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by Daniel Oulton

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Name: Daniel Oulton
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Well structured and presented report Good evidence of reading from a range of sources correctly cited and listed. Good evidence of testing of instruments but no evidence to support testing of design adaptations. Format is incorrect, should be 1.5 lines spacing.

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Executive summary *Not required in the brief*

This report will cover a hardware investigation into a specific CIM system, with descriptions of how each control loop functions to achieve the desired process. An investigation into the sensors used and their data sheets to see what accuracy and static sensitivity, each of these sensors will be investigated to see if there are industry 4.0 compatible sensors that can be used to replace them. The process of calibrating different sensors will be discussed along with their results and a discussion on how they performed. Improvements to the systems HMI screens are discussed to explain why changes have been made and how these changes have improved the systems.

Summaries should be written in the past tense.

Task 1 – System Investigation

Control Loops

The P&ID drawing for the CIM system shows the following control loops for the system:

TC11 – Temperature control in tank B1

TC31 – Flow control into each of the tanks

TC35 – Flow control into tank B1

TC41 – Level control to tank B1

Substation 1 – Process station

brief asks for 1.5 line spacing

The water level in the tank is controlled by two limit switches, LS543 and LS542, these ensure that the water level remains in the correct range for the system. LS542 the low-level switch interlocks with the heating element stopping it from activating if it has not been met. LS543 the high-level switch signals to the pump to switch off indicating the tank is full. LT541 is in control of the drain valve V500 to tank B0, LS542 also communicates with LY541 to control the water flow.

The heating previously mentioned is controlled by control loop TC511. This is interlocked to the low-level switch so it won't turn on until that is met. The temperature is monitored by TT511 for the temperature changes made through the addition and loss of water from V515/V516 and V500 respectively.

FC531 and FC535 both control the flow of water. FC535 controls the flow of water into tank B1 using the flow transmitter FT535 which signals to FC535 that sends a CV to pump amplifier LY541. FC531 controls the flow of water into the rest of the tanks. The flow is controlled by FC531 and FT531 which trigger VF531 to control the flow to solenoid valves V510, V511, and V512.

Substation 2 – Water recirculation

This substation supplies the recirculated water back into the system for reuse. Both the top and bottom tank have level transmitters, when the set level for these is reached the top tank will release water into the bottom tank, when the bottom level transmitter is met the DC pump will pump water into the top tank.

Sensors technical data

the ranges are not correct!

Sensor type	Sensor model	Range	Static sensitivity	Resolution
Temperature Sensor	PT100 RTD	-20°C - +100°C	0.05 mA per °C	0.02
Level sensor	Endress and Hauser PMC133	400 Bar	25mA per bar	0.5
Flow sensor	RS PRO Radial Flow Turbine Flow Meter	0.25 – 6.5 L/Min	0.04 mV per L	+/-0.25
Pressure sensor	GE Druck LPM5380	0-5 Bar	2V per bar	+/-0.25

The source used for the data presented in this table are, (Radionics Ltd, 2022), (Endress & Hauser, 2018), (GE Sensing, 2006), (Radionics Ltd, 2022).

The equations used to calculate the values were Static Sensitivity = $\frac{\text{output range of sensor}}{\text{input range of measured}}$ and
 Resolution = $\frac{\text{accuracy}}{100} \times \text{input}$

Task 2 – Research

Industry 4.0 is the collective working power of a workforce (people), the machines, and systems/software. This modernisation of process or industry 4.0 has been called the 4th industrial revolution, the next step in advancements to the industrial world. (Schume, 2020)

The IOT or internet of things is a big part of the smart sensor development and step towards smarter systems in industries, the principle of the IoT is to have everything interconnected from small things like sensors to the larger systems. Each of these would gather and distribute the data they are receiving as it is coming in allowing for faster and better data gathering. It can be seen with the industry 4.0 model of having “smart sensors” that the IoT of things is a big part of this push for interconnectivity throughout the workplace. (Dr. Kamlesh Lakhwani, 2020)

Each industrial revolution from the 1st to the ongoing 4th has been a process of removing some load from the human worker to increase productivity and output. The first industrial revolution was the change from hunter gathering to using farming techniques which included domesticating animals and using them for production and transportation, this then became the use of mechanics and machines to transfer away from muscle power. The 2nd was advancements made to the manufacturing process through the use of electricity and creation of the assembly line, this allowed for the advent of mass production. The 3rd was the beginning of automation in industry bringing computing, IT systems and robotics into the process. (Sudip Misra, 2021) The 4th is currently being undergone, and is the idea of “smart factories” (Miragliotta, 2014)

The processes factories used to use were isolated, each sensor performed their function and things ran. Industry 4.0 is the integration of smarter sensors that gather data and send it out to be analysed, this allows entire factories of data to be looked at to see what's happening and where. This makes the big improvement through industry 4.0 to be the collection of data from each sensor to send back to the PLC to make real time changes that effect the performance of the systems.

