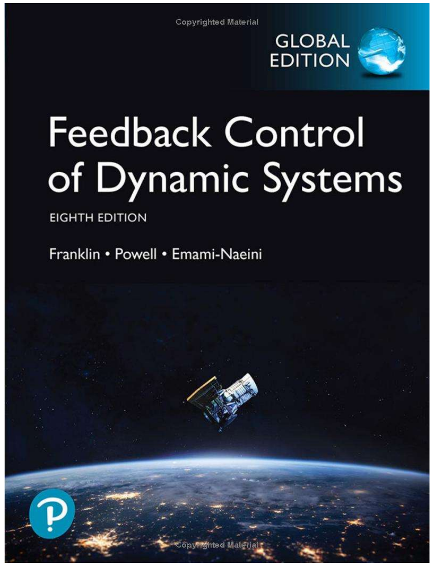
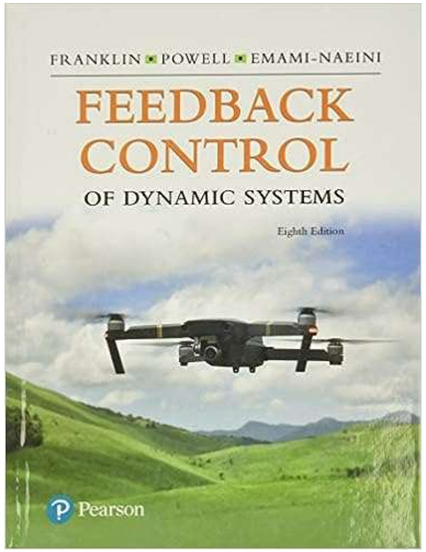


國立清華大學
National Tsing Hua University

PME320701

Feedback Control of Systems



Lecture 1

Instructor : Cheng-Hsien Liu 劉 承 賢

liuch@pme.nthu.edu.tw

http://mx.nthu.edu.tw/~chhsliu

Lecture in Chinese

09/02/2025

http://mx.nthu.edu.tw/~chhsliu/control/PME3207_Liu.html

國立清華大學 National Tsing Hua University

PME320701 Feedback Control of Systems (Control System I)

(Autumn 2025)

Course Information

Instructor: Liu, Cheng-Hsien (email: liuch@pme.nthu.edu.tw)
Office: Room 517, Engineering Building #1
Phone: (03) 5742496

Lectures: Time: Tuesday 10:10am- 12:00 & Thursday 11:10am~12:00
Location: Room 101, Engineering Building #1

Office Hours: Tuesday 1:30pm~3:00pm & appointment by email

- TAs: 李千侑 liqianyou3@gmail.com
- 王淳弘 dd111033206@gapp.nthu.edu.tw
- 蘇建翰 kevin14141732@gapp.nthu.edu.tw

Matlab/Simulink Invited lecturer: Mr. Kary Chang (senior engineer at Mathworks, Taiwan.)

TA hours: Schedule

Course Web site: http://mx.nthu.edu.tw/~chhsliu/control/PME3207_Liu.html

Course Objectives

The Goal of the course is to provide Undergraduate with basic concepts, principles and applications of feedback control in order to work on design of feedback control systems using classical control methods. Course content will include dynamic modeling, dynamic response, stability, classical methods of analysis and control: PID, Root Locus, Nyquist, Bode.

Temporary schedule for TA Hours

TA Hours-- 7:00pm~9:00pm (Tuesday) / classroom: 工程一館 Room 101 (暫定) (臨時若有更動, 助教 會在當晚演習課前以 eeclass.nthu.edu.tw 的 email 通知大家(會盡量中午前))

李千侑 liqianyou3@gmail.com

王淳弘 dd111033206@gapp.nthu.edu.tw

蘇建翰 kevin14141732@gapp.nthu.edu.

	Week	Mon	Tue	Wed	Thu	Fri	
Sep	1	1	2	3	4	5	09/02 class starts (無助教演習課)
	2	8	9(助教)	10	11(助教)	12	(無助教演習課)
	3	15	16(助教)	17	18(助教)	19	(無助教演習課)
	4	22	23	24	25	26	(TA Hours: 7:00pm~9:00pm (Tuesday))
	5	~~29~~	30				
Oct				1	2	3	
	6	~~6~~	7	8	9	~~10~~	
	7	13	14	15	16	17	
	8	20	21	22	23	~~24~~	10/21 1st Midterm (10:10am~大約12:40)

	9	27	28	29	30	31	10/28 Matlab Lecture given by invited Lecturer from Mathworks (7:00pm~10:00pm at 工程一館四樓動機系圖學教室) 要求必須出席算分
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	12	17	18	19	20	21	(Matlab HW 3)
	13	24	25	26	27	28	(Matlab HW 4)
Dec	14	1	2	3	4	5	
	15	8	9	10	11	12	
	16	15	16	17	18	19	12/16 Final Exam (10:00am ~(3 hours))

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  - Matlab: 17%
  - Final exam: 42% (temporary)
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Announcements

Handouts

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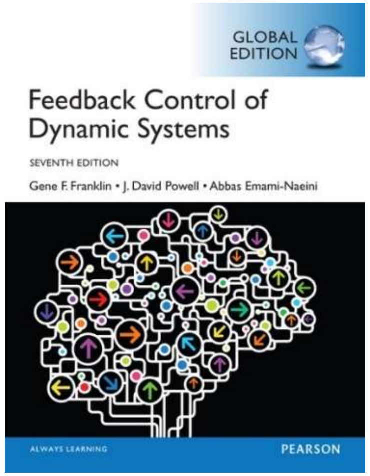
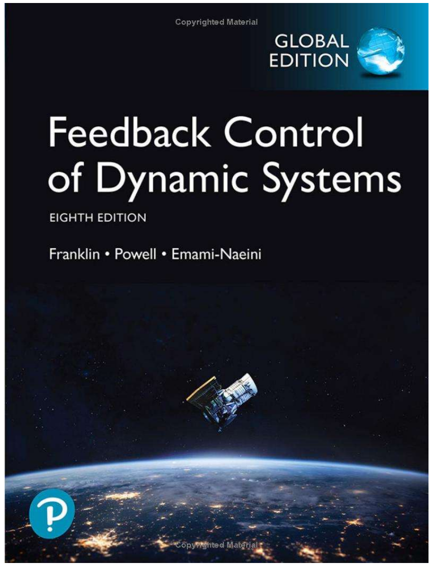
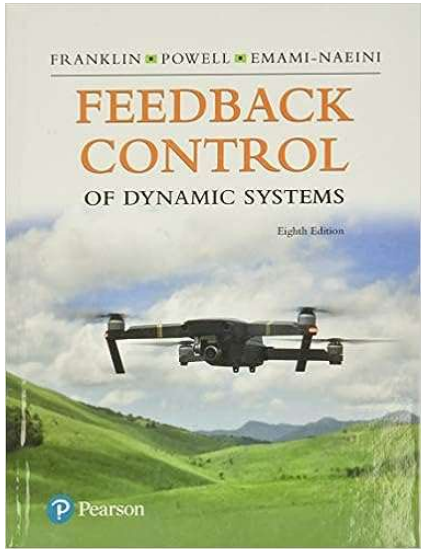


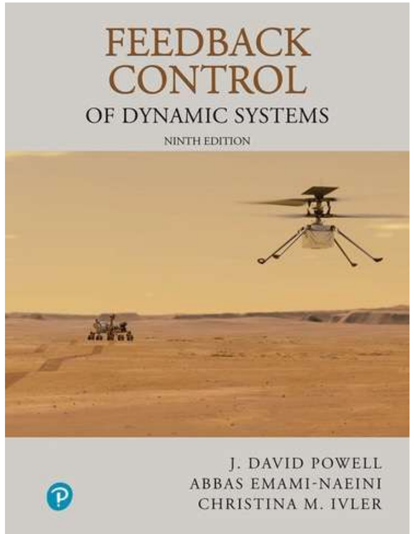
Franklin, Powell, Emami-Naeini, **7th edition, 2014**

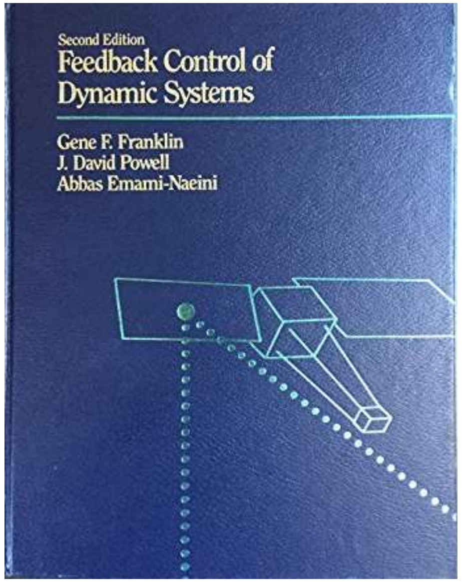
Powell and Emami-Naeini, "Feedback Control of Dynamic Systems, Pearson, **8th edition, 2020**



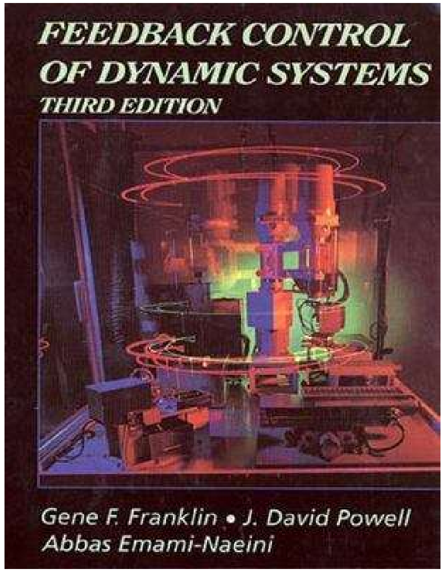


J David Powell, Abbas F. Emami-Naeini, **Christina M. Ivler(University of Portland), 9th edition, March 18, 2025**

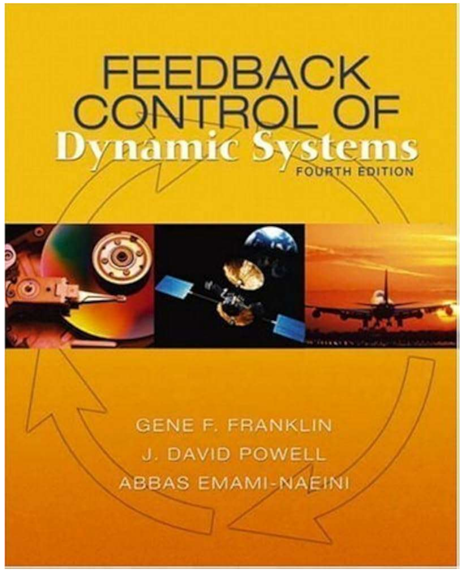




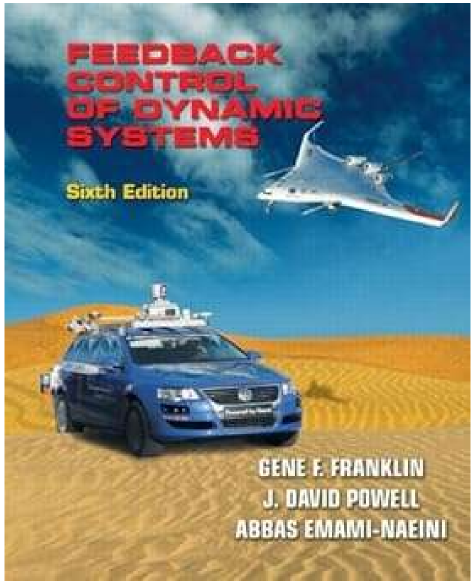
2nd edition, 1991



3rd edition, 1993

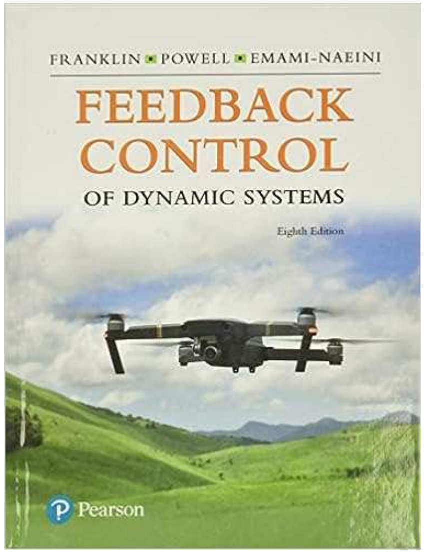


4th edition, 2002

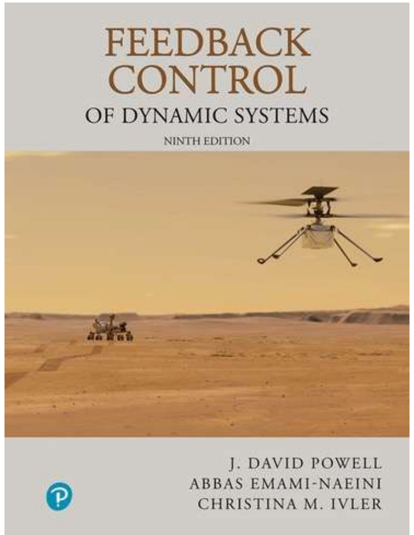


6th edition, 2009

Franklin, Powell, Emami-Naeini, **7th edition, 2014**



Powell and Emami-Naeini, **8th edition, 2020**



J David Powell, Abbas F. Emami-Naeini, **Christina M. Ivler(University of Portland), 9th edition, March 18, 2025**

http://mx.nthu.edu.tw/~chhsliu/control/PME3207_Liu.html

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Dec	14	1	2	3	4	5	
	15	8	9	10	11	12	
	16	15	16	17	18	19	12/16 Final Exam (10:00am ~(3 hours))

7:00pm出席上課點名(下課前第二次再點名)分數，學期總分加2分，同學出席遲到10分鐘進教室的同學，視同未出席，不計這2分成績

Temporary-

- **HW1~HW4為14分**
- **MATLAB Onramp 為1分**
- **Simulink Control design Onramp 為2分**

