

2024888

by Ethan Rigby

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TIME SUBMITTED	24-MAY-2021 08:47PM (UTC+0100)	WORD COUNT	2680
SUBMISSION ID	154662214	CHARACTER COUNT	15921

Course: HNC Electrical and Electronic Engineering
Module: SGEE4004 Programmable Logic Controllers
Assignment: 2. Level and Flow Control System
Name: Ethan Rigby
University number: 2024888
Date submitted: 24/05/2021
Word count: 2558

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1. Research

Description of each language and application

The International Electrotechnical Commission (IEC) have a list of defined standards used in PLC programming. The standards that dictate the PLC languages are 'IEC 61131-3'.

Manufacturers use these languages within their systems, but some manufacturers will have different names given to the languages. The five standard languages are as follows with a brief explanation:

Ladder Diagram (LD)- Ladder logic is a visual method of programming where you can directly see all the function you are applying to the system (switches, counters, timers, outputs etc). This style of programming is the most widely used across industry due to its effective and simplistic style. Ladder diagram is made from rungs separated by networks where the program can be easily sectioned to make it more readable and easier to fault find on. (this is called ladder due to the rungs and the graphics of the program) a visual representation of this languages is found in 'diagram 1'.

Ladder logic is quite a simple language in PLCs and doesn't have very advanced features. Therefore, it is mostly used in more simplistic systems such as an automatic mixing tank or a valve control system.

Instruction list (IL)- this language is not a visual based language, instead it shows a series of instructions. These instructions are abbreviated into simplistic terms (a diagram is shown of the abbreviations in 'diagram 2' (Sivaranjith, 2019)) instruction lists have two main benefits. The first is the low memory this program requires; this makes it perfect for fitting the program in the smallest PLC possible for the number of i/o required. Second benefit is the execution speed, due to the low level of words needed to execute a function this language runs extremely fast (Budimir, 2017). A visual representation of this languages is shown in 'diagram 3'.

This language is also not an advanced language therefore its application is based around more basic systems, for example it can be used for flow control or level control.

Structured text (ST)- This text is arguably the most powerful of the five languages, it allows for complex conditions to be made in a simpler form (Liam, 2018). Structured text is used in all PLCs but every manufacturer will structure it slightly differently to make it unique to their system. This style of programming is easy to follow as it is written as a sequence of steps typically. Structured text is mostly used in the more advanced and complex systems and for large scale systems. It is used in large scale systems due to its ability to shorten programs compared to other languages. For both novice programmers and experts this language can be easily followed and understood (Peter, 2015). An example of structured text is found in 'diagram 4'.

ST is an advanced language therefore it is used in more complex systems. An example of a complex system where this language will be used is, a multi conveyor system where there are multiple conveyors and multiple hoppers that would load a system with batches of set amounts of materials. This system would need a lot of precise and fast activating outputs which is why this language would be ideal.

Function Block Diagram (FBD)- function blocks are visual methods of programming like ladder logic. The function block executes a function dependant on the inputs and the state of the inputs it contains. This language will take many lines of programming and simplify it into one block, this block could be a variety of things such as counters, timers, MOVE, AND, OR limit etc. Due to the structure of the language describing the system is easier than the other 4 languages. An example of FBD is shown in 'diagram 5'.

FBD is a language that can be used to control a large-scale site, this is due to its easy-to-understand blocks that condense a lot of program into small areas. It's also a very well-structured language making it easy to fault find and follow steps on.

Sequential function chart (SFC)- this language like ladder and FBD is a visual based language, this helps the user break down a large complex system into smaller more tangible sections. This language can be simplified by understanding there being two main concepts (steps and transitions). A step is seen as the actual machine working at a point and the transition is the part that switches the system to the next step. This is the basic concept of the language, but it can also go into ore depth when it includes feedback loops or branching. Branching in these systems can be done in either parallel or as an alternative (Budimir, 2017) (an example of this is shown in 'diagram 6' that will also show what the language looks like.)

This language is a good language to use on a conveyer belt. Its structure makes it easy to implement the steps the system needs to take dependant on the location of the object. The language is also easy to read and can be used to describe the system in detail.

Languages used in TIA portal

Siemens TIA portal is the location in which the program is created on a siemens PLC. TIA portal lets the user work in 3 languages, these languages are Ladder (LAD), Function Block Diagram (FBD) and Structured Control Language (SCL). These 3 languages are commonly used among other manufacturers, but siemens have changed the names and abbreviations given to some. The table below shows the TIA portal language next to the standardised language.

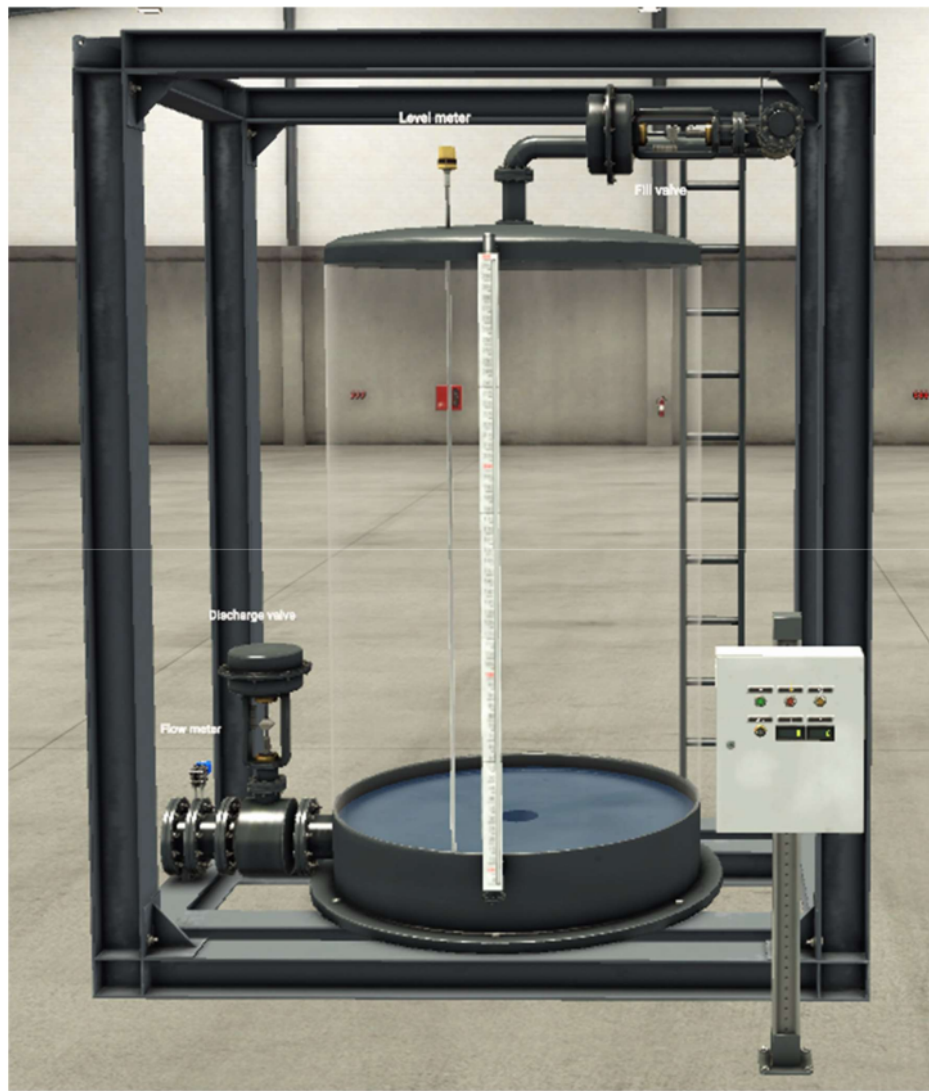
IEC standard language names	TIA portal language names
Ladder Diagram (LD)	Ladder (LAD)
Function Block Diagram (FBD)	Function Block Diagram (FBD)
Structured text (ST)	Structured Control Language (SCL)

Even though two of the languages are labelled differently they still get programmed in the same way as they are described above.

2. Hardware Design

Within the system created the following hardware devices were used:

- Capacitive level meter
- Differential pressure transmitter (flow meter)
- Orifice plate
- Fill valve
- Drain valve
- Siemens s7-1214c PLC
- AI extension module (AI4X13BIT_1)
- AQ extension module (AQ4X14BIT_1)
- KTP 1200 HMI screen
- Start button
- Stop button
- Reset button
- 3x indication lights
- Potentiometer
- 2x digital screens
- Panel
- Water tank



Start	%I0.0	%Q0.0	Start light
Reset	%I0.1	%Q0.1	Reset light
Stop	%I0.2	%Q0.2	Stop light
FACTORY I/O (Running)	%I0.3	(REAL) %QD30	Fill valve
Level meter	%ID30 (REAL)	(REAL) %QD34	Discharge valve
Flow meter	%ID34 (REAL)	(DINT) %QD38	SP
Setpoint	%ID38 (REAL)	(DINT) %QD42	PV

Figure 1//addresses of inputs and outputs in the system

Inputs

The system has 3 digital inputs and 3 analogue inputs. The 3 digital inputs are pushbuttons, being a start, stop and reset button. The start button is used to activate the system in and automatic mode, the stop button is used to pause the automatic sequence whilst the reset is to set the system and drain the liquid in the tank.

3 analogue inputs- these inputs consist of a potentiometer, capacitive level sensor and a differential pressure transmitter (DP). The capacitive level transmitter transmits a 0-10v signal dependant on the level of the water. The DP also transmits a 0-10v signal dependant on how much liquid is passing through the pipe at any given time. The DP also uses an orifice plate to create a difference in pressure between each side of the plate, the DP uses these different pressures to calculate the flow rate. The potentiometer is used to select a setpoint for the water. Addresses for all inputs are in 'figure 1'.

Outputs

There are 3 digital outputs and 4 analogue outputs. The 3 digital outputs are indication lamps for the 3 digital inputs, being start, stop, and reset buttons.

4 analogue outputs are- 2 digital screens, these screens take values from the program or process and visually display them on the front of the panel of factory i/o. one of these display screens is for the setpoint, whilst the other is for the process value. The 3rd analogue output is for the fill valve, the fill valve uses a 0-10v signal to open the valve anywhere within that range, the value of this signal is directly proportional to the amount the valve is opened by. The last analogue output is for the drain valve, this valve also works in a 0-10v signal with the same concept as the fill valve, but instead will discharge the water from the tank when opened. Addresses for all outputs are in 'figure 1'.

3. Program Design and Explanation

This program is separated into three sections, main block, flow control and level control. These systems each operate different things. Flow control activates the drain valve out of the tank, whilst the level control oversees the water entering the tank. The overall program allows semi-automatic control and manual control of a water tank. The water tank can be filled up to a desired setpoint and can meet that exact level and maintain circulation in the tank. This program used ladder logic mixed in with function blocks.

Level

Level control has 3 functions available, 2 of which are on semi-auto mode. These being PID mode and ON/OFF control. ON/OFF control will increase the water level up to the desired level but due to its lack of control over the outputting water it will only tell the system to stop when the water level reaches the setpoint exactly. PID control is in place to have a more sensitive approach to the setpoint.

The other mode is manual mode, this allows the tank to be filled up by pressing a button on the HMI to activate the fill valve and another to close it, these buttons work in pulses. When pressed multiple times the fill valve will open more until a factor of 10. The same occurs when pressing the close button.

The level control system is in the appendix with the logic and HMI screen.

what about full auto mode?

Flow

Flow control determines the volume of the water leaving the water tank dependant on which mode is activated. Flow control has 2 functions, one being a semi-automatic mode. When flow control is activated, and semi-automatic control is selected, and level control has PID control on the drain valve is put in use within the system. When the level of water overcomes the setpoint the drain valve will open to drain the water to the setpoint. Then the setpoint is reached the flow out of the tank and the amount of water entering the tank is equal, this makes the liquid in the tank flow in and out whilst maintaining a desired setpoint.

The other mode is manual mode, this mode works in the exact same way as the level manual control in the sense that opening and closing the valve can be done in steps (pulses).

The flow control system is in the appendix with the logic and HMI screen.

