

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Aleksandar Sucic	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	9.9
Engagement with a wide range of literature, including sources retrieved independently. Generally sound referencing technique.		
2. Knowledge and Understanding Skills	40	25.6
Task 1 achieved 50%. Task 2 achieved 65% Task 3 achieved 74% Showed some competent knowledge of the basic underlying concepts and principles for assessment but in Task 1 have included a device that is really considered to be a proximity device. Excellent work in producing the IL code for Task 3.		
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	24.3
Task 4 achieved 80%. 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	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)		69%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

PLC Program Design and Simulation

Programmable Logic Controllers

HNC Electrical/Electronic Engineering & Instrumentation Engineering

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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.

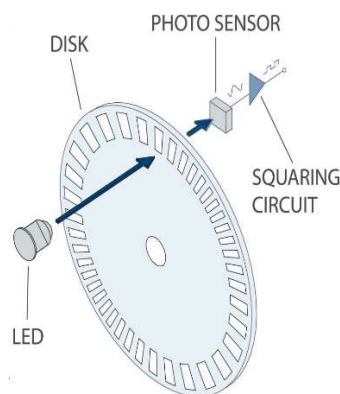
Task 1 – PLC analogue and discrete I/O

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

Proximity sensors are non-contact devices which work by detecting either the presence or absence of a foreign object. They are very useful for dangerous or expensive applications where contact with other objects could damage outputs. Many proximity sensors provide a very precise yet quick response. ✓

One type of a proximity sensor is an optical encoder, an optical sensor consists of a light source, an optical disc, a light sensor and signal conditioning circuitry to process the signals. The optical disc is loaded onto a shaft of a motor of which speed it is reading as the disc will rotate at the same speed as the motor. The disc has slots in it that align with the light source (most commonly an infrared LED) as the disc rotates, the light slots block when the LED signal is received by a phototransistor. Phototransistor doesn't pick up ambient light, therefore any other light apart from the infrared LED will not impact the results. The phototransistor is connected to a circuit that calculates the result. When the disk blocks the light, 0 volts drop across the load resistor, when the light shines, there is very little resistance on the transistor. The volt potential, provided from Schmitt trigger, computes the pulse information, and presents them as square waves, this information can then be processed by a computer which can then present the results, allowing the user to know the speed at which the motor was spinning. ✓



This is not really a proximity detector. It does detect rotation position

Figure 1 - Diagram of optical sensor construction (Encoder Products Company, 2018)

The disc has three pins, one common and two contact pins. As it rotates, the discs contact zones is an area where the pins will contact the common pin. These pulses will reveal whether the rotation is clockwise or anticlockwise. If the most northern pin is called pin A and the most southern, pin B, and understanding the signal is offset by 90 degrees, it is visible that when A is followed by B the encoder rotates clockwise, as the northern A pin makes contact before the southern B pin. These sensors are used to measure speed and rotational direction in equipment such as motors. ✓

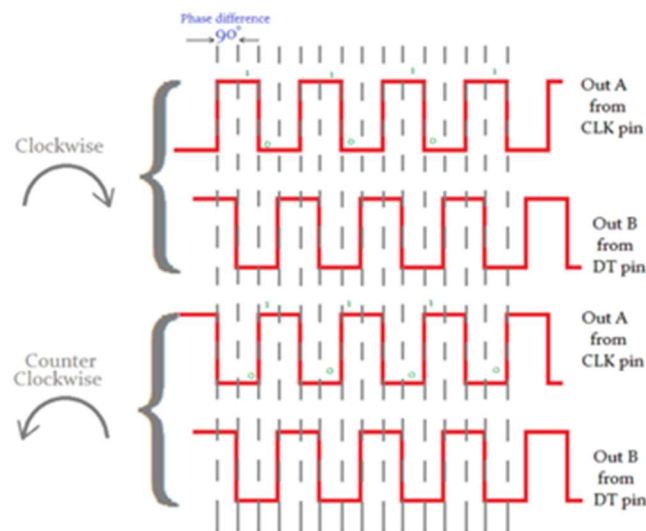


Figure 2 - Output signal from pins A and B contacting Common pin C (Newton, 2022)

Another type of proximity sensor is an inductive proximity sensor, this sensor can detect metals. There are various types of inductive proximity sensors, the high frequency oscillation type sensor utilises magnetic induction. It consists of an internal coil, an oscillator, and a soft iron core. The coil is wound around the core and connected to the oscillator circuit. Once the electromagnetic field is created by the sensor any metal that is caught in range experiences an eddy current targeted by the sensor. The eddy current of the metal now interacts the original field from the sensor reducing the sensors amplitude. "This change in amplitude is detected by the oscillator circuit and an output signal is generated accordingly, in a special circuit that includes a Schmitt trigger. This output signal is then used to trigger a relay or an alarm, depending on the application of the sensor." (William, 2023) ✓

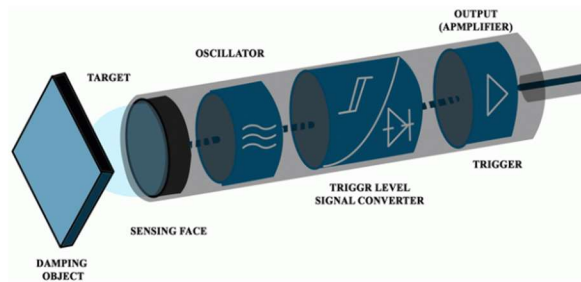


Figure 3 - Inductive Proximity sensor diagram (William, 2023)

When a ferrous metal is in the sensors range, the oscillation frequency drops, when a nonferrous metal is detected the frequency increases. The proximity sensor has a reference frequency, when the oscillation frequency is higher than the set reference frequency, the sensor signals a detection. "The nonferrous-metal type incorporates an oscillation circuit in which energy loss caused by the induction current flowing in the target affects the change of the oscillation frequency." (Sensor Basics, undated)

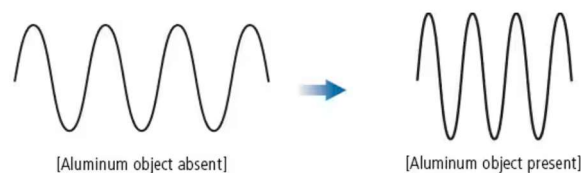


Figure 4 - Oscillation (Sensor Basics, undated)

These proximity sensors are used in automation and robotics, where reliable detection for metals is essential. For example, when connected to a PLC, once sensing a metal is in place the PLC can produce an output for a milling machine to turn on and drill certain locations on the metal, or action a soldering machine to solder components when the metal is in place.

- Displacement.

A displacement sensor provides a measure the previously recorded starting position and the new current position between a set reference point and the new location that the target has moved to.