Both the low level and high level sensors in the level substation could be replaced with a sensor that is up to industry 4.0 standards. A sensor that could achieve this level measurement is the Vegapuls WL 61 Shown in figure 10. This sensor uses microwaves to detect the level and upon reading the technical specifications can also be used to measure flow. (Vega, 2018) Making this switch would also reduce the number of I/O used in the PLC and save on cables runs.

The temperature control sensor could be changed out with the Danfoss MBT 3560 sensor shown in Figure 11, this sensor is able to measure a wider range of temperature than the current sensor.

The flow sensor can be replaced with the Turck FS+ shown in figure 12.

Each of these sensors would push the CIM system towards the future of industry 4.0 standards as they each have the potential to have I/O links given them the ability for efficient remote monitoring with their parameters able to be and giving notifications when there are faults in the system. A good change that these new sensors present is that their parameters and calibration can be changed remotely cutting the time needed as the values recorded can be seen remotely and then the changes can be made at the same time.

you could have looked at I-O link standard in more detail and selected versions to replace existing sensors.

Task 3 – Environmental, Sustainable Development, Commercial Risk and Codes of Practice

The two separate parts the system can be split into, tank B0/B1 and the rest of the tanks, are both somewhat self-sufficient. The water from tank B1 goes into tank B0 which then returns to tank B1 through the DC pump. Each of the other tanks drain into the collect tank before being recirculated and pumped back into the system. The reason its stated to be somewhat self sufficient is that some level of water will be lost through the drying chamber each time as the items will never have all of the water removed. The system will also need to be flushed of the water in it occasionally and replaced with new water, but the collection system in place will allow the water to be used many times over. This makes the system more environmentally friendly as it will not need to be constantly topped up with new water.

This system reusing its water for as long as possible is a good promotion and use of sustainable engineering. The design of this system would comply with UK-Spec which is the “The UK Standard for Professional Engineering Competence and Commitment” which all professional engineers within the UK must carry out their work in accordance to. (Engineering Council , 2020). In accordance with this all engineers should consider the impact of any project they pursue, this means they should strive to create a more sustainable world through the actions they take. Not only does this include any new designs it means looking at what can be reused or regenerated where possible, the impact on the local and wider environment is to be thought of at all times. (Engineering Council, 2020) The full breadth of the sustainability is to ensure that the best and most environmentally stable, processes are used to support future development. (The Engineering Council , 2020)

CE Marking is used in the EU and EEA which includes the countries in the EU and the European economic area. When purchasing any equipment in these countries it is important to check that they have this marking as it signifies that the product meets the EU standards. If you are the company producing these products then you must make sure through compliance testing that the product meets and satisfies the regulations and legislations necessary before you can print this on your product. (Department for Business, Energy & Industrial Statergy , 2020)

When installing new machines and calibrating sensors there are codes of practice that must be conformed to. The standard that should be conformed to in the UK is BS7671 which came into effect on the 31st of December 2018, this standard applies to electrical installations. Any work should be completed to this standard where possible, any systems that were in place do not need to be modified to meet the standard but if additional aspects are added on they should comply. (IET, 2018) ISO17025 is the international standard for the calibration of sensors, when sensors are to be tested they should be sure to be tested in locations that have their ISO17025 certification. (iso, iec, 2017). Another standard that should be worked towards is BS 6739 which covers the installation of control systems and covers measurement systems and sensors. (BSI, 2020)

Task 4 – Calibration of Pressure Sensor

The pressure sensor was tested *by connecting it* through connected to a compressed air source and taking measurements of the output voltage every half Bar when the pressure was rising and then again when it is falling. Before starting these measurements, the pressure was set to 0Bar and a small adjustment terminal on the sensor was adjusted until it was outputting 0V as the data sheet stated this should be the value at this pressure. Each of these voltage and pressure readings were then plotted to a graph that can be seen in figure 1. Table 1 can be seen for each of the readings taken. The sensor used on this is the GE Druck LPM5380.

Given the recorded and expected results for this sensor have come out similar and in the linear way expected it can be said that the calibration performed at the start was successful.

The highest hysteresis error recorded on this sensor was -0.06 Which registered twice.

%FSD ?

