



LEVEL 4 ASSESSMENT SPECIFICATION

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Programme:	HNC Instrumentation Engineering		
Module:	Instrumentation, Automation and Control		
Module code:	PCEE4009	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Nigel Richards	Internal Verifier:	Jason Pointer
Assignment Title:	Temperature Measurement System and Signal Transmission	Word count (or equivalent):	2000
Submission deadline:	14/01/23	Return date of provisional marks & written feedback:	06/02/23
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. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
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.

Introduction

You are working as an Instrumentation Engineer for Solero Measurement Systems Ltd.

Your line manager needs a report on how to select the most appropriate sensor with a view of incorporating them into some of the company's measurement systems.

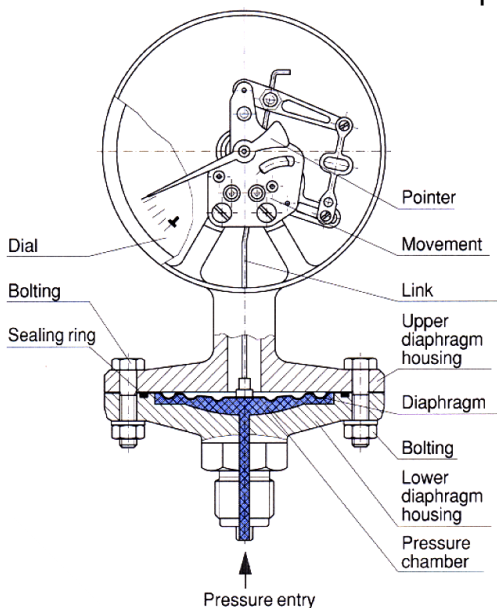
Task 1 –Sensor Functionality

The company would like you to write a report discussing the construction and key features (process variables, performance, benefit, limitations) of 2 different but common pressure sensors with respect to measuring and control system applications

Pressure sensors are a vital part to any system in any industry. These sensors help the operators to understand what is happening in the system and help control it before any hazards are presented. Pressure is defined as a continuous physical force exerted on an object. This means that any pressure sensor requires a physical force to be exerted onto an object to cause a mechanical movement or change in volume.

Diaphragm

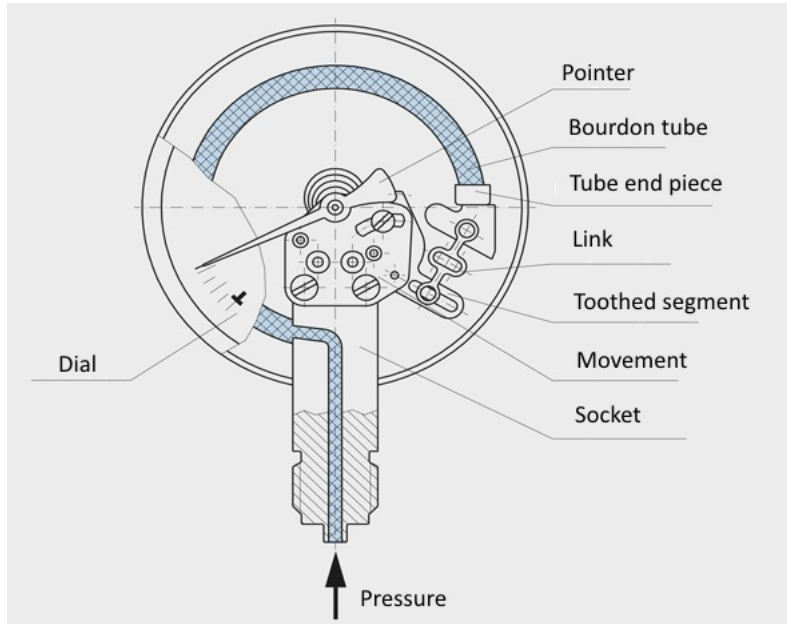
A diaphragm pressure sensor or a membrane sensor works on the principles of deflection of a circular plate. The deflection of this plate acts as the mechanical movement to change a volume. On one side is process pressure which acts as the high-pressure side. The other side is the low-pressure side which is the reference side and could be atmospheric, absolute or gauge. As the process pressure increases it causes a deflection onto the low-pressure side which changes its volume. In Figure 1 is



