

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Gareth Thomas	Student ID number:	
Programme:	HNC Electrical/Electronic Engineering, Power Systems Engineering & Instrumentation Engineering		
Module:	Industrial Measuring Systems		
Module code:	PCEE4003	Contribution to Overall Module Assessment (%):	100%
Lecturer:	Adam Jenkins	Internal Verifier:	Jason Pointer
Assignment Title:	Measurement Systems	Word count (or equivalent):	2000
Submission deadline:	15/05/20	Return date of provisional marks & written feedback:	29/05/2020
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)

LO1, LO2.

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	20	9.6
Engagement with a range of mostly relevant and credible sources. Need to use correct referencing method and make you research the correct datasheets.		
2. Knowledge and Understanding Skills	30	19.9
Task 1 achieved 72%. Task 2 achieved 60%. Task 4 achieved 70%. Task 5 achieved 65%. Task 6 achieved 65%. Competent knowledge of the basic underlying concepts and principles to covering the assignment tasks. Exhibits very good understanding which is reflect in marks for each task..		
3. Cognitive and Intellectual Skills	10	6
Sound evaluation of the underlying concepts and principles.		
4. Practical Application Skills	30	23.4
Very good approach to developing the calculations to obtain the relative solution for task 3. Excellent use of spreadsheets to obtain a range of solutions and to present these results.		
5. Transferable Skills for Life and Professional Practice	10	6.5
Work is accurate, coherent, fluent, well-structured and organised.		

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)		65%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		

Learner Name: Gareth Wyn Thomas

Course: HNC Instrumentation Engineering Year 1

Module Code: PCEE4003

Module Name: Industrial Measuring Systems

Lecturer: Jason Pointer

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Task1 Pressure Sensor

The Bourdon Tube Analogue Pressure Gauge	Resistive Strain Digital Pressure Gauge
• The Bourdon tube is an instrument for measuring the pressure of gases or liquids, consisting of a semicircular or coiled flexible metal tube fixed at one end and free to move at the other end. It is attached to a gauge that records the degree to which the tube is straightened by the pressure of liquid inside it (Morris, 2006). • Pressure sensors made with Bourdon tube are hollow elastic material (metal or rubber) tubes with one sealed end that flexes when pressure is applied to the open end. They transduce the elastic deformation of the tube wall (usually with approximately square section) into displacement. • The Bourdon tube is an almost rectangular or elliptical cross section tube made from materials such as stainless steel or phosphor bronze. • The elliptical cross section ensures that it has different modulus of elasticity in its cross section. This is then calibrated across a dial to indicate pressure. • The gauge operates on the principle that when pressurized a flattened tube tends to straighten or regain its circular cross-sectional form. • When a gauge is pressurized the Bourdon tube creates the dial tip to travel to indicate pressure measurement. By displacing the free end of the tube. • This displacement is measured by some form of displacement transducer (usually a potentiometer or LVDT although capacitive and optical sensors are also sometimes used). • The Bourdon gauge gives a direct reading from the applied pressure to the piston because the force that the weight applies to the liquid in the cylinder is equal to the product of the mass (in kg) and acceleration due to gravity ✓ • Pressure is constant from the cylinder to the bourdon gauge so the gauge should give a direct reading of the pressure caused by the dead weight on the	• A strain gauge is a sensor whose electrical resistance varies with applied force. It converts pressure into a change in electrical resistance which can then be measured (Morris, 2006). • The pressure gauge works on the principle of electrical conductance and the dependence of the conductor's resistive properties. • Whenever a conductor is stretched within the limits of its elasticity it does not break but gets narrower and longer and loses or increases its electrical resistance. • When a strain gauge is deformed (strained) its resistivity changes which can then be measured when a potential is applied across it. The change in resistance is correlated to a deformation in its shape which allows the strain to be quantified. • Applied pressure causes displacement of a diaphragm and this movement is measured by a displacement transducer. • Versions of such sensors can measure absolute pressure (up to 50 bar) and gauge pressure (up to 2000 bar) according to whether the space on one side of the diaphragm is respectively evacuated or is open to the atmosphere (Morris, 2006). • The diaphragm can be either plastic, metal alloy, stainless steel or ceramic. The metal diaphragm gives greater accuracy. • Stainless steel is normally used in high temperature or corrosive environments. Ceramic diaphragms are resistant to acids and alkalis and are used in harsh operating environments. • The typical magnitude of diaphragm displacement is 0.1mm which is well suited to a strain-gauge type of displacement measuring transducer. • Four strain gauges arranged in a bridge circuit configuration are normally used. ✓ • The output from voltage from the bridge is a function of the resistance change

piston (Bolton, 2015). ✓

Advantages

- Construction costs of Bourdon tube costs are low.
- They are of simple construction.
- They can be modified to give electrical outputs.
- They are safe for high pressure measurement.
- Accuracy is high (especially at high pressures).
- Can withstand pressures of up to 10,000 kilopascals.
- They can accurately record the same pressures multiple times ✓

Disadvantages

- They respond slowly to changes in pressure.
- They are subject to hysteresis.
 - a condition that causes the tube to react slower when moving from a high scale reading to a low scale reading resulting in the scale showing a slightly higher than actual reading.
- They are sensitive to shocks and vibrations.
- Amplification is essential as the displacement of the free end of the Bourdon tube is low.
- They cannot be used for precision measurement.
- They are medium-sensitive i.e. they are usually calibrated to only work with a particular medium. Using another medium can affect the reading owing to its own density and weight and thus result in error.
- The errors occur due to the relationship between the fluid being measured and the fluid used for calibration. The pointer of the Bourdon tube is normally set to zero during manufacture using air as the calibration medium. If a different fluid, especially liquid, is subsequently used the fluid in the tube will cause a nonzero deflection according to its weight compared with air. This can

due to the strain in the diaphragm. This automatically provides compensation for environmental temperature changes. ✓

Advantages

- Piezoelectric strain gauges are among the most sensitive (up to 10000 times more than the simpler types).
- Has many diverse uses including testing of ships' hulls, dams and oil drilling platforms.
- There are no moving parts.
- Inexpensive to produce.
- Easily handled as they are small. ✓

Disadvantages

- They are sensitive to overload and then get damaged.
- Performance is affected by humidity and temperature
- They are subject to hysteresis.
- Accuracy drops with prolonged use.
- It cannot be removed and reused (Morris, 2006). ✓

result in a reading error of as much as 6%. To overcome this the Bourdon tube can be calibrated with the fluid too be measured rather than air (Morris, 2006).



Task 2 Position Sensors

2 (a) A sensor that could be used to measure angular velocity of an electric motor from 0 to 1,800 rpm is an **inductive pick up tachometer** (Bolton, 2015).

The instrument is essentially a small electricity generator consisting of a coil which rotates in a magnetic field (Fig. 1). The faster the coil rotates the greater the e.m.f. induced in the coil. If electrical connections are made to the coil and the output fed to a voltmeter then the reading of the voltmeter is related to the angular velocity of the coil. Generators can have a coil rotating in a magnetic field as in figure 1, or have a magnet rotating past coils. Tachogenerators can be used for direct measurements of frequencies of rotating shafts with an accuracy of a few percent (Bolton, 2015).



