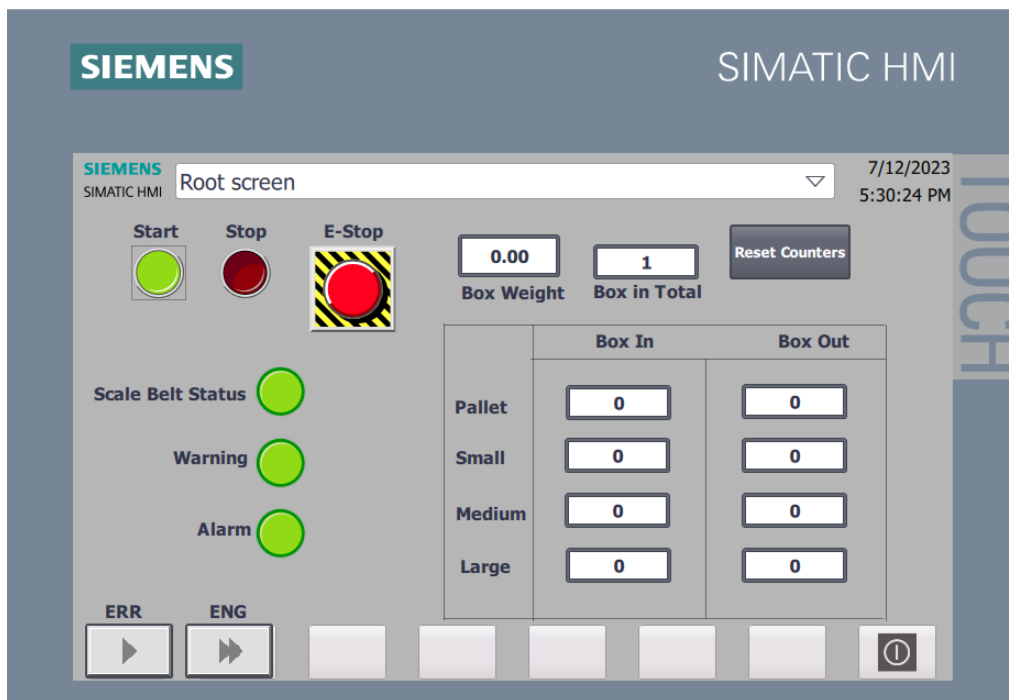
This is the engineering screen that can be navigated either through the root screen or the error screen. This screen shows all the box pre-sets to allow the engineer to input the allowable number of boxes not completing traverse before a warning or alarm is triggered. This screen is also the only screen in which the alarm can be re-set.



To input the pre-sets, the engineer needs to double click the box and use the keypad to enter the desired number.



Once all the pre-sets have been entered, the warning light will turn green. The alarm light will remain red until the alarm master re-set button is pressed.



Once all the alarms have been corrected, navigate back to the root screen. The box sorting system can now be started as there are no alarms or warnings present in the system.

Recommendations

There is always room for improvement or a better way to program, but the beauty of PLC programming is that there are always many different roots to get to the same solution. To improve the program, it is important to firstly review and look for any optimization opportunities. Identify ways to reduce the number of instructions and create far more efficient operations.

Safety is an important aspect in any modern equipment that is functioning using a PLC system, it is critical to implement safety measures and error checking. Ensuring that the program follows proper safety protocols, continuously using error checking to identify potential issues. The HSE (2023) state that the system should “Take the necessary actions to terminate the hazardous event to achieve safe state”.

If the author was to improve the program, there are a couple of things that would be considered:

1. Look at saving the allowable missing box alarm and warning parameters upon start up. This would allow the system to not alarm out upon start up of the system.
2. Look at using the conveyor scale to output a counter for the small and medium boxes. This would reduce the number of diffuse sensors and memory bits in the PLC and system itself.
3. Look at creating alarm history and storing previous alarms for data collection or creating error logging.
4. Define all inputs and outputs before starting to write the program (ACC, 2015).

Overall, the program satisfies the brief there is room for improvement. However, the author is happy with the overall outcome with challenges faced and knowledge gained. This was a more than enjoyable challenge.

List of References

CSD. (2021) The 8 Types of Industrial Control Systems, [online] [The 8 Types of Industrial Control Systems \(controlsdesign.com\)](https://www.controlsdesign.com) (Accessed: 15th June 2023).

Nevatio. (2021) What Are PLCs?, [online] [What are PLCs? \(nevatio.com\)](https://www.nevatio.com) (Accessed: 17th June 2023).

AutomationDirect. (2023) History of the PLC, [online] [History of the PLC | Library.AutomationDirect.com | #1 Value](https://www.automationdirect.com) (Accessed: 21st June 2023).

Eschweigart. (2012) SCADA Security Basics, [online] [SCADA Security Basics: Why are PLCs so Insecure? | Tofino Industrial Security Solution \(tofinosecurity.com\)](https://www.tofinosecurity.com) (Accessed: 24th June 2023).

Peko. (2023) The 7 Most Popular PLC Brands & Companies, [online] [The 7 Most Popular PLC Brands & Companies — PEKO Precision](https://www.peko.com) (Accessed: 24th June 2023).

RT. (2023) Differences of PLC by Siemens, Allen-Bradley and ABB, [online] [Battle of Giants - Differences of PLC by Siemens, Allen-Bradley and ABB | RoboticsTomorrow](https://www.robotics-tomorrow.com) (Accessed: 30th June 2023).

