

1702304

by Benjamin Morgan

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A well structured and presented report. Good evidence of research from a range of sources correctly cited using the Harvard Method. Good design adaptation but no testing evidence.

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1. System Investigation

There are 4 main control loops within the given P&ID diagram, these are identified as:

- 1) Loop 511 – Temperature control
- 2) Loop 541 – Level control
- 3) Loop 535 – Flow control
- 4) Loop 531 – Flow control

Loop 511 is responsible for measuring the temperature of the water within tank B1. The instrumentation used within loop 511 consists of a PT100 RTD that is connected to a signal conditioner. This conditioner converts the ohmic value from the PT100 transmitter into a useable 4-20mA signal, this range corresponds to a temperature range of 0-100°C. The temperature controller TC511 is a PID control loop within the PLC program, this is fed into a solid state relay (SSR) using PWM controls and then to a heating element.

Loop 541 is responsible for monitoring the level of water within the first tank. A pressure transducer is used for this, it converts the pressure reading into a level measurement. The transmitter outputs a 4-20mA signal to the level controller LC541, this is also contained within the PLC program. The controller feeds into LY541 which is a pump/amplifier that is responsible for the flow of water into the tank.

Loop 535 monitors and controls the flow of water leaving tank B1. The flow transmitter is a turbine flow meter, as the water flows through the turbine the frequency of rotation is measured in Hz, this signal is fed into a signal conditioner that converts the frequency into a 0-10V signal. This voltage signal is sent to the flow controller FC535, this is also contained within the PLC program. The PLC then inputs this signal into the amplifier LY541 that controls the pump that fills the tank. The CV fed to LY541 informs the pump what flow it must achieve to maintain the correct level.

The other flow control loop, 531 is used to monitor and control the flow of water from the recirculation tank into the other bays of the process station. The flow is measured via FT531, this is the same transmitter used in loop 535, this is connected to a signal conditioner. The signal is then fed to the controller FC531, this controls the proportional value; VF531, this is responsible for filling the tanks.

To gather technical data about each transmitter and signal conditioner, similar equipment was found on RS. A similar PT100 sensor was found, a section from the data sheet is shown in figure 1 (RS, 2022).

**Data sheet
CSOJ6**

RS Stock No. 407-1624

ENGLISH

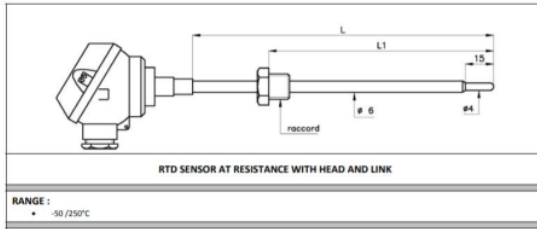


Figure 1 - Data Sheet Section for PT100 RTD

do not include datasheets

This shows the range of the device to be between -50-250°C. A data sheet for a temperature transmitter can be seen in the appendix (Fig.29) (eyc-tech, 2013), it shows the accuracy to be $\pm 0.1\%$ FSD, meaning that for the given application of 0-100°C, the accuracy would be $\pm 0.1^\circ\text{C}$.

The static sensitivity of the device is given as: $\frac{\text{output range of sensor}}{\text{input range of measurement}} = \frac{16\text{mA}}{100^\circ\text{C}} = 0.16\text{mA}/^\circ\text{C}$.

The data sheet for the pressure transducer was found and the section describing the accuracy can be seen in figure 2 (ifm Electronic, 2010). It shows the non-linearity error to be $\pm 0.5\%$ of the adjusted range, the hysteresis error to be $> 0.01\%$ FSD. It also shows the measurement range to be between 0-400 bar. If the highest range was used, the static sensitivity would be 0.04mA/Bar.

Operating instructions

Pressure Transmitter Cerabar PMC 133

Technical Data

see also TI 10SP100/2e

Construction, Materials

Housing: synthetic (POM) or cast aluminium
Protection: IP 65 (DIN 40050)

Wetted Materials

Process connection: 2.0401 brass or 1.4581 stainless steel (1.4571 stainless steel with high pressure measuring cell)
Ceramic diaphragm up to 60 bar:
aluminium oxide ceramic 96 %
Process seal gasket up to 60 bar:
e.g. Viton, EPDM, Kalrez, etc.
Above 100 bar: 1.4401 special steel diaphragm.

Permissible Temperatures

Operating limits:
Housing: $-20^\circ\text{C} \dots +70^\circ\text{C}$
Diaphragm: $-20^\circ\text{C} \dots +80^\circ\text{C}$
(up to $+130^\circ\text{C}$ for short periods)
Storage: $-40^\circ\text{C} \dots +85^\circ\text{C}$

Accuracy

• Ceramic measuring cell
Linearity: $\pm 0.2\%$ or $\pm 0.5\%$ of adjusted range
Hysteresis: better than 0.01% of full scale
Installation: any orientation
Temperature variation typical $\pm 0.15\%$ of full scale, of the measuring cell (see Table).
• High Pressure Measuring Cell
Linearity: $\pm 0.5\%$ of full scale
Hysteresis/Reproducibility: $\pm 0.1\%$ of full scale

Temperature effects of maximum measuring span	0...50 °C	-20...0 °C +80...75 °C
TK zero point	0.2 %/10K	0.3 %/10K
TK span	0.2 %/10K	0.3 %/10K

Technical Data
Measuring cells

Type of Max. cell	Max. permissible overload	T ₀	Type of pressure 0 gauge/A absolute
0...2 bar	10 bar	$\pm 0.6\text{ mbar}/10\text{ K}$	G
0...1 bar	10 bar	$\pm 0.3\text{ mbar}/10\text{ K}$	G
0...0.5 bar	20 bar	$\pm 0.3\text{ mbar}/10\text{ K}$	G
0...0.2 bar	40 bar	$\pm 0.3\text{ mbar}/10\text{ K}$	G
0...0.1 bar	10 bar	$\pm 0.6\text{ mbar}/10\text{ K}$	G
0...0.05 bar	10 bar	$\pm 0.6\text{ mbar}/10\text{ K}$	G
0...1 bar	10 bar	$\pm 1.5\text{ mbar}/10\text{ K}$	G or A
0...2 bar	20 bar	$\pm 3.0\text{ mbar}/10\text{ K}$	G or A
0...4 bar	20 bar	$\pm 6.0\text{ mbar}/10\text{ K}$	G or A
0...10 bar	40 bar	$\pm 15\text{ mbar}/10\text{ K}$	G or A
0...20 bar	40 bar	$\pm 30\text{ mbar}/10\text{ K}$	G or A
0...40 bar	60 bar	$\pm 60\text{ mbar}/10\text{ K}$	G or A
0...60 bar	80 bar	$\pm 90\text{ mbar}/10\text{ K}$	G or A
0...100 bar*	400 bar	$\pm 500 \dots \pm 750\text{ mbar}/10\text{ K}$	G or A
0...250 bar*	600 bar	$\pm 500 \dots \pm 750\text{ mbar}/10\text{ K}$	G or A
0...400 bar*	600 bar	$\pm 500 \dots \pm 1000\text{ mbar}/10\text{ K}$	G or A

* polysilicon sensor for high pressure

Figure 2 - Data Sheet Section for Pressure Transmitter

Figure 3 is a section from the data sheet of the flow meter (RS, 2022). It shows the range of the device to be 0.25-6.5L/min, the non-linearity error at FSD to be $\pm 1\%$. The data sheet for the required frequency to volatge signal conditioner can be seen in the appendix (Fig.30) (Phoenix Contact, 2022). The flow meter produces 500Hz at full scale (6.5L/min) and this would produce a 10V output form the conditioner, giving a static sensitivity of 0.02V/Hz or 1.54V/LPM.

