

PLC Report Andrew Prescott

by Andrew Prescott

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P.I.D. Drill Control System Using PLC and ladder logic

Introduction

The programmable logic controller (PLC) is a flexible tool that can control outputs following the code set by user requirements, this is often used in industry for automated manufacturing amongst other things. The aim for this report was to use a PLC to control a linear drill positioning system, complete with a user interface and safety precautions. The drill is controlled by a pulse width modulated (PWM) signal which is output from a P.I.D. controller within the PLC.

Pulse Width Modulation and Programmable Logic Controllers

PWM signals are often used to control analogue outputs most often motors using a digital source such as a microcontroller or in this case a PLC. A PWM signal is a square wave which has two main properties, the first is duty cycle this is the ratio of the high portion of the wave to the low portion of the wave and supplies a given average voltage to the attached load, the greater the width of the high section of the waveform the greater the average voltage supplied; hence the name pulse width modulation; the other is frequency of the signal [1]. This method is more efficient than supplying a load with a constant analogue signal as with PWM the load is switched reducing dissipation [2]. An example of an analogue signal and its equivalent PWM waveform can be seen below in figure 1 (frequency/period shown with dotted line) [3].

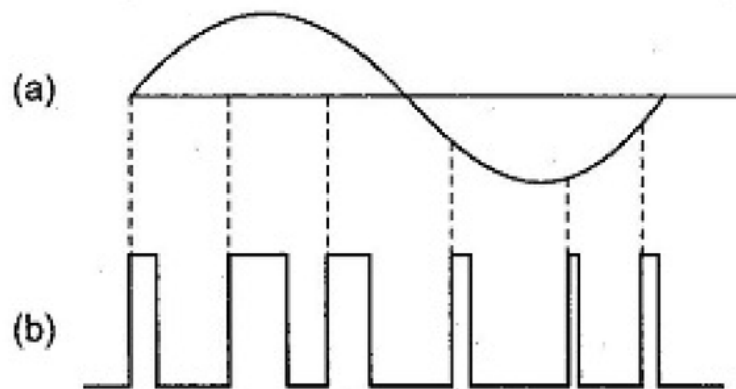


Figure 1 [3] Analogue (a) and equivalent PWM signal (b).

PWM signals are usually generated using a sawtooth waveform compared to the required analogue equivalent as shown in figure 2.

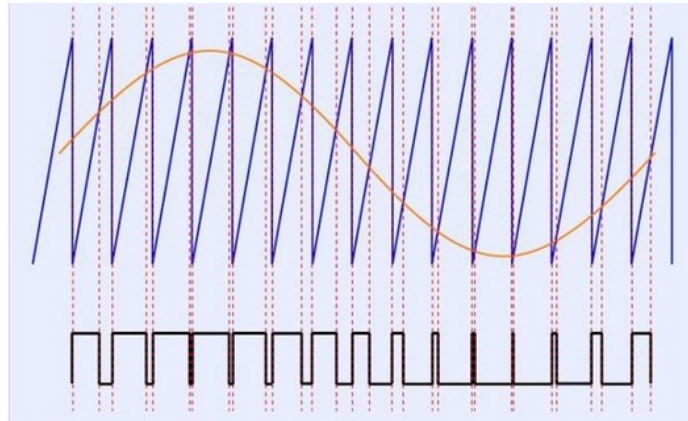


Figure 2 [4] Sawtooth generated PWM signal.

In this case PWM signals can also be generated completely digitally, a sawtooth waveform is generated using a timer (in a microcontroller or PLC) counting up then down (e.g. from 0 to 256 then back to 0) then this value is compared to a set point [1]. The time for the counter to complete one up and down cycle is twice the period of the generated waveform this is dictated by the clock frequency of the controller and timer. The duty cycle ($D = \frac{PW}{T}$, D is duty cycle, PW is the pulse width and T is the period) as mentioned is the pulse width in comparison to the period, in this case this is altered by changing the set/comparison point. This can be seen in figure 3.

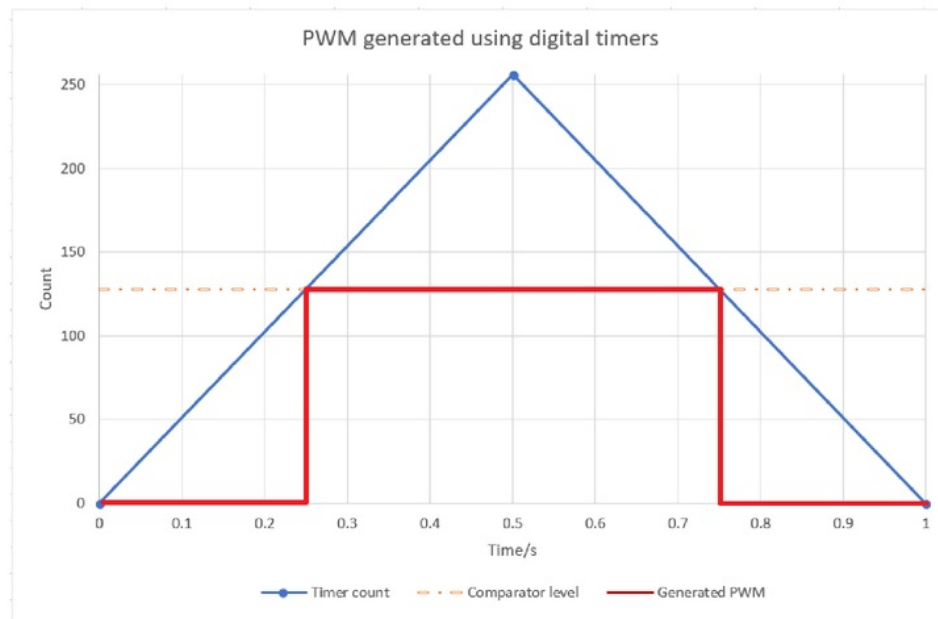


Figure 3 PWM signal with 50% duty cycle and 0.5s period

This PWM output can then be used to power outputs efficiently, the output can also be smoothed using a low pass filter if required to produce a steady output signal [4]. The advantages of PWM over analogue is

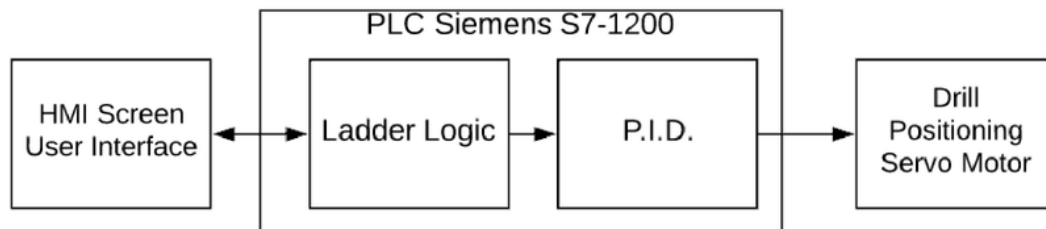
that PWM is much more efficient than analogue due to the switching nature, and this method can be easily generated by digital circuitry, such as a PLC, to power DC and stepper motors (voltage or duty cycle can be changed to alter torque or speed) amongst other devices; another advantage of PWM is that when powering a load such as an LED there is less need for current regulation [3]. The disadvantage of PWM is that there is a maximum resolution meaning that dependent on the clock speed of the device generating the pulses [1] [2].

Design Brief

The design specifications for the system are listed below.

- P.I.D Control system for drill positioning servo motor.
- Motor Drive – PWM.
- Max drive PWM output 85%
- Warning if PWM output is greater than 80% of max
- Alarm if PWM output is greater than 85% of max
- Absolute Max response time (to steady state) 20secs
- Absolute Max over-shoot to a step-change 5%
- Warning if output exceeds 75% of max
- Warning if position is greater than 80% of max
- Warning if position is less than 20% of max
- Alarm if position is greater than 90% of max
- Alarm if position is less than 10% of max
- System must include an Estop button

The system must use a PLC and a P.I.D. controller the block diagram is shown below.



MATLAB P.I.D. Design

To control the PWM output powering the motor position servo motor a P.I.D. controller is required. MATLAB and the open loop response from the system to a step change were used to produce the values for: K_p , K_i , K_d , these constants change the way the P.I.D. controller will respond. The design process for the P.I.D. controller is below.

Firstly, the variables for the P.I.D. controller were initialized, these were K_p , K_i , K_d , the plant data (open loop response from the system to a step change, inputdat) and the number of steps in this data (n). This is shown below in figure 4.

inputdat	106x1 double
kd	1
ki	1
kp	1
n	100

Figure 4 Initialization of variables

This information was then imported to the P.I.D. tool within MATLAB this enables the transfer function of the system to be found by attempting to graph match the response with a variety of methods. The first method was single pole, tuning manually gave the response in figure 5, and with the auto adjust tool to give the response in figure 6.

