

①

$$G_1(s) = \frac{e^{-s}}{s+0.1} = \frac{10}{1+10s} \left(\frac{e^{-s}}{e} \right) = \frac{k_p}{1+Ts} e^{-sL}$$

delay-

$$\boxed{k_p=10; T=10; L=1}$$

λ-tuning. P1 controller

$$C(s) = k \frac{1+sT_i}{sT_i}$$

$$\boxed{T_i = T = 10} \quad \boxed{k = \frac{T}{k_p(\lambda+L)}} = \frac{10}{10(\lambda+1)} = \frac{1}{1+\lambda}$$

$$\lambda = 2 \quad \boxed{k = \frac{1}{3} = 0.33}$$

λ-tuning PID Controller

$$C(s) = \frac{(1+sL/2)(1+sT)}{k_p s(L+\lambda)}$$

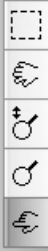
$$\boxed{C_{PID} = \frac{k(1+sT_i)(1+sT_d)}{sT_i}}$$

$$T_i = T = 10$$

$$T_d = L/2 = 1/2$$

$$k = \frac{1}{k_p} \cdot \frac{T}{L+\lambda} = \frac{1}{1+\lambda} = 0.5$$

$$\lambda = 1$$



Manipulation Mode

Interactive Learning Module: PID Basics

ILM: PID Basics



Instructions



Theory

Process

$$G(s) = \frac{10.03}{(10.00 s + 1)} e^{-1.000 s}$$

Kp: 10.03

T:

10.000

delay:

1.000

h: 5e-2

Controller

☐ P

☐ I

☒ PI

☐ PD

☐ PID

K: 0.33

Ti: 10

b: 1

Performance

Set point response

IAE

3.03

overshoot

0.00

0.03

kl

0.03

Load disturbances

IAE

0.00

0.03

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sigma_x

0.005

0.007

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Robustness

Ms

1.35

1.00

4.75

Gm

71.04

Pm

71.04

71.04

71.04

71.04

71.04

71.04

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71.04

71.04

71.04

Process Output

y

1.6

1.4

1.2

1.0

0.8

0.6

0.4

0.2

0.0

-0.2

-0.4

-0.6

-0.8

-1.0

-1.2

-1.4

-1.6

-1.8

-2.0

-2.2

-2.4

-2.6

-2.8

-3.0

-3.2

-3.4

-3.6

-3.8

-4.0

-4.2

-4.4

-4.6

-4.8

-5.0

-5.2

-5.4

-5.6

-5.8

-6.0

-6.2

-6.4

-6.6

-6.8

-7.0

-7.2

-7.4

-7.6

-7.8

-8.0

-8.2

-8.4

-8.6

-8.8

-9.0

-9.2

-9.4

-9.6

-9.8

-10.0

-10.2

-10.4

-10.6

-10.8

-11.0

-11.2

-11.4

-11.6

-11.8

-12.0

-12.2

-12.4

-12.6

-12.8

-13.0

-13.2

-13.4

-13.6

-13.8

-14.0

-14.2

-14.4

-14.6

-14.8

-15.0

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-15.4

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-16.0

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-16.6

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-25.4

-25.6

-25.8

-26.0

-26.2

-26.4

-26.6

-26.8

-27.0

-27.2

-27.4

-27.6

-27.8

-28.0

-28.2

-28.4

-28.6

-28.8

-29.0

-29.2

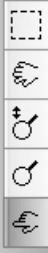
-29.4

-29.6

-29.8

-30.0

-30.2



Manipulation Mode

Interactive Learning Module: PID Basics

ILM: PID Basics



Instructions



Theory

Process

$$G(s) = \frac{10.03}{(10.00 s + 1)} e^{-1.000 s}$$

Kp: 10.03

Ti:

delay:

h: 5e-2

Controller

☐ P ☐ I ☐ PI ☐ PD ☒ PID

K: 0.5

Ti: 10

Td: 0.5

N: 10

b: 0.99

Performance

Set point response

IAE 2.65

overshoot 2.64

Load disturbances

IAE 16.78

kl 0.05

tmax 4.10

emax 1.56

Noise response

sigma_x 0.017

sigma_y 0.025

sigma_u 0.053

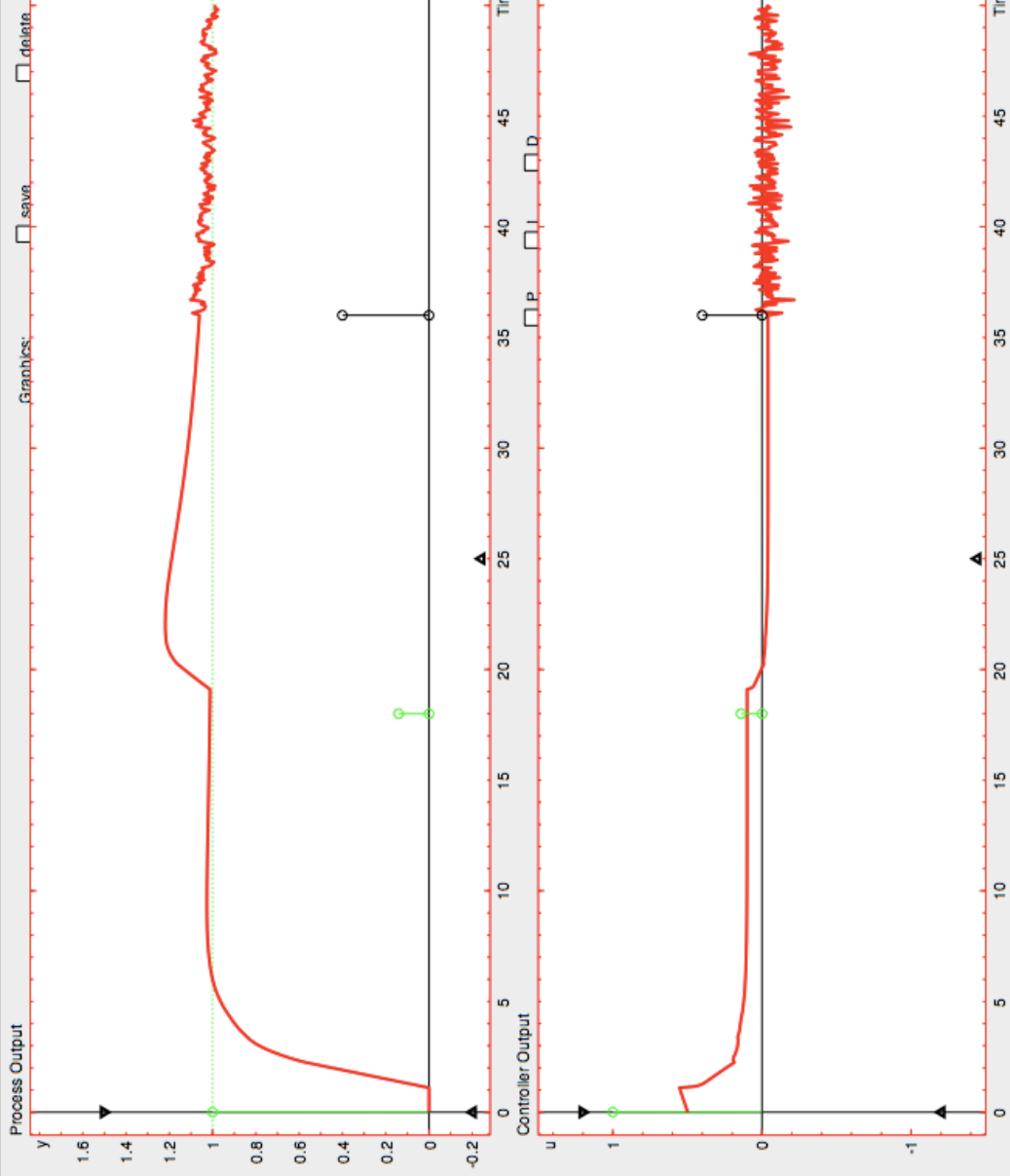
Robustness

Ms 1.52

Mt 1.00

Gm 2.97

Pm 75.64



$$G_2(s) = \frac{e^{-2s}}{s+5} = \frac{0.2}{1+0.2s} e^{-2s} \quad \frac{K_p}{1+sT} e^{-sL}$$

$$K_p = 0.2; T = 0.2; L = 2.$$

P1. - Haalman

$$K = \frac{2T}{3K_p L} = \frac{2 \times 0.2}{3 \times 0.2 \times 2} = \frac{1}{3} = \underline{\underline{0.33}}$$