4. System Testing

Description of test	Expected result	Actual result	Pass or fail	Reference to evidence
Fill valve open in manual (with pulses)	Water entering tank, increasing rate as button is pressed more.	Fill valve opened more when manual open button was pressed.	pass	Figure 8 Figure 16
Fill valve close in manual (with pulses)	Water entering tank, decreases rate as button is pressed more.	fill valve closes more when manual close button was pressed.	pass	Figure 9 Figure 17
drain valve open in manual (with pulses)	Water leaving tank, increasing rate as button is pressed more.	drain valve opened more when manual open button was pressed.	pass	Figure 10 Figure 18
drain valve closes in manual (with pulses)	Water leaving tank, decreases rate as button is pressed more.	drain valve closed more when manual close button was pressed.	pass	Figure 11 Figure 18
ON/OFF level control to setpoint	When setpoint is added and system in ON/OFF control p_v should overshoot and remain constant	Level raised above setpoint and settled	pass	Figure 12
PID level control to setpoint	When setpoint is added and system in PID control p_v should be on or extremely close to setpoint and remain constant	Level raised to setpoint with slight overshoot and remained constant	pass	Figure 13
PID mode and drain valve activated to get exact level with constant flow.	When PID mode is activated with drain valve slightly on the p_v should settle at the setpoint exactly as flow rate and fill rate will match exactly at that point	Level maintained at exact setpoint with any level changes corrected automatically	pass	Figure 14 Figure 15

5. Meeting the Customer Needs and Team Working

*you have forgotten about
auto mode*

Meeting customer needs

the program that is written and the HMI screens are made to be fully user friendly. There are many aspects that were added to the program purely for the customers needs. The program overall meets customers' requirements as shown in the test table above. Within every network of the program there are comments that state what each network does, this makes it easy for the operator of the system to change and tune the program to their desire. Graphs were also added into the HMI screens for the user to inspect and visually see the values that the system was providing, this makes it easy in the fault-finding stages of the system as they can go back to the time of fault and see what state the system was at.

Teamwork

On the teamwork section a call was made between 3 of us and we showed each of our programs and discussed the findings and upgrades each of us should make. Initially fault finding was executed with my program in monitor mode to identify an issue with my PID control mode, through the group discussion we found the issue located on the p part of the program and corrections were made. After the fault finding it was decided that push buttons on the HMI should change colour to make the current mode clear to the operator.

6. Conclusions and Recommendations

Overall, the program works very well for its intended purposes and a variety of modes are available that give precise or less precise control of the water level. Through testing the system it's clear that all functions that are within the program work sufficiently. When testing the system, the most precise mode was the PID mode with the drain valve on a low setpoint value. This made the setpoint and the pv exactly match. This was done due to the drain valve constantly reducing the water in the tank whilst the fill valve was getting to the setpoint value they both hit a point where they compensate for each other precisely. This occurred at the desired setpoint. This mode also made the system reactive to change in setpoint where if the value was dropped or raised the pv will linearise at the setpoint.

Through the teamworking process the visual aspects of the system were also improved to make it more user friendly and clear of the operations that were occurring. In terms of recommendations the auto mode should have been added to ensure that every customer function was added and tested. The auto mode was not added to this system, but the system does have a good range of abilities that work just as well as the auto mode and offer complete control of the system.

7. Citation List

Correct method of listing.

Good range of sources

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8. Appendix

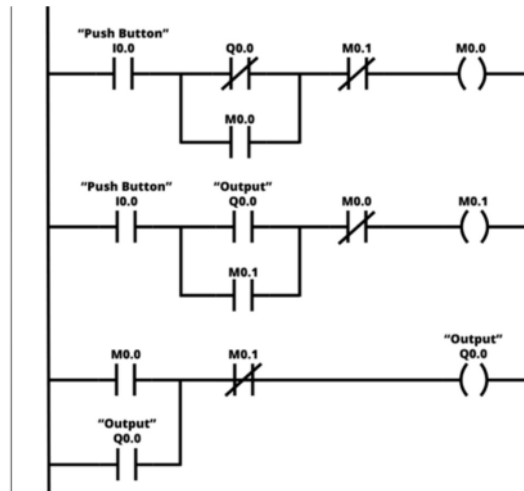


Figure 2-ladder diagram

(JR, 2015)

Instruction	Function	Operand
LD	Load NO contact	X, Y, M, S, T, C
LDI	Load NC contact	X, Y, M, S, T, C
AND	Connect NO contact in series	X, Y, M, S, T, C
ANI	Connect NC contact in series	X, Y, M, S, T, C
OR	Connect NO contact in parallel	X, Y, M, S, T, C
ORI	Connect NC contact in parallel	X, Y, M, S, T, C
ANB	Connect a block in series	N/A
ORB	Connect a block in parallel	N/A
MPS	Start of branches. Stores current result of program evaluation	N/A
MRD	Reads the stored current result from previous MPS	N/A
MPP	End of branches. Pops (reads and resets) the stored result in previous MPS	N/A
OUT	Output coil	Y, S, M
SET	Latches the ON status	Y, S, M

Figure 3-instruction list abbreviations

(Sivaranjith, 2019)

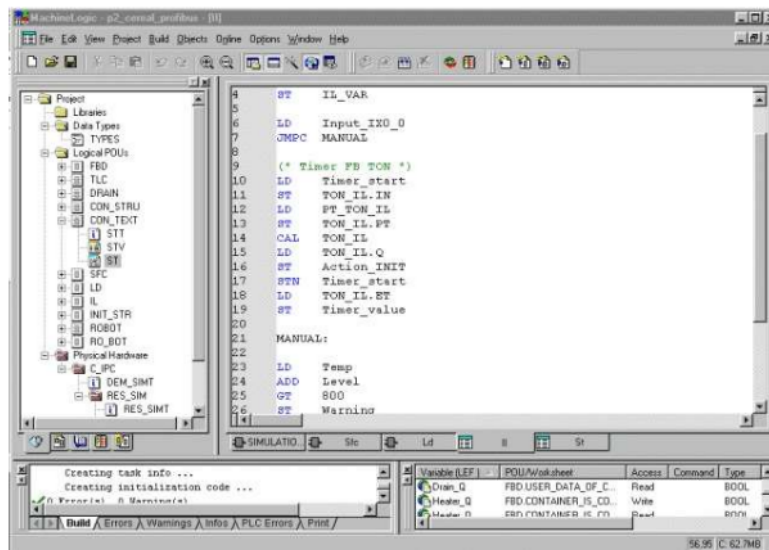


Figure 4-instruction list

(smartinstruclass, 2021)

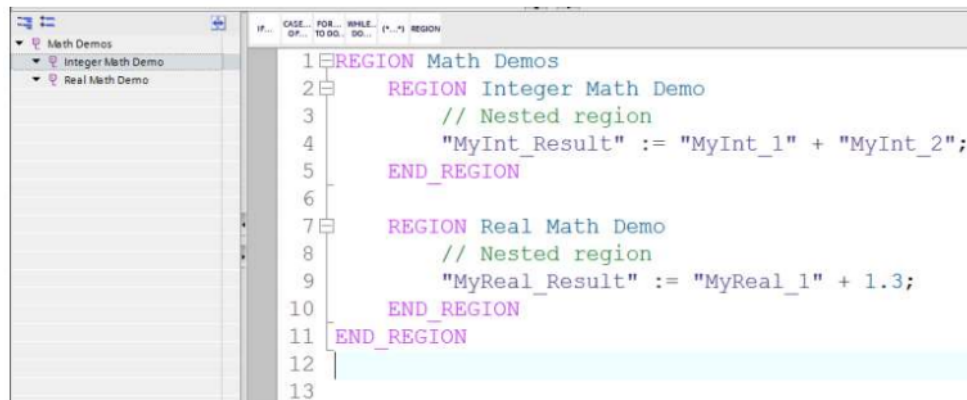


Figure 5-structured text

(John, 2020)

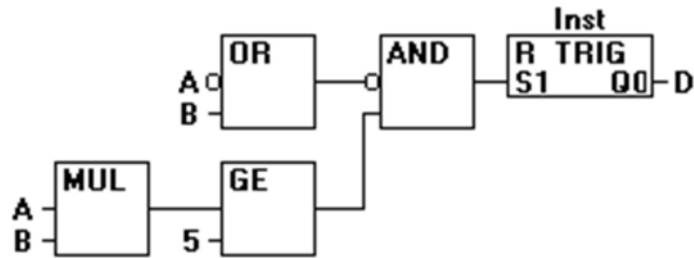


Figure 6-function block diagram

(Beckhoff, 2020)

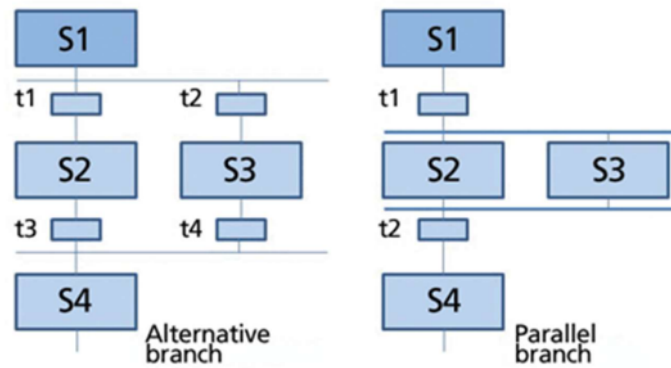
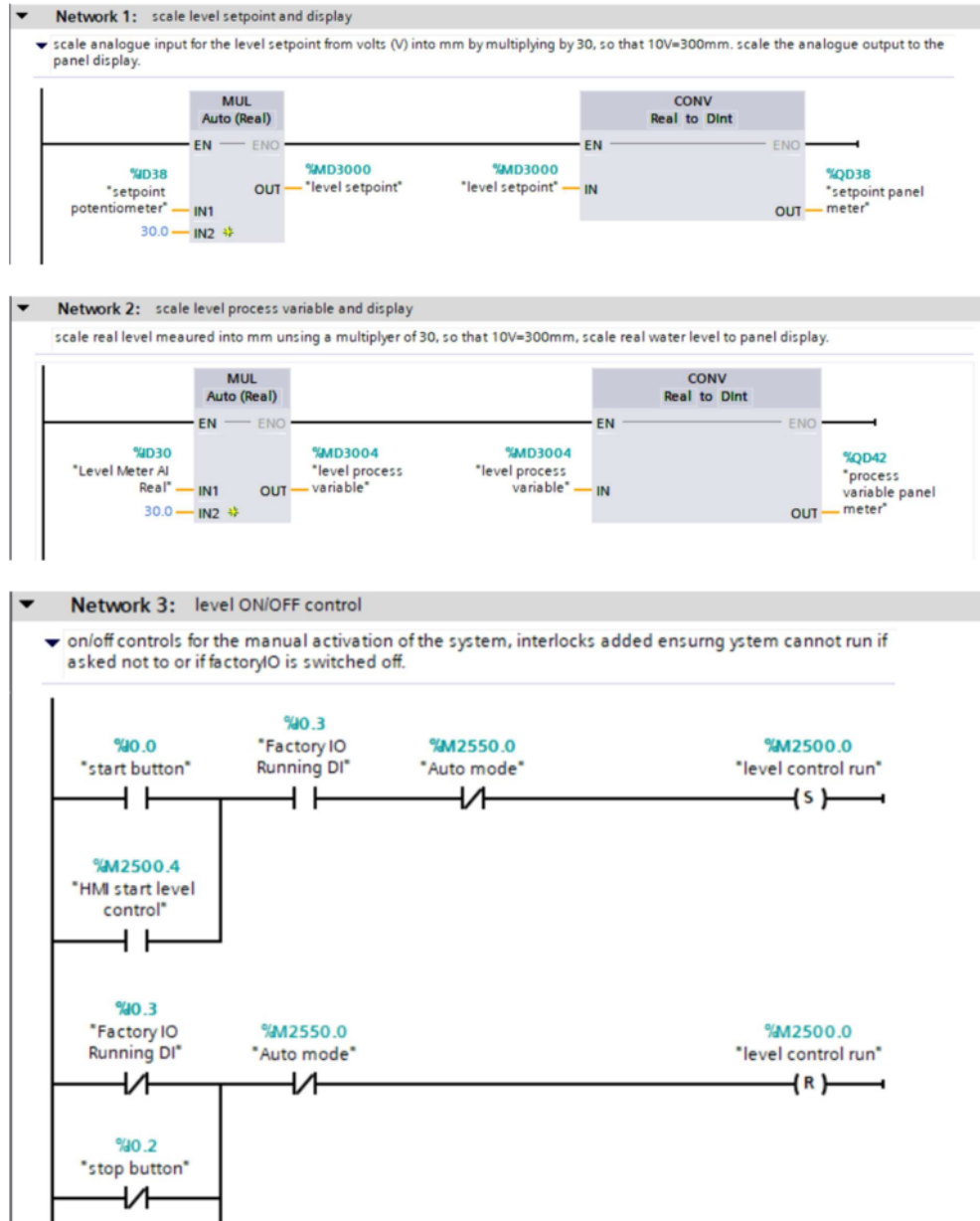