Colour Code	Grey Body (RS stock no. 257-149)	Beige Body (RS stock no. 257-133)
Flow Range	0.25-6.5 l/m	1.50-30.0 l/m
Linearity at FSD Frequency	$\pm 1.0\%$	$\pm 1.5\%$
Approximate Full Scale At Full Scale	500Hz	600Hz
Approximate Pulses per Litre	4600 pulses/litre	1200 pulses/litre

Figure 3 - Data Sheet Section for Flow Meter

The 2 systems are not electrically interconnected, the only shared connection is the water pipe that connects the water storage tank and the process station.

2. Research

The sensors used in the process station provide basic data about the system and often require a signal conditioner to produce a usable signal. Industry 4.0 is the transformation of industry via intelligent networking of processes and equipment with the assistance of ICT (i-SCOOP, 2022). Industry 4.0 aims to streamline and eliminate manual processes that are costly and prone to error. To do this communication between existing systems has to be digital (GmbH, 2019). To create this smart communication that will improve the efficiency, sensors must provide more information about the process. Figure 4 below shows what a sensor from each stage of industry is capable of (Andreas, et al., 2018).

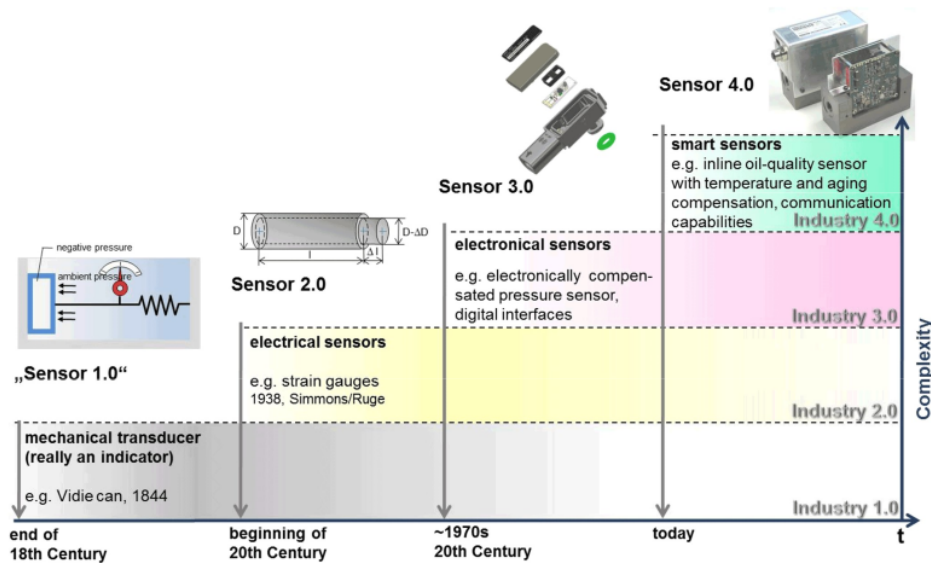


Figure 4 - Capability of Sensors from Each Generation of Industry

As the image describes, the sensors used in the process station are of 3.0 standard and only provide 1 piece of information, e.g. flow. For the sensor to be to industry 4.0 standard, it could also include information regarding the temperature of the water, the turbidity of the fluid and then also communicate this to the PLC itself.

Sensors that are compatible with industry 4.0 can help reduce breakdowns and aid with maintenance tasks with the additional information they provide. Industry 4.0 streamlines the automation process and via analysis of multiple variables can pre-emptively predict breakdowns (Al-Najjar, et al., 2018). The technology of the Internet of Things (IOT) allow data to be integrated from different works areas easily without long communication times. The various data sources will allow factories to quickly respond to changes within production or with failures (Al-Najjar, et al., 2018).

3. Environmental, Sustainable Development, Commercial Risk and Codes of Practice

The subsystems control a metal cleaning process, the process uses water, acid and 772 passivator, a substance that creates a protective coating, and a water re-circulation system. These chemicals can have a negative effect on the environment if not handled and disposed of correctly. Therefore, the chemicals have risk assessments and COSHH regulations surrounding them. Chemicals must be disposed of correctly; they will have designated waste storage, and these will likely be disposed of professionally.

The system should be run as efficiently as possible and produce the least possible waste, this is in order to promote sustainable engineering. The tanks used for the individual stations are relatively small, this means that smaller volumes of products are required. The water used in the rinsing stations is also recirculated means a set amount of water is required, this may need to be topped up occasionally. This further reduces material usage and waste. The tuning and control of the systems also allows energy usage to be controlled and reduced. By ensuring the process run efficiently and is tuned correctly, components such as heaters and pumps are only used when required.

The Royal Academy of Engineering and the Engineering Council define 4 core ethical principles, these being (Lawlor & et al, 2016) :

- 1) Accuracy and Rigour
- 2) Honesty and Integrity
- 3) Respect for Life, Law and the Public Good
- 4) Responsible Leadership: Listening and Informing

These values if followed will ensure engineers conduct quality work and record results accurately and truthfully, this can ensure that the plant runs smoothly and is monitored correctly. Following these principles will also ensure that the engineer is always considering what effects their actions can have on the environment around them and what they should do to protect it.

4. Calibration of Pressure Sensor

A calibration of a pressure sensor was conducted. The set up for the calibration consisted of air pressure being fed to a manual and electronic gauge, the manual gauge provides accurate pressure results. The voltage is then read from a multimeter connected to the sensor and compared to the gauge value. The results gathered from the calibration have been tabulated and graphically displayed below.

Measureand Pressure (Bar)	Output Voltage (Volts)		Linear Value (Volts)	Non-linearity error		Hysteresis error (Volts)
	Rising	Falling		Rising	Falling	
0	0.00	0	0	0	0	0
0.5	1.05	1.04	1	0.05	0.04	-0.01
1	2.01	2.02	2	0.01	0.02	0.01
1.5	3.01	3.02	3	0.01	0.02	0.01
2	3.98	3.99	4	-0.02	-0.01	0.01
2.5	5.00	5.01	5	0.00	0.01	0.01
3	6.00	6.01	6	0.00	0.01	0.01
3.5	6.98	7	7	-0.02	0.00	0.02
4	7.99	7.97	8	-0.01	-0.03	-0.02
4.5	8.99	8.98	9	-0.01	-0.02	-0.01
5	9.99	9.99	10	-0.01	-0.01	0.00

static sensitivity?

Figure 5 - Pressure Transmitter Calibration Table of Results

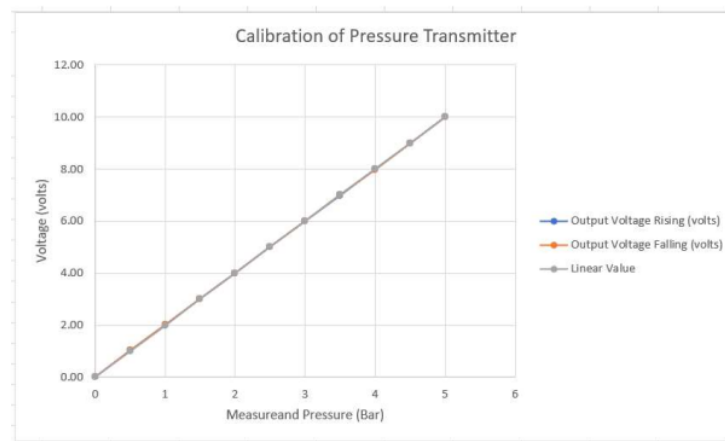


Figure 6 - Pressure Transmitter Calibration Graphical Results

As shown in the graph the results gathered produce a linear graph, where the voltage rises proportionally with the pressure. The non-linearity error for this sensor was very low with most values being around 0.01V, this equates to 0.1% of the FSD of the sensor. This is considered to be acceptable for this transmitter, as shown when compared to the similar pressure sensor found on RS (Fig7) (RS, 2022), which has an accuracy of $\pm 0.25\%$.

