

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Heather Raymond	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)

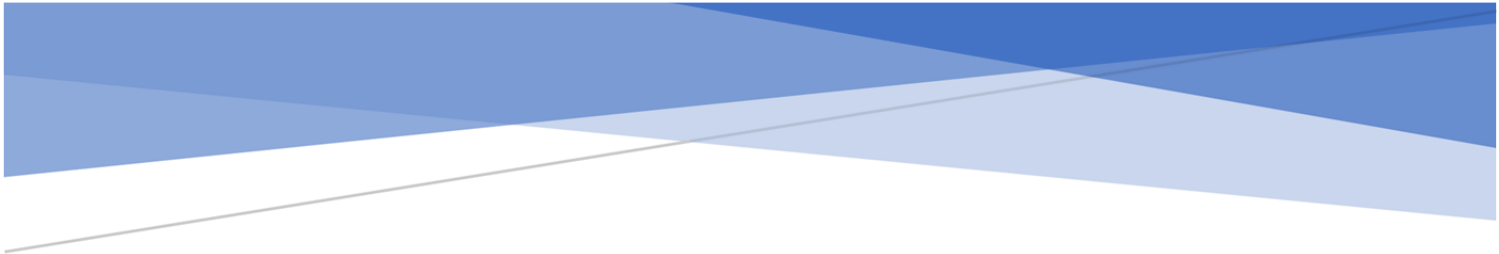
1. Demonstrate an understanding of the concepts of process control using an industry standard PLC.
2. Undertake basic PLC system design and implementation processes, comparing theoretical expectations to actual outputs ensuring correct operation and consideration of maintenance and reliability.

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	9.3
Engagement with a wide range of literature, including sources retrieved independently. Generally sound referencing technique.		
2. Knowledge and Understanding Skills	40	23.7
Task 1 achieved 45%. Task 2 achieved 66% Task 3 achieved 65% Showed some competent knowledge of the basic underlying concepts and principles for assessment but Task 1 have only included one device per 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	2.8
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	25.2
Task 4 achieved 82%. Task 5 achieved 86%. 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	6.6
Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed.		

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)		68%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		



PCEE4005

PLC Program design and simulation

Abstract

HNC Electronic and Electronic engineering and HNC instrumentation engineering,
Programmable Logic Controller Assignment 2



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TASK DESCRIPTION

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 sensor-



Figure 1, Source: <https://www.bakerhughes.com/bently-nevada/sensors/proximity-sensors>

An example of a proximity sensor that can be connected to a PLC is the 3300 XL Bently Nevada 8mm Proximitor system. The data sheet for this system can be accessed in Appendix A. The sensor outputs a voltage directly proportional to the distance between the probe tip and the observed conductive surface, with the capacity to measure the static position of a shaft and dynamic (vibration) values. This is all based on eddy current principles. One of the benefits of using this specific probe is that the components are backward compatible and interchangeable with other systems/ interfaces *Bolton W, 2015*. On the following pages are wiring diagrams of the Proximitor, *figures 2 & 3*, demonstrating how it connects to the Trinconix PLC at Valero Refinery- via junction boxes and through barriers. The sensor body itself contains a Zener diode, meant as a form of surge protection for the PLC. ✓

* Need to show which parts are your quote for the reference.

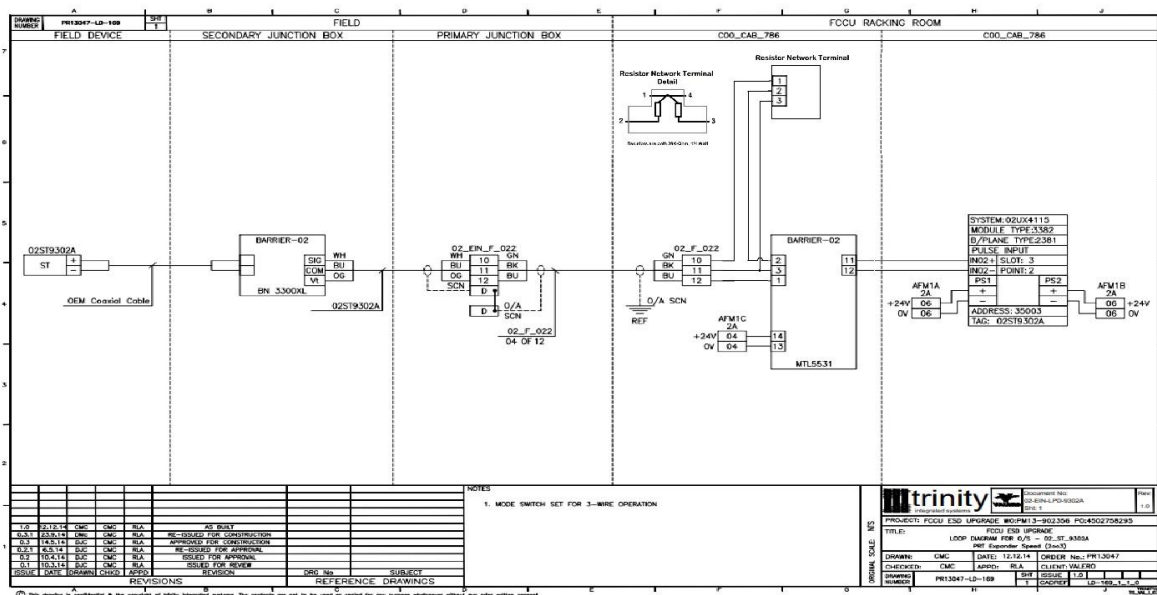
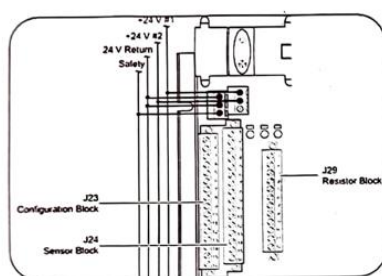


Figure 2, wiring diagram for the proximity sensor, Source: Valero Pembroke Refinery

Trident 3381 PI – Wiring an Active Sensor on Point 1



Configuration J23/J26 Signal	Point 1	Sensor J24/J25	Point 1	Resistor J29/J30	Point 1
V+	1	V+	1	V+	1
R+	2	IN+	2	IN+	2
FE	3	IN-	3	IN+	3
IN1-	4	Shield	4	IN-	4
FE	5				

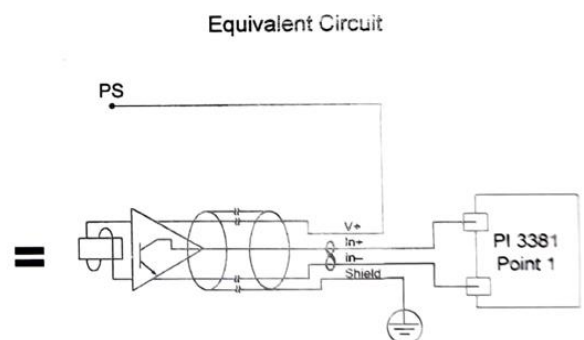
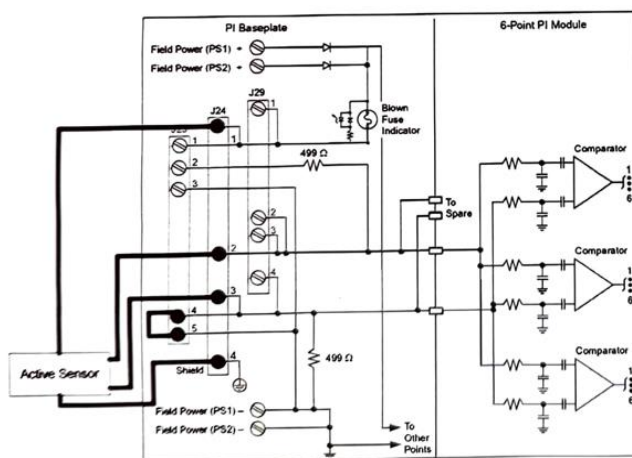


Figure 3, input circuit considerations, Source: Pembroke Refinery

A typical PLC cycle is divided into 2 different modes of operation- the scan mode and execution mode. Conversion from analogue signals typically require resistor networks and pulse width modulation, as evidenced in *figure 3* with the use of resistors and comparators within the probe module. During the scan cycle the processor scans the inputs in a serial mode and updates its internal memory as to the status of the inputs. *'Execution mode follows the I/O scan mode. In this mode the processor evaluates the input data stored in memory against the data programmed into the CPU. Scan time is the time required for the PLC to complete one I/O scan plus the execution cycle... A typical scan time is between 5 and 20 ms'* Dunn, W. 2018.



Figure 4, source: H Raymond. Example of barriers used between the sensing element and PLC input card

In this example, 3 proximitors are being used on Valero's Power Recovery Train expander section. The way these probes work within the logic of the PLC program is to shut down the machine via a 2 out of 3 voting system- in the event of an uncoupling of the shaft or high vibrations. The triconix PLC within this system uses functional block programming. The probes produce an ac signal which must be converted to a dc signal before reaching the input card, *Baker Hughes Company*, 2019.

The dc signal is cabled from the field device to a trident overspeed card in the control room, through a barrier into the triconix PLC and is then received by the control room systems (DCS) via a Modbus link. This signal appears as a waveform, within the region of 500mV, due to the probes seeing notches cut into in the shaft. *The trident product- guide states that the trigger voltage of the pulse input cards is 500mV. Systems, I. 2001, page 100.* This trigger threshold is non-adjustable. A voltage divider had to be implemented into the circuit, as false votes to trip were being created by noise on the waveform. At 250mV peak to peak, the pulse input card was not triggered, therefore did not affect the logic.

Capacitive displacement sensor

A datasheet/ manufacturers information is available in Appendix B, for a capacitive displacement sensor that could be connected to a PLC input card. The sensing element and the opposing measurement object represent the two plate electrodes. If a constant alternating current flows through the sensor capacitor, this amplitude on the sensor is proportional to the distance between electrodes. This alternating current is then demodulated and output as an analogue signal for example, *Micro-epsilon (2024).*

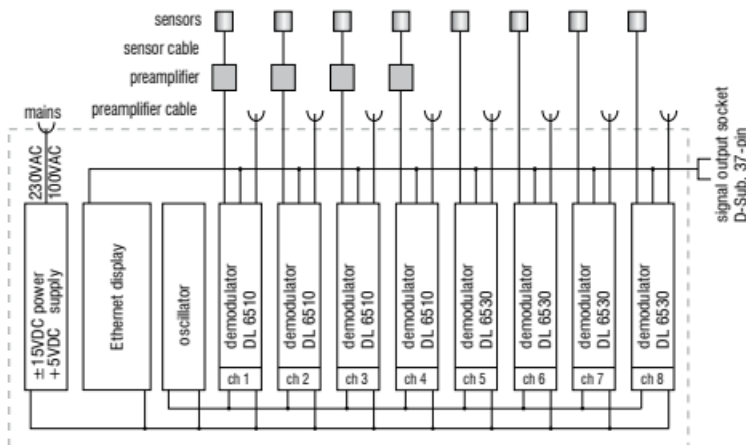
The sensor cables used within the system (triaxial), are extremely low noise and resistive to magnetic interference fields. Micro- Epsilon sensors are short circuit proof and the pre-amplifier will not get damaged if the front face of the sensor gets shorted by touching the conductive target. A modular version of this sensor and controller can be observed in *figure 5*. A modular design enables the system to be expanded at any time by up to 4 measuring channels.

'The DT6240-PROFINET is parameterized directly via the Industrial Ethernet interface. This is how the full sensor performance is directly integrated into the PLC via PROFINET without additional interface modules. The DL6230 demodulator provides high resolution measurements. The capaNCDDT 6222 is used for high-speed measurements up to 20 kHz. The compact controller can be used as a benchtop unit, wall-mounted unit or DIN rail-mounted via an adapter. The capaNCDDT 6200 is compatible with all sensor models from Micro-Epsilon.' *Micro-epsilon (2024).*

System design

The capaNCDT 6500 can be used for multi-channel operation and is modular in its design. Up to eight sensors can be connected to the signal conditioning electronics (Euro-size cards) via a preamplifier module.

For the DL6530 version, the pre-amplifier is integrated in the housing and is used for cable lengths up to 4 m (with CC cable) or 8 m (with CCg cable). For longer cable lengths, the external preamplifiers CP6001 or CPM6011 are used.



A measuring system with n measurement channels consists of:

1. controller DT6530 with power supply, display, Ethernet, oscillator and analog output
2. n x demodulator modules DL6510 (DL6530 with integral pre-amplifier)
3. n x pre-amplifier connecting cables
4. n x pre-amplifier modules CP6001
5. n x sensor cables
6. n x sensors

DL6510: One item of position 2 to 6 is needed for each channel. DL6530: One item of position 2, 5 and 6 is needed for each channel.