The highest non-linearity error was -0.04 on both the rising and falling.

Through looking at the graph and table you can see the accuracy of the results compared to the expected results, by the naked eye the difference between these lines is almost unnoticeable. The performance of the sensor is almost as good as the data sheet would suggest, the hysteresis and non-linearity errors are incredibly small, the performance of this sensor is good.

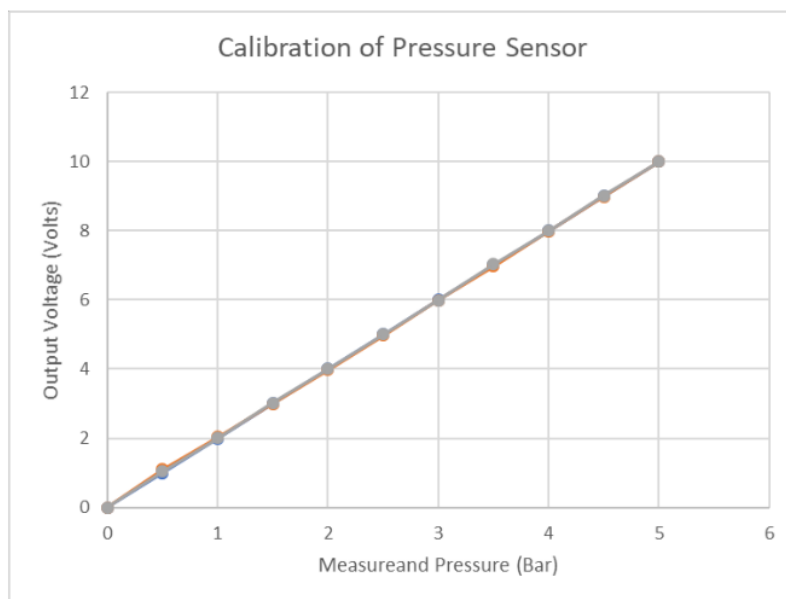


Figure 1: Pressure readings graph

Task 5 – Calibration of Temperature Sensor

The results can be seen below in figure 2 and the full results can be seen in table 2. The starting output on this can be seen to not be “zeroed” at 0 degrees C but much like the pressure sensor the recorded values and the expected results are incredibly similar so the sensor is acting like it should.

The highest hysteresis error recorded on this sensor was -0.02.

The highest non-linearity error was -0.15 on both the rising and falling.

By looking at the graph and table of results you can see the accuracy of the sensor is close to the expected and performs well with low hysteresis and non-linearity error.

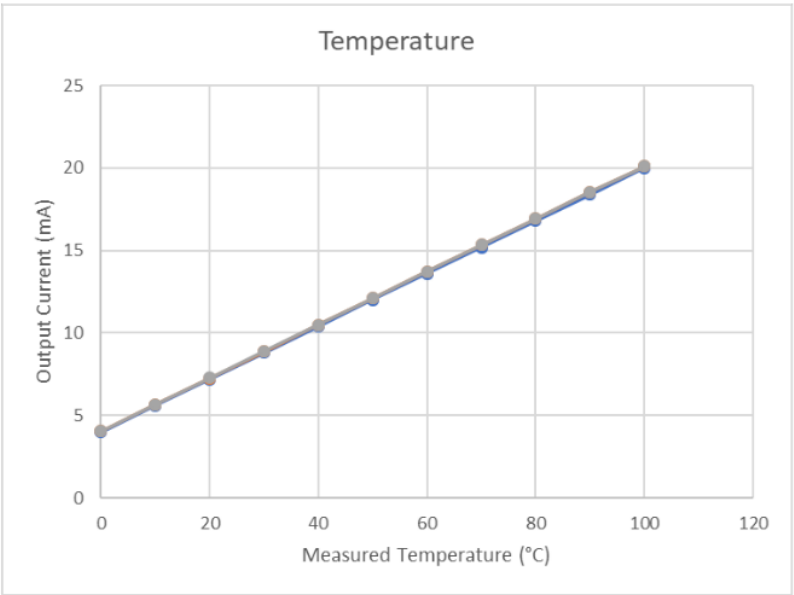


Figure 2: Temperature sensor graph

Task 6 – Calibration of Level Sensor

To gather the readings for the level sensor a tank was filled with water and then drained, readings were taken on the rise and fall, to control this rise and fall the connected HMI was used. The readings were taken by eye by looking at a tube with the measurements printed on the side. The results are shown in figure 3 and full results in table 3 as can be seen in the results the values don't start at 0, the amps start at 4mA and the level starts at 7cm. The level starts at 7cm due to tank limitations.

