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ภาคผนวก ก.

จากสมการที่ 3.5

$$c(t) = [\ 1 - [(T_1)EXP(-(t-L)/T_1)]/(T_1-T_2)$$

$$+ [(T_2)EXP(-(t-L)/T_2)]/(T_1-T_2)\ ]U(t-L) \text{ -----[3.5]}$$

หาอนุพันธ์ของสมการที่ 3.5 จะได้

$$d/dt\ C(t) = EXP(-(t-L)/T_1)/(T_1-T_2)$$

$$- EXP(-(t-L)/T_2)/(T_1-T_2) \text{ --------------[ก.1]}$$

หาอนุพันธ์ของสมการที่ ก.1 จะได้

$$d^2/dt^2\ C(t) = -\ EXP(-(t-L)/T_1)/(T_1(T_1-T_2))$$

$$+ EXP(-(t-L)/T_2)/(T_2(T_1-T_2)) \text{ --------[ก.2]}$$

ให้สมการที่ ก.2 = 0 และ เอา (T_1-T_2) คูณตลอด จะได้

$$0 = -\ EXP(-(t-L)/T_1)/T_1 + EXP(-(t-L)/T_2)/T_2$$

ย้ายข้างและจัดรูปใหม่จะได้

$$[EXP(-(t-L)/T_1)]/[EXP(-(t-L)/T_2) = T_1/T_2$$

$$EXP[(-(t-L)/T_1) + (-(t-L)/T_2)] = T_1/T_2 \text{ -----------[ก.3]}$$

Take ln สมการที่ ก.3 จะได้

$$(-(t-L)/T_1) + (-(t-L)/T_2)] = \ln (T_1/T_2)$$

$$(t-L)((T_1-T_2)/(T_1*T_2)) = \ln (T_1/T_2)$$

ให้ $a = T_1*T_2/(T_1-T_2)$ และ $n = T_1/T_2$ จะได้

$$T - L = (a)\ln(n)$$

เพราะฉะนั้น จะได้

$$t_m = t = L + (a)\ln (n)$$

โดยที่ t หรือ t_m เป็นเวลาที่เกิดความชันที่มากที่สุด (Maximum Slope)

ภาคผนวก ข.

วิธีแรกของ Powell (The First Powell Procedure)

สำหรับการหาค่าที่เหมาะสมที่สุดโดยวิธีแรกของ Powellนี้ จะเป็นการหาค่าที่เหมาะสมที่สุดของฟังก์ชัน n ตัวแปร โดยก่อนอื่นจะขอกำหนด

ฟังก์ชัน $Y = f(x_1,x_2,\ldots,x_n)$
เริ่มหาค่าที่เหมาะสมที่สุดจากจุดเริ่มต้น p_0
ต้องการหาค่า $x_1,x_2,\ldots,x_n$ ที่ทำให้ค่า Y มีค่าน้อยที่สุด

ก่อนอื่น ขอกำหนด $z_1,z_2,\ldots,z_n$ ให้เป็น Coordinate directions n ทิศทาง และให้ i เป็นตัวแปรแสดงทิศทางของการหาค่าที่เหมาะสมที่สุด

ขั้นตอนที่ 1 :-

เริ่มจากทิศทาง i ที่ i = 1 ไปเรื่อย ๆ จนถึงทิศทางที่ n จะหาค่าของ r_i ที่ทำให้ $f(p_{i-1}+r_iz_i)$ มีค่าน้อยที่สุด และกำหนดจุด $p_i = p_{i-1} + r_iz_i$

ขั้นตอนที่ 2 :-

เริ่มจากทิศทาง i ที่ i = 1 ไปเรื่อย ๆ จนถึงทิศทางที่ n-1 กำหนดทิศทางใหม่ โดยให้ $z_i = z_{i+1}$ และกำหนด z_n เป็นทิศทางที่มุ่งจากจุด p_0 มาจุด p_n หรือ (p_0-p_n)

ขั้นตอนที่ 3 :-

หาค่าของ r ที่ทำให้ $f(p_n + rz_n)$ มีค่าน้อยที่สุดและให้ $p_0 = p_n+rz_n$

หลังจากเสร็จขั้นตอนที่ 3 แล้ว ให้กลับไปเริ่มรอบใหม่ที่ขั้นตอนที่ 1 ใหม่ จนกว่าจะได้จุดที่ให้ค่าที่เหมาะสมที่สุดที่ต้องการ

ตามการหาค่าโดยวิธีที่ 1 ของ Powell นั้น สามารถพิสูจน์ได้ว่าไม่สามารถเข้าสู่จุดที่ให้ค่าที่เหมาะสมที่สุดจริงได้ในทุกฟังก์ชัน โดยจะยกตัวอย่างฟังก์ชัน 3 ตัวแปรดังนี้

$$f(x,y,z) = (x-y+z)^2+(-x+y+z)^2+(x+y-z)^2 \quad \text{------}[4.1]$$

โดยจะเริ่มหาค่าที่เหมาะสมที่สุดจากจุด (0.5,1,0.5)

จากสมการที่ 4.1 จะเห็นได้อย่างชัดเจนว่า ค่าที่เหมาะสมที่สุดสำหรับสมการนี้นั้น มีค่าอยู่ที่จุด (0,0,0) และค่าของ $f(x,y,z) = 0$ แต่จากการใช้วิธีที่ 1 ของ Powell พบว่า เมื่อเสร็จขั้นตอนที่ 1 แล้ว จะได้จุด p_3 ที่ (1/2,1/3,5/18) และเมื่อหาทิศทางใหม่ตามขั้นตอนที่ 2 จะได้ทิศทางใหม่คือ {(0,1,0),(0,0,1),(0,-2/3,-2/9)} ซึ่งจะเห็นได้ว่า ในรอบถัดไปของการหาค่าที่เหมาะสมที่สุดจะไม่มีการหาในทิศทางแกน x ซึ่งทำให้จุดที่ให้ค่าที่เหมาะสมที่สุดที่จะหาได้ไม่ใช่จุดที่ให้ค่าที่เหมาะสมที่สุดที่ $x = 0$ ซึ่งแสดงว่าวิธีนี้ใช้ไม่ได้กับ Strickly Convex Function

วิธีที่ 2 ของ Powell (Simplified Powell's Second Procedure)

ข้อแตกต่างระหว่างวิธีแรกและวิธีที่สองของ Powell ดูเหมือนว่าจะอยู่ที่หลักในการหาทิศทางที่จะหาจุดที่ให้ค่าที่เหมาะสมที่สุดใหม่ และหลักในการเลือกใช้ทิศทางที่เปลี่ยนใหม่นั้น ซึ่งวิธีการหาตามวิธีที่ 2 ของ Powell สามารถอธิบายได้ดังนี้

กำหนด $z_1^1,z_2^1,\ldots,z_n^1$ เป็น Coordinate Direction และมีขนาดเท่ากับ Normallize Unit ดังนั้น $||z_i^1|| = 1$ โดยที่ i เป็นตัวแปรแสดงทิศทางการหาค่าที่เหมาะสมที่สุด มีค่า $i = 1,2,\ldots,n$

กำหนด Scalar e โดยที่ e มีค่าอยู่ระหว่าง 0-1

กำหนด p_0^1 เป็นจุดเริ่มต้นของการหาค่าที่เหมาะสมที่สุด

กำหนด $d^1 = 1$ และกำหนดรอบการทำงาน k โดยเริ่มจาก k = 1

การทำงานรอบที่ k

ขั้นตอนที่ 1

เริ่มจากทิศทาง i ที่ i=1 ไปเรื่อย ๆ จนถึงทิศทางที่ n จะหาค่าของ r_i^k ที่ทำให้ $f(p_{i-1}^k+r_i^kz_i^k)$ มีค่าน้อยที่สุด และกำหนดจุด $p_i^k = p_{i-1}^k + r_i^kz_i^k$

ขั้นตอนที่ 2 :-

กำหนด $a^k = ||p_n^k-p_0^k||$ และ $z_{n+1}^k = (p_n^k-p_0^k)/a^k$ แล้วคำนวนหาค่า r_{n+1}^k ที่ทำให้ $f(p_n^k+r_{n+1}^kz_{n+1}^k)$ มีค่าน้อยที่สุด และกำหนดจุด $p_0^{k+1} = p_{n+1}^k = p_n^k + r_{n+1}^kz_{n+1}^k$

ขั้นตอนที่ 3

หาค่า $r_s^k = \mathrm{Max}\{r_i^k \mid i=1,2,...,n\}$

กรณีที่ 1 ถ้า $r_s^kd^k/a^k >= e$ ให้ $z_i^{k+1} = z_i^k$ สำหรับ i ที่ไม่เท่ากับ s และ ให้ $z_s^{k+1} = z_{n+1}^{k+1}$ สำหรับ i ที่เท่ากับ s และให้ $d^{k+1} = r_s^kd^k/a^k$

กรณีที่ 2 ถ้า $r_s^kd^k/a^k < e$ ให้ $z_i^{k+1} = z_i^k$, i=1,2,...,n และให้ $d^{k+1} = d^k$

เริ่มทำรอบการทำงานที่ k โดยแทน k ด้วย k+1 จนกระทั่งถึงจุดที่ให้ค่าที่เหมาะสมที่สุด

Powell ได้พิสูจน์ให้เห็นว่าการหาค่าที่เหมาะสมที่สุดตามวิธีที่ 2 นั้น สามารถแก้ปัญหาที่เกิดจากการหาค่าตามวิธีที่ 1 ซึ่งทำให้วิธีที่ 2 นี้ สามารถหาค่าได้กับฟังก์ชันที่มีลักษณะของ Strickly Convex Function แต่อย่างไรก็ตาม วิธีที่ 2 ของ Powell ถึงแม้จะทำการ Simplify แล้ว ก็ยังเห็นได้ว่าเป็นวิธีที่ยุ่งยากในการหาค่าที่เหมาะสมที่สุดอยู่ Willard I. Zangwill จึงได้พัฒนาวิธีที่ 2 ของ Powell ขึ้นมาใหม่ ซึ่งสามารถพิสูจน์ได้ว่า วิธีที่พัฒนานี้

เป็นวิธีที่ลู่เข้าสู่จุดที่ให้ค่าที่เหมาะสมที่สุด ใน Finite number of Iteration และสามารถพิสูจน์ได้ว่า วิธีนี้จะลู่เข้าแม้กับฟังก์ชันในลักษณะของ Strickly Convex function และสามารถหาหาค่าที่เหมาะสมที่สุดได้ทุกคำตอบ

ภาคผนวก ค.

A/D, D/A Specification

1. INTRODUCTION TO A/D, D/A CONVERTER CARD

1.1. GENERAL DESCRIPTION

A/D, D/A Converter card, Deer Mountain Inc. part No. DM-P005B, is designed for IBM PC, XT, AT expansion slot, DM-P005B including:

1) 4 indepedent CH.(CH0-CH3) of 12-bit D/A converter.
2) Choose channel 0 through "Continuous approximate compare mode" offer 8 CH. A/D converter.
3) CH0-CH3 through "voltage to current converting CKT", offer 4-20mA standard industrial control signal output, its convenient for remote control signal transmission.

1.2. FEATURES

(1) D/A converter voltage O/P

* Resolution: 12 bits.
* Current setting time: 500nS to 0.05% of full scale.
* Full scale O/P voltage range: 0Vdc-10Vdc.
* Nonlinear distortion: 0.05% of full scale.
* O/P voltage precision: 0.3% of FSR.
* O/P voltage precision temperature coefficient: 20 PPM of FSR/°C.
* Power supply rejection: ±0.05% of FSR/%.

(2) D/A converter current O/P

* Resolution: 12 bits.
* Current setting time: 800nS to 0.05% of full scale.
* Full scale O/P current range: 4mA-20mA.
* Nonlinear distortion: 0.05% of full scale.
* O/P current temperature coefficent: 30 PPM of FSR/°C.
* Power supply rejection: 0.005% of FSR/%.
* Including O/P short protection device.
* Max loading resistor RL(max): 600 OHM ±5%.

(3) A/D converter voltage input
- * 8 channel, single end I/P mode.
- * Resolution: 12 bits.
- * Conversion time: 1mS/channel.
- * I/P voltage range: 0-5Vdc.
- * I/P impedance: 200K OHM ±5%.
- * Nonlinear distortion: 0.1% of full scale.
- * Precision: 0.5% of FSR ±1 LSB.
- * Power supply rejection: ±0.005% of FSR%.
- * Including I/P protection circuit.

1.3. SPECIFICATIONS

(1) Electrical Specifications
- * Capacity: 4 channels D/A or 3 channels D/A, 8 channels A/D.
- * Input signal: 0-5Vdc.
- * Output signal: 0-10Vdc and 4-20mA.
- * Can be used with multiple cards in parallel.
- * I/O address selection: 380-3FFH.
- * Interface: all address, data and control signals are TTL compatible.
- * Power requirements: ±5Vdc/200mA, ±12Vdc/200mA.

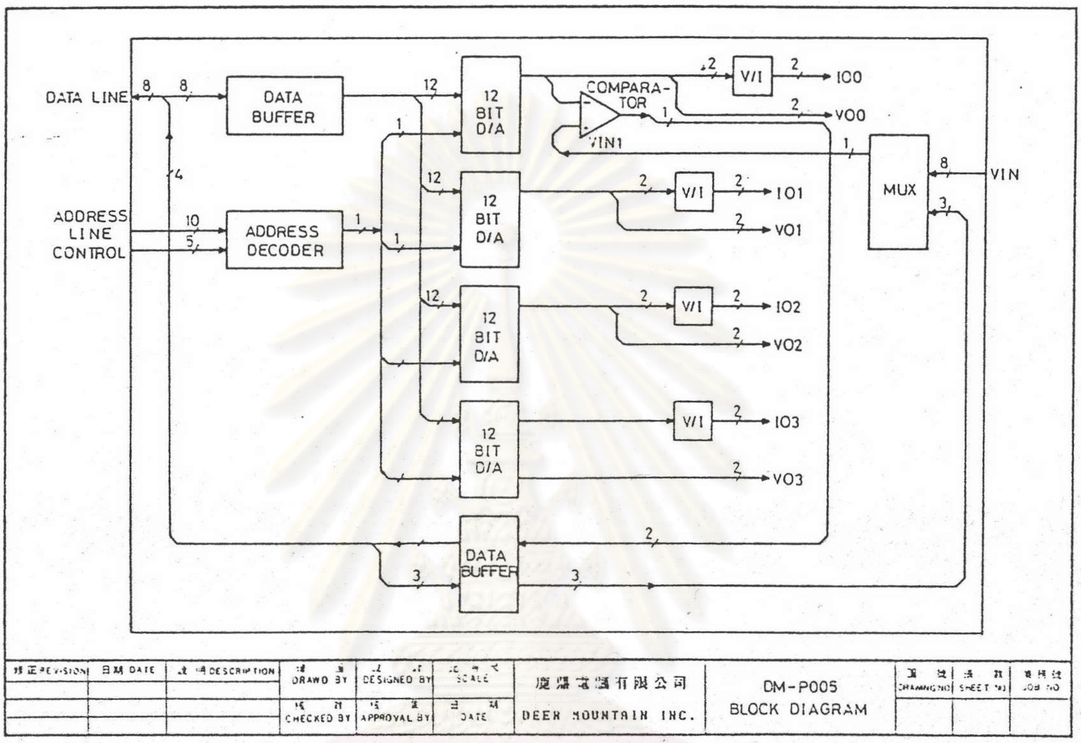
(2) Enviromental Specifications
- * Operating temperature: 0°C to 55°C.
- * Relative humidity: 0% to 90%.

(3) Mechanical Specifications
- * Meets general mechanical specifications of the IBM PC , XT, AT.
- * P.C.B. size:

  Length: 33.6cm
  Width : 10.4cm
  Height: 1.34cm
- * P.C.B. material: 1.6mm thickness FR-4.
- * P.C.B. gold finger thickness: 20u.
- * I/O connector: D-TYPE 37 pin, 1 set.
- * The locations of IC use circular hole socket, its gold inner contact/tin outer sleeve.

2. DESCRIPTION OF CIRCUIT

2.1. SCHEMATIC DIAGRAM



2.2. PRINCIPLES OF CKT

The DM-P005B has two functions as follows:

1) 4 channels D/A
   D/A output mode:
   * Voltage range is 0-10V.
   * Current range is 4-20mA.
2) A/D part: The user can select CH0 convert to 8 channels A/D by continous compare mode, A/D input is 0-5V.

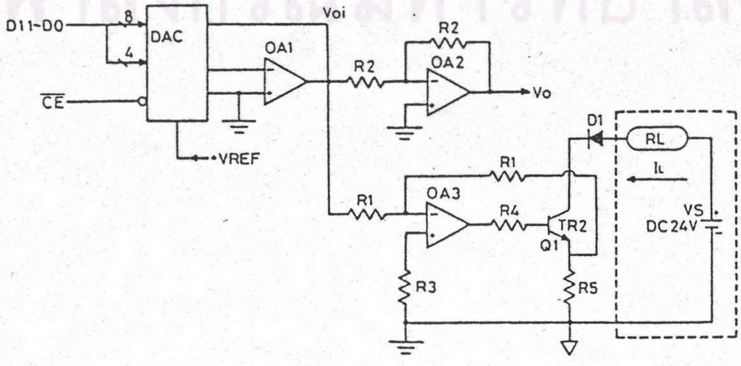


Fig 2-1

(1) 4-Channel D/A

DM-P005B use current multipling 12-bit DAC as D/A converter part.

