Automatic Control Theory - 自动控制原理 - SZU1101980036- 补充资料

- 补充资料将分发给考试学生。内容: (1) 中英词汇; (2) 重要公式及参考列表。
- 学生可以带字典进入考场

(1) 中英词汇

Introduction to feedback system

English	Chinese
feedback control system	反馈控制系统
block diagram	方框图
open loop control	开环控制
closed loop control	闭环控制
feedback	反馈
feedforward	前馈
accuracy	准确性
oscillation	振荡
instability	不稳定
sensitivity	敏感性
nonlinear effects	非线性效应
external disturbance	外部干扰
schematic diagram	原理图
cause and effect relationship	因果关系
summing point	总和点
takeoff point	起飞点
destination	目的地
plant or process	工厂或工序
error signal	错误信号
reference input	参考输入
manipulated variable	操纵变量

Difference equation and Laplace transform

English	Chinese
Differential Equation	微分方程
Newton’s Second Law of Motion	牛顿第二运动定律
Ohm’s Law	欧姆定律
Time-Invariant Equation	时间不变方程
Differential Operator	差分运算符
Characteristic Equation	特性方程式
Laplace Transform	拉普拉斯变换
Frequency Domain	频域

Time Domain	时域
Algebraic Technique	代数技术
Logarithm	对数
Inverse Laplace Transform	反拉普拉斯变换
Unit Step Function	单位步进函数
Linearity	线性
Poles and Zeros	极点和零点
Partial Fraction	部分分数
Linear Transformation	线性变换
Derivative and Integral	导数和积分
Initial Value Theorem	初值定理
Final Value Theorem	最终值定理
Time and Frequency Scaling	时间和频率缩放
Convolution Integral	卷积积分
Complex Convolution Integral	复卷积积分

Transfer function and system block diagram

English	**Chinese**
Transfer Function	传递函数
System Block Diagram	系统框图
Linear System	线性系统
Non-Linear System	非线性系统
Block Diagram	方框图
Block Diagram Reduction	框图缩减
Mathematical Model	数学模型
Single Input Single Output	单输入单输出
Linear Time Invariant System	线性时不变系统
Law of Superposition	叠加定律
Saturation and Dead Zone	饱和度和死区
Impulse Response Function	脉冲响应功能
System Identification	系统识别
Moment of Inertia	转动惯量
Direct Transfer Function	直接传递功能
Feedback Transfer Function	反馈传递函数
Open Loop and Closed Loop	开环和闭环
Disturbance	外部干扰
Transformation	转型

System flow graph

English	Chinese
signal flow graph	信号流图
nodes and branches	节点和分支
algebraic function	代数函数
source and sink	源和接收器
forward path	前进路径
loop gain	环路增益
Mason's Gain Formula	梅森增益公式
General Gain Formula	一般增益公式
two non-touching loops	两个非接触式循环

System modeling

English	Chinese
modeling	建 模
electrical system	电气系统
mechanical system	机械系统
electromechanical system	机电系统
Newton's Second Law	牛顿第二定律
Free Body Diagram	自由体图
Kirchhoff's Voltage Law	基尔霍夫电压定律
operational amplifier	运算放大器
analogous System	类比系统
armature and field current	电枢和励磁电流
servomotor	伺服
viscous friction	粘性摩擦

Routh Hurwitz and stability

English	Chinese
Routh Stability Criterion	Routh 稳定性准则
Hurwitz Stability Criterion	Hurwitz 稳定性准则
Poles and Zeros	极点和零点
denominator and numerator	分母和分子
s plane	S 平面
Matrix Determinant	矩阵行列式

Root locus analysis

English	Chinese
root locus	根位点
numerator and denominator	分子和分母
open loop transfer function	开环传递函数
characteristic equation	特征方程
polynomial	多项式
loci	基因
real and imaginary axis	实轴和虚轴
asymptote	渐近线
break away point	突破点
poles and zeros	极点和零点
gain margin	获得利润
damping ratio	阻尼比