The highest hysteresis error recorded on this sensor was -0.08.

The highest non-linearity error was -0.08 on both the rising.

The non-linearity error and the hysteresis are both the same results and very low, by looking at the full results the sensor can be seen to be performing well.

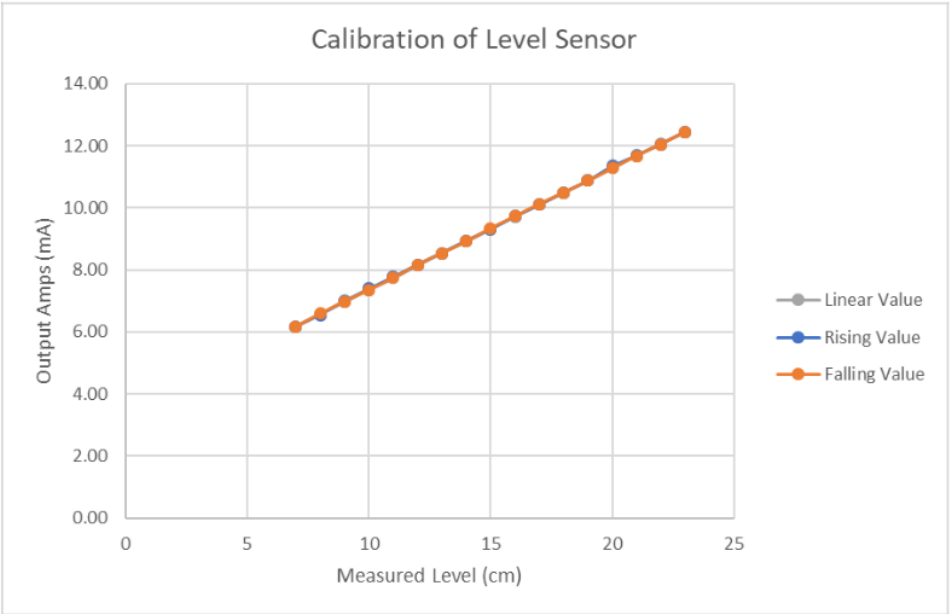


Figure 3: Level sensor graph

Task 7 – Calibration of Position Sensors

Figure 4 shows the plotted measurements recorded when moving the robot, where the plotted lines are the encoder and laser values. The measurements were taken by increasing the distance from the start position in increments of 100 using the HMI controls then took the laser and encoder readings from the HMI while also measuring the distance by eye. The full table of results can be seen in table 3, as can be seen in the results the measured data from the encoder and by eye are close to each other in value but the laser readings are less accurate and consistent. In reality the encoder is more likely to be accurate than using the human eye as human error can occur and the form of measurement – a tape measure underneath the arm – is far from the most reliable way to get an accurate distance.

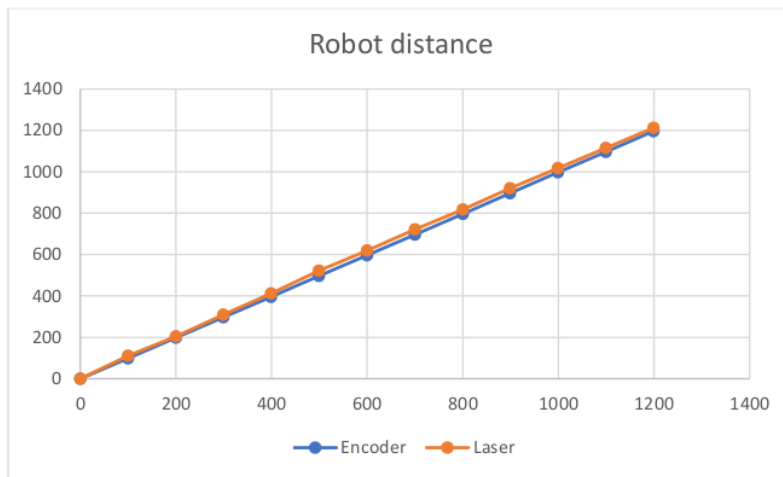


Figure 4: Robot position graph:

Task 8 – Design Adaptation for Maintenance and Reliability

Each of the systems HMI screens could do with some improvements to allow for better calibration of the systems. Most of the local HMI screens had no visual representation of the values being recorded or the elements that control the calibration.