所以總共是17分

http://mx.nthu.edu.tw/~chhsliu/control/PME3207_Liu.html

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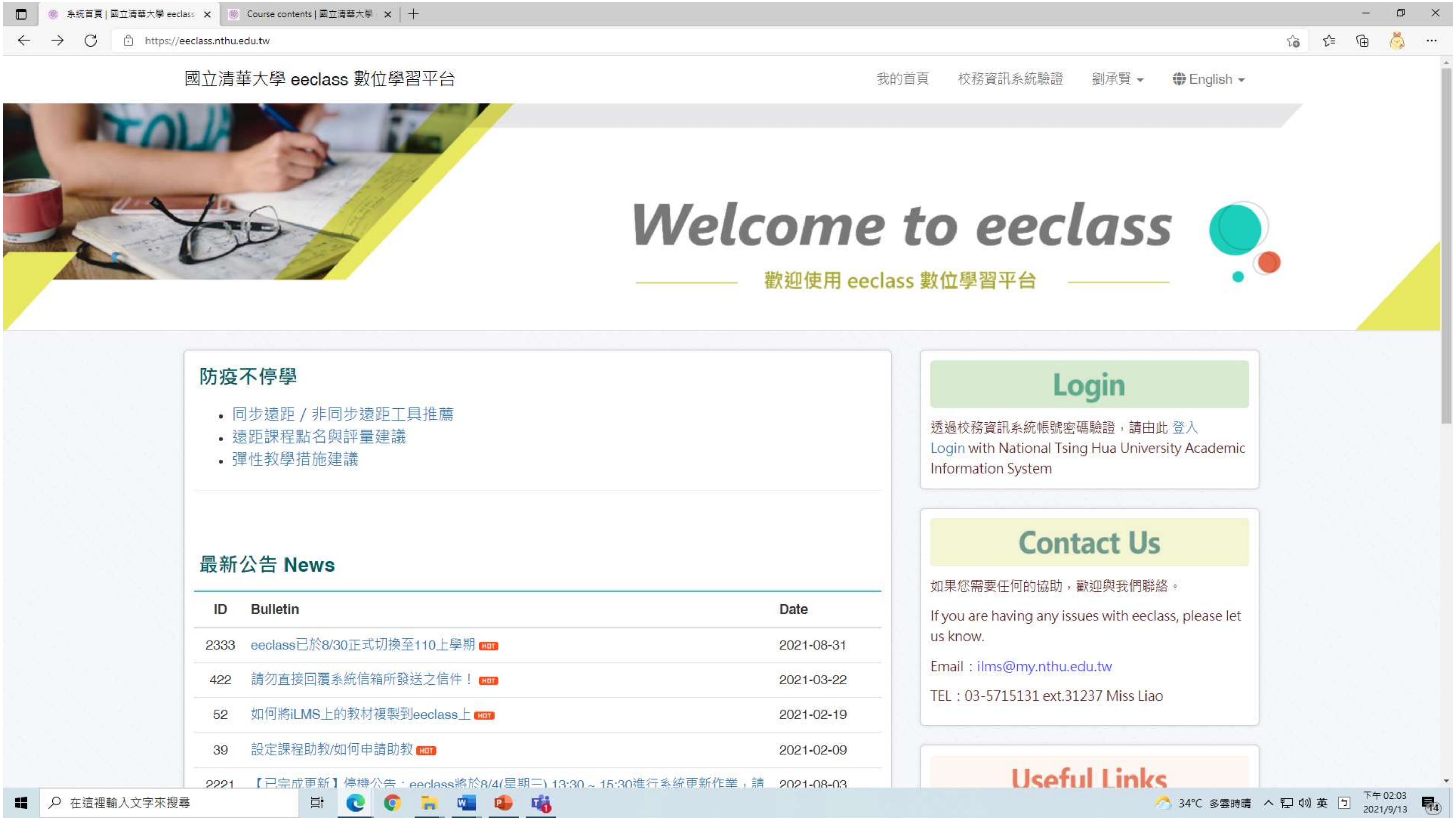
https://mx.nthu.edu.tw/~chhsliu/control/PME3207_ann.html

PME320701 Feedback Control of Systems (Autumn 2025)

Announcements

- **(09/01)**
  1. **Class lectures will be delivered in Chinese. The lecture notes will be mostly in English.**
  2. **First lecture starts on 10:10pm Sep. 2 at Room 101, Engineering Building #1（工程一館101).**
  3. **第二周9/9 & 9/11 以及 第三周9/16 & 9/18 助教上共六小時課**
  4. **All class notes will be available http://mx.nthu.edu.tw/~chhsliu/control/PME3207_handouts.html at first couples of weeks in case some of you had not been in class eeclass. Later all class notes and announcement will be only in class eeclass.**
  5. **TA hours and my office hours will start from the week of 9/23**
  6. **One Midterm and Final Exam will be based on http://mx.nthu.edu.tw/~chhsliu/control/TA_Hours.pdf .**
  7. **Also The midterm exam date and final exam date are fixed. If you predicted schedule conflict, this class might not appropriate for you to take. (Sorry about this.)**
  8. **這門課將盡量避免加簽,除非你/妳暑假初收到我email開放加簽或修課人數未滿60人,請帶當時email,開學第一周9/2周二下課時間找我加簽**

https://eeclass.nthu.edu.tw/



Chapter 1: An Overview and Brief History of Feedback Control

Chapter 2: Dynamic Models

Chapter 3: Dynamic Response

Chapter 4: A First Analysis of Feedback

Chapter 5: The Root-locus Design Method

Chapter 6: The Frequency-response Design Method

Chapter 7: State-space Design

Chapter 8: Digital Control

Chapter 9: Nonlinear Systems

Chapter 10: Control Systems Design: Principles and Case Studies

⇨ Appendix A: Laplace Transforms

Appendix B: Solutions to the Review Questions

Appendix C: MATLAB Commands

Appendix WA: A Review of Complex Variables

Appendix WB: Summary of Matrix Theory

Appendix WC: Controllability and Observability

Appendix WD: Ackermann's Formula for Pole Placement

Appendix W2.1.4: Complex Mechanical Systems

www.fpe7e.com

https://www.scsolutions.com/publication/feedback-control-of-dynamic-systems-seventh-edition/

Feedback Control of Dynamic Systems – Seventh Edition

Gene F. Franklin, J. David Powell, Abbas Emami-Naeini

Feedback Control of Dynamic Systems, 7th edition, Pearson, 2015, ISBN-10: 0133496597 • ISBN-

Website

Feedback Control of Dynamic Systems, 7/e covers the ma
and most scientists and prospective managers, needs
control, including concepts like stability, tracking, and r
presents the fundamentals along with comprehensive,
within a real-world context and with historical backgro
authors also provide case studies with close integratio

The book is available for purchase at the publisher's w

There is also a graduate level book on this material tha
implementations entitled: Digital Control of Dy c Sy

Download MATLAB m, mdl, and slx files (zip archive, 1.06 mb).

Table of Contents

Detailed table of contents (pdf, 72.7 kB).

Chapter 1: An Overview and Brief History of Feedback Control

FPE7-ALL.zip - WinRAR

檔案(F) 指令(C) 工具(S) 我的最愛(O) 選項(N) 說明(H)

加入 解壓縮到 測試 檢視 刪除 尋找 精靈 資訊 防毒 註解

FPE7-ALL.zip\ALL - ZIP 壓縮檔, 未封裝大小 1,119,372 位元組

名稱	大小	封裝後	類型	修改的日期	CRC32
f_ptos.m	262	174	M 檔案	2014/6/13 上...	4E25F...
f_tos.m	123	111	M 檔案	2014/6/13 上...	1363B...
fas.m	235	158	M 檔案	2014/6/13 上...	7852F...
fig2_3.m	287	209	M 檔案	2014/7/15 上...	7299E...
fig2_15.m	409	282	M 檔案	2014/6/15 下...	6EEEB...
fig2_17.mdl	29,632	7,944	MDL 檔案	2014/6/17 上...	8233D...
fig2_18.slx	15,749	15,251	SLX 檔案	2014/7/17 上...	364E2...
fig2_19a.m	444	288	M 檔案	2014/6/17 下...	D8697...
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fig2_19b.m	444	289	M 檔案	2014/6/17 下...	9F1C2...
fig2_19bx.slx	15,166	14,857	SLX 檔案	2014/7/17 上...	BB636...
fig3_04.m	648	362	M 檔案	2014/6/27 上...	6A34F...
fig3_05.m	984	504	M 檔案	2014/6/27 上...	F2C8F...
fig3_06.m	396	278	M 檔案	2014/6/21 上...	CA0C5...
fig3_07.m	716	399	M 檔案	2014/6/27 上...	43163...
fig3_08.m	749	412	M 檔案	2014/6/21 上...	2E11D...
fig3_14.m	1,123	546	M 檔案	2014/6/27 上...	D4171...
fig3_15.m	193	150	M 檔案	2014/6/27 上...	7F0EF...

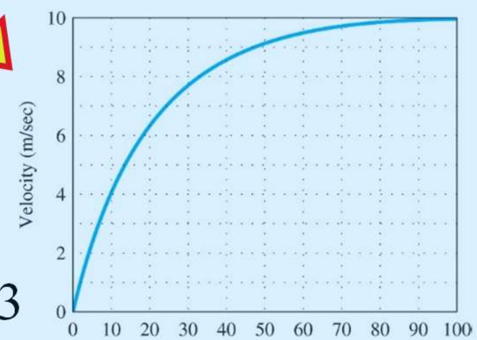


Figure 2.3

Chapter 1: An Overview and Brief History of Feedback Control

Chapter 2: Dynamic Models

Chapter 3: Dynamic Response

Chapter 4: A First Analysis of Feedback

Chapter 5: The Root-locus Design Method

Special M-files for root-locus (zip archive, 2.0 kB).

Chapter 6: The Frequency-response Design Method

Special M-files for Bode plots (zip archive, 932 bytes).
Paper on the shapes of Nyquist plots (pdf, 1.4 MB).

Chapter 7: State-space Design

Chapter 8: Digital Control

Chapter 9: Nonlinear Systems

Chapter 10: Control Systems Design: Principles and Case Studies

Appendix A: Laplace Transforms
Appendix B: Solutions to Review Problems
Appendix C: Matlab Commands

Bibliography

Web Appendices:

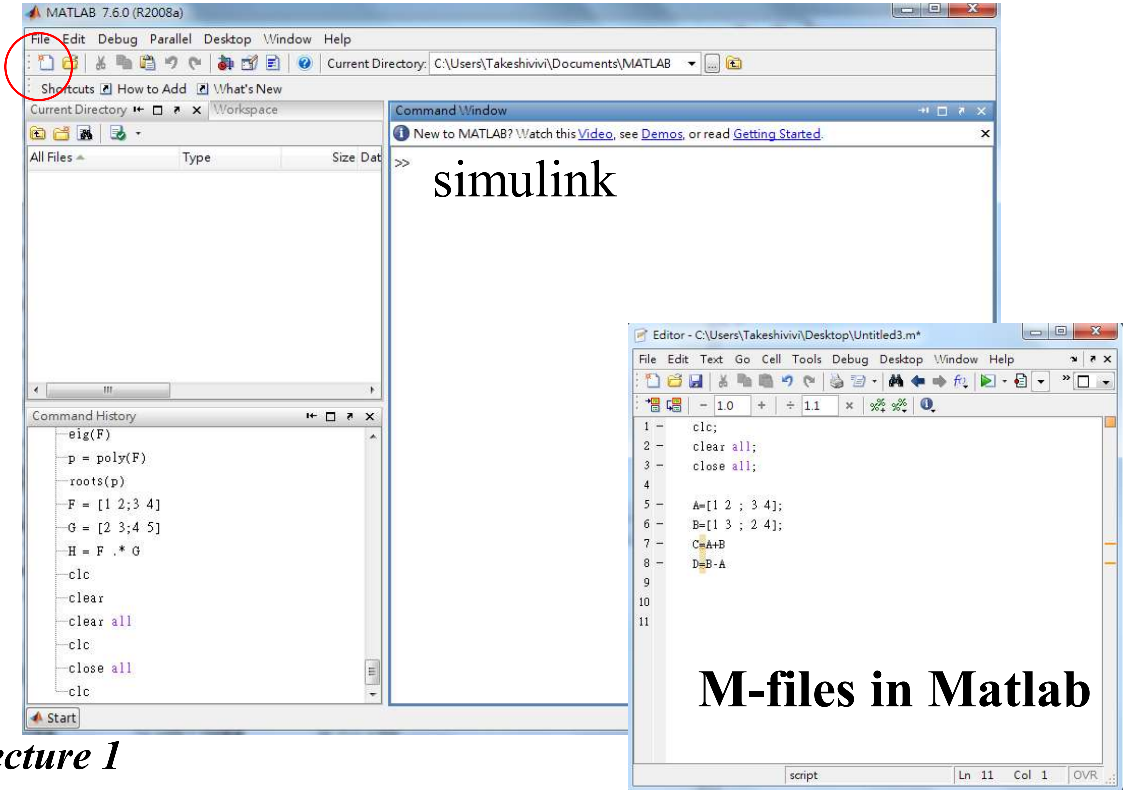
Download All Web Appendices

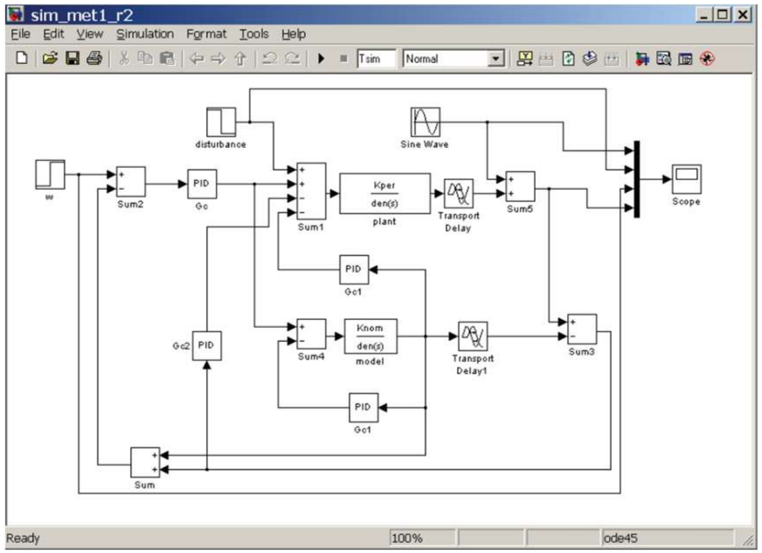
MATLAB-related tutorials

- RLtool tutorial (pdf, 422.9 kB).
- Simulink tutorial (pdf, 417.6 kB).

