

PSDE4033 Final Project Report

by Jordan Gough

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Final HNC Project Report

PSDE4033 – ELECTRICAL AND ELECTRONIC ENGINEERING PROJECT

JORDAN GOUGH

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Summary

This report documents the replacement of a mechanical cam timer with an Allen-Bradley MicroLogix1200 PLC, due to the unreliability of a controller relying on moving parts. By replacing the timer, the compressor should run with a minimal need for maintenance on the controller.

This report explains how this was achieved, covering the implementation of the solution, ranging from the identification of the issue, to the design and development phases and, finally, the installation and testing. The results of the tests carried out were collated into tables to allow effective comparison and analysis. The research on PLCs, Microchips and similar case-studies was used to adapt the project solution throughout, as more ideas became apparent.

The project was completed alongside a Gantt chart, allowing critical time management to play a role in finalising the solution by the deadline set. Along with the Gantt chart, a specification was used to highlight the key criteria that the solution had to meet to be deemed a success.

Good summary which covers the project outline.

Acknowledgements

I would like to thank Mathew Roberts for the assistance he provided in demonstrating the RSLogix500 programming software and the support shown during the development of the PLC program.

I am grateful for the help provided by Martyn Carroll during the testing procedures carried out on the system and the aid in gathering and collecting the results of the tests.

This project could not have been completed without the financial support from Valero, providing a budget for the components required for completion. It could also not be completed without the Instrument Department allowing the project to commence.

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*Good table of contents and good
use of the appendix for the test
results*

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*Table of figures is in
good order and
figures are clearly
identified.*

1. Introduction and Background Research

1.1 Introduction

Valero is a Fortune 500 company with a primary focus on oil refining. Despite a primary focus in the American refining sector, Valero purchased the Pembroke Refinery from Chevron in 2011, allowing them entry into the European sector.

No need for this history. You can go straight to the relevant part for your project.

One of the main products produced at Valero refineries is gasoline, which is made by blending different components together. Butane is one of the components used in the blending process and is imported and stored at the refinery.

Unfortunately, storing butane is difficult due to its boiling point of -1°C . Therefore, storing large volumes of butane require it to be in liquid-form, thus needing to be constantly cooled. If the butane does begin to boil, it will expand at a ratio of 233:1, meaning it is very important to control its state.

The refrigerated butane is stored at Pembroke Refinery in 3 tanks, seen below.



FIGURE 1 - TANK 831, TANK 832 AND TANK 833

The pressure of the butane vapour in these tanks is measured. When the pressure in each tank reaches an average of $800\text{mmH}_2\text{O}$, the vapour is compressed back down into a liquid. This is completed using one of the four compressors in place.



FIGURE 2 - COMPRESSOR 29-C-101C

The compressor's sequence is controlled using relay logic and a 24V timing cam.

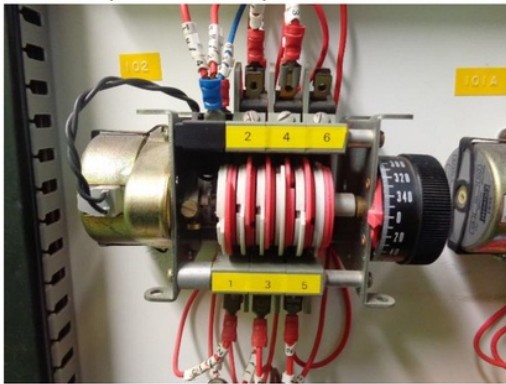


FIGURE 3 - TIMING CAM

Unfortunately, due to the moving parts involved and their age, the timing cams have become unreliable and an alternative method of controlling the sequence's timings should be explored.

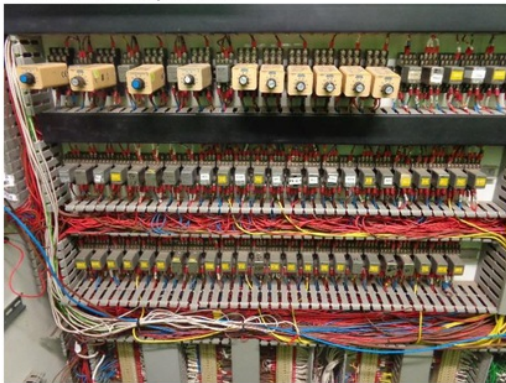


FIGURE 4 - RELAY PANEL

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exactl
y how
the
proce
ss is
control
led.*

1.2 Background Research

An example of the speed of a DC motor being controlled by a PLC and Microcontroller was completed by Upasana Sarma and P.K Bordoloi.

[Conferences](#) > [2017 14th IEEE India Council ...](#) [?](#)

Speed Control of A DC Motor Using PLC and PIC Microcontroller

2 Author(s) [Upasana Sarma ; P.K Bordoloi](#) [View All Authors](#)

FIGURE 5 - RESEARCH JOURNAL

Despite using PWM control to vary the speed of the motor, resolving the identified issue at Pembroke Refinery will require another method, possibly a PLC or microcontroller. However, it will also incorporate the existing relay logic.

[PIC16F877](#)

This example uses a Siemens PLC and a PIC16F887 microcontroller, which are common examples of controllers.

When designing the PLC program, the authors created a closed-feedback loop. This allowed them to set-up the PWM control for the motor, identifying the sensors involved and how they would be used, particularly, using an infrared sensor to monitor the speed of the motor.

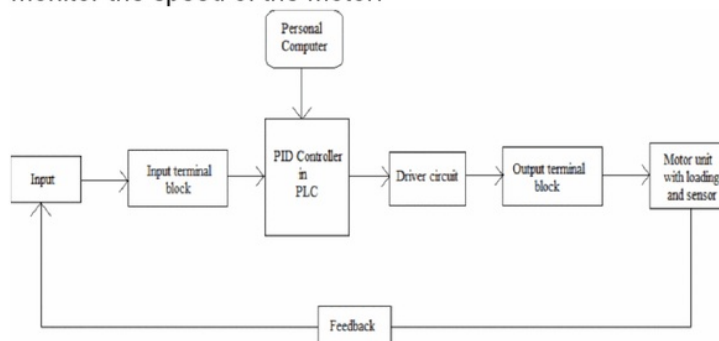


FIGURE 6 - JOURNAL PLC FEEDBACK LOOP

The PLC was mounted onto a panel which contained all the input and output devices required and items to keep it tidy, such as trunking and terminal blocks. This mounting idea is beneficial as it keeps the system together, which could be adapted to suit a chosen solution.

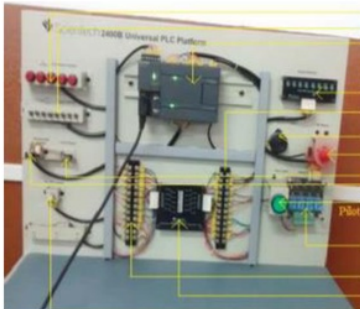


FIGURE 7 - JOURNAL PLC PANEL

Good reference

The microcontroller solution was implemented with pre-amplifier circuits and an LCD display. The display is useful for displaying the characteristics of the system. Diagrams of all the circuits used were included in the report. The pre-amplifier circuit is a standalone circuit, meaning that more space and materials will be required to construct it.

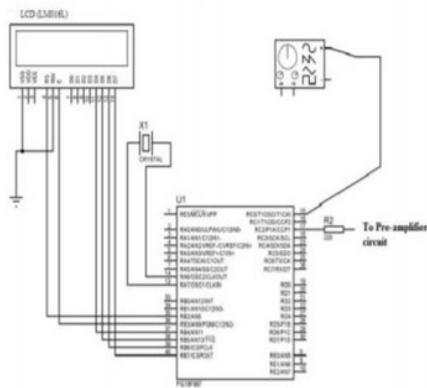


FIGURE 8 - JOURNAL MICROCONTROLLER CIRCUIT

The authors developed a flowchart to aid with the programming. This will highlight the main steps that the program must take and the transitional steps between them.

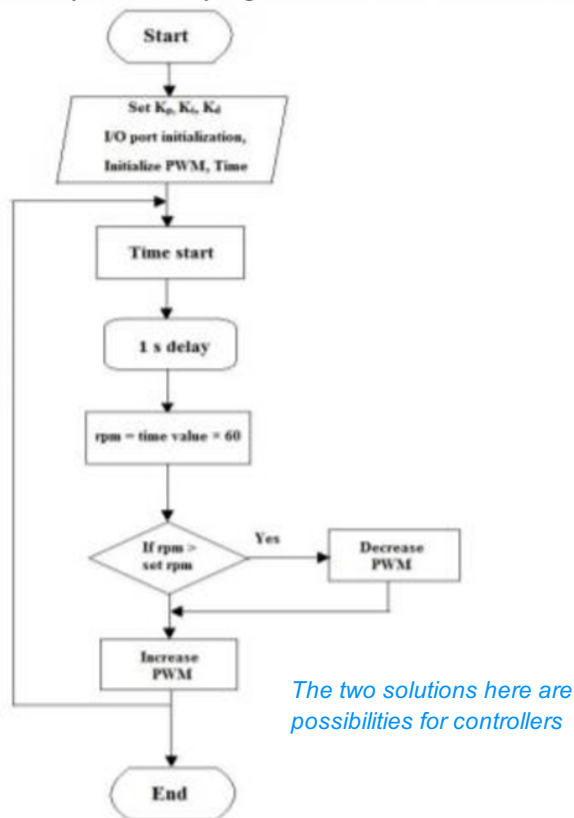


FIGURE 9 - JOURNAL FLOWCHART

Along with designing both PLC and microcontroller-based systems, the results from testing were included to verify the success of the methods introduced. The tests carried out included applying a load to the motor to see how the system responds. For practical testing, an oscilloscope was used to monitor the speed from the infrared sensor.

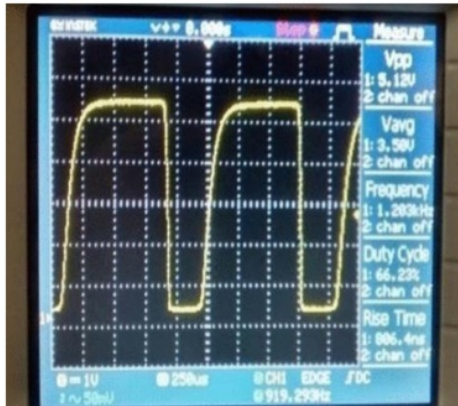


FIGURE 10 - JOURNAL TESTING

The results of the tests were displayed using graphical methods. This gives the authors a visual display of how the motor is responding with the PWM control, when a load is applied. (Sarma & Bordoloi, 2017)

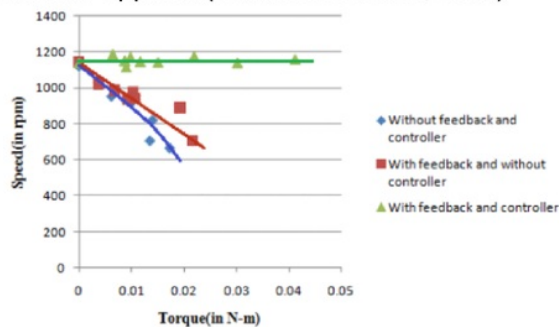


FIGURE 11 - JOURNAL GRAPH

This journal proves that a PLC or a microcontroller can be used to control a motor. Although not an identical scenario, it provides useful information on design and testing that can be adapted to fit.

*Good reference for
the alternative
systems*

2. Specification

A specification can be used to identify crucial criteria that must be met throughout the design, test and implementation of the project. These terms will determine the success of the solution.

2.1 Cost and Timing

A budget of £2000 was allocated to complete the improvement. This budget included the costs of the new controller selected, power supply, additional modules that may be required and materials to complete the installation. This budget will not cover the costs of any additional training required to operate the equipment. The project should be completed alongside the Gantt chart created.

2.2 Aesthetics

The controller and the 24V power supply should be mounted onto a panel inside the instrument shack, in both a secure, but accessible location. To ensure the installation is tidy, but also safe, the wiring used will be routed through trunking.

2.3 Reliability

To reduce downtime if the power supply failed, a back-up supply is required for the mounting panel. The number of moving parts should be reduced to a minimal amount to reduce the risk of failures. The solution should hold longevity and operate for at least 10 years, surpassing being replaced with new models by manufacturers, preventing additional spending.

Good reference to sustainability and recycling by using some of the existing components

2.4 Standards

The installation should comply with both ATEX regulations for hazardous area installations and Valero standards.

Good reference to codes of practice

2.5 Capacity

The controller must have at least 10 inputs and 10 outputs or have compatible expansion modules which can increase the I/O number.

2.6 Ergonomics

The controller should be maintainable by the on-site Instrumentation department only, with access prohibited to unauthorised personnel.

2.7 Operational Conditions

The controller should be able to operate between 10°C and 50°C.

2.8 Size

The mounting panel for the controller and power supplies should fit inside the logic cabinet.

2.9 Capabilities

Must be compatible with digital inputs from Emerson's Delta V control system.
Should also have potential for use with an HMI or alternative display for potential future addition. The controller is also required to withstand an industrial environment.

2.10 Functionality

The controller must be able to utilise retentive timers.