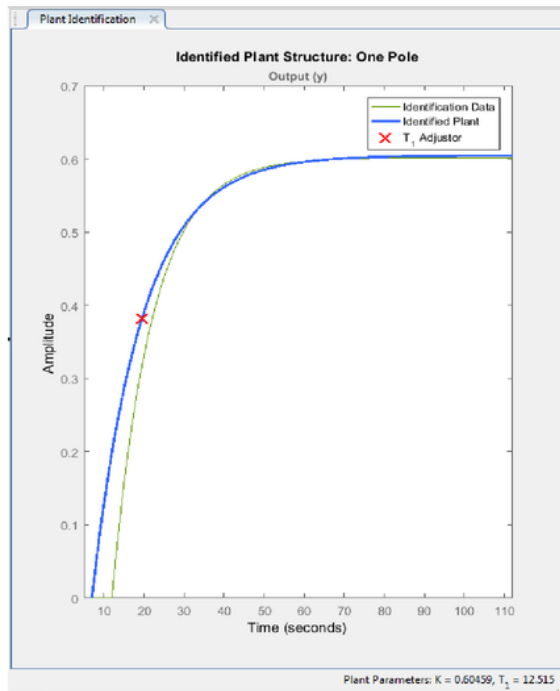


Figure 5 One pole response with manual tuning.

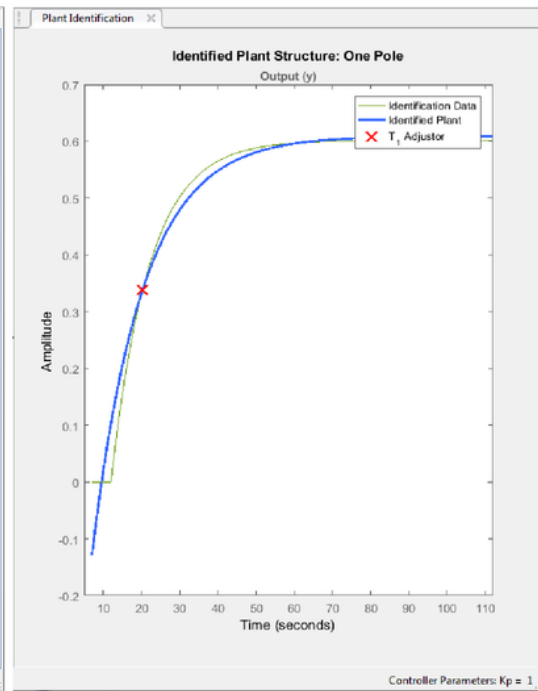


Figure 6 One pole response with auto tuning.

As can be seen from figures 5 and 6 the tuned response (blue line) and the actual response from the plant data (green line) are not an adequate match therefore using a two real pole this method was repeated using manual tuning, then the auto adjust tool the results from these are shown in figures 8 and 9.

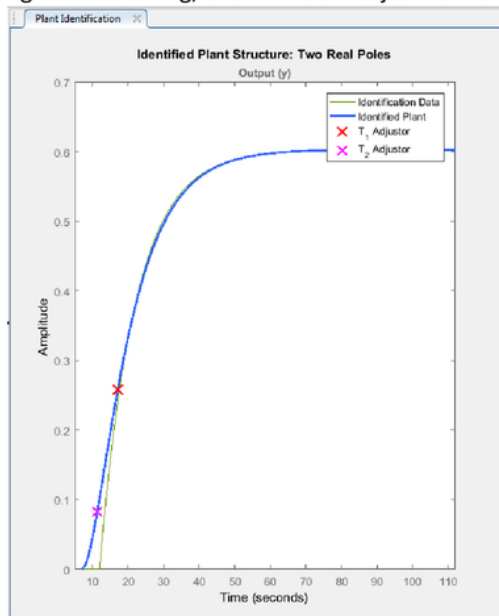


Figure 7 Two real pole response with manual tuning.

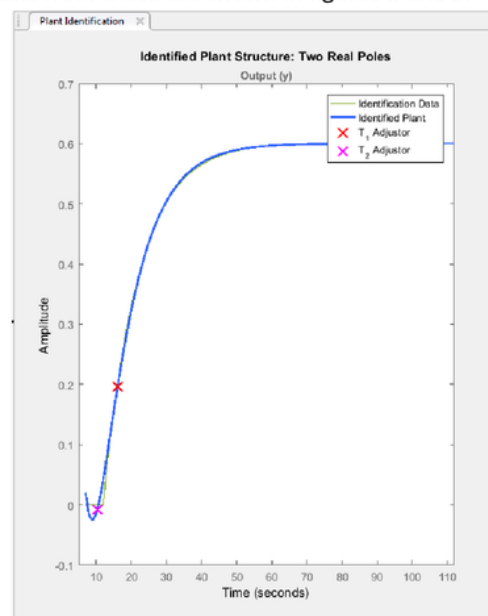


Figure 8 Two real pole response with auto tuning.

The auto tuned response in figure 8 was a very close match apart from a small part in the early section of the curve. To investigate if another method would give a better matched response an underdamped pair the manual and auto tuned responses are shown in figures 9 and 10.

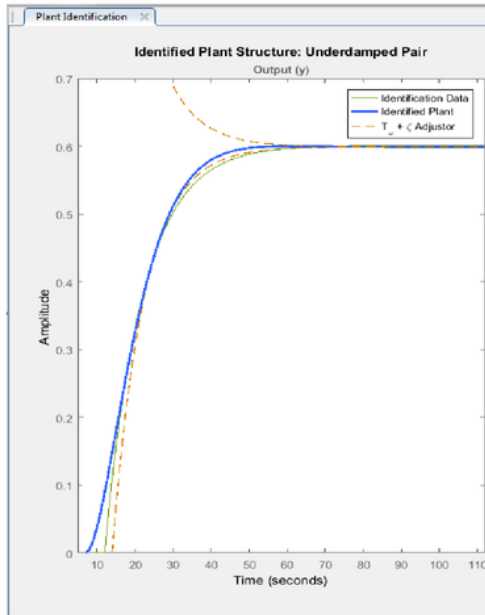


Figure 9 Underdamped pair response with manual tuning.

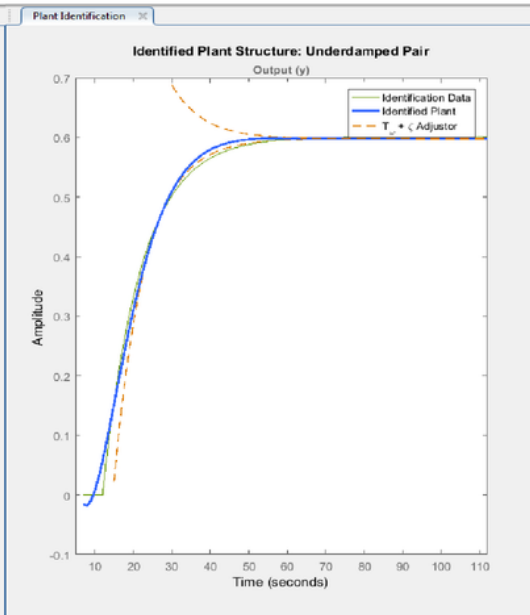


Figure 10 Underdamped pair response with auto tuning.

Neither of these responses in figures 9 and 10 are a better fit than the two real pole auto tuned response. To fully confirm the two real pole response in figure 8 was the best match, manually and auto tuned responses using an underdamped and real pole were tested these are shown in figures 11 and 12.

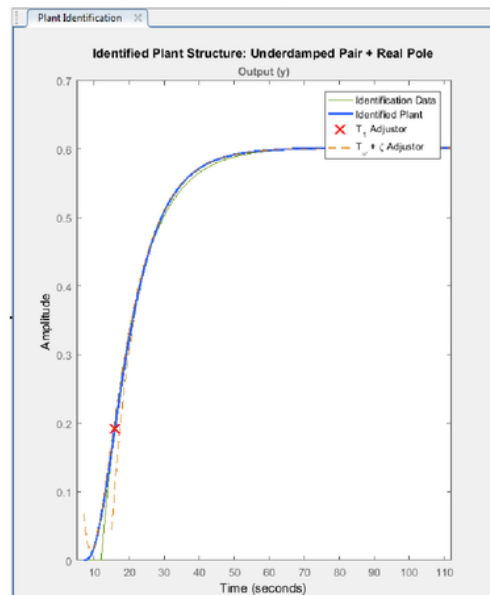


Figure 11 Underdamped and real pole manual tuning.

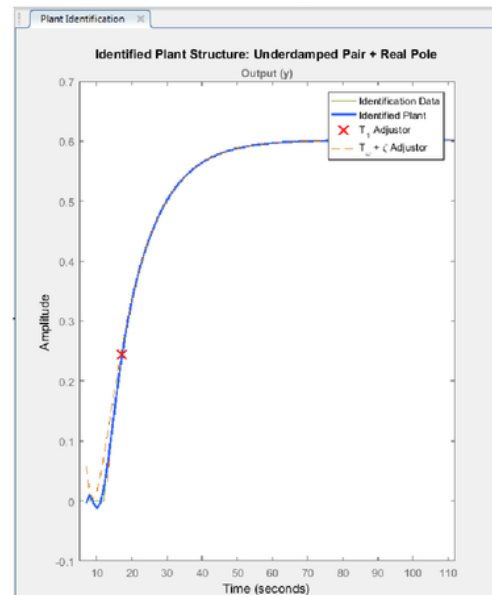


Figure 12 Underdamped and real pole auto tuned.

