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Design and analysis of a microprocessor based stepping motor control system.

Shih-Tein Hsu

DESIGN AND ANALYSIS OF
A MICROPROCESSOR BASED
STEPPING MOTOR CONTROL SYSTEM

by

Shih-Tein HSU

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Professor in Charge

Chairman of Department

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CONTENTS

ABSTRACT

An INTEL MCS-85 kit with 8085-CPU is used to control a SUPERIOR SLO-SYN55 stepping motor , while a mechanical shaft encoder provides a (gray-coded binary number) feedback signal. Here the normal hardware translator is replaced by a software sequencer, and a nonlinear deadbeat controller is considered. The plant, composed of a flexible,nonlinear shaft and a rigid inertia with friction,is considered as a 4th order nonlinear system with deadzone and pure delay. Parameters are identified by an experimental process, which is duplicated by a simulation program. There are so many problems raised during the study, on both hardware and software, that limit the accomplishment of this research. At the later stage of the project the author finds that the fixed-point algorithm is not suitable for the project. Since the author does not want to change our hardware, a floating point algorithm is written by the author. From this study the author gained information and experience which would contribute to other research.

CHAPTER 1

INTRODUCTION

Today the uses of digital computers (in particular microprocessors) for control implementations has increased significantly. In addition, stepping motors have been widely used in a variety of position and velocity DDC (direct digital control)application, like computer capstan drivers, numerical-controlled machines, solar-tracking devices, etc. Undoubtedly, because of the low cost of microprocessors, new areas of application for controlling stepping motors will become more feasible.

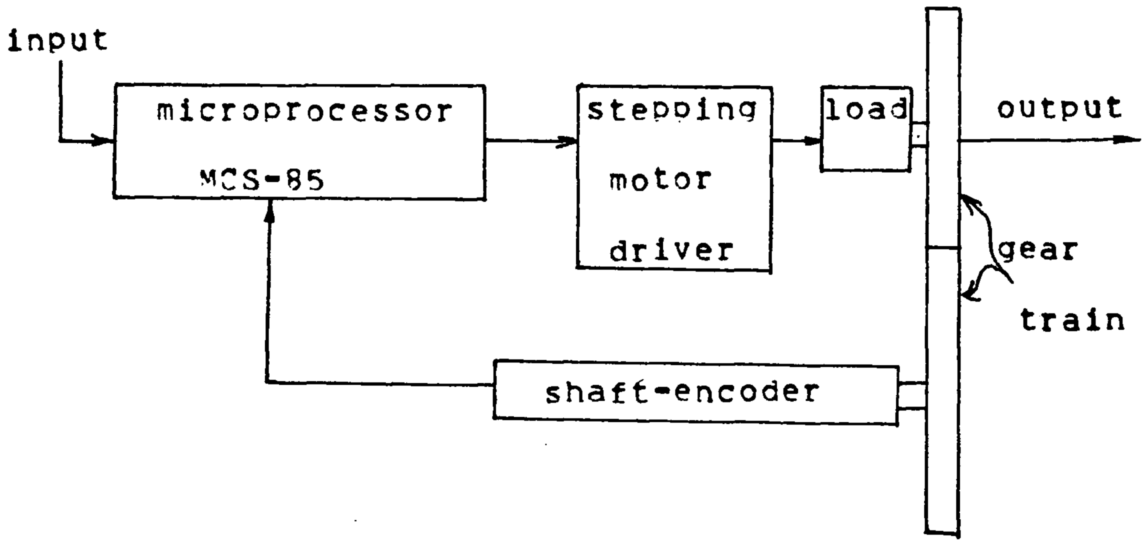
The object of this thesis is to attempt to design and analyze such an application of microprocessors, from the viewpoint of the whole system, instead of only single-step optimization as in most of the research on this topics. Here the system is lumped into a sampled-data control system with a pure delay and deadzone nonlinearity.

The control criterion is to gain finite-time settling control, i.e.,dead beat control. To achieve this goal, the author uses a VARIABLE-GAIN concept to solve this nonlinear problem.

CHAPTER 2

SYSTEM DESCRIPTION

The system is shown in the following figure:



From the figure the author divided the system into four parts:

1) plant or load which is the object that the author would like to control.

2) microprocessor (INTEL8085 in MCS85 kit) which has been used to accept and send I/O signals

and feedback signals to control the speed and direction of the stepping motor.

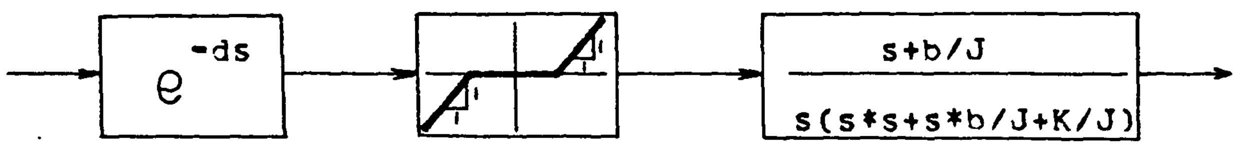
3) stepping motor which can be treated as an A/D converter.

4) shaft encoder;a mechanical encoder has been used to convert the position of the plant into a digital signal.

