

MARKING CRITERIA AND STUDENT FEEDBACK

This section details the assessment criteria. The extent to which these are demonstrated by you determines your mark. The marks available for each criterion 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.

Common Assessment Criteria Applied	Marks available	Marks awarded
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions.		
<i>clear evidence of reading along with comprehensive references</i>	10	10
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		
<i>A Very good effort. You lost marks in Task 1 by not describing instrumentation amplification. In task 2 did you missed the point regarding component changes + disturbances.</i>	50	41
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence		
<i>A good analysis of measurement system and T.F. in Task 4.</i>	10	10
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems.		
<i>in Task 4 I was expecting 'Hand' produced PZ diagrams before the Matlab confirmation</i>	25	19
5. Skills for Professional Practice Attributes in professional practice: individual and collaborative working; deployment of appropriate media; presentation and organisation.		
<i>Very good attempt - well presented.</i>	5	5

Assignment Mark Overall (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)		85. %
	Up to one-week late		
	Over one week late		

CS

GOWER COLLEGE, SWANSEA

Dynamics, Control and Instrumentation

HNC Year 2 Electronic Engineering

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Documented research notes and progress to the final presentation

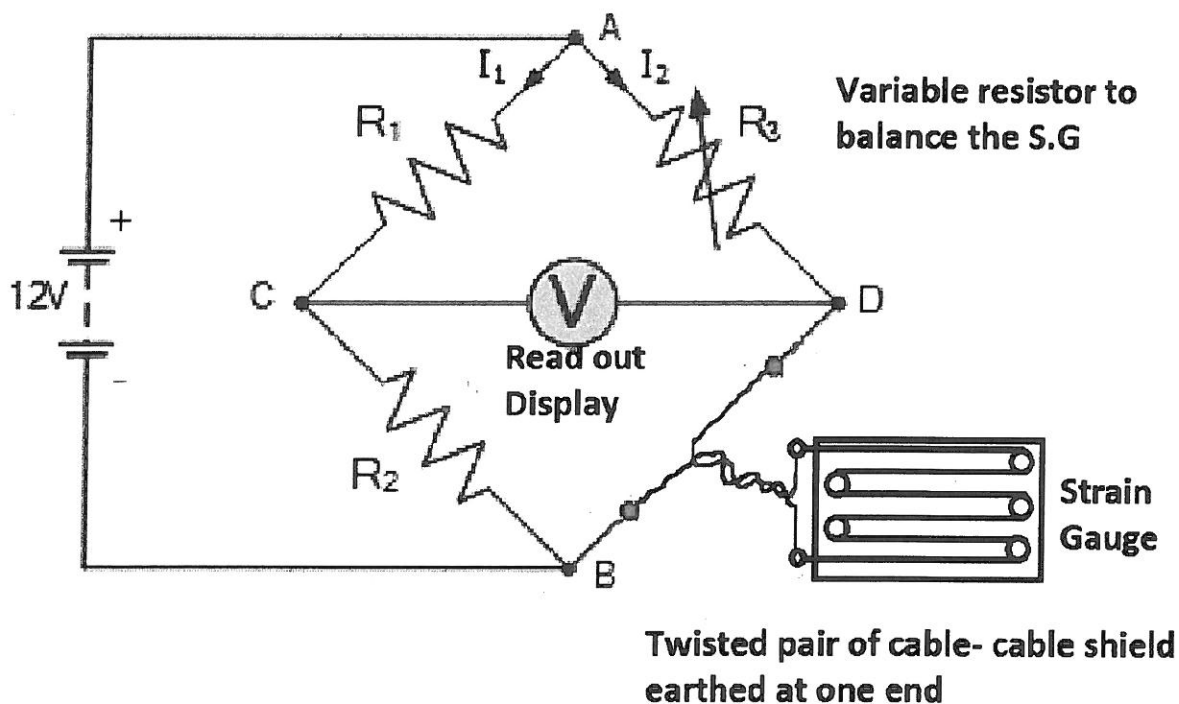
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Task 1

Determining the stress in a load bearing structure

a) The strain gauge (also known as a resistive pressure transducer) must be bonded securely to the steel strut. The strain gauge must be connected to a Wheatstone Bridge circuit. The millivolt output of a wheatstone Bridge circuit is connected to measuring device such as an oscilloscope or a digital meter and it must be fixed to the structure in the plain of the expected strain. ✓

A millivolt signal that is processed by a recorder is subject to noise from other electrical circuits. These are known as Eddies (magnetic fields) that surround cables and cause adverse readings. By using a twisted pair cable and grounding only one end of the cables shield this shields electrical interference. ✓



The Wheatstone Bridge is based on a stable system that becomes unstable when the mV output of the Strain Gauge varies. When ✓

$$\frac{R_1}{R_1 + R_2} = \frac{R_3}{R_3 + S.G.} = 0 \text{ volts}$$

If S.G. value changes then the voltage will not be equal to zero and this is what is used to measure the level of stress and therefore calculate the change in dimensions. ✓

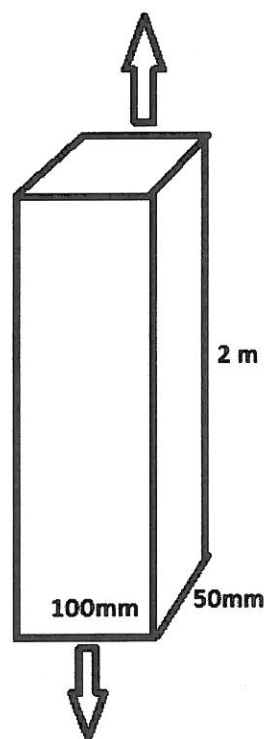
We must assume that the load bearing strut will be located in an environment subject to climatic extremes. The use of one strain gauge will not accurately reflect the true values. Using a pair on directly opposite sides of the strut will give equal readings as long as the force is in a longitudinal ✓

direction (for a lateral motion ie. The strut is bending one will give a positive and the other a negative reading).

Two strain gauges will also experience the same temperature changes as the heat will travel through the high specific heat capacity of the steel and the base material that the strain gauge is attached with. These minute expansions or contractions in dimensions will alter the cross sectional area of the metallic conducting tracks in the strain gauge thereby altering its resistance and giving false readings. This can be overcome using a temperature compensation unit. In addition to this the manufacturer will specify the operational limits of their products.

✓
(12) -

B)



Using a Wheatstone bridge using 120Ω resistors with the strain gauge connected the resistance of the strain gauge ($R_3 + R_x$) and the resistors ($R_1 + R_2$) are the same so that

$$\frac{R_1}{R_1 + R_2} = \frac{R_3}{R_3 + R_x} = 0 \text{ volts}$$

✓

When strain is applied to the strut the resistance of the strain gauge changes proportionally with the force.

Before the two loads are applied to the strut the stress has to be calculated.

