

# Simon Yau

*by* Simon Yau

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## System Investigation

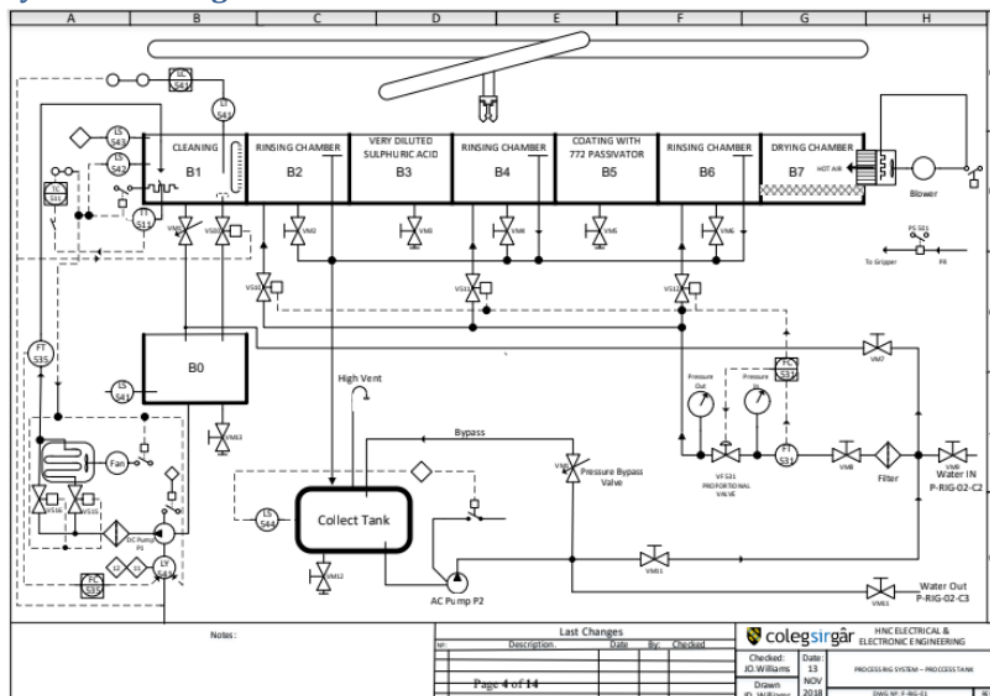


Figure 1 - P+ID Diagram of a Process Station

The P+ID diagram above is of a process station, it consist of process loops and instruments which will be investigated. By understanding what is in the P+ID diagram, a further understanding of the process station will be achieved.

While analysing figure 1, the instrument which can be identified are a pressure gauge, flow control sensor, level sensor and the flow sensor. Each of the sensors can be identified as;

TC535, flow control, water going into tank B1

TC511, temperature control, monitoring the temperature of B1

TC541, level control, monitoring the level of tank B1

TC531, flow control, water entering the tanks

The system purpose is to regulate the clean water level in tank B1 by monitoring the level and then controlling it accordingly by re-circulating it through the system to ensure that over flow does not occur. LC541 is the level controller which it receives input from the level transmitter of LT541, if the level is passed its value and then it is drained into tank B0 by a solenoid. TC511 regulates the temperature of tank B1 which is fed into an SSR by pulse width module controlling the heater, which is how it is able to control the temperature. If the temperature gets too hot, the solenoid V516 and

515 will activate, re-directing the flow of water into a radiator where a fan will be on, cooling the water as it flows through. Water flowing into the tanks is controlled by FC531 which controls the proportional valve VF531 and the solenoid V510, V511 and V512.



Figure 2 - Pressure Sensor

This is a Druck LPM5380, it has a range of up to 5 bars with an accuracy of  $\pm 0.04\%$  during full scale. (Druck, 2020) [Correctly cited](#)



Figure 3 - Pressure Transmitter

Endress + Hauser Cerabar PMC133 has a range of 0 – 40 mbar which operates between 12.5 and 20v DC and 4-20mA. While in full flow the sensor has an accuracy of 0.05% and at full scale it has a hysteresis of about 0.01%. (kit, 2020) [Correctly cited](#)

## Research

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Industry 4.0 is about having the ability to gather as much data from a sensor, even if it's about water flow, the temperature can be monitored, flow rate, volume of flow etc. To be able to gather a lot of data is an advantage when diagnosing faults or just fine tuning.



Figure 4 - ifm electronic Pressure Sensor

Replacing the pressures sensor will be the ifm electronic pressure sensor PN7592. It's able to measure pressure up to 100 bar, has an output type of PNP, NPN-NO/NC. The sensor is interchangeable between fluid and gas. Temperature range is -25-85°C and has an accuracy rating of  $\pm 0.5\%$ . (ifm, 2020)

Correctly cited

This is an inductive water flow sensor, it's only able to measure liquid between 0.2 L/min up to 50 L/min with a maximum pressure of 16 bar. It's able to take in liquids between -20-80°C and is capable of operating between -10-60°C. (RS, 2020)

Correctly cited



Figure 5 - ifm electronic SM Series Magnetic-Inductive Flow Meter

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## **Environmental, Sustainable Development, Commercial Risk and Codes of Practice**

Having the ability to contribute to the environment and social imperative so that it is enjoyed by the world today and for future generations, they are able to capitalise on the progress and also benefit from it. Being sustainable should not impact on future generation and should not undermine the possibility. (IET, 2020) Correctly cited

There are also important step which leaders of the industry have taken to ensure a sustainable plant.