2.11 Additional Considerations

When designing the system, more considerations must be made. Many of the safety systems used by the compressor or storage tanks are controlled by separate systems, for example Pressure Safety Valves. The trips involved in the logic must be incorporated. If the compressor finds itself in a state where it must be tripped, it cannot afford to continue running. This could lead to the machine becoming damaged and possibly becoming a risk to Health and Safety.

The relay cabinet housing the logic contains a 110V supply. This must be acknowledged and, ideally, identified with warning signs. This is because there is a possibility of the relays failing. If this were to happen, they would require replacing. Therefore, somebody would enter the cabinet to rectify the logic fault and may be unaware of the voltage present.

The main environmental consideration to make is ensuring that the tank pressure never reaches a limit high enough to set off the PSVs as this will release gaseous butane into the surrounding environment. This will be maintained by ensuring that the program starts when the 800mmH₂O limit is reached.

Good detail in the spec

3. Planning

3.1 Gantt Chart

To monitor the progress of the project development, a Gantt chart was used. This chart highlighted main steps required to reach completion and when they need to be completed by. This chart considers holiday breaks which will impact the development.

Throughout the course of the project development, the chart will be updated to show successes or failures and any other delays which were unforeseen. The initial Gantt chart developed, Figure 12, can be found below.

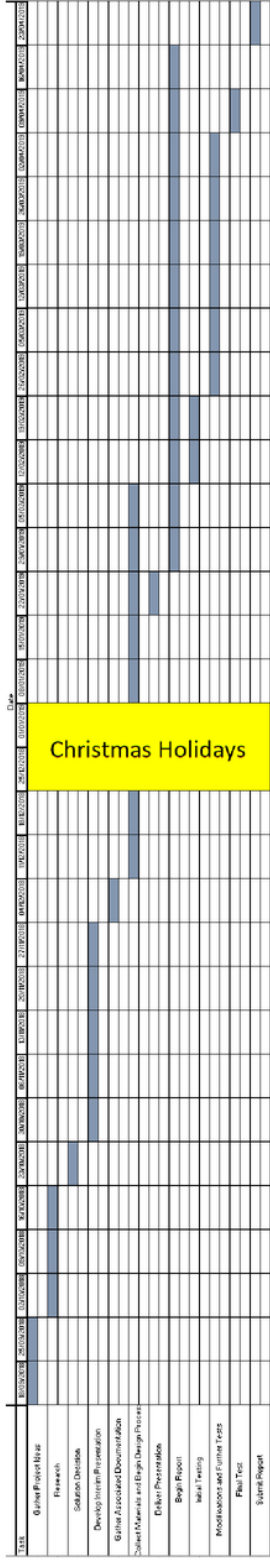


FIGURE 12 - INITIAL GANTT CHART

Good explanation and use of chart.

3.2 Testing

The solution will go through rigorous testing prior to being marked as complete. The following tests will be carried out.

- Simulated Laboratory Tests
- Practical Laboratory Tests (Downloaded to module)
- Initial Installed Practical Tests
- Further Installed Practical Tests
- Final Tests

To test the final solution, a testing table will be required, which can be seen below. Results and information will be added to this table following each test and will be found in the appendix.

Test	Expected Result	Actual Result	Success?	Modifications required
Initial Lab Test				
Initial Outside Test				
Additional Testing				
Final Test				

TABLE 1

To compare the result to the specification, the following table will be used. This table highlights the main criteria that the project will have to meet. To make the table more visually appealing, colour-coding will be used, with a green cell indicating success and a red cell indicating failure.

Specification Criteria	Success	Comments
Cost		
Timing		
Aesthetics		
Reliability		
Standards		
Capacity		
Ergonomics		
Operational Conditions		
Size		
Capabilities		
Functionality		

TABLE 2

*Test plan is
very
organised
and covers
what the
spec
requires*

4. Solutions Considered

To complete this project, three different solutions have been considered to automate the compressor sequence. These solutions were considered because they were all suitable for use in the desired role.

4.1 Solution 1 – Allen-Bradley PLC

The first possible solution is to use an Allen-Bradley PLC, specifically a MicroLogix 1200 controller. Allen-Bradley offer many different models with different characteristics. To determine the most suitable module for the task, the Allen-Bradley website can be filtered to match the criteria required.

This is a good point to make and can assist your budget.

The screenshot shows the 'Product Selection' window of the Allen-Bradley Product Configuration Assistant. On the left, a sidebar lists various configuration options with checkboxes. The 'Number Of Channels' section is expanded, showing '14 I/P, 10 O/P' selected. Other selected options include '24V DC' for Input Signal, Output Signal, and Power Supply. The 'Interface' section shows 'RS-232C Port' and 'RS-232C Port' selected. The 'Power Supply' section shows '24V DC' selected. The main table displays two results:

Catalog Number	Description	Accessories
1762-L24BXB	1762 MicroLogix 1200 System, MicroLogix 1200, 24V dc power, (10) standard 24V dc and (4) fast 24V dc digital inputs, (5) relay outputs, (4) standard 24V dc FET outputs, (1) fast 24V dc FET output	
1762-L24BXR	1762 MicroLogix 1200 System, MicroLogix 1200, 24V dc power, (10) standard 24V dc and (4) fast 24V dc digital inputs, (5) relay outputs, (4) standard 24V dc FET outputs, (1) fast 24V dc FET output, with Programming/HMI Port	

FIGURE 13 - PLC SELECTION

From the filtered results, the most appropriate model of PLC to use is the 1762-L24BXR. This is a 24VDC supply module with 14 inputs and 10 outputs. This model was chosen over the alternative because it comes equipped with an HMI port, which is important for future expansion. Although not required, the PLC also has the capability of using RS232 communications. (Allen-Bradley, 2015)

The PLC is programmed in the RSLogix500 software, using ladder logic. Despite being a sequence, ladder logic is better suited to the task because of the need for retentive timers, which are useable in the ladder. Retentive timers will be used in place of regular timers because the sequence will halt once it starts, then continue as required. Therefore, the timers must be held at the same elapsed time, and not reset, after the halt. (Bolton, 2009)

Also required to use the PLC is a 24VDC discrete input sink/source module. For a sink input, the current flows from the device, in this case the relay, to the input module. For a source input, the current flows from the PLC to the device.

The screenshot shows the 'Product Selection' window of the Allen-Bradley Product Configuration Assistant. On the left, a sidebar lists various configuration options with checkboxes. The 'Type' section is expanded, showing 'Discrete, Input' selected. The 'Special Features' section shows 'Standard' selected. The 'Input' section shows '8 Point, 120V AC' selected. The main table displays four results:

Catalog Number	Description	Accessories
1762-IA8	1762 MicroLogix 1200 System, 8 Point 120 VAC Input Module	
1762-IQ16	1762 MicroLogix 1200 System, 16 Point 24 VDC Sink/Source Input Module	
1762-IQ32T	1762 MicroLogix 1200 System, 32 Point 24 VDC Sink/Source Input Module	
1762-IQ8	1762 MicroLogix 1200 System, 8 Point 24 VDC Sink/Source Input Module	

FIGURE 14 - EXPANSION MODULE SELECTION

To implement this strategy, the PLC would replace the timing cam, using the existing relays as both the input and output devices. The inputs in use consist of the permissive start conditions, ISR13, Lube Oil Pressure and R60C. The outputs will be the Lube Oil Pump, Auxiliary Lube Oil Pump and each of the five cams. The input and output wiring will be taken from the existing wiring used on the timing cam.

To operate the PLC, a 24VDC UPS will be required. The PULS SL2.100 will be able to use the 115V supply already in place to provide the power. It is also mountable on top hat DIN rail, like the PLC. (PULS, n.d.)



FIGURE 15 - POWER SUPPLY SELECTION

Using a PLC is advantageous because it has a rugged, industrial design, making it suitable for use in the environment. It is also a control device familiar to the workforce, giving it much more maintainability. It also has little to no moving parts which ultimately increases the reliability, making it less susceptible to failure.

Despite being more familiar to the maintenance department, only trained personnel will be authorised to use and maintain this equipment. Therefore, there may be a requirement to provide additional training, as required.

*Good
solution
and
explained in
detail.*

4.2 Solution 2 – Microcontroller

An alternative to the PLC would be to use a microcontroller. An example of a microcontroller that could be used would be a PIC16F877 2 - 5.5V microchip.



FIGURE 16 - PIC16F877 MICROCHIP

This microchip has three counterparts which could also be considered. The comparison table found in the product specification shows that the PIC16F877 is the most powerful variation on offer.

Key Features PIC® MCU Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	3	3
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

FIGURE 17 - MICROCHIP COMPARISON

The PIC16F877 offers the most memory, along with the PIC16F876, but has more input channels, making it the more desirable and superior chip. Another important feature highlighted in the table is the timers, which are vital for the success of the upgrade. (Microchip, 2013)

To develop the program for the microchip, the Proteus CAD system can be used. This software can also be used for real-time viewing of the program's running. This is a software package that is available to use and features a very large variety of microchips. The programming language used to create the program is C language.

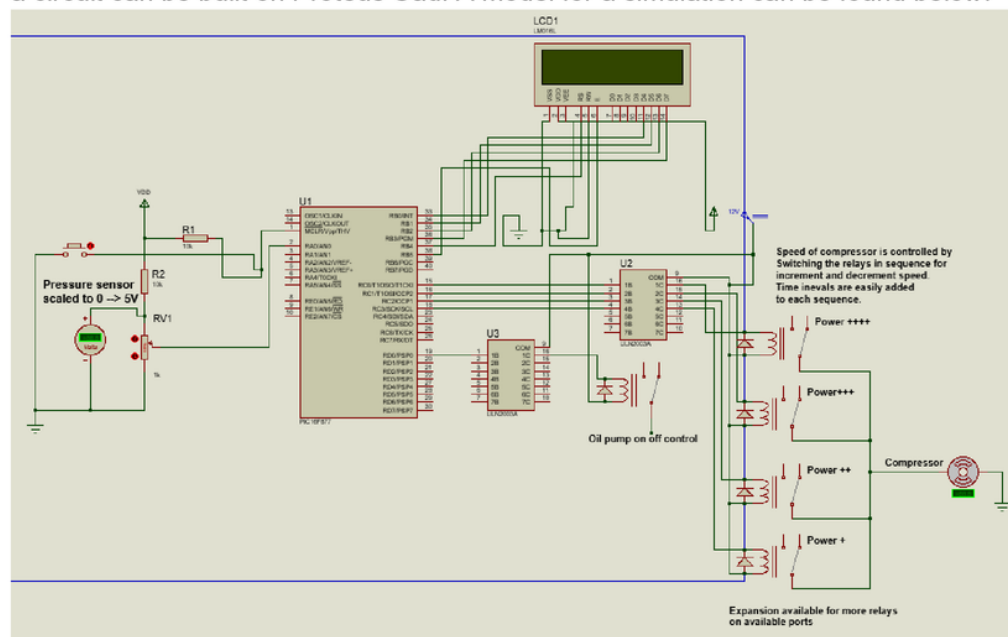
Again, the UPS would be required to make the supply voltage suitable for use with the microchip. However, to use the microchip, a suitable printed circuit board will be

required. This can also allow the microchip to use other features, such as an LCD display, to provide feedback on the system.

An advantage of using a microchip is the reduced cost of the components. A microchip is also typically developed by a skilled person, which would increase costs. This would lead to a program being designed correctly and to a high standard. Unfortunately, this will limit the number of personnel who can perform any required maintenance tasks. Once programmed, the chip cannot be reprogrammed. This will prevent anybody from making unauthorised changes to the program, but will also stop changes being made completely, potentially harming any further development of the system.

The chip is re-programmable but using a specialised download software.

To prove that a microcontroller can be used, a simulation can be set up. Using MPLab a C language code can be written to use for testing. This can be compiled using HITECH C compiler and converted to a Hex file. To use the hex file, a model of a circuit can be built on Proteus Cad. A model for a simulation can be found below.



Good example of the MCU and the connection arrangement.

FIGURE 18 - PROTEUS CAD MODEL

The hex file for the C code can be uploaded to the model. The C code can be found in the appendix. The model was tested, with evidence being found in the appendix.

From these tests, when the analogue input is set, the program runs through different states. For each state, the relays switch. From the model above, each relay switching increases the power of the compressor. The relays are switched from 12V to 0V and use a ULN2003 relay driver chip. This chip allows one device to switch several relays. However, the chip switches through an inverter, meaning a '0'

switches a '1', keeping the coil de-energised, and a '1' switches a '0', energising the coil. Further information about the chip can be found in the appendix.

