

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Kyle Clemson	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	3
Little or no evidence of reading and reliance on inappropriate sources. Referencing conventions are largely absent.		
2. Knowledge and Understanding Skills	30	17.3
Task 1 achieved 65%. Task 2 achieved 40%, Task 3 achieved 68%. Competent knowledge of the basic underlying concepts and principles of the work required for Task 1 and 3. Showed limited knowledge and understanding of the requirements of Task 2.		
3. Cognitive and Intellectual Skills	5	0.5
4. Practical Application Skills	40	28
Task 4 achieved 70%. Task 5 achieved 70%. 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	6.8
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)		56%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

PCEE4005 – Programmable Logic Controllers

Kyle T Clemson

Pembrokeshire College, on behalf of The University of Wales Trinity Saint David

11th January 2024

Lecturer – Jason Pointer

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1 | Programmable Logic Controllers

1.1 | Modular and Compact PLCs

Despite the various brands and configurations that Programmable Logic Controllers (henceforth referred to as PLCs) are categorized by, there are only two distinct types. Those being the Modular PLC (also known as Rack) and the Compact PLC (also known as Integrated). While similar at a baseline of operation, they are both tailored to specific needs. ✓

Modular PLCs are an essential part in industrial scale automation processes, designed to monitor and control machinery systems within a large-scale factory or manufacturing environment. Its most characterizing feature is all the components that make up the system are split into their own respective blocks (or modules) which are installed on a rack. This architectural design allows users to tailor the system to fit specific requirements by adding or removing modules. This provides the benefit of modular PLCs being incredibly versatile regarding their functionality, proving them to be very suitable, for more complex automation processes (such as the monitoring of power station turbines and generators, chemical processing plant monitoring and quality control, water treatment facility chemical dosing and filtration, steel factory production and casting. To name a few). However, due to this characterizing design, the modular PLC is held back by its purchasing price, as each individual component must be purchased separately. ✓

On the other hand, Compact PLCs are characterized by their integrated design. Housing all the necessary components of the system being contained within a single unit. This architectural feature renders the PLC more suitable for environments where there is limited space (without compromising on functionality), or in applications where a smaller-scale setup would be more beneficial. A compact PLC is often chosen for smaller and more simplistic automation processes (such as within vending machines, air conditioning systems, car park barrier control/payment systems) where extensive customization options are not required or necessary. Although, small customization options are still available with the optional extension of its I/O modules. ✓

Ultimately, the use of Module or Compact PLCs entirely depends on the scale of the controlled process, the specific requirements of the project, the accessibility of the area, and the overall complexity of the process. All these factors must be considered in detail when approaching a project to ensure the chosen variety provides cost-effective and reliable operation. ✓

1.2 | Components of a PLC

Despite the architectural differences between the two varieties of PLC, they both share fundamental components that are essential to their operational needs. Those being the **Central Processing Unit, Power Supply Unit, Input/Output Modules, Communication Ports**, and system **Memory**.

The **Central Processing Unit** (commonly referred to as the CPU) operates as the 'brain' of the system. It is responsible for performing complex logic calculations and fetching programmed instructions from the memory unit and executing them based off the information it receives

from the input ports. This component is essential to the overall speed and efficiency of a PLC system. ✓

The **Power Supply Unit** (commonly referred to as a PSU) is the component which acquires electrical power from a source, converts it to a form suitable to energize the PLC, and distributes it amongst the integrated components. The provided voltage levels are regulated to ensure the proper operation of all connected parts of the PLC. ✓

The **Input/Output Modules** (commonly referred to as I/O Ports/Modules) are how a PLC interacts with external control devices. They provide the function of receiving and transmitting signals to and from the PLC. More specifically, Input modules are connected to external devices such as sensors or switches, where any changes in their state is received by the input and converted into a format that the CPU can recognize. Input modules can either be Digital or Analog, with digital ports handling binary signals (1 or 0 states, such as a switch), whilst analog ports handle continuous process signals (current or voltage signals from a temperature sensor for example). On the other hand, Output modules then transmit the decided action to the controlled device. Output ports are also separated into Digital and Analog, sharing the same principle as the Input ports. ✓

Communication Ports are how the PLC communicated with any external devices or networks. There are various adaptations of ports that are used for this purpose, such as Serial Ports (allows connection to computers, Human-Machine Interface panels, or other PLC systems), Ethernet Ports (to enable communication over Ethernet network), and USB ports (allows the user to interface with the PLC). ✓

The system **Memory** functions as the storage location for all the PLCs data. This memory is split into two types, Random Access Memory (RAM) and Read-Only Memory (ROM). RAM is referred to as being 'Volatile' due to any stored data being lost whenever the system loses power. RAM is used to store all the temporary data such as process variables and the control program (only during operation). ROM acts the opposite to its counterpart, possessing the ability to retain its stored data even during the loss of power. ROM storage often contains the more essential software for a PLC, including its firmware, the user-developed program (which transfers to the RAM during start-up), and the operating system. ✓

Both variants of PLC require these core components to operate effectively, with the only differential feature being their respective design. The compact PLC hosts all components within one housing unit, with the I/O ports being located on either side of the housing. Whereas the rack PLC features all components within their own respective modules. ✓

Below is a simplistic view of how these core components of a PLC all work together, in the form of a block diagram (*figure 1*). As can be seen, the Power Supply Unit provides the electrical energy to energise the PLC and its I/O ports (as these would be separated on a modular PLC). The main 'block' of the PLC is what houses the Central Processing Unit, RAM (data) and ROM (user) components, and the various serial ports which may be installed onto the device. ✓

