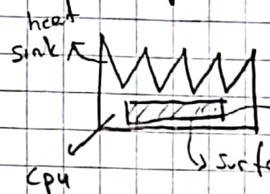
十一月 二十八日

* Distributed Parameter Systems and Lumped parameter Approximation

Ex Simplified CPU cooling problem



surface area : A_2 , α_2 : thermal conductivity , A material with fixed volume V

α_1 : thermal conductivity

surface area : A_1

ρ : density

c_p : specific heat.

CPU temp : $T_{in}(t)$, Heat sink temperature : $T(t)$ → dynamic variable of interest

Ambient temp : $T_{amb}(t)$

- The energy conservation law :

Heat accumulation = (in-flow of heat) − (out-flow of heat)

$$\underbrace{(V \cdot c_p \cdot \rho)}_{C} \frac{dT(t)}{dt} = A_1\alpha_1(T_{in}(t) - T(t)) - A_2\alpha_2(T(t) - T_{amb}(t))$$

C : thermal cap.

$$C\frac{dT(t)}{dt} + (\alpha_1 A_1 + \alpha_2 A_2)\, T(t) = A_1\alpha_1 T_{in}(t) + A_2\alpha_2 T_{amb}(t)$$

At steady-state we have $\frac{dT(t)}{dt} = 0$

$$(\alpha_1 A_1 + \alpha_2 A_2) T_{ss} = \alpha_1 A_1 T_{in_{ss}} + A_2\alpha_2 T_{amb_{ss}}$$

$$T_{ss} = \frac{\alpha_1 A_1 T_{in}^{ss} + \alpha_2 A_2 T_{amb}^{ss}}{\alpha_1 A_1 + \alpha_2 A_2}$$

we define the deviation values :

$\tau(t) = T(t) - T_{ss}$

$\tau_{in}(t) = T_{in}(t) - T_{in}^{ss}$

$\tau_{amb}(t) = T_{amb}(t) - T_{amb}^{ss}$

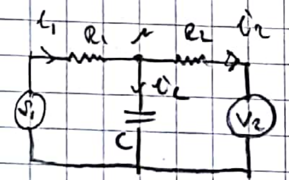
Scanned by CamScanner

$$C\frac{dT(t)}{dt} + (\alpha_1 A_1 + \alpha_2 A_2)\,T(t) = \alpha_1 A_1 T_{in}(t) + \alpha_2 A_2 T_{amb}(t)$$

zero initial cond + $\mathcal{L}\{\cdot\}$

$$[Cs + \alpha_1 A_1 + \alpha_2 A_2]\,T(s) = \alpha_1 A_1 T_{in}(s) + \alpha_2 A_2 T_{amb}(s)$$

$$T(s) = \underbrace{\frac{\alpha_1 A_1 T_{in}(s)}{Cs + \alpha_1 A_1 + \alpha_2 A_2}}_{\text{TF w.r.t. the input}} + \underbrace{\frac{\alpha_2 A_2 T_{amb}(s)}{Cs + \alpha_1 A_1 + \alpha_2 A_2}}_{\text{TF wrt " disturbance}}$$



KCL at N

$$i_1 - i_C - i_2 = 0$$

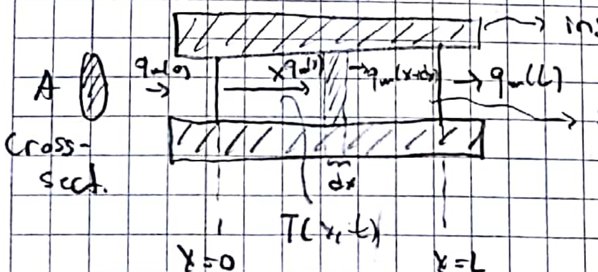
$$\frac{V_1 - V_C}{R_1} - C\frac{dV_C}{dt} - \frac{V_C - V_2}{R_2} = 0$$

$$C\frac{dV_C(t)}{dt} = \frac{1}{R_1}(V_1(t) - V_C(t)) - \frac{1}{R_2}(V_C(t) - V_2(t))$$

$\mathcal{L}$

$$\left(Cs + \frac{1}{R_1} + \frac{1}{R_2}\right)\hat{V}_C(s) = \frac{1}{R_1}\hat{V}_1(s) + \frac{1}{R_1}\hat{V}_2(t)$$

* Heat Conduction in a Solid Body



Assume that:

heat conduction coeff

material density

specific heat of material

co

- Heat balance equation for the element of length dx

$$\underbrace{(A \cdot dx\, \rho\, c_p) \frac{\partial T(x,t)}{\partial t}}_{\text{accumulation}} = \underbrace{\underbrace{A q_w(x)}_{\text{in-flow}} - \underbrace{A q_w(x+dx)}_{\text{out-flow}}}_{-A \frac{\partial q_w(x)}{\partial x} dx}$$

$$\rho\, c_p \frac{\partial T(x,t)}{\partial t} = -\frac{\partial q_w}{\partial x}$$

due to definition of derivative $\quad \frac{dq_w(x)}{dx} = \lim_{\Delta x \to 0} \frac{q_w(x+\Delta x) - q(x)}{\Delta x}$

Using Furier law of Thermal conduction

$$q_w = -\lambda \frac{\partial T(x,t)}{\partial x} \qquad \lambda: \text{Coeff. of thermal cond.}$$

