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ภาคผนวก ก.

โปรแกรมสำหรับไมโครคอมพิวเตอร์ในการควบคุมเครื่องกลึง

```
]LIST

2  REM  ***************************
3  REM  ******  MENU  PROGRAM  *****
4  REM  ***************************
5  TEXT
10  HOME : PRINT : PRINT  TAB( 18);" MENU ": PRINT  TAB( 18);"
    ==== ": PRINT
20  PRINT "1.TYPE 1 TO EDITOR PROGRAM "
30  PRINT "2.TYPE 2 TO LATHE MOVEMENT CONTROL PROGRAM "
40  PRINT "3.TYPE ANOTHER KEY TO STOP"
50  GET A$
55 D$ = " " +  CHR$ (4)
60  IF A$ = "1" THEN  PRINT D$;"RUN PLOT1"
70  IF A$ = "2" THEN  PRINT  CHR$ (4) + "BLOAD RUNTIME" +  CHR$
    (13) +  CHR$ (4) + "BRUN CUT.OBJ"
80  END
```

```
2  REM  *******************************
3  REM  ****** EDITOR PROGRAM *******
4  REM  *******************************
6  DIM B$(20),D(20),L1(20),L2(20),S(20),R(20),XO(20),YO(20),XE(
   20),YE(20)
7 DX = 1:DY = 1:XO = 0:YO = 0:I = 1:M = 0:CX = 1 / 80:CY = 1 /
   72:BX = 6:BY = 7
8  REM ***** SUB READ LIBARY FILE *****
9  DIM SN$(20),NO$(20)
10 D$ =  CHR$ (4)
12  PRINT D$;"OPEN LIBSHAPE"
14  PRINT D$;"READ LIBSHAPE"
16  INPUT M5
20  FOR I = 1 TO M5
22  INPUT SN$(I),NO$(I)
24  NEXT I
26  PRINT D$;"CLOSE LIBSHAPE"
28  REM ***** PRINT LIBARY OF SHAPE *****
30  HOME : PRINT : PRINT  TAB( 15);"SHAPE TABLE": PRINT  TAB( 1
   5);"===========": PRINT :J = 0:I = 0
32 I = I + 1:J = J + 1
34  IF I > M5 THEN  PRINT I;" CREAT NEW SHAPE ": GOTO 40
36  PRINT I;"  ";SN$(I);"      ";NO$(I)
38  IF J < 18 THEN 32
39  VTAB 20
40  PRINT "PRESS <RETURN> TO CONTINUE ": PRINT "OR YOUR SELECTE
   D NO. OF SHAPE ";: INPUT SE$
42  IF SE$ = NULL$ THEN J = 0: GOTO 32
44 P1 =  VAL (SE$)
45  IF P1 > M5 + 1 THEN 39
46  IF P1 > I THEN J = 0: GOTO 32
47  IF P1 = M5 + 1 THEN  GOTO 85
49  GOSUB 5600
50 N =  VAL (NO$(P1)):FA = 1
55  GOSUB 4310
58  VTAB 21: PRINT "DO YOU WANT TO SCALE UP OR DOWN "
60  INPUT " TYPE Y FOR YES OR N FOR NO ";AN$
63  IF AN$ = "Y" THEN  GOSUB 4300
65  GOTO 390
85 DX = 1:DY = 1:XO = 0:YO = 0:I = 1:M = 0
100  HGR : HCOLOR= 3
120  HPLOT 279,0 TO 0,0 TO 0,159
122  FOR JJ = 1 TO 279
124  FOR JK = 1 TO 4
126 JJ = JJ + 1
128  NEXT JK
130  IF JJ + 5 < 279 THEN  HPLOT JJ,0 TO JJ,3
132  IF JJ + 5 < 159 THEN  HPLOT 0,JJ TO 3,JJ
134  NEXT JJ
```

```
150  VTAB 21: PRINT "KEY IN THE SHAPE OF WORKPIECE
160  PRINT "CYLINDER=CY,CONE=CO,CURVE=CU,END=EN"
170  INPUT "ENTER THE SHAPE OF WORKPIECE ";AA$
180  IF AA$ = "CY" THEN  GOSUB 1000
190  IF AA$ = "CO" THEN  GOSUB 2000
200  IF AA$ = "CU" THEN  GOSUB 3000
210  IF AA$ = "EN" THEN  GOTO 4000
220  PRINT "PLEASE COLLECT YOUR INPUT AGAIN CY,CO,CU OR EN"
230  GOTO 170
390  PRINT "TYPE ANY KEY TO GOTO MENU": GET A$
395 D$ = " " +  CHR$ (4)
400  PRINT D$;"RUN MENU"
1000  PRINT "IF YOUR INPUT>999 THEN ABORT "
1001  INPUT "LENGHT OF CYLINDER IS (MM)  ";L
1005  IF L > 999 THEN  RETURN
1010  INPUT "DIAMETER OF CYLINDER IS (MM)  ";D
1015  IF D > 999 THEN  RETURN
1018  GOSUB 1300
1041  INPUT "TYPE 1 IF OK OR 0 IF NOT ";AN
1042  IF AN = 0 THEN  GOTO 1100
1043  IF I = 1 THEN  GOTO 1070
1044 XO = XO + (L * DX):YO = D / 2 * DY
1046 B$(I) = AA$:L1(I) = L:D(I) = D / 2:L2(I) = 0
1048 I = I + 1: GOTO 1080
1070 XO = L * DX:
1075  GOTO 1046
1076  HCOLOR= 0
1077  HPLOT L * DX,YO TO XO,YO
1078  HCOLOR= 3
1080  PRINT XO,YO: RETURN
1100  HCOLOR= 0: IF I = 1 THEN  GOTO 1077
1110  HPLOT (L * DX) + XO,D / 2 * DY TO XO,D / 2 * DY
1120  HPLOT  TO XO,YO
1130  HCOLOR= 3
1140  GOTO 1080
1300  IF I = 1 THEN  GOTO 1350
1310  HPLOT XO,YO TO XO,D / 2 * DY: HPLOT  TO (L * DX) + XO,D /
     2 * DY
1330  RETURN
1350 YO = D / 2 * DY
1360  HPLOT XO,YO TO L * DX,YO
1370  RETURN
2000  PRINT "IF YOUR INPUT>999 THEN ABORT "
2001  INPUT "SLOP OF CONE (DEGREE)= ";S
2005  IF S > 999 THEN  RETURN
2010  INPUT "LENGHT IN X-AXIS (MM)= ";L
2015  IF L > 999 THEN  RETURN
2020  IF S < 90 THEN  GOTO 2200
2030  IF S < 180 THEN  GOTO 2400
2040  IF S < 270 THEN  GOTO 2600
2050  IF S < 360 THEN  GOTO 2800
2060  RETURN
```

```
2200 S1 = 180 - S
2210  GOSUB 2300
2220  INPUT "TYPE 1 IF OK OR 0 IF NOT";AN
2230  IF AN = 0 THEN  GOTO 2270
2240 X0 = X0 + X:Y0 = Y0 + Y:D = Y0 / DY
2250 B$(I) = AA$:L1(I) = 0:L2(I) = L:S(I) = S:D(I) = D
2260 I = I + 1: PRINT X0,Y0: RETURN
2270  HCOLOR= 0
2280  HPLOT X0,Y0 TO X + X0,Y + Y0
2290  HCOLOR= 3: GOTO 2260
2300 PI = (3.14285714 * S1) / 180
2310 X = L * DX
2320 Y = X *  TAN (PI)
2330  IF Y + Y0 < 0 THEN  GOSUB 5000
2340  IF Y + Y0 > 159 THEN  GOSUB 5050
2350  IF X + X0 < 0 THEN  GOSUB 5100
2360  IF X + X0 > 279 THEN  GOSUB 5150
2370  HPLOT X0,Y0 TO X0 + X,Y0 + Y: RETURN
2400  GOSUB 2500
2410  INPUT "TYPE 1 IF OK OR 0 IF NOT ";AN
2420  IF AN = 1 THEN  GOTO 2470
2430  HCOLOR= 0
2440  HPLOT X0,Y0 TO X0 - X,Y0 + Y
2450  HCOLOR= 3
2460  GOTO 2490
2470 X0 = X0 - X:Y0 = Y0 + Y:D = Y0 / DY
2480 B$(I) = AA$:D(I) = D:L1(I) = 0:L2(I) = L:S(I) = S
2485 I = I + 1
2490  PRINT X0,Y0: RETURN
2500 PI = (3.14285714 * S) / 180
2510 X = L * DX
2520 Y = X *  TAN (PI)
2530  IF Y + Y0 < 0 THEN  GOSUB 5200
2540  IF Y + Y0 > 159 THEN  GOSUB 5250
2550  IF X0 - X < 0 THEN  GOSUB 5300
2560  IF X0 - X > 279 THEN  GOSUB 5350
2565  HPLOT X0,Y0 TO X0 - X,Y0 + Y
2570  RETURN
2600  GOSUB 2700
2610  INPUT "TYPE 1 IF OK OR 0 IF NOT";AN
2620  IF AN = 1 THEN  GOTO 2670
2630  HCOLOR= 0
2640  HPLOT X0,Y0 TO X0 - X,Y0 + Y
2650  HCOLOR= 3
2660  GOTO 2690
2670 X0 = X0 - X:Y0 = Y0 + Y:D = Y0 / DY
2680 B$(I) = AA$:L1(I) = 0:L2(I) = L:S(I) = S:D(I) = D
2685 I = I + 1
2690  PRINT X0,Y0: RETURN
2700 S1 = S - 180
```

```
2700 S1 = S - 180
2710 PI = (3.14285714 * S1) / 180
2720 X = L * DX
2730 Y = X *  TAN (PI)
2740  IF Y + YO < 0 THEN  GOSUB 5400
2750  IF Y + YO > 159 THEN  GOSUB 5450
2760  IF XO - X < 0 THEN  GOSUB 5500
2770  IF XO - X > 279 THEN  GOSUB 5550
2775  HPLOT XO,YO TO XO - X,YO + Y
2780  RETURN
2800 S1 = 360 - S: GOSUB 2300
2880  INPUT "TYPE 1 IF OK OR 0 IF NOT ";AN
2885  IF AN = 1 THEN  GOTO 2950
2890  HCOLOR= 0
2895  HPLOT XO,YO TO XO + X,YO + Y
2900  HCOLOR= 3
2905  GOTO 2980
2950 XO = X + XO:YO = Y + YO:D = YO / DY
2960 B$(I) = AA$:L1(I) = L:S(I) = S:L2(I) = L:D(I) = D
2970 I = I + 1
2980  PRINT XO,YO: RETURN
3000 U = XO:V = YO:W = M
3001  PRINT "IF YOUR INPUT>999 THEN ABORT"
3002  INPUT "CENTER OF CURVE XO,YO IS ";XO,YO
3003  IF XO > 999 OR YO > 999 THEN  RETURN
3004  INPUT "THE COORDINATE OF END POINT XE,YE ";XE,YE
3005  IF XE > 999 OR YE > 999 THEN  RETURN
3006  INPUT "ENTER THE QUADRAN OF CURVE (2 OR 4)";S
3012 XO(I) = XO:YO(I) = YO:XE(I) = XE:YE(I) = YE: GOTO 3281
3013 XO = XO * DX:YO = YO * DY
3014 XE = XE * DX:YE = YE * DY
3020 A = XO - XO
3030 B = YO - YO
3040 RB =  SQR (A * A + B * B)
3050 UX = A / RB
3060 UY = B / RB
3070 A = XE - XO
3080 B = YE - YO
3090 RE =  SQR (A * A + B * B)
3100 VX = A / RE
3110 VY = B / RE
3120 A = UX * VY - UY * VX
3130  IF A = 0 THEN WZ = 1: GOTO 3150
3140 WZ = (UX * VY - UY * VX) /  SQR ((UX * VY - UY * VX) ^ 2)
3150 NX =  - WZ * UY
3160 NY = WZ * UX
3170  DEF  FN AC(A) =  -  ATN (A /  SQR ( - A * A + 1)) + 1.570
   8
3180 A = UX * VX + UY * VY
3190 PT =  FN AC(A)
3200 PT = PT * 1.01
```

```
3200 PT = PT * 1.01
3210 R = (RB + RE) / 2
3220  FOR PHI = 0 TO PT STEP 3.14159 / 180
3230 A1 = R *  COS (PHI)
3240 B1 = R *  SIN (PHI)
3250 X = XO + A1 * UX + B1 * NX
3260 Y = YO + A1 * UY + B1 * NY
