

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Jaden Chapman	Student ID number:	
Programme:	HNC Electrical/Electronic Engineering & HNC Instrumentation Engineering		
Module:	Programmable Logic Controllers		
Module code:	PCEE4005	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Jason Pointer	Internal Verifier:	Nigel Richards
Assignment Title:	PLC Program design and simulation	Word count (or equivalent):	2000
Submission deadline:	02/05/24	Return date of provisional marks & written feedback:	19/05/24
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

1. Demonstrate an understanding of the concepts of process control using an industry standard PLC.
2. Undertake basic PLC system design and implementation processes, comparing theoretical expectations to actual outputs ensuring correct operation and consideration of maintenance and reliability.

STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	15	4.2
Some evidence of reading but no direct reference within the assignment.		
2. Knowledge and Understanding Skills	40	24.5
Task 1 achieved 48%. Task 2 achieved 60% Task 3 achieved 72% Showed some competent knowledge of the basic underlying concepts and principles for assessment but in Task 1 you have included an explanation of level sensor. Some good work in producing the IL code for Task 3 but should have used a branch command for the first rung.		
3. Cognitive and Intellectual Skills	5	2.4
Little evaluation of the underlying concepts and principles applied to the construction of the programs for Task 4 and 5.		
4. Practical Application Skills	30	22.8
Task 4 achieved 70%. Task 5 achieved 82%. An excellent application of the different software to produce fully functional programs to cover the requirements of Task 4 and 5. Required very little support in the development of these programs and was able to show full operation within the classroom.		
5. Transferable Skills for Life and Professional Practice	10	5.9
Work is coherent, very fluent and is presented professionally. Excellent layout making the assignment easy to read.		

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		60%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

JADEN CHAPMAN



PLC ASSIGNMENT 2

Lecturer: JASON POINTER

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Introduction

Programmable Logic Controllers are capable of accepting both discrete and analogue inputs. They are also capable of operating a range of equipment through the output interface. For this part of the assignment you are required to examine these aspects in detail.

Task 1 – PLC analogue and discrete I/O

- a) Identify and describe **two** different devices that could be connected to the PLC with respect to input circuits for each of the following measurement:
- Proximity
 - Displacement.

Proximity

Ultrasonic proximity sensors are mainly used to detect the presence of an object or measure the distance between the sensor and an object. The sensor operates by sending an ultrasonic pulse in the frequency range of 25-50kHz and detects how long it takes for this pulse to return. The time it takes for the pulse to return (known as time-of-flight) is then used to determine how far away the object is. It is common for the transmitter and receiver to be installed within the same transducer as this keeps cabling to a minimum and simplifies the installation process.

As for the sensors output pulse, it is preferred that the path of the pulse is kept as narrow as possible as if it is dispersed over too wide of a distance, it could cause interference between the emitted and reflected pulses.

A factor that sets the ultrasonic sensor apart from other types is its ability to accurately sense transparent objects and reflective surfaces such as liquid levels. This makes it desirable in applications that the photoelectric sensor or any light emitting sensor would find issue in accurately sensing.

One of the only downsides to the ultrasonic sensor is when detecting soft material such as wool as there is a possibility the sound might be absorbed by the material instead of being reflected.

Below, figure 1 displays the concept of an ultrasonic sensor:

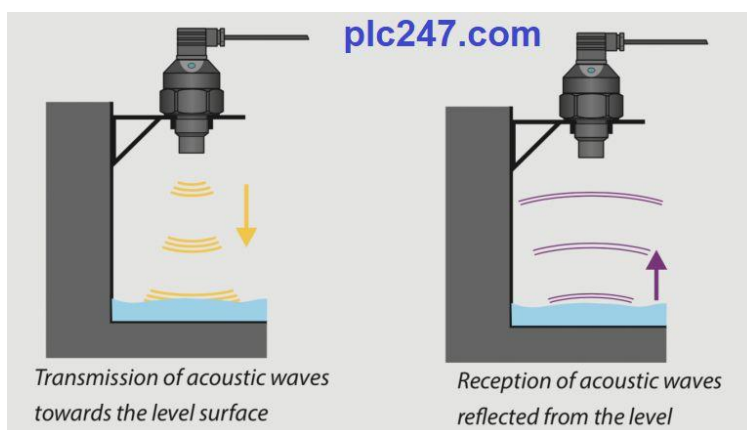


Figure 1 - Ultrasonic Proximity Sensor

Another type of non-contact proximity sensor commonly found in the industry is known as a capacitive proximity sensor and this switches the output when a change in capacitance is sensed. This kind of sensor consists of two conductive plates which are separated by an insulated material such as plastic, ceramic or simply an air gap. In the case of the capacitive proximity sensors, one of these plates is part of the sensor construction and the object being sensed acts as the other plate. Found inside the sensor is an oscillator circuit that generates an electric field. The presence of an object will produce a change in the capacitance value resulting in the output of the sensor switching. Depending on whether the cables inside the sensor are wired normally open or normally closed will determine whether a current will flow when an object is sensed, or whether the presence of an object will prevent the flow.

Typically, the sensor is capable of sensing objects up to 25mm away although some can measure up to 50mm without any issues. The sensing range is adjustable via a screw found on the non-sensing end of the device.

Whereas an ultrasonic sensor is most desirable in applications that consist of liquid or transparent objects, the capacitive sensor is more effective when using objects of a high density such as metals, woods, plastics or any other material that will interrupt an electric field. This device is commonly found on production lines to count the number of objects passing on a conveyor belt. The sensors are also small so are appropriate in situations where there is minimal space. They also function effectively in situations where the object is inside a bag or box as the sensor has the ability to disregard non-metallic objects.

Below, a diagram displaying the components of a capacitive sensor can be seen:

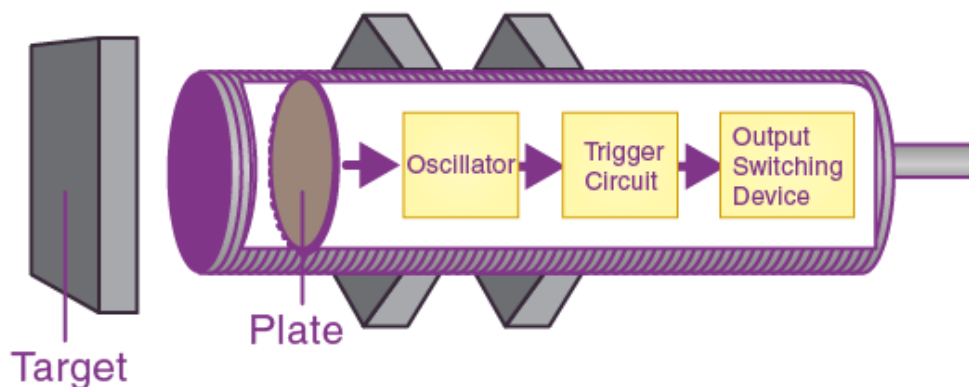


Figure 2 - Capacitive Sensor

Displacement

Torque tube displacers work on the principle of Archimedes' which states that 'the buoyancy force exerted on a body immersed in liquid is equal to the weight of the liquid displaced'. This means that as a level in a chamber rises, the supposed weight of the displacer becomes lighter and vice versa. The change in displacer weight can then be converted into an electronic or pneumatic signal to output a level reading.