The D/A converter includes three parts

1) D/A part: consist of OA1, DAC
OUTPUT VALTAGE Voi: 0-10V,
when input
D11-D0 is 0000H, Voi=-0.000V.
D11-D0 is 0FFFH, Voi=-9.996V.

2) Voltage output part: consist of OA2, R2.
Vo=-Voi by OA2, R2, output range is +0.000V-9.996V.

3) Current output part: consist of OA3, Q1, R5, D1, current output range: 4-20mA

Voi=1V	Il=4mA
Voi=5V	Il=20mA

the relation of output current Il and voltage output Voi :

Il=voi/Rl

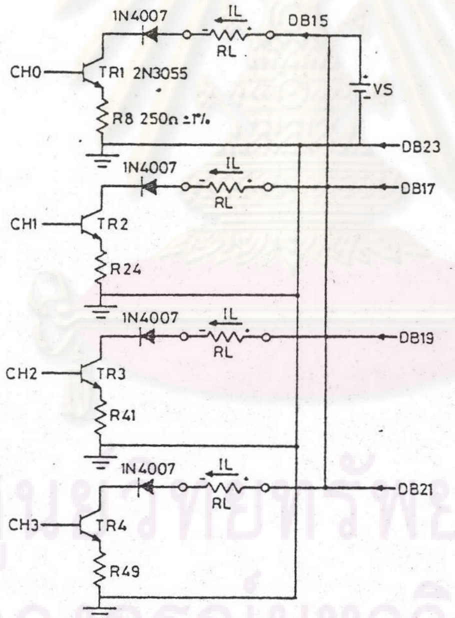


Fig 2-2

Vs min=24Vdc	Vs max=35Vdc
Rl min=0 OHM	Rl max=600 OHM

Remarks: Vs & Rl enable Q1 on, then occur current Il, user can use Il as remote control signal.

4) D/A channel port address arrangement:

	Low byte (D7-D0)	High byte (D11-D8)
CH0	380	381
CH1	382	383
CH2	384	385
CH3	386	387

D/A trasfer coefficient=Output Voltage(full scale)/2
=10V/4096
=2.241mV/bit

(2) A/D Part

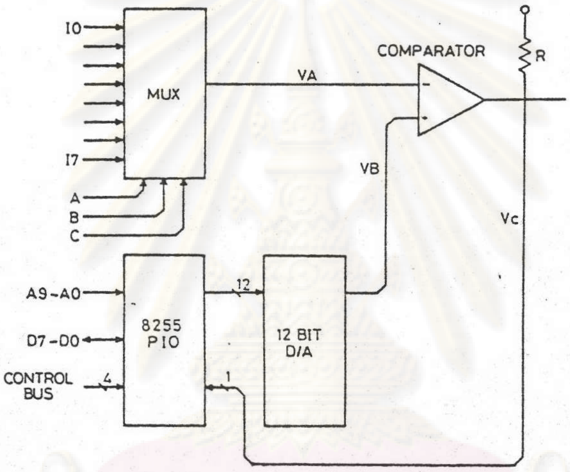


Fig 2-3

Pin A, B, C, of multiplex for channel selection. Vb of D/A output, it compare with Va, and the comparator output Vc is to 8255 of IBM PC, XT, AT main board. If Va>Vb, then Vc=0, software counter increases not stop until Vc="1", the contain of software counter is the binary of Va.
The CKT can be also named continuous compare converter.

2.3. ADDRESS DECODING CKT

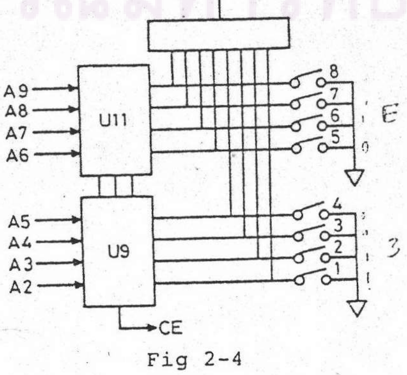


Fig 2-4

In Dip-Switch, pin OFF is logic "1", pin ON is logic "0". When address signal is equal with Dip-Switch setting $\overline{CE}$ sends a high pulse to D/A converter, pulse width is same as clock of IBM PC.

3. OPERATION DESCRIPTION

3.1. ADDRESS SELECTION

The board address can be set by Dip-Switch from 380-3FFH, each P.C.B. needs 10 address port, selecting mode as follows:

1) The relation of Dip-switch & address line as table 3-1

DIP-SW PIN NO.	8	7	6	5	4	3	2	1
ADDRESS LINE	A9	A8	A7	A6	A5	A4	A3	A2

Table 3-1

When Dip-Switch set "ON", represents the corresponding address line as ligic "0", otherwise as logic "1".

2) Example: DM-P005B address had been set 390-399H at our factory, then Dip-Switch setting as table 3-2

DIP-SW PIN NO.	8	7	6	5	4	3	2	1
DIP-SW STATUS	OFF	OFF	OFF	ON	ON	ON	OFF	OFF

Table 3-2

3.2. ANALOG I/O &DB-25 CONNECTOR ASSIGNMENT TABLE

DM-P005 use D-TYPE 25 pin connector as analog signal input & output, it define as table 3-3.

PIN NO	DESCRIPTION
1	A/D CH1 I/P Terminal
2	A/D CH2 I/P Terminal
3	A/D CH3 I/P Terminal
4	A/D CH4 I/P Terminal
5	A/D CH5 I/P Terminal
6	A/D CH6 I/P Terminal
7	A/D CH7 I/P Terminal
8	A/D CH8 I/P Terminal
9	D/A CH1 Voltage O/P Terminal
10	D/A CH2 Voltage O/P Terminal
11	D/A CH3 Voltage O/P Terminal
12	D/A CH4 Voltage O/P Terminal
13	NC
14	NC
15	Positive Terminal of CH1 Current O/P Channel
16	NC
17	Positive Terminal of CH2 Current O/P Channel
18	NC
19	Positive Terminal of CH3 Current O/P Channel
20	NC
21	Positive Terminal of CH4 Current O/P Channel
22	A/D, D/A Common Ground
23	A/D, D/A Common Ground
24	A/D, D/A Common Ground
25	A/D, D/A Common Ground

Notes:

1) DM-P005B choose CH. 0 through "continuous approximate compare mode" offer 8CH A/D, so D/A & A/D have mutual relation in voltage precision.
2) The precision of adjustment for D/A & A/D is VR2.

ภาคผนวก ง.

[ง.1] การประมาณค่าเวลาประวิง (Delay Time)

การประมาณค่าโดยวิธีการของ Pade

การประมาณค่าโดยวิธีการของ Pade นี้เป็นวิธีการประมาณค่า Differentiable Power Series ฟังก์ชันในรูปของ

$$d(x) = c_0 + c_1x + c_2x^2 + c_3x^3 + \ldots..$$

ให้อยู่ในรูปของฟังก์ชันตรรกยะ (Rational fraction)

$$F(x) = A_m(x)/B_m(x)$$

โดยที่

$$A_m(x) = a_0 + a_1x + a_2x^2 + \ldots + a_mx^m \text{ -----------[a]}$$

$$B_m(x) = b_0 + b_1x + b_2x^2 + \ldots + b_mx^m \text{ -----------[b]}$$

ค่า Coefficient ของ $A_m(x)$ และ $B_m(x)$ สามารถเขียนอยู่ในรูป matrix ได้ดังนี้

$$a = \begin{bmatrix} a_0 \\ a_1 \\ . \\ a_m \end{bmatrix} \qquad b = \begin{bmatrix} b_0 \\ b_1 \\ . \\ b_m \end{bmatrix}$$

กำหนด matrix $c_{p,q}$

$$c_{p,q} = \begin{bmatrix} c_q & c_{q-1} & \cdots & c_{q-p} \\ c_{q+1} & c_q & \cdots & c_{q-p+1} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ c_{p+q-1} & c_{q+p-2} & \cdots & c_{q-1} \end{bmatrix}$$

ค่า Coefficient ของสมการ [a] และ [b] หาได้จากสมการ matrix

$c_{m,m+1}b = 0$ และสมการ $c_{m+1,0}b = a$

การประมาณค่าอันดับหนึ่งของเวลาประวิง

กระจาย e^x ในรูปของ MacLaurin Series จะได้

$$e^x = 1 + x + x^2/2! + x^3/3! + \ldots$$

$m=1,\ c_0=1,\ c_1=1,\ c_2=1/2,\ c_3=1/6$

จะได้ $c_{1,2}b = \begin{vmatrix} 1/2 & 1 \end{vmatrix} \begin{bmatrix} b_0 \\ b_1 \end{bmatrix} = 0$ จะได้ $b_1 = -b_0/2$

$$c_{2,0}b = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} b_0 \\ b_1 \end{bmatrix} \quad \begin{bmatrix} a_0 \\ a_1 \end{bmatrix}$$

จะได้ $a_0 = b_0$ และ $b_0 + b_1 = a_1$

ให้ $a_0 = b_0 = 1$ เพราะฉะนั้นจะได้ $b_1 = 1/2$, $a_1= 1/2$

เพราะฉะนั้น จะได้

$$F(x) = (1 + x/2)/(1 - x/2) = d(x)$$

แทน x ด้วย $-Ls$ จะได้

$$EXP(-Ls) = (1- Ls/2)/(1 + Ls/2)$$

$$= (2 - Ls)/(2 + Ls)$$

การประมาณค่าอันดับสองของเวลาประวิง

$$F(x) = (a_0 + a_1x + a_2x^2)/(b_0 + b_1x + b_2x^2)$$

จะได้ $m=2$, $c_0=1$, $c_1=1$, $c_2=1/2$, $c_3=1/6$, $c_4=1/24$

$$c_{2,3} = \begin{bmatrix} c_3 & c_2 & c_1 \\ c_4 & c_3 & c_2 \end{bmatrix} \begin{bmatrix} 1/6 & 1/2 & 1 \\ 1/24 & 1/6 & 1/2 \end{bmatrix}$$

$$c_{3,0} = \begin{bmatrix} c_0 & 0 & 0 \\ c_1 & c_0 & 0 \\ c_2 & c_1 & c_0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1/2 & 1 & 1 \end{bmatrix}$$

เพราะว่า $c_{2,3}b = 0$

จะได้ $b_0/6 + b_1/2 + b_2 = 0$

$b_0/24 + b_1/6 + b_2/2 = 0$

เพราะว่า $c_{3,0}b = a$

จะได้ $a_0 = b_0$

$b_0 + b_1 = a_1$

$b_0/2 + b_1 + b_2 = a_2$

ให้ $a_0 = b_0 = 1$ จะได้ $a_1 = 1/2$, $a_2 = b_2 = 1/12$, $b_1 = -1/2$

เพราะฉะนั้นจะได้ $F(x) = (12 + 6x + x^2)/(12 - 6x + x^2)$

แทนค่า x ด้วย $-Ls$

$$e^{-Ls} = (12 - 6Ls + L^2s^2)/(12 + 6Ls + L^2s^2)$$

[ง.2] การหา Recursive Form ของเวลาประวิง

จาก $e^{-Ls} = (12 - 6Ls + L^2s^2)/(12 + 6Ls + L^2s^2)$

$$= 1 - 12Ls/(L^2s^2 + 6Ls + 12)$$

$$= 1 - (12s/L)/[(s+3/L)^2 + 3/L^2]$$

เปลี่ยนให้อยู่ในรูป Z-Transform จะได้

$$e^{-Ls} = (z-1)/z\ Z[\ 1/s - (12s/L)/[(s+3/L)^2 + 3/L^2]\ ]$$

$$= \frac{(z-1)}{z}\,\frac{z}{z-1} - \frac{12}{L}\,\frac{L}{3}\,\frac{ze^{-3T/L}\,\mathrm{Sin}(\ 3\ T/L)}{z^2 - 2z\mathrm{Cos}(\ 3\ T/L)e^{-3T/L} + e^{-6T/L}}$$

$$= 1 - \frac{4\ 3\ (z-1)\mathrm{Sin}(\ 3\ T/L)e^{-3T/L}}{z^2 - 2z\mathrm{Cos}(\ 3\ T/L)e^{-3T/L} + e^{-6T/L}}$$

$$= \frac{z^2 - 2\mathrm{Cos}(\ 3\ T/L)ze^{-3T/L} + e^{-6T/L} - 4\ 3\ \mathrm{Sin}(\ 3\ T/L)ze^{-3T/L} + 4\ 3\ \mathrm{Sin}(\ 3\ T/L)e^{-3T/L}}{z^2 - 2z\mathrm{Cos}(\ 3\ T/L)e^{-3T/L} + e^{-6T/L}}$$

$$= \frac{1 - (\ 2\mathrm{Cos}(\ 3\ T/L) + 4\ 3\ \mathrm{Sin}(\ 3\ T/L))e^{-3T/L}z^{-1} + (\ 4/\ 3\ \mathrm{Sin}(\ 3\ T/L)e^{-3T/L} + e^{-6T/L})z^{-2}}{1 - 2\mathrm{Cos}(\ 3\ T/L)e^{-3T/L}z^{-1} + e^{-6T/L}z^{-2}}$$

ทำ z^{-1}-Transform แล้วจัดรูปใหม่จะได้

$$c(k) = a[0]u[k] + a[1]u[k-1] + a[2]u[k-2] + b[0]c[k-1] + b[1]c[k-2]$$

โดยที่

$$a[0] = 1$$

$$a[1] = -[2\mathrm{Cos}(\ 3\ T/L) + 4\ 3\ \mathrm{Sin}(\ 3\ T/L)]e^{-3T/L}$$

$$a[2] = 4/\ 3\ \mathrm{Sin}(\ 3\ T/L)e^{-3T/L} + e^{-6T/L}$$

$$b[0] = 2\ \mathrm{Cos}(\ 3\ T/L)e^{-3T/L}$$

$$b[1] = e^{-6T/L}$$

[ง.3] การหา Recursive Form ของระบบ

- พิจารณาระบบหน่วงเกิน

$$C(s) = K/[s(s+T_1)(s+T_2)]$$

เปลี่ยนให้อยู่ในรูป Z-Transform จะได้

$$C(z) = (z-1)/z\ Z[\ K/[s(s+T_1)(s+T_2)]\ ] \quad \text{-------------}[*]$$

ใช้ Partial Fraction จะได้

$$K/[s(s+T_1)(s+T_2)] = A/s + B/(s+T_1) + C/(s+T_2)$$

โดยที่

$$A = K/T_1T_2$$

$$B = K/T_1(T_1-T_2)$$

$$C = -K/T_2(T_1-T_2)$$

จากสมการ [*] จะได้

$$C(z) = A + B(z-1)/(z-e^{-T_1T}) - C(z-1)/(z-e^{-T_2T})$$

ให้ $D = e^{-T_1T}$, $E = e^{-T_2T}$

$$C(z) = A + B(z-1)/(z-D) - C(z-1)/(z-E)$$

$$= \frac{(A+B+C)z^2 + (CD+C-AD-AE-BE-B)z + (ADE+BE-CD)}{z^2 - (D+E)z + DE}$$

$$= \frac{(A+B+C) + (CD+C-AD-AE-BE-B)z^{-1} + (ADE+BE-CD)z^{-2}}{1 - (D+E)z^{-1} + DEz^{-2}}$$

หา z^{-1}-Transform แล้วจัดรูปใหม่จะได้

$$c(k) = a[0]u[k] + a[1]u[k-1] + a[2]u[k-2] + b[0]c[k-1]$$
$$+ b[1]c[k-2]$$

โดยที่

$a[0] = A + B - C$

$a[1] = CD + C - AD - AE - BE - B$

$a[2] = ADE + BE - CD$

$b[0] = D + E$

$b[1] = DE$

$A = K/T_1T_2$

$B = K/T_1(T_1-T_2)$

$C = K/T_2(T_1-T_2)$

$D = e^{-T_1T}$

$E = e^{-T_2T}$

- พิจารณาระบบหน่วงวิกฤต

$C(s) = K/[s(s+T_1)^2]$

เปลี่ยนให้อยู่ในรูป Z-Transform จะได้

$C(z) = (z-1)/z\ Z[\ K/[s(s+T_1)^2]\ ]$ ------------------[**]