TeraSoft 鈦思科技 The Power of Driver for the Best!!

Computer-Aided Design/Simulation





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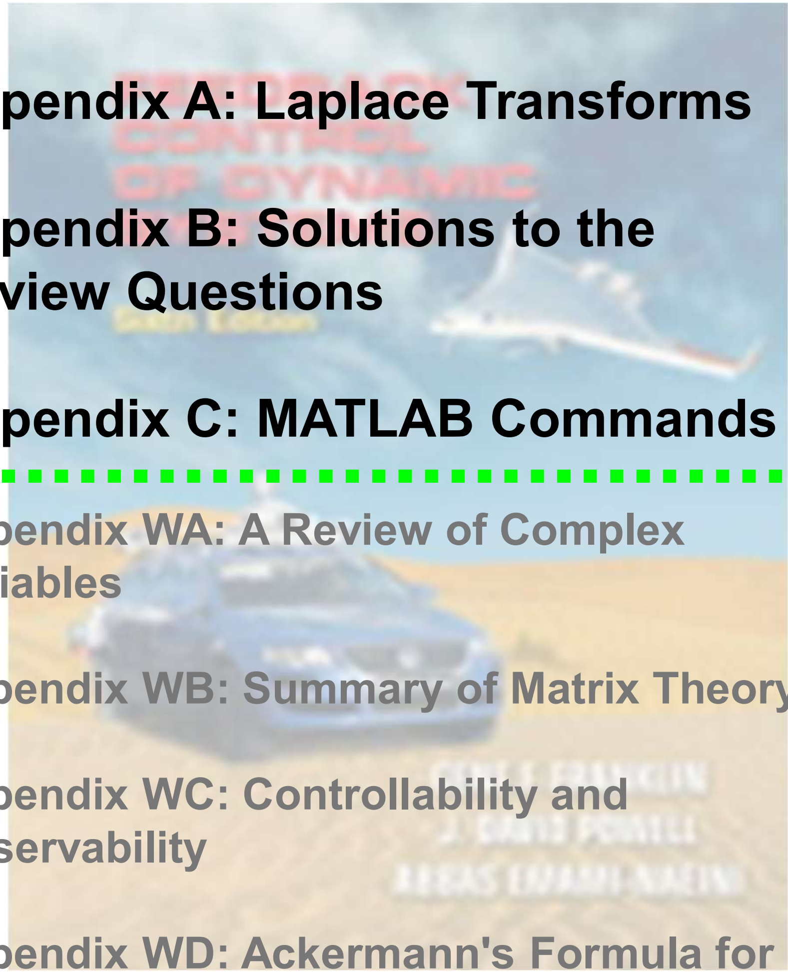

Appendix A: Laplace Transforms

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https://mx.nthu.edu.tw/~chhsliu/control/P...

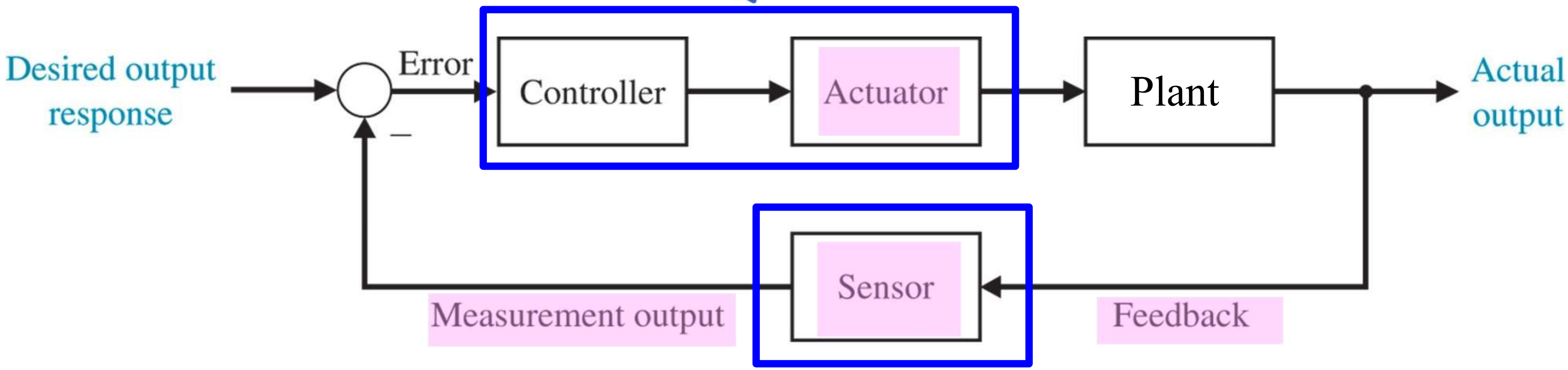
PME320701 Feedback Control of Systems (Autumn 2025)

Handouts

- Pre-reading material I (for your reading before class/ for fun!)
- Lecture 1—Introduction & Chapter 1
- Lecture 2~4—Chapter 2 ~ Chapter 3.4
- **The handouts will be on eeclass for the rest of this semester class.**

What Is Feedback Control? What are the Applications of Feedback Control?

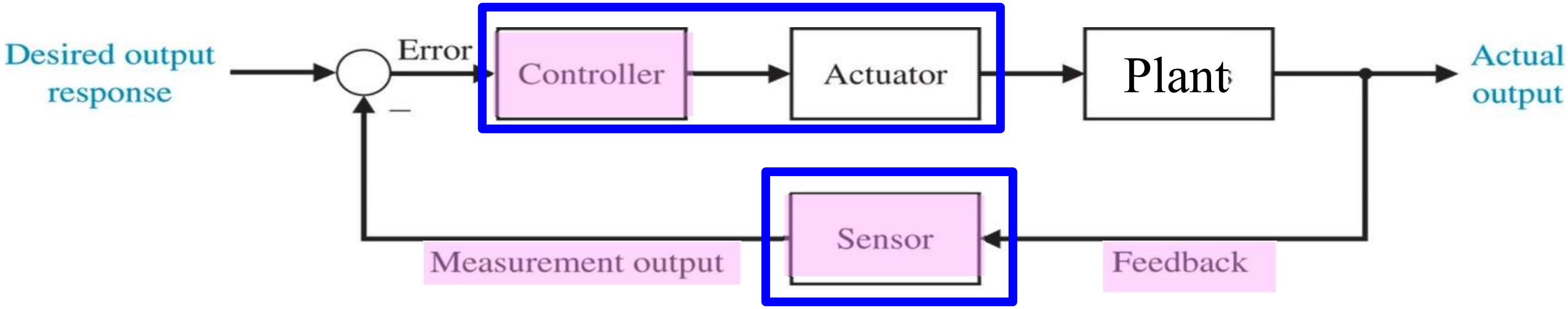
Feedback Control 迴授控制



Case Study I:

Case Study II: Autonomous vehicle/Autonomous driving

Feedback Control 迴授控制



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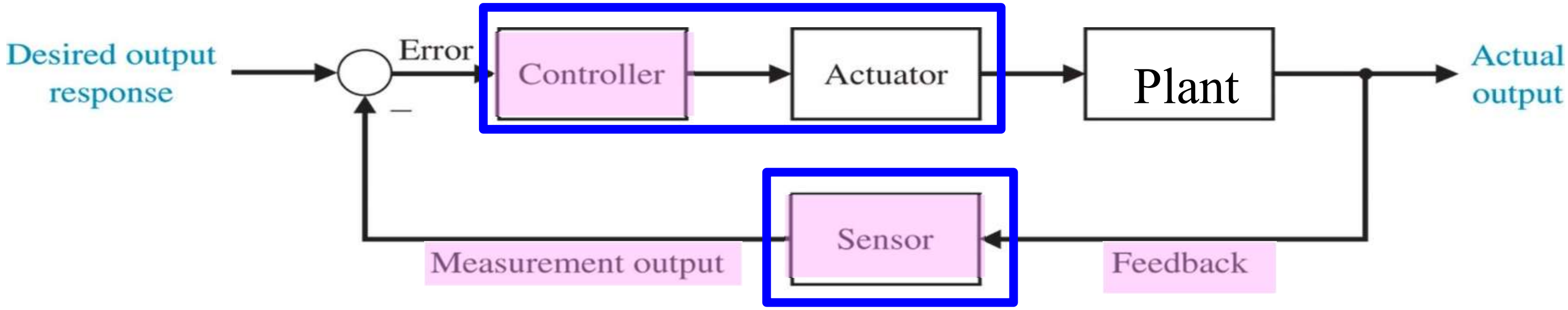
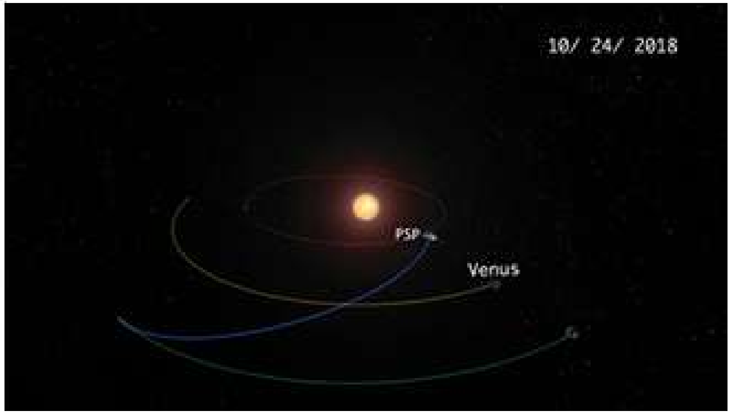


