Process Control

feedback controllers

1. measure controlled variable
2. compare measurement (process signal) with desired operating value (setpoint)
3. calculate error involved
4. based on this error signal, the controller will adjust the manipulated variable to compensate for the effects of the disturbances and keep the controlled variable as close to the setpoint

- takes control only after disturbances have occurred.

feedforward controllers

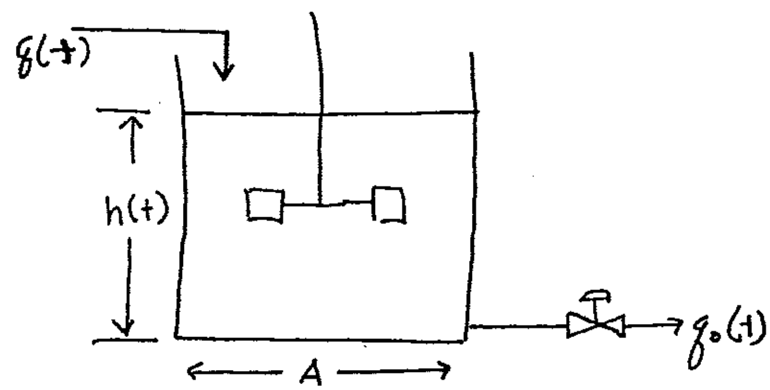
1. Identify all potential sources of disturbances that may affect process
2. Make measurements on these dist.
3. The controller makes appropriate corrective action to cancel out these disturbances

	advantages	disadvantages
feedback	1. Does not require identification and measurement of any disturbance 2. Insensitive to modeling errors 3. Insensitive to parameter changes	1. Waits until disturbances has been felt to take control 2. unsatisfactory for slow processes 3. may create instability
feedfwd	1. Acts before effect of dist. has been felt. 2. Good for slow process or with significant dead time 5. Does not introduce instability	1. Requires ID of all possible disturbances 2. Cannot cope with unmeasured dist. 3. Sensitive to process parameter varia 4. Requires good knowledge of process model

Basic Modelling Idea

1. Set up equations using a) conservation laws
   b) empirical relations
2. Get ODE, PDE models
3. Linearize if necessary
4. Deviation variable format.

Tank Level



material balance

accumulation = rate input - rate output

$$\frac{d}{dt}(\rho A h) = \rho q(t) - \rho q_o(t)$$

$$A \frac{dh}{dt} = q(t) - q_o(t)$$

- if output flow, q_o, is proportional to liquid height

$$A \frac{dh}{dt} = q(t) - \beta h$$

deviation variables

$h = h_s + h'$; $q = q_s + q'$

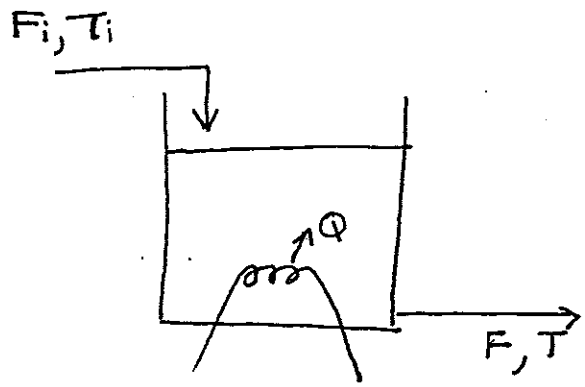
$$A\frac{d(\overset{0}{\cancel{h_s}}+h')}{dt} = q_s + q' - \beta h_s - \beta h'$$

$$A\frac{dh'}{dt} = q' - \beta h' + \underbrace{(q_s - \beta h_s)}_{0 \text{ steady state}}$$

$$\boxed{A\frac{dh'}{dt} = q' - \beta h'}$$

when Laplace transform taken, initial conditions are always zero

Heating Tank



energy balance:

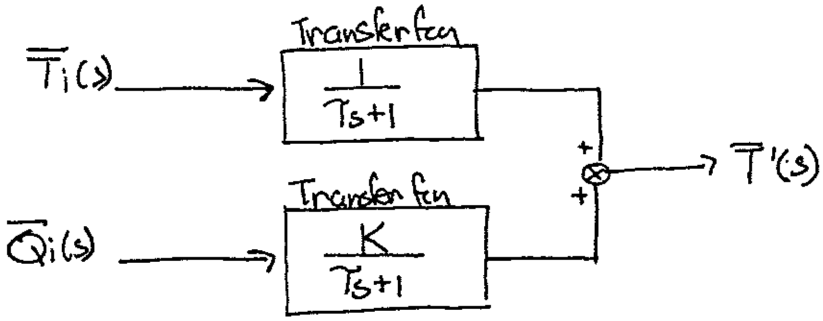
$$\rho C_p V\frac{dT}{dt} = \rho C_p F(T_i - T) + Q$$

$$\frac{\rho C_p V}{\rho C_p F}\frac{dT'}{dt} = \frac{\rho C_p F}{\rho C_p F}(T_i' - T') + \frac{Q'}{\rho C_p F}$$ deviation format

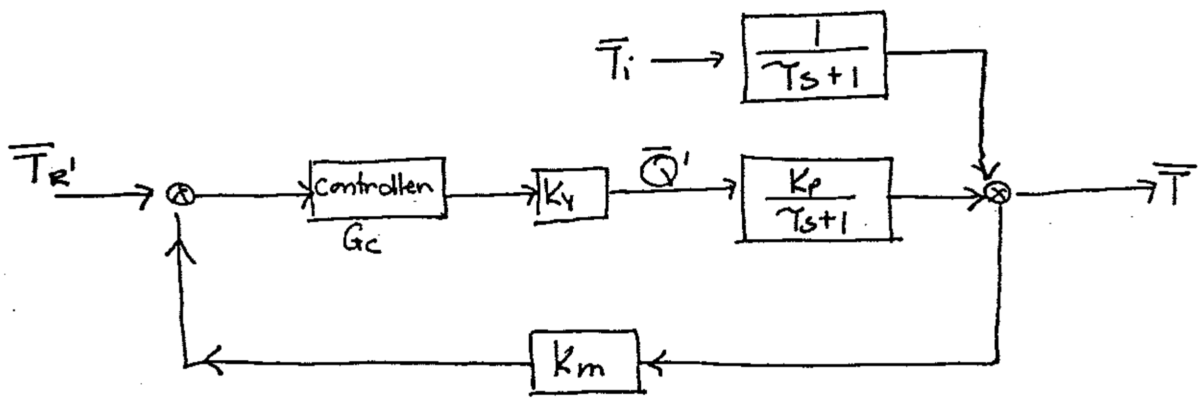
$$\tau\frac{dT'}{dt} = T_i' - T' + KQ'$$

Laplace: $\tau s\bar{T}'(s) = \bar{T}_i'(s) - \bar{T}'(s) + K\bar{Q}'(s)$

$$\boxed{\bar{T}'(s) = \frac{\bar{T}_i'(s)}{\tau s+1} + \frac{K\bar{Q}'(s)}{\tau s+1}}$$



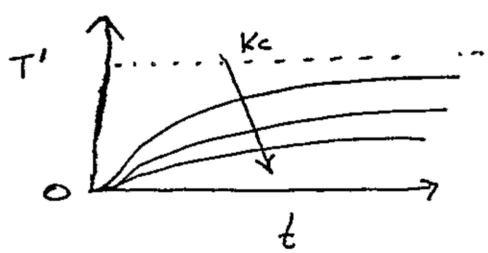
Consider



CONTROLLER TYPES

1) Proportional:

$$m(t) = k_c\,(e(t))$$
$$m'(t) = k_c\,(e'(t))$$
$$\overline{m}'(s) = k_c\,\overline{e}'(s) \qquad G_c(s) = k_c$$



* always an offset, wont reach goal

b) Integral:

$$\overline{m}'(s) = \frac{1}{\tau_I s}\,\overline{e}'(s)$$

based on area and history
sluggish — 1/s increases the order.

c) derivative

$$\bar{m}'(s) = \tau_D s\, \bar{\varepsilon}'(s)$$

* guesses the direction of error and acts on it. This one is not passive.