Figure 4, 5, and 6 show the updated HMI screens for the temperature, level, and flowrate instruments respectively, they are being discussed as one because the same changes were made in both HMIs. To allow for these screens to be used in a more efficient way, the Kp, KI, and Kd were added to this screen along with on off and run control. The addition of the K elements allows for calibration of the sensors from this HMI without needing to switch back to three engineers screen. In addition to these the Multiplier, Divisor, and offset were added for the same purpose. The graph has been added as a display of the current readings from the sensor.

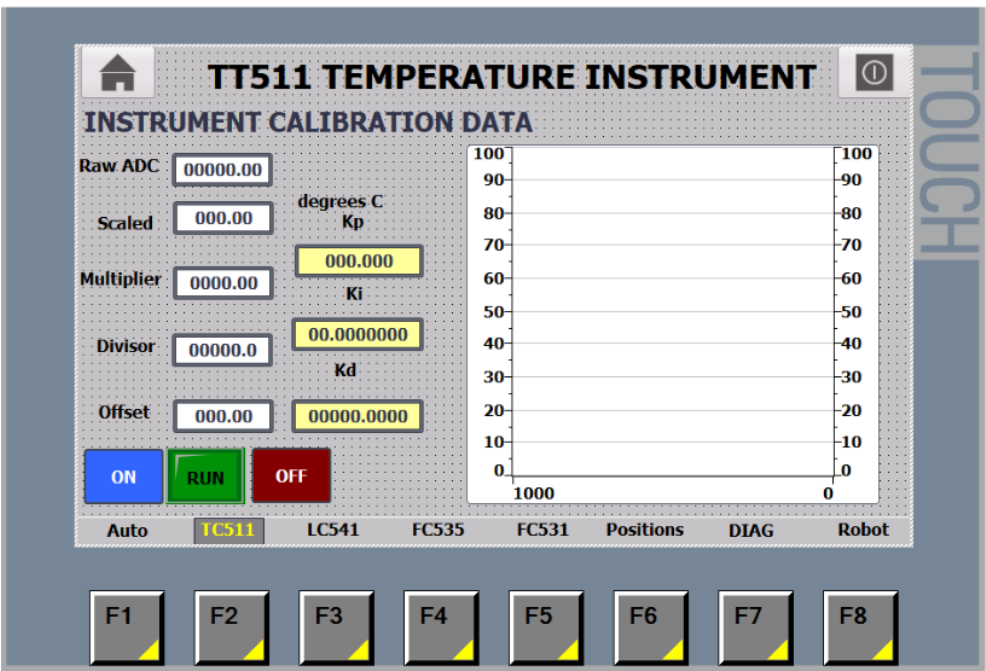


Figure 5: Temperature HMI

evidence of testing is missing and no testing table included

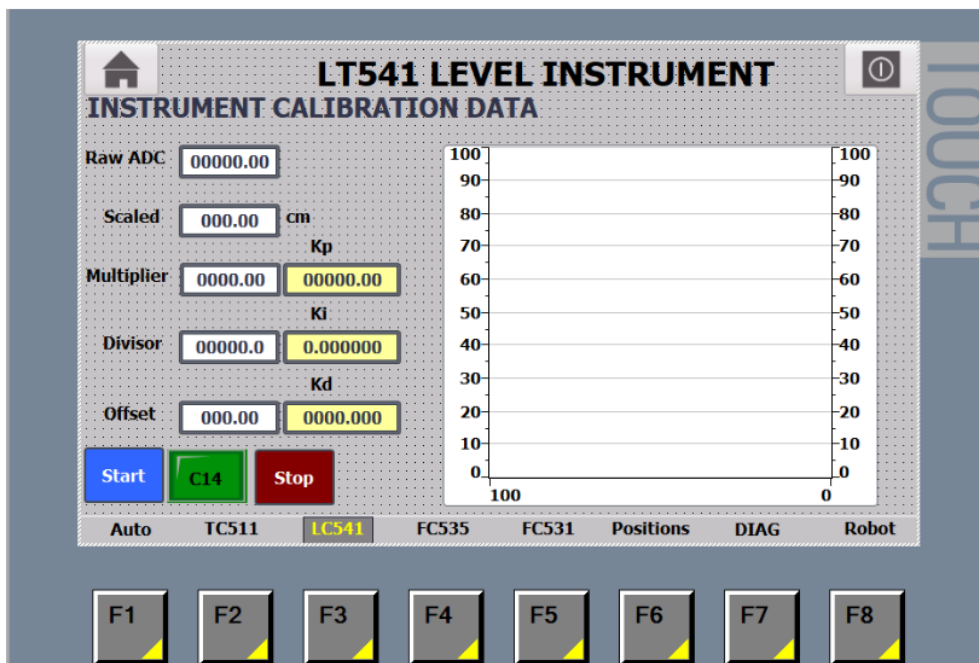


Figure 6: Temperature control

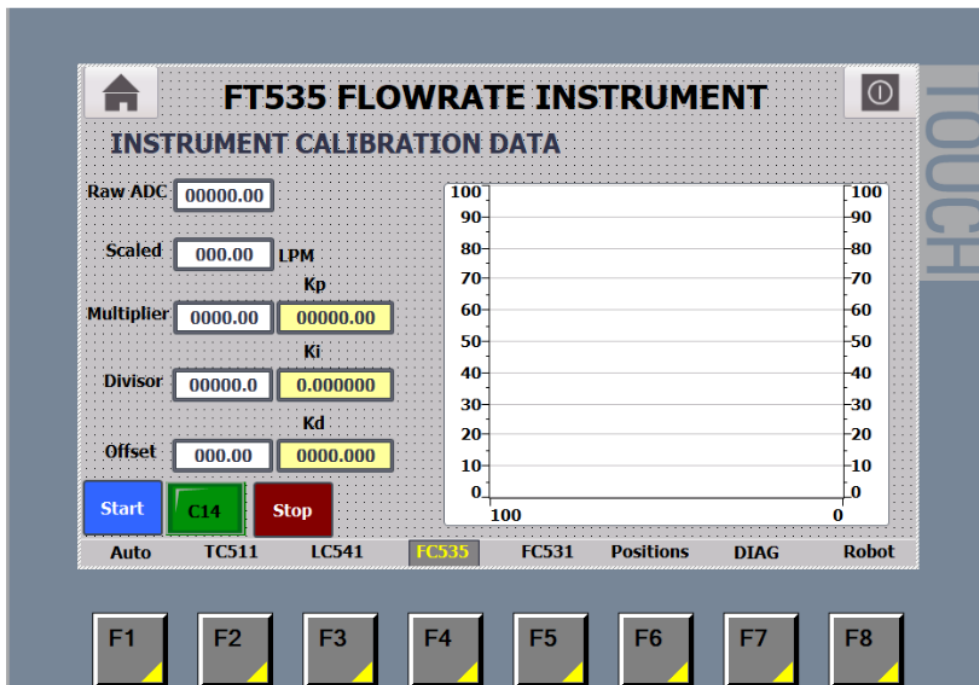


Figure 7: Flowrate screen