It is clear from figures 11 and 12 that these responses did not provide as close as a response to the identification data as figure 8 with the two real poles.

The response shown in figure 8 gave the response that was closest to the actual plant data, the transfer function of the system obtained from this was:

$$\frac{K}{(T_1 s + 1)(T_2 s + 1)}$$

Plant Parameters: $K = 0.60055$, $T_1 = 9.1068$, $T_2 = 3.3016$

$$\frac{0.60055}{(9.1068s + 1)(3.3016s + 1)}$$

This transfer function was then used to produce the optimal values for K_p , K_i , and K_d that give the output that best fits the specification: Rise time < 5 seconds, settling time < 20 seconds, overshoot < 5%. The process of obtaining these values is listed below.

First the transfer function was exported to the P.I.D. tuning tool, and the response of the plant with only the proportional control was plotted, this plot is shown below in figure 13.

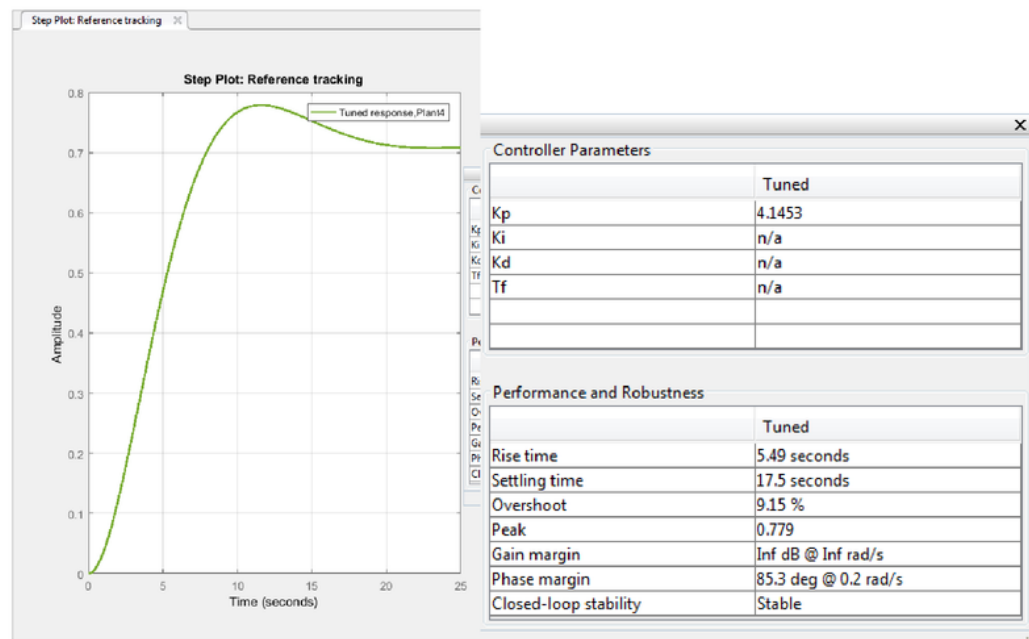


Figure 13 Proportional only control.

Although the best efforts were made to meet the specification it was impossible to meet all the requirements with any amount of tuning. Even if the response did meet the specification proportional only control always leaves an offset from the desired value. As no adequate response could be made with proportional only control, integral control was introduced alongside the proportional element; the response can be seen in figure 14.

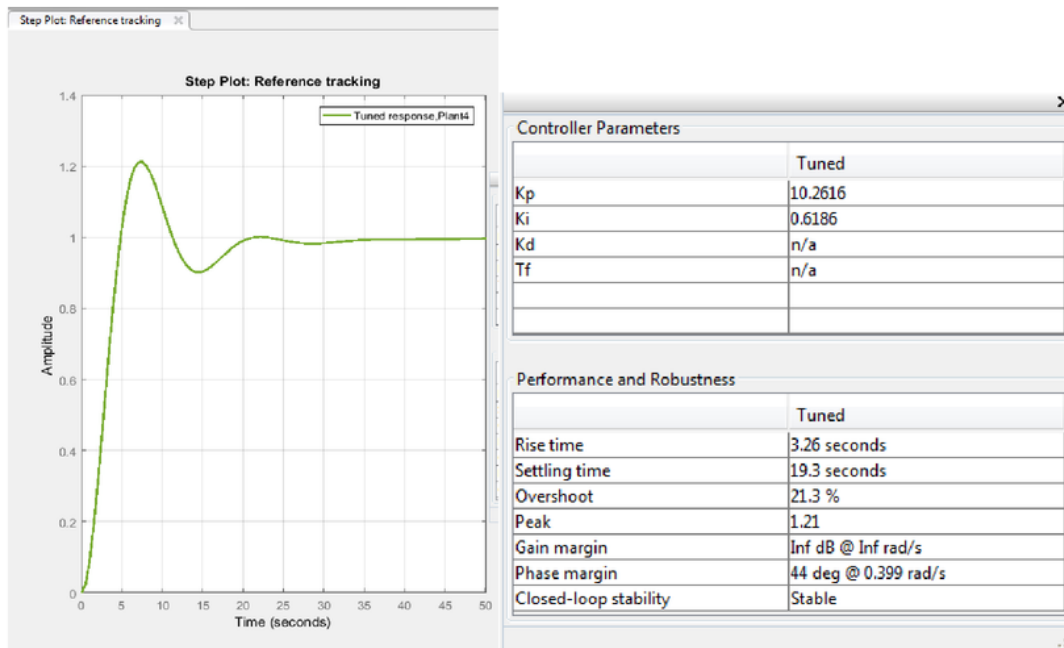


Figure 14 P.I. control.

Again, much like the proportional only control it was impossible to attain all three areas of the specification simultaneously, to meet the rise and settling time requirements the minimum overshoot requirement could not be met. As these methods were unsuccessful proportional, integral, and differential control was used. The results for the tuned P.I.D. controller are shown in figure 15.

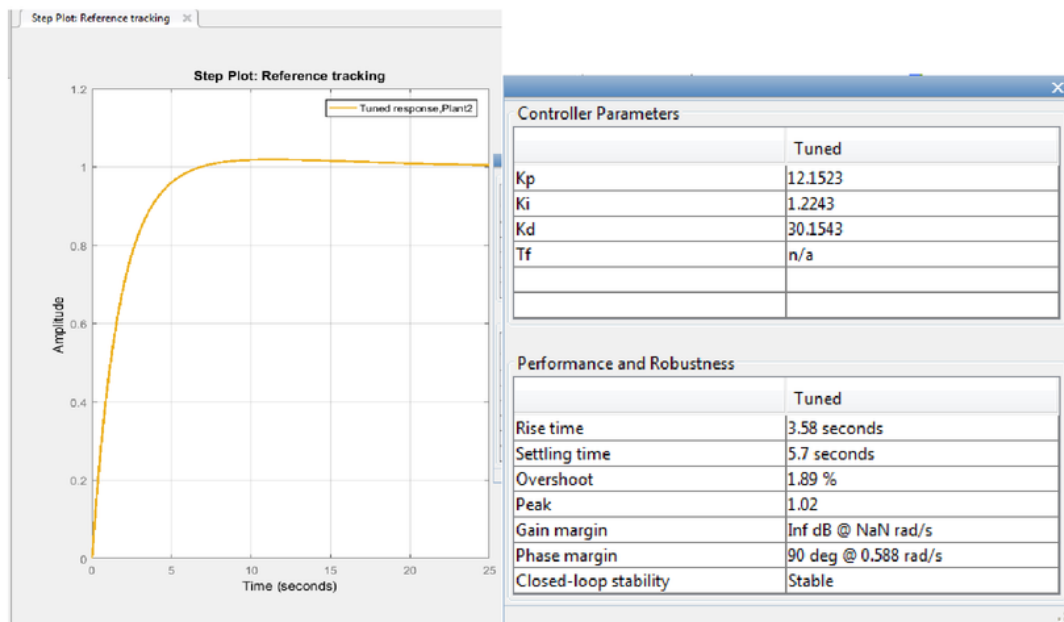


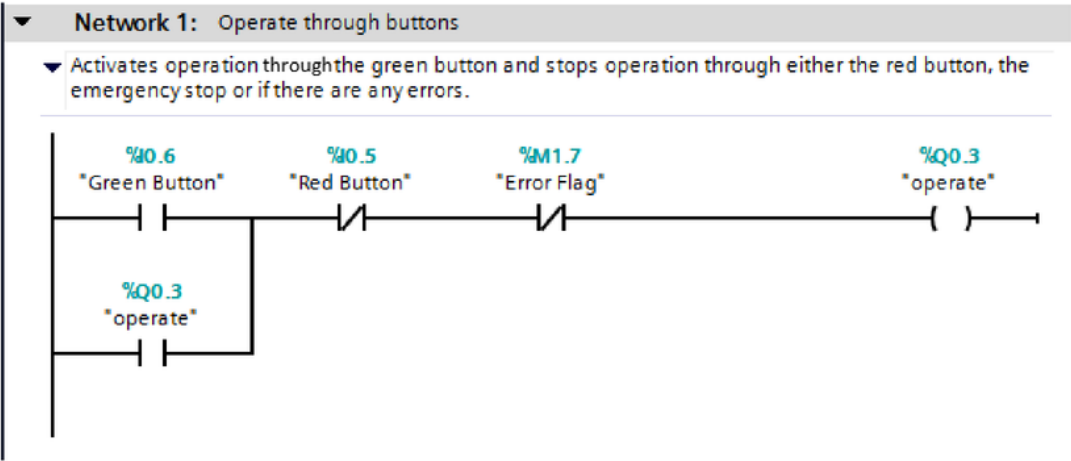
Figure 15 P.I.D. tuned control.