1. Vision Creation – To be able to make changes to the company's operation, to communicate the ambition and necessities of driving down the negative aspect of the industry such as preventing harmful emissions.
2. Early Success Through Early Pilots – Having the green light to be able to undergo the project. Small modest improvements are the key to sustainability as it shows determination and belief and that the changes are essential.
3. Passion to Lead – To communicate openly with others is a significant factor to success. Having a collective vision, engaging with others and support from others will ensure an early success.
4. Building Momentum – Having those early gains will help drive the project forward as it will show the development and growth of new ideas. With these growths, the company can look for outside suppliers for help knowing that the project is gaining momentum and suppliers will want to contribute.
5. Keep it Simple – By keeping it simple, the leaders are able to justify the approach and maintain the development. The challenge won't be easy but maintaining a straight forward approach and setting out the principles, improvements are sure to come.
6. Educating and Training – Bringing more people onto the project will help educate them and further train them which will then lead to them leading their own team. The more the company can branch out the more modest gains can be achieved driving the project even further.
7. Go Public – Showing the public the projects and the benefits it has with sustainability, there will surely be support from other companies that may have valuable information to help with the project. The public will see the benefit of the company and would want to work there. By going public, this keeps an open communication with the world that sustainability is achievable and is driving forward.

(IET, 2020) Correctly cited

## Calibration of Pressure Sensor

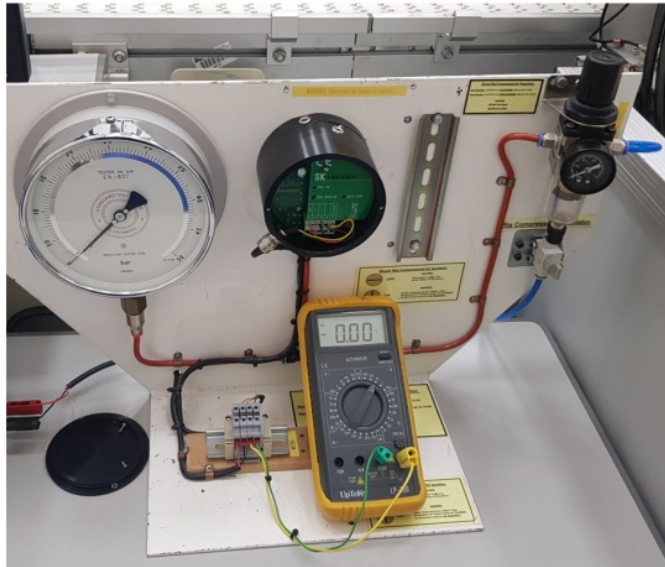


Figure 6 - Calibration of Pressure Sensor

The set up consist of a pressure sensor which read the air pressure in analogue and is then relayed to the pressure transmitter which will then allow the multi-meter to read the voltage of the pressure. When the pressure is at full bar or 5 bars, the voltage should read 10 volts. If it is not then adjustments will be made on the pressure transmitter to meet the desired value i.e. 10v. By changing the pressure from 0 to 5 bars, the pressure transmitter can be calibrated and a reliable signal is sent.

Once the calibration was completed, it was time to test it to ensure the accuracy of the calibration. Below is the table of results of the calibration.

| Pressure (bar) | Rising (V) | Falling (V) | linear Voltage | Non linear rising (V) | Non linear falling (V) | Hysteresis (%) |
|----------------|------------|-------------|----------------|-----------------------|------------------------|----------------|
| 0              | 0          | 0           | 0              | 0                     | 0                      | 0              |
| 0.5            | 1.05       | 1.05        | 1              | 0.05                  | 0.05                   | 0              |
| 1              | 2.05       | 2.02        | 2              | 0.05                  | 0.02                   | 0.03           |
| 1.5            | 3.03       | 3.02        | 3              | 0.03                  | 0.02                   | 0.01           |
| 2              | 4.02       | 4.03        | 4              | 0.02                  | 0.03                   | -0.01          |
| 2.5            | 5.02       | 5.04        | 5              | 0.02                  | 0.04                   | -0.02          |
| 3              | 6.01       | 6.03        | 6              | 0.01                  | 0.03                   | -0.02          |
| 3.5            | 7.03       | 7.04        | 7              | 0.03                  | 0.04                   | -0.01          |
| 4              | 8          | 8.04        | 8              | 0                     | 0.04                   | -0.04          |
| 4.5            | 9.06       | 9.04        | 9              | 0.06                  | 0.04                   | 0.02           |
| 5              | 10.1       | 10.05       | 10             | 0.1                   | 0.05                   | 0.05           |

Figure 7 - Calibration of Pressure Sensor Result

The hysteresis fell within the tolerance although not consistent; they still fall within the actual value.

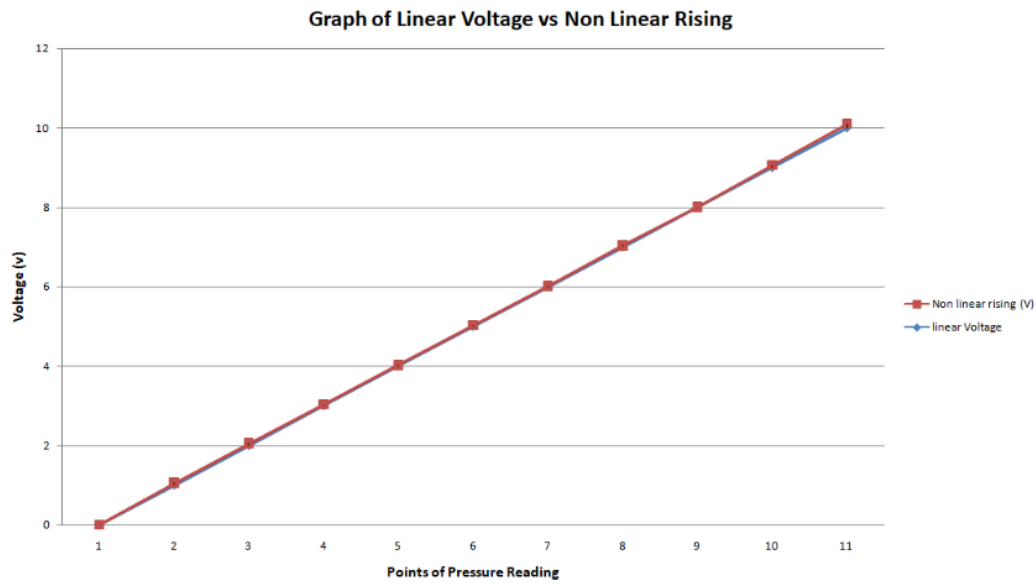


Figure 8 - Graph of Linear Voltage vs Non Linear Rising

Figure 8 compares the non linear voltage rising with the linear voltage. Linear voltage is barely visible as the non linear voltage rising is overlapped on the graph with traces of linear voltage around the 10 volt mark.