The displacer itself is a large, sealed tube which is weighted appropriately so that it is not able to simply float in the liquid. This hangs on one side of a lever on what's known as a knife-edge to eliminate friction during operation and the opposite side of this lever is welded to the torque tube. Inside this torque tube sits a rod which is welded at one end but free at the other and rotates axially as the tube itself rotates. This results in an angular displacement of the torque rod which is directly proportional to the displacer movement inside the chamber and therefore the liquid level. Like the displacer only moves a small amount inside the chamber, the rod will only rotate a small amount inside the tube. Below, an example of how a displacer sits inside the chamber can be seen:

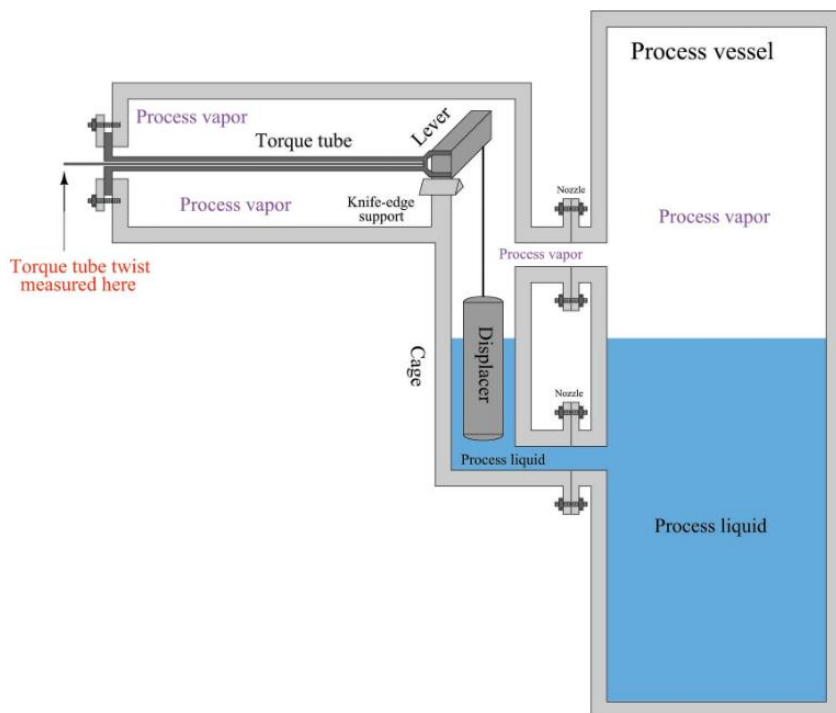


Figure 3 - Level Displacer

This is actually for level measurement.

This type of displacer is desired when attempting to measure an interface level as they have the ability to precisely measure liquids of two separate densities. The only rule is that the displacer must be fully submerged at all times as the instrument is not capable of telling the difference between a low liquid level and a low interface level. To calculate an interface level, the density of both liquids must be known. /

Another type of displacement sensor is known as a linear variable differential transformer (also known as LVDT). This is an electromechanical device that can be used to measure linear displacement within a system. Inside the device, a primary magnetic coil can be found in the centre and two secondary magnetic coils can be found an equal distance from the centre at either side. Sitting inside the cylinder is a ferromagnetic core that is attached to a push rod and based on its position, a relative voltage output will be produced determining the current position of the core and therefore, the displacement of it. ✓

The two secondary coils are electrically 180 degrees out of phase from each other and are connected in series. A continuous alternating current is applied to the primary coil resulting in a varying magnetic field which interacts with the two secondary coils resulting in a voltage and current being produced. As the two secondary coils are 180 degrees out of phase, the output voltage produced equates to the difference of the two voltages produced by both secondary coils. For example, when the rod is as far into the system as possible, a reading of 10V will be outputted and when the rod is as far out of the system as possible, -10V will be outputted. When the core is in the centre of the primary coil, the voltage output will be 0. ✓

A common application of the LVDT is to measure the vibration within a compressor as they're extremely robust as well as being capable of withstanding high operating temperatures. They can either be connected via lead wires or a connection socket although a connection socket allows for better stability whilst undergoing high vibrations. The vibration sensor can be configured with a PLC to switch a compressor off when the probe outputs a voltage that is synonymous with high vibrations to protect its components from being damaged. ✓

Below, a diagram displaying the components of a LVDT can be seen:

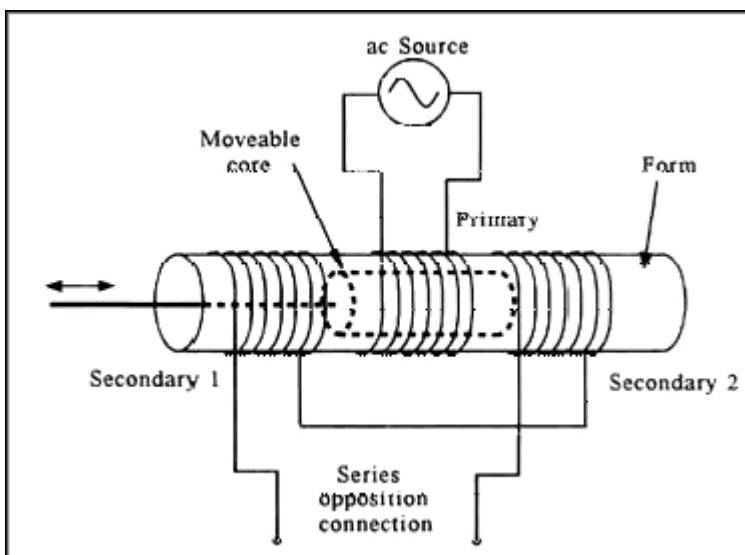


Figure 4 - LVDT

- b) A stepper motor is an output device that can be connected to a PLC. Using diagrams explain the construction and operation of a stepper motor.

A stepper motor is desired when precise stopping and starting (angle or motion distance) is more important than speed or power. This is due to their ability to make individual steps when control voltage is applied unlike other motors such as AC and DC. Not only can the stepper motor provide precise control, but it also does this without the need for an external feedback sensor.

This type of motor consists of stators and rotors which interact with multiple points of magnetism allowing for precise stepping. On average, the inside of the motor contains 200 points of magnetic interactions allowing for stepping control of 1.8 degrees. Furthermore, each of the coils inside the motor are capable of 'micro stepping' which is carried out by supplying the coil with a positive or negative partial current depending on which direction the user would like to travel in. More complex algorithms enable up to 256 micro steps per coil resulting in precise step control of 0.007 degrees. The only downside to the stepper motor is that its use is limited to low torque applications.

Below is a diagram displaying the operation of the stepper motor:

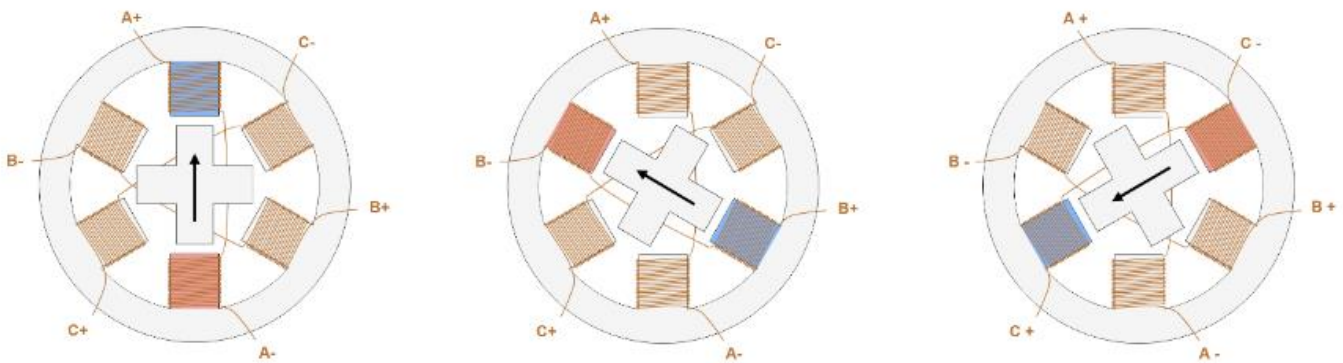


Figure 5 - Stepper Motor

The rotor can be seen to move depending on which coil current is flowing through. For example, in the far-left image, the current is flowing through 'A' attracting the rotor to align with that field.