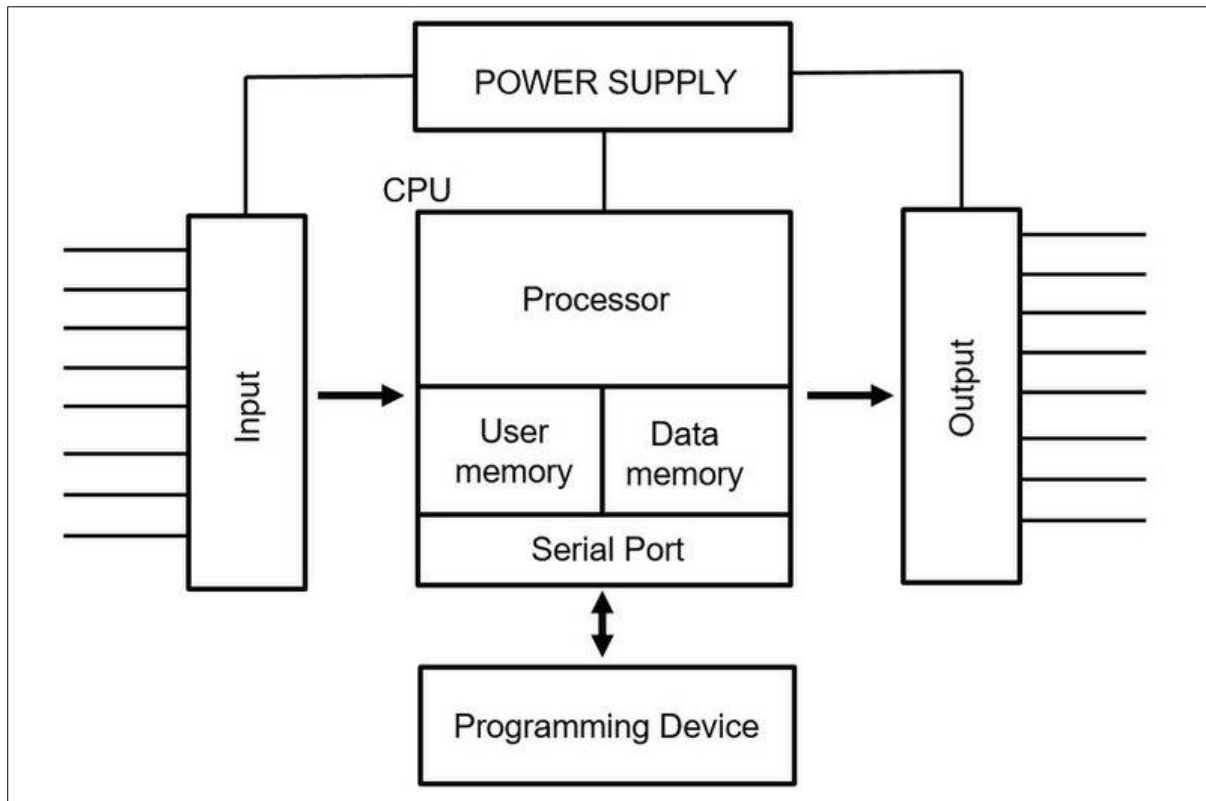


Figure 1: Simplistic Block Diagram of a PLC system. Source: Wikimedia Commons

Pictured below in (*figure 2*) is a front-face view of a Compact type PLC. Visible components include the 25V DC input to the power supply (upper left most of the device), the visual user display of the PLC, 12 DC input ports (upper centre of the device), an integrated ethernet communication port (central right hand side), and 6 output ports (lower portion of the device).



Figure 2: Compact PLC Source: Eaton company website

1.3 | PLC Protection

Various methods can be employed to protect PLC systems from external occurring faults. These methods are often used to protect the device(s) from electrical overloads that may travel through the I/O modules of the PLC and damaging the more critical internal components. Some of these methods are simplistic in nature regarding their operating principles and method of integration with the circuit. An example of these more simplistic methods is the insertion of fuses, circuit breakers, and resistors in series with the connections leading to the PLC modules, which will provide protection against current spikes from damaging the internal components. Whilst other methods may require more consideration regarding their installation, such as surge suppressors, transient voltage suppressors, and metal oxide varistors having to be installed in parallel with the system to divert any excess energy that may be transmitted.

One preferred method of protection from outside faults is the Optical Isolator. These devices provide complete isolation from external field devices by having a break in contact with the incoming or outgoing signal, acting as a barrier. This is achieved by means of an optocoupler (or opto-isolator). The operating principle of an optocoupler consists of a light-emitting diode being located on the input side of the connection (on the external side of the input module, and the internal side of the output module), and a photocell (or an alternate light-sensitive device) being located on the output side of the connection (on the component side of the input module, and the external side of the output module). When a signal is applied to the LED it begins to emit light, the intensity of which is directly proportional to the current of the input signal. The light is detected by the photocell which converts the intensity of the light into a corresponding electrical signal which is received by the PLC or transferred through the output.

2 | Logic Diagrams and Truth Tables

2.1 | Logic Circuit Truth Table

The following circuit was presented for the author to produce a truth table and Boolean algebra equation for its operation. The circuit is located in *figure 3*, whilst the truth table has been inserted in *figure 4*.