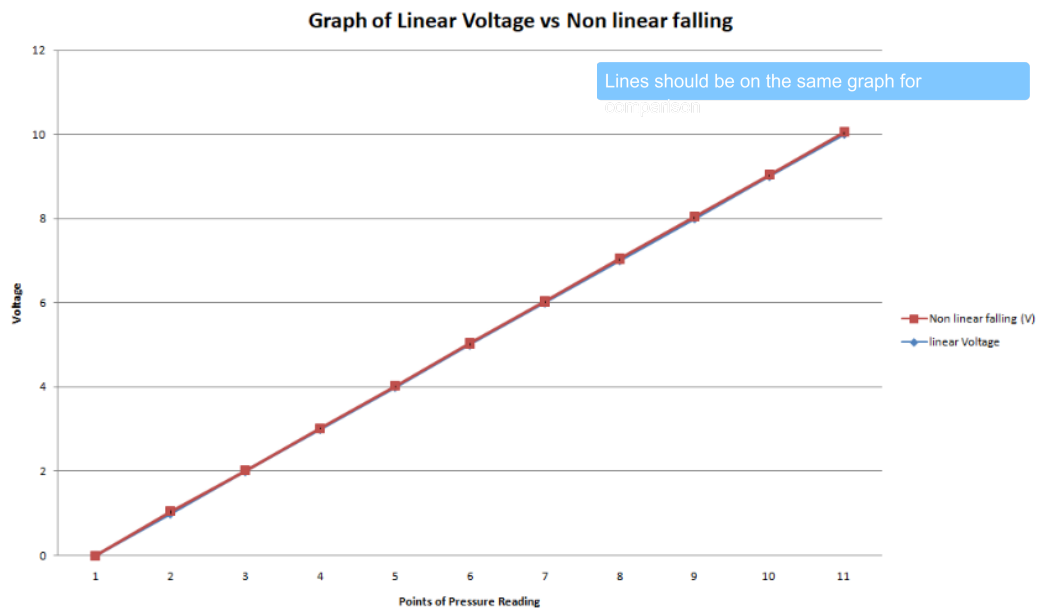


Figure 9 - Graph of Linear Voltage vs Non Linear Falling

## Calibration of Temperature Sensor

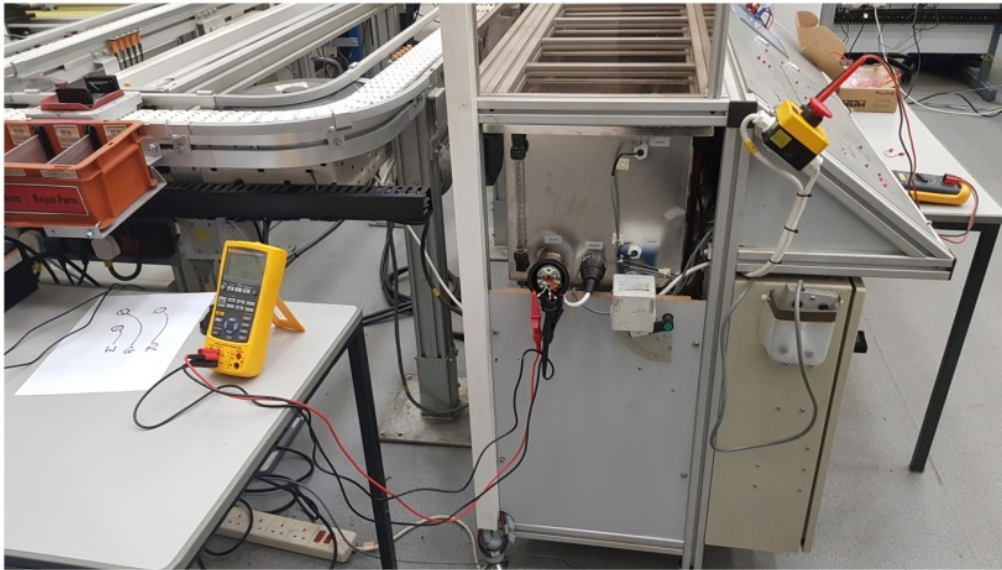


Figure 10 - Set up of calibrating temperature

Calibrating the temperature source required a fluke reader which was connected to the temperature control and the current output was measured with a multi-meter in mA. The temperature was set to 0°C and then incrementally increased by 10°C up to 100°C and then back down to 0°C.

| Temp | Rising mA | Falling mA | Linear | Rising Error | Falling Error | Hysteresis |
|------|-----------|------------|--------|--------------|---------------|------------|
| 0    | 4         | 4          | 4      | 0            | 0             | 0          |
| 10   | 5.6       | 5.6        | 5.6    | 0            | 0             | 0          |
| 20   | 7.2       | 7.2        | 7.2    | 0            | 0             | 0          |
| 30   | 8.8       | 8.8        | 8.8    | 0            | 0             | 0          |
| 40   | 10.4      | 10.4       | 10.4   | 0            | 0             | 0          |
| 50   | 12        | 12         | 12     | 0            | 0             | 0          |
| 60   | 13.6      | 13.6       | 13.6   | 0            | 0             | 0          |
| 70   | 15.2      | 15.2       | 15.2   | 0            | 0             | 0          |
| 80   | 16.8      | 16.8       | 16.8   | 0            | 0             | 0          |
| 90   | 18.4      | 18.4       | 18.4   | 0            | 0             | 0          |
| 100  | 20        | 20         | 20     | 0            | 0             | 0          |

Figure 11 - Temperature Calibration Result

Figure 11 shows the table of result of temperature calibration. There was no margin of error which means the temperature control was reading the temperature of the water very accurately.