3270  HPLOT XO,YO TO X,Y
3276 XO = X:YO = Y
3280  NEXT PHI: RETURN
3281  GOSUB 3013
3282  INPUT "TYPE 1 IF OK OR 0 IF NOT ";AN
3283  IF AN = 0 THEN  GOTO 3500
3290 B$(I) = AA$:D(I) = YE:L1(I) = 0:L2(I) = XE - U:R(I) = R:S(
     I) = S:I = I + 1
3310 XO = X:YO = Y
3320  PRINT XO,YO: RETURN
3500 XO = U:YO = V:M = W
3510 A = XO - XO:B = YO - YO
3520 RB =  SQR (A * A + B * B)
3530 UX = A / RB:UY = B / RB
3540 A = XE - XO:B = YE - YO
3550 RE =  SQR (A * A + B * B)
3560 VX = A / RE:VY = B / RE
3570 A = UX * VY - UY * VX
3580  IF A = 0 THEN WZ = 1: GOTO 3600
3590 WZ = (UX * VY - UY * VX) /  SQR ((UX * VY - UY * VX) ^ 2)
3600 NX =  - WZ * UY:NY = WZ * UX
3610  DEF  FN AD(A) =  -  ATN (A /  SQR ( - A * A + 1)) + 1.570
     8
3620 A = UX * VX + UY * VY
3630 PT =  FN AD(A):PT = PT * 1.01
3640 R = (RE + RB) / 2
3645  HCOLOR= 0
3650  FOR PHI = 0 TO PT STEP 3.14159 / 180
3660 A1 = R *  COS (PHI):B1 = R *  SIN (PHI)
3670 X = XO + A1 * UX + B1 * NX:Y = YO + A1 * UY + B1 * NY
3680  HPLOT XO,YO TO X,Y
3700 XO = X:YO = Y
3710  NEXT PHI
3715  HCOLOR= 3:M = W:XO = U:YO = V
3720  GOTO 3320
4000  HPLOT XO,YO TO XO,0
4010 B$(I) = AA$:D(I) = 0:L1(I) = 0:L2(I) = 0:N = I
4020  PRINT "DO YOU WANT TO SCALE UP OR SCALE DOWN"
4030  INPUT "TYPE Y FOR YES OR N FOR NO ";AN$
4040  IF AN$ = "Y" THEN  GOSUB 4300
4050  PRINT "DO YOU WANT TO SAVE THIS FORMATE"
4060  INPUT "TYPE Y FOR YES OR N FOR NO ";AN$
4070  IF AN$ = "Y" THEN  GOSUB 4800
4080  GOTO 390
4300  INPUT "ENTER THE SCALE FACTOR ";FA
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```
4300  INPUT "ENTER THE SCALE FACTOR ";FA
4310  HGR : HCOLOR= 3: HPLOT 0,0 TO 279,0: HPLOT 0,0 TO 0,159
4312  FOR JJ = 1 TO 279
4313  FOR JK = 1 TO 4
4314 JJ = JJ + 1
4315  NEXT JK
4316  IF JJ + 5 < 279 THEN  HPLOT JJ,0 TO JJ,3
4317  IF JJ + 5 < 159 THEN  HPLOT 0,JJ TO 3,JJ
4318  NEXT JJ
4319 XO = 0:YO = 0
4320  FOR I = 1 TO N
4330  IF  LEFT$ (B$(I),2) = "CY" THEN  GOSUB 4400: GOTO 4370
4340  IF  LEFT$ (B$(I),2) = "CO" THEN  GOSUB 4500: GOTO 4370
4350  IF  LEFT$ (B$(I),2) = "CU" THEN  GOSUB 4720: GOTO 4370
4360  IF  LEFT$ (B$(I),2) = "EN" THEN  GOSUB 4780
4370  NEXT I
4380  RETURN
4400 L = L1(I):D = D(I)
4410 L = L * FA:D = D * FA * 2
4420  GOSUB 1300
4430  IF I = 1 THEN XO = L * DX: RETURN
4440 XO = XO + (L * DX):YO = D / 2 * DY
4450  RETURN
4500 L = L2(I):S = S(I)
4510 L = L * FA
4520  IF S < 90 THEN  GOTO 4580
4530  IF S < 180 THEN  GOTO 4620
4540  IF S < 270 THEN  GOTO 4650
4550  IF S < 360 THEN  GOTO 4680
4560  RETURN
4580 S1 = 180 - S: GOSUB 2300
4590 XO = XO + X:YO = YO + Y: RETURN
4620  GOSUB 2500
4630 XO = XO - X:YO = YO + Y: RETURN
4650  GOSUB 2700
4660 XO = XO - X:YO = YO + Y: RETURN
4680 S1 = 360 - S: GOSUB 2300
4690 XO = XO + X:YO = YO + Y: RETURN
4720 XO = XO(I):YO = YO(I):XE = XE(I):YE = YE(I)
4730 XO = XO * FA:YO = YO * FA:XE = XE * FA:YE = YE * FA
4740  GOSUB 3013
4750 XO = X:YO = Y: RETURN
4780  HPLOT XO,YO TO XO,0: RETURN
4800  REM **** SUB APPEND SHAPE ****
4802 M5 = M5 + 1
4804  INPUT "NAME OF SHAPE ";SN$(M5)
4806 NO$(M5) =  STR$ (N)
4810 D$ =  CHR$ (4)
4812  PRINT D$;"OPEN LIBSHAPE"
4814  PRINT D$;"DELETE LIBSHAPE"
4820  PRINT D$;"OPEN LIBSHAPE"
```

```
4820  PRINT D$;"OPEN LIBSHAPE"
4830  PRINT D$;"WRITE LIBSHAPE"
4840  PRINT M5
4850  FOR I5 = 1 TO M5
4860  PRINT SN$(I5);",";NO$(I5)
4870  NEXT I5
4880  PRINT D$;"CLOSE LIBSHAPE"
4882 N6 =  VAL  (NO$(M5))
4883 D$ =  CHR$  (4)
4886  PRINT D$;"OPEN SHAPE,L200"
4889  PRINT D$;"WRITE SHAPE,R";P1
4890  FOR N1 = 0 TO N6
4894  PRINT L1(N1): PRINT L2(N1): PRINT D(N1): PRINT S(N1): PRI
   R(N1): PRINT XO(N1): PRINT YO(N1): PRINT XE(N1): PRINT YE(N
   1)
4910  NEXT N1
4914  FOR N1 = 0 TO N6: PRINT B$(N1): NEXT N1
4920  PRINT D$;"CLOSE SHAPE"
4930  RETURN
5000  IF YO = 0 THEN YO = 1
5010 Y =  - YO:X = Y /  TAN (PI): RETURN
5050 Y = 159 - YO:X = Y /  TAN (PI): RETURN
5100  IF XO = 0 THEN XO = 1
5110 X =  - XO:Y = X *  TAN (PI): RETURN
5150 X = 279 - XO:Y = X *  TAN (PI): RETURN
5200  IF YO = 0 THEN YO = 1
5210 Y =  - YO:X = Y /  TAN (PI): RETURN
5250 Y = 159 - YO:X = Y /  TAN (PI): RETURN
5300  IF XO = 0 THEN XO = 1
5310 X = XO:Y = X *  TAN (PI): RETURN
5350 X = XO - 279:Y = X *  TAN (PI): RETURN
5400  IF YO = 0 THEN YO = 1
5410 Y =  - YO:X = Y /  TAN (PI): RETURN
5450 Y = 159 - YO:X = Y /  TAN (PI): RETURN
5500  IF XO = 0 THEN XO = 1
5510 X = XO:Y = X *  TAN (PI): RETURN
5550 X = XO - 279
5560 Y = X *  TAN (PI)
5570  RETURN
5600  REM  *** READ RANDOM SHAPE FILE ***
5603  PRINT D$;"OPEN SHAPE,L200"
5604  PRINT D$;"READ SHAPE,R";P1
5610  FOR N1 = 0 TO  VAL  (NO$(P1))
5644  INPUT L1(N1): INPUT L2(N1): INPUT D(N1): INPUT S(N1): INF
   R(N1): INPUT XO(N1): INPUT YO(N1): INPUT XE(N1): INPUT YE(N
   1)
5650  NEXT N1
5654  FOR N1 = 0 TO  VAL  (NO$(P1)): INPUT B$(N1): NEXT N1
5660  PRINT D$;"CLOSE SHAPE"
5670  RETURN
```

```
1   REM  ******************************
2   REM  ****** LATHE MOVEMENT   ******
3   REM  ****** CONTROL PROGRAM ******
4   REM  ******************************
5   POKE  - 16289,0: POKE  - 16291,0: POKE  - 16293,0: POKE
     - 16295,0
6   DIM B$(20),D(20),L1(20),L2(20),S(20),R(20),X0(20),Y0(20
    ),XE(20),YE(20)
7 DX = 1:DY = 1:X0 = 0:Y0 = 0:I = 1:M = 0:CX = 1 / 80:CY =
     1 / 72:BX = 6:BY = 7
8   REM ***** SUB READ LIBARY FILE *****
9   DIM SN$(20),NO$(20)
10 D$ =  CHR$ (4)
12   PRINT D$;"OPEN LIBSHAPE"
14   PRINT D$;"READ LIBSHAPE"
16   INPUT M5
20   FOR I = 1 TO M5
22   INPUT SN$(I),NO$(I)
24   NEXT I
26   PRINT D$;"CLOSE LIBSHAPE"
28   REM ***** PRINT LIBARY OF SHAPE *****
29   TEXT
30   HOME : PRINT : PRINT  TAB( 15);"SHAPE TABLE": PRINT  TAB(
     15);"============": PRINT :J = 0:I = 0
32 I = I + 1:J = J + 1
34   IF I > M5 THEN  GOTO 40
36   PRINT I;"  ";SN$(I);"      ";NO$(I)
38   IF J < 18 THEN 32
39   VTAB 20
40   PRINT "PRESS <RETURN> TO CONTINUE ": PRINT "OR YOUR SE
     LECTED NO. OF SHAPE ";: INPUT SE$
42   IF SE$ = NULL$ THEN J = 0: GOTO 32
44 P1 =  VAL (SE$)
45   IF P1 > M5 + 1 THEN 39
46   IF P1 > I THEN J = 0: GOTO 32
47   IF P1 = M5 + 1 THEN  PRINT "PLEASE CORRECT YOUR INPUT
     AGAIN": GOTO 40
49   GOSUB 5600:N =  VAL (NO$(P1))
390   PRINT "*** ROUGHT CUT ROUNTINE ***"
400   INPUT "ENTER DEPTHOF CUT DEP  (MM) ";DEP:DP = DEP
402   INPUT "ENTER DELAY TIME (DEPTH) ";EL
404   INPUT "ENTER DELAY TIME (LEFT) ";EM
410   INPUT "ENTER DIAMETER OF WORKPIECE IN (MM)";DZ:DD = D
     Z / 2
415   TEXT
420 SW = 2:SV = 1:D1(0) = DD:L1(0) = 0:L2(0) = 0:LD = 0:FL
     = 0:DS = 0
425 W1 = SW:V1 = SV
430   FOR K = 1 TO N
440 LD = LD + L1(K) + L2(K)
450   NEXT K
```

```
450  NEXT K
460 L9 = LD
465  PRINT "LD= ";LD: GET A$
470  FOR K = 1 TO N
473 LD = LD - L1(K - 1) - L2(K)
475  IF L2(K) <  > 0 THEN D1(K) = D1(K - 1): GOTO 590
480 D1(K) = D(K) + CY:DR = D1(K - 1) - D1(K)
500  IF DR = 0 THEN  GOTO 590
510  IF DR <  = DP THEN DP = DR:FL = 1
515  PRINT "LD,DR,K=";LD;DR;K
516  IF LD <  = 0.0125 THEN  GOTO 560
520 SV = 1: GOSUB 6000
530  GOSUB 6200
532  IF DS = 0 THEN DS = DEP
534 MM = (DS / CY):M =  INT (MM)
536 SV = 2: GOSUB 6020
538  GOSUB 6200
540 DR = DR - DP
550  IF FL <  > 1 THEN  GOTO 510
560  IF SW <  > 2 THEN  GOSUB 6200
590 FL = 0:DP = DEP
595  PRINT "D1(K)=";D1(K)
600  NEXT K
602 MM = (DS / CY):M =  INT (MM)
604 SV = 1: GOSUB 6020
610  PRINT "*** FINISH CUT ROUNTINE ***"