University College London. (2021) What is the significance of a flow chart?, [online] [What is the significance of a flowchart? | Culture Online - UCL – University College London](https://www.cultureonline.co.uk) (Accessed: 1st July 2023).

Romanov, V. (2021) PLC Alarm Programming, [online] [PLC Alarm Programming - Fault Capturing Example in Ladder Logic RSLogix 500 Allen Bradley \(solisplc.com\)](https://www.solisplc.com) (Accessed: 3rd July 2023).

HSE. (2023) Control Systems, [online] [Control systems \(hse.gov.uk\)](https://www.hse.gov.uk) (Accessed: 10th July 2023).

ACC. (2015) Five Steps to PLC Program Development, [online] [Five Steps to PLC Program Development | ACC Automation](https://www.acc-automation.com) (Accessed: 12th July 2023).

Appendix

Totally Integrated Automation Portal

Project 6 - 04-7 / 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:

%FC9000

"MHJ-PLC-Lab-Function-S71200"

EN

ENO

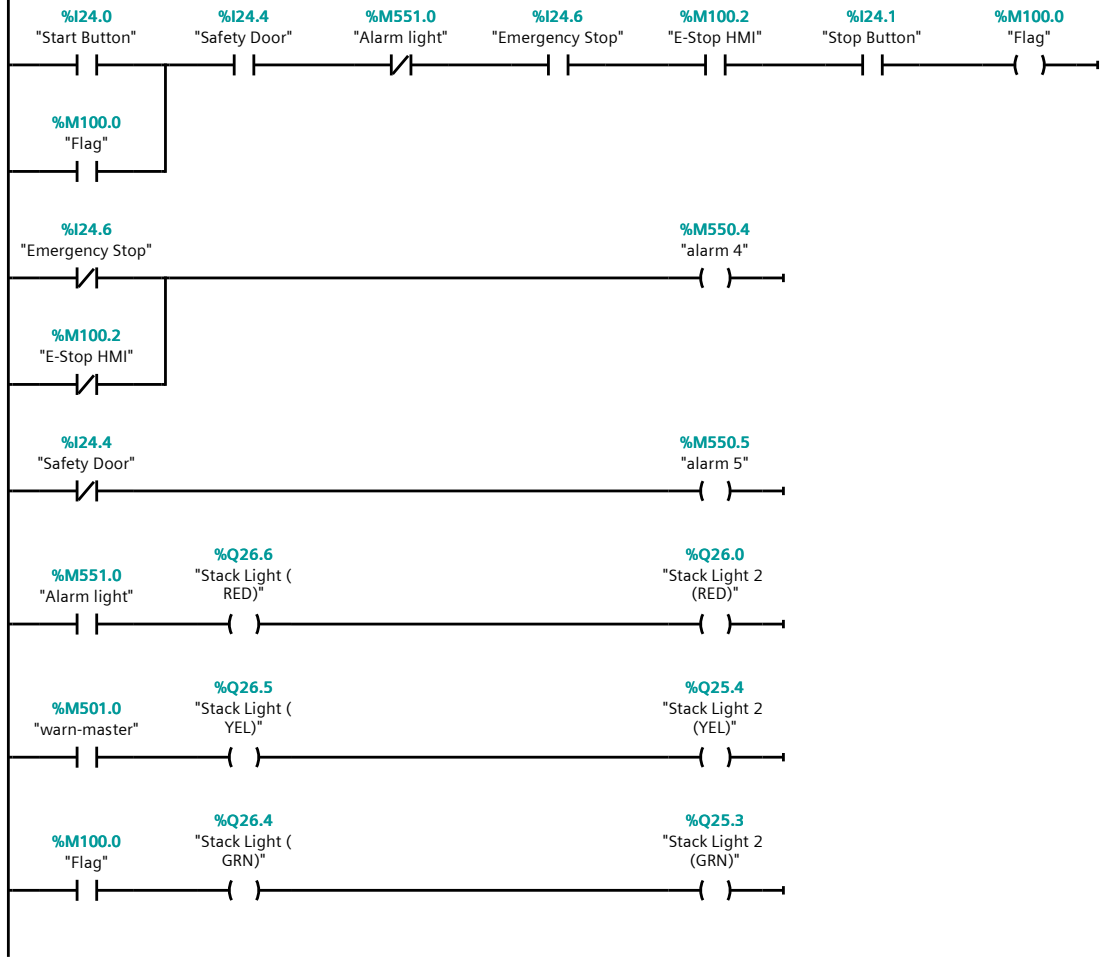
Network 2: Initial Start Up & Stack Lights

This network is for the inital start up of the system, there are certain conditions that need to be met in order for the system to start safely.

The safety door needs to be closed, there needs to be no alarm present which includes both the E-stop on the control panel and the HMI.