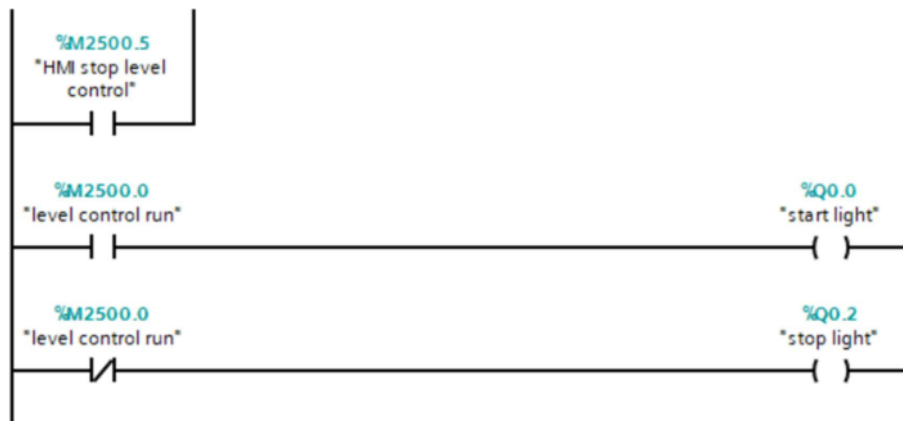
Figure 7-branching SFC

(Budimir, 2017)

Program images

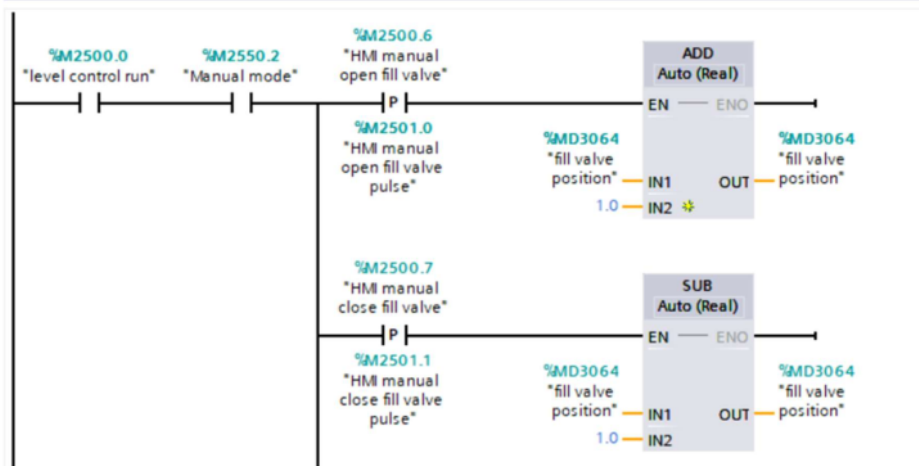
Level control

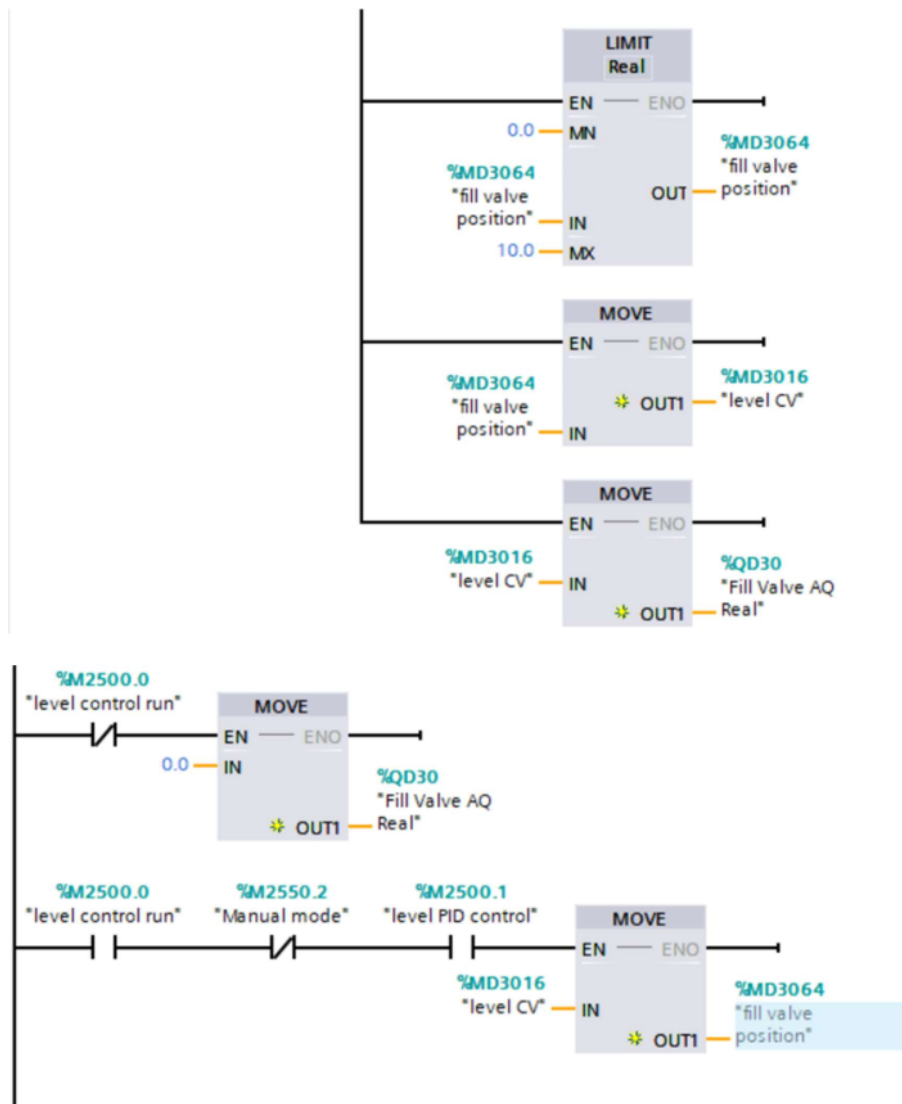




Network 4: level manual mode

- when manual fill button is pressed once the rate in which the tank fills will be 1, everytime the button is pressed the tank will fill up at a faster rate with a max rate of 10.





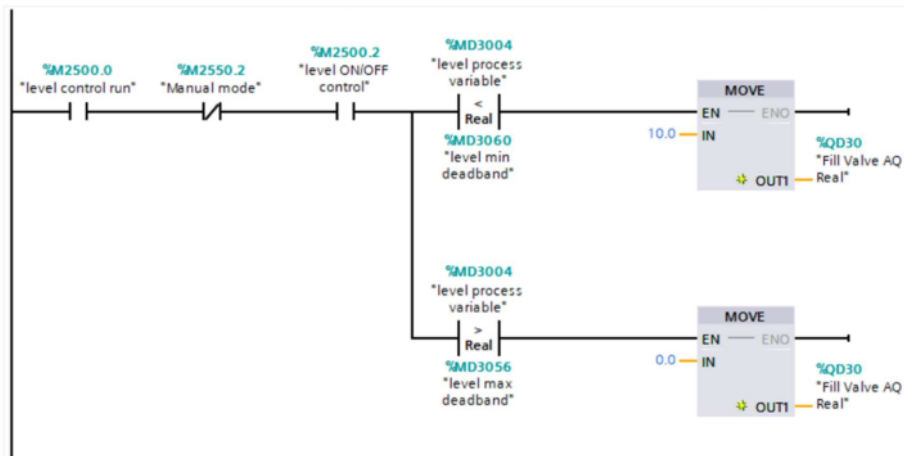
Network 5: ON/OFF control deadband

- the deadband is a value on each side of the setpoint in which the system allows the process variable to deviate, the deadband could be 2% each side of the setpoint and as long as the PV is within the bands the system will not try to correct it.



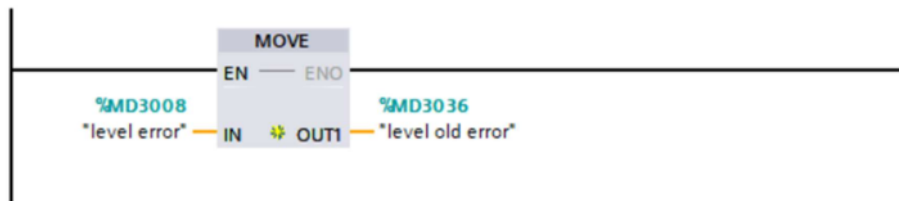
Network 6: level ON/OFF control with deadband

- ▼ this places the deadband points in the system, min point is below the setpoint and the max is above it at the same distance from the setpoint. the deadband works as stated in network 5.



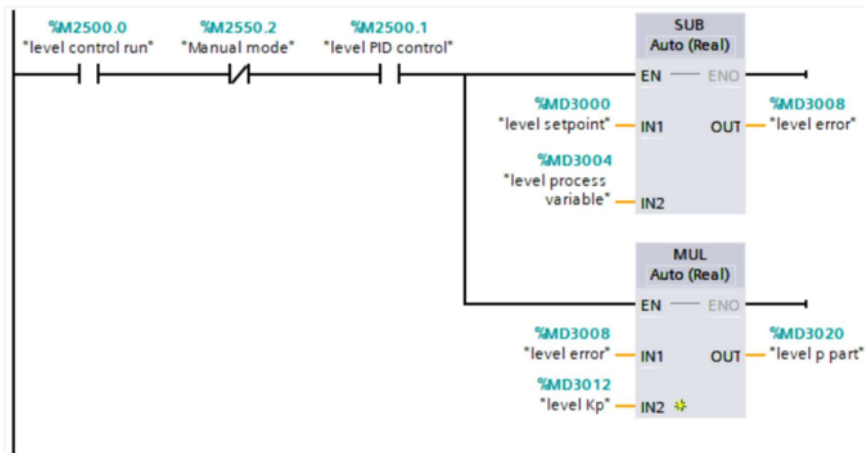
Network 7: store old error

- takes current error and converts it to old error to store and use.