an absolute pressure gauge. On the low-pressure side is a shaft which is connected to a series of linkages to mechanically move the gauge dial up and down its range. By attaching strain gauges to the plate, they will change resistance when it is deflected. this allows the sensor to be put into a control system as the changes in resistance can be transformed into a signal or output that can be read. These forms of pressure sensors are good for a wide range of processes including harmful substances as the plate acts as a seal. However, diaphragm pressure sensors can only be used in small pressure applications as their average maximum pressure is 25bar. Another limitation this sensor has is that it has an accuracy of $\pm 2\%$.

Bourdon Tube

Bourdon tubes operate on the same principles as a diaphragm as it used process pressure to produce mechanical movement inside the sensor. However, a bourdon tube works slightly differently to a diaphragm as it uses a 'C' shaped tube filled with the system process. as the pressure increases the tube wants to straighten out. As the tube is attached to a series of linkages it causes the dial to move. Figure 2 shows a bourdon tube pressure sensor diagram. As stated by (Reiser, 2016) bourdon gauges can handle "pressures up to 60 bar can be



displayed. For higher pressures, helical or spiral-type Bourdon tubes are used. Depending on the geometry, material and material thickness, pressures up to 7,000 bar can be realised." This presents the idea that bourdon tube gauges are for applications which use high pressures. Although this information is from an internally recognised manufacturer of measuring devices and equipment it is 7 years old and so means that the information can be outdated now. Other benefits to its use are that it has a long service life despite being very simple in design. Bourdon gauges also have a high

accuracy of $\pm 1\%$. There are some limitations however with using this form of pressure sensor. For example, bourdon gauges are susceptible to hysteresis due to the mechanical nature of how it works. Another limitation due to its mechanical operation is that it can be affected by vibrations and shocks in the process.

The company have shortlisted 2 Temperature sensors (Thermistor & RTD-both supplied) for incorporating into a system but want to investigate the accuracy and performance of each by using a resistor device as a low-level heating element operating over a five-minute period. The measurements will be compared with the results of an IC temperature sensor which is currently being used by the company. Using graphs as required analyse and compare of the results, referring to accuracy, sensitivity, errors, and response to recommend the most suitable sensor.