Actuators- (Combustion) Engine

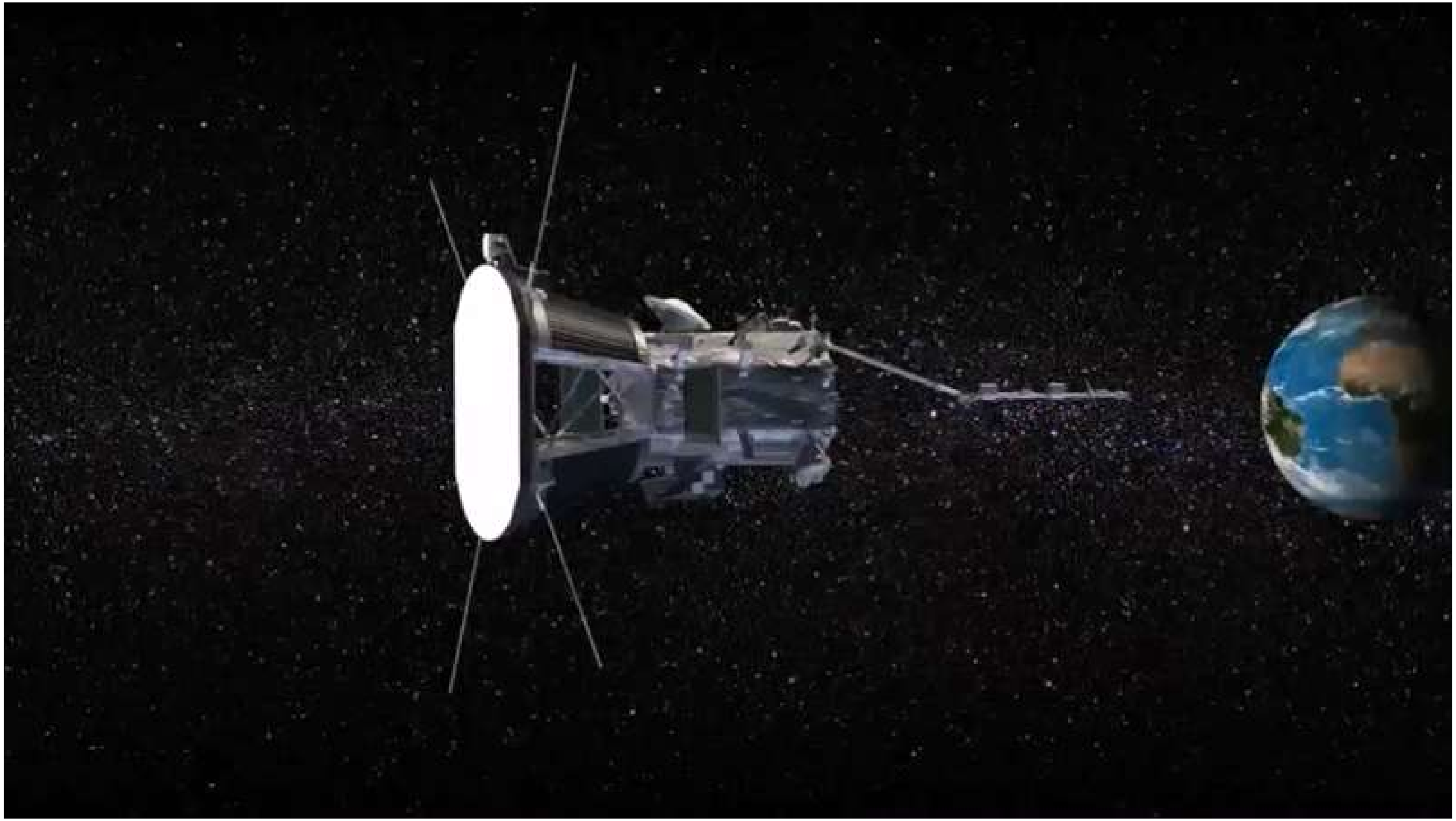
Car Engine

Transmission

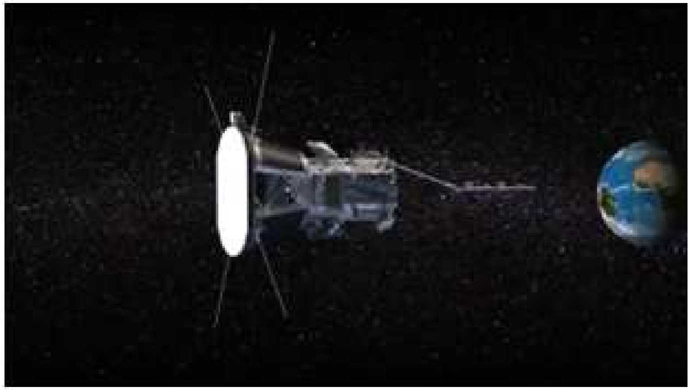
Case Study III: NASA Parker Solar Probe



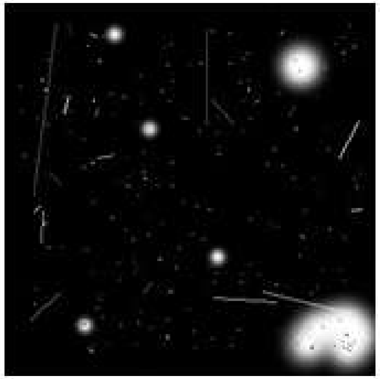
Case Study III: NASA Parker Solar Probe



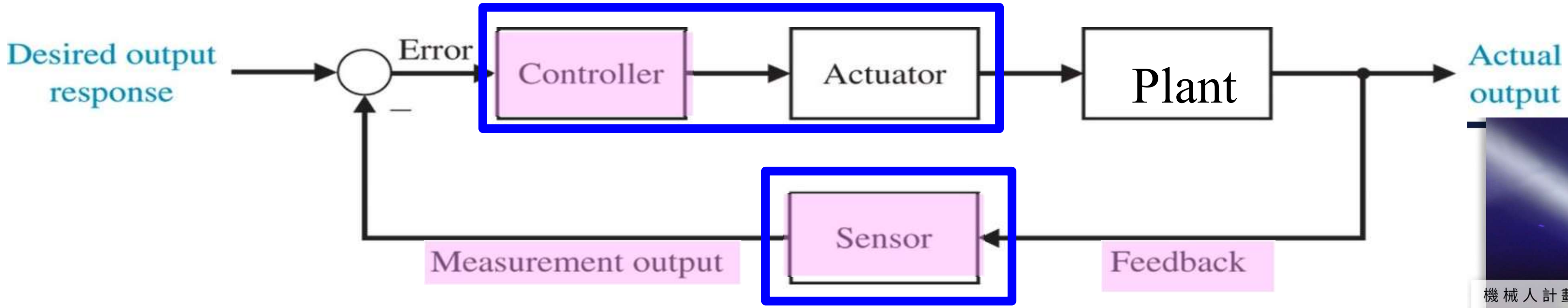
Case Study III: NASA Parker Solar Probe



Rocket thruster

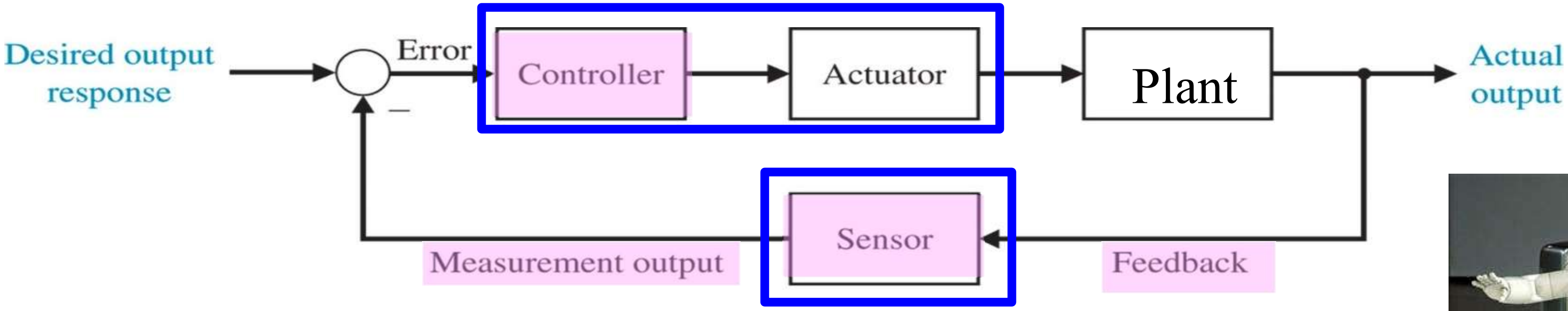


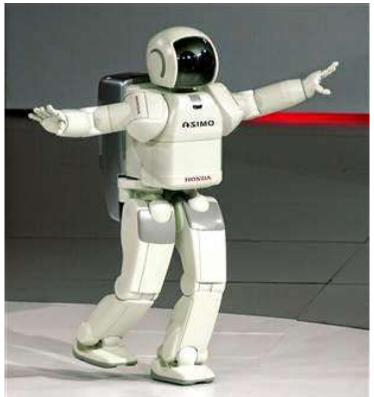
Case Study IV: Robot/ Robot Arms/Robot Hands



Honda announces to stop/ retitre Asimo humanoid robot after 2018

Case Study IV: Robot/ Robot Arms/Robot Hands

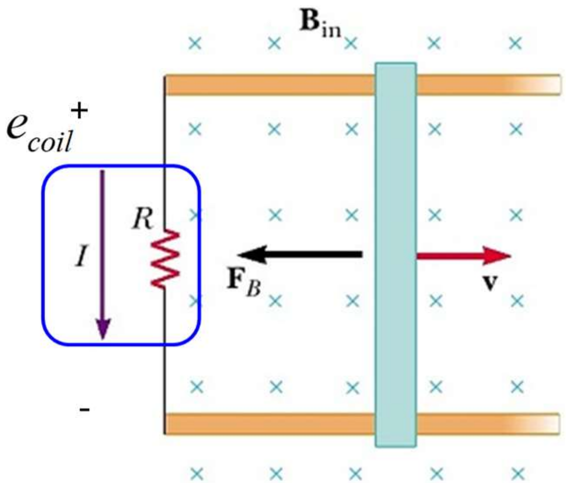


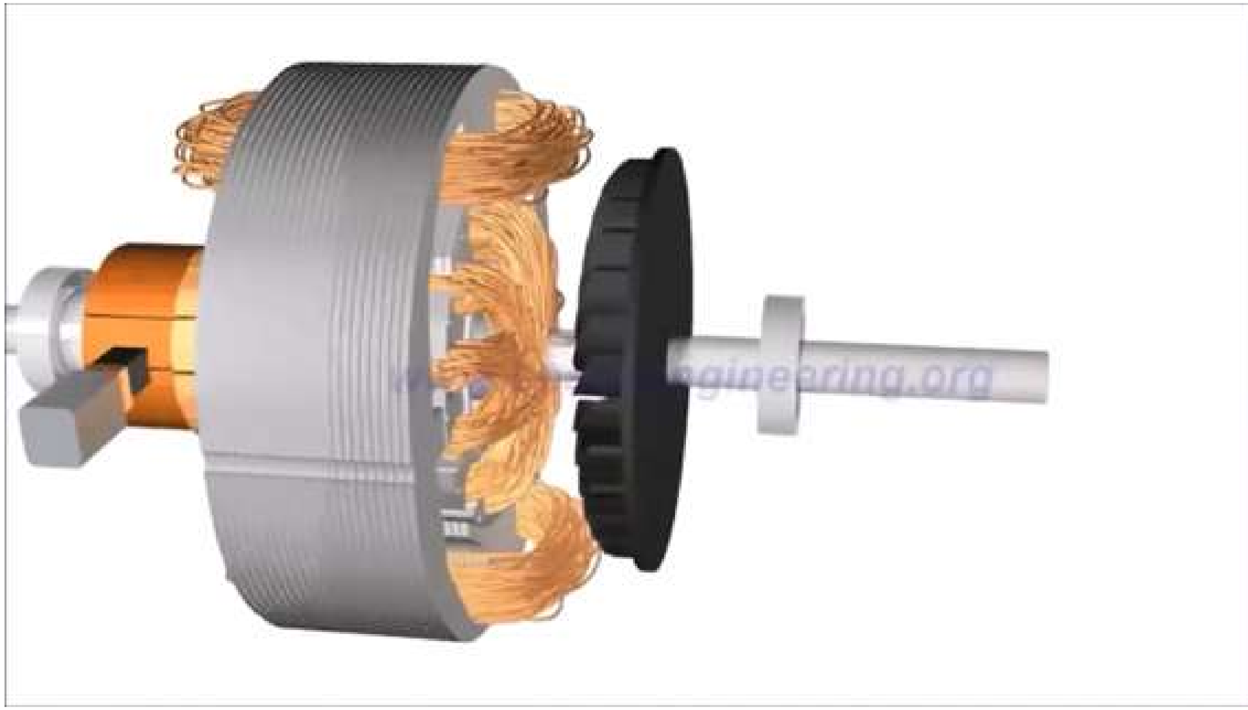


Actuators- (Electrical) Motor

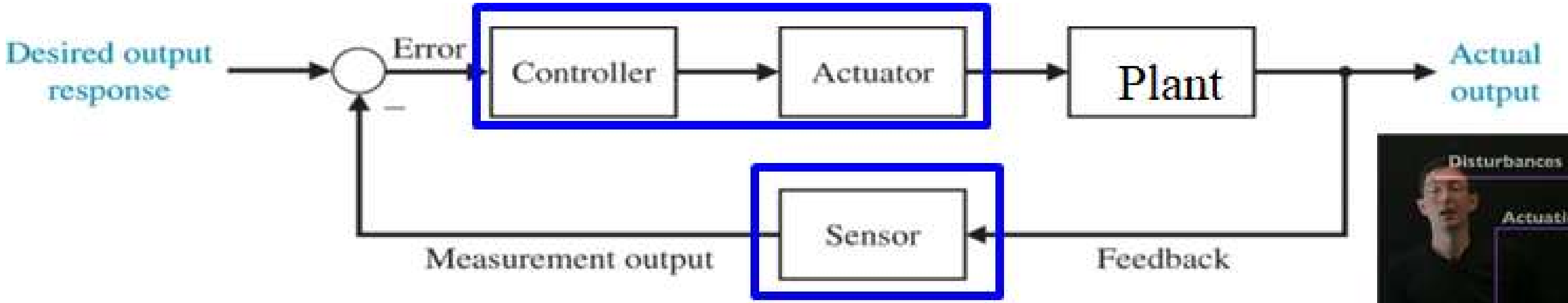
Electrical Motor

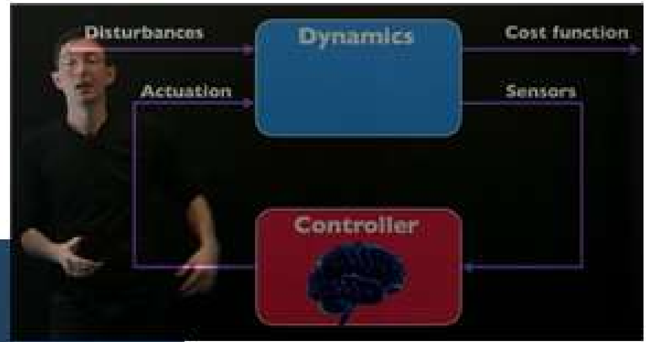
Lenz's Law





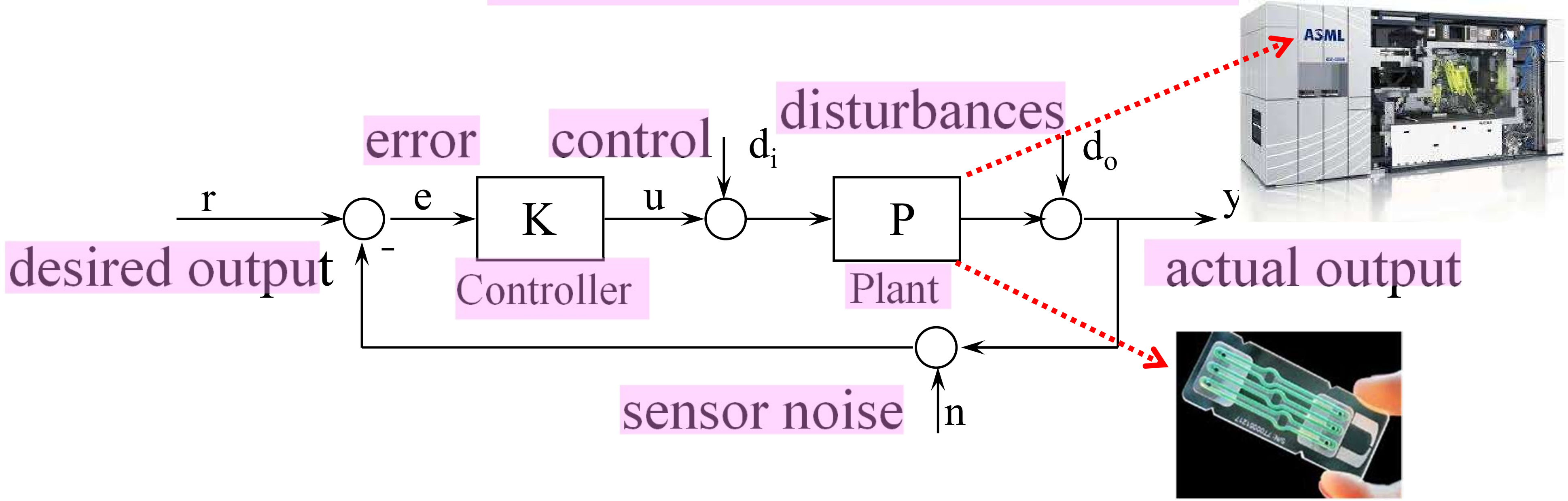
Google's DeepMind AI Just Taught Itself To Walk





https://www.youtube.com/watch?v=gn4nRCC9TwQ

What Is Feedback Control?



