2nd Report

Due： **June 3rd (Mon) 17:00**

Place： **S5-204A** (A box will be prepared)

Note： • A4 paper, both printing
• the following 6 items should be written on the cover

Subject Name, Report Number, **Department & Course**, Name, Student ID and Submission Date

Computer Access:

Install Guide http://www.t3.gsic.titech.ac.jp/matlab

Office Hour (Technical Support):

Place: S5-204A e-mail: tateam_at_hfg.sc.e.titech.ac.jp
Time: Friday 16:30-17:30

Lecture Information:

http://www.hfg.sc.e.titech.ac.jp/course/ROC/index.html

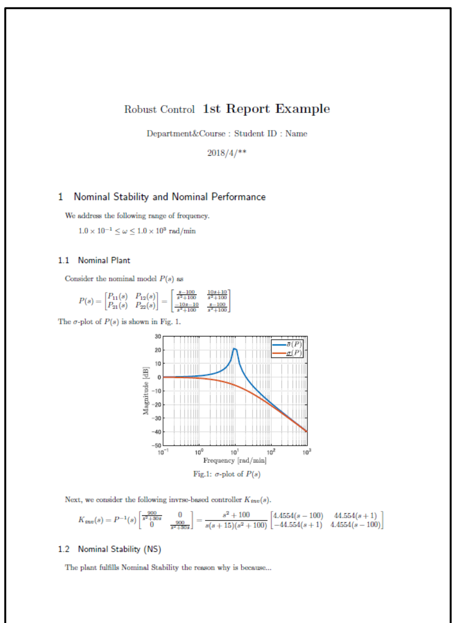
2nd Report

Please write your report in accordance with the following format.

Reports should be simple and clear.

The report example (format) can be downloaded by
http://www.hfg.sc.e.titech.ac.jp/course/ROC/handouts/ex/19Report1_ex.pdf

Please follow it.



Robust Control **1st Report Example**

Department&Course : Student ID : Name

2018/4/**

1 Nominal Stability and Nominal Performance

We address the following range of frequency.

$$1.0 \times 10^{-1} \leq \omega \leq 1.0 \times 10^{3} \text{ rad/min}$$

1.1 Nominal Plant

Consider the nominal model $P(s)$ as

$$P(s) = \begin{bmatrix} P_{11}(s) & P_{12}(s) \\ P_{21}(s) & P_{22}(s) \end{bmatrix} = \begin{bmatrix} \frac{s-100}{s^2+100} & \frac{10s+10}{s^2+100} \\ \frac{-10s-10}{s^2+100} & \frac{s-100}{s^2+100} \end{bmatrix}$$

The σ-plot of $P(s)$ is shown in Fig. 1.

Fig.1: σ-plot of $P(s)$

Next, we consider the following invrse-based controller $K_{inv}(s)$.

$$K_{inv}(s) = P^{-1}(s) \begin{bmatrix} \frac{900}{s^2+30s} & 0 \\ 0 & \frac{900}{s^2+30s} \end{bmatrix} = \frac{s^2+100}{s(s+15)(s^2+100)} \begin{bmatrix} 4.4554(s-100) & 44.554(s+1) \\ -44.554(s+1) & 4.4554(s-100) \end{bmatrix}$$

1.2 Nominal Stability (NS)

The plant fulfills Nominal Stability the reason why is because...

- Write your answer clearly…
- When you display figure, note that…
- etc…

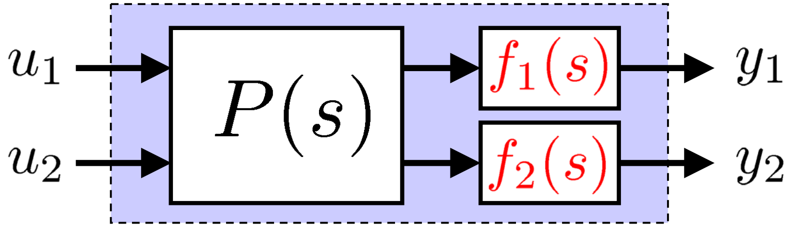
Distillation Process

Nominal Model

$$P(s)=\begin{bmatrix}P_{11}(s) & P_{12}(s)\\ P_{21}(s) & P_{22}(s)\end{bmatrix}=\begin{bmatrix}\frac{87.8}{75s+1} & \frac{-86.4}{75s+1}\\ \frac{108.2}{75s+1} & \frac{-109.6}{75s+1}\end{bmatrix}$$