The strain gauge is a thin metal foil fixed onto a flexible sheet usually made of plastic. The flexible sheet is bonded to the part which is to be measured. The flexible sheet also acts as an insulator to the current which is to run through the foil. The resistance changes when the measured object is under stress in parallel with the foils. The change in resistance is proportional

to deflection. Meaning, the larger the deflection, the larger the resistance. There are many diverse types of strain gauges, some use more sensors to measure strain in multiple directions, this is called a Wheatstone bridge. Most commonly, strain gauges have a resistance of around 100Ω . A formula is used to convert the resistance to a strain reading, these readings can then be processed and measured. ✓

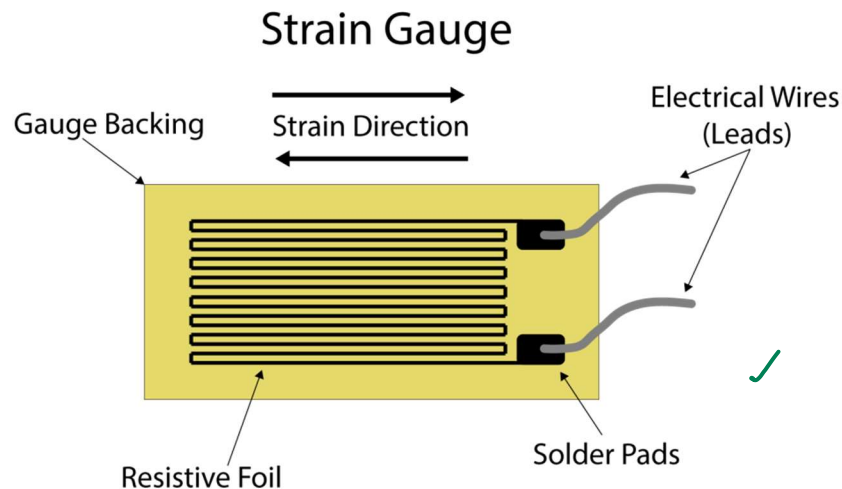


Figure 5 - Diagram of resistive strain gauge sensor (Nachazel, 2020)

The resistive strain gauge has a charge that runs through the foils, the strain gauge is not static, the charge that runs through the foils measures resistance. The results can be affected by a higher temperature, current creates heat when passing through resistive elements, and the current passing over the strain gauges and the Wheatstone bridge will cause heat increase therefore impacting measurements. Strain gauges can be used to measure leanings of buildings and bridges when adverse weather conditions hit. This can send an input to a PLC to sound an alarm for people to evacuate a building if the building has leaned too much and might be at risk of collapsing. ✓

Another type of displacement sensor is a potentiometer, the potentiometer utilises a physical contact between a wiper that is linked to a shaft that slides along a track. The movement and sliding on the shaft along the track "causes the resistance value between the wiper/slider and the two end connections to change giving an electrical signal output that has a proportional relationship between the actual wiper position on the resistive track and its resistance value." (Storr, 2022) Therefore the resistance is directly proportional to the actual physical position. In practice, the potentiometer's slider is directly linked to the object that is to move. There are two fixed connections to which a reference recorded DC voltage is applied across. The voltage is recorded from the wiper on the sliding contact. The arrangement creates a voltage divider circuit which is (as stated previously) proportional to the shaft, if the DC voltage applied across the ✓

resistive elements is 10V, this means when the slider is in its centre position the output signal will be 5V. AS the slider slides right the resistance increases.

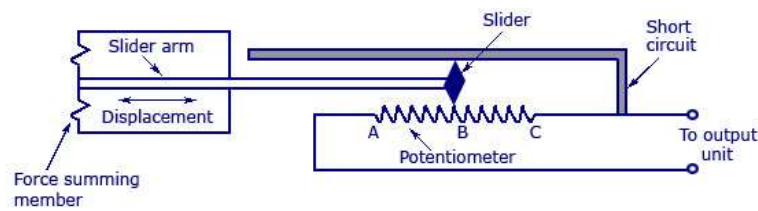


Figure 6 - Diagram of Linear Potentiometer, (John, 2011)

Potentiometers are used as a voltage divider in any electronic circuits therefore are really suitable to be used as user controls such as volume. *Good.*

- 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.

Stepper motors are brushless synchronous electric motors that rotate in small angular steps. Stepper motors are precision-based motors that are used for precision starting and stopping and repeated processes, they are a digital input-output motor. Just like a common electric motor they have electric coils however the series of coils in a stepper motor are arranged in a way that allows the quick stopping and starting with high precision. The coils are arranged in phases called steps in a way that the current passing through them hits them in these phases allowing the motor to be stopped very quickly. By having these steps, the motor is available to have many small rotations depended on the desired output of the PLC, with the user interface the user is able to set the number of degrees for the stepper motor to rotate. The stepper motor consists of a fixed housing that is set around toothed electromagnets that spin at the centre, the stepper motor uses pulsing electrical current and converts it “into precise one-step movements of this gear-like toothed component around a central shaft.” (RS, 2023) Each of the pulses moves the rotor through a fixed increment, the current can be switched between selected wire coils allowing the user to either choose full rotations or just partial rotations. ✓

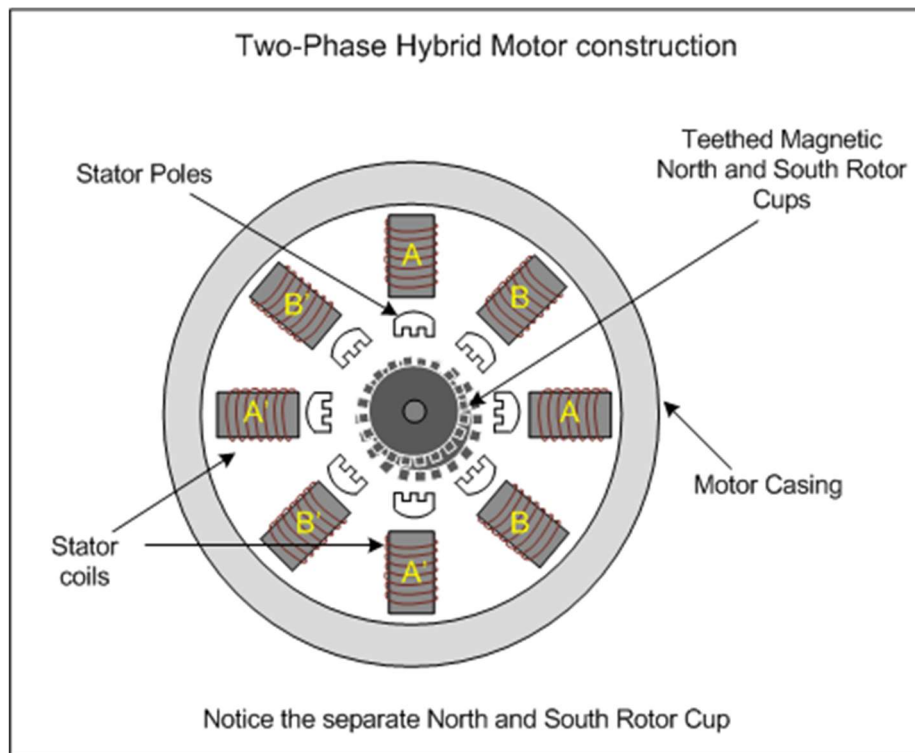


Figure 7 - Stepper motor construction diagram (Agnihotri, undated)

Hybrid motors have a magnetized rotor with steel caps, one end is north pole and the other a south pole, the motor is very precise as the rotor and stator have many teeth allowing the steps to be very small therefore allowing smaller movements allowing for more precision. When the coils are energised, the rotor rotates very marginally to align to the correct pole, the degree of rotation can sometimes be measured up to 2 decimal places due to its high precision. When the second set of coils is energised, it again moves the same margin of degrees, this is repeated continuously and is repeated by half stepping, to allow smooth more efficient movement. Hybrid motor shave teeth that are offset between 2 cups outside of the magnet rotor, this adds for even more precision as the teeth can align to either of these cups, this also offers higher torque-to-size ratios and greater output speeds than the traditional stepper motor. Stepper motors are used in many applications such as in milling machines and in robotic arms where millimetres of precision are required, they are used in a lot of computer systems such as scanners, printers, and camera lenses. ✓

Task 2 – SCADA (Supervisory Control and Data Acquisition)

SCADA (Supervisory Control and Data Acquisition) is used in conjunction with PLCs and human machine interface to aid in controlling, analysing, and inspecting industrial

devices and processes. “In addition to the PLCs connected to input and output devices, SCADA systems consist of supervisory computers, remote terminal units, communications devices and a human– machine interface (HMI).” (Anderson, Paul, et al. 2023) SCADA comprises of both hardware and software which allows operators to analyse process data from machinery and control the machinery and processes to get the desired outcomes remotely. SCADA systems have a wide range of applications but are most commonly used in manufacturing, transportation, power control and distribution and oil and gas industries.