IPSS Semi-Flush Mount Pressure Transmitter



- Piezo-resistive sensor, Ceramic or Silicon
- Accuracy <±0.25% FS BFSL
- Various outputs including Volts and mA.
- Pressure ranges from 100mbar to 100 bar
- Pressure reference, Gauge or Absolute

Suitable applications	
Environmental engineering	Automotive testing
Static tank level	Process pumping
Viscous and paste-like media	Sewage or grey water
Composite manufacturing	Injection moulding or infusion
Process control	Aggressive media

Performance	
Accuracy (Non-Linearity & Hysteresis)	<±0.25% / FS (BFSL)
Setting Errors (offsets)	2-wire Zero & Full Scale, <±0.5% / FS
	3-wire Zero & Full Scale, <±0.5% / FS
Permissible Load	2-wire $R_{in} = (V_S - V_{Smin})/0.02k\Omega$
	3-wire $R_{in} = 10k\Omega$
Influence Effects	Supply <0.005% FS / 1V
Load	0.05% FSD / kΩ

The semi-flush mount pressure transmitter, IPSS, has a piezo-resistive silicon or ceramic pressure sensor. The sensor is semi-flush to the housing making this product ideal for viscous or paste like media. The sensor and housing are made from stainless steel with a choice of internal 'O' ring seals to ensure the product is suitable for a wide range of applications.

The electronics incorporate a microprocessor-based amplifier, requiring no adjusting and giving stable electronics - especially in high vibration or shock applications.

Every device is temperature compensated, calibrated and supplied with a traceable serial number and calibration data*.

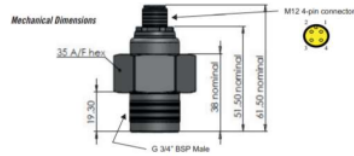


Figure 7 - Data Sheet of Comparable Pressure Transmitter

5. Calibration of Temperature Sensor

A PT100 RTD connected to a ^{lab} signal conditioner was calibrated in the workshop, a resistance signal was injected into the RTD, and the output current was recorded. The following readings were taken, and the results have tabulated and shown graphically.

Temperature Injected (°C)	Current recorded (mA)		Calculated current (mA)	Non-linearity error		Hysteresis Error (mA)
	rising	falling		rising	falling	
0	4.02	4.02	4	0.02	0.02	0
10	5.62	5.62	5.6	0.02	0.02	0
20	7.22	7.22	7.2	0.02	0.02	0
30	8.81	8.81	8.8	0.01	0.01	0
40	10.41	10.41	10.4	0.01	0.01	0
50	12.01	12.01	12	0.01	0.01	0
60	13.61	13.61	13.6	0.01	0.01	0
70	15.21	15.21	15.2	0.01	0.01	0
80	16.8	16.81	16.8	0	0.01	0.01
90	18.4	18.4	18.4	0	0	0
100	19.99	19.99	20	-0.01	-0.01	0

Figure 8 - Temperature Transmitter Calibration Table of Results

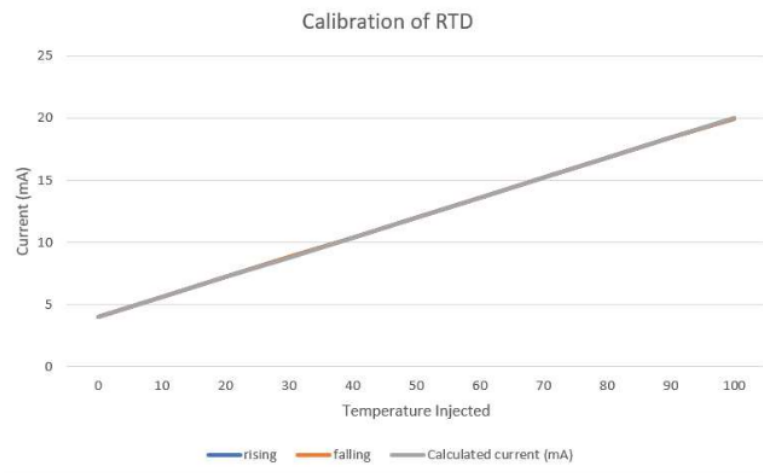


Figure 9 - Temperature Transmitter Calibration Graph of Results

The results gathered have produced a linear response where the mA reading proportionally rises with the rising temperature. The maximum non-linearity error was found to be 0.02, this equates to 0.1% of the FSD. Although the average was lower at 0.05% FSD. To compare, a similar signal conditioner was found on RS, a section of the data sheet is shown in figure 11, describing the accuracy of device (RS, 2022).

Weidmuller MCZ PT Series Signal Conditioner

RS Stock No.: 393-0235 | Mfr. Part No.: 8425720000 | Brand: Weidmuller

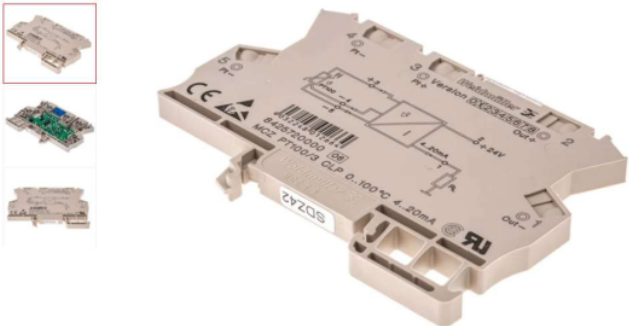


Figure 10 - Comparable Signal Conditioner

Technical data	
Input	PT 100 (according to IEC 751)
Connection	3-wire / 2-wire*
Max. wire resistance	each 50 Ω
Leadwire resistance effect	max. 0.006 °C/Ω
Supply current	0.8 mA
Output	4...20 mA**
Load	750 Ω at 24 V
Supply voltage	max:30V/min:9V+20mA x R _L
Residual ripple of supply voltage	max: 1.5 V at 100 Hz
Set time	10 ms
Accuracy	Type: 0.2 % max. 0.5 % v. FSR
Linearity	<0.1 % v. FSR
Temperature coefficient	max. ±250 ppm/°C
Open circuit recognition	yes
EMC	EMVG
	EN 50081-1
	EN 50082-2
Approvals	CE, UL, CSA
Ambient temperature	0 °C...+50 °C
Storage temperature	-20 °C...+85 °C
Conductor	AWG 22...12
Conductor cross-section	1.5 mm ²
Overall width	6 mm
* Putting a bridge between Pins 4 and 5	** current loop supplied
Dimensions and accessories see	Page 305

Figure 11 - Data Sheet from Comparable Signal Conditioner

This conditioner is shown to have a non-linearity error of 0.1% FSD. This is the same the results gathered, proving this transmitter is of good quality and is fit for purpose.

6. Calibration of Level Sensor

The calibration of the level sensor was gathered from a sight glass and a pressure transducer that is connected to a signal conditioner to convert to level. The current was then recorded using a multimeter. The results from the calibration were tabulated and displayed graphically, these are shown below.

Level Injected (cm)	Current recorded (mA)		Linear Value(mA)	Non-linearity error		Hysteresis Error (mA)
	rising	falling		rising	falling	
7	6.21	6.2	6.21	0	0.01	-0.01
8	6.61	6.6	6.61125	0.00125	0.01125	-0.01
9	7.01	6.96	7.0125	0.0025	0.0525	-0.05
10	7.43	7.37	7.41375	-0.01625	0.04375	-0.06
11	7.8	7.75	7.815	0.015	0.065	-0.05
12	8.23	8.15	8.21625	-0.01375	0.06625	-0.08
13	8.62	8.56	8.6175	-0.0025	0.0575	-0.06
14	9.01	8.9	9.01875	0.00875	0.11875	-0.11
15	9.39	9.31	9.42	0.03	0.11	-0.08
16	9.78	9.73	9.82125	0.04125	0.09125	-0.05
17	10.17	10.12	10.2225	0.0525	0.1025	-0.05
18	10.58	10.5	10.62375	0.04375	0.12375	-0.08
19	10.99	10.91	11.025	0.035	0.115	-0.08
20	11.41	11.31	11.42625	0.01625	0.11625	-0.1
21	11.82	11.71	11.8275	0.0075	0.1175	-0.11
22	12.18	12.09	12.22875	0.04875	0.13875	-0.09
23	12.63	12.63	12.63	0	0	0

static sensitivity?