ใช้ Partial Fraction จะได้

$K/[s(s+T_1)^2] = A/s + B/(s+T_1) + C/(s+T_1)^2$

โดยที่

$A = K/T_1{}^2$

$B = -K/T_1{}^2$

$C = -K/T_1$

จากสมการ [**] จะได้

$$C(z) = K/T_1{}^2 - K/T_1{}^2(z-1)/(z-e^{-T_1T})$$
$$- Te^{-T_1T}(z-1)/(z-e^{-T_1T})^2$$

$$= [\ -2Ke^{-T_1T}/T_1{}^2 + K/T_1{}^2(1+e^{-T_1T})-Te^{-T_1T}]z^{-1}$$

$$1 - 2e^{-T_1T}z^{-1} + e^{-2T_1T}z^{-2}$$

$$+ [Ke^{-2T_1T}/T_1{}^2 - Ke^{-T_1T}/T_1{}^2 + Te^{-T_1T}]z^{-2}$$

ทำ z^{-1}-Transform แล้วจัดรูปใหม่จะได้

$$c(k) = a[0]u[k] + a[1]u[k-1] + a[2]u[k-2] + b[0]c[k-1] + b[1]c[k-2]$$

โดยที่

$a[0] = 0$

$a[1] = -Ke^{-T_1T}/T_1{}^2 + K/T_1{}^2 - Te^{-T_1T}$

$a[2] = Ke^{-2T_1T}/T_1{}^2 - Ke^{-T_1T}/T_1{}^2 + Te^{-T_1T}$

$b[0] = 2e^{-T_1T}$

$b[1] = e^{-2T_1T}$

- พิจารณาระบบหน่วงขาด

$C(s) = K/[s(s^2+As+B)]$

เปลี่ยนให้อยู่ในรูป Z-Transform จะได้

$C(z) = (z-1)/z\ Z[\ K/[s(s^2+As+B)]\ ]$ -------------[***]

ใช้ Partial Fraction จะได้

$K/[s(s^2+As+B)] = p/s + (xs+y)/(s^2+As+B)$

โดยที่

$p = K/B$

$x = -K/B$

$y = -AK/B$

จากสมการ [***] จะได้

$C(z) = K/B\ [\ 1 - (z-1)(z-p)/((z^2-qz+r)\ ]$

โดยที่

$p = [\mathrm{Cos}(BT) + A\ \mathrm{Sin}(BT)/2B]\ e^{-AT/2}$

$q = 2\ \mathrm{Cos}(BT)e^{-AT/2}$

$r = e^{-AT/2}$

$$c(z) = K/B[[(p-q+1)z^{-1}+(r-p)z^{-2}]/[z^{2}-qz+r]]$$

ทำ z^{-1}-Transform แล้วจัดรูปใหม่จะได้

$$c(k) = a[0]u[k] + a[1]u[k-1] + a[2]u[k-2] + b[0]c[k-1] + b[1]c[k-2]$$

โดยที่

$a[0] = 0$

$a[1] = K/B(p-q+1)$

$a[2] = K(r-p)/B$

$b[0] = q$

$b[1] = -r$

ภาคผนวก จ.