In industry, SCADA systems use PLCs for a variety of reasons, these include measuring collecting and processing data from the plant, this data can then be decoded and presented with the use of HMI. HMI usually consists of a computer or sometimes just a screen and is used to show the data to the user in a user friendly, easily understood manner who can then read and understand the data. The user can then make changes and controls with the HMI to affect the output, the HMI sends these controls to the PLCs on the plant which affect the operations of components and equipment such as motors in the way set by the user, the user can then monitor the output recorded by the PLCs in the form of sensors on the HMI. The HMI helps the user control and analyse and report the findings remotely. An example of this process is shown in **Figure 7** below.

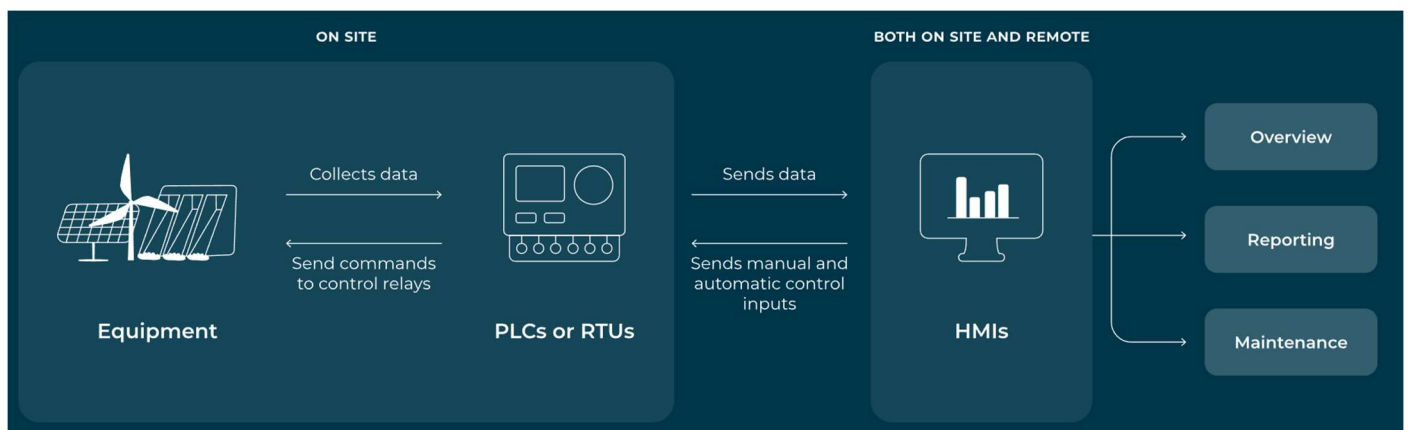


Figure 8 - (SCADA International, 2024)

SCADA systems are very helpful in industries such as oil and gas where there is lots of equipment involved working in conjunction with one another, all of this equipment will have PLCs monitoring factors such as speed, temperature, and flow of product. All the while the user has the ability to spot trends and produce outputs. An example of SCADA in gas and oil could include flow of product, an operator has been told that he is to fill a tank full of oil which has just been delivered for refining in the plant. The operator can use his HMI in the form of a computer to control the PLC on an actuator on the plant which will open a valve allowing the flow of product into the storage tank. All the while, PLC such as volumetric flow metres will be measuring the transfer rate and be

sending the information to the computer. The operator will also be able to monitor the level of the tank, receiving readings from laser-based PLCs, this will allow him to know when the tank is filling up in order to close the valve and divert flow of product. SCADA is also advantageous in emergency situations, if a motor is overheating, thermistors will send information to the HMI, where the operator can analyse and act quickly to turn of the motor to prevent it burning out or damaging other equipment. In this scenario, SCADA allows the operator to turn of the equipment quickly, by using the HMI, the motor can be turned off remotely without having to access the unit which could put people in danger. ✓

Task 3 – Instruction List

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 Connection

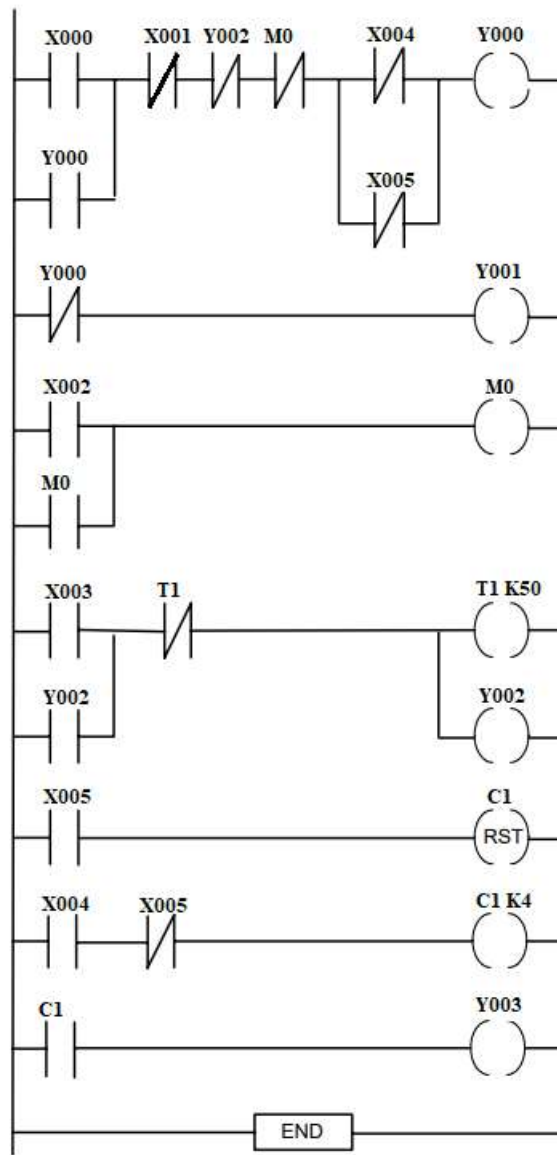


Figure 9 - Ladder Logic

LD	X000
OR	Y000
ANI	X001
ANI	<u>Y002</u>
ANI	M0
LD	X004
OR	X005
ANB	
OUT	Y000

Y002

✓

LDI	Y000
OUT	Y001
LD	X002
OR	M0
OUT	M0
LD	X003
OR	Y002
ANI	T1
OUT	T1
K50	
OUT	Y002
LD	X005
OUT	RST C1
LD	X004
ANI	X005
OUT	C1
K4	
LD	C1
OUT	Y003
END	

Table 2 - Instructional list for ladder logic in figure 8

Very well done.

