

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Kelly Williams	Student ID number:	
Programme:	HNC Instrumentation Engineering		
Module:	Instrumentation, Automation and Control		
Module code:	PCEE4011	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Jason Pointer	Internal Verifier:	Nigel Richards
Assignment Title:	Temperature Measurement System and Signal Transmission	Word count (or equivalent):	2000
Submission deadline:	23/01/25	Return date of provisional marks & written feedback:	06/02/25
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark: Work which is submitted up to 1 week late will be capped at 40% for the first attempt and will be awarded a mark of 0% for re-assessment. Late submission penalties may be lifted only if there is an approved extenuating circumstances claim. Work submitted more than 1 week late will be considered as a non-submission and will not be marked. The work may be considered as a submission for reassessment if offered by an Examining Board or if there is an approved extenuating circumstances claim.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

1. Explain the principles of operation for a range of industrial measuring systems and demonstrate an understanding of the requirement for interfacing sensors with conditioning, indication and analogue/digital signal transmission circuits.
2. Select an appropriate sensor for specific operation and demonstrate an understanding of their benefits and limitations with respect to measuring and control system applications.

STUDENT FEEDBACK FORM

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

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	15	9
Engagement with a wide range of literature, including sources retrieved independently. Generally sound referencing, with very few inaccuracies or inconsistencies.		
2. Knowledge and Understanding Skills	40	28.3
Task 1 - 66%. Task 2 - 72%. Task 3 - 75%. Task 4 - 70%. Excellent knowledge and understanding of the basic underlying concepts and principles for each task.		
3. Cognitive and Intellectual Skills	10	5.7
Good evaluation of the underlying concepts and principles for tasks 2 and 3.		
4. Practical Application Skills	25	19.88
Task 1 - 82%. Task 2 - 77%. An excellent application of practical work for tasks 2 and 3, very good use of the test equipment and Multisim to obtain the required test results.		
5. Transferable Skills for Life and Professional Practice	10	7
Work is coherent, very fluent and is presented professionally. Excellent layout making the assignment easy to read.		

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)

Late Submission Penalties (tick if appropriate)

Up to 1 week late (40% Max)

Over 1 week late (0%)

70%

TEMPERATURE MEASUREMENT SYSTEM AND SIGNAL TRANSMISSION

KELLY WILLIAMS

LECTURER: JASON POINTER



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Task 1

Platinum RTD

A platinum resistance temperature detector (RTD) is a temperature measurement sensor in which the resistance depends on the temperature. When the temperature changes, the sensors resistance changes. Platinum is the most common material used for constructing RTD sensors as it has a reliable, repeatable and linear temperature-resistance relationship. Jones (1974) states that platinum 'has a particularly high temperature coefficient of resistance and stability in use' (p.309). The RTD is constructed with the platinum wire (resistance element) is wound round a ceramic core and embedded within a protective casing, as shown in figure 1.1. The temperature coefficient of an RTD is $0.003851/^{\circ}\text{C}$ and can be calculated using the following formula:

$$\alpha = \frac{R_{100} - R_0}{R_0 \times 100^{\circ}\text{C}}$$

Where:

α = temperature coefficient

R_{100} = resistance at 100°C

R_0 = resistance at 0°C

Diefenderfer and Holton (1994) explain that 'at 0°C the length and area of the wire are usually chosen such that the resistance of the PRDT is 100.0Ω ' (p.131). Simply, a Pt100 has a resistance of 100 ohms at 0°C with an increase of 0.385 ohms per degree.

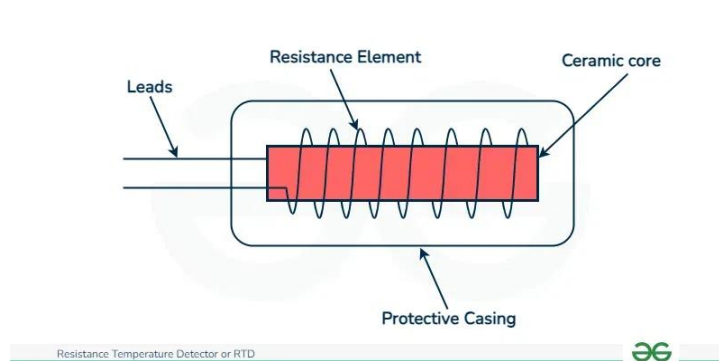


Figure 1.1 – RTD Construction

The key features of an RTD include high accuracy and stability. Pt100 sensors are available in different accuracy classes with the most common being AA, A, B and C. The accuracy of the sensor ranges from $\pm 0.1^{\circ}\text{C}$ to $\pm 0.6^{\circ}\text{C}$ which is defined in IEC 60751 (Beamex). RTDs are suitable for high-precision applications due to their long-term stability and minimal drift. They also have a wide temperature range typically from -200°C to $+500^{\circ}\text{C}$ as the one shown in appendix 1 but some sensors can work up to temperatures of $+850^{\circ}\text{C}$. Compared to thermistors, RTDs have a more linear resistance-to-temperature relationship making them easier to calibrate and fault find as shown in figure 1.2. ✓