Bode plots

English	Chinese
Bode Plot	波特图
high pass filter	高通滤波器
low pass filter	低通滤波器
band pass filter	带通滤波器
magnitude and phase response	幅度和相位响应
decibel	分贝
break point	断点
approximation	近似值
asymptote	渐近线
frequency	频率

PID control and tuning

English	Chinese
PID controller	PID 控制器
tuning	调音
algorithm	算法
Ziegler Nichols Method	齐格勒·尼科尔斯方法
feedback control	反馈控制
open loop system	开环系统
closed loop system	闭环系统
proportional control	比例控制
integral control	积分控制
derivative control	导数控制
	三期限控制器

the three-term controller	瞬态响应方法
transient response method	稳定性极限法
stability limit method	

Root locus design

English	Chinese
root locus design	根位点设计
gain factor	增益因数
open loop gain	开环增益
phase lead	相引线
phase lag	相位滞后
undamped natural frequency	无阻尼固有频率
damped natural frequency	阻尼固有频率
damping ratio	阻尼比
second order system	二阶系统
unit step response	单元阶跃响应
overshoot	过头
phase compensation	相位补偿
lag lead compensation	滞后超前补偿

Bode design and compensation

English	Chinese
Bode Plot Design Philosophy	博德地块设计理念
steady state performance	稳态性能
transient response	瞬态响应
relative stability	相对稳定性
gain margin	获得利润
phase margin	相位裕量
gain cross over frequency	增益交叉频率
gain factor compensation	增益因数补偿
phase lead compensation	相位引线补偿
phase lag compensation	相位滞后补偿

State space control

English	Chinese
state space control	状态空间控制
flow diagram	流程图
transfer function	传递函数
observable canonical form	可观察的规范形式
controllable canonical form	可控规范形式

diagonal canonical form	对角规范形式
Jordan canonical form	Jordan 规范形式
general state space equation	一般状态空间方程
state variable	状态变量
state space	状态空间
scalar and vector	标量和向量
integrator	积分器

Advanced control methods

English	Chinese
robust control	稳健的控制
feedforward compensation	前馈补偿
controllability and observability	可控性和可观察性
state feedback control	状态反馈控制
state observer	国家观察员
state estimator	状态估计器
adaptive control	自适应控制
self tuning regulator	自整定稳压器
friction model	摩擦模型
optimal control	最佳控制
performance index	性能指标
real time simulation	实时模拟
model reference adaptive control	型号参考自适应控制

(2) 重要公式及参考列表

Laplace transform and inverse transform (for control purpose)

