

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Wesley Hill	Student ID number:	
Programme:	HNC Electrical/Electronic Engineering & Instrumentation Engineering		
Module:	Programmable Logic Controllers		
Module code:	PCEE4005	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Jason Pointer	Internal Verifier:	Nigel Richards
Assignment Title:	Introduction to PLC Systems & Program Design	Word count (or equivalent):	2000
Submission deadline:	11/01/24	Return date of provisional marks & written feedback:	25/01/24
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

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

STUDENT FEEDBACK FORM

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

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	15	4.1
Little or no evidence of reading and reliance on inappropriate sources. Referencing conventions are largely absent.		
2. Knowledge and Understanding Skills	30	17.8
Task 1 achieved 60%. Task 2 achieved 58%, Task 3 achieved 60%. Competent knowledge of the basic underlying concepts and principles of the work required for Task 1, 2 and 3.		
3. Cognitive and Intellectual Skills	5	2.4
Limited evaluation of the underlying concepts and principles applied to the construction of the garage door controller.		
4. Practical Application Skills	40	31.6
Task 4 achieved 78%. Task 5 achieved 80%. An excellent application of the 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.		
5. Transferable Skills for Life and Professional Practice	10	5.8
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.)

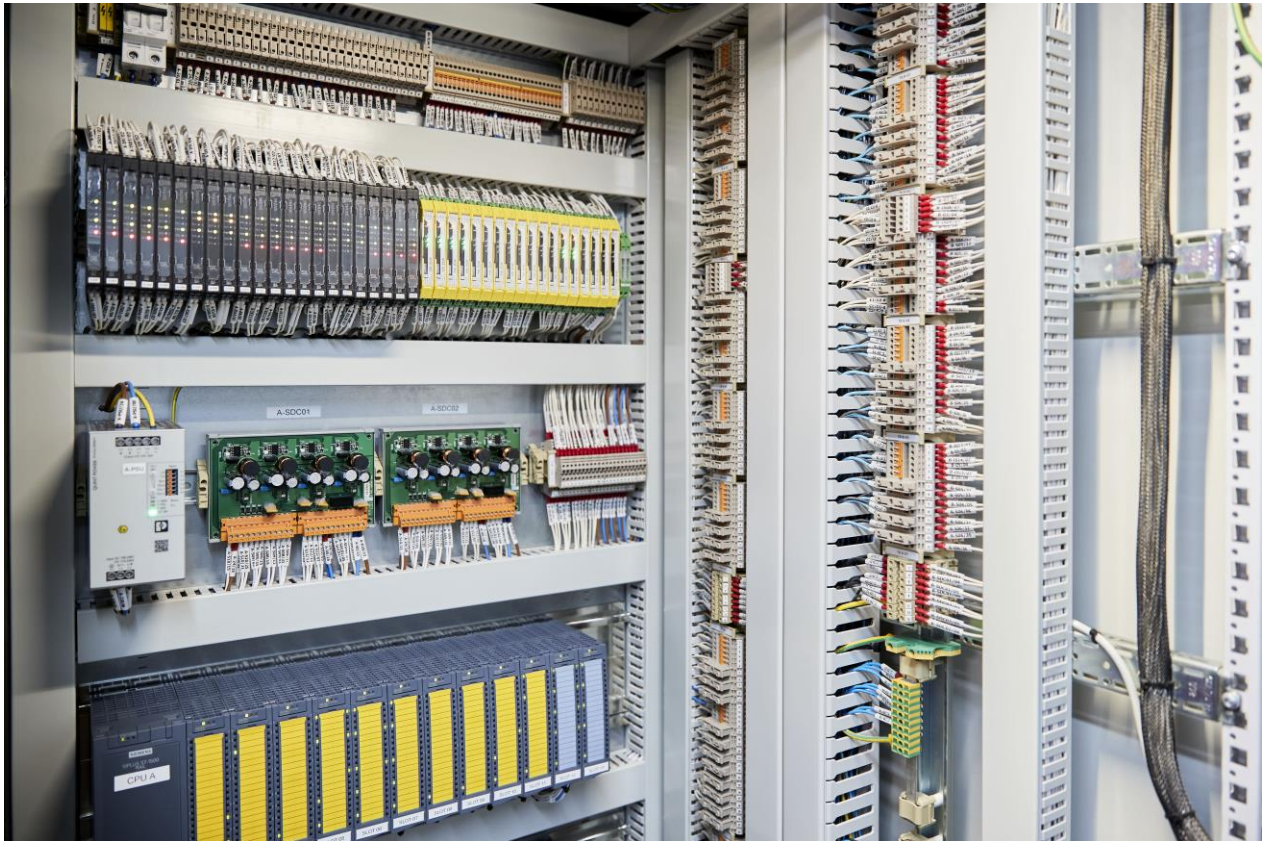
Late Submission Penalties (tick if appropriate)

Up to 1 week late (40% Max)

Over 1 week late (0%)

62%

HNC Electrical/Electronics Engineering Year 2
Unit name: Programmable Logic Controllers



Student Name: Wesley Hill
Student Number: 141916
Tutor Name: Jason Pointer

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Introduction

PLC's have allowed the engineering industry to revolutionise productivity and automation since it's adoption, with the first PLC being built in the 60s. The need for this robust equipment has grown and grown as has the manufacture and control of processes become more efficient and precise. This paper aims to look at Programmable Logic Controllers and the internal architecture of them, showing how they work and explaining how each component links to another and the outside world. With a PLC the internals are full of delicate electrical components which if exposed to large voltages they will be destroyed, this means they need to be protected, this paper will look at some of the protection methods used in real world applications.

This paper will also look at some logical circuits and Boolean equations which are used to analyse the logic behind a logical gate circuit, using a simulation package to then further analyse, visualize, and prove the logical circuit. Timers are essential in PLC programming, often used in manufacturing processes for a repeatable process such as on assembly lines for assembling components and products and on testing rigs that automatically tests the component.

Furthermore, the simulation package AlphaProgram is used to create a coin counting program, an automatic blending program, and an automatic drilling program, whilst looking at improvements and limitations to be made within the program.



Task 1 – Programmable Logic Controller types

A) Through your own research, describe in detail the two types of PLCs available. Include in your research the specifications that define each type, possible applications and any considerations that need to be assessed when selecting a specific PLC type.

PLC's, or programmable logic controllers are used in industry to perform logical actions based on a program, a program will have multiple functions and the PLC will perform the task depending on the feedback in the real world, making them widely used in the engineering industry to control processes and manufacture multiple parts at a high speed and efficiency. PLC's can come in two main forms, these include a fixed type PLC, and a modular or rack type PLC. A fixed type PLC has a fixed number of inputs and outputs that can be used for the process, typically they come in small modules however larger ones can be used. The image shows what a fixed type PLC looks like, normally small and compact and can be used for small projects without a need for an expansion into a wider more nuanced process.



Figure A – Shows a small compact, or fixed PLC.