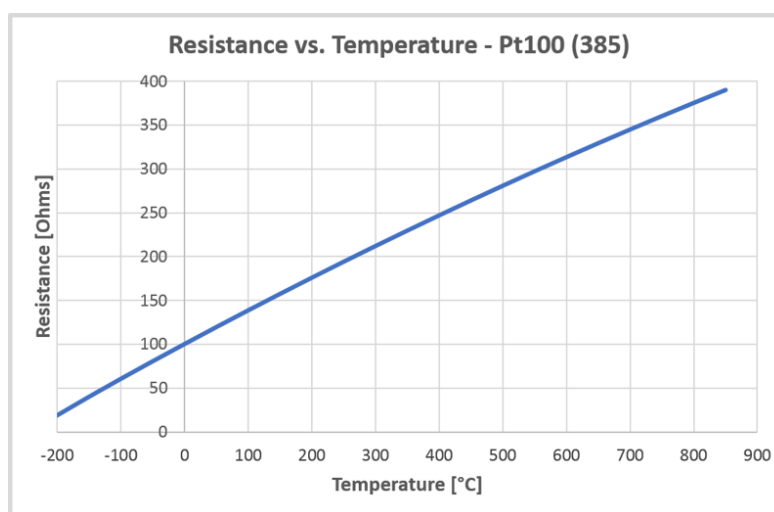


Figure 1.2 – Resistance vs Temperature Linearity

Platinum RTDs are ideal for high-temperature and high-precision measurements making them suitable for process control in oil and gas, chemical and pharmaceutical industries. RTDs are more sensitive to temperature changes and can respond quickly and accurately. When assessing the environmental considerations, RTDs are resistant to corrosive environment but may require a protective housing, such as a thermowell to protect it from the process medium and provide a longer life span. The constraints of using an RTD is that they are larger in size compared to a thermistor and require more space for installation and maintenance. Also, RTDs are more expensive but have higher precision of the manufacturing process. Typically, RTDs are easily available and can be configured for different industrial applications. ✓

NTC Thermistor

A negative temperature coefficient (NTC) thermistor is a type of temperature sensor typically made from ceramic material. The NTC thermistor has a negative temperature coefficient meaning that their resistance decreases as the temperature increases. Figure 1.3 shows the construction of a NTC thermistor where a piece of semiconductive material is placed between two conductors.

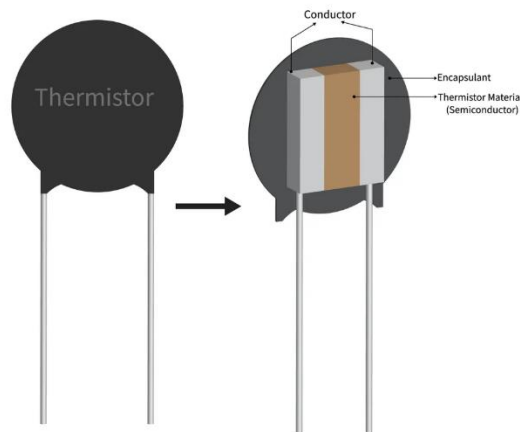


Figure 1.3 – NTC Thermistor Construction

Unlike the platinum RTD, a thermistor has a non-linear response to temperature change. Since the temperature-resistance curve is non-linear, special consideration is required during calibrations. The NTC thermistor is smaller in size compared to the RTD and are also inexpensive in contrast to other temperature sensors. The typical temperature range of a thermistor is -50°C to $+150^{\circ}\text{C}$ limiting its suitability for different processes. When measuring narrow temperature ranges, the thermistor can offer high accuracy but is generally less accurate than RTDs over a wide range. The thermistor shown in appendix 2 has a tolerance of $\pm 0.9\%$.

Thermistors are not as robust as RTDs as they are susceptible to moisture, humidity and harsh chemicals. The main constraint of a thermistor is their non-linear resistance response to temperature. They are not suitable for high temperature applications and would be inappropriate for process control where accuracy is important. Tooley (2015) describes that 'thermistors are widely used in temperature sensing and temperature compensating applications' (p.30). Compared to RTDs, NTC thermistors are cost-effective and would be suitable where high precision is not



critical or where there are budget constraints. They are widely available and can be easily sourced to be used in manufacturing and consumer electronics. Jones (1974) states 'a thermistor temperature element is considerably more sensitive than the conventional metal wire resistance element' (p.313).

would like to see more spec information.