We will see these elements in more detail in the following sections.

2.1 PLANT

A PIC development kit is available; in addition , a thick synthetic rubber hose is used as a flexible shaft to examine some nonlinearities. After some experiments and computer simulations,the author built a model using a block diagram as follows:



d=0.04sec; deadzone=±2.2 rad/sec ; B=0.004692Nms/rad

J=0.000439924 Kg-m2;K=10.213Nmm/rad;s is Laplace-operator

2.2 MICROPROCESSOR

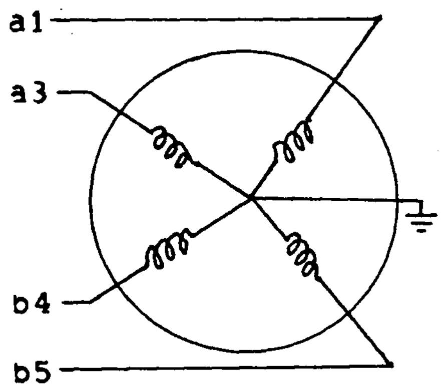
The INTEL MCS85 with 8085CPU has been expanded to achieve our requirements.INTEL8085 is a familiar chip; here the author lists some typical capacities:

1) 8-bit Byte structure;
2) 4 8-bit I/O ports;
3) 2 6-bit I/O ports;
4) 1.3 microsec per instruction cycle;
5) a BURR-BROWN MP20 A/D converter has been added to improve application ability;
6) series I/O is available;
7) memory size can be expanded to 64K, the project needs 2K bytes in EPROM(erasible programable read only memory),and 256 bytes in RAM(random access memory).

The microprocessor receives input commands and feedback signals, stores the control parameters,and saves previous positions and control values. With this information,the CPU can calculate new control values, and send out signals to drive the stepping motor with the required speed and direction through a CW-CCW sequencer program.

2.3 STEPPING MOTOR

The SUPERIOR SLOSYN-50 stepping motor is a bifilar winding motor, with 200 steps/ cycle. To move the motor, two of four windings should be energized. The energized sequences are shown as below:



cw ↓

a1	b4	a3	b5	code
1	0	0	1	9
1	1	0	0	c
0	1	1	0	6
0	0	1	1	3

↑ ccw

We are only interested in closed loop slew-mode motion of stepping motor. Here the author considers the stepping motor as an A/D converter, neglects all quantization, single-step phenomena,and slew effects. Also the author treat the stepping motor as a linear device.

2.4 SHAFT ENCODER

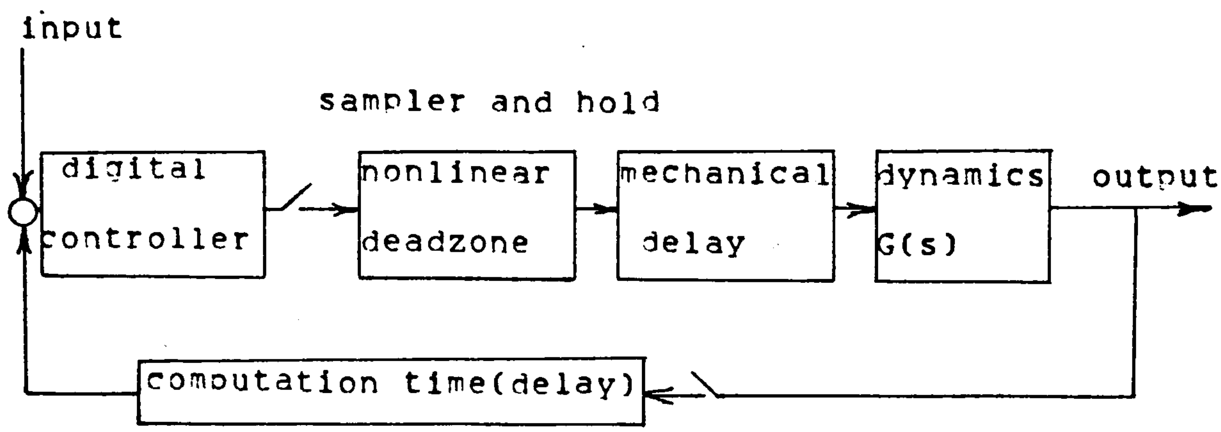
The mechanical shaft encoder has 256 positions (8-bits) and represents the binary value in gray-binary code, thus only one bit is changed when shifting one step in either direction. Here a brief Boolean-representation of

Gray-to-Binary conversion is given:

$$Bn(N)=[Bn(N+1)*-Gy(n)]+[-Bn(n+1)*Gv(n)]$$

Here Bn(n) is the nth bit of the natural binary code; and Gy(n) is the nth bit of the gray binary code.