A modular type PLC, or rack type PLC can be typically found in larger scale industry and are widely used to control processes in factories. Modular PLC types are typically larger PLC's and are used because extra modules can be bought and added/linked onto the main PLC to add more inputs and outputs to the process. This feature makes the modular type of PLC perfect for projects that may require scaling up as the process and demand for more I/O's grows. They are also easily scaled up as the same make and model can be bought from the manufacturer and communication between the PLC and the process/machinery can be kept in a localised location.

When selecting a PLC it is important to consider the type of project being taken on, for example a simple milk filling and bottling process that requires a bottle to be filled and then a cap put on, a small fixed PLC that has up to 10 inputs and 6 outputs can be used. This type of PLC is perfect for this application if that is all the process is meant to do, however if that process is within a large factory and there is a large scale of work

then a modular PLC would be preferred as it can offer more inputs and outputs as well as expansion options should the factory and the process grow. ✓

B) Explain with the aid of a diagram the main components within a PLC and show the appropriate connections to and from the outside world.

A PLC is tasked with producing logical outputs from any number of inputs, inputs typically tend to be types of sensors, manual push buttons or switches, limit switches, temperature sensors, etc. The PLC reads this data from the input devices using the central processing unit (CPU) the CPU will

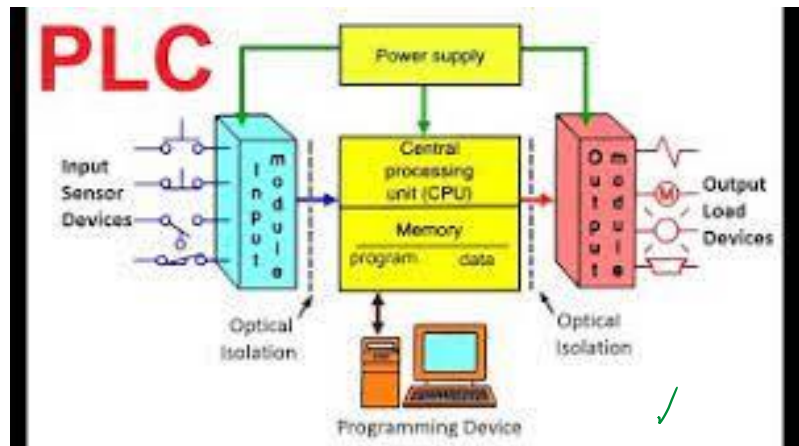


Figure B - shows the general components in a PLC and how they are connected.

perform logical actions based on its programming that is saved in memory and the data from the I/O modules. To protect the delicate internals of the PLC carried from the

input and output devices a safety measure is put in place. This safety measure is known as an optocoupler, in an optocoupler an LED is energised by the signal from an input device and the light is directed towards a photo receiver, that receives the light and thus, induces a voltage into the internal circuitry without having a direct electrical connection.

Therefore if there is a spike in the voltage it will not damage the CPU or memory of the PLC. This safety measure is also used to send signals to the output devices. (Tung, What is an Optocoupler and how it works - Jameco Electronics). The CPU will carry out all actions inside the PLC based on a clock signal, this will dictate the operating speed of a PLC. "The primary function of a clock generator is to provide a timing reference for the operation of digital circuits. The clock signal is used to synchronize the activities of various components within a digital system, ensuring that they operate in a coordinated and timed manner." (Sayed, Shift registers in PLC programs 2023). ✓

However, input and output devices require different voltages to operate, input devices such as a sensor can be powered by a 24V or 12V supply, a PLC's internals typically operate using 5V DC only so it does not damage the delicate CPU, memory or bus system. To achieve this a power supply is used, the power supply will provide the correct voltage required for the PLC's I/O modules, CPU, and memory unit. A power supply will transform the incoming voltage AC into the required 5V DC. A programming device, a ✓

laptop or computer is used to develop a program using software that is compatible with the PLC to transfer the program to the PLC, this program is then transferred to the memory unit of the PLC which will store this data to eventually be processed using the CPU when it is in use. The communications interface between the programming device and the PLC is used to transfer this data to the memory of the device. The data is then transferred around the internals of the PLC using a bus system, the bus system literally means a path in which an electrical signal can flow, this could be the printed tracks on a PCB. The data is transferred to the memory and stored in several forms, ROM (Read Only Memory) is used to store permanent data for the CPU and operating system to be able to run. RAM (Random Access Memory) is used for the user program and to store the data from input/output devices and for some of the internal data and values such as clock signal, timers etc. ✓

C) Identify methods of protecting a PLC input/output interface from potential electrical overloads or fault conditions that may occur in the field devices and explain how they are incorporated into the input and output interface.

An optocoupler, or optoisolator is often used to protect a PLC's internals such as the CPU from the output or input devices under fault conditions. An optocoupler, when energised with the correct voltage, will light up an LED, this LED light will be received by a photoreceiver and will allow current to flow into the delicate internals of the PLC. If the input voltage is too high, or in the wrong polarity, then the LED will simply not light up and light will not be received, only damaging the input side of the optocoupler. Additional protection is provided for an optocoupler in a PLC to prevent an electrical signal flowing in the wrong polarity. For DC units a diode is simply placed in the opposite direction so it will not allow current through it, A fuse can also be used in this path that will blow when there is a voltage that is too great for the LED to handle. For an AC input a bridge rectifier is used to convert the AC signal into DC, doing this means that the current can only flow in one direction through the LED. ✓

There is also an optocoupler used on the output module of the PLC, to protect from currents potentially back feeding from the output devices, as there would likely be a coil in some of these devices there are opportunities for a back E.M.F. To protect against over voltage or overcurrents even further a fuse is used that will stop electrical current from flowing any further if the voltage is too great, limiting the damages caused as a fuse is seen as a disposable item and is relatively cheap to purchase. Zener diode's can also be used to protect from overvoltages, as a Zener diode is commonly used as protection in circuits due to their working principle. If a Zener diode reaches ✓

it's maximum voltage, or breakdown voltage, it will not allow any more current to flow through it, disconnecting the load from the supply thus protecting the PLC in this case. Zener barriers are modules used to protect PLC's that are in hazardous environments such as on a oil refining plant, limiting excess voltage and current from non hazardous and hazardous areas. They monitor the current and voltage ensuring that it does not reach close to ignition levels should there be a fault in the circuit. ✓

Electromagnetic interference can also cause issues with a PLC, when there is a large amount of cables in a loom they will produce an electromagnetic field, this can cause interference and noise with other cabling carrying electrical signals. In some cases this can interfere with delicate signals related to a process that a PLC is controlling, this can be so integral that a filter is needed to filter out the unwanted interference with the electrical signal. ✓

Task 2 – Logic diagrams and truth tables

Task 2A) Produce a truth table and the Boolean equation for the logic circuit shown below (figure 1). Comment on the circuit output with respect to the inputs, noting any issues that may arise when using this configuration of logic gates.