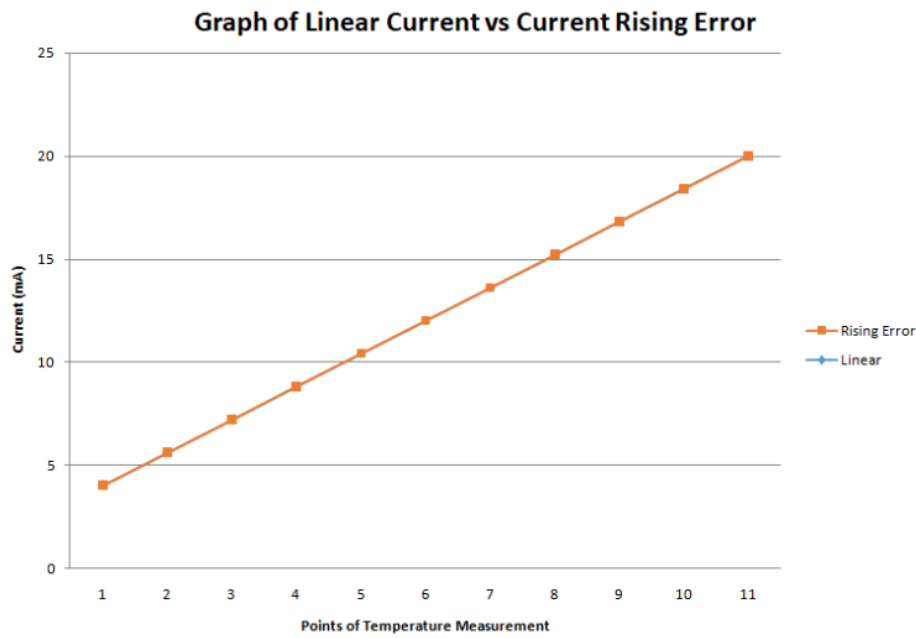


Figure 12 - Graph of Linear Current vs Current Rising Error

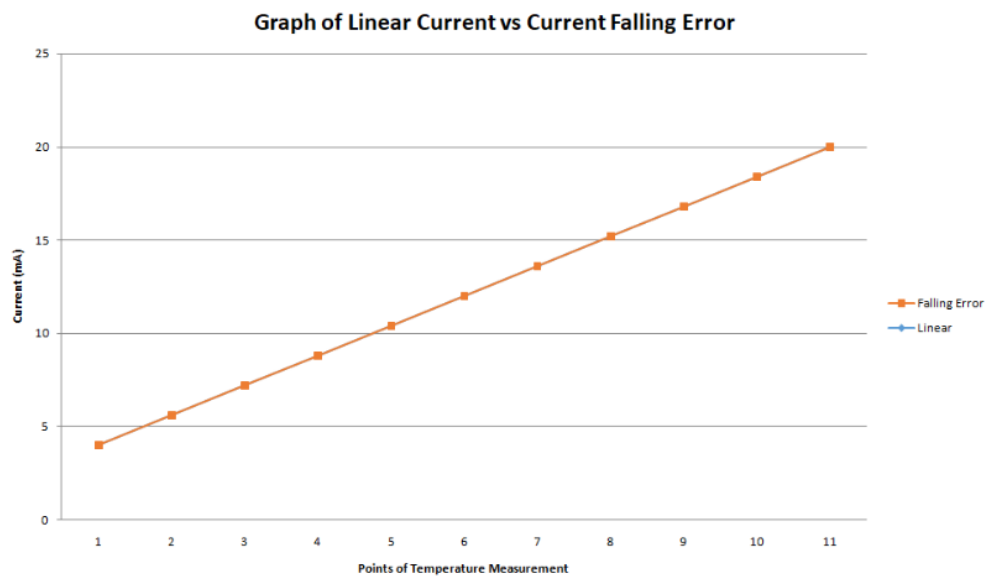


Figure 13 - Graph of Linear Current vs Current Falling Error

Because the margin of error was 0, there was no deviation on both of the graph suggesting that the temperature controller is monitoring the temperature correctly with no margin of error and does not require calibration.

### Calibration of Level Sensor

The level sensor is done by filling up the level meter up to 23cm and then releasing the water to 7cm and then readings are measured in increment of 1cm. The current is then measured by plugging the multi-meter to the process control connected to the level sensor and then reading the current in mA.



Figure 14 - Level Measurement

The linear current is then calculated by using,  $y=mx+c$ , this will then give the margin of error when the water level is falling and rising.

$$m = \frac{\text{Current at 23cm} - \text{current at 7cm}}{23\text{cm} - 7\text{cm}}$$

$$m = \frac{12.6 - 6.2}{23 - 7} = 0.4$$

$$c = y - mx$$

$$c = 12.6 - 23 * 0.4 = 3.4$$

$$y = 0.4x + 3.4$$

| Level (cm) | Rising Current (mA) | Falling Current (mA) | Linear | Rising Current Error | Falling Current Error | Hysteresis |
|------------|---------------------|----------------------|--------|----------------------|-----------------------|------------|
| 23         | 12.6                | 12.6                 | 12.6   | 0                    | 0                     | 0          |
| 22         | 12.2                | 12.1                 | 12.2   | 0                    | -0.1                  | 0.1        |
| 21         | 11.9                | 11.7                 | 11.8   | 0.1                  | -0.1                  | 0.2        |
| 20         | 11.4                | 11.4                 | 11.4   | 0                    | 0                     | 0          |
| 19         | 11                  | 10.9                 | 11     | 0                    | -0.1                  | 0.1        |
| 18         | 10.7                | 10.6                 | 10.6   | 0.1                  | 0                     | 0.1        |
| 17         | 10.3                | 10.2                 | 10.2   | 0.1                  | 0                     | 0.1        |
| 16         | 9.9                 | 9.8                  | 9.8    | 0.1                  | 0                     | 0.1        |
| 15         | 9.5                 | 9.4                  | 9.4    | 0.1                  | 0                     | 0.1        |
| 14         | 9.1                 | 8.9                  | 9      | 0.1                  | -0.1                  | 0.2        |
| 13         | 8.6                 | 8.6                  | 8.6    | 0                    | 0                     | 0          |
| 12         | 8.3                 | 8.1                  | 8.2    | 0.1                  | -0.1                  | 0.2        |
| 11         | 7.5                 | 7.8                  | 7.8    | -0.3                 | 0                     | -0.3       |
| 10         | 7.4                 | 7.4                  | 7.4    | 0                    | 0                     | 0          |
| 9          | 7                   | 7                    | 7      | 0                    | 0                     | 0          |
| 8          | 6.6                 | 6.6                  | 6.6    | 0                    | 0                     | 0          |
| 7          | 6.2                 | 6.2                  | 6.2    | 0                    | 0                     | 0          |