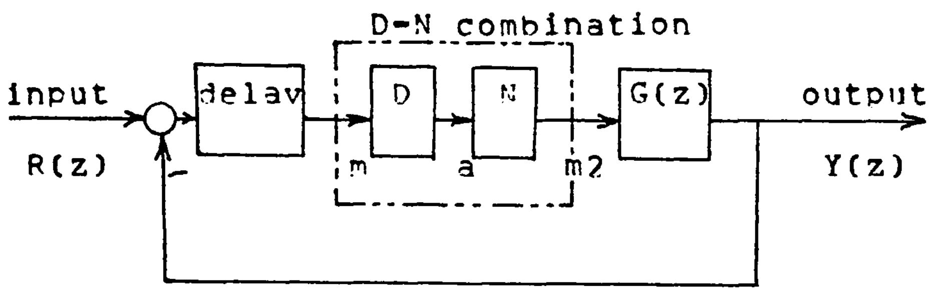
From these four elements the author built a mathematical model shown in the following block diagram:



CHAPTER 3

CONTROL ALGORITHM-DEADBEAT

Consider the lumped nolinear discretized model again:



The mechanical delay is lumped with the computation time,t, as a combination delay,to get the system more accessible. The big block enclosing D-block and N-block means that the digital controller and nonlinearity are considered as a nonlinear block--a variable gain unit. The combinational delay is denoted as "Ttou", and the sample period denoted as "Tsampleperiod". The dynamic block is digitized for both interval Ttou and Tsampleperiod-Ttou. The delay is moved to the front of the digital controller. Then, based on the paper by professor Tou (1961), an algorithm is developed.

First, the author derived two recursive equations:

$$\underline{V}(N+)=\underline{ZETA}(N)*\ \underline{V}(N)$$

$$\underline{V}(N+1)=\underline{PHI}(N+1)*\ \underline{V}(N+)$$

where $\underline{V}(N)'$=[R $\underline{Y}$ M], R is input command, $\underline{Y}$ is state vector, M is digital controller input value, (i.e.difference between input-command and true feedback signal). " ' " means transpose matrix.

time N means time N*Tsampleperiod

time N+ means time N*Tsampleperiod+delay Ttou

time N+1 means time (N+1)*Tsampleperiod

$\underline{ZETA}$(N) is transition matrix between time N to N+

$\underline{PHI}$(N+1) is transition matrix between time N+ to N+1,

also, $$\underline{PHI}(N+1)=\begin{pmatrix} 1 & 0 & 0 \\ 0 & \underline{A} & \underline{B}(N) \\ 0 & 0 & 1 \end{pmatrix}$$

and, $$\underline{ZETA}(N) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \underline{ALFA} & \underline{BETA}(N) \\ 1 & -1 & 0 \end{pmatrix}$$

here $\underline{A}$ and $\underline{ALFA}$ are transition matrices for the homogeneous differential equation DX/ DT= A1*X for time intervals N+ to N+1, and N to N+. B and BETA are transfer matrices corresponding to the convolution integral of inhomo.diff.equ. DX /DT =A1 * X + B1*U for time intervals N+ to N+1, and N to N+;

The object of deadbeat control is that: after K Tsampleperiod, the system will reach the given command and the elements of Y will be:

M=0., Y=[R,0 ....],i.e.,for position control system:

1) step position input, Y =(R, 0....)

2) ramp input, Y=(R, constant, 0...)

3) parabolic input, Y=(R, dR/dt, constant, 0.....)

Here the author only considered step input, and hoped the step response at the 4th Tsampleperiod reached the input command.

By the use of the VARIABLE-GAIN concept, in any sample interval from time N to N+1 , the D-N COMBINATION nonlinear block may be treated as a unit of variable gain Kn, or, K(N) which will be a different value for different sampling interval. It also depends on the characteristics of the nonlinear element N. While the input to the D-N combination block is called M, the author also calls the output of the D-N unit M2, which is related to M by

$$M2(N+)=K*M(N+)\quad ,$$

noting that M2 corresponds to "U" in

$$D\underline{X}/DT=\underline{A1}*\underline{X}+\underline{B1}*U$$

Now the author can see that the transfer matrices B and BETA are the product of the convolution integral multiplied by a corresponding K(N), separately.

After PHI and ZETA have been evaluated , some nonlinear techniques can be used to solve the recursive problem for K0, K1, K2, K3 , such that the deadbeat control can be achieved. Two subroutines were used from the IMSL library ZSYSTM and ZSERCH, to get these values. Since the simultaneous nonlinear equations are fourth order fully coupled nonlinear equations, i.e.,in the form of

$$F1(K)=(A+K1)*(A2+K2)*(A3+K3)*(A4*K4)$$

etc.

the computation process is very unstable and sensitive. Only through experimental inspection can the author know whether it is right or wrong. The equation is apppended at the end of this thesis for reference.

After the nonlinear gain have been calculated, it's not hard to follow the original concept of the VARIABLE-GAIN to calculate the output of the digital controller either analytically or graphically, Therefore the required digital controller for deadbeat response is given by:

$$D(Z)=\frac{A(0)+A(1)*Z(-1)+A(2)*Z(-2)+A(3)*Z(-3)}{M(0)+M(1)*Z(-1)+M(2)*Z(-2)+M(3)*Z(-3)}$$

Z(-1) means -1 power of Z-operator,etc.

from the definition of Z-transform the author got the 4-interval deadbeat control value "DELM" for zero initial condition is

DELM=((EN*XA+EN1*XA1+EN2*XA2+EN3*XA3)-(DELM1*XM1+
DELM2*XM2+DELM3*XM3))/XM0

Here EN denotes the input of the digital controller; EN1, the previous digital input; and EN2, EN3, etc. DELM is the output of digital controller; DELM1 is the previous value, and so on. A corresponds to the digital control input vector in the analysis, XM corresponds to the output vector. These variables are used in the control program written in PL/M high level programming language, which is a subset of the more familiar PL/1 language.