Area is measured in millimetres

$$100 * 50 = 5000\text{mm}^2 \text{ or } 5.0 \times 10^3 \text{ mm}^2$$

The elasticity of the steel is $E = 210\text{GPa}$ (giga pascals)

Load of 1.5MN (mega Newtons)

Therefore Stress $\sigma = \frac{\text{Force}}{\text{Area}}$

$$\sigma = \frac{1.5 \times 10^6}{5 \times 10^{-3}} = 0.3 \times 10^9 \text{ Pa (Pascals)}$$

Youngs modulus is $E = \frac{\sigma \text{ Stress}}{\epsilon \text{ Strain}}$ so to rearrange this to get strain $\epsilon = \frac{\sigma}{E}$

$$\epsilon = \frac{0.3 \times 10^9}{210 \times 10^9} = 1.429 \times 10^{-3}$$

Delta X (change in length) which will be referred to as $\Delta X = \text{strain} \times \text{Length}$

$$\Delta X = \epsilon \times L$$

$$1.429 \times 10^{-3} \times 2 = 2.86 \times 10^{-3} \text{ m}$$

The Wheatstone bridge will now be unbalanced as the internal resistance in the strain gauge has altered. There for $R_1/R_2 = R_3/\Delta R_x = \text{millivolts volts}$

Using the gauge factor formula

(change in resistance/nominal resistance)/strain

$$K = \frac{(\Delta R/R)}{\epsilon}$$

So to rearrange the formula to get the change in resistance $\Delta R = K R \epsilon$

$$2 \times 120 \times 1.429 \times 10^{-3} = 0.343 \Omega$$

Therefore the Wheatstone Bridge will now alter to this

$$\frac{120}{120+120} = \frac{120}{120+120.343}$$

$$0.5 \Omega = 0.4993 \Omega$$

There is a difference of $0.7 \times 10^{-3} \Omega$

To calculate the voltage change the following formula is used

$$\frac{V_{in} \times \text{Gauge Resistance}}{\text{Resistance} + \text{Gauge resistance}}$$

$$\text{Unstrained voltage} \quad \frac{10 \times 120}{120+120} = 5 \text{ Volts}$$

$$\text{Strained Voltage} = \frac{10 \times 120.343}{120 + 120.343} = 5.007 \text{ Volts}$$

Therefore with a load of 1.5MN applied there is a voltage increase of 7mV ✓

We can then work out Poisons ratio to work out the longitudinal strain for mild steel which is 0.29 (reference for this figure detailed in Reference section)

$$\epsilon = \frac{\Delta L}{L} \text{ This equation shows that change in length/nominal length)=Strain}$$

$$\epsilon = \frac{2.86 \times 10^{-3}}{2} = 1.43 \times 10^{-3} \text{ Pa which is the longitudinal strain}$$

Load of 2.5 MN (mega Newtons)

$$\text{Therefore Stress} \quad \sigma = \frac{\text{Force}}{\text{Area}}$$

$$\sigma = \frac{2.5 \times 10^6}{5 \times 10^{-3}} = 0.5 \times 10^9 \text{ Pa (Pascals)}$$

$$\text{Youngs modulus is } E = \frac{\sigma \text{ Stress}}{\epsilon \text{ Strain}} \text{ so to rearrange this to get strain } \epsilon = \frac{\sigma}{E}$$

$$\epsilon = \frac{0.5 \times 10^9}{210 \times 10^9} = 2.39 \times 10^{-3}$$

Delta X (change in length) which will be referred to as $\Delta X = \text{strain} \times \text{Length}$

$$\Delta X = \epsilon \times L$$

$$2.39 \times 10^{-3} \times 2 = 4.75 \times 10^{-3} \text{ m}$$

The Wheatstone bridge will now be unbalanced as the internal resistance in the strain gauge has altered. There for $R_1/R_2 = R_3/\Delta R_x = \text{millivolts volts}$

Using the gauge factor formula

$$(\text{change in resistance/nominal resistance})/\text{strain}$$

$$K = \frac{(\Delta R/R)}{\epsilon}$$

So to rearrange the formula to get the change in resistance $\Delta R = K R \epsilon$

$$2 \times 120 \times 2.39 \times 10^{-3} = 0.574 \Omega \quad \checkmark$$

Therefore the Wheatstone Bridge will now alter to this

$$\frac{120}{120+120} = \frac{120}{120+120.574}$$

$$0.5\Omega = 0.4988\Omega$$

There is a difference of $1.2 \times 10^{-3} \Omega$

To calculate the voltage change the following formula is used

$$\frac{V_{in} \times \text{Gauge Resistance}}{\text{Resistance} + \text{Gauge resistance}}$$

$$\text{Unstrained voltage} \quad \frac{10 \times 120}{120+120} = 5 \text{ Volts}$$

$$\text{Strained Voltage} \quad \frac{10 \times 120.574}{120+120.574} = 5.0118 \text{ Volts}$$

Therefore with a load of 1.5MN applied there is a voltage increase of 11.8mV

We can then work out Poisons ratio to work out the longitudinal strain for mild steel which is 0.29 (reference for this figure detailed in Reference section)

$$\epsilon = \frac{\Delta L}{L} \quad \text{This equation shows that change in length/nominal length} = \text{Strain}$$

$$\epsilon = \frac{4.75 \times 10^{-3}}{2} = 2.375 \times 10^{-3} \text{ Pa which is the longitudinal strain}$$

This is then put through an OP- amp with a common mode rejection ratio to magnify the readings for convenience and visual purposes.

✓
(10)

Task 2

A)

-Set point. A set point is a target value for a user defined variable of a system. It is often used to describe the standard configuration or norm for a system. ✓

- Overshoot. When a pre defined set of values are exceeded. Either a steady state or fixed point signal passes the target point. ✓

- Plant. The plant is the piece of equipment which the control system monitors. It is the relationship between the input and the output signal without the use of any feedback. ✓

- Control Variable. Is the output of the system which is regulated to be that of the setpoint or positive or negative to come back into line with the set point. ✓

- Controller. Is what monitors (either electrically or mechanically, expansions, contraction) the output signal and through the feedback loop controls the process value so as to match the setpoint. ie. It governs how much the process is altered to minimise the difference

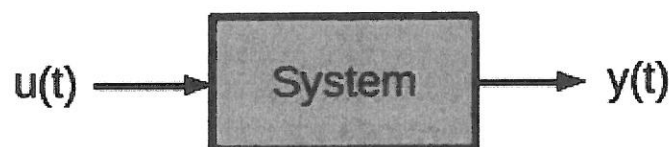
- Control law. Is the mathematical formula used by the controller. It monitors the plants output and uses this as its own input. The controller uses this input and applies its own algorithms to determine its output.

10

B)

A transfer function of a control system is the relationship between the systems output and input and is represented as a characteristic curve. A transfer function of a system is determined by using a Laplace transform. It switched a function of time when the initial condition is zero to a function of a complex number.

The diagram below shows how the input is processed by the system and the output adjusted accordingly.

