

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	James Bacon	Student ID number:	
Programme:	HNC Electrical/Electronic Engineering		
Module:	Programmable Logic Controllers		
Module code:	PCEE4005	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Jason Pointer	Internal Verifier:	Lance Rutherford
Assignment Title:	PLC Program design and simulation	Word count (or equivalent):	2000
Submission deadline:	14/05/20	Return date of provisional marks & written feedback:	28/05/20
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

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

STUDENT FEEDBACK FORM

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

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	15	10.5
Engagement with an extensive range of relevant and credible literature. An excellent mixture of relative sources including a range of text books and web sites.		
2. Knowledge and Understanding Skills	25	17.6
Task 1 achieved 75%. Task 2 achieved 58%. Excellent knowledge and understanding of the basic underlying concepts and principles of the work required for Task 1 and 2.		
3. Cognitive and Intellectual Skills	15	9
Sound evaluation of the underlying concepts and principles applied to the construction of the programs for Task 3 and 4, made a very good effort in discussing the construction of the programs.		
4. Practical Application Skills	35	29.1
Task 3 achieved 86%. Task 4 achieved 80%. An excellent application of the different software to produce fully functional programs to cover the requirements of Task 3 and 4. Required no support in the development of these programs and was able to show full operation.		
5. Transferable Skills for Life and Professional Practice	10	8
Work is coherent, very fluent and is presented professionally. Excellent layout making the assignment easy to read.		

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		74%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

PLC Program Design and Simulation

HNC Electrical and Electronic Engineering

James Bacon

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1.1 Overview of the Report

This report looks at the inputs and outputs of PLC and some example where these inputs and outputs are used within the industry.

1.2 PLC analogue and discrete I/O

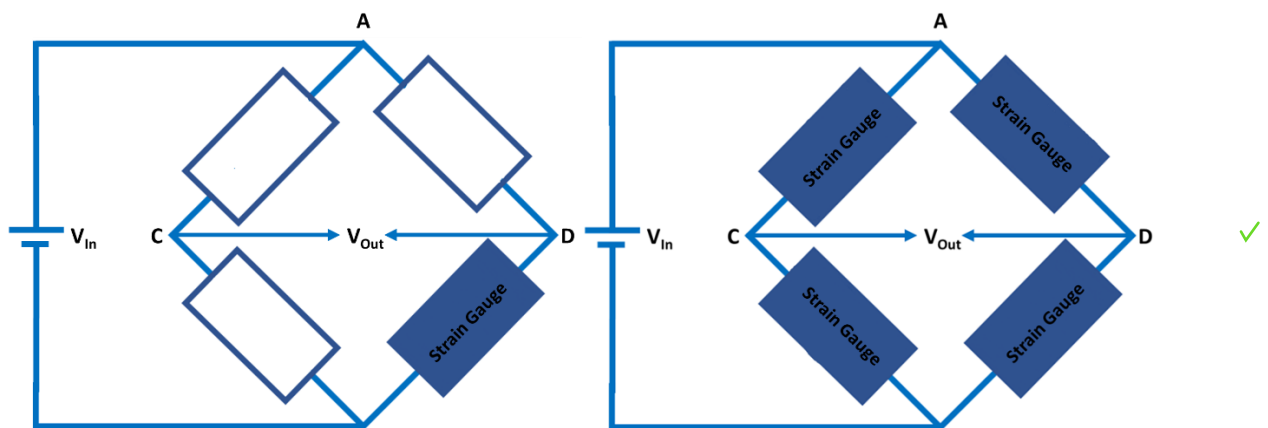
1.2.1 Question A, Inputs of PLC

There are many inputs which can be wired into to a PLC and one of these devices are **switches**. There are multiple different types of switches for example mechanical, flow or proximity. ‘A mechanical switch generates an on-off signal or signals as a result of some mechanical input causing the switch to open or close’ as Bolton (2007, p.19) explains. Therefore, a mechanical switch works by having a on or off signal which send as an input into the PLC. ✓

Another device which can be wired to PLC is **sensors** and which **s** can sense position, light, pressure and temperature. One of temperature sensor is a bimetallic sensor which give signal when a certain temperature is reached. This works by having a bimetals strip of two metals bounded together, the reasons for doing as explained by Figliola and Beasley (2011, p213) ‘Bimetallic strips employ one metal having a high coefficient of thermal expansion with another having a low coefficient, providing increased sensitivity’. Therefore, when the temperature increase on the sensor it begins to bend as one of the metals need to expand more the than other one. Once the temperature decreases the effect is the reversed. The bending movement is used on contact to either a make connection to give a on signal or to break connection to give an off signal to the PLC. ✓

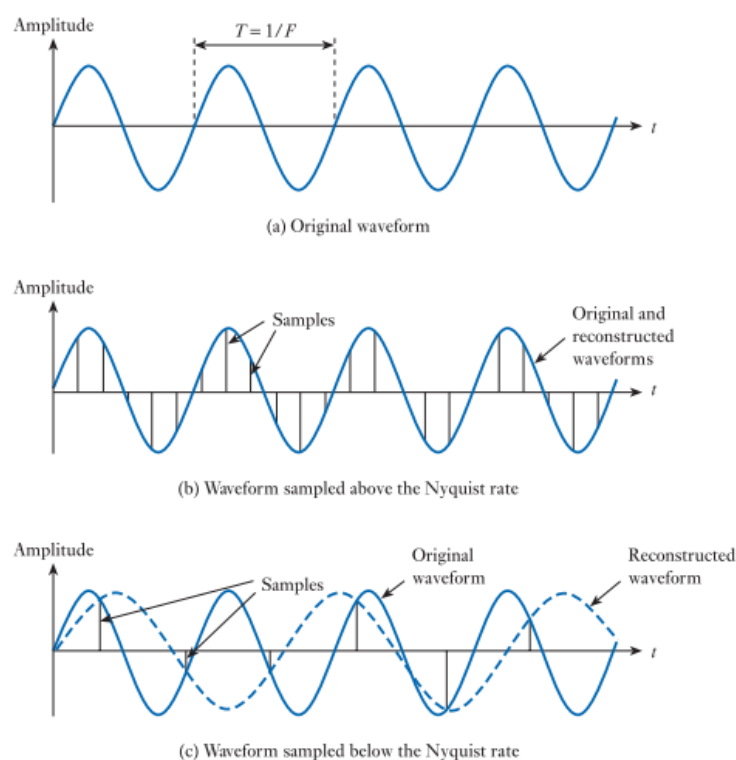
The **photoelectric sensors** are used within an **encoder**, an incremental encoder is used to measure angular displacement. The encoder works by having a beam of light typically light-emitting diode (LED) which detected by the either singular or multiple photoelectric sensors through slots in a disc. Alciatore and Histan (2012, p.387) describes what happen when two sensor are used, ‘As the shaft rotates, pulse trains occur on A and B at a frequency proportional to the shaft speed, and the lead-lag phase relationship between the signals yields the direction of rotation’. Therefore, when the disc rotates, the light beam is alternately transmitted and/or stopped going to the sensors as it goes through slots in the disc. This allow give a pulsed output to the light sensors which is feed to the PLC to give the angular displacement and rotation of the shaft. ✓

Strain gauges is another device that can be wired to PLC which is used to measure strain. These are attached to the material that will be measured for their strain. Once the metal deforms due to the strain, so will the strain gauge as a result as explained by Figliola and Beasley (2011, p469) 'the resistance of a strain gauge changes when it is deformed, and this is easily related to the local strain. Both metallic and semiconductor materials experience a change in electrical resistance when they are subjected to a strain'. These resistance values then are converted into a voltage signal for use within a PLC using a Wheatstone bridge. An alternative use of a Wheatstone bridge is to use four gauges as the arms of the bridge to give more accurate results of strain. As shown below: ✓



1.2.2 Question B, Analogue to Digital Conversion (ADC) process

Some of input used with PLC are analogue and required to be converted into digital to be used in the PLC. This is done by using the ADC conversion process. It begins with sampling the input analogue signal at given sampling rate, which is then amount of sample is done on analogue signal at regular intervals. Therefore, on higher sampling rate the digital output on ADC it will be closer to the analogue however more storage will be required for ADC. Unfortunately having a low sample rate on ADC will resulting in under sampling of analogue signal where it will begin missing crucial point in the signal. As shown below: ✓



Storey (2017, p.752)

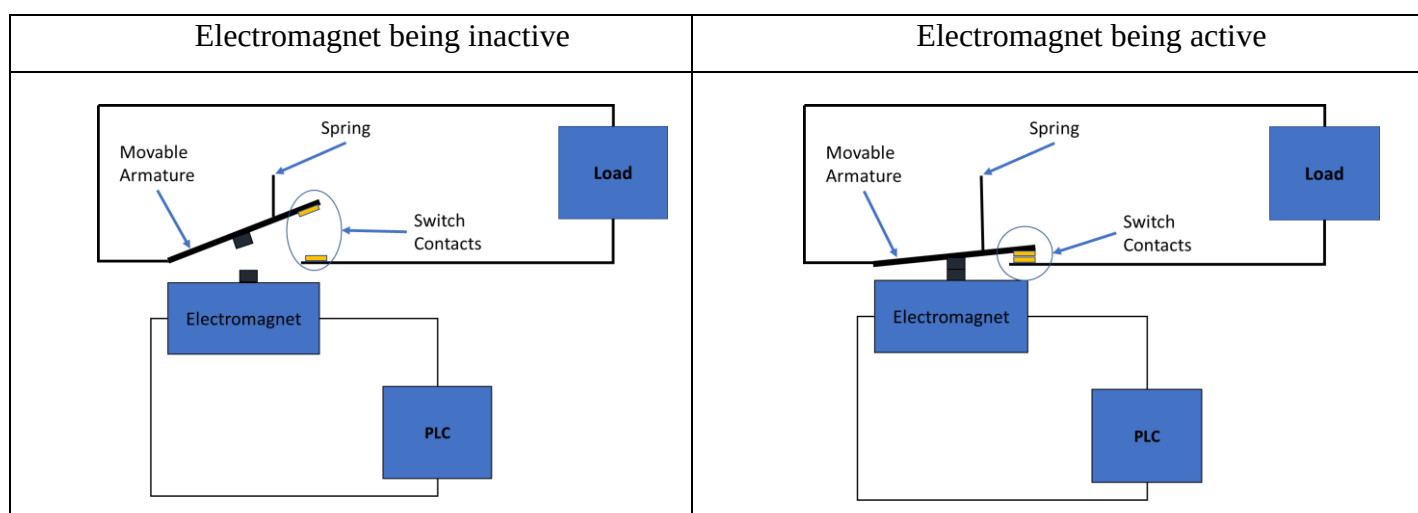
Once the sampling has been done the next process is quantization. The process of ‘quantization is where the range of the analog signal is broken down into a discrete number of bins. In coding, the bin “location” of the analog signal is converted into a digital number that can be understood by the computer’ as described by Kutz (2006, p.852). These outputs a fixed variable length in binary code for example an 8 bits ADC will have following variable output depending what being input to ADC: 000 001 010 011 100 101 110 111. Depending how many bits the ADC has some of the sampled analogue signal would be to the nearest bit which may not be equivalent to the original analogue value this is commonly known as the quantization error. So as result the more bits the ADC has, the more sampled analogue signal can be respect as digital signal without quantization error. ✓