- Design K s.t. closed loop system exhibits high performance.

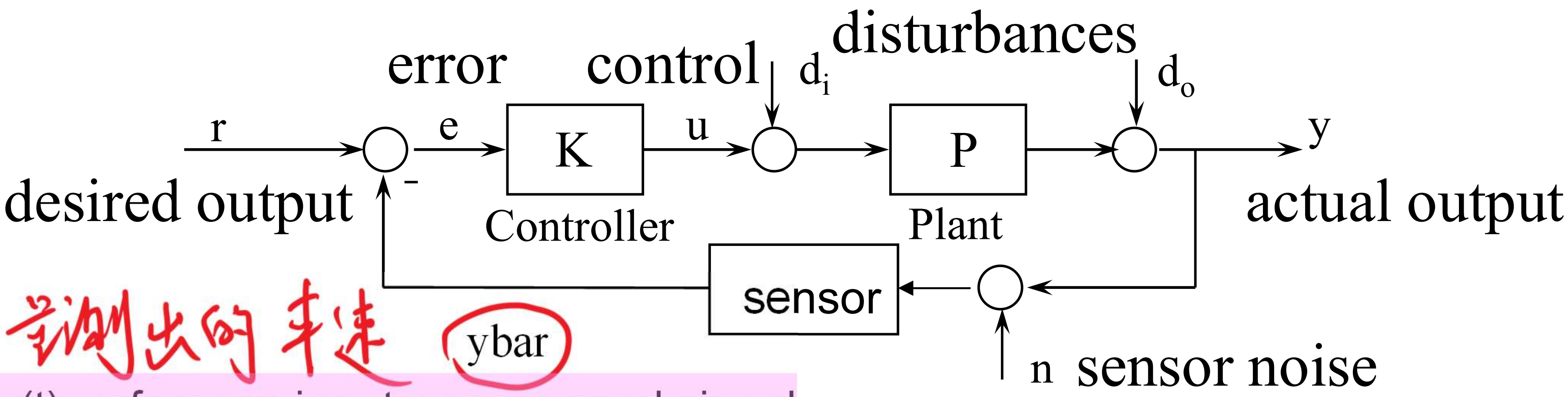
待控制的系統

- P : Physical System to be Controlled
- K : System to be Designed

controller 控制器
compensator 補償器

Do you need this course? I believe –yes!

Terms



量測出的車速

r(t): reference input or command signal

y(t): sensed/actual output

e(t)= r(t) - ybar(t)

u(t): control input

Plant P sometimes includes actuator dynamics

ybar: estimate of y

<u>Purpose</u>: find compensator/controller

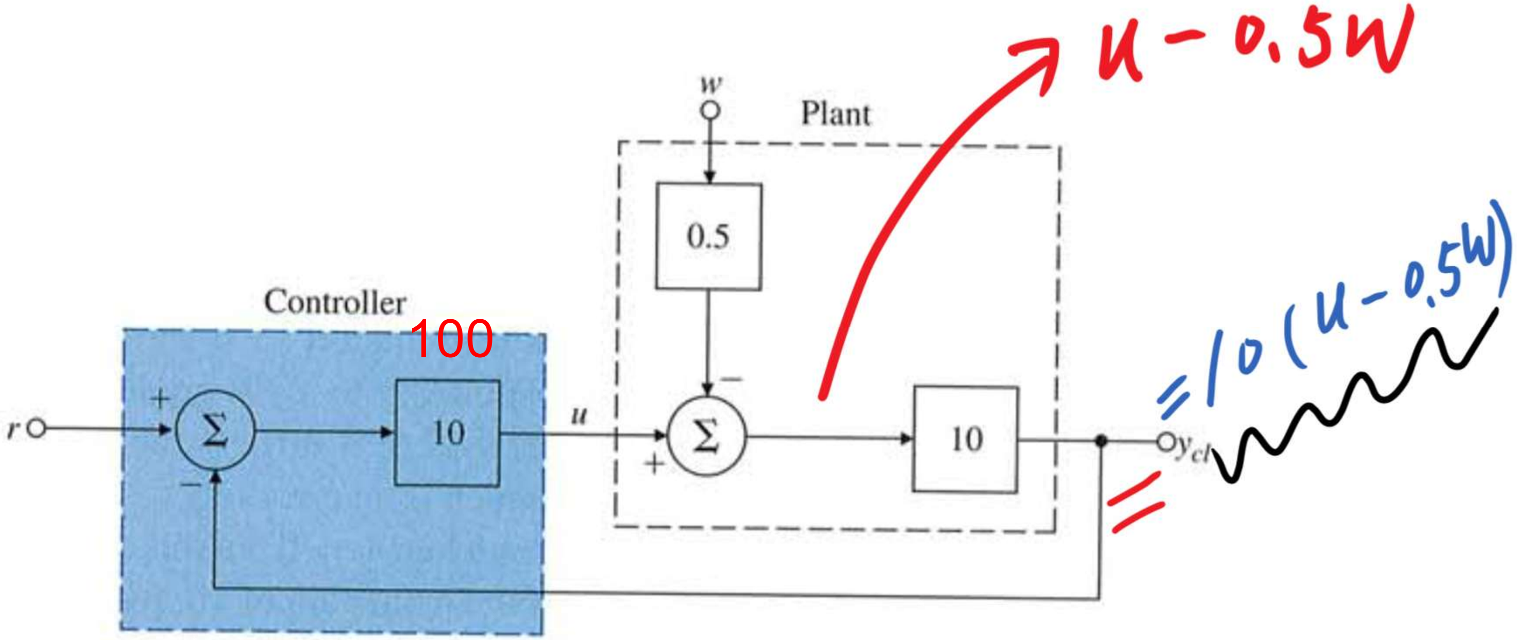
- error is "small"
- stability is "good"

If r(t) is a constant -> "regulator" problem

If r(t) =function of time -> "servo" or "tracking" problem

伺服 追踪

Figure 1.6
Closed-loop cruise control



$$\begin{cases} y_{cl} = 10u - 5w, \\ u = 10(r - y_{cl}). \end{cases}$$

Combining them yields

$$y_{cl} = 100r - 100y_{cl} - 5w,$$

$$101y_{cl} = 100r - 5w,$$

$$y_{cl} = \frac{100}{101}r - \frac{5}{101}w, \quad \leftarrow y_{cl} = \frac{1000}{1001}r - \frac{5}{1001}w$$

$$e_{cl} = \frac{r}{101} + \frac{5w}{101}.$$

Chapter 1: An Overview and Brief History of Feedback Control

Chapter 2: Dynamic Models

Chapter 3: Dynamic Response

Chapter 4: A First Analysis of Feedback

Chapter 5: The Root-locus Design Method

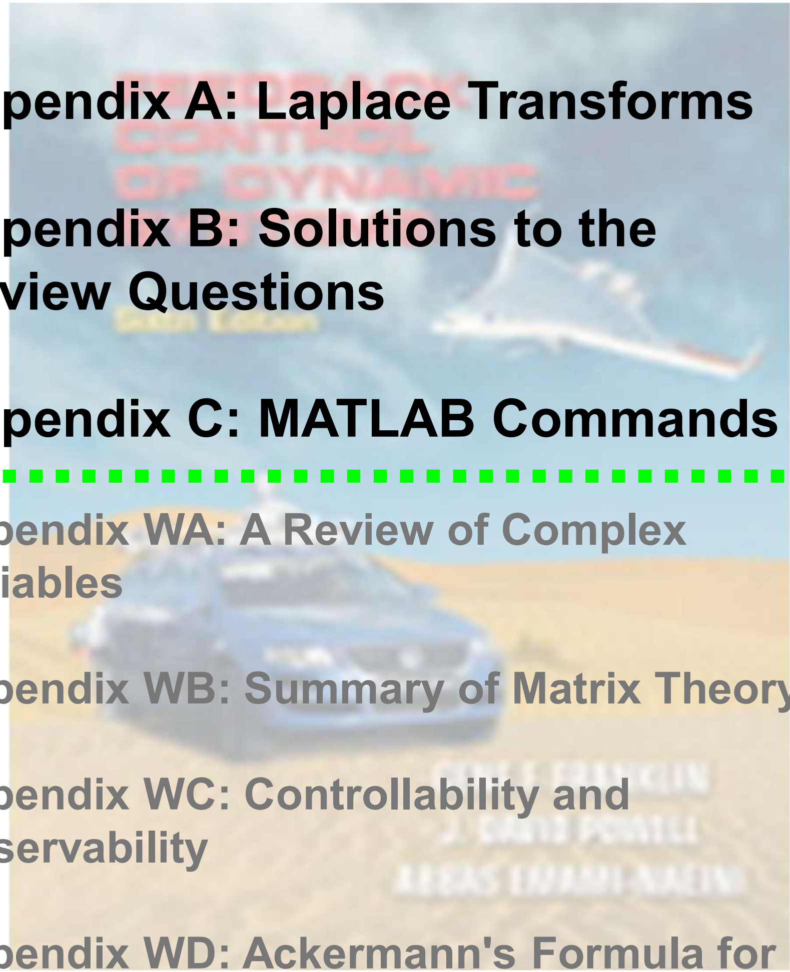
Chapter 6: The Frequency-response Design Method

Chapter 7: State-space Design

Chapter 8: Digital Control

Chapter 9: Nonlinear Systems

Chapter 10: Control Systems Design: Principles and Case Studies



Appendix A: Laplace Transforms

Appendix B: Solutions to the Review Questions

Appendix C: MATLAB Commands

Appendix WA: A Review of Complex Variables

Appendix WB: Summary of Matrix Theory

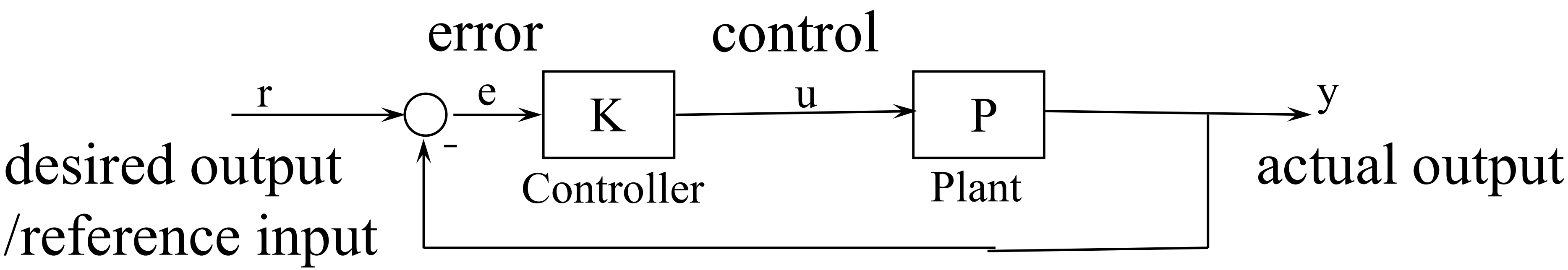
Appendix WC: Controllability and Observability

Appendix WD: Ackermann's Formula for Pole Placement

Appendix W2.1.4: Complex Mechanical Systems

4

A First Analysis of Feedback



4.1 The Basic Equations of Control

4.2 Control of Steady-State Error to Polynomial Inputs: System Type

4.3 The Three-Term Controller: PID Control

4.4 Feedforward Control by Plant Model Inversion

△ 4.5 Introduction to Digital Control

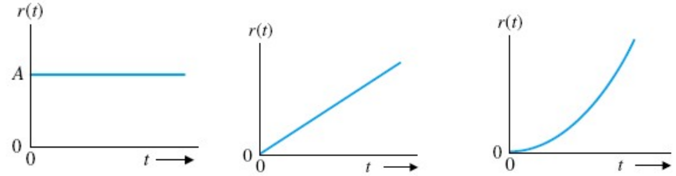
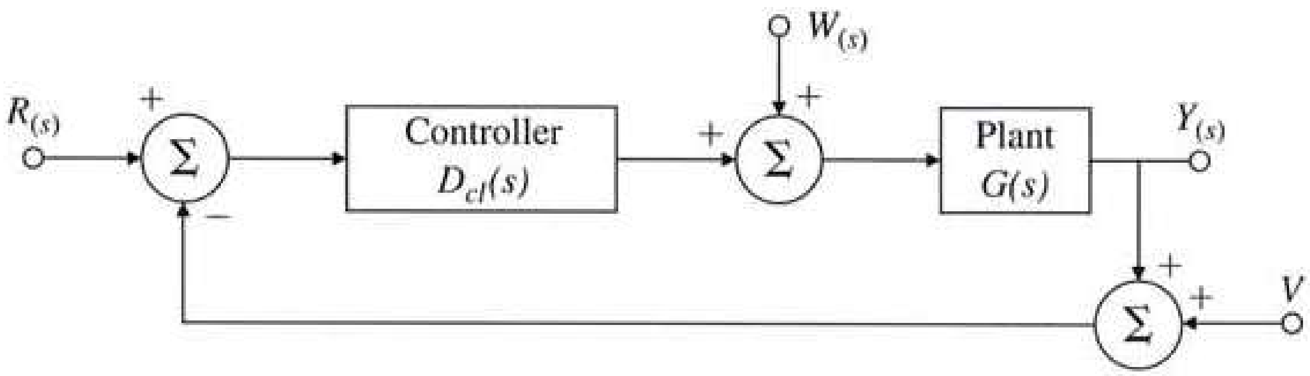


Figure 4.2
Closed-loop system showing the reference, R, control, U, disturbance, W, output, Y, and sensor noise, V



$$Y_{cl} = \frac{GD_{cl}}{1 + GD_{cl}} R + \frac{G}{1 + GD_{cl}} W - \frac{GD_{cl}}{1 + GD_{cl}} V. \quad (4.5)$$

