

Faith Over 1904483

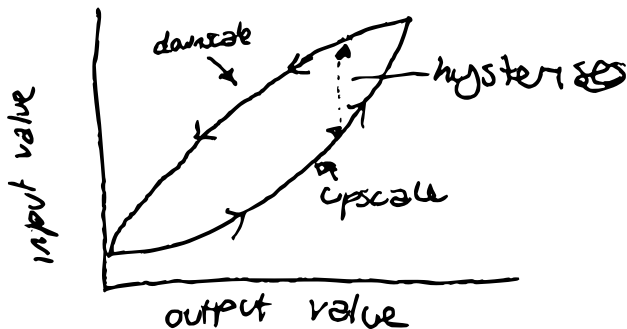
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QUESTION 1.

- (A) the ideal relationship is linear, so that change in θ_i is proportional to change in θ_o , and therefore input can be found from recorded output
- (B) hysteresis error is when transducers give different output values depending on whether the instrument is being loaded or unloaded (first point when increasing or decreasing load)



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(c) change in length of gauge wire is proportional to changes in resistance of device.

(d) i overall system sensitivity

$$75 \text{ m}\Omega/\text{mm} \rightarrow 75 \times 10^{-3}$$

$$150 \text{ mV}/\Omega \rightarrow 150 \times 10^{-3}$$

$$100 \text{ V/V} \rightarrow 100$$

$$1.78 \text{ cm}^{\text{mm}}/\text{V} \rightarrow 1.78 \times 10^{-1}$$

$$75 \times 10^{-3} \times 150 \times 10^{-3} \times 100 \times 1.78 \times 10^{-1}$$

$$0.20025 \text{ V}$$

$$\frac{\cancel{\Omega}}{\text{mm}} \frac{\cancel{\text{V}}}{\cancel{\Omega}} \frac{\cancel{\text{V}}}{\cancel{\text{V}}} \frac{\text{mm}}{\cancel{\text{V}}}$$

(d) ii $\rightarrow 0.20025 = \frac{C}{R} \rightarrow 0.20025 = \frac{12.75}{R}$

$$R = \frac{12.75 \times 10^{-1}}{0.20025} = 5.99 \text{ mm.}$$

(d) iii A wheatstone bridge is an electrical system used to measure an unknown resistance and convert change in resistance to change in voltage which

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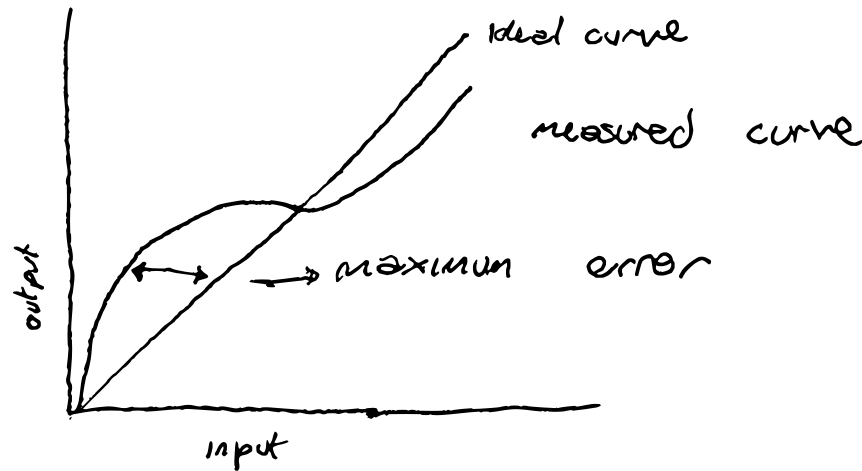
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can then be read & measured

- (e) when there is a curved measurement output, max error is either the input or output quantity expressed as a percentage of the full range



$$\frac{\Delta x}{x} \times 100\%$$

$$\frac{\Delta y}{y} \times 100\%$$

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QUESTION TWO

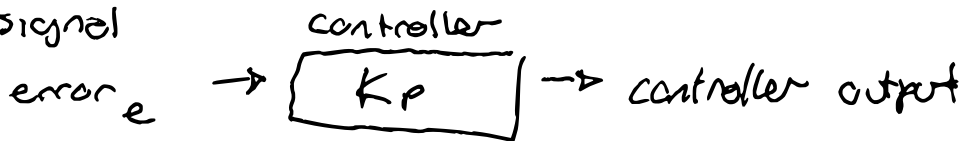
A control system comprises of elements and processes assembled for the purpose of controlling the output of the processes.

There are 3 main factors in any process system ① manipulated variables ② disturbances ③ controlled variables.

