

Scott Thomas - PLCs assignment

by Scott Thomas

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Table of figures

Figure 1 – Unitary PLC

Figure 2 – Modular PLC

Figure 3 – Rack mounted PLC

Figure 4 - Allen Bradley Micro810 PLC (Unitary)

Figure 5 - Siemens s7-1200 PLC (modular)

Figure 6 – Mitsubishi Q Series PLC

Figure 7 – Factory layout designed using Factory IO

Figure 8 – Factory layout

Figure 9 – Operational flow chart

Figure 10 – Root screen

Figure 11 – alarm screen

Figure 12 – Engineers screen

Appendices

Appendix 1 – Ladder logic programme

Abstract

Detailed in this report is the design and control of a factory system which sorts four different packages based on size and weight. The complete factory system design must include the design of a virtual factory using factory I/O; the design of a ladder logic circuit to control the virtual factory; HMI design to control the virtual factory system which must include a root screen which shows the counters for each of the different size/weight of boxes; and alarm and warning screen to show any errors to the operators and an engineers screen capable of re-setting and warnings or alarms

The factory is designed in Factory I/O and must contain and control the following:

- 4 conveyor belts
- 2 pushers
- 1 conveyor scale
- 2 diffuse sensors
- 1 emergency stop
- 2 buttons
- 1 siren
- 1 warning light
- 2 stack lights

Introduction

A Programmable Logic controller is an industrial digital computer designed to perform control function to control a process or system usually used for industrial applications.

The Programmable Logic Controller (PLC) is used in nearly every process in the modern manufacturing environment. The programmable controller was initially designed to replace electromechanical relay systems to make it far simpler to modify the operational control system. Previously, new wiring and physical relays would need to be added to modify the way the system works. With the introduction of the programmable logic controller, the engineer can connect a laptop and alter the control system in a fraction of the time and with no cost. It is also far more compact to use a PLC. Instead of having a large electrical cabinet full of relays, the control system can be neatly confined in the PLC. [1]

A PLC comprises of several parts. These include:

- Central Processing Unit (CPU)
- Power supply
- Input/Output (I/O) rack that cards are placed into

Most of the PLC's available for purchase are modular. This means that they allow the engineer to add a large variety of functionality. This includes:

- Motor control
- Position control
- Discrete analogue inputs and outputs
- Serial communication
- PID control [2]

Another piece of equipment that is vital to the operation and control of a system or process in the industrial environment is the Human-Machine Interface (HMI). A HMI is a user interface that connects a person to system, machine or a process. In the industrial environment, the HMI can be used to monitor machine inputs and outputs; track production trends and output of the system; visually display data and show any errors in the system which will show on the screen as warnings/alarms. [3]

Background Research

There are three main types of PLC. These are:

- Unitary (Also known as compact)
- Modular
- Rack mounted

A Unitary PLC is the most simple PLC. The unitary, or compact PLC has a fixed number of inputs and outputs which can not be expanded with the installation of additional modules. The unitary PLC contains a processor and ports for input and output connections and is usually attached directly to the device or application that is being controlled. [4]

Shown in figure 1 is a typical unitary PLC, in this case an Allen Bradley MicroLogix 1100

Figure 1 – Unitary PLC



[5]

A modular PLC is a type of PLC system that allows multiple expansions through the addition of modules. Installing additional modules allow the programmable logic controller additional features. This includes increased numbers of input and output units which are then easier to use as each component will be independent of each other. The communications module, Input/Output module and power supply are all separate from the microcontroller, so the engineer is required to connect them to create the complete PLC control system. [6]

Figure 2 – Modular PLC



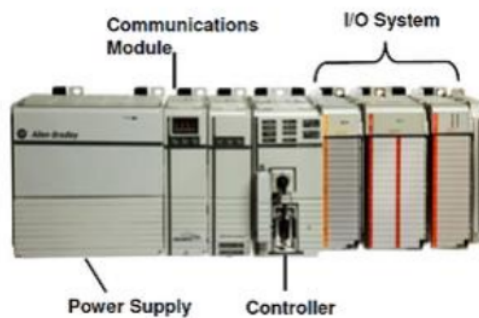
The rack mounted PLC has the largest physical size of all types of PLC's and they are also the most popular PLC type. Rack mounted PLC's are similar to modular PLC's but their size and shape is much different.

Using a rack mounted PLC system has many benefits for use on large processes. These benefits include:

- Built in power supply
- Emergency built in power supply so that if the power to the PLC is lost the built in battery will help the PLC save its memory. This means that the PLC programme will not be lost.
- Room for expansion – Modular systems were designed with expansion in mind and for the possibility to customise the system in the future.
- Greater number of I/O modules – Unitary PLC's has a limited number of inputs and outputs available which could cause issues with large automated systems. With a modular PLC, additional input and output modules can be connected. [8]
- Easier fault finding – It is easier to fault find with a modular system as the modules can be swapped out which is not possible on unitary systems. This will then lead to reduced downtime.
- Memory – Additional memory modules can be purchased if more memory is required for a large industrial process [9]

It can be seen in figure 3 how the separate modules are put together to provide a complete programmable logic controller system.

Figure 3 – Rack mounted PLC



[7]

Programable Logic Controllers currently available

Figure 4 - Allen Bradley Micro810 PLC (Unitary)

Cost - £117.72



The Allen Bradley Micro810 PLC, seen in figure 4, is designed to control small individual industrial machines. The small unitary PLC functions as a smart relay and features advanced user-friendly programming abilities and is compatible with a wide range of network interfaces.

Pro's	Con's
8 Amp output. Removes the need for external relays	No internal power supply
USB 2.0 communications port for easy connection	Only 8 input ports
Compact	Only 4 input ports
Cheap	Unitary, unable to expand the PLC in the future
	No analogue inputs
	No battery backup

[10]

As this PLC has only 12 Input/Output connections, it would not be appropriate for use on a large process and would only be appropriate for use on a single small machine. Another issue with this unitary PLC is that if an engineer would want to install more equipment on this machine, they would not be able to expand the PLC by adding new modules. This PLC is very cheap so it would be ideal to be used on a small prototype machine.