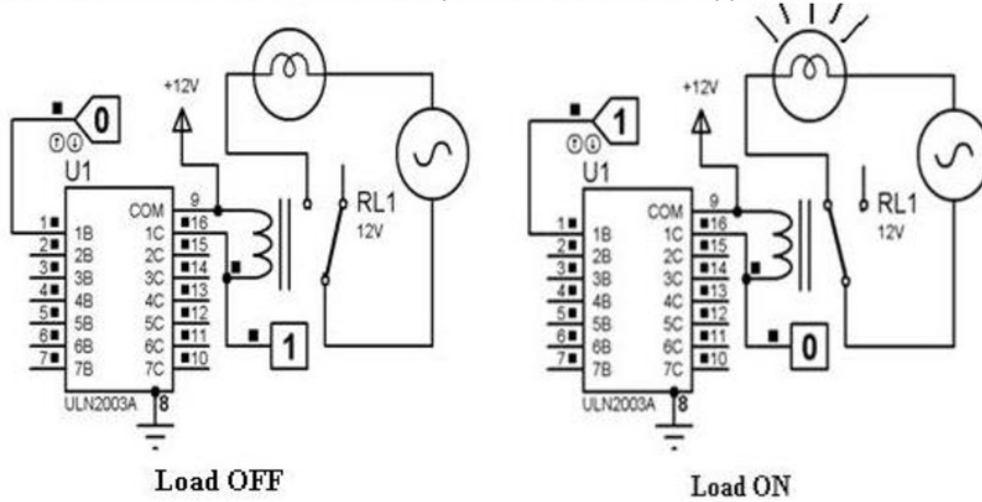


FIGURE 19 - ULN2003 OPERATION

Good use of images to explain relay operation using the ULN2003A chip which

4.3 Solution 3 – Servo Driver

Another possible method would be to use a servo driver. This would be used to control the speed of the compressor. However, this method would also require a controller to operate, such as a PLC or microprocessor. This means that the servo driver would be better suited to replace the relays used to increase and decrease the ramping of the compressor.

An example of a servo driver would be the SINAMICS G120.



FIGURE 20 - SERVO DRIVER

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d.*

*This shows you have
carried out
considerable
research into the
alternative and clearly
understand the
objective.*

5. Final Solution Design and Implementation

5.1 Final Solution Selection

Using a servo-driver to control the power and speed of the compressor would remove the need for some of the relays involved in the logic, but would not replace the timing cam. However, this would create a lot of unnecessary work. Therefore, the alternative solutions of the PLC and Microcontroller will be considered, due to their viability.

The decision will be made based on comparisons made between the two. A comparison table can be found below.

	PLC	Microcontroller
Cost	More expensive components. Less specialised labour.	Low cost components. Labour and training have increased costs.
Familiarity	Familiar to workforce.	Unfamiliar to workforce.
Expansion	Expansion modules and displays available.	Displays available.
Reliability	No moving parts. More robust and industrial design.	No moving parts.
Standards	Complies with ATEX regulations.	Does not comply with ATEX regulations.
Capacity	Enough I/O.	Enough I/O.
Functionality	Can use retentive timing functions.	Cannot use retentive times. Limited number of timers available for use.

TABLE 3

Table of comparison for evaluation of system possibilities is very good.

Both solutions fall within the budgetary constraints set within the specification. However, the familiarity of using PLCs and ladder logic will allow the solution to be developed and maintained independently. Whereas, the microcontroller may require a third-party due to the complexity and expertise required to create the program. Using the PLC would also limit the amount of training required.

The PLC and expansion module can be mounted onto top hat DIN rail, alongside the 24VDC UPS. By mounting these together, the amount of space required to hold them will be reduced. To mount the microcontroller, an additional DIN rail mounting bracket would be needed, which would add on to the space the controller is already using.

The microcontroller is not designed for an industrial environment in the way that the PLC is. The building in which the controller must be mounted in can sometimes find

itself to be dusty, which could possibly cause problems for both controllers. However, it is less likely to affect the PLC, by reducing the PLC's heat dissipation. This is only a minor problem due to the building temperature is maintained. The PLC also complies with the ATEX regulations for the area it is located in.

Both controllers have the capacity to handle the I/O required or can be expanded to fulfil the needs. They also both have the potential for the inclusion of a display. However, the microcontroller only has 3 timers, which is insufficient for the number of timers required.

*This is true but time delays
can be programmed for as*

Therefore, the solution chosen to replace the cam timer is the Allen-Bradley PLC. The main reason for this decision is the importance of using retentive timers to operate and run the compressor logic. It is also important that a controller is implemented which is familiar to the workforce. This will allow work to be completed by the employees currently working on-site, without the need of additional training or outside contractors. This is especially useful during the testing phase as the program can be tested and modified as required, then downloaded to the PLC in situ using a laptop with the RSLogix software installed. Any issues that may need rectifying can be found on the PLC by viewing the program's running operation live. The PLC's potential for expansion means an HMI can be introduced to monitor the progress of the sequence and the compressor, highlight any faults found. This would be superior to an LCD display as it provides more interaction possibilities. On top of a display, the expansion modules offered mean that one PLC could control more than just one compressor sequence, with a total of 4 compressors in place. This may require changing the MicroLogix 1200 for a more powerful PLC, but the amount of space used would still be minimal.

*The
arguments
are very*

*good and
you have
justified the
final choice.*

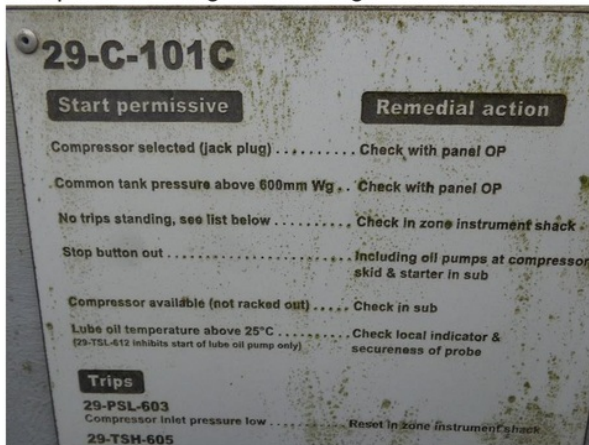
5.2 Solution Design

Prior to starting the design, the associated documentation was gathered. The main document required was the timing diagram. This diagram showed how much time each cam moved for and the angle-to-second ratio. This document can be found in the appendix. This document provided the information to use the retentive timers.

Another document found was a circuit drawing showing how the relays start the cams. This document was photocopied and modified by hand to show the different circuit behaviours for the compressor's running states. Each of these can be found in the appendix. These drawings aid with the relays that start some of the cams.

5.21 Permissive Logic

Before designing the sequence using the retentive timers, the permissive start conditions should be determined. Alongside the compressor is a sign indicating the permissive conditions and trip conditions for the compressor. Some of the trips are specific to the compressor whilst running, but the others are vital to starting the compressor. Images of the sign can be found below.



Explanation is clear and good reference to the appendix for relative data.

FIGURE 21 - PERMISSIVE CONDITIONS

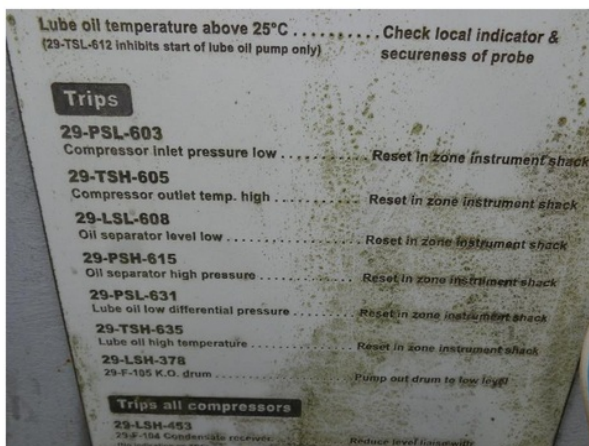


FIGURE 22 - TRIP CONDITIONS

A Cause and Effect Diagram for the system can be found in the appendix. Many of the trips come from switches found on an instrument panel alongside the compressor.

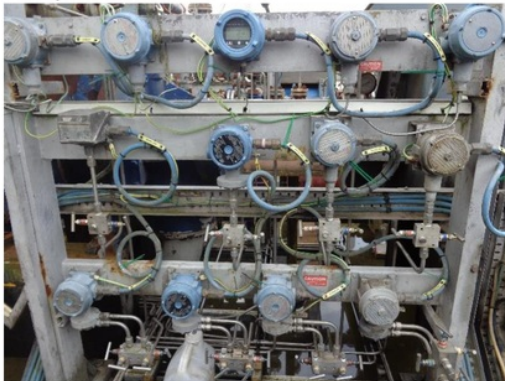


FIGURE 23 - INSTRUMENT PANEL TRIP SWITCHES

From the list, the important permissive conditions are 'Lube Oil Temperature above 25°C' and 'Oil Separator Low Level'. If these conditions are not met, the compressor will trip and shutdown during start-up. The sign also indicates that the common tank pressure must be above 600mmWg. Despite this limit, the compressor will not start until it reaches 800mmWg, which is well above the limit.

After determining these conditions, the design for the program can begin.

The inputs and outputs for the program were added to the program, along with the binary bits, which are digital conditions met within the program. Below is a list of all the inputs and binary bits.

B3:0		
B3:0/0	HIGH_PRESSURE_TRIP	Global
B3:0/1	PERMISSIVES	Global
B3:0/2	PRESSURE_HEALTHY	Global
B3:0/3	COMPRESSOR_RUNNING	Global
B3:0/4	CAM_RUN	Global
B3:0/5	R60C	Global
I:0/0	R20	Global
I:0/1	ISR13	Global
I:0/2	OIL_LEVEL	Global
I:0/3	OIL_TEMPERATURE	Global
I:0/4	LUBE_OIL_PRESSURE	Global
I:0.4	PRESSURE_INPUT	Global
N7:0	TANK_PRESSURE	Global
O:0/0	CAM_1	Global
O:0/1	LUBE_OIL_PUMP	Global
O:0/2	AUX_PUMP	Global
O:0/3	CAM_2	Global
O:0/4	CAM_3	Global
O:0/5	CAM_4	Global
O:0/6	CAM_5	Global

FIGURE 24 - I/O LIST

To permit laboratory testing, an analogue input scaling block will be used. This will allow the system to be tested without the presence of the common 800mmWg pressure signal required to start the compressor.

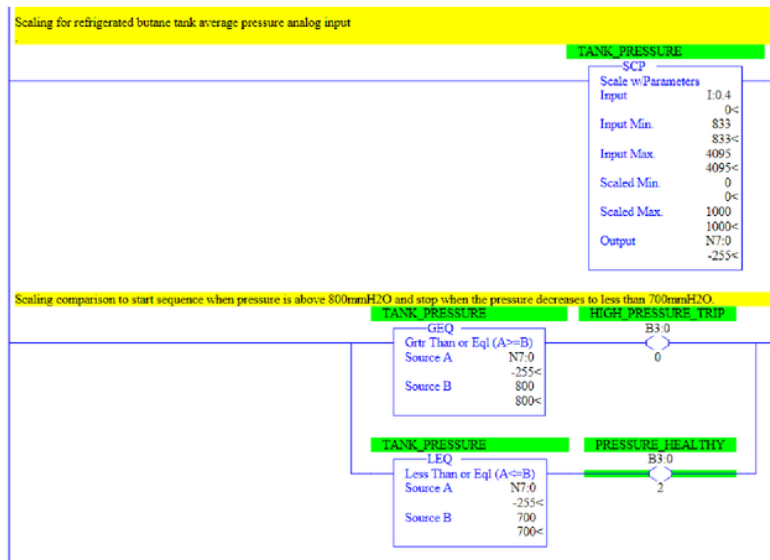


FIGURE 25 - ANALOGUE SIGNAL FOR TESTING

Comparison blocks are used to start and stop the compressor. When the pressure input reaches a value of 800mmWg or more, the 'High_Pressure_Trip' output will become true. Once the pressure drops to 700mmWg or less, the 'Pressure_Healthy' output will become true. The compressor's main signal comes from Relay 60C. This relay changes state when the pressure is high. This relay will change state again during the sequence, so it is latched with itself and is also operated when the pressure is below the limit.

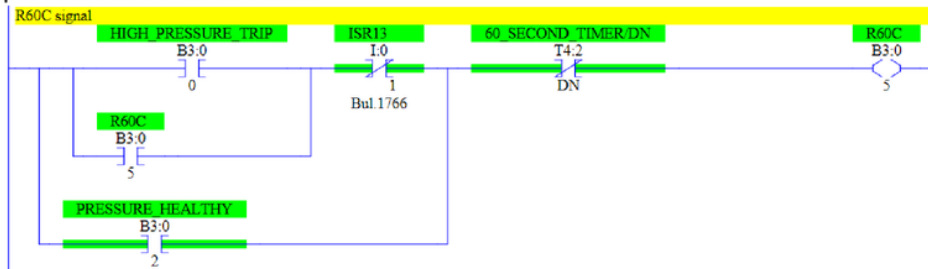


FIGURE 26 - R60C

A rung was added to consider the permissive conditions required to start the compressor. Despite being tagged as 'Oil_Level' and 'Oil_Temperature', the inputs come from Relays 53 and 54. Naming them as such makes them easier to identify.