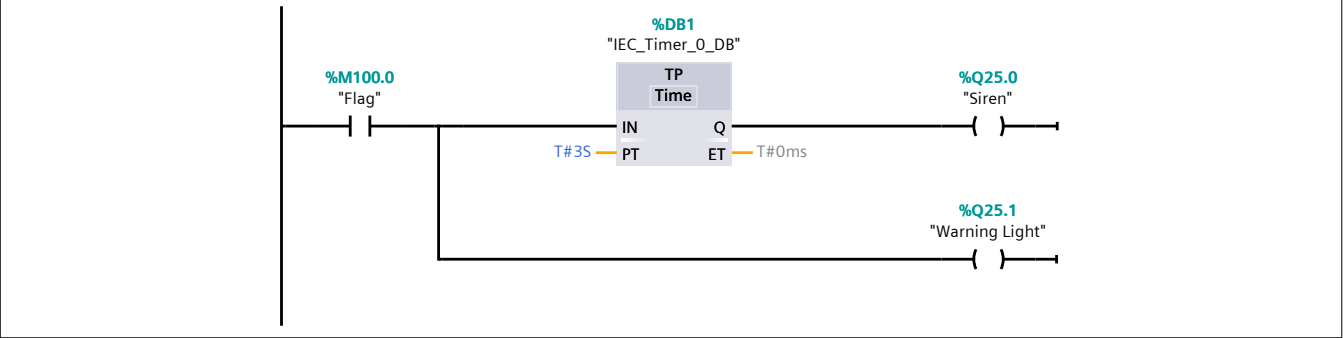
The flag is used as a condition, once triggered the flag keeps the system running until there are any changes to the system like an alarm.

This network also features the 2 stack lights that are used to visually indicate the systems condition to operators. If the flag has been met then the green light illuminates to indicate that the conveyor/system is running. Again any alarm triggers will project a red light and stop the system to indicate error or stop condition. A warning light will cause an amber light but the system will remain running, this just highlights that there is a potential issue with missing boxes.



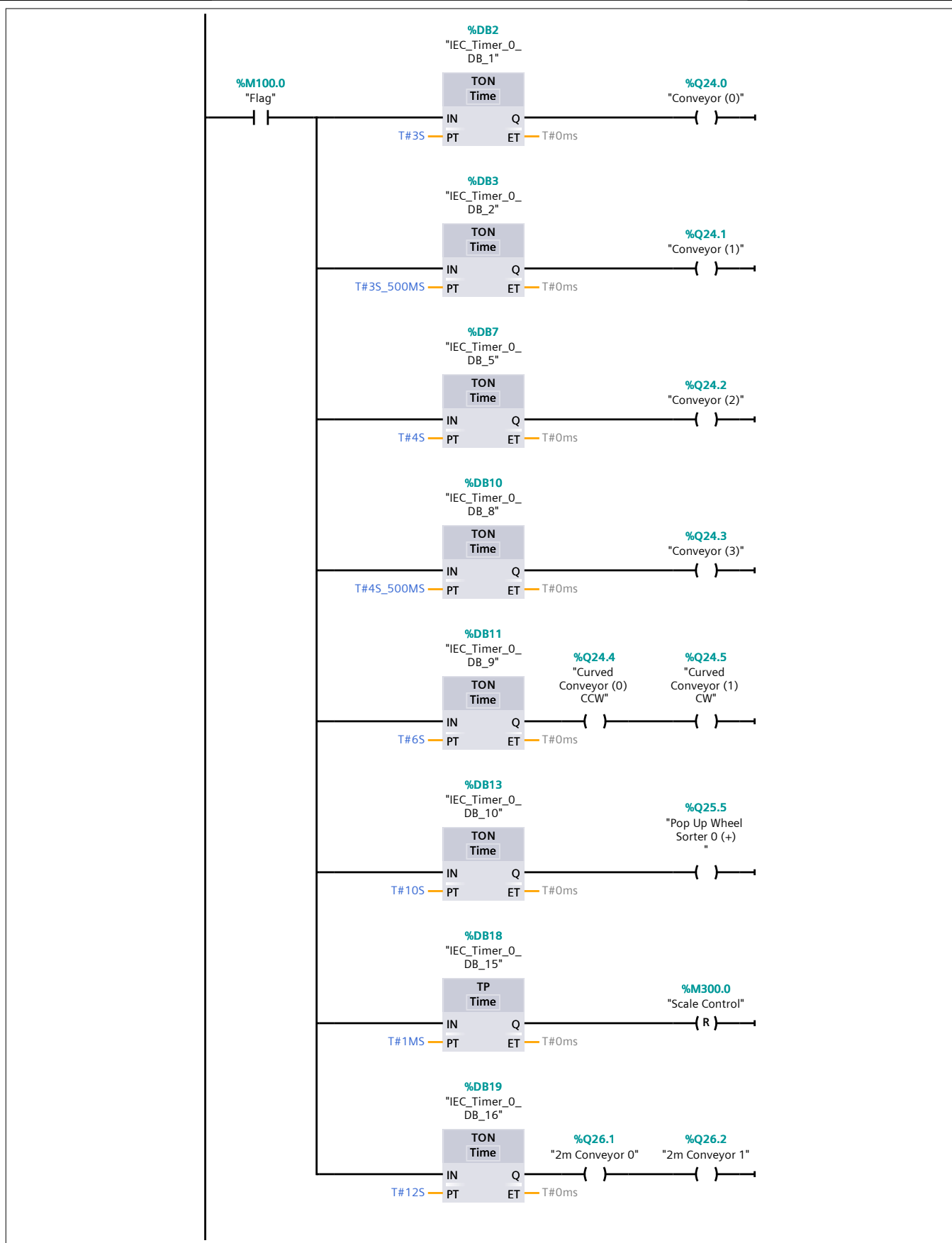
Network 3: Siren & Warning Light

This network features both a siren and warning light. Upon start-up, as long as the flag condition is met then the warning light illuminates and the siren sounds for 3 seconds to indicate that the conveyor system is about to begin.



