

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Kieran King	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	9.8
Engagement with a wide range of literature, including sources retrieved independently. Generally sound referencing technique.		
2. Knowledge and Understanding Skills	40	25.9
Task 1 achieved 64%. Task 2 achieved 65% Task 3 achieved 65% Showed competent knowledge of the basic underlying concepts and principles for assessment. 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	2.5
Good evaluation of the underlying concepts and principles applied to the construction of the programs for Task 4 and 5.		
4. Practical Application Skills	30	24.9
Task 4 achieved 82%. Task 5 achieved 84%. 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	7
Work is accurate, coherent, fluent, well-structured and organised.		

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)		70%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

Assignment Title: PLC Program design and simulation

Programme: HNC Electrical and Electronic Engineering

Lecturer: Jason Pointer



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Task 1 – PLC analogue and discrete I/O

A) Proximity and displacement devices

Proximity devices:

Capacitive proximity switch

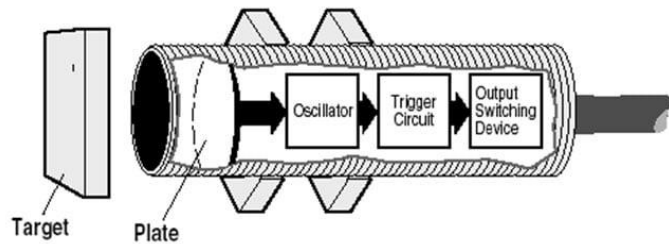


Figure 1- Capacitive proximity sensor construction (Bolton, 2015)

A non-contact sensor which has a probe consisting of a pair of parallel capacitor plates between which a potential difference is applied to produce an electrical field is known as a capacitive sensor as shown in figure 1. A capacitive proximity sensor can be used to detect the presence or absence of

object as well as for level sensing, liquid detection, and touch sensing applications. The sensor is typically known to operate over a range of 3 to 30mm

“The field is disturbed when it is moved close to an object. Thus, the proximity of the object is detected by a change in capacitance.” (Bolton, 2015)

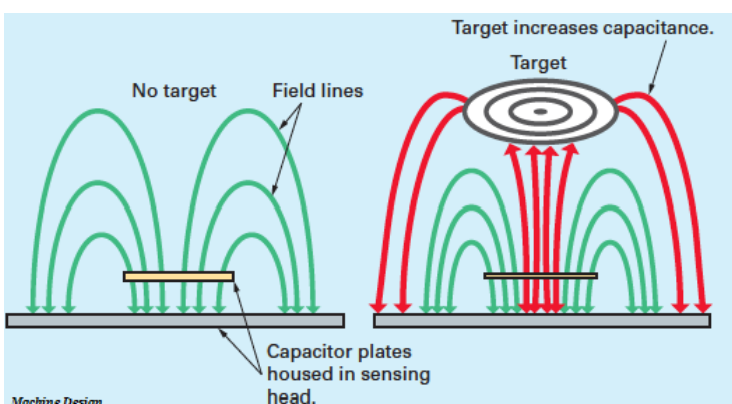


Figure 2- Capacitive proximity sensor working principle (Bolton, 2015)

The capacitance of the sensor depends on the separation distance for example the smaller the separation the higher the capacitance becomes due to the magnetic fields as shown in figure 2. As shown in figure 2 the capacitive proximity sensor is just one of the plates with the other being a metal object which the proximity needs to be detected from the change in capacitance.

The sensor can also be used on non-metallic objects as the capacitance depends on the dielectric between the plates. For example, the change in capacitance can be used as an input to a PLC to control equipment such as manufacturing, automotive, food processing and consumer electronics.

Inductive proximity switch

Another proximity switch which can be used as an input circuit for a PLC is an inductive proximity switch. The proximity switch consists of 4 main components which are the ferrite core with coils, an oscillator, a Schmitt trigger, and an output amplifier. This type of switch can typically detect object from 2 to 15mm. ✓

“When one end of this core approaches a ferrous metal object, there is a noticeable alteration in the amount of metallic core interacting with the coil, resulting in a shift in its inductance.” (Bolton, 2009) ✓

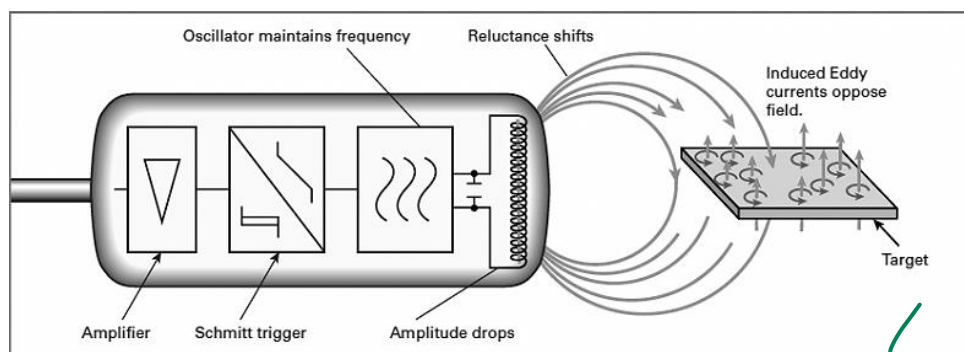


Figure 3- Inductive proximity switch (Kinney, 2022)

The change in the inductance can be monitored through a resonant circuit where the ferrous metal object alters the current with the circuit. The current variation can be used to trigger a PLC to produce a on or off mechanism. Once a metal

target is within the switches magnetic field small electrical currents induce on the surface of the metal causing a change of reluctance of the magnetic circuit as shown in figure 3. As the metal gets closer the amplitude shrinks until collapsed causing the Schmitt trigger to respond by supplying the PLC with an input. When the metal moves back out the circuit goes back to its normal state. ✓

Displacement

Strain gauge

Strain Gauge

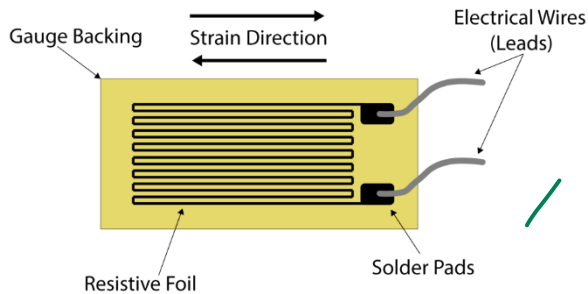


Figure 4- Strain gauge construction (Nachazel, 2020)

A type of displacement sensor such as a strain gauge sensor shown in figure 4 can be used as an input circuit for a PLC. The measured electrical resistance varies with the strain. The gauge as showed in figure 3 is composed of a metal foil insulated by a flexible substrate. The load cells are used to focus stress through beam elements where

the location of the strain gauge is. The pressure is converted from the strain gauge into an electrical signal which then can be measured. The electrical signals are then converted into numeric values by an integrated microprocessor. The numeric values are then displayed on the gauges digital display. The gauge can convert pressure, force, tension, and weight etc, into electrical resistance which can then be measured.

The working principle by (Bolton, 2009) states that-

"When a wire or strip of semiconductor is stretched, its resistance changes. The fractional change in resistance is proportional to the fractional change in length, i.e. strain."

$$\frac{\Delta R}{R} = G \times \text{strain}$$

where ΔR is the change in resistance for a wire of resistance R and G is a constant called the gauge factor."

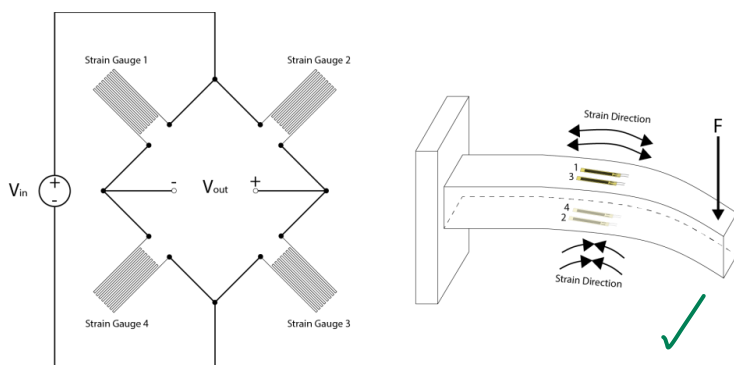


Figure 5- Wheatstone Bridge (Nachazel, 2020)

The change in resistance is converted into a voltage signal by a Wheatstone bridge. Figure 5 shows the configuration which the excitation voltage is applied across the circuit which then the output voltage is measured across the (–) and (+) V_{OUT} . The gauge is balanced and has

a zero-output voltage when there is no load acting on the load cell. Whereas if there is any change in the material being under strain the resistance increases and an output voltage is produced.

Linear variable differential transformer (LVDT)

A Linear variable differential transformer is a type of sensor which can be used to measure linear displacement (LVDT). The construction of the LVDT is shown below in figure 6 which shows consist of three symmetrically placed coils through which the ferrous rod moves.

The LVDT works on the principle of electromagnetic induction. The voltage output is related to the position of the ferrous rod. Alternating voltages, V_1 and V_2 are induced in the two secondary coils when an alternating current is applied to the primary coil. As stated by (Bolton, 2009) the output voltage can be found

“From the two secondary coils are connected so that their combined output is the difference between the two voltages, i.e. $v_1 - v_2$.”

This means that when the rod is central the two ac voltages are equal resulting in no output voltage. Whereas when the rod is displaced from the central position there is a difference between the secondary coil voltages which is the output. This shows that there is more of the rod in one secondary coil than the other. This is where $V_1 - V_2$ is used to find the position of the ferrous rod and the voltage output. The output for the LVDT is an AC voltage which then needs to be amplified so it can be converted to an analogue DC voltage as the input for the PLC.

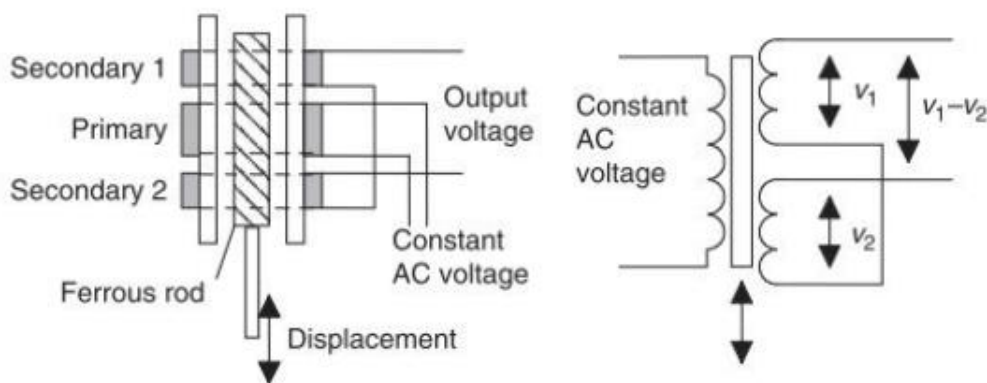


Figure 6- Linear Variable Differential Transformer Construction and working Principle (Bolton, 2009)

B) Stepper Motor

A stepper motor is an output device which can be connected to a PLC. A stepper motor is an electrical device which produces electrical pulses into mechanical rotation. This is done through equal angles where the name stepper comes from. For example, if the motors 1 pulse produces 3° then 120 pulses would produce a full rotation of 360° .