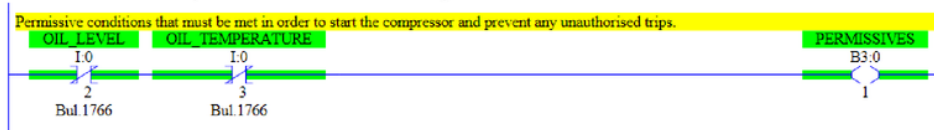


FIGURE 27 - PERMISSIVE LOGIC

When the sequence finishes, the lube oil pump runs for an additional 30 seconds. This allows the oil to continue cooling the compressor once it has stopped.

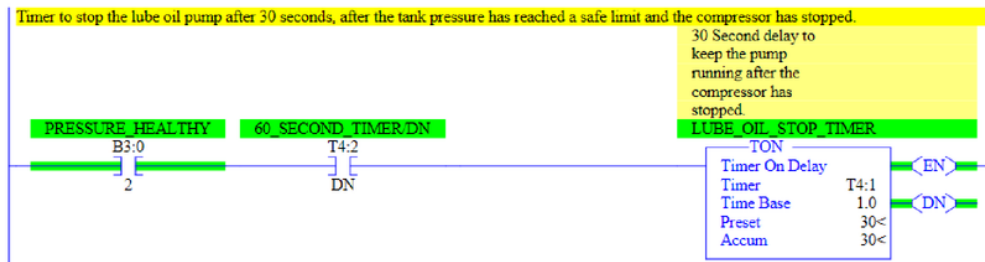


FIGURE 28 - LUBE OIL PUMP STOP TIMER

The lube oil pump has its own trip conditions. When the lube oil pump starts, it has 30 seconds to reach its operating pressure. If it does not reach its pressure within the timer, the lube oil pump will stop, and the auxiliary lube oil pump will run instead.

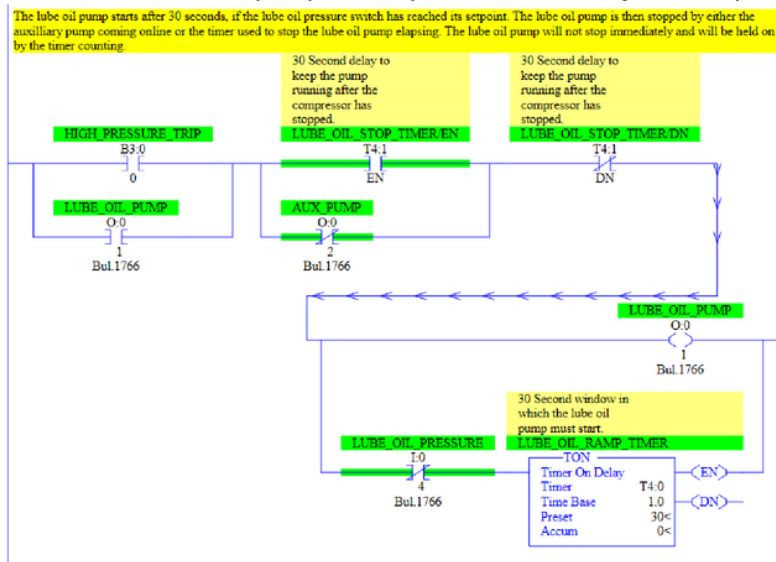


FIGURE 29 - LUBE OIL PUMP START

If the 'Lube_Oil_Ramp_Timer' reaches its limit, the auxiliary pump starts and is stopped using the same timer that would stop the lube oil pump.

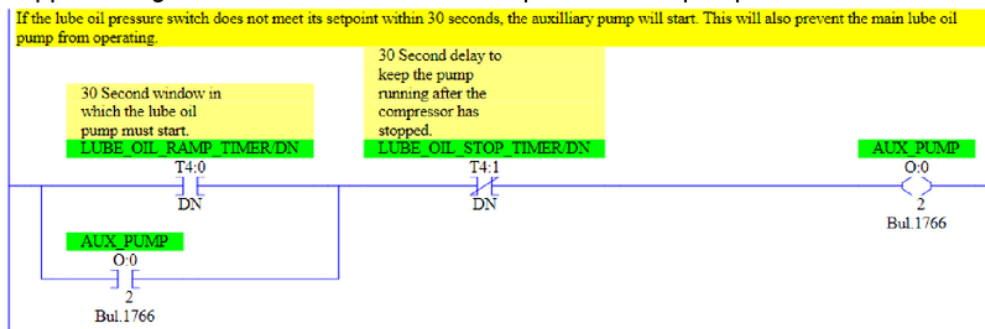


FIGURE 30 - AUX PUMP START

Once the pre-conditions have been met, the sequence timer can start. The timer is a 60 second timer. However, the sequence can run for a much longer period. This is due to the change in state of Relay 60C, which halts the timer whilst the pressure decreases. This is the reason for the use of retentive timers, highlighting their importance. These conditions also start the cams.

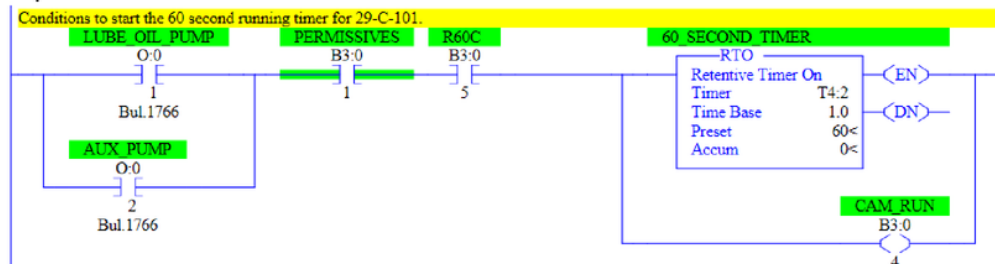


FIGURE 31 - SEQUENCE TIMER START

The program consists of two main parts – the permissive conditions to start the sequence and the sequence itself. To make it easier to follow, these parts were split into two subroutines. At the end of the permissive logic, a rung was added to move to the sequence timers.



FIGURE 32 - MOVE TO TIMERS

Cam 1 is the 'Start' cam and provides an output after 4 seconds, until 20 seconds. When the 4 second timer, T4:3, elapses, the 'Cam_1' output becomes true until T4:4 finishes. Then, the output become false again. Again, retentive timers are used because they will also be affected by the sequence halting.

Cam 1 is the 'Start' cam and provides an output after 4 seconds, until 20 seconds. When the 4 second timer, T4:3, elapses, the 'Cam_1' output becomes true until T4:4 finishes. Then, the output become false again. Again, retentive timers are used because they will also be affected by the sequence halting.

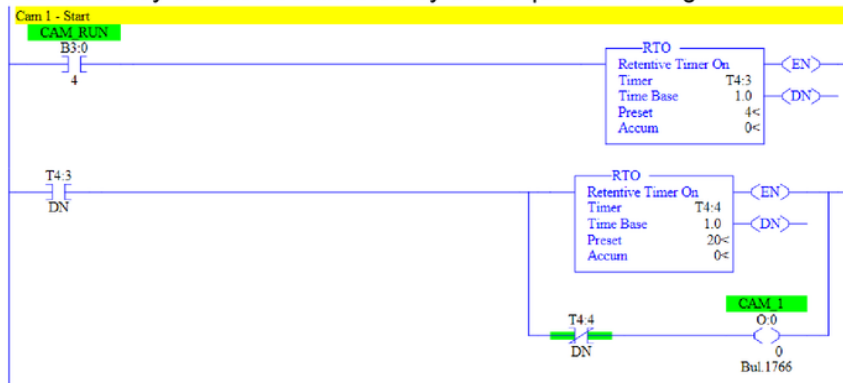


FIGURE 33 - CAM 1 TIMER

Cam 2 increases the compressors capacity. This is how much it can compress at any time. If the compressor is working correctly, it should reach 100%. If it is less than 100%, but greater than 40%, it will still compress, but will take much longer to complete the task. The compressor starts increasing capacity after 2 seconds and stops after a further 2 seconds.

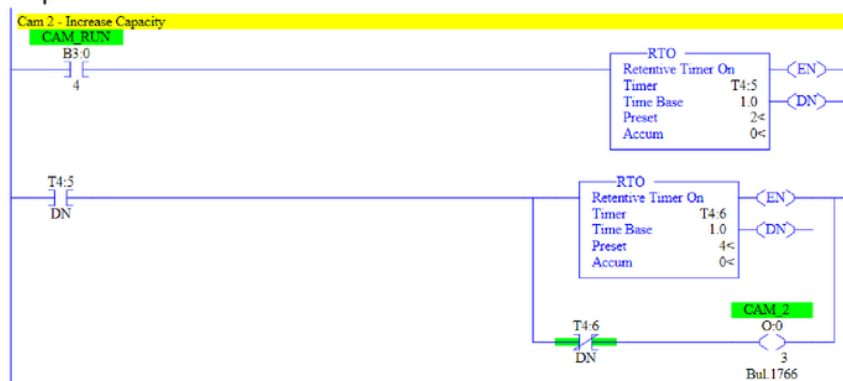


FIGURE 34 - CAM 2 TIMER

Cam 3 decreases the capacity once the compression has completed. The capacity begins decreasing after 8 seconds and finishes after 51 seconds. Although the decrease begins after 8 seconds, the sequence halts after 7 seconds, so it will remain at 100% until the lower pressure limit is reached and the sequence restarts.

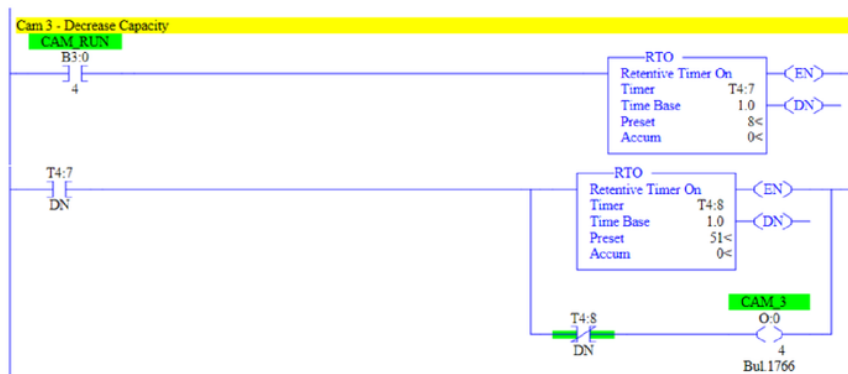


FIGURE 35 - CAM 3 TIMER

Cam 4 sends the signal that stops the lube oil pump. Unlike the previous cams, this cam is normally closed. Therefore, after 52 seconds, the cam turns off for 4 seconds, until 56 seconds. During this 4 second window, the lube oil begins to stop – despite not stopping until after the 30 second lube oil pump stop timer elapses.

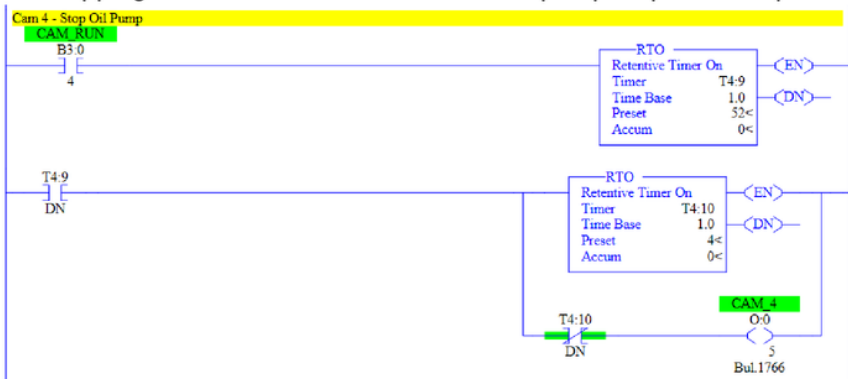


FIGURE 36 - CAM 4 TIMER

Cam 5 stops the timer motor. By installing the PLC, this function is no longer needed. However, it would require more unnecessary work to remove the wiring, so it was added to the program. Again, this cam is normally closed and opens after 0.2 seconds, until 2 seconds.

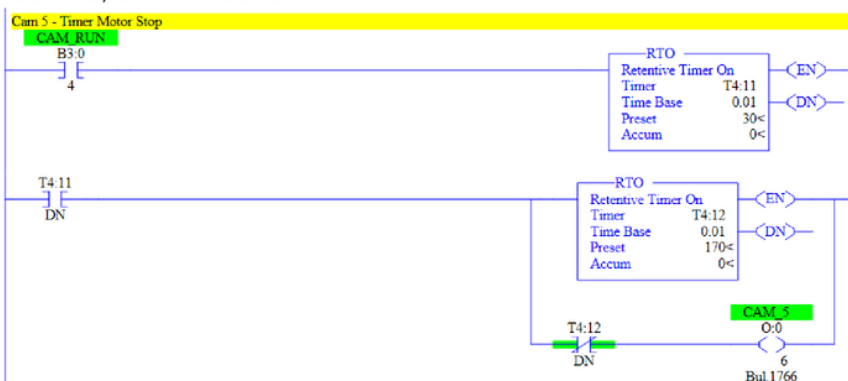


FIGURE 37 - CAM 5 TIMER

Once completed, the sequence must return to its starting point. Therefore, another rung was added to return to the 'Permissive' subroutine.