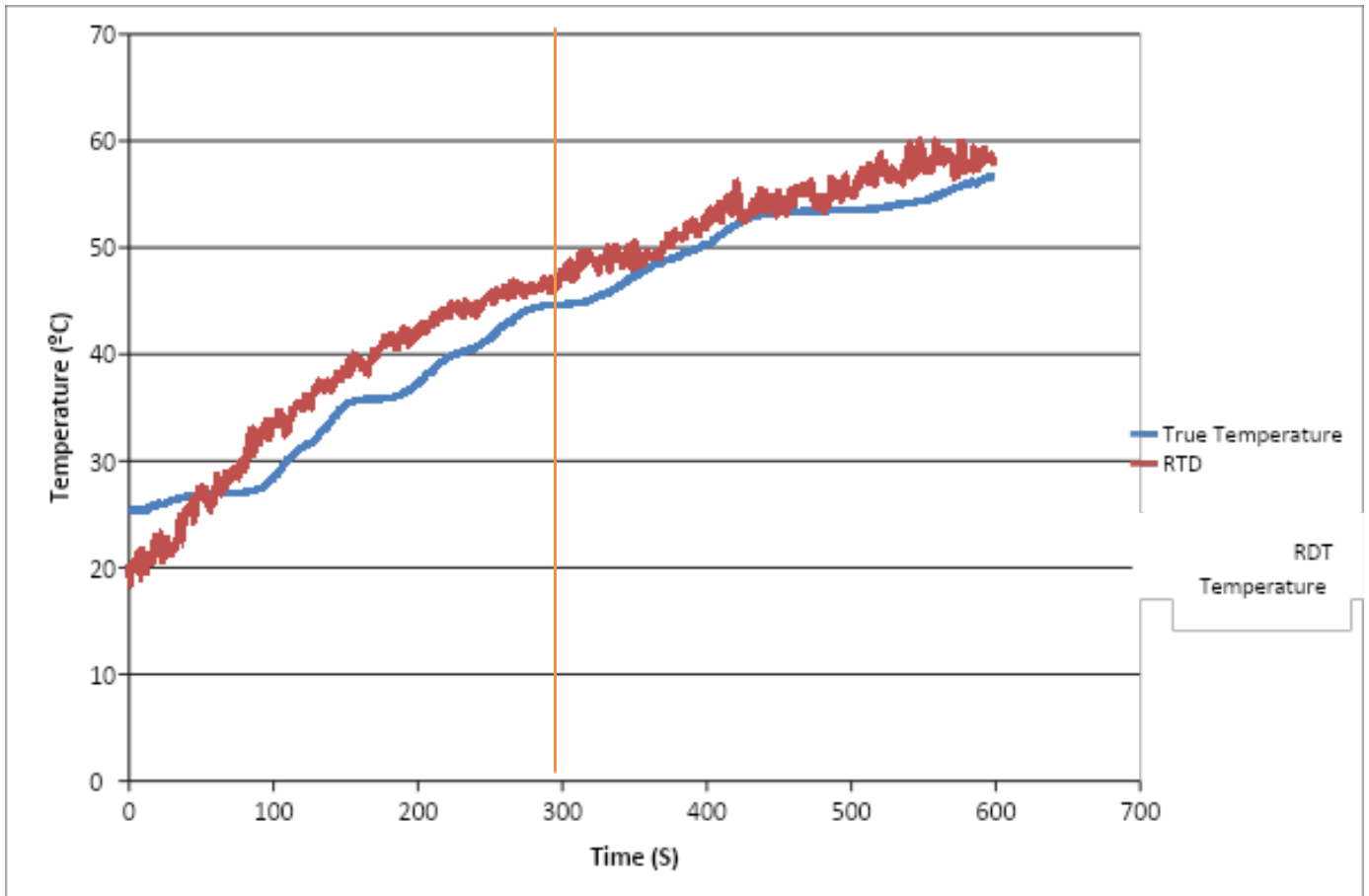


Figure 3 – RTD Temperature Results

Above in Figure 3 is the RTD results from the temperature testing. Here we will only look at the results between 0 and 300 seconds. As can be seen at 0 seconds the RTD is very inaccurate causing the results to be an error. As the timer goes on the true temperature very slowly increases until around 100 seconds into the test. The RTD however, follows a very linear but steep gradient. It is only around the 50 second mark that both the true temperature and RTD match. After this point the RTD fails to match the true temperature again in the time window. Towards the end of the time frame the RTD looks to almost mimic the true temperature as it starts to go flat however there is an error still between them as it inaccurate from the true temperature. Overall, the RTD has a very poor accuracy to the true temperature and has a poor response to changes in temperature. However, the RTD does follow a very jagged but linear line which is good as it can be predicted what its reading will be over the temperature range in the time frame chosen. The RTD is also very sensitive to change however the results do not follow order and decrease and increase over the linear line. This could be due many other issues such as noise or even air changes due to an air flow in the test room. ✓