620  FOR I = N TO 1 STEP  - 1
625  PRINT "B$=";B$(I)
630  IF B$(I) = "EN" THEN  GOSUB 6600
640  IF B$(I) = "CO" THEN  GOSUB 6800
650  IF B$(I) = "CY" THEN  GOSUB 7000
660  IF B$(I) = "CU" THEN  GOSUB 7200
670  NEXT I
680 SW = 1:LD = L9
690  GOSUB 6200
700  PRINT "*** WORKDONE COMPLETE ***"
710  PRINT "TYPE ANY KEY TO GOTO MENU": GET A$
720 D$ = "  " +  CHR$ (4)
730  PRINT D$;"RUN MENU"
1500  POKE  - 16290,1: POKE  - 16289,0
1510  FOR K2 = 1 TO EL: NEXT K2
1520  RETURN
1600  POKE  - 16292,1: POKE  - 16291,0: FOR K2 = 1 TO 10: NEXT
    K2: RETURN : REM  ** OUT **
1700  POKE  - 16296,1: POKE  - 16295,0: RETURN : REM ** RI
    GHT **
1800  POKE  - 16294,1: POKE  - 16293,0
1810  FOR K2 = 1 TO EN: NEXT K2
1820  RETURN
```

```
5600  REM  *** READ RANDOM SHAPE FILE ***
5603  PRINT O$;"OPEN SHAPE,L200"
5604  PRINT D$;"READ SHAPE,R";P1
5610  FOR N1 = 0 TO  VAL (NO$(P1))
5644  INPUT L1(N1): INPUT L2(N1): INPUT D(N1): INPUT S(N1)
    : INPUT R(N1): INPUT XO(N1): INPUT YO(N1): INPUT XE(N1
    ): INPUT YE(N1)
5650  NEXT N1
5654  FOR N1 = 0 TO  VAL (NO$(P1)): INPUT B$(N1): NEXT N1
5660  PRINT O$;"CLOSE SHAPE"
5670  RETURN
6000  PRINT "*** IN-OUT MOVE SUBROUTINE***
6005  PRINT "SV=";SV
6010 MM = ((DP + DS) / CY):M =  INT (MM)
6020  IF MM - M >  = 0.5 THEN M = M + 1: GOTO 6035
6030  IF M = 0 THEN  RETURN
6035  IF SV <  > V1 THEN M = M + BY
6040  FOR K1 = 1 TO M
6050  ON SV GOSUB 1500,1600
6060  NEXT K1
6070 V1 = SV: RETURN
6200  PRINT " ** LEFT-RIGHT MOVE ROUTINE**"
6205  PRINT "SW=";SW
6210 MM = (LD / CX):M =  INT (MM)
6220  IF MM - M >  = 0.5 THEN M = M + 1: GOTO 6235
6230  IF M = 0 THEN  RETURN
6235  IF SW <  > W1 THEN M = M + BX
6240  FOR K1 = 1 TO M
6250  ON SW GOSUB 1700,1800
6260  NEXT K1
6265 W1 = SW
6270  IF SW = 1 THEN SW = 2: RETURN
6280 SW = 1: RETURN
6600  PRINT "** END ROUNTINE **":
6610 MM = (D1(K - 1) - D1(K)) / CY:M =  INT (MM)
6620  IF MM - M >  = 0.5 THEN M = M + 1
6630 SV = 2
6640  GOSUB 6035
6650  RETURN
6800  PRINT "** CONE ROUNTIEN **": GET A$
6810 L4 = 0: GOSUB 7400
6820 L = L2(I):DP = DEP:PHI = ((22 / 7) * S(I)) / 180:FL =
    0:DS = 0:L3 = 0
6830  GOSUB 8400:Y = DR
6840 SV = 1: GOSUB 7600
6850 X = (DP /  TAN (PHI))
6860  GOSUB 7800
6862  IF FL = 0 THEN  GOTO 6960
6864  GOTO 8800
6870 M = 1:SV = 2: GOSUB 6035
```

```
6870 M = 1:SV = 2: GOSUB 6035
6880 Y1 = Y1 - CY
6890  IF Y1 <  = 0 THEN  GOTO 9400
6900  GOTO 8850
6960  IF DS = 0 THEN DS = DEP
6962 MM = (DS / CY):M =  INT (MM)
6964 SV = 2: GOSUB 7630
6970 SW = 1: GOSUB 7810
6980 DR = DR - DP: GOTO 6840
7000  PRINT "** CYLINDER ROUNTINE**"
7010 L = L1(I):DP = DEP:DS = DEP
7020  GOSUB 7400
7030 DR = D1(I) - D(I)
7040  IF DR <  = 0 THEN  GOTO 7090
7050  IF DR <  = DP THEN DP = DR
7060 MM = (DP / CY):M =  INT (MM)
7070  IF MM - M >  = 0.5 THEN M = M + 1
7080 SV = 1: GOSUB 6035
7090 SW = 2:MM = (L / CX):M =  INT (MM)
7100  IF MM - M >  = 0.5 THEN M = M + 1: GOTO 7120
7110  IF M = 0 THEN SW = W1: GOTO 7172
7120  GOSUB 6235
7130  IF DR - DS <  = 0 THEN  RETURN
7140  GOSUB 6235
7150 DP = DP + DEP
7160  GOTO 7050
7172  IF DR - DS <  = 0 THEN  RETURN
7174  GOTO 7150
7200  PRINT "** CURVE ROUNTINE **"
7210 L4 = 0: GOSUB 7400
7220 L = L2(I):DP = DEP:FL = 0:DS = 0:L3 = 0:Y = 0
7222  GOSUB 8400
7225  IF S(I) = 2 THEN  GOTO 7500
7230 SV = 1: GOSUB 7600:Y = Y + DP
7240 X =  SQR ((2 * R(I) * Y) - (Y * Y))
7250 L3 = X:SW = 2: GOSUB 7810
7253  IF FL = 0 THEN  GOTO 7350
7254  GOTO 9000
7255  IF AX = 0 THEN  GOTO 9070
7258  IF CX / AX <  = 0 THEN  GOTO 9070
7260 M = 1:SW = 2: GOSUB 6235
7270 X1 = X1 - CX
7280  IF X1 <  = 0 THEN  GOTO 9400
7290  GOTO 9050
7350  IF DS = 0 THEN DS = DEP
7352 MM = (DS / CY):M =  INT (MM)
7354 SV = 2: GOSUB 7630
7360 SW = 1: GOSUB 7810
7370 DR = DR - DP: GOTO 7230
7400  PRINT "** SUB (1) **"
```

```
7400  PRINT "** SUB (1) **"
7405  IF B$(I + 1) = "CU" THEN  RETURN
7407  IF B$(I + 1) = "CO" THEN  RETURN
7408  IF (I + 1) = N THEN  RETURN
7410 DR = D1(I) - D(I + 1)
7420  IF DR > 0 THEN SV = 2: GOTO 7450
7430  IF DR = 0 THEN  RETURN
7440 DR = D(I + 1) - D1(I):SV = 1
7450 MM = (DR / CY):M =  INT (MM)
7460  IF MM - M >  = 0.5 THEN M = M + 1: GOTO 7480
7470  IF M = 0 THEN  RETURN
7480  GOSUB 6035
7490  RETURN
7500 SV = 1: GOSUB 7600:Y = Y + DP
7505  IF Y >  = R(I) THEN X = 0: GOTO 7515
7510 X =  SQR ((R(I) * R(I)) - (Y * Y))
7515 SW = 2:MM = X / CX:M =  INT (MM): GOSUB 7820
7520  IF FL = 0 THEN  GOTO 7570
7525  GOTO 9200
7528  IF CX / AX <  = 0 THEN  GOTO 9270
7530 M = 1:SW = 2: GOSUB 6235
7540 X1 = X1 + CX
7550  IF X1 >  = L THEN  GOTO 9400
7560  GOTO 9250
7570  IF DS = 0 THEN DS = DEP
7572 MM = (DS / CY):M =  INT (MM)
7574 SV = 2: GOSUB 7630
7575 SW = 1:MM = X / CX:M =  INT (MM): GOSUB 7820
7580 DR = DR - DP: GOTO 7500
7600  PRINT "** SUB (2) **"
7610  IF DR <  = DP THEN DP = DR:FL = 1
7620 MM = ((DP + DS) / CY):M =  INT (MM)
7630  IF MM - M >  = 0.5 THEN M = M + 1: GOTO 7650
7640  IF M = 0 THEN  RETURN
7650  GOSUB 6035
7670  RETURN
7800  PRINT "***** SUB (3) *****"
7805 SW = 2:L3 = L3 + X
7810 MM = ((L - L3) / CX):M =  INT (MM)
7820  IF MM - M >  = 0.5 THEN M = M + 1: GOTO 7840
7830  IF M = 0 THEN  GOTO 7855
7840  GOSUB 6235
7855  PRINT "L3=";L3
7860  RETURN
8400  IF B$(I - 1) = "CO" THEN  GOTO 8450
8410  IF B$(I - 1) = "CU" THEN  GOTO 8450
8420 DR = D1(I) - D(I)
8430  RETURN
8450 DR = D1(I) - D(I - 1)
```

```
8450 DR = D1(I) - D(I - 1)
8460  IF DR = 0 THEN  GOTO 8580
8470  IF DR <  = DP THEN DP = DR:FL = 1
8480 SV = 1: GOSUB 6000
8490 MM = (L / CX):M =  INT (MM)
8500 SW = 2: GOSUB 6220
8510  IF DS = 0 THEN DS = DEP
8520 MM = (DS / CY):M =  INT (MM)
8530 SV = 2: GOSUB 6020
8540 MM = (L / CX):M =  INT (MM)
8550 SW = 1: GOSUB 6220
8560 DR = DR - DP
8570  IF FL = 0 THEN  GOTO 8470
8572 MM = (DS / CY):M =  INT (MM)
8574  IF MM - M >  = 0.5 THEN M = M + 1
8576 SV = 1: GOSUB 6035
8580 DR = D(I - 1) - D(I)
8590 FL = 0:DS = 0:L3 = 0:DP = DEP
8600  RETURN
8800 X = 0
8810 Y1 = (L - X) *  TAN (PHI):MM = Y1 / CY:M =  INT (MM)
8820 Y1 = M * CY
8830 X = X + CX
8840 Y2 = (L - X) *  TAN (PHI)
8850 AY = (Y1 - Y2)
8860  IF CY / AY >  = 0.5 THEN  GOTO 6870
8870 M = 1:SW = 2: GOSUB 6235
8880  IF (L - X) <  = 0 THEN  GOTO 9400
8890  GOTO 8810
9000 X1 =  SQR ((2 * R(I) * Y) - (Y * Y))
9010 MM = X1 / CX:M =  INT (MM)
9020 X1 = M * CX
9030 Y = Y - CY
9035  IF Y < 0 THEN Y = 0
9040 X2 =  SQR ((2 * R(I) * Y) - (Y * Y))
9050 AX = (X1 - X2)
9058  IF AX = 0 THEN  GOTO 9070
9060  IF CX / AX <  = 0.5 THEN  GOTO 7258
9070 M = 1:SV = 2: GOSUB 6035
9080  IF Y <  = 0 THEN  GOTO 9400
9090  GOTO 9030
9200  IF Y > R(I) THEN X1 = 0: GOTO 9210
9205 X1 =  SQR ((R(I) * R(I)) - (Y * Y))
9210 MM = X1 / CX:M =  INT (MM)
9220 X1 = M * CX
9230 Y = Y - CY
```

```
9230 Y = Y - CY
9235  IF Y < 0 THEN Y = 0
9238  IF Y > R(I) THEN Y = R(I)
9240 X2 =  SQR ((R(I) * R(I)) - (Y * Y))
9250 AX = (X2 - X1)
9255  IF AX = 0 THEN  GOTO 9270
9260  IF CX / AX <  = 0.5 THEN  GOTO 7528
9270 M = 1:SV = 2: GOSUB 6035
9280  IF Y <  = 0 THEN  GOTO 9400
9290  GOTO 9230
9400  IF B$(I - 1) = "CO" THEN  GOTO 9450
9410  IF B$(I - 1) = "CU" THEN  GOTO 9450
9420  RETURN
9450 DR = DI(I) - D(I - 1)
9460  IF DR = 0 THEN  RETURN
9470 MM = DR / CY:M =  INT (MM)
9480  IF MM - M >  = 0.5 THEN M = M + 1
9490 SV = 2: GOSUB 6035
9500  RETURN
```