Figure 7 shows the updated HMI for the robot control screen. The changes made to this were to add a visual representation of the robots' current position along its path. These changes made to support this can be seen in Figures 8 and 9, where a new tag "Scaled int mm" has been added and the incoming encoder value is put through a CONV function block to go from a Real to an Int using the new tag. The HMI then had visual blocks added that are tagged for animation based on the new "Scaled int mm" value, allowing it to move as the value increases or decreases.

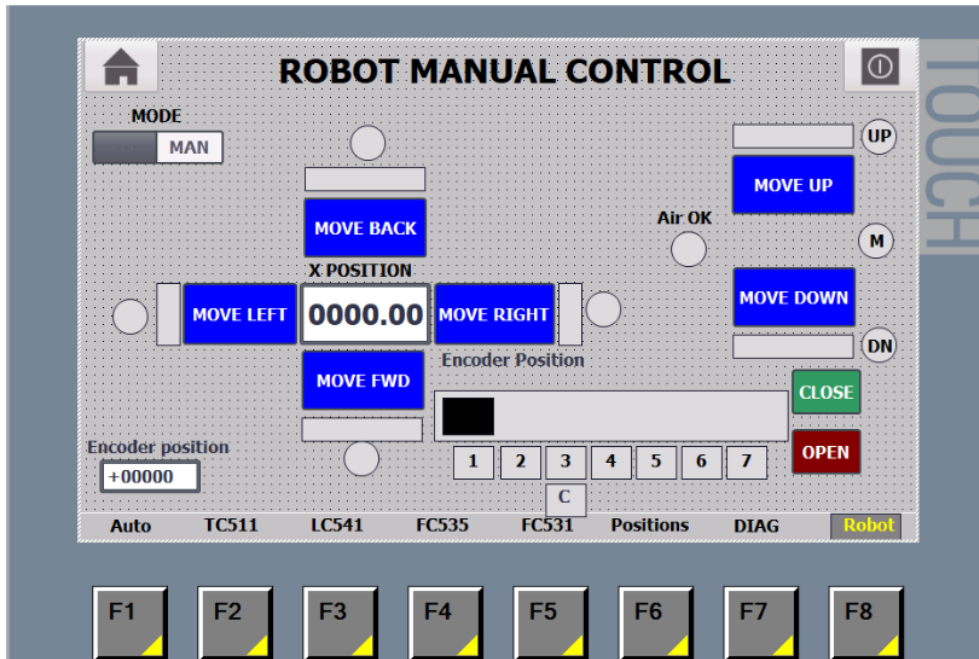


Figure 8: Robot control HMI screen

Each of the changes made to these systems will allow for a better user experience through reducing the number of screens needed for the calibration of each sensor while still locking some functionality behind the engineering screens to prevent too much change. By having a visual representation and the values to change to calibration on the same screen it can be accurately be seen how the changes are affecting the sensor in real time.