Figure 5 - Siemens s7-1200 PLC (modular)

Cost - £512.40



This Siemens PLC, seen in figure 5, is a high-performance unitary PLC with a compact design. This PLC comes with integrated IO and communication interfaces. It also has 2 analogue inputs, 14 digital inputs and 10 digital transistor outputs.

Pro's	Con's
High speed digital transistor outputs	No internal power supply
Compact	24 I/O
Integrated ethernet interface	More expensive
High performance CPU	No relay output
Analogue inputs	No battery backup
Can be expanded with the use of extra modules	

[11]

The Siemens s7-1200 PLC would be ideal for small industrial processes. The PLC contains analogue inputs which would be ideal to connect straight to sensor outputs. The PLC also has 10 digital transistor outputs which switch very quickly but cannot switch much current so relays will need to be connected to these outputs.

Figure 6 – Mitsubishi Q Series PLC

Cost - £553.80



The Mitsubishi Q series PLC, seen in figure 6, is a rack mounted PLC. This PLC has an integrated power supply unit, emergency battery backup and a CPU. There is space in the rack for 5 additional modules which will be used for communications modules and Input/Output cards and a variety of other modules to for the engineer to customise it for specific uses.

Pro's	Con's
Internal power supply	Expensive
Emergency battery backup	Large
Expandable	
USB and RS-232 communications	
Ethernet connectivity	

[13]

The Rack mounted PLC is the ideal choice to use on large industrial processes/systems. It is the most expandable of all the PLC types so it can be used on very large systems. It is very customisable, the engineer can purchase a variety of different modules for different purposes. The only issues with this type of PLC is that they can take up a lot of space in the panel and the price as just the base product is more expensive than the other two examples and extra modules will need to be purchased before the PLC is capable of functioning.

Equipment

The computer programme 'Factory IO' was used to design a factory process capable of sorting four packages of different sizes and weights.

Components used:

- 1 green button to start the process
- 1 green light to show that the process was running
- 1 red button to stop the process
- 1 red light to show that the process had stopped
- 1 siren to warn when the process was starting
- 3 pushers were used to separate the 3 different sizes of packages
- 3 diffuse sensors to sort the sizes of the packages and control the pushers
- 1 diffuse sensor to stop the weighing scale conveyor
- 4 diffuse sensors to count the amount of each size of package
- Several conveyors to transport the packages
- Conveyor scale to weigh the packages
- 2 stack lights
- Pop up wheel sorter
- Random package emitter to emit the 4 different size packages required
- 4 package removers to remove the packages after they have been weighed.

To produce the ladder logic program Siemens Totally Integrated Automation (TIA) portal was used. This programming package allows an engineer to produce a complete ladder logic programme. This includes the use of normally open and closed contacts, outputs, timers and counters. This package also allows the design of HMI screens to be produced.

Method

The factory was designed as can be seen in figure 7 and 8. The sorting process starts with a random package emitter, set to emit four different size packages varying in size and weight. The emitter starts at the end of the conveyor. The package then travels along the conveyor until it reaches the diffuse sensor that is set to the size of the package. Each of the three sensors are set to different heights to sort the packages. When the package reaches the appropriate sensor, the pusher will push the package to appropriate location. The first two sizes of package are sorted on the size of the box and removed. The small and medium boxes are pushed onto the next conveyor by pusher 2. This package then travels along the conveyor until they reach the weighing conveyor. The package is then weighed. If the package weighs more than 4.25kg, the package goes onto the pop-up conveyors which transports the package to the left when it is counted and then removed. If the package weighs more than 4.25kg, the package moves onto the pop-up conveyor which transports the package to the right where it is counted and then removed.