Figure 12 - Level Sensor Calibration Table of Results

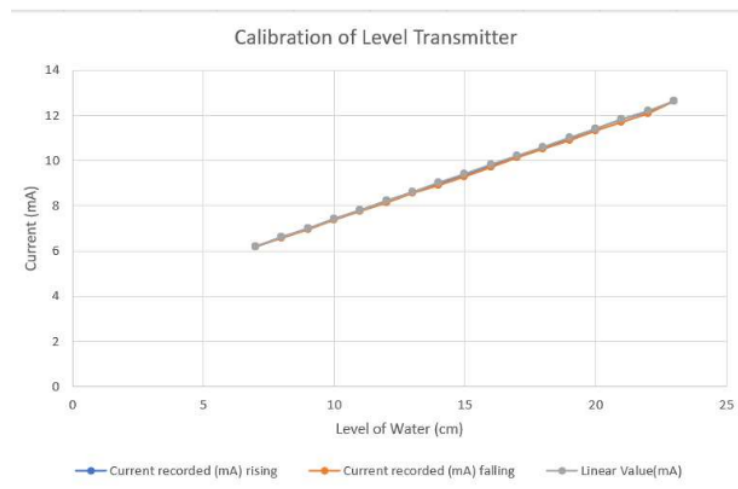


Figure 13 -Level Sensor Calibration Graph of Results

The results gathered produced a linear graph. The current recorded rose proportionally to the level of water. Some of the results at the top end of the range were slightly below the linear value. The largest non-linearity error was 0.13875, this equates to an error of 1.099% FSD.

The pressure transmitter may produce spurious results due to temperature changes of the water; this could be the cause of the larger non-linearity errors experienced.

The data sheet for the transmitter is shown in Figure 14 in the appendix, the non-linearity error calculated is outside of the range given on the data sheet (Endress + Hauser, 2022). This could be due to the sight glass level not being exact when measurements were taken.

7. Calibration of Distance Sensor

The 2 methods of distance measurement used were, a laser and an encoder. The data was collected using an HMI screen adjacent to the devices. The results gathered have been tabulated and graphically displayed below.

Rising					
Laser	Encoder	Tape Measure	Laser distance Travelled (mm)	Encoder distance travelled (mm)	Error
238.65	43.8	200	0	0	0
344.8	142.3	300	106.15	98.5	7.65
441.5	242.4	400	202.85	198.6	4.25
539.65	342	500	301	298.2	2.8
647	442.8	600	408.35	399	9.35
756.9	543.6	700	518.25	499.8	18.45
858.1	642	800	619.45	598.2	21.25
959.15	740.9	900	720.5	697.1	23.4
1057.5	842.9	1000	818.85	799.1	19.75
1163.5	944.6	1100	924.85	900.8	24.05
1261	1043.4	1200	1022.35	999.6	22.75
1358.1	1142.9	1300	1119.45	1099.1	20.35
1455.4	1243.3	1400	1216.75	1199.5	17.25

Figure 14 - Distance Sensor Calibration Table of Results (Rising)

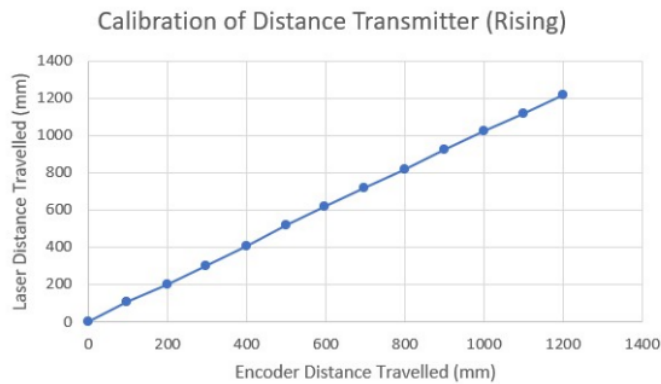


Figure 15 - Distance Sensor Calibration Graph of Results (Rising)

Falling					
Laser	Encoder	Tape Measure	Laser distance Travelled (mm)	Encoder distance travelled (mm)	Error
1450.5	1241	1400	0	0	0
1349.5	1141.3	1300	-101	-99.7	-1.3
1254.5	1042.1	1200	-196	-198.9	2.9
1165.5	943.7	1100	-285	-297.3	12.3
1057.4	840.5	999	-393.1	-400.5	7.4
960.2	743.6	902	-490.3	-497.4	7.1
857.6	643.4	802	-592.9	-597.6	4.7
756.5	543.2	702	-694	-697.8	3.8
650.3	446.2	604	-800.2	-794.8	-5.4
453.7	345.9	504	-996.8	-895.1	-101.7
439.2	246.5	405	-1011.3	-994.5	-16.8
343.2	144.6	303	-1107.3	-1096.4	-10.9
235.4	37.6	195	-1215.1	-1203.4	-11.7

Figure 16 - Distance Sensor Calibration Table of Results (Falling)

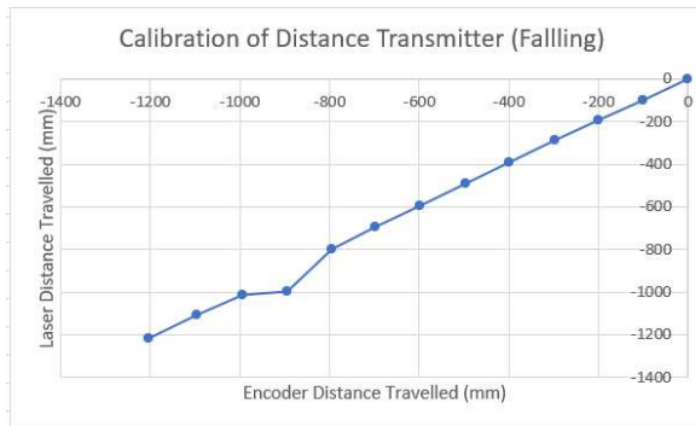


Figure 17 - Distance Sensor Calibration Graph of Results (Falling)

The graph produced from the rising values shows a generally linear ^{relationship} line, the maximum error was 24.05mm, this is a 1.91% error of the maximum distance. The graph for the falling results is also generally linear, except for the anomalous result around the 900mm point. This is where the largest error was experienced for the falling results which was 101.7mm, this is likely due to an error when reading the distance the measurement was taken. The next largest error was 16.8mm, equating to an error of 1.38% FSD. While the laser is not very accurate it produced repeatable results. For example, the values obtained at the 1000mm tape measure mark were 1057.5mm (rising) and 1057.4mm (falling).

The data sheet for the laser is shown in figure 19 (ifm Electronic, 2010), it describes the accuracy of the laser at different distance ranges.