↳ space continuous version of heat conduction over an interface

$$\rho c_p \frac{\partial T(x,t)}{\partial t} = -\frac{\partial}{\partial x}\left[-\lambda \frac{\partial T(x,t)}{\partial x}\right]$$

$$\frac{\partial T(x,t)}{\partial t} = \frac{\lambda}{\rho c_p} \frac{\partial^2 T(x,t)}{\partial x^2} \quad , \quad a = \frac{\lambda}{\rho c_p} : \text{factor of heat conductivity}$$

partial diff eqn in x and t of heat propagation within solid body

十二月 三日

- The solution of the PDE requires boundary conditions (space) at $x=0$ and $x=L$ and initial condition (time) for $t=0$

E.g.
$$\left.\begin{aligned} T(0,t) &= T^0(t) \\ T(L,t) &= T^L(t) \end{aligned}\right\} \text{ still function of } t$$

The initial condition:

$T(x,0) = T_0(x)$ is still func. of the space variable

- The steady-state conditions inside the slab

Assume constant steady-state boundary temperature T^0 and T^L given to us

steady-state implies that I have $\frac{\partial T(x,t)}{\partial t} = 0$

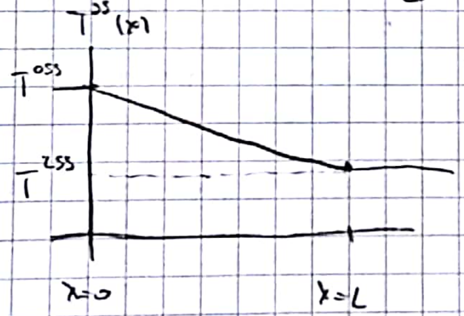
$$0 = \cancel{\alpha} \frac{\partial^2 T(x,t)}{\partial x^2} \rightarrow 0 = \frac{d^2 T(x,t)}{dx^2}$$

$T^{ss}(x) = C_1 x + C_2$, use boundry condition to determin C_1, C_2

$$x = 0 \;, \quad T^{ss}(0) = T^{0ss} = (C_1 x + C_2)\Big|_{x=0} = C_2$$

$$x = L \;, \quad T^{ss}(L) = T^{Lss} = (C_1 x + C_2)\Big|_{x=L} = C_1 L + C_2 \rightarrow C_1 = \frac{T^{Lss} - T^{0ss}}{L}$$

$$T^{ss}(x) = T^{0ss} + \frac{T^{Lss} - T^{0ss}}{L} x$$



- Note: Two approaches to design controllers

a) "Late-pass" to use PDE model directly to design controller and use numerical approximations later in the process (Begin our scope)

b) "Early-pass" Discritize space variable at the beginning and obtaining a higher order ordinary diff eqn (Lumped parameter approximation)

finite element method

- Solution of the PDE

Assume an infinite slab ($L \to \infty$)

Assume steady-state : $T^{ss} = T_c$

Define " Delta variable" $\tau(x,t) = T(x,t) - T_c$

$$\frac{\partial \tau(x,t)}{\partial t} = a \frac{\partial^2 \tau(x,t)}{\partial x^2}$$

$\mathcal{L}\{\}$

$$s\tau(x,s) - \underbrace{\tau(x,0)}_{\text{0 due to operating point}} = a \frac{\partial^2 \tau(x,s)}{\partial x^2}$$

$\Rightarrow$ PDE reduced to an ordinary diff eqn. in x

Since we have $L \to \infty$ we assume that the end of the infinite slab is not effected by transient changes

$\tau(x,t) = 0$ as $x \to \infty$

$$\frac{\partial^2 \tau(x,s)}{\partial x^2} = \left(\sqrt{\frac{s}{a}}\right)^2 \tau(x,s)$$

The homogeneous solution to this D.E is

$$\tau(x,s) = k_1 e^{-x\sqrt{\frac{s}{a}}} + k_2 e^{x\sqrt{\frac{s}{a}}}$$

we have $\tau(x,s) = 0$ as $x \to \infty$

$$\lim_{x \to \infty} \tau(x,s) = 0 \rightarrow k_2 = 0$$

Now use boundary condition at $x = 0$

$$\tau(0,t) = \tau^{o}(t) \xrightarrow{\mathcal{L}\{\}} \tau(0,s) = \tau^{o}(s)$$

$$\tau(x,s) = k_1 e^{-x\sqrt{\frac{s}{a}}} \Big|_{x=0} = \tau^{o}(s) = k_1$$

$$\tau(x,s) = \tau^{o}(s)\, e^{-x\sqrt{\frac{s}{a}}}$$

Scanned by CamScanner

十二月 五日

Now let us consider a step temperature function at the boundary

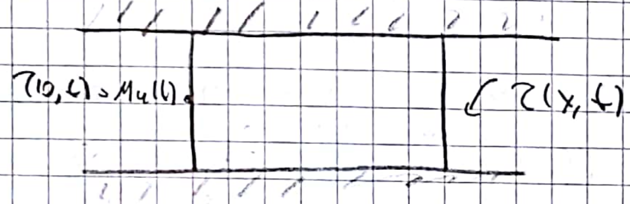
$$T(0,t) = M\,u(t) \xrightarrow{\mathcal{L}\{\cdot\}} T(0,s) = T^{\circ}(s) = \frac{M}{s}$$

$$\rightarrow T(x,s) = \frac{M}{s} e^{-x\sqrt{\frac{s}{a}}}$$

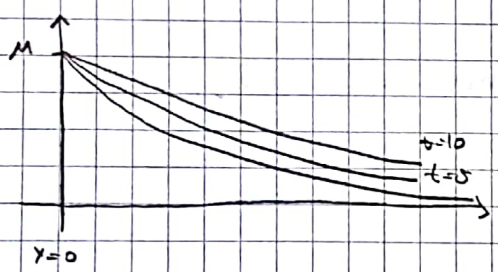
$$\mathrm{erfc}\left(\frac{k}{2\sqrt{t}}\right) \xleftrightarrow{\mathcal{L}} \frac{1}{s} e^{-k\sqrt{s}}$$, erfc(t): complementary error func.