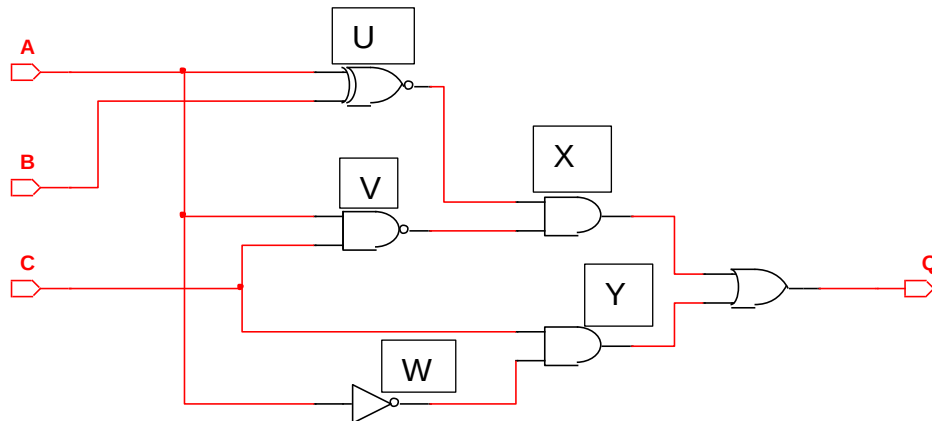


Figure 1. Logic Gate Circuit

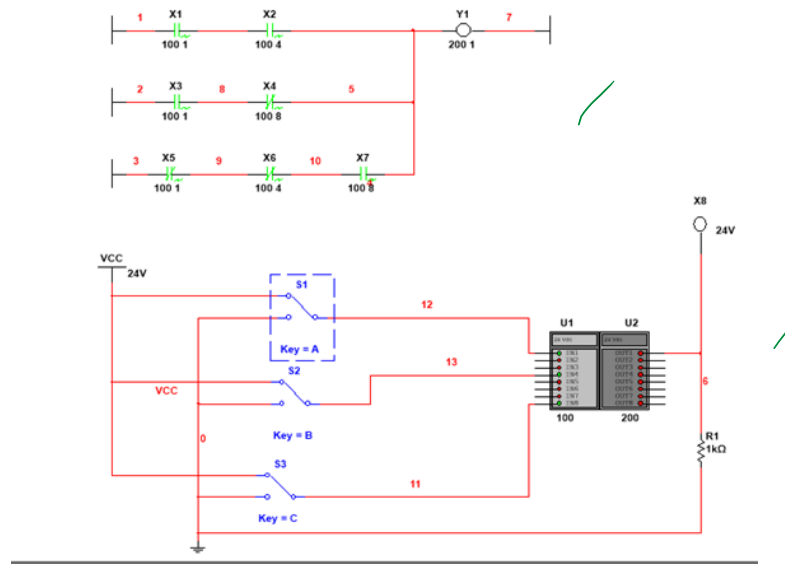
A	B	C	U	V	W	X	Y	Q
0	0	0	1	1	1	1	0	1
0	0	1	1	1	1	1	1	1
0	1	0	0	1	1	0	0	0
0	1	1	0	1	1	0	1	1
1	0	0	0	1	0	0	0	0
1	0	1	0	0	0	0	0	0
1	1	0	1	1	0	1	0	1
1	1	1	1	0	0	0	0	0

$$Q = \bar{A} \cdot \bar{B} \cdot \bar{C} + \bar{A} \cdot \bar{B} \cdot C + \bar{A} \cdot B \cdot C + A \cdot B \cdot \bar{C} \quad \checkmark$$

As can be seen in the following question, the Boolean equation can be simplified, this will result in less logic gates being used and less space being used on a chip. ✓

B) Simplify the Boolean equation and produce the ladder logic diagram for the circuit. Simulate the ladder logic design using suitable software and confirm function.

$$Q = \bar{A}.\bar{B} + \bar{A}.C + A.B.\bar{C} \quad \checkmark$$



This image shows the program in ladder logic, where the LED will light up when certain keys are pressed to show a HIGH output signal.

		BC			
A		00	01	11	10
	00	1	1	1	0
	01	0	0	0	1

Need to show the groupings

Did the system work for all inputs?

Task 3 - Timers

3a) With the aid of suitable timing diagrams explain the operation of each timer type listed below:

- On-delay timer

On delay timers are used to apply a set amount of time before a signal comes on, for example an on delay timer with a time of 10 seconds would take 10 seconds before the signal came on. A timing diagram is shown to show the incoming signal to the timer and then the output signal.

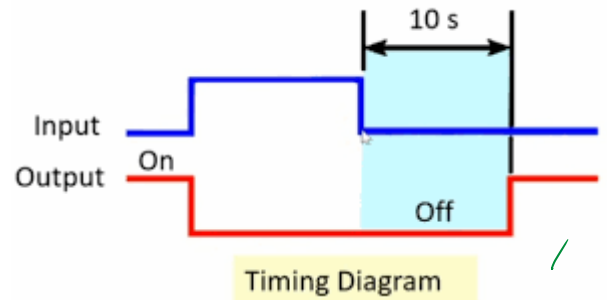


Figure C – Timing Diagram of an On delay timer.

- Off-delay timer

An off delay timer is the opposite of an on delay timer, where the output signal will stay on for a set period of time after the input signal. A timing diagram is shown which shows this signal.

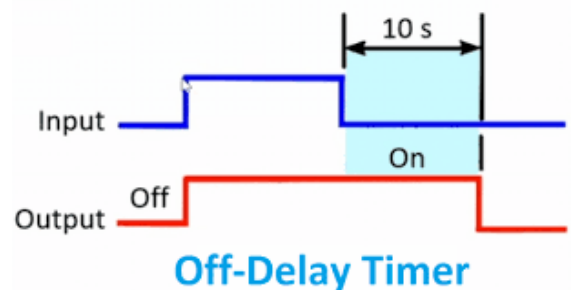


Figure D – Timing diagram of an off delay timer

- Pulse timer.

A pulse timer is used to pulse a signal on/off for set amount of times, for example a signal might pulse every 30 seconds releasing an output signal, this can be done continuously in a repetitive program.

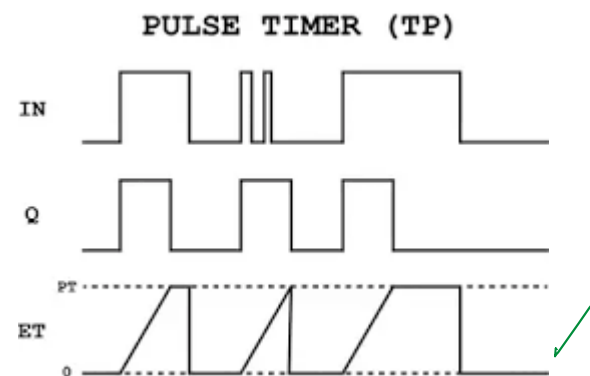


Figure E – Shows the timing diagram for a pulse timer.