ภาคผนวก ข.

ไอซีเบอร์ที่ใช้ในการวิจัย และ เทคโนโลยี Stepping Motor

TIMER — NE/SE555/SE555C/SA555

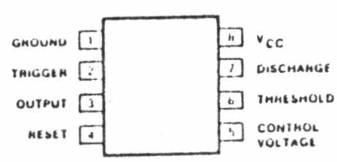
SA555F,N,N-14 • SE555F,T,N,N-14 • SE555C,F,T,N,N-14 • NE555F,T,N,N-14

FEATURES

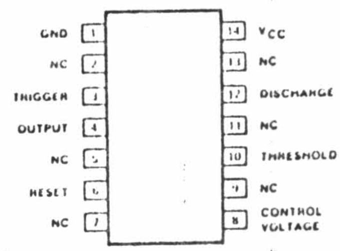
- Turn off time less than 2μs
- Maximum operating frequency greater than 500kHz
- Timing from microseconds to hours
- Operates in both astable and monostable modes
- High output current
- Adjustable duty cycle
- TTL compatible
- Temperature stability of 0.005% per °C
- SE555 Mil std 883A,B,C available M38510 (JAN) approved, M38510 processing available.

PIN CONFIGURATIONS

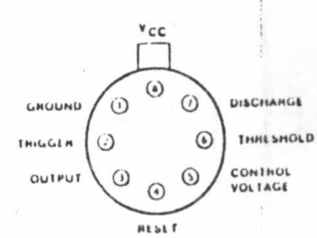
N PACKAGE



F,N-14 PACKAGE



T PACKAGE



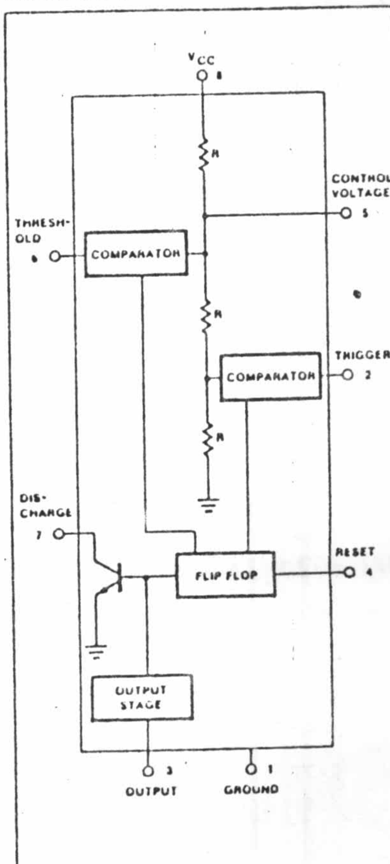
APPLICATIONS

- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Missing pulse detector

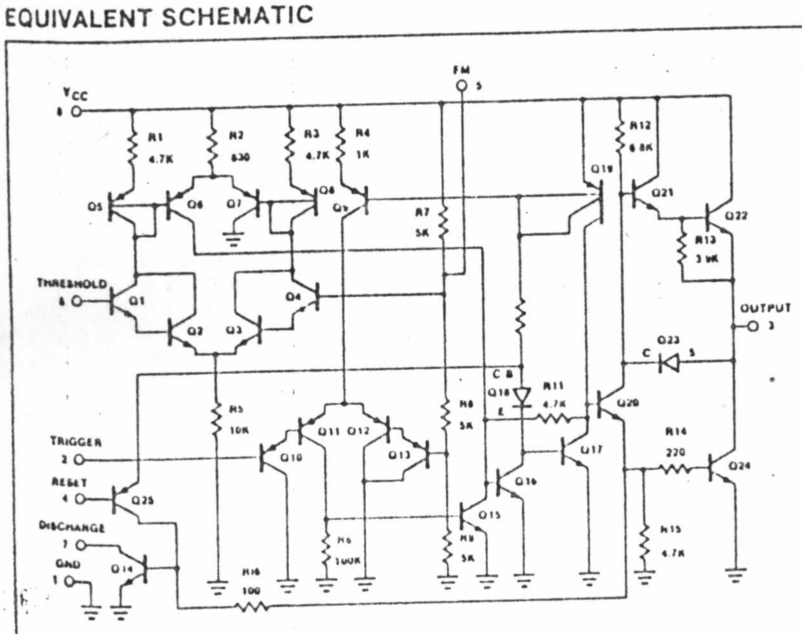
ABSOLUTE MAXIMUM RATINGS

PARAMETER	RATING	UNIT
Supply voltage		
SE555	+18	V
NE555, SE555C, SA555	+16	V
Power dissipation	600	mW
Operating temperature range		
NE555	0 to +70	°C
SA555	-40 to +85	°C
SE555, SE555C	-55 to +125	°C
Storage temperature range	-65 to +150	°C
Load temperature (soldering, 60sec)	300	°C

BLOCK DIAGRAM



EQUIVALENT SCHEMATIC



DC ELECTRICAL CHARACTERISTICS $T_A = 25°C$, $V_{CC} = +5V$ to $+15$ unless otherwise specified.

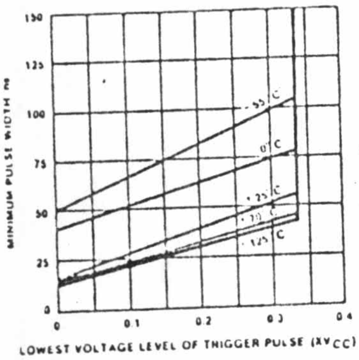
PARAMETER	TEST CONDITIONS	SE555 Min	SE555 Typ	SE555 Max	NE555/SE555C/SA555 Min	NE555/SE555C/SA555 Typ	NE555/SE555C/SA555 Max	UNIT
Supply voltage		4.5		18	4.5		16	V
Supply current (low state)[1]	$V_{CC} = 5V$ $R_L = \infty$		3	5		3	6	mA
	$V_{CC} = 15V$ $R_L = \infty$		10	12		10	15	mA
Timing error (monostable)	$R_A = 2K\Omega$ to $100K\Omega$, $C = 0.1\mu F$							
Initial accuracy[2]			0.5	2.0		1.0	3.0	%
Drift with temperature			30	100		50		ppm/°C
Drift with supply voltage			0.05	0.2		0.1	0.5	%/V
Timing error (astable)	R_A, $R_B = 1k\Omega$ to $100k\Omega$, $C = 0.1\mu F$, $V_{CC} = 15V$							
Initial accuracy[2]			1.5			2.25		%
Drift with temperature			90			150		ppm/°C
Drift with supply voltage			0.15			0.3		%/V
Control voltage level	$V_{CC} = 15V$	9.6	10.0	10.4	9.0	10.0	11.0	V
	$V_{CC} = 5V$	2.9	3.33	3.8	2.6	3.33	4.0	V
Threshold voltage	$V_{CC} = 15V$	9.4	10.0	10.6	8.8	10.0	11.2	V
	$V_{CC} = 5V$	2.7	3.33	4.0	2.4	3.33	4.2	V
Threshold current[3]			0.1	0.25		0.1	0.25	µA
Trigger voltage	$V_{CC} = 15V$	4.8	5.0	5.2	4.5	5.0	5.6	V
	$V_{CC} = 5V$	1.45	1.67	1.9	1.1	1.67	2.2	V
Trigger current	$V_{TRIG} = 0V$		0.5	0.9		0.5	2.0	µA
Reset voltage[4]		0.4	0.7	1.0	0.4	0.7	1.0	V
Reset current			0.1	0.4		0.1	0.4	mA
Reset current	$V_{RESET} = 0V$		0.4	1.0		0.4	1.5	mA
Output voltage (low)	$V_{CC} = 15V$							
	$I_{SINK} = 10mA$		0.1	0.15		0.1	0.25	V
	$I_{SINK} = 50mA$		0.4	0.5		0.4	0.75	V
	$I_{SINK} = 100mA$		2.0	2.2		2.0	2.5	V
	$I_{SINK} = 200mA$		2.5			2.5		V
	$V_{CC} = 5V$							
	$I_{SINK} = 8mA$		0.1	0.25		0.3	0.4	V
	$I_{SINK} = 5mA$		0.05	0.2		0.25	0.35	V
Output voltage (high)	$V_{CC} = 15V$							
	$I_{SOURCE} = 200mA$		12.5			12.5		V
	$I_{SOURCE} = 100mA$	13.0	13.3		12.75	13.3		V
	$V_{CC} = 5V$							
	$I_{SOURCE} = 100mA$	3.0	3.3		2.75	3.3		V
Turn off time[5]	$V_{RESET} = V_{CC}$		0.5	2.0		0.5		µs
Rise time of output			100	200		100	300	ns
Fall time of output			100	200		100	300	ns
Discharge leakage current			20	100		20	100	na