•**Former Exam: The differential equation** $\dot{y} + 60y = 600v_a - 1500w$

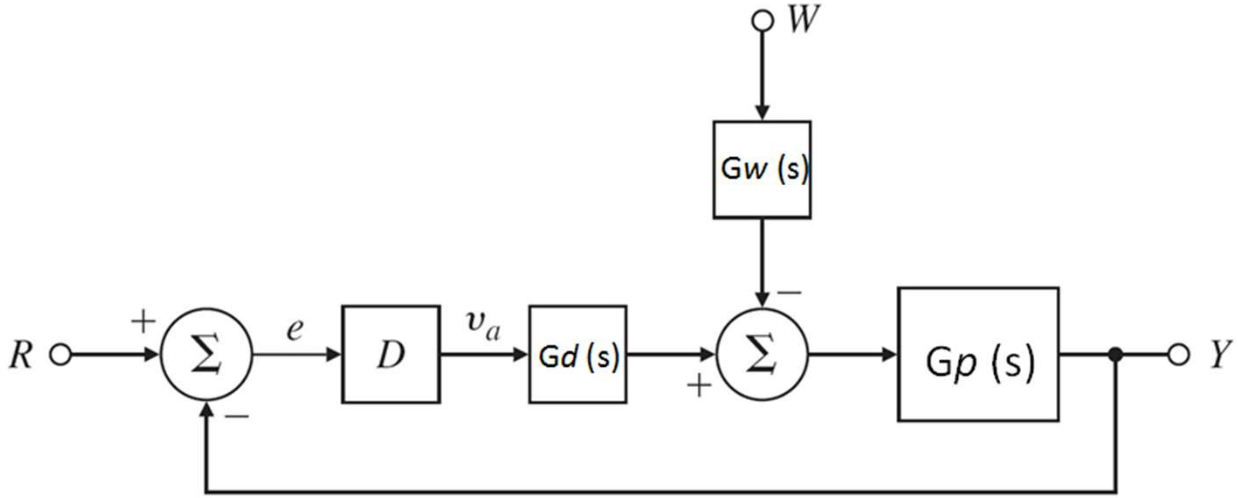
represents the relationship shown in below block diagram.

Assume $v_a = +(0.1e + 12\int_0^t edt)$

$e = r - y$

What are $D(s)$, $G_d(s)$, $G_w(s)$, $G_p(s)$

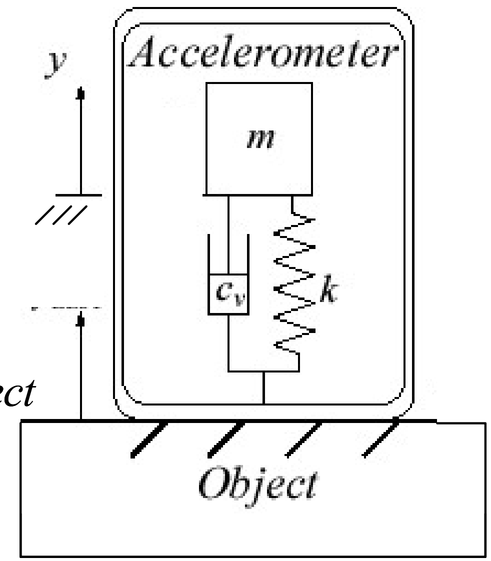
(Nots: $Gp(s)$ is not a constant gain!) (10 pts).



Example: ***Accelerometer***

Write the equation of motion for the following system by using the parameters- $m, k, c_v, y,$

$y_{object}\ ,\ \dot{y}_{object}\ ,\ \ddot{y}_{object}$



y_{object}

$\ddot{y}_{object}$ $\dot{y}_{object}$

(1) Mechanical System
- ① $F = ma$ ←
- ② $Torque = I\alpha$ ←

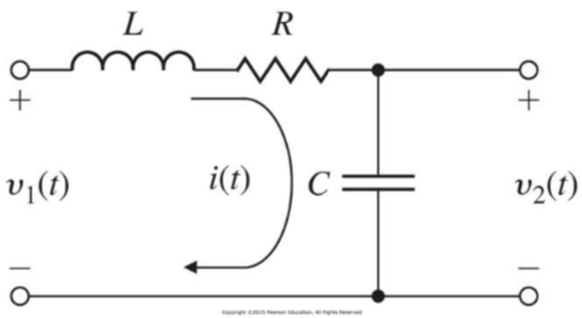
(2) Electrical System
- Kirchhoff's voltage law
- Kirchhoff's current law

機電整合系統(Mechatronics/ Electro Mechanical Systems…)

$$\Rightarrow\ m\ddot{y} = -c_v(\dot{y} - \dot{y}_{object}) - k(y - y_{object})$$

$$\Rightarrow\ m\ddot{y} + c_v\dot{y} + ky = c_v\dot{y}_{object} + ky_{object}$$

Example: ***Circuitry***



(1) Mechanical System
- ① $F = ma$ ←
- ② Torque $= I\alpha$ ←

(2) Electrical System
- Kirchhoff's voltage law
- Kirchhoff's current law

機電整合系統 (Mechatronics/ Electro Mechanical Systems…)

$$\Rightarrow \begin{cases} V_1 - V_2 = L\dfrac{di}{dt} + Ri \\ i = C\dfrac{dV_2}{dt} \end{cases}$$

$$\Rightarrow \quad LC\, d^2V_2/dt^2 + RC\, dV_2/dt + V_2 = V_1$$

Laplace

$$\Rightarrow \quad \frac{V_2(s)}{V_1(s)} = \frac{1}{s^2CL + sCR + 1}$$

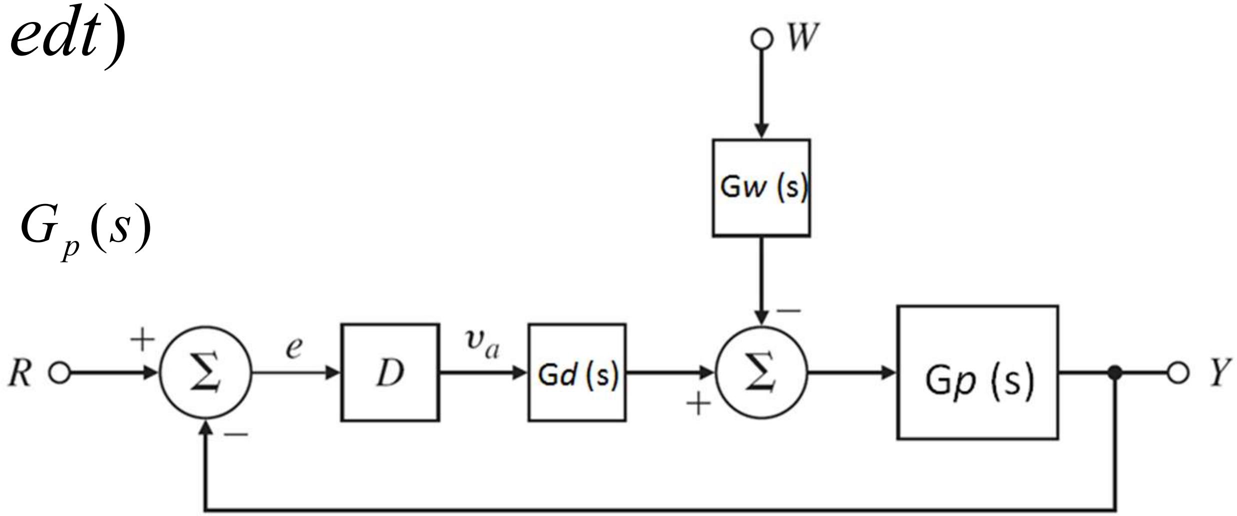
•**Former Exam: The differential equation** $\dot{y} + 60y = 600v_a - 1500w$

represents the relationship shown in below block diagram.

Assume $v_a = +(0.1e + 12\int_0^t e\,dt)$

$e = r - y$

What are $D(s)$, $G_d(s)$, $G_w(s)$, $G_p(s)$

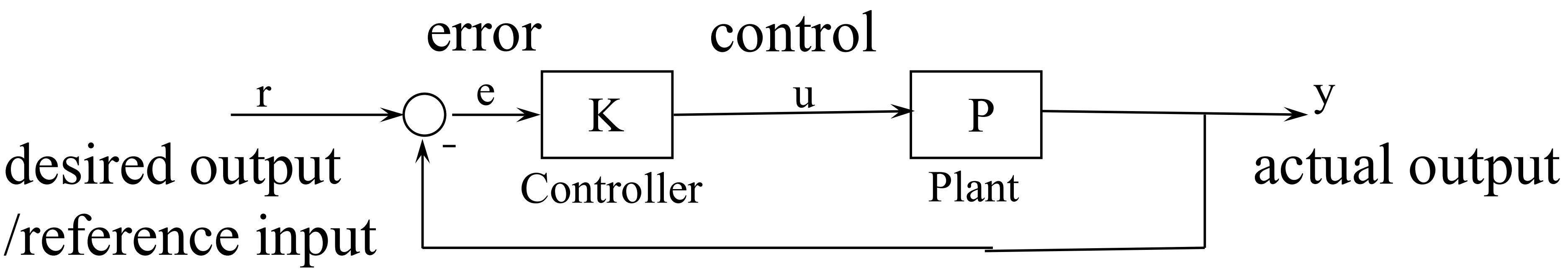


$$Y = \frac{600}{s+60} V_a - \frac{1500}{s+60} W$$

$$\Rightarrow G_d = 600 \ ; \quad G_W = 1500 \ ; \quad G_p = \frac{1}{s+60}$$

$$D(s) = 0.1 + \frac{12}{s} \ \#$$

4 A First Analysis of Feedback



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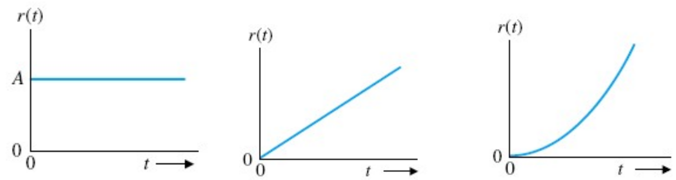
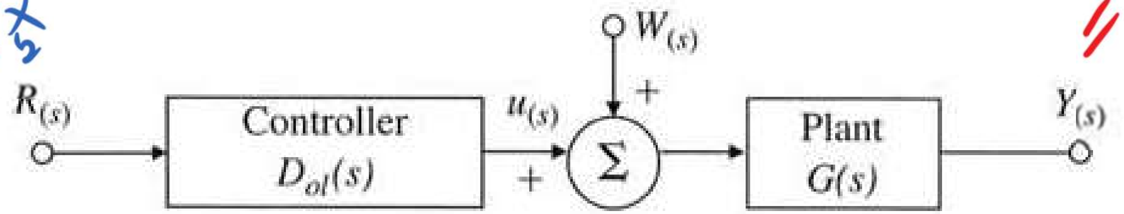


4.1 The Basic Equations of Control

Figure 4.1
Open-loop system showing reference, R, control, U, disturbance, W, and output Y

開路



// Y_{ol} ↓ open loop

$$Y_{ol} = GD_{ol}R + GW \tag{4.1}$$

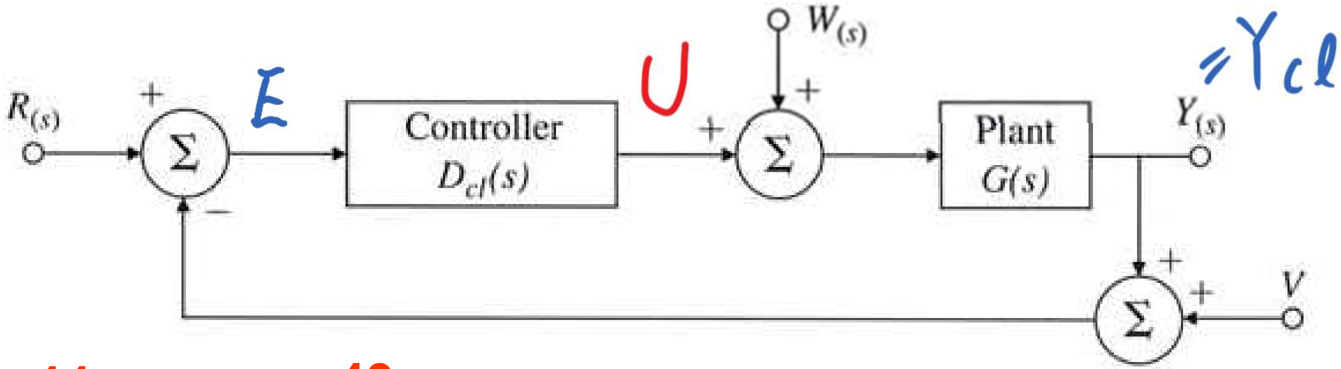
the error, the difference between reference input and system output, is given by

$$\begin{aligned} E_{ol} &= R - Y_{ol} && (4.2) \\ &= R - [GD_{ol}R + GW] && (4.3) \\ &= [1 - GD_{ol}]R - GW. && (4.4) \end{aligned}$$

open-loop transfer function in this case is $T_{ol}(s) = G(s)D_{ol}(s)$

$$\frac{Y}{R} = T_{ol}$$

Figure 4.2
Closed-loop system showing the reference, R, control, U, disturbance, W, output, Y, and sensor noise, V



p. 42 p. 44 p. 43

$$Y_{cl} = \frac{GD_{cl}}{1+GD_{cl}}R + \frac{G}{1+GD_{cl}}W - \frac{GD_{cl}}{1+GD_{cl}}V. \quad (4.5)$$

closed-loop

$$U = \frac{D_{cl}}{1+GD_{cl}}R - \frac{GD_{cl}}{1+GD_{cl}}W - \frac{D_{cl}}{1+GD_{cl}}V. \quad (4.6)$$

the error, $E_{cl} = R - Y_{cl}$.

$$E_{cl} = R - \left[\frac{GD_{cl}}{1+GD_{cl}}R + \frac{G}{1+GD_{cl}}W - \frac{GD_{cl}}{1+GD_{cl}}V\right] \quad (4.7)$$

$$= \frac{1}{1+GD_{cl}}R - \frac{G}{1+GD_{cl}}W + \frac{GD_{cl}}{1+GD_{cl}}V \quad (4.8)$$

the closed-loop transfer function is $T_{cl} = \dfrac{GD_{cl}}{1+\underline{GD_{cl}}}$.