System configuration

System capaNCDT 6500 (with integral pre-amplifier):

- DT6530 / DT6530C Rack
- Demodulator DL6530
- Sensor cable
- Sensor

System capaNCDT 6510 (with external pre-amplifier):

- DT6530 / DT6530C Rack
- Demodulator DL6510
- Sensor cable
- Sensor
- Pre-amplifier CPM6011 / CP6001
- Pre-amplifier cable



CPM6011
External pre-amplifier for
standard measurements



CP6001
External pre-amplifier for high
precision measurements



DT6530C 2 channel rack



DT6530 8 channel rack

Figure 5, source: <https://www.micro-epsilon.com/download/products/cat--capaNCDT--en.pdf>

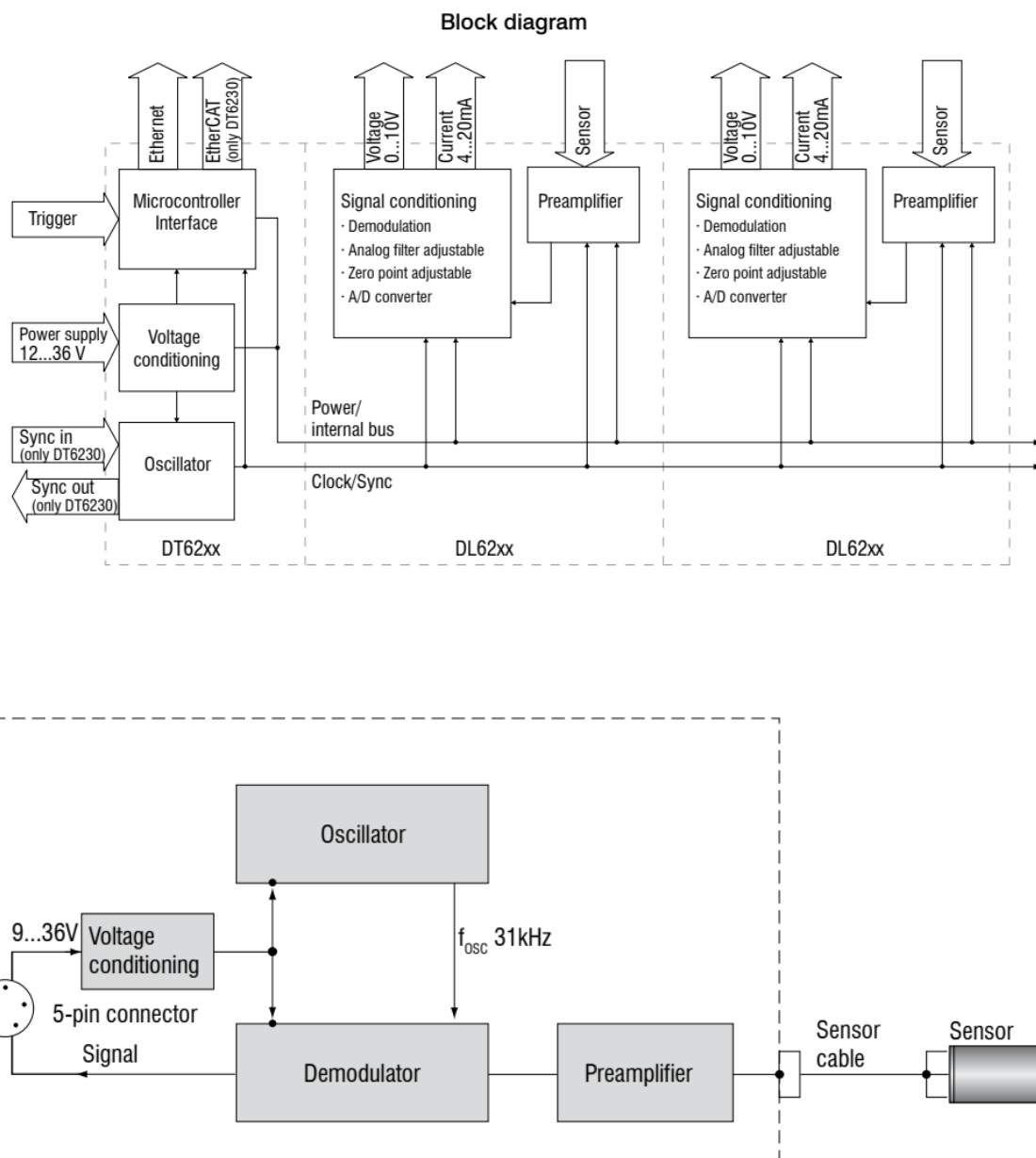


Figure 6, source: <https://www.micro-epsilon.com/download/products/cat--capaNCDT--en.pdf>

Figure 6 shows a block diagram of how the sensor interfaces with the PLC controller. This diagram includes the method by which the voltages are conditioned- then synced on or out depending on the setup. Proximity and displacement sensors will give a range of values to a PLC, and various outputs can be included in the program. The PLC can then potentially perform functions such as machine shutdowns, alarms and voting systems depending on the number of sensors. Phillips, R. (2022).

You was asked to explain 2 different types for each sensor.

- 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.

One type of stepper motor is the permanent magnet type. See figure 7 as an example of the working principle of such a motor. Panchal, R.D. (2021).

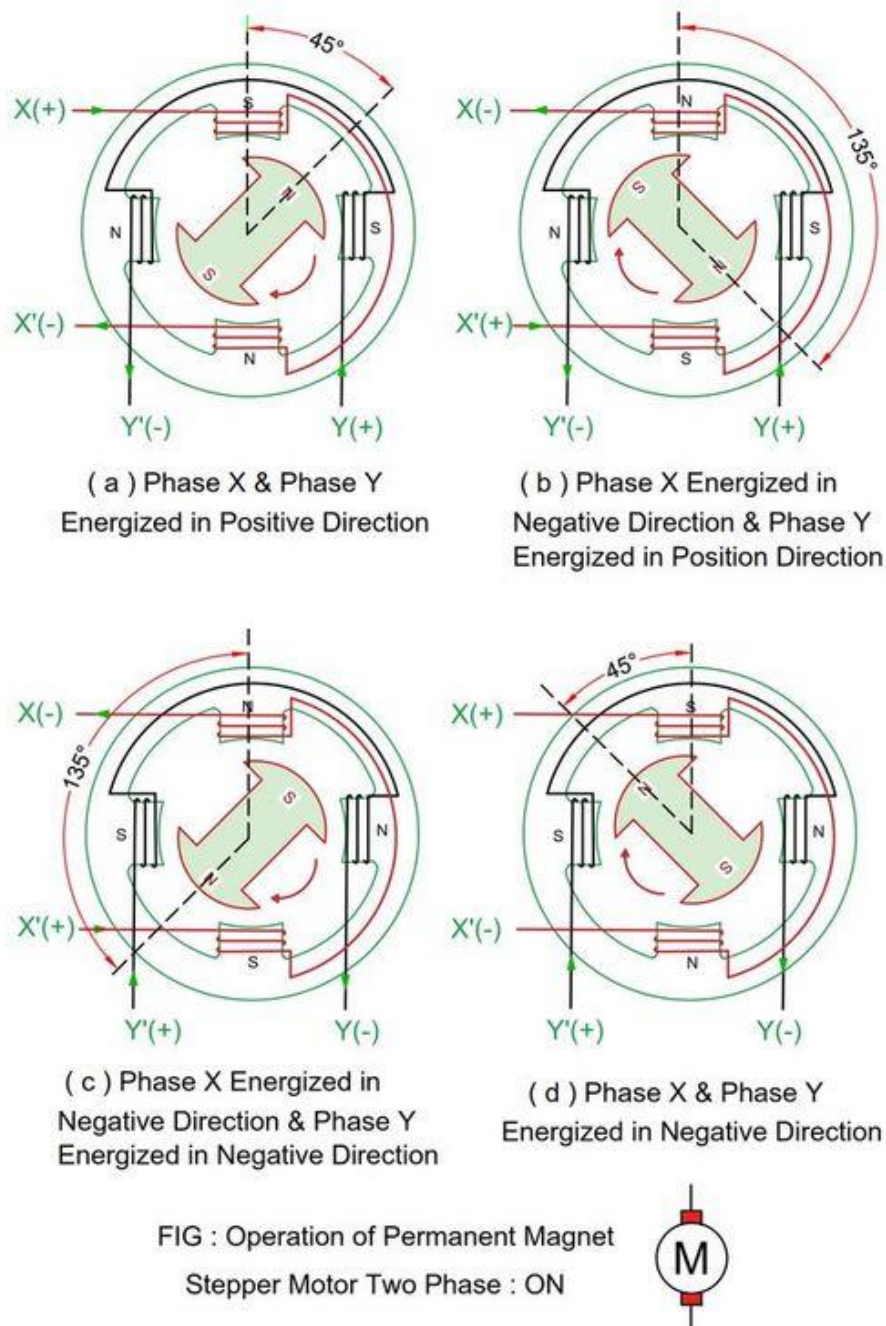


Figure 7, source: <https://www.myelectrical2015.com/2021/12/permanent-magnet-stepper-motor.html>

Stepper motors rotate in specific increments without encoder feedback or PID loops. With the permanent magnet type, the rotor is made from 2 permanent magnet rotors that are slightly offset from one another. The permanent magnet is axially magnetized, as shown in *figure 7*. When current is applied to windings, poles on the stator are magnetized and align with the opposite poles. A PM type stepper motor is simple in construction and cheap to manufacture compared to other types. The permanent magnets allow for high torque output. Due to PM type motors having large resolution as compared to other types, these are typically used for simple positioning. For higher resolutions, half-stepping or micro stepping is required. An additional difference is that PM type stepper motors use constant voltage drivers, which are trickier to use than constant current chop drivers. *Tang, J. (2022).*

‘Stepper motors can be reversed by changing the sequence of the driving phases. Stepper motors are available with stepping angles of 0.9, 1.8, 3.6, 7.5, 15, and 18 degrees. Since the motor steps a known angle with each input pulse, feedback is not required’ Dunn, W. (2018).

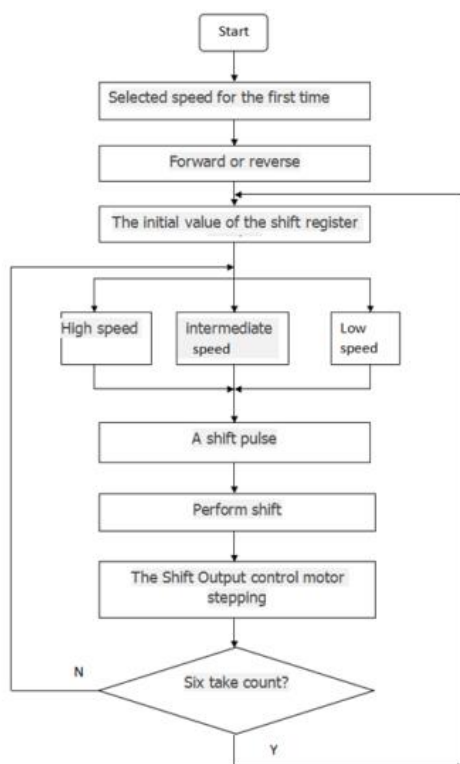


Figure 8 shows a block diagram of how a stepper motor would interface with a PLC program. There are 2 main ways to connect a PLC to a stepper motor. One is to have a stepper motor at both ends of the wire winding to the output points of the PLC, with each coil in a specific order to achieve the poles required to create a magnetic field. Another way is to use PLC high speed pulse output. *Chong, Y. (2015)*

Figure 8, source: <https://www.atlantis-press.com/article/18100.pdf>

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 where possible include industrial examples.

Data is obtained from devices such as sensors, switches and relays via I/O modules and Remote terminal units (RTUs). This data is then sent to a SCADA system, which has the primary function of data acquisition and logging. SCADA systems acquire and transform the captured data using its own software, which can then be programmed for control and fault detection. This data is then presented through a Human Machine interface, which can be in the form of on-screen visuals, such as graphs, data charts, tables and various diagrams. HMI controls can aid in operational activities in industrial environments. *BALLOUZ, M.A. (2022).*

Some key features of a SCADA system are as follows. *'It's essential to mention that a top SCADA system should be built on 64-bit technology, which will allow you to access faster processors with the higher memory capacity of 64-bit computing... A top SCADA should have the capability of high-speed, mission-critical data collection through a historian that can log data at a speed greater than 100,000 tags per second'* *BALLOUZ, M.A. (2022).*

Figure 9, page 13, shows how a SCADA system is integrated with other technologies for data acquisition and control, such as PLCs and input devices. Appendix C shows various examples of HMI interfaces for SCADA systems, from the beginnings of the software in the 1990s, to the more graphical representations of the early 2000s and then to modern day interfaces of the 2020s, Sahakian, E (2020).

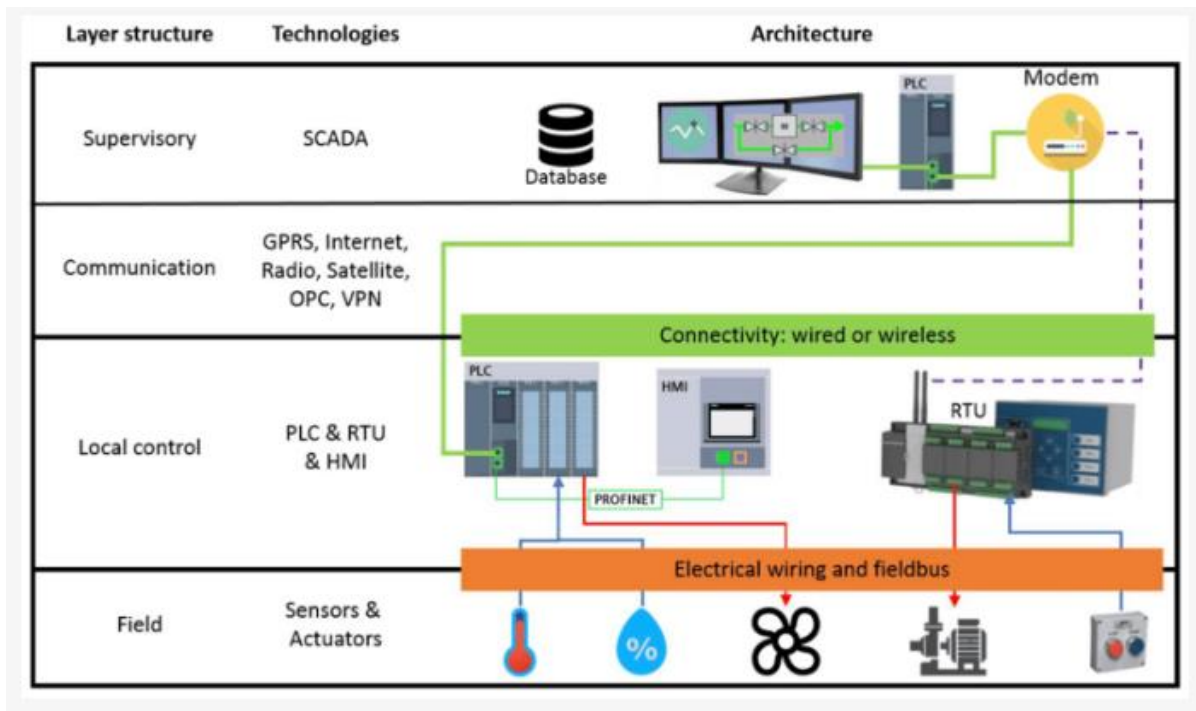


Figure 9, source: <https://www.mdpi.com/2071-1050/13/9/4950>

Desirable traits of a SCADA system include the possibility of comms with certain “protocols” inclusive of BACnet, OPC, databases, web services, Internet of Things (IoT), simple network management protocol (SNMP), message queuing telemetry transport (MQTT) and structured query language (SQL)’ Burke, T (2022). As shown in Appendix C, a SCADA system should provide fast, scalable and secure visualization on desktop devices and screens. Support of rich WPF and script-less, thin client HTML5 technology is desirable. ‘SCADA systems should be designed to negotiate internal communications for redundancy, load balancing, and scalability throughout the enterprise Burke, T (2022).’