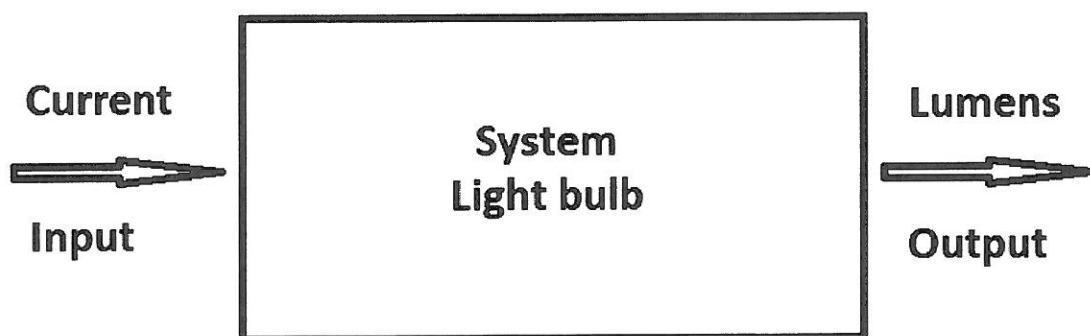


(<https://x-engineer.org/wp-content/uploads/2017/04/System-input-output.jpg?428282&428282>)

Example 1:

This is an open loop system G_s (the transfer function) is equal to the input divided by the output as shown in the formula below

$$G_{(s)} = \frac{\text{Steady state input}}{\text{Steady state output}}$$

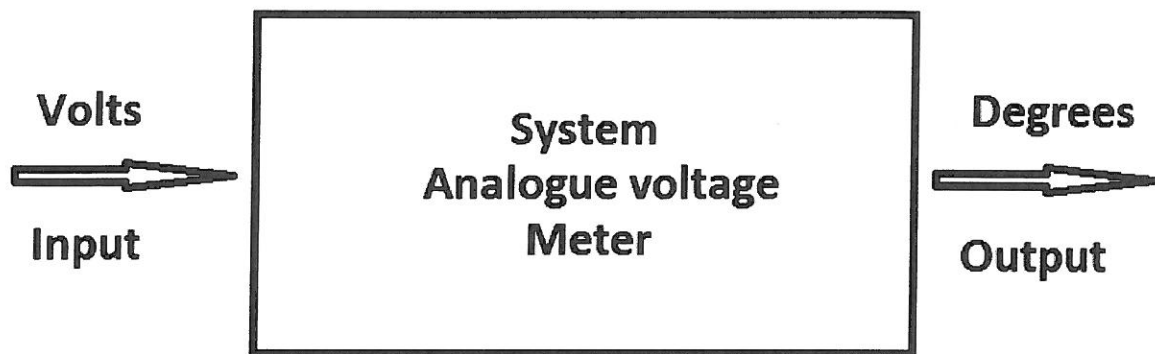


Input current passes through the resistive coil of the lamp and creates heat. Part of this heat energy is emitted as light (or lumens).

Example 2:

This is an open loop system G_s (the transfer function) is equal to the input divided by the output as shown in the formula below

$$G(s) = \frac{\text{Steady state input}}{\text{Steady state output}}$$



A voltage is measured using the meters probes. It excites a coil within the meter pulling the calibrated needle across the scale. This is an open loop system

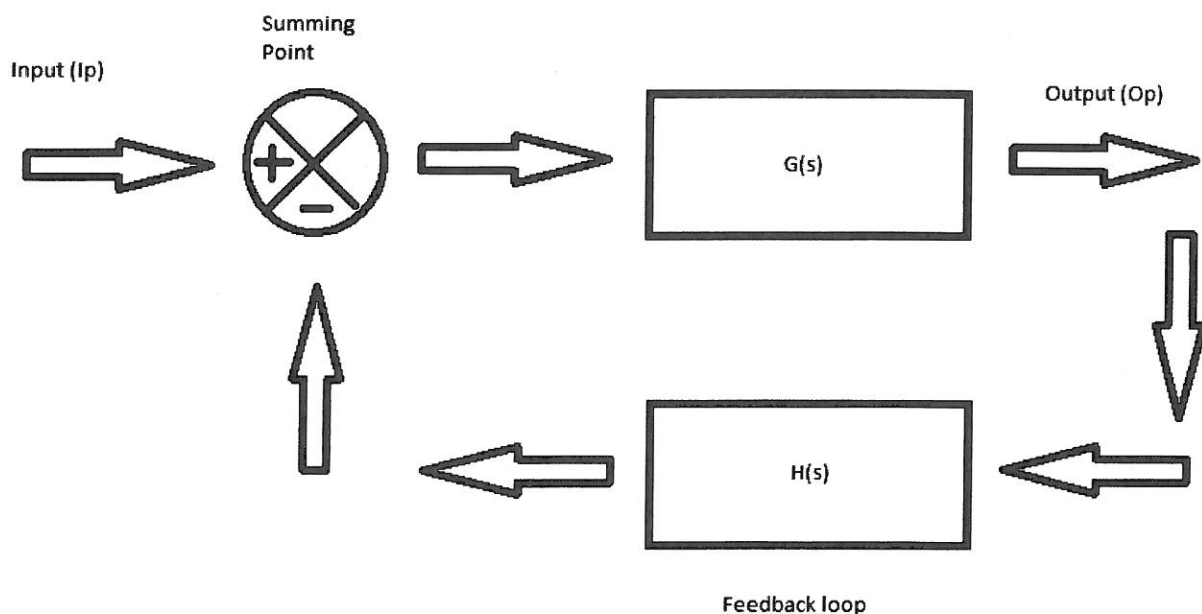
Example 3:

This is a closed loop system as it has upper and lower set points. The formula below explains a closed loop system

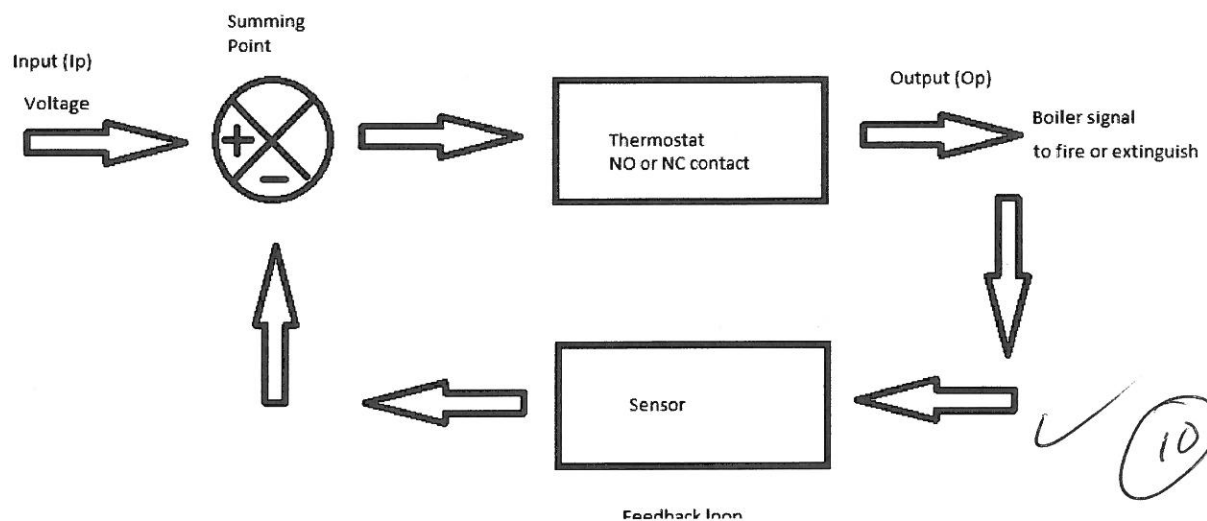
$$G(s) = \frac{\text{Output}}{\text{Input}} = \frac{G_1(s)}{1 + G_1(s)H(s)}$$

G_1 is the 'open loop' part of the system

H_s is the feedback error loop as shown in the schematic below



The temperature expands or contracts the bimetallic strip within the thermometer. Once it passes the set point it switches the contacts to either close or open the signal to the boiler to ignite.