1.2.3 Question C, Outputs of PLC

One of these devices that could be wired as output of a PLC are indicators. These include buzzer and LED. This work similar to a switch input device has mentioned above where it has on or off signal which is controlled by PLC. When the PLC give a on signal on the indicator output the LED will alight and/or buzzer begin to buzz. If the LED light turned off or buzzer stop buzzing then there is off signal given from the PLC. These are typically used with other output device to indicate their state instead having output to themselves. ✓

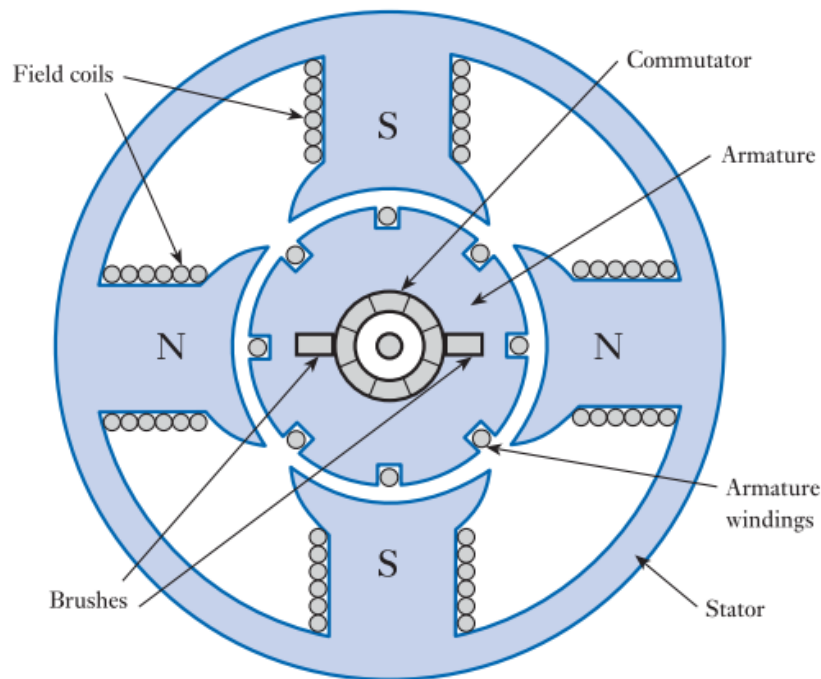
A directional control valves could be used as output from PLC, there are many different types of valves from flow control value, operated valve and spool valve. The 'Flow-control valves are used to regulate either the flow or the pressure of a fluid by their electronic actuation. They generally function by allowing flow while in their open position, stopping flow when closed' as stated by Figliola and Beasley (2011, p.538) as the main function of control valve. Therefore, the PLC can use the valve for directional control of the flow. Thus, the valve could open when on signal is given from the PLC and in doing so can operate other devices within controlled systems. One of example of this is piston within cylinder moving as direct cause of the valve opening. ✓

Relay is one of most common devices that are used as output device of PLC. These relays usually used as control circuit for much bigger circuit. A relay uses the principle of electromagnetism to operate as ✓ shown on the **next page**:



What can be seen from the diagram as described by Alciatore, and Histan (2012, p.433) is that ‘An electromechanical relay is a solenoid used to make or break mechanical contact between electrical leads. A small voltage input to the solenoid controls a potentially large current through the relay contacts’. Therefore, if a on signal given from the PLC the electromagnet generates a magnetic field on current passing through it. This will then cause the armature to move towards the electromagnet and the switch point contacts will become closed. When PLC is giving an off signal will be current passing though electromagnet therefore the armature moves away from electromagnet causing the contacts to become open. ✓

One of the main circuits for a reply to control are ones with motors connected to them however the **motor** could be connected straight to the PLC. There are many types of motor which are D.C. motor, brushless D.C. motor and stepper motors. Below is example of D.C. motor:



Storey (2017, p.188)

What can be seen above is that the armature is mounted within the magnetic field produced by permanent magnets this are typically referred to as field coils. When current pass through the armature the force acting on the coil resulting in rotation. The brush and the commutator are used to ensure revert in current flowing of the coil at every half rotation. The speed of the armature rotate can be increase, by increasing the number of coils and placing these coils within slots on a cylinder of ferromagnetic material which can been seen above. ✓

1.2.4 Question D, Outputs PLC Output Switching Process

In order to give an output on a PLC an output unit is needed. Within PLC these can either be a relay, transistor or triac. However, two most common types are relay and transistors. As discussed above the relay work by mechanical switching. When the output becomes active the two contacts become closed to allow current to flow through the connected circuit. Whereas the transistor works by electronic switching by using either NPN or PNP configuration of transistor. The switching on NPN transistor only work when current flows through the base of the transistor, at which point the current will flow from the collector to the emitter. Whereas the switching in PNP transistor works when there is no current at the base of the transistor and the current will flow through from emitter to collector. Example of these output switching process can be seen below:

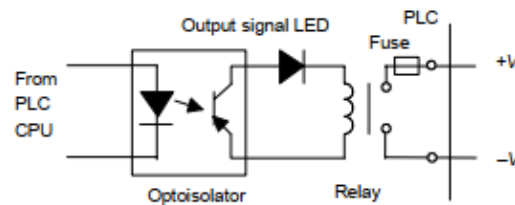


Figure 4.7 Relay output unit

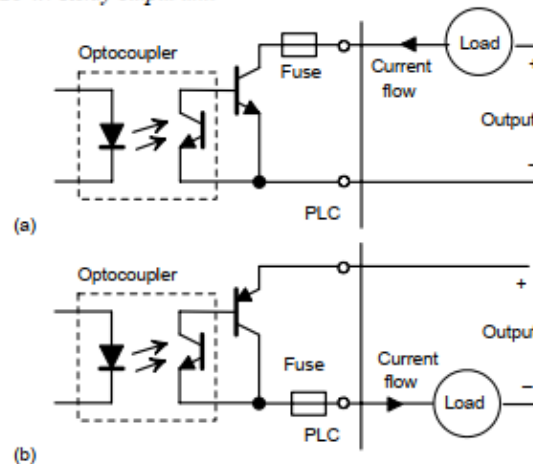


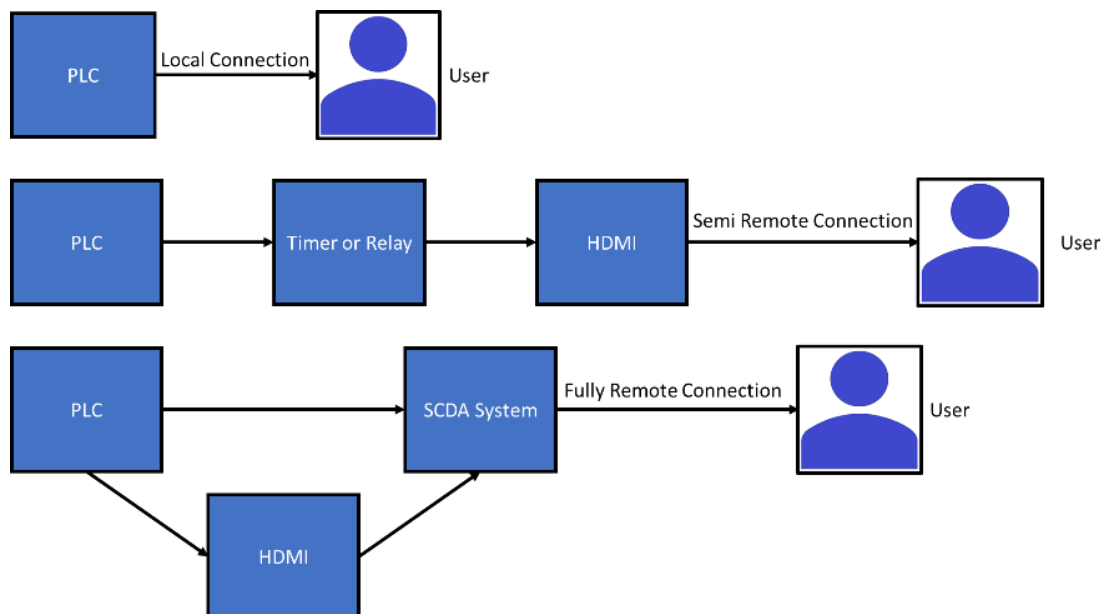
Figure 4.8 Basic forms of transistor output: (a) current sinking, (b) current sourcing

Bolton (2007, p.57)

What can be seen from these output types is that the transistor has fixed output polar depending on configuration as NPN gives a negative output whereas PNP gives a positive output. However, using the relay, the polarity can have negative or positive output depending on wiring configuration. A benefit from using transistor is that response time to switching is much greater due to it being electronic switching whereas the relay is mechanical switch. However, the mechanical switch is not affected by the load due circuit being disconnected on being deactivated. The electronic switching is not as it is connected to load meaning the current will attempt to be draw from the transistor and has the potential to damage the transistor.