<u>Commercial Controllers</u>

1) P

$$G_c(s) = k_c$$

2) PI

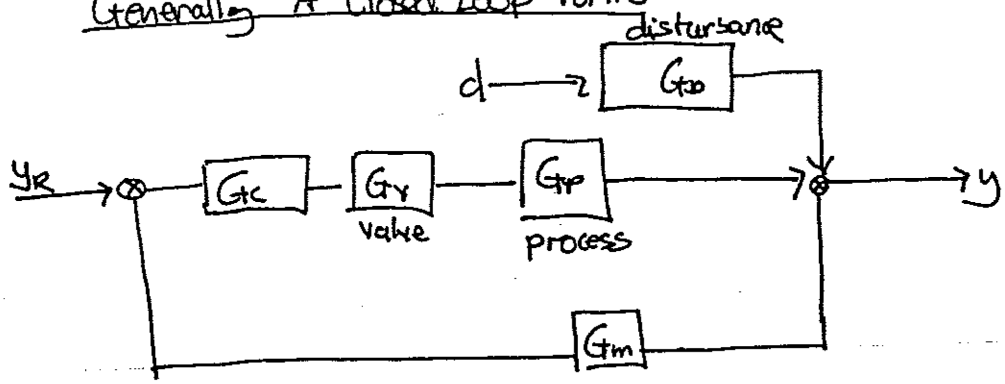
$$G_c(s) = k_c\left[1 + \frac{1}{\tau_I s}\right]$$

3) PID

$$G_c(s) = k_c\left[1 + \frac{1}{\tau_I s} + \tau_D s\right]$$ faster

4) PD has offset

<u>Generally A Closed Loop Form</u>



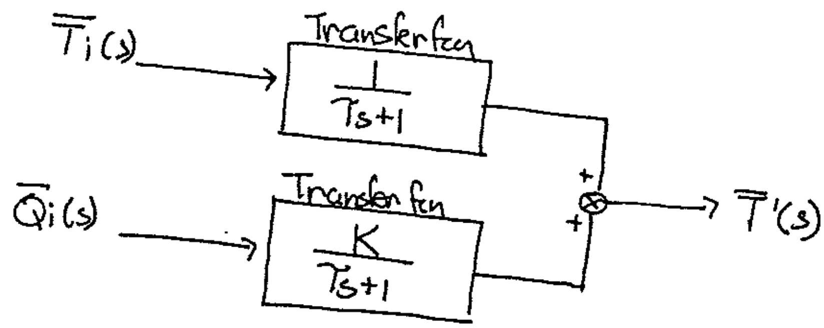
$$y = \frac{G_D}{1 + G_p G_m G_c G_v}\, d + \frac{G_p G_v G_c}{1 + G_p G_m G_c G_v}\, y_r$$