A transducer is used to give a digital output, the frequency of the digital output being related to the angular velocity. Figure 2 shows the construction of an inductive pick up tachometer. A wheel with cogs is attached to the rotating shaft. As the cogs on the wheel move past the magnet a change in the magnetic flux through the coil is produced and this results in an e.m.f. being induced within the coil. Each cog moving past the magnet results in a voltage pulse in the coil. The frequency of these pulses i.e. the number of pulses produced per second is related to the angular velocity.

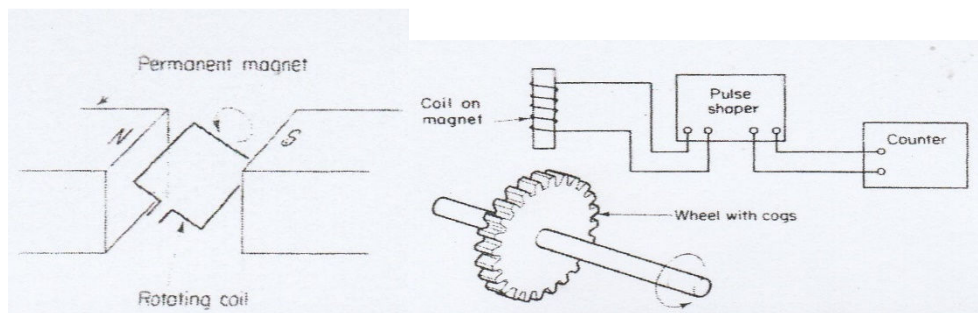


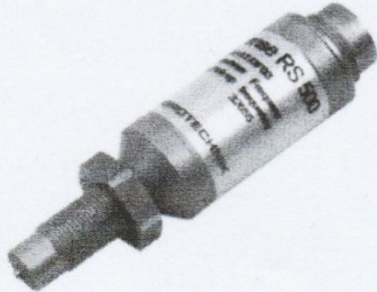
Figure 1 (Bolton, 2015).

Figure 2 (Bolton, 2015).

Data sheet on the next page obtained from <https://www.hydrotechnik.co.uk/rs500-inductive-pickup-sensor-rotational-speed-frequency-output>.



RS500 Inductive Pickup Sensor for Rotational Speed Frequency Output



- Order code: 3410-1600-XXXXF0X

- **RS500 Inductive Pickup Sensor for Rotational Speed Frequency Output**

See details of our most common options below.

Please see the downloadable datasheet or get in touch for further options.

Screw In Thread Size	Electrical Connector	Measuring Range (Hz)	Output Signal
M10x0.75	M16	1...10000	Frequency Square Wave (PnP)
M14x1	M16	1...10000	Frequency Square Wave (PnP)

	HySense RS 500	
	Induktivaufnehmer mit aktivem Push-Pull Ausgang	Inductive pickup with active push-pull output

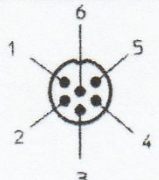
Beschreibung <i>Description</i>	Der hochpräzise sowie dynamische Drehzahlsensor HySense® RS 500 detektiert berührungslos rotierende ferromagnetische Turbinenläufer, Zahnräder und ähnliche Komponenten und generiert daraus ein Impuls- ausgangssignal. Diese Detektion erfolgt auf Basis der Induktionsgesetze. Des Weiteren besteht die Möglichkeit dieses Ausgangssignal, mit Hilfe einer implementierten Tabelle sensorextern zu linearisieren. Aufgrund des konstruktiven Designs wird eine hohe IP Schutzart erreicht, sodass der Einbau in nahezu jeder Applikation möglich ist. Diese robuste Bauweise garantiert ebenfalls eine hohe mechanische Standfestigkeit und rundet das Produkt ab.	The high-precision and dynamic speed sensor HySense® RS 500 detects contactless rotating ferromagnetic turbine rotors, gears and similar components and generates a pulse output signal. This detection is based on the induction laws. By means of an implemented table it is furthermore possible to linearize this signal externally. Due to the constructive design a high IP rating is achieved, so that an installation is possible in almost any application. This robust design also guarantees a high mechanical durability and completes the product.
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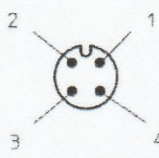
Eigenschaften <i>Qualities</i>	• Qualifiziert für den Einsatz in industriellen Applikationen • Frequenzsignal • Frequenzbereich ~1...10000Hz • Automatische Sensorerkennung und Linearisierung ISDS¹ • Robustes Design	• Qualified for use in industrial applications • Frequency output signal • Frequency range ~1...10000Hz • Automatic sensor detection and linearization ISDS¹ • Robust design
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Verwendungszweck <i>Designated use</i>	Der Drehzahlsensor HySense® RS 500 ist für vielfältige Aufgaben entwickelt worden und detektiert berührungslos rotierende ferromagnetische Turbinenläufer, Zahnräder und ähnliche Komponenten in industriellen Applikationen über die Änderung des magnetischen Flusses.	The rotation speed sensor HySense® RS 500 has been developed for a wide range of tasks and detects contactless rotating ferromagnetic turbine rotors, gears and similar components in industrial applications by the change of the magnetic flux.
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¹ ISDS (intelligent sensor detection system) ist ein Hydrotechnik-spezifisches Datenprotokoll, welches eine automatische Sensorerkennung sowie Parametrisierung in Hydrotechnik Messgeräten realisiert. Über dieses Protokoll ist eine Linearisierungstabelle mit bis zu 10 Stützstellen implementierbar.

ISDS (intelligent sensor detection system) is a Hydrotechnik specific data protocol, which automatically detects and implements the sensor characteristics in Hydrotechnik measuring instruments. With the help of this protocol it is possible to use a table with up to 10 linearization points.

Pinbelegungen Pin assignments	Bezeichnung Labeling	Nr. No	Funktion	Function
Rundsteckverbinder M16 x 0.75 mit Schraubverriegelung, Ausführung 06-a, 6-polig, Stecker DIN EN 61076-2-106 Circular connectors M16 x 0.75 with screw-locking, layout 06-a, 6 poles, male IEC / DIN EN 61076-2-106				
 M16 6p	Pinbelegung 3 / Pin assignment 3			
	Signal	1	f-Signal	f-signal
	GND	2	Masse	Ground
	+Ub	3	Versorgungsspannung	Supply voltage
	NC	4	nicht verbunden	not connected
	NC	5	nicht verbunden	not connected
	ISDS	6	Sensorerkennung	Sensor detection

Pinbelegungen Pin assignments	Bezeichnung Labeling	Nr. No	Funktion	Function
Rundsteckverbinder M12 x 1 mit Schraubverriegelung, A-Kodierung, 4-polig, Stecker IEC / DIN EN 61076-2-101 Circular connectors M12 x 1 with screw-locking, A-coding, 4 poles, male IEC / DIN EN 61076-2-101				
 M12 4p	Pinbelegung 7 / Pin assignment 7			
	+Ub	1	Versorgungsspannung	Supply voltage
	ISDS	2	Sensorerkennung	Sensor detection
	GND	3	Masse	Ground
	Signal	4	f-Signal	Pulse signal