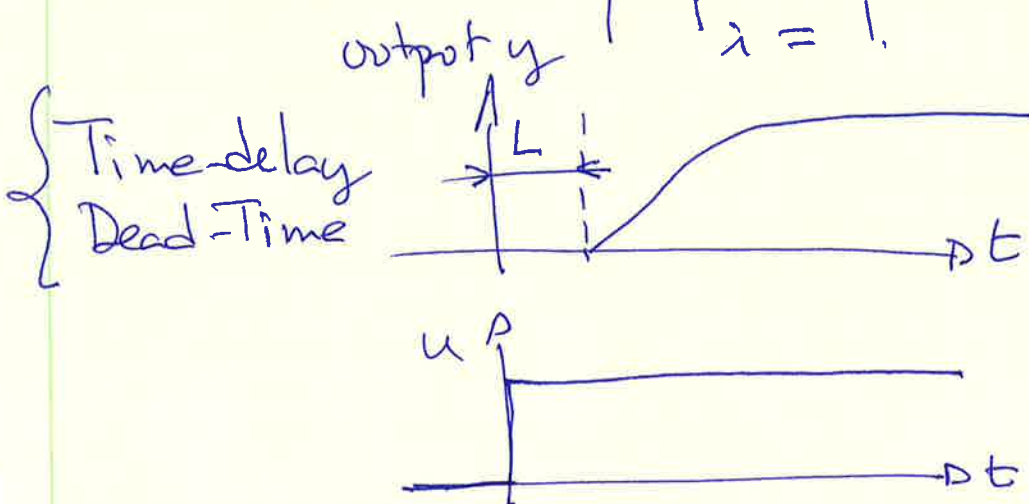
$$\underline{\underline{T_i = T = 0.2.}}$$

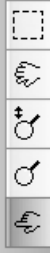
$$G_3(s) = \frac{5e^{-2s}}{s+1} = \frac{5}{1+s} e^{-2s}.$$

$$K_p = 5; T = 1; L = 2.$$

Haalman: $K = \frac{2T}{3K_p L} = \frac{2 \times 1}{3 \times 5 \times 2} = 0.067$

$$T_i = 1.$$





Manipulation Mode

Interactive Learning Module: PID Basics

ILM: PID Basics



Instructions

Theory

Process

$$G(s) = \frac{5.01}{(1.00 s + 1)}$$

Kp: 5.01

T:

1.000

delay:

2.000

h: 5e-2

Controller

☐ P

☐ I

☒ PI

☐ PD

☐ PID

K: 6.8e-2

Ti: 1

b: 0.99

Performance

Set point response

IAE 4.56

IAE 21.68

tmax 4.60

overshoot 20.95

kl 0.07

emax 4.47

sigma_x 0.005

sigma_y 0.022

sigma_u 0.002

Noise response

Robustness

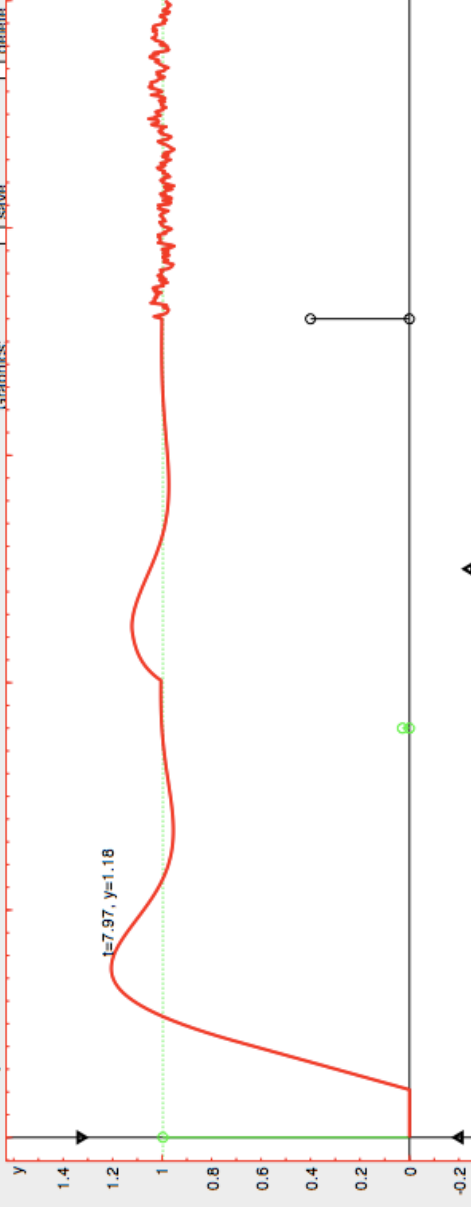
Ms 1.95

Mt 1.21

Gm 2.31

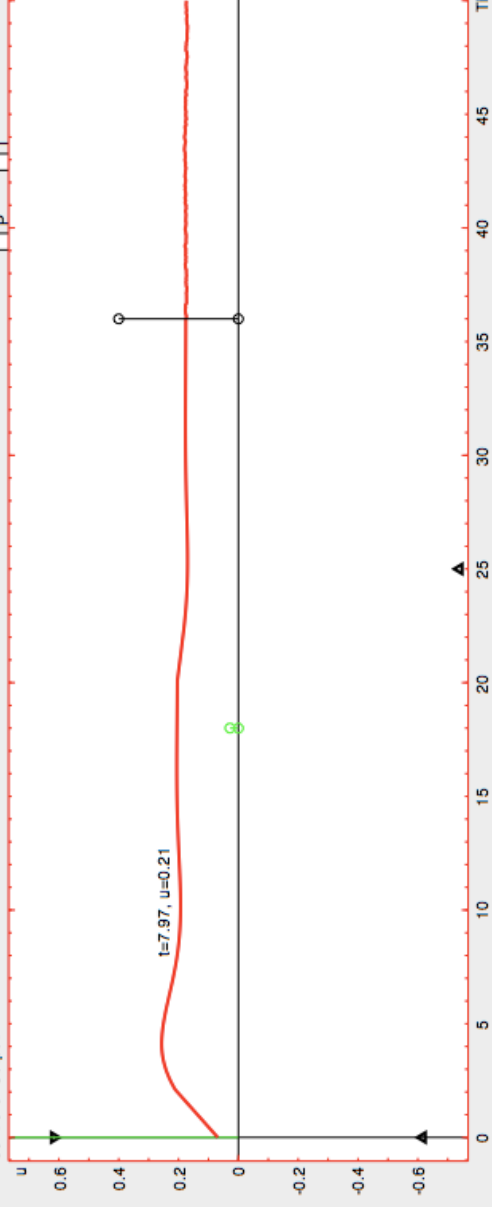
Pm 51.07

Process Output



A

Controller Output



A

$$(4). G_4(s) = \frac{10}{s^2 + 4s + 13} = \frac{10}{s^2 + 2\zeta\omega_n + \omega_n^2}.$$

$$n=2.$$

$$\deg Acl = 2n-1$$

$$\omega_n = \sqrt{13} \approx 3.6 \quad \zeta = 0.55$$

$$\deg Acl = 4.$$

$$\zeta_c \approx 0.7 \quad \omega_{nc} = 5$$

min complex

$$\left[\frac{p_1 s + p_0}{s + l_0} \right]$$

$$A_{cl} = (s^2 + 7s + 25)(s + 10)^2$$

$$\left[C(s) = \frac{p_2 s^2 + p_1 s + p_0}{s(s + l_0)} \right]$$

$$\bar{L} = s + l_0$$

$$P = p_2 s^2 + p_1 s + p_0$$

$$A_0 s \bar{L} + B_0 P = A_{cl}$$

$$(s^2 + 4s + 13)s(s + 10) + 10(p_2 s^2 + p_1 s + p_0) = (s^2 + 7s + 25)(s + 10)^2$$

$$(s^2 + 4s + 13)(s^2 + 10s) + 10(p_2 s^2 + p_1 s + p_0) = s^4 + 27s^3 + 265s^2 + 1200s + 2500$$

$$\{ s^4 + (10+4)s^3 + (13 + 40 + 10p_2)s^2$$

$$+ (130 + 10p_1)s + 10p_0 = s^4 + 27s^3 + 265s^2 + 1200s + 2500.$$

$$l_0 = 23$$

$$13 + 40 + 10p_2 = 265.$$

$$10p_2 = 140$$

$$p_2 = 14$$

$$260 + 10p_1 = 1200.$$

$$10p_1 = 931$$

$$p_1 = 93.1$$

$$p_0 = 250$$

$$C(s) = \frac{14s^2 + 93.1s + 250}{s(s + 23)}$$

$$G_S(s) = \frac{10 e^{-s}}{(s+1)(s+2)} = 5 \frac{e^{-s}}{(1+s)(10 \cdot s)}$$

Skogestad Internal Model Control
SIMC "

$$K_p = 5; \tau_1 = 1; \tau_2 = 0.5; \theta = 1.$$

$$\tau_i = \tau_1 \quad \tau_d = \tau_2.$$

$$K_c = \frac{1}{K_p} \cdot \frac{\tau_1}{\tau_c + \theta} = 0.067.$$

closed-loop
time constant

$$\boxed{\tau_c = 2.}$$

ILM: PID Basics



Instructions



Theory

Process

$$G(s) = \frac{5.01}{(0.50 s + 1)(1.00 s + 1)}$$

Kp: 5.01

iii

Delay:

Controller

OP OI OPI OPD OPD

III

Td: 0.5

N: 10

b:1

Performance

Set point response

IAE

overshooting

358

7.08

Load disturbances

IAE 16.74

0.07

	max	3.70
max	3.70	3.70

emax	3.72
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Noise response

sigma x 0.004

0

sigma_v 0.021

2

slama_u 0.007

0

Robustness

Ms 1.35

Mt 1.00

Gm 6.73

Pm 63.76