Task 2

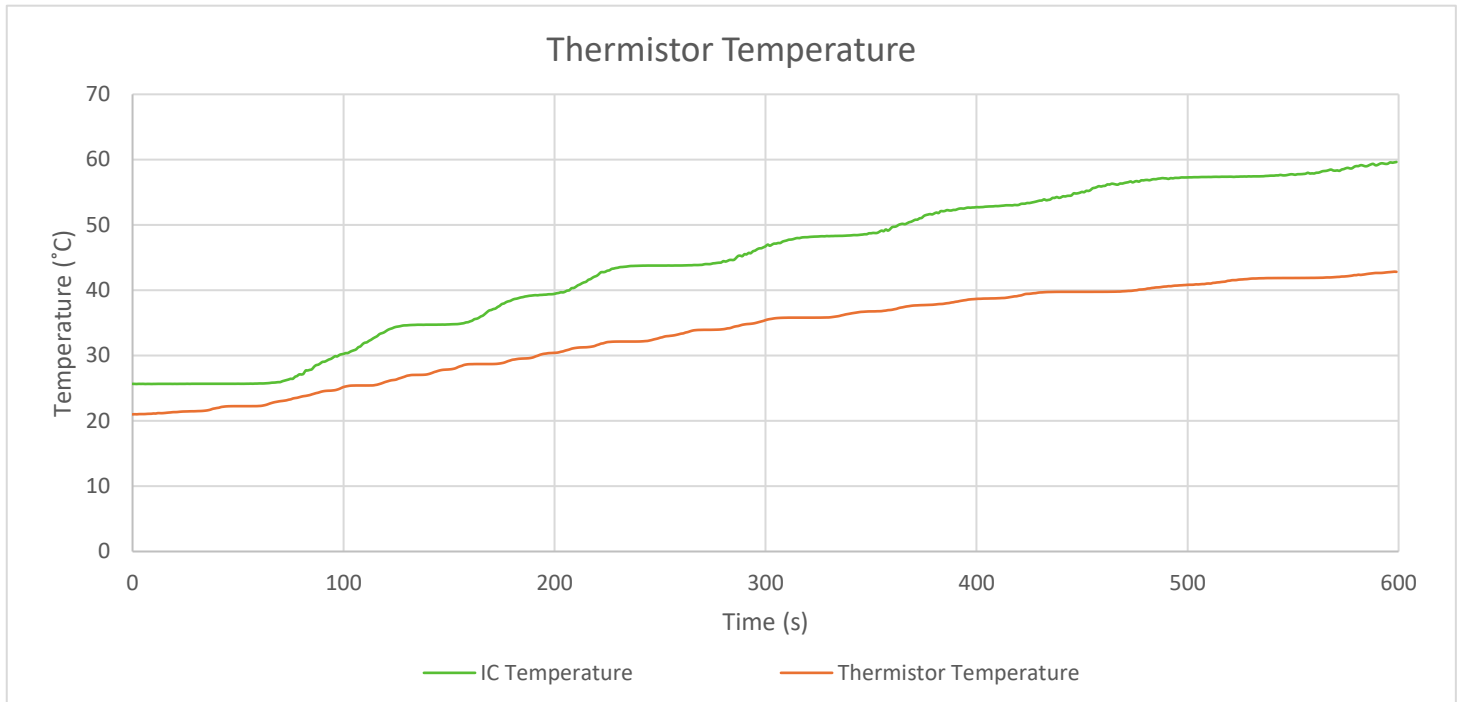


Figure 2.1 – Thermistor Temperature Graph

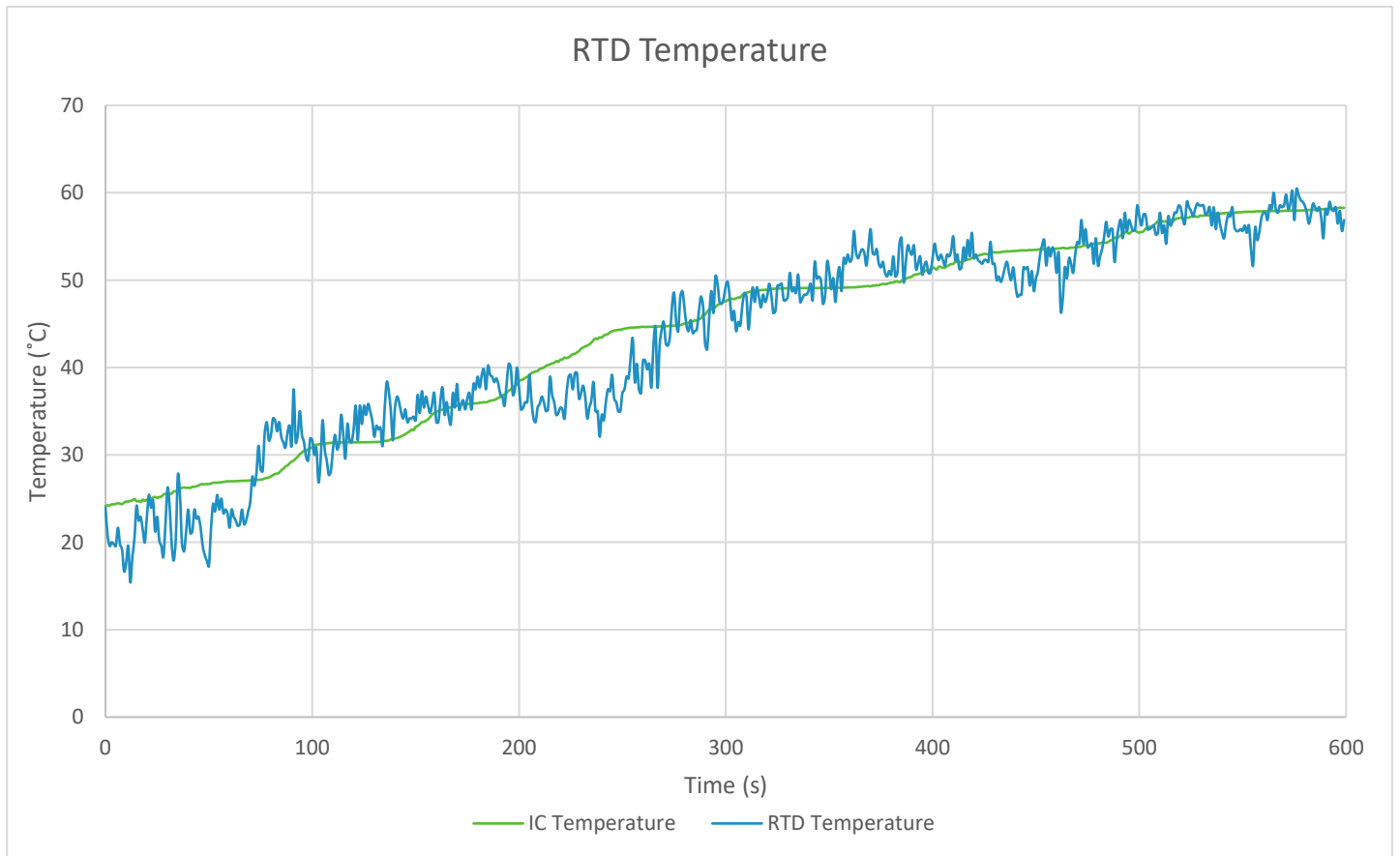


Figure 2.2 – RTD Temperature Graph

When analysing the graphs in figure 2.1 and figure 2.2 it can be seen that the readings from the RTD sensor are consistently close to the IC sensor. The accuracy of the RTD is high compared to the thermistor. It typically measures the same temperature as the IC sensor. From the start of the analysis, the thermistor sensor has nearly a 20% error and continues to have a low accuracy as the temperature is increased. ✓

Over time, the thermistor reading drifts further away from the IC sensor reading generating a larger percentage error. Since it is a slow but consistent shift from the reference error, it can be determined that there is an error in the sensor's performance. The percentage error generated over the analysis for both sensors can be seen in figure 2.3. it shows that there is a consistent error with the thermistor sensor, but the RTD sensor generally has a low percentage error. ✓

The sensitivity of the RTD sensor is quite high and is visible from the data collected in figure 2.2. Although the RTD readings follow the true value, the sensor is oversensitive, constantly changing as the temperature is increased and produces an uneven response. To have a smoother response, the readings could have been taken every 5 seconds. The thermistor sensor is less sensitive to temperature change and deviates from the IC sensor as the temperature is increased. ✓

The response from the RTD sensor show that there are fluctuations with the data collected which suggests that the sensors stability is a concern. However, the sensor responds quickly to the change in temperature and can maintain a high level of accuracy. Whereas the thermistor sensor does not exhibit any fluctuations but has a slower response to the temperature change. Also, with the RTD sensor its output can be predicted which aids with fault finding whereas the thermistor has an exponential response and cannot be predicted easily. ✓

Based on the comparison of the sensors to the IC temperature sensor, the RTD sensor is more accurate and reliable. For process control, an RTD sensor would be selected due to its ability to provide accurate readings and respond quickly to temperature changes. The response time of the RTD is quicker than that is the



thermistor. By analysing the percentage error shown in figure 2.3, the RTDs performance is more accurate and would be the preferable sensor.