1.3 Supervisory Control and Data Acquisition (SCADA)

Supervisory Control and Data Acquisition (SCADA) system, is a system which is used to maintain and industrial control systems (ICS). These work by having connection between the PLC and SCADA systems and many PLC manufacture even produce their own SCADA software to use with their PLC's. Example are Honeywell (2020) 'Experion SCADA system' or Siemens (2020) 'SIMATIC SCADA System'. These are used to allow easily control or maintenance of the PLC to ensure the ICS is operating at maximum level allow therefore this is **fully remote connection**. This is used instead of having personnel on a **local connection** which is them right next to PLC to control or maintain the systems/PLC. However, before the SCADA systems was designed timers and relays were used as a **semi remote connection** as these would connect to multiple Human Machine Interface (HMI) to allow some control over ICS remotely. This did have it as problems has more PLC were added onto ICS, the more likely there going to be rack's full of relay or timer. The connection type can be seen below:



The benefit of using a SCADA system as seen on the diagrams above is that there less steps for the user to access to the PLC's. This will be more cost effect on larger systems as there will not need to have racks full of relay or having to hire large amount of personnel. As technology have been increased over the last few years the current SCADA systems can be monitor from mobile device. The systems can be seen many industries as Inductive Automation (2020) explains the SCADA can be seen in the following sectors 'Energy, Food and beverage, Manufacturing, Oil and gas, Power, Recycling, Transportation and Water and waste'.

However even though a SCADA is useful and has variety of benefits, there are downsides as it will be costly to upgrade existing system to be capable of SCADA and cost of retraining staff to use the SCADA system. One other major issue is cyber security with SCADA systems has Doffman (2020) explain that it is possible that Iran already has SCADA attack capabilities in place, hidden deep within U.S. SCADA environments, waiting for the right time to attack'. Therefore, if SCADA systems is used then extra security will need to be added for example additional firewall or anti-virus security on the SCADA systems to ensure a cyber-attack does not occur on the system. ✓

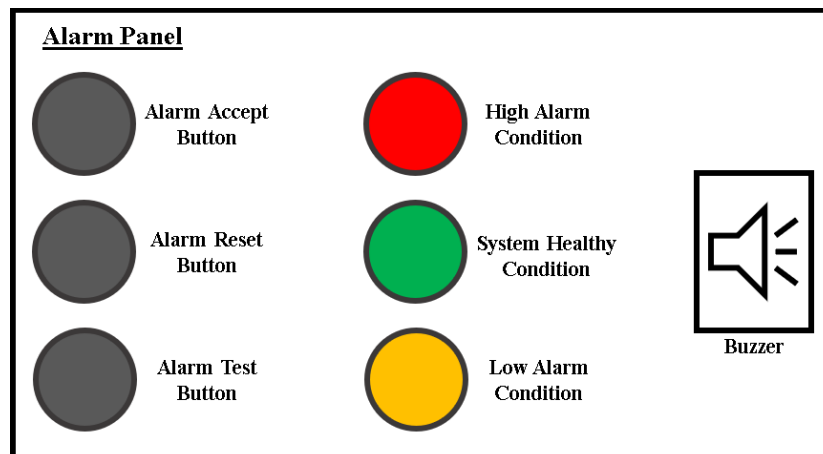
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1.4 Task 3

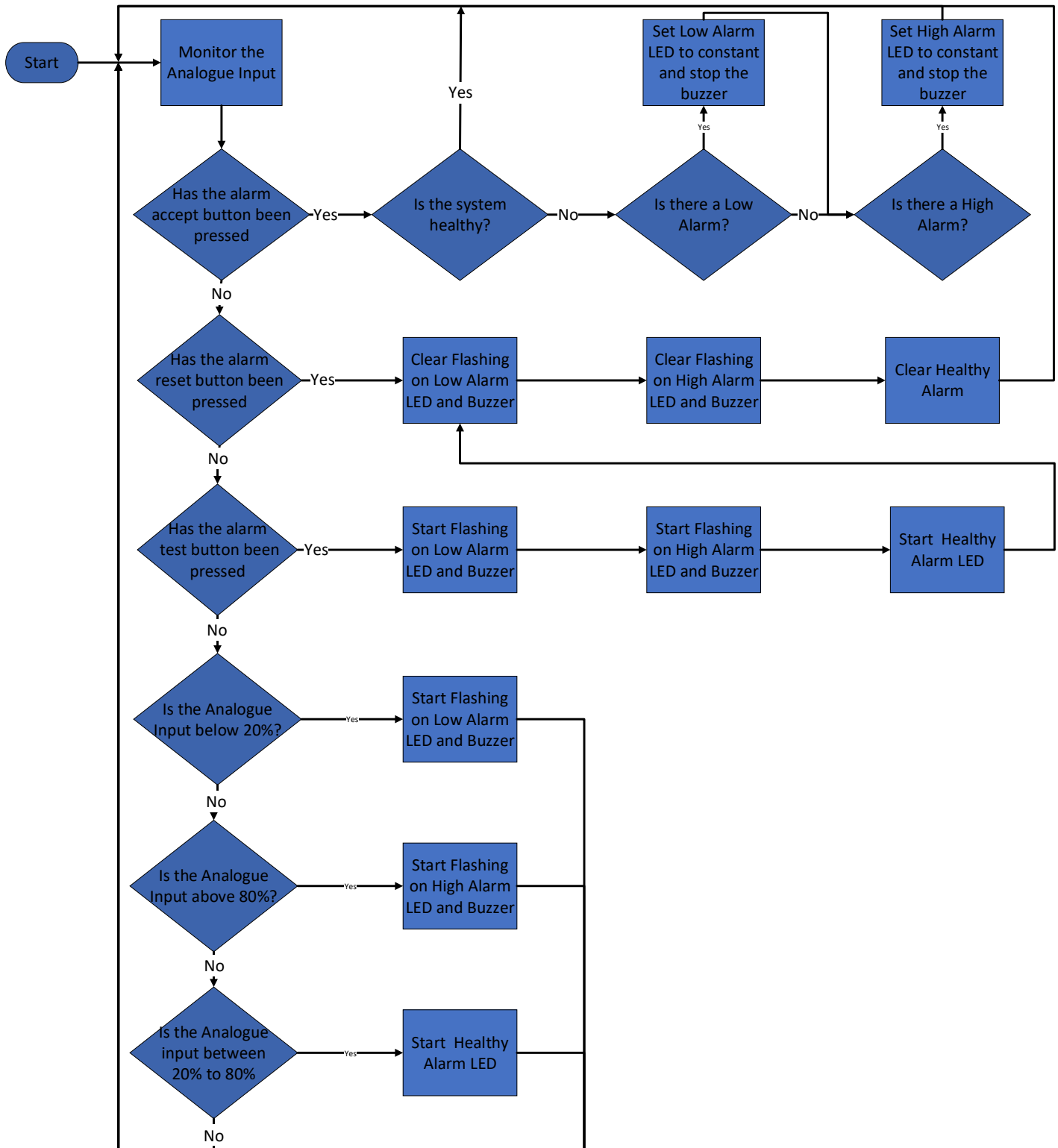
1.4.1 Declaring Input, Outputs and Functions:

Input	Output
Analogue Input	High Alarm LED
Momentary Button 1 (Alarm Accept)	System Healthy LED
Momentary Button 2 (Alarm Reset)	Low Alarm LED
Momentary Button 1 (Alarm Test)	Buzzer
Functions	
Compare (>440 = above 80 and <110= below 20%)	
Set/Reset	
Timer	

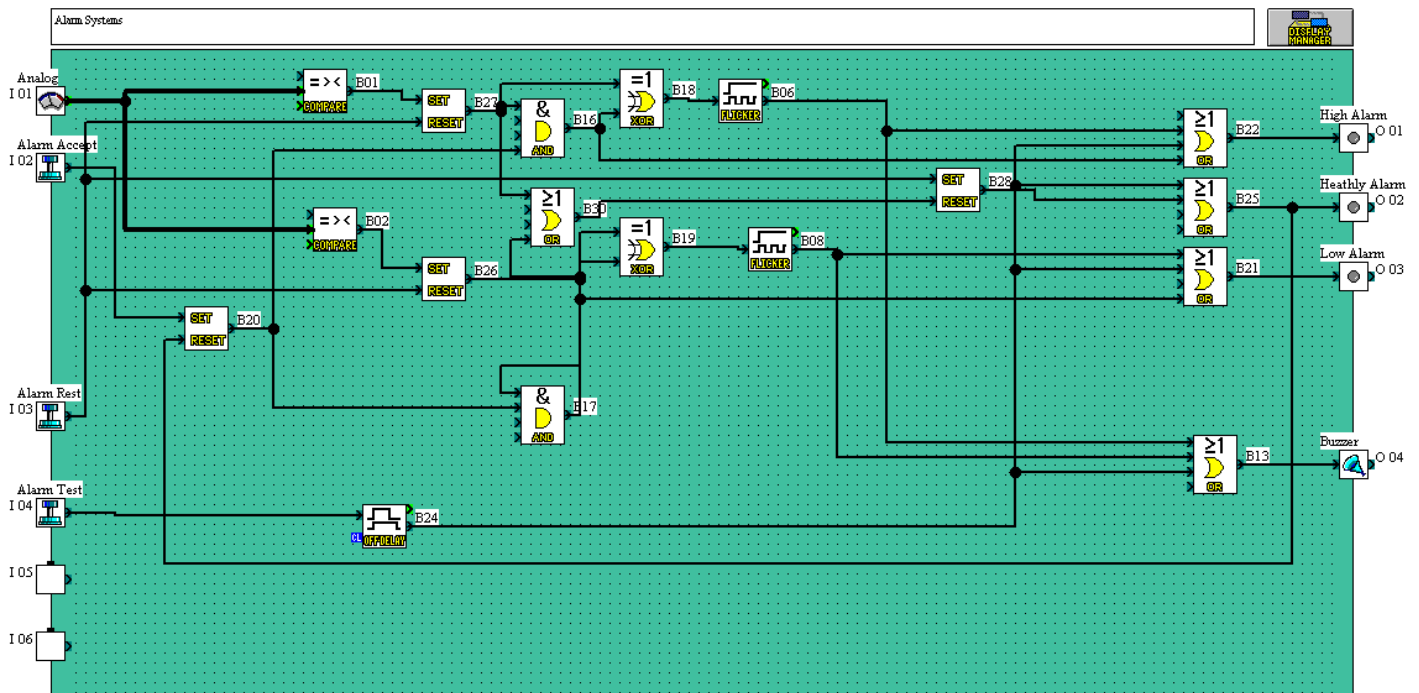
1.4.2 Designed HMI:



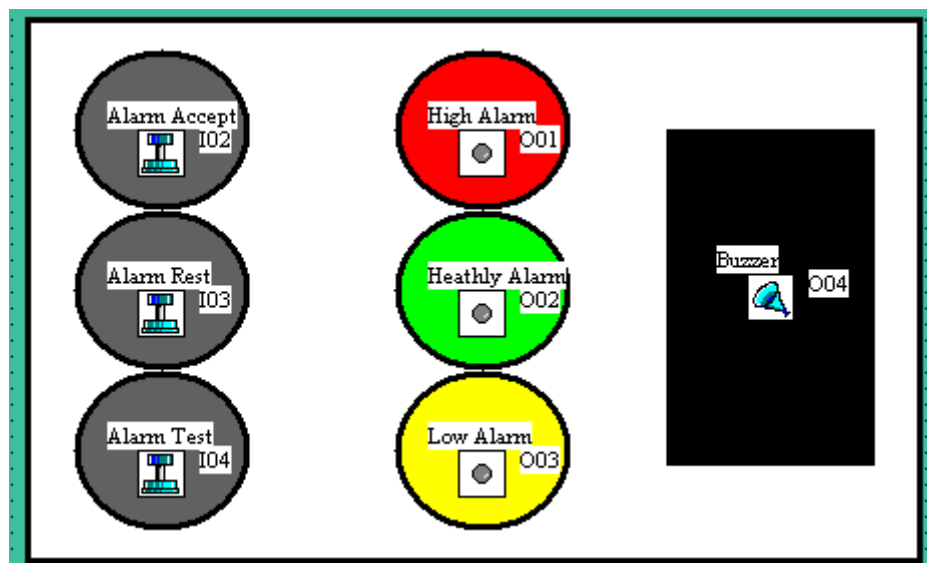
1.4.3 Flowchart



1.4.4 Designed PLC using Functional Blocks

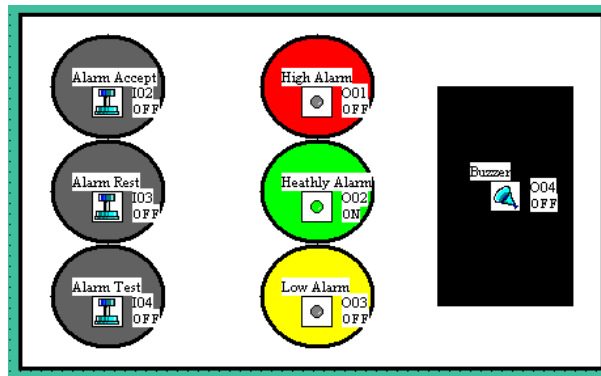
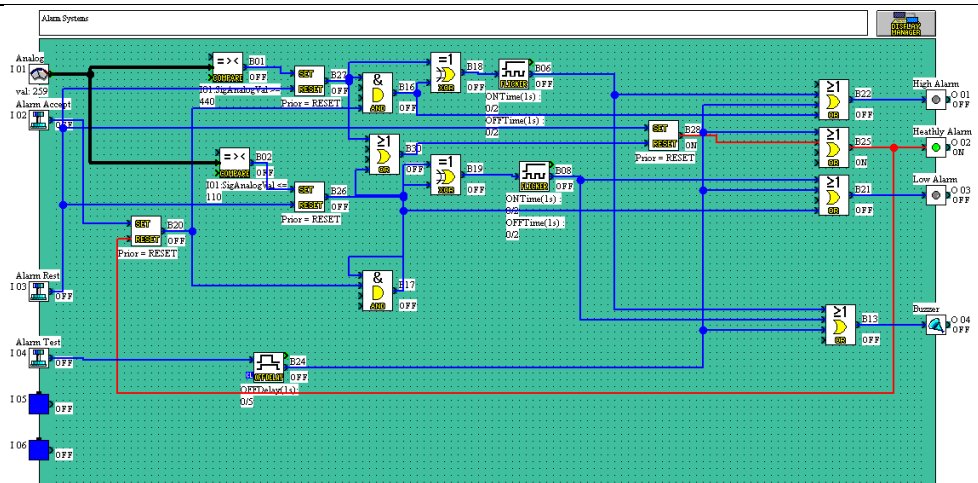


1.4.5 Designed HMI using Functional Blocks

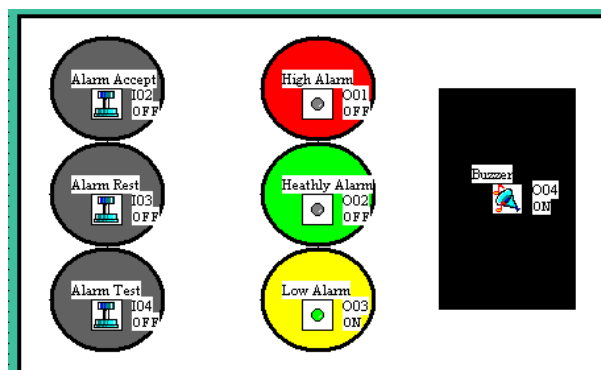
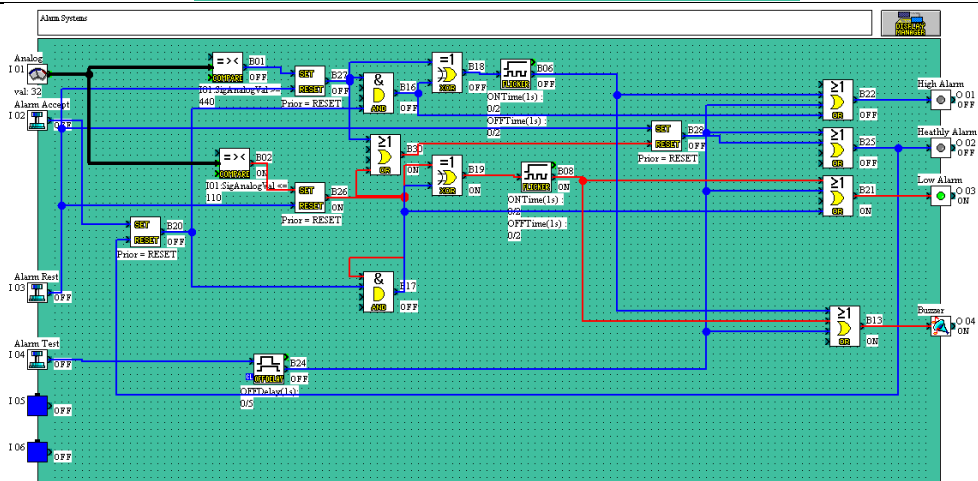


1.4.6 Testing the Design

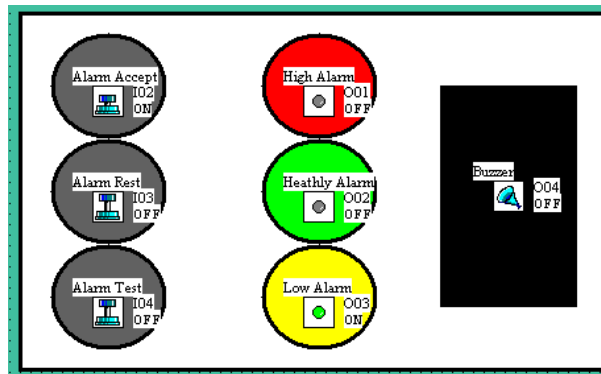
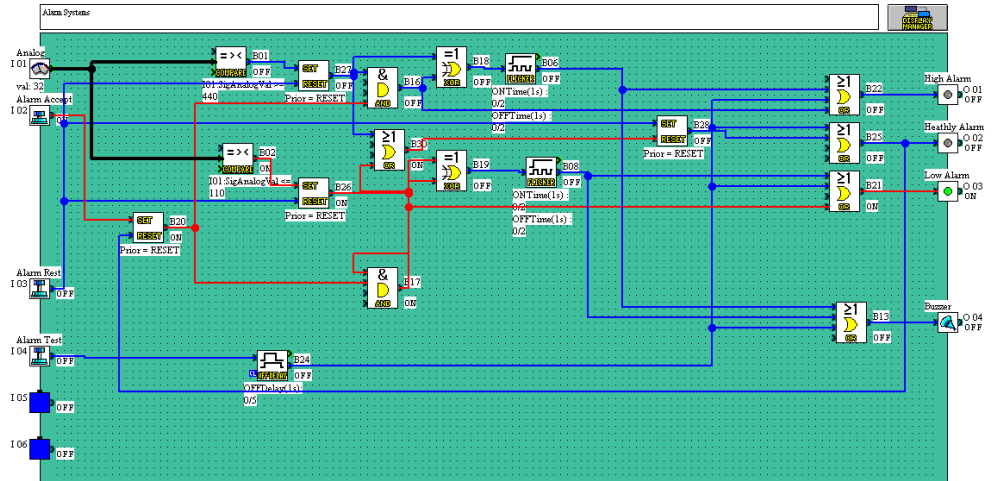
System Healthy between
20% and 80%



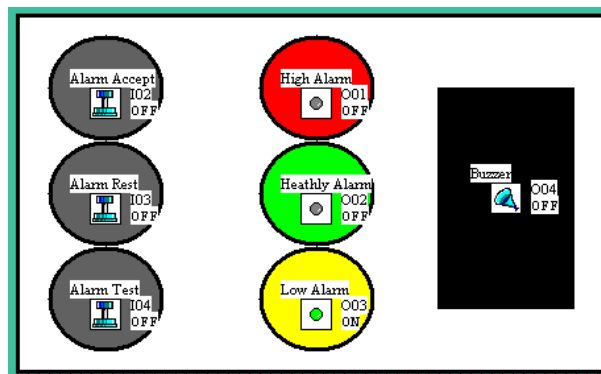
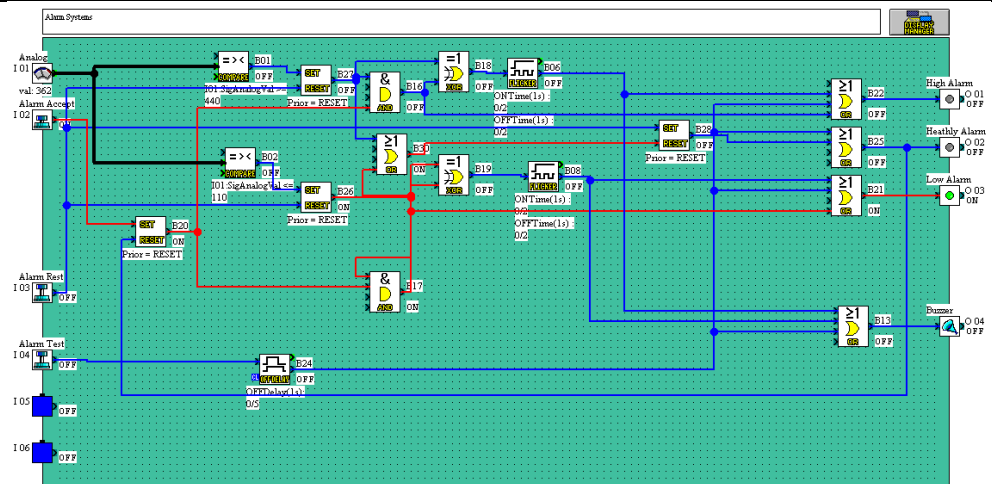
System Low under 20%
(without alarm accept)