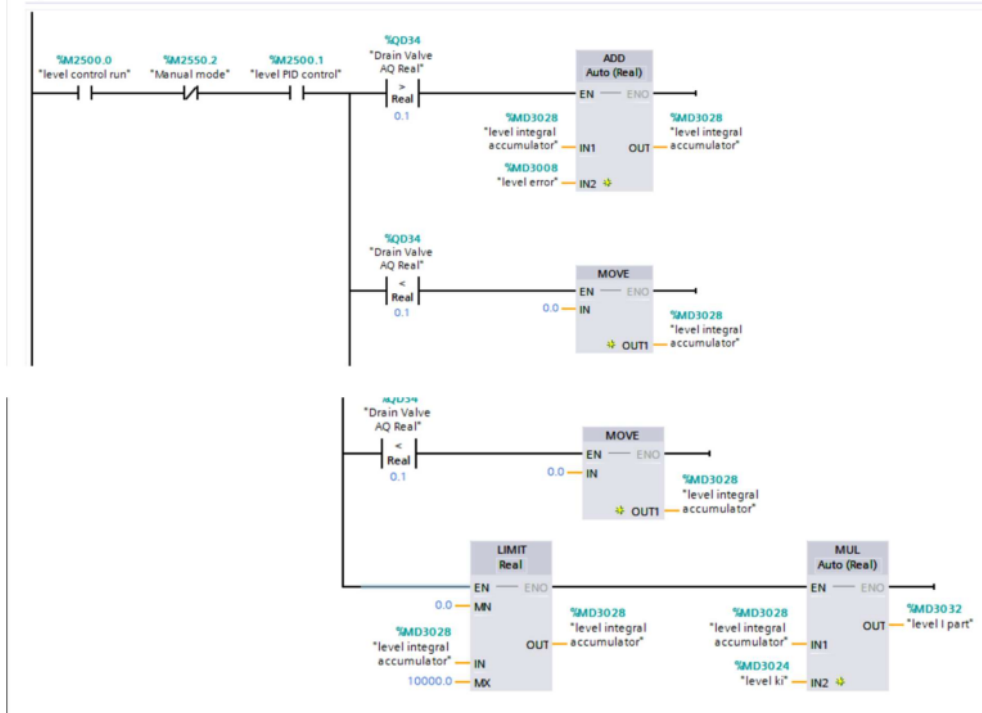
Network 8: level PID control-calculate the error and the p part

- ▼ error-the error is the difference between the setpoint and the process variable. this shows how far out the value is from is desired level.
p part-the p part is the proportional gain, this determines the systems output response in response to the error, this will increase and decrease the systems reaction depending on how close the pv is to the setpoint.



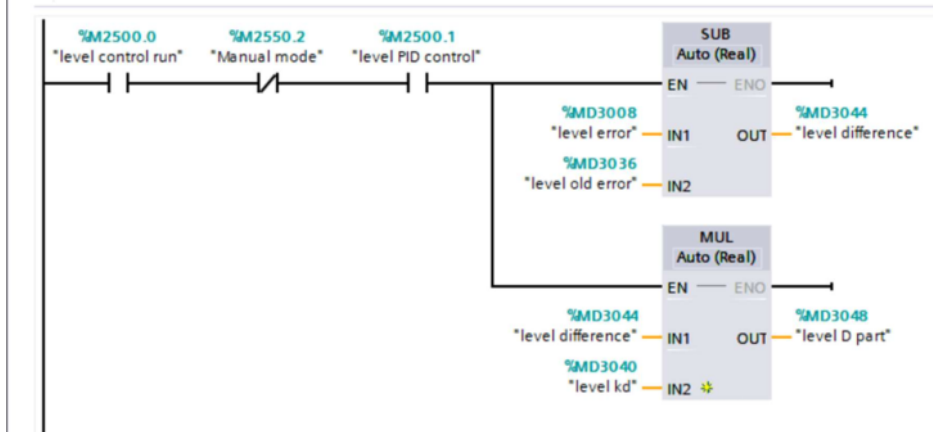
Network 9: level PID control-calculating the I part

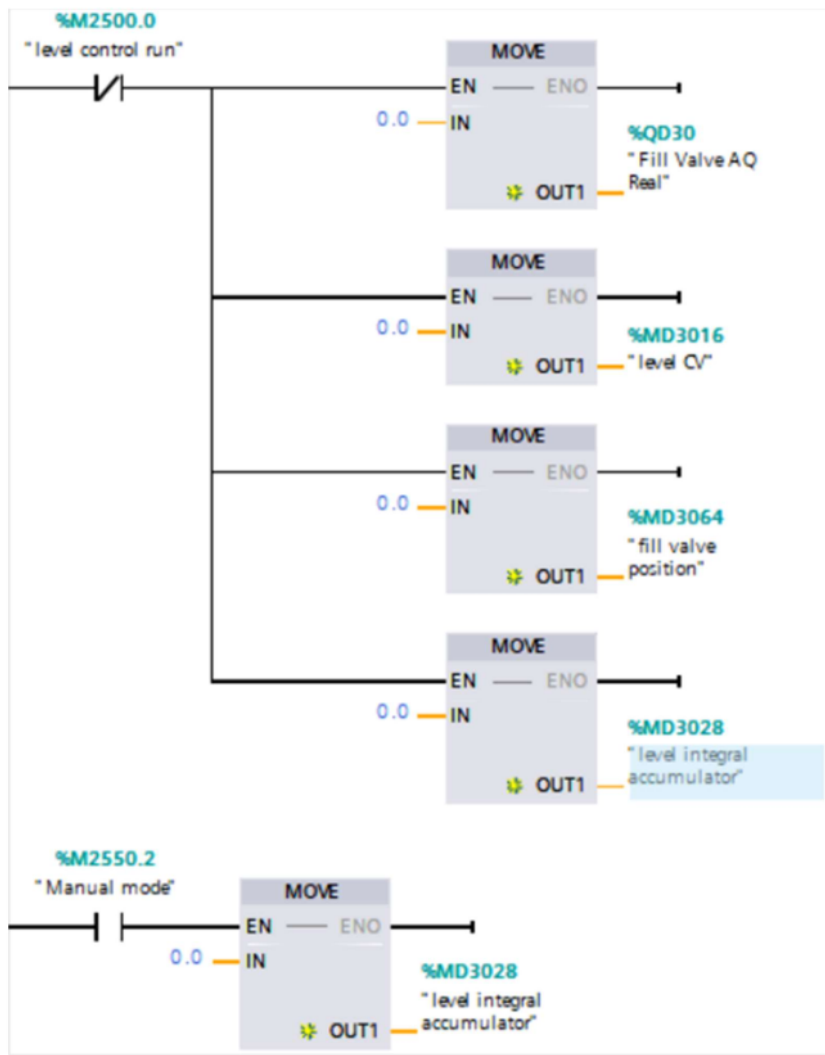
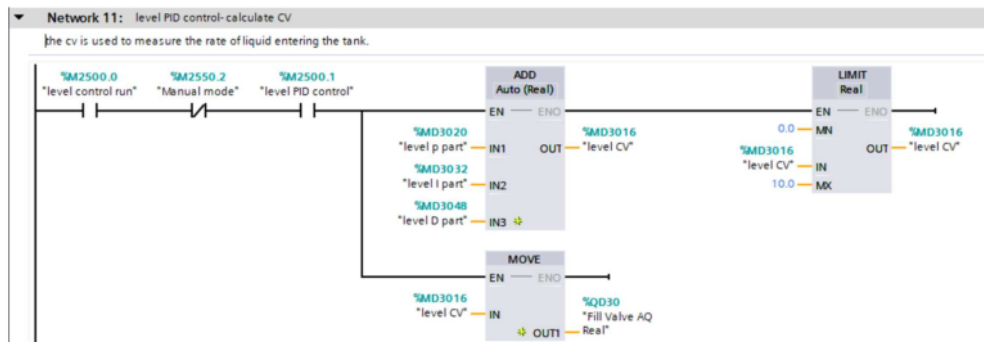
i part-integral is used to finely tune the pv to the setpoint, it does this by slowly increasing the rate of water entering h tank by a factor of 0.1. when the value is reached the system will maintain its level.



Network 10: level PID control-calculate the D part

d part-this is the derivative, the derivative is used to slow the value of flow into the system on approaching the error, similar to the proportional but is more precise and gets the value closer to the setpoint with a smaller overshoot.

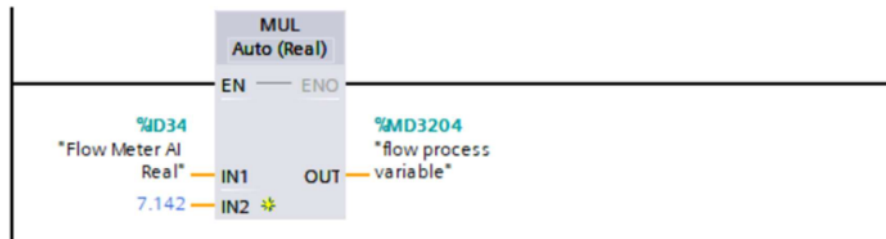




Flow control

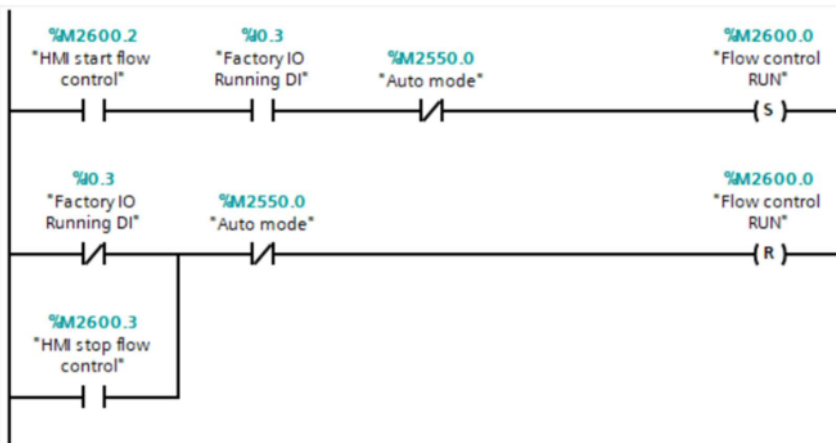
▼ Network 1: read in analogue input for flow

takes the real value given from the flow meter and converts it to the process variable.