Should state the type of stepper motor.

Task 2 – SCADA (Supervisory Control and Data Acquisition)

SCADA systems are now used in multiply engineering industries like Valero and Puffin Potatoes where they are an essential part of their operation.

Produce a report discussing the key features of SCADA systems and how HMI and PLCs are integrated into them and were possible include industrial examples.

SCADA, also known as Supervisory Control and Data Acquisition, is a system used to monitor and control field equipment to ensure efficient running of plant processes. This gives workers the ability to access equipment remotely from an HMI panel and make changes to the process as necessary. The need for on-site maintenance is massively reduced with the introduction of this system and allows companies to utilise resources elsewhere. ✓

The system incorporates both software and hardware and is made up of three main components; field equipment such as sensors and transmitters, PLC and HMI. Equipment in the field is responsible for measuring data and sending it to a PLC. The data is then analysed by the PLC and displayed via an HMI interface where the process can be monitored and controlled by the panel operator. Data can be acquired by equipment in the field, but commands can also be sent from the HMI via the PLC to override the field sensor output and alter equipment state. This is useful when carrying out maintenance checks on equipment such as valves and pumps to ensure they're capable of opening/closing or starting/stopping as required. ✓

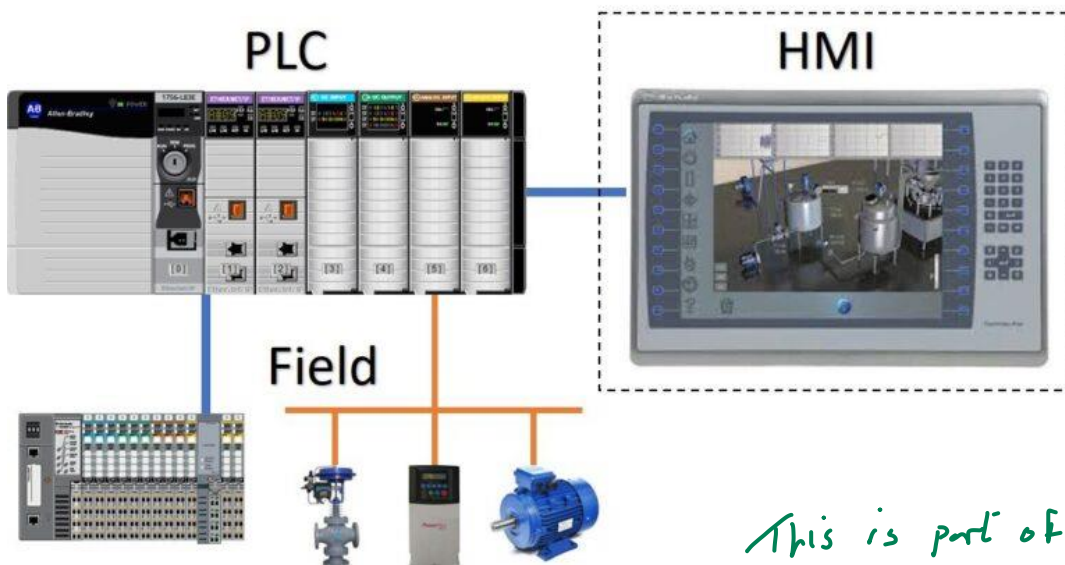


Figure 6 - SCADA System

This is part of the SCADA system. ✓

The plant consists of both input and output devices that can be monitored and controlled via the HMI. Examples of input devices consist of pressure transmitters, level sensors and temperature sensors and these all deliver measurement readings to the PLC. Some examples of output devices are motors, pumps and valves that receive commands from the PLC as plant conditions change. ✓

The programmable logic controller acts as the bridge between the field and panel. It receives data from sensors in the field, analyses this and then sends commands back out into the field to any relevant output devices. It also sends the field data to the panel so that the operator can monitor and control the process in real time. The PLC uses some form of programming language to represent and essentially map out the process graphically. Some examples of programming methods are known as ladder logic, structured text and sequential function charts.

Human machine interface is responsible for displaying the data from all the field equipment in a simple way to make it as easy as possible for the operator. Alarms can be configured within the HMI to alert the operator when action on a specific piece of equipment needs to be taken. For example, an alarm can be configured so that when the level in a tank reaches a specific height, the operator is alerted and can act accordingly. An appropriate action might be to send a command to the PLC to drive an outlet valve open therefore allowing the contents of the tank to be transported elsewhere.

Task 3 – Instruction List

A Bottle packing production line involving a conveyor is being used to transport bottles to a packaging unit, the items being loaded onto the conveyor, checked to ensure they are full, capped and then the correct number (4) of bottles being packed in a container. The required control actions are thus: if a bottle is not full the conveyor is stopped; activation of the capping machine when a bottle is at the required position, the conveyor being stopped during this time; count four bottles and activate the packing machine, the conveyor being stopped if another bottle comes to the packing point at that time; sound an alarm when the conveyor is stopped. On the next page is the ladder logic required for PLC.

Inputs		Outputs	
X000	Start switch	Y000	Conveyor motor
X001	Stop switch	Y001	Alarm
X002	Sensor for bottle not full position 1	Y002	Capping
X003	Sensor for bottle present	Y003	Packing Machine
X004	Sensor for bottle not full position 2		
X005	Stop conveyor switch		

Table 1 – Input/Output connections

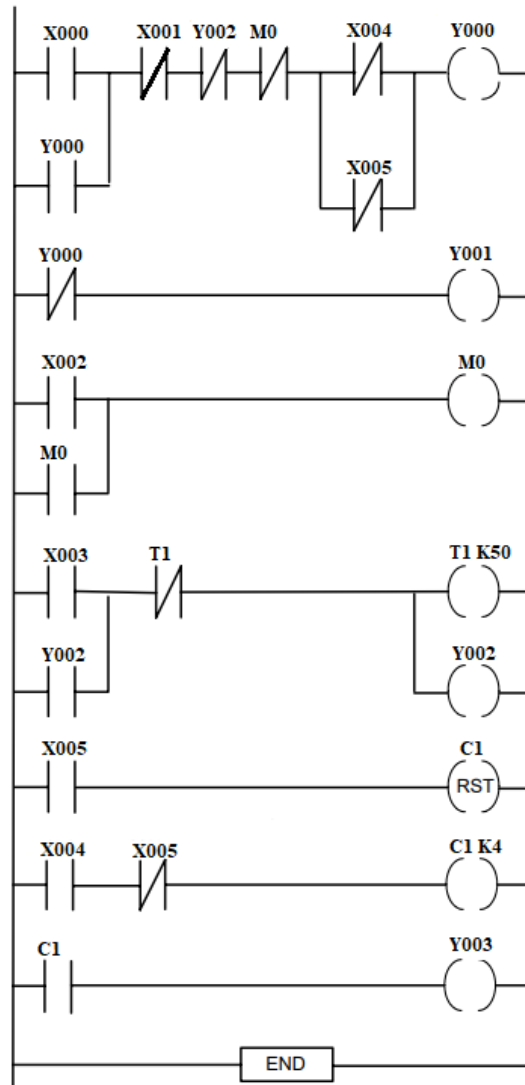


Figure 2 – Ladder logic

From the ladder logic develop the **instruction list** that will also control the conveyor systems.