Task 4 - Temperature Alarm Panel

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

Table 3 - Alarm Outputs

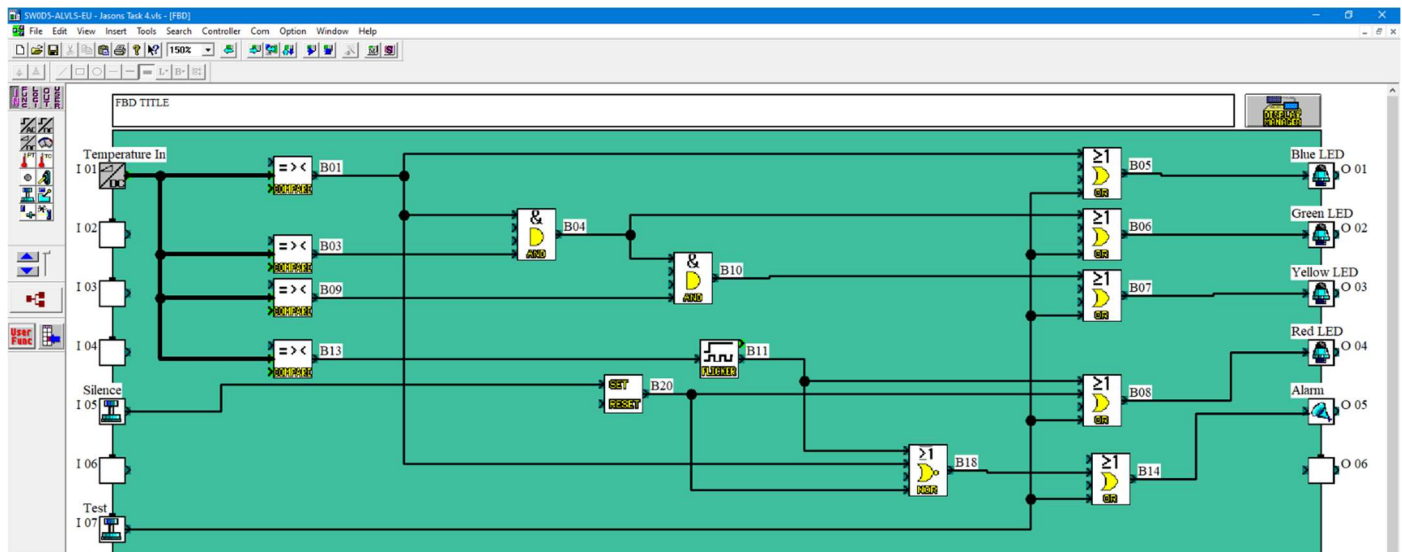


Figure 10 – Temperature Alarm Panel Simulink Diagram

Temperature alarm panel diagram on Mitsubishi's programming software 'ALPHA'.

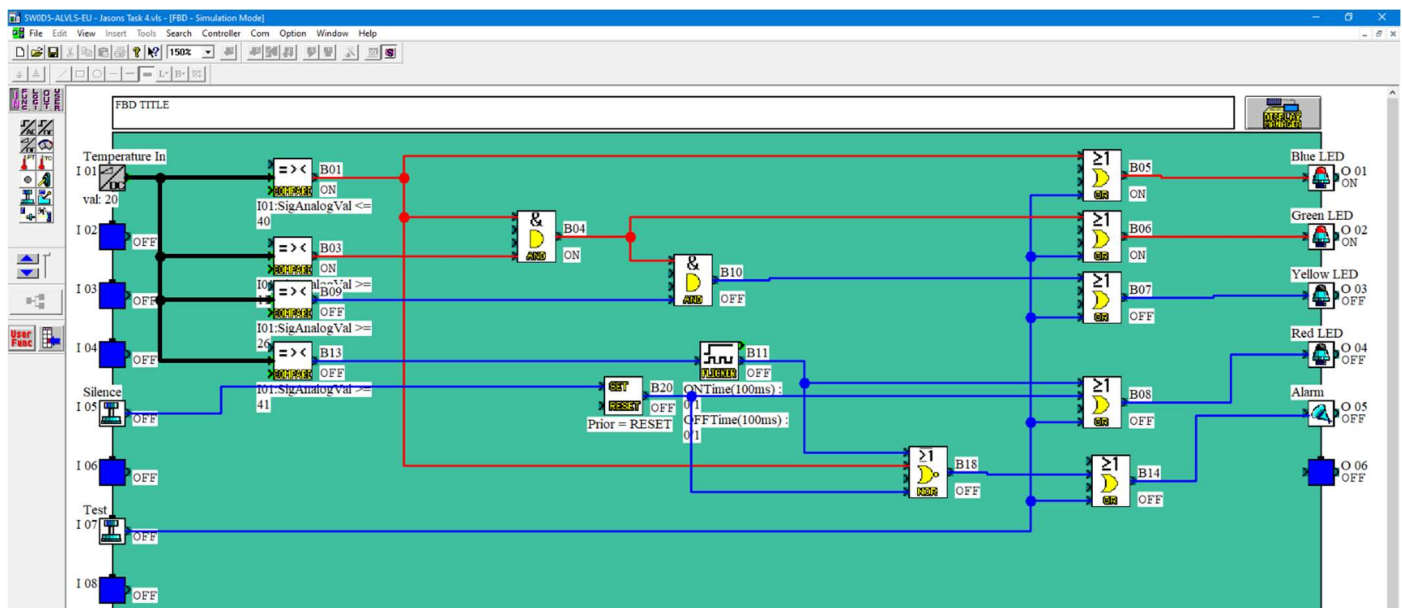


Figure 11 - Temperature Alarm Panel Simulink Diagram Temperature in = 20 C

Diagram shows the two LEDs, blue and green, lit up for a temperature of 20°C

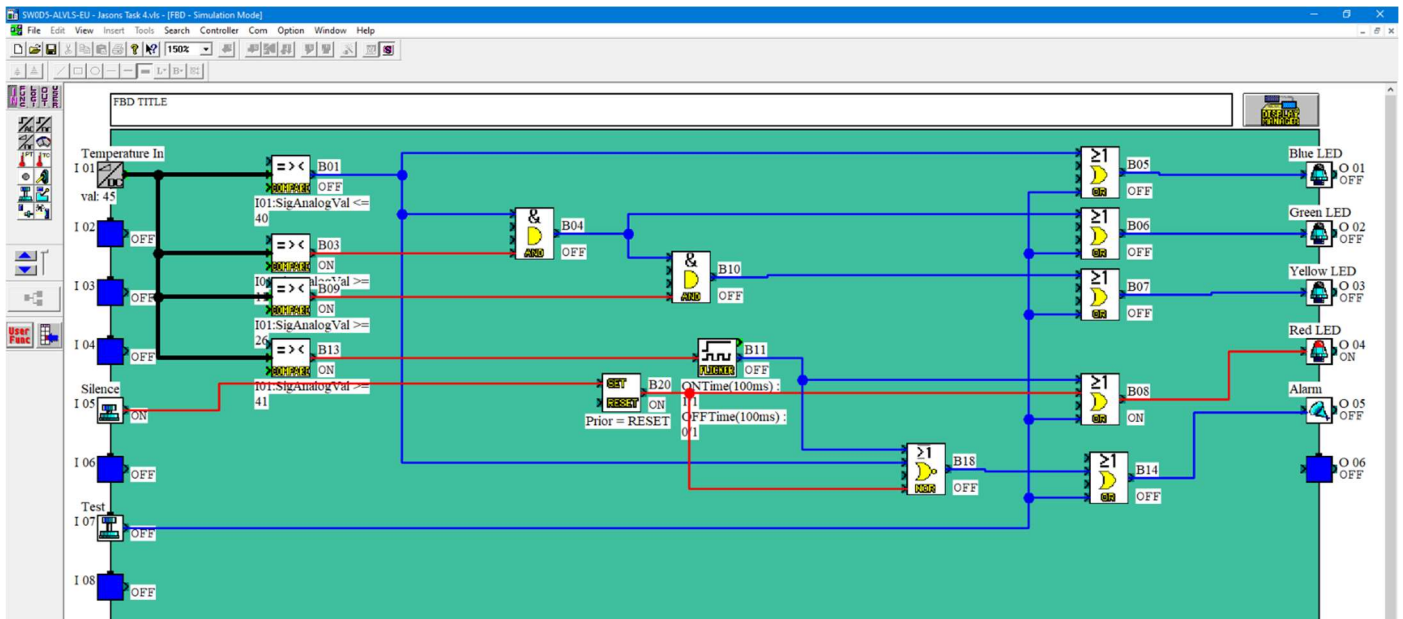


Figure 12 - Temperature Alarm Panel Simulink Diagram Temperature in = 45 C

Figure shows temperature input of 45°C, the alarm has been silenced using the 'silence' button, when the alarm is silenced the red LED stops flashing and remains permanently lit. The red LED and alarm systems are only applicable when the temperature reaches 41°C.