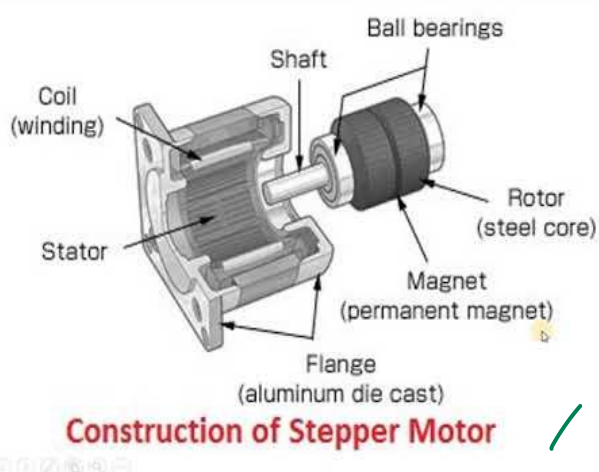


Figure 7 shows the construction of a stepper motor which contains a shaft, bearings, rotor, magnet, flange, coil, and a stator. The rotor is made of soft steel and is a cylindrical with four poles, i.e. fewer poles than on the stator. The rotor is the rotating part of the motor consisting of a permanent magnet or toothed gear. The stator is the stationary part of the motor which is constructed with multiphase windings typically either 3 or 4 windings would required for several

poles. This is dependant on the desired angular displacement per input pulse. The output shaft is where the mechanical work is done. The bearings are to support the shaft and allow it to rotate smoothly. Lastly all motors have a housing which encloses the parts to give protection for the internal components and for safety off others near the equipment.

When it comes to stepper motors there are two basic forms one being the permanent magnet type which has a permanent magnet as the rotor shown in figure 7 and the other being a variable reluctance type with a soft steel rotor.

Permanent magnet stepper motor

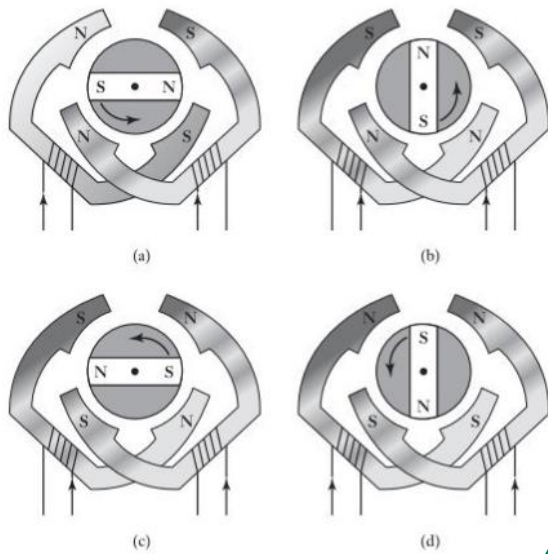


Figure 8 shows the 2-phase stepper motor with 90° steps. The basic elements of this type of stepper motor contains two pairs of stator poles. Figure 8 shows the different positions of the magnet rotor coils as they energise in different directions.

The poles are activated when current is passed through the appropriate field winding with the coils being such that opposite poles are emitted on opposite coils. The motor works on the principle of magnetic attraction and repulsion.

Figure 8- Permanent magnet stepper motor (Bolton, 2015)

“When a current is applied to one of the coils, it generates a magnetic field, which attracts the permanent magnets in the rotor toward it. As the rotor moves towards the magnetic field, it aligns with the next set of poles in the stator, and the current to the previous coil is turned off.” (LinEngineering, 2023)

This is then repeated for each coil so that the motor moves in a precise and controlled manner. The polarities associated with each step can be seen in figure 9 below-

Step	Pole 1	Pole 2	Pole 3	Pole 4
1	North	South	South	North
2	South	North	South	North
3	South	North	North	South
4	North	South	North	South
5	Repeat of steps 1 to 4			

Figure 9- Rotor positions (Bolton, 2009)

This shows there are 4 possible positions which are 0° , 90° , 180° and 270°

Variable reluctance stepper motor

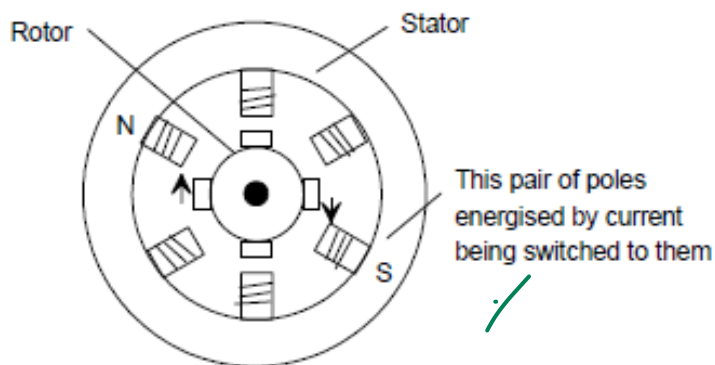


Figure 10- Variable reluctance stepper motor principle (Bolton, 2009)

A variable reluctance stepper motor operates based on the principle of magnetic reluctance, which is the opposition to magnetic flux. The stepper motor consists of a rotor and a stator as shown in figure 10. The rotor is made up of soft steel and has several teeth and a stator with multiple of poles having more than the number of the

rotor's teeth. The stator poles when energized in a specific sequence create a magnetic field that interacts with the rotor.

(Bolton, 2009) stated that "When one pair of poles is activated, a magnetic field is produced which attracts the nearest pair of rotor teeth so that the teeth and poles line up. This is termed the position of minimum reluctance."

The motor can be made to rotate to line up with the next poles by sequentially switching the current from one pair of poles to the next creating a rotation to take place in steps. The step angle for the motor depends on the number of the rotor's teeth and the number of poles on the stator.

Task 2 – SCADA (Supervisory Control and Data Acquisition)

Introduction

“The term SCADA, which stands for supervisory control and data acquisition system is widely used for systems that can both control and monitor industrial processes. This involves the control and gathering of data.” (Bolton, 2009)

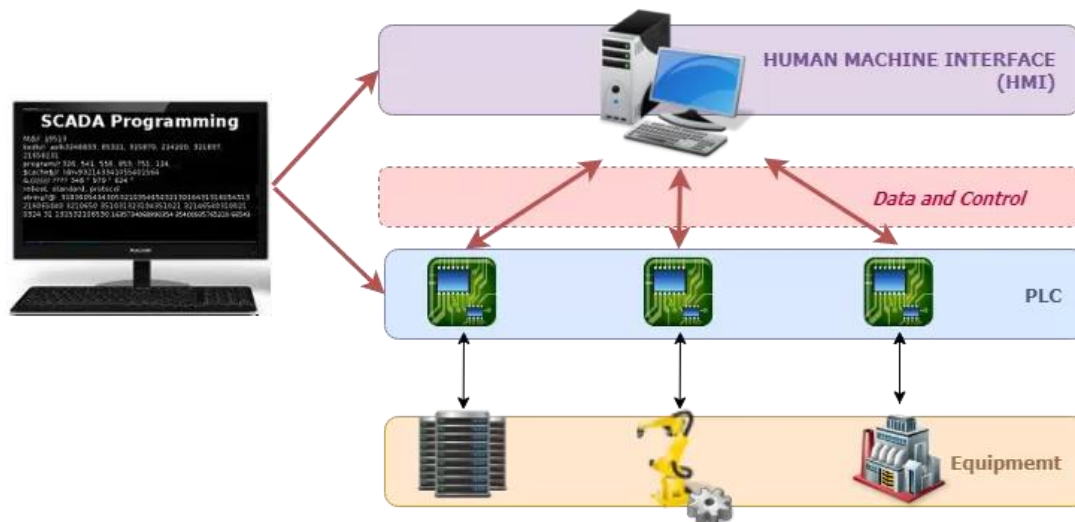


Figure 11-SCADA Diagram (DPSDelecom, 2022)

Figure 11 shows a basic diagram of how the SCADA system works and interacts. SCADA systems are typically used in manufacturing, transportation, oil and gas, water management, renewable energy also power distributions and control systems. The report aims to discuss the key features of SCADA systems and how human machine interfaces and programmable logic controllers are integrated into them whilst also including industrial examples.

Key features of SCADA Systems

1. Real-Time monitoring: SCADA systems allow operators to have up to date information about the processes being monitored. The real time data acquisition and monitoring is provided through various parameters such as flow rate, temperature, pressure weight, speed and more.
2. Data Acquisition: SCADA systems collect the data from the parameters and network devices connected to PLC's.
“This raw data is then sent to a PLC to process, and then on to an HMI for a human operator to analyse and make decisions as required.” (Colleges, 2021)
3. Control Functions: Operators can have remote control of industrial processes using SCADA systems to adjust parameters, initiate actions and respond to alarms from locations away from the equipment such as control rooms.
4. Alarm Management: When abnormal conditions or deviations occur within a process or equipment the SCADA systems have functionalities which can trigger alarms to alert the operators. The Alarms can be in many or multiple forms such as visual, audible, or sent through notifications.
5. Historical Data Storage: The information gathered through SCADA from the parameters can be stored as historical data for analysis, reporting and compliance purposes. This data can then be used to improve performance efficiency and troubleshooting.



Integration of HMI's and PLC's

1. Human Machine Interfaces (HMI's) : HMIs are a user interface or dashboard which connects a person/operator to a machine, system, or device. HMI's can visually display data, track production time, trends, and tags, oversee KPI's, monitor machine inputs and outputs and much more. For example, figure 12 shows a type of advanced HMI screen which is used by the operators onsite at Valero for the process control for the units. In the figure shown the operator can see the flow rates, temperatures, pressure, and the process inputs and outputs, capacity etc. HMIs are integrated in the SCADA system so the operator can monitor process parameters, issue commands, acknowledge alarms and access historical data.