$$F(s) = \int_0^\infty f(t)\, e^{-st}\, dt \quad [1]$$

Use the following equation for inverse transform

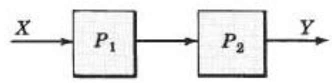
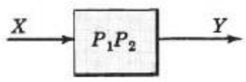
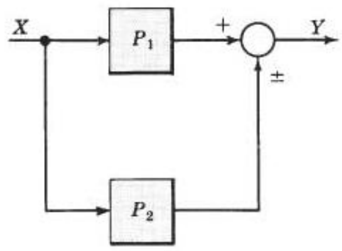
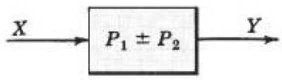
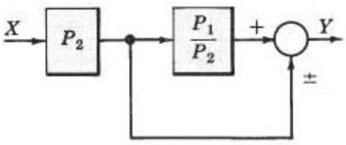
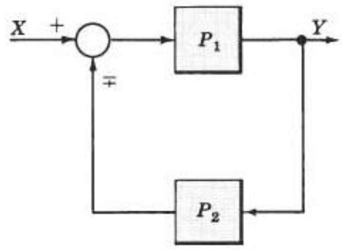
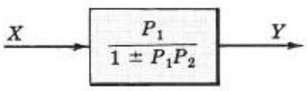
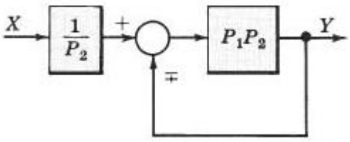
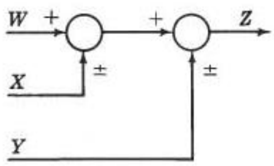
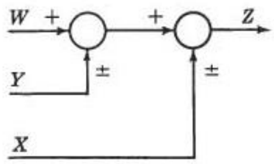
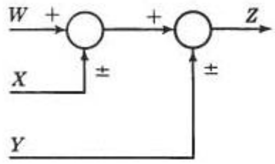
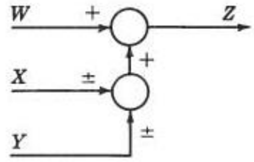
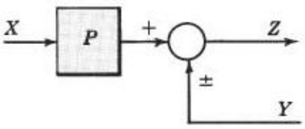
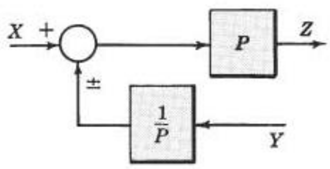
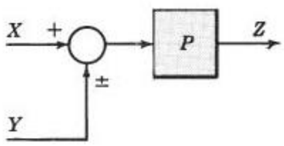
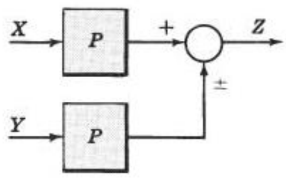
$$f(t) = \frac{1}{2\pi j}\int_{\alpha-\infty}^{\alpha+\infty} F(s) e^{-st} ds$$

Laplace transform for some common signals

Table 4.1 Laplace transforms

Laplace transform	*Time function*	*Description of time function*
1		A unit impulse
$\frac{1}{s}$		A unit step function
$\frac{e^{-st}}{s}$		A delayed unit step function
$\frac{1-e^{-st}}{s}$		A rectangular pulse of duration T
$\frac{1}{s^2}$	t	A unit slope ramp function
$\frac{1}{s^3}$	$\frac{t^2}{2}$	
$\frac{1}{s+a}$	e^{-at}	Exponential decay
$\frac{1}{(s+a)^2}$	te^{-at}	
$\frac{2}{(s+a)^3}$	t^2e^{-at}	
$\frac{a}{s(s+a)}$	$1-e^{-at}$	Exponential growth
$\frac{a}{s^2(s+a)}$	$t-\frac{(1-e^{-at})}{a}$	
$\frac{a^2}{s(s+a)^2}$	$1-e^{-at}-ate^{-at}$	
$\frac{s}{(s+a)^2}$	$(1-at)e^{-at}$	
$\frac{1}{(s+a)(s+b)}$	$\frac{e^{-at}-e^{-bt}}{b-a}$	
$\frac{ab}{s(s+a)(s+b)}$	$1-\frac{b}{b-a}e^{-at}+\frac{a}{b-a}e^{-bt}$	
$\frac{1}{(s+a)(s+b)(s+c)}$	$\frac{e^{-at}}{(b-a)(c-a)}+\frac{e^{-bt}}{(c-a)(a-b)}+\frac{e^{-ct}}{(a-c)(b-c)}$	
$\frac{\omega}{s^2+\omega^2}$	$\sin\omega t$	Sine wave
$\frac{s}{s^2+\omega^2}$	$\cos\omega t$	Cosine wave
$\frac{\omega}{(s+a)^2+\omega^2}$	$e^{-at}\sin\omega t$	Damped sine wave
$\frac{s+a}{(s+a)^2+\omega^2}$	$e^{-at}\cos\omega t$	Damped cosine wave
$\frac{\omega^2}{s(s^2+\omega^2)}$	$1-\cos\omega t$	
$\frac{\omega^2}{s^2+2\zeta\omega s+\omega^2}$	$\frac{\omega}{\surd(1-\zeta^2)}e^{-\zeta\omega t}\sin[\omega\surd(1-\zeta^2)t]$	
$\frac{\omega^2}{s(s^2+2\zeta\omega s+\omega^2)}$ with $\zeta < 1$	$1-\frac{1}{\surd(1-\zeta^2)}e^{-\zeta\omega t}\sin[\omega\surd(1-\zeta^2)t+\phi]$ with $\zeta=\cos\phi$	