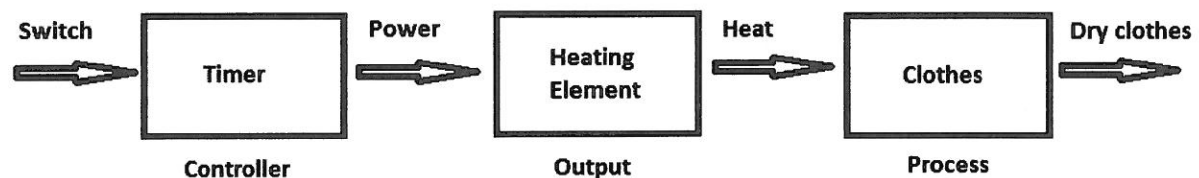


c)

Open and closed loop systems.

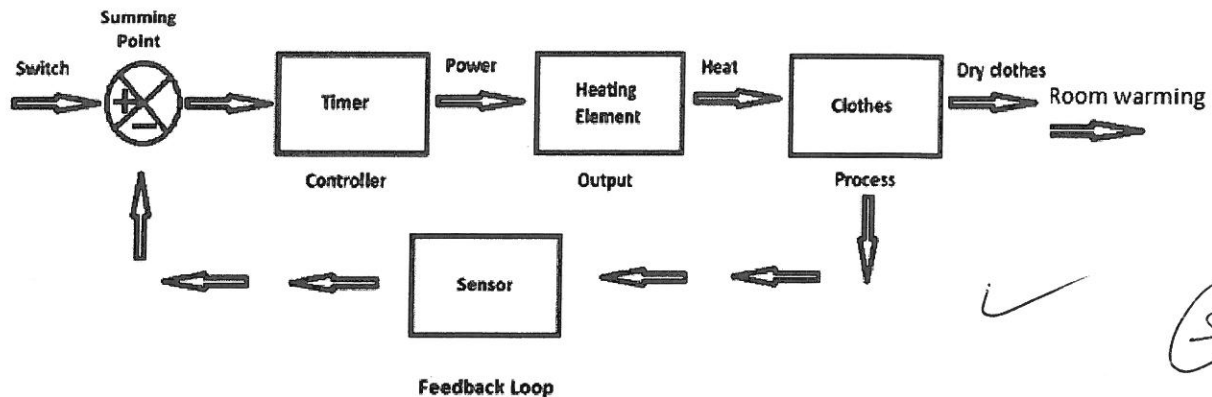
An open loop system is one that only responds to the input signal received- therefore if the input is stable so is the output. There are no disturbances or variations within the system and the output is always mathematically related to the input. The system is always stable.

An example would be a basic tumble drier



A closed loop system is also known as a feedback system. It comprises a forward or open loop system but has one or more feedback loops going through a summing system to regulate the output between a maximum and minimum set point or a single defined set point. The system is not stable.

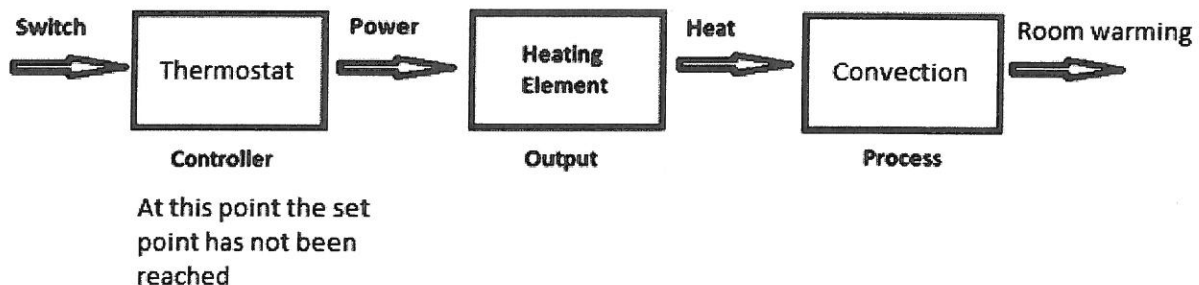
An example would be a higher model tumble drier with a drying sensor



In this example the sensor monitors the humidity within the chamber and once it reaches a set point it can either switch off the drier or reduce the heat and blow cooler air for the clothes not to become a fire risk.

D)

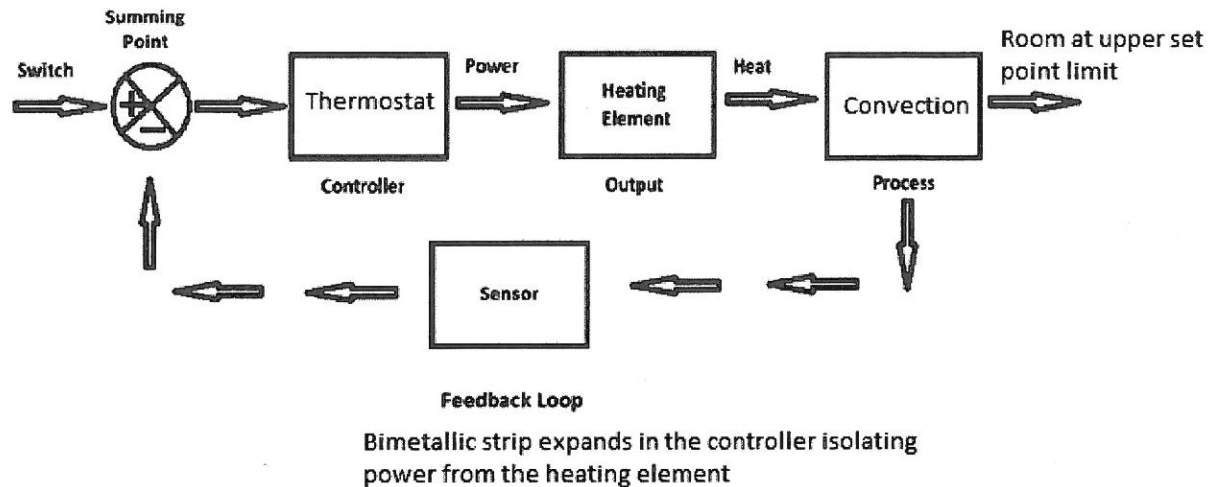
A good example of a closed loop system is an oil filled radiator. Simply it works by monitoring the ambient air temperature through a thermostat. The main power switch is turned on to allow electrical current to flow through the thermostat and be converted to heat in the element. This heats the oil in the radiator and through convection the room is warmed. At this point the system is working as an open loop system as one input is controlling the output as show in the flow chart below (the set point has not been reached).



Once the heater has been on and has warmed the room to a set point defined by the thermostat this system then utilises the feedback loop (or error signal).