Network 4: System Conveyors

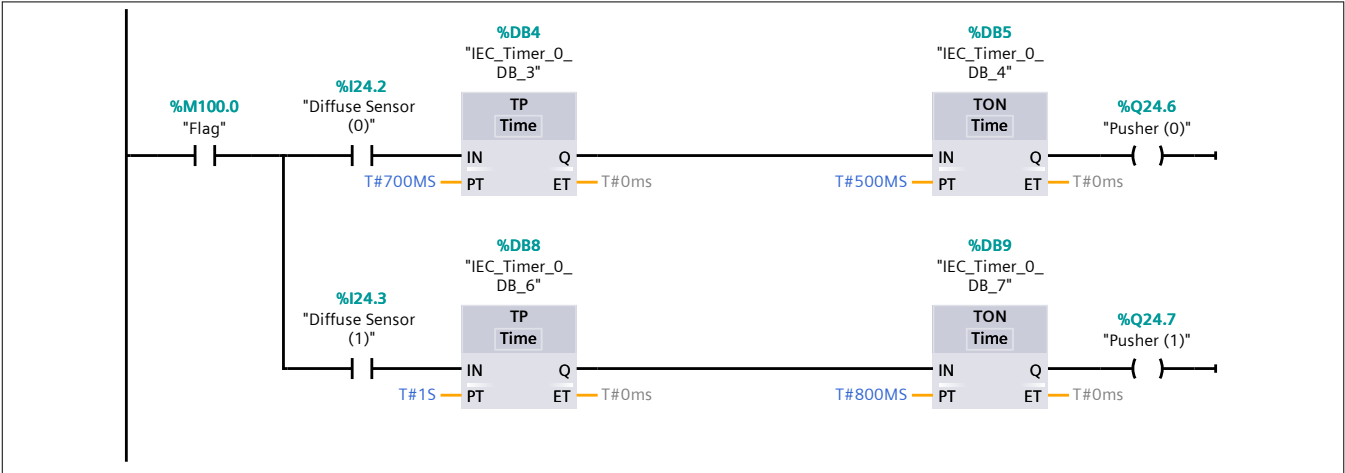
This network features all of the system conveyors that start at delayed times to decrease the chance of an electrical surge in the system. Again, once the flag condition is met then the system conveyors start. in the event of any alarm or error, the conveyors will stop.



Network 5: Pusher

This network is for the pushers that sort the boxes onto different conveyors. Once the flag is active, the boxes will travel along the conveyor and when the diffuse sensor is triggered, a pulse will be generated and a time on condi-

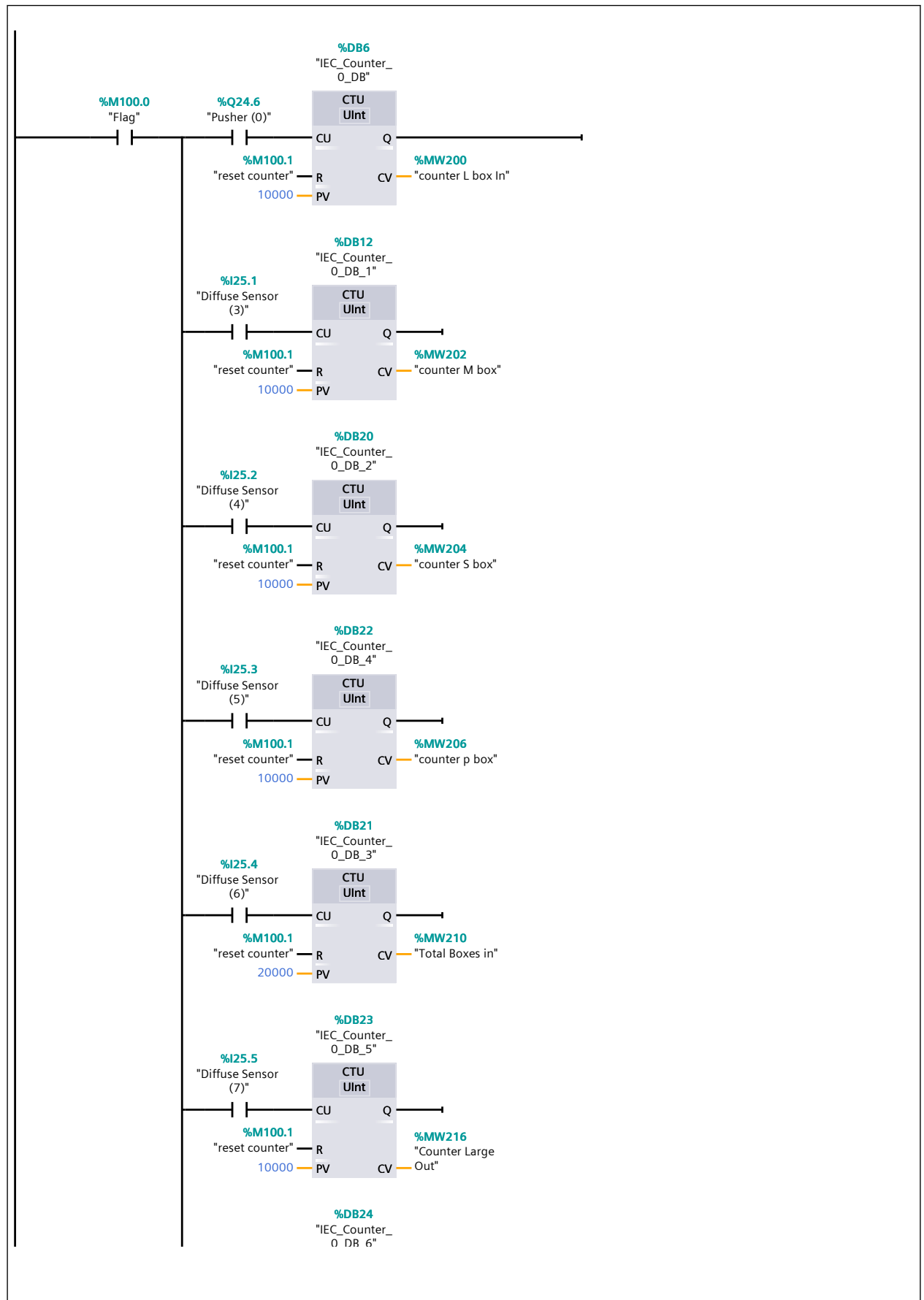
tion will occur in which the pusher is active. There is sufficient time and speed in which the pusher has been programmed to ensure the effective transfer of the relevant sized box onto the conveyor.