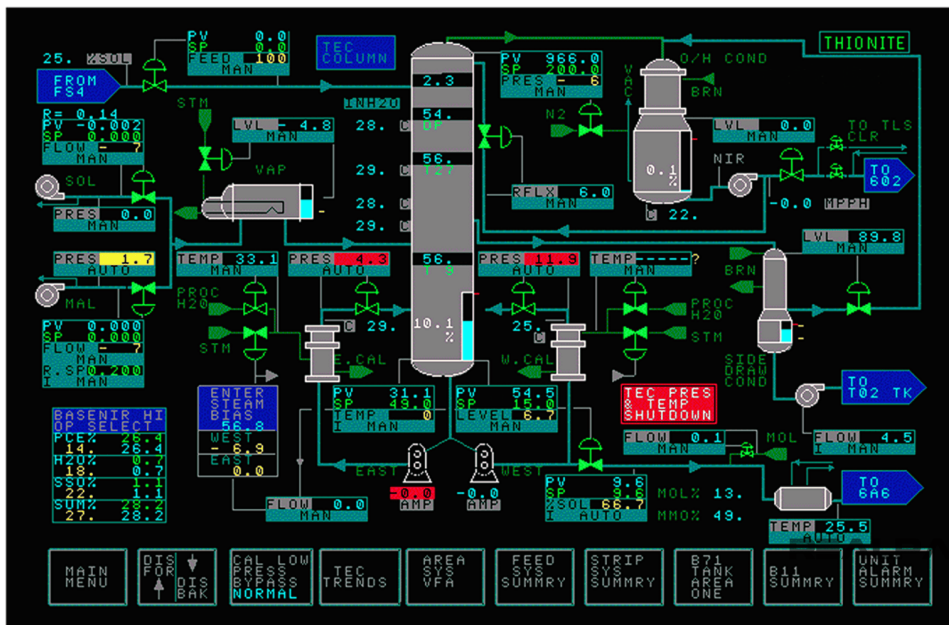


Figure 12- Advanced HMI Screen (Gregory, 2020)

2. PLC's: "PLCs collect data from inputs such as parameters and translate that data into information that can be used by the SCADA system and understood by operators. PLCs also receive signals back from the SCADA system to facilitate control functions". (Solutions, 2020)

The PLC is responsible for executing control logic and automation task. The PLC integrates with the SCADA system and HMI to exchange data, commands and status updates ensuring there is effective integration between the control system and operator interface.

Industrial example

Oil and Gas industry: SCADA systems are used at Valero to monitor and control operations such as refining, production, and distribution. The HMI allows the operators onsite to have a graphical interface to monitor key parameters within the process such as pressure, flow rates, temperatures, and valve positions. The SCADA system can also trigger alarms to notify the operator. For example, the operator could receive a high flow rate alarm which the operator can check on the HMI and adjust the rate by sending a signal from the HMI to the PLC to close the valve by a specific percentage. The PLC s control the operation based on the input and send a signal to the relays to operate for example in this case the relay would send a signal to the motor operated valve to close. ✓

Conclusion

To conclude SCADA systems, play a vital role in modern industrial automation with their key features of real time monitoring, data acquisition, control functions and alarm management. Effective communication and interaction between operators and the control system enabling efficient monitoring control and management of processes is achieved through the integration of the HMIs and PLC's. SCADA systems will remain to help industries to evolve for the future. ✓

Task 3 – Instruction List

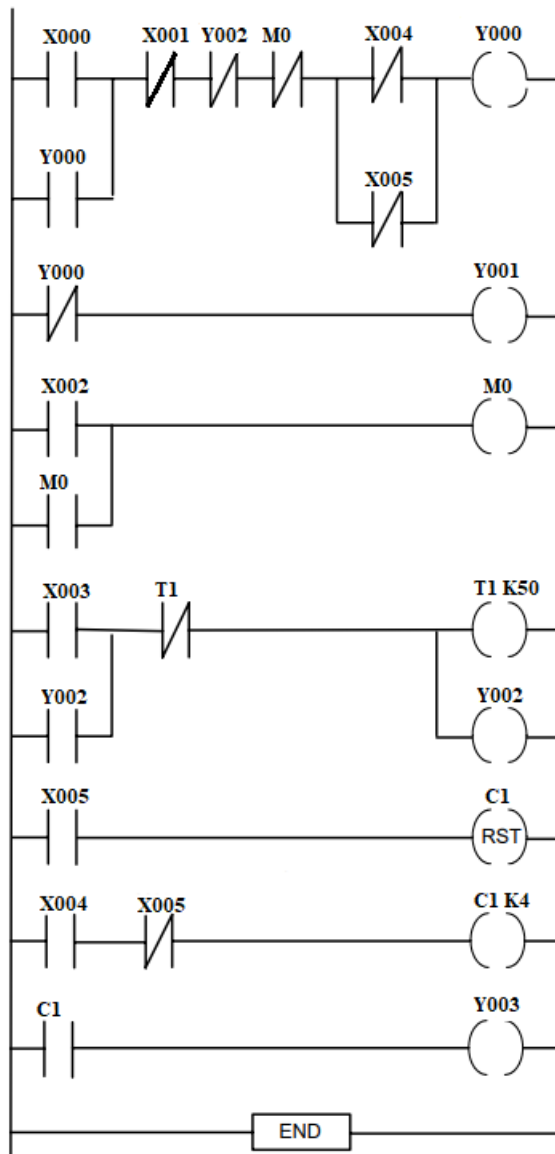


Figure 13- Ladder Logic

The instruction list for the bottle packing production line can be shown below.

This has been produced from the ladder logic shown in figure 13.

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

→ Need to use branch instruction.

LDI Y000
OUT Y001

LD X002
OR M0
OUT M0

LD X003
OR Y002
ANI T1
OUT T1
K 50

OUT Y002
LD X005
RST C1

LD X004
ANI X005
OUT C1

K 4
LD C1
OUT Y003

END

Task 4 - Temperature Alarm Panel

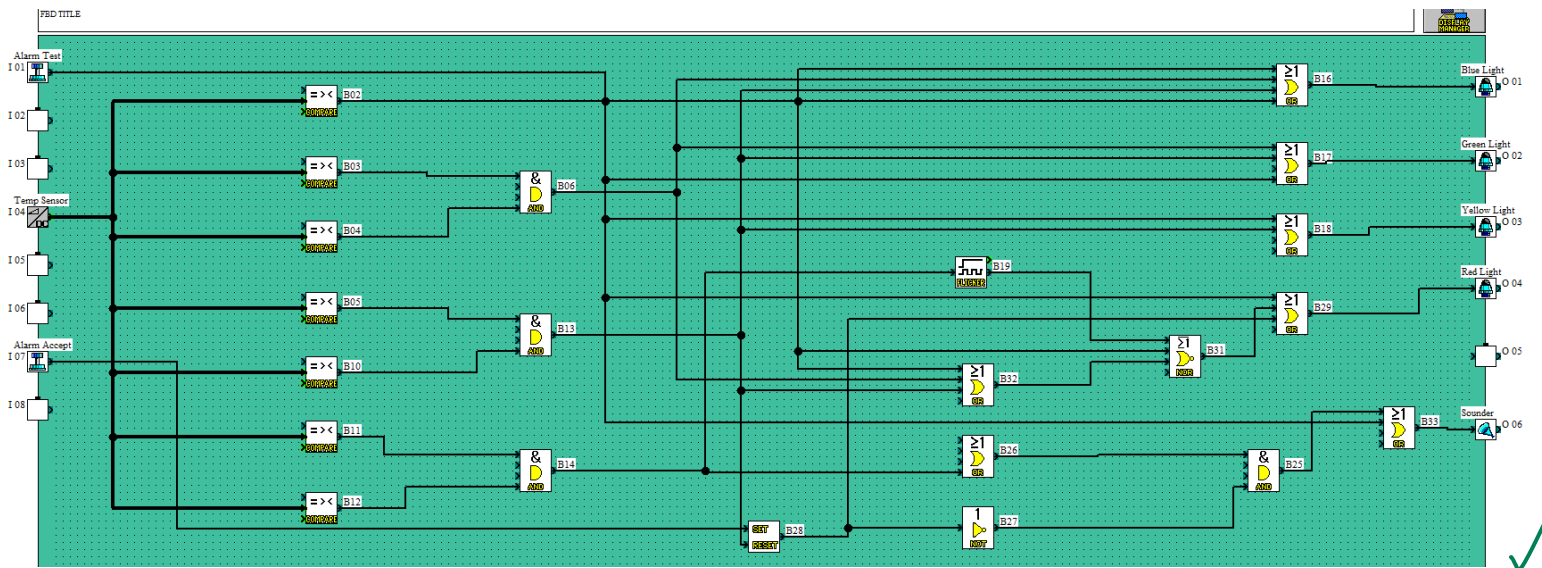


Figure 14- Mitsubishi PLC Alarm System Monitoring Temperature

Figure 14 shows the Mitsubishi PLC analogue input functionality has been used to design and simulate an alarm system to monitor a temperature range of 0 to 50°C which will indicate using a series of lights. The output responses for the alarm can be seen below in table 1.

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

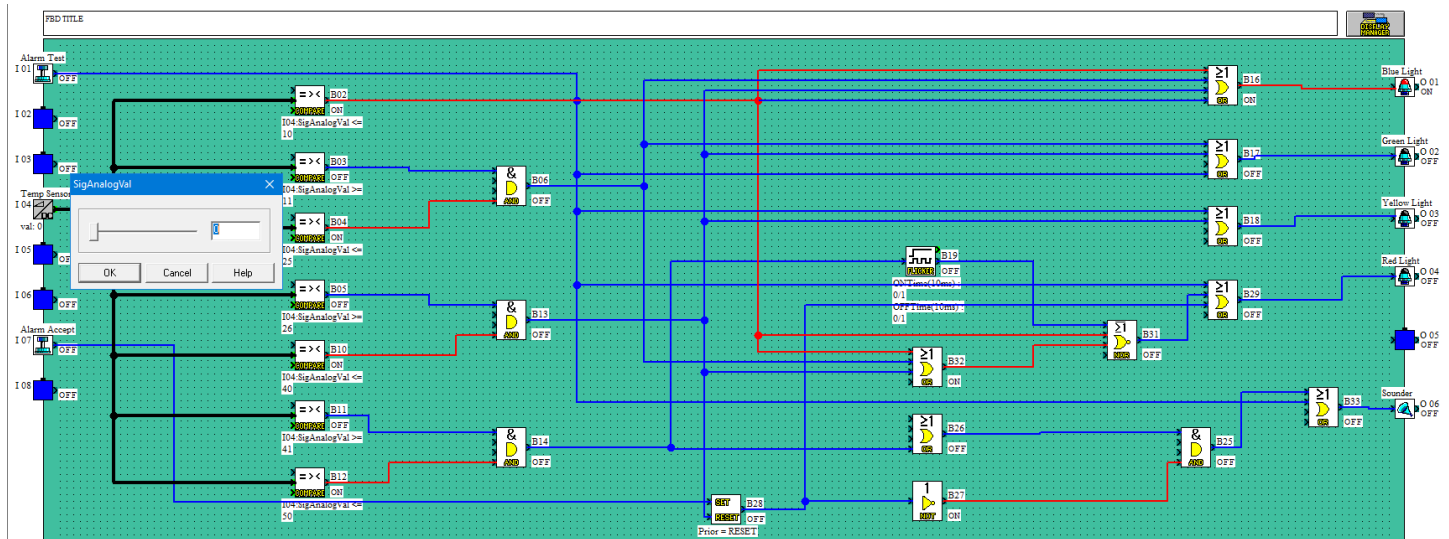


Figure 15- Blue alarm lights functioning correctly

Figure 15 shows that when the temperature is between 0-10°C the blue light alarm is on as required.