The output convection of the heat causes the bimetallic coil in the thermostat to expand until it reaches the upper set point where the electrical contact is opened (the summing point). This causes the circuit to become open and current can no longer flow to the heating element. The element cools, so does the oil and the rate of convection reduces. Once the room cools slightly the bimetallic switch contracts and reaches the lower set point- the contact is closed (the summing point) and power is restored to the element- this process continues until the thermostat is adjusted or the heater is electrically isolated. ✓

The closed loop system is shown below



If this was an open loop system then the element would stay on and continue to heat the room until a maximum temperature is reached where heat absorption into the walls and fixtures equals the heaters output. With the closed loop system it is possible to regulate the heat. The advantages of this include a comfortable ambient temperature and energy conservation. ✓ (L)

Task 3

A)

Linear displacement. A linear variable displacement transducer is an electromechanical device that can detect linear motion of an object. It does this by passing an iron core through a primary and two secondary windings of the transducer. As the iron core passes through it creates a magnetic field (EMF) from the AC in the primary coil which produces small mV in the secondary windings that can be read by instrumentation- this EMF is relative to the displacement. ✓

Rotational displacement. This is a sensor that relates a position to that of another position on an axis. The older versions used a wiper attached to the shaft sweeping across the resistive track of a potentiometer. Modern versions follow a similar principle to the linear displacement sensor and measure the inductive field from an AC exciter coil across two secondary coils at 90° to each other. Depending on the EMF strength in each coil the position of the stator can be read. ✓

Pressure sensor. There are many different types of pressure sensors, they can be electrical or mechanical. For the electrical sensors there are again many different types. Pressure transducers can either measure absolute or gauge (These are used on Hospital Sterilisation Units when absolute vacuum needs to be measured). These work by using a ceramic diaphragm that is so thin it is able to flex with the varying pressure- it acts upon the oil reservoir behind (fluids can not be compressed and distribute the force evenly over the whole area) which in turn transfers the pressure on to a piezoresistive sensor. ✓

These sensors contain crystals which are either conductors or semi conductors and the pressure acting upon them alters the position of the electrons. By aligning or misaligning these electrons the resistive value is changed. It is for this reason that transducers are measured in milliOhms or millivolts. ✓

Presence (of a metallic item). Also known as a inductive proximity sensor. It is a non contact sensor that can detect both ferrous (such as iron) and non metallic (such as aluminium) metals. It has two outputs- open and closed- some models have adjustable built in timers to hold the open or closed signal for a defined length of time. An example would be on a simple combustion engine vehicle with three solenoids for forwards, neutral and reverse. Here the presence sensor would pick up a metal tag spinning on the driveshaft to stop the opposite direction being selected until the vehicle has come to a stop.

Vibration sensor. These detect linear velocity, displacement or acceleration. They work by having a conductive central shaft wrapped in piezoresistive crystals with a seismic mass on the outer side (ie. The outer wall vibrates). The vibration causes the electrons to constantly align and misalign resulting in a proportional resistive 4-20 mA output proportional to the vibration frequency or intensity.

B)

A mA transducer works by supplying a voltage to the primary and secondary coils (known as a current loop) within the transducer. Following the principles of Ohms law the output current is measured not the voltage. The current varies as the piezoresistive crystals align and misalign altering their resistive value.

A mV transducer uses a three wire configuration to generate a 0-10 volt analogue output signal. It is a voltage divider. The piezoelectric crystals create a small charge on their surface when a pressure is applied. It is this charge that needs to be amplified using the voltage divider.

There are many advantages for using the 4-20mA transducer over the 0-10 or 0-5 volt version.

-The mV transducer requires 3 wires whereas the mA transducer needs only a 2 wire twisted pair. This shielded twisted pair resists external noise and disturbances. It also makes installation quicker and more simple.

-The 4-20mA transducer has a range between 4mA (closed circuit) and 20mA (open circuit). A reading of 0mA will indicate a fault (which will make fault diagnosis simpler). For mV transducer with an output of 0v to 10V , zero volts could either indicate an actual reading of 0v or that its not working.

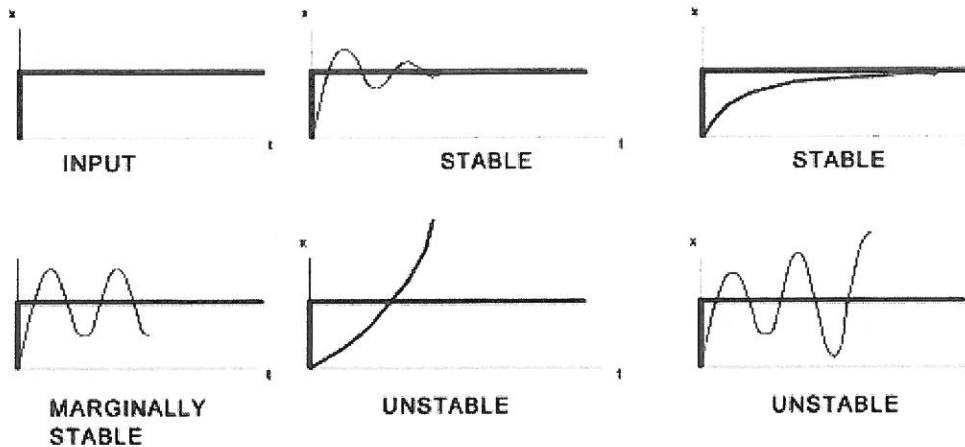
-The mV output signal is subject to voltage drop over longer runs and between connections whereas as the mA signal is not subject to signal degradation.

-The current loop inside the mA transducer is subject to voltage drop but not current variations meaning that the output signal will not vary.

-A mV transducer cannot measure a static condition and in some instances the ambient temperature can affect the surface charge of the crystals.

Task 4

A)



Reference to graph in Reference section

A stable system is one that can regulate itself using a feedback system with a summing point within the minimum and maximum set points (top three graphs) with no overshoot (bottom middle graph). The closer the output is kept to the setpoint and the less variation there is on the x axis the more stable it is.

The system is also stable if every bounded input produces a bounded output which settles to equilibrium as it travels down the Y axis.

B)

The poles (indicated by x) and zeros (indicated by o) shown on the plotted graph depict a transfer function in a complex plane which illustrates amongst other things whether a system is stable.