Task 9 – Conclusions and Recommendations

Despite the current sensors barring the laser on the robots positioning being very accurate and true to what the specifications suggest the current CIM system has good functionality towards being sustainable and conforming with UK-Spec as the goal is to promote environmentally friendly and sustainable systems. The functionality of the system however could be upgraded to be more in line with the new industry 4.0 standard that systems are moving towards through replacing and upgrading the sensors used to more advanced types.

Through using industry 4.0 capable devices any maintenance and changes can be made quicker and with more accuracy as the I/O from these new sensors can be monitored more closely to see any changes in the system. The addition of the new HMI screens is a time saver and therefore money saver as you no longer have to switch between screens to see and make the changes needed. As the world progresses in this direction every company should try to do the same as to not get left behind. The laser sensor on the robot instrumentation should be removed as the values shown are not accurate and give a false sense of the robots' location.

Task 10 – Team Working

Many aspects of this report required teamwork to successfully complete each section. To complete the calibration and testing sections of this a team of three was formed, each member of the team took on roles to get the readings correctly and quickly. One role was to control the instrumentation, another was to read the measurements, and the last was to record each of these in an excel document and distribute the results to the others.

To complete the new sections on the HMI screens discussions were held on the best way to implement the necessary changes, through the collaborative effort each of these changes were completed.

Task 11 – Citation List

good range of sources

BSI, 2020. *BS 6739*. 8th ed. London: BSI.

Danfoss, 2022. *MBT 3560, temperature sensor with built-in transmitter*. [Online] Available at: <https://www.danfoss.com/en-gb/products/sen/sensors-and-transmitters/industrial-temperature-sensors/mbt-3560/#tab-overview> [Accessed 23 1 2022].

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Vega, 2022. *VEGAPULS WL 61*. [Online]
Available at: <https://www.vega.com/en-uk/products/product-catalog/level/radar/vegapuls-wl-61>
[Accessed 23 1 2022].

Table 1: Pressure sensor measurements

Measure pressure and	Output Voltage		Linear Value	Non-linearity error		Hysteresis Error
	Rising	Falling		Rising	Falling	
0	0	0	0	0	0	0
0.5	1.1	1.04	1	-0.1	-0.04	-0.06
1	2.04	2.01	2	-0.04	-0.01	-0.03
1.5	2.99	3.02	3	0.01	-0.02	0.03
2	3.98	4.01	4	0.02	-0.01	0.03
2.5	4.97	5.01	5	0.03	-0.01	0.04
3	5.99	5.99	6	0.01	0.01	0
3.5	6.97	7.03	7	0.03	-0.03	0.06
4	7.98	8	8	0.02	0	0.02
4.5	8.98	9.01	9	0.02	-0.01	0.03
5	10	10	10	0	0	0

Table 2: Temperature sensor measurements

Measure and Temperature (°C)	Output Current (mA)		Linear Value	Non-linearity error		Hysteresis Error
	Rising	Falling		Rising	Falling	
0	4.06	4.06	4	0	0	0
10	5.66	5.66	5.6	-0.06	-0.06	0
20	7.27	7.29	7.2	-0.07	-0.09	0.02
30	8.88	8.89	8.8	-0.08	-0.09	0.01
40	10.5	10.5	10.4	-0.1	-0.1	0
50	12.11	12.11	12	-0.11	-0.11	0
60	13.72	13.72	13.6	-0.12	-0.12	0
70	15.33	15.33	15.2	-0.13	-0.13	0
80	16.94	16.94	16.8	-0.14	-0.14	0
90	18.55	18.55	18.4	-0.15	-0.15	0
100	20.1	20.1	20	-0.1	-0.1	0

Table 3: Position sensor readings

Distance	Encoder	Laser
0	0	0
100	98.2	110.7
200	198.2	204.32
299	297.2	309.81
399	395.9	411.67
499	496.1	521.53
600	596.9	619.5
700	696.9	721.26
800	796.9	818.48
899	896.5	919.77
999	997.3	1017.59
1099	1095.8	1114.94
1199	1196.5	1212.3