3b) Explain how they can be used for sequences outputs and cascaded timers.

On delay, off delay and pulse timers can be used in a program to create a sequence, Using an input that will start a timer, this timer will then start and eventually switch on an output, the output could be a motor, solenoid valve, piston etc. Timers can also be used in a series to allow a longer time delay than what is allowed by programming software on a PLC, this is known as cascaded timers. A timer can be used in a program to control a sequenced process, for example a signal could switch a timer on which will output to a motor, however this signal could also be linked to another timer that has a greater delay than the one previously so it will only start after the previous timer has switched off, thus switching on another output. For example in a blending system that uses slow blending and fast blending, a on/off timer can be used to turn on another on/off timer which will only turn on after the previous timer has finished. Each timer will switch on an output for a set period of time and this can be repeated multiple times to create a sequence. An on delay timer can be used set to it's maximum 999 seconds, and then another timer can be used after this to increase the time of the delay until an output comes on. ✓

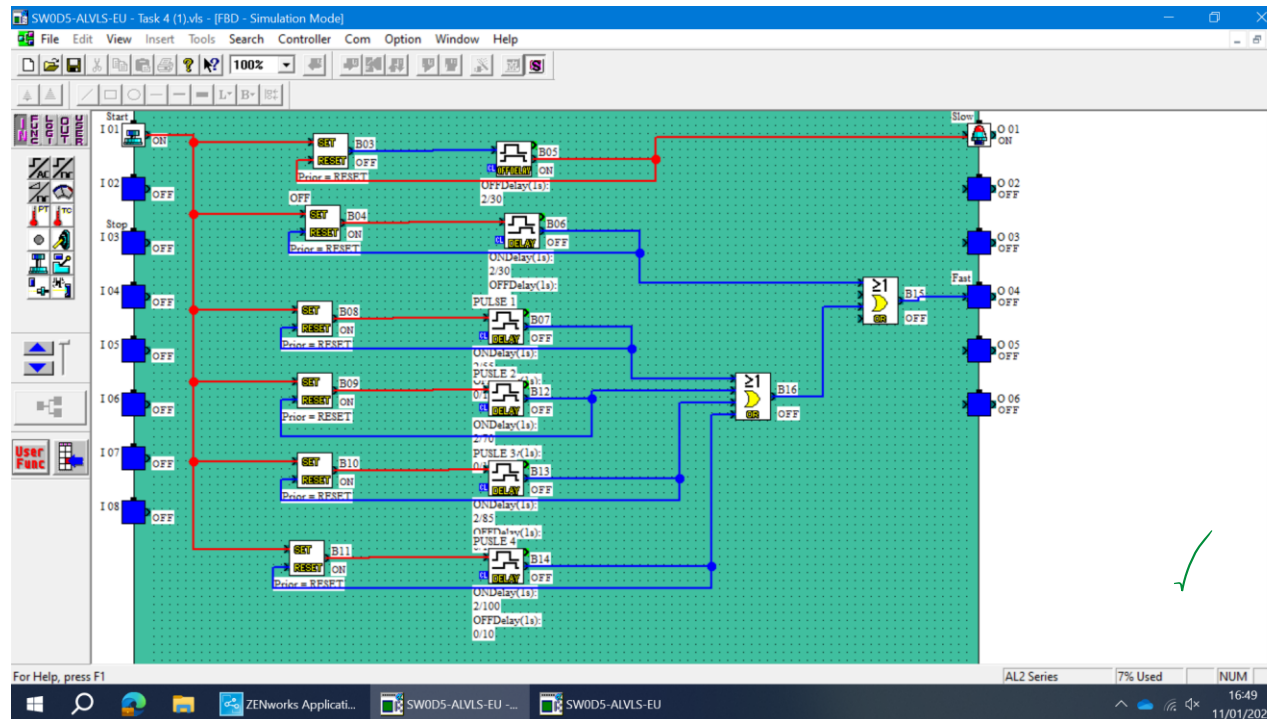
Task 4 – Programming Problems

Use the Mitsubishi Alpha software to develop programs to meet the following sequential operations:

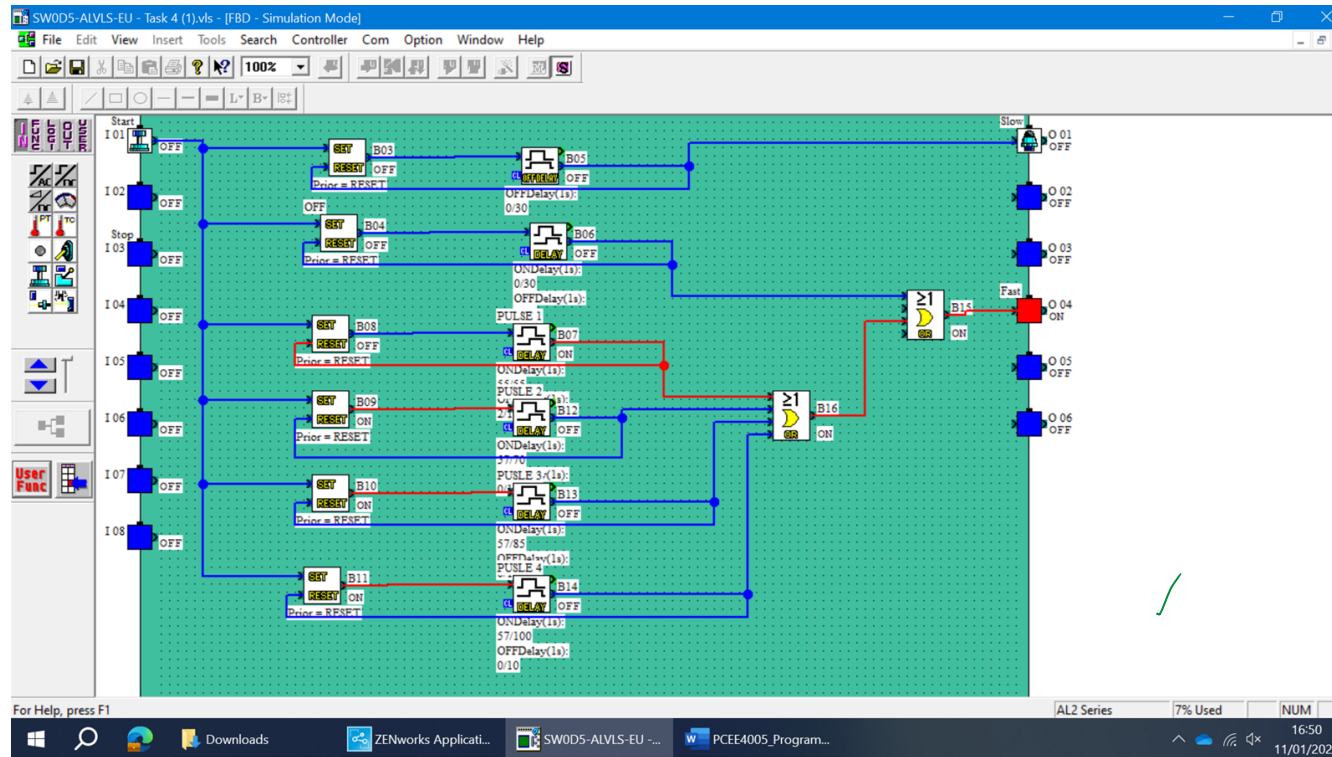
4A) For a food processing blending system the following timings are required for each stage of mixing:

1. 30 seconds of slow blending
2. 20 seconds of fast blending
3. 60 seconds period containing pulses of 10 second fast blending and 5 second off.