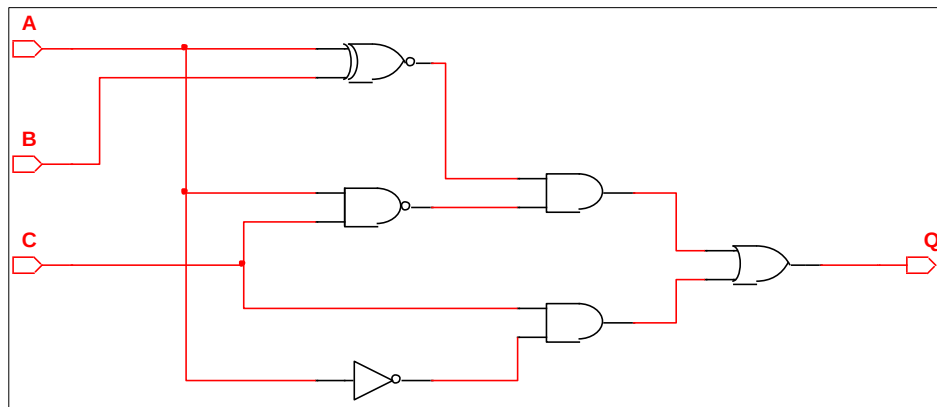


Figure 3: Logic gate circuit

A	B	C	R	S	T	U	V	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

Table 1: Circuit truth table

By studying the truth table above, the algebra equation of $Q = \overline{A}BC + \overline{A}B\overline{C} + A\overline{B}C + ABC\overline{C}$ can be deduced from the findings.

2.2 | Simplification of Truth Tables

A ladder logic diagram was produced by means of the Multisim circuit creation software to test the functionality of the circuit, as seen in *figure 4* below.

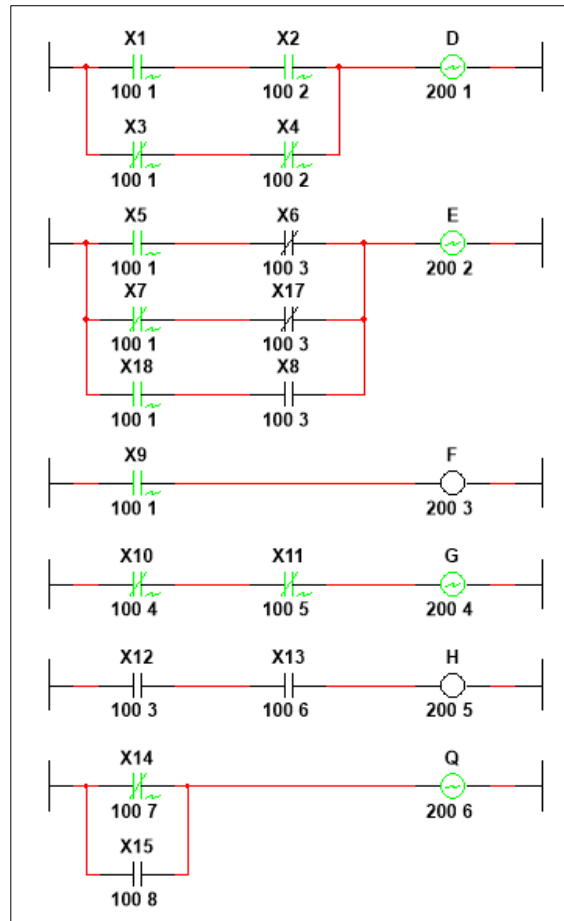


Figure 4: Multisim circuit for the logic gates.

This is not the simplified version.

Also why are there so many output coils?

Alongside this, the Boolean equation stated previously was simplified by means of a Karnaugh map. It was found that the expression simplifies to the equation $Q = \overline{A}B + \overline{A}C + ABC$ ✓

1	1	1	0
0	0	0	1

Table 2: Karnaugh map of the Boolean equation

✓

Need to show the groups.

No circuit diagram showing the PLC.

3 | Timers

3.1 | The Operation of Timers

Among all the functions that are utilized when programming PLC systems, timers are one of the most useful and diverse. Timers are a key function to creating time-sensitive operations as they introduce the capability to insert time delays into a program which require a strict timing of events, such as timing the energization of a motor after a set cooling period, or the coordination of robotic arms on a manufacturing line to maintain precision and accuracy. The function of timers can be altered to provide a small variety of operations, these being the **On-delay**, **Off-delay**, and **Pulse** timers. ✓

On-delay timers are used to introduce a delay between the initial input signal and the activation of the output control signal from the timer block. After receiving the input signal the timer enters a state where the signal is not transferred until the predetermined amount of time has passed, in which the signal is then transmitted after the set delay has concluded. The output signal from the on-delay timer will remain energized until the input signal is lost, or a separate signal is received to the clear function of the timer. Visual aid for this operation can be seen below in *figure 5*. ✓