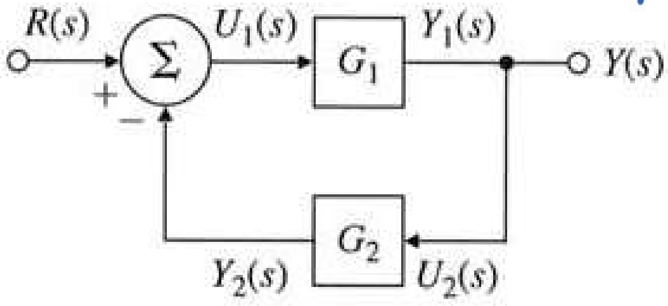
loop gain

3.2 System Modeling Diagrams

3.2.1 The Block Diagram

negative feedback

$Y_1(s)$

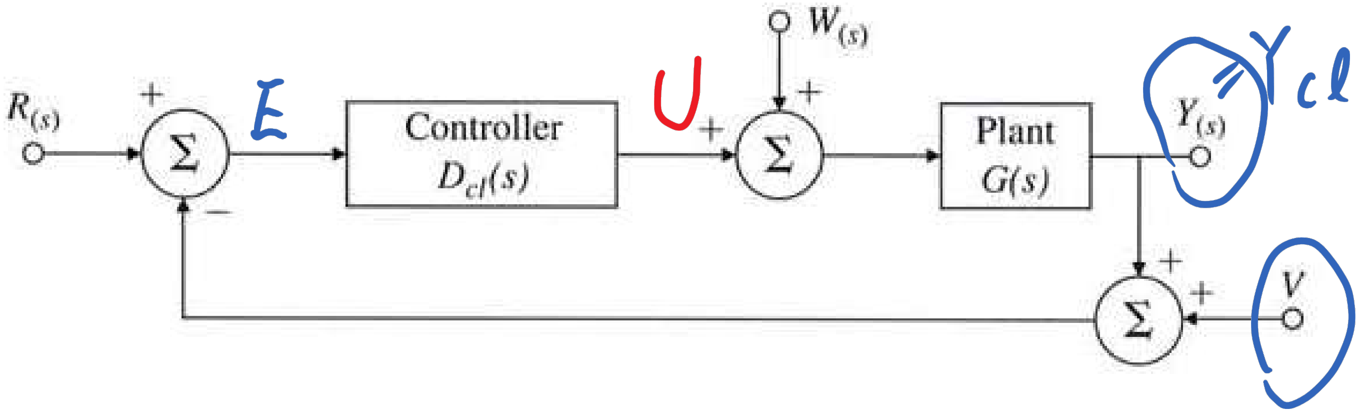


$$\frac{Y(s)}{R(s)} = \frac{G_1}{1 + G_1 G_2}$$

$$\left\{\begin{aligned} U_1(s) &= R(s) - Y_2(s), \\ Y_2(s) &= G_2(s)G_1(s)U_1(s) \\ Y_1(s) &= G_1(s)U_1(s), \end{aligned}\right.$$

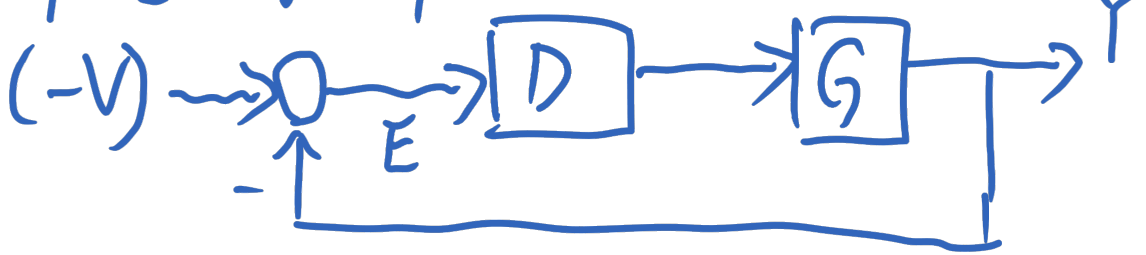
$$\Rightarrow \quad Y_1(s) = \frac{G_1(s)}{1 + G_1(s)G_2(s)} R(s).$$

Figure 4.2
Closed-loop system showing the reference, R, control, U, disturbance, W, output, Y, and sensor noise, V



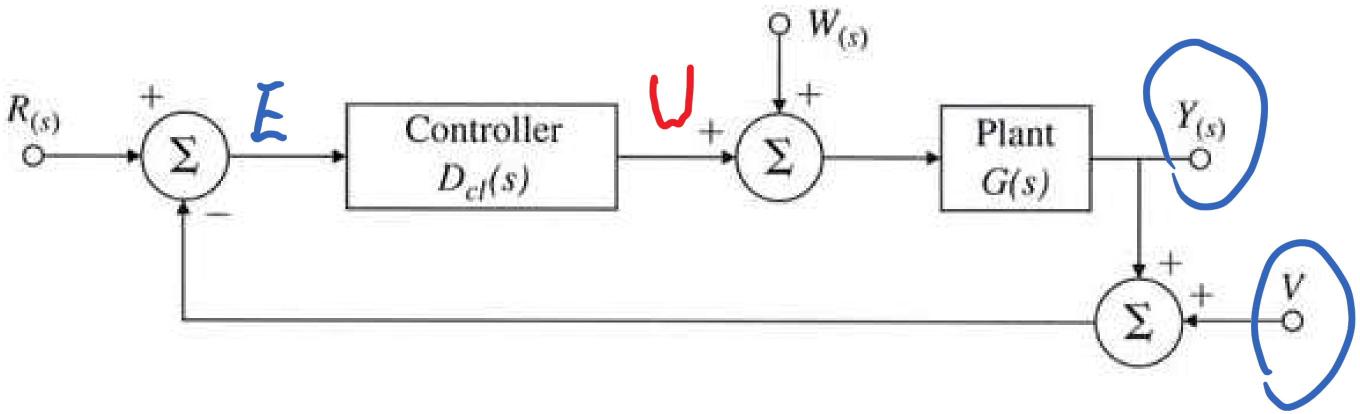
$$\Rightarrow \quad Y_{cl} = \frac{GD_{cl}}{1+GD_{cl}}R + \frac{G}{1+GD_{cl}}W - \frac{GD_{cl}}{1+GD_{cl}}V. \qquad (4.5)$$

$$\begin{Bmatrix} R \to 0 \\ W \to 0 \end{Bmatrix} \quad E = \overset{0}{\cancel{R}} - V - Y = -V - Y$$



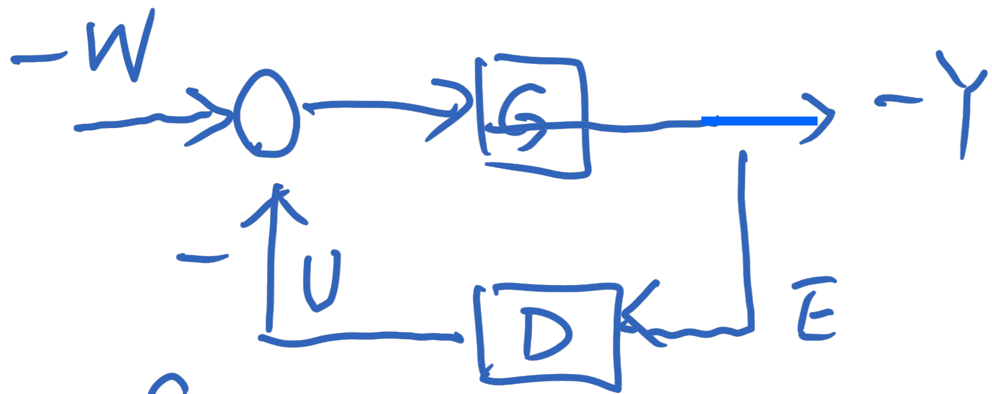
$$\Rightarrow \quad \frac{Y}{(-V)} = \frac{GD}{1+GD}$$

Figure 4.2
Closed-loop system showing the reference, R, control, U, disturbance, W, output, Y, and sensor noise, V



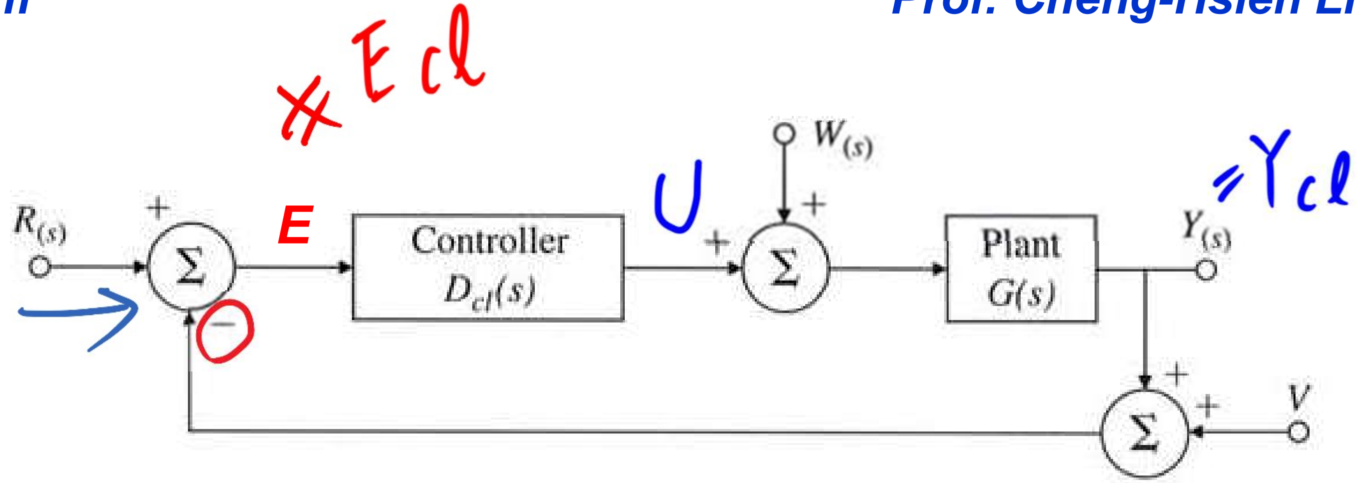
$W \rightarrow Y$

$$\begin{pmatrix} R \to 0 \\ V \to 0 \end{pmatrix} \quad E = \cancel{R} - Y = R - G(U + W) = -GU - GW$$



$$\Rightarrow \frac{Y}{W} = \frac{-Y}{-W} = \frac{G}{1+GD}$$

Figure 4.2
Closed-loop system showing the reference, R, control, U, disturbance, W, output, Y, and sensor noise, V

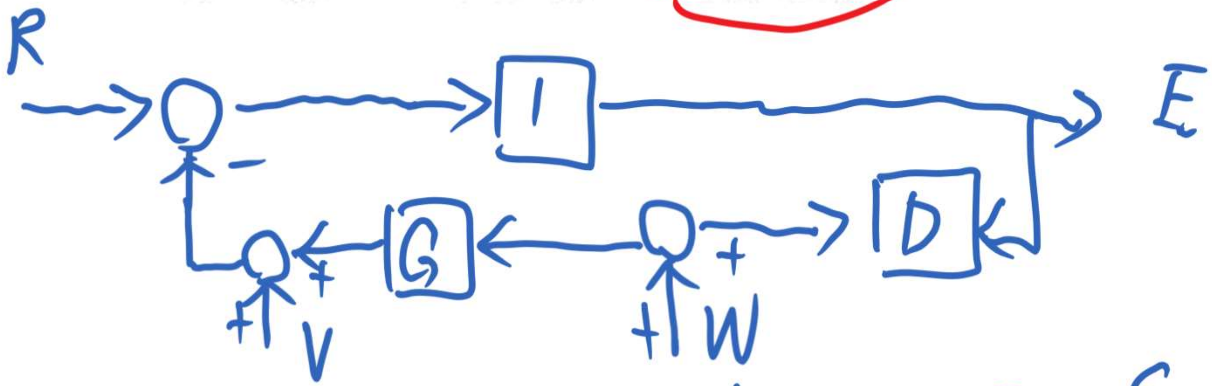


⇨ the error, $E_{cl} = R - Y_{cl}$.

$$Y_{cl} = \frac{GD_{cl}}{1+GD_{cl}}R + \frac{G}{1+GD_{cl}}W - \frac{GD_{cl}}{1+GD_{cl}}V. \tag{4.5}$$

$$E_{cl} = R - \left[\frac{GD_{cl}}{1+GD_{cl}}R + \frac{G}{1+GD_{cl}}W - \frac{GD_{cl}}{1+GD_{cl}}V\right] \tag{4.7}$$

$$= \frac{1}{1+GD_{cl}}R - \frac{G}{1+GD_{cl}}W + \frac{GD_{cl}}{1+GD_{cl}}V. \tag{4.8}$$



$$E = \frac{1}{1+GD}R - \frac{1}{1+GD}V - \frac{G}{1+GD}W$$

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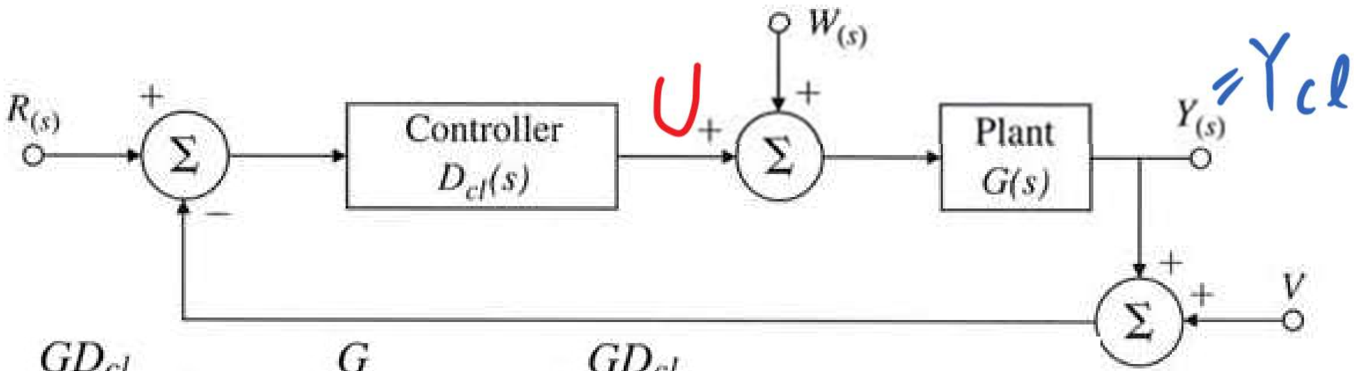


$$Y_{cl} = \frac{GD_{cl}}{1+GD_{cl}}R + \frac{G}{1+GD_{cl}}W - \frac{GD_{cl}}{1+GD_{cl}}V. \tag{4.5}$$