The cycle should be started using a momentary 'on' switch, run automatically and terminate once the pulse period has finished. Indicator lights should be used to inform the user of each stage of the cycle.

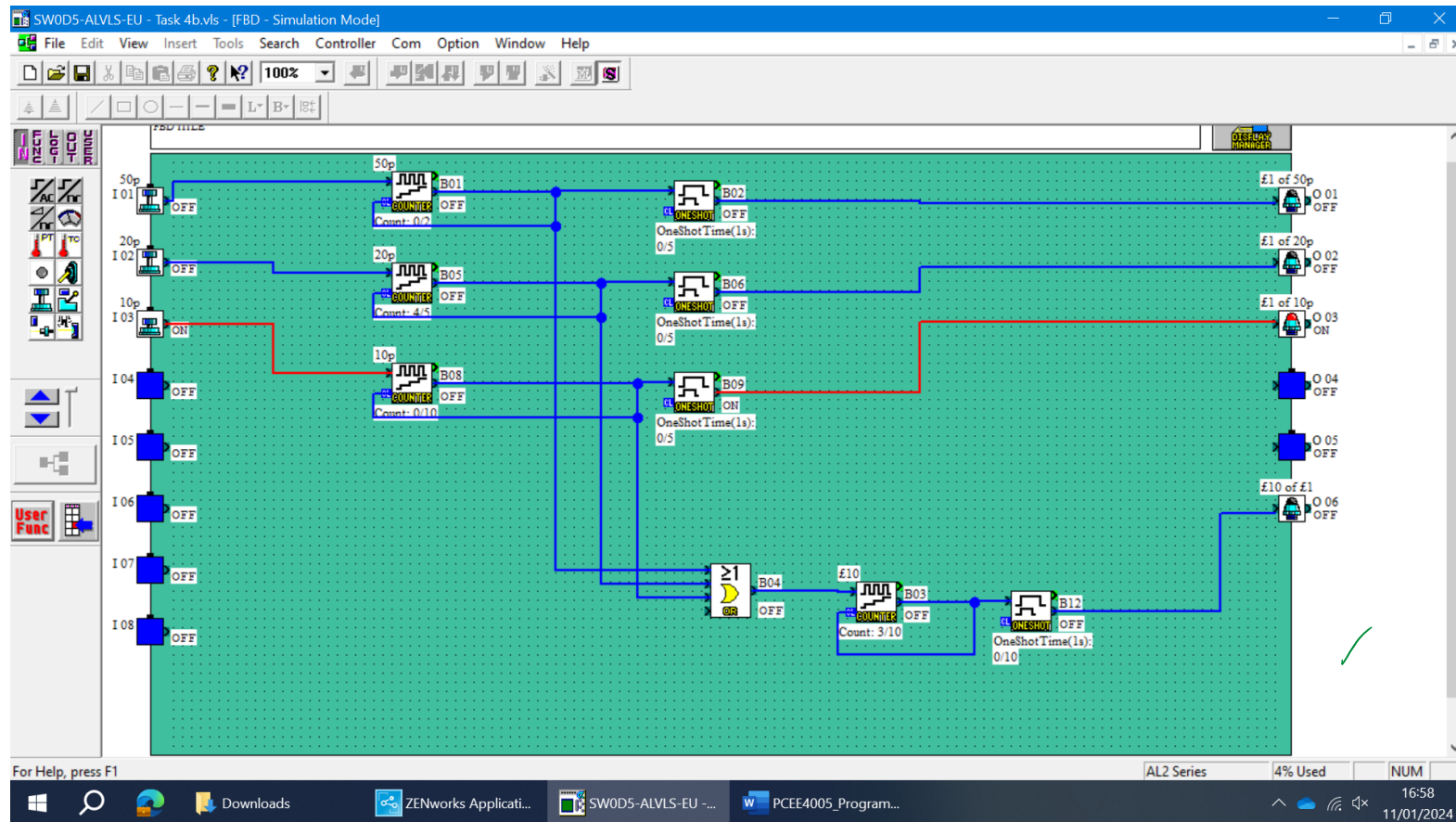


This image shows the blender using a timer off delay to begin the slow blending.