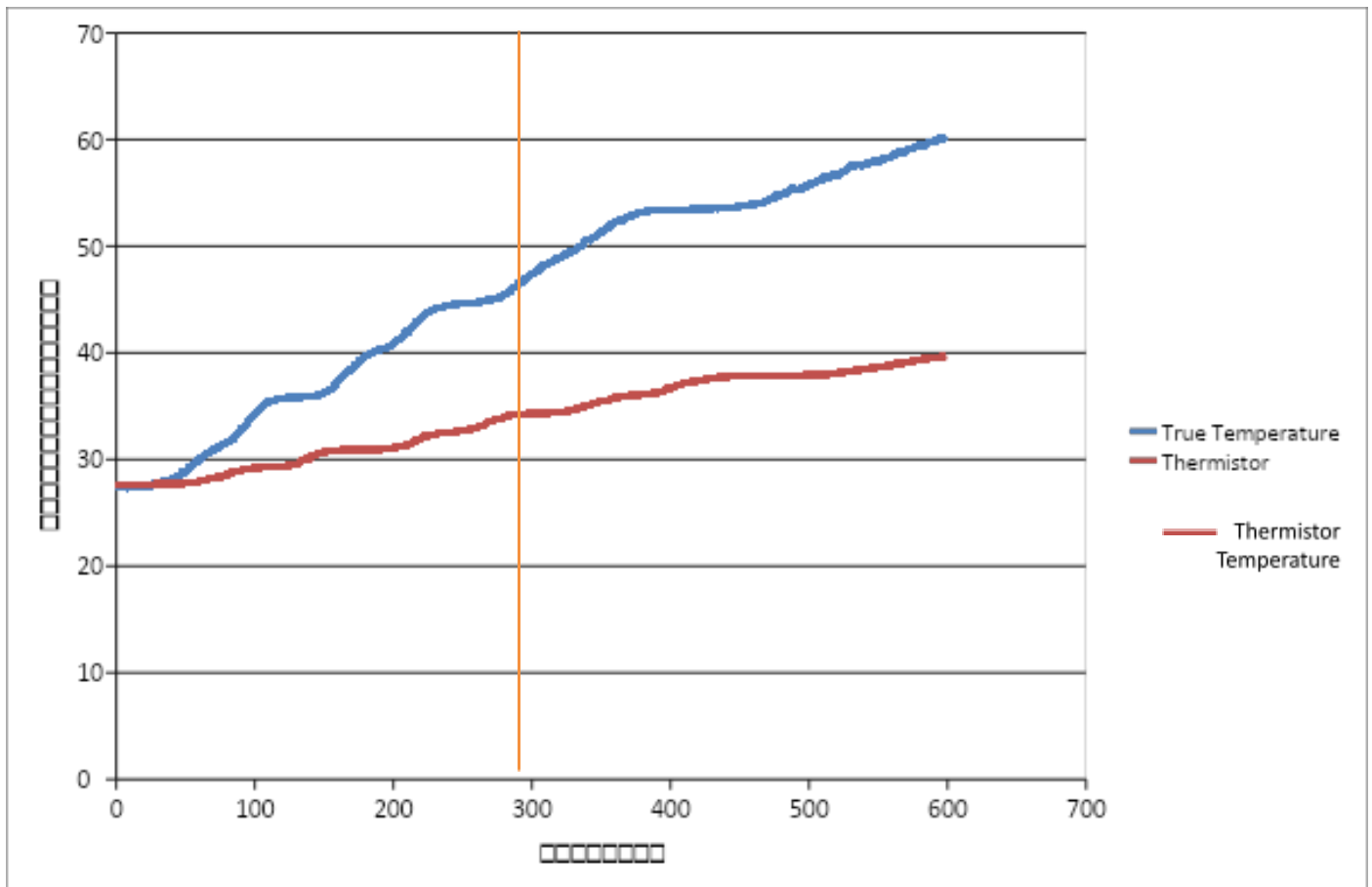


Figure 4 – Thermistor Temperature Results

In figure 4 the thermistor went under the same test and so the same time will be used so that both results are equal. At 0 seconds the thermistor is very accurate with the true temperature and remains accurate till around 50 seconds into the test. After the 50 seconds the thermistors error increase dramatically and continues to during the 5 minutes. The response of the thermistor almost seems to be the same as the true temperature as it rises and the settles out and then repeats however the aptitude of the readings are different. The thermistor does not follow a linear line with the true temperature after the 50 seconds which does not allow its readings to be predicted during a time frame and it would also be hard to condition the signal to bring it closer to the true temperature. Overall, the thermistor is inaccurate after a set time and its errors only get worse as the test goes on. The response of the thermistor does seem to mimic the true temperature however due to the error and inaccuracy the readings are completely different.