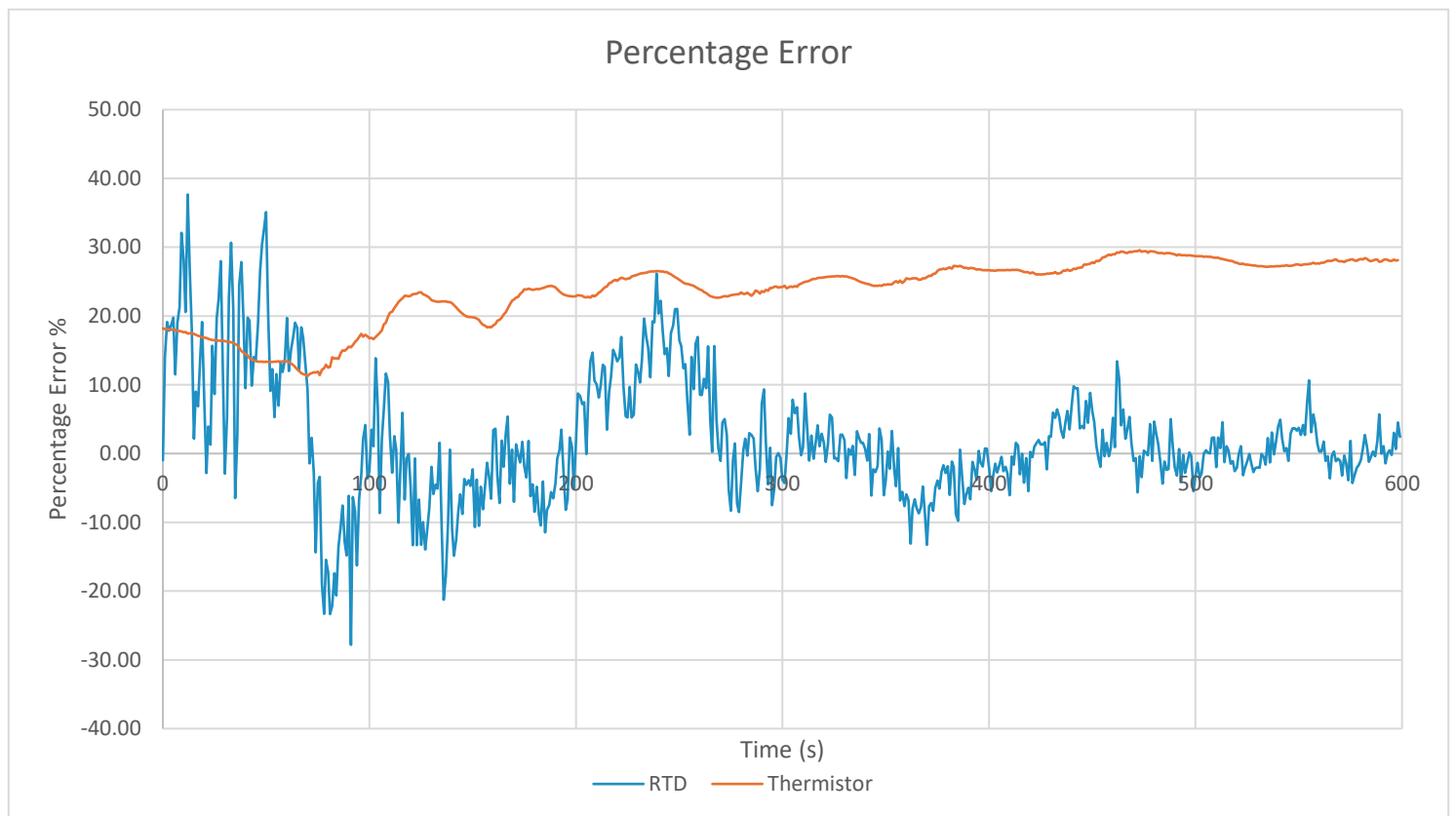


Figure 2.3 – Percentage Error Graph



Task 3

Based on the evaluation of the two sensors that have been tested, the RTD was the more suitable sensor due to its accuracy and response time.