Uncertain Plant Model

$$\tilde{P}(s)=\begin{bmatrix}f_1(s) & 0\\ 0 & f_2(s)\end{bmatrix}P(s)$$



$$f_i(s)=k_i\frac{-\frac{\theta_i}{2}s+1}{\frac{\theta_i}{2}s+1},\ i=1,2$$

Gain Margin: $0.8\le k_i\le 1.2$

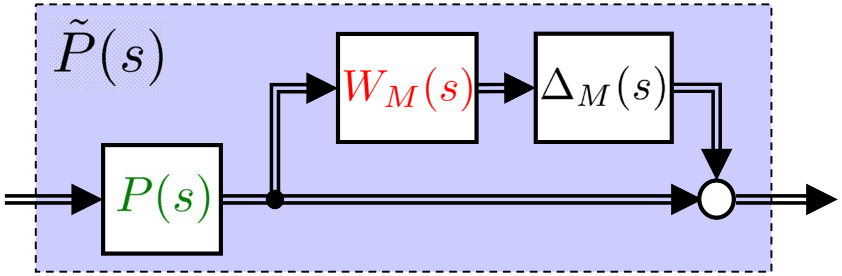
Delay Margin: $0\le \theta_i\le 1$ [min]

Multiplicative (Output) Uncertainty

$$\Pi_o=\{\tilde{P}(s)|\tilde{P}(s)=(I+\Delta_M(s)W_M(s))P(s),\ \|\Delta_M\|_\infty\le 1\}$$

$W_M(s)=w_M(s)I_2,$

$w_M(s)$: result in 2.2



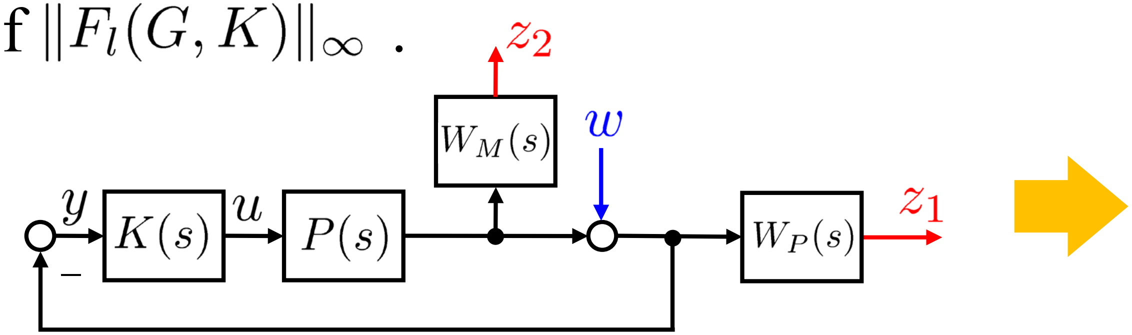
Performance Weight

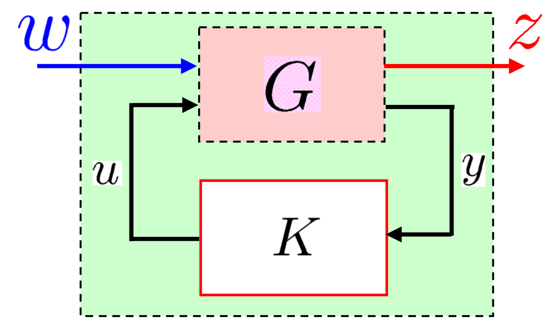
$W_P(s)=w_p(s)I_2$, $w_p(s)$: used in 1st report

[3] H_∞ Control Problem (55 pts.)

3.1 Generalized plant and mixed sensitivity problem

Show MATLAB commands to build the following generalized plant G by using W_M and W_P you derive in the 1st report.
Then, design H_∞ controller $K_\infty(s)$ by "hinfsyn" and show the value of $\|F_l(G,K)\|_\infty$.





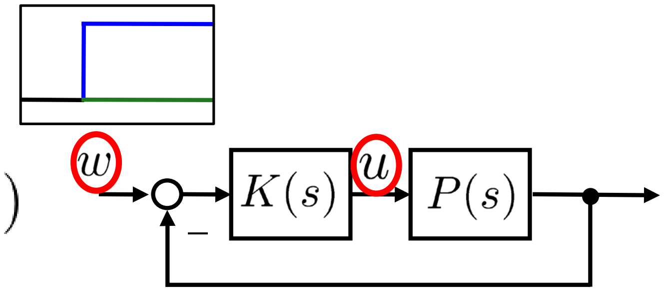
$$z = F_l(G,K)w$$

3.2 For the system with the controller $K_\infty(s)$ derived in 3.1, check (i)NS, (ii)NP and (iii)RS and show σ-plot of (iv) $K_\infty(s)$, (v) $L_o(s)$ and (vi)step responses from reference signal $[1.0\ 0]^T$.

3.3 Rebuild the weights W'_P so that the mixed sensitivity problem is solved and the time responses of the closed loop system become faster than that of 3.1. Explain the steps to rebuild the weight matrices and compare the results with 3.2.