Network 6: Counters

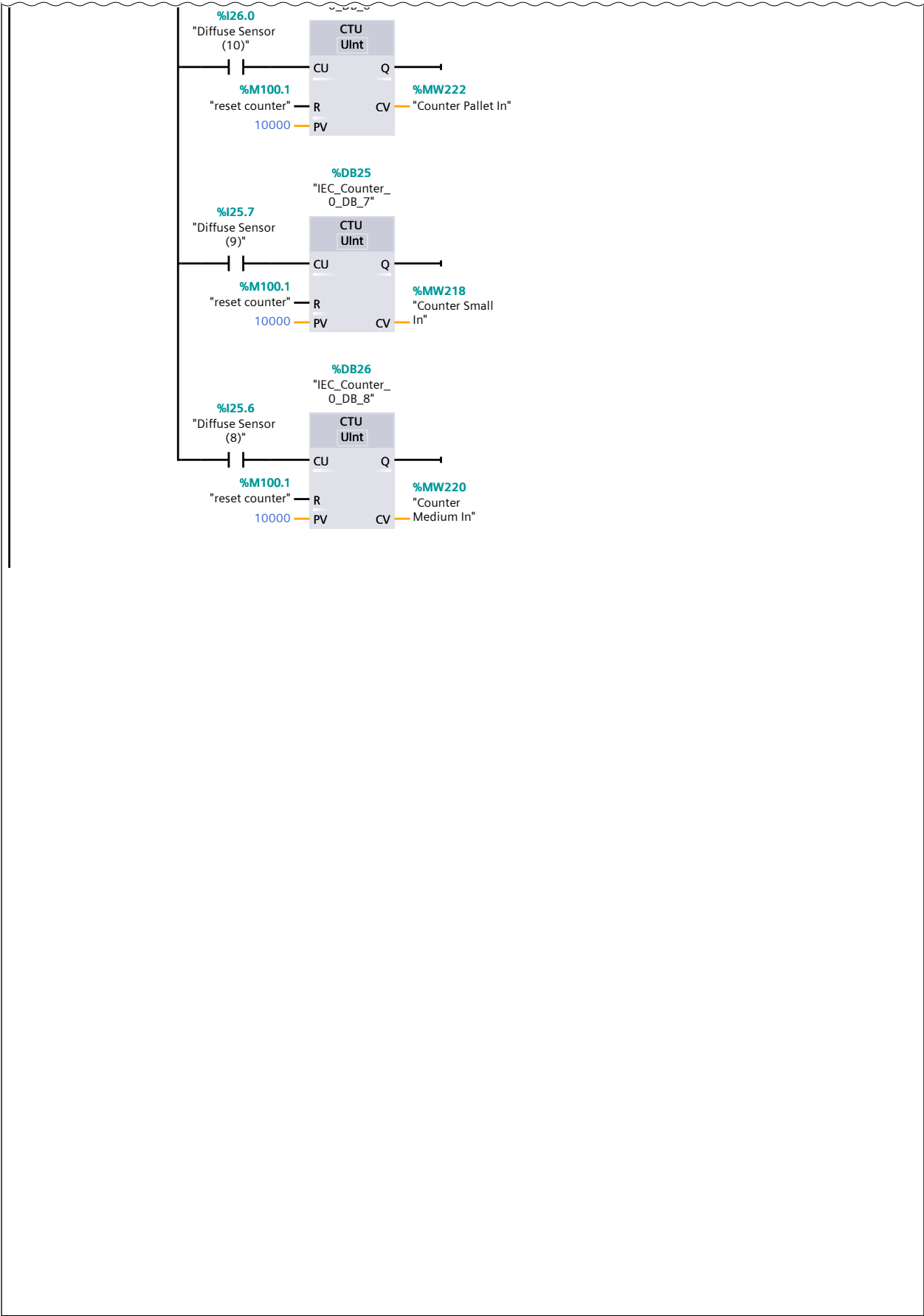
This is where the counters are triggered, these are the counters for total boxes into and out of the system by size. these are triggered by different inputs such as the triggering of the diffuse sensor or activating the pusher.