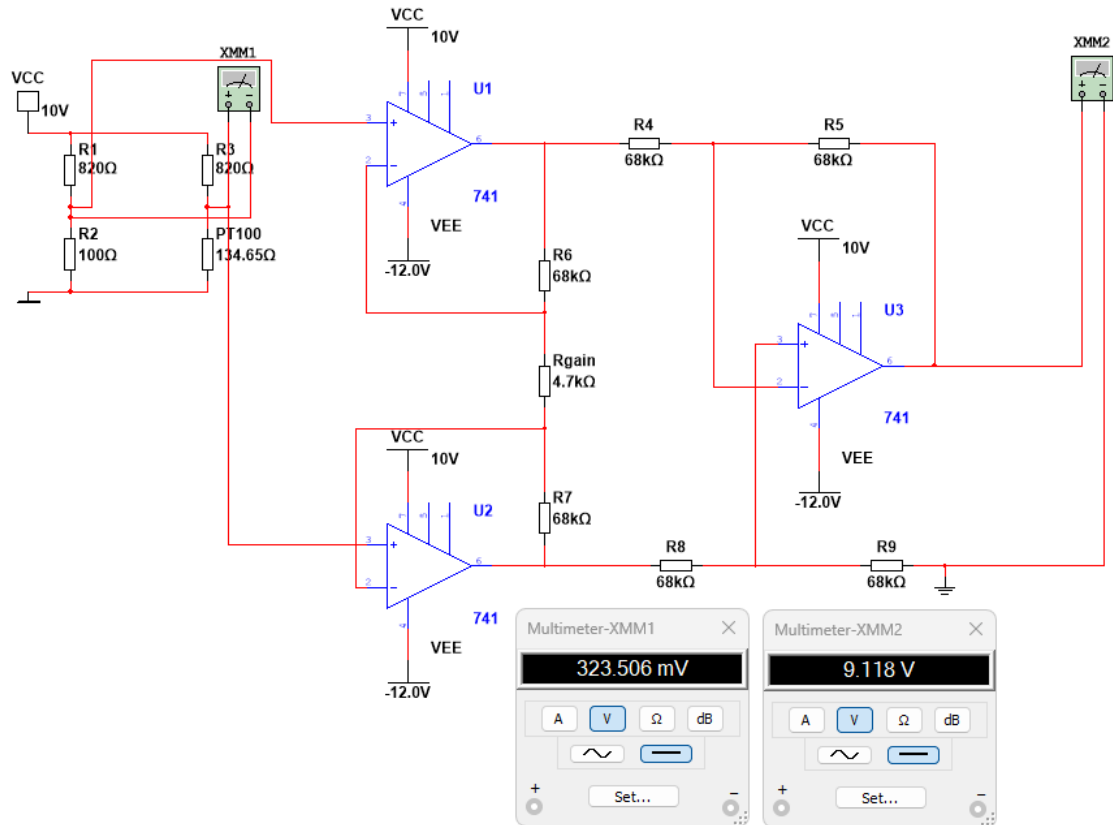


Figure 3.1 – Signal Processing Circuit

PT100

$$R_T = R_0 + \alpha t$$

$$\alpha = 0.385$$

$$\text{at } 10^\circ\text{C } R_0 = 100\Omega$$

$$R_T = 100 + 10 \times 0.385$$

$$R_T = 103.85\Omega$$

$$V_{out} = V_{in} \left(\frac{R_3}{R_1 + R_2} - \frac{PT100}{R_2 + PT100} \right)$$

Instrumentational Amplifier

$$A_v = \left(1 + \frac{2R}{R_{gain}}\right)$$

$$A_v = \frac{V_{out}}{V_{in}}$$

$$\text{at } 100^{\circ}\text{C } V_{out} = 10\text{V}$$

$$A_v = \frac{10}{0.35801}$$

$$A_v = 27.93$$

$$R = \frac{R_{gain} \times (A_v - 1)}{2}$$

$$R = \frac{4.7 \times (27.93 - 1)}{2}$$

$$R = 63.29\text{k}\Omega$$

Nearest value $68\text{k}\Omega$

Wheatstone Bridge			Instrumental Amplifier		
R1 =	820	Ω	R =	68	$\text{k}\Omega$
R2 =	820	Ω	R _{gain} =	4.7	$\text{k}\Omega$
R3 =	100	Ω	V _s =	10	V

Temperature ($^{\circ}\text{C}$)	PT 100 (Ω)	Bridge Output Voltage (mV)	Amplifier Output Voltage (V)
0	100	0.00	0.00
10	103.85	37.14	1.11
20	107.7	73.98	2.21
30	111.55	110.51	3.31
40	115.4	146.74	4.39
50	119.25	182.67	5.47
60	123.1	218.31	6.54
70	126.95	253.66	7.59
80	130.8	288.73	8.64
90	134.65	323.51	9.68
100	138.5	358.01	10.72

Table 3.1 – Calculated Values

Temperature (°C)	PT 100 (Ω)	Bridge Output Voltage (mV)	Amplifier Output Voltage (V)
0	100	-0.86	0.003176
10	103.85	37.144	1.115
20	107.7	73.979	2.217
30	111.55	110.509	3.311
40	115.4	146.74	4.395
50	119.25	182.673	5.471
60	123.1	218.312	6.537
70	126.95	253.662	7.595
80	130.8	288.726	8.645
90	134.65	323.506	9.118
100	138.5	358.008	9.118

Table 3.2 – Measured Values

The overall performance of the circuit provides an accurate output voltage across the temperature range of 0-100°C. comparing the measured results to the calculated results show that there are small differences. The actual obtains results differ from the calculated results since the nearest equivalent resistor value must be used for the simulation. With the simulation, exact resistance values are used whereas in reality each resistor will have its own tolerance and would therefore change the output readings. There would also be potential losses in the op amp, and it has the potential to generate its own internal voltage. This would be the reasoning for why there is a voltage reading from the amplifier at 0°C on the measured values.