Block diagram reduction

	Transformation	Equation	Block Diagram	Equivalent Block Diagram
1	Combining Blocks in Cascade	$Y = (P_1P_2)X$		
2	Combining Blocks in Parallel; or Eliminating a Forward Loop	$Y = P_1X \pm P_2X$		
3	Removing a Block from a Forward Path	$Y = P_1X \pm P_2X$		
4	Eliminating a Feedback Loop	$Y = P_1(X \mp P_2Y)$		
5	Removing a Block from a Feedback Loop	$Y = P_1(X \mp P_2Y)$		
6a	Rearranging Summing Points	$Z = W \pm X \pm Y$		
6b	Rearranging Summing Points	$Z = W \pm X \pm Y$		
7	Moving a Summing Point Ahead of a Block	$Z = PX \pm Y$		
8	Moving a Summing Point Beyond a Block	$Z = P[X \pm Y]$		

Mason's gain formula (general gain formula) for signal flow graph

A structured method to obtain the gain formula for a given SFG.

$$M = \frac{y_{out}}{y_{in}} = \sum_{k=1}^{N} \frac{M_k \Delta_k}{\Delta}$$

y_{in}	input node variable
y_{out}	output node variable
M	gain between y_{in} and y_{out}
N	total number of forward paths between y_{in} and y_{out}
M_k	gain of the k^{th} forward path between y_{in} and y_{out}

Δ = 1 – (sum of gains of all individual loops) + (sum of products-of-gains of all possible combinations of two non-touching loops) – (sum of products-of-gains of all possible combinations of three non-touching loops) + …..

Δ_k = the Δ of the part of signal flow graph that is non-touching with the forward path.

The Routh Criterion Table

The Routh criterion is a method for determining continuous system stability, for systems with an nth-order characteristic equation of the form:

$$a_n s^n + a_{n-1} s^{n-1} + \cdots + a_1 s + a_0 = 0$$

The criterion is applied using a **Routh table** defined as follows:

s^n	a_n	a_{n-2}	a_{n-4}	$\cdots$
s^{n-1}	a_{n-1}	a_{n-3}	a_{n-5}	$\cdots$
.	b_1	b_2	b_3	$\cdots$
.	c_1	c_2	c_3	$\cdots$
.	$\cdots$	$\cdots$	$\cdots$	$\cdots$

where $a_n, a_{n-1}, \ldots, a_0$ are the coefficients of the characteristic equation and

$$b_1 \equiv \frac{a_{n-1}a_{n-2} - a_n a_{n-3}}{a_{n-1}} \qquad b_2 \equiv \frac{a_{n-1}a_{n-4} - a_n a_{n-5}}{a_{n-1}} \qquad \text{etc.}$$

$$c_1 \equiv \frac{b_1 a_{n-3} - a_{n-1} b_2}{b_1} \qquad c_2 \equiv \frac{b_1 a_{n-5} - a_{n-1} b_3}{b_1} \qquad \text{etc.}$$

The table is continued horizontally and vertically until only zeros are obtained. Any row can be multiplied by a positive constant before the next row is computed without disturbing the properties of the table.