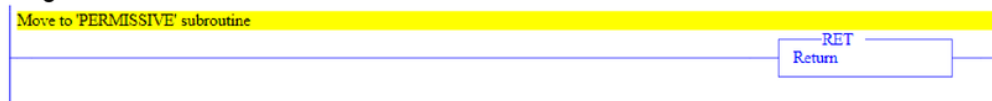


FIGURE 38 - RETURN TO PERMISSIVE

A flowchart, found in the appendix, was created to show the system's operation. The flowchart contains all the major steps that the sequence must go through and the conditions or inputs that must be true to progress. This provides a summary, simplifying the operation for users who may not be adept at ladder logic.

The program sequence looks good and demonstrates good practical skills and working knowledge of the technical part of the system.

5.3 Initial Software Testing

Before taking the PLC to the field for installation, the program was downloaded for initial testing. This was carried out in the lab, which is why the analogue input block was added to simulate the pressure.

A current source was connected to the PLC to simulate a 4-20mA signal. The current was increased until the simulated pressure reached the trip point. The other permissive conditions were forced using the software, allowing the sequence to run. After the program halted at 7 seconds, the current was held for a small duration, before being reduced to the low-pressure limit. Then the current was reduced to resume the sequence.

After 60 seconds, the sequence ended successfully. However, the timers did not reset. This is because the retentive timers had to be reset in the ladder. So, a series of rungs were added to reset every timer in the logic after the 60 second timer finishes.

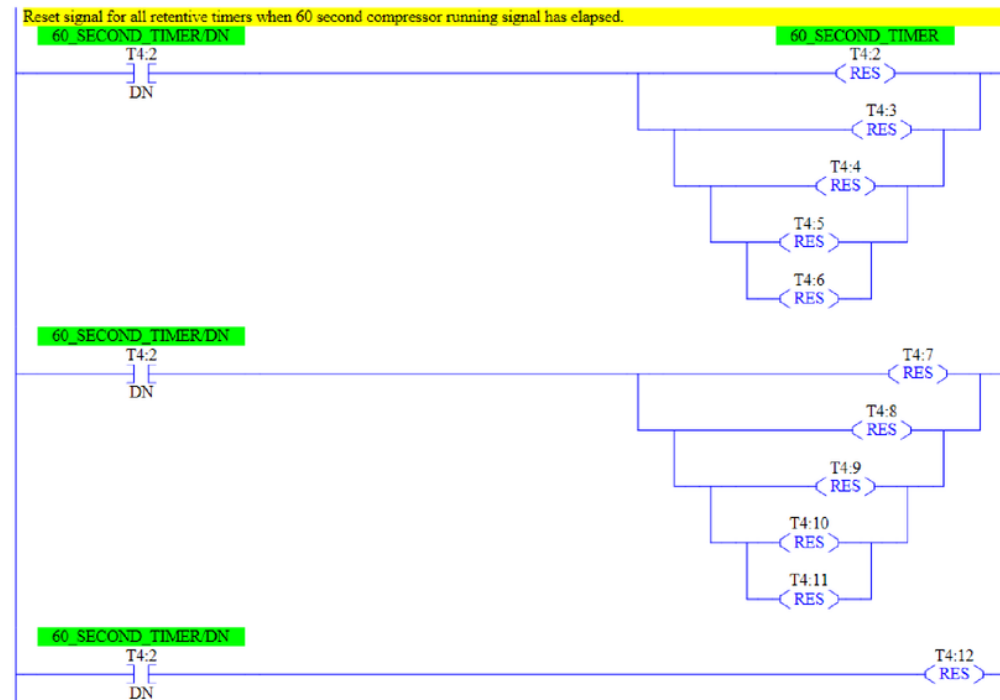


FIGURE 39 - RETENTIVE TIMERS RESET

Further testing was carried out, with the initial test repeated to test the timer reset. Additionally, tests were carried out using a 24V supply in the workshop and input devices – providing more accurate tests. Along with these tests, the sequence was run with the permissive conditions not met, to ensure that the program stopped successfully. The updated testing table can be found in the appendix.

Good test under fault conditions to prove the system will not run under these faulty conditions. A good test considering the volatile gases involved.

5.4 Mounting and Implementation

To bring the components together, top hat DIN rail and trunking were mounted onto an aluminium sheet. These materials were collected from the workshop and didn't require purchasing. If the materials were purchased, the costs would be as follows.

- Allen-Bradley PLC - £473 (Allen-Bradley, n.d.)
- Power Supply (2) - £134 each (RS Components, n.d.)
- Din Rail - £4 per metre (RS Components, n.d.)
- Trunking - £9.86 per 2 metres (RS Components, n.d.)
- PLC Expansion Module - £281 (Allen-Bradley, n.d.)

The PLC, additional module and 24VDC UPS were mounted on to the DIN rail and wired up as much as they could be. At the time of the panel construction, only one UPS was available.



FIGURE 40 - PLC MOUNTING PANEL

The PLC was then taken to the instrument shack in which it will be housed. This building is constantly locked, and access is only provided to authorised personnel.



FIGURE 41 - INSTRUMENT SHACK

The cabinet in which the PLC will reside had a panel mounted onto the door, which was not in use. This panel had an abundance of indicator lights which were not connected to anything. So, with clarification from the project department, this panel was removed to mount this panel in its place. This will save space in the cabinet.



*Utilising existing
space is a good
method of recycling.*

FIGURE 42 - LOCATION FOR MOUNTING PANEL

Once mounted, the relays were wired up to the PLC for the I/O devices, ready for field testing.

6. Testing and Results

6.1 Initial Installation Testing

Once the PLC and panel was installed, the initial installation test can begin. To ensure that the compressor sequence can run, the Operator responsible for the system must select the required compressor as the one to be used. The compressor and lube oil pump must all be checked over to ensure that no stop buttons are in as this will prevent running operation.

Once the tank pressure was reached, the PLC received a digital signal from the Delta V control system and started running the sequence. It was found during the testing that the sequence halted after 7 seconds, as it should, but remained halted. This caused the compressor to run continuously until it was stopped manually.



FIGURE 43 - PLC DURING TESTING

To identify the fault causing this, the sequence was restarted, and the program was viewed live. Using the LEDs on the front of the PLC, it was seen that inputs and outputs were switching when they shouldn't be. This was likely due to the EMF inside the cabinet, generated by the large amounts of wiring. As a temporary solution, the panel and PLC were moved outside of the cabinet. The results of the test can be found in the appendix.

Good explanation and proves that most projects never work first time and require investigation.

6.2 Further Testing

Once mounted in a new location, the program was tested again. However, this time without the background EMF influencing it.

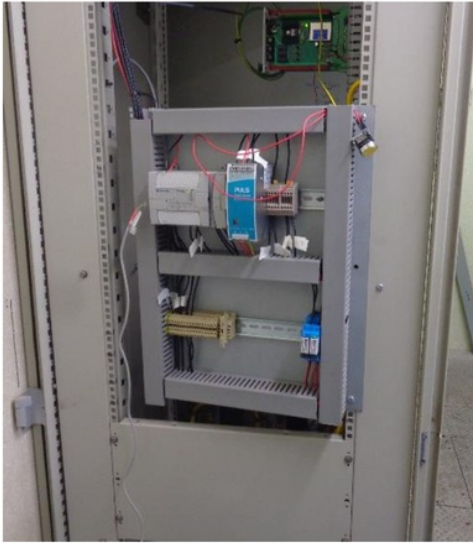


FIGURE 44 - REMOUNTED PANEL

There is good reference to the appendix for the relevant test data.

This test was successful, with the sequence halting and resuming correctly and running until the end. The retentive timers also reset, which puts the sequence into position for repeatability. An updated testing table can be seen in the appendix.

6.3 Final Test

To complete the final test of the program, the laptop was removed, and the PLC was left alone to run in the instrument shack, which was vacated and locked securely.

The compressor was monitored from the field, to ensure it was running correctly, and from the control room, to ensure it interacted with the Operator's control system correctly. The sequence was monitored multiple times and each test was successful. The sequence would reset itself at the end of the 60 second timer, allowing it to restart as required.

The tests were time consuming as the tank pressures can be affected by the weather. However, it was important to verify the program's repeatability.

Following the successful final test, the equipment can be handed over to Operations as a complete system. The final testing table results can be found below in Table 4.

Test	Expected Result	Actual Result	Success?	Modifications required
Initial Lab Test	Sequence will run from when a high pressure is simulated until a low pressure is simulated. Sequence will reset after completion.	Sequence completed successfully, but timers did not reset.	No.	Reset for retentive timers.
Secondary Lab Test	Sequence runs successfully and stops when the trips/permissive conditions are incorrect.	Sequence ran correctly and stopped/reset as required.	Yes.	None.
Initial Outside Test	Compressor starts when the tank pressure reaches it set-point. The sequence halts after 7 seconds and resumes once the lower limit was reached.	Compressor started and sequence halted. However, background EMF caused issues with the PLC's I/O and the sequence did not resume once halted. Compressor had to be stopped manually.	No.	Relocate PLC to location without background EMF and test again.
Additional Testing	Compressor starts when the tank pressure reaches it set-point. The sequence halts after 7 seconds and resumes once the lower limit was reached.	Sequence completed successfully, halting and resuming at the correct time.	Yes.	None.
Final Test	The sequence should prove repeatability by running multiple times without	The sequence demonstrated successful repeatability and did not	Yes.	None.

	any issues. The laptop will be removed, and the PLC will run alone.	highlight any more faults, allowing the system to continue without live viewing on the laptop. The program also interacted with the Delta V control system, changing the states on the screens as required.		
--	---	---	--	--

TABLE 4

Explanation of test procedures is clear and the use of tables for analysis is a good method. The problem encountered is evident in the table.

7. Discussion, Conclusions and Recommendations

7.1 Discussion

To verify the project's success, it can be compared to the original solution A comparison table can be seen below.

Specification Criteria	Success	Comments
Cost	Yes	None
Timing	No	Unforeseen issues caused delays in completion
Aesthetics	No	Background EMF caused the PLC to be temporarily relocated
Reliability	No	Back-up UPS yet to arrive after ordering.
Standards	Yes	None
Capacity	Yes	None
Ergonomics	Yes	None
Operational Conditions	Yes	None
Size	Yes	Despite fitting inside cabinet, it cannot remain in the cabinet
Capabilities	Yes	None
Functionality	Yes	None

TABLE 5 - SPECIFICATION COMPARISON

From the table, the project did not meet all the specification criteria. However, the criteria that was not met does not affect the functionality of the solution and rather delays the project meeting all the criteria. There was no way to control the delays in timing and receiving the back-up power supply and the background EMF causing the PLC to be relocated.

7.2 Conclusions

The aim of this project was to identify a suitable replacement for a mechanical timing cam and design and implement a solution to replace it for a device with minimal moving parts. This aim was achieved by obtaining an Allen-Bradley PLC and designing a ladder logic PLC program that uses retentive timers to control the running sequence. The use of a PLC was decided upon through comparison between itself and a microcontroller, with research completed to support each probable solution.

Following the design and development of the solution, a range of tests were completed, in both the workshop's electronics lab and in the field. Not all the tests were successful, but they did identify issues with the program which were corrected and tested again. Ultimately, the final test was successful.

To aid with the development of the project, a specification was developed, highlighting all the required criteria that the solution had to meet to be a successful

solution. Unfortunately, not all the criteria were met due to unforeseen issues that could not be controlled. However, there will be opportunities to rectify these issues, once more materials were obtained. The issues that were found do not prevent the system from working and more affect the practicality of the installation.

This is a good conclusion and identifies the strong points and the errors encountered in the system performance.

The project was mainly kept on time. However, as with the specification, some unforeseen issues did cause delays to the completion of the project. This was typically due to finding time to complete this upgrade alongside completing other scheduled work, which took priority.

7.3 Recommendations

To ensure that the installation meets the specification, it is vital that the back-up UPS is installed as soon as it is obtained. This is a crucial part of the installation which must be rectified. Due to moving the PLC and panel outside of the relay logic cabinet, a new permanent location must be found. There is enough wall space inside the instrument shack to install a stainless-steel cabinet that will protect the PLC and UPS and keep it away from any background EMF.

Following the success of replacing the timing cam, there are two possible alternatives that could be taken to further develop the project. One of the options would be to install three more PLCs, one for each compressor. This will remove all the timing cams and make the entire system free of moving parts. The other option would be to obtain a larger PLC that has the capacity to operate the timing sequence for all four of the compressors on one module. This would reduce the amount of space taken up by four separate modules but would mean that a potential PLC failure would inhibit the system. The system should also have an HMI installed for monitoring. One issue encountered during the testing was the amount of time required to wait for the tank pressure to increase. The HMI could display useful information including the common tank pressure, which compressor is the chosen lead compressor and a display of the timers, to show the sequence's progress.

The recommendation address the problems encountered during testing and are design related. This rounds the project report off very effectively.

8. References

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[Accessed 28 April 2019].
- Sarma, U. & Bordoloi, P., 2017. *Speed Control of A DC Motor Using PLC and PIC Microcontroller*. Roorkee, IEEE, pp. 1-6.