$$T(x,t) = M\,\mathrm{erfc}\left(\frac{x}{2\sqrt{at}}\right)$$

Ex Unit step response at a fixed distance x inside slab

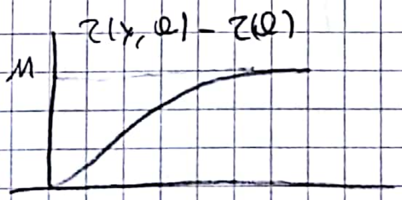


Ex Fixed time t, variable distance x.



- let $\theta = \left(\frac{a}{x^2}\right)t$ a scaling of the time variable

$$T(x,t) = M\,\mathrm{erfc}\left(\frac{1}{2}\sqrt{\frac{x^2}{at}}\right) = M\,\mathrm{erfc}\left(\frac{1}{2}\sqrt{\frac{at}{\theta a t}}\right) = M\,\mathrm{erfc}\left(\frac{1}{2\sqrt{\theta}}\right)$$



- we worked with "Delta variable" around the steady-state

$$T(0,t) = T_i + M u(t)$$

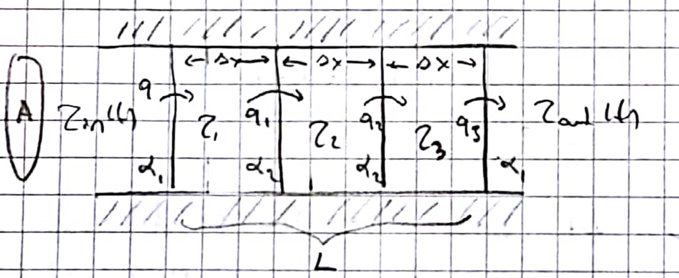
$$T(x,t) = T_i + M\,\mathrm{erf}\left(\frac{x}{2\sqrt{\alpha t}}\right)$$

Lumped Parameter Approximation (of distributed Models)

Low order PDE → Higher order ODE (order will depend on the resolution of discretization)

→ System of interconnected lower order ODE

Ex $N=3$



Assuming we again operate around the operating point

$T_i(0) = 0$ $\quad T_i(t)$ is uniform inside

Energy Balance eqn:

$$\underbrace{(A\,\Delta x\,\rho\,c_p)}_{\Delta c} \frac{dT_1}{dt} = \alpha_1 A(T_{in} - T_1) - \alpha_2 A(T_1 - T_2)$$

$$= \alpha_1 T_{in} - (\alpha_1 + \alpha_2) T_1 + \alpha_2 T_2$$

For second slice

$$\frac{\Delta c}{A}\frac{dT_2}{dt} = \alpha_2(T_1 - T_2) - \alpha_2(T_2 - T_3) = \alpha_2 T_1 - 2\alpha_2 T_2 + \alpha_2 T_3$$

last slice

$$\frac{\Delta c}{A}\frac{dT_3}{dt} = \alpha_2(T_2 - T_3) - \alpha_1(T_3 - T_{out}) = \alpha_2 T_2 - (\alpha_1 + \alpha_2) T_3 + \alpha_1 T_{out}$$

if we take T_1, T_2, T_3 as the state variable

$$\begin{bmatrix} \dot{T}_1 \\ \dot{T}_2 \\ \dot{T}_3 \end{bmatrix} = \frac{A}{\Delta C}\begin{bmatrix} -\alpha_1-\alpha_2 & \alpha_2 & 0 \\ \alpha_2 & -2\alpha_2 & \alpha_2 \\ 0 & \alpha_2 & -\alpha_1-\alpha_2 \end{bmatrix}\begin{bmatrix} T_1 \\ T_2 \\ T_3 \end{bmatrix} + \frac{A}{\Delta C}\begin{bmatrix} \alpha_1 & 0 \\ 0 & 0 \\ 0 & \alpha_1 \end{bmatrix}\begin{bmatrix} T_{in} \\ T_{out} \end{bmatrix}$$

Remember in the continious problem (distributed) we had $a = \frac{\lambda}{\rho \cdot C_p}$

How to find the correspondence between λ and α ?

Using the finite difference approximation to the derivative

$$\frac{\partial^2 T(x,t)}{\partial x^2} \cong \frac{T(x+2\Delta x,t) - T(x+\Delta x,t) - [T(x+\Delta x,t) - T(x,t)]}{(\Delta x)^2}$$

$$\cong \frac{T(x+2\Delta x,t) - 2T(x+\Delta x,t) + T(x,t)}{(\Delta x)^2}$$

Define: $T_i(t) = T(i\Delta x, t)$ and $T(x,t) = T_i(t)$ for $(i-1)\Delta x < x < i\Delta x$

$$\frac{\partial^2 T(x,t)}{\partial x^2} \cong \frac{T(x+\Delta x,t) - 2T(x,t) + T(x-\Delta x,t)}{(\Delta x)^2}$$