Program Listing

```
#include    <stdio.h>
#include    <io.h>
#include    <dos.h>
#include    <math.h>
#include    <conio.h>
#include    <stdarg.h>
#include    <stdlib.h>
#include    <attrib.h>

int         clr();
int         writemem();
int         cattrib();
int         gotorc();
int         getkey();
int         steady();
int         testmag(int out,int data,int setvalue,int stopvalue,
            int maxtime);
double      pow(double x,double y);
double      sqrt(double x);
double      fabs(double x);
void        stepmag(int outchno,double *magnitude,int *error);
void        restoredata(int outchno,double magnitude,int *error);
void        slopetest(void);
void        identify(double magnitude);
void        clrscr(void);
double      acos(double x);
double      sqrt(double x);
double      chord(double l,int *opt);
double      fabs(double x);
int         steady();
void        stepmag(int outchno,double *magnitude,int *error,
            int action);
void        restoredata(int outchno,double magnitude,int *error);
void        slopetest(void);
void        identify(double magnitude,double *gn,double *delay,
            double *para1,double *para2,int *state);
double      func1(double r,double n);
double      func2(double r,double n);
double      log(double x);
double      acos(double x);
double      exp(double x);
```

```
extern  int     chanal=2;
extern  int     *point=0;
extern  int     otimes=0;
extern  int     otimem=0;
extern  int     ntimes=0;
extern  int     ntimem=0;
extern  int     num=16440;
extern  int     number=65534;
extern  int     interval=20;
extern  int     errorcode=0;
extern  int     opt=0;
extern  int     lenght=0;
extern  double  maxdelaytime=0,maxsteadytime=0,presentsv=0;
extern  double  step=0.2,mvc=0,pvc=0,anc=0,bnc=0,cnc=0;
extern  double  ts=0.216;
extern  double  a[3]={0,0,0};
extern  double  b[3]={0,0,0};
extern  double  c[3]={0,0,0};
extern  double  d[3]={0,0,0};
extern  double  hilim=100;
extern  double  lowlim=0;



main()

{

FILE            *in;
int             i,j,ii,p,row,col,outchno,inchno,index;
int             samdata[8220];
double          k,l,proc1,proc2;
char            msg[11];

/******************     LOGO     ******************/

hidecur();
logo();

/****************** INITIALIZE #1 ******************/

point = &samdata[0];

/******************    DRAW BOX    ******************/

drawbox();

/****************** READ DATA #1  ******************/

movup(5,13,15,64,8,Normal);
writemem(0,5,23,Highlight,"Please choose data come from :-  ");
writemem(0,8,16,Normal," [ 1 ]  From data file. ");
writemem(0,10,16,Normal," [ 2 ]  From Process Interface. [Identify
System]");
```

```
writemem(0,20,6,Reverse,"  Input Requirement Data  ");
row = 8;
col = 16;
cattrib(0,row,col,50,Reverse);
index = 1;
do {
    p = getkey();
    switch(p)
      {
        case HOME_KEY:
        case PGUP_KEY:  {
                index = 1;
                cattrib(0,row,col,50,Normal);
                row = 8;
                col = 16;
                cattrib(0,row,col,50,Reverse);
                break;
                }
        case END_KEY:
        case PGDN_KEY:  {
                index = 2;
                cattrib(0,row,col,50,Normal);
                col = 16;
                row = 10;
                cattrib(0,row,col,50,Reverse);
                break;
                }
        case DOWN_KEY:  {
                cattrib(0,row,col,50,Normal);
                index++;
                row = 10;
                if(index > 2)


                  {
                    index = 1;
                    row = 8;
                    col = 16;
                  }
                cattrib(0,row,col,50,Reverse);
                break;
                }
        case UP_KEY:    {
                cattrib(0,row,col,50,Normal);
                index--;
                row = 8;
                if(index < 1)
                  {
                    index = 2;
                    row = 10;
                    col = 16;
                  }
                cattrib(0,row,col,50,Reverse);
```

```
                  break;
                  }
          case '\r':
          case '\n':  {
                  row = 0;
                  break;
                  }
          default:
                  break;
        }
} while (row != 0);

/**************  READ DATA & IDEN FROM FILE  ***************/

if (index == 1)
  {
    movup(5,10,15,66,6,Normal);
    presentsv = 50.0;
    fiden(&k,&l,&proc1,&proc2,&opt);
  }

/**************  READ DATA & IDEN FROM PROCESS  *************/

  else if (index == 2)
    {
     movup(5,10,15,66,6,Normal);
     pciden(&k,&l,&proc1,&proc2,&opt);
    }

/********************* SHOW VALUE ***********************/

movup(4,15,3,75,12,Normal);
writemem(0,5,18,Highlight,"  Identify System Transfer Function is
:-  ");
movup(20,22,3,37,3,Normal);
writemem(0,21,4,Reverse,"  Response of Identify System  ");
writemem(0,8,20,Normal,"  G(s) = ");
writeva(0,7,29,Normal,"            %+.4lf*S",(-1.0*l));
writeva(0,8,30,Underline,"     %.4lf*e          ",k);
if(opt==2)
  {
    writemem(0,9,29,Normal,"    2   ");
    writeva(0,10,29,Normal,"    S %+.4lf*S %+.4lf",proc1,proc2);
  }



 else if (opt==0¦¦opt==1)
    writeva(0,10,29,Normal," (S %+.4lf)(S %+.4lf)",proc1,proc2);
writemem(0,14,21,Highlight,"  Optimum                        Quit ");
cattrib(0,14,21,11,Reverse);
row = 14;
col = 21;
ii = 11;
index = 1;
```

```
do {
    p = getkey();
    switch(p)
      {
        case LEFT_KEY:
        case RIGHT_KEY: {
                cattrib(0,row,col,ii,Highlight);
                if (index == 1)
                  {
                    col = 47;
                    ii = 10;
                    index = 2;
                  }
                  else {
                    col = 21;
                    ii = 11;
                    index = 1;
                    }
                cattrib(0,row,col,ii,Reverse);
                break;
                }
        case '\r':
        case '\n':  {
                row = 0;
                break;
                }
        default:  break;
       }
 } while (row != 0);


 /********************** OPTIMIZE  VALUE *************************/

 if (index == 1)
   {
   optimize(k,l,proc1,proc2,opt);
   }
 gotorc(1,0);
 showcur();
 writemem(0,0,0,Reverse,"  Bye-Bye  and have a nice DOS.  ");
 sound(1000);
 delay(200);
 sound(1600);
 delay(500);
 nosound();

 }
```

```
fiden(double *gn,double *delay,double *para1,double *para2,int *opt)

{

FILE      *in;
extern    double  maxsteadytime,maxdelaytime;



char      name[15];
double    time[3],inp[3],out[5000],slope[2];
double    ts,ti,area,maxslope,ai,ao,lamda,tm;
double    c,t1,t2,ceta,neta,k,gain,r,q,w;
double    e = 0.3678794412,eps = 0.000001;
long int  l,m,n;
int       i,j,state;

area = 0.0;
maxslope = 0.0;
i = 1;
do {
    state = 1;
    writemem(0,7,30,Highlight,"Enter File's Name :-  ");
    writemem(0,10,34,Normal,"              ");
    cattrib(0,10,34,12,Reverse);
    showcur();
    gotorc(10,34);
    scanf("%s",&name);
    writemem(0,20,45,Normal,"                             ");
    writemem(0,21,45,Normal,"                             ");
    if((in = fopen(name,"r"))==NULL)
      {
        writemem(0,20,45,Reverse,"  Can not open input file.  ");
        writemem(0,21,45,ReverseBlink,"         TRY AGAIN !     ");
        state = 0;
      }
   } while (state == 0);
state = 1;
hidecur();
l = fileno(in);
m = filelength(l);
for ( j=0;j<=1;j++)
  {
    fscanf(in,"%lf",&time[j]);
    fseek(in,1,SEEK_CUR);
    fscanf(in,"%lf",&inp[j]);
    fseek(in,1,SEEK_CUR);
    fscanf(in,"%lf",&out[j]);
    fseek(in,1,SEEK_CUR);
  }
ts = time[1]-time[0];                    /*find sampling interval*/
do
  {
    i = i + 1;
    fscanf(in,"%lf",&time[2]);
    fseek(in,1,SEEK_CUR);
    fscanf(in,"%lf",&inp[2]);
    fseek(in,1,SEEK_CUR);
    fscanf(in,"%lf",&out[i]);
    fseek(in,1,SEEK_CUR);
    n = ftell(in);
    if ( ( i >= 500 ) && ( fabs(out[i] - out[i-1]) < eps) )
      {
        state = 0;
        c = out[i];
      }
    if ( i == 4999 )
      {
        writemem(0,20,45,Reverse,"  Can't store all of data!  ");
        writemem(0,20,45,ReverseBlink,"      Program Terminated    ");
        return(1);
      }


  } while ( n <= m && state == 1 );
fcloseall();
maxsteadytime = ts*i;
gain = c/inp[2];
k = 1.0/c;
for (j=0;j<=i;j++)
    out[j] = k*out[j];
for ( j=1;j<=i;j++ )
  {
    ao = ( out[j-1] + out[j] )/2.0;
    area = area + ( 1.0 - ao )*ts;
    slope[1] = ( out[j] - out[j-1] )/ts;
    if ( slope[1] < slope[0] )
        {
          if ( maxslope < slope[0] )
            {
              maxslope = slope[0];
              ti = j;
            }
        }
      else
        {
          if ( maxslope < slope[1] )
            {
              maxslope = slope[1];
              ti = j;
            }
        }
    slope[0] = slope[1];
  }
tm = ( 2.0 - out[ti] - out[(ti-1)] + maxslope*(((ti-1)*ts)+(ti*ts)))
/(2*maxslope);
lamda = maxslope*(tm-area);
```

```
neta = chord(lamda,&i);
*opt = i;
if ( *opt == 0 )
  {
   t1 = t2 = 1.0/(maxslope*e);
   ceta = area - 2.0*t1;
   k = gain/(t1*t2);
   r = 1.0/t1;
   q = 1.0/t2;
  }
 else if (*opt == 1)
   {
    ai = 1.0/(1.0-neta);
    ao = pow(neta,ai);
    t2 = ao/maxslope;
    ai = neta/(1.0-neta);
    ao = pow(neta,ai);
    t1 = ao/maxslope;
    ceta = area - t2*(neta+1.0)/neta;
    k = gain/(t1*t2);
    r = 1.0/t1;
    q = 1.0/t2;
   }
  else
   {
    ai = acos(neta);
    ao = 1.0-pow(neta,2.0);
    ao = sqrt(ao);
    w = ai/(ao*(tm-area));
    ceta = area - 2*neta/w;



    k = gain*w*w;
    r = 2.0*neta*w;
    q = w*w;
   }
*gn = k;
*delay = maxdelaytime = ceta;
*para1 = r;
*para2 = q;

}

void    pciden(double *k,double *l,double *t1,double *t2,int *state)

{

extern  int     chanal;
extern  int     *point;
extern  int     number;
extern  int     opt;
extern  int     lenght;
extern  double  maxdelaytime,maxsteadytime,presentsv;
```

```
FILE                 *out;
int                  i,ii,p,row,col,outchno,inchno,index;
int                  error,action;
double               magnitude;
char                 msg[11];
double               yr;

/*************  READ DATA FROM PROCESS  *************/

writemem(0,5,32,Highlight,"Approximate Data");
writemem(0,7,16,Normal,"Maximum Delay time           :-
second");
writemem(0,8,16,Normal,"Maximum Steady state time   :-
second");
writemem(0,9,16,Normal,"Present Process Value       :-
%     ");
writemem(0,10,16,Normal,"Final Element Action        :-
[0-Direct,1-Reverse]");
writemem(0,12,34,Highlight,"    Ready    ");
writemem(0,20,6,Reverse,"  Input Requirement Data  ");
row = 7;
col = 46;
cattrib(0,row,col,11,Reverse);
index = 1;
gotorc(row,col);
do {
    if(index != 5)
        showcur();
      else
        hidecur();
    p = getkey();
    writemem(0,20,49,Normal,"                        ");
    writemem(0,21,49,Normal,"                        ");
    if ( (p >= 0x30 && p<= 0x39) ¦¦ (p==0x2E))
      {
        i = 0;
        do {
            if ( (p >= 0x30 && p<= 0x39) ¦¦ (p==0x2E))
              {

                  putch(p);
                  cattrib(0,row,col,11,Reverse);

                  msg[i] = p;
                  i++;
                  if(i>10)
                    {
                      i=0;
                      gotorc(row,col);
                    }
                }
              p = getkey();
              if(p == 0x08)
                {
```

```
            ii = col + i - 1;
            if(i!=0)
              {
                i--;
                gotorc(row,ii);
                putch(' ');
                cattrib(0,row,col,11,Reverse);
                gotorc(row,ii);
              }
          }
       } while( p != 0x0D);
    msg[i] = '\0';
    if (index == 1)
        maxdelaytime = atof(msg);
      else if(index == 2)
          maxsteadytime = atof(msg);
        else if(index == 3)
            presentsv = atof(msg);
          else if(index == 4)
             action = atoi(msg);
    for(ii=i;ii<=10;ii++)
        putch(' ');
  }
switch(p)
  {
    case HOME_KEY:
    case PGUP_KEY:  {
            index = 1;
            cattrib(0,row,col,11,Highlight);
            row = 7;
            col = 46;
            cattrib(0,row,col,11,Reverse);
                gotorc(row,col);
            break;
            }
    case END_KEY:
    case PGDN_KEY: {
            index = 5;
            cattrib(0,row,col,11,Highlight);
            col = 34;
            row = 12;
            cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
            break;
            }
     case DOWN_KEY:  {
            cattrib(0,row,col,11,Highlight);
            index++;
            if(index > 5)
               {
                 index = 1;
                 row = 7;
```

```
                    col = 46;
                  }
                  else if (index == 5)
                    {
                    row = 12;
                    col = 34;
                    }
                    else
                    row++;
                cattrib(0,row,col,11,Reverse);
                     gotorc(row,col);
                break;
                }
        case UP_KEY:     {
                cattrib(0,row,col,11,Highlight);
                index--;
                if(index < 1)
                  {
                    index = 5;
                    row = 12;
                    col = 34;
                  }
                  else if (index == 4)
                    {
                    row = 10;
                    col = 46;
                    }
                    else
                      {
                    row--;
                      }
                 cattrib(0,row,col,11,Reverse);
                     gotorc(row,col);
                 break;
                 }
         case '\r':
         case '\n': {
                 if (index==5)
                     index = 100;
                   else
                     {
                        cattrib(0,row,col,11,Highlight);
                        index++;
                         if(index > 5)
                         {
                            index = 1;
                            row = 7;
                            col = 46;
                         }
                         else if (index == 5)
                           {
                             row = 12;
                             col = 34;
```

```
                                  }
                                  else
                                    {
                                        row++;
                                    }
                               cattrib(0,row,col,11,Reverse);
                               gotorc(row,col);
                            }
                        break;
                        }


                default:  {
                            writemem(0,20,49,Reverse,"   Keypress Error ! ");
                            writemem(0,21,49,ReverseBlink,"   TRY  AGAIN !");
                            break;
                        }
              }
        } while (index != 100);
        yr = maxsteadytime/86.4;
        lenght = ceil(yr);

        /*****************  READ DATA #2  *****************/

        writemem(0,5,29,Highlight,"Input/Output Port Data");
        writemem(0,7,16,Normal,"        Output Port (0-3) :-              ");
        writemem(0,8,16,Normal,"        Input Port  (0-7) :-              ");
        writemem(0,9,16,Normal,"                                          ");
        writemem(0,10,16,Normal,"
");
        writemem(0,12,34,Highlight,"           ");
        writemem(0,11,34,Highlight,"   Ready   ");
        row = 7;
        col = 45;
        cattrib(0,row,col,11,Reverse);
        index = 1;
        gotorc(row,col);
        do {
            if ( index !=3 )
                showcur();
              else
                hidecur();
            p = getkey();
            writemem(0,20,49,Normal,"                      ");
            writemem(0,21,49,Normal,"                      ");
            if ( (index == 1) && (p >= 0x30) && (p<= 0x33) )
              {
                do {
                    if ( p>=0x30 && p<=0x33  )
                      {
                        putch(p);
                        cattrib(0,row,col,1,Reverse);
                        gotorc(row,col);
                        msg[0] = p;
```

```
          }
        p = getkey();
        if(p == 0x08)
          {
            gotorc(row,col);
            putch(' ');
            cattrib(0,row,col,1,Reverse);
            gotorc(row,col);
            msg[0] = ' ';
          }
       } while( (p != 0x0D) );
    msg[1] = '\0';
    outchno = atoi(msg);
  }
if ( (index == 2) && (p >= 0x30) && (p<= 0x37) )
  {
    do {
        if ( p>=0x30 && p<=0x37 )
          {
            putch(p);
            cattrib(0,row,col,1,Reverse);
            gotorc(row,col);


            msg[0] = p;
          }
        p = getkey();
        if(p == 0x08)
          {
            gotorc(row,col);
            putch(' ');
            cattrib(0,row,col,1,Reverse);
            gotorc(row,col);
            msg[0] = ' ';
          }
       } while( (p != 0x0D) );
    msg[1] = '\0';
    inchno = atoi(msg);
  }
switch(p)
  {
    case HOME_KEY:
    case PGUP_KEY:  {
            index = 1;
            cattrib(0,row,col,11,Highlight);
            row = 7;
            col = 45;
            cattrib(0,row,col,11,Reverse);
                gotorc(row,col);
            break;
            }
    case END_KEY:
    case PGDN_KEY:  {
            index = 3;
        cattrib(0,row,col,11,Highlight);
        col = 34;
        row = 11;
        cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
        break;
        }
case DOWN_KEY:  {
        cattrib(0,row,col,11,Highlight);
        index++;
        if(index > 3)
          {
            index = 1;
            row = 7;
            col = 45;
          }
          else if (index == 3)
            {
            row = 11;
            col = 34;
            }
            else
            row++;
        cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
        break;
        }
case UP_KEY:    {
        cattrib(0,row,col,11,Highlight);
        index--;
        if(index < 1)
          {
            index = 3;


            row = 11;
            col = 34;
          }
          else if (index == 2)
            {
            row = 8;
            col = 45;
            }
            else
              {
            row--;
              }
        cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
        break;
        }
case '\b':  {
        gotorc(row,col);
        putch(' ');
```

```
              gotorc(row,col);
              msg[0] = ' ';
              break;
              }
      case '\r':
      case '\n':  {
              if (index==3)
                  index = 100;
                else
                  {
                     cattrib(0,row,col,11,Highlight);
                     index++;
                     if(index > 3)
                      {
                          index = 1;
                          row = 7;
                          col = 45;
                      }
                      else if (index == 3)
                         {
                           row = 11;
                           col = 34;
                         }
                         else
                           {
                               row++;
                           }
                      cattrib(0,row,col,11,Reverse);
                      gotorc(row,col);
                   }
               break;
               }
       default:  {
                   writemem(0,20,49,Reverse,"   Keypress Error ! ");
                   writemem(0,21,49,ReverseBlink,"   TRY  AGAIN !");
                   break;
               }
      }
} while (index != 100);

/****************** OUT PRESENT SV *****************/

writemem(0,20,2,Reverse,"  Find Step Disturbance Magnitude.  ");
magnitude = 403.2 + presentsv*16.128;



p = floor(magnitude);
output(outchno,p);
magnitude = 0;

/******************  INITIALIZE#2  *****************/

chanal = inchno;
```

```
/****************** FIND STEP MAG  *****************/

error = 0;
number = -2;
opt = 0;
stepmag(outchno,&magnitude,&error,action);
if (error == 1)
  {
    writemem(0,20,46,Reverse,"    System GAIN too low    ");
    writemem(0,21,46,Reverse,"  Can't used this method!  ");
    writemem(0,22,46,ReverseBlink," 10 s.  Program Terminated ");
    delay(10000);
    clr();
    gotorc(0,0);
    showcur();
    exit(0);
  }

/******************  RESTORE DATA  *****************/

number = -2;
opt = 0;
if ( action == 1)
    magnitude = -1.0*magnitude;
writemem(0,20,2,Normal,"                                                  ");
writemem(0,20,10,Reverse,"     Restore Data     ");
restoredata(outchno,magnitude,&error);
if ( action == 1)
    magnitude = -1.0*magnitude;
magnitude = fabs(magnitude);

/***************** IDENTIFY SYSTEM *****************/

writemem(0,20,10,Reverse,"    Identify System    ");
identify(magnitude,k,l,t1,t2,state);
writemem(0,20,10,Normal,"                       ");

}

identify(double magnitude,double *gn,double *delay,double *para1,
         double *para2,int *state)

{

extern  double  ts;
extern  int     number;
extern  int     *point;
extern  int     lenght;
extern  double   presentsv;
double           k,l,t1,t2;
double           input,t;
double           area,maxslope,slopen,ai,ao,lamda,tm;
double           c,ceta,neta,gain,r,q,w;
double           e = 0.3678794412;
double           sumx,sumy,sumxx,sumxy,x,y;
```

```
int              i,j,n,sv,offset,opt;

/***********************     INITIALIZE     ***********************/

area = 0.0;
maxslope = 0.0;
slopen = 0.0;
n = number/2.0;
input = 1.0;
ceta = 403.2 + presentsv*16.128;
neta = magnitude*16.128;
w = *point;
sv = floor(ceta);
offset = ceta - w;
j = floor(neta);

/*********************  FIND GAIN & PARAMETER *********************/

c = (*(point+n)-sv+offset)/neta;
gain = c/input;
k = 1.0/c;
for (i=1;i<=n;i++)
  {
    r = (*(point + i - 1) - sv + offset)*k/neta;
    q = (*(point + i) - sv + offset)*k/neta;
    ao = ( r + q )/2.0;
    area = area + (1.0-ao)*ts;
   }

/*********************   FIND MAXIMUM SLOPE   *********************/

sumx = sumy = sumxy = sumxx = 0.0;
for(j=lenght*20;j<=n;j++)
  {
    t = ts*j;
     for(i=0;i<lenght*20;i=i+lenght)
      {
        x = t - (i*ts);
        y = ((*(point+j-i)-sv+offset)*k)/neta;
          sumx = sumx + x;
          sumy = sumy + y;
          sumxy = sumxy + x*y;
          sumxx = sumxx + x*x;
        }
    slopen = ((20*sumxy)-(sumx*sumy))/((20*sumxx)-(sumx*sumx));
    if( slopen > maxslope )
      {
       maxslope = slopen;
       ao = sumy/20.0 - slopen*sumx/20.0;
      }
  }
```

```
tm = (input - ao)/maxslope;
lamda = fabs(maxslope*(tm-area));
neta = chord(lamda,&opt);
if ( opt == 0 )
   {
     t1 = t2 = 1.0/(maxslope*e);
     ceta = area - 2.0*t1;
     k = gain/(t1*t2);
     r = 1.0/t1;
     q = 1.0/t2;
   }


  else if (opt == 1)
    {
       ai = 1.0/(1.0-neta);
       ao = pow(neta,ai);
       t2 = ao/maxslope;
       ai = neta/(1.0-neta);
       ao = pow(neta,ai);
       t1 = ao/maxslope;
       ceta = area - t2*(neta+1.0)/neta;
       k = gain/(t1*t2);
       r = 1.0/t1;
       q = 1.0/t2;
     }
    else
      {
       ai = acos(neta);
       ao = 1.0-pow(neta,2.0);
       ao = sqrt(ao);
       w = ai/(ao*(tm-area));
       ceta = area - 2*neta/w;
       k = gain*w*w;
       r = 2.0*neta*w;
       q = w*w;
      }
 *gn = k;
 *delay = ceta;
 *state = opt;
 *para1 = r;
 *para2 = q;
 }

 double       chord(double lamda,int *opt)

 {

 double       start,stop,x,fstart,fstop,fx;
 double       crit = 0.3678794412,eps  = 0.0005;
 int          i;

 i = 0;
 start = 0.0000000001;
 stop = 0.9999999999;
 if ( fabs(lamda - crit) < eps )
     {
       *opt = 0;
       x = 1.0;
       return(x);
     }
   else if ( lamda < crit )
          {
             *opt = 1;
             fstart = func1(lamda,start);
             fstop = func1(lamda,stop);
          }
        else
            {
              *opt = 2;
              fstart = func2(lamda,start);
              fstop = func2(lamda,stop);
            }
 if ( fabs(fstart) < eps )
    return(start);
  else if ( fabs(fstop) < eps )


          return(stop);
do
  {
    x = ( start*fstop - stop*fstart )/( fstop - fstart );
    if ( *opt == 1 )
        fx = func1(lamda,x);
      else if ( *opt == 2 )
        fx = func2(lamda,x);
    if ( fabs(fx) < eps )
        return(x);
    if ( fx*fstart < 0 )
        {
          stop = x;
          fstop = fx;
        }
      else
        {
          start = x;
          fstart = fx;
        }
  } while ( i == 0 );
}

double      func1(double r,double n)

{

double      a,b;
```

```
a = 1.0/(1.0-n);
b = pow(n,a);
a = b/(n-1);
b = log(n);
return((a*b)-r);

}

double       func2(double r,double n)

{

double       a,b,c,d;

a = acos(n);
c = 1.0-pow(n,2.0);
b = sqrt(c);
c = -1.0*a*n/b;
d = exp(c);
c = a*d/b;
return(c-r);

}

void         stepmag(int out,double *magnitude,int *error,int action)

{

extern  int     *point;
extern  int     opt;
extern  int     errorcode;
extern  int     number;
extern  double  maxdelaytime;
extern  double  maxsteadytime;



extern  double  presentsv;
extern  double  ts;

int             sv,data,time,cond;
double          r,mvalue,value,dbias,onepercent,fivepercent,spstep;

dbias = 403.2;
onepercent = 16.128;
spstep = 0;
fivepercent = onepercent*5;
value = dbias + presentsv*onepercent;
sv = floor(value);
r = (maxdelaytime + maxsteadytime)/ts;
time = 2*floor(r);
opt = 0;
while ( opt == 0 && spstep <= 20*onepercent )
  {
      spstep = spstep + fivepercent;
      if ( action == 1 )
             value = value - fivepercent;
       else if (action==0)
             value = value + fivepercent;
      mvalue = dbias + presentsv*onepercent + 0.6*spstep;
     data = floor(value);
     cond = floor(mvalue);
     number = -2;
     steady();
     opt = 0;
     number = -2;
     testmag(out,data,sv,cond,time);
     if (opt == 1)
         *magnitude = spstep/onepercent;
  }
if (opt == 0 && spstep> 20*onepercent)
    *error = 1;
}

void        restoredata(int out,double magnitude,int error)

{

extern  int      *point;
extern  int      opt;
extern  int      errorcode;
extern  int      number;
extern  double   maxdelaytime;
extern  double   maxsteadytime;
extern  double   presentsv;
extern  double   ts;

int              sv,data,time,cond;
double           r,mvalue,value,dbias,onepercent,fivepercent,spstep;

ts = 0.216;
dbias = 403.2;
onepercent = 16.128;
error = 0;
steady();
value = dbias + presentsv*onepercent;
sv = floor(value);
spstep = value + magnitude*onepercent;
data = floor(spstep);
opt = 0;



number = -2;
keepdata(out,data,sv,error);

}
```

```
void        slopetes()

{

extern  int     *point;
extern  int     number;
extern  int     opt,lenght;
extern  int     otimes,otimem;
extern  double  maxdelaytime,maxsteadytime;
double          slope,sumx,sumy,sumxy,sumxx;
double          intv,t,x,y,eps;
int             pt,i,j;

eps = 0.00001;
intv =0.216;
pt = number/2;
t = pt*intv;
if( t > maxdelaytime && pt > lenght*20 )
  {
    sumx = sumy = sumxy = sumxx = 0.0;
    for(i=0;i<lenght*20;i=i+lenght)
      {
        x = t - (i*intv);
        y = ((*(point+pt-i)*0.0024801573)-1.0)*25.0;
        sumx = sumx + x;
        sumy = sumy + y;
        sumxy = sumxy + x*y;
        sumxx = sumxx + x*x;
      }