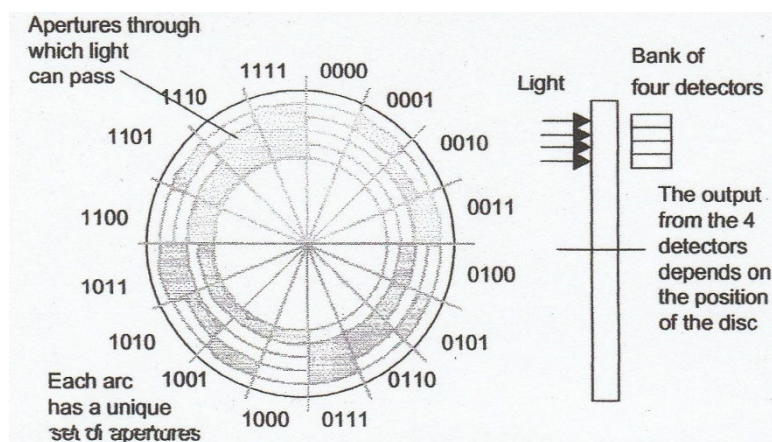
Eigenschaften characteristics		Referenzbedingungen / Reference conditions: Umgebungstemperatur Ta = 25°C / environmental temperature Ta = 77° F			
Parameter	Min	Typ.	Max	Einheit Units	Bemerkung Remarks
Versorgungsspannung / supply	8		30	VDC	
Stromaufnahme / current			3	mA	@ 24V
Spannungsfestigkeit / breakdown voltage		36		VDC	
Ausgangssignal / signal out		f		Hz	ISDS ermöglicht weitere Größen und Einheiten ISDS offers additional dimensions and units
Ausgang Pegel / Output level „1“	+Ub – 2 V		+Ub	VDC	@ 10 kΩ Mess- widerstand / measuring resistor
Ausgang Pegel / Output level „0“		<0.5	1	VDC	
Betriebstemperatur / working temp.	-25		85	°C	
	-13		185	°F	
Lagerungstemperatur / storage temp.	-40		85	°C	
	-40		185	°F	
Frequenzbereich Eingang / frequency range input	~ 1		10000	Hz	Abhängig von der Ein- bausituation. Depends on the instal- lation situation.

2 (b) A sensor that could be used to measure the rotation of a 3-way ball valve through 180° operation is an **optical sensor in conjunction with an optical encoder**.

An absolute encoder is a device which provides a digital output of the actual position as a result of an angular displacement whilst an incremental encoder detects changes in displacement from some datum position (Morris, 2006). The absolute encoder gives an output in the form of a binary number of several digits, each such number representing a particular angular position. The diagram below shows the basic form of such an encoder. The rotating disc shown has four concentric circles of slots and four sensors to detect the light pulses. The slots are arranged in such a way that the sequential output from the sensors is a number in the binary code each number corresponding to a particular angular position. Typical encoders tend to have up to 10 or 12 tracks. The number of bits in the binary number will be equal to the number of tracks. Thus 10 tracks will have 10 bits and so the number of positions that can be detected is 2^{10} (i.e. 1024). The rotating wheel of the absolute encoder in the diagram has the binary code shown but in practice this is modified to the Gray code (Bolton, 2015). This code, unlike normal binary, has only one bit changing in moving from one number to the next as shown below. ✓

0000 0001 0011 0010 0011 0111 0101 0100 1100 1101 1111.

The optical sensor is used to determine whether an object is present or not. Photoelectric switch devices operate as transmissive types where the object being detected breaks a beam of light (in this case the rotating wheel) and the infrared radiation and stops it reaching the detector. The radiation emitter is generally a light emitting diode (LED) (Morris, 2006). ✓



Rotating wheel of optical encoder (Morris, 2006).

Data sheet on the next page obtained from https://www.bamo.eu/international/_ftp/da1014-02.pdf.

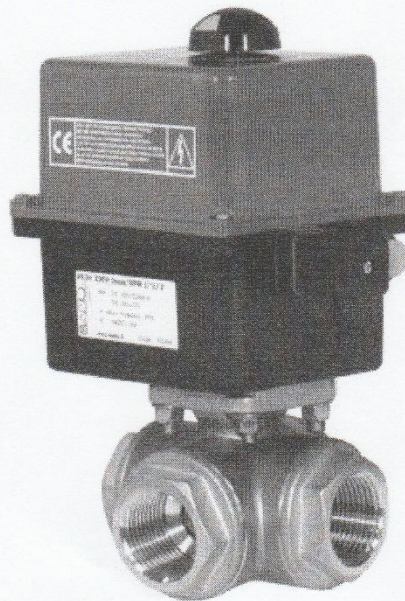


Electrically actuated 3-way ball valve VE3V - Stainless steel

PDF Version Manual Quotation

Previous Next

VE3V - INOX



- **Stainless steel body**
- **Fittings from BSP 1/4" to 2"**
- **Electric actuator with position pointer and emergency manual override**

DESCRIPTION

Electrically actuated 3-way ball valves are useful for redirecting or to stop the flow of liquids in piping systems. These models are designed for aggressive liquids; In standard versions they allow a manual operating for maintenance (or emergency operations) and a position pointer. The power supply must be switched off before a manual operating. All operating modes (according bore shapes) are described in the data-sheet da913-20.

Electrically actuated 3-way ball valve
VE3V - Stainless steel

General Catalog 1014-02
05/11/2019 08:51

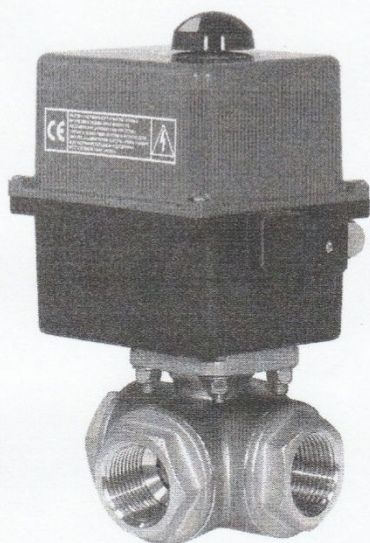
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https://www.bamo.eu/international/s4_page2011.htm

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Electrically actuated 3-way ball valves VE3V - Stainless steel



- Stainless steel body
- Fittings from BSP 1/4" to 2"
- Electric actuator with position pointer and emergency manual override

DESCRIPTION

Electrically actuated 3-way ball valves are useful for redirecting or to stop the flow of liquids in piping systems. These models are designed for aggressive liquids; In standard versions they allow a manual operating for maintenance (or emergency operations) and a position pointer. The power supply must be switched off before a manual operating.

All operating modes (according bore shapes) are described in the data-sheet da913-20.