CHAPTER 4

CONTROL PROGRAM STRUCTURE

Considering the control algorithm:

DELM=((EN*XA+EN1*XA1+EN2*XA2+EN3*XA3)-(DELM1*XM1+DELM2*XM2+DELM3*XM3))/XM0

It will be only a basic arithmetic calculation, but, it is not as easy as it looks. Since such simple things are calculated in machine-like assembly language, that means that we should think in Binary(2-base B or 16-base H) terms:

1+5=1+0101B=1010B,

2*5=10B+10B+10B+10B+10B,

9/3=1001B/11B,

1.1+5.=1.199999AH+5.H

=.8CCCCDH*2**1+.A0H*2**3,

etc.

To build this kind of arithmetic algorithm without some handy software packages, it should be considered from the foundation of number theory. Originally the author use fixed-point arithmetic algorithms to solve the problem, but it did not work, because of the characteristics of the control parameters. Near the end of the project, a floating-point algorithm was written to overcome this difficulty.

Here is a brief description of the floating-point numbers:

1) Sign-magnitude form,
2) all real value except for internal operators are normalized to 4-Byte numbers(0-31Bit),
3) 0-7Bits are for 128-Biased exponential term,
4) 31Bit is Sign bit,
5) 8-30Bits are fraction part with implicit most significient "1" in 31Bit, i.e.,the Sign bit.
6) radix point is left of the 31Bit.

[FOR EXAMPLE]:

-51/128=-(1/4+1/8+1/64+1/128) =-.0110011B

=-.110011 *2 **-1

= 1 SIGN BIT

OCCH 0H 0H   FRACTION PART

128-1=7FH EXPONENTIAL TERM

=-.CC00007F H

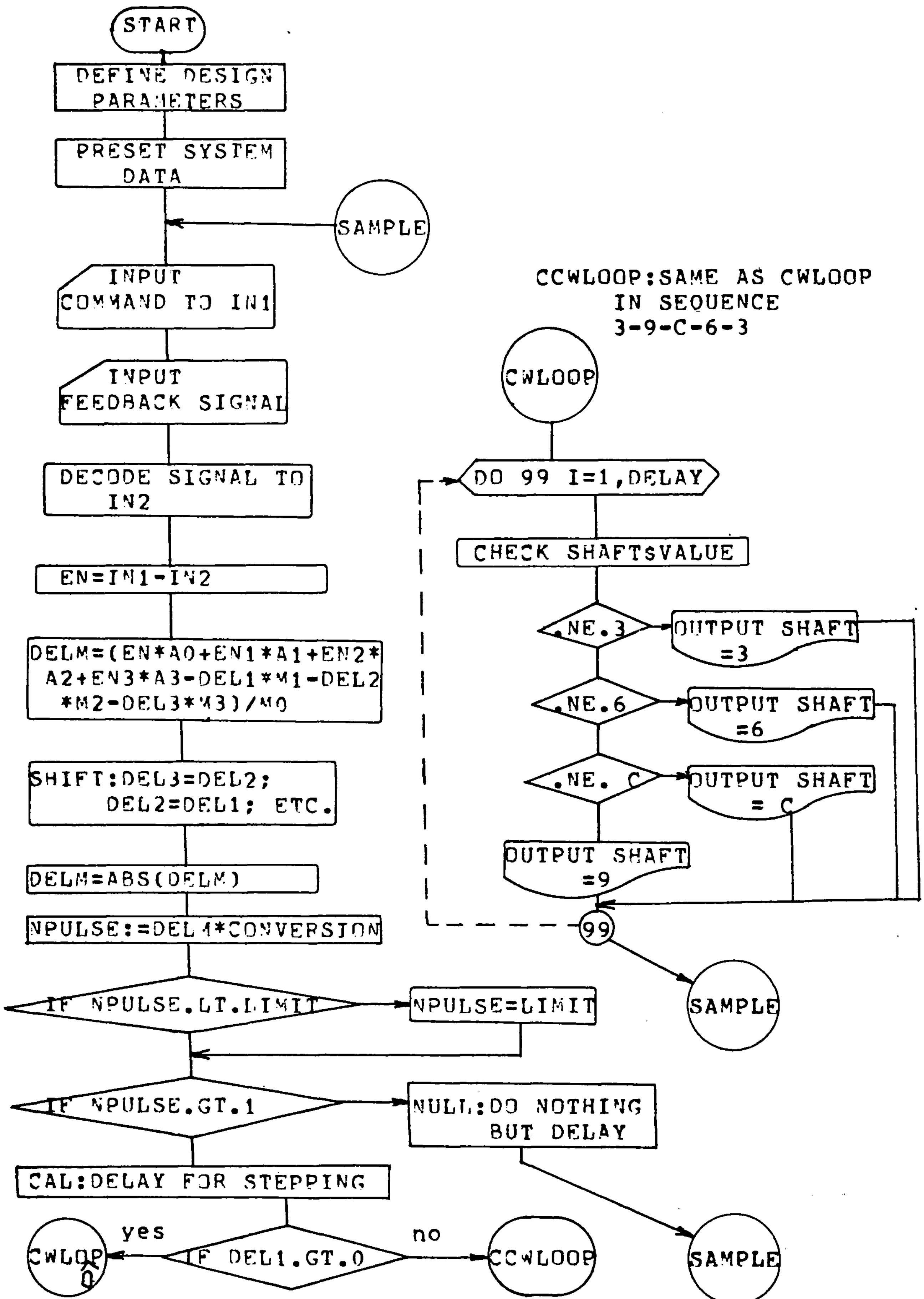
=7FH 0H 0H CCH AT MEMORY IN INCREASED ORDER,