Figure 7 – Factory layout designed using Factory IO

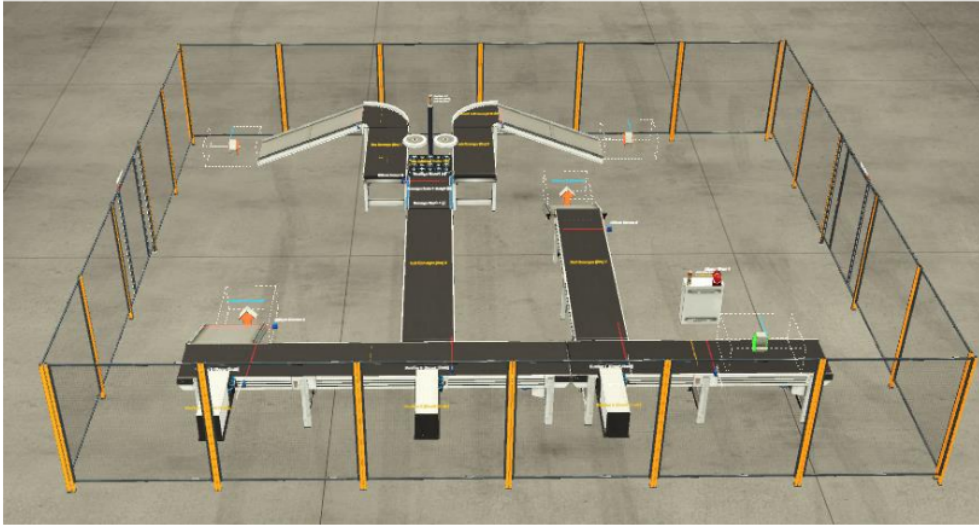
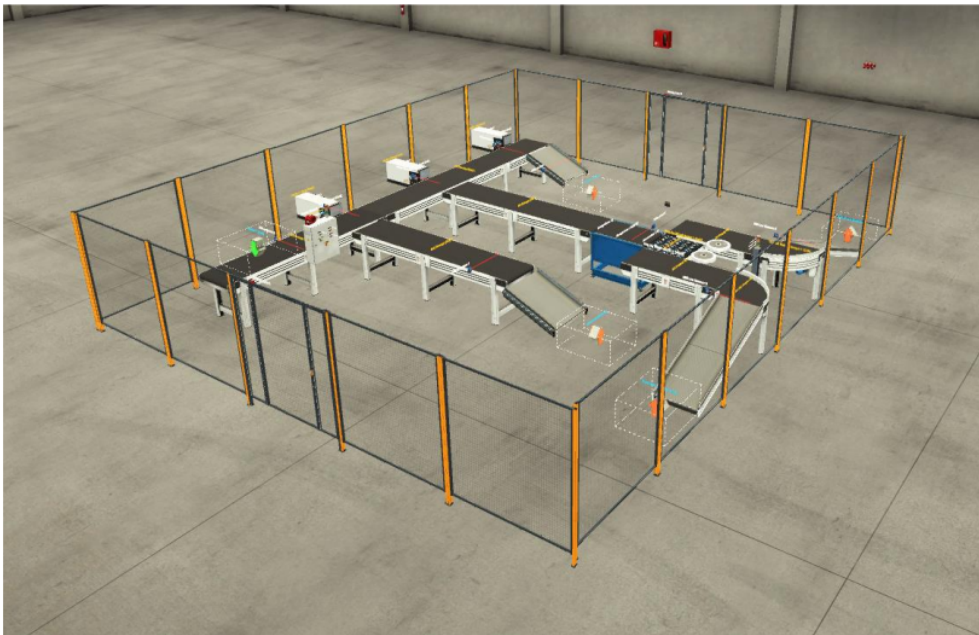
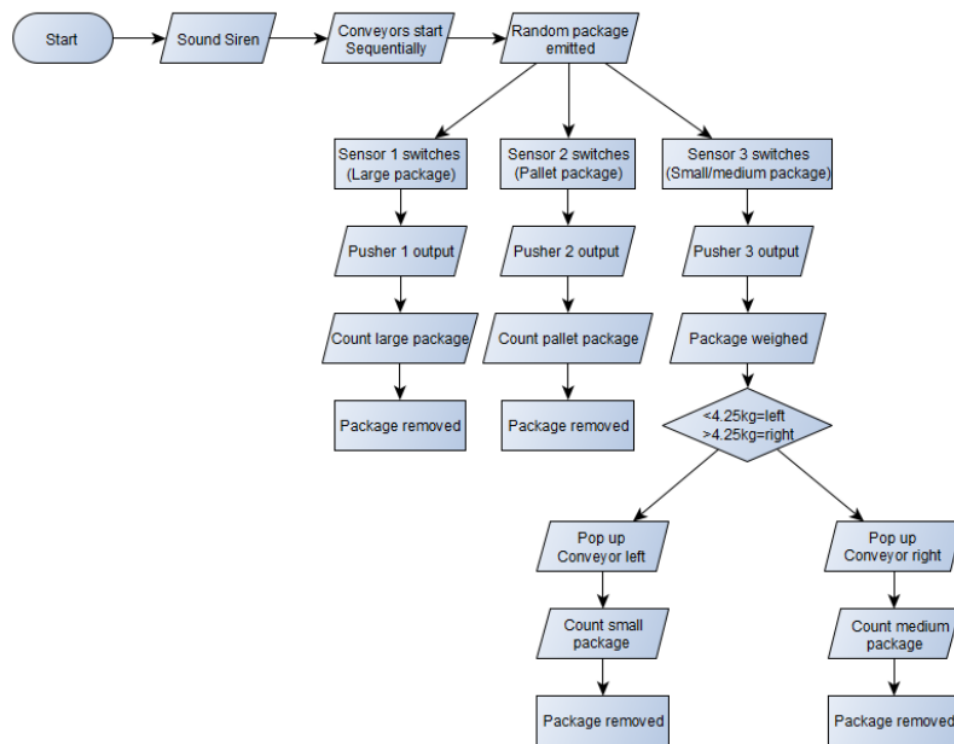


Figure 8 – Factory layout



Flow Chart

Figure 9 – Operational flow chart



Seen in figure 9 is the operational flow chart for the factory designed. The system starts when the start button is pressed. The siren then sounds for two seconds to warn people that the conveyors are about to start. The conveyors then start in sequence. The conveyors start in sequence to reduce start up current. If all of the conveyors start at the same time, it would result in a very large current draw. This would lead to tripping issues and would put a large strain on contactors and other electrical components.

Random packages are then emitted. There are four different size packages emitted. These are large boxes, pallet boxes, small and medium boxes. To sort the packages by size, the diffuse sensors are set at different heights to ensure that the pushers switch at the correct moment to ensure that the packages go to the desired location. When diffuse sensor 1 switches, pusher 1 energises and the package goes down the first conveyor. The package is then counted, and the count is shown on the HMI. The package is then removed. For the pallet package, the diffuse sensor is set lower as the pallet package is smaller. Sensor switches and after a set amount of time, which is set in the ladder logic programme, pusher 2 energises and pushes the package onto the conveyor. The package is then counted, and the package is removed. For the small/medium packages they are sorted by weight. Diffuse sensor 3 switches, energising pusher 3 after a set amount of time to ensure it energises when the package is in position. The package then stops on the weighing scale conveyor. If the package weighs less than 4.25kg, the pop-up conveyor will move the package to the left. The small package is then counted and added to the small package count. If the package weighs over

4.25kg, then the pop-up conveyor moves the package to the right where the medium package is then counted and added to the medium box count.

Alarm Strategy

The system is designed in a way that if any packages fall off the conveyor, then an alarm will go off. These alarms can be seen in the ladder logic diagram in appendix one. The Alarms are located in networks 15, 17, 18 and 19. The error counters are located in network 9 and 10. These errors are calculated using 'up down' counters. For example, in network 9 the large box error counter is shown. The error counts up when pusher 2 is energised. The counter then counts down when diffuse sensor 7 is switched. This means that if the box falls off the conveyor on the way to the package remover, the error will stay on the counter and a warning light will come on. If the errors reach the set point an alarm will sound and the system will stop.

Total errors are also calculated in the same way. The counter counts up on diffuse sensor 8 which is located at the start of the process, so each box is counted. The counter then counts down when diffuse sensor 0, 5 or 6 is switched as well as pusher 1, these are all connected in parallel and can be seen in network 10 of the ladder logic diagram in appendix 1.

When an alarm is activated, the engineer would have to go into the engineer's screen and press the master reset button before the system can be restarted.

HMI design

The HMI screens were designed using Siemens TIA. There are three screens used in total which are a root screen seen in figure 10, an alarm screen seen in figure 11 and an engineers screen seen in figure 12.

The root screen is the main operating screen. This screen has a start button and a stop button for controlling the system. It also has an emergency stop button which when pressed must be reset through the engineers page. This screen also has the counters to show how much of each package has been counted and a total counter.