Industrial examples of the use of SCADA systems include electrical power generation, transmission and distribution (for the detection of current flow, monitoring the operation of breakers and to take power grids on and off). SCADA systems monitor and regulate water flow, reservoir levels and pipe pressures in the water, wastewater and sewage industries. The Oil and Gas industry uses SCADA systems to automate refining processes and to interface control systems with PLCS, sensors and instruments in the field Smith, H (2021).

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	
X000	Start switch
X001	Stop switch
X002	Sensor for bottle not full position 1
X003	Sensor for bottle present
X004	Sensor for bottle not full position 2
X005	Stop conveyor switch

Outputs	
Y000	Conveyor motor
Y001	Alarm
Y002	Capping
Y003	Packing Machine

Table 1 – Input/Output connections

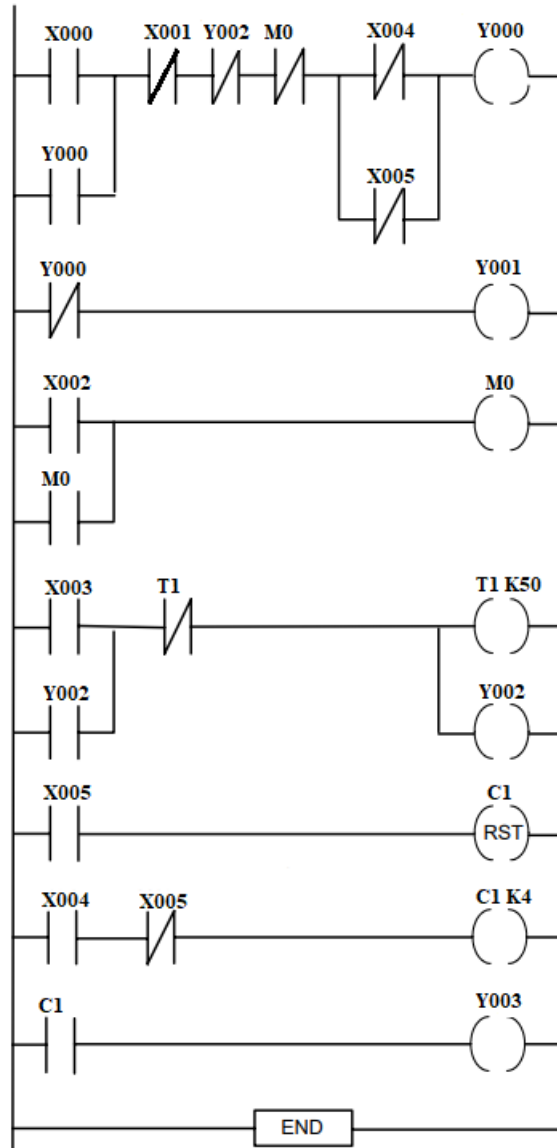


Figure 10 – Ladder logic

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

See below for the instructional list version of the ladder logic shown in *figure 10*, that can also be used to control the conveyor systems.

LD X000

OR Y000

ANI X001

ANI Y002

ANI M0

ANI X004

ORI X005 *→ should use ORB*

OUT Y000

LDI Y000

OUT Y001

LD X002

OR M0

OUT M0

LD X003

OR Y002

ANI T1

OUT T1

K50

OUT Y002

LD X005

RST C1



LD X004

ANI X005

K4



OUT C1

LD C1

OUT Y003



END

Good.

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.

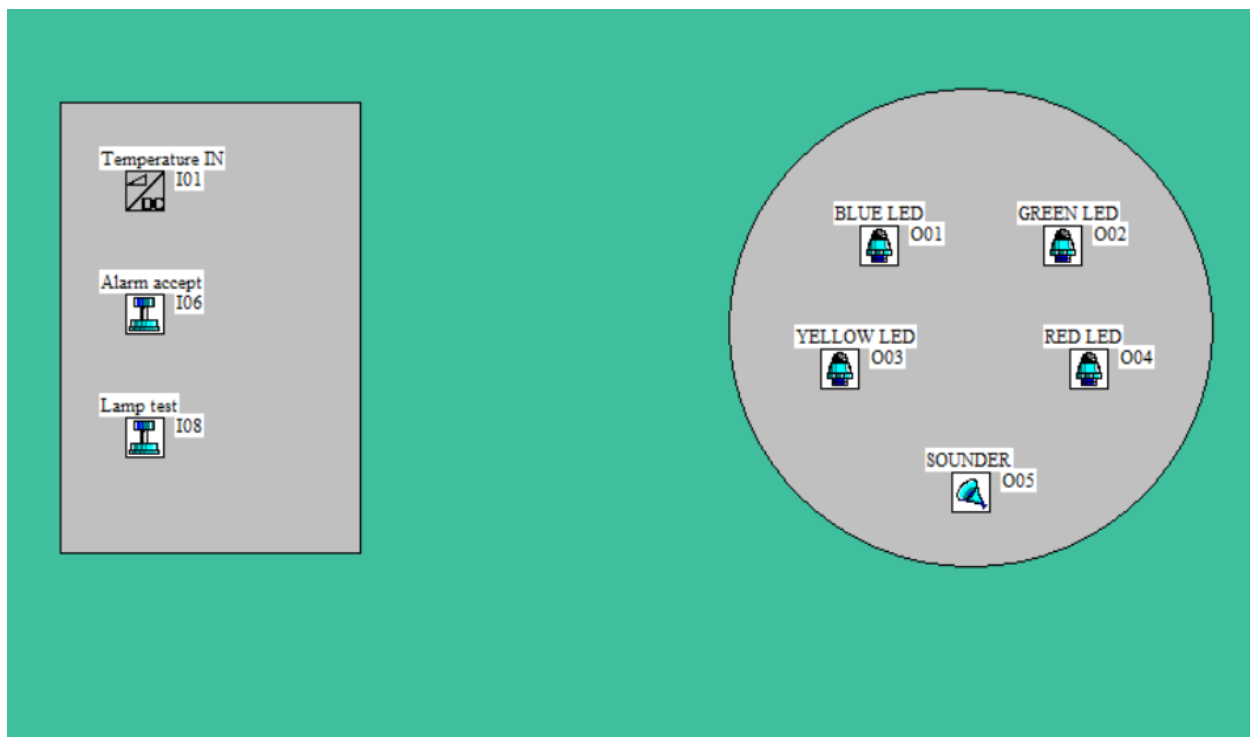
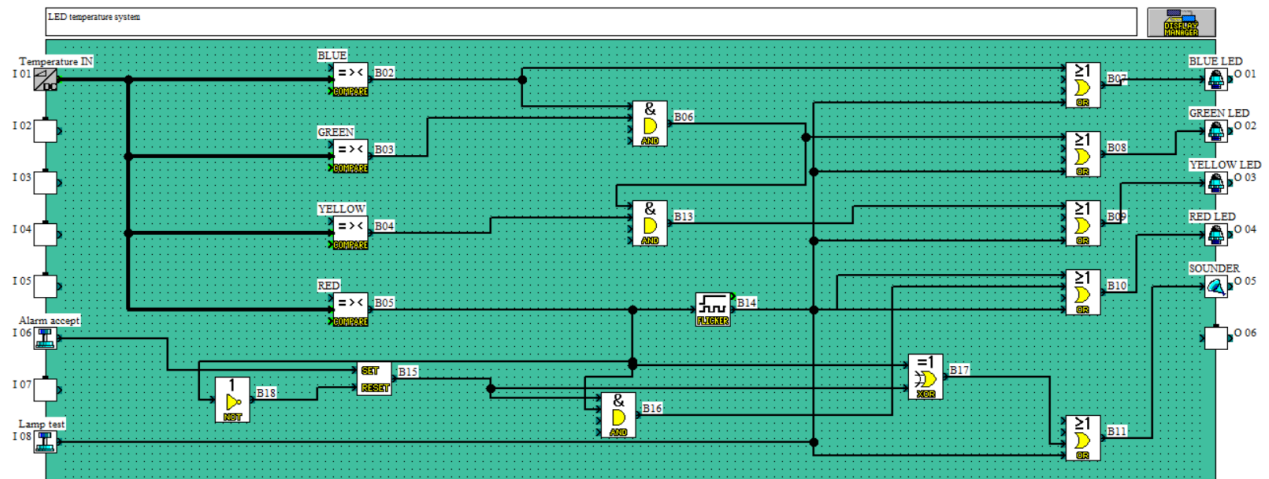


Figure 11, Completed program and HMI

Figure 11, shows the completed program (created in Alpha programming software). This is a fully working program in line with the brief and has been demonstrated to the tutor. On the following pages are screenshots of the program in action, demonstrating the programming requirements of this task have been met.

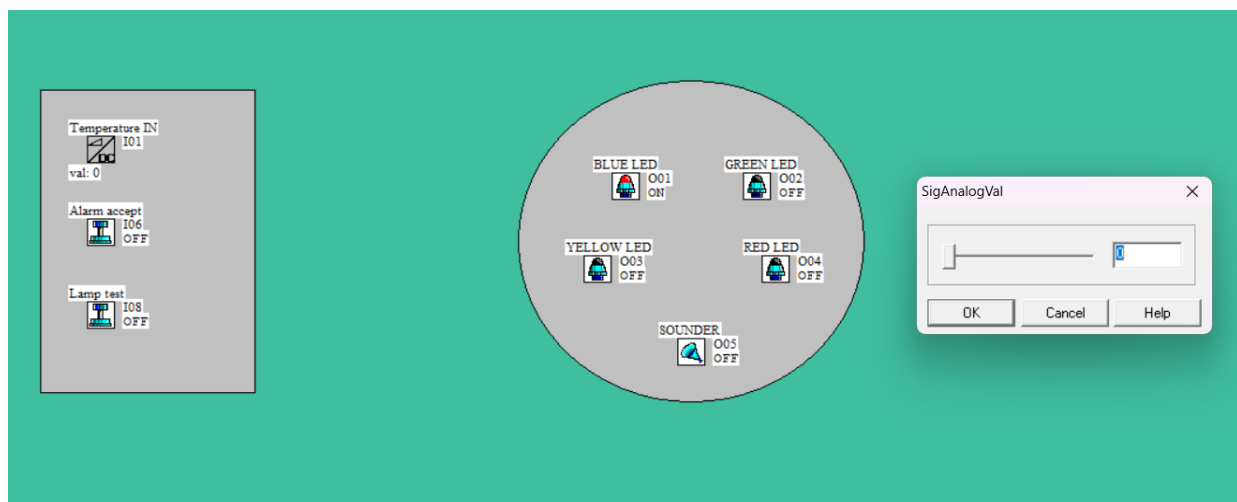
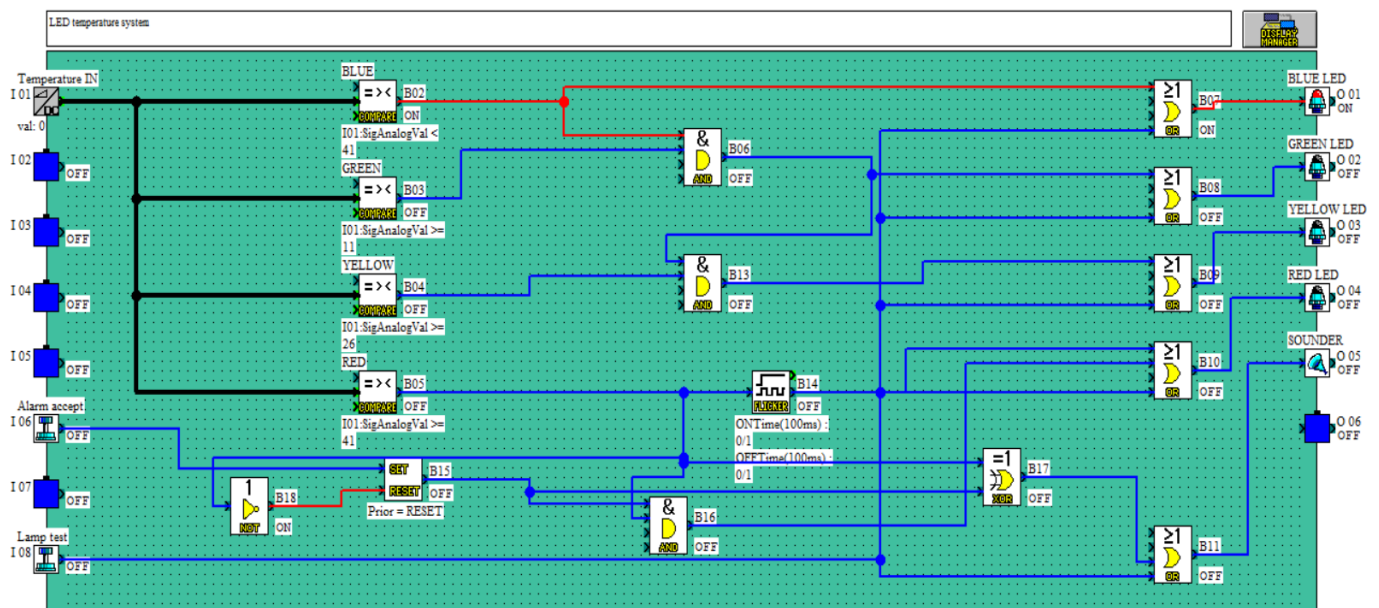


Figure 12, lower temperature sensor

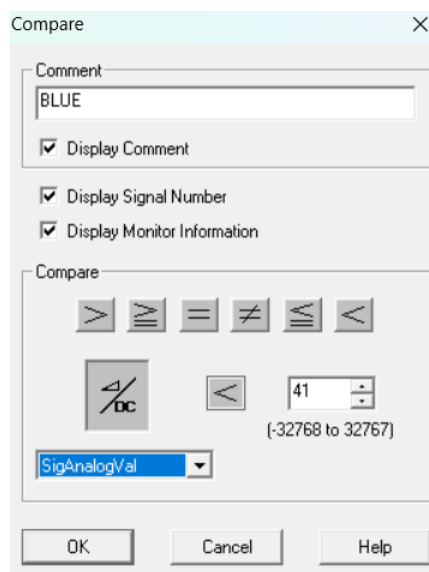


Figure 12 shows the Blue LED activation at temperatures between 0 and 10°C. As shown, a comparator function is used to achieve this- along with AND/ OR gates. Anything less than 41°C and the blue LED will activate. But it will deactivate above 41°C as required by the program, through the use of AND/ OR gates.