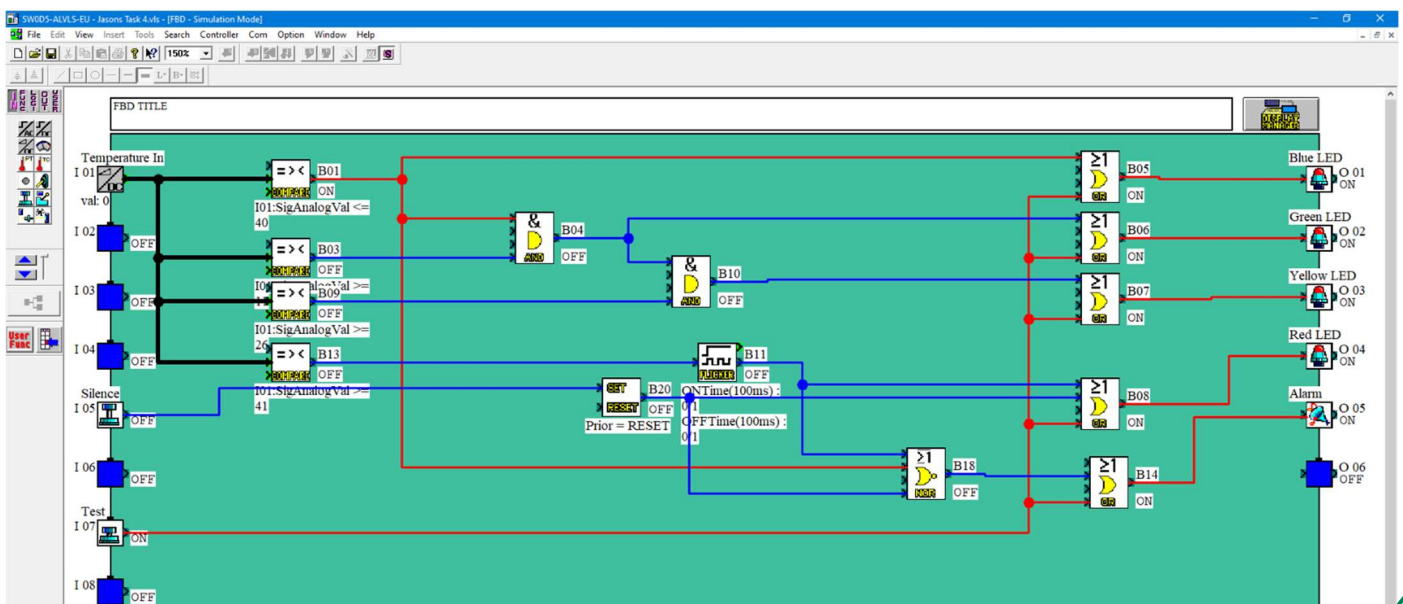


Figure 13 = Temperature Alarm Panel Simulink Diagram, Test

The Test button is used to show all applications working, the figure shows that when the test button is pressed all the LEDs light up and the Alarm sounds.

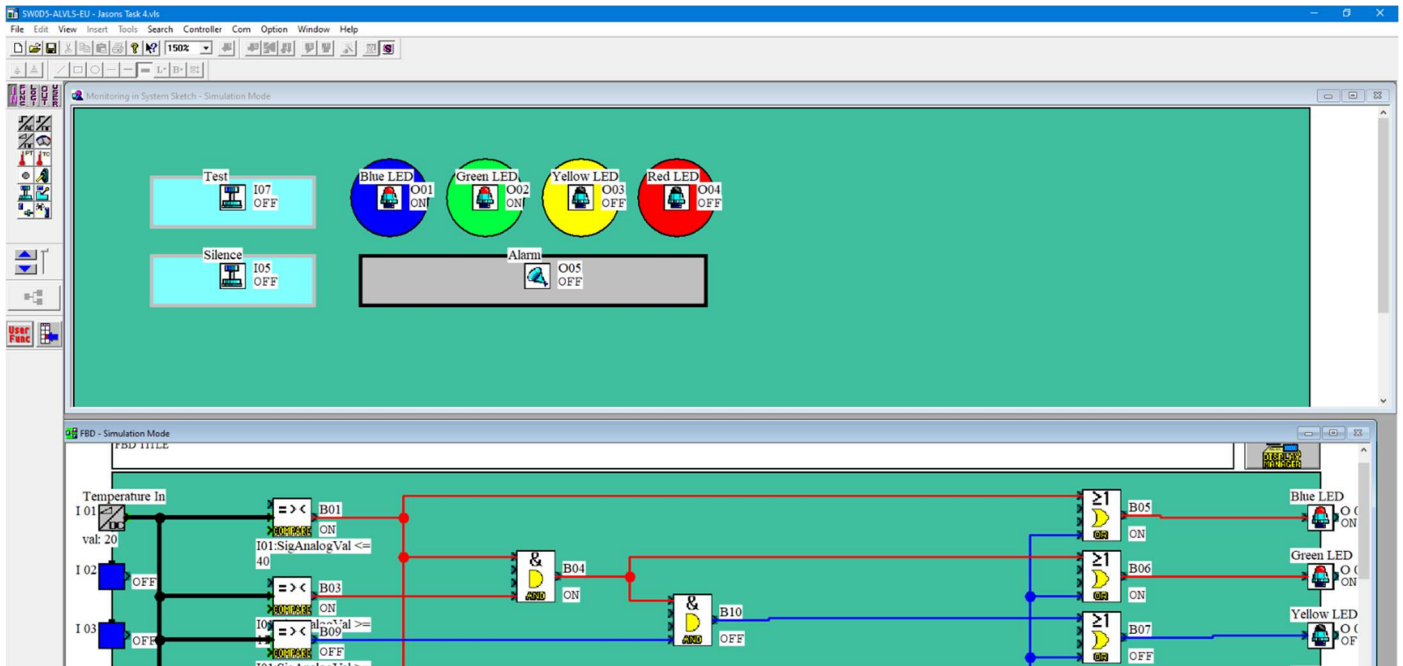


Figure 14 - Simulink Diagram and user interface Temperature in = 20 C

This figure shows the user interface above the diagram, this example shows Blue and Green LEDs lit up for the temperature input of 20°C. When both LEDs are lit, it indicates that the temperature is between 11 and 25°C