NOTES

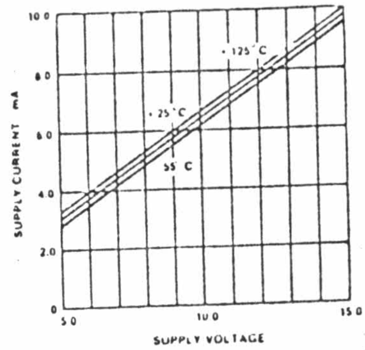
1. Supply current when output high typically 1mA less.
2. Tested at $V_{CC} = 5V$ and $V_{CC} = 15V$.
3. This will determine the maximum value of $R_A + R_B$, for 15V operation, the max total R = 10 megohm, and for 5V operation, the max total R = 3.4 megohm.
4. Specified with trigge input high.
5. Time measured fr positive going input pulse from 0 to 0.8xV_{CC} into the threshold to the drop from hi to low of the output. Trigger is tied to threshold.

TYPICAL PERFORMANCE CHARACTERISTICS

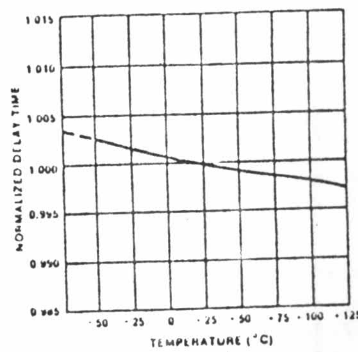
MINIMUM PULSE WIDTH REQUIRED FOR TRIGGERING



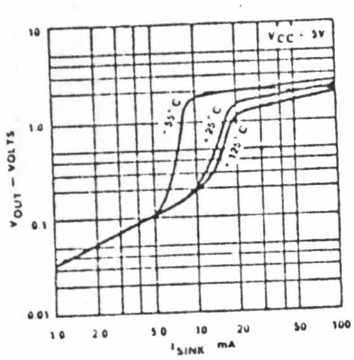
SUPPLY CURRENT vs SUPPLY VOLTAGE



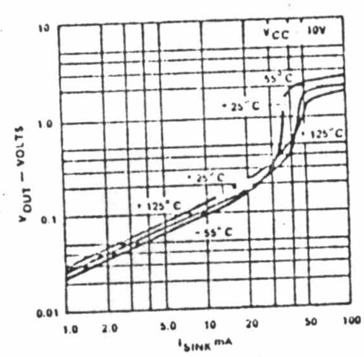
DELAY TIME vs TEMPERATURE



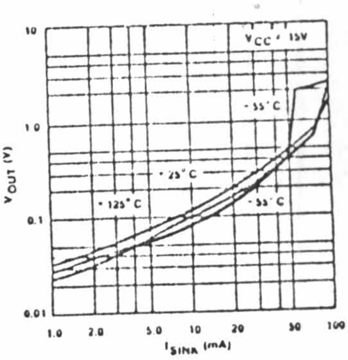
LOW OUTPUT VOLTAGE vs OUTPUT SINK CURRENT



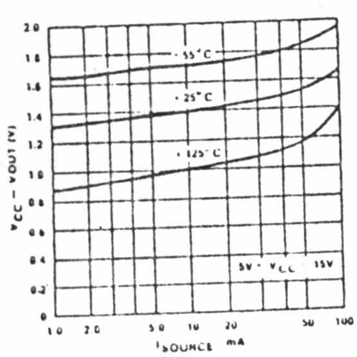
LOW OUTPUT VOLTAGE vs OUTPUT SINK CURRENT



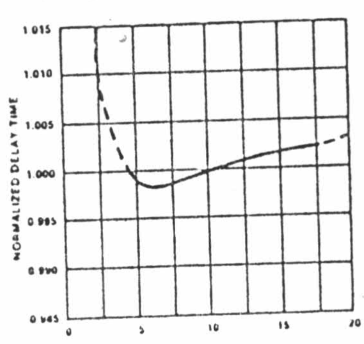
LOW OUTPUT VOLTAGE vs OUTPUT SINK CURRENT



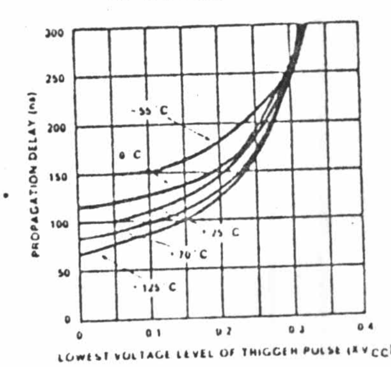
HIGH OUTPUT VOLTAGE DROP vs OUTPUT SOURCE CURRENT



DELAY TIME vs SUPPLY VOLTAGE



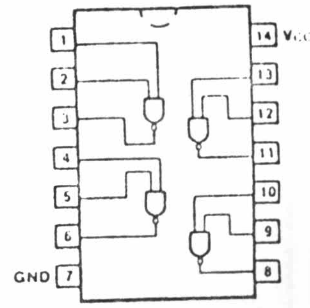
PROPAGATION DELAY vs VOLTAGE LEVEL OF TRIGGER PULSE



54/7403
54S/74S03
54LS/74LS03

QUAD 2-INPUT NAND GATE
(With Open-Collector Output)

CONNECTION DIAGRAM
PINOUT A



ORDERING CODE: See Section 9

PKGS	PIN OUT	COMMERCIAL GRADE	MILITARY GRADE	PKG TYPE
		V_{CC} = +5.0 V ±5%, T_A = 0°C to +70°C	V_{CC} = +5.0 V ±10%, T_A = -55°C to +125°C	
Plastic DIP (P)	A	7403PC, 74S03PC 74LS03PC		9A
Ceramic DIP (D)	A	7403DC, 74S03DC 74LS03DC	5403DM, 54S03DM 54LS03DM	6A
Flatpak (F)	A	7403FC, 74S03FC 74LS03FC	5403FM, 54S03FM 54LS03FM	3I

INPUT LOADING/FAN-OUT: See Section 3 for U.L. definitions

PINS	54/74 (U.L.) HIGH/LOW	54/74S (U.L.) HIGH/LOW	54/74LS (U.L.) HIGH/LOW
Inputs	1.0/1.0	1.25/1.25	0.5/0.25
Outputs	OC**/10	OC**/12.5	OC**/5.0 (2.5)

DC AND AC CHARACTERISTICS: See Section 3*

SYMBOL	PARAMETER	54/74		54/74S		54/74LS		UNITS	CONDITIONS	
		Min	Max	Min	Max	Min	Max			
I_{CCH}	Power Supply Current		8.0		13.2		1.6	mA	V_{IN} = Gnd	V_{CC} = Max
I_{CCL}			22		36		4.4		V_{IN} = Open	
t_{PLH}	Propagation Delay		45	2.0	7.5		22	ns	Figs. 3-2, 3-4	
t_{PHL}			15	2.0	7.0		18			

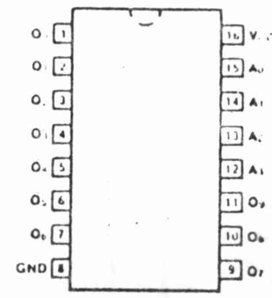
*DC limits apply over operating temperature range; AC limits apply at T_A = +25°C and V_{CC} = +5.0 V.
**OC — Open Collector

54/7442A • 54LS/74LS42
54/7443A • 54/7444A
1-of-10 DECODER

DESCRIPTION - The '42, '43 and '44 are multipurpose decoders. For any valid input combination, one and only one output is LOW. For all invalid input combinations all outputs are HIGH. The '42 accepts four BCD inputs and provides ten mutually exclusive outputs; the '43 accepts four lines of EXCESS-3 encoded data and provides ten mutually exclusive outputs; the '44 accepts four lines of EXCESS-3 Gray encoded data and provides ten mutually exclusive totem pole outputs.

- MULTIFUNCTION CAPABILITY
- MUTUALLY EXCLUSIVE OUTPUTS
- DEMULTIPLEXING CAPABILITY
- FULLY TTL AND CMOS COMPATIBLE

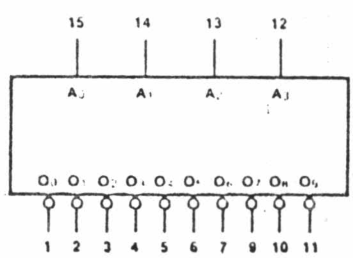
CONNECTION DIAGRAM
PINOUT A



ORDERING CODE: See Section 9

PKGS	PIN OUT	COMMERCIAL GRADE	MILITARY GRADE	PKG TYPE
		Vcc = +5.0 V ±5%, T_A = 0°C to +70°C	Vcc = +5.0 V ±10%, T_A = -55°C to +125°C	
Plastic DIP (P)	A	7442APC, 74LS42PC 7443APC, 7444APC		9B
Ceramic DIP (D)	A	7442ADC, 74LS42DC 7443ADC, 7444ADC	5442ADM, 54LS42DM 5443ADM, 5444ADM	6B
Flatpak (F)	A	7442AFC, 74LS42FC 7443AFC, 7444AFC	5442AFM, 54LS42FM 5443AFM, 5444AFM	4L

LOGIC SYMBOL



Vcc = Pin 16
GND = Pin 8

INPUT LOADING/FAN-OUT: See Section 3 for U.L. definitions

PIN NAMES	DESCRIPTION	54/74 (U.L.) HIGH/LOW	54/74LS (U.L.) HIGH/LOW
$A_0 - A_3$	BCD Inputs ('42)	1.0/1.0	0.5/0.25
$A_0 - A_3$	EXCESS-3 Inputs ('43)	1.0/1.0	
$A_0 - A_3$	EXCESS-3 GRAY Inputs ('44)	1.0/1.0	
$\bar{O}_0 - \bar{O}_9$	Decimal Outputs (Active LOW)	20/10	10/5.0 (2.5)

FUNCTIONAL DESCRIPTION — Logically, the '42, '43 and '44 differ only in their input codes. The '42 accepts the standard 8421 BCD code. The '43 accepts the EXCESS-3 decimal code while the '44 accepts the EXCESS-3 Gray code. For any input combination within the assigned ten states, only one output is LOW, as shown in the Truth Table. For all invalid input combinations, all ten outputs are HIGH.