*Good reference list with dates
accessed for on-line sources*

9. Appendix

C-Program Code

```
#include <pic.h>
#include "LCD.h"

void Display_LCD_Value(int line, int value);
void DisplayPump(int line);           //Function prototypes
void DisplayState(int line);

void Delay(int t);                    //Function prototype

int state=0, i, j, pump;              //global variables

//////////////////////////////////////
void main(void)                       //Main Function
{
    int value=0, low_byte=0, high_byte=0;

    TRISA = 0xFF;                     //Configure port
    A = 1111 1111 INPUTS
    TRISB = 0x80;                     //Configure port
    B = 1000 0000 OUTPUTS
    TRISC = 0x00;                     //Configure port
    C = 0000 0000 OUTPUTS
    TRISD = 0x00;                     //Configure port D = 0000
    0000 0000 OUTPUTS

    ADCON0 = 0b10001001;             //select RA1 as analogue input,
    Fosc/32 ADCON1 = 0b10000100;     //select RA0, RA1, RA3 as
    analogue, rest are digital

    LCD_Startup();                   //Function
    header, runs function in LCD.c

    while(1)                         //Start super-
    loop
    {
        // if (RB7==0) pump = 0;
        // else pump = 1;

        ADCON0 = ADCON0 | 0b00000100; //set GODONE bit to 1;
        GO_DONE = 1;
        while(GO_DONE == 1);           //check the GODONE bit is still 1
        Delay(100);                    //wait

        for ADC to settle
        low_byte = ADRESL;
        high_byte = ADRESH;
        value = low_byte + 256*high_byte; //calculate analogue value
        Display_LCD_Value(0,value);      //send to display

        DisplayState(1);               // displays the state on
        line 1 of LCD
        //DisplayPump(0);

        switch(state)                  //Controls flow
        depending on state value
        {
            case 0:
                RD0 = 0;
                RD1 = 0;
                RD2 = 0;
                RD3 = 0;
```

```

state to equal 1
                                if(RA2) state = 1;
                                //If RA1 is equal to 1 set
                                //
                                if(RA3 >= 512) state = 1;
                                break;
                                //This breaks out from each case

                                case 1:
                                //Case 1, run if state equals 1
                                RD0 = 1;
                                RD1 = 1;
                                RD2 = 0;
                                RD3 = 0;
                                Delay(1000);
                                state = 2;
                                break;
                                //This breaks out from each case

                                case 2:
                                //Case 2, run if state equals 2
                                RD0 = 0;
                                RD1 = 1;
                                RD2 = 0;
                                RD3 = 0;
                                Delay(1000);
                                state = 3;
                                break;
                                //This breaks out from each case

                                case 3:
                                RD0 = 0;
                                RD1 = 0;
                                RD2 = 1;
                                RD3 = 0;
                                //Case 3, run if state equals 3
                                Delay(1000);
                                state = 4;
                                break;
                                //This breaks out from each case

                                case 4:
                                //Case 4, run if state equals 4
                                RD0 = 0;
                                RD1 = 0;
                                RD2 = 0;
                                RD3 = 1;
                                Delay(1000);
                                state = 5;
                                break;
                                //This breaks out from each case

                                case 5:
                                //Case 5, run if state equals 5
                                RD0 = 0;
                                RD1 = 1;
                                RD2 = 0;
                                RD3 = 1;
                                Delay(1000);
                                state = 6;
                                break;
                                //This breaks out from each case

                                case 6:
                                //Case 6, run if state equals 6
                                RD0 = 1;
                                RD1 = 0;
                                RD2 = 1;

```

```

        RD3 = 0;
        Delay(1000);
        state = 7;
        break;
//This breaks out from each case

        case 7:

            //Case 7, run if state equals 7
            Delay(1000);
            state = 8;
            break;
//This breaks out from each case

        case 8:
//Case 8, run if state equals 8

            Delay(1000);
            state = 9;
            break;
//This breaks out from each case

        case 9:
//Case 9, run if state equals 9

            Delay(1000);
            state = 0;
            break;
//This breaks out from each case

    }
    while(RA1 || RA2 || RA3);
RA3 are active do nothing This freezes the display form setting the variables
//also sorts the delay for the debounce on the push buttons
}

////////////////////////////////////end of program run////////////////////////////////////
////////////////////////////////////Function prototype for delay////////////////////////////////////

void Delay(int t)
{
    for(i=0;i<t;i++) // Outer loop
    {
        for(j=0;j<50;j++); // inner loop
    }
}

////////////////////////////////////Funtion prototype to display the state////////////////////////////////////

void DisplayState(int line)
{
    char state_string[10] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
    state_string[0] = 'S';
    state_string[1] = 't';
    state_string[2] = 'a';
    state_string[3] = 't';
    state_string[4] = 'e';
    state_string[5] = ':';
    state_string[6] = ' ';
    state_string[7] = (char) state + 48;
    state_string[8] = 0;

    DisplayString(line, state_string);

```

```

}

void Display_LCD_Value(int line, int value)
{
    char string[7]={0,0,0,0,0,0,0};
    int units=0, tens=0, hunds =0, thous=0, temp=0;

    thous    = value / 1000;
    temp     = value % 1000;
    hunds    = temp / 100;
    temp     = temp % 100;
    tens     = temp / 10;
    units    = temp % 10;

    string[0] = (char)thous + 48;
    string[1] = (char)hunds + 48;
    string[2] = (char)tens  + 48;
    string[3] = (char)units + 48;
    string[4] = 0;

    DisplayString(line,string);
}

```

Microcontroller Testing

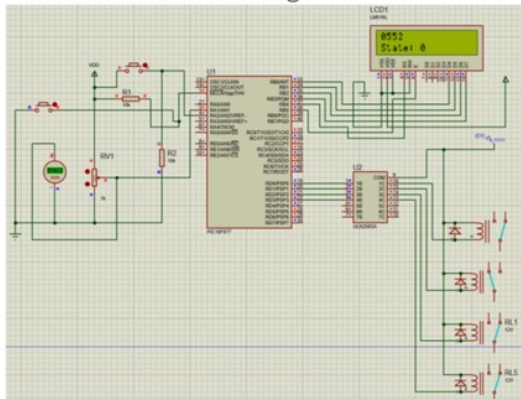


FIGURE 45 - NO RELAYS SWITCHED - AT STATE 0

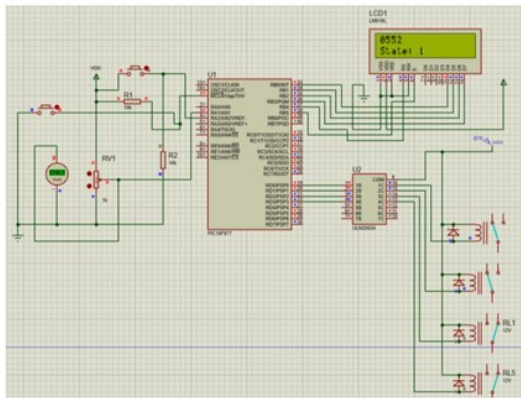


FIGURE 46 - RELAYS SWITCHED WITH DELAY - AT STATE 1

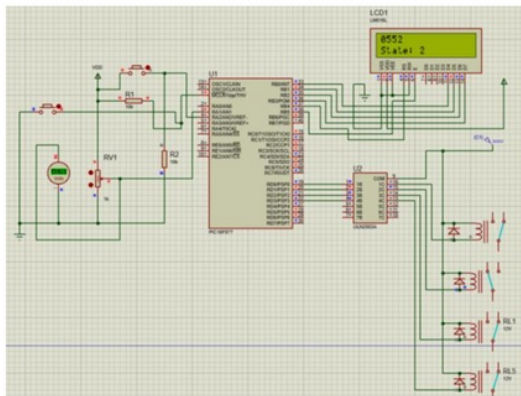


FIGURE 47 - RELAYS SWITCHED WITH DELAY - AT STATE 2

Good test to demonstrate how a MCU is a possibility to control the system sequence.

For the analogue input sensor;

5V is the max voltage [10 Bit Analogue I/P Channel]

$5V / 1024 = 0.0048828 \text{ V/bit resolution.}$

$1V / 0.0048828 = 204.883 \text{ bits / volt}$

The binary count for 1V would be 204.883.

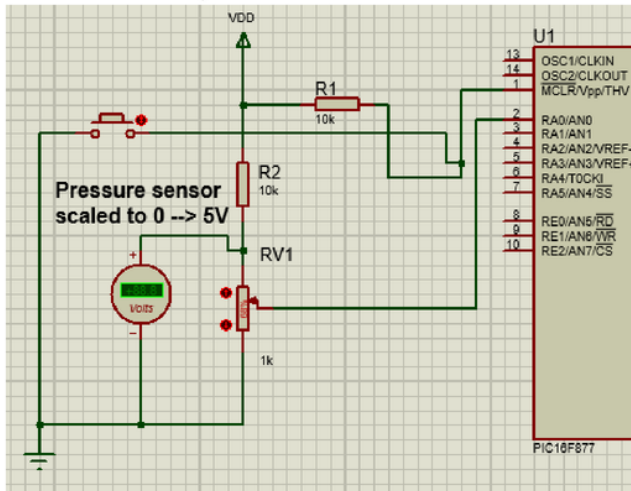


FIGURE 48 - ANALOGUE SENSOR

Good demonstration on how the analogue input can be handled.

ULN2003 Relay Driver

One of these circuits would be required for each relay and would add several components.

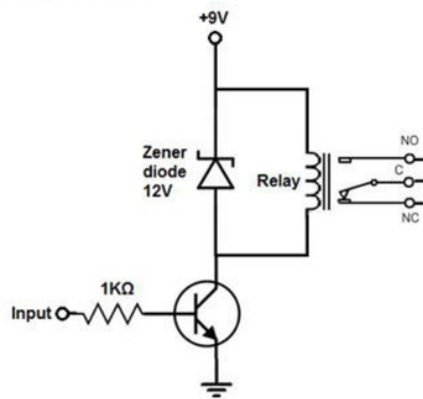
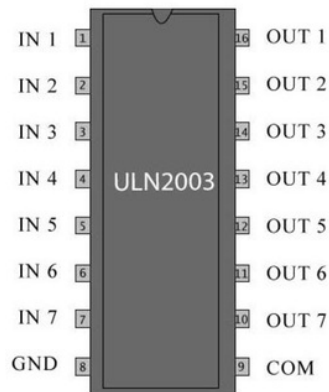


FIGURE 49 - TRANSISTOR DRIVEN RELAY COIL CIRCUIT

The ULN2003 relay driver which is a 'High Voltage Darlington Transistor Array', shown below. Pin 9 is the common positive 12V static for one terminal of the coil.



*this shows the importance
the driver chip and how it
makes the design easier and
more stable.*

FIGURE 50 - ULN2003 PINS

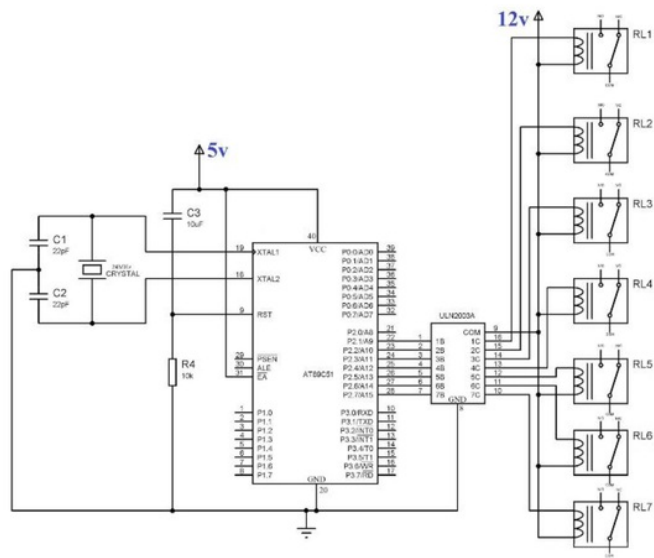
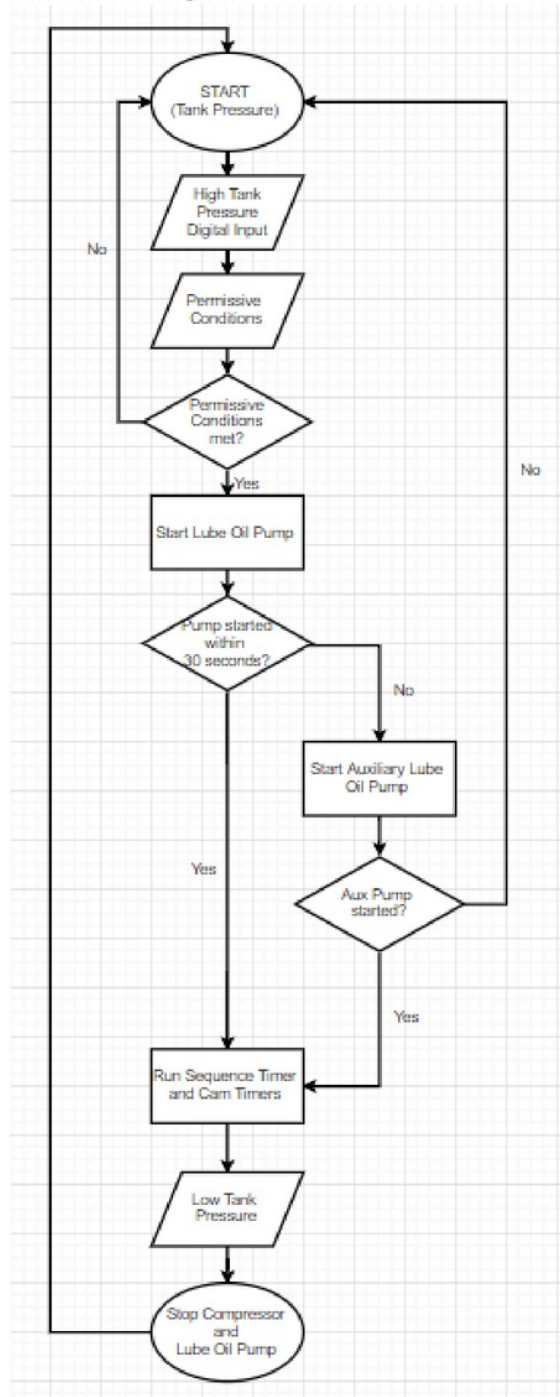