The output from this P.I.D. meets all areas of the specification, it has a rise time of less than 5 seconds (3.58 seconds), a settling time of less than 20 seconds (5.7 seconds), and an overshoot of less than 5% (1.89%). This tool also gives the control parameters for $K_p = 12.1523$, $K_i = 1.2243$, $K_d = 30.1543$, these values can be used later in the system creation for the P.I.D. within the PLC.

Ladder Logic

To control the inputs and outputs of the system a PLC with the correct programming is required, the ladder logic, tag tables (full tag table in index), and their operation is shown below.

Network 1

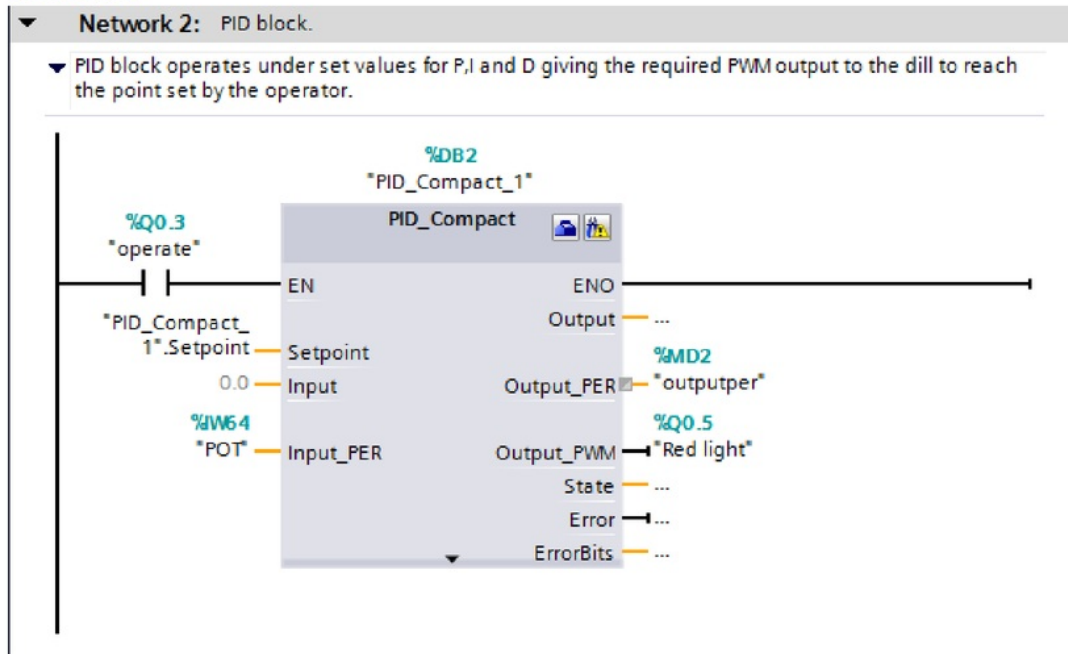


This network involves the following tags.

	Name	Data type	Address	Retain	Visibl...	Acces...
1	Red Button	Bool	%I0.5	☐	☒	☒
2	Green Button	Bool	%I0.6	☐	☒	☒
3	operate	Bool	%Q0.3	☐	☒	☒
21	Error Flag	Bool	%M1.7	☒	☒	☒
24	EStop	Bool	%M100.2	☐	☒	☒

1. Red button - Physical button on console.
2. Green button – Physical button on console.
3. Operate – Boolean that dictates when the system operates.
21. Error flag – An error indicator which is set if any error occurs (covered in network 7)
24. Estop – Emergency stop button (covered in user interface section).

Network 2



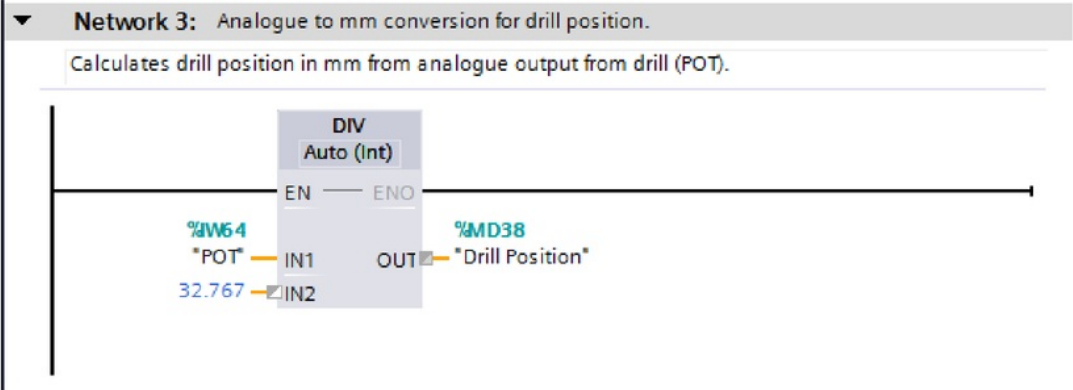
The P.I.D. block variables can be set by the operator through the user interface, this is covered in the user interface section. The P.I.D. activated when operate is set, this moves the drill using a set PWM dictated by the P.I.D. and the user set point and current drill position, this output is indicated with a red light.

This network involves the following tags:

	Name	Data type	Address	Retain	Visibl...	Acces...
3	operate	Bool	%Q0.3	☐	☒	☒
4	Red light	Bool	%Q0.5	☐	☒	☒
6	POT	Int	%IW64	☐	☒	☒
37	outputper	Real	%MD2	☐	☒	☒

3. Operate – Dictates operation of P.I.D. block.
4. Red light – Indicates operation of P.I.D.
6. POT – Analogue input of drill position.
37. Outputper – Output percentage from P.I.D. (duty cycle)

Network 3



This uses the analogue input of the drill position and calculates the position in millimetres.

Tags used in this network are:

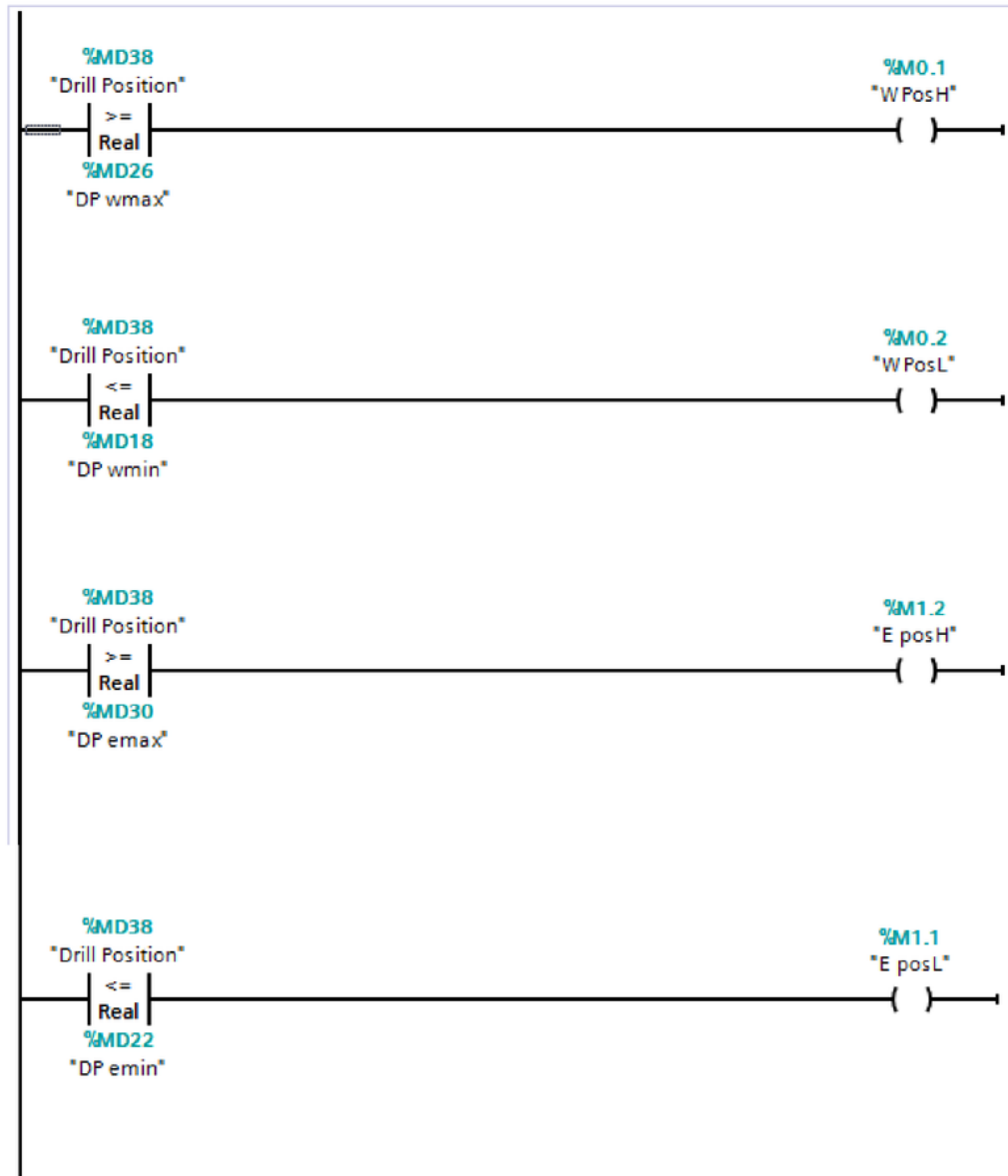
		Name	Data type	Address	Retain	Visibl...	Acces...
6		POT	Int	%IW64	☐	☒	☒
34		Drill Position	Real	%MD38	☐	☒	☒