Network 6: Counters (1.1 / 2.1)



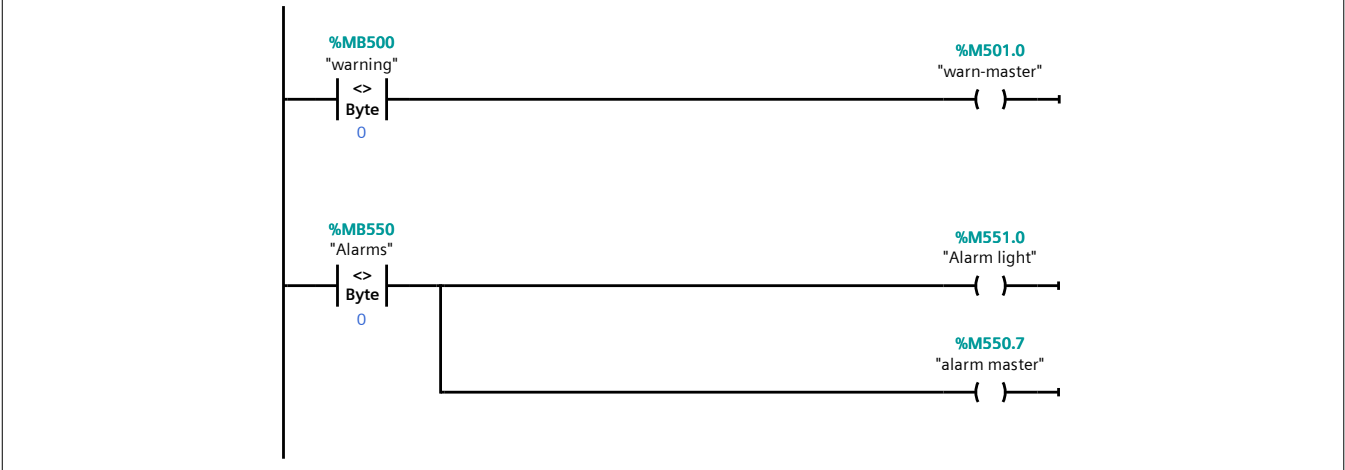
Network 6: Counters (2.1 / 2.1)

1.1 (Page1 - 5)



Network 7: Alarm & Warnings

Warning and Alarm master outputs. Warnings or Alarms (Bits) will be triggered and the master warning bytes will illuminate. Errors and Warnings are illustrated as individual lights on a screen of the HMI. The HMI home screen only has the Alarm and Warning master keeping the HMI far more neat and professional.



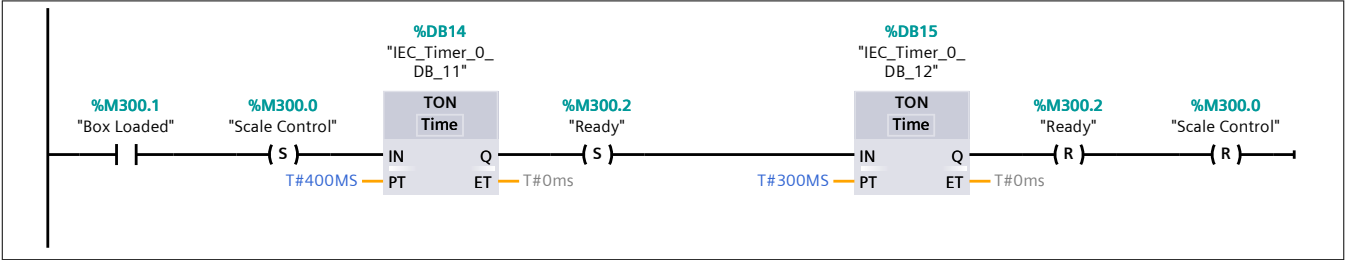
Network 8: Scale Conveyor

This network controls the scale conveyor.



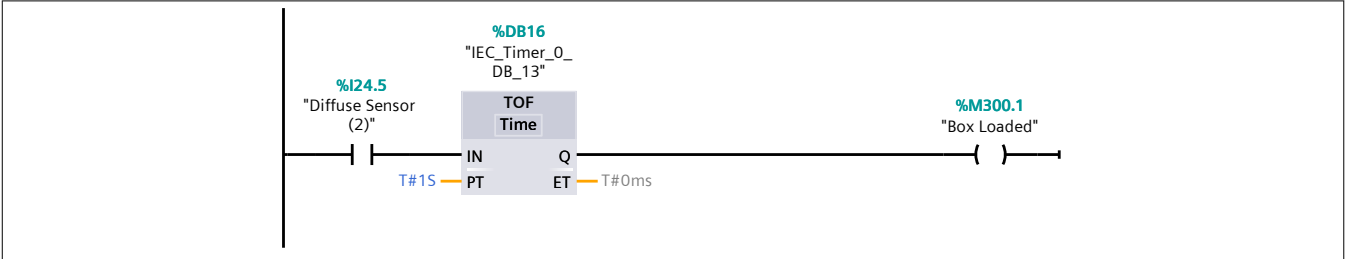
Network 9: Weigh

This network controls the weighing operation for the system. when 'box loaded' is triggered, scale control is set after a period of time a 'ready' memory bit is set. after a certain time, both the ready and scale control will be reset.