TECHNICAL FEATURES

3-way Ball valves:

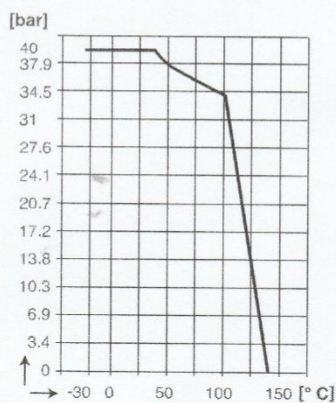
Body	AISI 316
Seals	PTFE
T or L bore shapes	AISI 316
Ball seat	PTFE, glass-fiber reinforced (15 %)
Fittings	BSP, female threads
Pressure limit	40 bar
Operating temperature	-30 ... +100 °C; up to 140 °C on request From and over 100 °C: Please request confirmation on feasibility

Electric actuator:

Movement	90°
Emergency override:	Manual
Duty rating	30 %
Protection	IP 65
Connections	1 Cable gland: M20 - ISO 1 connector 3 poles + ground, DIN 43650
Consumption	1/4" up to 1": 15 W 1 1/4" up to 2": 45 W
Multi-voltage power supplies	100 ... 240 V AC 50/60 Hz and 100 ... 350 V DC or 24 V AC 50/60 Hz and 24 V DC

OPTIONS	Fail safe (back to 0° in case of power failure) Electronic positioning servo on 4-20 mA signal (or 0-20 mA, or 0-10 V)
---------	---

EC Conformity: The instrument meets the legal requirements of the current European Directives.



Pressure vs. Temperature

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Electrically actuated 3-way
ball valves
VE3V - Stainless steel

04-11-2019

D-1014.02-EN-AC

METAL

1014-02 /1

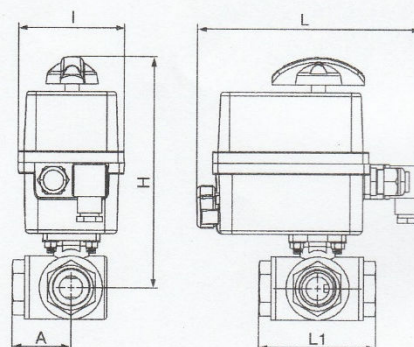
Non-contractual document: Subject to amendments due to improvements

CODE NUMBERS AND REFERENCES

		24 V AC & 24 V DC		100 ... 240 V AC & 100 ... 350 V DC	
ND	ND	Ball L bored	Ball T bored	Ball L bored	Ball T bored
1/4"	10	M 1014 101	M 1014 121	M 1014 141	M 1014 161
3/8"	12	M 1014 102	M 1014 122	M 1014 142	M 1014 162
1/2"	15	M 1014 103	M 1014 123	M 1014 143	M 1014 163
3/4"	20	M 1014 104	M 1014 124	M 1014 144	M 1014 164
1"	25	M 1014 105	M 1014 125	M 1014 145	M 1014 165
1 1/4"	32	M 1014 106	M 1014 126	M 1014 146	M 1014 166
1 1/2"	40	M 1014 107	M 1014 127	M 1014 147	M 1014 167
2"	50	M 1014 108	M 1014 128	M 1014 148	M 1014 168

DIMENSIONS [mm]

ND	ND	A	L1	I	L	H
1/4"	10	40	80	92	193	181
3/8"	12					183
1/2"	15					191
3/4"	20	44	88			196
1"	25	50	100	128	208	205
1 1/4"	32	61	123			247
1 1/2"	40	71	149			258
2"	50	85	171			



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Electrically actuated 3-way
 ball valves
VE3V - Stainless steel

04-11-2019

D-1014.02-EN-AC

METAL

1014-02 /2

Task 3 Temperature Sensor Characteristics

3. (A) Calculating the resistance of a PT100 platinum type resistance temperature device (RTD) to measure the temperature of a process from 0°C to 100°C.

The resistance of a metal varies with temperature according to the relationship:

$$R_m = R_0(1 + \alpha_1 T + \alpha_2 T^2 + \alpha_3 T^3 + \dots + \alpha_n T^n)$$

This equation is non-linear and so is inconvenient for measuring purposes. The equation becomes linear if all terms in $\alpha_2 T^2$ and higher powers of T are negligible such that the resistance and temperature related according to:

$$R_m = R_0 (1 + \alpha T_m) \quad \checkmark$$

This equation is approximately true over a limited temperature range for metals such as platinum, copper and nickel.

R_0 is the nominal resistance at 0°C and in this case is 100 Ω

R_m is the resistance of the metal at T°C

T_m is the difference between temperature of the metal and reference temperature in this case 0°C

α is the temperature coefficient of resistance in this case $3.85 \times 10^{-3} \text{ } ^\circ\text{C}^{-1}$

Calculate R_m for a temperature of 20°C

$$R_m = 100 \times (1 + 0.00385(20-0))$$

$$= 100 \times (1 + 0.00385(20))$$

$$= 100 \times (1.077)$$

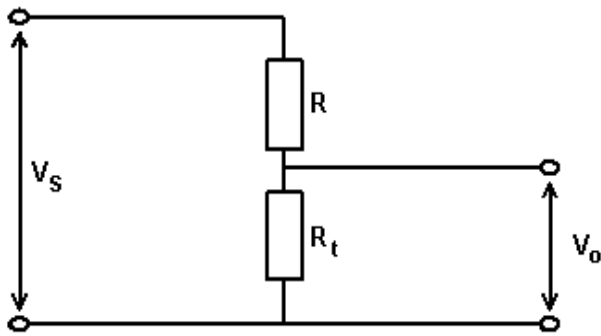
$$= 107.7 \text{ } \Omega \quad \checkmark$$

The results for the calculation of R_m for temperatures between 0 °C and 100°C in 5°C intervals are tabulated below

Temperature	Resistance		Temperature	Resistance
0 °C	100 Ω		55 °C	121.175 Ω
5 °C	101.925 Ω		60 °C	123.1 Ω
10 °C	103.85 Ω		65 °C	125.025 Ω
15 °C	105.775 Ω		70 °C	126.95 Ω
20 °C	107.7 Ω		75 °C	128.875 Ω
25 °C	109.625 Ω		80 °C	130.8 Ω
30 °C	111.55 Ω		85 °C	132.725 Ω
35 °C	113.475 Ω		90 °C	134.65 Ω
40 °C	115.4 Ω		95 °C	136.575 Ω
45 °C	117.325 Ω		100 °C	138.5 Ω
50 °C	119.25 Ω			

$\checkmark$

3. (b)



Voltage Divider

The platinum RTD is to be used in a voltage divider circuit.