The alarm screen shows the status of all the alarms and warnings. It also shows the condition of the emergency stop.

The engineers screen seen in figure 12 shows the error counters. This page also has a master reset button. If the emergency stop is pressed or an alarm sound then the master reset button must be pressed to restart the system.

Figure 10 – Root screen

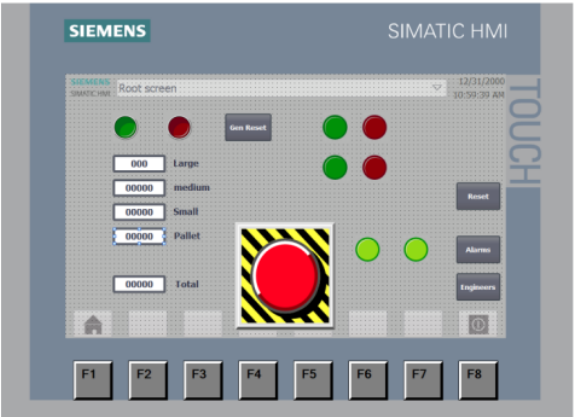


Figure 11 – alarm screen

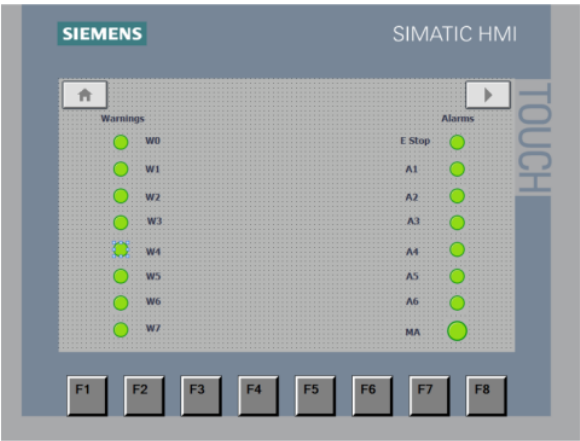
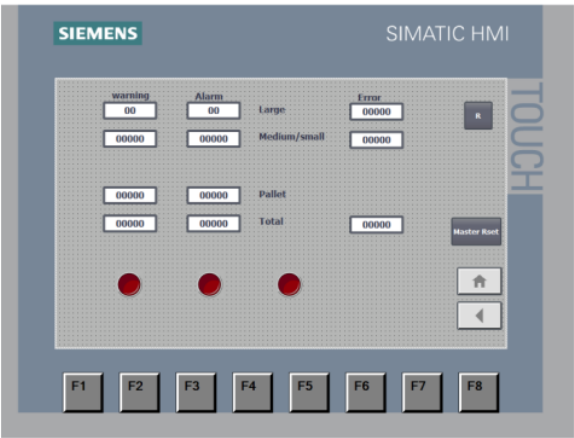


Figure 12 – Engineers screen



Ladder logic brief

Network 1:

Network 1 is the PLC communications block. This is used to communicate between the programming software and Factory IO.

Network 2:

Network 2 houses the start operations. When the start button is pressed, the operate flag will switch on. The operate flag then starts the process of switching on the conveyors in sequence. The operate flag is then connected in parallel with the start button to 'latch' the operate flag. This means that the system will continue to run unless the stop button is pressed or an alarm is active.

Network 3:

Network 3 resets the scale conveyor by pressing the general reset button on the HMI root screen

Network 4:

Network 4 starts the conveyors in sequence. The siren first sounds for 2 seconds and then the conveyor A starts up. The rest of the conveyors then start up 0.5 to 1 second apart. The starting of these conveyors is done in sequence to reduce start up current draw which could cause overloading causing damage to electrical components and tripping issues.

Network 5:

Network 5 switches on the green and red lights to indicate if the system is running or not. When the operate flag is on then the green light will be on. When the operate flag is off then the red light will be on.

Network 6:

Network 6 is used to control pusher 1. When diffuse sensor switches, indicating that there is a box present, the timer starts and when the timer is finished, pusher 1 is activated pushing the box to the desired location. This timing was determined by running the programme in factory IO and adjusting the timer to ensure the pusher was activated at the correct time.

Network 7:

Network 7 is used to control pusher 2 and works in the same way as network 6 except it switches off diffuse sensor 2 and the timing is different.

Network 8:

Network 8 is used to control pusher 3 and works in the same way as network 6 except it switches off diffuse sensor 3 and the timing is different.

Network 9:

Network 9 controls the package counters and the error counters. Taking the medium count as an example, each time diffuse sensor 0 switches, the medium count goes up which then displays on the root screen of the HMI. The error counters work by using a up down counter. Looking at the large box error, each time pusher 2 switches, the errors count up. When diffuse sensor 5 switches, the error goes down. This ensure that if any package falls off the conveyor belt then the error will count up.

Network 10:

Network 10 is a continuation of network 9 and houses the pallet count and the total errors counter.

Network 11:

Network 11 house the warning and alarm flags. If any warnings are present, the warning flag will be on. If any alarms are on, the master alarm and alarm flag will turn on.

Network 12:

Network 12 switches on the scale conveyor. When diffuse sensor 4 is switched, the conveyor will stop so that the package can be weighed. After the timer is finished the scale conveyors will start back up and the package will continue to the pop-up conveyor.

Network 13:

Network 13 shows a digital display to show how much the package weighs.

Network 14:

Network 14 controls the pop-up conveyor. If the package weighs less than 4.25kg, the pop-up conveyor will move the package to the left. If the package weighs more than 4.25kg, the pop-up conveyors will move the package to the right.

Network 15, 17, 18 & 19:

Network 15, 17, 18 & 19 control warnings and alarms if there is an error with the counts.

Network 16:

Network 16 controls the stack lights.