LD X000
OR Y000
ANI X001
ANI Y002
ANI M0
ANI X004
ORI X005
ANB
OUT Y000

LDI Y000
OUT Y001

LD X002
OR M0
OUT M0

LD X003
OR Y002
ANI T1
OUT T1
K 50
OUT Y002

LD X005
OUT RST C1

LD X004
ANI X005
OUT C1
K 4

LD C1
OUT Y003

Task 4 - Temperature Alarm Panel

For this programming task you are required to use the Mitsubishi PLC analogue input functionality to design and simulate a temperature alarm system to monitor a temperature range of 0 to 50°C which will indicate using a series of lights. The table 2 shows the output response for the alarm.

Table 2 – Alarm Outputs

Temperature Settings (°C)	Blue light	Green Light	Yellow Light	Red Light	Sounder
0 to 10	On				
11 to 25	On	On			
26 to 40	On	On	On		
41 to 50				On	On

When the temperature is in the highest range an audible and flashing visual alarm should be activated.

The system should have the following controls:

- A momentary ‘alarm accept’ button that should cancel the audible alarm and set the visual alarm from flashing to a steady state condition.
- A momentary ‘alarm test’ button that allows the user to check the lamps and audible alarm are functioning correctly.

In addition, construct a Human Machine Interface (HMI) panel to demonstrate the operation of your program. You may use the Mitsubishi Alpha program development system ‘sketch window’ to construct the HMI.

To complete this task you are required to demonstrate the operation the program to your Tutor and include a copy of the program in your report.

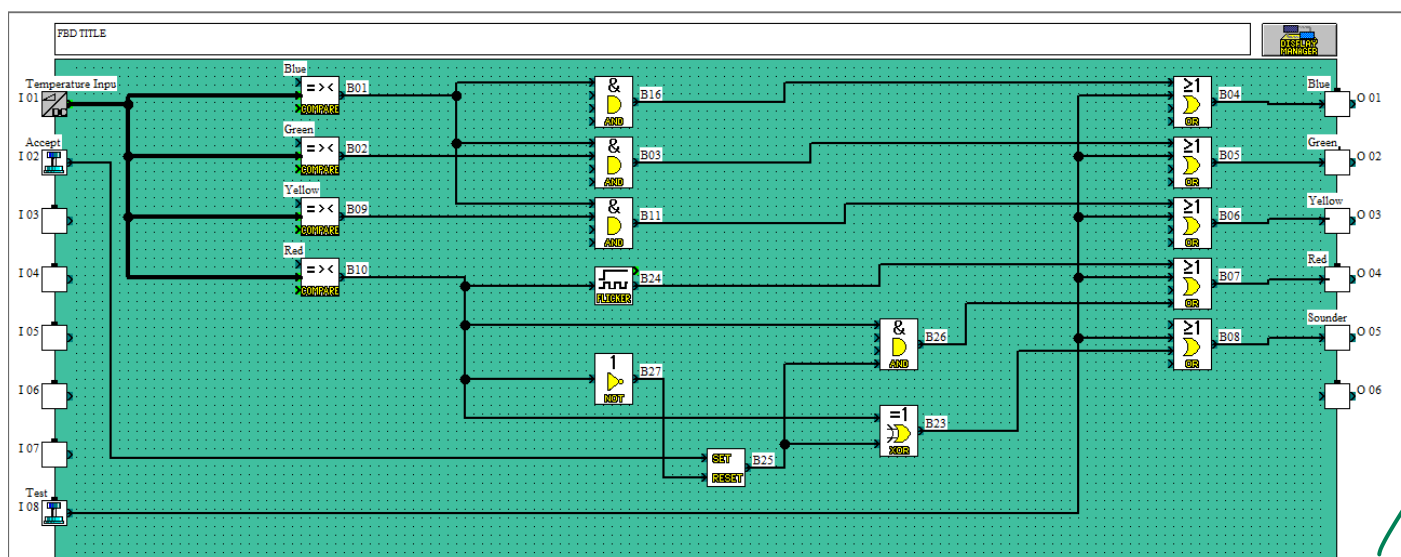


Figure 7 - Program

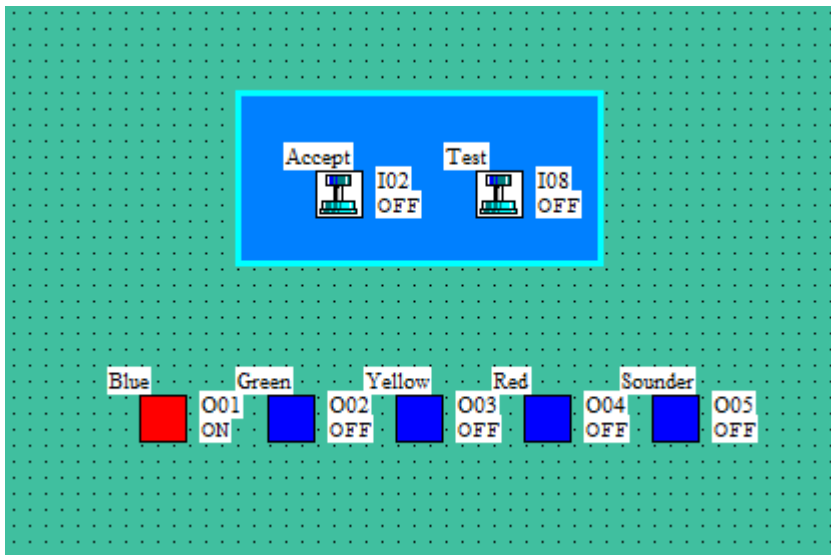


Figure 8 - Temperature 0-10°C

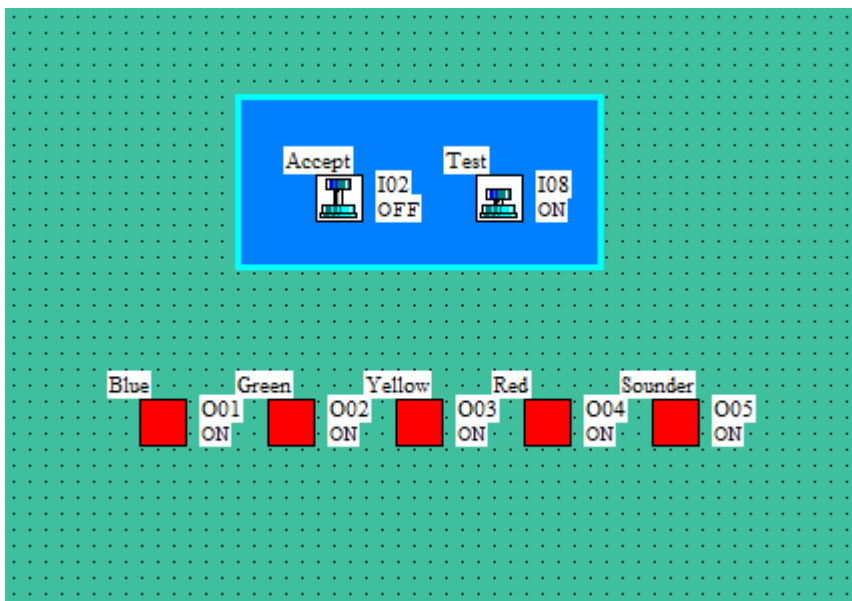


Figure 9 - Test

Would like to see more testing in your report. You need that all parts function correctly.