- 6. POT - Analogue input of drill position.
- 34. Drill Position – Drill position in millimetres.

Network 4

Network 4: Warnings and errors for drill position

Compares set values with the drill's current position and activates the appropriate warning or error.



This uses the current drill position and compares it with the values for the warnings and errors set by the operator in the engineering screen, and outputs these errors and warnings to the warnings and errors screen, more on these in the user interface section.

Tags used in this network:

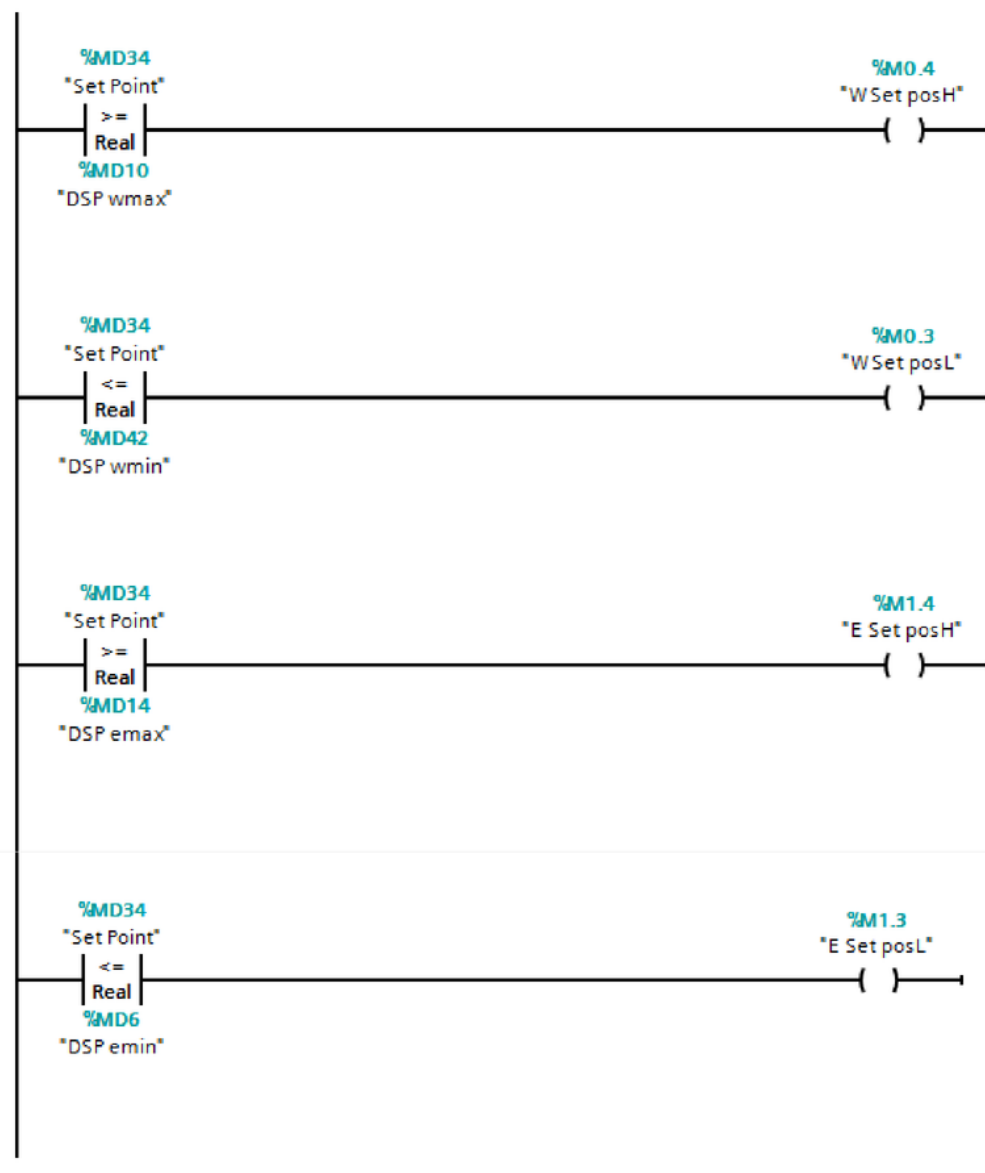
	Name	Data type	Address	Retain	Visibl...	Acces...
8	 WPosH	Bool	%MO.1	☒	☒	☒
9	 WPosL	Bool	%MO.2	☒	☒	☒
13	 E posL	Bool	%M1.1	☒	☒	☒
14	 E posH	Bool	%M1.2	☒	☒	☒
29	 DP wmin	Real	%MD18	☒	☒	☒
30	 DP emin	Real	%MD22	☒	☒	☒
31	 DP wmax	Real	%MD26	☒	☒	☒
32	 DP emax	Real	%MD30	☒	☒	☒
34	 Drill Position	Real	%MD38	☐	☒	☒

8. WPosH – Warning indicator shown on warnings and error screen for drill position being higher than the set warning value.
9. WPosL – Warning indicator shown on warnings and error screen for drill position being below than the set warning value.
13. EposL – Error indicator shown on the warnings and errors screen for the drill position being below the set error value.
14. EposH – Error indicator shown on the warnings and errors screen for the drill position being higher than the set error value.
29. DPwmin – Value set in the engineering screen for the warning point for low drill position.
30. DPemin – Value set in the engineering screen for the error point for low drill position.
31. DPwmax – Value set in the engineering screen for the warning point for high drill position.
32. DPemax – Value set in the engineering screen for the error point for high drill position.
34. Drill Position – Current drill position in millimetres.

Network 5

Network 5: Warnings and errors for set position

Compares the user input set position with the set values, outputs the appropriate warning or error.



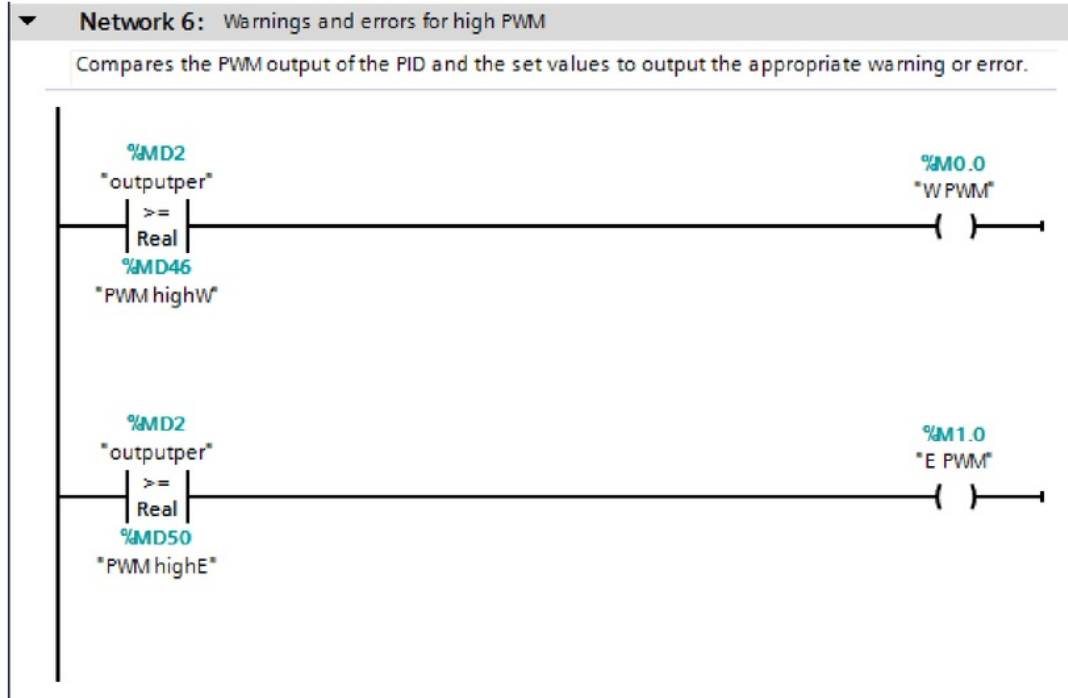
This uses the user input set point for the drill and compares it with the values for the warnings and errors set by the operator in the engineering screen, and outputs these errors and warnings to the warnings and errors screen, more on these in the user interface section.