Repeatability / Accuracy				
Sampling rate 50 Hz				
	Repeatability of the measured values		Accuracy	
	white (90 % remission)	grey (18 % remission)	white (90 % remission)	grey (18 % remission)
200...1000 mm	± 5.0 mm	± 7.5 mm	± 15.0 mm	± 18.0 mm
1000...2000 mm	± 5.5 mm	± 10.0 mm	± 15.0 mm	± 20.0 mm
2000...4000 mm	± 17.5 mm	± 22.5 mm	± 25.0 mm	± 32.0 mm
4000...6000 mm	± 27.5 mm	± 40.0 mm	± 35.0 mm	± 50.0 mm
6000...10000 mm	± 60.0 mm	--	± 70.0 mm	--

Repeatability / Accuracy				
Sampling rate 1 Hz				
	Repeatability of the measured values		Accuracy	
	white (90 % remission)	grey (18 % remission)	white (90 % remission)	grey (18 % remission)
200...1000 mm	± 4.0 mm	± 4.5 mm	± 14.0 mm	± 15.0 mm
1000...2000 mm	± 4.5 mm	± 6.0 mm	± 14.5 mm	± 16.0 mm
2000...4000 mm	± 13.5 mm	± 14.5 mm	± 23.5 mm	± 24.0 mm
4000...6000 mm	± 19.0 mm	± 21.0 mm	± 29.0 mm	± 31.0 mm
6000...10000 mm	± 37.0 mm	--	± 47.0 mm	--

Figure 18 - Data Sheet Section for Laser Distance Transmitter

Here it is shown that at distances between 200-1000mm the laser has an accuracy of $\pm 15\text{mm}$, this means that the laser was within tolerance for the data sheet when gathering falling values, but it was often out of tolerance in the range when gathering rising values.

8. Design Adaptation for Maintenance and Reliability

The given program was analysed, and the group decided there were 4 main alterations that could be made. All of the changes were for the HMI screens, the 4 alterations were:

- 1) Add graphs to the screens for the loops; TT511, LT541, FT535 and, FT531
- 2) Add stop/start controls for the heater and pump
- 3) Display PID values on each screen
- 4) Add an animation for the movement of the robot arm and show laser position

All the HMI screens are shown in the appendix. Each screen was designed with maintenance and testing in mind. All of the corresponding data is clearly displayed on each page along with a graphical representation of what is happening within the system. This allows engineers to clearly see what is happening within the systems and also allows them to make on the fly tuning changes to the system. For the systems that required control, the appropriate controls were added to the HMI screen, allowing the system to be easily controlled. On the final page that shows the controls for the robot arm and its position, an animated sliding box was added, it shows the arm's position over the bays of the process station. To allow this, a line of code was added to the main program, it is shown in fig 20 below.

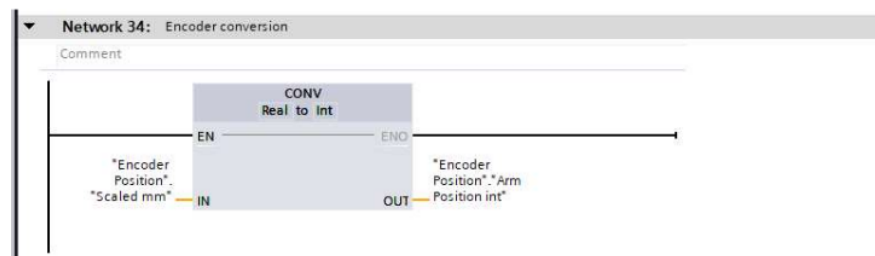


Figure 19 - Line of Code to Convert Real Value to Integer

This line of code is required to change the real value of the encoder position into an integer. This value is used within the animation as the value that determines how far along the described line the box moves. The tags used for the animation are shown on the HMI screenshot.

where is your testing evidence and table?

9. Conclusions and Recommendations

Throughout the report the given system was investigated, the instrumentation within each control loop was described and the technical data surrounding them was given and the relevant information was extracted. Then research was conducted into the next generation of sensors and how they can be used within industry 4.0. The benefits of these next generation of instruments were described and how they can aid manufacturing and maintenance.

The calibration of multiple instruments was then performed, and the associated data was collected and presented. From the data acquired the suitability and performance of the devices was commented on and was often found to be out of tolerance or borderline acceptable. Therefore, it would be best to suggest that the instruments are replaced and updated with better models that could be integrated into an industry 4.0 system.

Finally, the given PLC program was analysed and within a group a set of improvements were decided upon. These were implemented and provided much needed data on the individual process loops. The use of more advanced sensors could provide more information that would be useful to an engineer performing maintenance on the system.

10. Team Working

The author worked as part of a team of 2 to calibrate a range of transmitters and also investigate, test, and improve the given system. During the calibration process for each transmitter the author was responsible for creating the spreadsheets that displayed the data and also gathering the data from the process. The design of the HMI screens was completed by working closely as a pair, discussions were had about the placement of instrument values and graphs. When creating the animation for the robot arm, both team members worked together to figure out how to make this possible. Testing of the HMI screens was also conducted as a pair, one member controlled the system using the local HMI while the other captured screenshots on the computer and aided with any troubleshooting.

11. Citation List

Al-Najjar, B., Algabroun, H. & Jonsson, M., 2018. Maintenance 4.0 to fulfill the demands of Industry 4.0 and Factory of the Future. *International Journal of Engineering Research and Applications*, 8(11), pp. 20-31.

Andreas, S., Nikolai, H. & Tizian, S., 2018. *Sensors 4.0 – smart sensors and measurement technology enable Industry 4.0*. [Online]
Available at: <https://jsss.copernicus.org/articles/7/359/2018/>
[Accessed 24 January 2022].

Endress + Hauser, 2022. *Pressure Transmitter Cerabar PMC 133 Data Sheet*. [Online]
Available at: <https://portal.endress.com/dla/5000000/1746/000/00/KA004PA3.PDF>
[Accessed 24 January 2022].

eyc-tech, 2013. *TP02 Temperature Transmitter for DIN-rail Type Data Sheet*. [Online]
Available at: <https://docs.rs-online.com/0494/0900766b815c95d2.pdf>
[Accessed 24 January 2022].

GmbH, i. l., 2019. *Requirements for Industry 4.0 — What is technically necessary?*. [Online]
Available at: <https://medium.com/@inray.industriesoftware/requirements-for-industry-4-0-what-is-technically-necessary-18ee6bbb7351>
[Accessed 24 January 2022].

ifm Electronic, 2010. *DSARS0048784.Pdf Preview*. [Online]
Available at:
<https://www.datasheetarchive.com/pdf/download.php?id=1d3b4768d4adf8096e30d3b61e4ea321f156e9&type=P&term=O1DLF3KG>
[Accessed 24 January 2022].

i-SCOOP, 2022. *Industry 4.0 and the fourth industrial revolution explained*. [Online]
Available at: <https://www.i-scoop.eu/industry-4-0/#~:text=Industry%204.0%20has%20been%20defined,and%20creating%20the%20smart%20factory%E2%80%9D>
[Accessed 24 January 2022].

Lawlor, R. & et al, 2016. *Engineering In Society*, s.l.: Royal Academy of Engineering.

Phoenix Contact, 2022. *MINI MCR-SL-F-UI-NC Data Sheet*. [Online]
Available at: <https://docs.rs-online.com/7442/0900766b8171571c.pdf>
[Accessed 24 January 2022].

RS, 2022. *Data sheet CSOJ6*. [Online]
Available at: <https://docs.rs-online.com/26c9/0900766b8157a373.pdf>
[Accessed 24 January 2022].

RS, 2022. *IPSS Semi-Flush Mount Pressure Transmitter Data Sheet*. [Online]
Available at: <https://docs.rs-online.com/d2c7/0900766b8162ad00.pdf>
[Accessed 24 January 2022].

RS, 2022. *RS Pro Liquid Acetal Copolymer 4.5 → 16 V dc Sensor/Switch without Indicator, 20bar Pressure Data Sheet*. [Online]

good range of sources

Available at: <https://docs.rs-online.com/8ca9/0900766b81501392.pdf>
[Accessed 24 January 2022].

RS, 2022. *RTD Thermocouple Conditioners Data Sheet*. [Online]
Available at: <https://docs.rs-online.com/4fdd/0900766b801303f7.pdf>
[Accessed 24 January 2022].