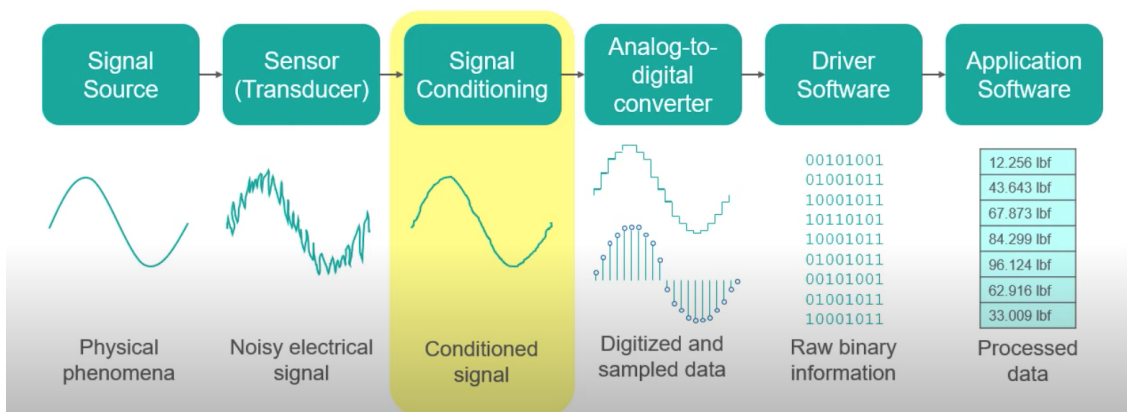
In comparison between the ~~RTD~~ and thermistor, the thermistor has a longer time where it matches the true temperature however the ~~RTD~~ does follow a closer linear line to the true temperature. This ~~has~~ has a big advantage as the results can be predicted and will some signal conditioning the results could be made smoother by reducing noise or ensuring the tests are done in sterile conditions. The amplitude could also be addressed when conditioning ~~the~~ the signal as this can be brought down to bring it in line with the true temperature.

Task 3 – Sensor Design

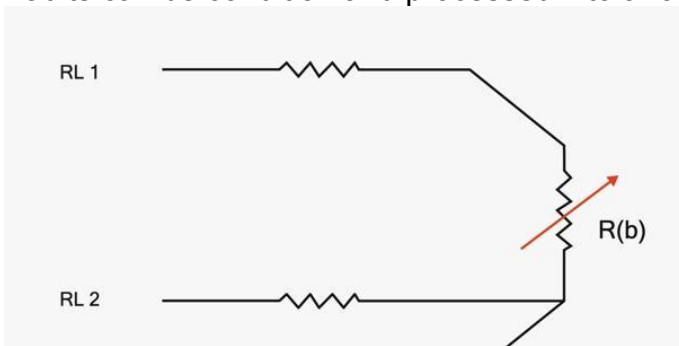
If your chosen temperature sensor was to be incorporated in to the system it will need some form of signal processing. Explain the need for signal conditioning and processing in order to fully utilise the sensor in a practical application. Justify a suitable measuring circuit that will convert the resistance of the sensor to a comparative current value. (Input range: User defined Output range: 4 to 20 mA)

As described by (Smith, 2021) "Signal conditioning is an electronic circuit that manipulates a signal in a way that prepares it for the next stage of processing. Many data acquisition applications involve environmental or mechanical measurement from sensors, such as temperature and vibration. These sensors require signal conditioning before a data acquisition device can effectively and accurately measure the signal.". Although this was stated in 2021 which is now 2 years old it is backed up by (Anon., 2022) "Signal conditioning is the technique of making a signal from a sensor or transducer suitable for processing by data acquisition equipment.". They also give a good example of a type of signal conditioning "measuring a voltage signal smaller than a few millivolts, you might need to amplify it.". From both these references and experience at Valero it is important to condition and process a signal as it allows trust in what is being read. It allows those working on the sensor or those using it for data to be able to better understand what the systems current state is without having issues such as noise or signals that are too small to be recognised by the PLC. From the example given this would be devices such as thermocouples as they produce a very small voltage with the change in temperature. Conditioning it by amplifying the signal gives it enough strength to not only be able to read but also travel from the sensor in the field to the PLC. Another type of conditioning is filtering out noise. This helps to smooth the signal from the sensor which allows a better reading in the control room. Signal conditioning can also help remove any false readings like the filter, as any readings outside the set parameters of the sensor will be removed. Any strange signals such as anomalies can also go through a filter and be removed also.