Task 5 – Construction Site Lift

For this task you are required to develop a program to control the lift system on a building site (figure 3). You will use the Mitsubishi FX PLC (ladder logic) to control the process.

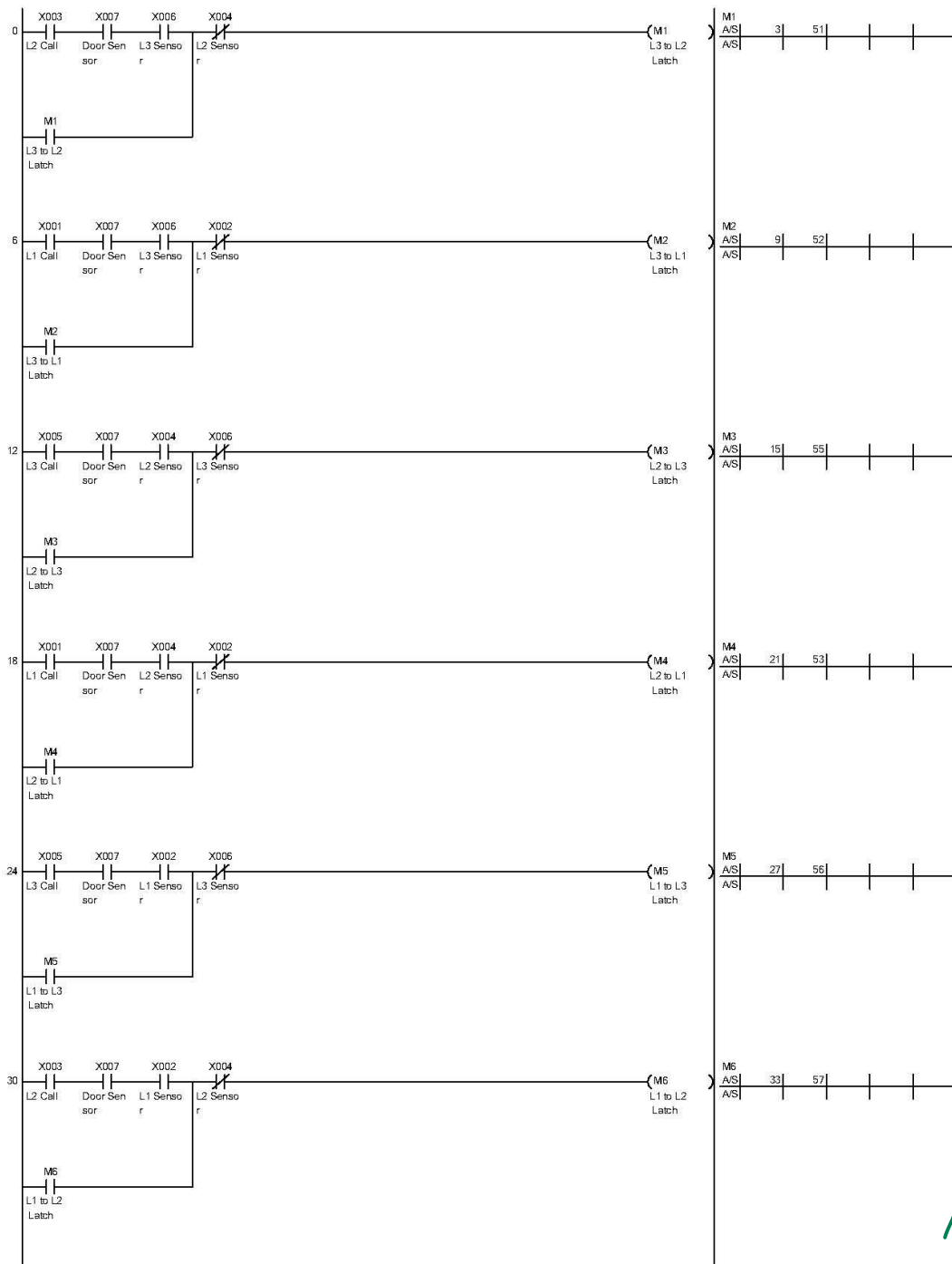
Lift Motor Control: The control system is required to move the lift carriage to the required level on pressing a releasing the appropriate level ‘call’ button.

1. Prior to operating any switches the lift motor should be stationary with the lift carriage at a fixed level position. The level light should be on to indicate to the operator the current carriage position.
2. On pressing and releasing the ‘call’ button for a level the motor should engage and move the carriage to that level. During this operation the previous level light should turn off and the new level light will turn on.
3. The door for the lift will be manually opened and closed. When closed the door will be locked in position and cannot be open until the lift is at the required level. There will be a 5 second delay once the lift is in a stationary position before the door lock will disengage and a light will turn on to indicate the door can be opened.
4. The lift cannot move position if the door is open.

Note: A safety feature should be installed in your program to ensure that once the carriage is in motion it cannot be ‘called’ to any other level until it has completed its transit between levels.