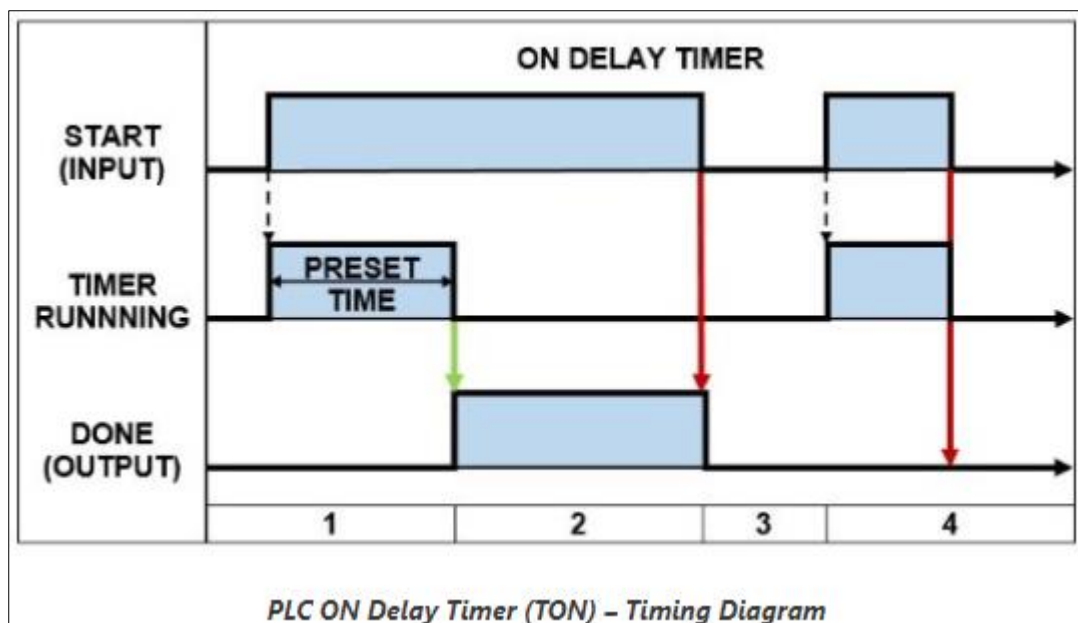


Figure 5: PLC On-delay timing diagram. Source: Ladder logic world

Off-delay timers introduce a delay between the loss of the input signal and the halting of signal transmission through the timer output. Upon receiving an input control signal the timer will energize the output to the controlled device simultaneously. After the initial input signal to the timer block has been lost, the internal timing mechanism will begin whilst the output signal continues to be transmitted. It is only when the predetermined time has elapsed that the output signal is halted. Visual aid for this operation can be seen below in *figure 6*.

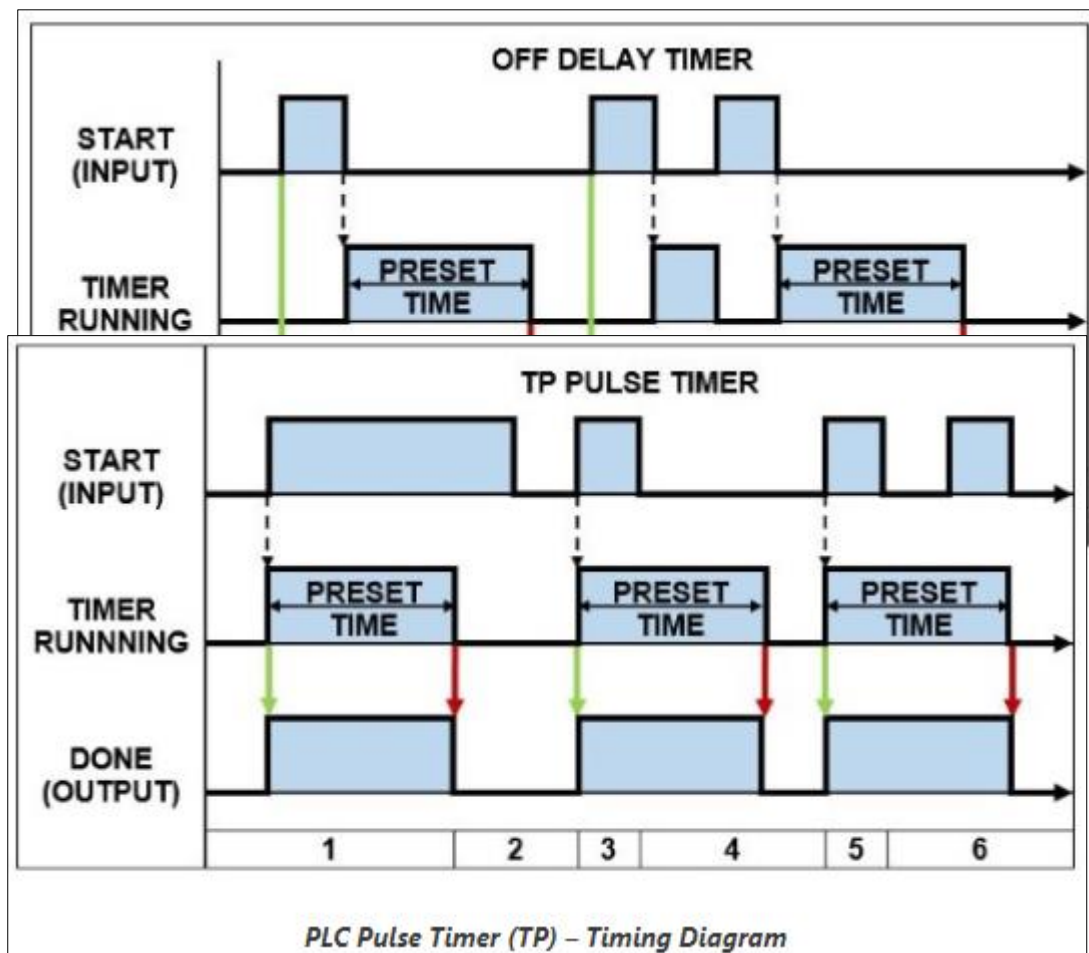


Figure 7: Pulse timer timing diagram. Source: Ladder logic world

Pulse timers introduce the capability to provide an output signal to a device for a set amount of time. To explain further, when an input signal is received by the pulse timer block it is immediately transferred through the output as a control signal. However, this outgoing signal will continue to operate for a predetermined amount of time regardless of whether the input state changes or exceeds the output time. Visual aid for this operation can be seen below in *figure 7*.