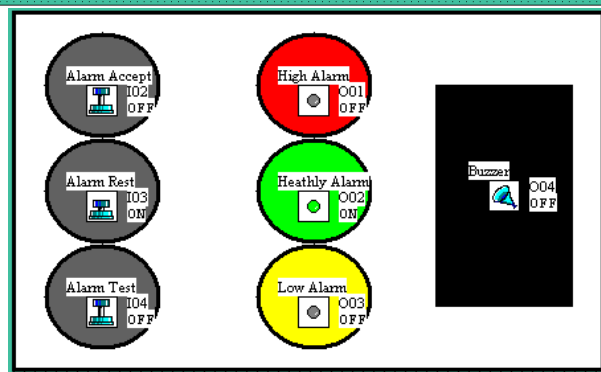
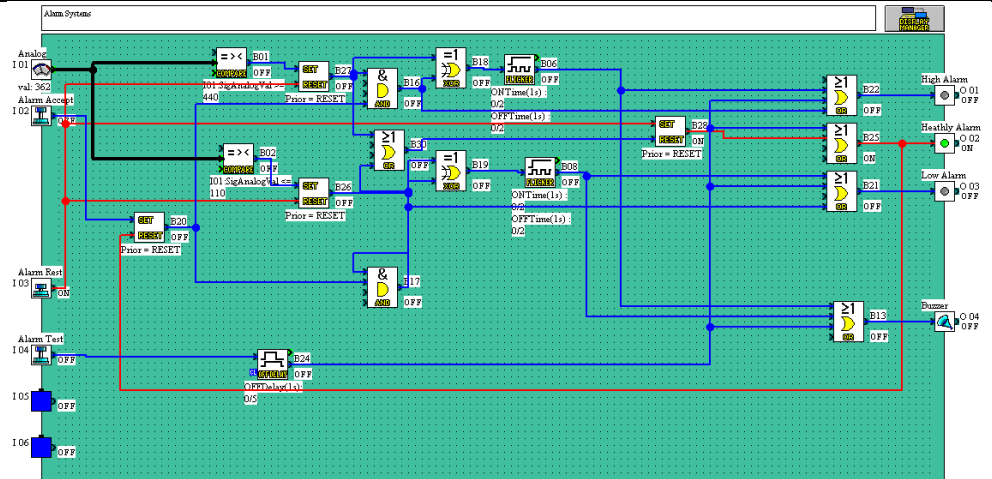
System Low under 20%
(with alarm accept)



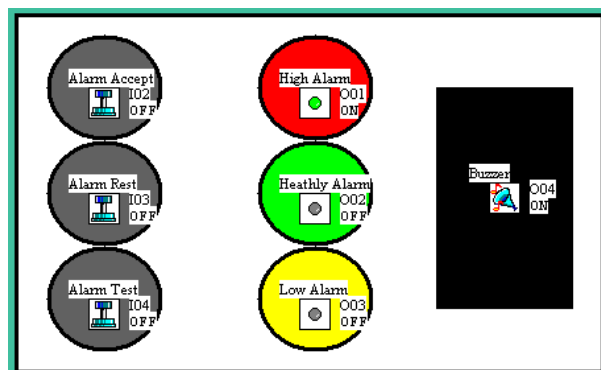
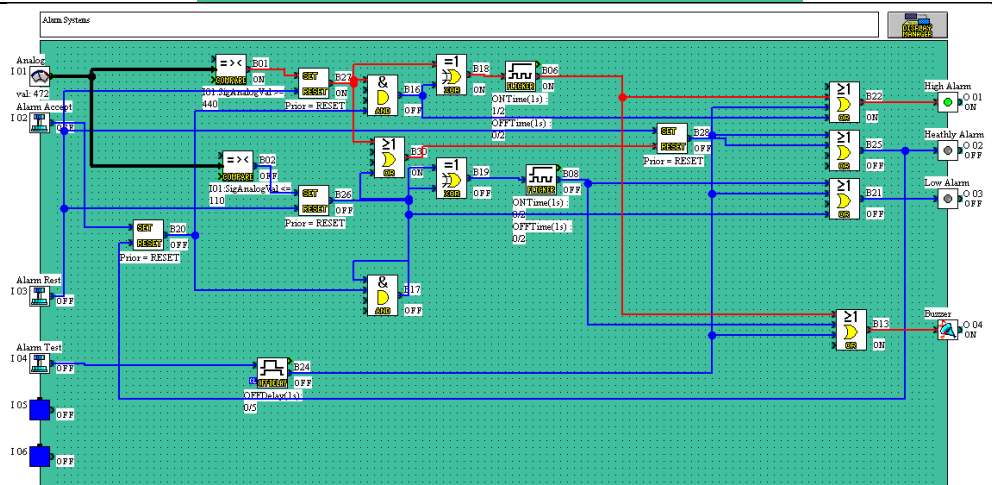
System Returning back to
normal (without alarm reset)



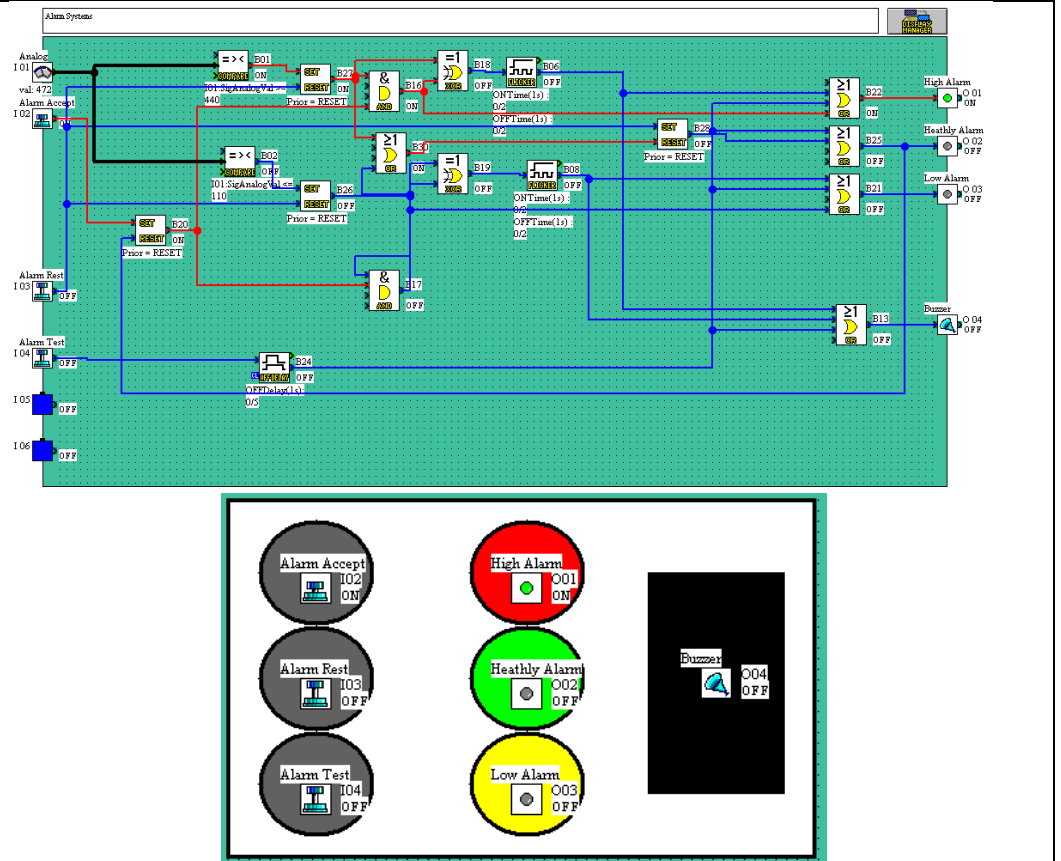
System Returning back to
normal (with alarm reset)



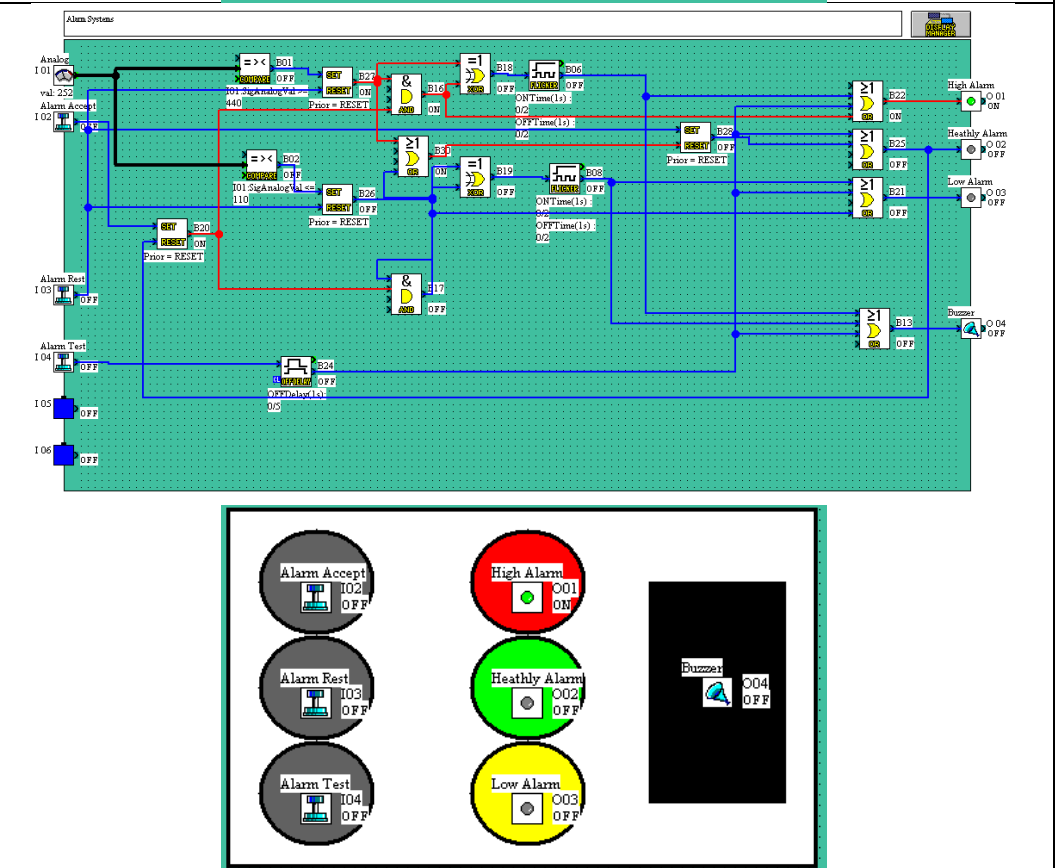
System high above 80%
(without alarm accept)