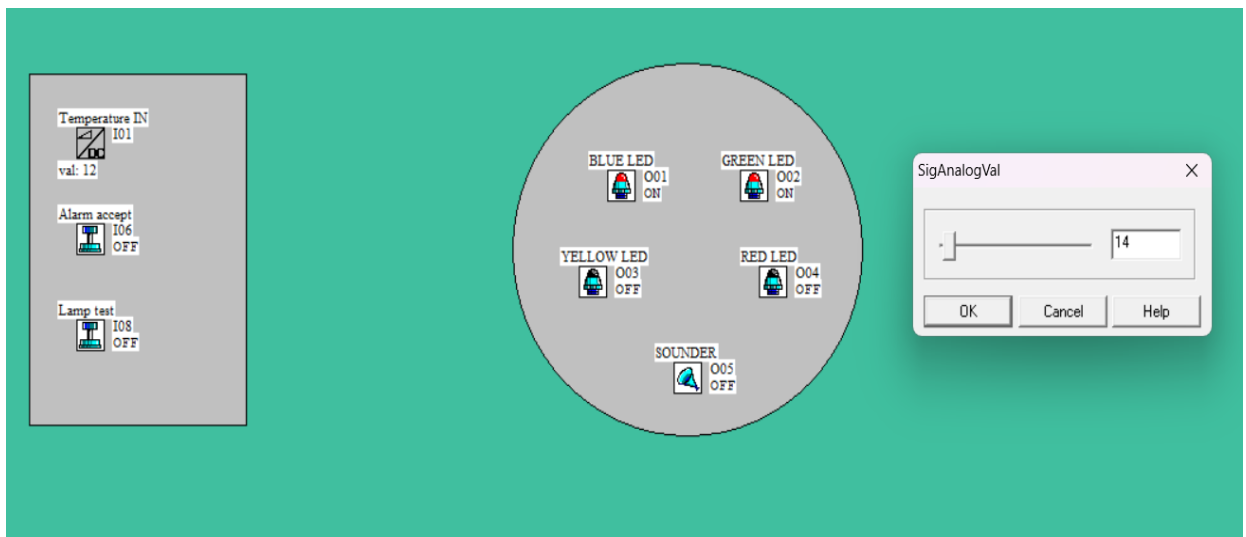
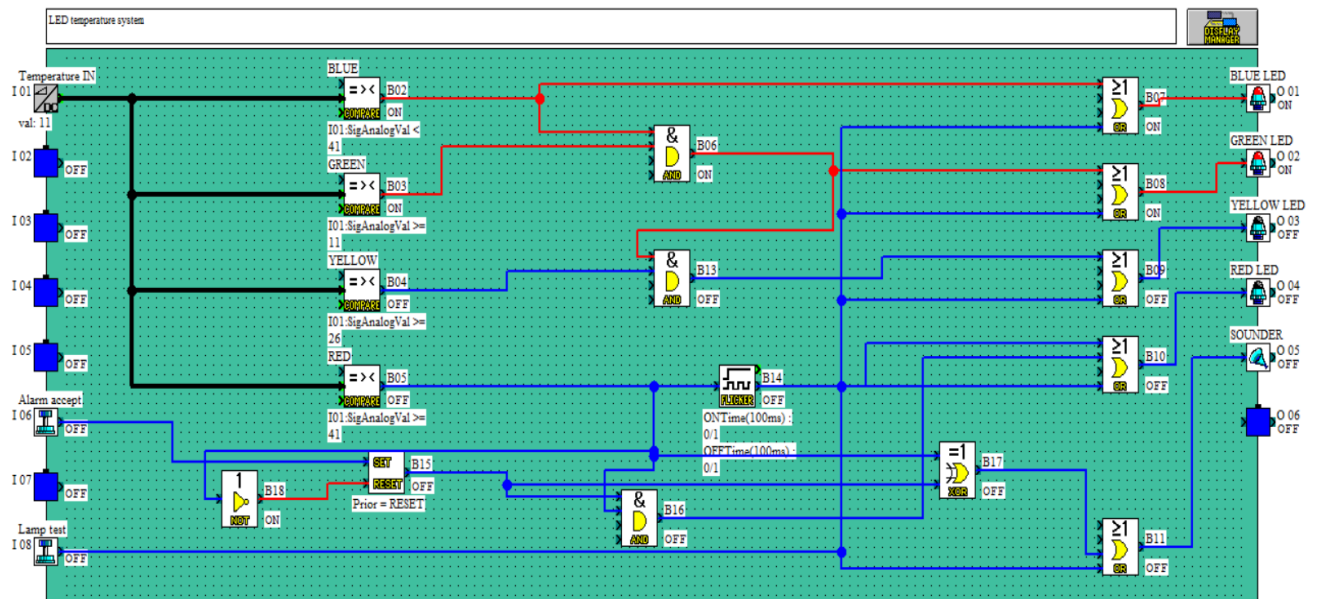


Figure 13, Activation of the green LED, blue remains on

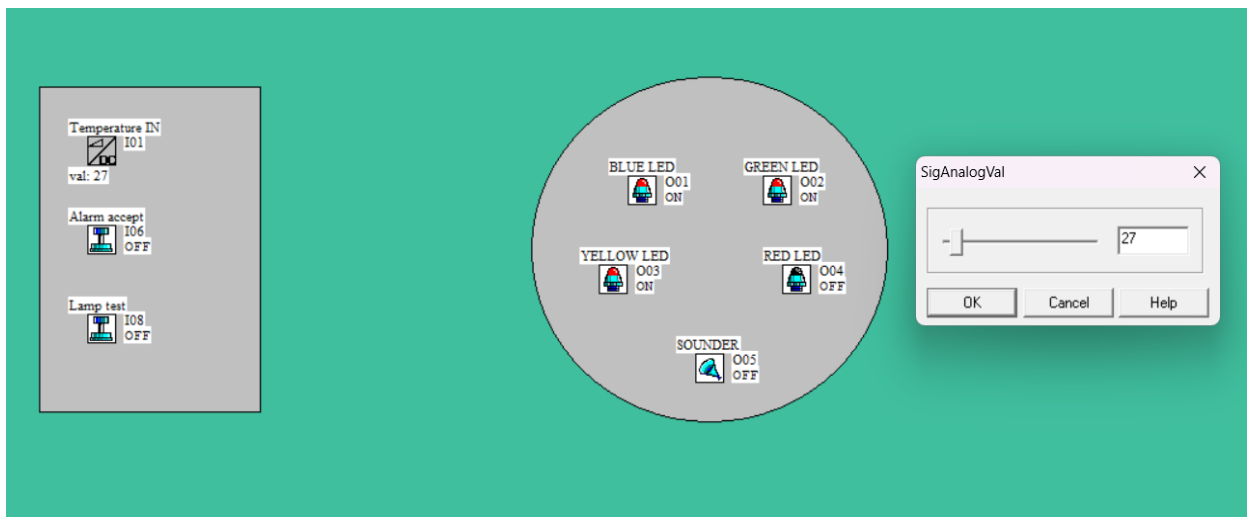
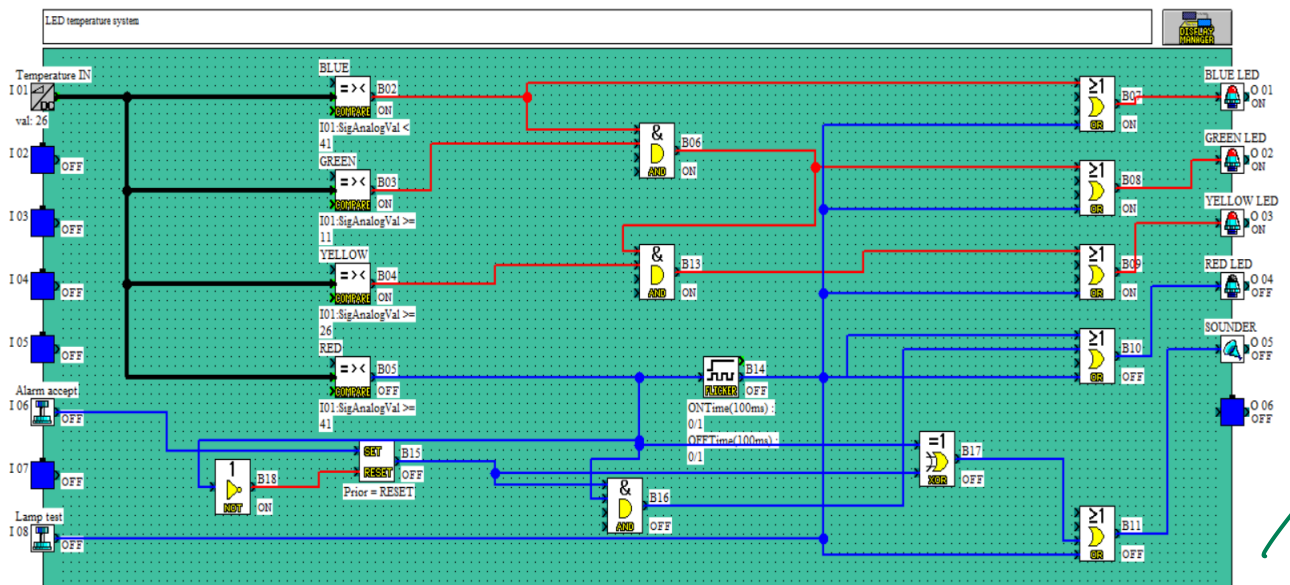


Figure 14, Activation of the Yellow LED at the required temperature range 26 to 40°C

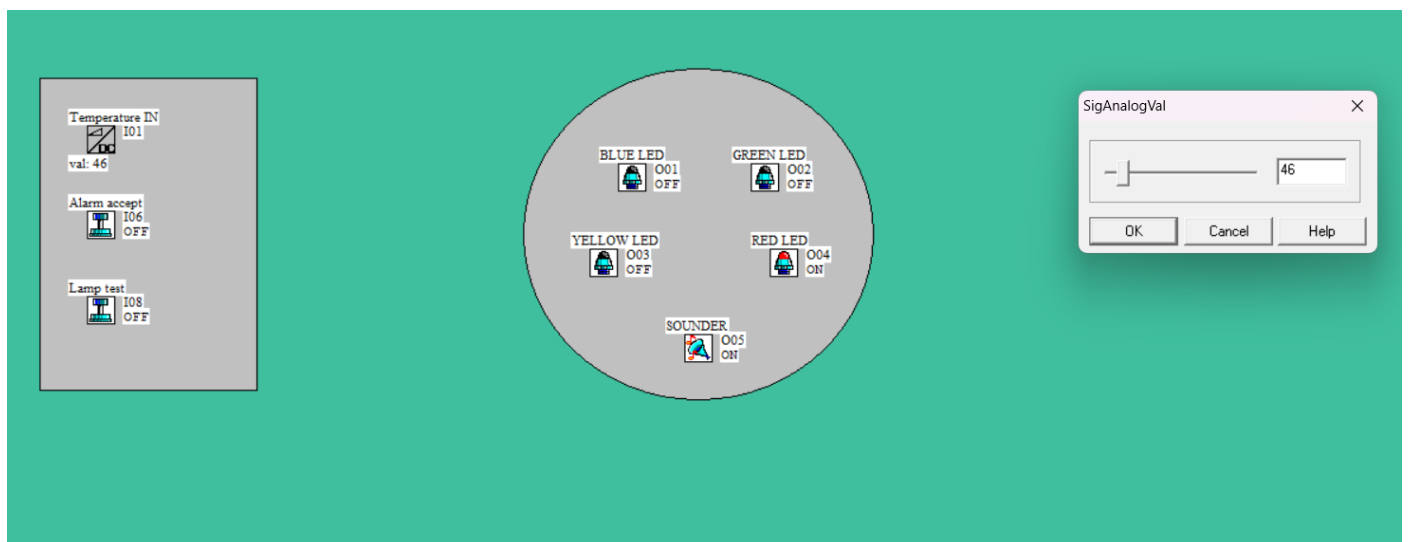
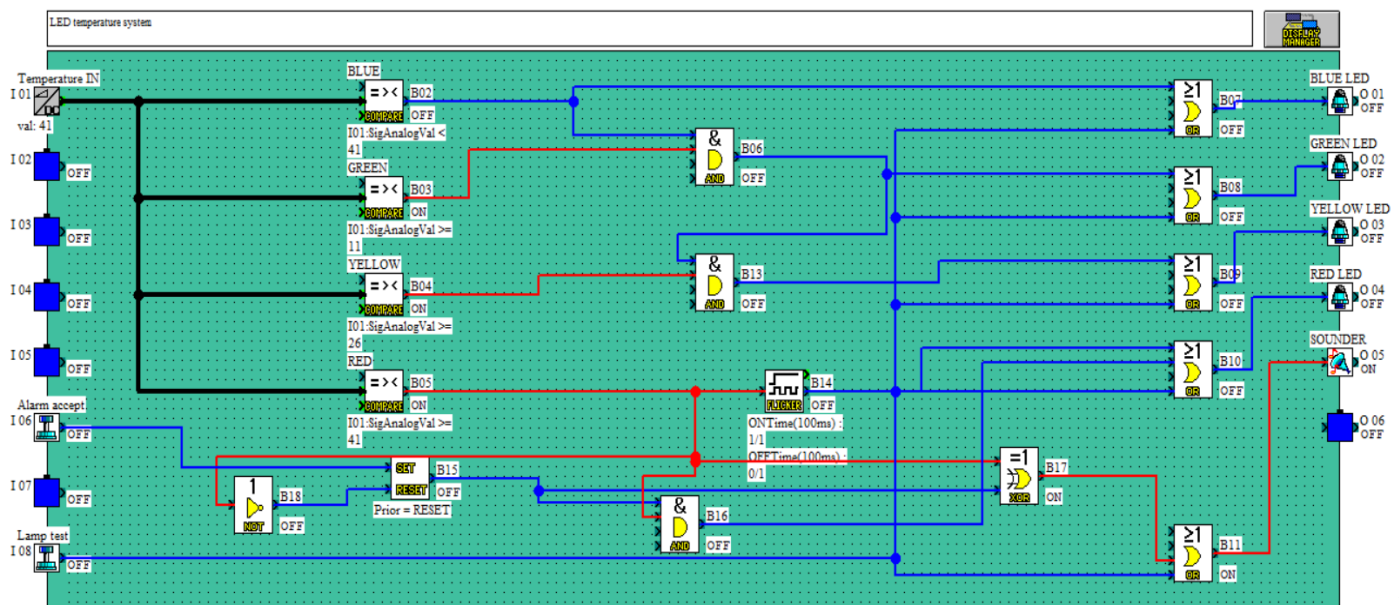