3.2 | The use of Cascaded timers and Sequencing Outputs

The common application of the timer functions is their use in cascaded sequences of delays and sequential controlling operations. **Cascaded** operations involve having multiple timer

functions connected in series, with each timer input being controlled by the output of the one previous. While **Sequential** operations refers to the times operation or deactivation of outputs to achieve specific process order. Inserting a combination of timer variants in a cascaded fashion provides the ability to order a sequence of events in a process. For example, it can be seen below in *Figure 8* that a cascaded sequence of on and off-delay timers have been implemented in such a way that the on-delay timer operates one second after the off-delay timer is set to deactivate its output control, producing a set order of operations which activate in a sequence. Pulse timers may be implemented into a process such as this if there was a requirement for the short duration operation of an output, such as the brief activation of a bell when an elevator reaches its desired floor.



4 | Programming Problems

4.1 | Food processing blending system

The author was tasked with creating software for a food processing blending system which had to follow a set routine of timings for each stage of the process. Those timing being “30 seconds of slow blending. 20 seconds of fast blending. 60 seconds period containing pulses of 10 second fast blending and 5 seconds off.” as well as the program having to “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.”

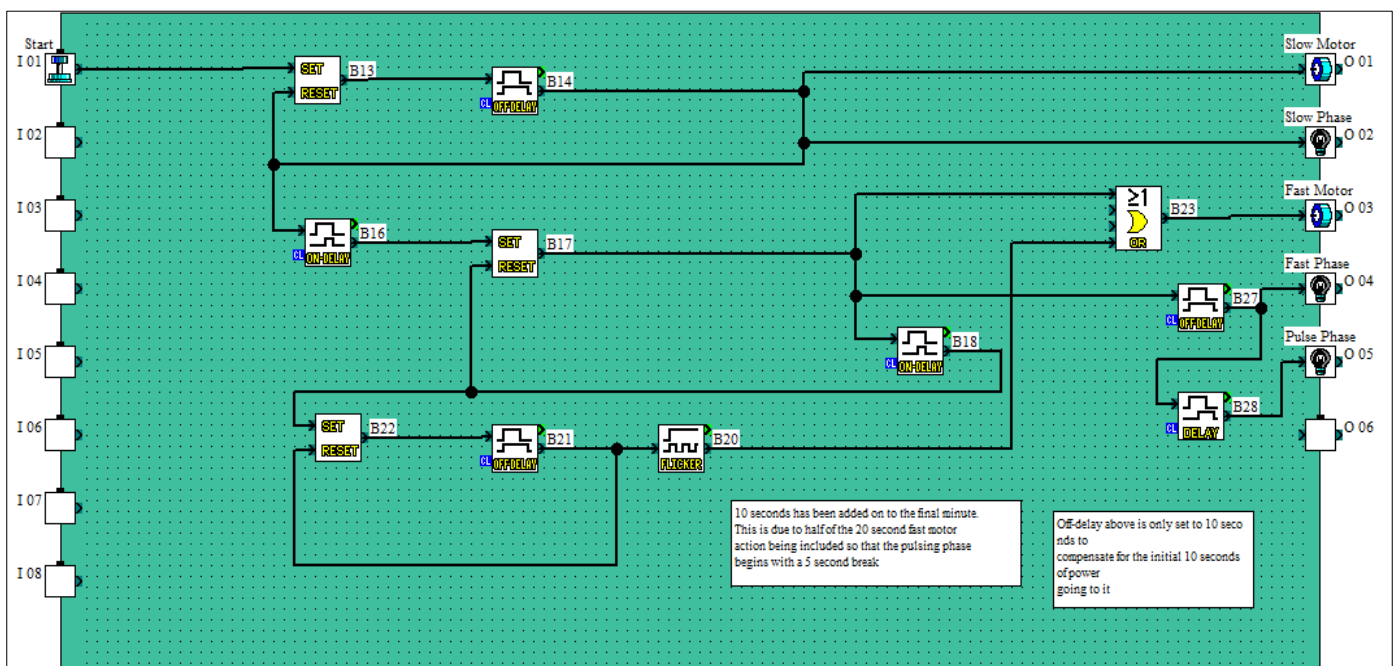


Figure 8: Food processing blending program

The created program utilizes a series of cascaded timers to separate and operate the three cycles in the required sequence, with the start and end of each process stage being activated in a precisely timed sequence of operation.

Need a statement that confirm the operation.

4.2 | Coin counting system

The author was also tasked with creating software which monitors the input count of each coin being inserted into a coin counting system. The specific requirement being the counter “determining the totals of 10, 20, and 50 pence coins” with the addition of “a different coloured light coming on for each coin entered, and a final light coming on when a total of 10 pounds has been reached.”