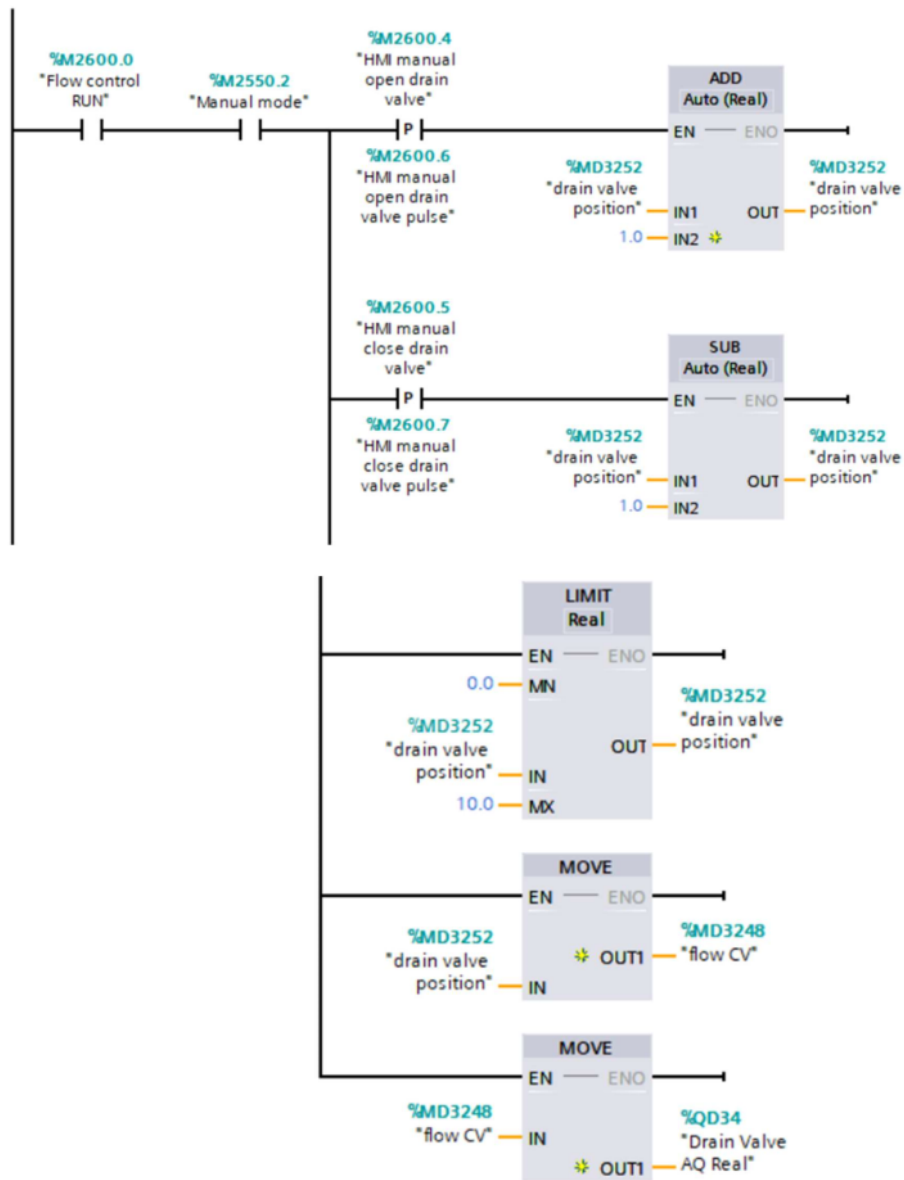
▼ Network 2: flow control

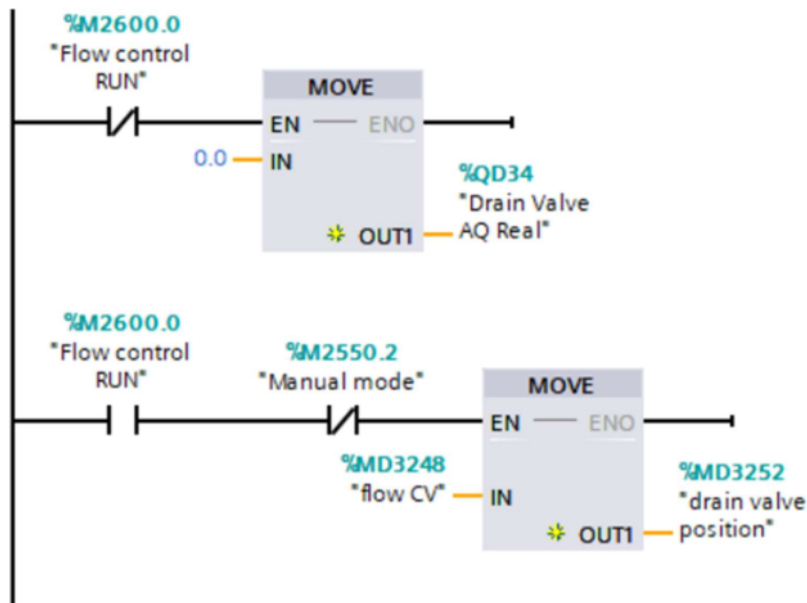
▼ activates the flow control in order for the drain valve to function. if off the tank will not be able to drain.



▼ **Network 3:** manual drain valve control

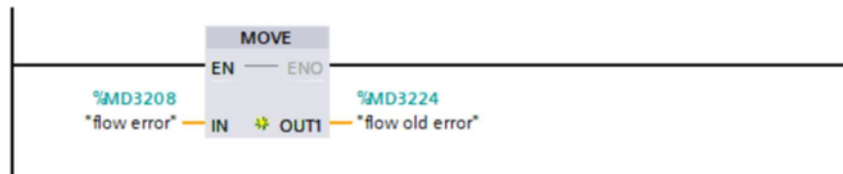
- ▼ opens or closes the drain valve when either 'open' or 'close' is activated on the HMI screen. the ratio on which the vave opens increases by a factor of 1 everytime the button for the desired function is clicked.





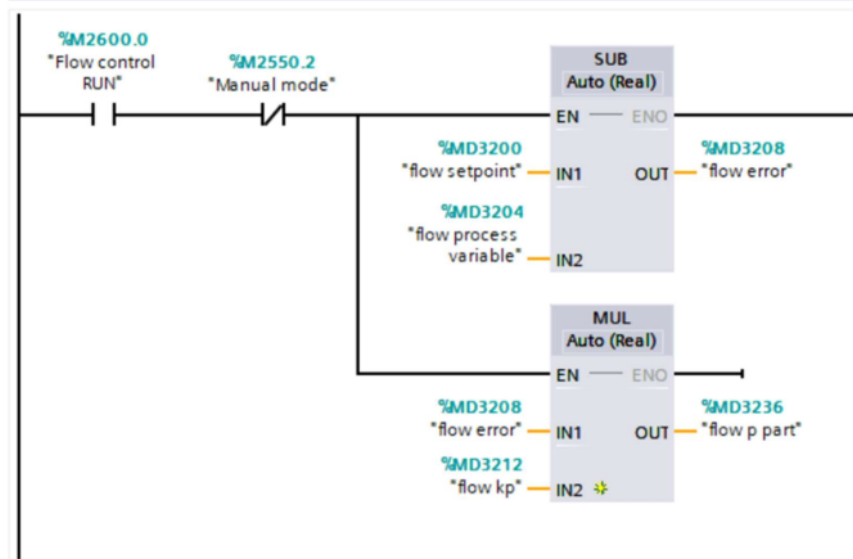
▼ Network 4: store old error

takes current data and stores it as old data to use.



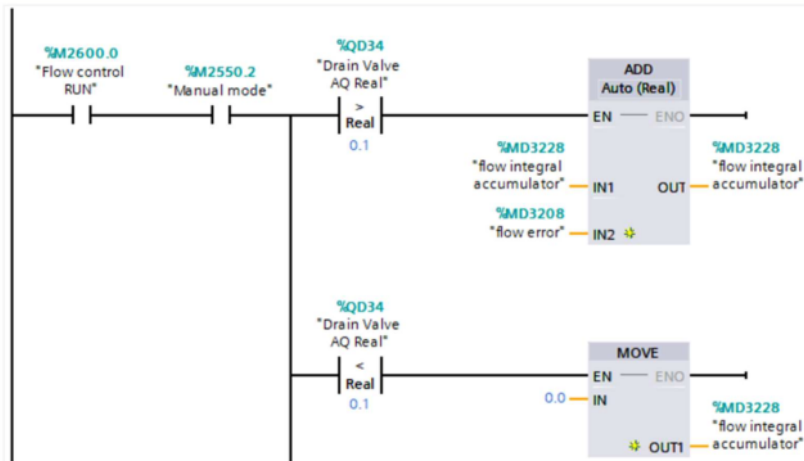
Network 5: flow PID control - calculate the error and the p part

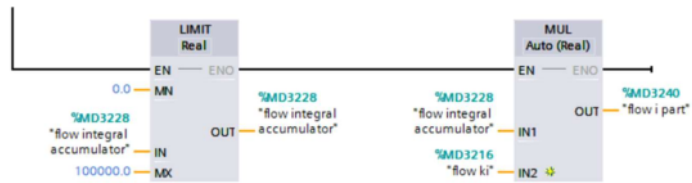
- error-difference between setpoint and process variable, shows how much out the flow is out by. p part-flow error multiplied by the flow rate to give p part, the proportional gain will increase the value of the output if not close to setpoint, but when approaching the setpoint (smaller error) the proportional gain will decrease the rate in which the level drops.



Network 6: Flow PID control - calculate the i part

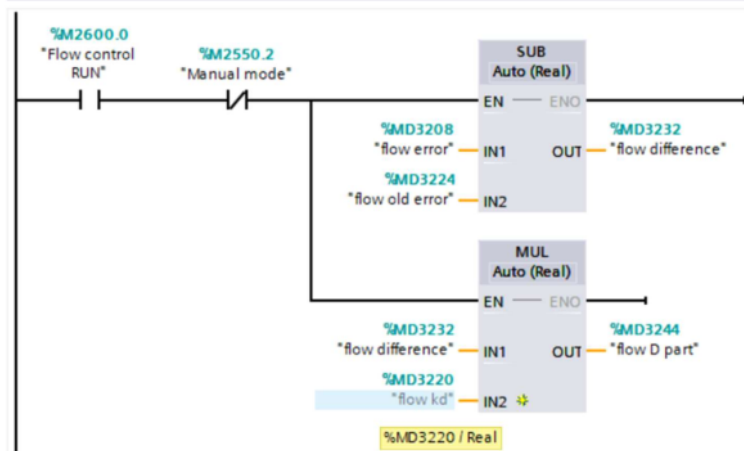
- PID mode controls the level in which the water stays at, its a more precise method of maintaining water level. the i part of this is the 'integral', this adds a small volume of water to the tank until the error becomes zero.





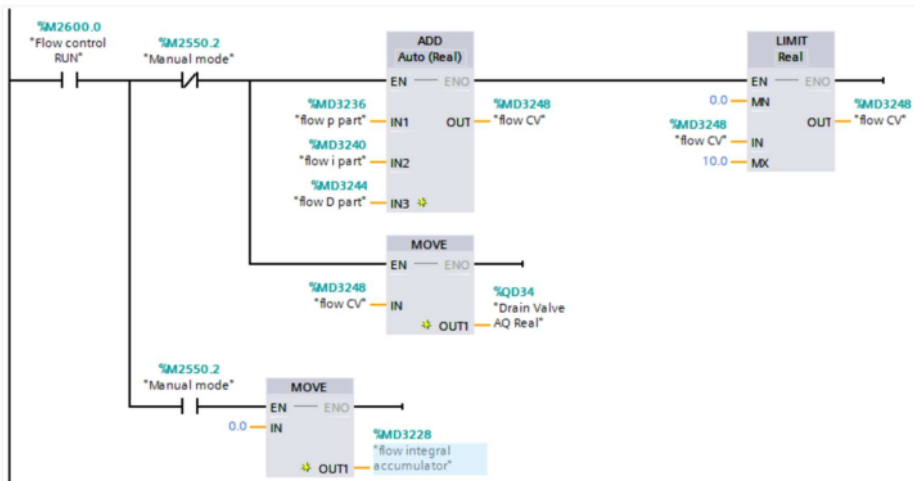
Network 7: flow PID control - calculate the D part

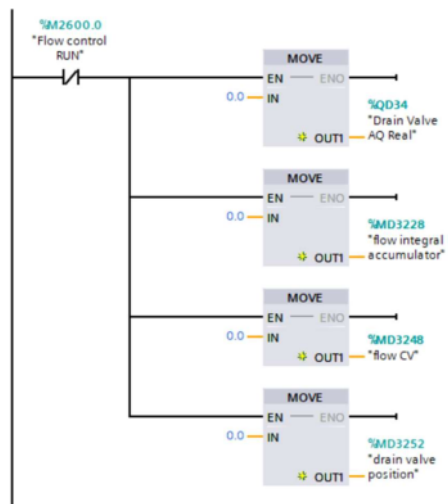
- the d part (the 'derivative') is there to dampen the rate in which the water level drops, when the level gets closer to the desired setpoint the drain valve will slowly close to prevent the level of the water going under the setpoint as much.