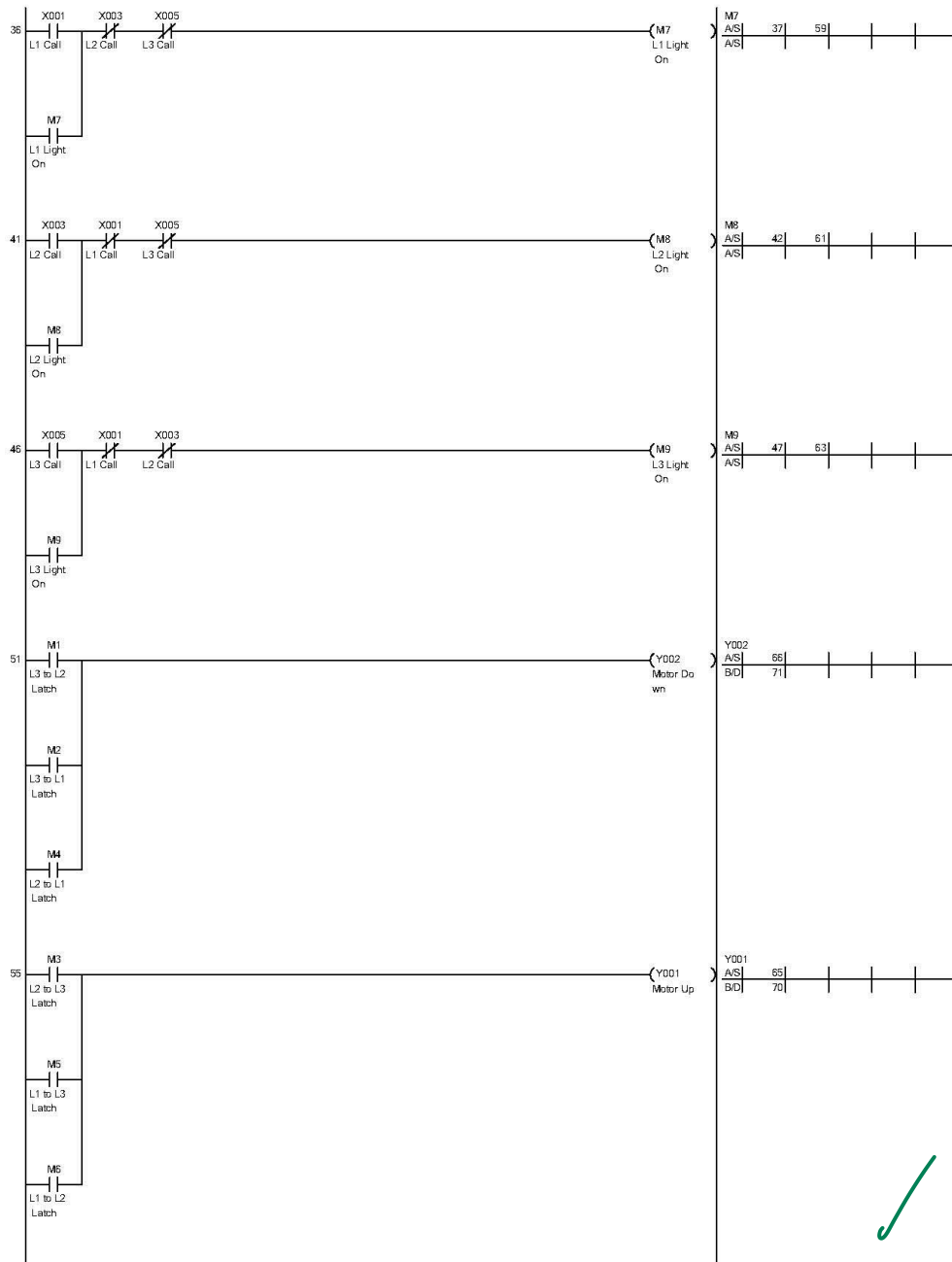
PLC and Simulator Termination

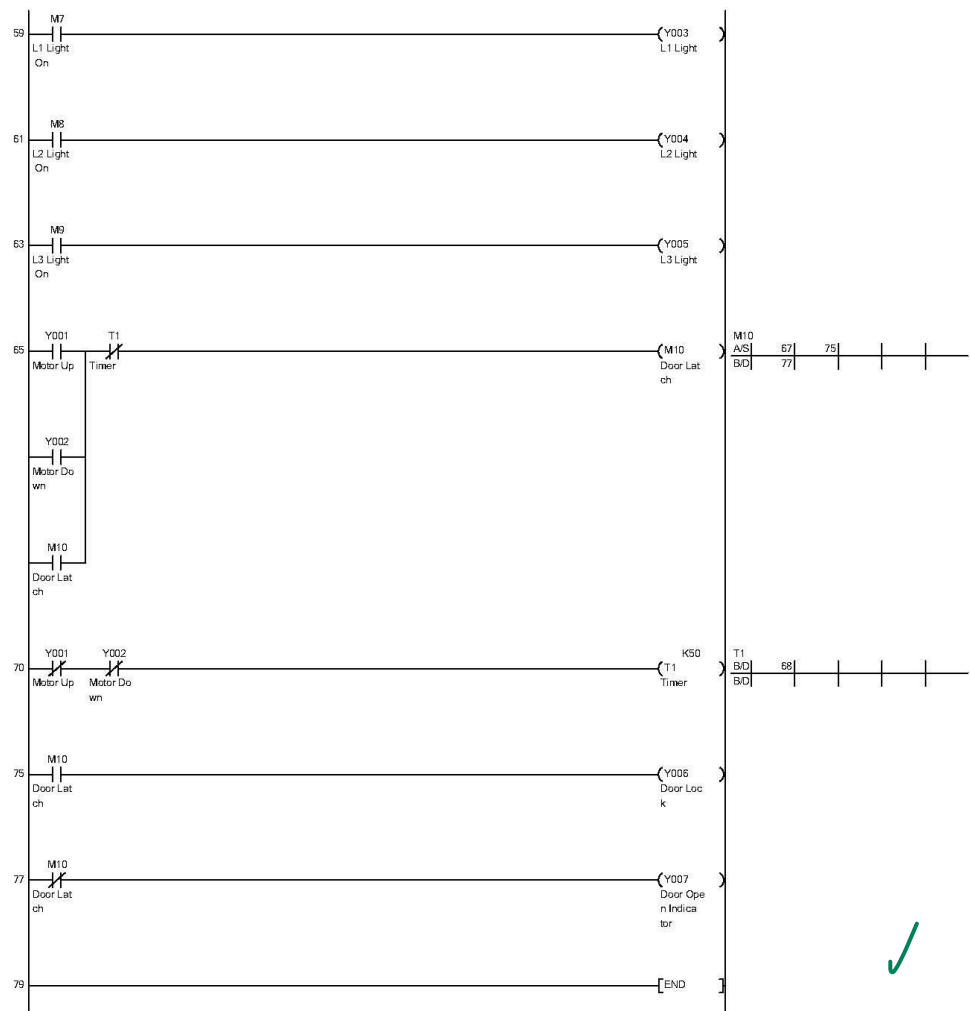
PLC Input		PLC Output	
01	Level 1 call button	01	Motors up
02	Level 1 sensor	02	Motor down
03	Level 2 call button	03	Level 1 indicator light
04	Level 2 sensor	04	Level 2 indicator light
05	Level 3 call button	05	Level 3 indicator light
06	Level 3 sensor	06	Solenoid latch for door
07	Locked door sensor	07	Open door indicator light



Ladder
Data Name : MAIN

3/21/2024





Lift System

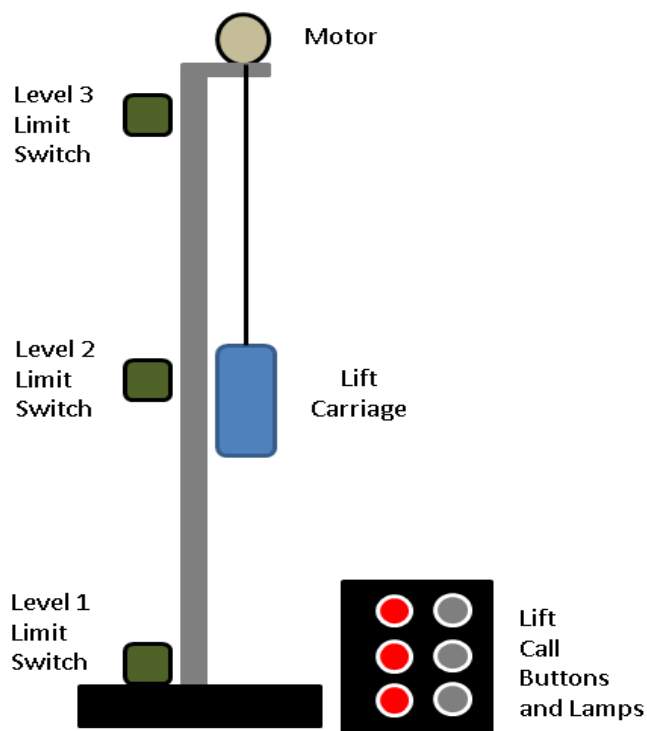


Figure 3 – Lift System

On completion of this task you are required to demonstrate the operation of your program to your Tutor using the process simulator. Include a printed copy of your program in your report and briefly discuss the program operation. Evaluate the operation of the program and compare it against the design specification. Comment on any additional functionality that could have been incorporated into your program to improve the process operated efficiently and any additional safety features.