The tags used in this network:

	Name	Data type	Address	Retain	Visibl...	Acces...
10	 WSet posL	Bool	%M0.3	☒	☒	☒
11	 WSet posH	Bool	%M0.4	☒	☒	☒
15	 E Set posL	Bool	%M1.3	☒	☒	☒
16	 E Set posH	Bool	%M1.4	☒	☒	☒
25	 DSP wmin	Real	%MD42	☒	☒	☒
26	 DSP emin	Real	%MD6	☒	☒	☒
27	 DSP wmax	Real	%MD10	☒	☒	☒
28	 DSP emax	Real	%MD14	☒	☒	☒
33	 Set Point	Real	%MD34	☒	☒	☒

- 10. WSetposL – Warning indicator shown on warnings and errors screen if the set position is lower than the warning value set.
- 11. WSetposH – Warning indicator shown on warnings and errors screen if the set position is higher than the warning value set.
- 15. ESetposL – Error indicator shown on warnings and errors screen if the set position is lower than the warning value set.
- 16. ESetposH – Error indicator shown on warnings and errors screen if the set position is higher than the warning value set.
- 25. DSPwmin – Value set in the engineering screen for the warning point for low drill set point.
- 26. DSPemin – Value set in the engineering screen for the error point for low drill set point.
- 27. DSPwmax – Value set in the engineering screen for the warning point for high drill set point.
- 28. DSPemax – Value set in the engineering screen for the error point for high drill set point.
- 33. Set Point – The drill position set point entered by the user on the main screen.

Network 6



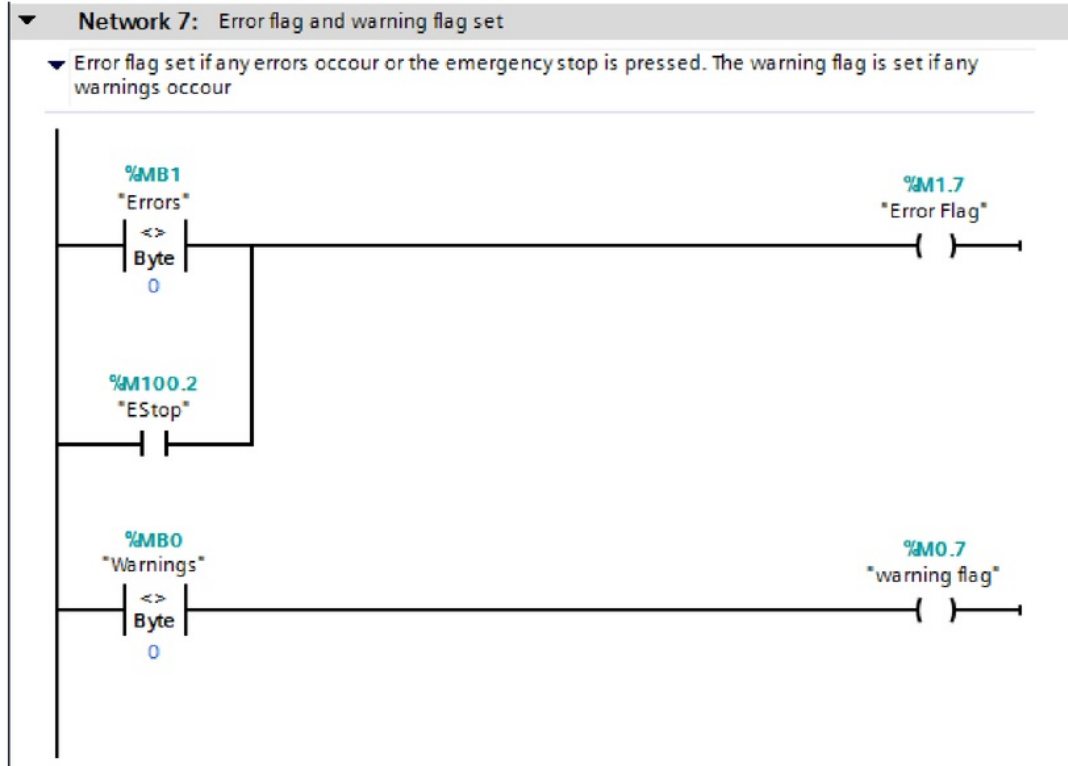
This activates the appropriate warning or error if the output of the P.I.D. exceeds the set value.

The tags used in this network:

	Name	Data type	Address	Retain	Visibl...	Acces...
7	W PWM	Bool	%M0.0	☒	☒	☒
12	E PWM	Bool	%M1.0	☒	☒	☒
37	outputper	Real	%MD2	☐	☒	☒
38	PWM highW	Real	%MD46	☒	☒	☒
39	PWM highE	Real	%MD50	☒	☒	☒

- 7. W PWM – Error indicator if the duty cycle of the PWM from the P.I.D. exceeds the user set value.
- 12. E PWM – Warning indicator if the duty cycle of the PWM from the P.I.D. exceeds the user set value.
- 37. Outputper – Output percentage of P.I.D. (duty cycle of PWM)
- 38. PWMhighW – Value set in engineering screen to set the warning point for high PWM output.
- 39. PWMhighE – Value set in engineering screen to set the error point for high PWM output.

Network 7



This sets the error flag if any errors occur or if the emergency stop button is pressed, the warning flag is set if any warnings occur.

Tags used in this network:

	Name	Data type	Address	Retain	Visibl...	Acces...
21	Error Flag	Bool	%M1.7	☒	☒	☒
24	EStop	Bool	%M100.2	☐	☒	☒
35	Errors	Byte	%MB1	☒	☒	☒
36	Warnings	Byte	%MB0	☒	☒	☒
40	warning flag	Bool	%M0.7	☒	☒	☒

- 21. Error Flag – An error indicator that is shown on all screens, if any error occurs or the emergency stop button is pressed.
- 24. EStop – The emergency stop button shown on the main screen (more discussed in the user interface section).
- 35. Errors – A byte which contains all errors. These are listed below:

	Name	Data type	Address	Retain	Visibl...	Acces...
12	 E PWM	Bool	%M1.0	☒	☒	☒
13	 E posL	Bool	%M1.1	☒	☒	☒
14	 E posH	Bool	%M1.2	☒	☒	☒
15	 E Set posL	Bool	%M1.3	☒	☒	☒
16	 E Set posH	Bool	%M1.4	☒	☒	☒
19	 Error 1	Bool	%M1.5	☒	☒	☒
20	 Error 2	Bool	%M1.6	☒	☒	☒
21	 Error Flag	Bool	%M1.7	☒	☒	☒

36. Warnings – A byte which contains all warnings. These are listed below:

	Name	Data type	Address	Retain	Visibl...	Acces...
7	 WPWM	Bool	%M0.0	☒	☒	☒
8	 WPosH	Bool	%M0.1	☒	☒	☒
9	 WPosL	Bool	%M0.2	☒	☒	☒
10	 WSet posL	Bool	%M0.3	☒	☒	☒
11	 WSet posH	Bool	%M0.4	☒	☒	☒
17	 Warning 2	Bool	%M0.6	☒	☒	☒
18	 Warning 1	Bool	%M0.5	☒	☒	☒
40	 warning flag	Bool	%M0.7	☒	☒	☒

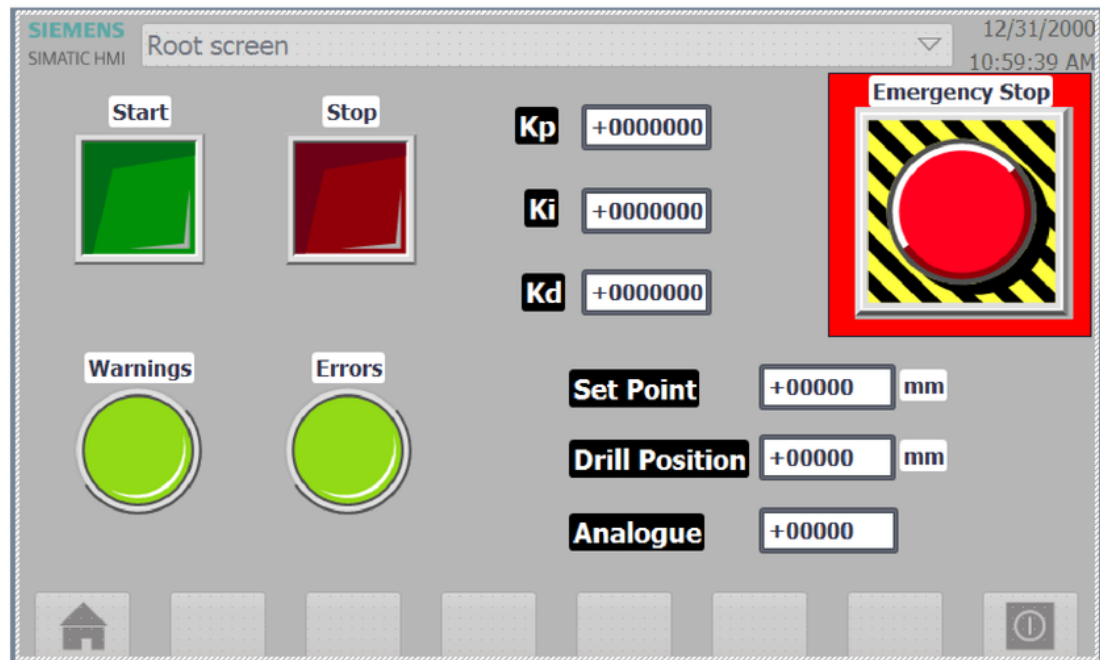
40. Warning flag – A warning indicator that is shown on all screens if any warning occurs.