The '42 can be used as a conventional 1-of-8 decoder by treating the most significant input A_3 as an active LOW Enable. Similarly, it can be used as an 8-output demultiplexer by using A_3 as the data input.

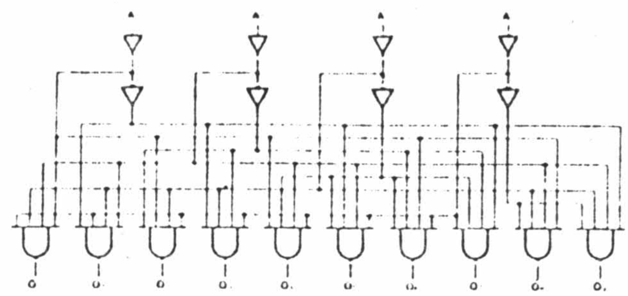
TRUTH TABLE

'42A • 'LS42 BCD INPUT				'43A EXCESS-3 INPUT				'44A EXCESS-3 GRAY INPUT				ALL TYPES DECIMAL OUTPUT									
A_3	A_2	A_1	A_0	A_3	A_2	A_1	A_0	A_3	A_2	A_1	A_0	$\bar{O}_0$	$\bar{O}_1$	$\bar{O}_2$	$\bar{O}_3$	$\bar{O}_4$	$\bar{O}_5$	$\bar{O}_6$	$\bar{O}_7$	$\bar{O}_8$	$\bar{O}_9$
L	L	L	L	L	L	H	H	L	L	H	L	L	H	H	H	H	H	H	H	H	H
L	L	L	H	L	H	L	L	L	H	H	L	H	L	H	H	H	H	H	H	H	H
L	L	H	L	L	H	L	H	L	H	H	H	H	H	L	H	H	H	H	H	H	H
L	L	H	H	L	H	H	L	L	H	L	H	H	H	H	L	H	H	H	H	H	H
L	H	L	L	L	H	H	H	L	H	L	L	H	H	H	H	L	H	H	H	H	H
L	H	L	H	H	L	L	L	H	H	L	L	H	H	H	H	H	L	H	H	H	H
L	H	H	L	H	L	L	H	H	H	L	H	H	H	H	H	H	H	L	H	H	H
L	H	H	H	H	L	H	L	H	H	H	H	H	H	H	H	H	H	H	L	H	H
H	L	L	L	H	L	H	H	H	H	H	L	H	H	H	H	H	H	H	H	L	H
H	L	L	H	H	H	L	L	H	L	H	L	H	H	H	H	H	H	H	H	H	L
H	L	H	L	H	H	L	H	H	L	H	H	H	H	H	H	H	H	H	H	H	H
H	L	H	H	H	H	H	L	H	L	L	H	H	H	H	H	H	H	H	H	H	H
H	H	L	L	H	H	H	H	H	L	L	L	H	H	H	H	H	H	H	H	H	H
H	H	L	H	L	L	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H
H	H	H	L	L	L	L	H	L	L	L	H	H	H	H	H	H	H	H	H	H	H
H	H	H	H	L	L	H	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H

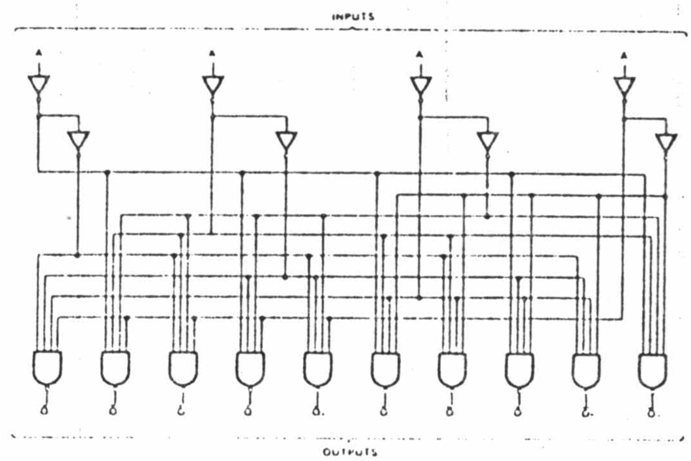
H = HIGH Voltage Level
L = LOW Voltage Level

LOGIC DIAGRAMS

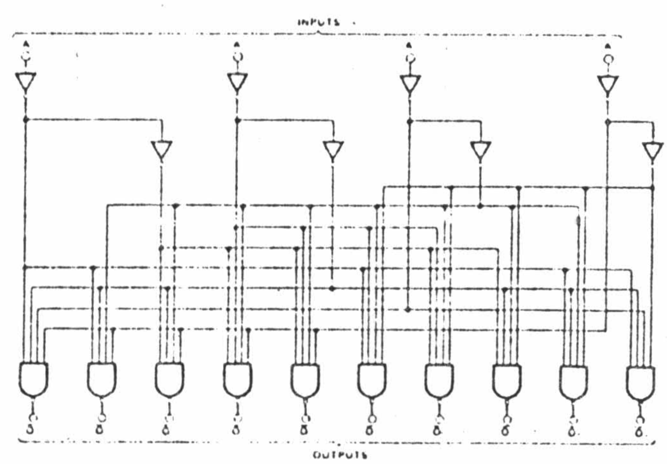
'42A • 'LS42



'43A



'44A



DC CHARACTERISTICS OVER OPERATING TEMPERATURE RANGE (unless otherwise specified)

SYMBOL	PARAMETER		54/74		54/74LS		UNITS	CONDITIONS
			Min	Max	Min	Max		
I_{OS}	Output Short Circuit Current	XM	-20	-55	-20	-100	mA	V_{CC} = Max
		XC	-18	-55	-20	-100		
I_{CC}	Power Supply Current	XM		41		12	mA	V_{CC} = Max
		XC		56		12		

AC CHARACTERISTICS: V_{CC} = +5.0 V, T_A = +25° C (See Section 3 for waveforms and load configurations)

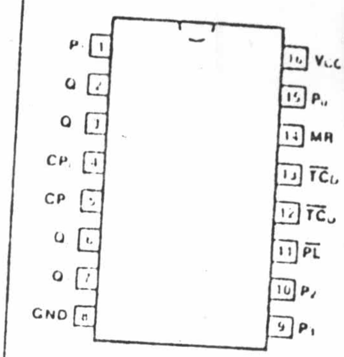
SYMBOL	PARAMETER	54/74		54/74LS		UNITS	CONDITIONS
		C_L = 15 pF R_L = 400 Ω		C_L = 15 pF			
		Min	Max	Min	Max		
t_{PLH} t_{PHL}	Propagation Delay A_n to $\overline{O}_n$, 2 Levels		25 25		18 25	ns	Figs. 3-1, 3-20
t_{PLH} t_{PHL}	Propagation Delay A_n to $\overline{O}_n$, 3 Levels		30 30		20 27	ns	Figs. 3-1, 3-20

54/74193
54LS/74LS193

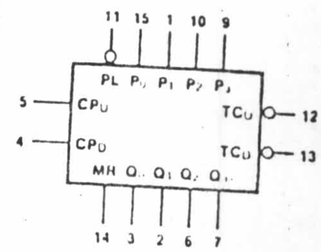
UP/DOWN BINARY COUNTER
(With Separate Up/down Clocks)

DESCRIPTION — The '193 is an up/down modulo-16 binary counter. Sep-arate Count Up and Count Down Clocks are used and in either counting mode the circuits operate synchronously. The outputs change state synchronous with the LOW-to-HIGH transitions on the clock inputs. Separate Terminal Count Up and Terminal Count Down outputs are provided which are used as the clocks for subsequent stages without extra logic, thus simplifying multistage counter designs. Individual preset inputs allow the circuits to be used as programmable counters. Both the Parallel Load ($\overline{PL}$) and the Master Reset (MR) inputs asynchronously override the clocks. For functional description and detail specifications please refer to the '192 data sheet.

CONNECTION DIAGRAM
PINOUT A



LOGIC SYMBOL



Vcc = Pin 16
GND = Pin 8

ORDERING CODE: See Section 9

PKGS	PIN OUT	COMMERCIAL GRADE Vcc = +5.0 V ±5%, T_A = 0°C to +70°C	MILITARY GRADE Vcc = +5.0 V ±10%, T_A = -55°C to +125°C	PKG TYPE
Plastic DIP (P)	A	74193PC, 74LS193PC		9B
Ceramic DIP (D)	A	74193DC, 74LS193DC	54193DM, 54LS193DM	6B
Flatpak (F)	A	74193FC, 74LS193FC	54193FM, 54LS193FM	4L

INPUT LOADING/FAN-OUT: See Section 3 for U.L. definitions

PIN NAMES	DESCRIPTION	54/74 (U.L.) HIGH/LOW	54/74LS (U.L.) HIGH/LOW
CP_U	Count Up Clock Input (Active Rising Edge)	1.0/1.0	0.5/0.25
CP_D	Count Down Clock Input (Active Rising Edge)	1.0/1.0	0.5/0.25
MR	Asynchronous Master Reset Input (Active HIGH)	1.0/1.0	0.5/0.25
$\overline{PL}$	Asynchronous Parallel Load Input (Active LOW)	1.0/1.0	0.5/0.25
$P_0 - P_3$	Parallel Data Inputs	1.0/1.0	0.5/0.25
$Q_0 - Q_3$	Flip-flop Outputs	20/10	10/5.0 (2.5)
$\overline{TC}_D$	Terminal Count Down (Borrow) Output (Active LOW)	20/10	10/5.0 (2.5)
$\overline{TC}_U$	Terminal Count Up (Carry) Output (Active LOW)	20/10	10/5.0 (2.5)

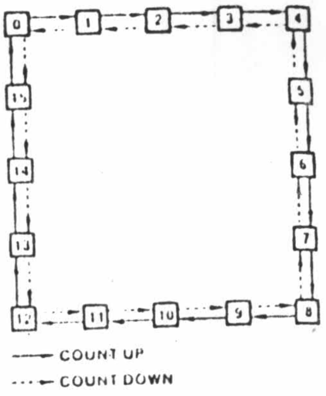
193

MODE SELECT TABLE

MR	$\overline{PL}$	CP_U	CP_D	MODE
H	X	X	X	Reset (Asyn.)
L	L	X	X	Preset (Asyn.)
L	H	H	H	No Change
L	H	_/‾	H	Count Up
L	H	H	_/‾	Count Down