V_s is the supply voltage which is 10 volt

V_o is output voltage across R_t

R is a resistor of magnitude 100 ohms

R_t is the platinum RTD

To calculate the output voltage V_o make use of the formula:

$$V_o = \frac{R_t}{(R + R_t)} \times V_s \quad \checkmark$$

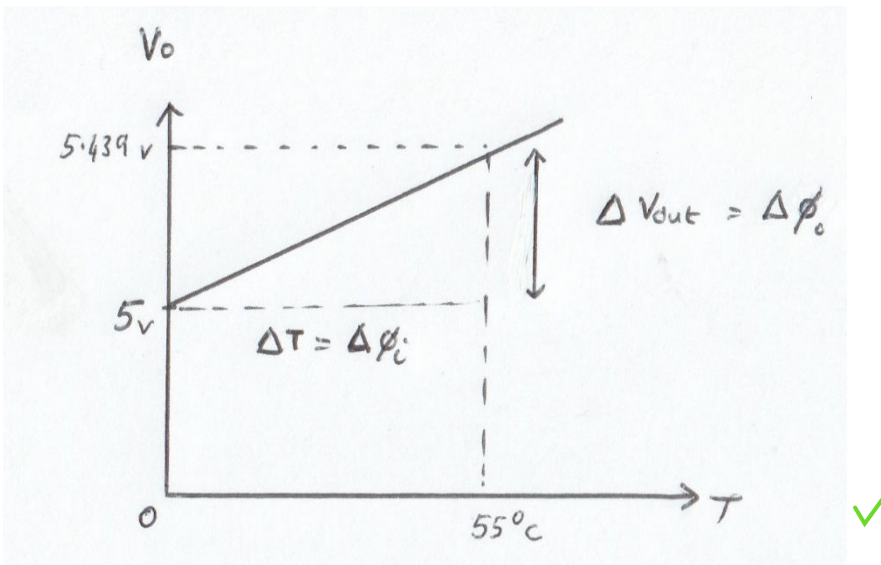
Calculate V_o for a RTD in the temperature range 0°C to 100°C at 20°C

$$V_o = \frac{107.7}{(100 + 107.7)} \times 10$$

$$= \frac{1077}{(207.7)} = 5.185 \text{ volts} \quad \checkmark$$

Temperature	Resistance R_t	Output voltage V_o		Temperature	Resistance	Output voltage
0°C	100 Ω	5 V		55°C	121.175 Ω	5.479 v
5°C	101.925 Ω	5.048 v		60°C	123.1 Ω	5.518 v
10°C	103.85 Ω	5.094 v		65°C	125.025 Ω	5.556 v
15°C	105.775 Ω	5.140 v		70°C	126.95 Ω	5.594 v
20°C	107.7 Ω	5.185 v		75°C	128.875 Ω	5.631 v
25°C	109.625 Ω	5.230 v		80°C	130.8 Ω	5.667 v
30°C	111.55 Ω	5.273 v		85°C	132.725 Ω	5.703 v
35°C	113.475 Ω	5.316 v		90°C	134.65 Ω	5.738 v
40°C	115.4 Ω	5.357 v		95°C	136.575 Ω	5.773 v
45°C	117.325 Ω	5.399 v		100°C	138.5 Ω	5.807 v
50°C	119.25 Ω	5.439 v				

3. (c) Assuming the input and output responses are linear the sensitivity of the circuit is found from the gradient of the graph of output voltage (V_o) measured in volts against Temperature (T) measured in $^{\circ}\text{C}$.



Sensitivity = $\frac{\text{Change in output voltage}}{\text{Change in temperature}}$

$$= \frac{\Delta \phi_o}{\Delta \phi_i}$$

At 55°C the output voltage is 5.439 V and at 0°C is 5v

$$\text{Sensitivity} = \frac{5.439 - 5}{55 - 0}$$

$$\text{Sensitivity} = 0.00798 \text{ V}/^{\circ}\text{C}$$



3. (d) Calculation of output response to a step change in input from 0°C to 50°C in 1ms steps to steady state condition

Values of temperature were obtained using the formula

$$T_m = T_{ss}(1 - e^{-t/T})$$



where T_{ss} is the steady state value of temperature (in this case 50°C)

T is the time constant (in this case 5ms)

$$\text{When } t \text{ is } 1\text{ms} \quad T_m = 50 \times (1 - e^{-1/5})$$

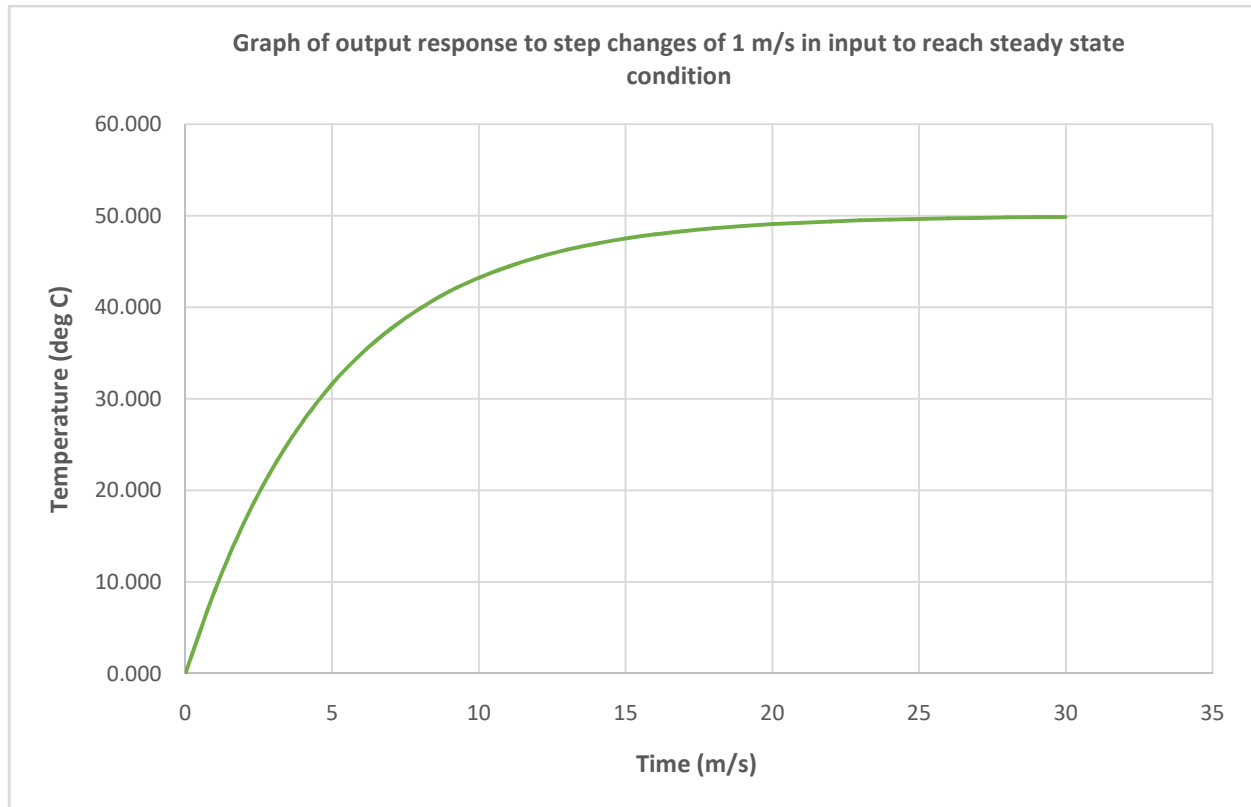
$$= 50 \times (1 - 0.8187)$$

$$= 9.063^{\circ}\text{C}$$



The remaining values were calculated using excel programme and are tabulated below.