WHILE 51/128=.110011 *2**-1

=4C00007F H

=7FH 0H 0H 4CH IN MEMORY .

The details of the program would be shown on the follow flow chart, and, a listing of PL/M80 source file, which is available from the author or Professor Johnson for further reference.


START
DEFINE DESIGN PARAMETERS
PRESET SYSTEM DATA
SAMPLE
INPUT COMMAND TO IN1
INPUT FEEDBACK SIGNAL
DECODE SIGNAL TO IN2
EN=IN1-IN2
DELM=(EN*A0+EN1*A1+EN2*A2+EN3*A3-DEL1*M1-DEL2*M2-DEL3*M3)/M0
SHIFT:DEL3=DEL2; DEL2=DEL1; ETC.
DELM=ABS(DELM)
NPULSE:=DELM*CONVERSION
IF NPULSE.LT.LIMIT
NPULSE=LIMIT
IF NPULSE.GT.1
NULL:DO NOTHING BUT DELAY
CAL:DELAY FOR STEPPING
yes
IF DEL1.GT.0
no
CWLOOP
CCWLOOP
SAMPLE
CCWLOOP:SAME AS CWLOOP IN SEQUENCE 3-9-C-6-3
CWLOOP
DO 99 I=1,DELAY
CHECK SHAFTSVALUE
.NE.3
OUTPUT SHAFT =3
.NE.6
OUTPUT SHAFT =6
.NE. C
OUTPUT SHAFT = C
OUTPUT SHAFT =9
99
SAMPLE

CHAPTER 5

RESULT AND DISCUSSION

An A-stable integration algorithm has been used to simulate the nonlinear control system. The result is shown in the figure on the next page. Since the system is a position control system,only the plot of position verses time is presented.

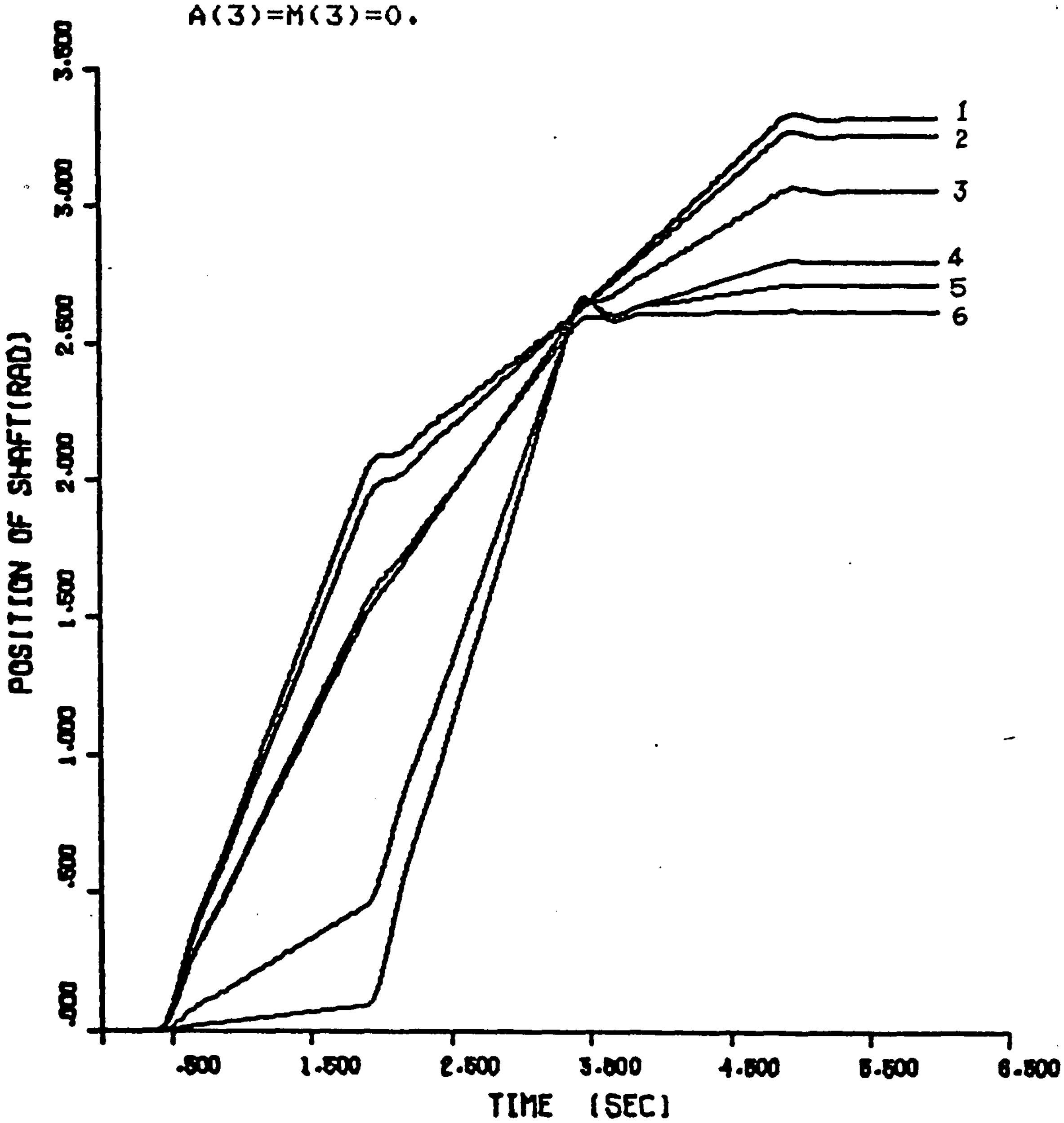
Since the equations of K0-K1-K2-K3 are 4th order full coupled algebraic equations,solutions are not always guaranteed, because of the possibility of complex value solutions.