H = HIGH Voltage Level
L = LOW Voltage Level
X = Immaterial
Z = High Impedance

STATE DIAGRAM

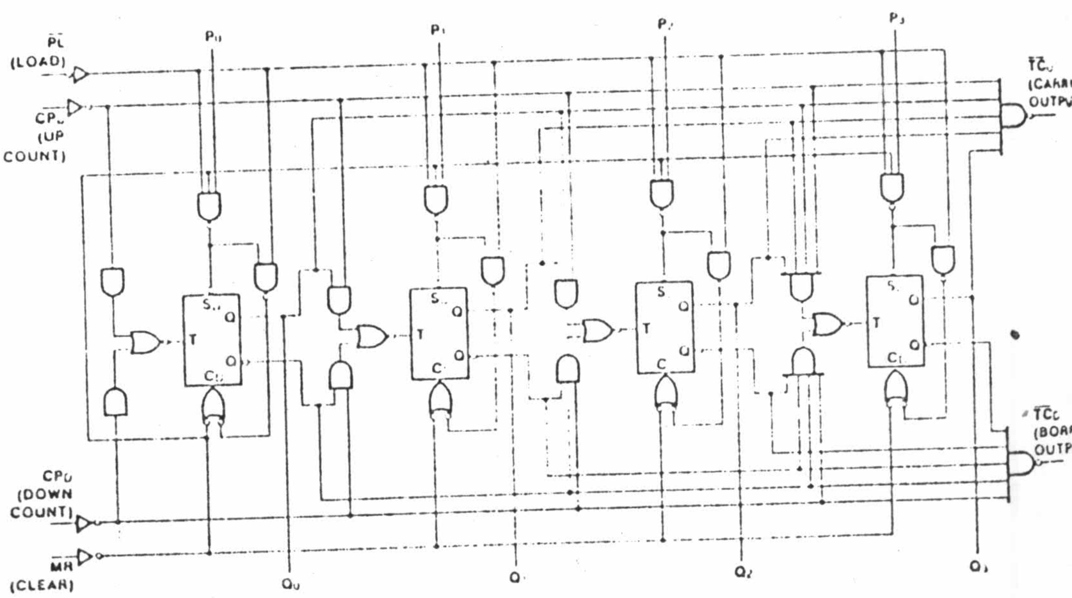


LOGIC EQUATIONS FOR TERMINAL COUNT

$$\overline{TC_U} = Q_0 \cdot Q_1 \cdot Q_2 \cdot Q_3 \cdot \overline{CP_U}$$

$$\overline{TC_D} = \overline{Q}_0 \cdot \overline{Q}_1 \cdot \overline{Q}_2 \cdot \overline{Q}_3 \cdot \overline{CP_D}$$

LOGIC DIAGRAM



The stepper motor is a device used to convert electrical pulses into discrete mechanical rotational movements.

The North American Philips Controls Corporation stepper motors described in this handbook are two-phase permanent magnet motors which provide discrete angular movement every time the polarity of a winding is changed.

CONSTRUCTION

In a typical motor, electrical power is applied to two coils. Two stator cups formed around each of these coils with pole pairs mechanically displaced by ½ a pole pitch, become alternately energized North and South magnetic poles. Between the two stator-coil pairs the displacement is ¼ of a pole pitch.

The permanent magnet rotor is magnetized with the same number of pole pairs as contained by one stator-coil section.

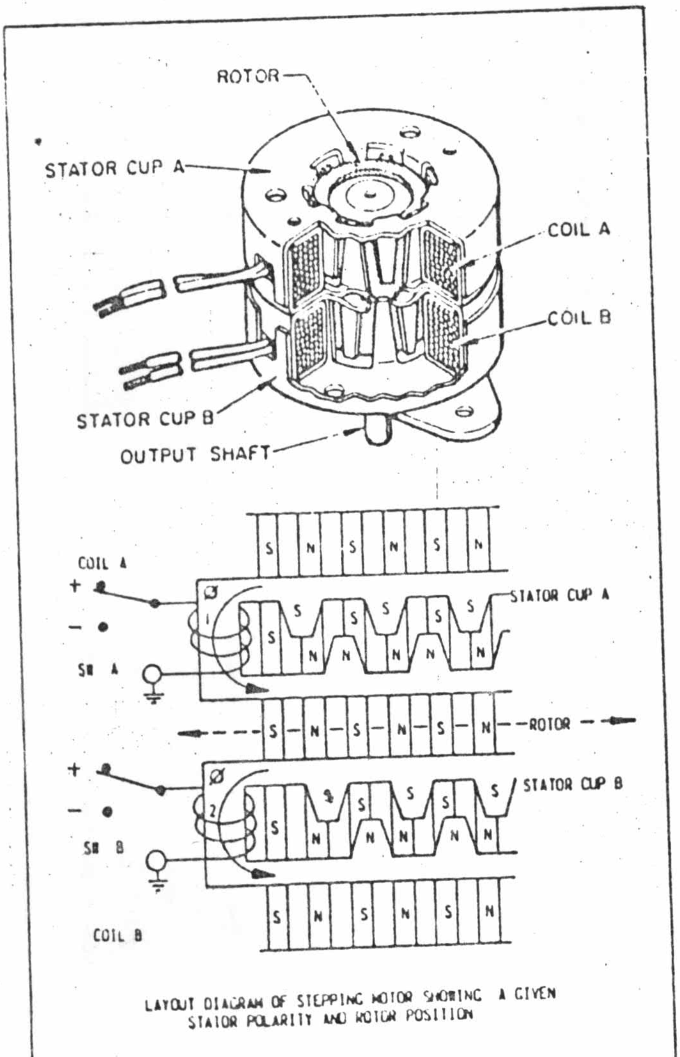
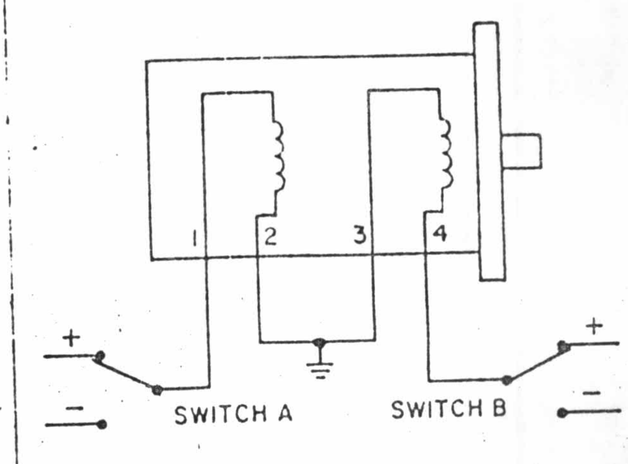


Fig. 1 Cutaway 2 Ø Permanent Magnet Stepper Motor.

Interaction between the rotor and stator (opposite poles attracting and likes repelling) causes the rotor to move ¼ of a pole pitch per winding polarity change. A two-phase motor with 12 pole pairs per stator-coil section would thus move 48 steps per revolution or 7.5° per step.

ELECTRICAL INPUT

The normal electrical input is a four-step switching sequence as is shown in Figure 2.



CW ROTATION ↓ / CCW ROTATION ↑

STEP	COIL A	COIL B
1	+	+
2	+	−
3	−	−
4	−	+
1	+	+

Fig. 2 Schematic — 4-Step Switching Sequence.

Continuing the sequence causes the rotor to rotate forward. Reversing the sequence reverses the direction of rotation. Thus, the stepper motor can be easily controlled by a pulse input drive which can be a two flip-flop logic circuit operated either open or closed loop. Operated at a fixed frequency, the electrical input to the motor is a two-phase 90° shifted square wave as shown below.

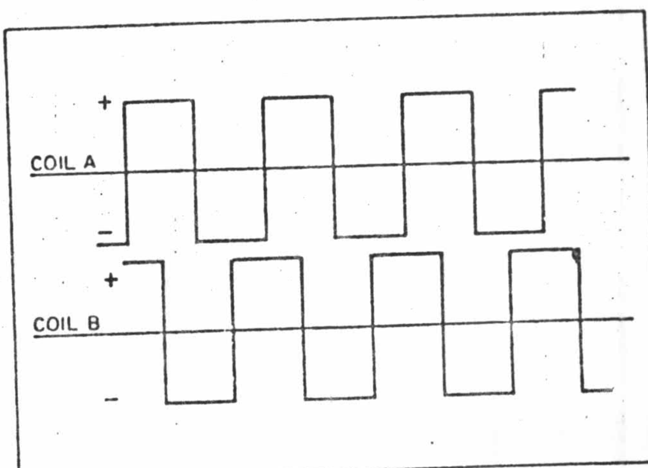


Fig. 3 Voltage Wave Form — Fixed Frequency — 4-Step Sequence.

Since each step of the rotor can be controlled by a pulse input to a drive circuit, the stepper motor used with modern digital circuits, micro-processors and transistors provides accurate speed and position control along with long life and reliability.

STEP ANGLE

Step angles for steppers are available in a range from .72° to 90°. Standard step angles for North American Philips Controls Corporation Steppers are:

7.5° — 48 steps per rev
15° — 24 steps per rev
18° — 20 steps per rev

A movement of any multiple of these angles is possible. For example, six steps of a 15° stepper motor would give a movement of 90°.

ACCURACY

The no load or constant load accuracy of each step is within ±6.5%, noncumulative. Therefore, a 7.5° stepper motor will position to within 0.5°, whether the rotational movement is 7.5° — one step, or 7,500° — one thousand steps.

The step error is noncumulative. It averages out to zero within a 4-step sequence which corresponds to 360 electrical degrees. A particular step condition of the 4-step sequence repeatedly uses the same coil, magnetic polarity and flux path. Thus, the most accurate movement would be to step in multiples of four since electrical and magnetic inbalances are eliminated. Increased accuracy also results from movements which are multiples of two steps. Keeping this in mind, positioning applications should use 2 or 4 steps (or multiples thereof) for each desired measured increment, wherever possible.

TORQUE

The torque produced by a specific stepper motor depends on several factors:

1/ The Step Rate
2/ The Drive Current Supplied to the Windings
3/ The Drive Design

HOLDING TORQUE

At standstill (zero steps/sec. and rated current) the torque required to deflect the rotor a full step is called the Holding Torque. Normally, the holding torque is higher than the running torque and thus acts as a strong brake in holding a load. Since deflection varies with load, the higher the holding torque the more accurate the position will be held. Note in the curve below that a two step deflection corresponding to a phase displacement of 180° results in zero torque. A one step plus or minus displacement represents the initial lag that occurs when the motor is given a step command.

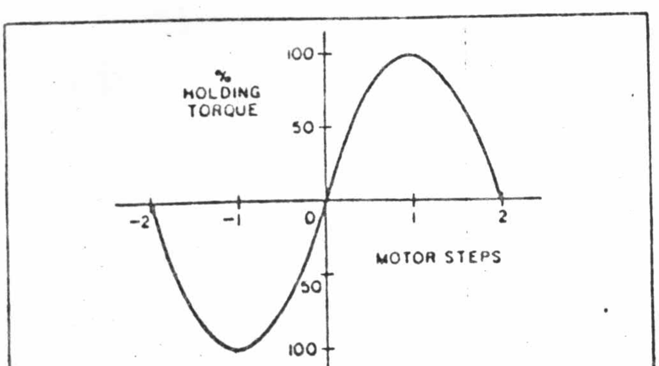


Fig. 4 Torque Deflection.