12. Appendix

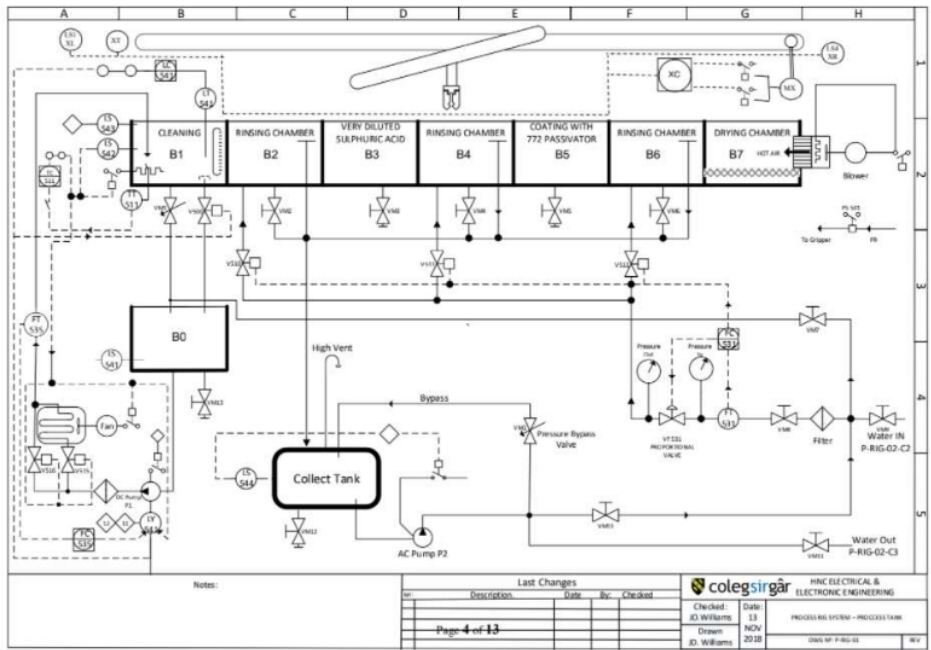


Figure 20 - P&ID Diagram 1

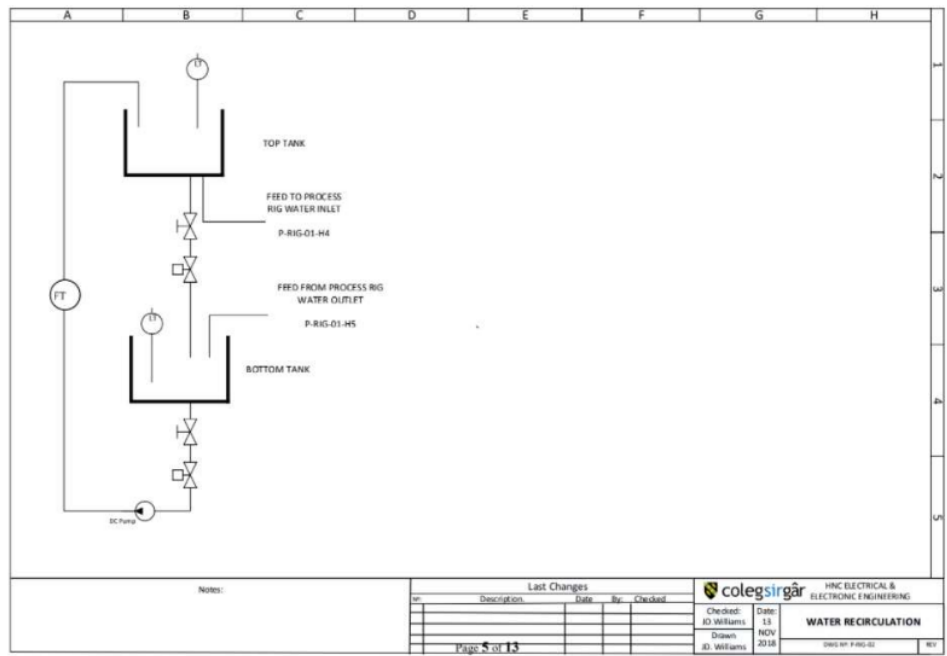


Figure 21 - P&ID Diagram 2

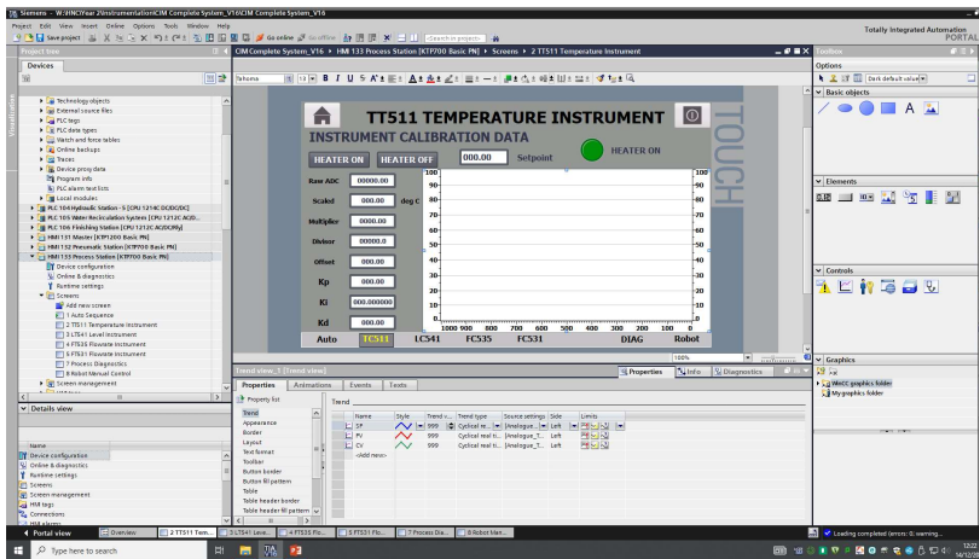


Figure 22 - HMI Screen for Loop TT511

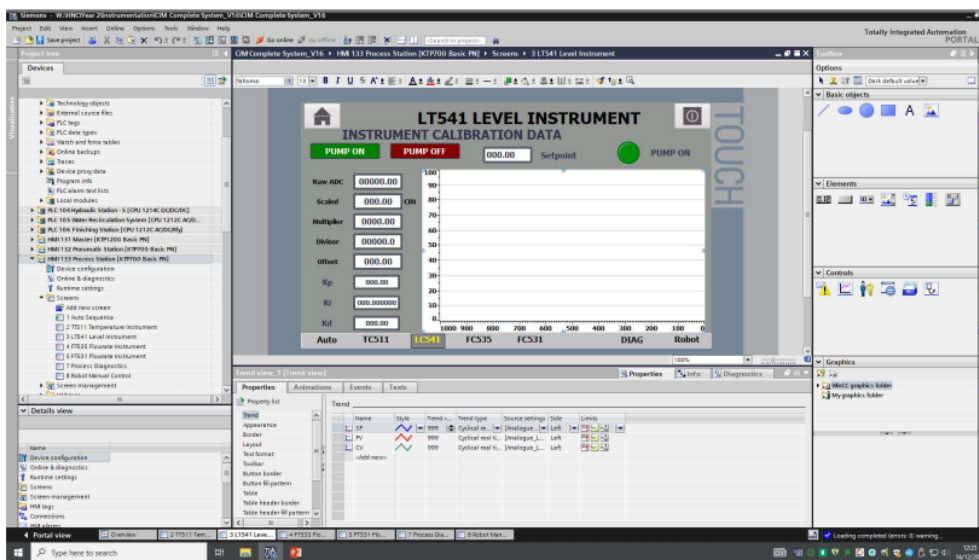


Figure 23 - HMI Screen for Loop LT541

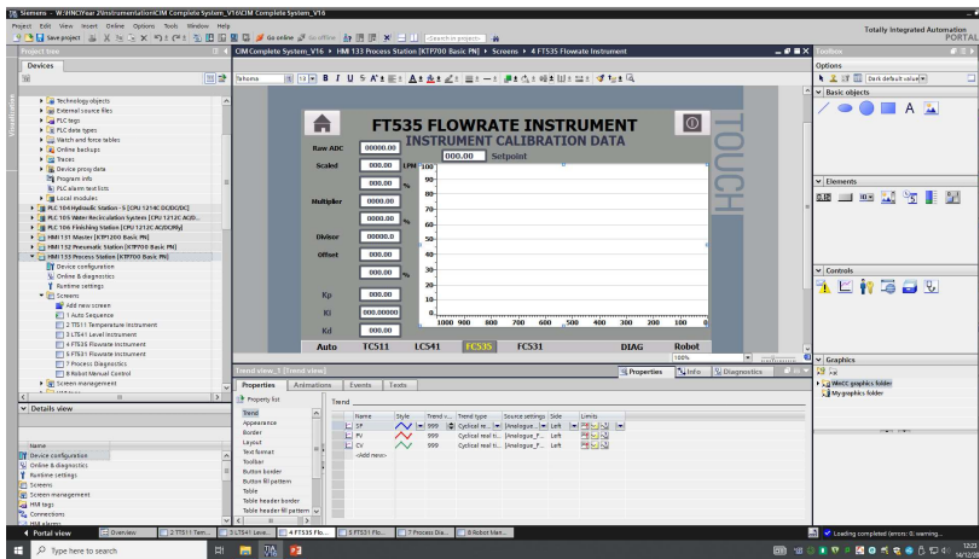


Figure 24 - HMI Screen for Loop FT535

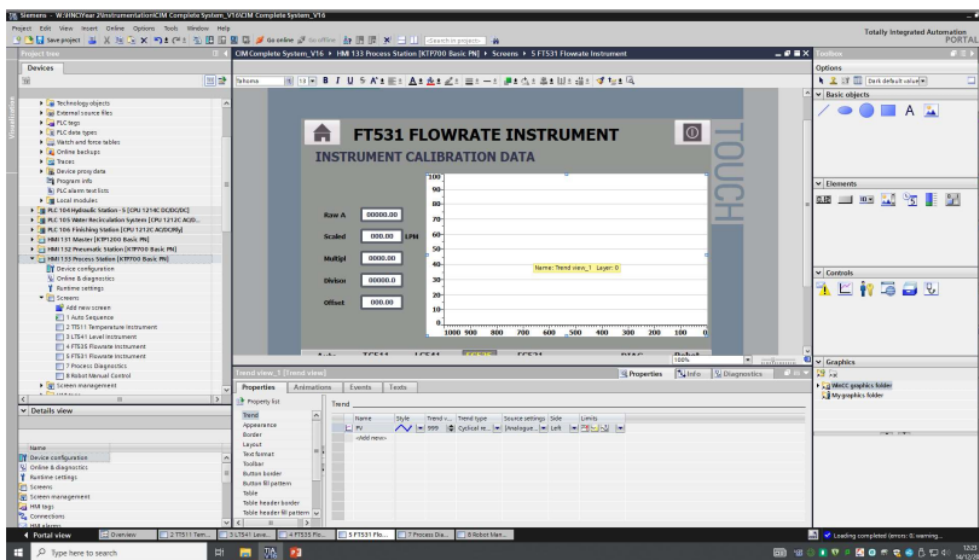


Figure 25 - HMI Screen for Loop FT531

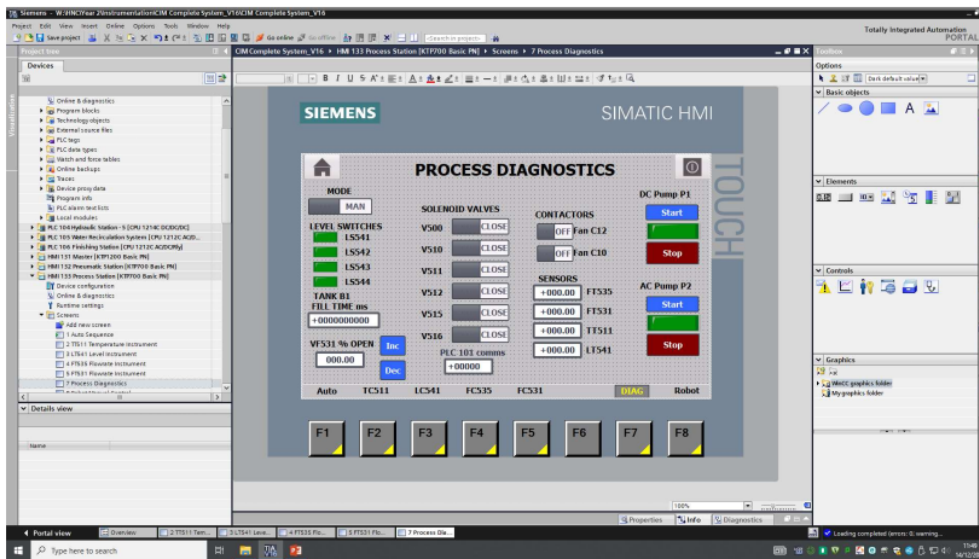


Figure 26 - HMI Screen for Process Diagnostics

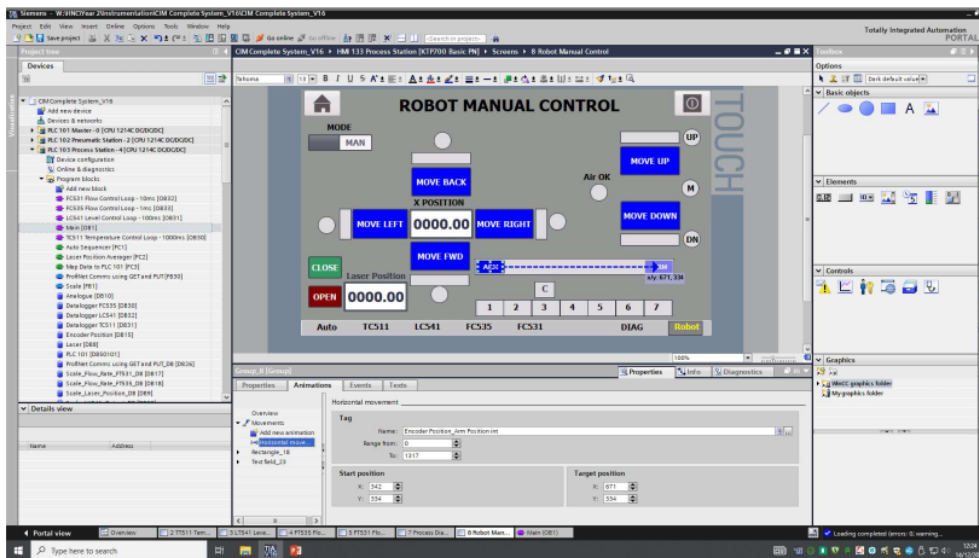


Figure 27 - HMI Screen for Robot Arm Control

TP02 Temperature Transmitter for DIN-rail Type



APPLICATIONS

Features

- Special IC for RTD; high accuracy is assured.
- TP02 with smaller volume so lesser space for installation is required.
- High quality and low price.
- DIN-rail type; quick to install.

Applications

- Monitoring for long-distance temperature signal transmission.
- For industries in heating / ventilation / air conditioning / cooling / water power / electricity, etc.
- For process in agriculture / green house / environmental engineering / food / pharmaceutical industry.