Figure 15 - Table of Results of Water Level

Figure 15 shows little deviations while the water level changes. While the water level rises, the current is above the linear current which was worked out with the equation in page 9 with the exception at 11cm when the current was under the linear current by 0.3mA. While the water level was falling there were a few current dropping by 0.1mA. Looking at the rising and falling errors in figure 15, the measurement was pretty accurate with a lot of them having no errors.

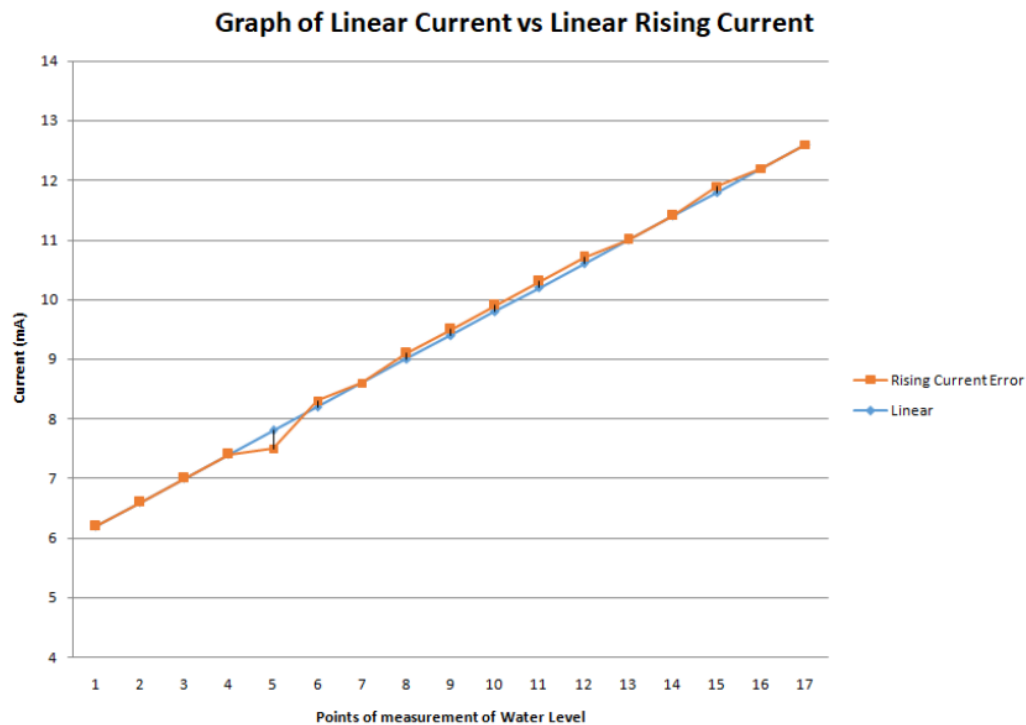


Figure 16 - Graph of Linear Current vs Linear Rising Current

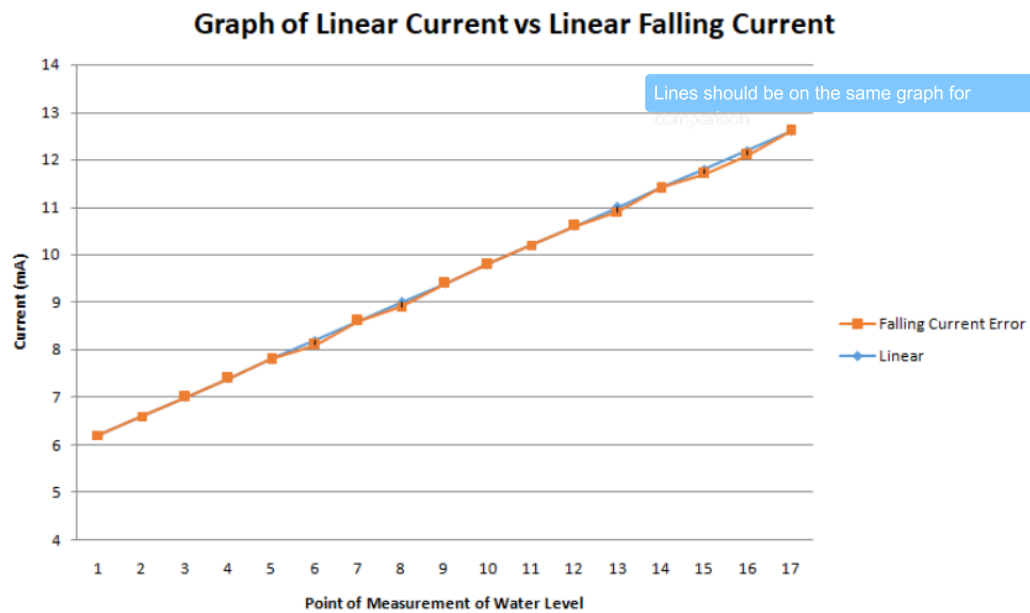


Figure 17 - Graph of Linear Current vs Linear Falling Current

Deviation of  $\pm 0.1\text{mA}$  can be seen on figure 16 and figure 17 with the exception of  $-0.3\text{mA}$  at 11cm when the water was rising. The trend shows the rising and falling current being consistent with the linear current.