4.1.1 Stability

the system characteristic equation $$1 + GD_{cl} = 0 \tag{4.9}$$

the system poles are the roots of $1 + GD_{cl} = 0$

$$1 + \frac{b(s)c(s)}{a(s)d(s)} = 0 \tag{4.10}$$

$$a(s)d(s) + b(s)c(s) = 0. \tag{4.11}$$

↔ **3.6.3 Routh's Stability Criterion**

4.1.2 Tracking

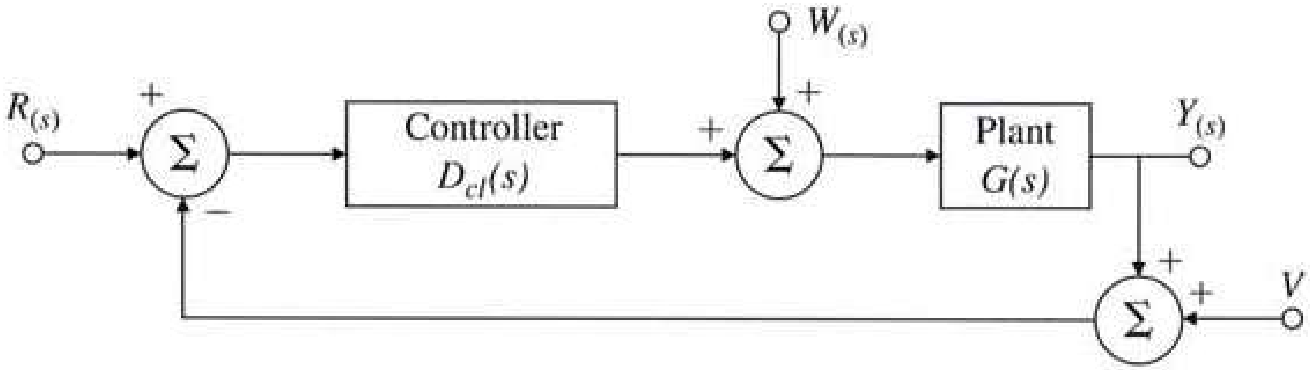
Y follows R (Y 要跟得上 R)

4.1.3 Regulation

$R = 0 \Rightarrow y(t) \to 0$

4.1.4 ~~Sensitivity~~

(自行參考，不考)



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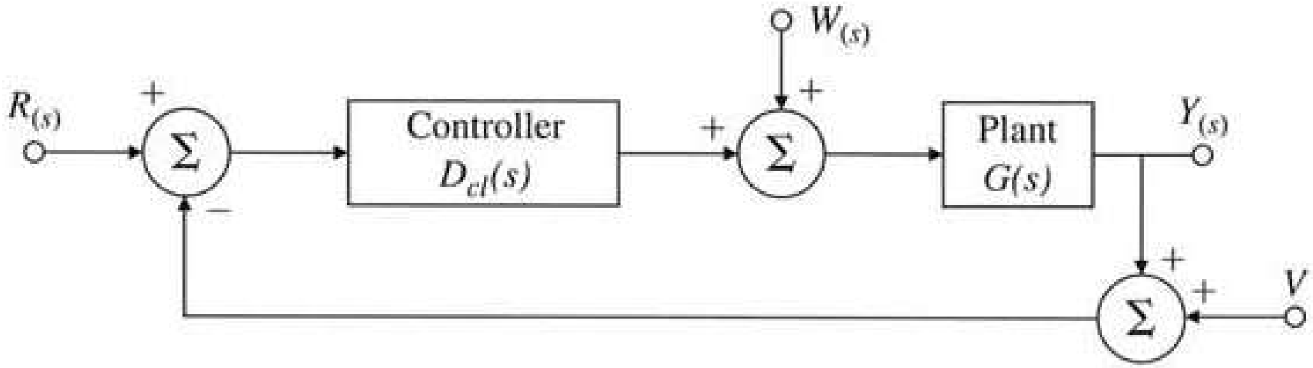
$$Y_{cl} = \frac{GD_{cl}}{1+GD_{cl}}R + \frac{G}{1+GD_{cl}}W - \frac{GD_{cl}}{1+GD_{cl}}V. \tag{4.5}$$

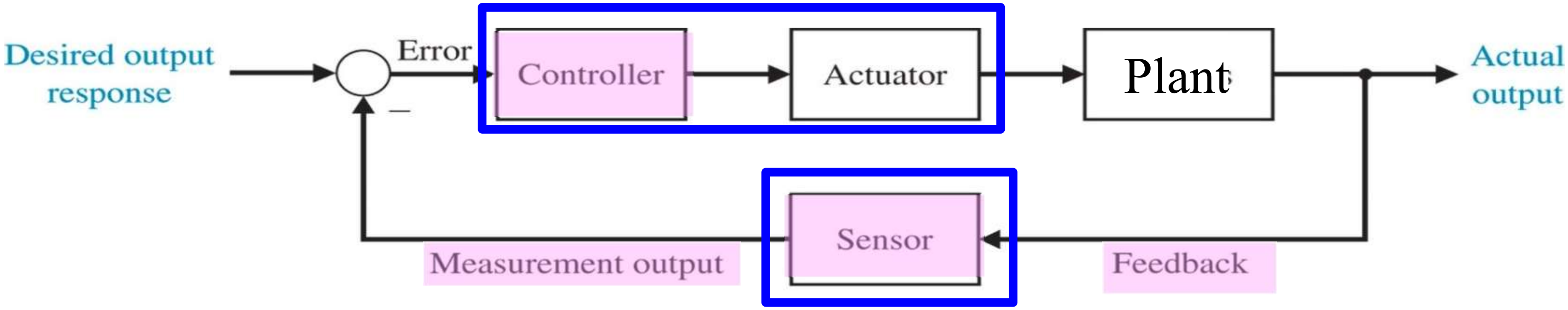
What does Feedback Control do?

D

1. Static response (steady-state) $s = j\omega \big|_{\omega \to 0}$
2. Dynamic response (transient) ← $s = j\omega \big|_{\omega \to \text{很大}}$
3. Disturbance rejection → $\left.\frac{Y}{W}\right|_s \to 0$ & $\left.\frac{Y}{V}\right|_s \to 0$

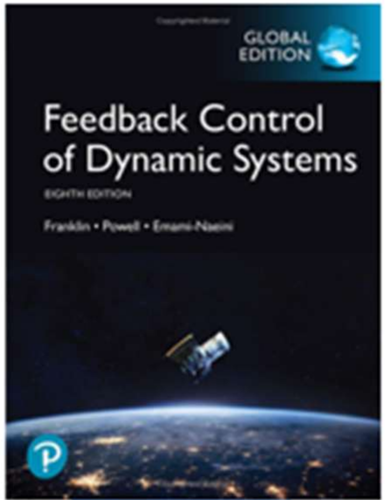
Feedback Control





Feedback Control of System

Prof. Cheng-Hsien Liu



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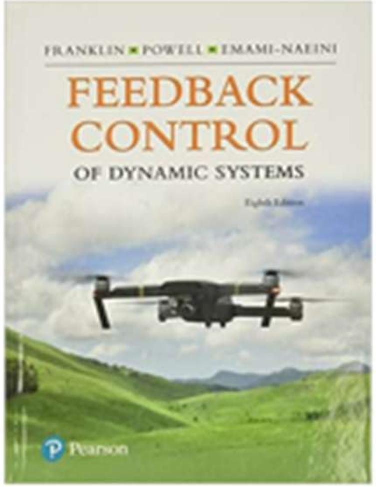
National Tsing Hua University

PME320701

Feedback Control of Systems



Lecture 2~4 (Chapter 2 & 3)

Instructor :

Cheng-Hsien Liu

劉 承 賢

助教： 李千侑
王淳弘
蘇建翰

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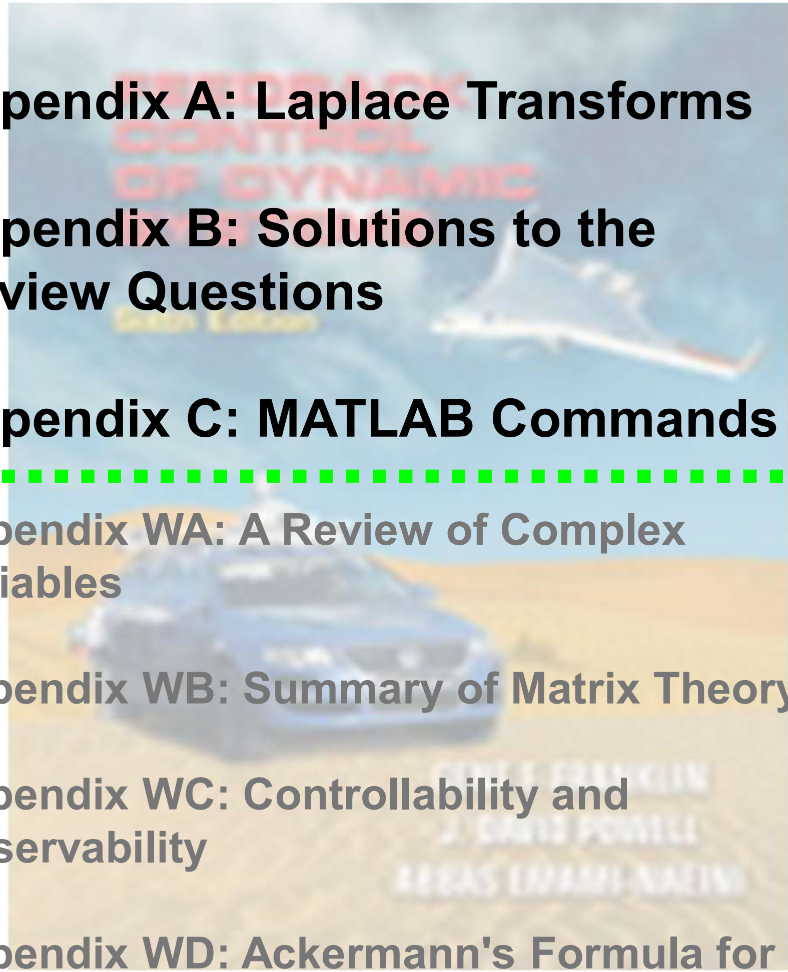

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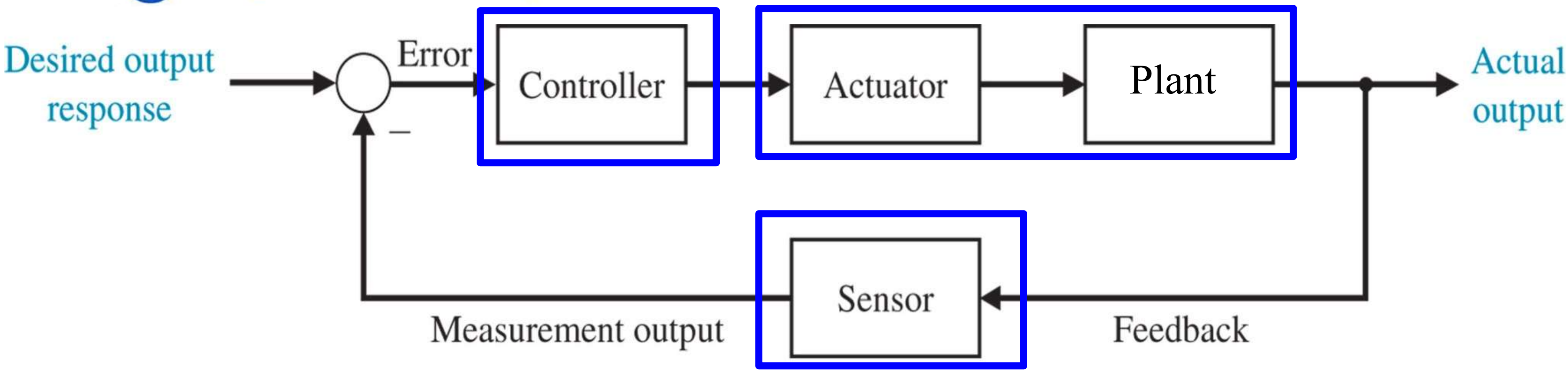
3 Dynamic Response



3.1 Review of Laplace Transforms

3.2.1 The Block Diagram

3.3 Effect of Pole Locations

3.4 Time-Domain Specifications

3.5 Effects of Zeros and Additional Poles

3.6.3 Routh's Stability Criterion

$$\frac{Y(s)}{F(s)} = \frac{b_m s^m + b_{m-1} s^{m-1} + \cdots + b_1 s + b_0}{s^n + a_{n-1} s^{n-1} + \cdots + a_1 s + a_0} = K\frac{(s+z_1)(s+z_2)\cdots(s+z_m)}{(s+p_1)(s+p_2)\cdots(s+p_n)}$$