Here all the solutions did exhibit two typical characteristics of deadbeat control: being ripple-free and finite time settling; but did not match the given command well. There are some reasons for this:

1) accuracy may not be good enough on both simulation and nonlinear equations solutions.

CURVE	A0	A1	A2	M0	M1	M2
1	3.540	2.584	2.200	3.142	1.651	.272
2	3.472	2.661	2.200	3.142	1.737	.328
3	3.199	2.948	2.200	3.142	2.054	.530
4	3.230	3.103	2.201	3.142	2.225	.640
5	2.505	3.628	2.201	3.142	2.804	1.012
6	2.261	3.872	2.201	3.142	3.074	1.185

A(3)=M(3)=0.



STEPPING MOTOR CONTROL SYSTEM

2) maybe it is a steady-state offset.

Just like bang-bang control for the relay problem,response will stop around the equilibrium point inside the deadzone.

3) maybe the real solution does not exist.

There are many ways to eliminate the steady state errors;using a properly designed analog filter,or digital filter. Here the author would like to put a gain-adjuster in the digital controller:

1) either manual control or feedback control
2) gain adjusting only after the 3rd sample periods
3) the filter should reduce the error from 10 % to 1 % after 6th Tsampleperiod.

Noting that our plant has a free integrator,it means that no steady state error will occur for the linear control system. But here the offset is almost certain because of:

1) in physical situation: our input command and feedback signal are positions,while the control is velocity(i.e., the time derivative of position).A zero control may contribute to the error.
2) the existance of the nonlinearities.

The steady state offset situation and the adjustable gain filter has similar cases on other research. Here the author would like to point out the paper by D.Jacobs and L.F.Donaghey at Lawrence Berkeley Laboratory,UC Berkeley:

On their nonlinear deadbeat thermal control,only the linear part had been considered. They used an intelligent strategy of shifting the internal setpoint to reach the steady state requirement(called steady state forcing).

In the 3rd chapter we said that "the object of the deadbeat control is that: after K sample periods,the system will reach the given command", but that is not completely true since "K" is not chosen arbitrarily,but depending on the characteristics of the plant and the nonlinearities. Here all the solutions show that the system will reach the steady state in three sample periods.

Also, the author would like to point out that at the end of the paper, there is an implicit danger.Since the stepping motors are too complicated , we used the velocity instead of the torque as the control command to make the system accessible at our facilities. For a real engineering system,the author would recommend consideration of the more complex model with the torque as the control command.

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APPENDIX I

IMPLEMENTATION OF DEADBEAT PARAMETERS

State Variable representation of plant is

$$\dot{Y} = A1*Y + B1*U$$

$$= \begin{pmatrix} 0 & K/J & b/J \\ 0 & 0 & 1 \\ 0 & -K/J & -b/J \end{pmatrix} *Y+ \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} *K(N)*M(N)$$

$$= \begin{pmatrix} 0 & 232.154 & 10.6655 \\ 0 & 0 & 1 \\ 0 & -232.154 & -10.6655 \end{pmatrix} *Y+ \begin{pmatrix} 0 \\ 0 \\ K(n) \end{pmatrix} *M(n)$$

$$e^{A1*t} = \begin{pmatrix} 1 & 16.2655*e^{-5.3328t}*\sin(14.273*t) & 1+1.06752*e^{-5.3328t}*\sin(14.273*t-1.21326) \\ 0 & 1.06752*e^{-5.3328t}*\sin(14.273*t+1.21323) & 0.0700623*e^{-5.3328t}*\sin(14.273*t) \\ 0 & -16.2655*e^{-5.3328t}*\sin(14.273*t) & 1.06752*e^{-5.3328t}*\sin(14.273*t+1.9284) \end{pmatrix}$$