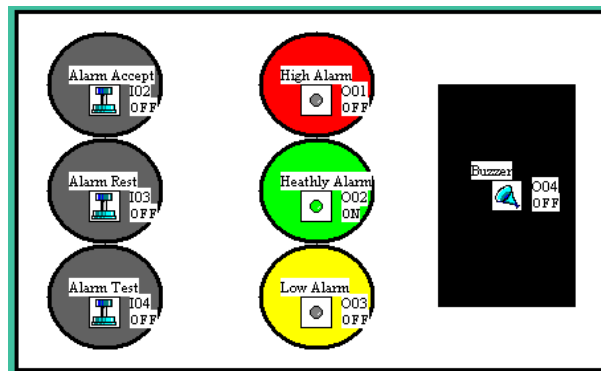
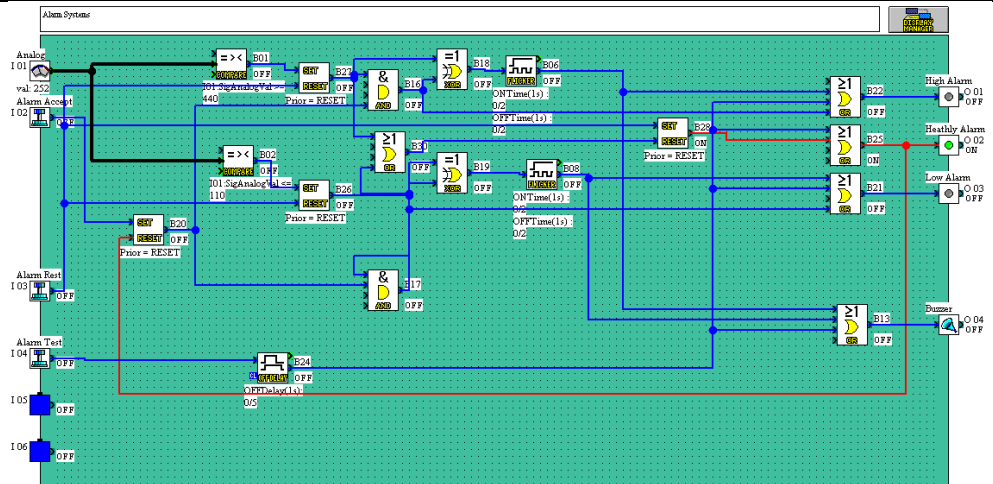
System high above 80%
(with alarm accept)



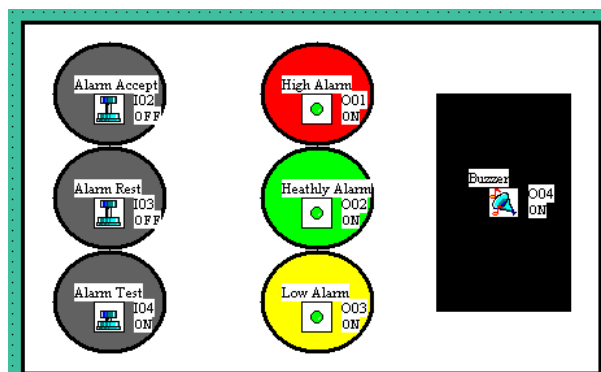
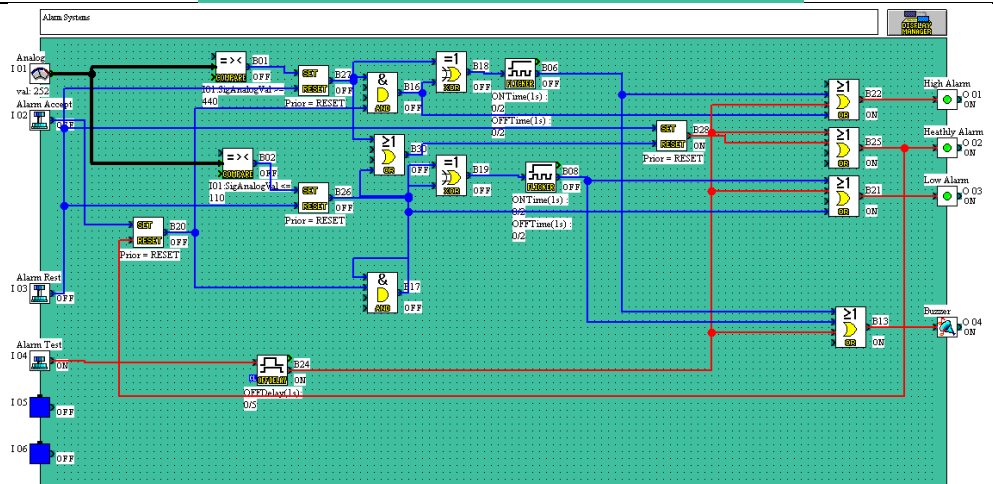
System Returning back to
normal (without alarm reset)



System Returning back to
normal (with alarm reset)



Alarm test



1.4.7 Comments

This is a complex alarm system and does function as it should when analog input goes to high or low as alarms are raised when these conditions are met. However further improvements could be made for example adding extra outputs to measure level just before reaching high and low to prevent going too high or low. This could result in different PLC being used due increase in outputs. Alternative could have LED for High or Low come on with health LED to indicate close to low level whilst still being with healthy range. At its current state the alarm system works as expected.

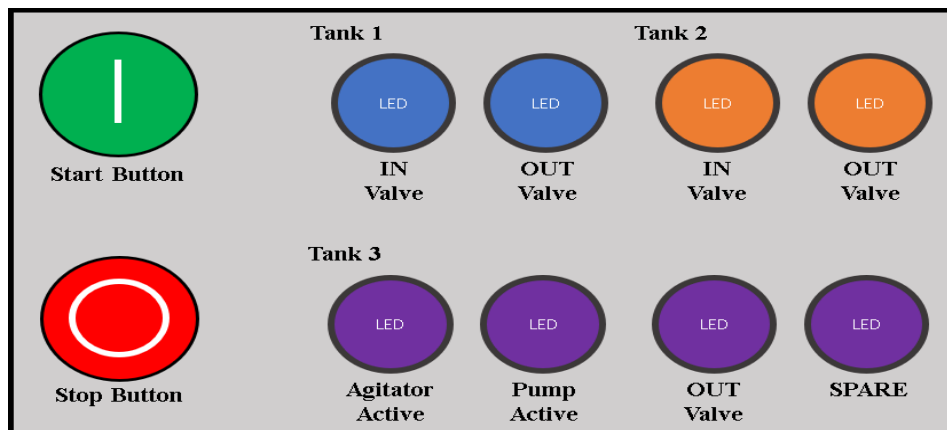


1.5 Task 4

1.5.1 Declaring Input, outputs and Functions:

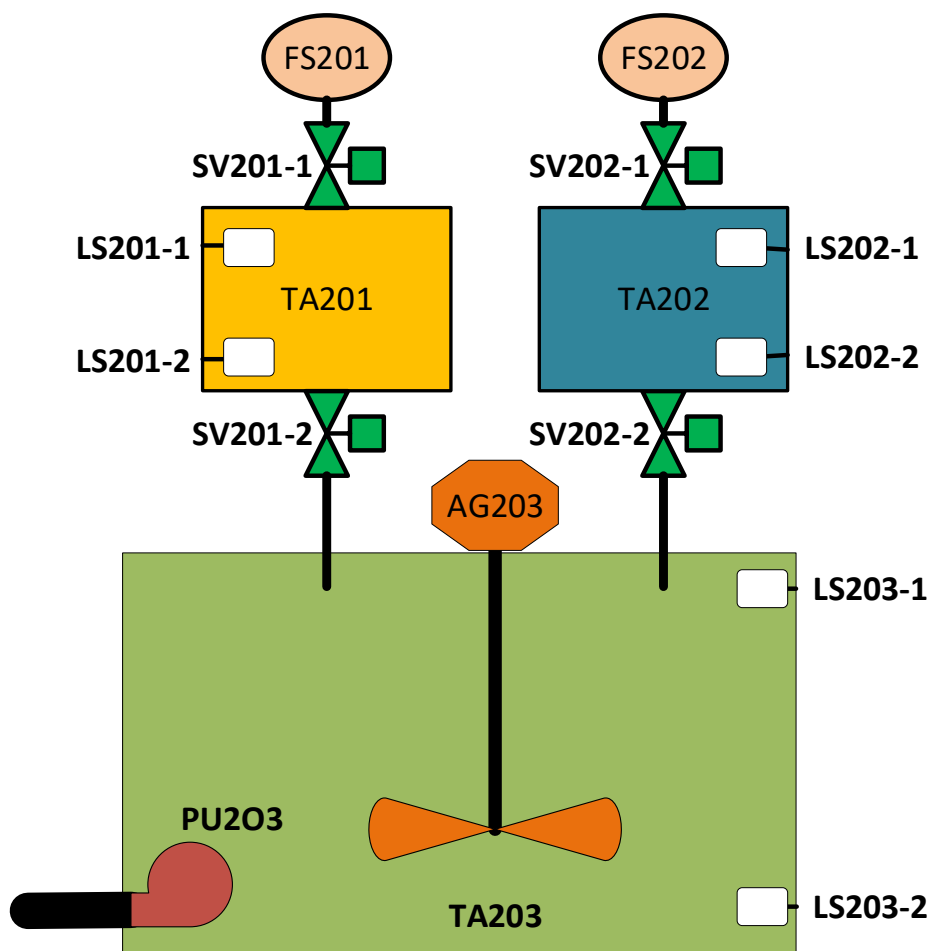
Input		Output (All outputs will have panel light on the HMI)	
0	Filling process start switch (NO)	0	Pump (PU203)
1	Process emergency stop switch (NC)	1	Agitator (AG203)
2	Tank 1 (TA201) high level switch (LS201-1)	2	Valve SV203
3	Tank 1 (TA201) low level switch (LS201-2)	3	Valve SV201-1
4	Tank 2 (TA202) high level switch (LS202-1)	4	Valve SV201-2
5	Tank 2 (TA202) low level switch (LS202-2)	5	Valve SV202-1
6	Tank 1 (TA201) Flow switch (FS201)	6	Valve SV202-2
7	Tank 2 (TA202) Flow switch (FS202)	7	Spare
8	Tank 2 (TA203) high level switch (LS302-1)		
9	Tank 2 (TA203) low level switch (LS302-2)		
10	Spare		
11	Spare		
Functions			
Timers			