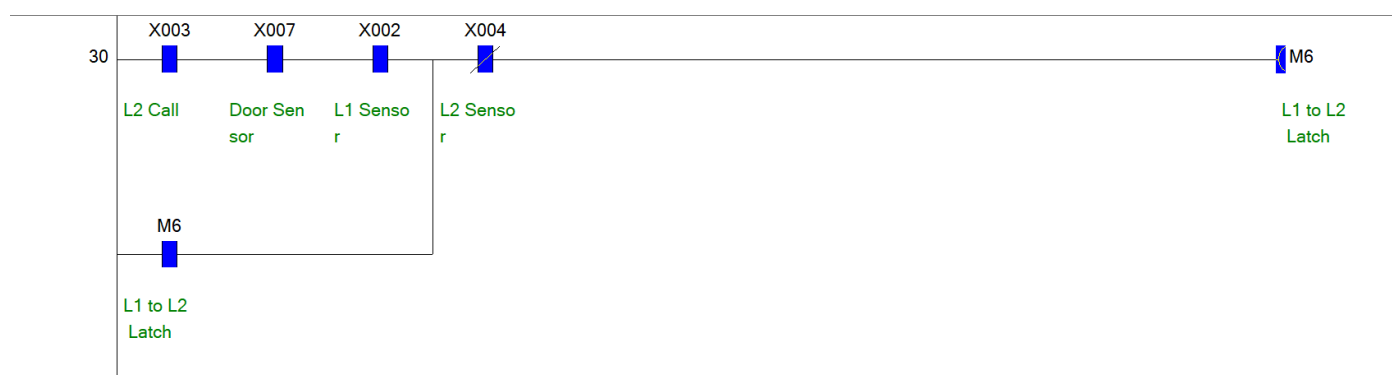


Figure 10 - L1 to L2 Latch

X003, X007 and X002 are normally open contacts and X004 is a normally closed contact. These are all in series so must be closed to energise M6 coil.

If the door sensor and L1 sensor are both made when the call button is pressed at L2, this latches and enables the next step of the sequence to begin. As the L2 sensor is a normally closed contact, as soon as the lift reaches L2, the contact will de-energise and break the circuit resulting in the latch disengaging.

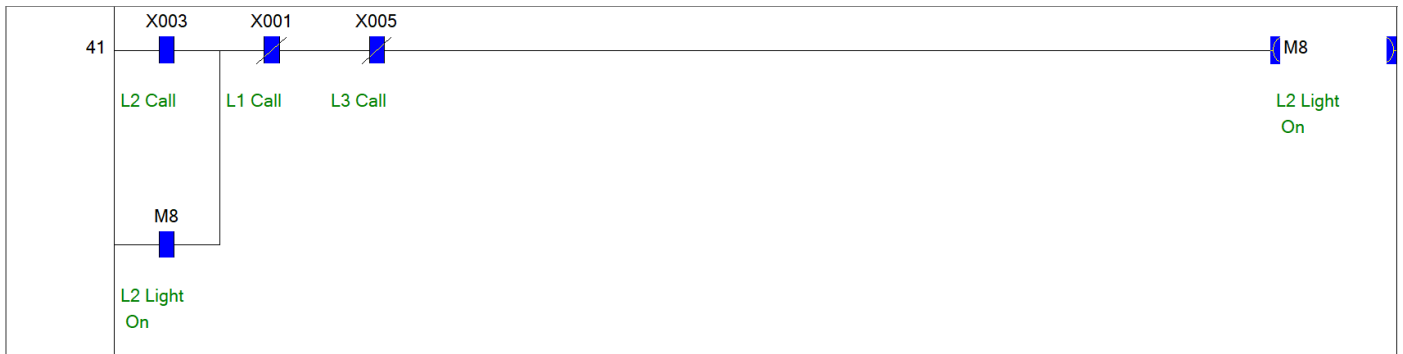


Figure 11 - L2 Light On

X003 is a normally open contact and X001 and X005 are normally closed contacts. These are all in series so must be closed to energise M8 coil.

When the L2 call button is pressed, the light for L2 will immediately come on.

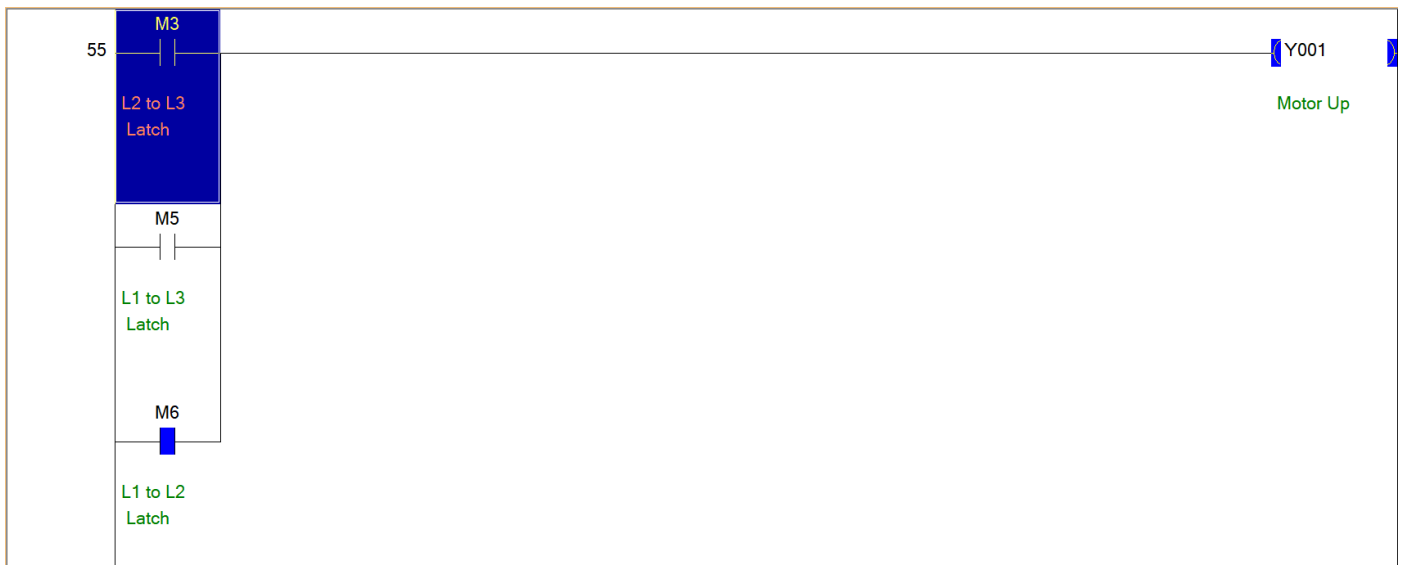


Figure 12 - Motor Up

M3, M5 and M6 are all normally open contacts in parallel. This means that only one of them needs to be closed in order for Y001 coil to be energised. In the demonstration above, M6 coil is energised resulting in the Y001 coil being energised as well.

When all the conditions for L1 to L2 Latch are met, the motor will begin moving upward towards L2.