User Interface and Guide

The networks listed above allow the system to meet the specification with the correct user input. The ability for the user to control the system requires some form of user interface; the design and creation of this user interface is below.

Main Screen

This is the main screen used to operate the drill system, from this screen the system can be started or stopped, and several system variables can be changed. The screen and its features are shown below.



Item	Description
Start 	Start button: Associated with the operate tag. Pressing this button will activate the system.
Stop 	Stop button: Associated with the operate tag. When pressed the system will stop.

	Emergency stop button: Associated with the Estop tag. If this button is pressed the system will stop.
	Kp: Associated with the Kp variable within the P.I.D. controller, this variable controls the proportional gain. Ki: Associated with the Ki variable within the P.I.D. controller, this variable controls the integral gain. Kd: Associated with the Kd variable within the P.I.D. controller, this variable controls the derivative gain. Note: For the desired output for the plant use the following values $K_p = 12.1523$, $K_i = 1.2243$, $K_d = 30.1543$
	Warning indicator: Associated with the warning flag tag, when pressed user will be taken to warnings and errors screen (shown later). When the warning indicator is green (left) no warnings have occurred. When the warning indicator is red (right) a warning has occurred.
	Error indicator: Associated with the error flag tag, when pressed user will be taken to the warnings and errors screen (shown later). When the error indicator is green (left) no errors have occurred. When the error indicator is red (right) an error has occurred.
	Set point: Associated with the SetPoint tag. This allows the user to enter the required position for the drill in millimeters. Drill position: Associated with the Drill Position tag. This shows the drill's current position in millimeters. Analogue: Associated with the POT tag. This shows the current position of the drill with a raw analogue value.



Screen navigation buttons: These are located below the touch screen. If the most left button is pressed, the user will be returned to the main (home) screen. If the first button from the left is pressed the user will be taken to the engineering screen. If the second button from the left is pressed the user will be taken to the warnings and errors screen.

Engineering Screen

This screen allows the values that trigger warnings and errors when exceeded.

Warnings	Errors			Return Home
		Drill Position	+00000 mm	
		Analogue	+00000	
Error Minimum	Warning Minimum	Property	Warning Maximum	Error Maximum
+00000	+00000	Drill Set Point mm	+00000	+00000
+00000	+00000	Drill position mm	+00000	+00000
PID Control Constants		Drill movement speed	+00000	+00000
Kp	+0000000			
Ki	+0000000			
	Kd		+0000000	

Item	Description
Warnings	Warning indicator: Associated with the warning flag tag, when pressed user will be taken to warnings and errors screen (shown later). When the warning indicator is grey (left) no warnings have occurred. When the warning indicator is red (right) a warning has occurred.

Errors  Errors 	Error indicator: Associated with the error flag tag, when pressed user will be taken to the warnings and errors screen (shown later). When the error indicator is grey (left) no errors have occurred. When the error indicator is red (right) an error has occurred.
Drill Position +00000 mm Analogue +00000	Drill position: Associated with the Drill Position tag. This shows the drill's current position in millimeters. Analogue: Associated with the POT tag. This shows the current position of the drill with a raw analogue value.
Return Home 	Home Button: When this button is pressed the user will return to the main (home) screen.
PID Control Constants Kp +0000000 Kd +0000000 Ki +0000000	Kp: Associated with the Kp variable within the P.I.D. controller, this variable controls the proportional gain. Ki: Associated with the Ki variable within the P.I.D. controller, this variable controls the integral gain. Kd: Associated with the Kd variable within the P.I.D. controller, this variable controls the derivative gain. Note: For the desired output for the plant use the following values $K_p = 12.1523$, $K_i = 1.2243$, $K_d = 30.1543$
Error Minimum +00000 +00000 Warning Minimum +00000 +00000 Property Drill Set Point mm Drill position mm Drill movement speed Warning Maximum +00000 +00000 +00000 Error Maximum +00000 +00000 +00000	Warning and error values: This section of the screen allows the user to set the appropriate values for errors and warnings to occur. Drill Set Point mm: The two fields to the left allow the user to set the warning point (orange, associated with the DSP wmin tag) and the error point (red, associated with the DSP emin tag) for the minimum drill set point. The two fields to the right of this property allow the user to set the warning point for the maximum drill set position (orange, associated with the DSP wmax tag) and the error point (red, associated with the DSP emax tag). Drill position mm: The two fields to the left allow the user to set the warning point (orange, associated with the DP wmin tag) and

Error Minimum

+00000

+00000

Warning Minimum

+00000

+00000

Property

Drill Set Point mm

Drill position mm

Drill movement speed

Warning Maximum

+00000

+00000

+00000

Error Maximum

+00000

+00000

+00000

the error point (red, associated with the DP emin tag) for the minimum drill position.

The two fields to the right of this property allow the user to set the warning point for the maximum drill position (orange, associated with the DP wmax tag) and the error point (red, associated with the DP emax tag).

Drill movement speed: The fields to the right of this property allow the user to set the warning point (orange, associated with the PWM highW tag) and error point (red, associated with the PWM highE tag) for a high PWM output from the P.I.D. controller to the drill.

Warnings and Errors screen

This screen allows the user to view any warnings or errors that have occurred in the system.

Warnings

PWM High

Set Point High

Set Point Low

Drill Position High

Drill Position Low

Warning 1

Warning 2

Warning Flag

Errors

PWM High

Set Point High

Set Point Low

Drill Position High

Drill Position Low

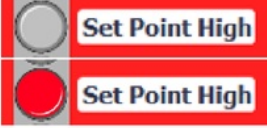
Error 1

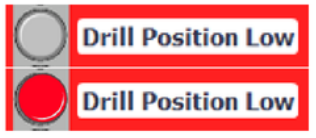
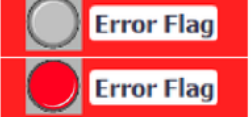
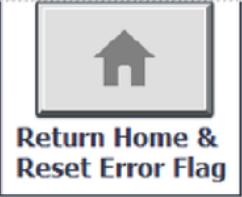
Error 2

Error Flag

Return Home & Reset Error Flag

Item	Description
PWM High	Warning PWM High (orange background): This is a warning that occurs if the PWM output from the system exceeds the warning value set on the engineering screen. No warning (top), warning occurred (bottom). This is associated with the WPWM tag.
PWM High	

	Warning set point high (orange background): This is a warning that occurs if the user set point for the drill exceeds the warning for maximum set point from the engineering screen. No warning (top), warning occurred (bottom). This is associated with the WSet posH tag.
	Warning set point low (orange background): This is a warning that occurs if the user set point for the drill goes below the warning for minimum set point from the engineering screen. No warning (top), warning occurred (bottom). This is associated with the WSet posL tag.
	Warning drill position high (orange background): This is a warning that occurs if the position of the drill goes above the maximum set point for a warning from the engineering screen. No warning (top), warning occurred (bottom). This is associated with the W posH tag.
	Warning drill position low (orange background): This is a warning that occurs if the position of the drill goes below the minimum set point for a warning from the engineering screen. No warning (top), warning occurred (bottom). This is associated with the W posL tag.
	Warning 1 and 2: These warnings are place holders and should not occur during normal function of the system. These are associated with Warning 1 and warning 2 tags.
	Warning Flag: This is a warning that will trigger if any warning occurs. No warning (top), warning occurred (bottom). This is associated with the warning flag tag.
	Error PWM High (red background): This is an error that occurs if the PWM output from the system exceeds the error value set on the engineering screen. No error (top), error occurred (bottom). This is associated with the EPWM tag.
	Error set point high (red background): This is an error that occurs if the user set point for the drill exceeds the error for maximum set point from the engineering screen. No error (top), error occurred (bottom). This is associated with the ESet posH tag.
	Error set point low (red background): This is an error that occurs if the user set point for the drill goes below the error for minimum set point from the engineering screen. No error (top), error occurred (bottom). This is associated with the ESet posL tag.