1.5.2 Designed HMI:



✓

1.5.3 Overall System Design



✓

1.5.4 Process Operation

On pressing and releasing the start button NO the following automated sequence should be initiated unless stop button NC is pressed in which case all valve should close and Pump PU203 should stop running.

Step 1:

- Ensure all valves are set to closed and pump PU203 is deactivated
- Ensure that tank TA201 low level switch LS201-2 is active otherwise open valve SV201-1 until low level switch LS201-2 is active.
- Ensure that tank TA202 low level switch LS202-2 is active otherwise open valve SV202-1 until low level switch LS202-2 is active.
- Ensure that tank TA203 low level switch LS203-2 is active otherwise turn on pump PU203 until low level switch LS203-2 is active.

Step 2:

- Fill tank TA201 with syrup by opening valve SV201-1 whilst monitoring the flow into the tank with flow switch FS201. If flow is low close valve SV201-1 until normal flow is returned, continue to fill tank until high level switch LS201-1 is triggered.
- Fill tank TA202 with water by opening valve SV202-1 whilst monitoring the flow into the tank with flow switch FS202. If flow is low close valve SV202-1 until normal flow is returned, continue to fill tank until high level switch LS202-1 is triggered.

Step 3

- Start TA203 agitator AG203.
- Once agitator AG203 has started, hold contents in TA202 for 30 seconds, then open valve SV202-2 to transfer the contents of TA202 to TA203.
- Once agitator AG203 has started, hold contents in TA201 for 60 seconds, then open valve SV201-2 to transfer the contents of TA201 to TA203.
- Close valve SV202-2 and SV201-2 if high level switch is active LS203-1. Otherwise close valve SV202-2 when low level switch LS202-2 becomes active and close valve SV201-2 when low level switch LS201-2 is active.

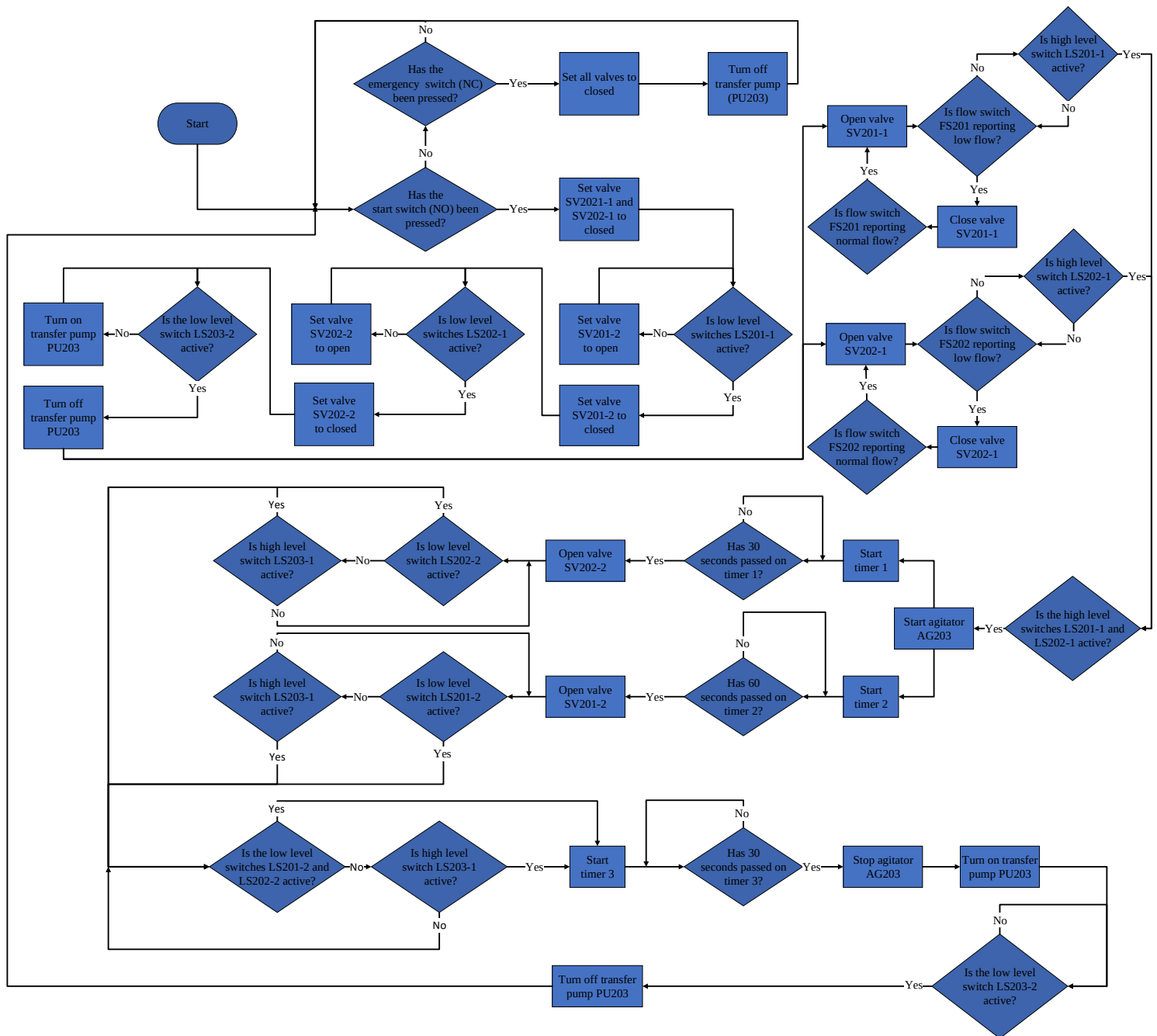
Step 4:

- Blend contents in TA203 for a further 30 seconds, then stop agitator AG203.
- Turn on Pump PU203 until low level switch LS203-2 is active then turn off pump PU203.

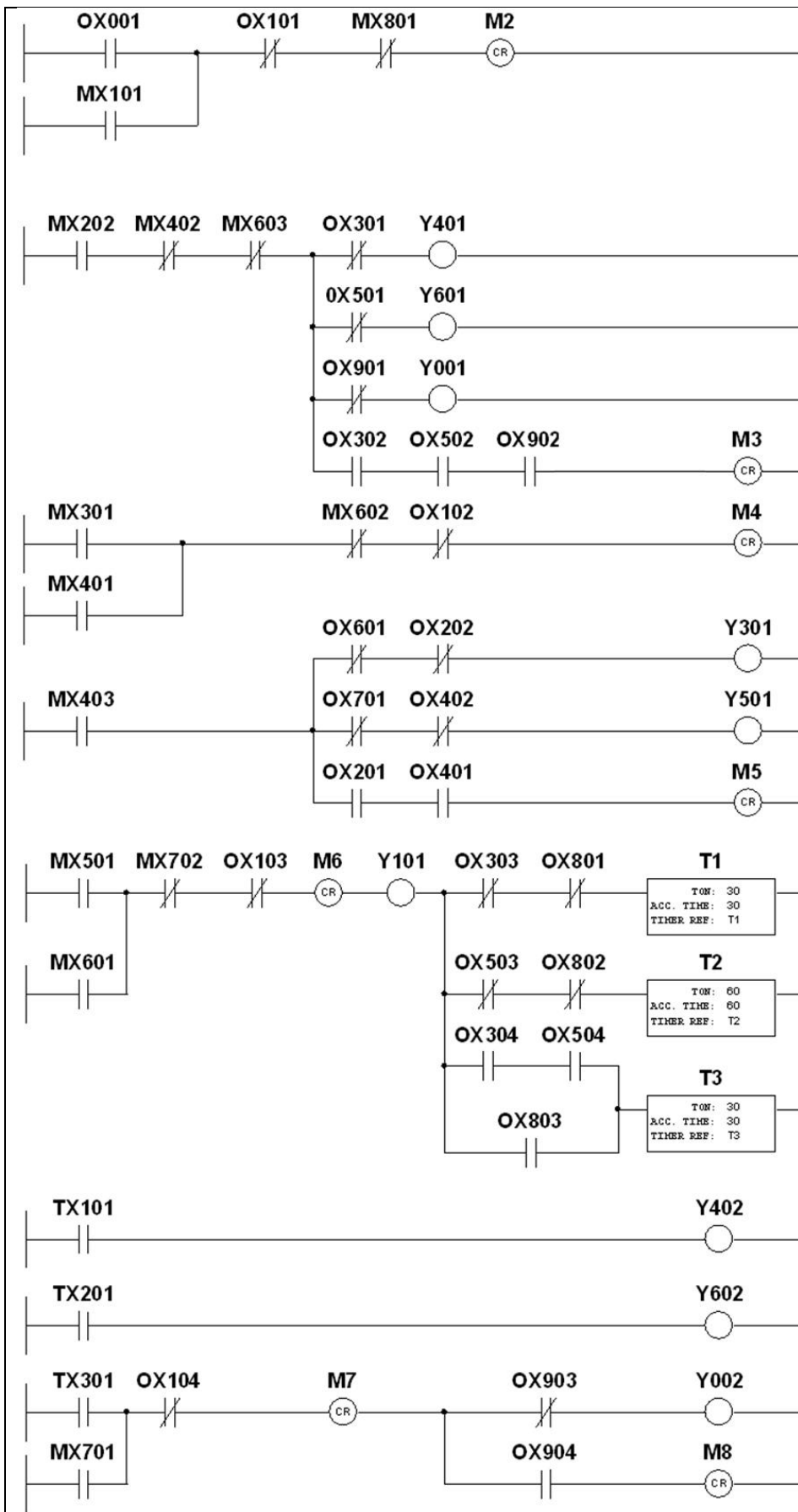
Operation complete.