Task 4

Fieldbus Foundation

The fieldbus foundation is a digital communication system which similarly to HART protocol, has two-way communication. It allows for both analogue and digital data to be transmitted between field devices and bidirectional communication between the control system and field devices. Communication between devices can be achieved without the need of a central controller. Figure 4.1 shows the connections between the devices and the network and how the fieldbus foundations with allow for communication between them all. ✓

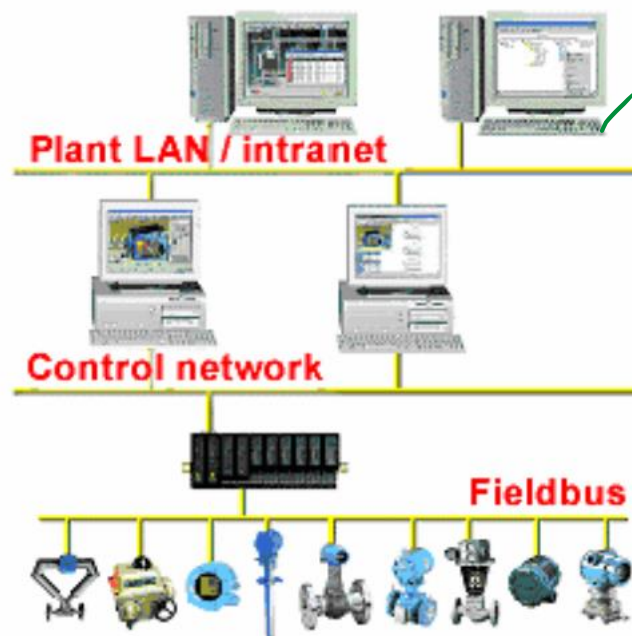


Figure 4.1 – Fieldbus Foundation

The fieldbus foundation has very little limitations supporting up to 32 devices on a single pair of wires. Communications speeds are generally quite high enabling real time data to be communicated and displayed without any time delay (Emerson). Foundation fieldbus devices can also communicate if they are operating correctly and indicate if the information, they are sending back is good, bad or uncertain. Unlike other methods of signal transmission, this eliminates the need of routine checks thus saving money. However, Powell and Vanderlinde (2013) state that 'Foundation Fieldbus require more than one protocol to create all the different applications in a process plant' (p.9). ✓



Application of fieldbus foundation include oil and gas where there are often complex processes and precise control, and monitoring is required. Data can be sent at high speed and automation control is available. ✓

HART Protocol

HART (Highway Addressable Remote Transducer) is a communication protocol which is called a hybrid protocol because it combines both analogue and digital communication (Emerson). Analogue signals can be communicated via 4-20mA signals whilst also communicating additional information on a digital signal. The digital signal is also carried by a 4-20mA signal but does not affect the analogue reading as it is removed from the analogue signal by filtering techniques.

HART protocol can send and receive digital information but can only communicate one way with analogue signal. Using analogue signal, information is sent only one way either from the host to the device or from the device to the host. HART digital communication signal enables control signals to be sent as well as information to be sent back. For example, a valve controller can be told how much to move and can also send the host what is happening with the valve. Compared to Profibus and fieldbus foundation, HART protocol does operate at a slower speed making it not suitable for critical processes. As described by Powell and Vanderlinde (2013) 'HART is a fairly simple protocol and does not have the detailed profile concept of PROFIBUS PA' (p.15). ✓

Applications of HART protocol includes process industries where the process is required to be monitored in terms of flow, pressure, temperature and level measurement. Analogue signals can be easily communicated using this type of protocol and provides the ability to access device diagnostics. ✓

Profibus

Profibus, short for "Process Field Bus" is another communication protocol to share data effectively. Profibus PA is used to monitor measuring instruments within the process and can be used to replace conventional systems like HART. Profibus DP is used to operate sensors and actuator within the process and is used for fast control

processes. Worth (2023) states that 'Profibus DP and PA systems can be combined through the use of a segment coupler' which is shown in figure 4.2. Profibus is designed to support high-speed data transfer✓ and is used in environments where fast and reliable communication is crucial.