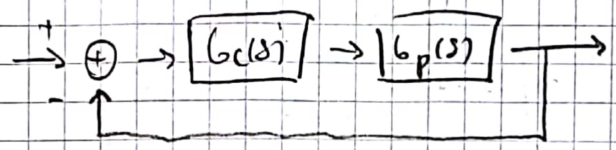
$$\frac{dT_i(t)}{dt} = \frac{a}{(\Delta x)^2}\left[T_{i+1}(t) - T_i(t) + T_{i-1}(t) \right]$$

$\sim$

$$\frac{\lambda}{\rho C_p (\Delta x)^2} = \frac{\alpha_2}{\rho C_p \Delta x} \rightarrow \frac{\lambda}{\Delta x} = \alpha_2$$

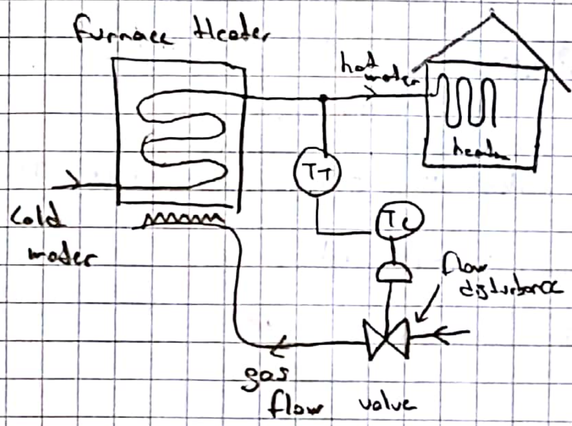
十二月 十日

Multi-Loop Systems



* Cascade Control

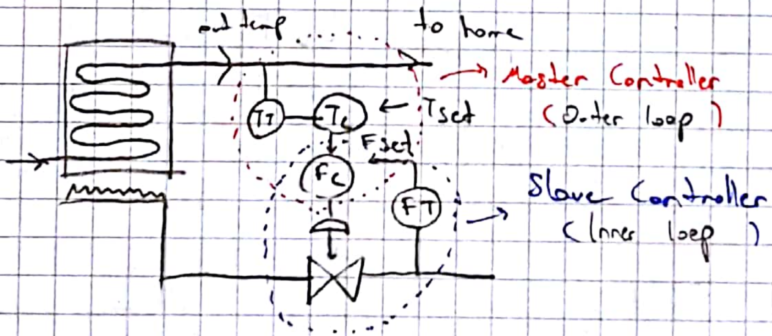
Consider the heating problem (Temp. Control)



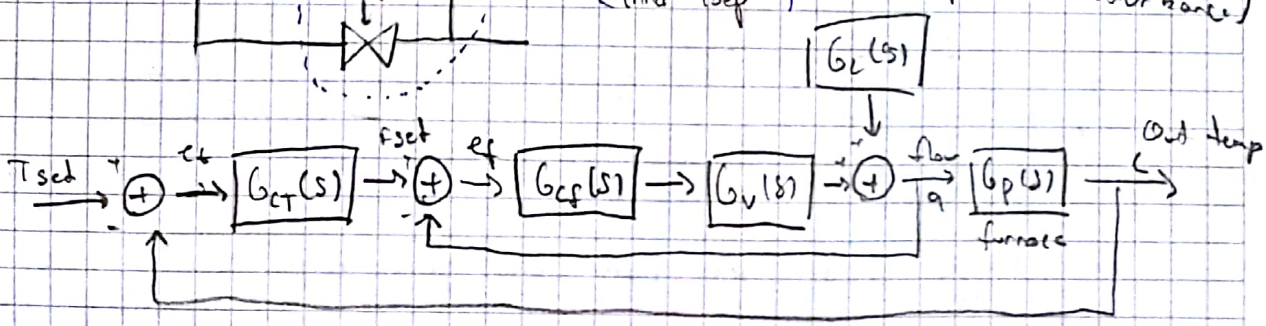
TT: Temperature Transmitter

TC: Temp. Controller

Idea is that add a flow measurement and a flow controller and combine with Tc

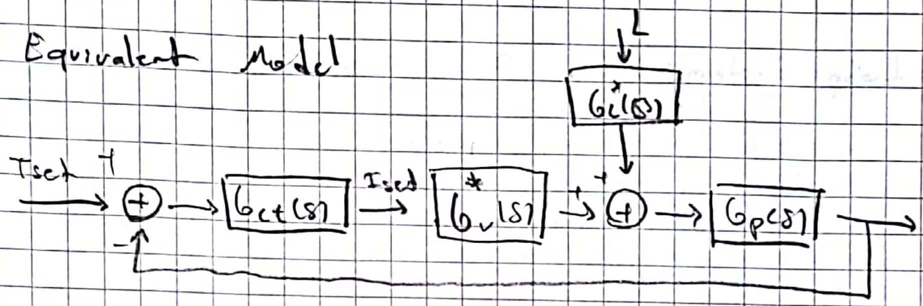


(flow disturbance)



"Cascade control"

- Equivalent Model



$a = G_L \cdot L + G_v \cdot G_{cf}\,(F_{set} - a)$

$(1+G_v G_{cf})a = G_L \cdot L + G_v G_{cf} F_{set} \rightarrow a = \frac{G_L}{1+G_v G_{cf}} L + \frac{G_v G_{cf}}{1+G_v G_{cf}} F_{set}$

$G_L^*(s) = \frac{G_L(s)}{1+G_v(s)G_{cf}(s)}$ $\qquad G_v^*(s) = \frac{G_v(s)G_{cf}(s)}{1+G_v(s)G_{cf}(s)}$

- Claims: 1- Cascode Control can make the system more stable (?)

2- " " " " the valve appear to be much faster (?)