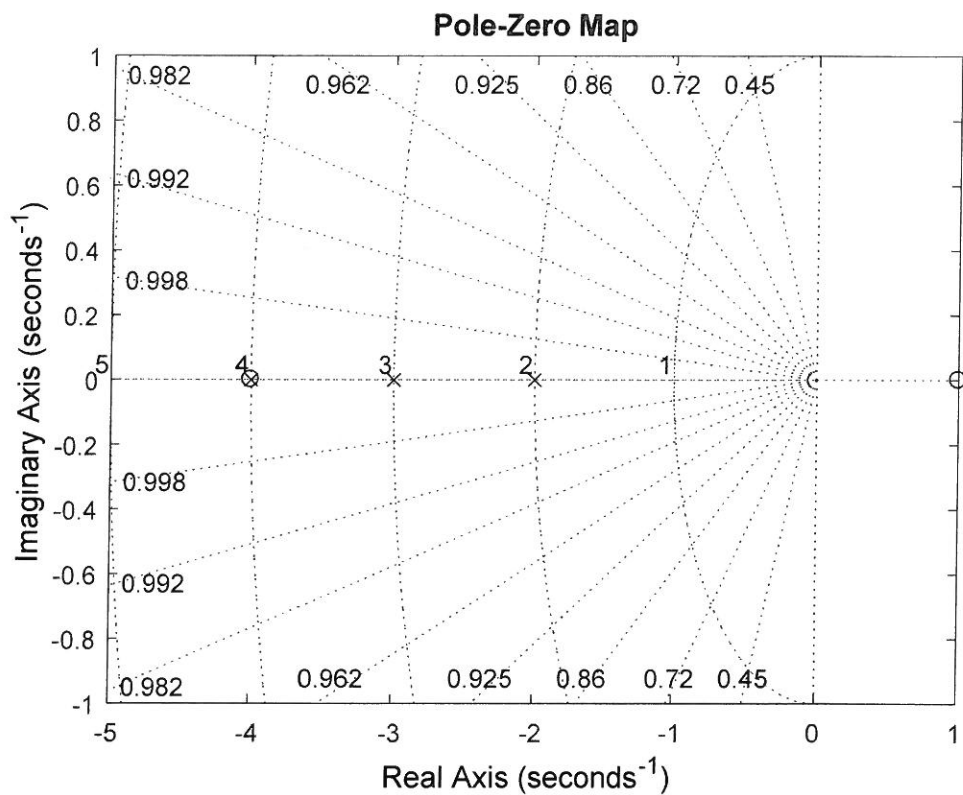
For a stable system the poles need to appear on the left hand side (negative values) of the s plane domain of the Laplace Transform.

The zeros of the system are the roots of the numerator polynomial

The poles of the system are the roots of the denominator polynomial.

A polynomial is a mathematical expression that consists of constants variables and exponents

A root is a value for which a given function equals zero. Hence N roots are the numerators and D roots are the denominator.



>> N= [1 3 -4] This is my numerator

D= [1 9 26 24] This is my denominator

Nroots= roots(N)

Droots= roots(D)

system= tf([N],[D])

pzmap (system)

grid on

N = 1 3 -4

D = 1 9 26 24

Nroots = -4

1

Droots = -4.0000

-3.0000

-2.0000



As these are all negative so will be in the left hand plane of the S domain which shows the system is stable

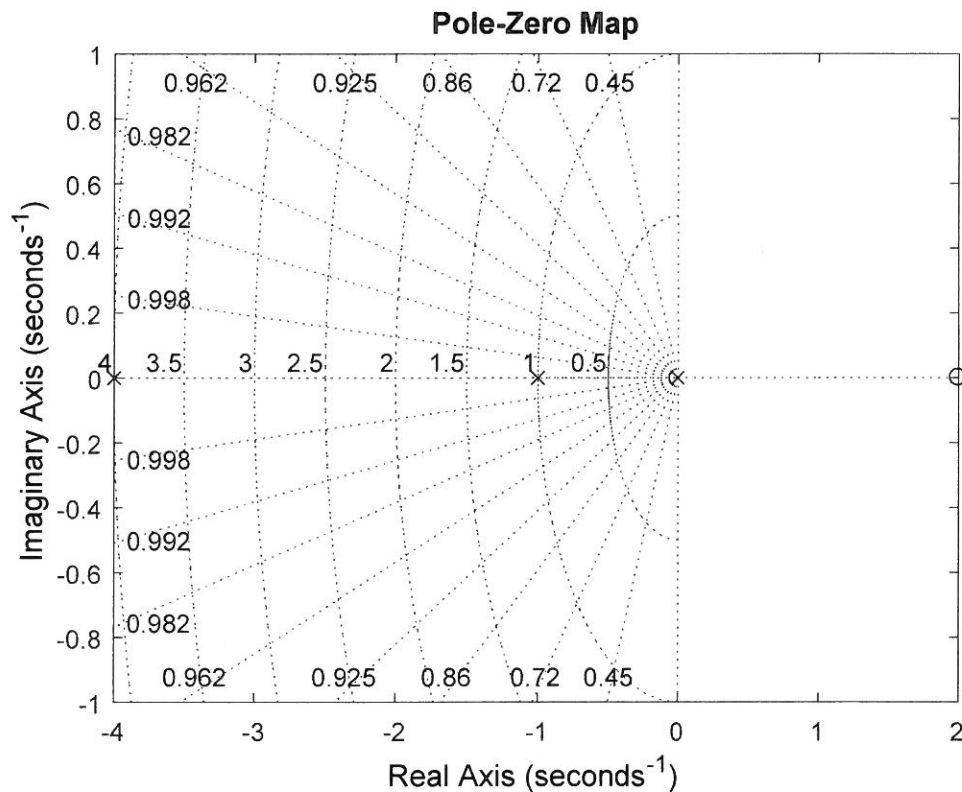
system = $s^2 + 3s - 4$ This is the system transfer function

$$\frac{s^2 + 3s - 4}{s^3 + 9s^2 + 26s + 24}$$



Continuous-time transfer function.

Task 4 B Part ii)



```
N= [1 -2]
D= [1 5 4 0]
Nroots= roots(N)
Droots= roots(D)
system= tf([N],[D])
pzmap(system)
grid on
```



N= 1 -2

D= 1 5 4 0

Nroots = 2

Droots = 0 -4 -1

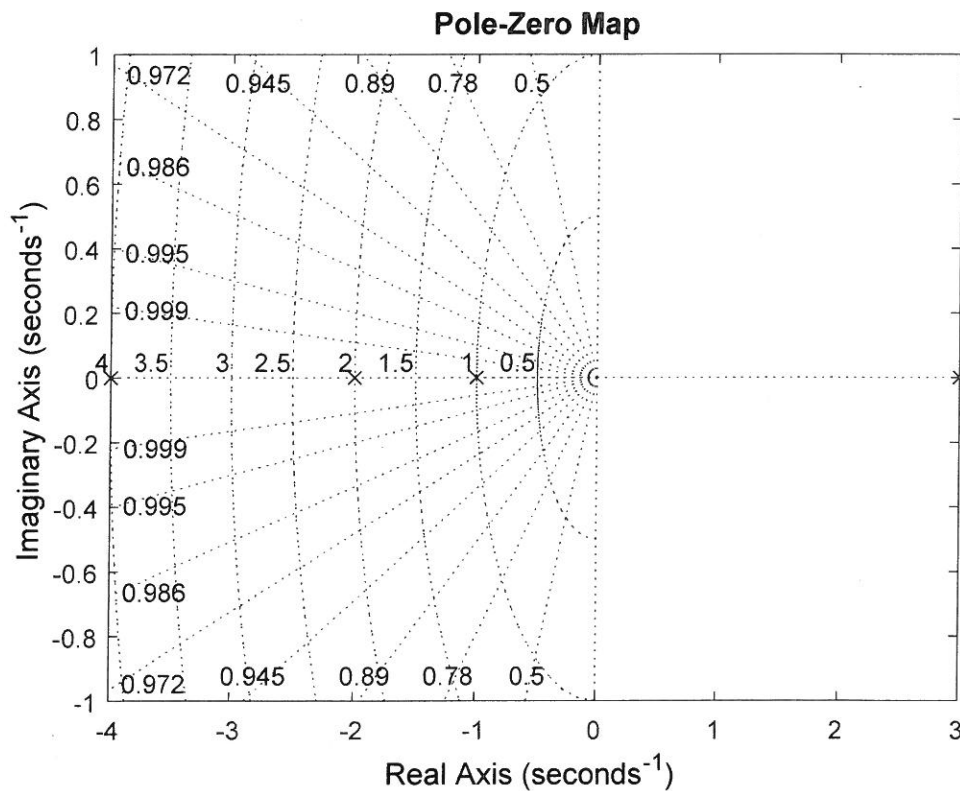
system = $s - 2$

$$s^3 + 5s^2 + 4s$$

As these are all negative so will be in the left hand plane of the S domain which shows the system is stable

Continuous-time transfer function.