Disturbances act on the process and move controlled variables from their set point, manipulated variables are adjusted so the set point of the controlled variable is maintained despite disturbances. The benefits of automating these adjustments is a reduction in risk & possible waste - e.g. temperature control in storage of food manufacturing facility, increased reliability & reactivity to disturbances

(B) A PID controller is an amalgamation of : proportional, integral & derivative controllers

- Proportional controllers produce control actions proportional to the error signal



- Derivative control produces a control action which is proportional to the rate which the error is changing.

$$\text{output} = K_D \frac{de}{dt} \rightarrow \text{(differential error)}$$

$\rightarrow$ (differential time)

- Integral control produces a control action which continues to increase as long as the signal persists, or where the rate of the change of control is proportional to the input error signal e

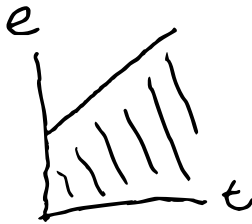
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$$\text{output} = K_I \int_0^t e \, dt.$$



→ integration of the error signal with respect to time gives us $e e$

Therefore, PID combines all of the above resulting in no offset error, reduces output oscillations. When the above 3 formulae are combined it gives us:

$$I_{out} = K_P \left(e + K_I \int e \, dt + K_D \frac{de}{dt} \right) + I_0$$

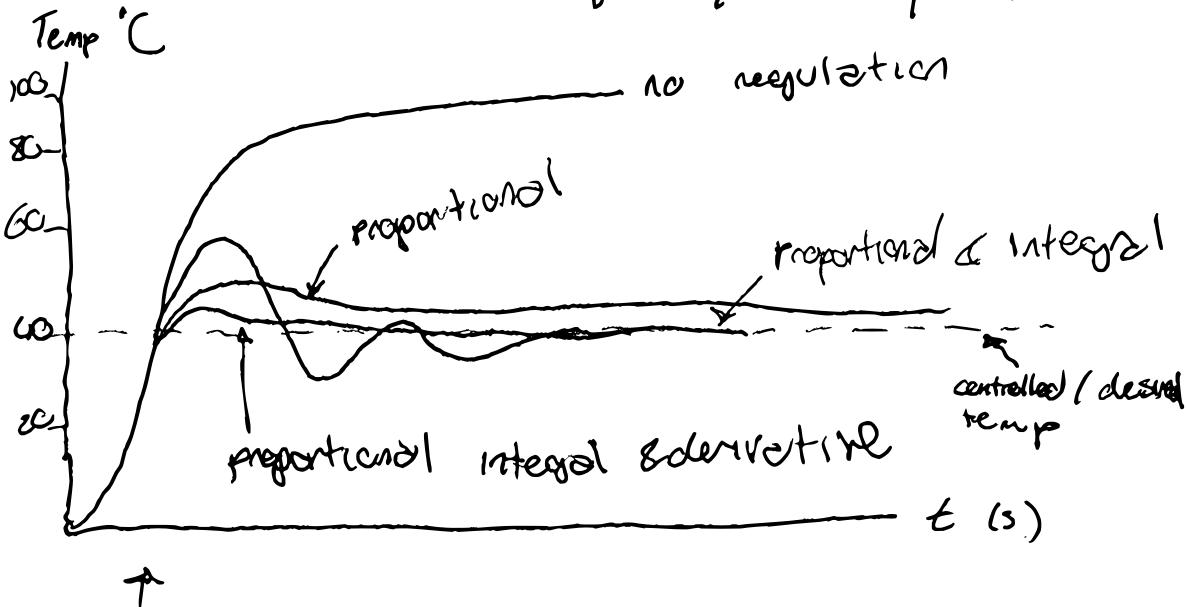
Suitable in processes which respond slowly such as temperature

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↑
Visual depiction that proportional alone doesn't guarantee desired state & integral doesn't control oscillations as well as PID combination

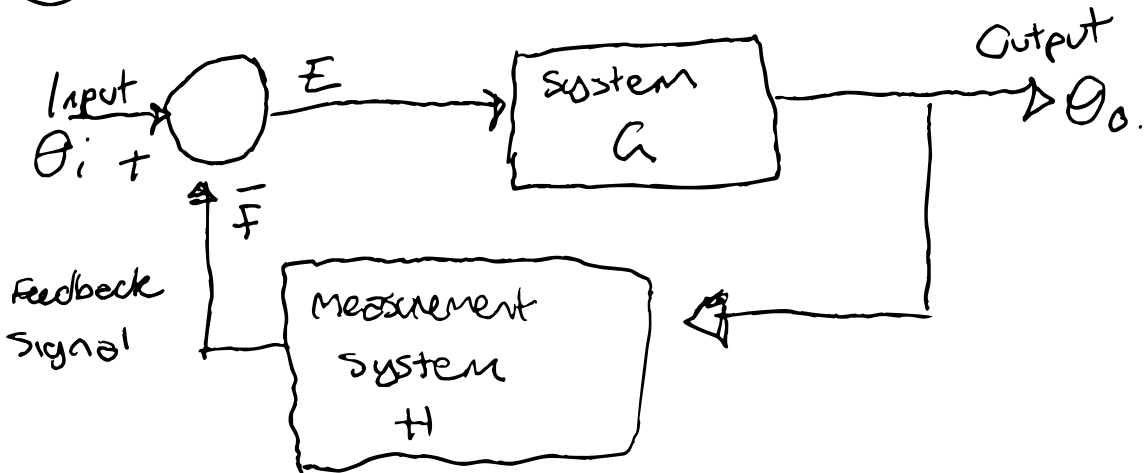
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(c)