Figure 15, activation of Sounder and red LED

Figure 15 shows the activation of the Sounder and Red LED at temperatures above 41°C. At this point the blue, green and yellow LEDs deactivate- via the use of comparators and a NOT gate tied into the system when the red LED and sounder are activated. A flicker function is used within the program to turn the red led on and off until an Alarm accept button is pressed. Figure 16, page 24 shows activation of the alarm accept button- with the sounder deactivating and the red LED remaining in a steady state.

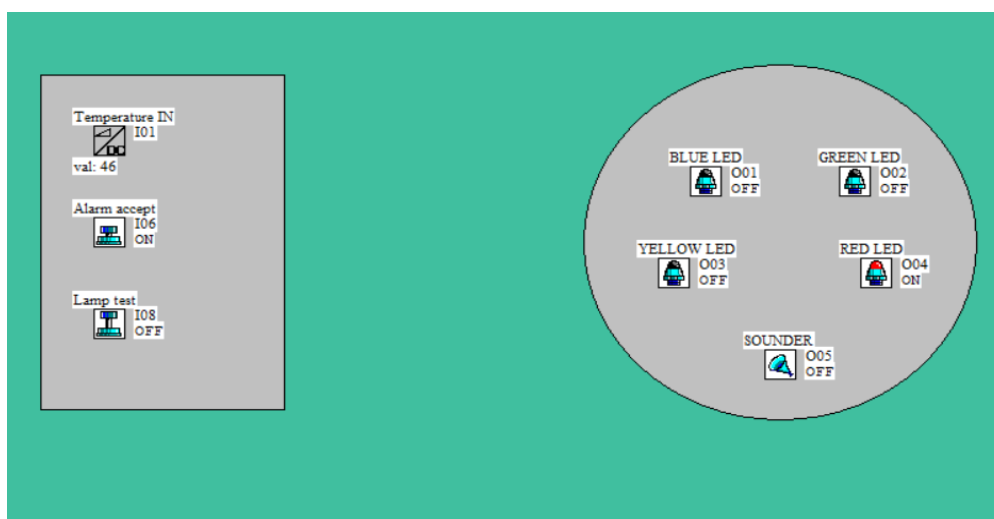
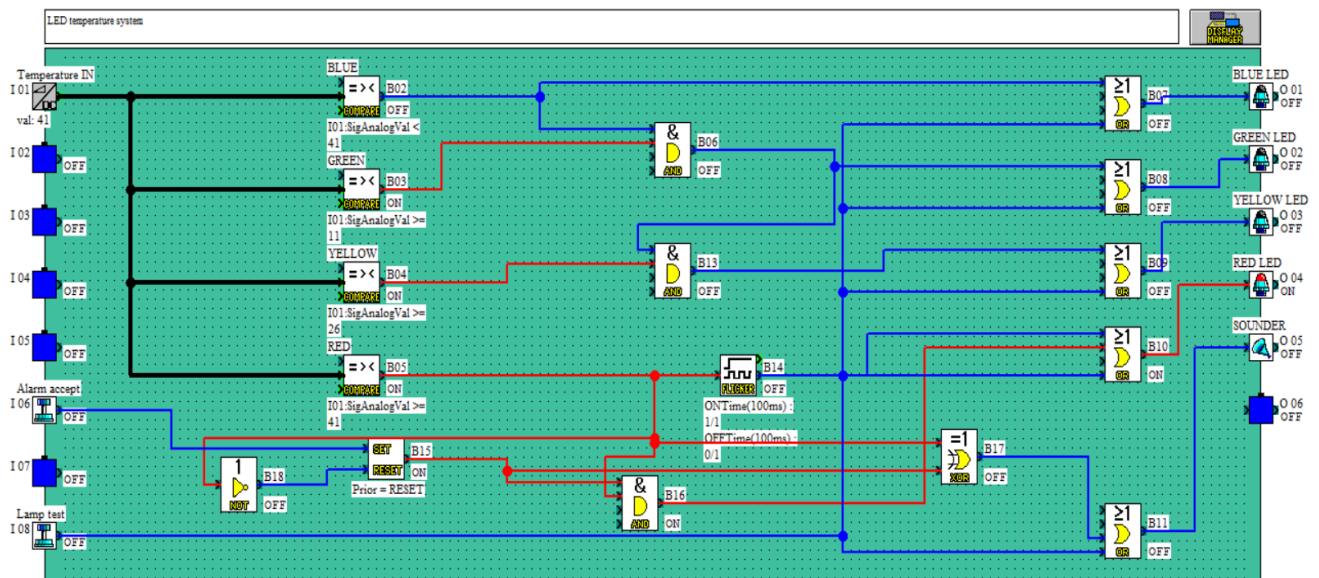
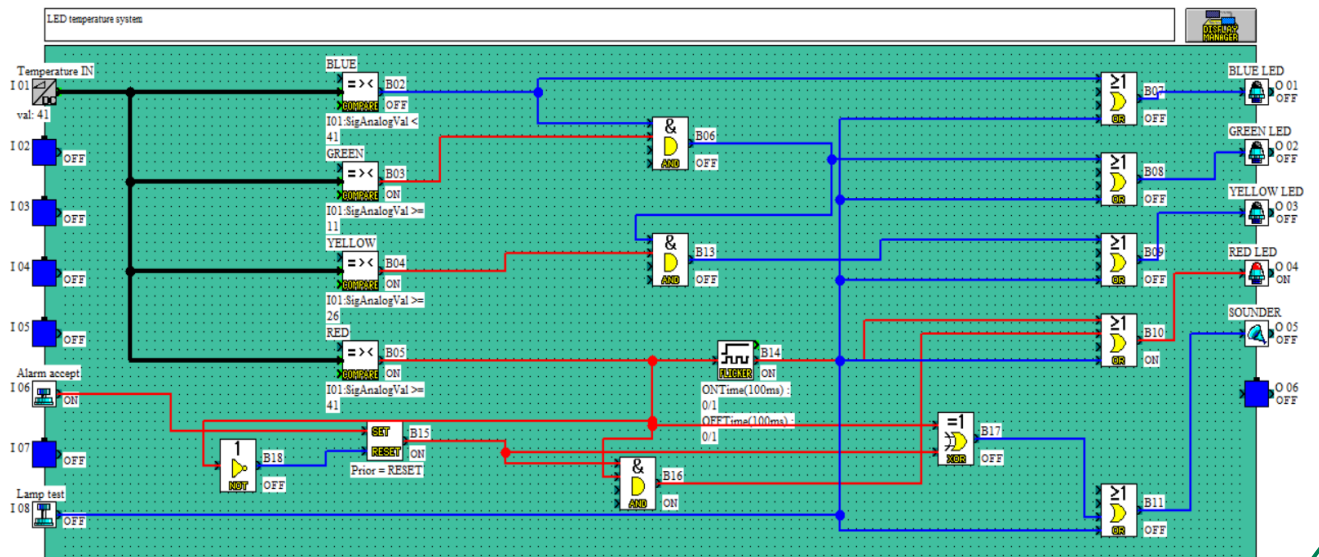


Figure 16, pressing the Alarm accept button on and off, state is then latched

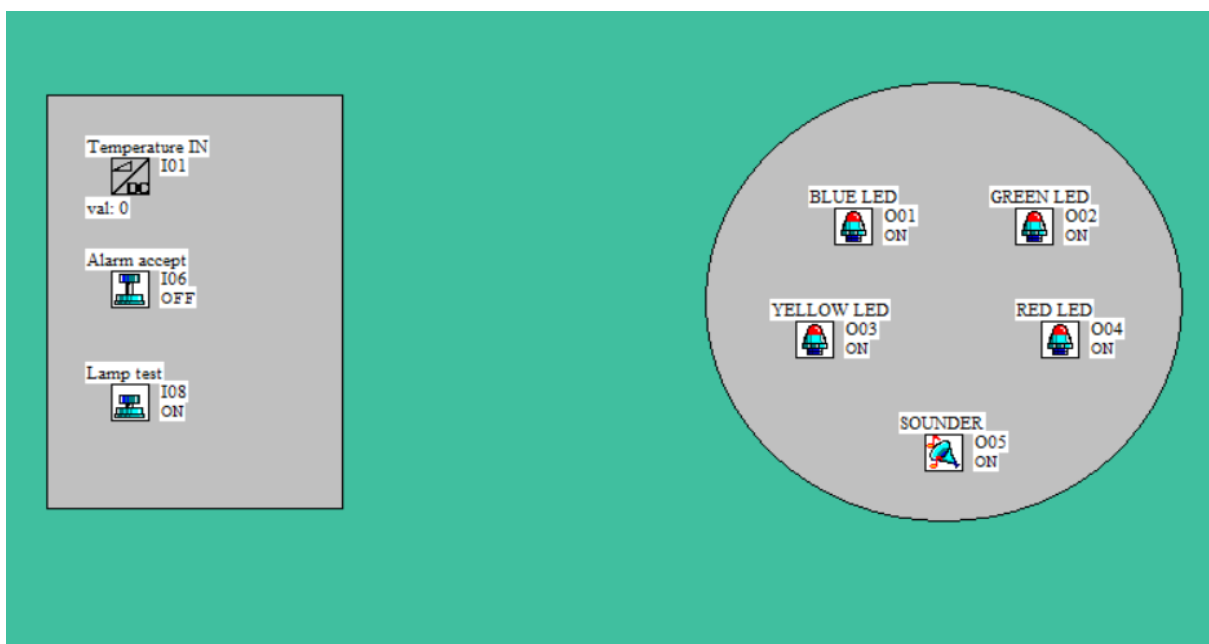
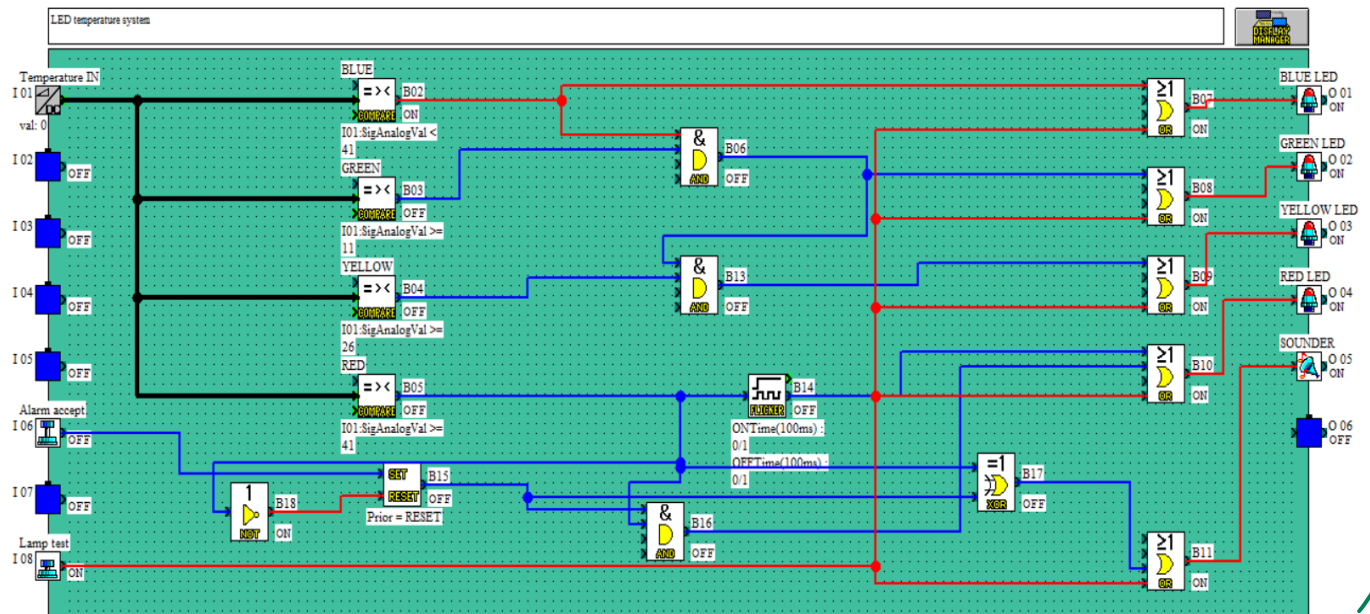