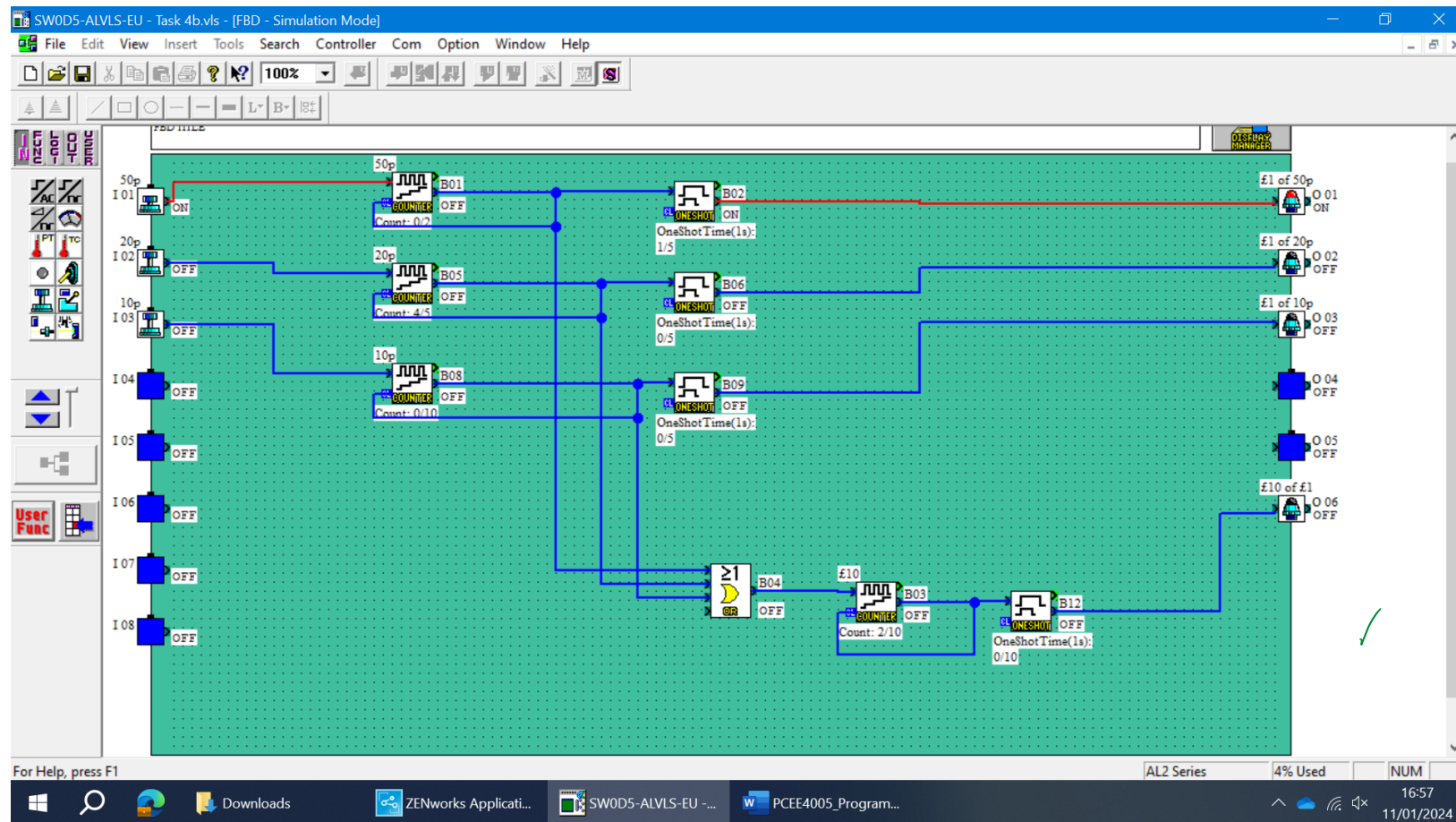


This image shows the blending program on it's first set of fast blending, to do this multiple on/off delays were used to sequentially turn on the same output. This will be repeated a further 4 times.

4B) A coin counting system is required to determine the totals of 10, 20 and 50 pence coins. Each time a coin reaches the total of a pound a different colour light will come on for each coin total. Also, a running total of every pound will be monitored and a final light will come on when the total has reached 10 pounds.



This image shows the coin counting program counting up to a £1 of 10 pennies, as shown this also goes into a counter for £10.



This image shows the counter counting £1 using 50p's, to achieve this count a one shot is used with a counter, the counter will reset once it reaches it's target value.

Task 5 – Automatic Drilling System

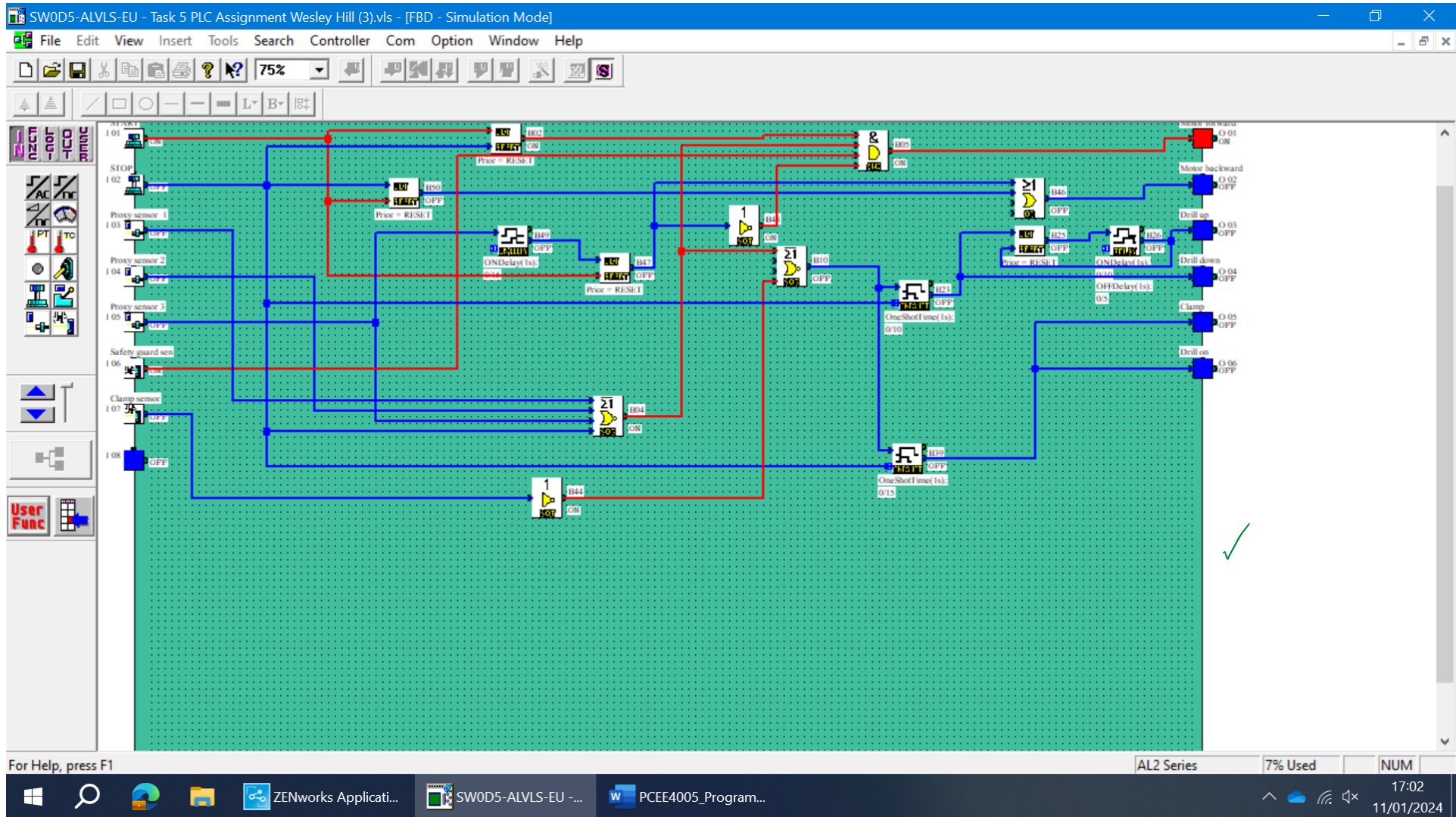
To complete this task, you are required to demonstrate the operation of your program and discuss its functionality including any improvements that could be made to the system.