	Error drill position high (red background): This is an error that occurs if the position of the drill goes above the maximum set point for an error from the engineering screen. No error (top), error occurred (bottom). This is associated with the E posH tag.
	Error drill position low (red background): This is an error that occurs if the position of the drill goes below the minimum set point for an error from the engineering screen. No warning (top), warning occurred (bottom). This is associated with the E posL tag.
	Error 1 and 2: These errors are place holders and should not occur during normal function of the system. These are associated with Error 1 and Error 2 tags.
	Error Flag: This is an error that will trigger if any error occurs. No error (top), error occurred (bottom). This is associated with the Error Flag tag.
	Home button: When this button is pressed the user is directed to the main (home) screen, it will also clear the error and warning flags if there are not still errors or warnings within the system.

System evaluation

As a whole the system achieved all aspects of the specification given in the design brief, however this did not mean there were not areas for improvement. All screens displayed the needed information however, the layout of the user interface could have been a lot clearer and more professional, e.g. equal distances between objects, resize objects dependant on purpose and intended use, or better labelling of objects and buttons for definite association (such as the engineering screen properties section) etc. Warnings and errors could have been indicated with more than just a change of colour (e.g. a buzzer), this could aid people with colour blindness and would mean if the operator was not looking at the screen during the causation of a warning or error they would still be alerted. Tags (full table shown in the index) could have been more clearly named to allow users to more easily edit the ladder logic if necessary. The engineering screen had many areas for improvement as many of the data entry points are not clearly associated with their function and were not equally spaced this is shown below in figure 16.

Error Minimum	Warning Minimum	Property	Warning Maximum	Error Maximum
+00000	+00000	Drill Set Point mm	+00000	+00000
+00000	+00000	Drill position mm	+00000	+00000
		Drill movement speed	+00000	+00000

Figure 16 Engineering screen poor layout.

The errors and warnings screen and the main screen had a lot of free space perhaps a few of the elements could have been made larger to provide clarity and better layout figure 17.

Warnings

PWM High

Set Point High

Set Point Low

Drill Position High

Drill Position Low

Warning 1

Warning 2

Warning Flag

Errors

PWM High

Set Point High

Set Point Low

Drill Position High

Drill Position Low

Error 1

Error 2

Error Flag

Return Home & Reset Error Flag

Figure 17 Warnings and errors screen poor spatial use.

Different fonts or different indicator objects could have been used to increase emphasis and clarity for certain objects such as indicating a difference between button labels, data entry labels, and data labels on the main screen figure 19.

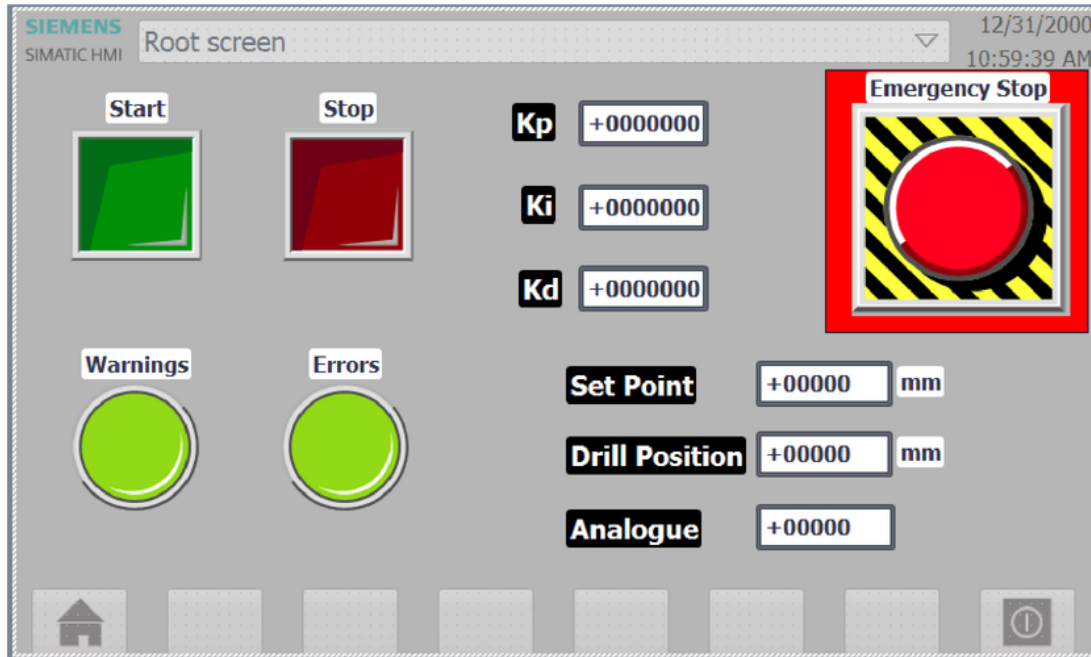


Figure 19 Poor labelling of objects on main screen.

Bibliography

- [1] M. Barr, "Introduction to Pulse Width Modulation," Embedded, 31 August 2001. [Online]. Available: <https://www.embedded.com/electronics-blogs/beginner-s-corner/4023833/Introduction-to-Pulse-Width-Modulation>. [Accessed 20 April 2018].
- [2] P. Horowitz and W. Hill, "Digital-to-Analogue Converters," in *The Art of Electronics*, New York, Cambridge University Press, 2015, pp. 881-891.
- [3] IEEEGUIDE, "Pulse Width Modulation," IEEEGUIDE, 2014. [Online]. [Accessed 20 April 2018].
- [4] G. Lazaridis, "PWM Modulation," PCB heaven, 09 March 2009. [Online]. Available: http://pcbheaven.com/wikipages/PWM_Modulation/. [Accessed 20 April 2018].

Index

	Name	Data type	Address	Retain	Visibl...	Acces...
1	 Red Button	Bool	 %I0.5	☐	☒	☒
2	 Green Button	Bool	%I0.6	☐	☒	☒
3	 operate	Bool	%Q0.3	☐	☒	☒
4	 Red light	Bool	%Q0.5	☐	☒	☒
5	 Green light	Bool	%Q0.6	☐	☒	☒
6	 POT	Int	%IW64	☐	☒	☒
7	 W PWM	Bool	%MO.0	☒	☒	☒
8	 W PosH	Bool	%MO.1	☒	☒	☒
9	 W PosL	Bool	%MO.2	☒	☒	☒
10	 W Set posL	Bool	%MO.3	☒	☒	☒
11	 W Set posH	Bool	%MO.4	☒	☒	☒
12	 E PWM	Bool	%M1.0	☒	☒	☒
13	 E posL	Bool	%M1.1	☒	☒	☒
14	 E posH	Bool	%M1.2	☒	☒	☒
15	 E Set posL	Bool	%M1.3	☒	☒	☒
16	 E Set posH	Bool	%M1.4	☒	☒	☒
17	 Warning 2	Bool	%MO.6	☒	☒	☒
18	 Warning 1	Bool	%MO.5	☒	☒	☒
19	 Error 1	Bool	%M1.5	☒	☒	☒
20	 Error 2	Bool	%M1.6	☒	☒	☒
21	 Error Flag	Bool	%M1.7	☒	☒	☒
22	 StartButton	Bool	%M100.0	☐	☒	☒
23	 StopButton	Bool	%M100.1	☐	☒	☒
24	 EStop	Bool	%M100.2	☐	☒	☒
25	 DSP wmin	Real	%MD42	☒	☒	☒
26	 DSP emin	Real	%MD6	☒	☒	☒
27	 DSP wmax	Real	%MD10	☒	☒	☒
28	 DSP emax	Real	%MD14	☒	☒	☒
29	 DP wmin	Real	%MD18	☒	☒	☒
30	 DP emin	Real	%MD22	☒	☒	☒
	Name	Data type	Address	Retain	Visibl...	Acces...
31	 DP wmax	Real	%MD26	☒	☒	☒
32	 DP emax	Real	%MD30	☒	☒	☒
33	 Set Point	Real	%MD34	☒	☒	☒
34	 Drill Position	Real	%MD38	☒	☒	☒
35	 Errors	Byte	%MB1	☒	☒	☒
36	 Warnings	Byte	%MB0	☒	☒	☒
37	 outputper	Real	%MD2	☒	☒	☒
38	 PWM highW	Real	%MD46	☒	☒	☒
39	 PWM highE	Real	%MD50	☒	☒	☒
40	 warning flag	Bool	%MO.7	☒	☒	☒

PLC Report Andrew Prescott

GRADEMARK REPORT

FINAL GRADE

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Instructor

66/100

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ANDREW PRESCOTT

66.40

RESEARCH-INFORMED LITERATURE



The literature review is clear but limited with reasonable background information but would have been improved with a more detail, along with a PWM advantage/disadvantage table.60%

9

KNOWLEDGE AND UNDERSTANDING



The ladder logic program is clear and well

ANALYSIS



The mechanism for generating the transfer function from the plant input output response curve is very good. Your method is vague but documented with good graphics. 68%

17

PRACTICAL APPLICATION AND DEP.



Your screens are functional and uncluttered and very well documented. All screens are nicely laid out and make it easy to identify faults/warnings and allow for user input and navigation. Good fault audit document. Poor attempt at improvements.68%

13.6

SKILLS FOR PROFESSIONAL PRAC.



The report is reasonably well presented with the author using sufficient images and illustrations to allow the reader to digest information readily.62%

9.3