3.4

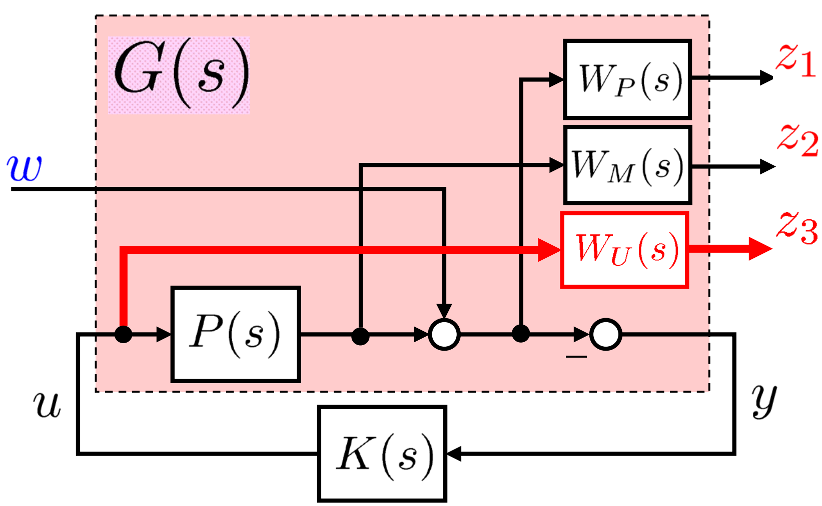
Consider the closed-loop system with $K_\infty(s)$ derived in 3.1. Show the step responses of $u(t)$ from reference signal $w(t) = \begin{bmatrix} 1.0 & 0 \end{bmatrix}^T$.



Consider the following input weight: $W_U(s) = 0.15 \begin{bmatrix} \frac{1.2s+1}{0.001s+1} & 0 \\ 0 & \frac{1.2s+1}{0.001s+1} \end{bmatrix}$

3.5

Design H_∞ controller for the generalized plant using W_P and W_M in 3.1 and $W_U(s)$. Then, compare σ-plot of (i) $K_\infty(s)$, (ii) $L_o(s)$ and (iii) step responses from reference signal $[1.0\ 0]^T$ to output in 3.2. Also, compare (iv) step responses of $u(t)$ in 3.4.



MATLAB Command

```
%Generalized Plant%
systemnames = 'Pnom WP WM WU';
inputvar = '[w(2);u(2)]';
outputvar = '[WP;WM;WU;-w-Pnom]';
input_to_Pnom = '[u]';
input_to_WP = '[w+Pnom]';
input_to_WM = ' [Pnom]';
input_to_WU = ' [u]';
G = sysic;
```

Bonus H_∞ and H_2 Control Problem

```
[K, CL, gam, info] = h2syn(G, nmeas, ncon)
```

4.1

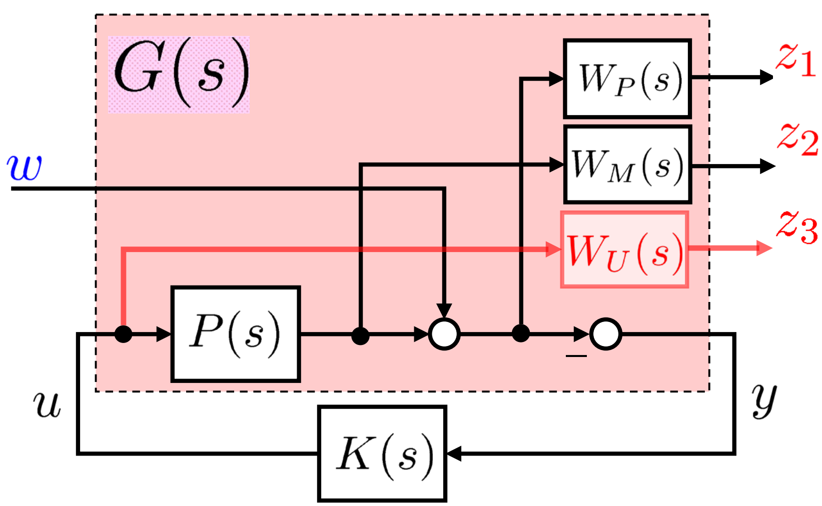
Design H_2 controller $K_2(s)$ by "h2syn" for the generalized plant using W_P and W_M in 3.1 and $W_U(s)$ below.

$$W_U(s) = 0.001 \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Necessary to solve H_2 problem, but no influence on the design

4.2

Compare the results of H_∞ controller designed in 3.1 to the results of H_2 controller. For examples, σ-plot of the controllers, $L_o(s)$, step responses from reference signal $[1.0\ 0]^T$ and so on.



MATLAB Command

```
systemnames = 'Pnom WP WM WU';
inputvar = '[w(2);u(2)]';
outputvar = '[WP;WM;WU;-w-Pnom]';
input_to_Pnom = '[u]';
input_to_WP = '[w+Pnom]';
input_to_WM = ' [Pnom]';
input_to_WU = ' [u]';
G = sysic;
```