TP02	-	1	1	1	0	-	1
Installation		Function	Input	Output	Power Supply		Temperature Range
02: DIN-rail way		1: 1-channel	1: PT1000 (3-wire)	1: 4-20mA	0: 10-30VDC 2: 5-wire loop power 3: 0-30VDC		1: -50~+50°C 4: 0~100°C 5: 0~200°C W: special span

DIMENSION



CONNECTION DIAGRAM

TECHNICAL SHEET

INPUT	
Input	PT 1000 (3-wire)
Cable resistance	≤ 50 Ω (3-wires with the same resistance)
PT1000 sensor current	≤ 0.8mA
ZERO adjustment range	±10 %
SPAN adjustment range	±10 %
OUTPUT	
Output	4-20mA; 2-wire
Accuracy	± 0.1 % of F.S.
Load resistance	≤ (supply voltage - 8V) / 0.024A
Load resistance stability	±0.05% / 1000
Power stability	±0.025% / V
Temperature drift	≤ ±0.015% / °C
Calibration temperature	20~25°C
Response time	≤ 250 ms

Figure 28 - Data Sheet for PT100 Signal Conditioner

Operating instructions

Pressure Transmitter Cerabar PMC 133

Technical Data

see also Ti 105P/001e

Construction, Materials

Housing: synthetic (POM) or cast aluminium
Protection: IP 65 (DIN 40050)

Wetted Materials

Process connection: 2.0401 brass or 1.4581 stainless steel (1.4571 stainless steel with high pressure measuring cell)
Ceramic diaphragm up to 60 bar:
aluminum oxide ceramic 98 %
Process seal gasket up to 60 bar:
e.g. Viton, EPDM, Kalrez, etc.
Above 100 bar: 1.4401 special steel diaphragm

Permissible Temperatures

Operating limits:
Housing: -20 °C ... +70 °C
Diaphragm: -20 °C ... +80 °C
(up to +130 °C for short periods)
Storage: -40 °C ... +85 °C

Accuracy

- Ceramic measuring cell
Linearity: ±0.2 % or ±0.5 % of adjusted range
Hysteresis: better than 0.01% of full scale
Installation: any orientation
Temperature variation typical ±0.15 %/10 °C of full scale, of the measuring cell (see Table).
- High Pressure Measuring Cell
Linearity: ±0.5 % of full scale
Hysteresis/Reproducibility: ±0.1 % of full scale

Temperature effects of maximum measuring span	0...50 °C	-20...0 °C +55...75 °C
Tk zero point	0.2 %/10K	0.3 %/10K
Tk span	0.2 %/10K	0.3 %/10K

Technical Data
Measuring cells

Type of Meas. cell	Max. permiss. overload	T ₁	Type of pressure G gauge-A absolute
G...0...+0.2 bar	10 bar	± 0.6 mbar/10 K	G
G...1...+1 bar	10 bar	± 0.6 mbar/10 K	G
G...1...+3 bar	25 bar	± 0.6 mbar/10 K	G
G...1...+8 bar	40 bar	± 0.6 mbar/10 K	G
G...0.2 bar	10 bar	± 0.6 mbar/10 K	G
G...0.2 bar	10 bar	± 0.6 mbar/10 K	G
G...0.1 bar	10 bar	± 0.6 mbar/10 K	G or A
G...0.1 bar	10 bar	± 1.5 mbar/10 K	G or A
G...0.2 bar	25 bar	± 0.6 mbar/10 K	G or A
G...0.4 bar	25 bar	± 0.6 mbar/10 K	G or A
G...10 bar	40 bar	± 1.5 mbar/10 K	G or A
G...20 bar	40 bar	± 3.0 mbar/10 K	G or A
G...40 bar	60 bar	± 3.0 mbar/10 K	G or A
G...60 bar	80 bar	± 3.0 mbar/10 K	G or A
G...100 bar	160 bar	± 3.0 mbar/10 K	G or A
G...250 bar*	400 bar	± 5.0 mbar/10 K	G or A
G...400 bar*	600 bar	± 5.0 mbar/10 K	G or A
G...600 bar*	800 bar	± 5.0 mbar/10 K	G or A

* polysilicone sensor for high pressure

Figure 29 - Data Sheet Section for Pressure Transmitter

4 Technical data

Input	
Description of the input	Frequency input
Configuration/parameter	Yes
Available input signals	4xTxDSP transducer outputs NAMUR outputs Flange plug contact (dry contact)
Max. voltage input signal	50 V (sin. DC voltage)
Frequency measuring range	0.002 Hz ... 20 kHz (2P wheels) 0.002 Hz ... 80 kHz (T each-in wheel)
Output	
Output description	Voltage output / current output
Voltage output signal	0 V ... 3 V 1 V ... 5 V 0 V ... 5 V
Max. voltage output signal	approx. 12.5 V
Current output signal	0 mA ... 20 mA 4 mA ... 20 mA 20 mA ... 0 mA 20 mA ... 4 mA
Max. current output signal	24.8 mA
Configuration/parameter	Yes
Load/output load voltage output	$\geq 10 \Omega$
Range	0.25 mV/div
Load/output load current output	500 Ω (at 20 mA)
Supply	
Supply voltage range	9.6 V DC ... 30 V DC; The T connector ME 6.2 TBUB 2.1/3/5-07-0/01 DIN Order No. 380101 can be used to bridge the supply voltage. It can be triggered onto a 30 mm DIN rail according to EN 60715
Typical current consumption	0.26 mA (at $I_{bias} = 20$ mA, 24 V DC, load 500 Ω)
Power consumption	~ 800 mW (at $I_{bias} = 20$ mA, 24 V DC, load 500 Ω)
Diagnostic and status indicators	
Status display	LED red
General data	
Transmission error in the set measuring range	0.1 %
Maximum temperature coefficient	0.01 %/K
Time response (0-95%)	< 30 ms (At $I = 500$ Hz)
Electrical isolation	Basic insulation according to EN 61010
Surge voltage category	II
Mounting position	Any
Degree of protection	IP20
Protection degree	0
Rated insulation voltage	50 V AC/DC
Test voltage, insulated supply	1.5 kV (30 Hz, 1 min.)
Dimensions W x H x D	62 mm (5) x 100 x 100 mm
Type of housing	PBT green

Figure 30 - Data Sheet for F-V Signal Conditioner

1702304

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

61 / 100

PAGE 1

Text Comment. A well structured and presented report. Good evidence of reseach from a range of sources correctly cited using the Harvard Method. Good design adaptation but no testing evidence.

PAGE 2

PAGE 3

PAGE 4

Text Comment. do not include datasheets

PAGE 5

PAGE 6

Text Comment. what about I-O link?

PAGE 7

PAGE 8

Text Comment. static sensitivity?

PAGE 9

PAGE 10

Text Comment. lab

Text Comment. signal conditioner

PAGE 11

PAGE 12

Text Comment. static sensitivity?

PAGE 13

PAGE 14

PAGE 15

Text Comment. relationship

PAGE 16

PAGE 17

Text Comment. where is your testing evidence and table?

PAGE 18

PAGE 19

PAGE 20

Text Comment. good range of sources

PAGE 21

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26

PAGE 27

1. ENGAGEMENT WITH LITERATURE

-  Engagement with an extensive range of relevant and credible literature. Consistently accurate application of referencing. (14/20) **14**

2. KNOWLEDGE AND UNDERSTANDING

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

3. COGNITIVE AND INTELLECTUAL

-  Good evaluation of the underlying concepts and principles. Can interpret qualitative and quantitative data, with minor errors. An emerging ability to use evidence to support the argument. Mostly valid arguments and logical judgements. 11/20 **11**

4. PRACTICAL APPLICATION

-  A good and appropriate application of basic methods, materials, tools and/or techniques. Clear appreciation of the context of the application. **11**

Good evidence of different approaches to problem-solving in particular contexts and proposes mostly appropriate solutions. 11/20

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 13/20

13