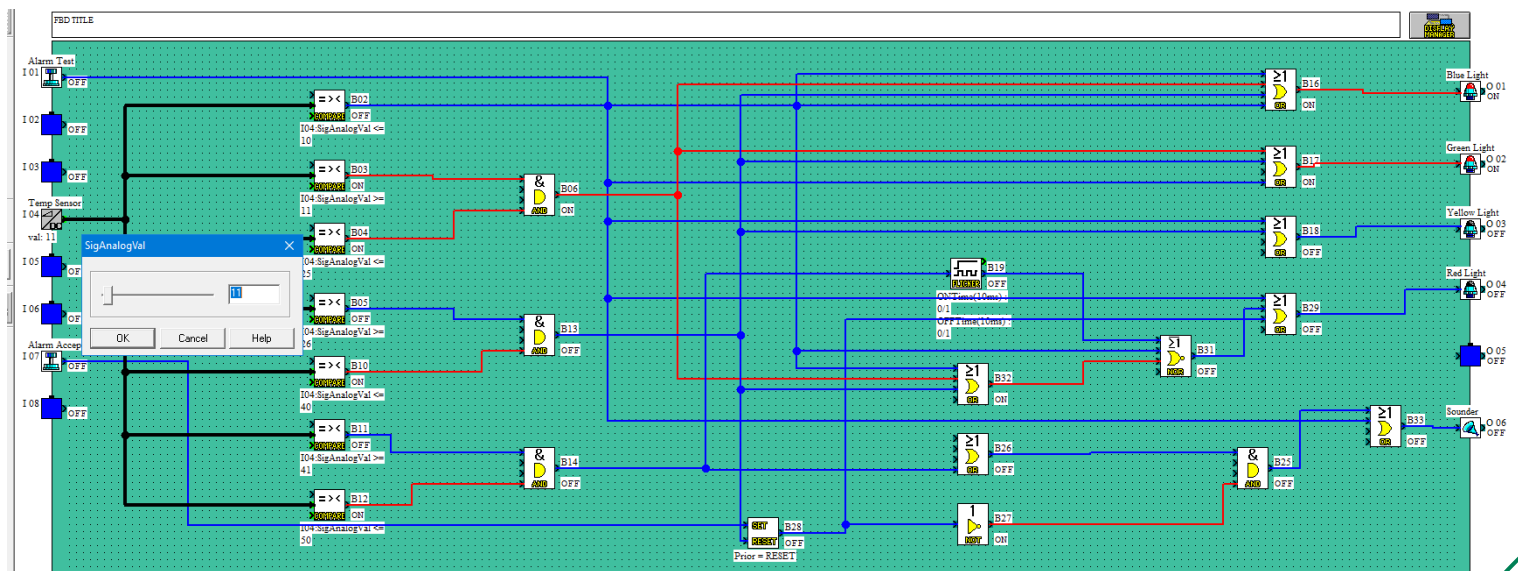


Figure 16- Blue and green light alarm functioning correctly

Figure 16 shows that when the temperature is 11°C the blue and green light are on as required.

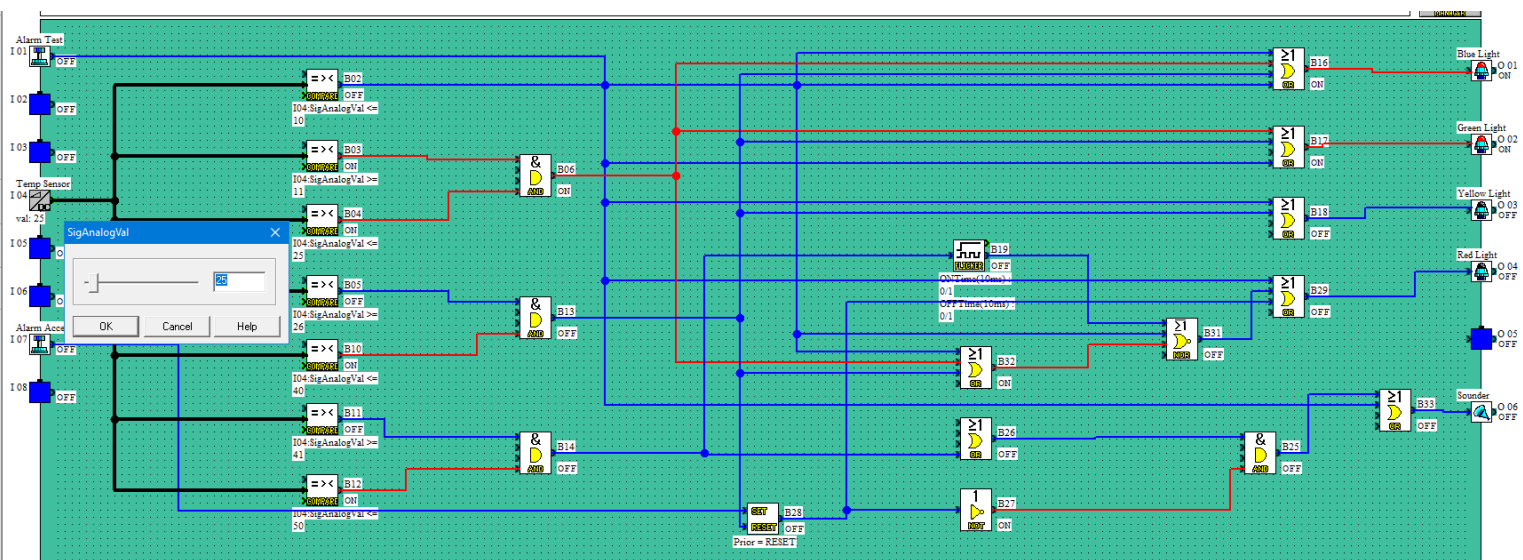


Figure 17- Showing that the green alarm light range works

Figure 17 shows that the temperature is 25 and the blue and green light are still on showing that between 11-25 those 2 lights are on as required.

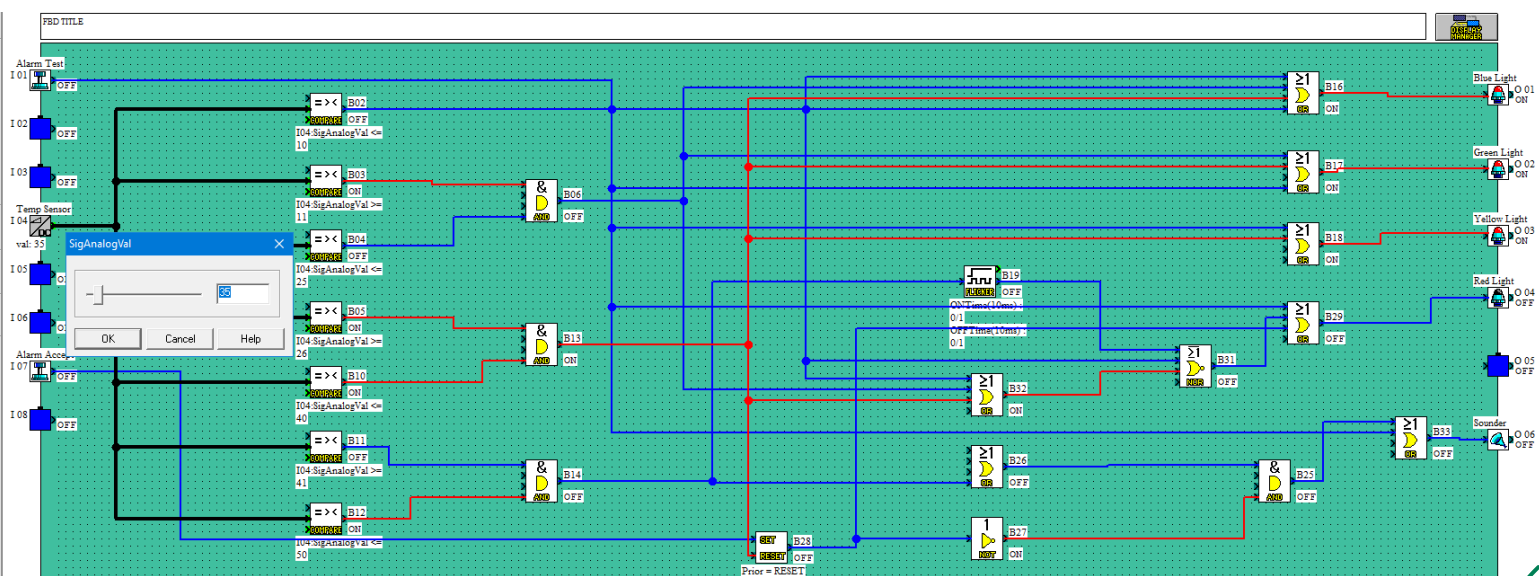


Figure 18- Blue, Green and Yellow alarm lights functioning correctly

Figure 18 shows that when the temperature is 35°C that the blue, green, and yellow alarm light are on as required by the output table.

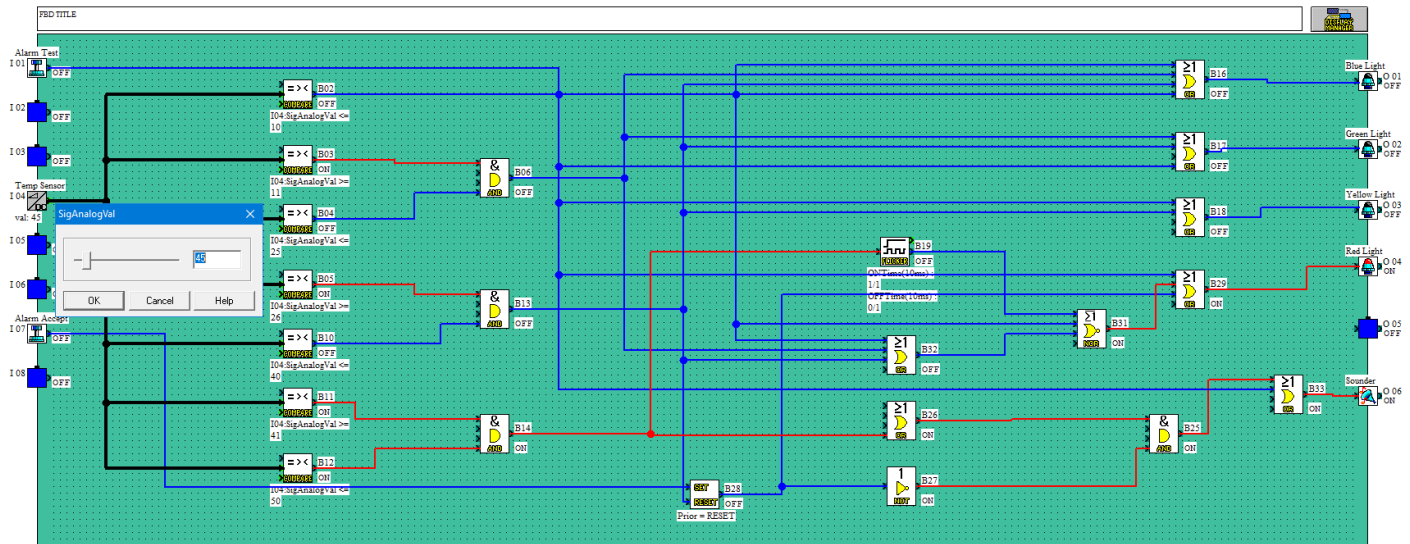


Figure 19- Red alarms light and sounder comes on when required with the other alarms clearing

Figure 19 above shows that when the temperature is between 41 and 50°C only the red light is flashing, and the sounder is on as required.