The Routh Criterion: *All the roots of the characteristic equation have negative real parts if and only if the elements of the first column of the Routh table have the same sign. Otherwise, the number of roots with positive real parts is equal to the number of changes of sign.*

Root Locus Asymptotes

For large distances from the origin in the complex plane, the branches of a root-locus approach a set of straight-line asymptotes. These asymptotes emanate from a point in the complex plane on the real axis called the **center of asymptotes** σ_c given by

$$\sigma_c = -\frac{\sum_{i=1}^{n} p_i - \sum_{i=1}^{m} z_i}{n-m} \qquad (13.6)$$

where $-p_i$ are the poles, $-z_i$ are the zeros, n is the number of poles, and m the number of zeros of GH.

The angles between the asymptotes and the real axis are given by

$$\beta = \begin{cases} \dfrac{(2l+1)180}{n-m} \text{ degrees} & \text{for } K>0 \\ \dfrac{(2l)180}{n-m} \text{ degrees} & \text{for } K<0 \end{cases} \qquad (13.7)$$

for $l = 0, 1, 2, \ldots, n-m-1$. This results in a number of asymptotes equal to $n-m$.

Root Locus breakaway points

The location of the breakaway point can be determined by solving the following equation for σ_b:

$$\sum_{i=1}^{n} \frac{1}{(\sigma_b + p_i)} = \sum_{i=1}^{m} \frac{1}{(\sigma_b + z_i)} \qquad (13.8)$$

Root Locus departure angle

The **departure angle** of the root-locus from a *complex pole* is given by

$$\theta_D = 180° + \arg GH' \qquad (13.9)$$

where $\arg GH'$ is the phase angle of GH computed at the complex pole, but ignoring the contribution of that particular pole.

PID (or three term controller)

$$G_c(s) = K_p + \frac{K_i}{s} + K_d s$$

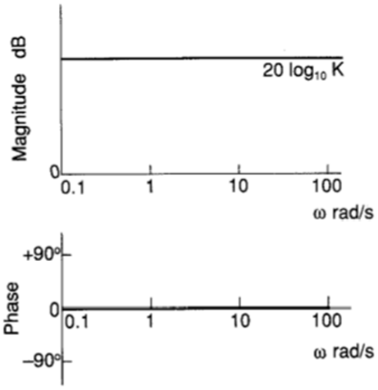
Since the integral time constant τ_i is K_p/K_i and the derivative time constant τ_d is K_d/K_p equation [15] can be written as

$$G_c(s) = K_p\left(1 + \frac{K_i}{K_p s} + \frac{K_d s}{K_p}\right)$$

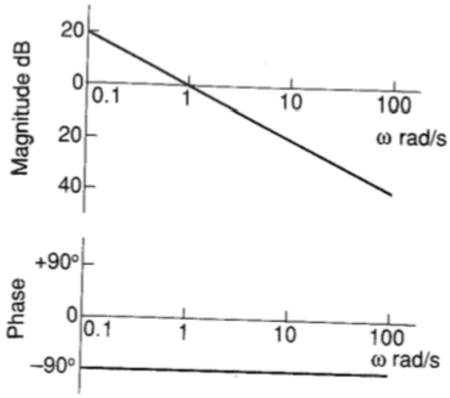
$$G_c(s) = K_p\left(1 + \frac{1}{\tau_i s} + \tau_d s\right) \qquad [17]$$