### Calibration of Flow Sensor

Working out the volume of the tank is done by multiplying the width by length and then by height. This is then times by 1000 to convert into litres.

$$(0.098 * 0.14 * 0.138) * 1000 = 1.89 \text{ litres}$$

By starting the flow, water will start to flow filling up the tank, as it reaches the high level alarm, it will be tripped indicating that the flow has stopped and timing can stop. The time is in seconds so converting it to minutes is divided by 60 seconds. The total volume of the tank is then divided by the time it took giving litres per minute. This will give the calculated flow rate.

$$\text{Flow Rate} = \frac{\text{Volume of Tank (1.89 litre)}}{\text{Time it took (minutes)}}$$

The calculated flow rate is then compared to the measured flow rate as seen in figure 18.

|            |            | Flow Rate                  |                              |            |
|------------|------------|----------------------------|------------------------------|------------|
| Time (sec) | Time (min) | Measured Flow Rate (l/min) | Calculated Flow Rate (l/min) | Hysteresis |
| 171        | 2.85       | 0.6                        | 0.66                         | 0.06       |
| 118        | 1.97       | 1                          | 0.96                         | -0.04      |
| 87.6       | 1.46       | 1.4                        | 1.29                         | -0.11      |
| 68         | 1.13       | 1.8                        | 1.67                         | -0.13      |

Figure 18 - Flow Rate Converted to l/min

Compared together the result is similar but not as close to each other as the hysteresis suggest.

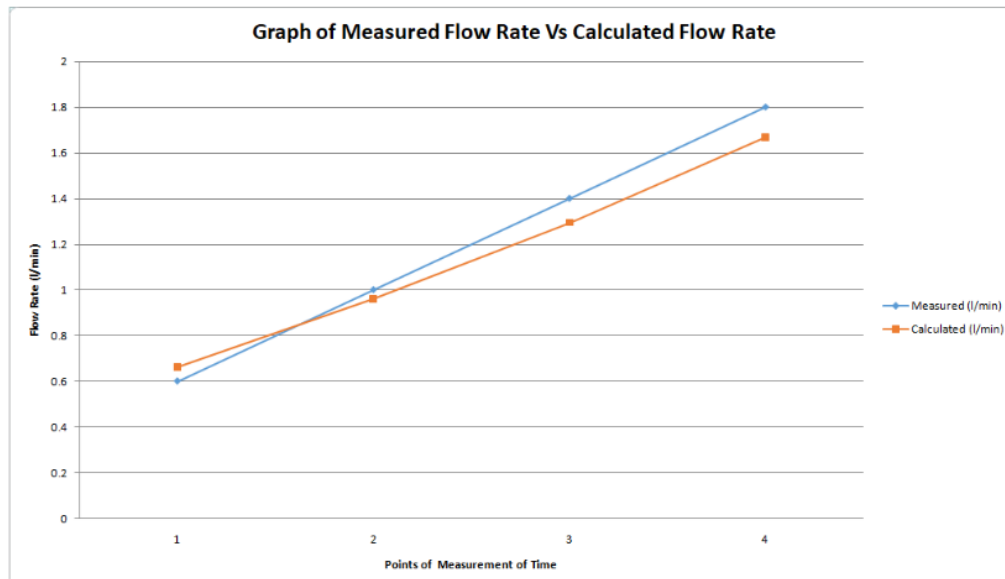


Figure 19 - Graph of Flow Rate

The graph shows the results to be similar but given enough dating point, the graph would show a wider gap which would suggest replacement is needed or further calibration is required.

### Design Adaptation for Maintenance and Reliability

The issue with the HMI screen is the accessibility of the buttons and the displays of the results so by having them in one screen they are easy viewed. Each screen will need the graph, the measurements value, the set points and the buttons i.e. start, stop and LED.

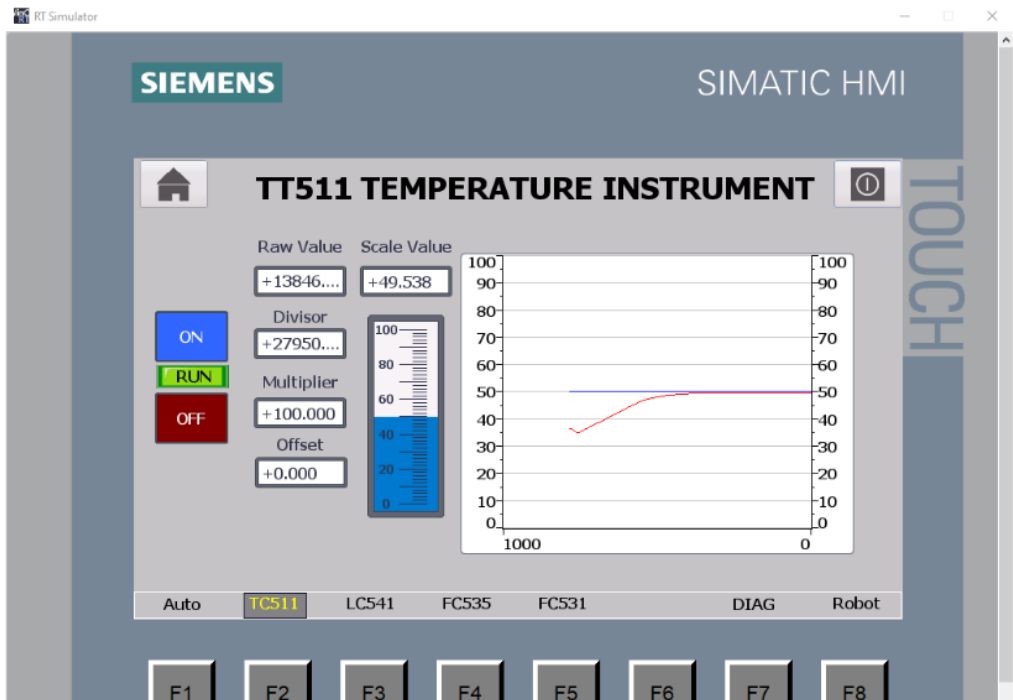


Figure 20 - HMI Screen of Temperature

The 'ON' button will be tagged with TC511 HMI Control start on the press and release, this will start the process.