Task 4 Part B iii)



```
N= [1]
D= [1 4 -7 -34 -24]
Nroots= roots(N)
Droots= roots(D)
system= tf([N],[D])
pzmap(system)
grid on
```

N = 1

D = 1 4 -7 -34 -24

Nroots = 0x1 empty double column vector

Droots = 3.0000 -4.0000 -2.0000 -1.0000

system = 1

$$s^4 + 4s^3 - 7s^2 - 34s - 24$$

The Routh Hurwitz theory shows whether all the roots of a polynomial (as shown in the formula above) of a linear system have negative real parts.

The table below has been completed by taking the first, third and fourth numeric variables of the constants (s) and put in the exponential row S^4

The second and fourth numeric variables of the constants (s) are put in the exponential row s^3 .

This continues down to the last row S^0 . The missing figures are completed by using matrices.

For example

$$b1 = - \begin{bmatrix} a4 & a2 \\ a3 & a1 \\ a3 \end{bmatrix} = - \begin{bmatrix} 1 & -7 \\ 4 & -34 \\ 4 \end{bmatrix} = \frac{(a4 \times a1) - (a3 \times a2)}{a3} = \frac{(4 \times -7) - (-34 \times 1)}{4} = 1.5$$

S^4	1 a4	-7 a2	-24 a0
S^3	4 a3	-34 a1	0
S^2	1.5 b1	0 b2	0
S^1	30 c1	0	0
S^0	-24 d1	0	0

This system is unstable as one of the pole signs has changed from positive to negative and one is on the right hand side of the s-domain of the Laplace Transform

Continuous-time transfer function.



References

Task 1.

Wheatstone bridge image

<https://www.electronics-tutorials.ws/blog/wheatstone-bridge.html>

Nicholas Davies HNC Electronic Engineering Year 2

Youngs modulus extra research

<https://www.britannica.com/science/Youngs-modulus>

Poissons ratio for mild steel

<http://silver.neep.wisc.edu/~lakes/PoissonIntro.html>

Strain gauge design

<https://www.brown.edu/Departments/Engineering/Courses/En123/Lectures/StrainFromCyber.htm>

Task 2

Definitions

<https://www.britannica.com/science/control-theory-mathematics#ref828088>

https://www.cds.caltech.edu/~murray/wiki/Could_you_give_a_precise_definition_for_%22Control_Law%22%3F

Task 3

Definitions

<https://www.omega.com/technical-learning/linear-variable-displacement-transducers.html>

<https://www.sensorsmag.com/components/understanding-linear-position-sensing-technologies>

<http://www.futureelectronics.com/en/sensors/angular-position.aspx>

<http://www.sensorland.com/HowPage004.html>

http://www.fargocontrols.com/sensors/inductive_op.html

Part B- 4-20mA basics

<https://www.predig.com/indicatorpage/back-basics-fundamentals-4-20-ma-current-loops>

<http://www.instrumentationtoday.com/piezoelectric-transducer/2011/07/>

Task 4

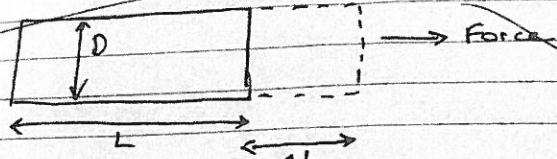
<http://www.roymech.co.uk/Related/Control/Stability.html>

Documented research notes and progress to the final presentation

wrong a strain gauge wheatstone bridge

$$R_1 + R_2 = R_3 + R_4 = 0V$$

R_4 is replaced with strain gauge



$E = \frac{\Delta L}{L} \text{ change in length / normal length}$ Poisson strain $\frac{\Delta D}{D} = \epsilon_T$

Typical ranges between 30 → 3000 Ω usual are 120, 150 + 1000 Ω

$\rightarrow \frac{120 \Omega}{120} = \frac{120}{120} = 0 \text{ volts}$

Using Poisson's ratio it is possible to work out longitudinal strain

0.29

1.5MN $\epsilon = \frac{\Delta L}{L} = \frac{2.86 \times 10^{-3}}{2} = 1.43 \times 10^{-3}$ Po

$\epsilon_T = \frac{\Delta D}{D}$

Task 1.

b) Young's modulus - also known as elastic modulus
relationship between stress + strain in a material $E = \frac{\sigma}{\epsilon}$

E = strain

E = Young's modulus

F = force exerted on the object

A = cross sectional area

ΔL = amount the object changes

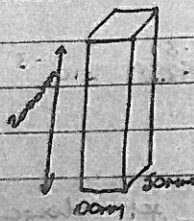
L_0 = original length of the object L_n = new length

Hooke's law = force needed to extend or compress a spring

$$F = kx$$

dimensions in mm not meters Modulus of elasticity 210 GPa

$$E = \frac{\sigma}{\epsilon} \text{ stress} / \text{strain}$$



Elasticity 210 GPa

$$E = \frac{\sigma}{\epsilon} \text{ 210 GPa}$$

1st we calculate the stress. To do this we need to find area: $50 \times 100 = 5000 \text{ mm}^2$ or $5.0 \times 10^{-3} \text{ m}^2$

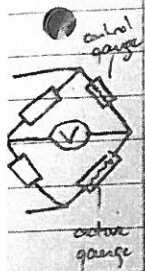
Task 1

load bearing struct. on a building - structure for temperature extremes. - assume worst case scenario

① - propose a measurement system - any special arrangements to maximise quality of the measurement.

Youngs modulus.

The strain gauge must be bonded securely to the steel strut.



Must be connected to a Wheatstone Bridge Circuit. This is a divided bridge circuit.

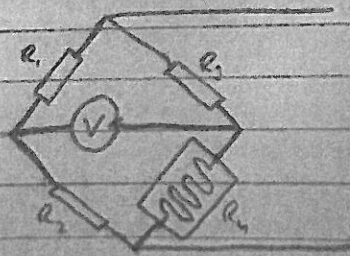
Strain gauge transducers employ 4 strain gauge elements connected to form a Wheatstone bridge circuit.

Wheatstone output is mV per V input.

R_1, R_2, R_3, R_4 are all equal. If the strain gauge R_4 changes then system will become unbalanced - there will be a voltage.