Bode Plots

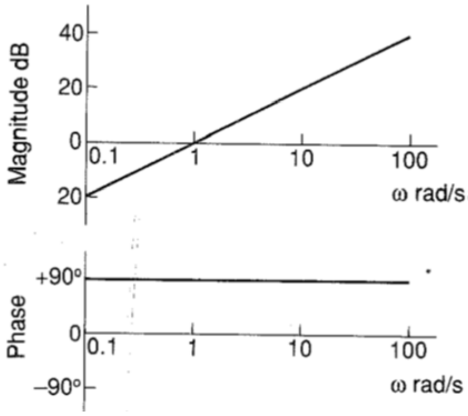
Constant Gain



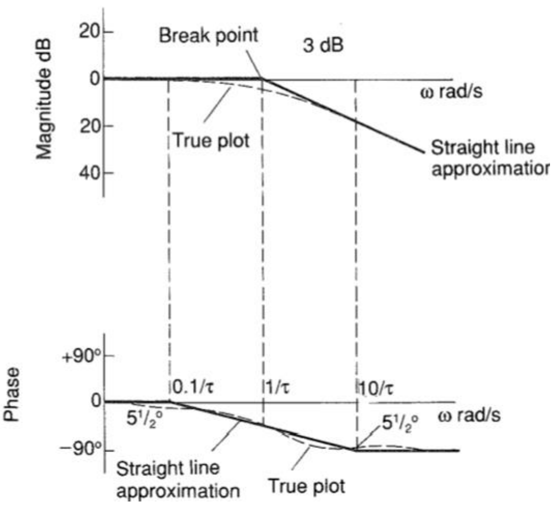
A Pole at Origin



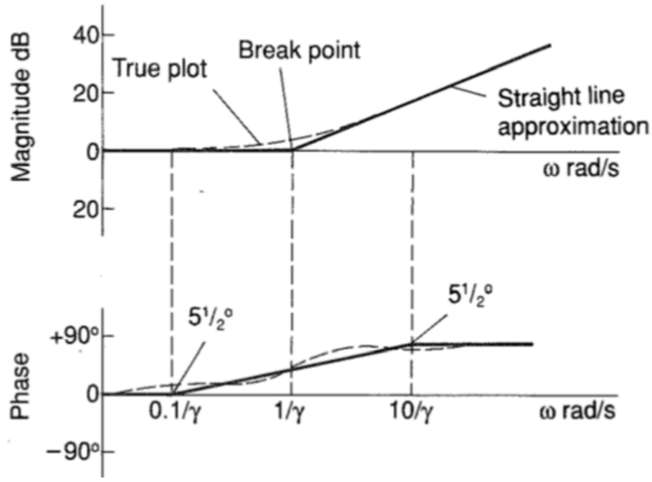
A Zero at Origin



A Real Pole



A Real Zero



Ziegler Nichols tables

Table 5.2 Ziegler-Nichols tuning parameters using transient response.

	K_p	T_I	T_D
P	$1/RL$		
PI	$0.9/RL$	$3L$	
PID	$1.2/RL$	$2L$	$0.5L$

Table 5.3 Ziegler-Nichols tuning parameters using stability limit.

	K_p	T_I	T_D
P	$0.5K_u$		
PI	$0.45K_u$	$P_u/1.2$	
PID	$0.6K_u$	$P_u/2$	$P_u/8$

Lead/Lag compensation

The transfer function for a continuous system lead network, presented in Equation (6.2), is