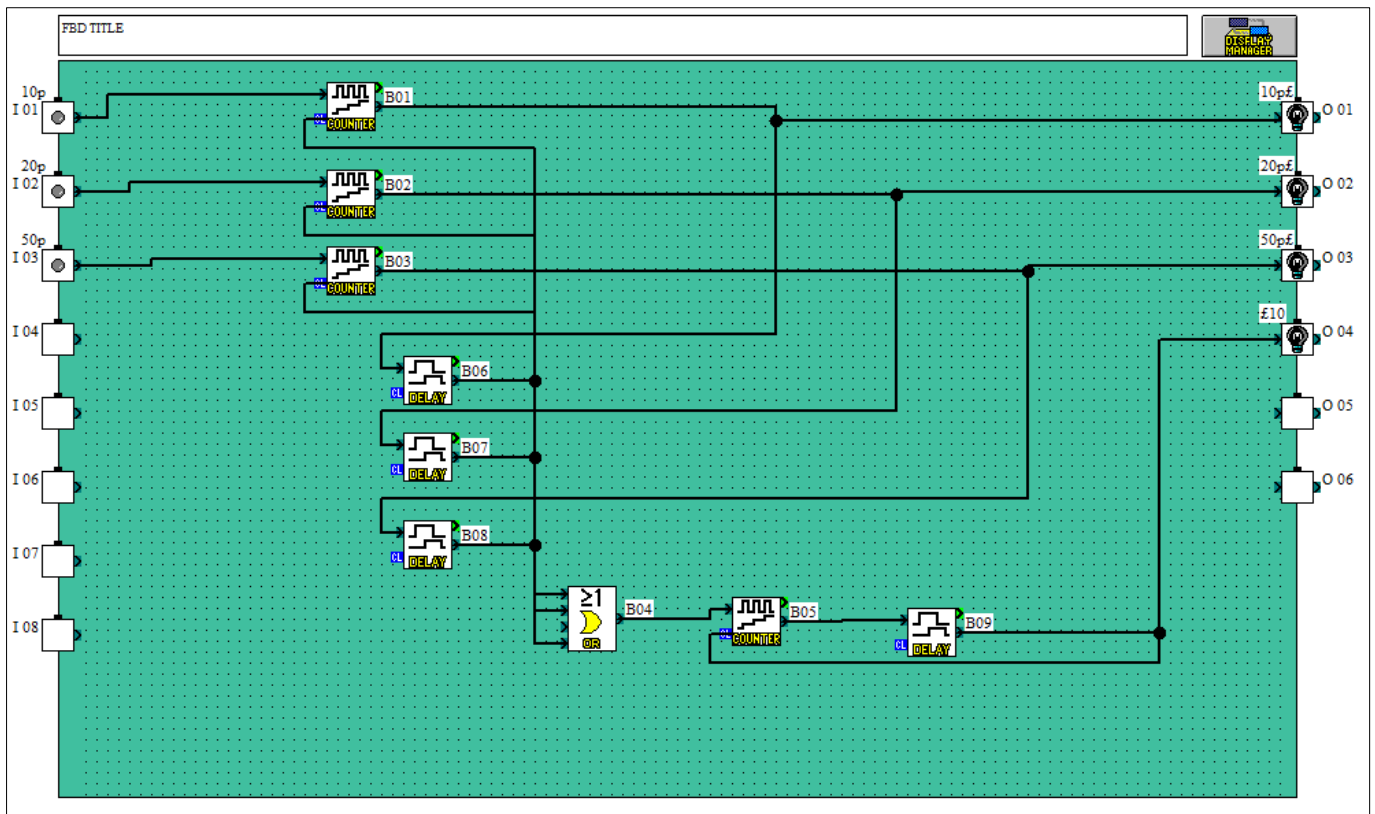


Figure 9: Coin counting program

Be careful with the layout.

This program features the use of the counter function blocks to energise the appropriate light source for each coin being inserted. The counters to the left operate once each of the respective coin totals equal 1 pound, with a secondary counter monitoring each pound total until an overall total of 10 pounds is reached. The delay blocks are used to reset the counter totals after the light has illuminated for a set amount of time.

No confirmation of operation.

5 | Automatic Drilling System

5.1 | Drilling system program

The final assigned task requested the creation of a PLC program which controlled an automatic drilling system. In theory, the system was to cover the following requirements, “*1. Motor to move the bar to position 1, this will start the drill. 2. The bar will be clamped, and the drill will be lowered (10 seconds down, and 5 seconds up). 3. The clamp will be released, and the motor will move to position 2 and step 3 repeated. 4. The clamp will be released, and the bar will move to position 3 and step 3 repeated. 5. The drill will stop, the bar unclamped, and the motor to return to its start position.*”

For phase 1, the pressing of the start button is held by a set/reset function block which holds the activated signal (note that the reset of this block is controlled by the guard of the drill, preventing operation whilst the guard is in the upwards position). This begins the forward movement of the motor until the first sensor is energized, which stops the drill (by means of an exclusive OR gate) and triggers a delay and one-shot signal, starting the drill.

Phase 2 includes the clamp being operated along with the drill starting, before a cascade of delay function blocks control the timing of the downwards drill motion of 10 seconds, before a one second pause and the drill returning upwards for 5 seconds.

Phase 3 includes the clearing of the initial delay from phase 1, allowing the drill to continue moving forward until the second position sensor is energized. Repeating the process above for this phase and phase 4.

After the completion of phase 4, the counter block (which has been monitoring each trigger of the sensors) energises after the three sensors have operated. This signal prevents the forward motor signal from activating its output (by means of another XOR gate) and instead operates the backwards motor output. Returning the motor to its starting point.

An improvement could be made by learning and utilizing Boolean function blocks as part of the program as they would provide a method of implementing logical operations without the need of several logic gates cluttering the visuals of the program screen (as well as making the operation more understandable from an outside perspective). Most functions used within the program could be executed with more precision with this method, except for XOR gates. Although, this could be achieved with edge detection or comparison functions.