Figure 17, Pressing the Lamp test button to show functionality

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 18). 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

Table 3- I/O listing for lift program

Lift System

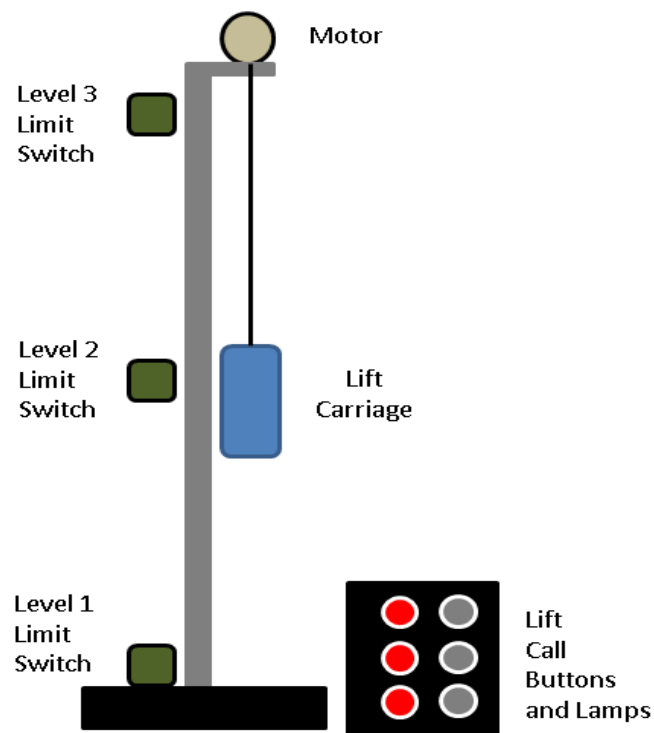
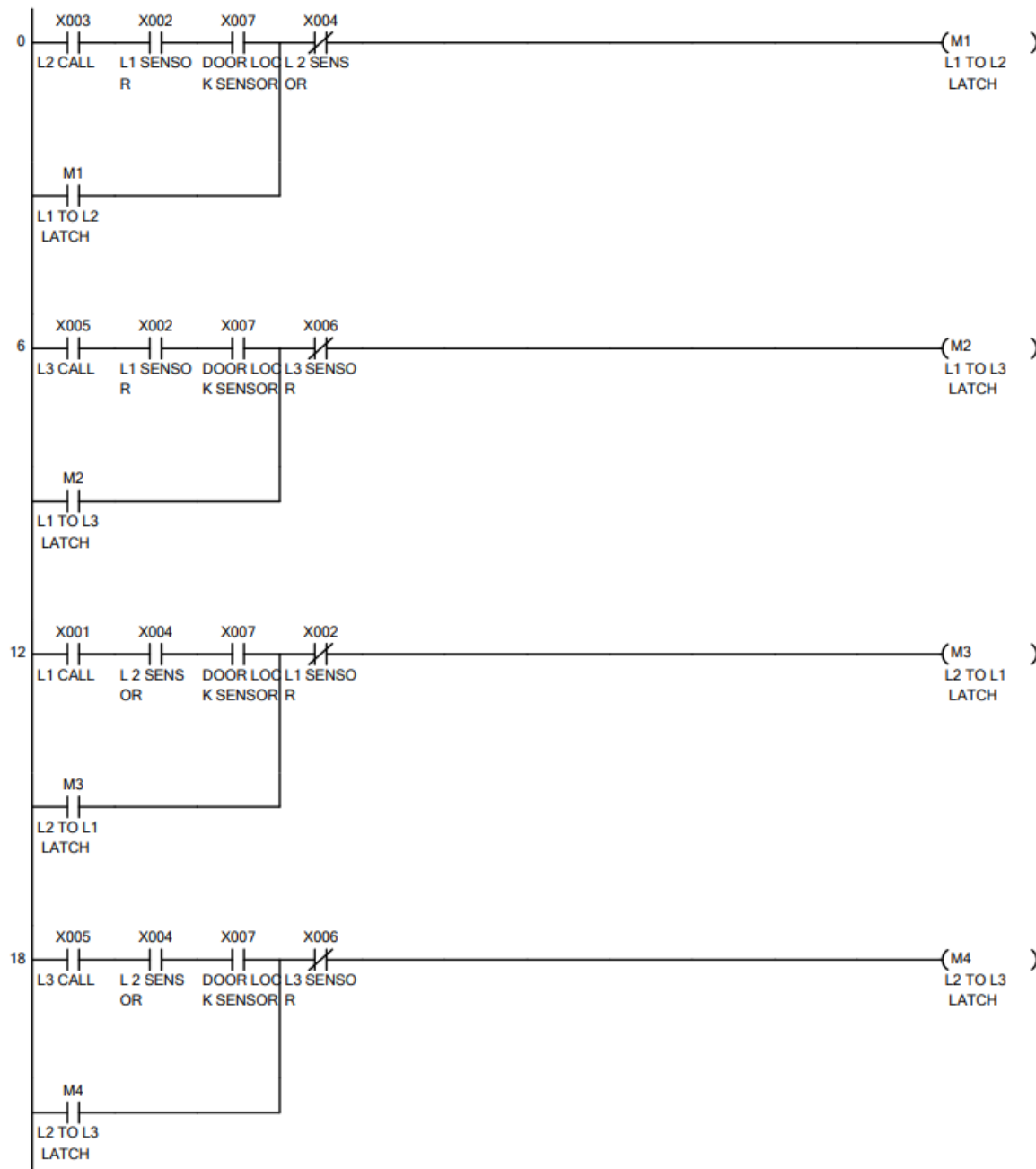
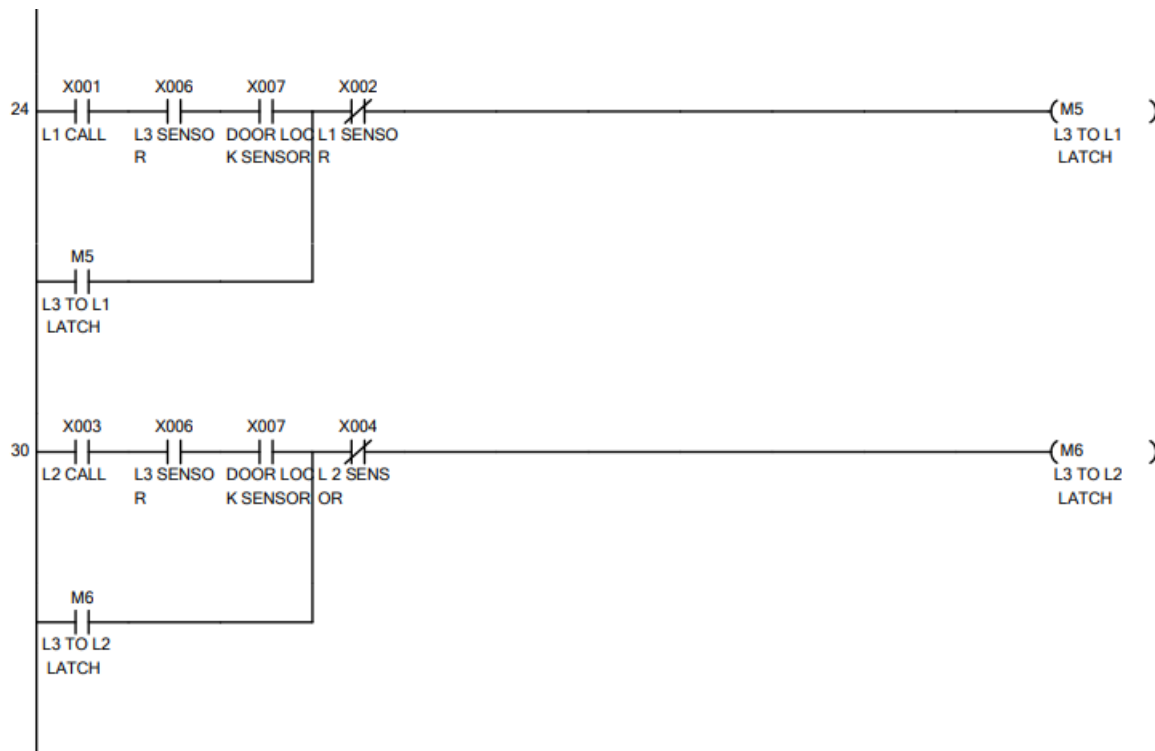


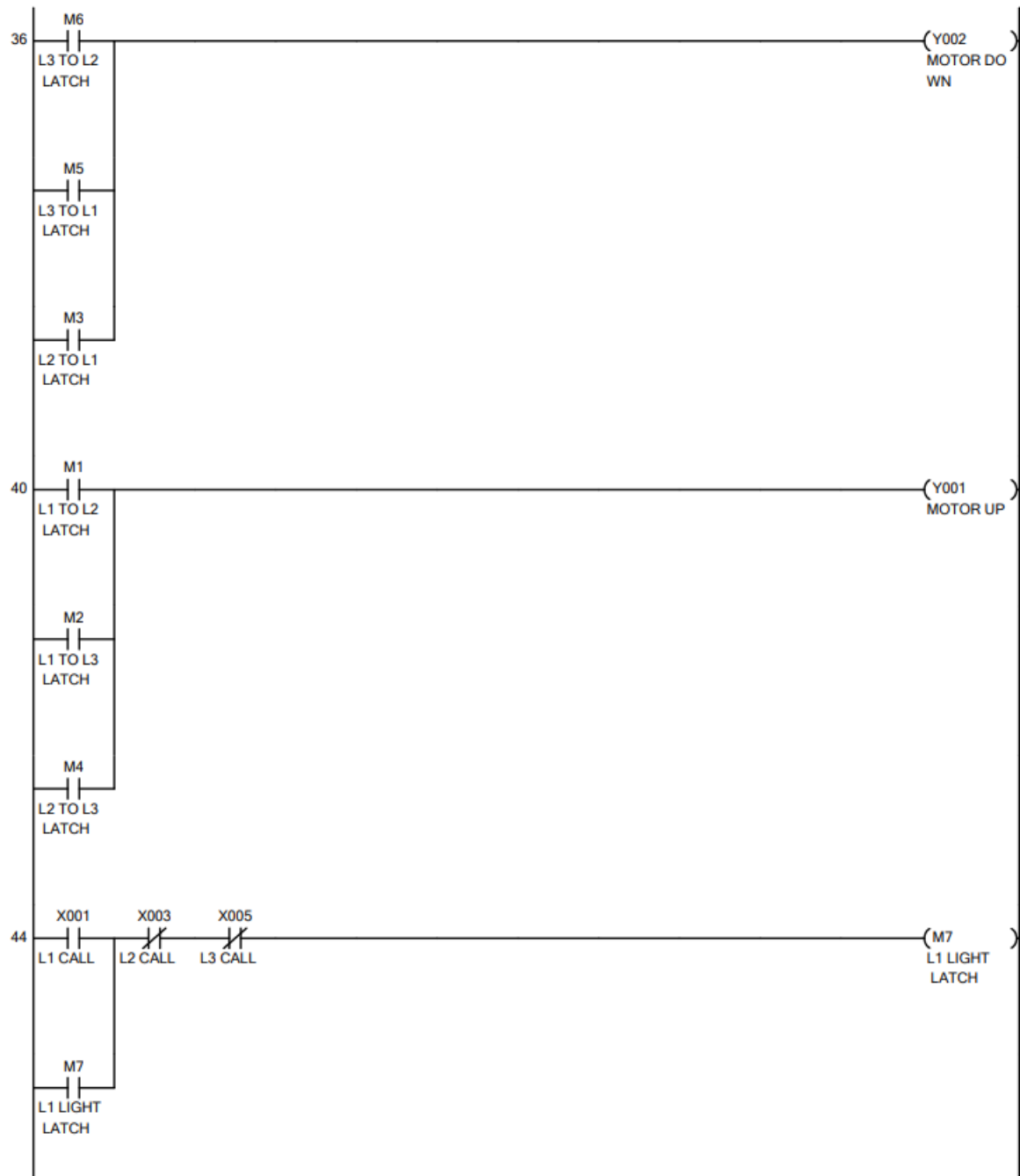
Figure 18 – Lift System

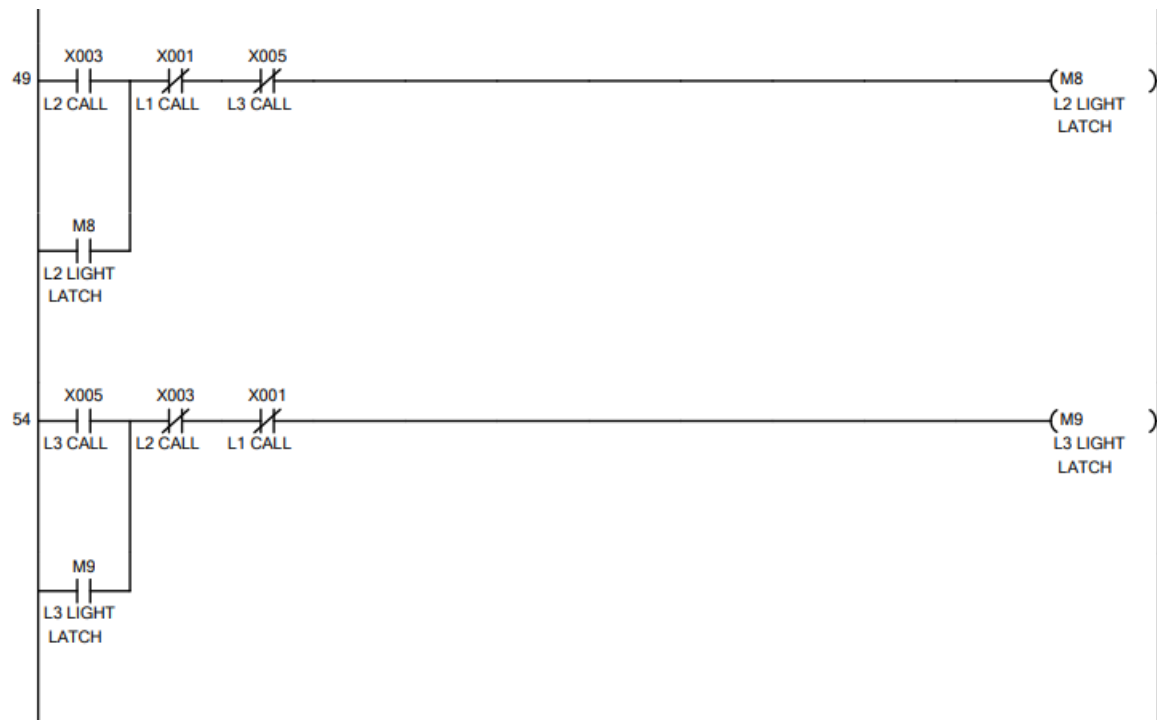
On completion of this task, you are required to demonstrate the operation of your program to your Tutor using the process simulator. Include a printed copy of your program in your report and briefly discuss the program operation. Evaluate the operation of the program and compare it against the design 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 19 on the following pages shows the completed ladder logic for this program. A copy has also been given to the tutor of this course for verification.