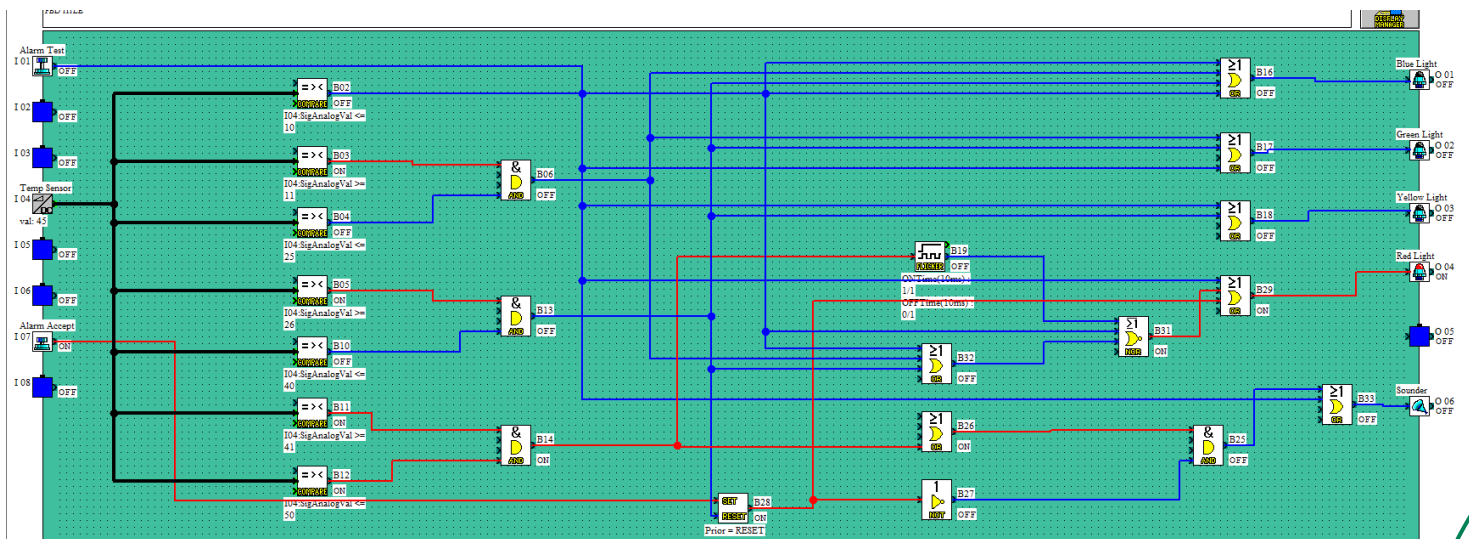


Figure 20- Alarm accept button working as required

Figure 20 shows that when the alarm accept is pressed the red light stays on and the sounder goes off to show the alarm temperature has been acknowledged by the user.

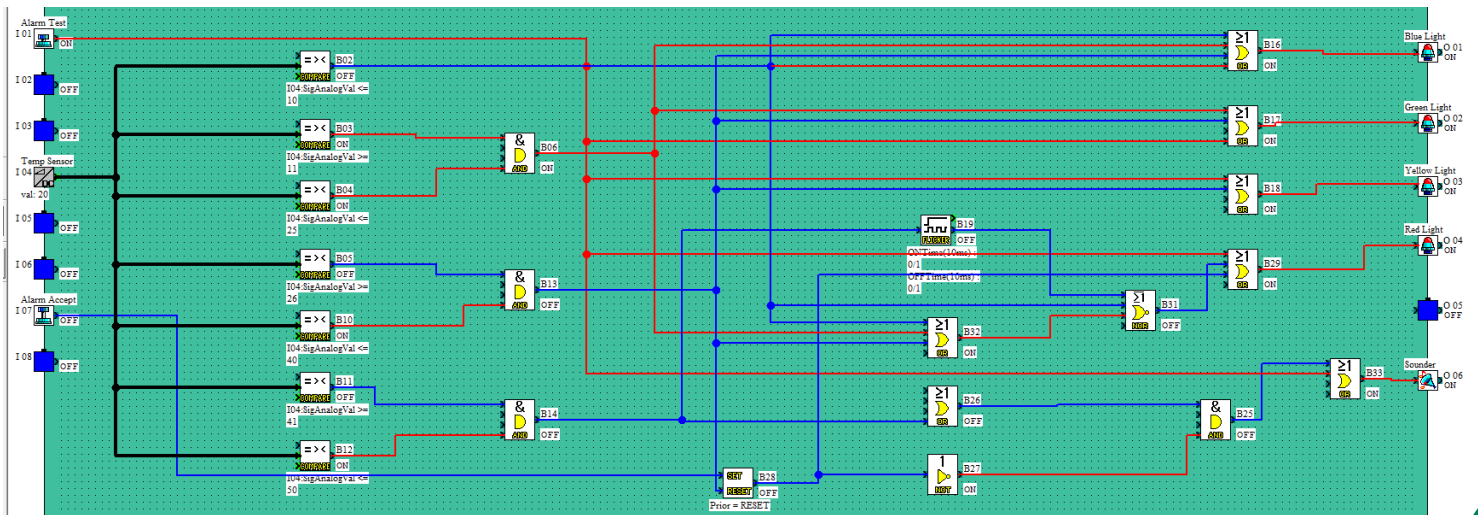


Figure 21-Test alarm functioning correctly

Figure 21 above shows that when the test alarm is hit all the lights and sounder come on as required.

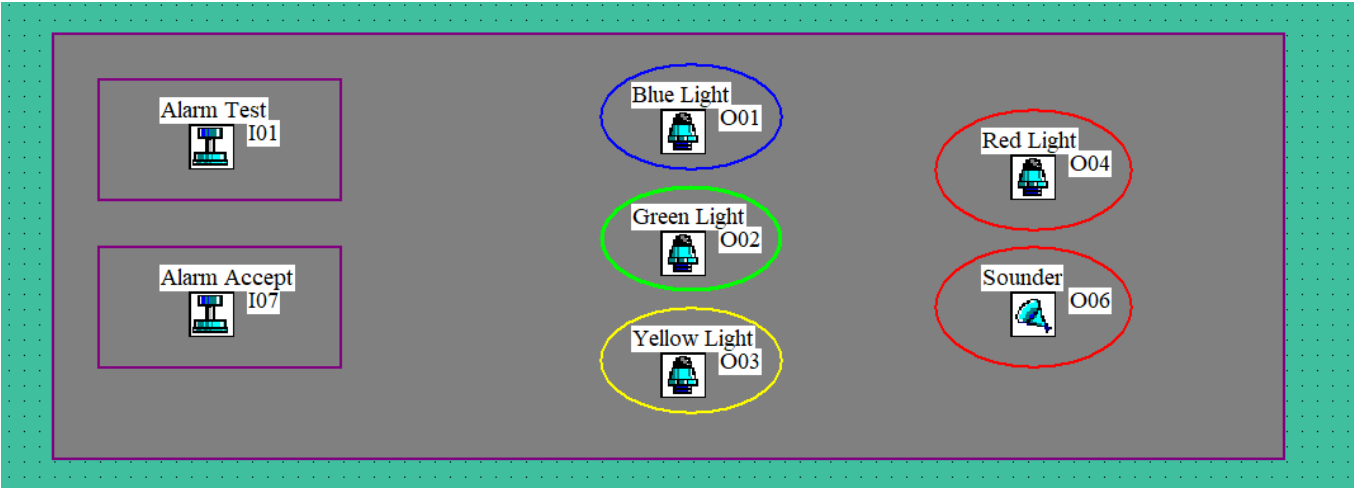


Figure 22- Human machine interface(HMI)

Figure 22 shows a Human Machine Interface (HMI) panel to demonstrate the operation of the program.

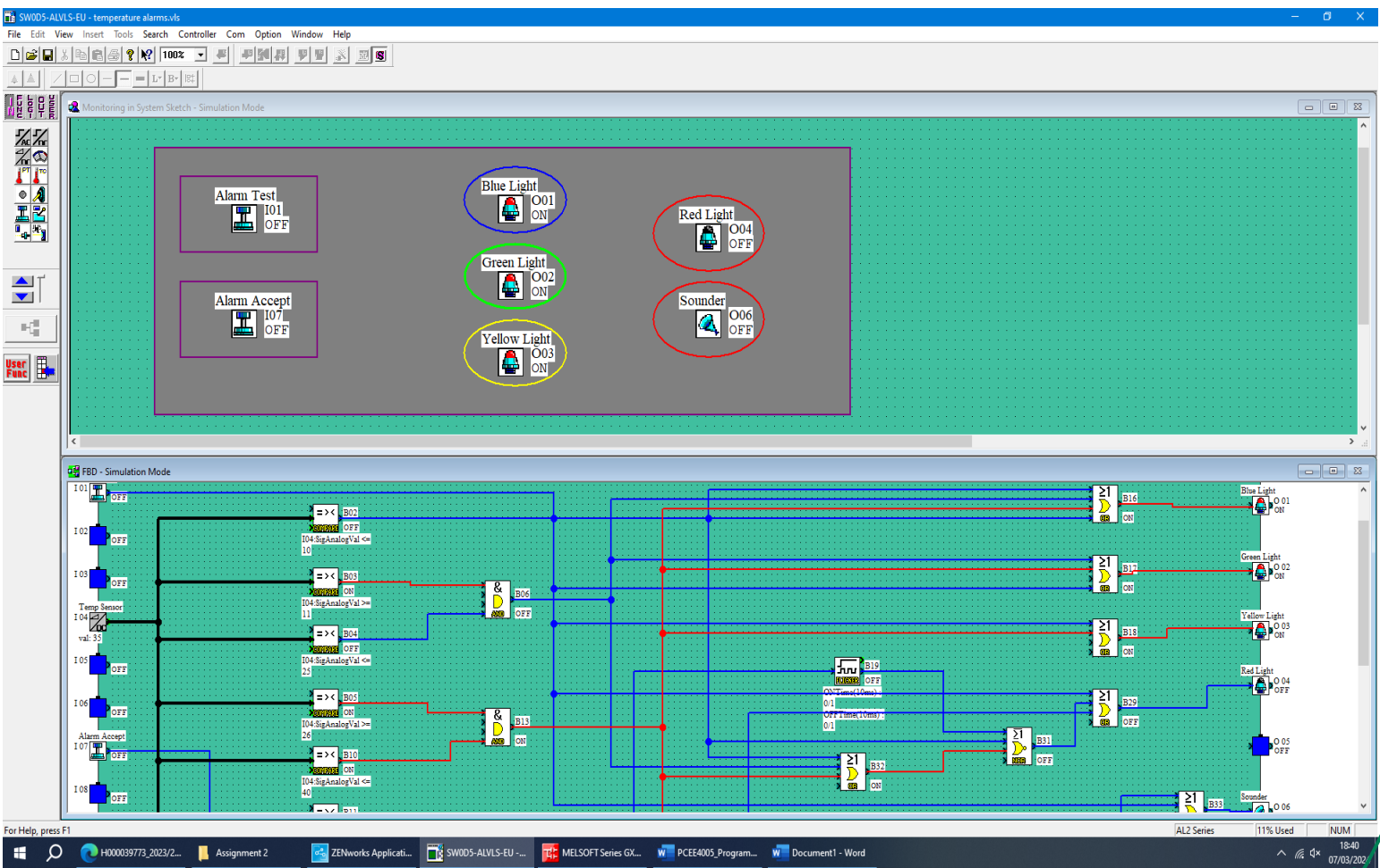


Figure 23- HMI panel Functioning

Figure 23 shows the HMI panel working with the operation of the program.