    slope = ((20*sumxy)-(sumx*sumy))/((20*sumxx)-(sumx*sumx));
    if(slope < 0)
        slope = slope*(-1);
    if( (slope < eps) || (t >= maxsteadytime) )
        opt = 1;
  }
}

optimize(double gain,double tdelay,double para1,double para2,
         int status)

{

extern  double  ts,mvc,pvc;
extern  double  a[],b[],c[],d[],hilim,lowlim;

double  pid[3],o,l,q[14];
double  dx,eps,result;
int     i,ii,p,row,col;
int     pi,index,max;
char        mass[10];

drawbox();
```

```
/*-------------- Initialize Data ---------------------*/

pid[1] = 100;            /* Proportional Band [PB] */
pid[0] = 10000;          /*   Integral Time [Ti]   */
pid[2] = 0;              /*  Derivative Time [Td]  */



hilim = 100;
lowlim = 0;

/*------------ Read Controller Data ------------------*/

writemem(0,1,37,Highlight,"INPUT");
movup(5,13,15,75,9,Normal);
movup(20,22,3,37,3,Normal);
writemem(0,5,17,Reverse,"    Input start point of Controller Parameter
   ");
writemem(0,8,20,Normal,"Proportional Band (PB) := ");
writemem(0,9,20,Normal,"Integral time (Ti)     := ");
writemem(0,10,20,Normal,"Derivetive time (Td)   := ");
writemem(0,11,20,Normal,"High Limit (%)         := ");
writemem(0,12,20,Normal,"Low Limit (%)          := ");
writemem(0,14,37,Highlight,"Ready");
writemem(0,21,6,Reverse,"  Input Start Parameter  ");
cattrib(0,8,47,11,Reverse);
row = 8;
col = 47;
index = 1;
gotorc(row,col);
do {
    if(index != 6)
        showcur();
      else
        hidecur();
    p = getKey();
    writemem(0,20,49,Normal,"                       ");
    writemem(0,21,49,Normal,"                       ");
    if ( (p >= 0x30 && p<= 0x39) || (p==0x2E))
      {
        i = 0;
        do {
            if ( (p >= 0x30 && p<= 0x39) || (p==0x2e))
              {
                putch(p);
                cattrib(0,row,col,11,Reverse);
                mass[i] = p;
                i++;
                if(i>10)
                  {
                    i=0;
                    gotorc(row,col);
                  }
              }
```

```
       p = getkey();
       if (p == 0x08)
         {
           ii = col + i - 1;
           if (i!=0)
             {
               i--;
               gotorc(row,ii);
               putch(' ');
               cattrib(0,row,col,11,Reverse);
               gotorc(row,ii);
             }
         }
      } while( p != 0x0D);
   mass[i] = '\0';
   switch (index)
     {


       case 1 :
           {
           pid[1] = atof(mass);
           break;
           }
       case 2 :
           {
           pid[0] = atof(mass);
           break;
           }
       case 3 :
           {
           pid[2] = atof(mass);
           break;
           }
       case 4 :
           {
           hilim = atof(mass);
           hilim = hilim/100.0;
           break;
           }
       case 5 :
           {
           lowlim = atof(mass);
           lowlim = lowlim/100.0;
           break;
           }
      }
  }
switch(p)
  {
    case HOME_KEY:
    case PGUP_KEY:  {
            index = 1;
```

```
        cattrib(0,row,col,11,Highlight);
        row = 8;
        col = 47;
        cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
        break;
        }
case END_KEY:
case PGDN_KEY:  {
        index = 6;
        cattrib(0,row,col,11,Highlight);
        col = 34;
        row = 14;
        cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
        break;
        }
case DOWN_KEY:  {
        cattrib(0,row,col,11,Highlight);
        index++;
        if(index > 6)
          {
            index = 1;
            row = 8;
            col = 47;
          }
          else if (index == 6)
            {
            row = 14;


            col = 34;
            }
            else
            row++;
        cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
        break;
        }
case UP_KEY:    {
        cattrib(0,row,col,11,Highlight);
        index--;
        if(index < 1)
          {
            index = 6;
            row = 14;
            col = 34;
          }
          else if (index == 5)
            {
                row = 12;
                col = 47;
            }
            else
```

```
                    {
                  row--;
                    }
              cattrib(0,row,col,11,Reverse);
                  gotorc(row,col);
              break;
              }
      case '\r':
      case '\n':  {
              if (index==6)
                  index = 100;
                else
                  {
                     cattrib(0,row,col,11,Highlight);
                     index++;
                     if(index > 6)
                      {
                          index = 1;
                          row = 8;
                          col = 47;
                      }
                      else if (index == 6)
                        {
                           row = 14;
                           col = 34;
                        }
                        else
                          {
                               row++;
                          }
                      cattrib(0,row,col,11,Reverse);
                      gotorc(row,col);
                   }
               break;
               }
       default:  {
                   writemem(0,20,49,Reverse,"  Keypress Error ! ");
                   writemem(0,21,49,ReverseBlink,"    TRY  AGAIN !");
                   break;
               }


      }
} while (index != 100);

/*---------------- Choose Performance Index ------------------*/

movup(5,14,15,75,10,Normal);
movup(20,22,3,37,3,Normal);
writemem(0,5,20,Reverse,"   Choose Performace Index for Optimum    ");
writemem(0,8,26,Highlight," 1.  For No Overshoot ");
writemem(0,9,26,Highlight," 2.  ISE. Performance Index ");
writemem(0,10,26,Highlight," 3.  IAE. Performance Index ");
writemem(0,11,26,Highlight," 4.  ITAE. Performance Index ");
writemem(0,12,26,Highlight," 5.  ISE. PI. Hurwitz Method ");
writemem(0,21,5,Reverse,"  Choose Performance Index  ");
pi = selectmenu(8,23,35,1,5);

/*--------------- Read Optimal Process Data ------------------*/

movup(5,14,15,75,10,Normal);
movup(20,22,3,37,3,Normal);
writemem(0,5,26,Reverse,"   Optimal Criteria Data  ");
writemem(0,8,20,Highlight," Search Step Size [0.2]   := ");
writemem(0,9,20,Highlight," Precition Index  [0.001] := ");
writemem(0,10,20,Highlight," Max Iteration    [25]    := ");
writemem(0,12,37,Highlight,"Ready");
writemem(0,21,6,Reverse,"  Input Optimal Parameter  ");
cattrib(0,8,49,11,Reverse);
row = 8;
col = 49;
index = 1;
gotorc(row,col);
do {
    if(index != 4)
        showcur();
      else
        hidecur();
    p = getkey();
    writemem(0,20,49,Normal,"                        ");
    writemem(0,21,49,Normal,"                        ");
    if ( (p >= 0x30 && p<= 0x39) || (p==0x2E))
      {
        i = 0;
        do {
            if ( (p >= 0x30 && p<= 0x39) || (p==0x2E))
              {
                putch(p);
                cattrib(0,row,col,11,Reverse);
                mass[i] = p;
                i++;
                if(i>10)
                  {
                    i=0;
                    gotorc(row,col);
                  }
              }
            p = getkey();
            if (p == 0x08)
              {
                ii = col + i - 1;
                if (i!=0)
                  {
                    i--;
                    gotorc(row,ii);
```

```
                 putch(' ');
                 cattrib(0,row,col,11,Reverse);
                 gotorc(row,ii);
               }
           }
        } while( p != 0x0D);
    mass[i] = '\0';
    switch (index)
      {
        case 1 :
            {
            dx = atof(mass);
            break;
            }
        case 2 :
            {
            eps = atof(mass);
            break;
            }
        case 3 :
            {
            max = atoi(mass);
            break;
            }
      }
  }
switch(p)
  {
    case HOME_KEY:
    case PGUP_KEY:  {
            index = 1;
            cattrib(0,row,col,11,Highlight);
            row = 8;
            col = 49;
            cattrib(0,row,col,11,Reverse);
                gotorc(row,col);
            break;
            }
    case END_KEY:
    case PGDN_KEY:  {
            index = 4;
            cattrib(0,row,col,11,Highlight);
            col = 34;
            row = 12;
            cattrib(0,row,col,11,Reverse);
                gotorc(row,col);
            break;
            }
    case DOWN_KEY:  {
            cattrib(0,row,col,11,Highlight);
            index++;
            if(index > 4)
              {
                index = 1;
```

```
             row = 8;
             col = 49;
           }
           else if (index == 4)
             {
             row = 12;
             col = 34;
             }
             else



             row++;
        cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
        break;
        }
case UP_KEY:    {
        cattrib(0,row,col,11,Highlight);
        index--;
        if(index < 1)
          {
            index = 4;
            row = 12;
            col = 34;
          }
          else if (index == 3)
            {
                row = 10;
                col = 49;
            }
            else
              {
            row--;
              }
        cattrib(0,row,col,11,Reverse);
            gotorc(row,col);
        break;
        }
case '\r':
case '\n':  {
        if (index==4)
            index = 100;
          else
            {
               cattrib(0,row,col,11,Highlight);
               index++;
               if(index > 4)
                {
                   index = 1;
                   row = 8;
                   col = 49;
                }
                else if (index == 4)
                  {
                    row = 12;
```

```
                            col = 34;
                          }
                          else
                            {
                                row++;
                            }
                       cattrib(0,row,col,11,Reverse);
                       gotorc(row,col);
                    }
                break;
                }
        default:  {
                    writemem(0,20,49,Reverse,"   Keypress Error ! ");
                    writemem(0,21,49,ReverseBlink,"  TRY  AGAIN ! ");
                    break;
                }
      }
} while (index != 100);
if (pi != 5)



 {
    if( (status == 0) || (status == 1) )
        damp1(gain,tdelay,para1,para2);
    if( status == 2 )
        damp2(gain,tdelay,para1,para2);
    mvc = pconst(pid[0],pid[1],pid[2],eps);
 }
 else
   {
     if (status == 0 || status ==1 )
       {
          o = para1+para2;
          l = para1*para2;
          para1 = o;
          para2 = l;
          hconst(gain,tdelay,para1,para2,q);
       }
   }
 writemem(0,1,36,Highlight,"OUTPUT");
 movup(5,13,15,75,9,Normal);
 movup(20,22,3,37,3,Normal);
 writemem(0,5,25,Highlight,"   Parameter of Controller   ");
 if ( pi ==1 )
     writemem(0,7,23,Highlight," No Overshoot Performance Index ");
   else if (pi == 2)
       writemem(0,7,27,Highlight," ISE. Performance Index ");
     else if (pi == 3)
         writemem(0,7,27,Highlight," IAE. Performance Index ");
       else if (pi == 4)
           writemem(0,7,26,Highlight," ITAE. Performance Index ");
           else if (pi == 5)
                  writemem(0,7,26,Highlight," ISE. PI. Hurtz Method ");
 writemem(0,8,30,Highlight,"Iteration #  ");
 writemem(0,10,20,Normal,"Proportional Band (PB)  := ");
writemem(0,11,20,Normal,"Integral time (Ti)        := ");
writemem(0,12,20,Normal,"Derivetive time (Td)      := ");
writemem(0,21,4,Reverse,"  Output Controller Parameter  ");
writemem(0,8,42,Reverse,"  0  ");
writeva(0,10,47,Reverse," %7.3f  ",pid[1]);
writeva(0,11,47,Reverse," %7.3f  ",pid[0]);
writeva(0,12,47,Reverse," %7.3f  ",pid[2]);
writemem(0,14,20,Highlight,"Performance Index Value := ");
powell(pi,pid,&result,dx,eps,max,q);
movup(20,22,3,37,3,Normal);
writemem(0,5,25,Highlight,"      Optimum Parameters        ");
writemem(0,8,30,Normal,"                    ");
writemem(0,10,20,Normal,"Proportional Band (PB)  := ");
writemem(0,11,20,Normal,"Integral time (Ti)      := ");
writemem(0,12,20,Normal,"Derivetive time (Td)    := ");
writemem(0,21,4,Reverse,"  Optimum Controller Parameter  ");
writeva(0,10,47,Reverse," %7.3lf  ",pid[1]);
writeva(0,11,47,Reverse," %7.3lf  ",pid[0]);
writeva(0,12,47,Reverse," %7.3lf  ",pid[2]);
writemem(0,14,20,Highlight,"Performance Index Value := ");
writeva(0,14,47,Reverse,"%7.3lf   ",result);
sound(500);
delay(200);
sound(2000);
delay(500);
nosound();
delay(1000);
}


void        damp1(double k,double l,double p1,double p2)

{

extern  double  ts,a[],b[],c[],d[];

double      p,q,r,a1,a2,ap,aq,ar;
double      x,y,m,n,e;
double      ceta1,expo1,aa,j;
int         i;

ceta1 = sqrt(3.0)*ts/l;
expo1 = exp(-3.0*ts/l);
p = 6.9282*expo1*sin(ceta1);
q = 2.0*expo1*cos(ceta1);
r = exp(-6.0*ts/l);
x = k/(p1*p2);
y = k/(p1*(p1-p2));
m = k/(p2*(p1-p2));
n = exp(-1.0*p1*ts);
e = exp(-1.0*p2*ts);
a[0] = 1.0;
a[1] = -1.0*(p+q);
```

```
a[2] = p+r;
b[0] = 0.0;
b[1] = q;
b[2] = -r;
c[0] = x+y-m;
c[1] = m*(n+1)-x*(n+e)-y*(e+1);
c[2] = x*n*e + y*e - m*n;
d[0] = 0.0;
d[1] = n+e;
d[2] = -1.0*n*e;

}

void        damp2(double k,double l,double p1,double p2)

{

extern  double  ts,a[],b[],c[],d[];

double      p,q,r,a1,a2,ap,aq,ar;
double      ceta1,expo1,aa,j;
int         i;

ceta1 = sqrt(3.0)*ts/l;
expo1 = exp(-3.0*ts/l);
p = 6.9282*expo1*sin(ceta1);
q = 2.0*expo1*cos(ceta1);
r = exp(-6.0*ts/l);
ceta1 = -1.0*p1*ts/2.0;
expo1 = exp(ceta1);
ceta1 = p2 - p1*p1/4.0;
aa = sqrt(ceta1);
ceta1 = ts*aa;
ap = expo1*(cos(ceta1)+p1*sin(ceta1)/(2.0*aa));
aq = 2.0*expo1*cos(ceta1);
ar = exp(-1.0*p1*ts);
a1 = k*(ap-aq+1)/p2;
a2 = k*(ar-ap)/p2;
a[0] = 1.0;
a[1] = -1.0*(p+q);


a[2] = (p+r);
b[0] = 0.0;
b[1] =  q;
b[2] = -1.0*r;
c[0] = 0;
c[1] = a1;
c[2] = a2;
d[0] = 0;
d[1] = aq;
d[2] = -1.0*ar;

}
```

```
double      pconst(double ti,double pb,double td,double eps)

{

extern  double  ts,step,mvc,pvc,anc,bnc,cnc;
extern  double  maxdelaytime,maxsteadytime,presentsv;
extern  double  a[],b[],c[],d[],hilim,lowlim;
double          u[4],v[4],mv[10],o[10],en[10];
double          an[2],bn[2],cn[2];
double          kp,tf,t,bias,x,y,n,epps;
double          slope,sumx,sumy,sumxy,sumxx;
int             count,i,status,num;

/**************** initialize **********************/

t = 0;
status = 0;
count = 0;
bias = 0.5;
num = 10;
epps = 0.0001;
kp = 100/pb;
n = 8;
tf = td/n;
for(i=0;i<=1;i++)
  {
    o[i] = u[i] = mv[i] = v[i] = bias;
    an[i] = bn[i] = cn[i] = en[i] = 0.0;
  }
for(i=2;i<=3;i++)
  {
    o[i] = u[i] = mv[i] = v[i] = bias;
    en[i] = 0.0;
  }
for(i=4;i<=9;i++)
  {
    o[i] = mv[i] = bias;
    en[i] = 0.0;
  }

/*********** Find steady state of MV[] ************/

do {
    t = t + ts;
    count = count + 1;
    en[0] = u[0] - o[0];
    /******** Stop Cond. ********/
    if( t > maxdelaytime && count > 10 )
      {
        sumx = sumy = sumxy = sumxx = 0.0;
  for( i=0;i<=9;i++)
    {
      x = t - (i*ts);
      y = o[i];
      sumx = sumx + x;
      sumy = sumy + y;
      sumxy = sumxy + x*y;
      sumxx = sumxx + pow(x,2);
    }
  slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
  if( fabs(slope) < epps )
    {
      if ( fabs(en[0]) > eps )
        {
          if ( t >= 2*maxsteadytime )
              status = 1;
        }
        else
          status = 1;
    }
    else
      if ( t > 3*maxsteadytime )
          status = 1;
 }
/******** Controller ********/
an[0] = Kp*en[0];
bn[0] = bn[1] + an[0]*ts/ti;
cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])
    /(6.0*(tf+ts)));
mv[0] = an[0]+bn[0]-cn[0]+bias;
if(mv[0]>hilim)
    mv[0]=hilim;
if(mv[0]<lowlim)
    mv[0]=lowlim;
/********   Process   ********/
v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
/******** Iteration  ********/
an[1] = an[0];
bn[1] = bn[0];
cn[1] = cn[0];
 for(i=8;i>=3;i--)
   {
     mv[i+1] = mv[i];
     o[i+1] = o[i];
     en[i+1] = en[i];
   }
 for(i=2;i>=0;i--)
   {
     mv[i+1] = mv[i];
     o[i+1] = o[i];
     en[i+1] = en[i];
     u[i+1] = u[i];
     v[i+1] = v[i];
```

```
      }
    } while (status==0);
anc = an[0];
bnc = bn[0];
cnc = cn[0];
pvc = o[0];
return(mv[0]);
}



void        powell(pi,kid,v,dx,eps,max,q)

double      kid[],*v,dx,eps,q[];
int         pi,max;

{

extern  double  step;
double      xn[4][3],s[3][3];
double      x[3],yn[4],f[4],del[4],z[3];
double      y,g,h;
int         i,j,l,count;

/* initialize */

for ( i=0;i<=2;i++ )
  {
    xn[0][i] = x[i] = kid[i];
    for ( j=0;j<=2;j++ )
      {
        if ( i==j )
            s[i][j] = 1;
          else
            s[i][j] = 0;
      }
  }
switch (pi)
  {
    case 1 :
      {
        y = yn[0] = f[0] = nonshoot(xn[0][0],xn[0][1],xn[0][2],eps);
        for(i=0;i<=2;i++)
         {
           g = s[1][i];
           s[1][i]=s[0][i];
           s[0][i]=g;
         }
        break;
      }
    case 2 :
      {
        y = yn[0] = f[0] = ise(xn[0][0],xn[0][1],xn[0][2],eps);
        break;
      }
```

```
   case 3 :
     {
       y = yn[0] = f[0] = iae(xn[0][0],xn[0][1],xn[0][2],eps);
       break;
     }
   case 4 :
     {
       y = yn[0] = f[0] = itae(xn[0][0],xn[0][1],xn[0][2],eps);
         break;
     }
   case 5 :
     {
       isehurz(q,xn[0][1],xn[0][0],xn[0][2],&y);
       yn[0] = f[0] = y;
       break;
     }
   default :
       break;
 }


writeva(0,14,47,Reverse,"  %7.3lf ",f[0]);
count = 0;

/* END initialize */

do
  {
    count = count + 1;
    /* step #1 */
    for ( i=0;i<=2;i++ )
      {
        dscp(pi,x,&y,dx,s[i],eps,max,q);
        f[i+1] = y;
      }
    writemem(0,8,42,Normal,"       ");
    writemem(0,10,46,Normal,"            ");
    writemem(0,11,46,Normal,"            ");
    writemem(0,12,46,Normal,"            ");
    writemem(0,14,46,Normal,"            ");
    writeva(0,8,42,Reverse," %d ",count);
    writeva(0,10,47,Reverse," %7.3f  ",x[1]);
    writeva(0,11,47,Reverse," %7.3f  ",x[0]);
    writeva(0,12,47,Reverse," %7.3f  ",x[2]);
    writeva(0,14,47,Reverse," %7.3lf ",y);
    sound(1600);
    delay(500);
    nosound();

    /* test for stop */
    g = 0;
    for ( i=0;i<=2;i++ )
      {
        h = (x[i]-xn[0][i])*(x[i]-xn[0][i]);
    g = g + h;
  }
g = sqrt(g);
if ( g <= eps )
  {
    for ( i=0;i<=2;i++ )
        kid[i] = x[i];
    *v = y;
    break;
  }
/* step #2 */
for(i=0;i<=2;i++)
  {
    xn[1][i] = x[i];
    xn[2][i] = 2.0*xn[1][i] - xn[0][i];
    if ( xn[2][i] <= 0.0 )
       xn[2][i] = 0.00001;
    if ( xn[2][i] > 9999.0)
      xn[2][i] = 9999.0;
  }
yn[1] = f[3];
switch (pi)
  {
    case 1 :
      {
        yn[2] = nonshoot(xn[2][0],xn[2][1],xn[2][2],eps);
        break;
      }
    case 2 :
      {



        yn[2] = ise(xn[2][0],xn[2][1],xn[2][2],eps);
        break;
      }
    case 3 :
      {
        yn[2] = iae(xn[2][0],xn[2][1],xn[2][2],eps);
        break;
      }
    case 4 :
      {
        yn[2] = itae(xn[2][0],xn[2][1],xn[2][2],eps);
        break;
      }
    case 5 :
      {
        isehurz(q,xn[0][1],xn[0][0],xn[0][2],&yn[2]);
        break;
      }
    default :
        break;
  }
/* step #3 */
for(i=1;i<=3;i++)
```

```
  {
    del[i] = fabs(f[i-1] - f[i]);
  }
if ( del[1] < del [2] )
  {
    del[0] = del[2];
    for ( j=0;j<=2;j++ )
      {
        z[j] = s[1][j];
      }
    l = 1;
  }
 else
  {
    del[0] = del[1];
    for ( j=0;j<=2;j++ )
      {
        z[j] = s[0][j];
      }
    l = 0;
  }
if ( del[3] > del [0] )
  {
    del[0] = del[3];
    for ( j=0;j<=2;j++ )
      {
        z[j] = s[2][j];
      }
    l = 2;
  }
g = yn[0]-yn[1]-del[0];
h = pow(g,2);
g = yn[0] - yn[2];
g = pow(g,2);
if ( (yn[2] >= yn[0]) ||
   ( (yn[0]-2.0*yn[1]+yn[2])*h >= 0.5*del[0]*g ))
  {
    if ( yn[1] <= yn[2] )
      {
        for ( i=0;i<=2;i++ )


            xn[0][i] = x[i] = xn[1][i];
        y = yn[1];
      }
      else
        {
        for ( i=0;i<=2;i++ )
            xn[0][i] = x[i] = xn[2][i];
        y = yn[2];
        }
   }
  else
   {
     g = 0;
```

```
       for ( i=0;i<=2;i++ )
         {
           h = (xn[1][i]-xn[0][i])*(xn[1][i]-xn[0][i]);
           g = g + h;
         }
       g = sqrt(g);
       for ( i=0;i<=2;i++ )
         {
           z[i] = xn[1][i] - xn[0][i];
           z[i] = z[i]/g;
         }
       for ( i=1;i<=2;i++ )
         {
           if (i == 2)
               for ( j=0;j<=2;j++ )
                   s[i][j] = z[j];
             else
               for ( j=0;j<=2;j++ )
                   s[i][j] = s[i+1][j];
         }
        if ( yn[1] <= yn[2] )
           {
            for ( i=0;i<=2;i++ )
                xn[0][i] = x[i] = xn[1][i];
            y = yn[1];
           }
          else
            {
            for ( i=0;i<=2;i++ )
               xn[0][i] = x[i] = xn[2][i];
            y = yn[2];
            }
      }
   } while ( count < max );
if ( count == max )
  {
    if ( yn[1] <= yn[2] )
      {
        for ( i=0;i<=2;i++ )
            kid[i] = xn[1][i];
        *v = yn[1];
      }
     else
       {
        for ( i=0;i<=2;i++ )
            kid[i] = xn[2][i];
        *v = yn[2];
       }
   }
 }
```

```
void        dscp(pi,xo,yo,dx,di,eps,max,pq)

double      xo[],*yo,dx,di[],eps,pq[];
int         pi,max;

{

extern  double  step;
double          x[4][3],y[4],xz[3],a[3],b[3],c[3];
double          yz,z,q[2],w;
int             i,j,k,l,count,state;

state = 0;
for(i=0;i<=2;i++)
    x[0][i] = xo[i];
y[0] = *yo;
for(i=0;i<=2;i++)
  {
     x[1][i] = x[0][i] + dx*di[i];
     if( x[1][i] < 0 )
    x[1][i] = 0.00001;
     if(x[1][i] > 9999.0)
    x[1][i] = 9999.0;
  }
switch (pi)
  {
    case 1 :
      {
        y[1] = nonshoot(x[1][0],x[1][1],x[1][2],eps);
        break;
      }
    case 2 :
      {
        y[1] = ise(x[1][0],x[1][1],x[1][2],eps);
        break;
      }
    case 3 :
      {
        y[1] = iae(x[1][0],x[1][1],x[1][2],eps);
        break;
      }
    case 4 :
      {
        y[1] = itae(x[1][0],x[1][1],x[1][2],eps);
        break;
      }
    case 5 :
      {
        isehurz(pq,x[1][1],x[1][0],x[1][2],&y[1]);
        break;
      }
    default :
        break;
  }
```

```
if ( y[1] >= y[0] )
  {
    dx = -2.0*dx;
    for(i=0;i<=2;i++)
      {
        a[0] = x[0][i];
        x[0][i] = x[1][i];
        x[1][i] = a[0];



      }
    a[0] = y[0];
    y[0] = y[1];
    y[1] = a[0];
  }
 else
    dx = 2.0*dx;
for(i=0;i<=2;i++)
  {
    x[2][i] = x[1][i] + dx*di[i];
    if( x[2][i] < 0 )
    x[2][i] = 0.00001;
    if(x[2][i] > 9999.0)
    x[2][i] = 9999.0;
  }
switch (pi)
  {
    case 1 :
      {
        y[2] = nonshoot(x[2][0],x[2][1],x[2][2],eps);
        break;
      }
    case 2 :
      {
        y[2] = ise(x[2][0],x[2][1],x[2][2],eps);
        break;
      }
    case 3 :
      {
        y[2] = iae(x[2][0],x[2][1],x[2][2],eps);
        break;
      }
    case 4 :
      {
        y[2] = itae(x[2][0],x[2][1],x[2][2],eps);
        break;
      }
    case 5 :
      {
        isehurz(pq,x[2][1],x[2][0],x[2][2],&y[2]);
        break;
      }
    default :
        break;
  }
q[0] = 0;
q[1] = 0;
while ( y[2] <= y[1] && fabs(y[1]-y[2]) > 0.00001 && state == 0 )
  {
    for (i=0;i<=1;i++ )
       {
        y[i] = y[i+1];
        for(k=0;k<=2;k++)
            x[i][k] = x[i+1][k];
       }
    dx = 2.0*dx;
    for(i=0;i<=2;i++)
      {
        x[2][i] = x[1][i] + dx*di[i];
        if ( x[2][i] <= 0 )
        x[2][i] = 0.00001;
        if ( x[2][i] > 9999.0)
        x[2][i] = 9999.0;



      }
    for(i=0;i<=2;i++)
      {
        q[1] = q[1] + x[2][i];
      }
    if( q[1] == q[0])
        state = 1;
      else
        {
        q[0] = q[1];
        q[1] = 0;
        switch (pi)
         {
           case 1 :
            {
                y[2] = nonshoot(x[2][0],x[2][1],x[2][2],eps);
                break;
            }
           case 2 :
            {
                y[2] = ise(x[2][0],x[2][1],x[2][2],eps);
                break;
            }
           case 3 :
            {
                y[2] = iae(x[2][0],x[2][1],x[2][2],eps);
                break;
            }
           case 4 :
            {
                y[2] = itae(x[2][0],x[2][1],x[2][2],eps);
                break;
            }
            case 5 :
             {
                isehurz(pq,x[2][1],x[2][0],x[2][2],&y[2]);
                break;
             }
           default :
                break;
         }
        }
  }
for(i=0;i<=2;i++)
    x[3][i] = x[2][i];
y[3] = y[2];
for(i=0;i<=2;i++)
    x[2][i] = x[3][i] - 0.5*dx*di[i];
switch (pi)
  {
    case 1 :
      {
        y[2] = nonshoot(x[2][0],x[2][1],x[2][2],eps);
        break;
      }
    case 2 :
      {
        y[2] = ise(x[2][0],x[2][1],x[2][2],eps);
        break;
      }
    case 3 :
      {
        y[2] = iae(x[2][0],x[2][1],x[2][2],eps);


        break;
      }
    case 4 :
      {
        y[2] = itae(x[2][0],x[2][1],x[2][2],eps);
        break;
      }
    case 5 :
      {
        isehurz(pq,x[2][1],x[2][0],x[2][2],&y[2]);
        break;
      }
    default :
        break;
  }
 if ( y[1] >= y[2] )
     for (i=0;i<=2;i++)
       {
         for(k=0;k<=2;k++)
```

```
            x[i][k] = x[i+1][k];
        y[i] = y[i+1];
      }
if ( y[0] <= y[1] )
  {
    for(i=0;i<=2;i++)
        xz[i] = x[0][i];
    yz = y[0];
  }
 else
  {
    for(i=0;i<=2;i++)
        xz[i] = x[1][i];
    yz = y[1];
  }
if( yz >= y[2] )
  {
    for(i=0;i<=2;i++)
        xz[i] = x[2][i];
    yz = y[2];
  }
count = 0;
j = 1;
q[0] = 0;
q[1] = 0;
do
{
    count = count + 1;
    for(i=0;i<=2;i++)
      {
        if ( di[i] != 0 )
          {
            a[i] = pow(x[0][i],2.0);
            b[i] = pow(x[1][i],2.0);
            c[i] = pow(x[2][i],2.0);
            w = ((x[1][i]-x[2][i])*y[0] + (x[2][i]-x[0][i])*y[1] +
                (x[0][i]-x[1][i])*y[2] );
            if (w == 0)
                w = 0.00001;
            x[3][i] = 0.5*( (b[i]-c[i])*y[0] + (c[i]-a[i])*y[1] +
                      (a[i]-b[i])*y[2] )/w;
            if ( x[3][i]<=0 )
               x[3][i] = 0.00001;
            if (x[3][i] > 9999.0)



               x[3][i] = 9999.0;
           }
       }
     for(i=0;i<=2;i++)
       {
         q[1] = q[1] + x[3][i];
       }
```

```
if( q[1] == q[0])
  count = max;
 else
  {
  q[0] = q[1];
  q[1] = 0;
      switch (pi)
   {
     case 1 :
     {
        y[3] = nonshoot(x[3][0],x[3][1],x[3][2],eps);
        break;
     }
     case 2 :
     {
        y[3] = ise(x[3][0],x[3][1],x[3][2],eps);
        break;
     }
     case 3 :
     {
        y[3] = iae(x[3][0],x[3][1],x[3][2],eps);
        break;
     }
     case 4 :
     {
        y[3] = itae(x[3][0],x[3][1],x[3][2],eps);
        break;
     }
     case 5 :
      {
        isehurz(pq,x[3][1],x[3][0],x[3][2],&y[3]);
        break;
      }
     default :
    break;
   }
  }
 if ( fabs(yz - y[3]) < eps )
  {
   if ( yz < y[3] )
    {
     j = 0;
     for(i=0;i<=2;i++)
       xo[i]= xz[i];
     *yo = yz;
    }
   else
    {
     j = 0;
     for(i=0;i<=2;i++)
       xo[i]= x[3][i];
     *yo = y[3];
    }
  }
```

```
     else
      {


        for (i=0;i<=2;i++)
          {
            for (k=0;k<=2;k++)
              {
                if ( y[k] > y[k+1] )
                  {
                    z = y[k];
                    y[k] = y[k+1];
                    y[k+1] = z;
                    for(l=0;l<=2;l++)
                      {
                        z = x[k][l];
                        x[k][l] = x[k+1][l];
                        x[k+1][l] = z;
                      }