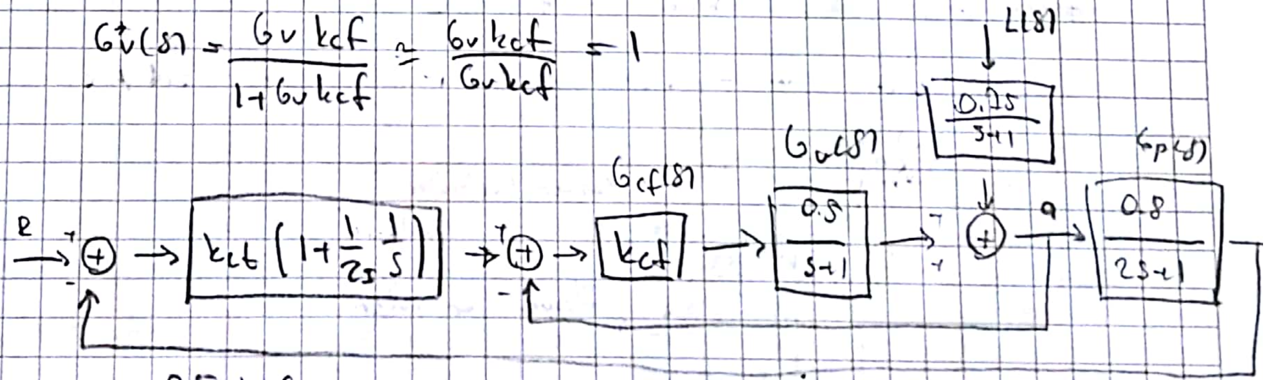
Assume: $G_{cf} = k_{cf}$ a proportional controller

Let k_{cf} be very large!

$G_L^*(s) = \frac{G_L}{1+G_v k_{cf}} \simeq 0$ will reduced to very small

$G_v^*(s) = \frac{G_v k_{cf}}{1+G_v k_{cf}} \simeq \frac{G_v k_{cf}}{G_v k_{cf}} = 1$

Ex



$G_v^* = \frac{\frac{0.5}{s+1}k_{cf}}{1+\frac{0.5}{s+1}k_{cf}} = \frac{0.5k_{cf}/(1+0.5k_{cf})}{\left(\frac{1}{1+0.5k_{cf}}\right)s+1}$ Assume ideal sensor

for large k_{cf}, we have unit gain and small time constant for valve

$$G_c^* = \frac{G_L}{1+G_v k_{cf}} = \frac{\frac{0.75}{s+1}}{1+\frac{0.5}{s+1}k_{cf}} = \frac{0.75/1+0.5k_{cf}}{\left(\frac{1}{1+0.5k_{cf}}\right)s+1}$$

- Q: Determine slave controller gain such that the virtual valve" time constant is 1/10 of the original time constant.

$G_v(s) = \frac{0.5}{s+1} \rightarrow \tau_v = 1$

$G_v^*(s) = \frac{0.5k_{cf}/1+0.5k_{cf}}{\left(\frac{1}{1+0.5k_{cf}}\right)s+1} \rightarrow \tau_v^* = \frac{1}{1+0.5k_{cf}} = \frac{1}{10}$, $k_{cf} = 18$

- Steady-state flow rate in responce to unit step input as " desired flow rate"

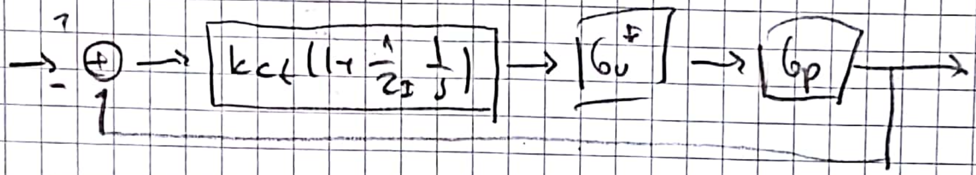
$A(s) = \frac{0.5k_{cf}}{s+1+0.5k_{cf}} \frac{1}{s}$, $\lim_{t\to 0} a(t) \rightarrow \lim_{s\to 0} sA(s) = s\frac{1}{s}\frac{0.5k_{cf}}{s+1+0.5k_{cf}} = 0.9$

% 10 error

- The inner loop is Type 0 and has 10 ess on the desired flow rate. But the other controller makes the system Type 1 and will eliminate this error at the output.
- The design of master (outer) loop controller requirements; stable system, fast enough, Reasonable overshoot.
- Approach : Make attemps for τ_I

$$\left.\begin{aligned} \tau_I &= 0.05 \\ \tau_I &= 0.5 \\ \tau_I &= 5 \end{aligned}\right\} \rightarrow \text{use fast root-locus sketches to make decision}$$

Assume L=0

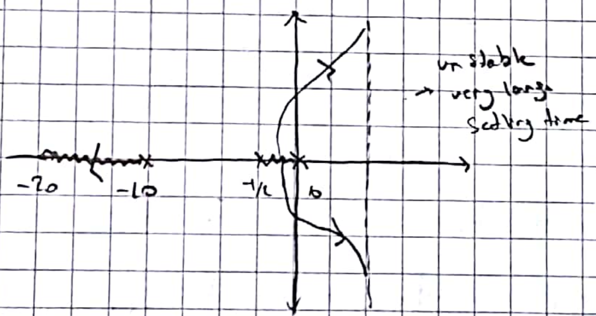


Characteristic Eqn.