$$\textcircled{1} \quad G = \frac{\theta_o}{E} \quad \therefore E = \frac{\theta_o}{G}$$

$$\textcircled{2} \quad H = \frac{F}{\theta_o} \quad \therefore F = H \times \theta_o$$

$$\textcircled{3} \quad E = \theta_i - F$$

By substituting equations $\textcircled{1}$ & $\textcircled{2}$ into $\textcircled{3}$

$$\frac{\theta_o}{G} = \theta_i - (H \times \theta_o)$$

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Simplified

$$\theta_0 \left(\frac{1 + G \times H}{G} \right) = \theta_i$$

rearrange by dividing both sides by θ_i & $\frac{1 + G \times H}{G}$

$$\frac{\theta_0}{\theta_i} = \frac{G}{1 + G \times H}$$

(d) $G_1 = 10 \text{ mA/V}$

$G_2 = 2.5 \text{ mm/mA}$

$H = 150 \text{ mV/mm} \rightarrow 150 \times 10^{-3} \text{ V/mm}$

Transfer function = $\frac{(10 \times 2.5)}{1 + (10 \times 2.5 \times 150 \times 10^{-3})}$

$$= 5.26 \text{ V} \quad \frac{\text{mA}}{\text{V}} \quad \frac{\text{mm}}{\text{mA}} \quad \frac{\text{V}}{\text{mm}}$$

(e) conveyor speed) & temperature control of a furnace

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QUESTION 3.

$$a) G_1 = 15$$

$$G_2 = 0.35$$

$$H = ?$$

$$E_{ss} = 0.$$

$$\text{using } E_{ss} = 0; \left(\frac{G}{1+GH} - 1 \right)$$

$$\text{zero steady state means } \frac{G}{1+GH} = 1$$

therefore

$$\frac{(15 \times 0.35)}{1 + (15 \times 0.35)H} = 1.$$

$\therefore$

$$1 + (15 \times 0.35)H = (15 \times 0.35)$$

$\therefore$

$$H = \frac{(15 \times 0.35) - 1}{(15 \times 0.35)}$$

$$H = 0.809523$$

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(b) :

using

$$\tau \frac{d\theta_o}{dt} + \theta_o = G_{ss} \theta_i.$$

into

$$\frac{di}{dt} + \frac{R}{L} i = \frac{V}{L}.$$

then

$$\tau = 1.$$

$$\theta_o = i$$

$$\frac{R}{L} i = \theta_o \approx \frac{R}{L} = i.$$

$$G_{ss} \theta_i = \frac{V}{L}.$$

Sub into

$$\theta_o = G_{ss} \theta_i [1 - e^{-t/\tau}]$$

$$i = \frac{V}{L} [1 - e^{-\frac{t}{\tau}}]$$

$$\text{ii} \quad R = 2.5 \\ L = 500$$

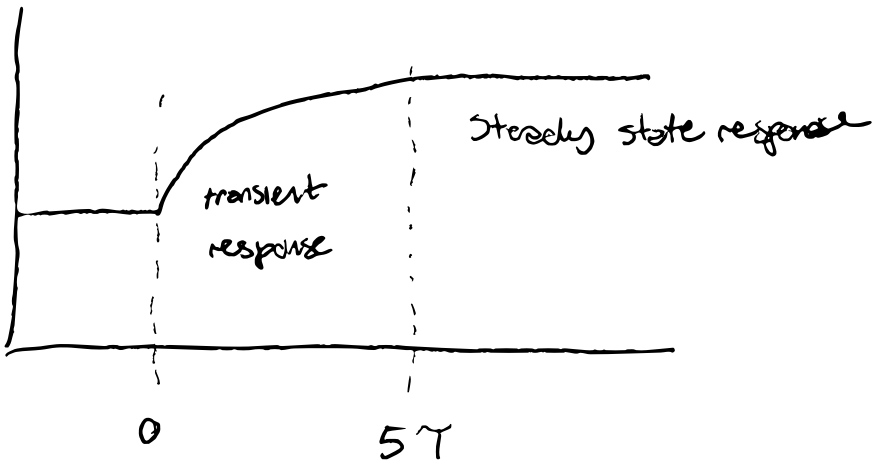
$$\frac{R}{L} i = \theta_o$$

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$$(c) \quad y(t) = \tilde{y}(t) + \bar{y}(t)$$

where $\tilde{y}$ = transient response - a result of change in the system input & generally dies away after a short interval of time

And $\bar{y}$ = Steady state response - that which remains after all transient responses have died down completely (see graph above)

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