                  }
              }
          }
        for (i=0;i<=2;i++)
            xz[i] = x[0][i];
        yz = y[0];
      }
} while ( (j!=0) && (count!=max) );
if ( count == max )
  {
    for(i=0;i<=2;i++)
        xo[i]= x[0][i];
    *yo = y[0];
  }
}

double      iae(double ti,double pb,double td,double eps)

{

extern  double  ts,step,mvc,pvc,anc,bnc,cnc;
extern  double  maxdelaytime,maxsteadytime,presentsv;
extern  double  a[],b[],c[],d[],hilim,lowlim;
double          u[4],mv[10],v[4],o[10],en[10];
double          an[2],bn[2],cn[2];
double          kp,tf,t,er,inp,bias,x,y,n,epps;
double          slope,sumx,sumy,sumxy,sumxx;
int             count,i,status,num;

/**************** initialize *********************/

t = 0;
epps = 0.0001;
status = 0;
count = 0;
```

```
bias = 0.5;
er = 0.0;
num = 10;
kp = 100/pb;
n = 8.0;
tf = td/n;
for(i=0;i<=1;i++)
  {
    mv[i] = v[i] = mvc;
    o[i] = pvc;
    u[i] = presentsv/100;
    an[i] = anc;
    bn[i] = bnc;



    cn[i] = cnc;
    en[i] = 0.0;
  }
 for(i=2;i<=3;i++)
  {
    mv[i] = v[i] = mvc;
    o[i] = pvc;
    u[i] = presentsv/100;
    en[i] = 0.0;
  }
 for(i=4;i<=9;i++)
  {
    mv[i] = mvc;
    o[i] = pvc;
    en[i] = 0.0;
  }

 inp = u[0] + step;

 /*********** Find steady state of MV[] ************/

 do {
     t = t + ts;
     count = count + 1;
     en[0] = u[0] - o[0];
     /******** Stop Cond. ********/
     if( count > 10 && t > 3*maxdelaytime )
       {
         sumx = sumy = sumxy = sumxx = 0.0;
         for( i=0;i<=9;i++)
           {
             x = t-(i*ts);
             y = o[i];
             sumx = sumx + x;
             sumy = sumy + y;
             sumxy = sumxy + x*y;
             sumxx = sumxx + pow(x,2);
           }
```

```
        slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
        if( fabs(slope) < epps )
           {
              if ( fabs(en[0]) > eps )
                 {
                    if ( t >= 2*maxsteadytime )
                          status = 1;
                 }
                 else
                    status = 1;
           }
           else
              if ( t > 3*maxsteadytime )
                    status = 1;
      }
   /******** Controller ********/
   an[0] = kp*en[0];
   bn[0] = bn[1] + an[0]*ts/ti;
   cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])/
               (6.0*(tf+ts)));
   mv[0] = an[0]+bn[0]+cn[0]+bias;
   if(mv[0]>hilim)
         mv[0]=hilim;
   if(mv[0]<lowlim)
         mv[0]=lowlim;



    /********   Process   ********/
    v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
    o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
    /********  Iteration  ********/
    an[1] = an[0];
    bn[1] = bn[0];
    cn[1] = cn[0];
    for(i=8;i>=3;i--)
       {
          mv[i+1] = mv[i];
          o[i+1] = o[i];
          en[i+1] = en[i];
       }
    for(i=2;i>=0;i--)
       {
          mv[i+1] = mv[i];
          o[i+1] = o[i];
          en[i+1] = en[i];
          u[i+1] = u[i];
          v[i+1] = v[i];
       }
    } while (status==0);

/***************    Loop    **********************/

pvc = o[0];
mvc = mv[0];
```

```
t = 0;
count = 0;
status = 0;
do {
    t = t + ts;
    count = count + 1;
    u[0] = inp;
    en[0] = u[0] - o[0];
    /********    IAE     ********/
    er = er + fabs(en[0]);
    /******** Stop Cond. ********/
    if( t > maxdelaytime && count > 10 )
      {
        sumx = sumy = sumxy = sumxx = 0.0;
        for( i=0;i<=9;i++)
          {
            x = t-(i*ts);
            y = o[i];
            sumx = sumx + x;
            sumy = sumy + y;
            sumxy = sumxy + x*y;
            sumxx = sumxx + pow(x,2);
          }
        slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
        if( fabs(slope) < epps )
          {
            if ( fabs(en[0]) > eps )
              {
                if ( t >= 2*maxsteadytime )
                    status = 1;
              }
              else
                status = 1;
          }
          else
            if ( t > 3*maxsteadytime )


                status = 1;
      }
     /******** Controller ********/
     an[0] = kp*en[0];
     bn[0] = bn[1] + an[0]*ts/ti;
     cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])
             /(6.0*(tf+ts)));
     mv[0] = an[0]+bn[0]+cn[0]+bias;
     if(mv[0]>hilim)
         mv[0]=hilim;
     if(mv[0]<lowlim)
         mv[0]=lowlim;
     /********   Process   ********/
     v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
     o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
     /********  Iteration  ********/
    an[1] = an[0];
    bn[1] = bn[0];
    cn[1] = cn[0];
    for(i=8;i>=3;i--)
      {
        mv[i+1] = mv[i];
        o[i+1] = o[i];
        en[i+1] = en[i];
      }
    for(i=2;i>=0;i--)
      {
        mv[i+1] = mv[i];
        o[i+1] = o[i];
        en[i+1] = en[i];
        u[i+1] = u[i];
        v[i+1] = v[i];
      }
   } while (status==0);
er = er*ts;
return(er);
}

double      ise(double ti,double pb,double td,double eps)

{

extern  double  ts,step,mvc,pvc,anc,bnc,cnc;
extern  double  maxdelaytime,maxsteadytime,presentsv;
extern  double  a[],b[],c[],d[],hilim,lowlim;
double          u[4],mv[10],v[4],o[10],en[10];
double          an[2],bn[2],cn[2];
double          kp,tf,t,er,inp,bias,x,y,n,epps,err;
double          slope,sumx,sumy,sumxy,sumxx;
int             count,i,status,num;

/**************** initialize **********************/

t = 0;
epps = 0.0001;
status = 0;
count = 0;
bias = 0.5;
er = 0.0;
num = 10;
kp = 100/pb;
n = 8.0;
tf = td/n;



for(i=0;i<=1;i++)
  {
    mv[i] = v[i] = mvc;
    o[i] = pvc;
    u[i] = presentsv/100;
    an[i] = anc;
    bn[i] = bnc;
    cn[i] = cnc;
    en[i] = 0.0;
  }
for(i=2;i<=3;i++)
  {
    mv[i] = v[i] = mvc;
    o[i] = pvc;
    u[i] = presentsv/100;
    en[i] = 0.0;
  }
for(i=4;i<=9;i++)
  {
    mv[i] = mvc;
    o[i] = pvc;
    en[i] = 0.0;
  }

inp = u[0] + step;

/*********** Find steady state of MV[] ************/

do {
    t = t + ts;
    count = count + 1;
    en[0] = u[0] - o[0];
    /******** Stop Cond. ********/
    if( count > 10 && t > 3*maxdelaytime )
      {
        sumx = sumy = sumxy = sumxx = 0.0;
        for( i=0;i<=9;i++)
          {
            x = t-(i*ts);
            y = o[i];
            sumx = sumx + x;
            sumy = sumy + y;
            sumxy = sumxy + x*y;
            sumxx = sumxx + pow(x,2);
          }
        slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
        if( fabs(slope) < epps )
          {
            if ( fabs(en[0]) > eps )
              {
                if ( t >= 2*maxsteadytime )
                    status = 1;
              }
              else
                status = 1;
          }
          else
            if ( t > 3*maxsteadytime )
                status = 1;
      }
```

```
     /******** Controller ********/
     an[0] = kp*en[0];
     bn[0] = bn[1] + an[0]*ts/ti;



     cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])
             /(6.0*(tf+ts)));
     mv[0] = an[0]+bn[0]+cn[0]+bias;
     if(mv[0]>hilim)
         mv[0]=hilim;
     if(mv[0]<lowlim)
         mv[0]=lowlim;
     /********   Process   ********/
     v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
     o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
     /********  Iteration  ********/
     an[1] = an[0];
     bn[1] = bn[0];
     cn[1] = cn[0];
     for(i=8;i>=3;i--)
       {
         mv[i+1] = mv[i];
         o[i+1] = o[i];
         en[i+1] = en[i];
       }
     for(i=2;i>=0;i--)
       {
         mv[i+1] = mv[i];
         o[i+1] = o[i];
         en[i+1] = en[i];
         u[i+1] = u[i];
         v[i+1] = v[i];
       }
    } while (status==0);

/****************      Loop      **********************/

pvc = o[0];
mvc = mv[0];
t = 0;
count = 0;
status = 0;
do {
    t = t + ts;
    count = count + 1;
    u[0] = inp;
    en[0] = u[0] - o[0];
    err = en[0]*100.0;
    /********    ISE      ********/
    er = er + err*err;
    /******** Stop Cond. ********/
    if( t > maxdelaytime && count > 10 )
      {
        sumx = sumy = sumxy = sumxx = 0.0;
```

```
  for( i=0;i<=9;i++)
   {
    x = t-(i*ts);
    y = o[i];
    sumx = sumx + x;
    sumy = sumy + y;
    sumxy = sumxy + x*y;
    sumxx = sumxx + pow(x,2);
   }
  slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
  if( fabs(slope) < epps )
   {
    if ( fabs(en[0]) > eps )
     {


      if ( t >= 2*maxsteadytime )
        status = 1;
     }
     else
      status = 1;
   }
   else
    if ( t > 3*maxsteadytime )
      status = 1;
 }
/******** Controller ********/
an[0] = kp*en[0];
bn[0] = bn[1] + an[0]*ts/ti;
cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])
    /(6.0*(tf+ts)));
mv[0] = an[0]+bn[0]+cn[0]+bias;
if(mv[0]>hilim)
  mv[0]=hilim;
if(mv[0]<lowlim)
  mv[0]=lowlim;
/********  Process  ********/
v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
/********  Iteration  ********/
an[1] = an[0];
bn[1] = bn[0];
cn[1] = cn[0];
for(i=8;i>=3;i--)
 {
  mv[i+1] = mv[i];
  o[i+1] = o[i];
  en[i+1] = en[i];
 }
for(i=2;i>=0;i--)
 {
  mv[i+1] = mv[i];
  o[i+1] = o[i];
```

```
        en[i+1] = en[i];
        u[i+1] = u[i];
        v[i+1] = v[i];
      }
   } while (status==0);
er = er*ts;
return(er);
}

double      itae(double ti,double pb,double td,double eps)

{

extern  double  ts,step,mvc,pvc,anc,bnc,cnc;
extern  double  maxdelaytime,maxsteadytime,presentsv;
extern  double  a[],b[],c[],d[],hilim,lowlim;
double          u[4],mv[10],v[4],o[10],en[10];
double          an[2],bn[2],cn[2];
double          kp,tf,t,er,inp,bias,x,y,n,epps;
double          slope,sumx,sumy,sumxy,sumxx;
int             count,i,status,num;

/**************** initialize *********************/

t = 0;
epps = 0.0001;



status = 0;
count = 0;
bias = 0.5;
er = 0.0;
num = 10;
kp = 100/pb;
n = 8.0;
tf = td/n;
for(i=0;i<=1;i++)
   {
     mv[i] = v[i] = mvc;
     o[i] = pvc;
     u[i] = presentsv/100;
     an[i] = anc;
     bn[i] = bnc;
     cn[i] = cnc;
     en[i] = 0.0;
   }
 for(i=2;i<=3;i++)
   {
     mv[i] = v[i] = mvc;
     o[i] = pvc;
     u[i] = presentsv/100;
     en[i] = 0.0;
   }
```

```
for(i=4;i<=9;i++)
  {
    mv[i] = mvc;
    o[i] = pvc;
    en[i] = 0.0;
  }

inp = u[0] + step;

/*********** Find steady state of MV[] ************/

do {
    t = t + ts;
    count = count + 1;
    en[0] = u[0] - o[0];
    /******** Stop Cond. ********/
    if( count > 10 && t > 3*maxdelaytime )
      {
        sumx = sumy = sumxy = sumxx = 0.0;
        for( i=0;i<=9;i++)
          {
            x = t-(i*ts);
            y = o[i];
            sumx = sumx + x;
            sumy = sumy + y;
            sumxy = sumxy + x*y;
            sumxx = sumxx + pow(x,2);
          }
        slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
        if( fabs(slope) < epps )
          {
            if ( fabs(en[0]) > eps )
              {
                if ( t >= 2*maxsteadytime )
                    status = 1;
              }
              else
                status = 1;



          }
          else
            if ( t > 3*maxsteadytime )
                status = 1;
      }
      /******** Controller ********/
      an[0] = kp*en[0];
      bn[0] = bn[1] + an[0]*ts/ti;
      cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])
              /(6.0*(tf+ts)));
      mv[0] = an[0]+bn[0]+cn[0]+bias;
      if(mv[0]>hilim)
          mv[0]=hilim;
      if(mv[0]<lowlim)
          mv[0]=lowlim;
    /********   Process  ********/
    v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
    o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
    /********  Iteration  ********/
    an[1] = an[0];
    bn[1] = bn[0];
    cn[1] = cn[0];
    for(i=8;i>=3;i--)
      {
        mv[i+1] = mv[i];
        o[i+1] = o[i];
        en[i+1] = en[i];
      }
    for(i=2;i>=0;i--)
      {
        mv[i+1] = mv[i];
        o[i+1] = o[i];
        en[i+1] = en[i];
        u[i+1] = u[i];
        v[i+1] = v[i];
      }
   } while (status==0);

/****************    Loop    **********************/

pvc = o[0];
mvc = mv[0];
t = 0;
count = 0;
status = 0;
do {
    t = t + ts;
    count = count + 1;
    u[0] = inp;
    en[0] = u[0] - o[0];
    /********     ITAE     ********/
    er = er + t*fabs(en[0]);
    /******** Stop Cond. ********/
    if( t > maxdelaytime && count > 10 )
      {
        sumx = sumy = sumxy = sumxx = 0.0;
        for( i=0;i<=9;i++)
          {
            x = t-(i*ts);
            y = o[i];
            sumx = sumx + x;
            sumy = sumy + y;
            sumxy = sumxy + x*y;


            sumxx = sumxx + pow(x,2);
          }
        slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
   if( fabs(slope) < epps )
    {
     if ( fabs(en[0]) > eps )
      {
       if ( t >= 2*maxsteadytime )
         status = 1;
      }
      else
       status = 1;
    }
    else
     if ( t > 3*maxsteadytime )
       status = 1;
  }
 /******** Controller ********/
 an[0] = kp*en[0];
 bn[0] = bn[1] + an[0]*ts/ti;
 cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])
     /(6.0*(tf+ts)));
 mv[0] = an[0]+bn[0]+cn[0]+bias;
 if(mv[0]>hilim)
   mv[0]=hilim;
 if(mv[0]<lowlim)
   mv[0]=lowlim;
 /********   Process   ********/
 v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
 o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
 /********  Iteration  ********/
 an[1] = an[0];
 bn[1] = bn[0];
 cn[1] = cn[0];
 for(i=8;i>=3;i--)
  {
   mv[i+1] = mv[i];
   o[i+1] = o[i];
   en[i+1] = en[i];
  }
 for(i=2;i>=0;i--)
  {
   mv[i+1] = mv[i];
   o[i+1] = o[i];
   en[i+1] = en[i];
   u[i+1] = u[i];
   v[i+1] = v[i];
  }
 } while (status==0);
er = er*ts;
return(er);
}
```

```
double      nonshoot(double ti,double pb,double td,double eps)

{

extern  double  ts,step,mvc,pvc,anc,bnc,cnc;
extern  double  maxdelaytime,maxsteadytime,presentsv;
extern  double  a[],b[],c[],d[],hilim,lowlim;
double           u[4],mv[10],v[4],o[10],en[10];
double               an[2],bn[2],cn[2];
double          kp,tf,t,er,inp,bias,x,y,n,epps;



double               slope,sumx,sumy,sumxy,sumxx,weight;
int             count,i,status,num;

/**************** initialize **********************/

t = 0;
epps = 0.0001;
status = 0;
count = 0;
bias = 0.5;
er = 0.0;
num = 10;
kp = 100/pb;
n = 8.0;
tf = td/n;
for(i=0;i<=1;i++)
  {
    mv[i] = v[i] = mvc;
    o[i] = pvc;
    u[i] = presentsv/100;
    an[i] = anc;
    bn[i] = bnc;
    cn[i] = cnc;
    en[i] = 0.0;
  }
for(i=2;i<=3;i++)
  {
    mv[i] = v[i] = mvc;
    o[i] = pvc;
    u[i] = presentsv/100;
    en[i] = 0.0;
  }
for(i=4;i<=9;i++)
  {
    mv[i] = mvc;
    o[i] = pvc;
    en[i] = 0.0;
  }

inp = u[0] + step;
```

```
/*********** Find steady state of MV[] ************/

do {
    t = t + ts;
    count = count + 1;
    en[0] = u[0] - o[0];
    /******** Stop Cond. ********/
    if( count > 10 && t > 3*maxdelaytime )
      {
        sumx = sumy = sumxy = sumxx = 0.0;
        for( i=0;i<=9;i++)
          {
            x = t-(i*ts);
            y = o[i];
            sumx = sumx + x;
            sumy = sumy + y;
            sumxy = sumxy + x*y;
            sumxx = sumxx + pow(x,2);
          }
        slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
        if( fabs(slope) < epps )
          {



            if ( fabs(en[0]) > eps )
              {
                if ( t >= 2*maxsteadytime )
                    status = 1;
              }
              else
                status = 1;
          }
          else
            if ( t > 3*maxsteadytime )
                status = 1;
      }
    /******** Controller ********/
    an[0] = kp*en[0];
    bn[0] = bn[1] + an[0]*ts/ti;
    cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])
    /(6.0*(tf+ts)));
    mv[0] = an[0]+bn[0]+cn[0]+bias;
    if(mv[0]>hilim)
        mv[0]=hilim;
    if(mv[0]<lowlim)
        mv[0]=lowlim;
    /********   Process   ********/
    v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
    o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
    /********  Iteration  ********/
    an[1] = an[0];
    bn[1] = bn[0];
    cn[1] = cn[0];
    for(i=8;i>=3;i--)
      {
        mv[i+1] = mv[i];
        o[i+1] = o[i];
        en[i+1] = en[i];
      }
    for(i=2;i>=0;i--)
      {
        mv[i+1] = mv[i];
        o[i+1] = o[i];
        en[i+1] = en[i];
        u[i+1] = u[i];
        v[i+1] = v[i];
      }
   } while (status==0);

/****************     Loop     **********************/

pvc = o[0];
mvc = mv[0];
t = 0;
count = 0;
status = 0;
do {
    t = t + ts;
    count = count + 1;
    u[0] = inp;
    en[0] = u[0] - o[0];
    /********    non shoot      ********/
    if ( en[0] < 0 )
        weight = 1000.0;
      else
        weight = 0.0;
    er = er + t*fabs(en[0]) + weight*fabs(en[0]);


    /******** Stop Cond. ********/
    if( t > maxdelaytime && count > 10 )
      {
        sumx = sumy = sumxy = sumxx = 0.0;
        for( i=0;i<=9;i++)
          {
            x = t-(i*ts);
            y = o[i];
            sumx = sumx + x;
            sumy = sumy + y;
            sumxy = sumxy + x*y;
            sumxx = sumxx + pow(x,2);
          }
        slope = (num*sumxy - sumx*sumy)/(num*sumxx - pow(sumx,2.0));
        if( fabs(slope) < epps )
          {
            if ( fabs(en[0]) > eps )
              {
                if ( t >= 2*maxsteadytime )
                     status = 1;
              }
              else
                status = 1;
          }
        else
           if ( t > 3*maxsteadytime )
                status = 1;
     }
   /******** Controller ********/
   an[0] = kp*en[0];
   bn[0] = bn[1] + an[0]*ts/ti;
   cn[0] = (tf*cn[1] + kp*td*(o[0]-o[3]-3.0*o[2]+3.0*o[1])
           /(6.0*(tf+ts)));
   mv[0] = an[0]+bn[0]+cn[0]+bias;
   if(mv[0]>hilim)
       mv[0]=hilim;
   if(mv[0]<lowlim)
       mv[0]=lowlim;
   /********   Process  ********/
   v[0] = mv[0] + a[1]*mv[1] + a[2]*mv[2] + b[1]*v[1] + b[2]*v[2];
   o[0] = c[0]*v[0] + c[1]*v[1] + c[2]*v[2] + d[1]*o[1] + d[2]*o[2];
   /********  Iteration  ********/
   an[1] = an[0];
   bn[1] = bn[0];
   cn[1] = cn[0];
   for(i=8;i>=3;i--)
     {
       mv[i+1] = mv[i];
       o[i+1] = o[i];
       en[i+1] = en[i];
     }
    for(i=2;i>=0;i--)
     {
       mv[i+1] = mv[i];
       o[i+1] = o[i];
       en[i+1] = en[i];
       u[i+1] = u[i];
       v[i+1] = v[i];
     }
   } while (status==0);
er = er*ts;
return(er);
}



clr(void)

{
```

```
_AH = 6;
_AL = 25;
_CH = 0;
_CL = 0;
_DH = 24;
_DL = 79;
_BH = 7;
geninterrupt(0x10);
gotorc(0,0);

}

int gotorc ( int row, int col)

{

_AH = 2;
_BH = 0;
_DH = row;
_DL = col;
geninterrupt(0x10);

}

writemem(int page,int row,int col,int attribute,char *string)

{

register    int offset = (page<<12) + col + col + row*160;

     while(*string!='\0')
     {
     pokeb(monitor, offset++, *string++);
     pokeb(monitor, offset++, (char)attribute);
     }

}

writeva(int page, int row, int col, int attrib, char *msg, ...)

{

char      buf[256];
va_list   ap;
va_start  (ap,msg);
vsprintf  (buf,msg,ap);
writemem(page,row,col,attrib,buf);

}

int cattrib(int page,int row,int col,int lenght,int newattrib)

{
```

```
register    int offset=(page<<12)+col+col+row*160;
register    int i;

offset++;



for(i=0;i<lenght;i++)
  {
    pokeb(monitor,offset,(char)newattrib);
    offset+=2;
  }

}

int getkey()

{

register    int c;

_AH =0;
geninterrupt(0x16);
c = _AX & 0x00FF;
if(c==0)  c=0x100+(_AX>>8);
return c;

}

movup(int rowb,int rowe,int colb,int cole,int line,int attrib)

{

_AH = 6;
_AL = line;
_CH = rowb;
_CL = colb;
_DH = rowe;
_DL = cole;
_BH = attrib;
geninterrupt(0x10);
gotorc(rowe-line+1,colb);

}

movdn(int rowb,int rowe,int colb,int cole,int line,int attrib)

{

_AH = 6;
_AL = line;
_CH = rowb;
_CL = colb;
_DH = rowe;
_DL = cole;
```

```
_BH = attrib;
geninterrupt(0x10);
gotorc(rowe-line+1,colb);

}

int showcur(void)

{

_AH = 1;
_CH = 12;
_CL = 13;
geninterrupt(0x10);




}

int hidecur(void)

{

_AH = 1;
_CH = 14;
_CL = 14;
geninterrupt(0x10);

}

int     selectmenu(int startrow,int startcol,int lenght,int step,
        int number)

{

int     index,p;
int     row,col;

index = 1;
row = startrow;
col = startcol;
cattrib(0,row,col,lenght,Reverse);
do {
    p = getkey();
    writemem(0,20,49,Normal,"                      ");
    writemem(0,21,49,Normal,"                      ");
    switch(p)
      {
        case HOME_KEY:
        case PGUP_KEY:  {
                index = 1;
                cattrib(0,row,col,lenght,Highlight);
                row = startrow;
                cattrib(0,row,col,lenght,Reverse);
                break;
                }
        case END_KEY:
        case PGDN_KEY:  {
                index = number;
                cattrib(0,row,col,lenght,Highlight);
                row = startrow + (number-1)*step;
                cattrib(0,row,col,lenght,Reverse);
                break;
                }
        case DOWN_KEY:  {
                cattrib(0,row,col,lenght,Highlight);
                index++;
                row = row + step;
                if( index > number )
                  {
                    index = 1;
                    row = startrow;
                  }
                cattrib(0,row,col,lenght,Reverse);
                break;
                }
        case UP_KEY:    {
                cattrib(0,row,col,lenght,Highlight);
                index--;
                row = row - step;


                if(index < 1)
                  {
                    index = number;
                    row = startrow + (number-1)*step;
                  }
                cattrib(0,row,col,lenght,Reverse);
                break;
                }
        case '\r':
        case '\n':
                {
                row = 1000;
                break;
                }
        default  :
                {
                writemem(0,20,49,Reverse,"   Keypress Error !   ");
                writemem(0,21,49,ReverseBlink,"     TRY  AGAIN !  ");
                break;
                }
      }
} while (row != 1000);
return(index);

}
```

```
void    logo(void)

{

int          i;

/******************      LOGO      ******************/

clr();
cattrib(0,0,0,80,Reverse);
cattrib(0,1,0,80,Reverse);
cattrib(0,2,0,80,Reverse);
for(i=3;i<=21;i++)
  {
    cattrib(0,i,0,16,Reverse);
    cattrib(0,i,64,16,Reverse);
   }
cattrib(0,22,0,80,Reverse);
cattrib(0,23,0,80,Reverse);
cattrib(0,24,0,80,Reverse);
writemem(0,6,24,Highlight,"Optimum Tuning of PID Controller");
writemem(0,9,39,Normal,"By");
writemem(0,11,31,Normal,"Pisanu  Kijpaitulaya");
writemem(0,13,30,Normal,"Master Degree Student");
writemem(0,14,28,Normal,"Chulalongkorn University");
writemem(0,17,20,Highlight,"Adviser :- ");
writemem(0,19,28,Highlight,"Dr. Somboon  Chongchaikij");
delay(5000);

}

void            drawbox(void)

{

int          i;


clrscr();
writemem(0,0,0,Normal,"ฬ");
for(i=1;i<=78;i++)
    writemem(0,0,i,Normal,"ภ");
writemem(0,0,79,Normal,"ฝ");
writemem(0,1,0,Normal,"ผ");
writemem(0,1,79,Normal,"ฝ");
writemem(0,2,0,Normal,"ส");
writemem(0,2,79,Normal,"ซ");
for(i=1;i<=78;i++)
    writemem(0,2,i,Normal,"ว");
for(i=3;i<=15;i++)
  {
    writemem(0,i,0,Normal,"ผ");
    writemem(0,i,79,Normal,"ผ");
  }
writemem(0,16,0,Normal,"ะ");
for(i=1;i<=78;i++)
    writemem(0,16,i,Normal,"ภ");
writemem(0,16,39,Normal,"ฮ");
writemem(0,16,79,Normal,"ป");
writemem(0,17,0,Normal,"ผ");
writemem(0,17,39,Normal,"ผ");
writemem(0,17,79,Normal,"ผ");
writemem(0,18,0,Normal,"ส");
writemem(0,18,79,Normal,"ธ");
for(i=1;i<=78;i++)
    writemem(0,18,i,Normal,"ว");
writemem(0,18,39,Normal,"ฯ");
for(i=19;i<=23;i++)
  {
    writemem(0,i,0,Normal,"ผ");
    writemem(0,i,39,Normal,"ผ");
    writemem(0,i,79,Normal,"ผ");
  }
writemem(0,24,0,Normal,"ห");
for(i=1;i<=78;i++)
    writemem(0,24,i,Normal,"ภ");
writemem(0,24,79,Normal,"ฟ");
writemem(0,24,39,Normal,"อ");
writemem(0,1,37,Highlight,"INPUT");
writemem(0,17,15,Highlight,"MESSAGE");
writemem(0,17,52,Highlight,"ERROR MESSAGE");

}
steady.asm

              dosseg

              .model small

              extrn      _slopetes:PROC   ;

              .data

              count      db    0bh        ;
              extrn      _otimes:word     ;
              extrn      _otimem:word     ;
              extrn      _ntimes:word     ;
              extrn      _ntimem:word     ;
              extrn      _chanal:word     ;
              extrn      _point:word      ;
              extrn      _number:word     ;



              extrn      _num:word        ;
              extrn      _interval:word   ;
              extrn      _errorcode:word  ;
              extrn      _opt:word        ;
```

```
                .code

                PUBLIC    _steady

_steady         proc  near
                push  bp
                push  si
                push  di
                mov   _errorcode,00h
                mov   ah,2ch
                int   21h
                mov   cx,0000h
                mov   cl,dl
                mov   _otimem,cx
                mov   cl,dh
                mov   _otimes,cx
_begin      :   mov   ah,2ch
                int   21h
                mov   cx,0000h
                mov   cl,dl
                mov   _ntimem,cx
                mov   cl,dh
                mov   _ntimes,cx
                cmp   _otimes,cx
                jz    _nadjust
_adjust     :   mov   ax,_otimem
                mov   bl,64h
                sub   bl,al
                mov   ax,_ntimem
                add   al,bl
                cmp   ax,_interval
                jae   _atd
                jmp   _begin
_nadjust    :   mov   bx,_ntimem
                sub   bx,_otimem
                cmp   bx,_interval
                jb    _begin
_atd        :   mov   ax,_ntimes
                mov   _otimes,ax
                mov   ax,_ntimem
                mov   _otimem,ax
                add   _number,02h
                mov   di,_number
                cmp   di,_num
                jne   _inp
                mov   _errorcode,0ffffh
                pop   di
                pop   si
                pop   bp
                ret
_inp        :   mov   count,0bh
                mov   dx,0388h
                mov   ax,_chanal
                out   dx,ax
```

```
                   mov   ax,1800h
                   push  ax
                   mov   bx,0800h
_agn          :    mov   dx,0380h


                   mov   al,bl
                   out   dx,al
                   inc   dl
                   mov   al,bh
                   out   dx,al
                   mov   cx,0010h
_wt1          :    loop  _wt1
                   mov   dx,0389h
                   in    al,dx
                   and   al,01h
                   jnz   _anx
                   pop   ax
                   sar   ax,1
                   or    bx,ax
                   push  ax
                   cmp   count,0
                   je    _ext
                   dec   count
                   jmp   _agn
_anx          :    pop   ax
                   sar   ax,1
                   xor   bx,ax
                   push  ax
                   cmp   count,0
                   je    _ext
                   dec   count
                   jmp   _agn
_ext          :    pop   ax
                   mov   ax,bx
                   mov   bx,_point
                   mov   [bx+di],ax
                   call  _slopetes
                   cmp   _opt,0
                   jnz   _last
                   jmp   _begin
_last         :    pop   di
                   pop   si
                   pop   bp
                   ret
_steady            endp
                   end
```