Task 5 – Construction Site Lift

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

Table 2

Lift System

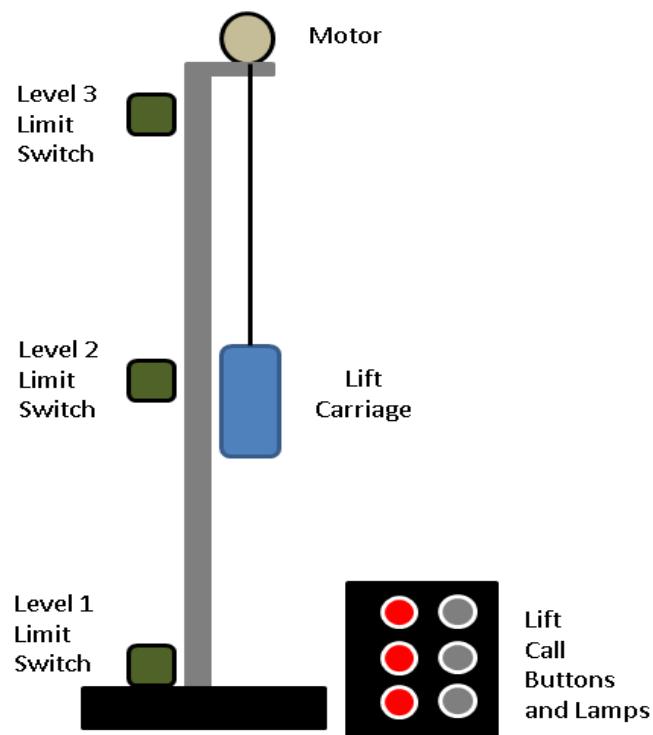
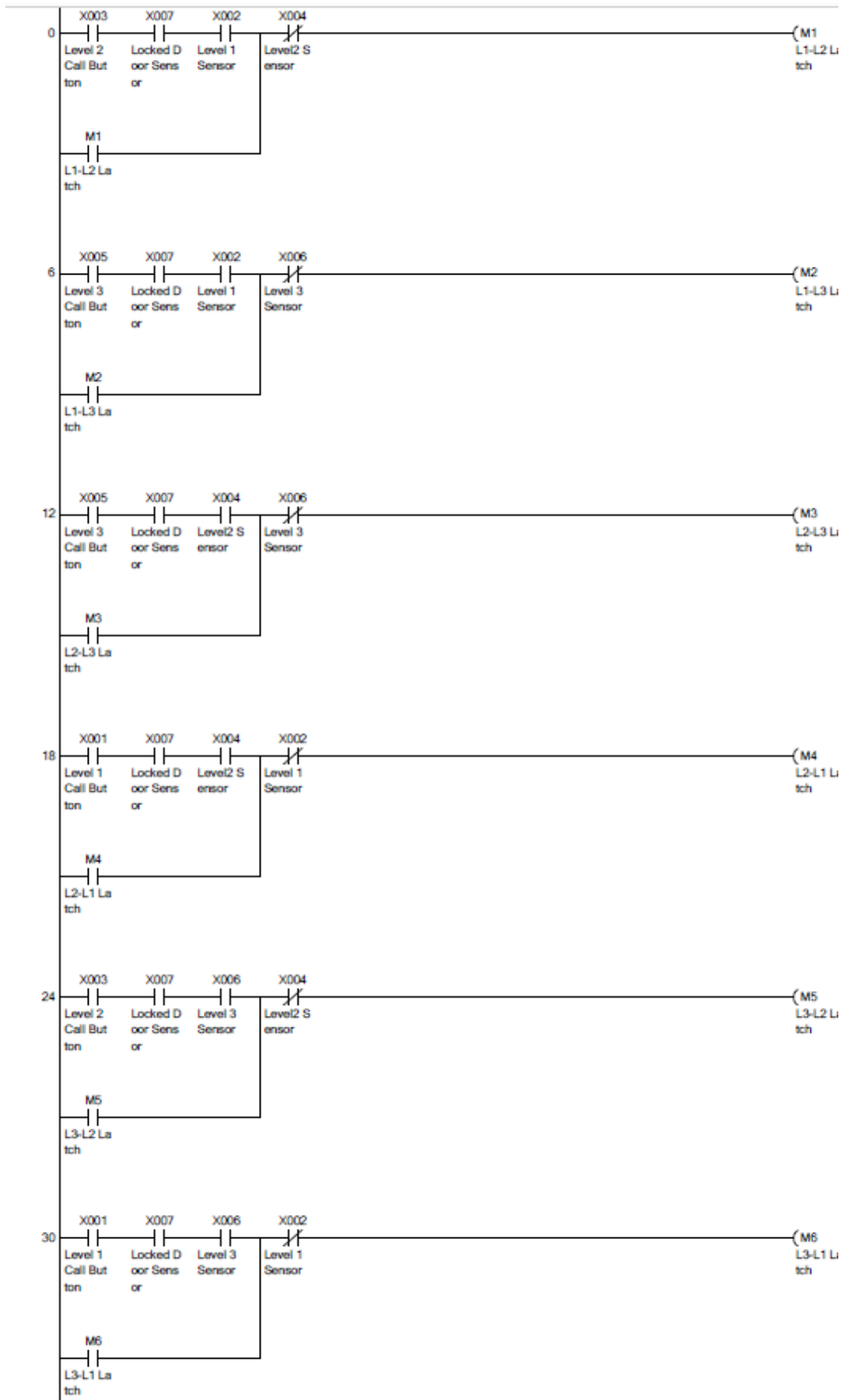


Figure 24- Lift system

Shown below is a Mitsubishi FX PLC program which controls the lift system as shown in figure 24. The input and output controls used can be seen in table 2.