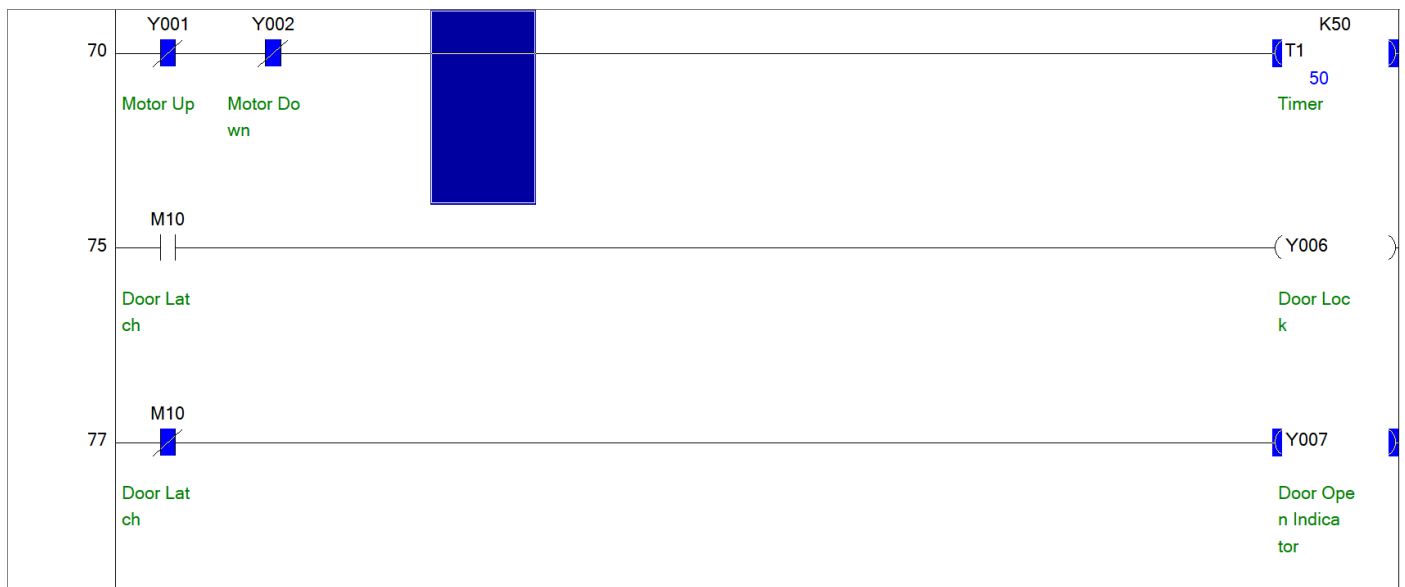


Figure 13 - Door Open Indicator

Y001 and Y002 are both normally closed contacts. When Y001 is energised, the normally closed Y001 contact becomes open. When this contact becomes closed again, a timer of 5 seconds will be activated. Once 5 seconds is up, the M10 will be become de-energised resulting in the normally closed contact energising Y007.

Once the lift has reached its destination, a 5 second timer will begin. After 5 seconds, the door will become unlatched, and this results in the door open indicator coming on.



Figure 14 - Door Latch

Y001 is a normally open contact and T1 is a normally closed contact and these are both in series. Once Y001 becomes closed, M10 is energised.

In the demonstration above, when the lift is moving upward, the door is latched. This allows the next step in the sequence to happen.

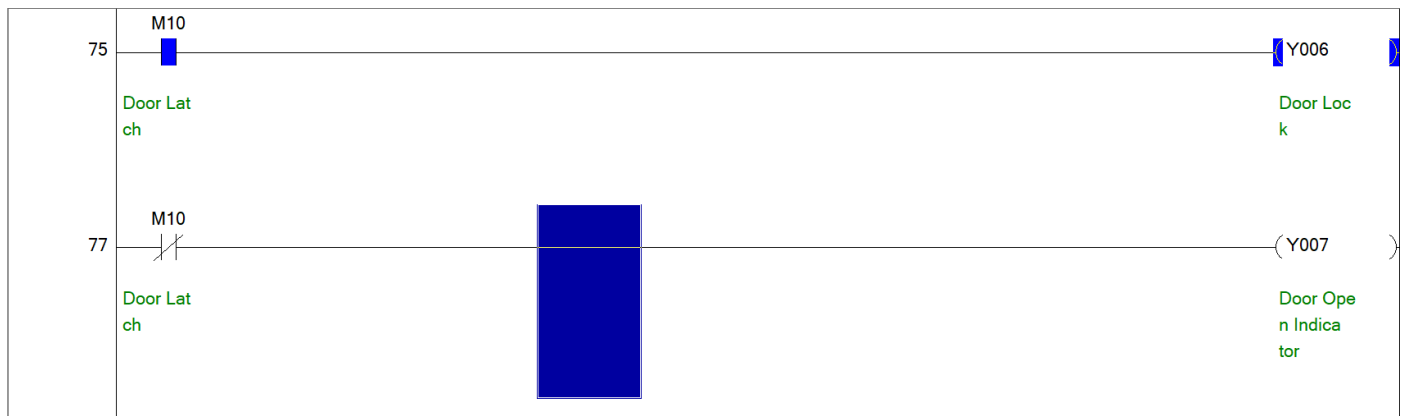


Figure 15 - Door Locked

M10 is a normally open contact and will energise Y006 when closed.

Whilst the lift is travelling, the door is locked.

One of the features that could have been added to improve the safety of the system is a sensor that displays a flashing LED when the weight of the lift exceeds a maximum capacity. This could be configured so that, when travelling from floor to floor, the latch will not be made if the weight capacity of the lift has been exceeded reducing the likelihood of a lift malfunctioning. ✓

Another safety feature that could be added in the future is an emergency button that will stop the lift wherever it is and alert others outside that they're in trouble. This could also be configured with the latches travelling from floor to floor as a normally closed contact so that when it is pushed, the motor will stop moving either up or down. An LED could also be configured to display on each of the floors the lift travels to. ✓

In the current design, an LED only displays on the floor that the lift is being called to and doesn't display on the floors that it passes through whilst travelling to its destination. This would be a useful addition as it would enable users to see exactly where the lift is. ✓

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Figure 1 – PLC 247. 2024. *What is ultrasonic sensor [Online]* Available at: <https://plc247.com/what-is-ultrasonic-sensor/>
Image Accessed on: 11/04/24

Figure 2 – Byju's. 2024. *Capacitive Sensors [Online]* Available at: <https://byjus.com/physics/capacitive-sensors/>
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Figure 3 – Control. 2023. *Displacement [Online]* Available at: <https://control.com/textbook/continuous-level-measurement/displacement/#:~:text=Applied%20to%20a%20displacer%2Dtype,lighter%20from%20the%20rod's%20perspective.> Image Accessed on: 11/04/24

Figure 4 – Ni. 2023. *Measuring position and displacement with LVDTs [Online]* Available at: <https://www.ni.com/en/shop/data-acquisition/measuring-position-and-displacement-with-lvdt.html>
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Figure 5 – Monolithic Power. 2024. *Stepper Motor Basics, Types and Uses [Online]* Available at: <https://www.monolithicpower.com/stepper-motors-basics-types-uses> Image Accessed on: 11/04/24

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SCADA. 2023. *What is SCADA?* [Online] Available at: <https://scada-international.com/what-is-scada/#:~:text=What%20does%20SCADA%20stand%20for,data%20from%20the%20industrial%20equipment>. Accessed on: 30/04/24

There is lack of text books and you have quite no references in your report.