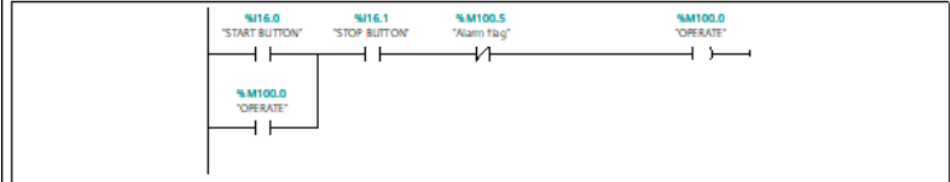
Appendix 1 – Ladder logic programme

Network 1:



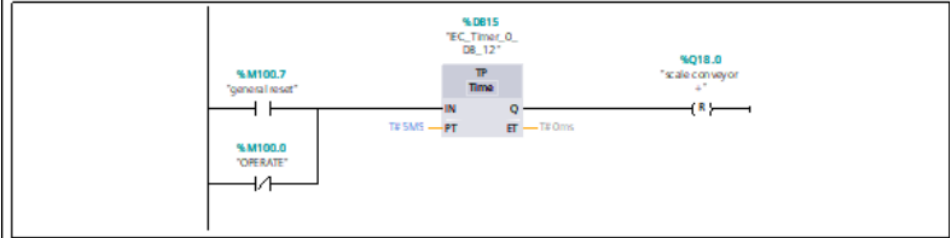
Network 2:

START OPERATIONS



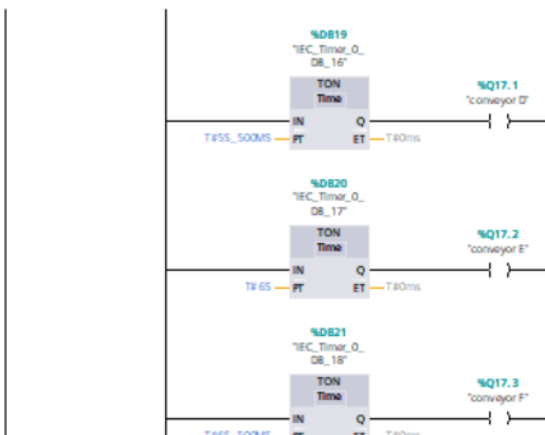
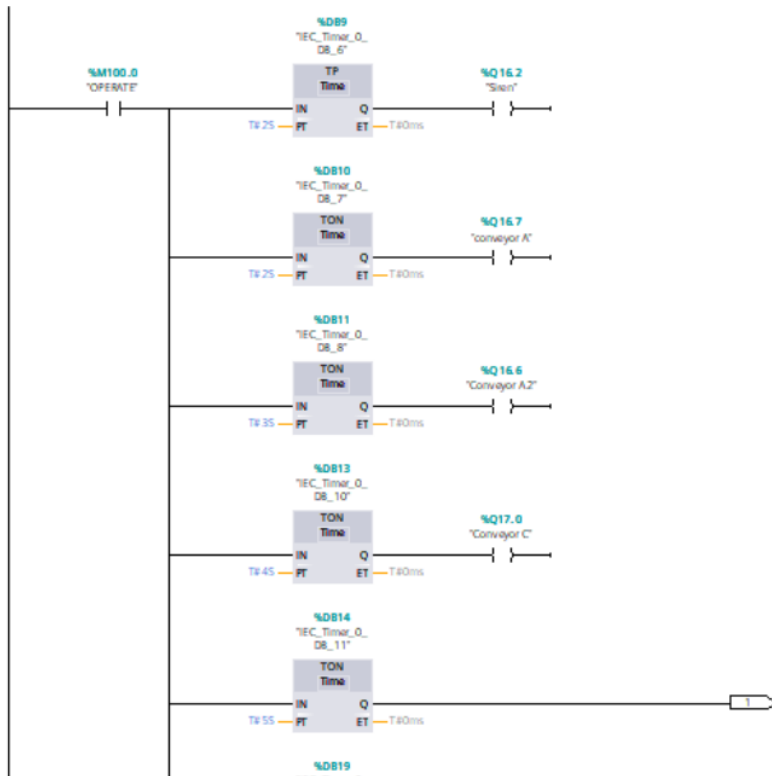
Network 3:

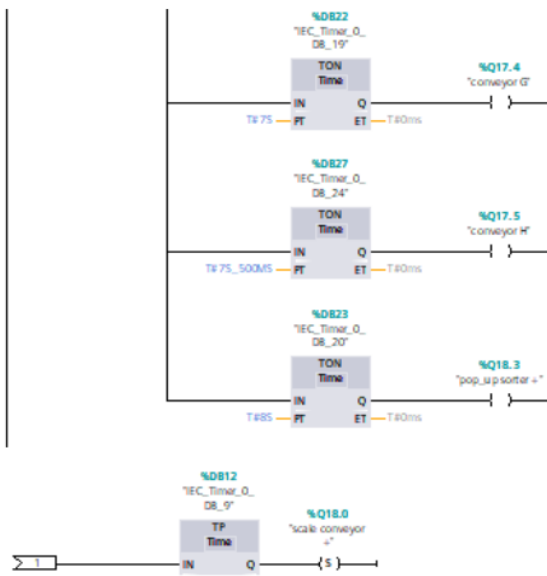
General reset



Network 4:

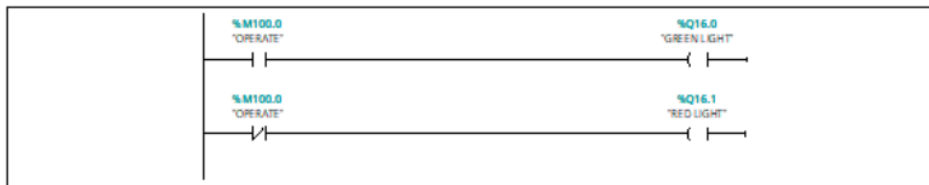
start conveyors in sequence





Network 5:

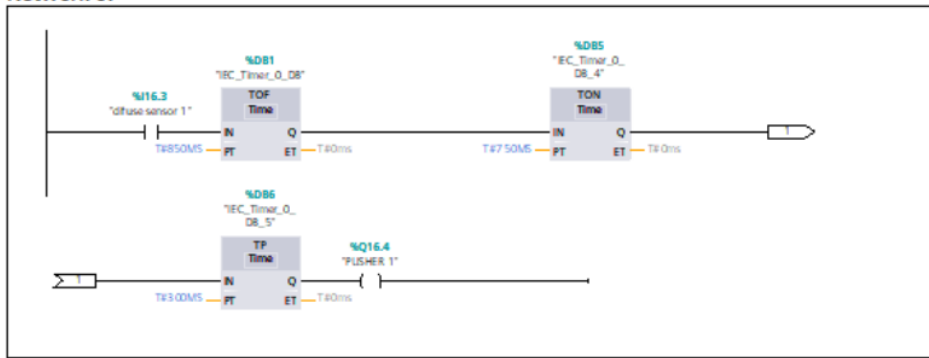
Lights



Network 6:

Difuse sensor 1

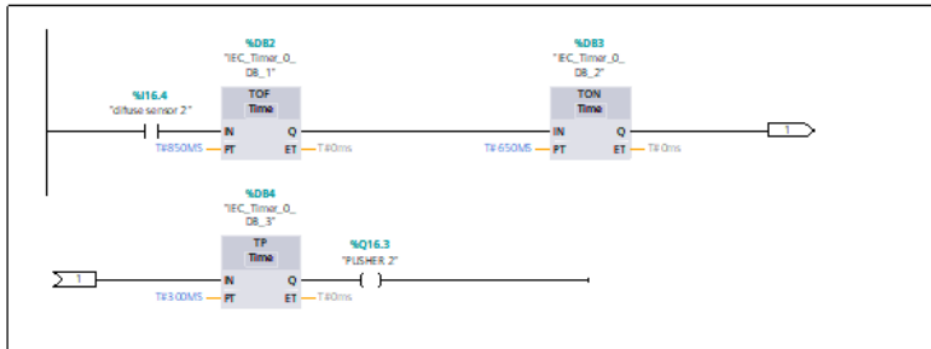
Network 6:



Network 7:

Difuse sensor 2

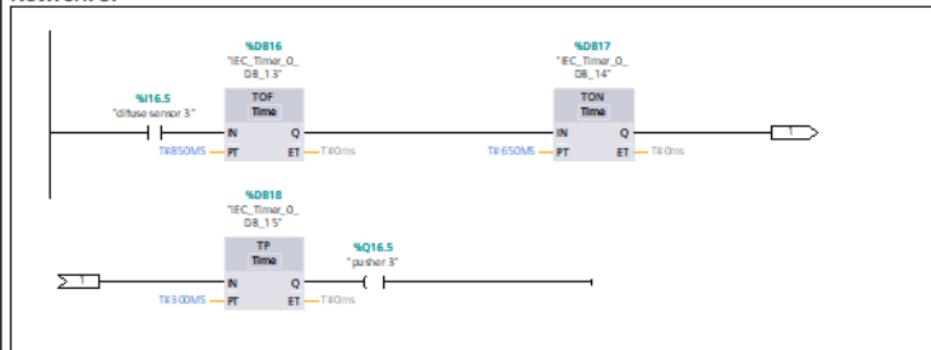
Network 7:



Network 8:

Difuse sensor 3

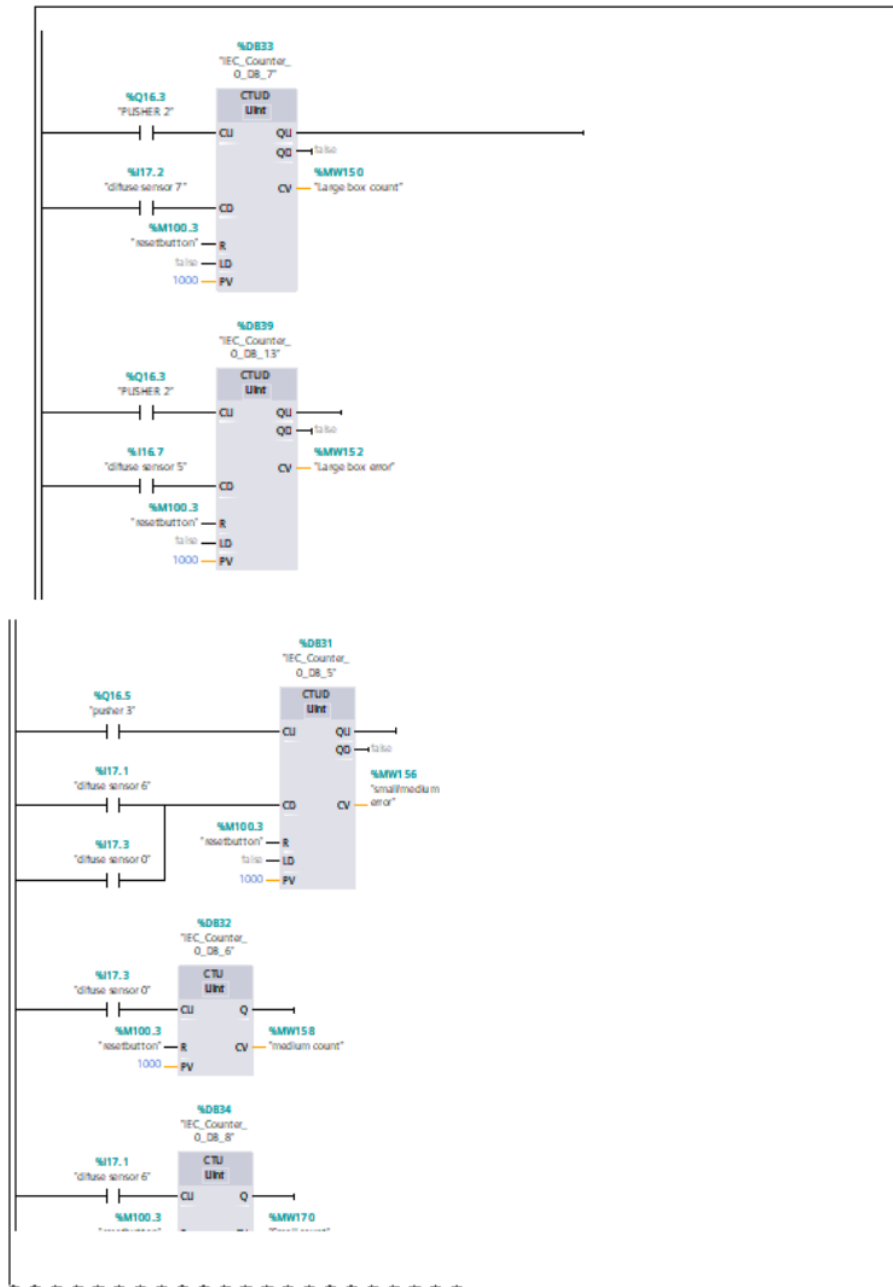
Network 8:



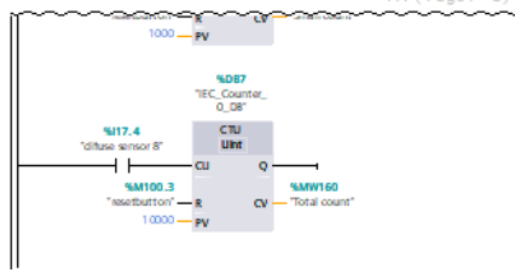
Network 9:

Pusher 1 & 2 counters

Network 9: (1.1 / 2.1)

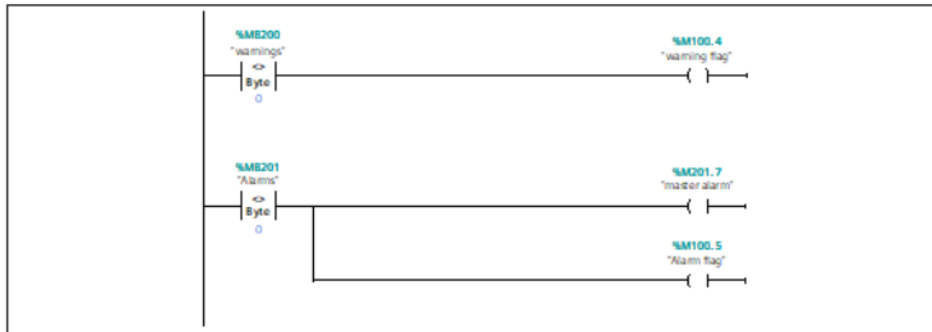


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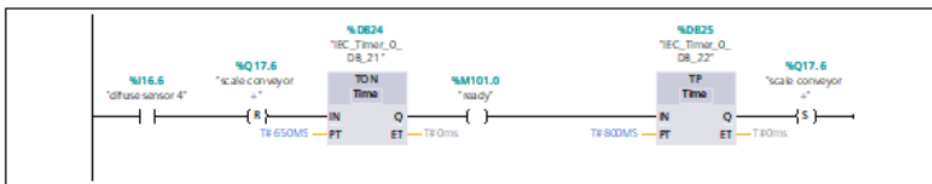
Network 11: check for warnings or alarms

Master alarm and flags



Network 12:

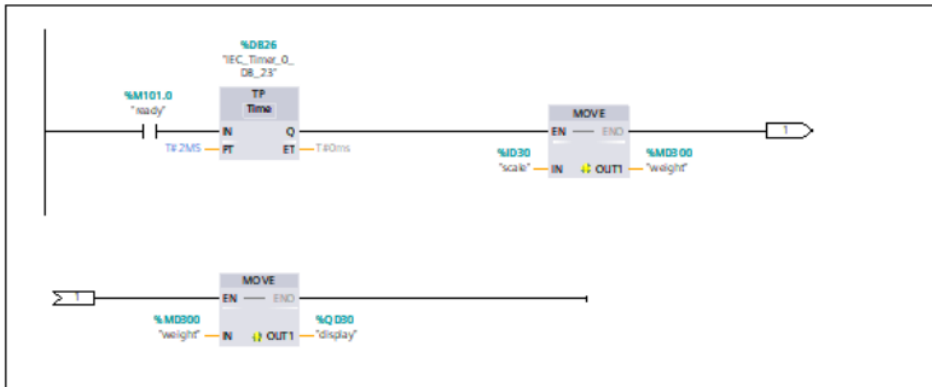
Conveyor scale



Network 13:

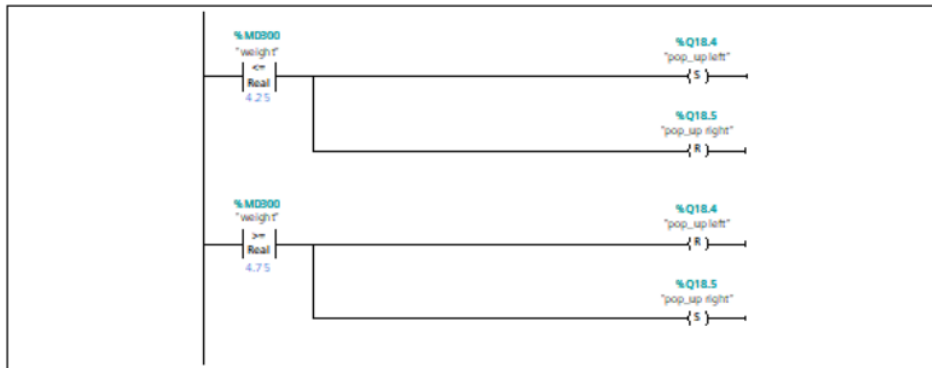
conveyor scale

Network 13:



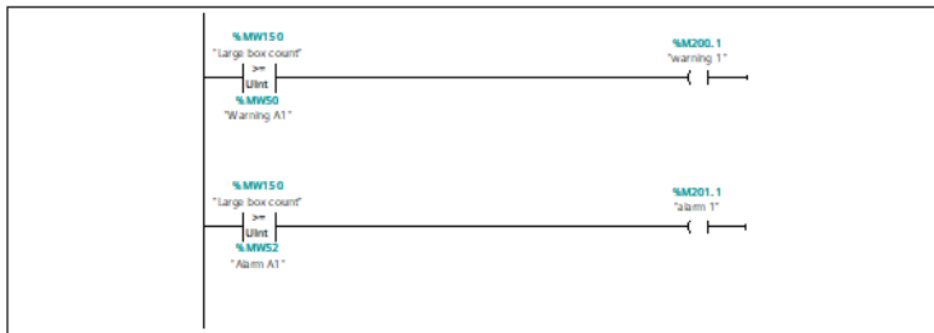
Network 14:

Weighing sorting

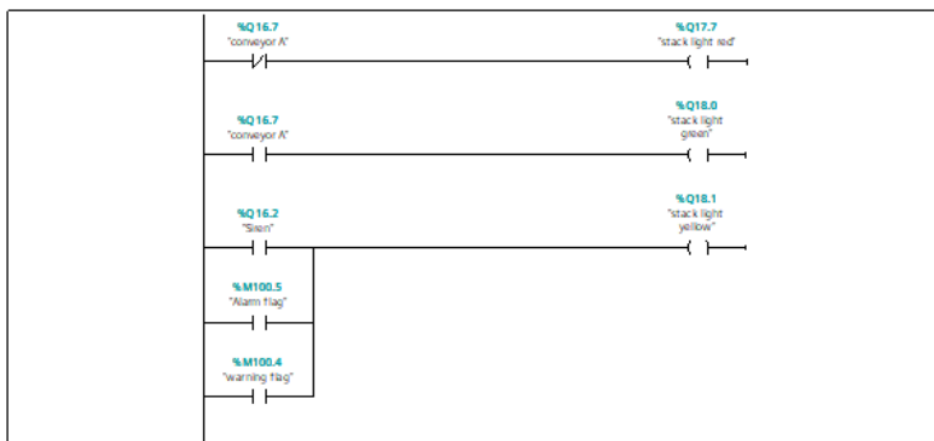


Network 15:

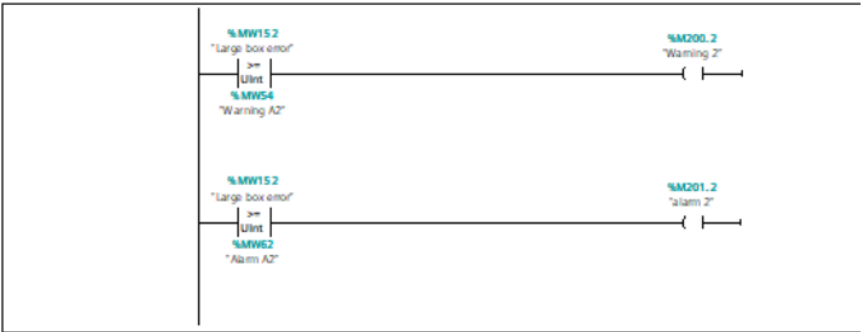
Large box error warning/alarm



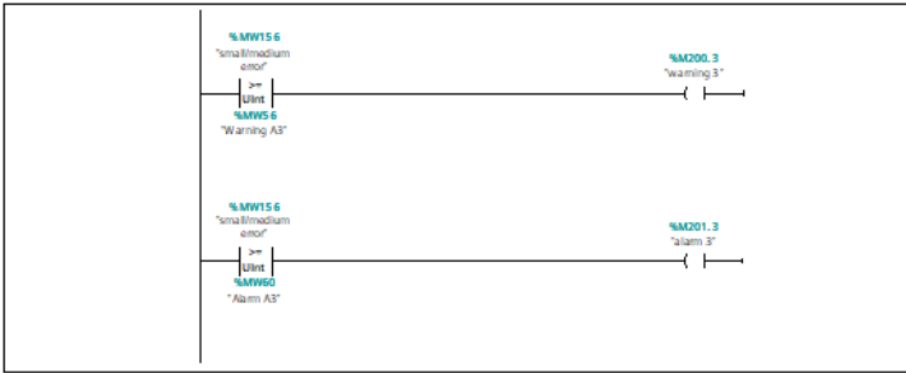
Network 16:



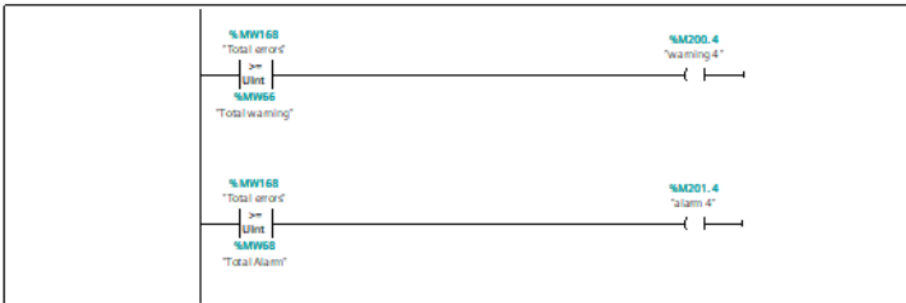
Network 17:



Network 18:



Network 19:



References

- [1] [What Is a PLC? An Introduction to Programmable Logic Controllers - Technical Articles](#)
- [2] [What Is a PLC? An Introduction to Programmable Logic Controllers - Technical Articles](#)
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- [4] [The Types of PLCs \(techwalla.com\)](#)
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- [6] [What are the different types of PLC? - PLC Basics \(basicplc.com\)](#)
- [7] [Advantages of a Modular PLC Over a Fixed PLC? \(isu.edu\)](#)
- [8] [Advantages of a Modular PLC Over a Fixed PLC? \(isu.edu\)](#)
- [9] [What are the different types of PLC? - PLC Basics \(basicplc.com\)](#)
- [10] [2080-LC10-12QWB | Allen Bradley Micro810 PLC CPU - 8 Inputs, 4 Outputs, Relay, USB Networking | RS \(rs-online.com\)](#)
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- [12] [Modular PLC - S7-300 - Siemens Automation and Engineering - for controllers \(directindustry.com\)](#)
- [13] [Q00UJCPU | Mitsubishi Q Series PLC CPU, For Use With MELSEC Q Series, Ethernet Networking, Mini USB Interface | RS \(rs-online.com\)](#)

Scott Thomas - PLCs assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

60/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10

PAGE 11

PAGE 12

PAGE 13

PAGE 14

PAGE 15

PAGE 16

PAGE 17

GRADING FORM: SMU GENERIC_GJ

SCOTT THOMAS

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RESEARCH-INFORMED LITERATURE



Good literature review of PLCs on the market, could have been improved with a few more devices. 68%

KNOWLEDGE AND UNDERSTANDING



Good literature review of PLCs on the market, could have been improved with a few more devices. 68%

ANALYSIS



Your ladder logic program is reasonable but poorly documented. 55%

PRACTICAL APPLICATION AND DEP.



our HMI screens are nicely laid out with informative for the operator but the alarm screen has no description of the errors except estop. 60%

SKILLS FOR PROFESSIONAL PRAC.



The report is reasonably presented. The illustrations are good and clear. A limited selection of references. 65%