Cropped
your diagram
too much



Figure 25- Ladder logic for lift PLC program

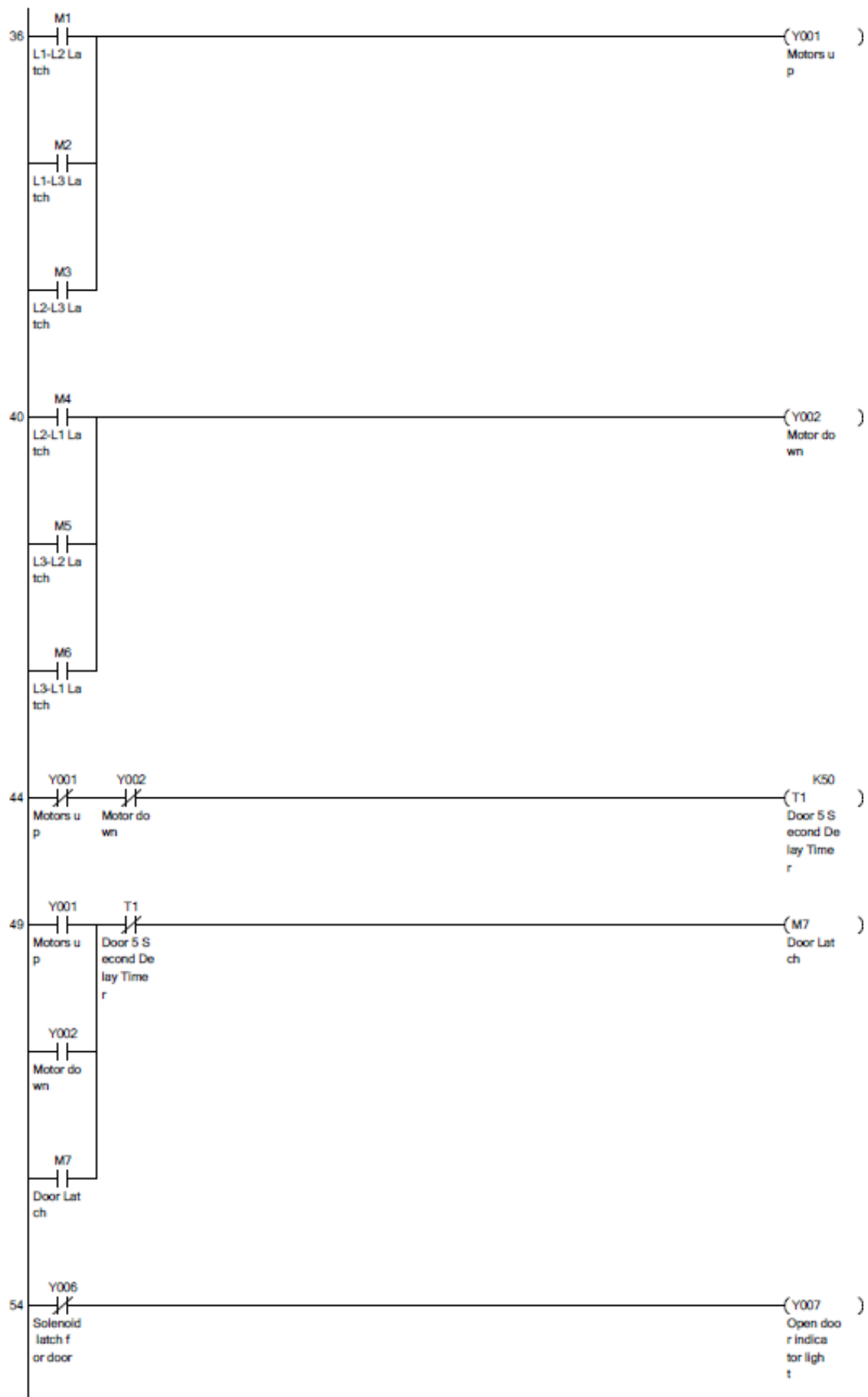


Figure 26- Ladder logic for lift PLC program

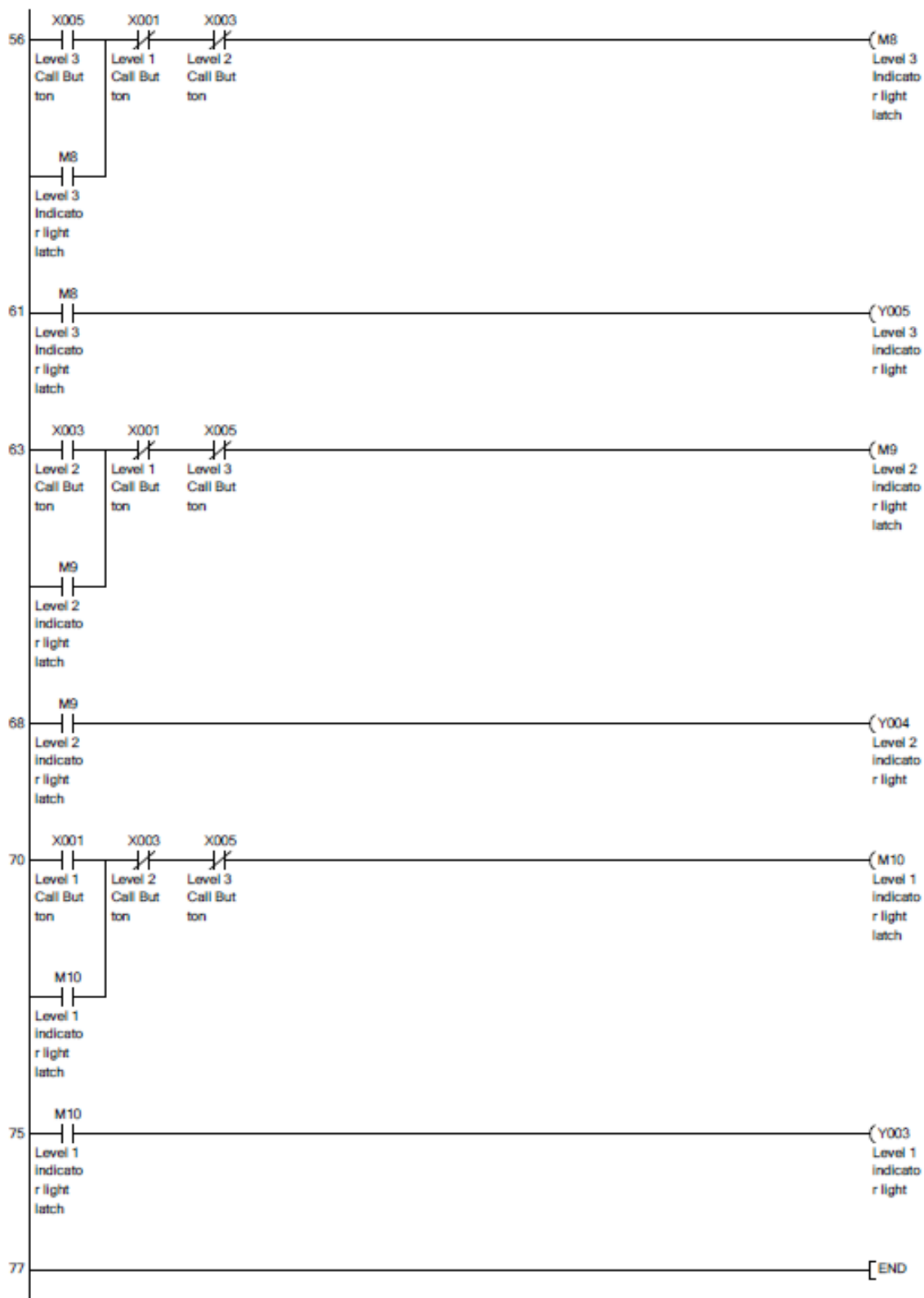


Figure 27- Ladder logic for lift PLC system

Figures 25, 26 and 27 shows the program used to control the lift system on a building site. The program used was Mitsubishi FX PLC (ladder logic) to control the process.

Ladder logic simulation

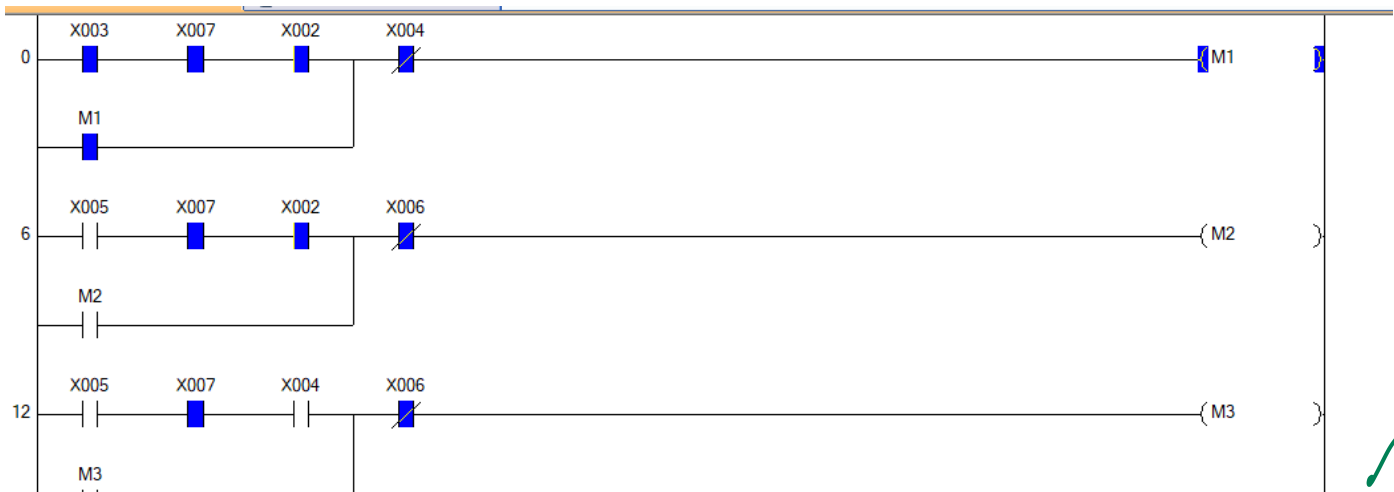


Figure 28- Level 1 to Level 2 Latch Functioning correctly

Figure 28 shows the level 1 to level 2 latch being activated due to the call button 2 being pressed.

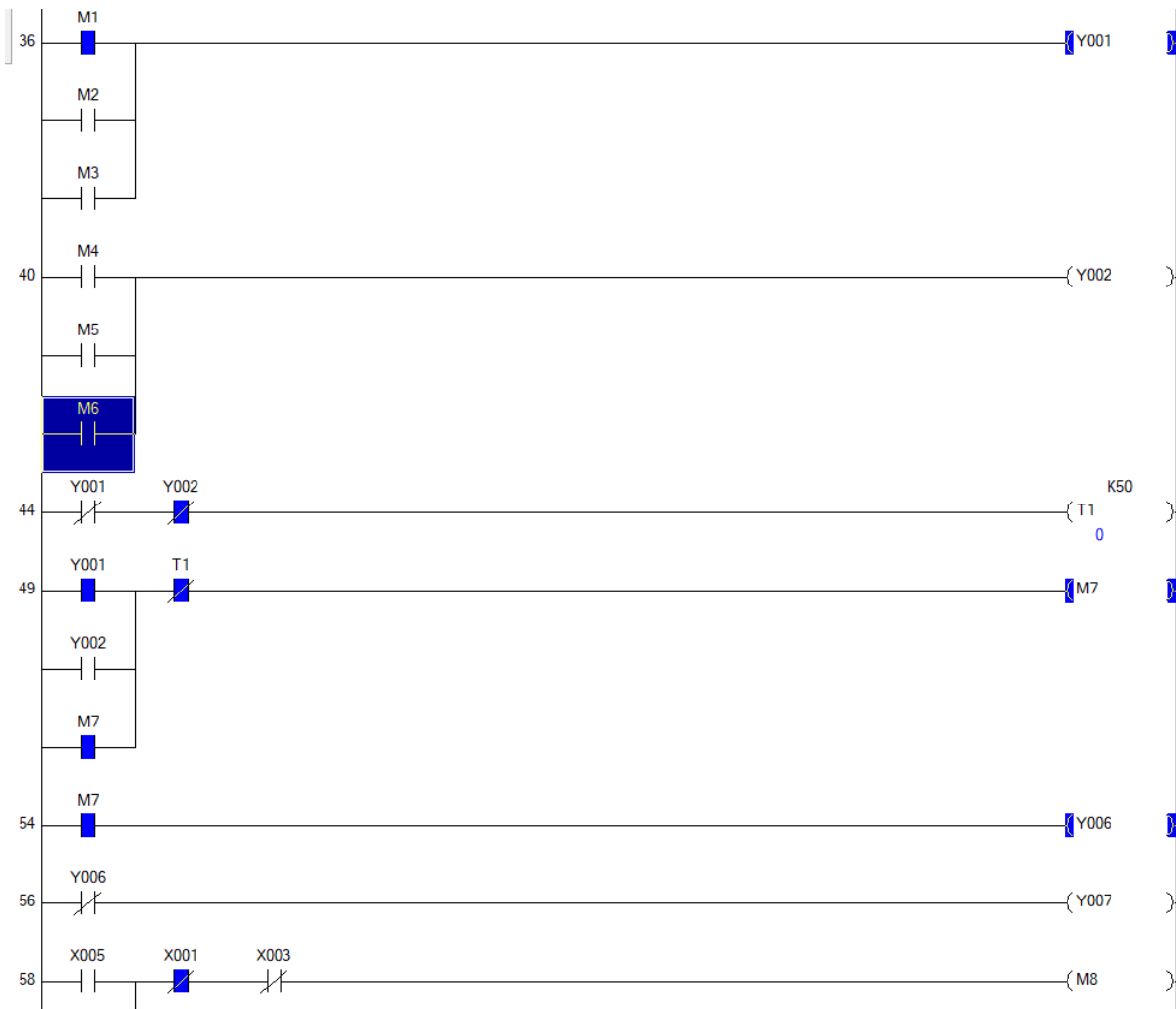


Figure 29- Shows the latches working for the motor the locked door. Also door indicator light functioning correctly

Figure 29 shows that M1 has been latched from the call button 2 and the motor is going up from level 1 to level 2. This figure also shows that M7 has been latched for the locked door sensor and has been used below to latch the solenoid for the door shown as Y006. Y007 is the open-door indicator light is off as it has been deactivated due to the door solenoid latch is activated.