By using two they will both experience same temperature change. The internal structure of extensometers changes as does the base material with which it is attached. - this can cause dimensional changes so a temp compensation circuit is required.

Manufacture supplies specifications on operational limits.



$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \text{ then } V_o = \text{strain } (R_4)$$

otherwise there will be a mV output.

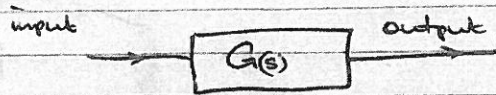
Use a twisted pair to shield noise - connect it to a shielded amplifier.

$$\left(\frac{1}{s^2 + 2\zeta\omega_n s + \omega_n^2} \right)$$

$$\omega = 2\pi f \text{ radians}$$

$$\frac{1}{ms^2 + cs + k}$$

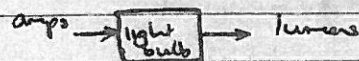
Control system



this is a transfer function

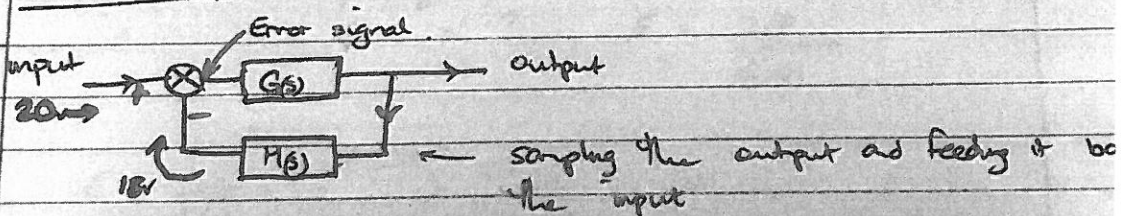
$G(s)$ = transfer function
= $\frac{\text{steady state output}}{\text{steady state input}}$

for example



these are examples of open loop systems.

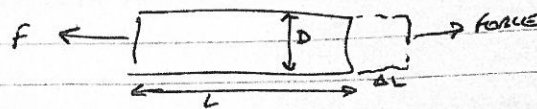
Feedback systems (or closed loop system)



known as a summing point

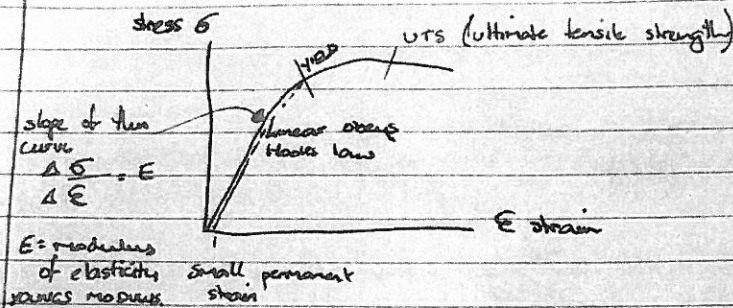
feedback 20V $20 + (-18) = 2V \rightarrow$ keeps working & balances itself

an open loop system is stable but closed loop isn't



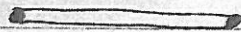
$$\epsilon = \frac{\Delta L}{L} \quad \text{Poisson strain} \quad \frac{\Delta D}{D} = \epsilon_T$$

$$\sigma = \frac{\text{force}}{\text{area}}$$



stress = Pascals

strain = $\frac{\Delta L}{L}$ so just a number



$$R = \rho \frac{L}{A}$$

ρ = Res? Read up a bit?!

Poisson ratio

$$\nu = \frac{-\epsilon_T}{\epsilon}$$

typically less than 1
eg. for steel its 0.25 to 0.3

Practical strain gauge

Range between 30 $\rightarrow$ 3000 Ω (unstrained value)

usual ones are 120 Ω , 150 Ω , 1000 Ω .

G.F. - gauge factor.

$\frac{\text{change in resistance over nominal resistance}}{\text{change in length over nominal length}}$

$$G.F. = \frac{\Delta R / R}{\epsilon} \quad (\text{typically answer will be milli strain } 1 \times 10^{-3})$$

commonly used in analysis of systems such as single input single output filters. Refers to linear the invariant. Most systems have non linear input/output characteristics

A closed loop control system is also known as a feedback control system.

It comprises of a forward system (open loop system) but has one or more feedback loops to control the output between set points.

An open loop control system does not have a feedback system so the output is entirely dependant on the input signal received.

There are no disturbances or variations

Advantages & disadvantages of 4-20 mA transducers.

4-20

Run over long distances with minimal signal degradation compared to mV with voltage drop - especially with a max voltage of 10V

- varying current loop load impedance will not affect the signal

- has zero reading indicator, the sensor is working correctly.

- uses a twisted pair so reduces noise & disturbance

- transmit via a current loop

2 wire means simple & inexpensive to connect & troubleshoot.

4 mA indicates closed 20 mA indicates open - 0 mA indicates fault.

especially in interconnecting wiring.

mV disadvantage - cannot measure in static condition

- small voltage high impedance cable

- temp may output may vary to temp of crystals

Plant: relationship between input + output signal without use of any feedback is the piece of equipment that

C.V = is the output and it is designed to meet the set point.

Controller - looks at signal representing the process value watches the setpoint + adjusts the process to minimize the difference

C.L = mathematical formula used by the controller to determine the output its outputs for the plant. It monitors the plants output and uses it as its own input. The controller then uses this + applies it to a algorithm to control its output.

transfer function - 2nd order transfer function

is a mathematical function giving corresponding output value for each possible value of the input. It is represented by a transfer characteristic curve provides information which controls behaviour of a component in the system -

Laplace transform of a function is a complex function of a complex variable. continuous time signals irrespective whether system is stable or unstable

$$T.F = \frac{\text{output}}{\text{input}} = \frac{F(s)}{X(s)}$$

comparable of natural frequency

$$\frac{120}{120} = \frac{120}{S. Gauge}$$

$$gauge factor = \frac{\left(\frac{\text{change in resistance}}{\text{nominal resistance}} \right)}{\text{strain}}$$

thin film metal (eg. constantan) is 2

1.5 MW a system using 120 Ω resistor

$$G.F. = 2$$

$$\text{strain} = \epsilon$$

$$\Delta R = \text{change in resistance}$$

$$\text{so } \Delta R = KRE$$

$$\Delta R = 2 \times 120 \times 1.429 \times 10^{-3}$$

$$K = \frac{\left(\frac{\Delta R}{R} \right)}{\epsilon}$$

$$2K = \frac{\Delta R \times \epsilon}{R}$$

$$K(R) = \Delta R \times \epsilon$$

$$\Delta R = KR \times \epsilon$$

$$(2 \times 120) \times 1.429 \times 10^{-3}$$

$$= 343 \text{ m}\Omega$$

strain gauge $120 + 343 \text{ m}\Omega = 120.343 \Omega$ vs 120Ω output of $343 \text{ m}\Omega$

Poisson's Ratio of 0.29 for strain gauge material

$$\epsilon = \frac{\Delta L}{L} = \frac{2.86 \times 10^{-3}}{2} = 1.43 \times 10^{-3} \text{ Pa}$$

put it through an OP-AMP - CMRR common mode rejection ratio