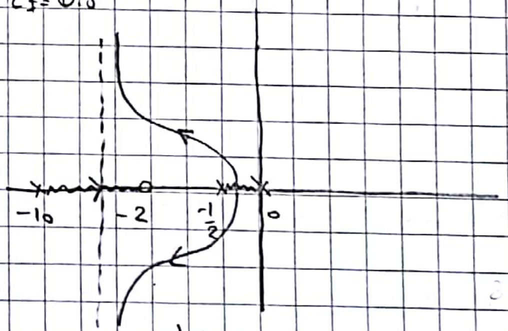
$$q(s) = 1 + k_{ct}\frac{Z(s)}{P(s)} = 1 + k_{ct}\left(\frac{\tau_I s+1}{\tau_I s}\right)\left(\frac{0.9}{0.1s+1}\right)\left(\frac{0.8}{2s+1}\right)$$

→ $\tau_I = 0.05$, open loop zeros → $s = -1/\tau_I = -20$

open loop poles → $s = 0, -10, -1/2$



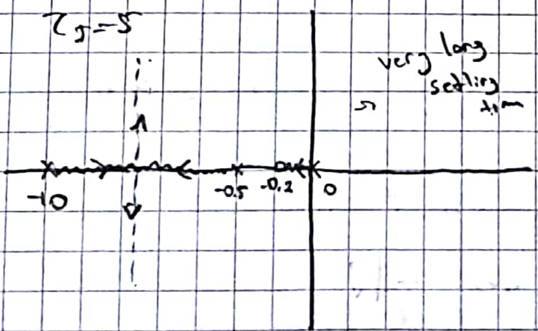
$\tau_I = 0.5$



2 asymptotes $\sigma_0 = \frac{\Sigma p - \Sigma z}{\# p - \# z} \simeq 4.75.$

$\sigma_0 = \frac{-\frac{1}{2}-10+2}{2} = -4.25$

$\tau_I = 5$



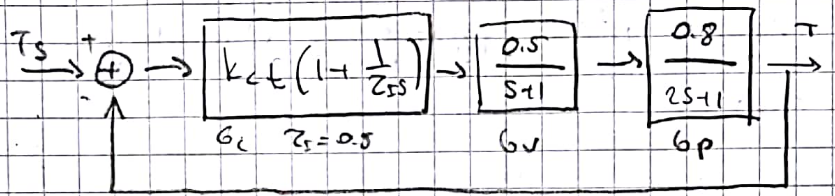
10.1

$s+0.15$

$\sigma_0 = \frac{-10.5+0.2}{2} = -5.15$

十二月 十二日

- Q: what would be the behaviour without slave loop.



(what would be the new range of k_{cf}

Use Routh_Hurwitz

Closed loop characteristic eqn:

$$q(s) = 1 + G_c G_v G_p = 1 + k_{cf}\left(\frac{\tau_I s+1}{\tau_I s}\right)\left(\frac{0.5}{s+1}\right)\left(\frac{0.8}{2s+1}\right)$$

$$q(s) = s^3 + 1.5 s^2 + (0.5+0.2k_{cf})s + 0.4k_{cf}$$

s^3	1	$0.5+0.2k_{cf}$
s^2	1.5	$0.4k_{cf}$
s	a	0
s^0	$0.4k_{cf}$	

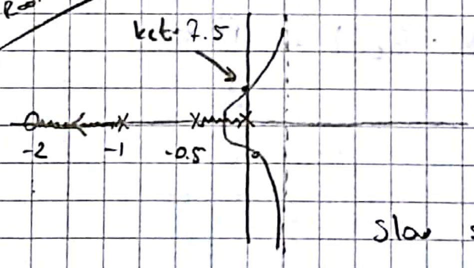
$0.4k_{cf} \to 0.4k_{cf} > 0$, $k_{cf} > 0$

$$a = \frac{(1.5)(0.5+0.2k_{cf}) - 0.4k_{cf}}{1.5}$$

$a > 0 \to 0.75 + 0.3k_{cf} - 0.4k_{cf} > 0$

$7.5 > k_{cf}$

Root-locus



☆ Note in root locus

$$k = \frac{(0.5)(0.8)}{2\tau_I} k_{cf}$$

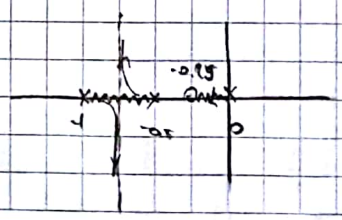
$$\sigma_0 = \frac{-1-0.5+2}{2} = 0.25$$

Slow system with very limited stable range for k_{cf}

- Is there a better τ_I for the current classical feedback control?

Idea is to take centroid to the left

$\tau_I = 4$



$\sigma_0 = -0.625$ more stable (?)

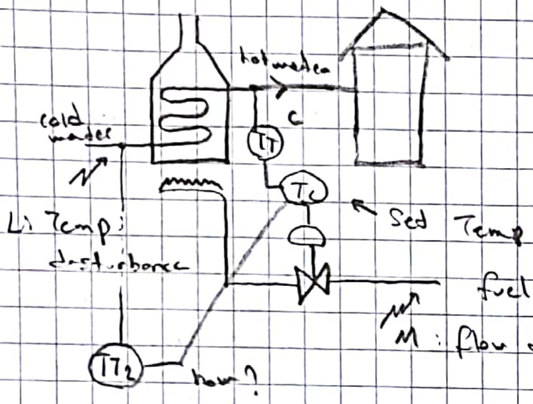
much slower.

十二月 十七日

Disturbance Feed forward Control

Idea: Take a very proactive approach to eliminating the disturbance

- Ex: Temp Cond.