$$P_{\text{lead}} = \frac{s+a}{s+b}$$

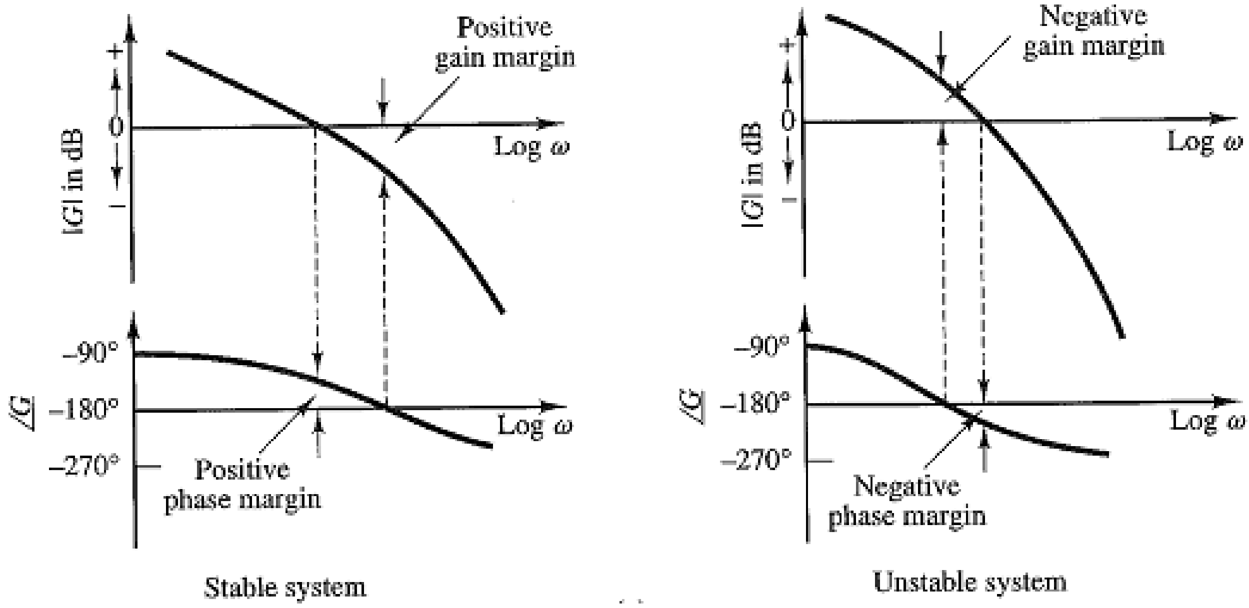
where $a < b$.

The transfer function for a continuous system lag network, presented in Equation (6.3), is

$$P_{\text{Lag}} = \frac{a}{b}\left[\frac{s+b}{s+a}\right]$$

where $a < b$.

Gain and phase margin



Controllable canonical form

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \cdot \\ \cdot \\ \cdot \\ \dot{x}_{n-1} \\ \dot{x}_n \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ 0 & 0 & 0 & \cdots & 1 \\ -a_n & -a_{n-1} & -a_{n-2} & \cdots & -a_1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_{n-1} \\ x_n \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \\ 1 \end{bmatrix} u$$

$$y = [b_n - a_n b_0 \;\vdots\; b_{n-1} - a_{n-1} b_0 \;\vdots\; \cdots \;\vdots\; b_1 - a_1 b_0] \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} + b_0 u$$

Observable canonical form

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \cdot \\ \cdot \\ \cdot \\ \dot{x}_n \end{bmatrix} = \begin{bmatrix} 0 & 0 & \cdots & 0 & -a_n \\ 1 & 0 & \cdots & 0 & -a_{n-1} \\ \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & & \cdot & \cdot \\ 0 & 0 & \cdots & 1 & -a_1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} + \begin{bmatrix} b_n - a_n b_0 \\ b_{n-1} - a_{n-1} b_0 \\ \cdot \\ \cdot \\ \cdot \\ b_1 - a_1 b_0 \end{bmatrix} u$$

$$y = [0 \quad 0 \quad \cdots \quad 0 \quad 1] \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_{n-1} \\ x_n \end{bmatrix} + b_0 u$$

Diagonal canonical form

$$\frac{Y(s)}{U(s)} = \frac{b_0 s^n + b_1 s^{n-1} + \cdots + b_{n-1} s + b_n}{(s + p_1)(s + p_2) \cdots (s + p_n)}$$

$$= b_0 + \frac{c_1}{s + p_1} + \frac{c_2}{s + p_2} + \cdots + \frac{c_n}{s + p_n} \qquad (11\text{–}7)$$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \cdot \\ \cdot \\ \cdot \\ \dot{x}_n \end{bmatrix} = \begin{bmatrix} -p_1 & & & & & 0 \\ & -p_2 & & & & \\ & & \cdot & & & \\ & & & \cdot & & \\ & & & & \cdot & \\ 0 & & & & & -p_n \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ \cdot \\ \cdot \\ \cdot \\ 1 \end{bmatrix} u \qquad (11\text{–}8)$$

$$y = [c_1 \quad c_2 \quad \cdots \quad c_n] \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} + b_0 u \qquad (11\text{–}9)$$

---End ---