Ohe 'OFF' button is then tagged with TC511 HMI Control Stop on the press and release, this will stop the process.

The LED is tagged with TC511 Control RUN and will indicate when the process is running.

The set points are then tagged with the analogue.

|                               |                   |      |                  |                             |                |
|-------------------------------|-------------------|------|------------------|-----------------------------|----------------|
| Analogue_TC511 SP             | Default tag table | Real | HMI_Connectio... | PLC 103 Process Station - 4 | Analogue.* ... |
| Analogue_TT511 Divisor        | Default tag table | Real | HMI_Connectio... | PLC 103 Process Station - 4 | Analogue.* ... |
| Analogue_TT511 Multiplier     | Default tag table | Real | HMI_Connectio... | PLC 103 Process Station - 4 | Analogue.* ... |
| Analogue_TT511 Offset         | Default tag table | Real | HMI_Connectio... | PLC 103 Process Station - 4 | Analogue.* ... |
| Analogue_TT511 Raw Temp...    | Default tag table | Real | HMI_Connectio... | PLC 103 Process Station - 4 | Analogue.* ... |
| Analogue_TT511 Scaled Temp... | Default tag table | Real | HMI_Connectio... | PLC 103 Process Station - 4 | Analogue.* ... |

Figure 21 - Analogue PLC Tags

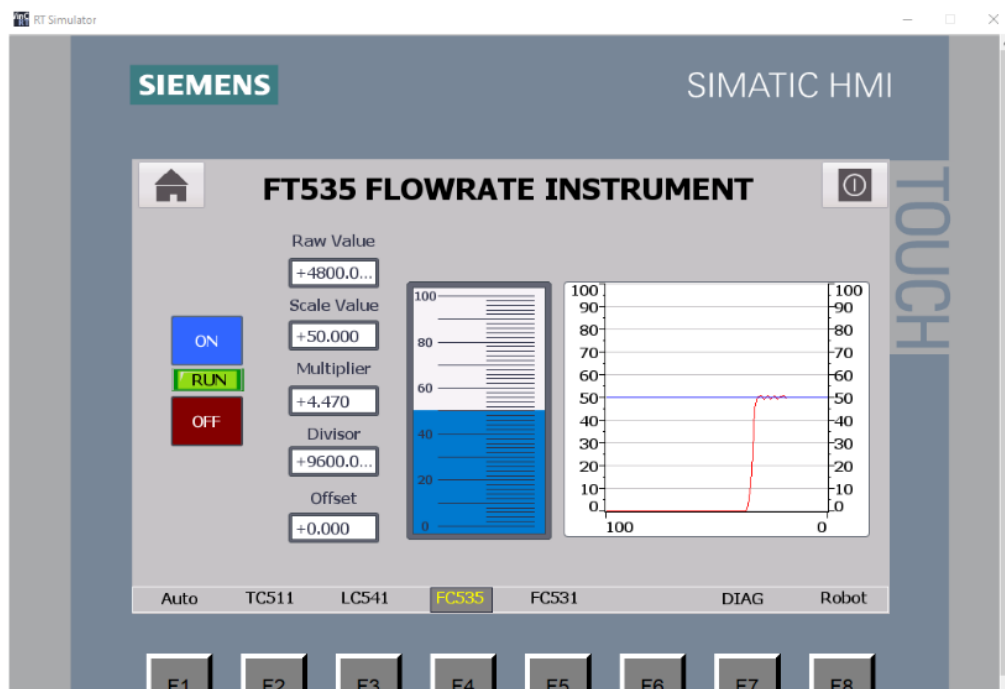


Figure 22 - HMI Screen of Flow Rate

The 'ON' button will be tagged with FC535 HMI Control start on the press and release, this will start the process.

The 'OFF' button is then tagged with FC535 HMI Control Stop on the press and release, this will stop the process.

The LED is tagged with FC535 Control RUN and will indicate when the process is running.

The set points are then tagged with the analogue.

|                                 |                   |      |                   |                             |               |
|---------------------------------|-------------------|------|-------------------|-----------------------------|---------------|
| Analogue_FT535 Divisor          | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_FT535 Multiplier       | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_FT535 Multiplier %     | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_FT535 Offset           | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_FT535 Offset %         | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_FT535 Raw Flowrate     | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_FT535 Scaled Flowra... | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_FT535 Scaled Flowra... | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |

Figure 23 - Analogue PLC Tag

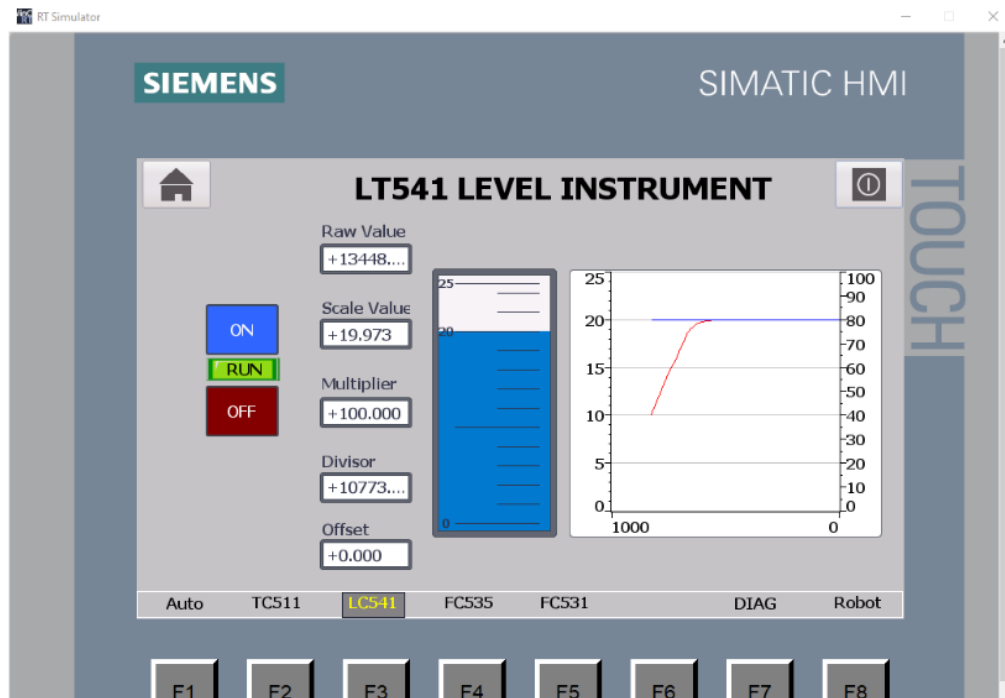


Figure 24 - HMI Screen of Level Control

The 'ON' button will be tagged with LC541 HMI Control start on the press and release, this will start the process.