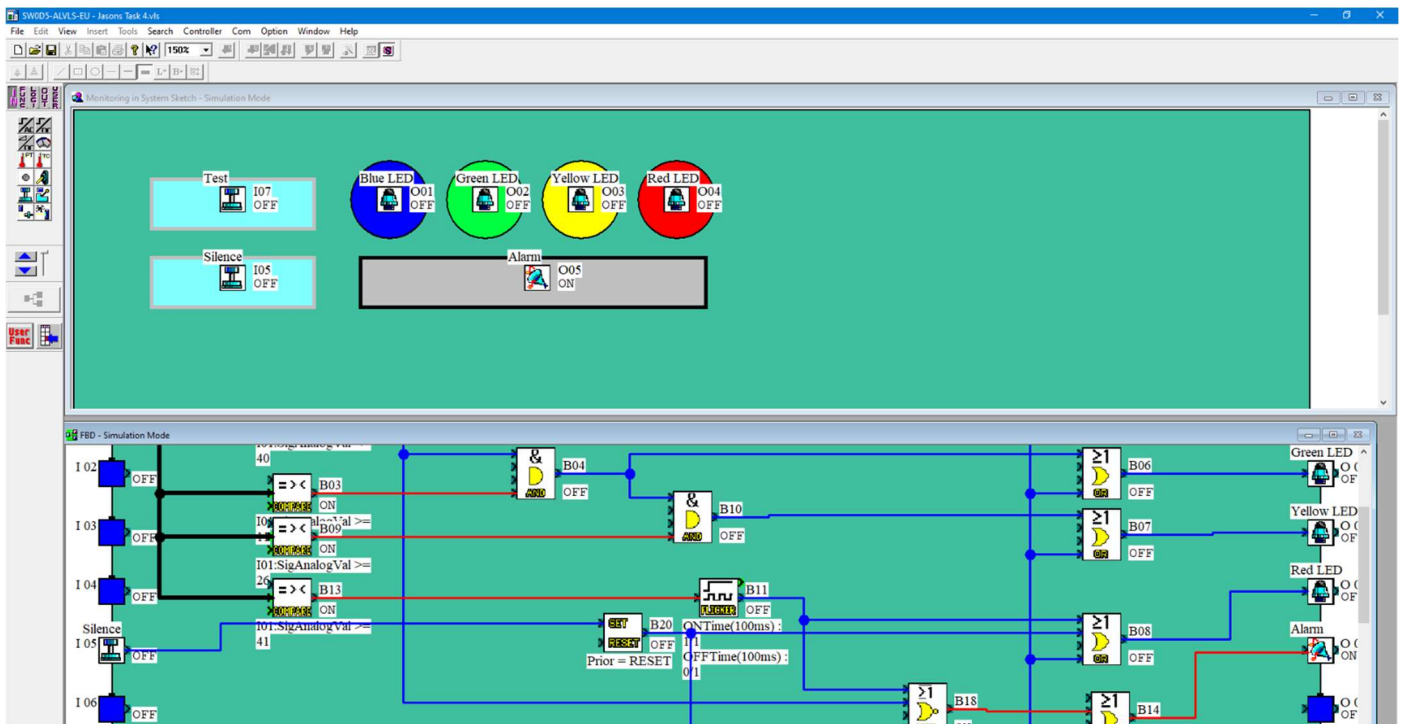


Figure 15 - Simulink Diagram and user interface Alarm

The figures above and below show the sounder alternating with the red LED which indicates the temperature has exceeded 40°C, this is presented both with the diagram and the user interface.