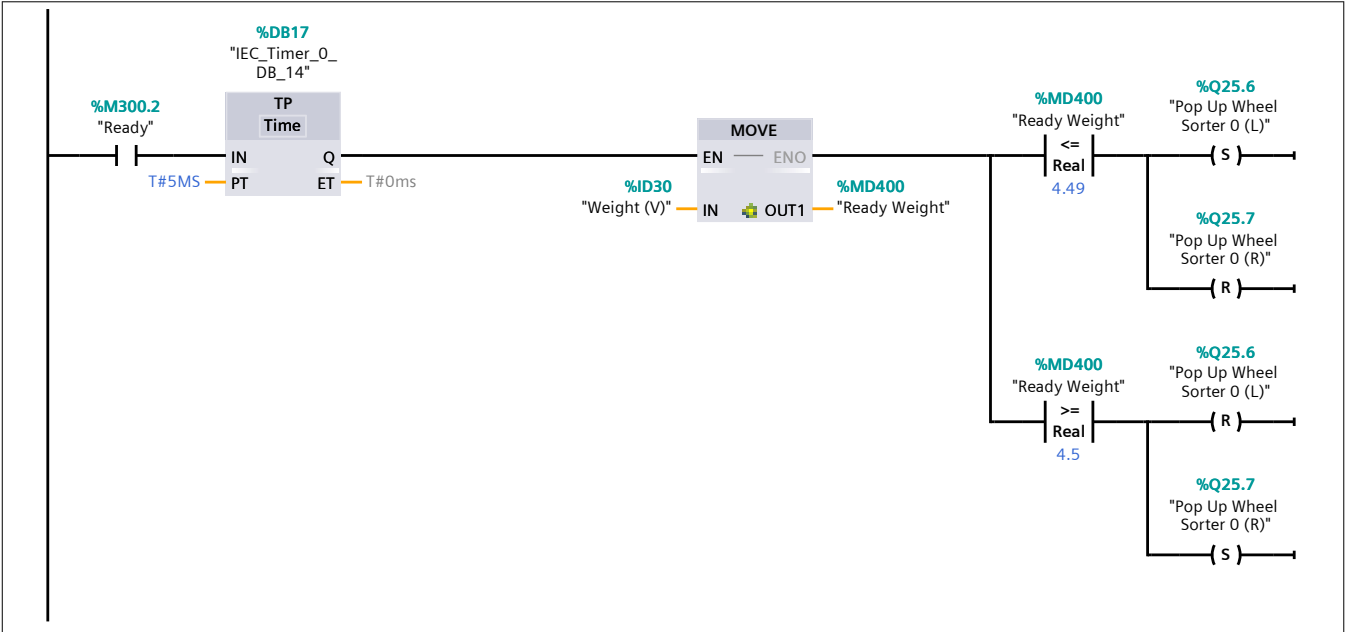
Network 10: Diff Sensor for Scale Conveyor

This is also part of the weigh process. when the box triggers the diff sensor, an off delay is set for 1s and box loaded is given as an output to start the above network.



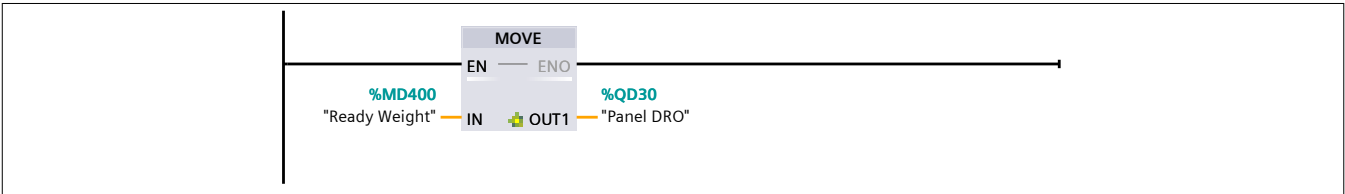
Network 11: Sorter Direction Control

When the 'ready' bit is triggered, a pulse begins which allows the scale conveyor to take a weight and distinguish the direction in which the pop up wheel sorter will drive the box, sorting the boxes into small and medium.



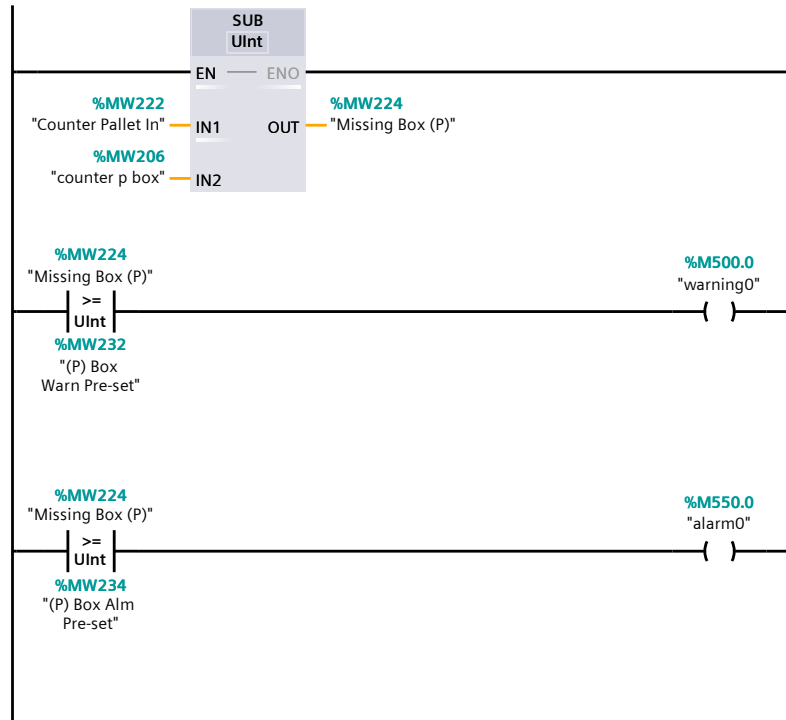
Network 12: Weight Digital Read-out

This rung turns the ready weight into a real digital read-out which is on the control panel of the system.