Processing a signal is done after it is conditioned as now it can look at the signal being received and translate/ manipulate it into a form that can be understood by the user. The process from sensor through to data being read can be seen below in figure 5.



In the previous task I chose the RTD as the best temperature sensor from both the tests. However, it did have its downsides which could be seen. By incorporating it into a measuring system these faults can be condition and processed into a form that is understandable.

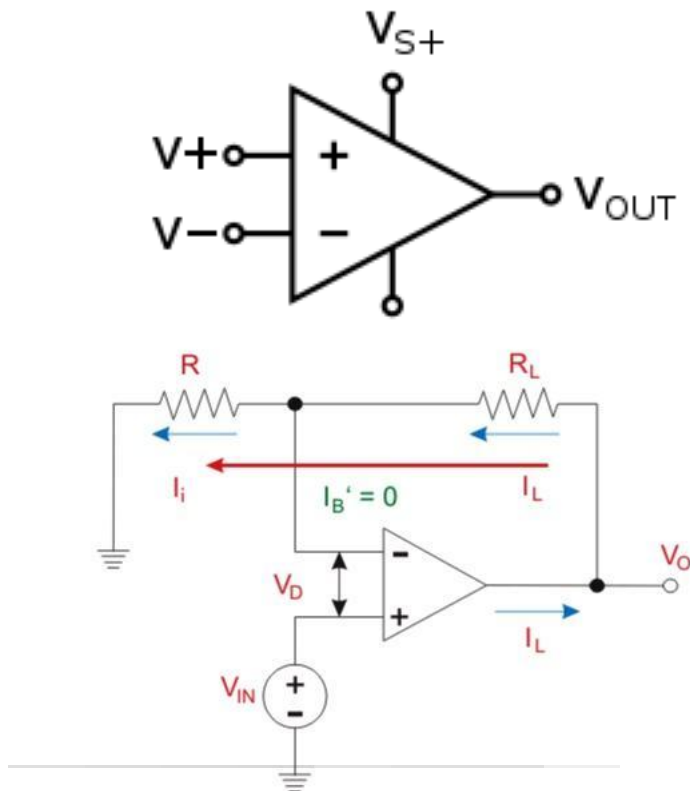


Firstly, we need to understand that RTD's don't work like other temperature sensors as they are not passive, meaning that they need to be powered by the signal conditioner. It is recommended that with RTD's to use a 3 or 4

wire circuit. This can be seen in figure 6. 2 wire circuits are not recognised as a good recommendation as the resistance in the lead wire will be added onto the reading displaying inaccurate high temperatures. In a 3-wire circuit the resistance between RL1 and 2 is measured and the resistance between RL2 and 3 is subtracted. The offset is recognised by the signal conditioner and is removed from the final reading. By adding a fourth wire into the circuit will make it more accurate as RL1 and 4 will provide power while RL2 and 3 will output the lead wires resistance to the signal conditioner.

In terms of converting a RTD voltage signal into a 4-20mA output an Op-Amp can be used. this can be built into a circuit making this converter small and easy to install with the correct understanding. An Op-Amp as seen in figure 7 is comprised of two power legs, an output and a negative (inverting) leg and a positive (non-inverting) leg. How an Op-Amp can be implemented into a conversion circuit can be seen in figure 8.

In figure 8, V_d represents the difference in voltage from the RTD compared to the constant voltage on the non-inverting input. When the RTD is at ambient the inverting input will be equal with V_{in} which will result in 0 volts output on the Op-Amp. When the temperature increases the RTD resistance also increase, causing a drop in voltage on the inverting input. This drop in voltage creates the difference between + and -. I_L on the output is then returned to the inverting input making both inputs almost equal. Due to the high-impedance the return loop is also linked to ground and so the current won't go back to the Op-Amp. This current to ground when measured will give the current conversion. In the circuit the correct resistors will need to be selected for the application. Using the correct resistors will enable the circuit to be used as a 4-20mA output.



more detail to explain would have shown more depth

Task 4 – Signal Transmission

Finally, the company would like you to produce a short report explaining the key principles and benefits of the HART Protocol as part of a signal transmission system.