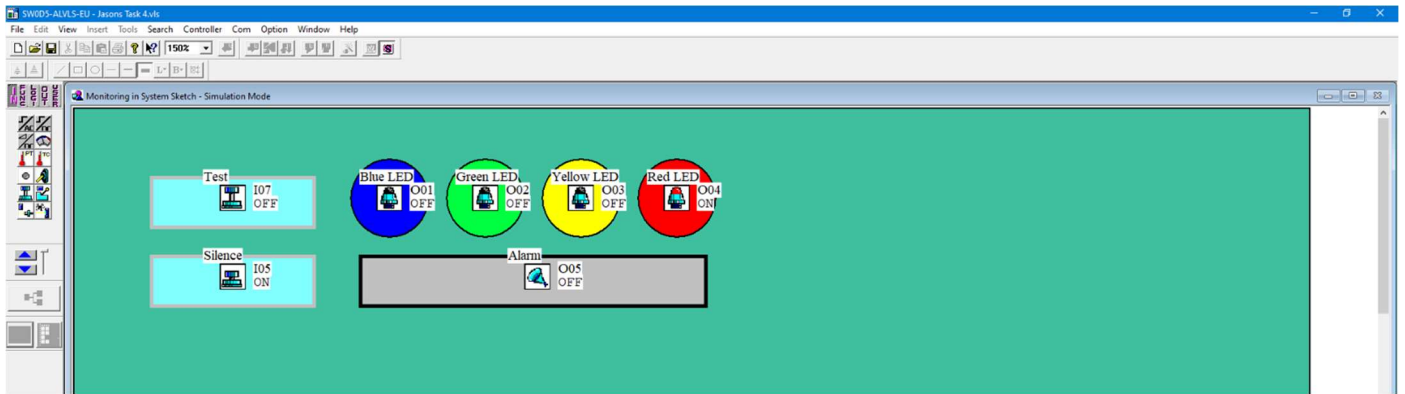


Figure 16 - Simulink Diagram and user interface Red LED

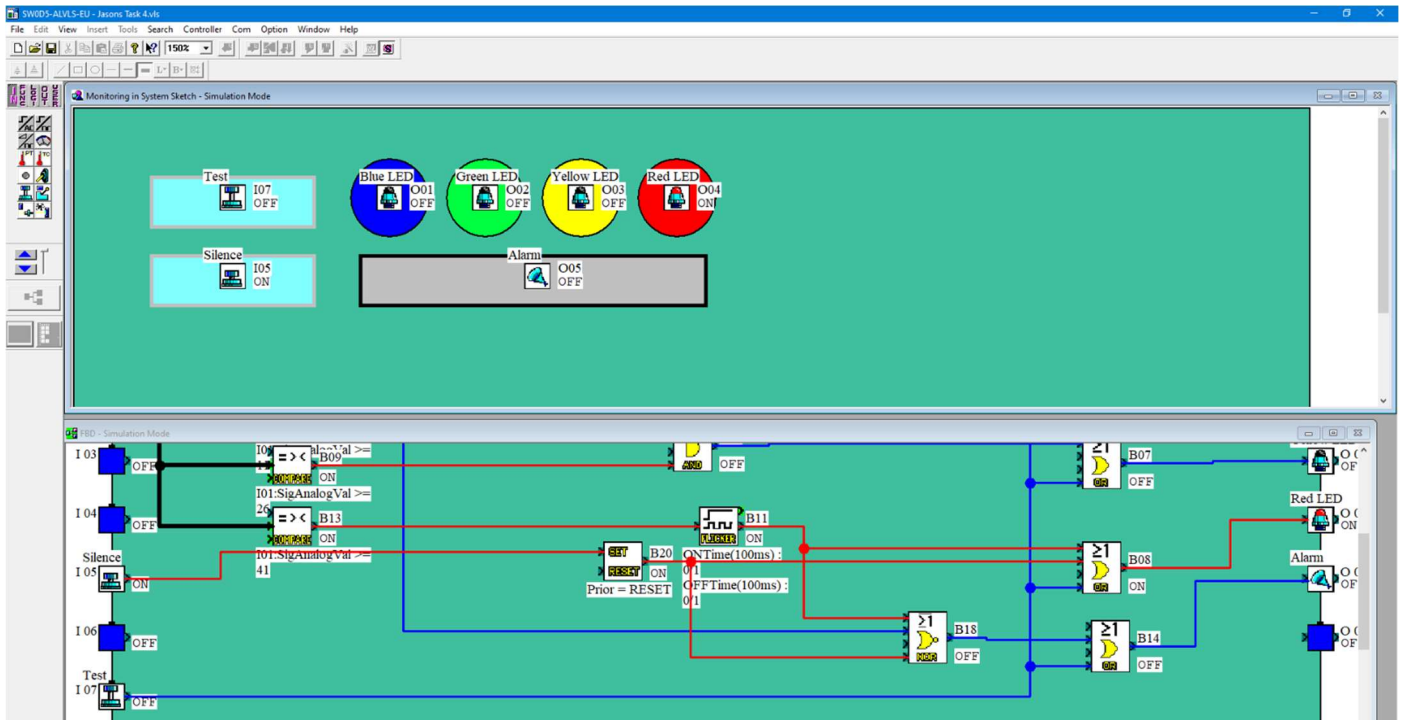


Figure 17 - Simulink Diagram and user interface Silenced Alarm

When silence button is pressed, the alarm turns off and the red LED remains permanently lit.

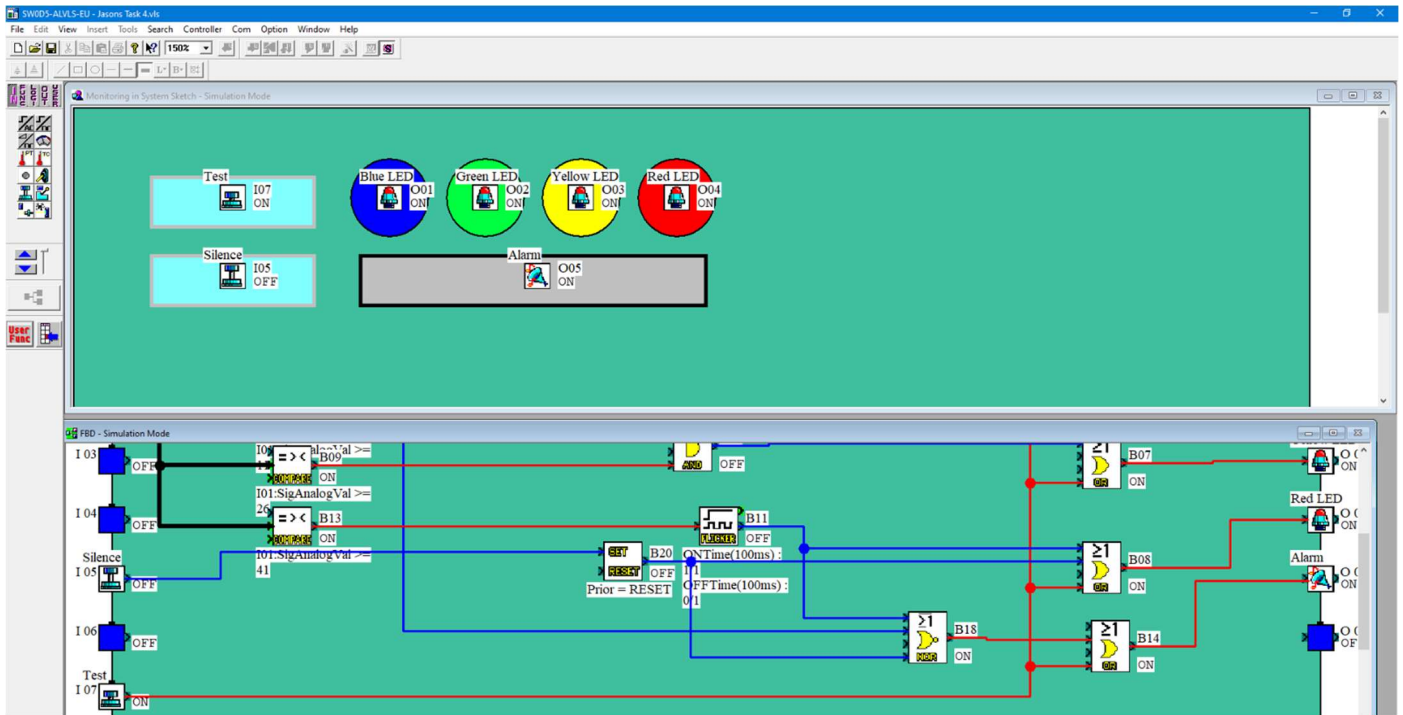


Figure 18 - Simulink Diagram and user interface Test

The figure above shows all LEDs and sounder activated when test button is pressed with user interface.

Very good program, well done.!