FIGURE 51 - TYPICAL ULN2003 CIRCUIT DESIGN

M C U h a s n o p r o b l e m h a n d l i n g t i m e r s e q u e n c e s a n d a r e f a i r l y e a s y t o p r

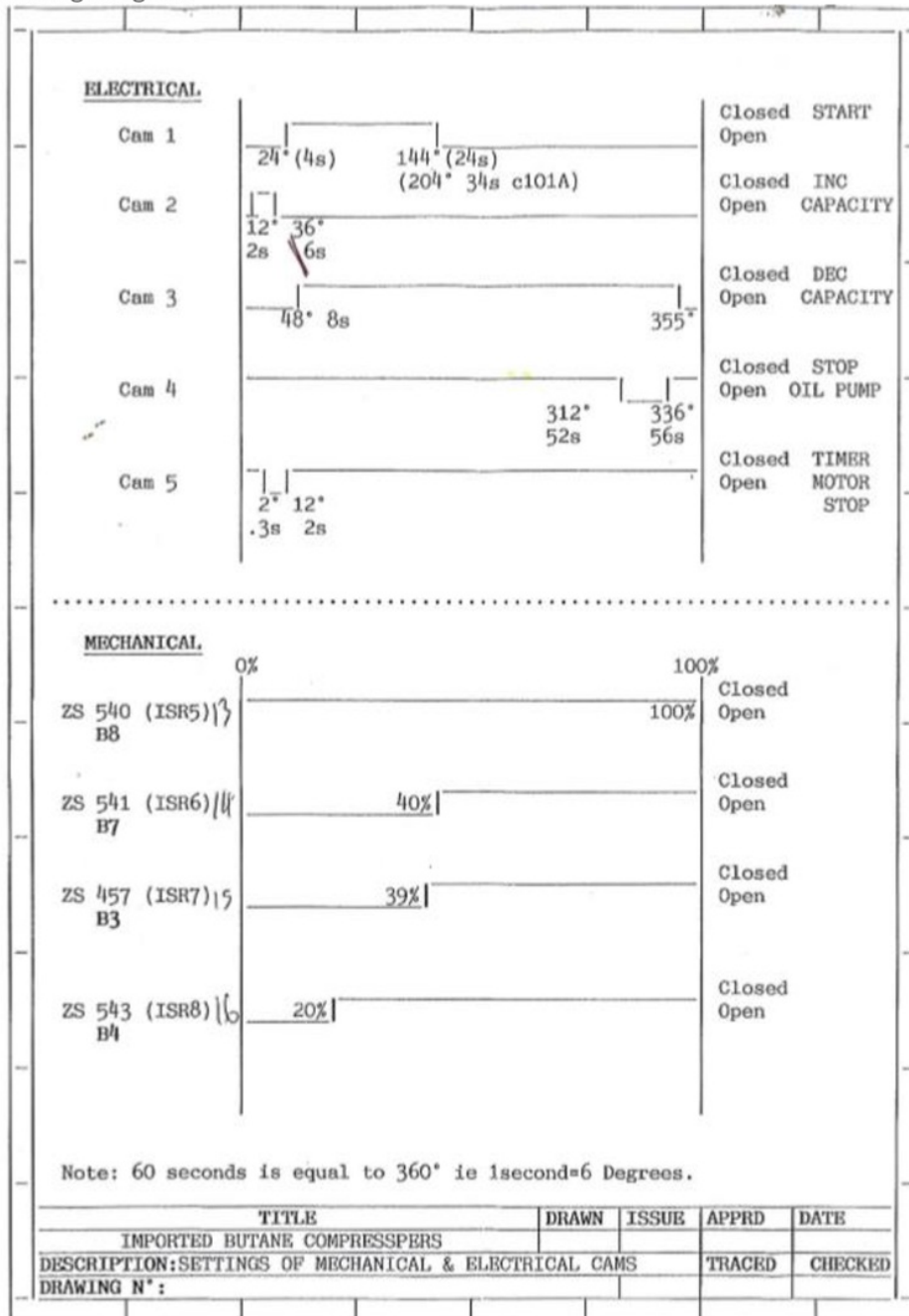
Flowchart Diagram



Good use of the flowchart which is one of the more effective ways to demonstrate sequencing with conditioning

FIGURE 52 - SOLUTION FLOWCHART

Timing Diagram

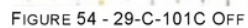


Good to see an example of the industrial test samples.

FIGURE 53 - TIMING DIAGRAM

This diagram shows the operation of the mechanical cam timer. As per the drawing, 6° of rotation is equivalent to 1 second. Therefore, full rotation would take 60 seconds.

The following diagrams show how the circuit behaves at different points during the sequence.



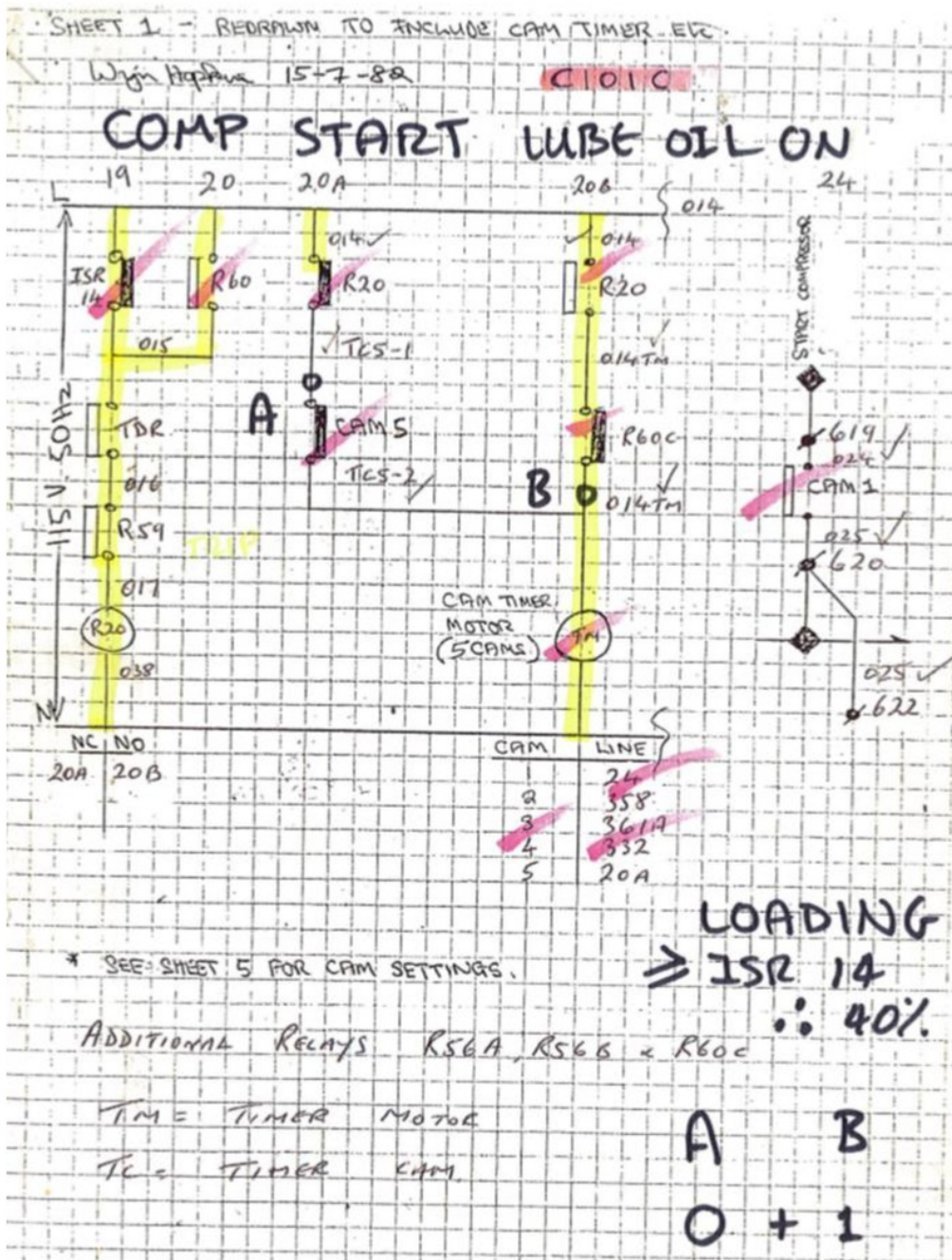
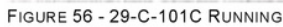


FIGURE 55 - 29-C-101C START SIGNAL



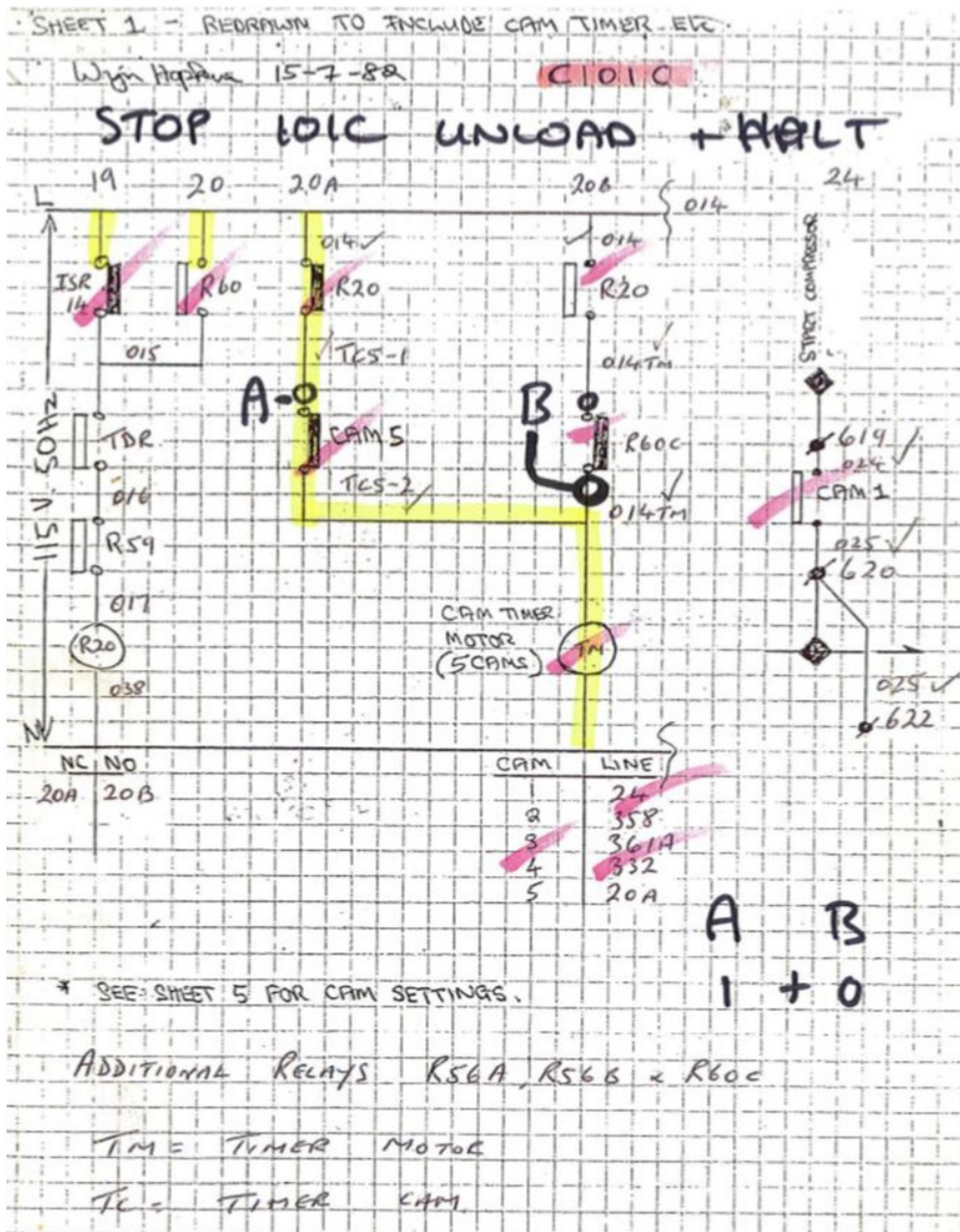


FIGURE 57 - 29-C-101C UNLOADING AND STOPPING

Good
evidenc
e of lab
work.