1.5.5 Flowchart



1.5.6 Ladder Logic



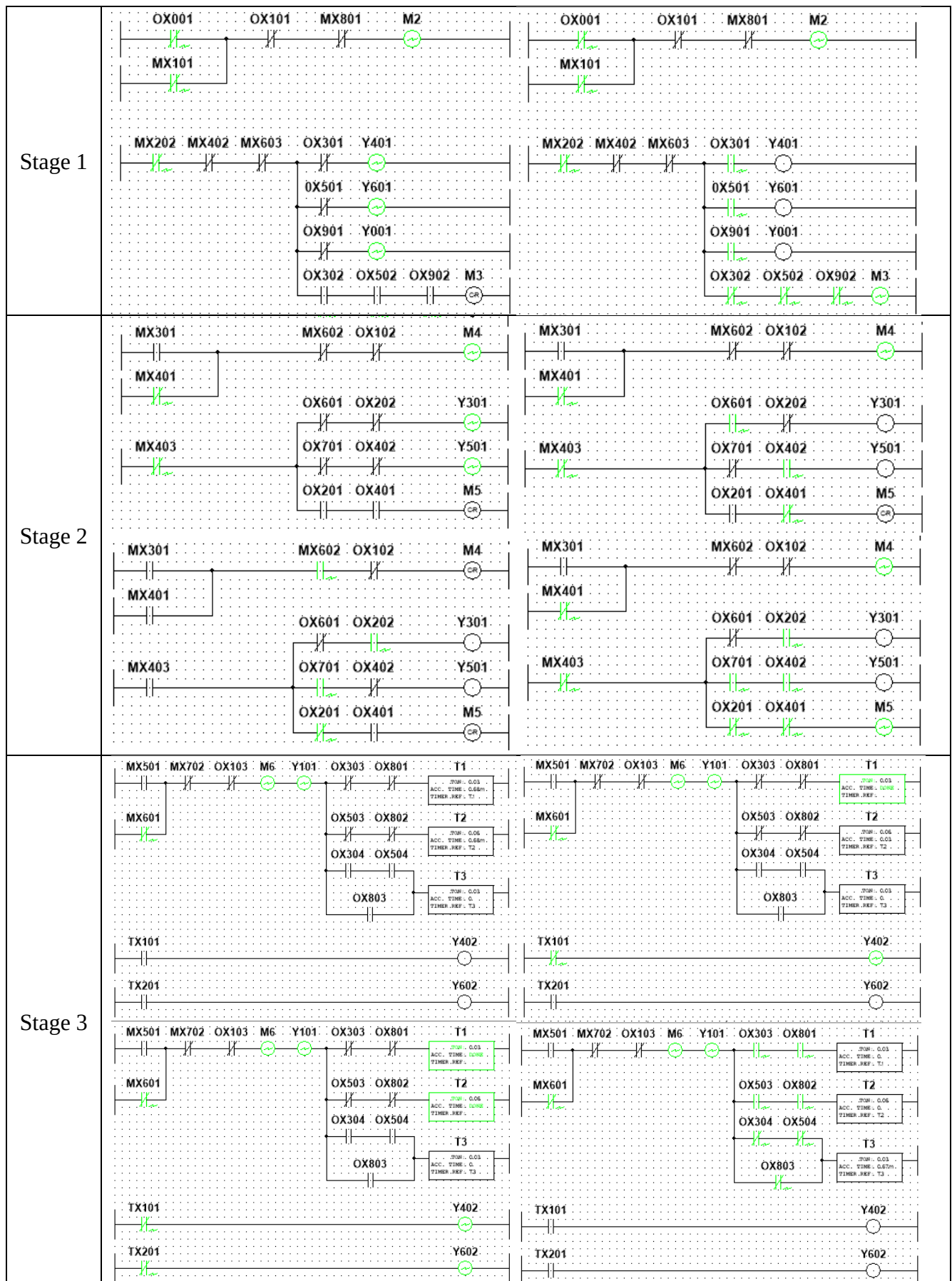
Key:
OX = Input Number
(OX [Input Number]
[Reference Number])

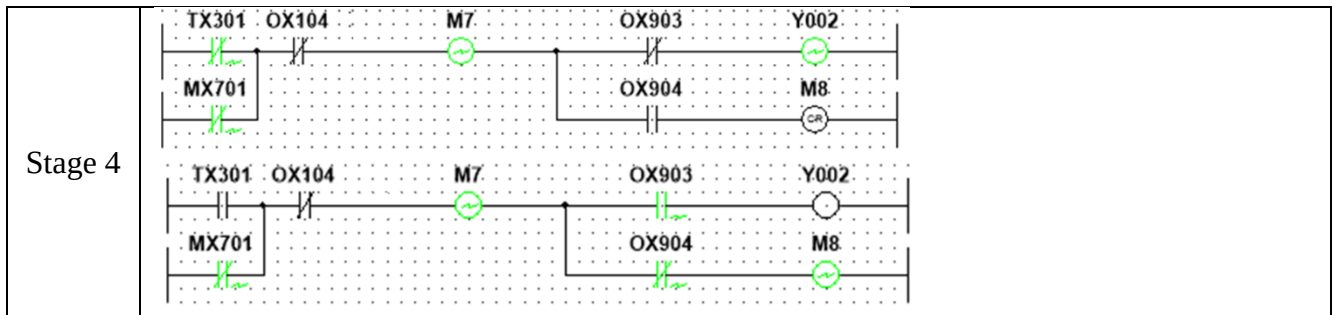
Y = Output Number
(Y [Output Number]
[Reference Number])

MX/M = Internal Relays
(MX/M [Relay Number]
[Reference Number])

T/TX = Internal Timer
(TX [Timer Number]
[Reference Number])

1.5.7 Testing the Design





1.5.8 Comments

This is a very simple Manufacturing circuit as it only requires mixing contents from two tanks before allowing to output from tank 3. The PLC and circuit could be used to open valve into flow switch from the master tank or control outputs tanks from the pump. A bigger PLC might be required as there are only two spare input slots on the current PLC. However, all the operations are working as expected within circuit therefore the designed PLC meets requirements.



2.1 Reference Page and Biography

3.1 Reference Page

Honeywell (2020). 'SCADA Experion System from Honeywell'. [Online] *Honeywell*. Available at: <https://www.honeywellprocess.com/en-US/explore/products/control-monitoring-and-safety-systems/scada-systems/Pages/default.aspx> [Accessed: March 2020]

Simatic (2020). 'SIMATIC SCADA Systems'. [Online] *Siemens*. Available at: <https://new.siemens.com/global/en/products/automation/industry-software/automation-software/scada.html> [Accessed: March 2020]

Inductive Automation (2020). 'What is SCADA?'. [Online] *Inductive Automation*. Available at: <https://inductiveautomation.com/resources/article/what-is-scada> [Accessed: March 2020]

Doffman, Z. (2020). 'Iran's 'Critical' Cyberattack Threat: This Is What Is Really Happening Right Now'. [Online] *Forbes*. Available at: <https://www.forbes.com/sites/zakdoffman/2020/01/11/irans-critical-cyberattack-threat-this-is-what-is-really-happening-right-now/> [Accessed: March 2020]

Storey, N. (2017). *Electronics A Systems Approach*. 6th Edition. Harlow England: Pearson.

Alciatore, D. and Hstand, M. (2012). *Introduction to Mechatronics and Measurement Systems*. 4th Edition. New York: McGraw-Hill.

Figliola R and Beasley D. (2011). *Theory and Design for Mechanical Measurements*. 5th Edition. New York: John Wiley & Sons.

Bolton, W. (2006). *Programmable Logic Controllers*. 4rd Edition. Oxford: Newnes.

Kutz, M. (2006). *Mechanical Engineers' Handbook*. 3rd Edition. New York, New York: John Wiley & Sons Inc.

3.2 Bibliography

Flaherty, K. (2020). 'U.S. Government Issues Powerful Cyberattack Warning As Gas Pipeline Forced Into Two Day Shut Down'. [Online] *Forbes*. Available at:

<https://www.forbes.com/sites/kateoflahertyuk/2020/02/19/us-government-issues-powerful-cyberattack-warning-as-gas-pipeline-forced-into-two-day-shut-down/> [Accessed: March 2020]

Flaherty, K. (2019). 'Iranian Hackers Are Going After A Disturbing New Physical Target'. [Online] *Forbes*. Available at: <https://www.forbes.com/sites/kateoflahertyuk/2019/11/21/iranian-hackers-could-be-going-after-a-disturbing-new-physical-target/> [Accessed: March 2020]

Bird, J. (2017). *Electrical Circuit Theory and Technology*. 6th Edition. New York: Routledge.

Bird, J. (2014). *Electrical Engineering Principles and Applications*. 6th Edition. Harlow England: Pearson.

Hambley, A. (2013) *Electrical Engineering Principles and Applications*. 6th Edition. Upper Saddle River, N.J.: Pearson.

Hiley, J. Brown, K. Smith, I. (2012). *Hughes Electrical and Electronic Technology*. 11th Edition. Essex: Pearson Education Limited.

Petruzella, F. (2011). *Programmable Logic Controllers*. 4th Edition. Boston: McGraw-Hill.

De, D. (2010). *Basic Electronics*. India: Pearson Education.

Bolton, W. (2009). *Programmable Logic Controllers*. 5th Edition. Oxford: Newnes.

Robertson, C. (2008). *Fundamental Electrical and Electronic Principles*. 3rd Edition. Oxford: Newnes.

Bolton, W. (2003). *Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering*. 3rd Edition. Upper Saddle River: Pearson Education.