Task 5 – Construction Site Lift

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 4 - PLC Inputs and Outputs

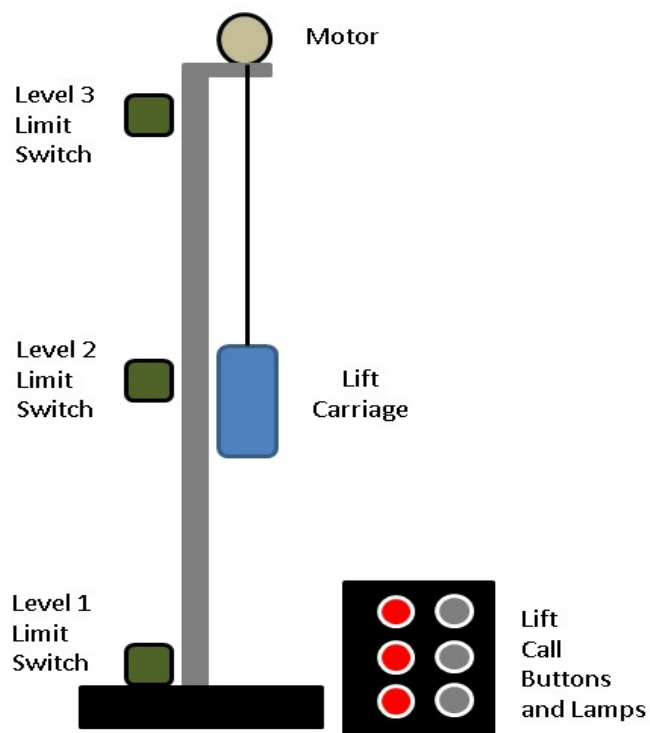


Figure 19 - Lift System

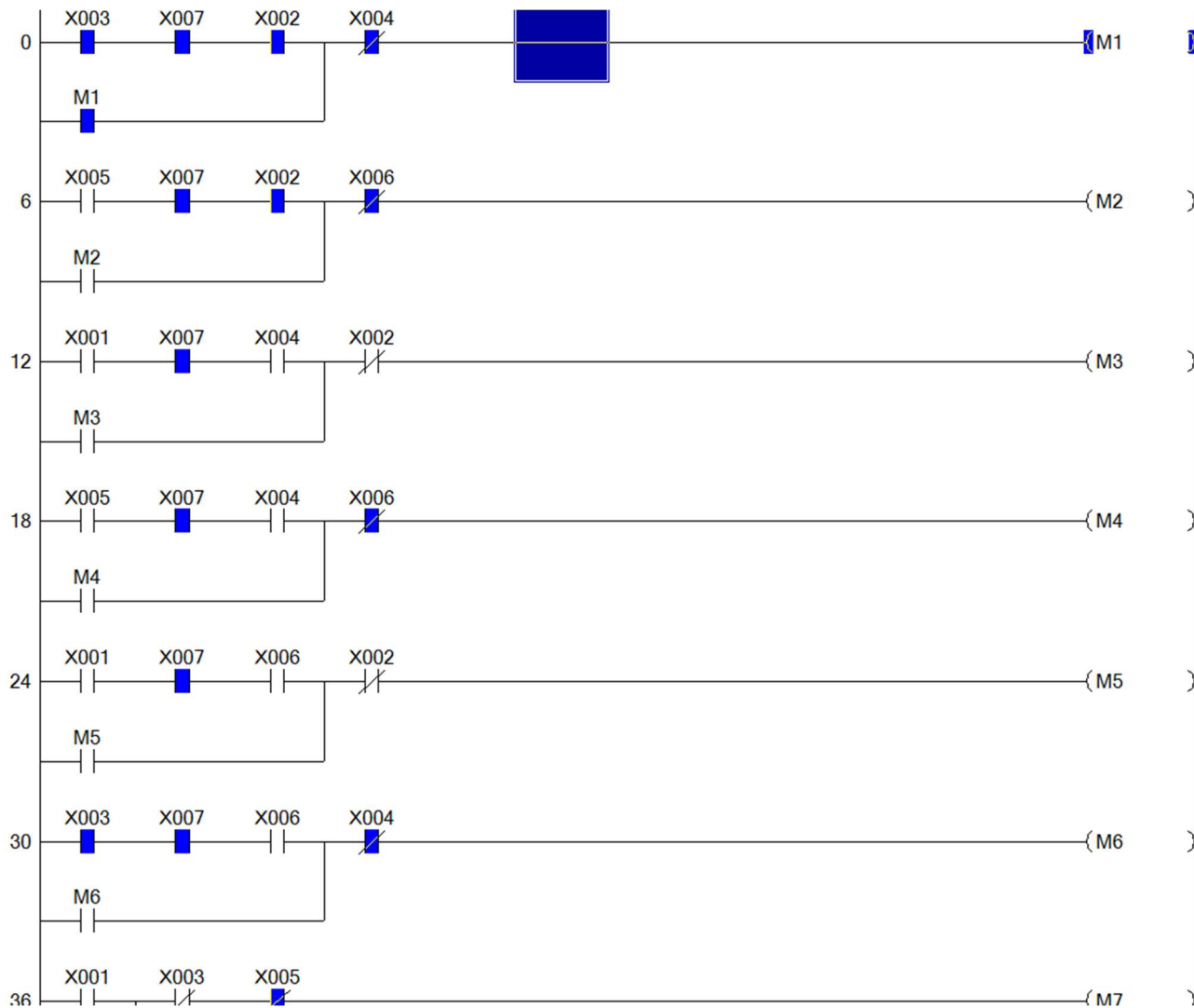


Figure 20 - Lift System Ladder Logic

In Rung 0 X002 and X003 activates M1, M1 is the level 1 to the Level 2 Latch. X003 is the level 2 call button, X002 is the Level 1 sensor, indicating the lift is on level 1.

By pressing X003, you call the lift to move from Level 1 to level 2.

M1 is latched which is the level 1 to level 2.

Need to state where your final program is. (At the end)

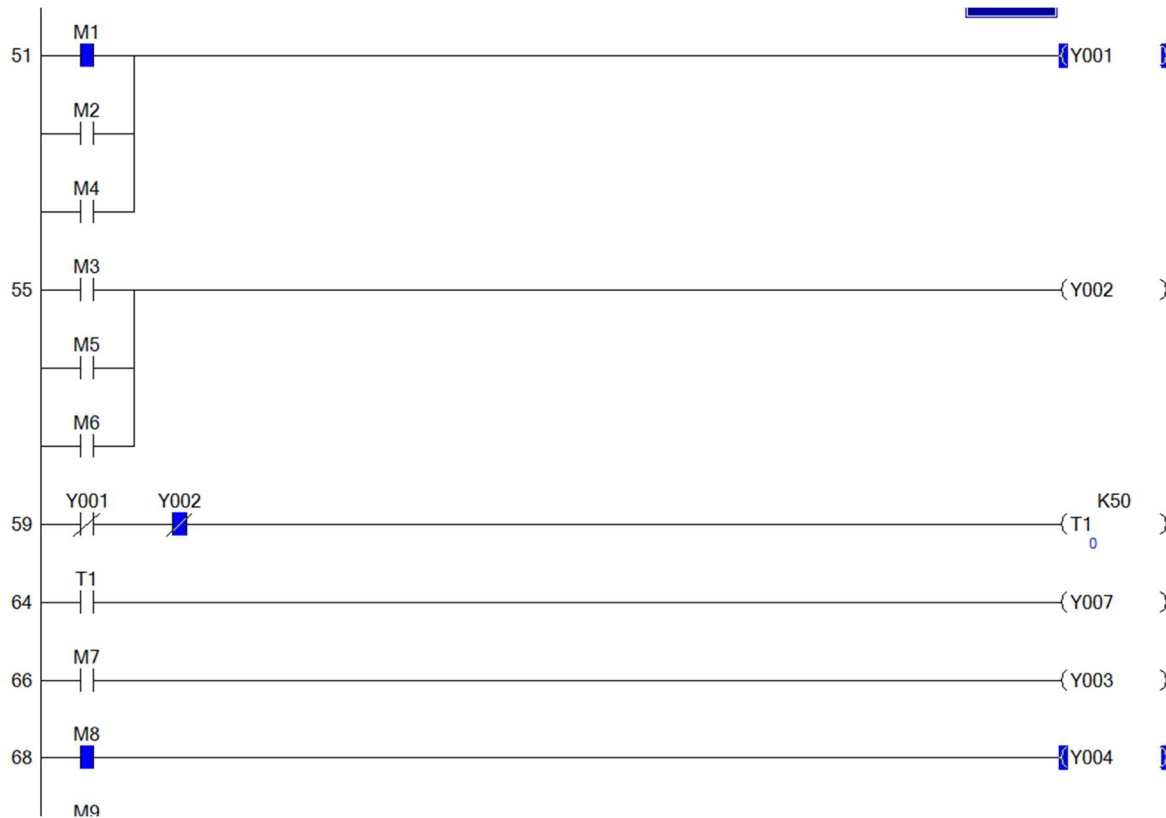


Figure 21 - Lift System Ladder Logic M1 activated

Since M1 is activated in Rung 51, it activates Y001 showing the motor going up to level 2
Y004 in Rung 68 shows the level 2 indicator light



Figure 22 - Lift System Ladder Logic Y006 activated.

Rung 77 shows Y006, the solenoid latch locked while the lift is moving.



Figure 23 - Lift System Ladder Logic Y006 disengaged.

Rung 77 shows the solenoid lock (Y6) disengaging,

← and it shows That after the timer T1 counts down to 90ms (5 seconds) Y7 activates which is the open door light, letting the person know they can exit/ enter. *Why have you state 90ms?*

The system works as designed, however, there are a few improvements that could be added to the overall function of the lift. One improvement is including an emergency override, this control would allow the user to cancel all the opened and closed contacts and de energise any outputs, the override would then allow the user to choose where they wanted to go, this would be an essential safety feature and would only be used in emergencies. Automatic doors would also be advantageous and would remove certain risks such as pinch points. Speakers announcing what level the lift has stopped at would remind the user leaving the lift what level they are on. Another feature would be indicator lights inside the lift lighting up showing what floor they're traveling through and changing as the lift moves between the floors.

The full ladder logic for the program is included in the Appendix with all the comments for every command on every rung

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Would like to see more text-books in your list.

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Appendix – Ladder Logic for Task 5