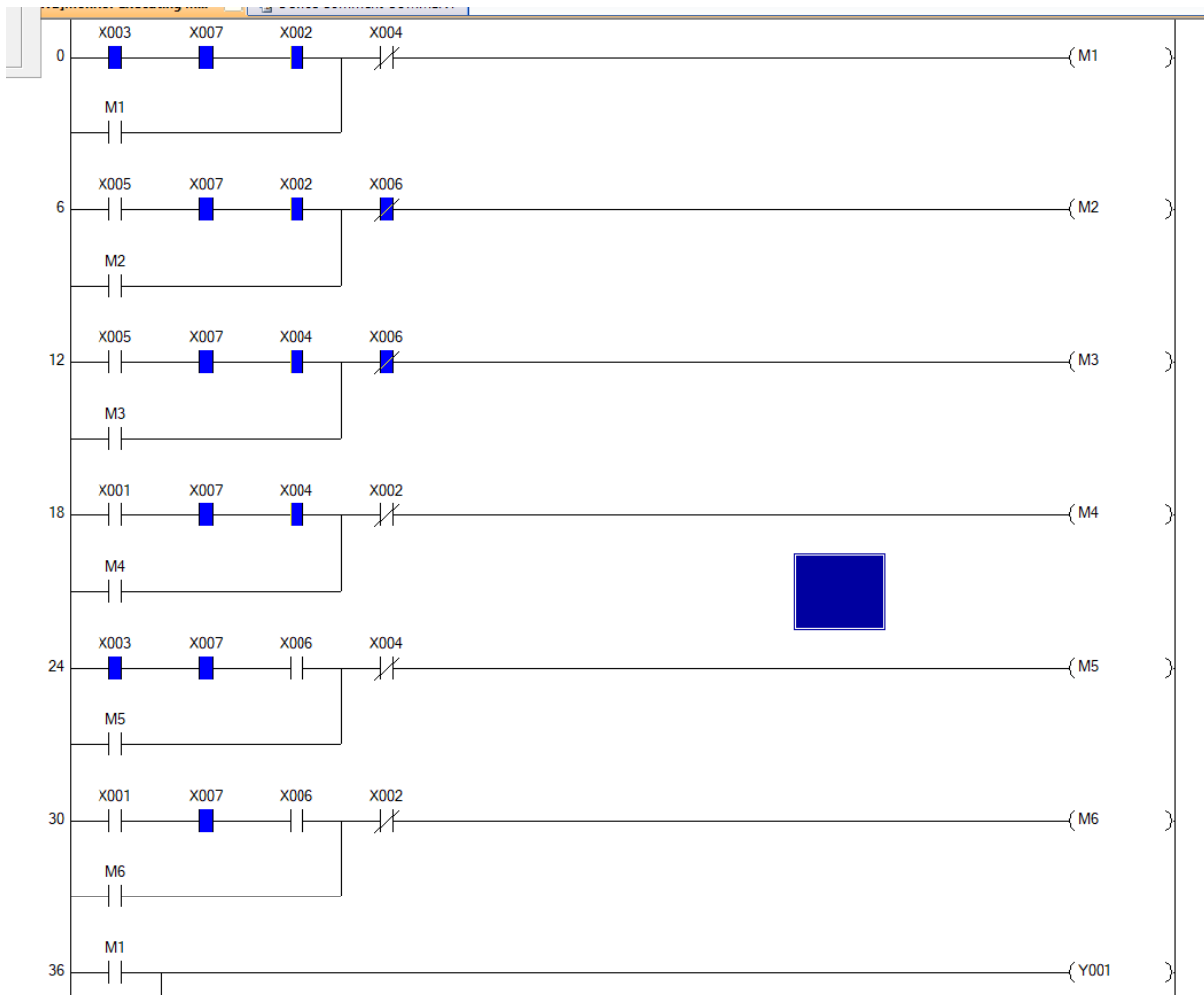


Figure 30- Latch for level 2 functioning correctly

This figure shows that M9 has been latched for the level 2 indicator light. Y004 is then activated from this latch showing the level 2 indicator light.

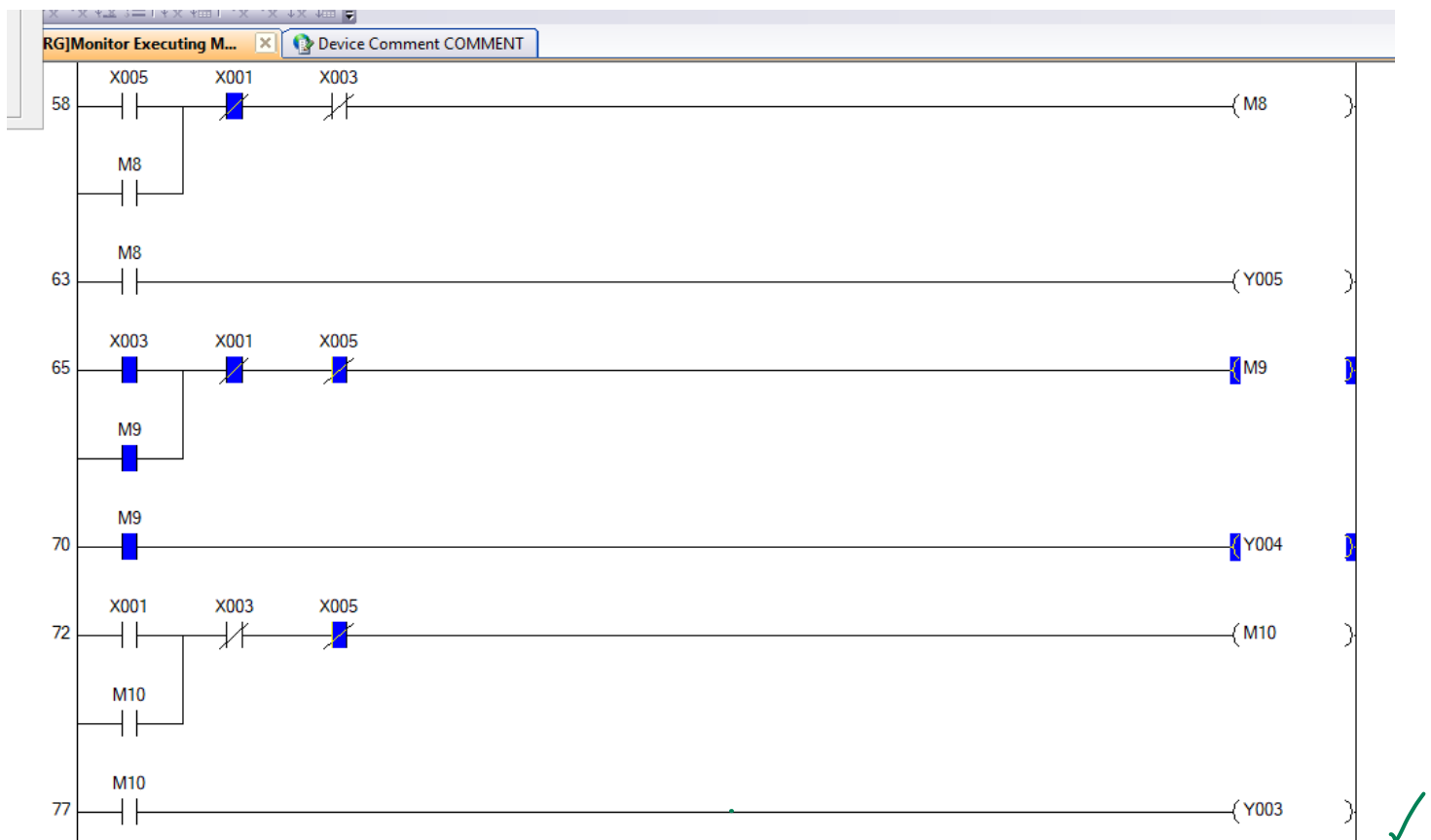


Figure 31- Level 2 latch and motor deactivated

Figure 31 shows that Y004 is now on as the lift has reached level 2 and the motor has deactivated.

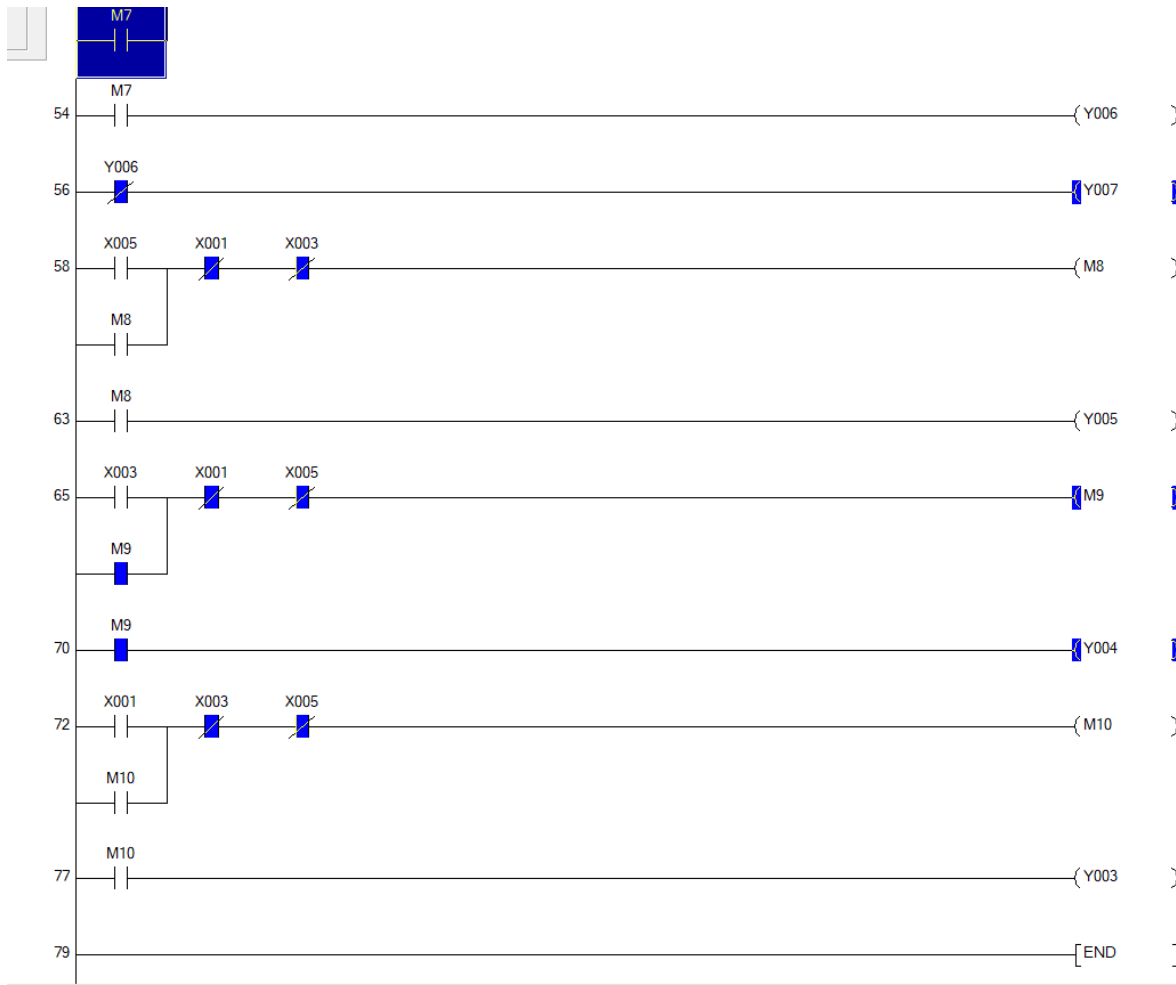


Figure 32- Level 2 indicator light and door light are on and door opened

Figure 32 shows that once the lift has reached level 2 the indicator light is on, and the door has opened which can be seen as the open-door indicator light is activated as shown by Y007.

The operation of the program shown above meets with the design specification required. The simulating test above proves that the lift going from level 1 to level 2 functions correctly. The test for the other 5 movements in the system have also been simulated and were successful in meeting the required criteria.

From the completion and evaluation of the program there could have been some additional functionalities that could have been incorporated into the program to improve the process to operate more efficiently and safer.

Firstly, the lift could have had automatic doors making it easier, efficient, and aesthetically pleasing to the users. Another additional functionality could have been to have an emergency button and procedure. This could set an alarm to allow people to know the lift is stuck or the users need help etc. Lastly another safety feature which could have been is a load cell to check the weight. This would allow the users and the PLC to know if the lift is at a safe weight before being allowed to move levels. ✓

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Would like to see more text books being used.

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