Assume

→ We have a "Process Model"

→ "we can write the proper variable c in terms of the "input variable" M, L

→ if the plant is non-linear or we specify an operating point: M, L and delta variable

- Idea: Introduce a pre-computed change to M (the manipulated variable) to compensate the disturbance L

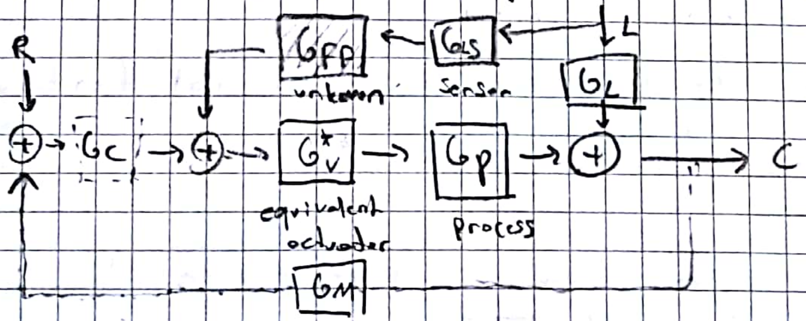
We have:

$C = G_L L + G_p M$ (if we operate around the op) we want $C = R$

$C = R = G_L L + G_p M \rightarrow M = \frac{1}{G_p}(R - G_L L) = \underbrace{\frac{1}{G_p}}_{} R - \underbrace{\frac{G_L}{G_p}}_{} L$

- Note: We will assume that the reference tracking with later be handled by a closed-loop controller | reference tracking controller | Disturbance Feed forward Controller.

G_{FF}: "Disturbance feed forward Controller"



ideal scenario is $C=0$ (at SS the delta output is at zero and should stay at 0)

$$C = G_L L + G_{LS} \cdot G_{FF} \cdot G_v^* \cdot G_p \cdot L = (G_L + G_{LS} G_{FF} G_v^* G_p) L = 0$$

$$G_{FF} = -\frac{G_L}{G_{LS} G_v^* G_p}$$ → unfortunately this tf for G_{FF} is not realizable)

- Ex: $G_v^* = \frac{1}{0.1S+1}$; $G_p = \frac{0.8}{2S+1}$; $G_L = \frac{1}{2S+1}$ → usually have the same time constant as the plant

$G_{LS} = \frac{1}{0.1S+1}$ (Disturbance sensor)

$$G_{FF} = -\frac{\frac{1}{2S+1}}{\frac{1}{0.1S+1} \cdot \frac{1}{0.1S+1} \cdot \frac{0.8}{2S+1}} = -\frac{(0.1S+1)^2}{0.8}$$

improper TF
Deg(Num) > Deg(Den)
→ not causal

- Ex: $G_p(S) = \frac{0.8}{2S+1} e^{-\theta S}$ FOPDT Model

$$G_{FF} = -\frac{1}{0.8}(0.1S+1)^2 e^{+\theta S}$$ ← a time advance, you need θ time into future to implement G_{FF}

$G_p = \frac{k_p}{\tau_p S+1}$, $G_v^* = \frac{k_v}{\tau_v S+1}$, $G_L = \frac{k_L}{\tau_L S+1}$, $G_{LS} = \frac{k_{LS}}{\tau_{LS} S+1}$

$$G_{FF} = -\frac{\frac{k_L}{\tau_L S+1}}{k_{LS} k_v k_p \cdot \frac{1}{(\tau_{LS} S+1)(\tau_v S+1)(\tau_p S+1)}} = \frac{(\tau_{LS} S+1)(\tau_v S+1)(\tau_p S+1)}{k_{LS} k_v k_p (\tau_L S+1)}$$

$G_{LS} \cong k_{LS}$ for a "very fast" sensor (small τ)

1. If we assume a fast disturbance sensor
2. If we " a fast actuator (which also can be achieved by cascade controller)

$G_v^* \cong k_v$

with these assumptions; the FF controller

$$G_{FF} \simeq -\frac{k_L}{k_{LS}\, k_v^{*}\, k_p} \frac{(\tau_p s+1)}{(\tau_L s+1)}$$ ⇒ dynamic compensator.

- In general G_{FF} transfer function is a lead-lag compensator.

$$G_{FF} = k_{FF} \frac{\tau_{lead} s+1}{\tau_{lag} s+1}$$

- Note we can also have $G_{FF} = k_{FF}$ "steady-state compensator" if G_L and G_p has some time constant and sensor and actuator time constant τ_{LS}, τ_v much smaller than τ_p
- Other practical note: we can tune G_{FF}, it can start at $\tau_{lead} \simeq \tau_{LS} + \tau_v^{*}$, $\tau_{lag} \simeq 0.1\, \tau_{lead}$

Feedforward - Feedback Architecture

- Note: Disturbance feedback architecture is almost always used with the output feedback, because
- We do not a very precise model G_p of plant.
- Measurement errors (output disturbance)
- Errors in feedforward components
- Unmeasured load variables.