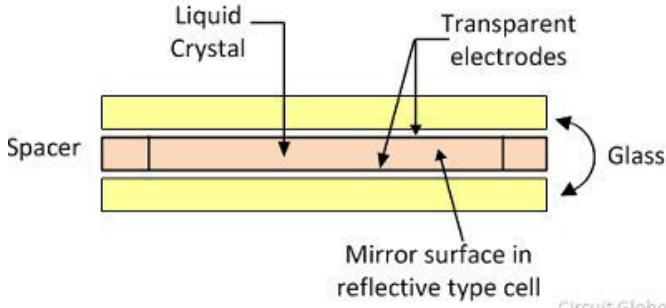
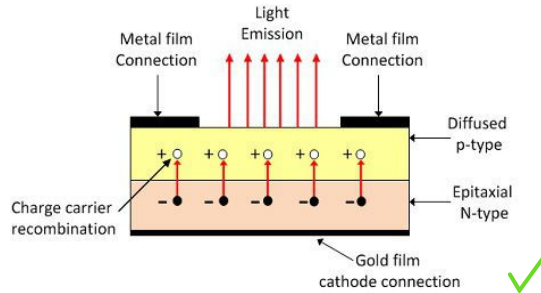
Time (ms)	Temp ($^{\circ}\text{C}$)		Time (ms)	Temp ($^{\circ}\text{C}$)
0	0.000		16	47.962
1	9.063		17	48.331
2	16.484		18	48.634
3	22.559		19	48.881
4	27.534		20	49.084
5	31.605		21	49.250
6	34.940		22	49.386
7	37.670		23	49.497
8	39.905		24	49.589
9	41.735		25	49.663
10	43.233		26	49.724
11	44.460		27	49.774
12	45.464		28	49.815
13	46.286		29	49.849
14	46.959		30	49.876
15	47.511			



TASK 4 Indicators

4. (a)

Display devices are the output devices for presentation of information in text or image form. An output device provides a way of showing information to an observer (Morris, 2006). Seven segment displays were created to display decimal numbers. The seven segments enable the display to show numbers from 0 to 9 and additionally upper-case letters A, C, E, F and lower-case letters b and d (Bolton, 2015). The display consists of seven separate segments hence the name. Each of the segments have two different states: on and off. Different combinations of 'turned on' segments will result in different numbers and letters shown. Seven segment displays rely on different display technologies based on LCD or LED.

LCD Seven Segment display	LED Seven Segment Display
- A liquid crystal display (LCD) has material which joins together the properties of both liquid and crystals. They have a temperature range within which the particles are essentially as mobile as they might be in a liquid, however are gathered together in an order form similar to a crystal (Bolton, 2015). - The LCD can be easily interfaced with a microcontroller to display a message or status of the device. - The LCD is used for displaying text and images in the form of dot matrix or segments (Morris, 2006). - The LCD has a liquid crystal filament which is filled between the transparent electrodes. When the current passes between the electrodes, the filaments become energized and emit visible light. - The construction of a liquid crystal display is shown below. ✓  https://circuitglobe.com/ ✓ - The liquid crystal used in the display	- A light emitting diode (LED) is the most commonly used device for displaying the status of microcontroller pins. These display devices are commonly used for the indication of alarms, inputs and timers (Morris, 2006). - There are two ways of connecting LEDs to microcontroller units. Either through active high logic or active low logic. Active high logic means LED will be ON when port pin is 1 and LED will be OFF when pin is 0. Active high means LED will be OFF when port pin is 1 and LED will be OFF when port pin is 0. - The LED is a PN junction diode which emits light when an electric current flows through it in the forward direction. The LED is constructed by doping the p-type and n-type material. When the power is applied across the LED the recombination of P-type and N-type material charges takes place. The recombination of charges gives energy in the form of heat and light (Bolton, 2015). ✓  https://circuitglobe.com/ ✓ - The semiconductor material allows light to pass through (translucent) which

has the property of both solid and liquid. When the potential is not applied across the liquid crystal, it becomes transparent but after activation, the crystal scatters light in all directions and appears to be bright.

- The LCD consumes less power and also has seven segment displays. It is however a slow device and requires more time for switching.
- The DC reduces the lifespan and hence they are used mainly with AC having a frequency less than 500Hz (Morris, 2006).



emits through their junction. The semiconductor material used is galvanized arsenide's., which generates red or yellow light. It is also available in green, red and amber colour.

- A 7-segment LED display consists of 7 LEDs arranged in the form of Square '8' and a single **Led** as dot character.
- Different characters 0 to 9 are displayed on a 7-segment display.
- They are available in common cathode mode and common anode mode. There are state lines in LED, anode is given to positive terminal and cathode is given to negative terminal then the LED will glow.
- In common cathode, the negative terminals of all LEDs are connected to the common pins to ground and a particular LED glows when its corresponding pin is given high. The cathodes of all LEDs are connected together to a single terminal and the anodes of all LEDs are left alone.
- In common anode arrangement the common pin is given a high logic and the LED pins are given low to display a number. In common anode, all the anodes are connected together and all the cathodes are left alone. Thus when the first signal is high or 1 then there is a lean in display if not there is no lean in display (Bolton, 2015).



Advantages & Disadvantage

- The LCD uses mercury which pollutes the environment
- The LCD contrast ratio is greater than the LED. (*The contrast ratio is the ratio of the luminance of the visible and darker light of the screen.*)
- LCD displays light in all directions

Advantages & Disadvantage

- The LED does not use mercury.
- Use of direct current on the LED has no effect but it reduces the lifespan of the LCD.
- The switching time of the LED is less as compared with the LCD. (*The switching time is the active and deactivated time of their display.*)

• LCD uses less power than LED because the LCD is made up of plasma which requires less power for activation. • LCD has less resolution than LED. (The resolution is the number of pixels on the screen's display.) • The LCD uses cold cathode fluorescent lamp which provides the backlight of the screen. (The backlight refers to the turning on and off of the displays for better vision.) • The LCD uses liquid filaments which are filled between glass electrodes which are energized for the emission of light.	• The LED uses gallium arsenide's which when heated emit light. • The display area of LED is less than the LCD because LED uses PN-junction diode which displays light in only one direction. • The LED uses PN-junction diodes for displaying the backlight. • The LED is a PN-junction diode which emits visible light when the forward bias applies across it.
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4. (b)

Some items of equipment require signals to be inputted in digital form whereas many instrumentation transducers produce the output signal in analogue form (4 – 20mA). An analogue to digital conversion (ADC) instrument is therefore used at the interface to complete this task(Morris, 2006).

The simplest ADC is a voltage comparator, as it can determine whether an input voltage is larger or smaller than a given reference voltage, returning a binary result of 0 or 1. Variations on this simple comparison process can improve the **resolution**(defined as the smallest change in parameter measurable by an instrument), from a single 0 or 1 to a binary number extending to very many digits (Harrison, 2015).

Many well-refined ADC methods are available, usually all contained within a single electronic component. Higher resolution conversions require a longer time than lower resolution conversion, and/or more extensive circuitry.