Network 8: flow PID control - calculate the cv

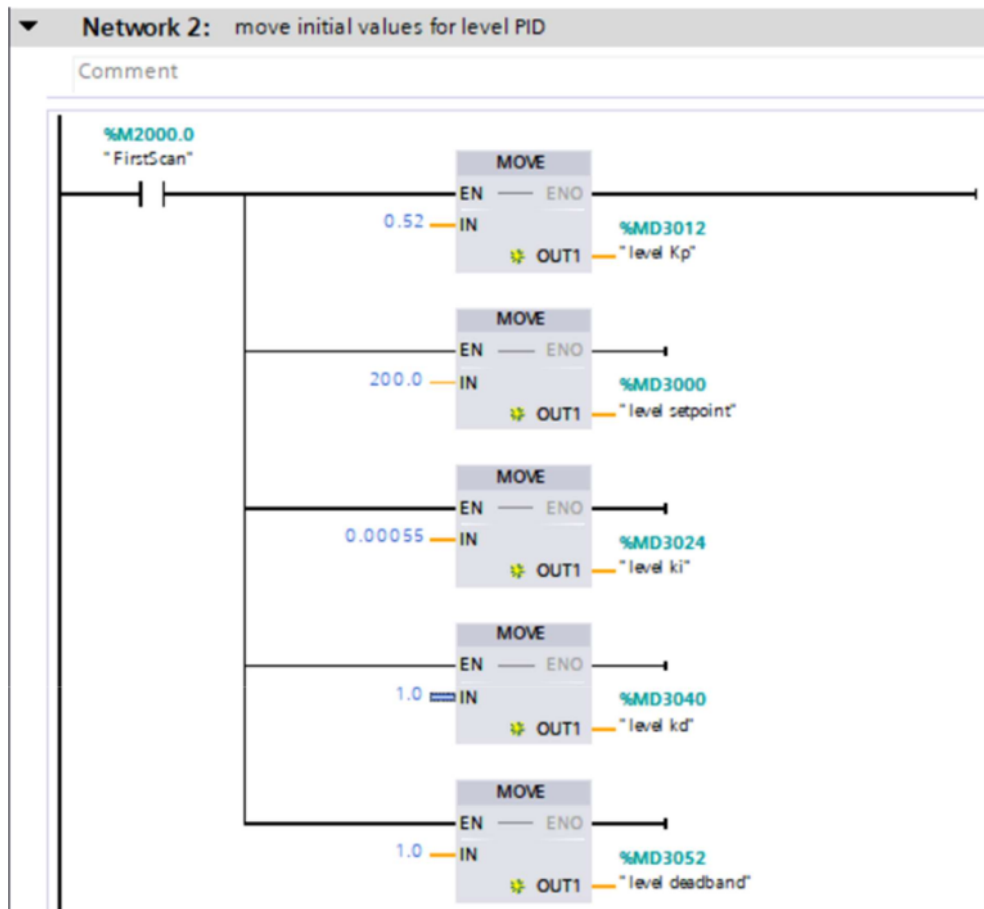
the cv is used to measure the flow of the liquid passing through the drain valve





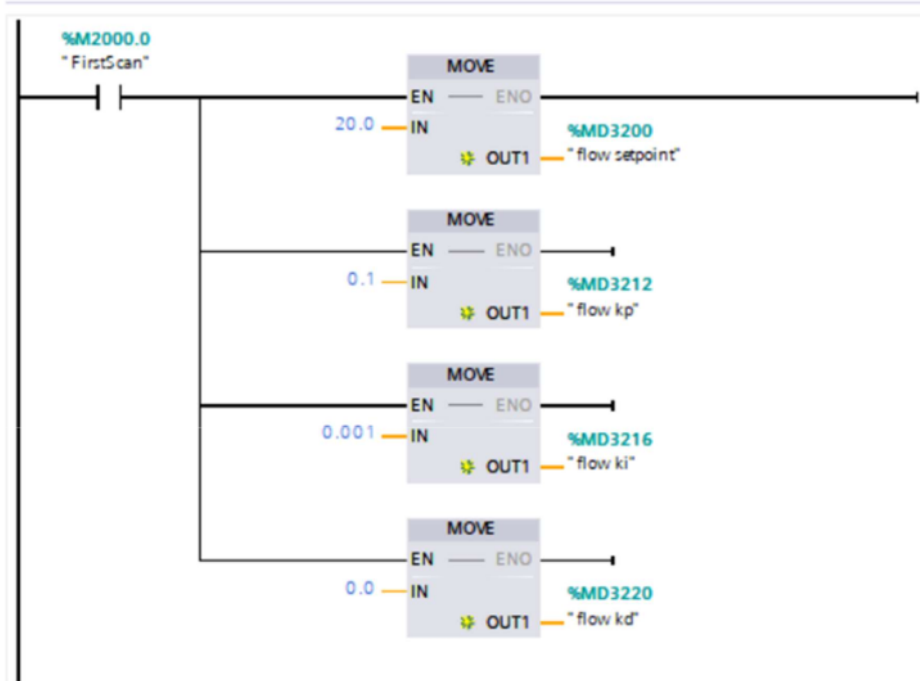
Main



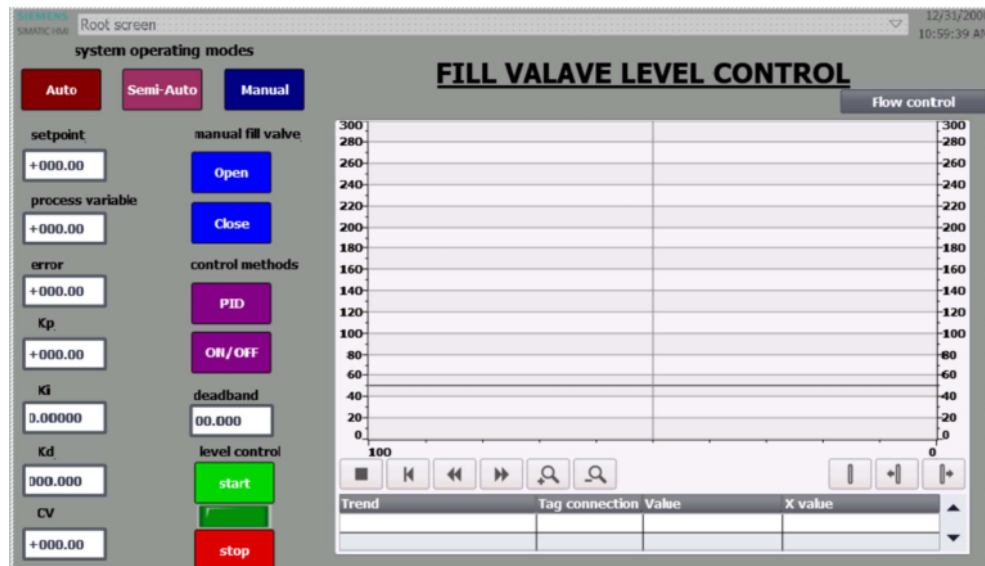
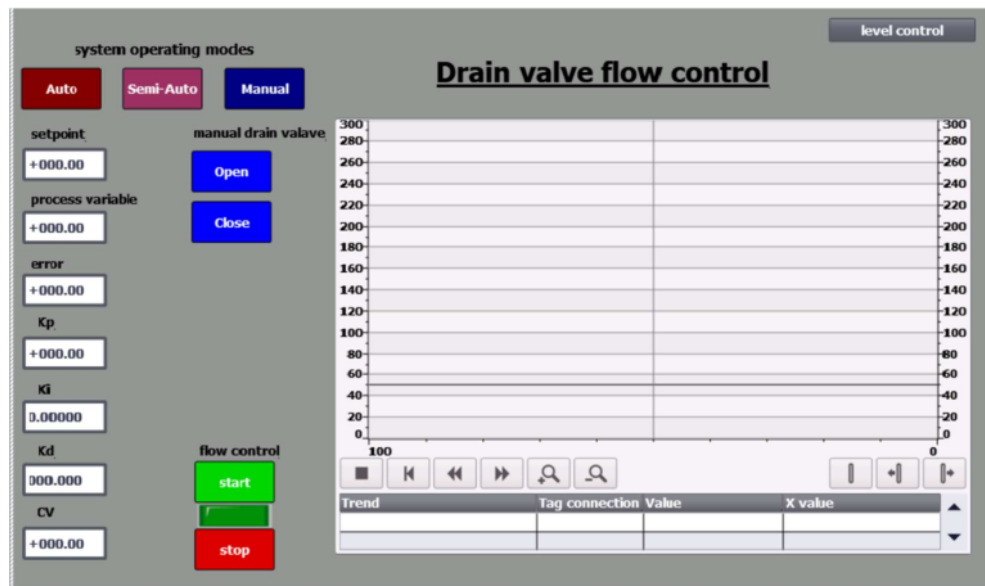