The 'OFF' button is then tagged with LC541 HMI Control Stop on the press and release, this will stop the process.

The LED is tagged with LC541 Control RUN and will indicate when the process is running.

The set points are then tagged with the analogue.

|                               |                   |      |                   |                             |               |
|-------------------------------|-------------------|------|-------------------|-----------------------------|---------------|
| Analogue_LT541 Divisor        | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_LT541 Multiplier     | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_LT541 Offset         | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_LT541 Raw Level Real | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |
| Analogue_LT541 Scaled Level   | Default tag table | Real | HMI_Connection... | PLC 103 Process Station - 4 | Analogue.*... |

Figure 25 - Analogue PLC Tag

## **Conclusions and Recommendations**

As technology improves, the instruments will need less calibrating and maintenance performed on it. With level control, temperature and pressure, they were pretty spot on as they were correctly calibrated to a point where the hysteresis was close to each other. The flow rate was an issue as there was no reliable way of measuring it and the one practical result gathered was not similar. More data points would have made the results better but looking at figure 19, it would have shown that further calibration was needed or a better reliable test was needed.

The HMI screen was a huge improvement as it allowed the user to have everything they needed on one screen without having to switch back and forward. The start/stop to allow for the process to begin, the set points gave control of the equipment and graph readily on the same screen to view when the process is running. There was some issue with the PLC tagging when the buttons were moved to a different screen but the issue was quickly resolved by simply re-tagging them.

Having to work from home was an issue as it made group work difficult but communication was key to completing this assignment as the practical was done before Christmas and the HMI screen could be done with simulations and pairing with someone who had a working TIA portal.

### **Team Working**

Joshua Wyn Williams and Sean Parry was the group assigned for the practical measurement. We all contributed in calibrating, reading out results and logging down the data.

Working with Ashleigh Francis and Joshua Williams on the HMI screen, the author and Joshua had to rely on Ashleigh as he had TIA portal. The author and Joshua had inputs to the HMI screen and directed Ashleigh to placement such as the layout and tagging. Ashleigh then Ran the test and screenshot the results which he shared with us.

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Correct method of  
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[https://uk.rs-online.com/web/p/flow-sensors/7406424/?cm\\_mmc=UK-PLA-DS3A- -google- -CSS UK EN Automation %26 Control Gear Whoop- -Flow+Sensors Whoop- -7406424&matchtype=&pla-475992046070&gclid=CjwKCAiAjeSABhAPEiwAqfxURf8NaMyZRQfnTo-b1W0i5mZWVrN-euAuyBLJQR](https://uk.rs-online.com/web/p/flow-sensors/7406424/?cm_mmc=UK-PLA-DS3A_-google_-CSS UK EN Automation %26 Control Gear Whoop- -Flow+Sensors Whoop- -7406424&matchtype=&pla-475992046070&gclid=CjwKCAiAjeSABhAPEiwAqfxURf8NaMyZRQfnTo-b1W0i5mZWVrN-euAuyBLJQR) [29 Jan 2021].

FINAL GRADE

GENERAL COMMENTS

**Instructor**

**58**/100

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QM

### Good Structure

Report is structured exactly as stated in the assignment brief.

QM

### Sections should be numbered according to the brief

**Text Comment.** Some tasks are missing

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QM

### Correctly cited

Citation method conforms to Harvard standard, well done.

QM

### Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 6

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QM

### Sections should be numbered according to the brief

QM

### Correctly cited

Citation method conforms to Harvard standard, well done.



## Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 7

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## Sections should be numbered according to the brief



## Correctly cited

Citation method conforms to Harvard standard, well done.



## Correctly cited

Citation method conforms to Harvard standard, well done.

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## Lines should be on the same graph for comparison

Both lines should be on the same graph for comparison, this can be easily done by selecting both columns when inserting a graph from spreadsheet data.

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## Lines should be on the same graph for comparison

Both lines should be on the same graph for comparison, this can be easily done by selecting both columns when inserting a graph from spreadsheet data.

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QM

**Correct method of listing.**

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

GRADING FORM: NEW CSG-RUBRIC

**SIMON YAU****58****1. ENGAGEMENT WITH LITERATURE**

Engagement with an appropriate range of literature, including sources retrieved independently. Citation and listing method are correct. (11/20)

**11****2. KNOWLEDGE AND UNDERSTANDING**

Knowledge of the basic underlying concepts and principles is accurate with a good understanding of the field of study but lacks depth and/or breadth. (11/20)

**11****3. COGNITIVE AND INTELLECTUAL**



Sound evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data accurately. Ability to devise arguments using evidence to make mostly appropriate and valid judgements. (12/20)

**12**

#### **4. PRACTICAL APPLICATION**



A very good application of a range of basic methods, materials, tools and/or techniques. Very good consideration of the context of the application. Very good evidence of different approaches to problem-solving in particular contexts and proposes (12/20)

**12**

#### **5. TRANSFERABLE SKILLS**



Work is accurate, coherent, fluent, well-structured and organised. Can work effectively independently and/or as part of a team, with very good contribution to group activities. Demonstrates very good skills for employment requiring the exercise of some personal responsibility, with just occasional minor weaknesses (12/20)

**12**