As attached to the report, there are screenshots of the program made in Mitsubishi Alpha. This program was created by Wesley Hill and the I/O connections are as follows:

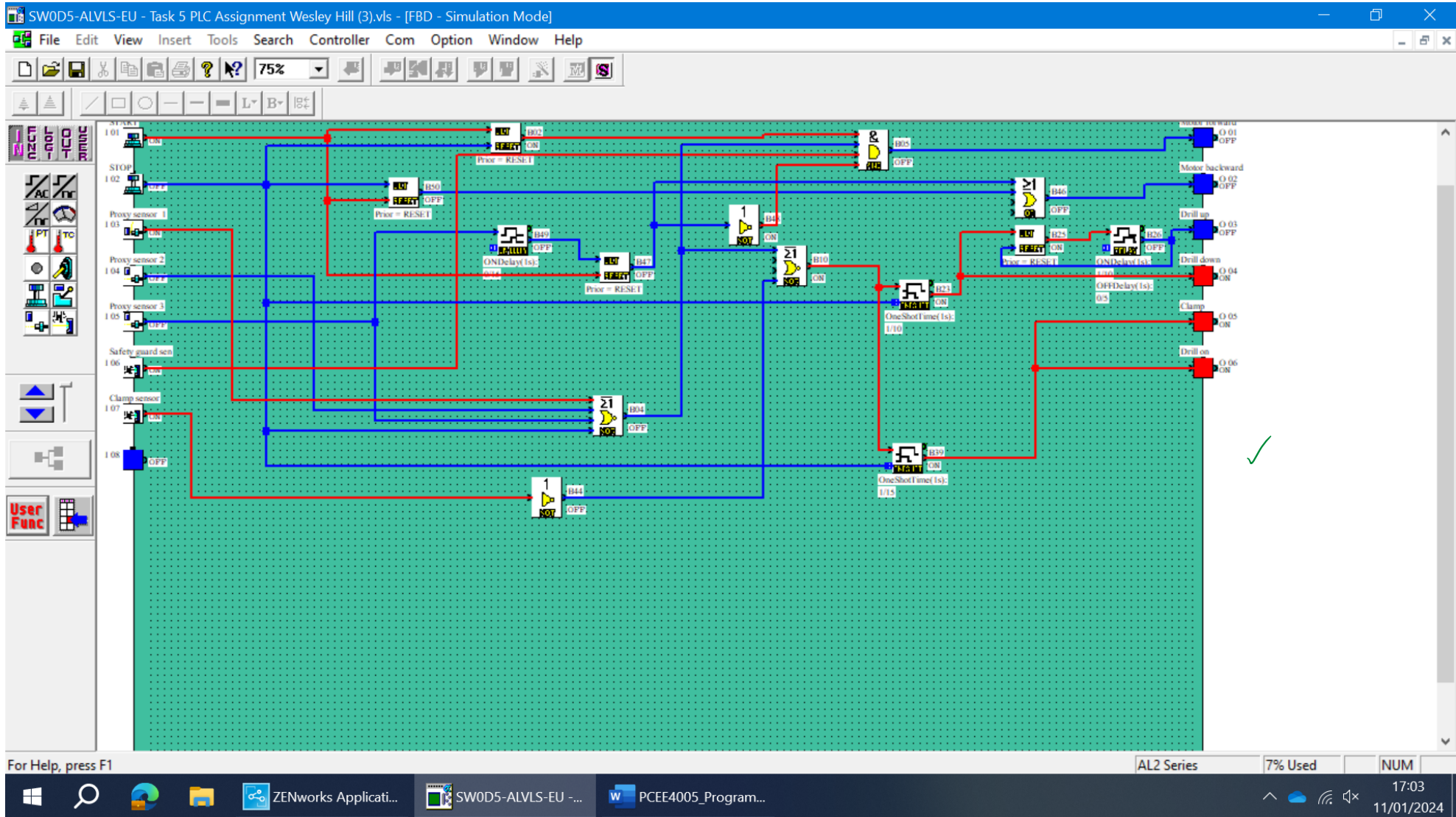
PLC I/O Connection			
Input		Output	
1	Start button	1	Motor forward
2	Stop button	2	Motor backward
3	Proximity sensor 1	3	Drill servo up control
4	Proximity sensor 2	4	Drill servo down control
5	Proximity sensor 3	5	Clamp
6	Safety Guard	6	Drill on
7	Clamp sensor		

The program of the automatic drilling system is shown to work to the required specification, the specification is as follows:

- The process will start when the safety guard is pulled down and start button is pressed.
- The motor will move the bar to position 1, this will start the drill.
- The bar will be clamped and the drill will be lowered. It will take 10 seconds to drill through the bar and 5 seconds to return to its start position.
- The clamp will be released and the motor will move the bar to position 2 and step 3 is repeated.
- The clamp will be released and the motor will move the bar to position 3 and step 3 is repeated.
- The drill will be stopped, bar will be unclamped and the motor will return to start position.
- If the stop button is pressed the drill will return to its up position and stop. The bar will be unclamped and the motor return to its start position.



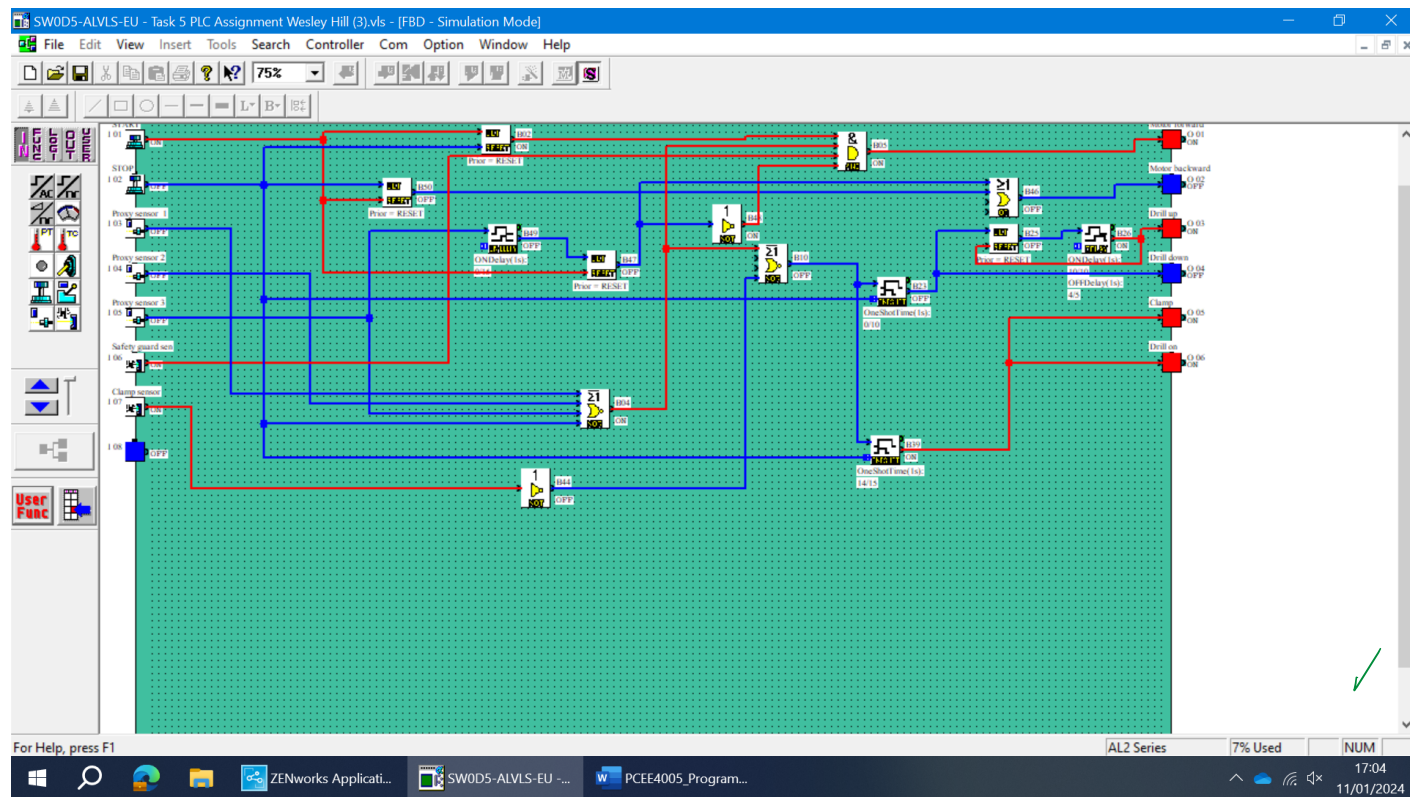
This image shows the motor starting, it will only start when the start button is pressed and the safety guard is down, this will then drive the bar forwards until it reaches the first proximity sensor.