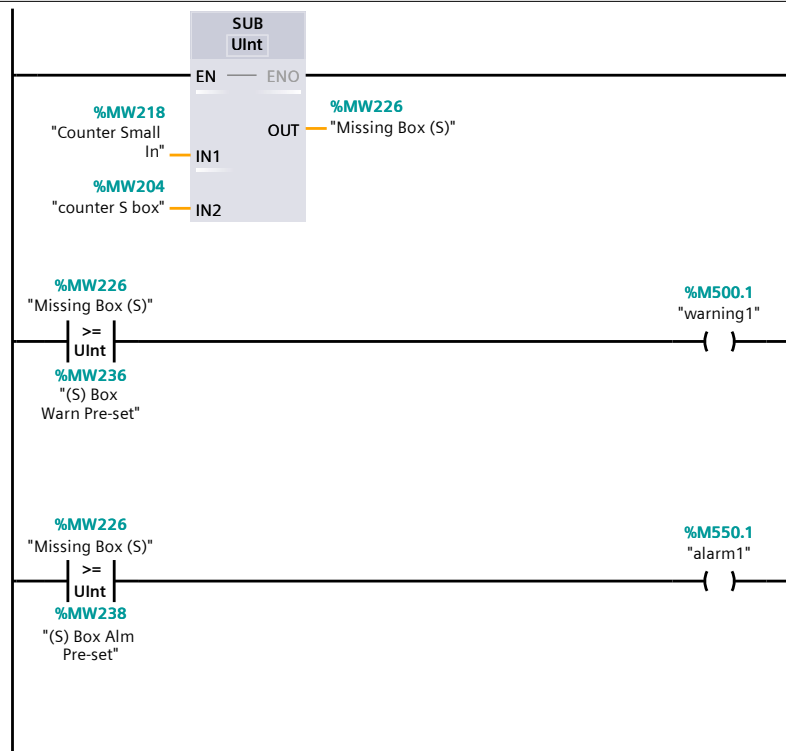
Network 13: Pallet Box Error & Warning

This network subtracts the value from the counter of the palletized boxes in from boxes leaving the system. This value is then taken and compared to the warning & alarm pre-sets which are set on the HMI by an engineer. If the value of the subtraction is greater than a value pre-set then a warning or an alarm will be triggered.



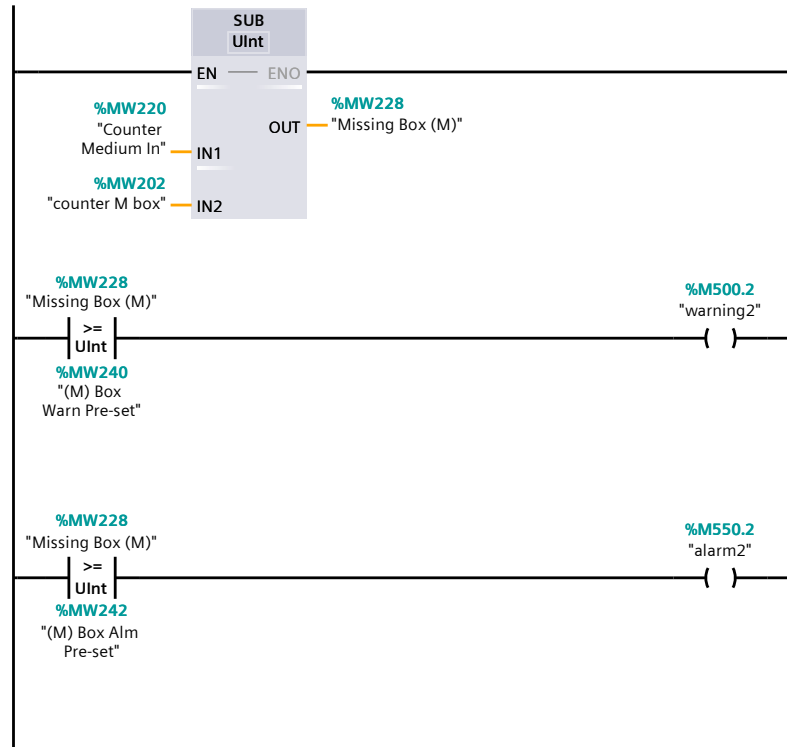
Network 14: Small Box Error & Warning

This network subtracts the value from the counter of the small boxes in from boxes leaving the system. This value is then taken and compared to the warning & alarm pre-sets which are set on the HMI by an engineer. If the value of the subtraction is greater than a value pre-set then a warning or an alarm will be triggered.



Network 15: Medium Box Error & Warning

This network subtracts the value from the counter of the medium boxes in from boxes leaving the system. This value is then taken and compared to the warning & alarm pre-sets which are set on the HMI by an engineer. If the value of the subtraction is greater than a value pre-set then a warning or an alarm will be triggered.



Network 16: Large Box Error & Warning

This network subtracts the value from the counter of the large boxes in from boxes leaving the system. This value is then taken and compared to the warning & alarm pre-sets which are set on the HMI by an engineer. If the value of the subtraction is greater than a value pre-set then a warning or an alarm will be triggered.