The outcome of the ADC is a numerical result expressed in the binary number system. For binary numbers, each digit is known as a bit, and hence increasing the number of bits in a binary number increases the size of the number. A group of bits is called a word. The word is what represents the digital version of the analogue voltage. There are basic rules with binary numbers, for example we have $0+0=0$, $0+1=1$, $1+1=10$. If we start with 000 and add 1 we obtain 001. If we add afurther¹ we have 010. Adding another 1 gives 011. With three bits in a word we have the words of 000 001 010 011 100 101 110 111. Therefore, there are eight possible words which can be used to represent the analogue input. The word length possible with an analogue to digital converter determines its resolution(Bolton, 2015).

When an instrument shows a particular output reading there is a lower limit on the magnitude of change in the input measured quantity that produces an observable change in the instrument output. A major factor influencing the resolution of an instrument is how finely its output scale is divided into subdivisions.

In order to convert the analogue input to digital input it is necessary to sample the analogue signal at regular intervals of time. Each of these samples is then converted into an equivalent digital value (Bolton, 2015). However, the conversion takes a finite time during which the analogue signal can be changing in value. In this process the next sample of the analogue signal cannot be taken until the conversion of the previous sample to digital form is completed. Thus, in the design of an ADC the speed of conversion is important.

An ADC is also subject to a factor that affects the quality of a signal when it is converted from analogue to digital and this is called **quantization** (Morris, 2006). This describes the procedure whereby the continuous analogue signal is converted into a number of discrete level's. At any particular value of the analogue signal the digital representation is either the discrete level; immediately above this value or the discrete level immediately below this value. If the difference between two successive discrete levels is represented by the parameter then the maximum error in each digital sample of the raw analogue signal is $\pm Q/2$. The error is called the **quantization error** and is proportional to the resolution of the ADC (i.e. the number of bits used to represent the samples in digital form) (Morris, 2006).

As variations occur in conditions certain instrument characteristics change. The ADC's **sensitivity** is a measure of the change in instrument output that occurs when the measured quantity changes (Harrison, 2015). Calibrations and specifications of an ADC are only valid under controlled conditions of temperature, pressure etc. The standard ambient conditions are usually expressed in the ADC's specification (Harrison, 2015).

Environmental changes can affect instruments when the zero reading is modified by change in ambient conditions and causes a constant error that exists over the full range of the instrument's measurement. This is called zero drift (or bias) (Morris, 2006). If the characteristic of an instrument is sensitive to several environmental parameters there will be several bias coefficients. Another effect is sensitivity drift (also known as scale factor drift) and this defines the amount by which the ADC's sensitivity of measurement varies as the ambient conditions change and is quantified by sensitivity drift coefficients defining how much drift there is for a unit of change in parameter (Harrison, 2015).



Task 5 Signal Transmission

5. (a)

Measurement signals have to be transmitted over distances from the point of measurement to a display unit or a process control unit. Listed below are the advantages and disadvantages of current and voltage signal transmission.

Advantages current signal transmission	Disadvantages current signal transmission
• Current is equal at all parts of a conductor no matter the distance over which it is measured and makes data transmission reliable. With or without cable resistance, the current at the indicator is the same as the current at the transmitter, and therefore there is no error incurred as there might be with a voltage signal system. • Attenuation can be minimized if signals are transmitted as varying current signal i.e. using current loop transmission with currents in the range 4mA to 20mA (Bolton, 2015). • The level of 4mA rather than 0mA indicates the zero-signal level since it would not be possible to distinguish between a zero-value signal and break in a transmission line (Bolton, 2015). • Long distance communication uses serial communication rather than parallel communication as the sequence of bits used to describe a value is sent in sequence along a single transmission line whereas for parallel communication each bit is sent along a separate parallel transmission line (Bolton, 2015). • Digital signal transmission enables corruption effects to be reduced using error coding to detect whether corruption has occurred (Bolton, 2015). • It uses less wiring and connections than other signals which reduces initial set up costs.	• Current loops can only transmit one particular process signal. • Multiple loops must be created in situations where there are numerous process variables that require transmission. Running so much wire could lead to problems with ground loops if independent loops are not properly isolated. These isolation requirements become more complicated as the number of loops increases (Harrison, 2015). • Typically has to be converted from a voltage signal. • Risk of ignition of hazardous gases. ✓

• It is less sensitive to background noise i.e. unwanted signals that may be picked up by a measurement system and interfere with the signals being measured. • Signal can use live zero. ✓	
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Advantages voltage signal transmission	Disadvantages voltage signal transmission
• They are easily measured. • Easily transmitted. • Can be easily amplified. ✓	• If the conductor has a high impedance and has electrical interference, then the input voltage signal will degrade, and a valid voltage may not reach the output receiver. • The system accuracy can be influenced by excessive cable resistance. • Analogue voltage signals can experience corruption due to induced noise (i.e. unwanted signals that may be picked up by a measurement system) (Bolton, 2015). • A cable, having a small amount of resistance along its length, will consequently drop a small amount of voltage, leaving less voltage across the indicator's leads than what is across the leads of the transmitter. This loss of voltage, however small, constitutes an error in measurement. • Analogue voltage signals can suffer corruption due to induced noise and the resistance of the connecting cables can result in attenuation of the voltage, the voltage drop across the output being reduced by that across the line resistance. Such effects can be reduced by the use of signal amplification and shielding with the connecting cables. However, because of these problems, such signals are not generally used for large distance transmission (Morris, 2006). ✓

5. (b)

The operation of a measuring system can be described in a generalized manner in terms of functional elements. Each functional element is made up of a component or groups of components which perform required and definite steps in the measurement, but they do not provide the precise details of the physical aspects of a specific system.

Conversion. The conversion element converts the output of the primary sensing element to an electrical signal. This is done by a device which converts a physical quantity into an electrical quantity (a transducer) (Harrison, 2015). For the instrument to perform the desired function, it may be necessary to convert this output signal from the sensor to some other suitable form while preserving the information content of the original signal. For example, suppose the output from the sensing element is in the form of very small displacement which is difficult to measure mechanically, it is converted in to corresponding electrical signal with the help of transducer (a strain gauge) for further processing. If the output at this stage is in analogue form and the next stage of the system accepts an input signal only in digital form an analogue-digital converter (ADC) is used (Morris, 2006). ✓

Amplification. This process performs two functions. It increases the resolution of the input signal e.g. the output of an electronic temperature sensor, which is probably in the millivolts range is probably too low for an ADC to process directly. In this case it is necessary to bring the voltage level up to that required by the ADC. The amplification process also increases its signal-to-noise ratio (Morris, 2006). ✓

The **elimination** process is sometimes called “calibration” (Harrison, 2015). It is simply a procedure where the result of measurement recorded by an instrument is compared with the measurement result of a standard. A standard is a measuring device intended to define, to represent physically, to conserve or to reproduce the unit of measurement in order to transmit it to other measuring instruments by comparison. The calibration itself is usually carried out by measuring the quantity over the whole range required and by defining either one correction factor for the whole range, for a constant systematic error or a correction curve or equation for the whole range. Applying this correction to the measurement result eliminates the systematic error and gives the corrected result of measurement. ✓