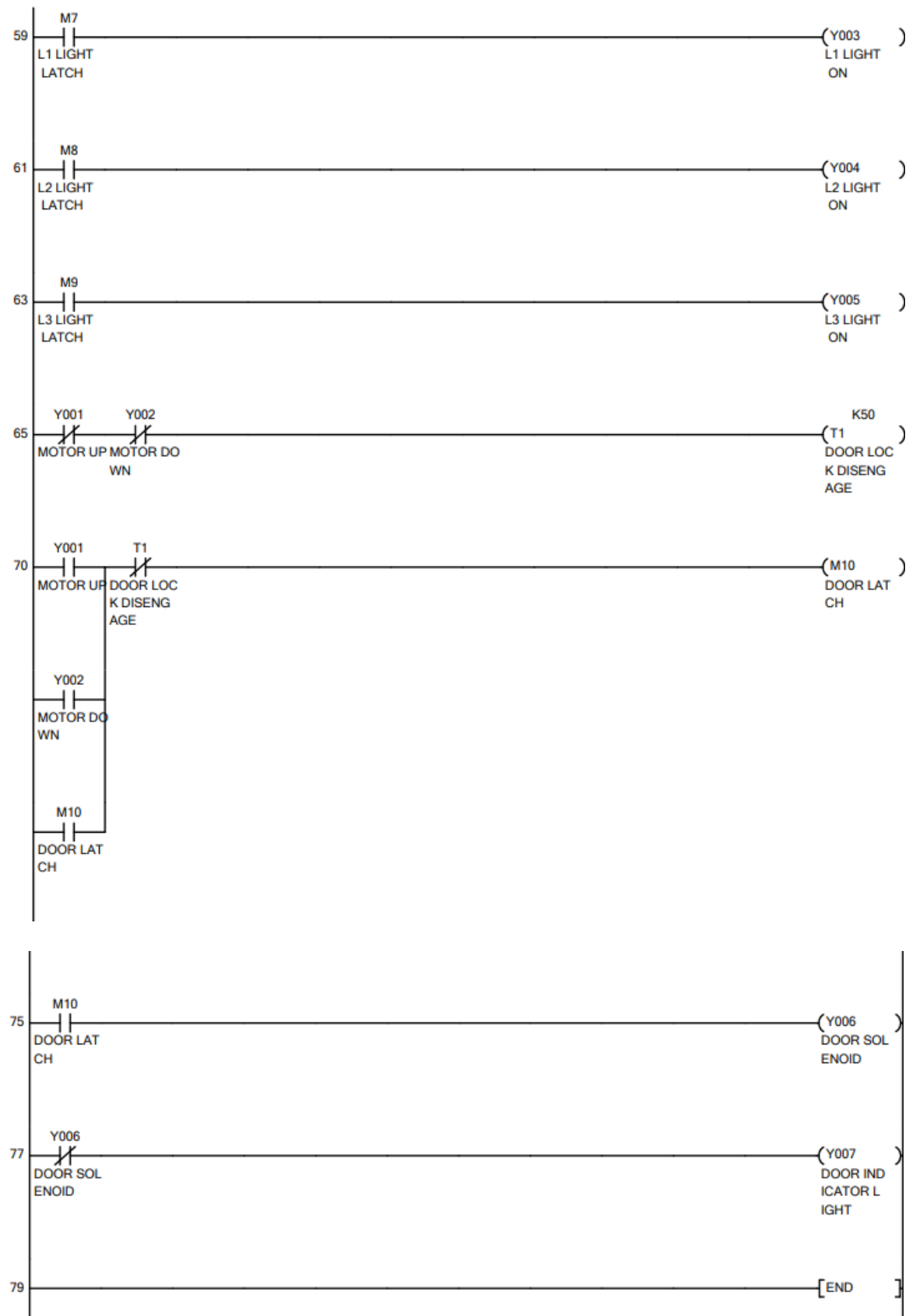
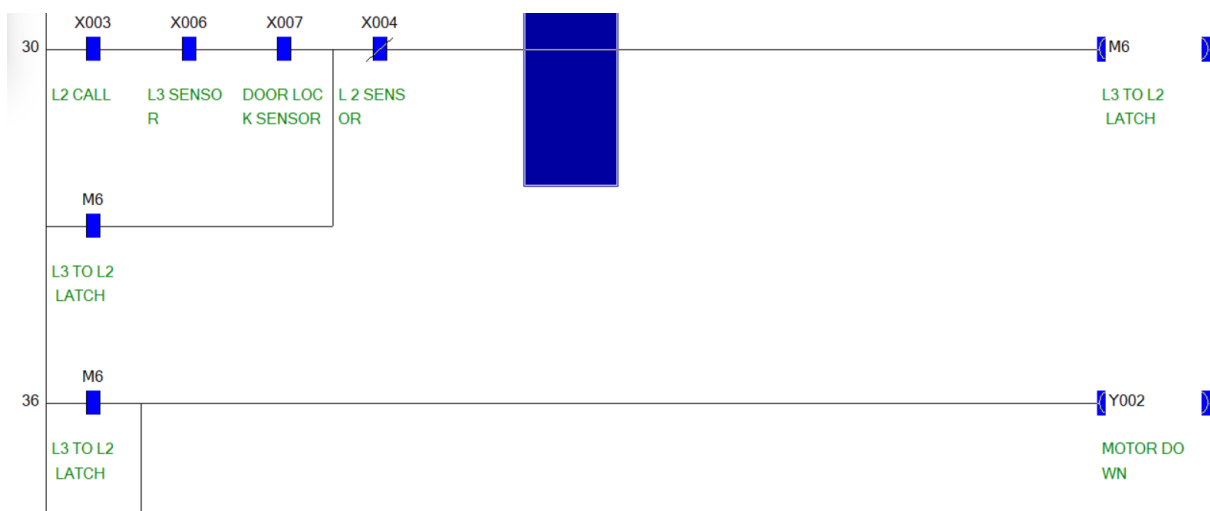
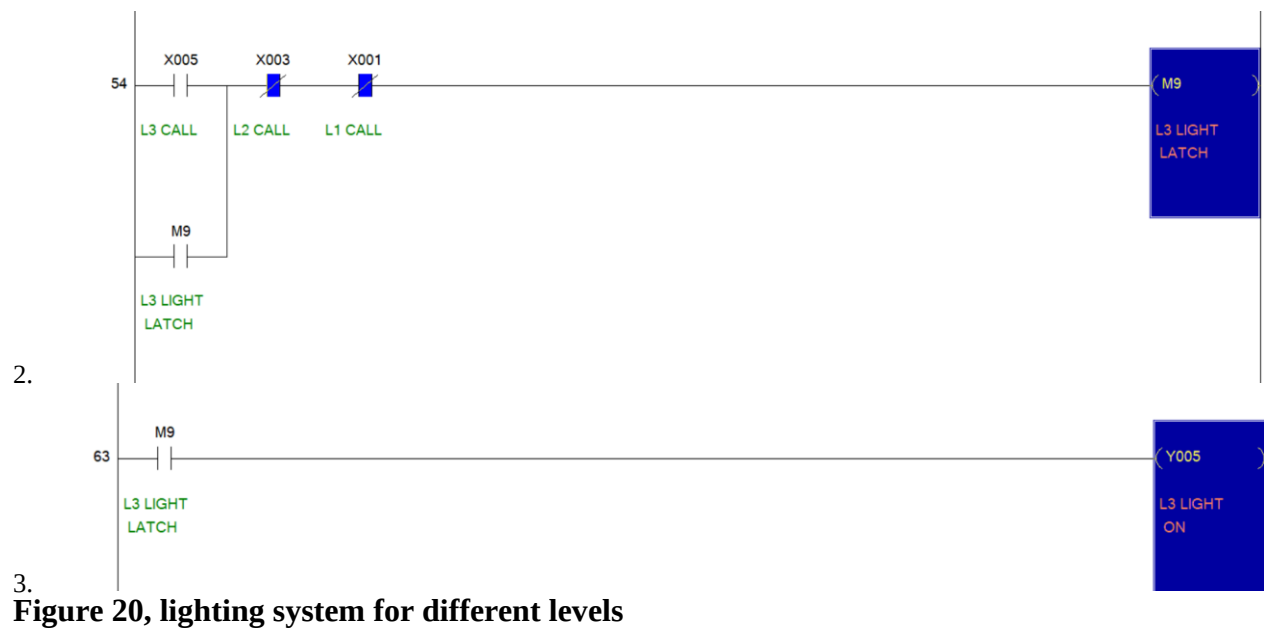


Figure 19, completed program (ladder logic created in GX Works 2)

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.' See logic for the lighting system in figure 20. Room for improvement here could be the inclusion of a light indicator for ground floor position, as well as, levels 1, 2 and 3. This logic changes when the call button is pressed and the lift is travelling to the desired floor, as per figure 21.



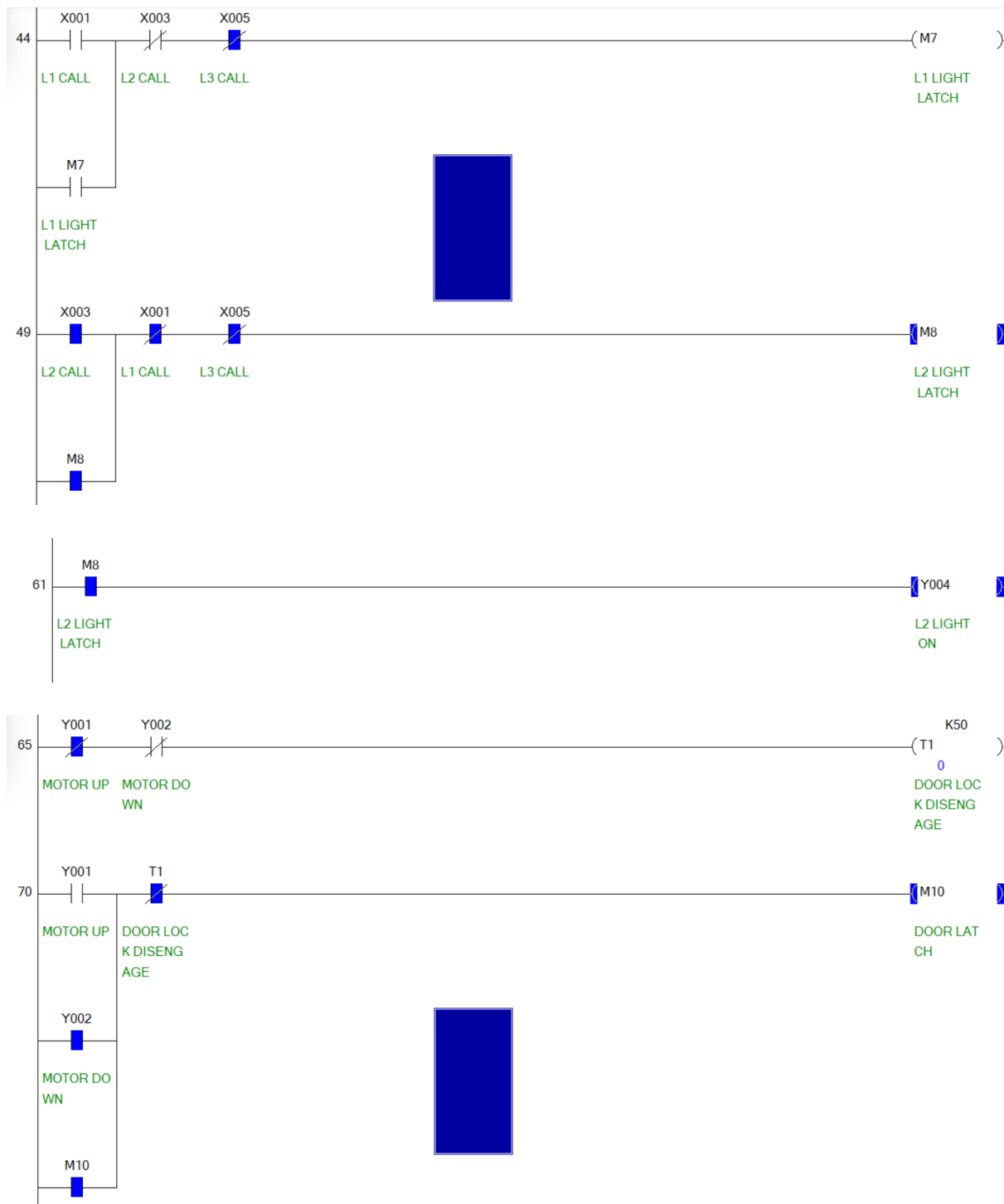
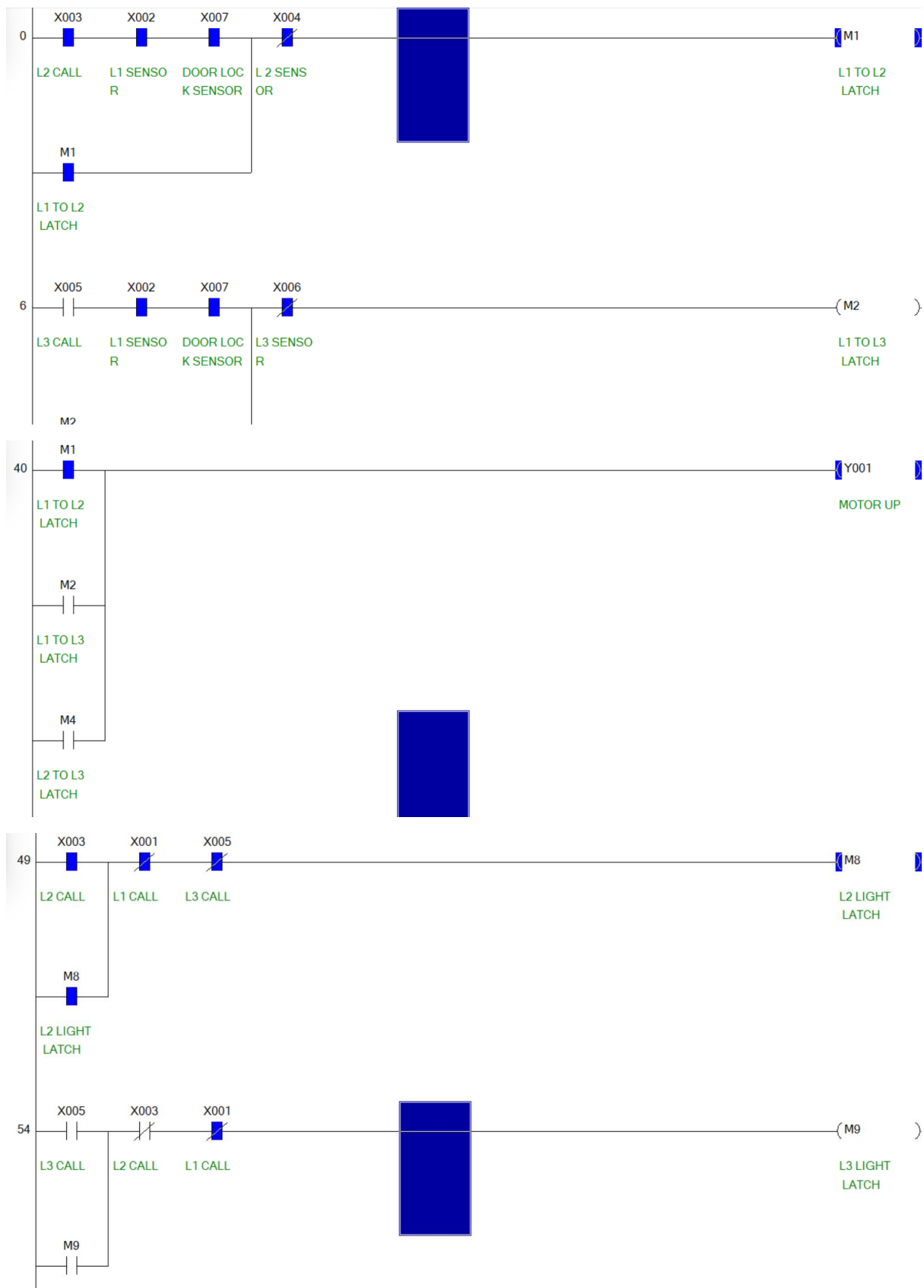