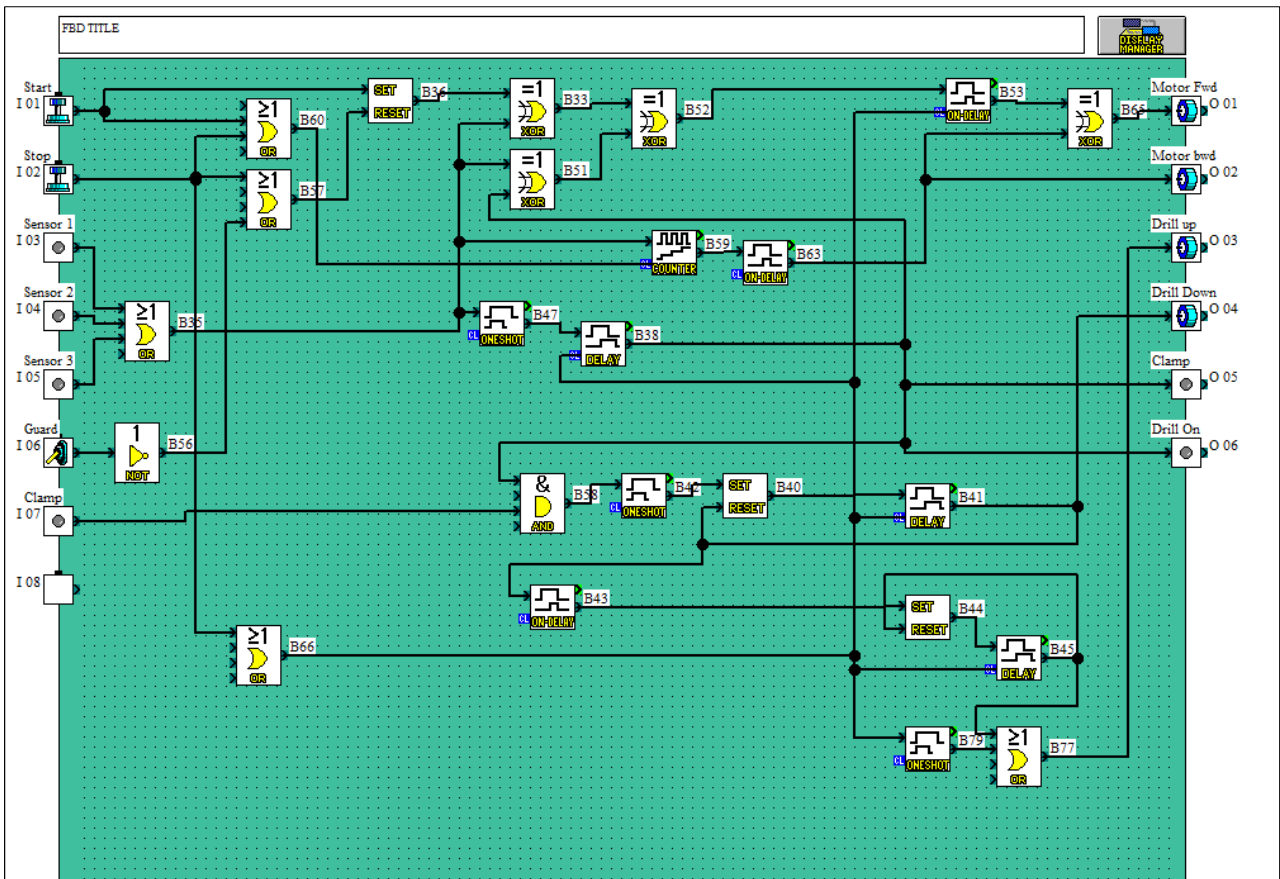


Figure 10: Automatic drilling program

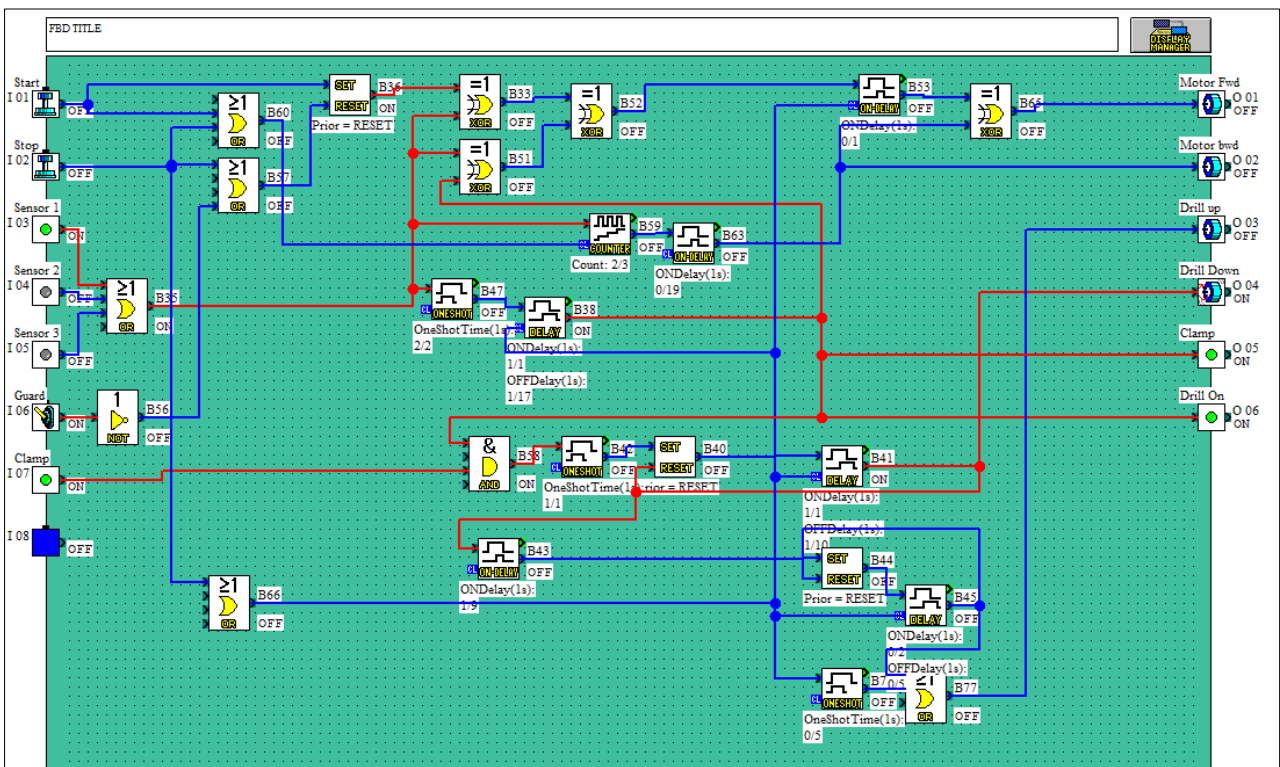


Figure 11: Downward drilling motion on the program

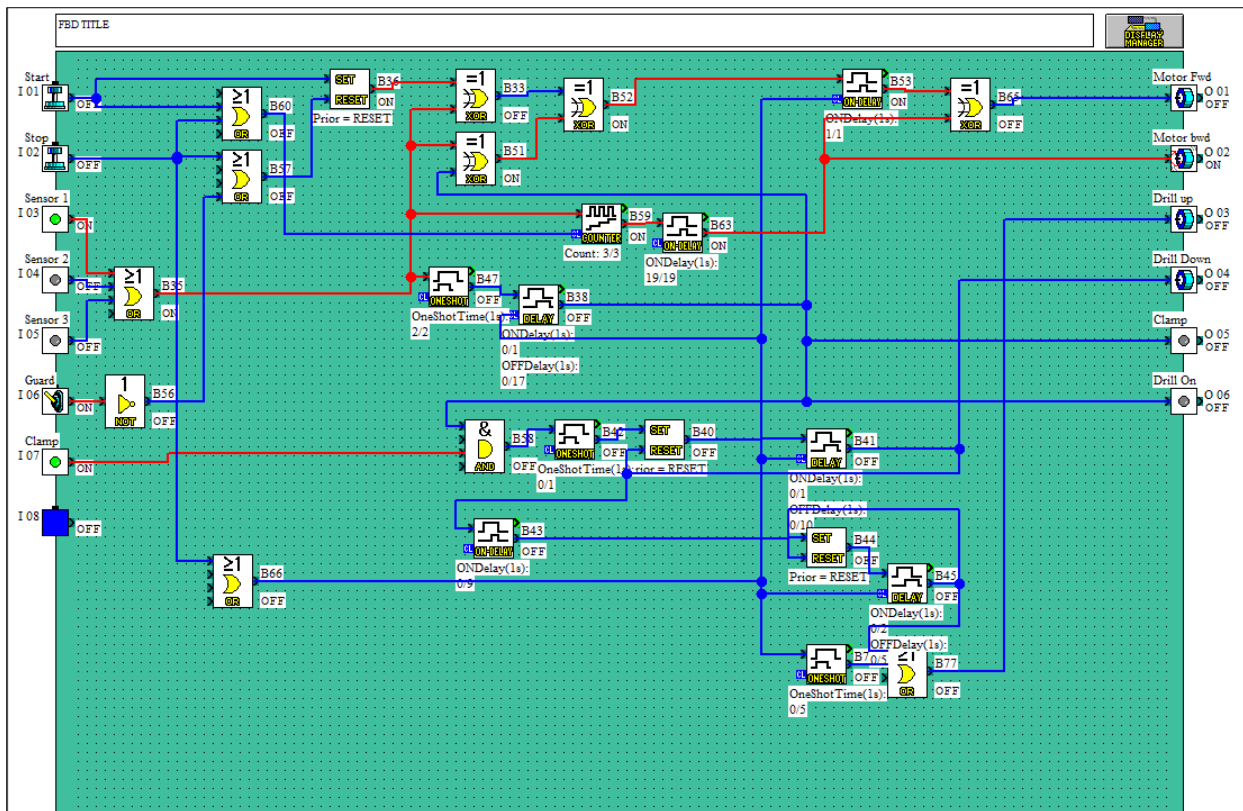


Figure 12: Motor returning to its starting position.

Again no statement about to confirm operation.

Appendix

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(<https://www.youtube.com/watch?v=sdqHTUlv3oU>) – Pub. Sep 2023 *← Do not state youtube as reference*

PLCs, A complete guide – RS Online – (<https://uk.rs-online.com/web/content/discovery/ideas-and-advice/plcs-programmable-logic-controllers-guide>) – Pub. Jan 2023

As well as literature and study materials supplied by Pembrokeshire College and teaching staff during the academic term. ✓

END

No references included

Need to include some books