This image shows the drill going down with the clamp and drill on, this is caused by a off delay timer which will stay on for the duration that the drill takes to drill the material.

The drill does this using a start button to activate a set/reset which goes into a logic AND gate to activate the motor running forward. The sensors used also all go into a logic NAND gate that is used to stop the motor from going forwards when a sensor is activated and it is drilling. To drill for the required amount of time a few on/off delay timers are used with a set reset to input the signal to each of these timers, the timer will activate to send the drill down whilst the other timers are set and remain off for a short period of time whilst the drill is drilling. The drill will then return to it's maximum height and switch off until the next sensor is activated. The process will also only stop on the stop button however it will not start unless the safety guard is down. This program however, is flawed in some ways, firstly the safety guard must be down for the process to start, yet it can technically be opened and the program will still carry out each task as it should. This increases the risk greatly of a potential entanglement within the machinery, making it unsafe and not technically legally able to be used in the UK under multiple regulations including the Provision and Use of Work Equipment Regulations. ✓

The use of timers in this program could also be improved, as each timer is activating the drill there is no way of clearing the signal from the timer to stop the output under fault conditions, this means that if something goes wrong such as someone is caught in the machinery or the bar has not been clamped properly etc, then the drill will still undergo it's cycle of drilling down, and returning up before stopping, this is another safety feature that is missing from the program making it potentially dangerous to operate. In reality each of the timers should have a way of clearing the signal from them should a fault happen such as the guard going up or the emergency stop button being pressed. In the real world the sensors would need to be overridden somehow as in the current program they will not turn off until they are manually turned off during the simulation, therefore this may be a limitation in the choice of program, PLC, or programming language, as a ladder diagram may be more suited to carrying out this sequence. The clamp can also remain on in the program even if the motor is driving forwards or backwards due to it being controlled by a timer, again this can result in a fault. ✓



This image shows a potential fault with the program, the clamp and drill are still on whilst it is returning up however because a sensor was tripped it can result in the motor returning whilst these are still on, with the clamp still on.

References

Tung, M. (no date) *What is an Optocoupler and how it works - Jameco electronics*. Available at: <https://www.jameco.com/Jameco/workshop/Howitworks/what-is-an-optocoupler-and-how-it-works.html> (Accessed: 02 January 2024).

Sayed, M.M. (2023) *Shift registers in PLC programs, LinkedIn*. Available at: <https://www.linkedin.com/pulse/shift-registers-plc-programs-mostafa-mohamed-sayed-xbjwc#:~:text=The%20clock%20signal%20is%20used,a%20coordinated%20and%20timed%20manne>r. (Accessed: 02 January 2024).

Need more sources, also a lack of text books

Figure A -

https://www.google.com/imgres?imgurl=http%3A%2F%2F5.imimg.com%2Fdata5%2FQR%2FJB%2FVY%2FIOS-37763009%2Fproduct-jpeg-500x500.png&tbnid=-DHOQGtmH81D2M&vet=12ahUKEwji-uTG0MSDaxU6kCcCHX7wBQUQMygMegUIARC6AQ..i&imgrefurl=https%3A%2F%2Fm.indiamart.com%2Fproddetail%2Fmitsubishi-melsec-plc-21687740788.html&docid=3YvvGcW_IYNjrM&w=500&h=500&q=mitsubishi%20melsec%20plc&ved=2ahUKEwji-uTG0MSDaxU6kCcCHX7wBQUQMygMegUIARC6AQ

Figure B - https://www.google.com/imgres?imgurl=https%3A%2F%2Finstrumentationtools.com%2Fwp-content%2Fuploads%2F2019%2F07%2FPLC-Components.png&tbnid=3JSiv4a2n5bCM&vet=12ahUKEwjRju__0sSDaxViAfsDHfZSAqEQMygAegQIARBL..i&imgrefurl=https%3A%2F%2Finstrumentationtools.com%2Fcomponents-of-plc%2F&docid=oiGAMvq1XPOFVM&w=902&h=525&q=components%20of%20plc&ved=2ahUKEwjRju__0sSDaxViAfsDHfZSAqEQMygAegQIARBL

Figure C - https://www.google.com/imgres?imgurl=https%3A%2F%2Fqph.cf2.quoracdn.net%2Fmain-qimg-07c827ca56943034047cb359570df5bf&tbnid=Bv_HI0EZnwUewM&vet=12ahUKEwiusNz8SDaxXAsCcCHclsDacQMyghegUIARCQAQ..i&imgrefurl=https%3A%2F%2Fwww.quora.com%2FWhats-the-difference-between-an-ON-delay-and-an-OFF-delay-timer&docid=tKdFQbbUyQ-PPM&w=302&h=167&q=on%20delay%20timer%20timing%20diagram&ved=2ahUKEwiusNz8SDaxXAsCcCHclsDacQMyghegUIARCQAQ

Figure D - https://www.google.com/imgres?imgurl=https%3A%2F%2Fwww.geya.net%2Fwp-content%2Fuploads%2F2022%2F08%2Fwechat-image_20220826161058.png&tbnid=4Inf_6fqkFAJzM&vet=12ahUKEwui9d2_08SDaxWSU6QEHa

BzA-0QMygBegQIARBI..i&imgrefurl=https%3A%2F%2Fwww.geya.net%2Foff-delay-timer-relay-meaning-working-and-application%2F&docid=MjNXljOGAHlXWM&w=567&h=303&q=Off%20delay%20timer%20timing%20diagram&ved=2ahUKEwui9d2_08SDAxWSU6QEHaBzA-0QMygBegQIARBI ✓

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