testmag.asm

```
                   dosseg

                   .model small
                   extrn      _slopetes:PROC    ;

                   .data

                   count      db     0bh          ;
                   cond       dw     0000h        ;
                   extrn      _otimes:word        ;
                   extrn      _otimem:word        ;
                   extrn      _ntimes:word        ;
                   extrn      _ntimem:word        ;
                   extrn      _chanal:word        ;
                   extrn      _point:word         ;
                   extrn      _number:word        ;
                   extrn      _num:word           ;
                   extrn      _interval:word      ;



                   extrn      _errorcode:word     ;
                   extrn      _opt:word           ;

                   .code

                   PUBLIC     _testmag

_testmag           proc    near
                   push    bp
                   push    si
                   push    di
                   mov     bp,sp
                   mov     dx,[bp+14]
                   mov     cond,dx
                   mov     dx,[bp+8]
                   xor     dh,dh
                   shl     dl,1
                   add     dx,0380h
                   mov     ax,[bp+10]
                   out     dx,al
                   inc     dx
                   mov     al,ah
                   out     dx,al
                   mov     _errorcode,00h
                   mov     ah,2ch
                   int     21h
                   mov     cx,0000h
                   mov     cl,dl
                   mov     _otimem,cx
                   mov     cl,dh
                   mov     _otimes,cx
_begin          :  mov     ah,2ch
                   int     21h
                   mov     cx,0000h
                   mov     cl,dl
                   mov     _ntimem,cx
```

```
                mov   cl,dh
                mov   _ntimes,cx
                cmp   _otimes,cx
                jz    _nadjust
_adjust      :  mov   ax,_otimem
                mov   bl,64h
                sub   bl,al
                mov   ax,_ntimem
                add   al,bl
                cmp   ax,_interval
                jae   _atd
                jmp   _begin
_nadjust     :  mov   bx,_ntimem
                sub   bx,_otimem
                cmp   bx,_interval
                jb    _begin
_atd         :  mov   ax,_ntimes
                mov   _otimes,ax
                mov   ax,_ntimem
                mov   _otimem,ax
                add   _number,02h
                mov   di,_number
                cmp   di,_num
                jne   _inp
                mov   _errorcode,0ffffh
                pop   di
                pop   si


                pop   bp
                ret
_inp         :  mov   count,0bh
                mov   dx,0388h
                mov   ax,_chanal
                out   dx,ax
                mov   ax,1800h
                push  ax
                mov   bx,0800h
_agn         :  mov   dx,0380h
                mov   al,bl
                out   dx,al
                inc   dl
                mov   al,bh
                out   dx,al
                mov   cx,0010h
_wt1         :  loop  _wt1
                mov   dx,0389h
                in    al,dx
                and   al,01h
                jnz   _anx
                pop   ax
                sar   ax,1
                or    bx,ax
                push  ax
```

```
                    cmp   count,0
                    je    _ext
                    dec   count
                    jmp   _agn
_anx           :    pop   ax
                    sar   ax,1
                    xor   bx,ax
                    push  ax
                    cmp   count,0
                    je    _ext
                    dec   count
                    jmp   _agn
_ext           :    pop   ax
                    mov   ax,bx
                    mov   bx,_point
                    mov   [bx+di],ax
                    cmp   ax,cond
                    jae   _last
                  mov   cx,[bp+16]
                    cmp   cx,_number
                    jb    _maxtime
                    jmp   _begin
_last          :    mov   _opt,1
_maxtime       :    mov    dx,[bp+8]
                    xor    dh,dh
                    shl    dl,1
                    add    dx,0380h
                    mov    ax,[bp+12]
                    out    dx,al
                    inc    dx
                    mov    al,ah
                    out    dx,al
                    pop   di
                    pop   si
                    pop   bp
                    ret
_testmag            endp
                    end
```