Table 4: Level sensor table

Measure and Level (cm)	Output Amps (mA)		Linear Value	Non-linearity error		Hysteresis Error
	Rising	Falling		Rising	Falling	
7	6.18	6.18	6.18	0.00	0.00	0
8	6.55	6.59	6.57	0.02	-0.02	0.04
9	7	6.99	6.97	-0.04	-0.03	-0.01
10	7.4	7.36	7.36	-0.04	0.00	-0.04
11	7.78	7.75	7.75	-0.03	0.00	-0.03
12	8.17	8.16	8.14	-0.03	-0.02	-0.01
13	8.53	8.54	8.54	0.01	0.00	0.01
14	8.94	8.92	8.93	-0.01	0.01	-0.02
15	9.32	9.34	9.32	0.00	-0.02	0.02
16	9.73	9.73	9.71	-0.02	-0.02	0
17	10.11	10.12	10.11	0.00	-0.01	0.01
18	10.49	10.49	10.50	0.01	0.01	0
19	10.88	10.89	10.89	0.01	0.00	0.01
20	11.36	11.28	11.28	-0.08	0.00	-0.08
21	11.7	11.67	11.68	-0.02	0.01	-0.03
22	12.05	12.04	12.07	0.02	0.03	-0.01
23	12.46	12.46	12.46	0.00	0.00	0

Encoder Position								
	Name	Data type	Start value	Retain	Accessible f...	Writa...	Visible in ...	Setpoint
1	Static			☐	☐	☐	☐	☐
2	Raw count	Real	0.0	☐	☒	☒	☒	☐
3	Offset	Real	0.0	☐	☒	☒	☒	☐
4	Count	Real	0.0	☐	☒	☒	☒	☐
5	Scaled mm	Real	0.0	☐	☒	☒	☒	☐
6	scaled int mm	Int	0	☐	☒	☒	☒	☐

Figure 9: New tag

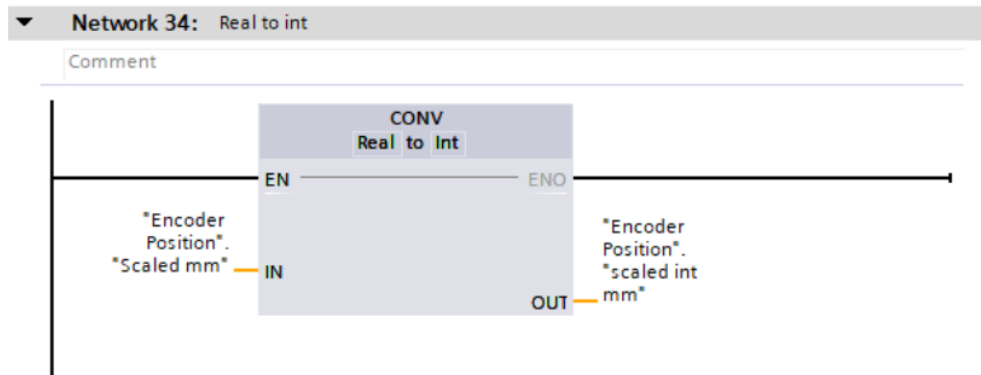


Figure 10: New network



Figure 11: Vagapuls WL 61 (Vega, 2022)



Figure 12: Danfoss MBT 3560 (Danfoss, 2022)



Figure 13: Turck Flow sensor (Turck, 2019)

FINAL GRADE

GENERAL COMMENTS

Instructor

58/100

PAGE 1

Text Comment. Well structured and presented report Good evidence of reading from a range of sources correctly cited and listed. Good evidence of testing of instruments but no evidence to support testing of design adaptations. Format is incorrect, should be 1.5 lines spacing.

PAGE 2

PAGE 3

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PAGE 7

Text Comment. by connecting it

Text Comment. %FSD ?

Text Comment. evidence of testing is missing and no testing table included

Text Comment. good range of sources

GRADING FORM: NEW CSG-RUBRIC

DANIEL OULTON

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. 12/20

12

2. KNOWLEDGE AND UNDERSTANDING

-  Competent knowledge of the basic underlying concepts and principles. Exhibits very good understanding. 12/20

12

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 good and appropriate application of basic methods, materials, tools and/or techniques. Clear

10

appreciation of the context of the application.
Good evidence of different approaches to
problem-solving in particular contexts and
proposes mostly appropriate solutions. 10/20

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 weakness. 12/20

12