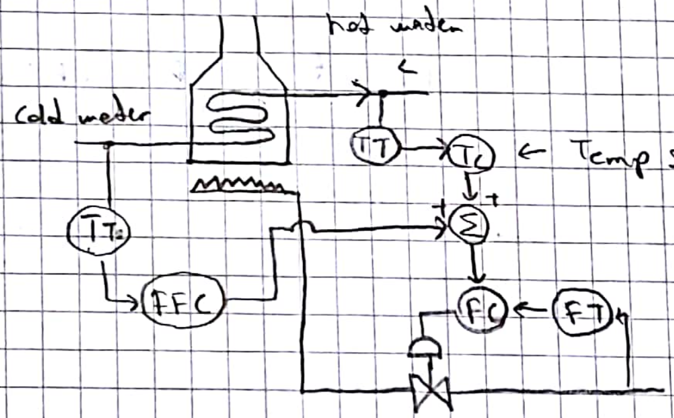
$$C = [G_L + G_{LS} G_{FF} G_v^{*} G_p] L + G_p G_v^{*} G_c E \quad , \quad E = R - C G_M$$

$$C = \left[\frac{G_L + G_{LS} G_{FF} G_v^{*} G_p}{1 + G_m G_c G_v^{*} G_p}\right] L + \left[\frac{G_c G_v^{*} G_p}{1 + G_m G_c G_v^{*} G_p}\right] R$$

- Note that the denominator of both TFs are the same and they do not have G_{FF} term.

→ Design of G_{FF} does not effect the stability properties of the overall system. (Leaving us free to design it to achieve best disturbance rejection)

- All parts in same process diagram

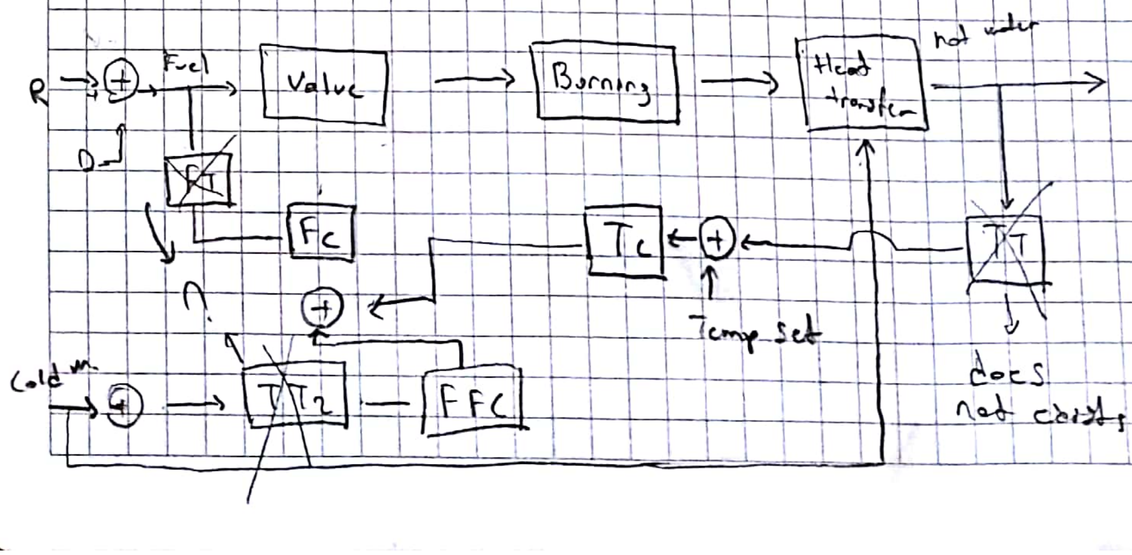


十二月 二十四日

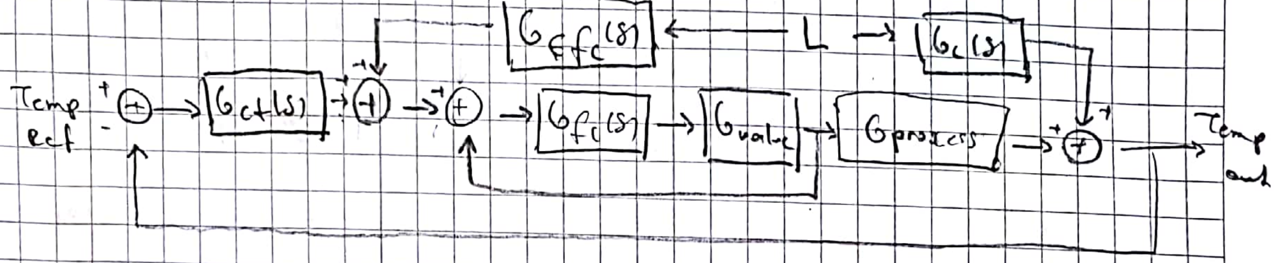
* Sketch the block diagram corresponding to the process diagram

Exercise

Wrong, blocks are s domain Valve → $G_v(s)$ should be



* First identify output, input then feed back later other parts



* Engine ECU Design

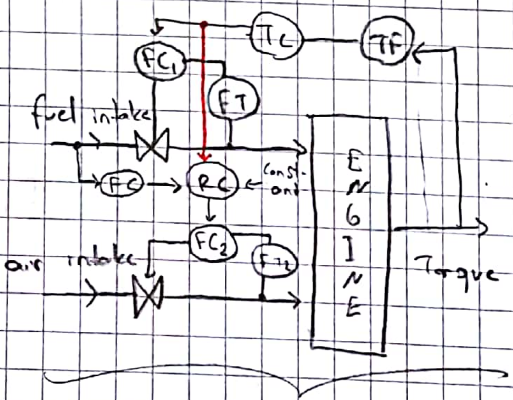
- Task: control fuel flow to maintain efficient burn (max power, min polution)

Manipulated variables:

1. Fuel flow
2. Air flow

$F = \frac{F_f}{F_A}$ RC: "Ratio Controller"

Process Variable: Engine Torque



"Ratio Control"