$$\int_0^t e^{\underline{A1}(t-s)} ds * \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

$$= \begin{pmatrix} t-0.0700624*e^{-5.3328t}*\sin(14.273*t) \\ 0.00432742+0.0045983*e^{-5.3328t}*\sin(14.273*t-1.9284) \\ 0.0700624*e^{-5.3328t}*\sin(14.273*t) \end{pmatrix}$$

$$\underline{ALFA} = e^{\underline{A1}*Ttou}$$

$$\underline{A} = e^{\underline{A1}*(Tsampleperiod-Ttou)}$$

$$\underline{BETA} = \int_0^{Ttou} e^{\underline{A1}(Ttou-s)} ds * \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

$$\underline{B} = \int_0^{Tsampleperiod} e^{\underline{A1}(Tsampleperiod-s)} ds * \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

Note: in order to simplify the writing,<u>BETA</u> and <u>B</u> are not same as the <u>BETA</u>(N) and <u>B</u>(N) in the Text,instead set <u>BEAT</u>(N)= <u>BETA</u>*K(N)

<u>B</u>(N) =<u>B</u>*K(N)

Let

<u>ALFA</u>=

$$\begin{pmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{pmatrix}$$

<u>A</u>=

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}$$

<u>BETA</u> =

$$\begin{pmatrix} \beta_{1} \\ \beta_{2} \\ \beta_{3} \end{pmatrix}$$

<u>B</u> =

$$\begin{pmatrix} b_{1} \\ b_{2} \\ b_{3} \end{pmatrix}$$

Then

transition matrices <u>PHI</u>(N) and ,<u>ZETA</u>(N) will become .

$\underline{PHI}(N)=$

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & a_{11} & a_{12} & a_{13} & b1K(N) \\ 0 & a_{21} & a_{22} & a_{23} & b2K(N) \\ 0 & a_{31} & a_{32} & a_{33} & b3K(N) \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

$\underline{ZETA}(N)=$

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & \alpha_{11} & \alpha_{12} & \alpha_{13} & \beta_1 K(N) \\ 0 & \alpha_{21} & \alpha_{22} & \alpha_{23} & \beta_2 K(N) \\ 0 & \alpha_{31} & \alpha_{32} & \alpha_{33} & \beta_3 K(N) \\ 1 & -1 & 0 & 0 & 0 \end{pmatrix}$$

by transfer Matrices Relations:

$\underline{V}(N+) = \underline{ZETA}(N) * \underline{V}(N)$

$\underline{V}(N+1) = \underline{PHI}(N) * \underline{V}(N+)$

get

$\underline{V}(0)=$

$$\begin{pmatrix} \lambda \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

; λ is input step command

$$\underline{V}(0+) = \begin{pmatrix} \lambda \\ 0 \\ 0 \\ 0 \\ \lambda \end{pmatrix}$$

$$\underline{V}(1) = \underline{PHI}(N) \ast \underline{V}(0+) = \begin{pmatrix} \lambda \\ b1K0\lambda \\ b2K0\lambda \\ b3K0\lambda \\ \lambda \end{pmatrix} = \begin{pmatrix} \lambda \\ C1 \\ C2 \\ C3 \\ \lambda \end{pmatrix}$$

$$\underline{V}(1+) = \underline{ZETA}(1) \ast \underline{V}(1) = \begin{pmatrix} \lambda \\ \alpha_{11}\, c1 + \alpha_{12}\, c2 + \alpha_{13}\, c3 + \beta 1K0 \\ \alpha_{11}\, c1 + \alpha_{22}\, c2 + \alpha_{23}\, c3 + \beta 2K0 \\ \alpha_{31}\, c1 + \alpha_{32}\, c2 + \alpha_{33}\, c3 + \beta 3K0 \\ \lambda - c1 \end{pmatrix}$$

$$= \begin{pmatrix} \lambda \\ d1 \\ d2 \\ d3 \\ \lambda - c1 \end{pmatrix}$$

$$\underline{V}(2) = \underline{PHI}(2)\underline{V}(1+) = \begin{pmatrix} \lambda \\ a_{11}\, d1 + a_{12}\, d2 + a_{13}\, d3 + b1K1(\ -c1) \\ a_{21}\, d1 + a_{22}\, d2 + a_{23}\, d3 + b2K1(\ -c1) \\ a_{31}\, d1 + a_{32}\, d2 + a_{33}\, d3 + b3K1(\ -c1) \\ \lambda - c1 \end{pmatrix}$$

$$= \begin{pmatrix} \lambda \\ e1 \\ e2 \\ e3 \\ \lambda - c1 \end{pmatrix}$$

continuing

$$\underline{V}(2+) = \begin{pmatrix} \lambda \\ f1 \\ f2 \\ f3 \\ \lambda - e1 \end{pmatrix}$$

$$\underline{V}(3) = \begin{pmatrix} \lambda \\ g1 \\ g2 \\ g3 \\ \lambda - e1 \end{pmatrix}$$

$$\underline{V}(3+) = \begin{pmatrix} \lambda \\ h1 \\ h2 \\ h3 \\ \lambda - g1 \end{pmatrix}$$

$$\underline{V}(4) = \begin{pmatrix} \lambda \\ p1 \\ p2 \\ p3 \\ \lambda - g1 \end{pmatrix}$$

$$\underline{V}(4+) = \begin{pmatrix} \lambda \\ \alpha_{11} p1 + \alpha_{12} p2 + \alpha_{13} p3 + \beta 1 K3(\quad -g1) \\ \alpha_{21} p1 + \alpha_{22} p2 + \alpha_{23} p3 + \beta 2 K3(\quad -g1) \\ \alpha_{31} p1 + \alpha_{32} p2 + \alpha_{33} p3 + \beta 3 K3(\quad -g1) \\ \lambda - p1 \end{pmatrix}$$