Figure 21, demonstration of the lift moving down from Level 3 to Level 2

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.' See this functionality demonstrated with figures 21 and 22.



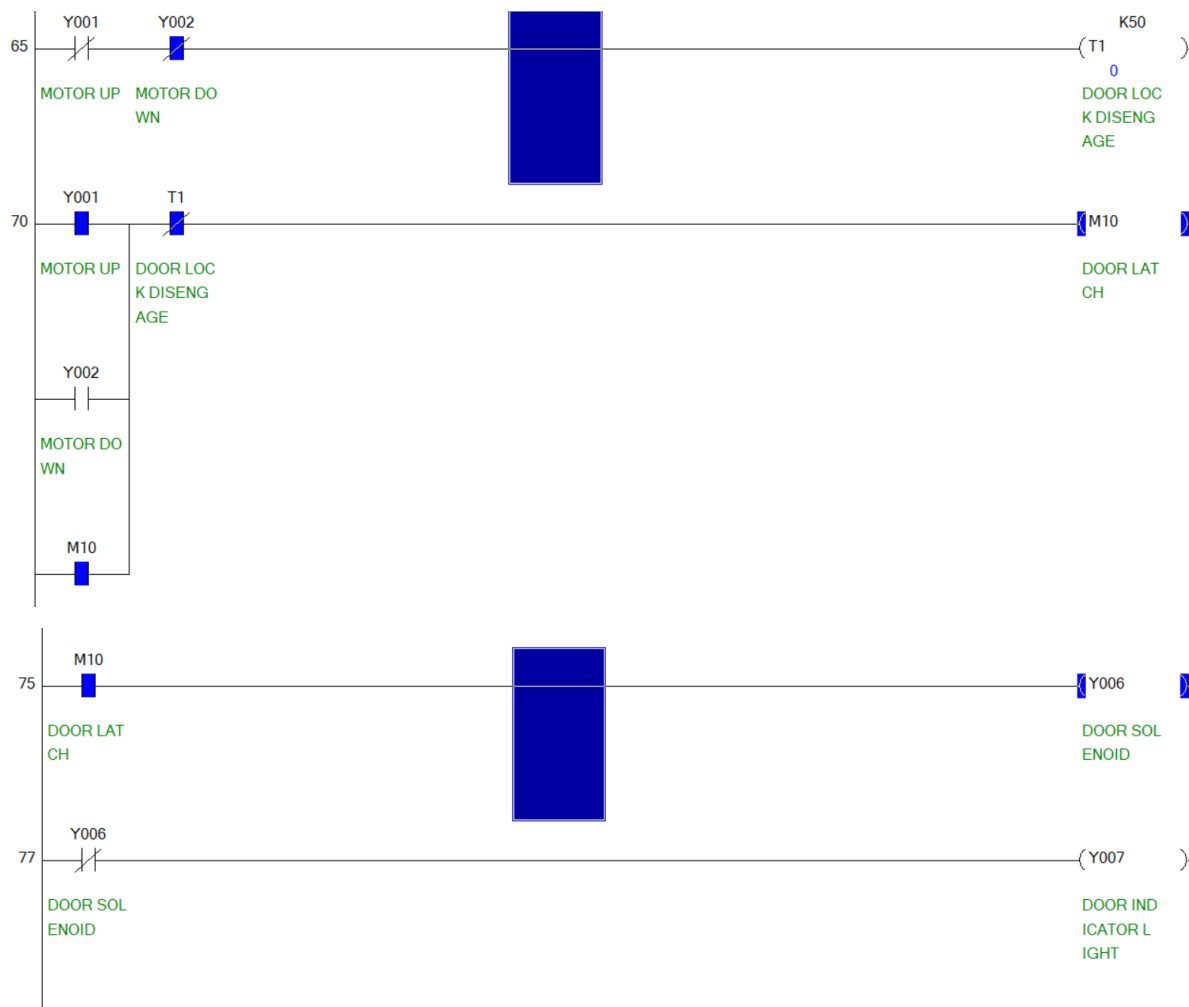


Figure 22, demonstration of lift moving up from Level 1 to Level 2

4. 'The lift cannot move position if the door is open.' As shown in figures 21 and 22, The lift will not move position unless X007 is engaged (door position sensor). In order for the lift to move position, say from Level 1 to Level 2, X003, X002 and X007 all need to be switched to the 'ON' position within the logic.

'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.' This feature is shown in both figures 21 and 22 when the lift is in motion, it is latched to whatever floor it has been called to within the program. The lift door is locked during this procedure. And the desired level latched through the use of open and closed contacts. Where level 2 is selected, level 1 and level 3 are, within the logic, the opposing contacts.

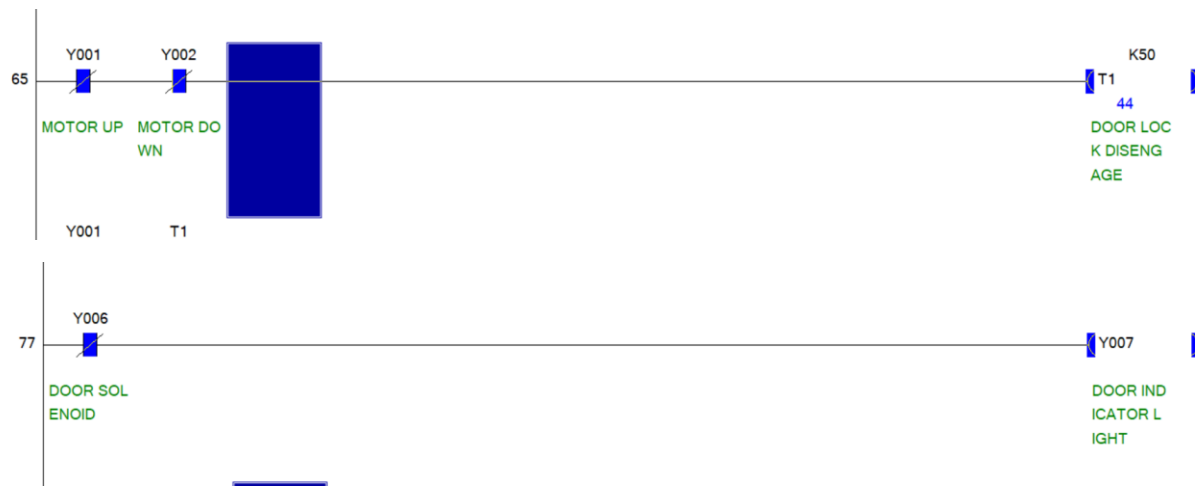


Figure 23, door lock disengagement counter in action

‘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.’

This functionality is shown in *figure 23*, with the use of a counter within the program. The closed contacts both being activated on Y001 and Y002 indicates the lift is stationary, therefore after a 5 second delay, the door can be unlocked and opened. A possible improvement could be the use of motion sensing for the door to open, or the use of a button to open the door- rather than to manually open it. Just small quality of life improvements that could be made in the program.

To improve safety, maybe there could be sensors used to detect faults with the lift- such as low power supply, worn cables, electrical faults within the system. Possibly the inclusion of a warning light for service intervals after the lift has performed a certain number of movements. The lift could be programmed to not engage if there is too much weight being added to it- beyond its design specification.

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Appendix A

Data sheet for Bently Nevada Proximity probes (Task 1)

<https://dam.bakerhughes.com/m/23d2a1de24360b13/original/3300-XL-8mm-Proximity-Transducer-System-Datasheet-141194-pdf.pdf>.

Electrical

Proximitior Sensor Input	Accepts one non-contacting 3300-series 5 mm, 3300 XL 8 mm Proximity Probe and Extension Cable.
Power	Requires -17.5 Vdc to -26 Vdc when installed with non- incendive circuit connected per installation drawing 140979 at 12 mA maximum consumption, -23 Vdc to -26 Vdc with barriers. Operation at a more positive voltage than -23.5 Vdc can result in reduced linear range.
Supply Sensitivity	Less than 2 mV change in output voltage per volt change in input voltage.
Output Resistance	50 Ω

Appendix B

Datasheet/ manufacturers information for displacement sensor, (Task 1)

<https://www.micro-epsilon.co.uk/fileadmin/download/products/cat--capaNCDT--en.pdf>

Controller type	DT6530	DT6530 with pre-amplifier CPM6011
Resolution static ¹⁾	0.000075 % FSO	0.0006 % FSO
Resolution dynamic ¹⁾	0.002 % FSO (8.5 kHz)	0.015 % FSO (8.5kHz)
Data rate analog output	8.5 kHz (-3 dB)	8.5 kHz (-3 dB)
Bandwidth (switchable)	20 Hz; 1 kHz; 8.5 kHz	20 Hz; 1 kHz; 8.5 kHz
Data rate digital output	4 x 7.8 kSa/s; 8 x 3.9 kSa/s	4 x 7.8 kSa/s; 8 x 3.9 kSa/s
Linearity (typ.)	≤ ±0.025 % FSO	≤ ±0.05 % FSO
Max. sensitivity deviation	≤ ±0.05 % FSO	≤ ±0.1 % FSO
Repeatability	0.0003 % FSO	0.001 % FSO
Long-term stability	±0.002 % FSO / month	±0.02 % FSO / month
Synchronous operation	yes	yes
Insulator measurement	yes	no
Temperature stability	± digital: 5 ppm/°C analog: 10 ppm/°C	80 ppm
Temperature range (during operation)	Sensor	-50 ... + 200 °C
	Controller	+10 ... +60 °C
Temperature range (storage)	-10 ... +75 °C	-10 ... +75 °C
Supply	230 VAC	230 VAC
Output	0 ... 10 V (max. 10 mA short circuit proof); 4 ... 20 mA (load max. 500 Ω)	0 ... 10 V (max. 10 mA short circuit proof); 4 ... 20 mA (load max. 500 Ω)
	optional: 0 ... 20 mA (load max. 500 Ω)	optional: 0 ... 20 mA (load max. 500 Ω)
	Ethernet 24 Bit; EtherCAT	Ethernet 24 Bit; EtherCAT
Sensors	suitable for all sensors	suitable for all sensors
Sensor cable standard	CC cable ≤ 1 m	CC cable ≤ 1 m
	CCm cable = 1.4 m	CCm cable = 1.4 m
	CCg cable = 2 m	CCg cable = 2 m
Sensor cable (special tuning)	double / triple / quadruple standard cable length	double / triple / quadruple standard cable length
Trigger	TTL, 5 V	TTL, 5 V
No. of channels	max. 8	max. 8

FSO = Full Scale Output

¹⁾ RMS noise related to mid of measuring range

Appendix C- examples of SCADA HMI

Source: <https://www.verttech.com/blog/scada-screens-of-the-2020s>

From 1990s, to early 2000s and modern day