▼ **Network 3:** move initial values for flow PID

Comment



HMI screens



System testing evidence

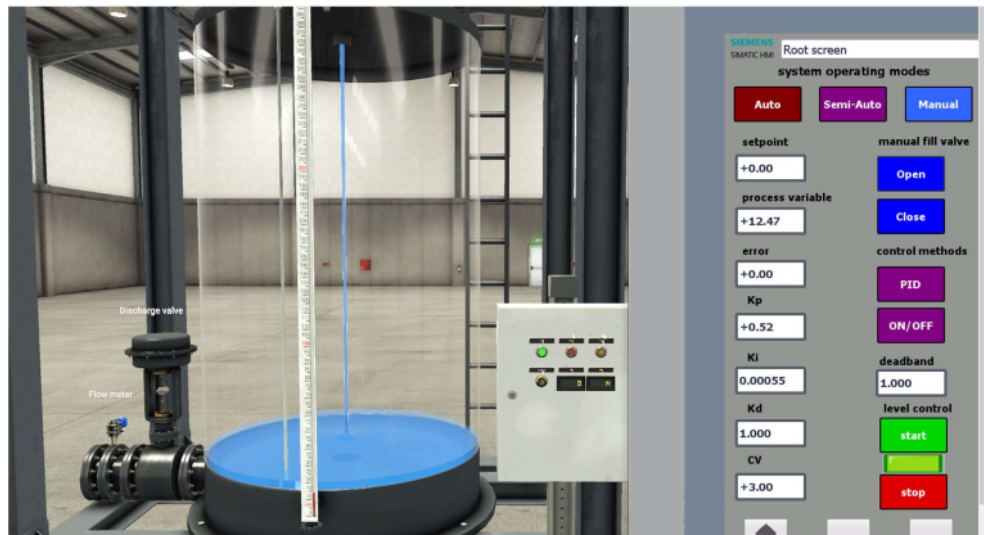


Figure 8

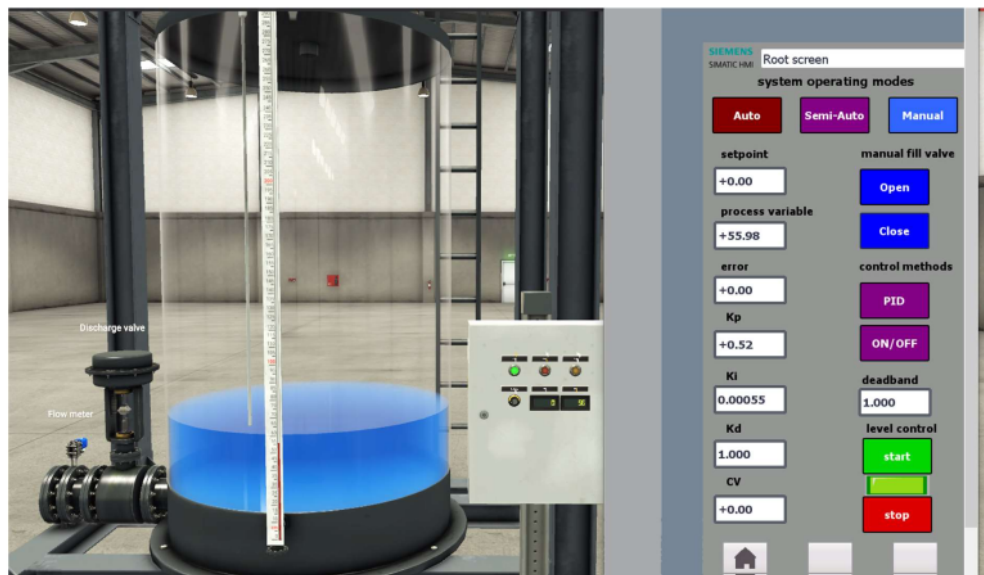


Figure 9



Figure 10



Figure 11

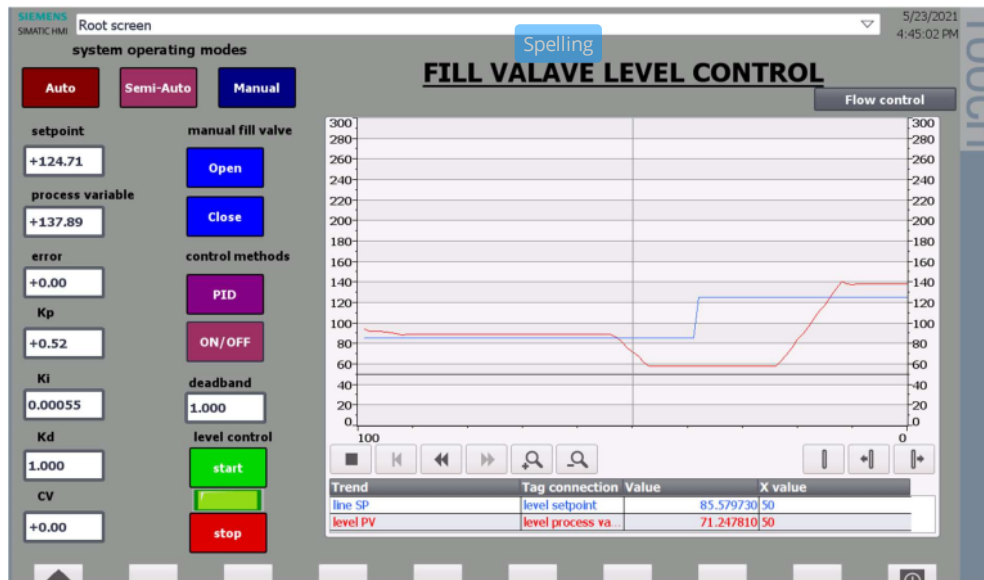


Figure 12

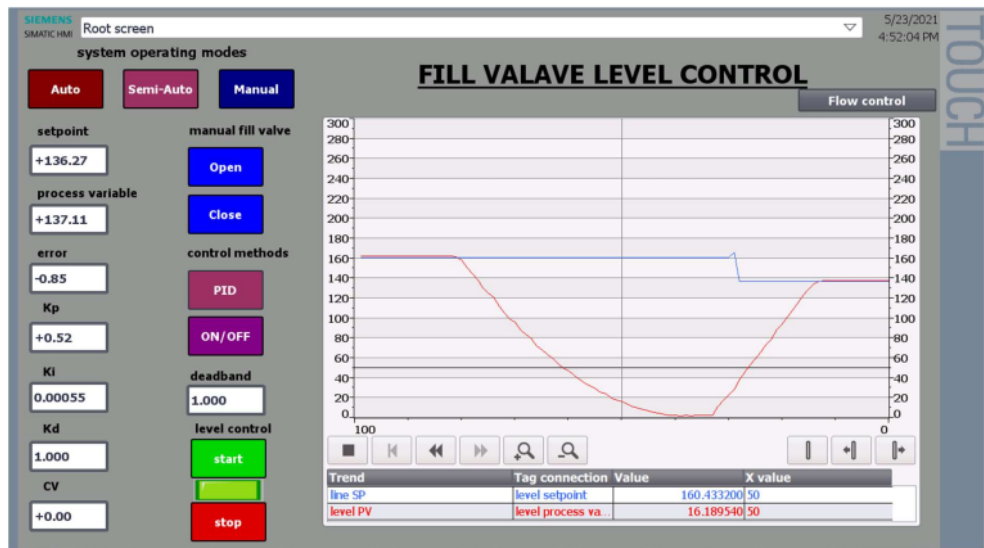


Figure 13

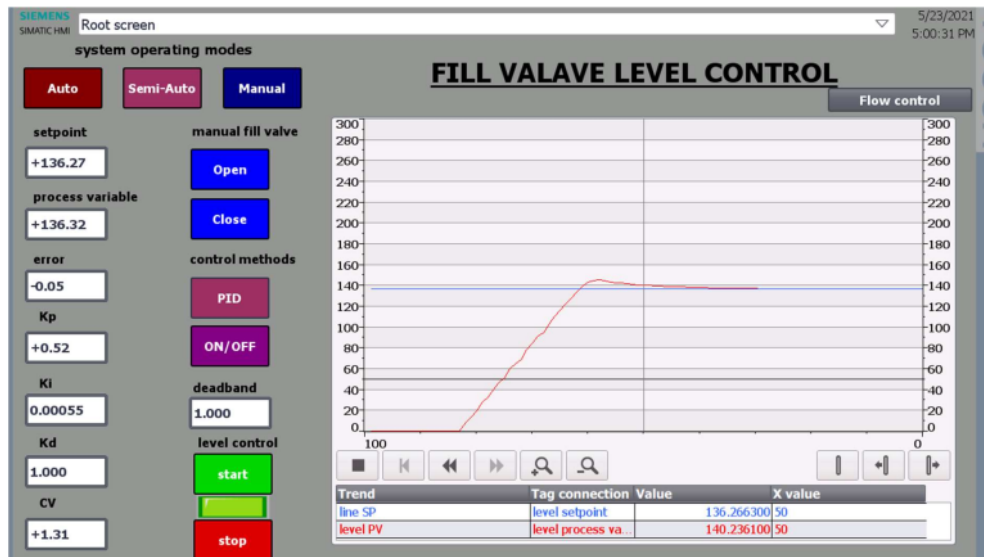


Figure 14

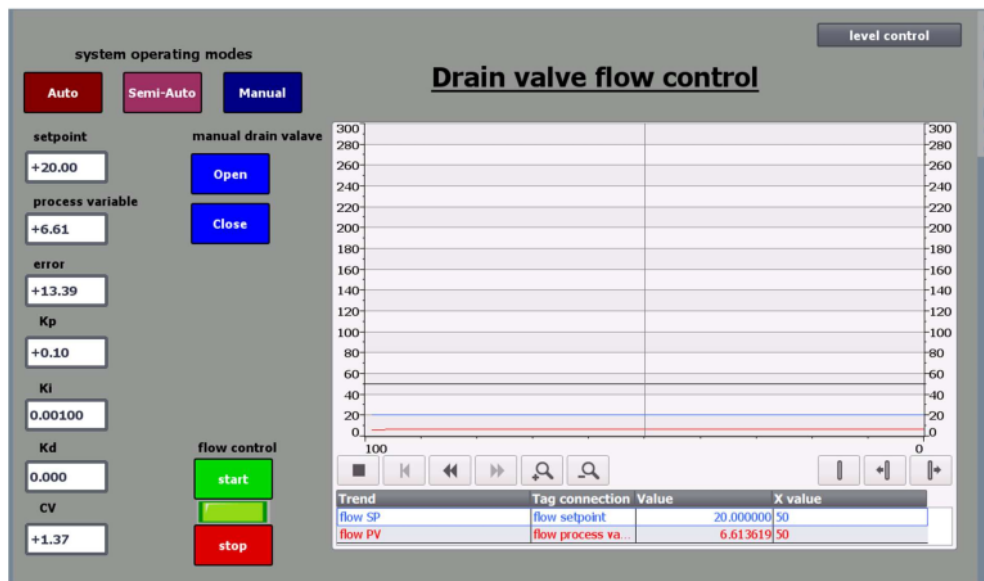


Figure 15

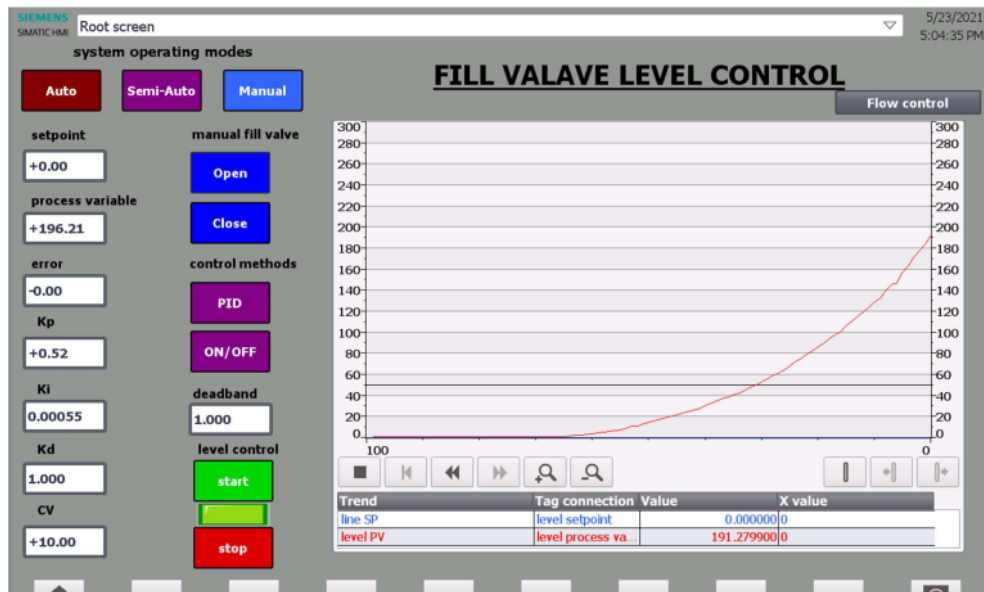


Figure 16

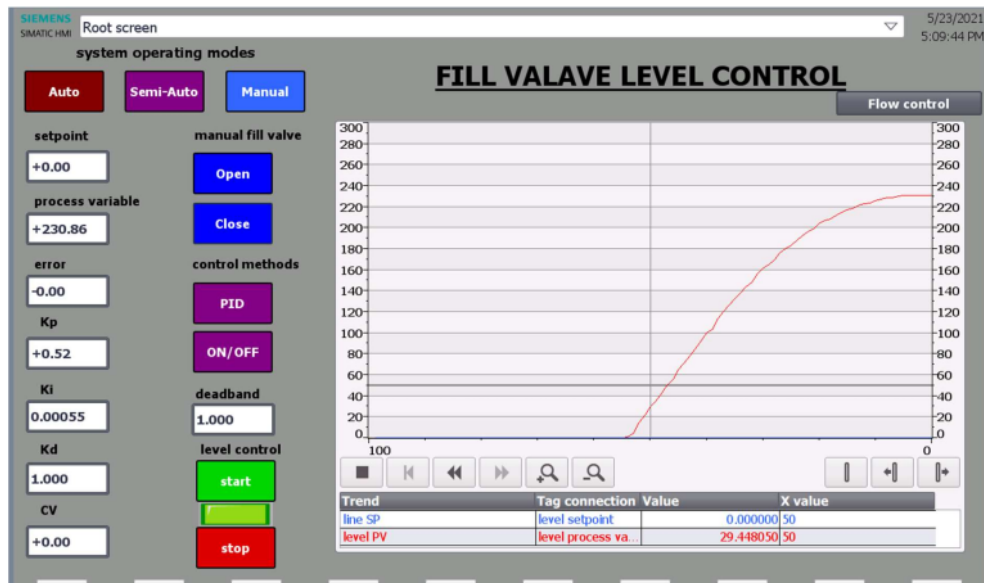


Figure 17

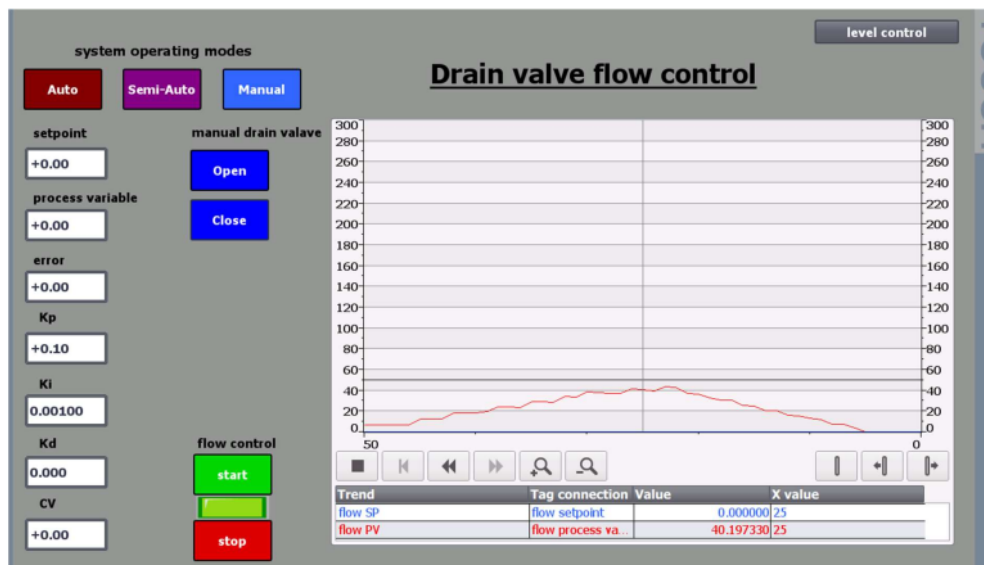
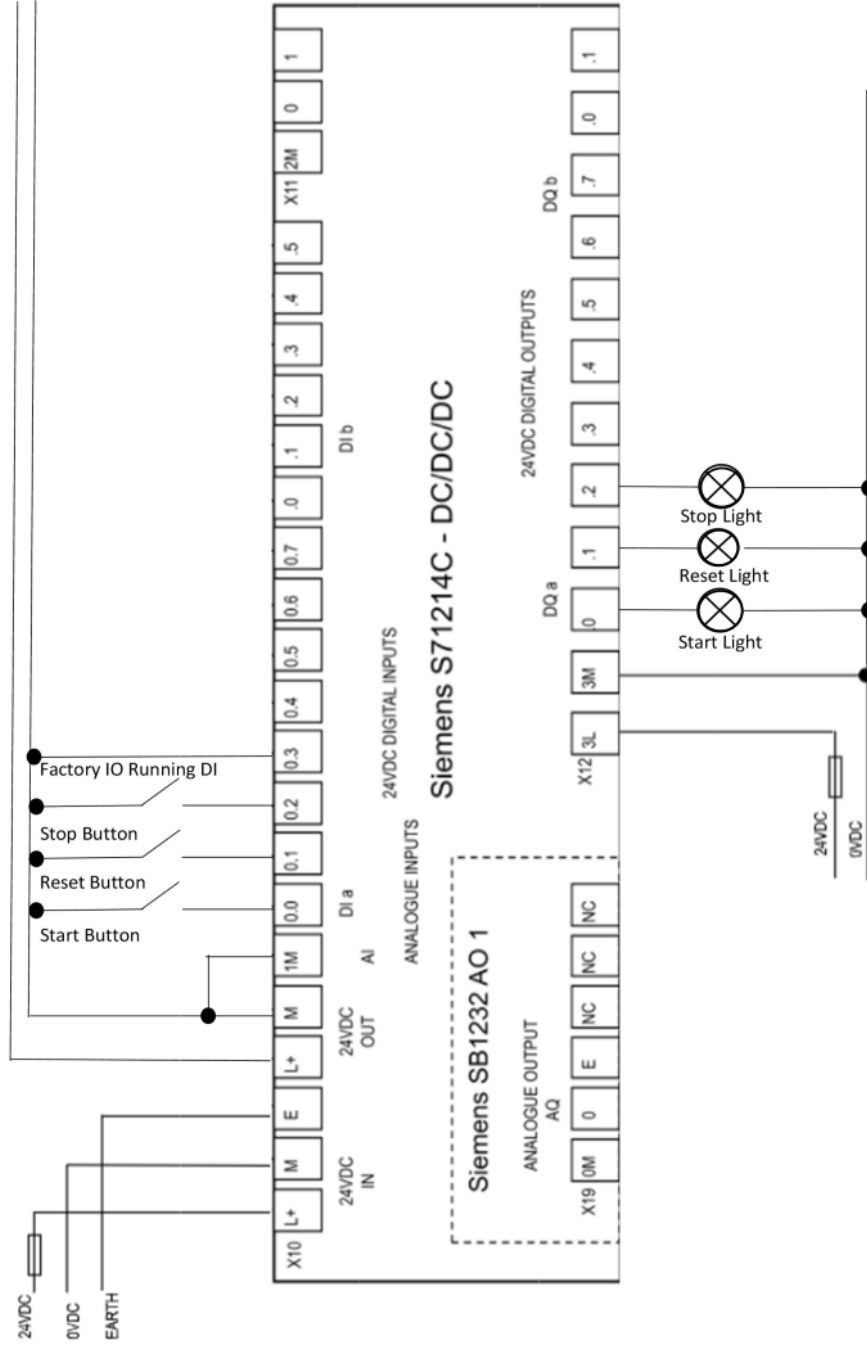
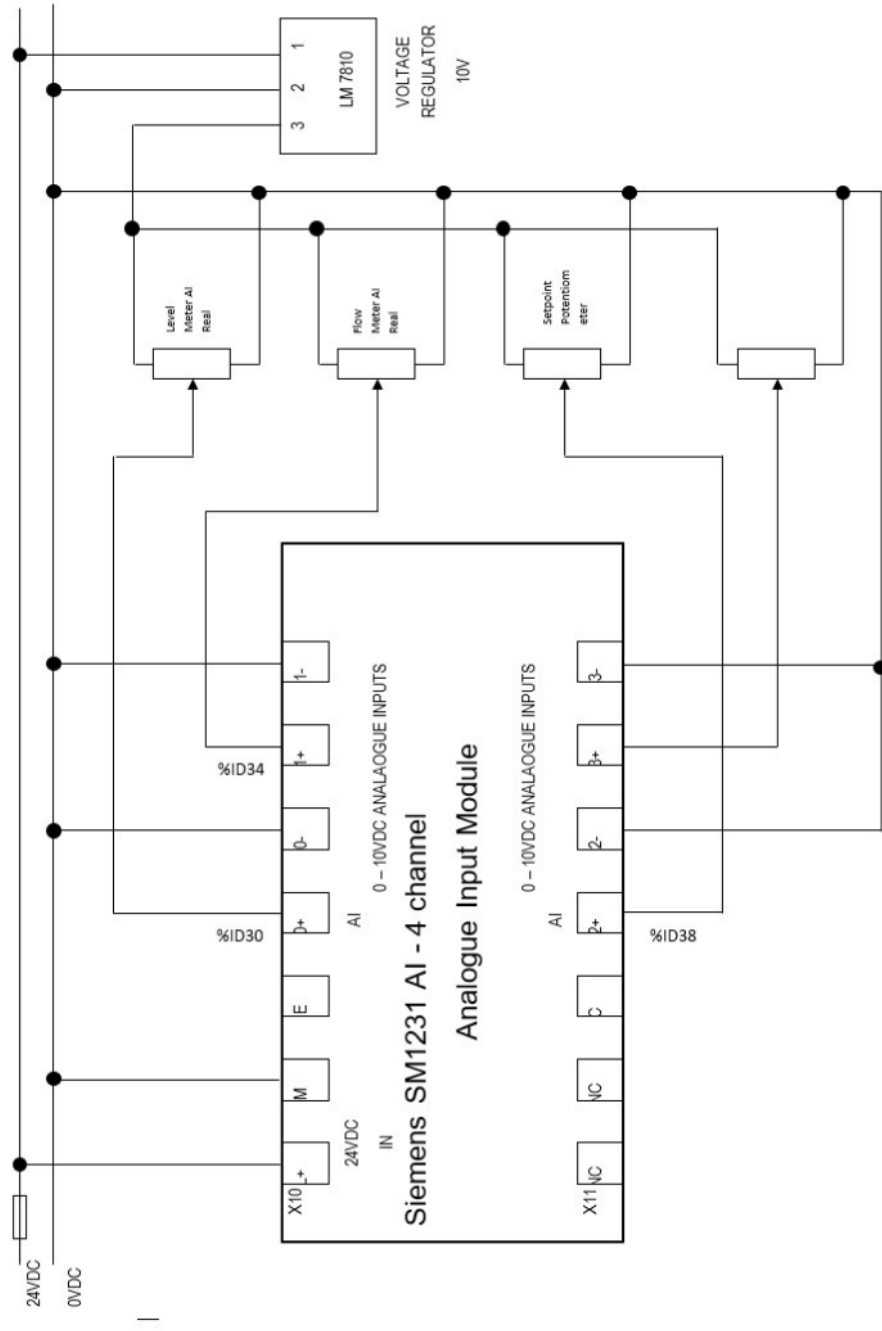


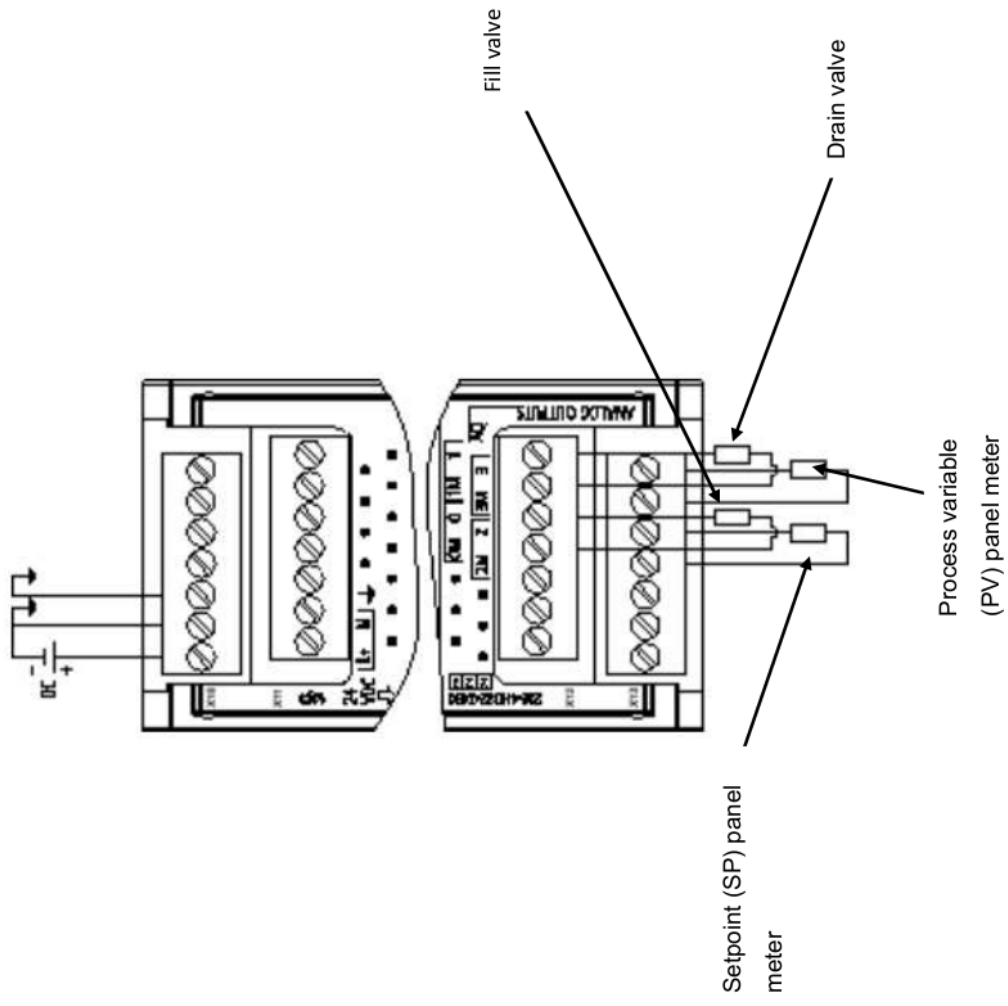
Figure 18

Hardware design electrical drawings





the analogue output drawing should look much like the input module



FINAL GRADE

GENERAL COMMENTS

Instructor

72/100

PAGE 1

PAGE 2

QM

Good Structure

Report is structured exactly as stated in the assignment brief.

PAGE 3

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 4

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

Text Comment. what about full auto mode?

Text Comment. you have forgotten about auto mode

QM

Good range of sources

You have demonstrated reading from a good range of sources shown by your list below

QM

Correct method of listing.

You have listed your sources correctly according to the Harvard method.



Spelling

Spelling error

Text Comment. the analogue output drawing should look much like the input module

GRADING FORM: NEW CSG-RUBRIC

ETHAN RIGBY

72

1. ENGAGEMENT WITH LITERATURE



Engagement with a wide range of literature, including sources retrieved independently. Selection of relevant and credible sources. Generally sound referencing, with no/very few inaccuracies or inconsistencies. (13/20)

13

2. KNOWLEDGE AND UNDERSTANDING



Excellent knowledge and understanding of the basic underlying concepts and principles of the subject. (15/20)

15

3. COGNITIVE AND INTELLECTUAL



Excellent evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data accurately and with some insight. Excellent ability to devise arguments using evidence and make appropriate and valid judgements. (16/20)

16

4. PRACTICAL APPLICATION



An advanced application of a range of taught, basic methods, materials, tools and/or techniques. The context of the application is well considered, and insightful. Excellent evidence of different approaches to problem-solving in particular contexts and proposes appropriate solutions. (14/20)

14

5. TRANSFERABLE SKILLS



Work is coherent, very fluent and is presented professionally. Can work effectively independently and/or as part of a team, with an excellent contribution to group activities. Demonstrates excellent skills for employment requiring the exercise of some personal responsibility with an appetite for further development (14/20)