keepdata.asm

```
                    dosseg

                    .model small

                    extrn     _slopetes:PROC    ;

                    .data

                    count     db    0bh         ;
```

```
                time       dw    0000h        ;
                cond       dw    0000h        ;
                extrn      _otimes:word       ;
                extrn      _otimem:word       ;
                extrn      _ntimes:word       ;
                extrn      _ntimem:word       ;
                extrn      _chanal:word       ;
                extrn      _point:word        ;
                extrn      _number:word       ;
                extrn      _num:word          ;
                extrn      _interval:word     ;
                extrn      _errorcode:word    ;
                extrn      _opt:word          ;

                .code

                PUBLIC     _keepdata

_keepdata       proc    near
                push    bp
                push    si
                push    di
                mov     bp,sp
                mov     dx,[bp+8]
                xor     dh,dh
                shl     dl,1
                add     dx,0380h
                mov     ax,[bp+10]
                out     dx,al
                inc     dx
                mov     al,ah
                out     dx,al
                mov    _errorcode,00h
                mov    ah,2ch
                int    21h
                mov    cx,0000h
                mov    cl,dl
                mov    _otimem,cx
                mov    cl,dh
                mov    _otimes,cx
_begin       :  mov    ah,2ch
                int    21h
                mov    cx,0000h
                mov    cl,dl
                mov    _ntimem,cx
                mov    cl,dh
                mov    _ntimes,cx
                cmp    _otimes,cx
                jz     _nadjust
_adjust      :  mov    ax,_otimem
                mov    bl,64h


                sub    bl,al
                mov   ax,_ntimem
                add   al,bl
                cmp   ax,_interval
                jae   _atd
                jmp   _begin
_nadjust    :   mov   bx,_ntimem
                sub   bx,_otimem
                cmp   bx,_interval
                jb    _begin
_atd        :   mov   ax,_ntimes
                mov   _otimes,ax
                mov   ax,_ntimem
                mov   _otimem,ax
                add   _number,02h
                mov   di,_number
                cmp   di,_num
                jne   _inp
                mov   _errorcode,0ffffh
                pop   di
                pop   si
                pop   bp
                ret
_inp        :   mov   count,0bh
                mov   dx,0388h
                mov   ax,_chanal
                out   dx,ax
                mov   ax,1800h
                push  ax
                mov   bx,0800h
_agn        :   mov   dx,0380h
                mov   al,bl
                out   dx,al
                inc   dl
                mov   al,bh
                out   dx,al
                mov   cx,0010h
_wt1        :   loop  _wt1
                mov   dx,0389h
                in    al,dx
                and   al,01h
                jnz   _anx
                pop   ax
                sar   ax,1
                or    bx,ax
                push  ax
                cmp   count,0
                je    _ext
                dec   count
                jmp   _agn
_anx        :   pop   ax
                sar   ax,1
                xor   bx,ax
                push  ax
```

```
                 cmp    count,0
                 je     _ext
                 dec    count
                 jmp    _agn
_ext         :   pop    ax
                 mov    ax,bx
                 mov    bx,_point
                 mov    [bx+di],ax
                 call   _slopetes


                 cmp    _opt,1
                 je     _last
                 jmp    _begin
_last        :   mov     dx,[bp+8]
                 xor     dh,dh
                 shl     dl,1
                 add     dx,0380h
                 mov     ax,[bp+12]
                 out     dx,al
                 inc     dx
                 mov     al,ah
                 out     dx,al
                 pop    di
                 pop    si
                 pop    bp
                 ret
_keepdata        endp
                 end

output.asm

                 dosseg
                 .model small

                 .data

                 .code

                 PUBLIC _output

_output          proc   near
                 push   bp
                 push   si
                 push   di
                 mov    bp,sp
                 mov    dx,[bp+8]
                 xor    dh,dh
                 shl    dl,1
                 add    dx,0380h
                 mov    ax,[bp+10]
                 out    dx,al
                 inc    dx
```

```
                mov     al,ah
                out     dx,al
                pop     di
                pop     si
                pop     bp
                ret
_output         endp
                end
```

ประวัติผู้เขียน

นายพิษณุ กิจไพฑูรย์ เกิดเมื่อวันที่ 1 ตุลาคม พ.ศ. 2507 ที่กรุงเทพมหานคร สำเร็จการศึกษาขั้นปริญญาบัณฑิต ในสาขาวิศวกรรมไฟฟ้า จากคณะวิศวกรรมศาสตร์ มหาวิทยาลัยขอนแก่น เมื่อปีการศึกษา 2529.