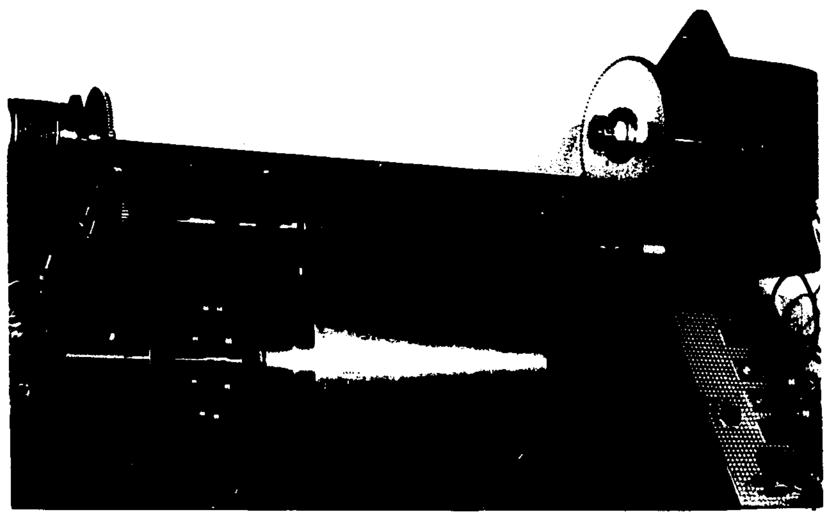
$$= \begin{pmatrix} \lambda \\ \lambda \\ 0 \\ 0 \\ 0 \end{pmatrix}$$ ----Object of Deadbeat Control

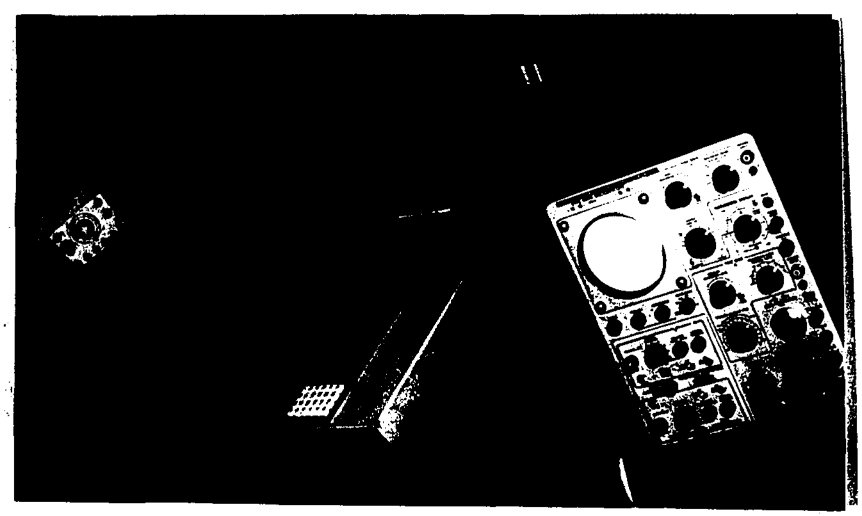
then,when K0,K1,K2,K3, satisfied this condition

Deadbeat purpose has been achieved.

APPENDIX II

SYSTEM LAYOUT PICTURE





BIOGRAPHY

Mr. Shih-tein Hsu was born on December 19,1951 in Peikang, Yuin-lin Hsieng,Taiwan,Republic of China, as the youngest child of a mid-class family. His father,Dr.Sih-kuei Hsu, being a medical doctor for about twenty years,died when Mr.Shih-tein hsu was only four years old. After that,his mother,Mrs.Tsai-shai HsuKuo,a classical Chinese intelligent woman,raised her eight children, supporting them by being a sewing machine operator,store-keeper,etc. Some years later, the elder children had taken the burden of their mother to support the younger children. It was at this time that the family come in contact with the Christian religion and became Christian at that so called Sacred Place of Taiwan traditional religion.

Mr.Shih-tein Hsu had been an undergraduate student at National Taiwan University and received the degree of Bachelor of Science in the Department of Mechanical Engineering. Since graduating, he has been a research assistant in Chun-Shan Institute of Science and Technology for 4 years. After he was award a fellowship from the Chinese government to study abroad, he came to Lehigh University. He will go back to his work as soon as he finishes his studies and gets the degree of Master of Science.

His special interests are in mechanical systems design and analysis. He also hopes to extend his interests to fluid and thermal related mechanical system design.