[illegible]

This diagram is used to show the different trip conditions and permissive conditions and how the compressor is affected when the conditions change.

Testing Results
Initial Lab Test

Test	Expected Result	Actual Result	Success?	Modifications required
Initial Lab Test	Sequence will run from when a high pressure is simulated until a low pressure is simulated. Sequence will reset after completion.	Sequence completed successfully, but timers did not reset.	No.	Reset for retentive timers.
Secondary Lab Test				
Initial Outside Test				
Additional Testing				
Final Test				

TABLE 6

Secondary Lab Test

Test	Expected Result	Actual Result	Success?	Modifications required
Initial Lab Test	Sequence will run from when a high pressure is simulated until a low pressure is simulated. Sequence will reset after completion.	Sequence completed successfully, but timers did not reset.	No.	Reset for retentive timers.
Secondary Lab Test	Sequence runs successfully and stops when the trips/permissive conditions are incorrect.	Sequence ran correctly and stopped/reset as required.	Yes.	None.
Initial Outside Test				
Additional Testing				
Final Test				

TABLE 7

Initial Outside Test

Test	Expected Result	Actual Result	Success?	Modifications required
Initial Lab Test	Sequence will run from when a high pressure is simulated until a low pressure is simulated. Sequence will reset after completion.	Sequence completed successfully, but timers did not reset.	No.	Reset for retentive timers.
Secondary Lab Test	Sequence runs successfully and stops when the trips/permissive conditions are incorrect.	Sequence ran correctly and stopped/reset as required.	Yes.	None.
Initial Outside Test	Compressor starts when the tank pressure reaches it setpoint. The sequence halts after 7 seconds and resumes once the lower limit was reached.	Compressor started and sequence halted. However, background EMF caused issues with the PLC's I/O and the sequence did not resume once halted. Compressor had to be stopped manually.	No.	Relocate PLC to location without background EMF and test again.
Additional Testing				
Final Test				

TABLE 8

Additional Testing

Test	Expected Result	Actual Result	Success?	Modifications required
Initial Lab Test	Sequence will run from when a high pressure is simulated until a low pressure is simulated. Sequence will reset after completion.	Sequence completed successfully, but timers did not reset.	No.	Reset for retentive timers.
Secondary Lab Test	Sequence runs successfully and stops when the trips/permissive conditions are incorrect.	Sequence ran correctly and stopped/reset as required.	Yes.	None.
Initial Outside Test	Compressor starts when the tank pressure reaches it setpoint. The sequence halts after 7 seconds and resumes once the lower limit was reached.	Compressor started and sequence halted. However, background EMF caused issues with the PLC's I/O and the sequence did not resume once halted. Compressor had to be stopped manually.	No.	Relocate PLC to location without background EMF and test again.
Additional Testing	Compressor starts when the tank pressure reaches it setpoint. The sequence halts after 7 seconds and resumes once the lower limit was reached.	Sequence completed successfully, halting and resuming at the correct time.	Yes.	None.
Final Test				

TABLE 9

All the test results are here and are referenced from the main report.

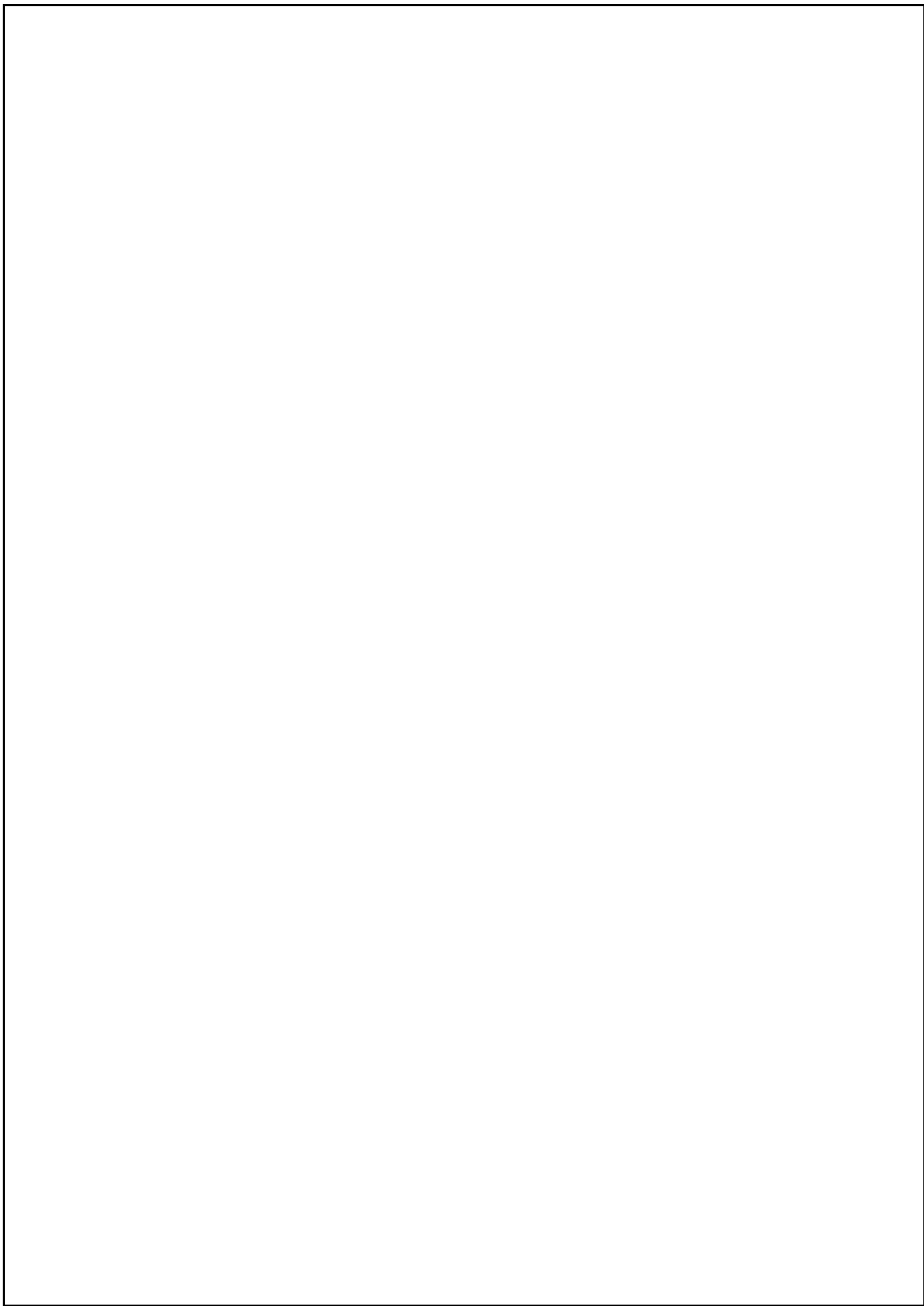
Final Gantt Chart



FIGURE 59 - FINAL GANTT CHART

This is the Gantt Chart with the actual timings added for comparison with the expected timings. As seen, there is three weeks of overlap, with the actual timings taking longer than expected. This is due to unforeseen circumstances.

The Gantt chart is very good and clear to see the actual and expected timelines.



PSDE4033 Final Project Report

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

81/100

Instructor

PAGE 1

PAGE 2

Text Comment. Good summary which covers the project outline.

PAGE 3

PAGE 4

PAGE 5

Text Comment. Good table of contents and good use of the appendix for the test results

PAGE 6

PAGE 7

Text Comment. Table of figures is in good order and figures are clearly identified.

PAGE 8

Text Comment. No need for this history. You can go straight to the relevant part for your project.

PAGE 9

Text Comment. Good images with explanations. This shows exactly how the process is controlled.

PAGE 10

Text Comment. PIC16F877

Text Comment. Good reference

PAGE 11

Text Comment. The two solutions here are possibilities for controllers

PAGE 12

Text Comment. Good reference for the alternative systems

PAGE 13

Text Comment. Good reference to sustainability and recycling by using some of the existing components

Text Comment. Good reference to codes of practice

PAGE 14

Text Comment. Good detail in the spec

PAGE 15

PAGE 16

Text Comment. Good explanation and use of chart.

PAGE 17

Text Comment. Test plan is very organised and covers what the spec requires

PAGE 18

Text Comment. This is a good point to make and can assist your budget.

PAGE 19

Text Comment. Good solution and explained in detail.

PAGE 20

PAGE 21

Text Comment. The chip is re-programmable but using a specialised download software.

Text Comment. Good example of the MCU and the connection arrangement.

PAGE 22

Text Comment. Good use of images to explain relay operation using the ULN2003A chip which simplifies the task for the MCU.

PAGE 23

Text Comment. A good argument for this method.

Text Comment. This shows you have carried out considerable research into the alternative and clearly understand the objective.

PAGE 24

Text Comment. Table of comparison for evaluation of system possibilities is very good.

PAGE 25

Text Comment. This is true but time delays can be programmed for as many delays as necessary. This is almost limitless with MCU's.

Text Comment. The arguments are very good and you have justified the final choice.

PAGE 26

Text Comment. Explanation is clear and good reference to the appendix for relative data.

PAGE 27

PAGE 28

PAGE 29

PAGE 30

PAGE 31

PAGE 32

PAGE 33

Text Comment. The program sequence looks good and demonstrates good practical skills and working knowledge of the technical part of the system.

Text Comment. Good test under fault conditions to prove the system will not run under these faulty conditions. A good test considering the volatile gases involved.

Text Comment. Utilising existing space is a good method of recycling.

Text Comment. Good explanation and proves that most projects never work first time and require investigation.

Text Comment. There is good reference to the appendix for the relevant test data.

Text Comment. Explanation of test procedures is clear and the use of tables for analysis is a good method. The problem encountered is evident in the table.

Text Comment. This is a good conclusion and identifies the strong points and the errors encountered in the system performance.

Text Comment. The recommendation address the problems encountered during testing and are design related. This rounds the project report off very effectively.

Text Comment. Good reference list with dates accessed for on-line sources

Text Comment. Good test to demonstrate how a MCU is a possibility to control the system sequence.

Text Comment. Good demonstration how the analogue input can be handled.

Text Comment. this shows the importance the driver chip and how it makes the design easier and more stable.

Text Comment. MCU has no problem handling timer sequences and are fairly easy to program due to many repetitive states in the program as shown in the listing above. You clearly understand how and why this a possible alternative solution.

Text Comment. Good use of the flowchart which is one of the more effective ways to demonstrate sequencing with conditioning.

Text Comment. Good to see an example of the industrial test samples.

Text Comment. Good evidence of lab work.

Text Comment. All the test results are here and are referenced from the main report.

Text Comment. The Gantt chart is very good and clear to see the actual and expected timelines.

GRADING FORM: CSG-RUBIC

JORDAN GOUGH

0

RESEARCH-INFORMED LITERATURE



The research and sources are relevant to the project. However there should be more refs for the length of the report. The background research is evident in the report. 7.5/10 The number of references is appropriate for the report but should be more for the length of the report. 6.5/10

14/20

KNOWLEDGE AND UNDERSTANDING



The specification is clear and coupled with the background research shows exactly what the objective is and the requirements. You have also

16/20

discussed the sustainability and recycling possibilities. 8/10 Solutions considered shows a good comprehensive understanding of what is needed for the system and alternative methods. The effort made here is very good. 8/10

ANALYSIS



Testing and results is comprehensive and the alternative system has been justified by testing practically. The initial test plan shows what is required in the final testing. There has been a good effort made in this section and underpins the understanding. The referencing to the full set of results in the appendix is very good. 8.5/10 The conclusion covers the practical issues and indicates recommendations for these issues. The issues with industrial procedure issues have been identified and further planning as a recommendation. The conclusion is very good and compares the outcome with the initial spec. The problems are identified and also what part of the spec was not met through unforeseen variables. The recommendations addressed these findings and good logical future recommendations have been put forward. 8.5/10

17/20

PRACTICAL APPLICATION AND DEP.



The planning for the project using Gant charts is good and shows the predicted and actual timeline comparison. The level of detail in the chart and explanation is good. 4/5 Solutions considered are very good and explained well. Practical testing has

21/25

been carried out on the solutions which shows a good hands on approach. 8.5/10 Implementation has been completed for the chosen solution and to some extent the alternative solutions. There is substantial evidence to support the process. A good effort with the practical approach. 8.5/10

SKILLS FOR PROFESSIONAL PRAC.



The quality of the report is very good and professional. The only issue is that there should be more relevant sources and refs with length of the project. Otherwise a well structured report and well written. 13/15

13/15