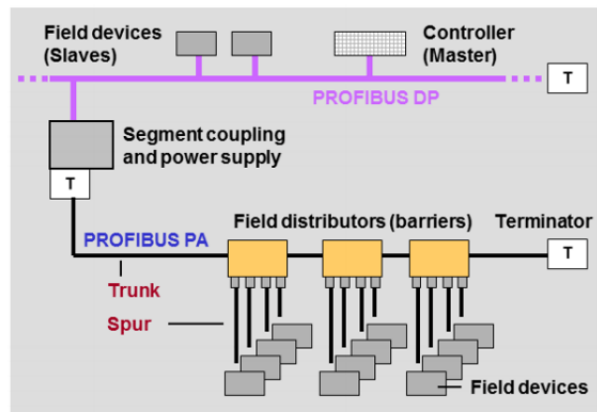


Figure 4.2 – Profibus DP/PA

The advantage of using Profibus over HART is that high speed data transfer is achievable and will operate with a large network size. It also can integrate both digital and analogue devices. Since Profibus is supported from a wide range of manufacturers, it is easily accessible and is not limited with the type of field devices used. Powell and Vandelinde (2013) states that 'In PROFIBUS and PROFINET, the values in the field devices can be simulated, making it very easy and fast to simulate a control loop and significantly speeding up commissioning' (p.5). ✓

Applications of Profibus include process control within industries such as pharmaceuticals and chemical processing. Equipment such as pumps valves and sensors can be controlled using this form of signal transmission. Analogue signals such as temperature and pressure can be communicated using Profibus, as well as valve positions. ✓

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Figure 1.1 - <https://media.geeksforgeeks.org/wp-content/uploads/20240219132347/image-199.webp>

Figure 1.2 - https://cdn2.hubspot.net/hubfs/2203666/Calibration%20Essentials%20Temperature%20Book.pdf?_hstc=107807261.995e43c2eb1a5067b3316c650382a7a9.1718780856005.1718780856005.1718780856005.1&_hssc=107807261.1.1718780856005&_hsfp=325150612&_hsCtaTracking=72532d13-73bc-4aeb-8d4d-baec1eb8acbf%7C1a23daf6-7eef-448e-a721-28729d6ee498

Figure 1.3 - <https://images.wevolver.com/eyJidWNrZXQiOiJ3ZXZvbHZlci1wcm9qZWNO0LWltYWdlcyIsImt1eSI6ImZyb2FsYS8xNzlxOTk4ODQzOTcxLXRoZXJtaXN0b3JfaW50ZXJuYWxfc3RydWN0dXJlX2R5YWdyYW0uanBnIiwizWRpdHMiOncicmVzaXplIjp7IndpZHRoljo5NTAsImZpdCI6ImNvdmdVylIn19fQ==>

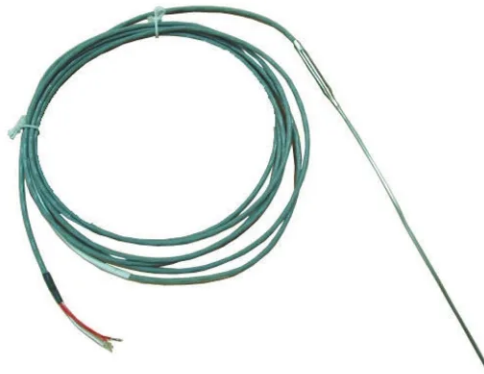
Figure 4.2 - <https://toolbox.igus.com/wp-content/uploads/2024/02/profibus-line-topology-dp-pa.png>

Appendix 1

Correge PT100 RTD Sensor, 2.5mm Dia, 500mm Long, 3 Wire, Probe, +500°C Max ATEX



RS Stock No.: **547-7310** | Mfr. Part No.: **EX 04106** | Brand: [Correge](#)



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Technical Reference	Legislation and Compliance	Product Details	Specifications
Attribute		Value	
Sensor Type		PT100	
Probe Length		500mm	
Probe Diameter		2.5mm	
Minimum Temperature Sensed		-200°C	
Maximum Temperature Sensed		+500°C	
Termination Type		Cable	
Cable Length		3m	
Probe Material		Stainless Steel	
Process Connection		Probe	
Number Of Wires		3	
Hazardous Area Certification		ATEX	



Appendix 2

Internal

Thermistor ICs



Product Description

Upgrade your temperature sensing and control game with RS PRO NTC Thermistors. Designed for precision and reliability, these high-quality thermistors are perfect for a wide range of applications. Whether you need to monitor temperature in industrial processes, HVAC systems, or electronic devices, our thermistors have got you covered. With their ability to accurately measure temperature by analysing the change in resistance, you can trust RS PRO NTC Thermistors to provide accurate and dependable results every time.

General Specifications

Temperature Coefficient Type	NTC
Thermal Time Constant	10s
Resistance @ 25 °C	10kΩ
Tolerance	±0.9%
Maximum Power Rating	75mW
Length	63.5mm
Depth	2.4mm
Dimensions	2.4 x 63.5mm
Maximum Operating Temperature	+150°C
Minimum Operating Temperature	-80°C