HART (Highway Addressable Remote Transducer) protocol is a hybrid automation controller as it can be used for both analogue and digital applications. The HART protocol was developed by Rosemount as an update from the Bell 202 communication standards from the 1980's. It is widely used due to its capability to communicate using 4-20mA on instrument and process loops by simply connecting onto the cabling pairs between the field device and host or PLC, making it easy to use as seen in Figure 10. However, this is only possible if the equipment is classed as 'smart' which means it has HART protocol built into it. At Valero Pembroke refinery a lot of the old instruments have been replaced with 'smart' instruments. This has allowed maintenance and installation of these devices to be made more efficient. Emerson is just one of many manufacturers that produce HART communication tools for those working in the industries to connect onto smart equipment for commissioning, reconfiguration, diagnostics, and statuses. Emerson's latest model 'Trex' as seen in Figure 9 is built for easy use with its touch screen and even offers lessons on how to use each mode. A HART protocol device has two forms of operation which are Point to Point and Multi-drop.

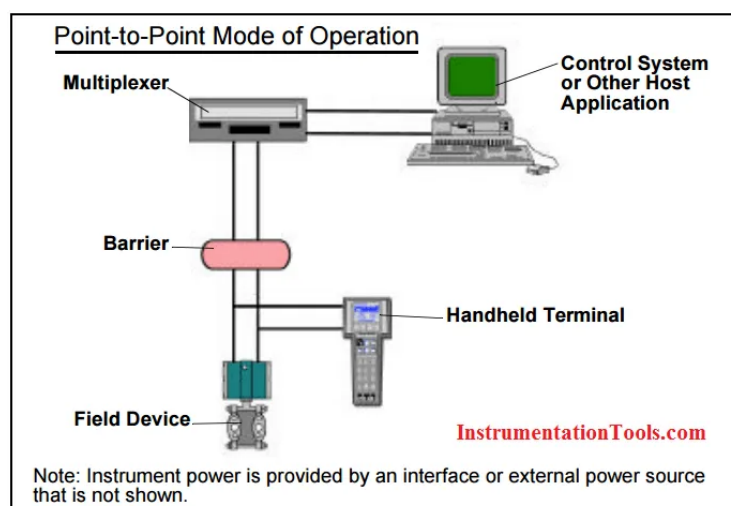
Point to Point

Point to point is an operation that can only be done on one device at a time. The digital signal is laid over the 4-20mA current as both the digital signal and current are seen as a valid signal between both the controller and instrument. An example of this could be a pressure calibrator setting the 4-20mA signal and then the temperature could be sent digitally over with the same wires.

Multi-drop

Multi-drop mode allows the HART to operate over many instruments. However, this has a massive limitation as the signal can only be set at 4mA. This does allow the user to see many readings from all instruments it is connected to.

Due to these different modes, it has allowed HART protocol to be applied to not just simple systems but also distinctly sophisticated systems such as safety loops, shut-down loops and controllers. Within HART protocol devices is the ability to investigate and change the equipment's ranges and reference points. This is a helpful aid as when carrying out work at Valero it is possible to see what the current reading is being outputted from the equipment. It is also possible when there is a zero error such as when the equipment is isolated from the process variables to carry out a 'zero trim' when then set's the current reading to 4mA. This can also be done to the span.



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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		
Some appropriate Referencing relevant to Subject. Need to get convention right throughout An appropriate range of literature	20	11
2. Knowledge and Understanding Skills		
A clear understanding although lacks depth in areas, some reference to workplace	35	23
3. Cognitive and Intellectual Skills		
Using the data and some justification of choices evident. Interpretation of a with some insight.	10	7
4. Practical Application Skills		
Good evidence of application of basic methods & techniques to propose mostly appropriate solution while also considering your workplace.	25	13
5. Transferable Skills for Life and Professional Practice		
Well structured & organised. Fluent & well presented	10	7

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)		61 %
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

Tom Davies – Moodle Feedback - Assignment 1

1. Formatting text - use 1.5 line spacing
- 2 What was the point of comment about outdated info? 7yrs?
3. So RTD is recommended.
4. Add Ref to your OP Amp solution