The **manipulation** element manipulates and amplifies the output of the variable conversion element. It also removes noise (if present) in the signal. The function of a variable manipulation element is to manipulate the signal presented to this element while preserving the original nature of the signal. For example, a voltage amplifier acts as a variable manipulation element. The amplifier accepts a small voltage signal as input and produces an output signal which is also voltage but of greater magnitude. The variable manipulation element could be either placed after the variable conversion element or it may precede the variable conversion element (Morris, 2006). ✓

Protection against high currents or high voltages is an important element in a measurement system. High current or voltage can damage sensors in the apparatus. A high current can be protected against by placing a series resistor into the input line to limit the current to an acceptable level and fuse if the current does exceed a safe level. Protection against high voltage and wrong polarity voltages may be obtained by using a Zenor diode circuit. The Zenor diode with a reverse voltage connected across it has a high resistance up to a particular voltage at which it suddenly breaks down and becomes conducting if it is exceeded (Bolton, 2015). ✓

Task 6 Basic control systems

6. (a)

In a system that employs open loop control, the value of the input variable is set to a given value in the expectation that the output will reach this desired value. In such a system there is no automatic comparison of the actual output value with the desired output value in order to compensate for any differences. Therefore open loop control may be regarded as a system that needs human operator intervention to monitor performance and to modify matters if the outcome is not correct (Tooley, Dingle 2005).

It is also referred to as non-feedback system as it is a type of continuous control system in which the output has no influence or effect on the control action of the input signal. In other words, in an open-loop control system the output is neither measured nor “fed back” for comparison with the input. Therefore, an open-loop system is expected to faithfully follow its input command or set point regardless of the result (Tooley, Dingle 2005). ✓

Example

An example of an open loop system is an electric clothes dryer. Depending upon the amount of clothes or how wet they are, a user or operator would set a timer (controller) to say 30 minutes and at the end of the 30 minutes the dryer will automatically stop and turn-off even if the clothes were still wet or damp.

In this case, the control action is the manual operator assessing the wetness of the clothes and setting the process (the drier) accordingly.

In this example, the clothes dryer would be an open-loop system as it does not monitor or measure the condition of the output signal, which is the dryness of the clothes. Then the accuracy of the drying process, or success of drying the clothes will depend on the experience of the user (operator).

However, the user may adjust or fine tune the drying process of the system at any time by increasing or decreasing the timing controllers drying time, if they think that the original drying process will not be met. ✓

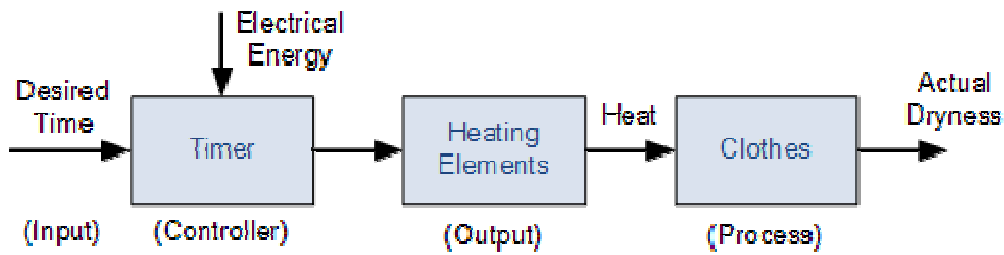
Advantage

An advantage of open-loop control is that it is potentially cheap and simple to implement making it ideal for use in well-defined systems where the relationship between input and output is direct and not influenced by any outside disturbances. The input command is the only factor responsible for providing the control signal. ✓

Disadvantage.

An open-loop system has no knowledge of the output condition so cannot self-correct any errors it could make when the pre-set value drifts, even if this results in large deviations from the pre-set value. ✓

Open-loop Drying System Block Diagram

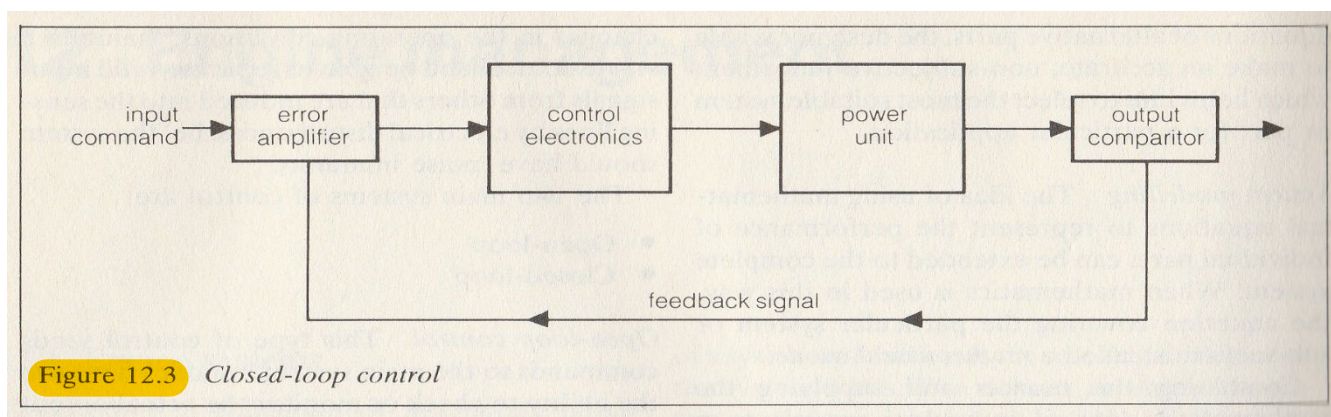


<https://www.electronics-tutorials.ws/systems/open-loop-system.html>

6. (b) Closed Loop Control System

Practical engineering systems make use of closed loop control. The loop may be closed by human operators who determine the deviation between the desired and actual output. In most cases however the action of the system is made fully automatic and no human intervention is necessary other than initially setting the desired value to the output (Tooley, Dingle 2005).

The closed loop control system has a means for measuring the output and feeding back a signal to allow a comparison to be made between the command signal and the system's output (Hillier, 1989).



Block diagram of a closed loop control system with major components (Hillier, 1989).

1. The input command sets the desired value
2. The error amplifier or comparison element compares the measured output value to the desired input value.
3. The control electronics contains a switch or relay and location of the element that controls the process.
4. The output is the desired result. The output sensor is operative during the normal operating range, but when a pre-set limit is exceeded the feedback circuit passes a signal back to the input; this allows an alteration to be made to the command input

5. The feedback signal from the output sensor is passed back to the input where it is compared by use of an error amplifier. This intensifies and processes the signal to allow it to be compared with the input command. If the output differs from that commanded by the input, the command signal is altered until the required output is obtained.
- A *closed loop proportional control system* uses a sensor in the output to generate a signal proportional to the output, therefore the magnitude of the feedback signal indicates the system's output.
 - A *closed loop limit cycle control system* uses the feedback to signal when a given limit is exceeded. ✓



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