regulatory - change in disturbance

servo - change in set point

Std

F



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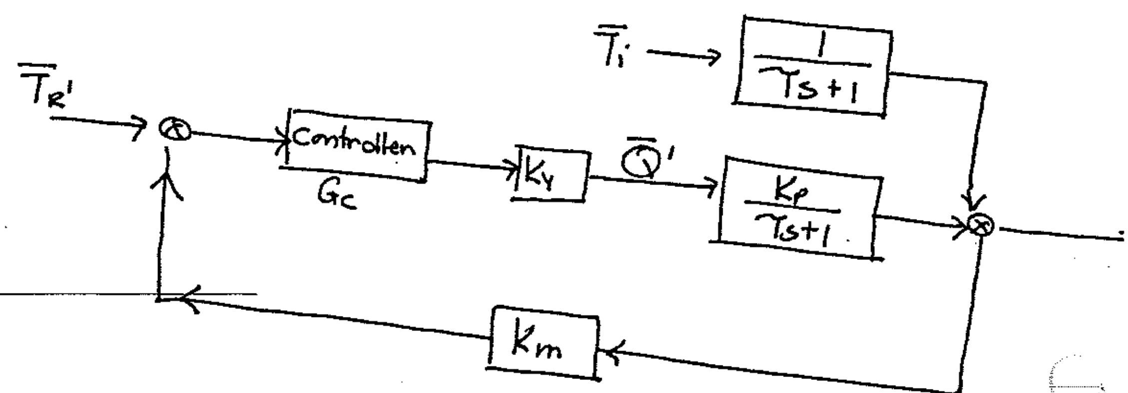

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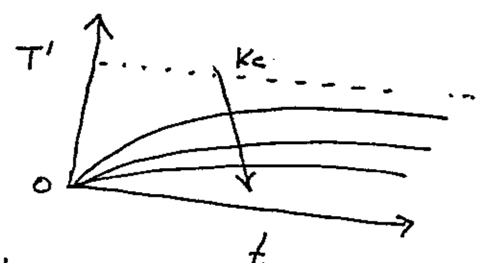


* always an offset, wont reach.

b) Integral:

$$\overline{m}'(s) = \frac{1}{\tau_I s}\,\overline{e}'(s)$$

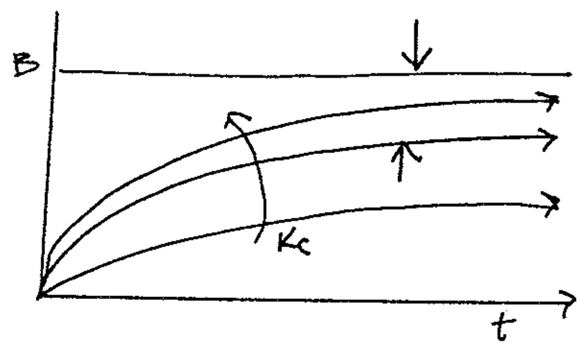
based on area of

sluggish b/c increases order.

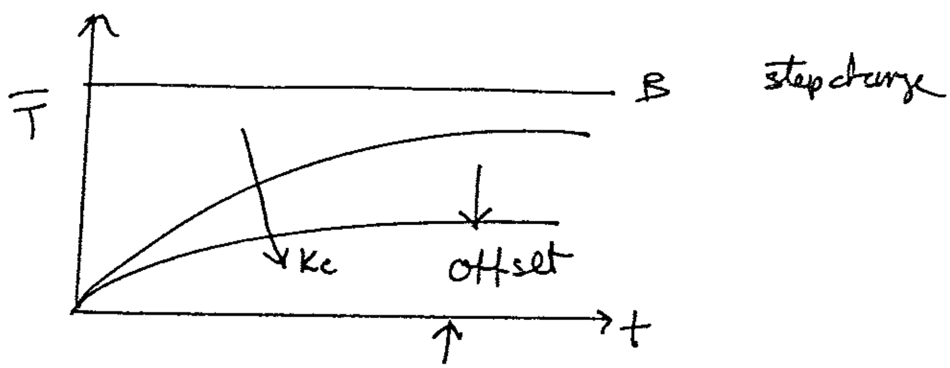
Stability

P-controllers (usually gives first order response)

Servo problem - always has offset



regulator problem . offset



PI control

- gives a second order response
  - under damped (oscillation)
  - over damped (no oscillation)
- offset is eliminated
- as Kc ↑ response becomes less oscillatory
- as τ ↓ systems is more oscillatory

PID control

$$G_c = K_c \left(1 + \frac{1}{\tau_I s} + \tau_D s\right)$$

- PD controllers do not eliminate offset
- derivative controllers are not perfect
  in commercial controllers, it is approximated

Higher order systems can lead to ~~s~~ instability + oscillations.