RESIDUAL TORQUE

The non-energized detent torque of a PM stepper motor is called residual torque. A result of the permanent magnet flux and bearing friction, it has a value of approximately 1/10 the holding torque. This characteristic of PM steppers is useful in holding a load in the proper position even when the motor is de-energized. The position, however, will not be held as accurately as when the motor is energized.

DYNAMIC TORQUE

A typical torque versus step rate characteristic curve is shown in Figure 5.

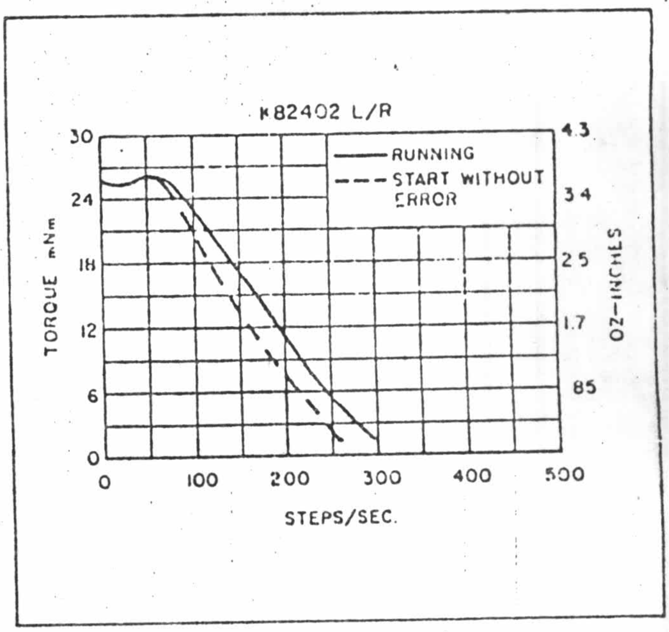


Fig. 5 Speed/Torque — (NAPCC K82402 L/R Stepper).

The **Start Without Error** curve shows what torque load the motor can start and stop without loss of a step when started and stopped at a constant step or pulse rate.

The **Running** curve is the torque available when the motor is slowly accelerated to the operating rate. It is thus the actual dynamic torque produced by the motor. This curve is sometimes called the slew curve.

The difference between the Running and the Start Without Error torque curves is the torque lost due to accelerating the motor rotor inertia.

The speed-torque characteristic curves are the key to selecting the right motor and the control drive method for a specific application.

In order to properly analyze application requirements, the load torque must be defined as being either Frictional and/or Inertial. A "Handy Formula" section in this handbook on pages 12 and 13 may assist you in resolving the load torque values. Also, an additional "Application Notes" section is located on pages 10 and 11.

Use the Start Without Error curve if the control circuit provides no acceleration and the load is frictional only.

Applications where:

No acceleration — Frictional Load

Example: Frictional Torque Load

Using a torque wrench, a frictional load is measured to be 10.6 mNm (1.5 oz-in). It is desired to move this load 67.5° in .06 sec. or less.

Solution:

1. If a 7.5° motor is used, then the motor would have to take 9 steps to move 67.5°.

   A rate of $v = \frac{9}{.06} = 150$ step/sec. or higher is thus required.

2. Referring to Fig. 6, the maximum Start Without Error rate with a torque of 10.6 mNm is 170 steps/sec. (It is assumed no acceleration control is provided).

3. Therefore, a K82402 motor could be used at 150 steps per second — allowing a safety factor.

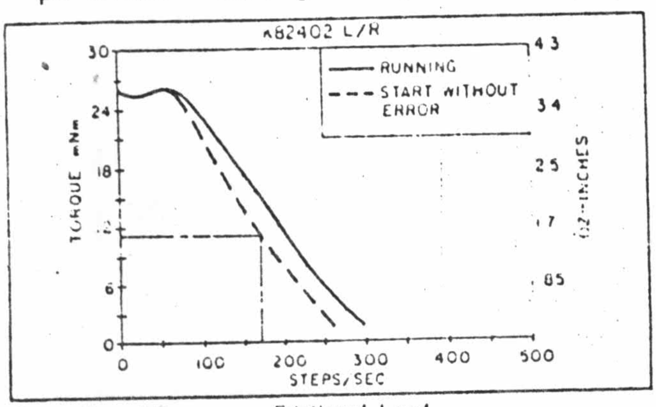


Fig. 6 Speed/Torque — Frictional Load.

Use the Running curve, in conjunction with a Torque = Inertia x Acceleration equation ($T = J\alpha$), when the load is inertial and/or acceleration control is provided.

In this equation, acceleration or ramping $\alpha = \frac{\Delta v}{\Delta t}$ is in radians/sec².

RAMPING

Acceleration control or ramping is normally accomplished by gating on a voltage controlled oscillator and associated charging capacitor. Varying the RC time constant will give different ramping times. A typical VCO acceleration control frequency plot for an incremental movement with equal acceleration and deceleration time would be as shown in Fig. 7.

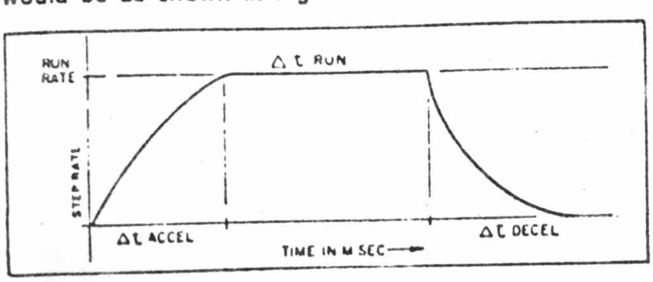


Fig. 7 Step Rate/Time.

Acceleration may also be accomplished by dividing the frequency. For example, the frequency could start at a ¼ rate, go to a ½ rate, ¾ rate and finally the running rate.

A. **Applications where:**
   Ramping acceleration or deceleration control time allowed

$$T_J(\text{Torque mNm}) = J_T \times \frac{\Delta v}{\Delta t} \times K$$

Where J_T = Rotor Inertia (g.m²) plus Load Inertia (g.m²)

Δv = Step rate change
Δt = Time allowed for acceleration in seconds
$K = \frac{2\pi}{\text{steps/rev}}$ (converts steps/sec to radians/sec)
K = .13 for 7.5° — 48 steps/revolution
K = .26 for 15° — 24 steps/revolution
K = .314 for 18° — 20 steps/revolution

In order to solve an application problem using acceleration ramping, it is usually necessary to make several estimates according to a procedure similar to the one used to solve the following example.

Example: Frictional Torque plus Inertial Load with Acceleration Control.

An assembly device must move 4 mm in less than 0.5 sec. The motor will drive a lead screw through a gear ratio. The lead screw and gear ratio were selected so that 100 steps of a 7.5° motor = 4 mm. The total Inertial Load (rotor + gear + screw) = 25 x 10^{-4} g.m². The Frictional Load = 6 mNm

Solution:

1. Select a stepper motor running curve which allows a torque in excess of 6 mNm at a step rate greater than

$$v = \frac{100 \text{ steps}}{0.5 \text{ sec}} = 200 \text{ steps/sec.}$$

Referring to Fig. 8, determine the maximum possible rate (vF) with the frictional load only.

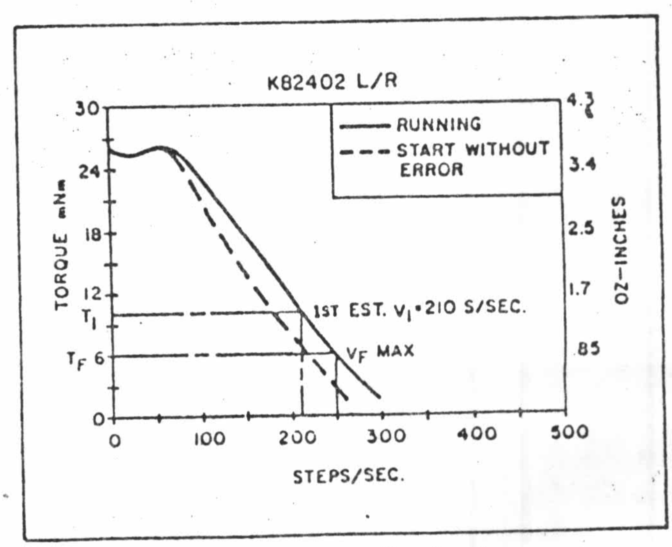


Fig. 8 Speed/Torque — Friction Plus Inertia.

2. Make a first estimate of a working rate (a running rate less than the maximum) and determine the torque available to accelerate the inertia (excess over T_F).

$$T_1 - T_F = 10 - 6 = 4 \text{ mNm}$$

(torque available for acceleration at 210 steps/sec).

3. Using a 60% safety factor

$$(4 \text{ mNm} \times .6 = 2.4 \text{ mNm}),$$

calculate Δt to accelerate. (Refer to Fig. 7).

From the $T_J = J_T \times \frac{\Delta v}{\Delta t} \times K$ equation.

$$2.4 \text{ mNm} = \frac{25 \times 10^{-4} \times 210 \times .13}{\Delta t}$$

Therefore to accelerate $\Delta t = .028$ sec

Note: The same amount of time is allowed to decelerate.

4. The number of steps used to accelerate and decelerate,

$$N_A + N_D = \frac{v}{2} \Delta t \times 2$$

$$\text{or } N_A + N_D = v\Delta t$$

$$= 210\ (.03) = 6 \text{ steps}$$

5. The time to move at the run rate

$$\Delta t_{run} = N_T - (N_A + N_D) = \frac{100-6}{210} = .447 \text{ sec}$$

Where N_t = Total move of 100 steps

6. The total time to move is thus

$$\Delta t_{run} + \Delta t_{accel} + \Delta t_{decel}$$

$$.447 + .028 + .028 = 0.5 \text{ sec}$$

This is the first estimate. You may make the move slower if more safety is desired, or faster if you want to optimize it. At this time, you may wish to consider a faster motor drive combination as will be discussed on page 8.

B. **Applications where:**

No ramping acceleration or deceleration control time allowed.

Even though no acceleration time is provided, the stepper motor can lag a maximum of 2 steps or 180 electrical degrees. If the motor goes from zero steps/sec to v steps/sec, the lag time Δt would be $\frac{2}{v}$ sec.

Thus the torque equation for no acceleration or deceleration is:

$$\textbf{T (Torque mNm)} = J_T \times \frac{v^2}{2} \times K$$

Where:

J Rotor Inertia (g.m²) plus Load Inertia (g.m²)

$$v = \text{Steps sec rate}$$

$$K = \frac{2\pi}{\text{step/rev}}$$

("K" values as shown in application A on page 4)

Example: Friction plus Inertia — No acceleration ramping.

A tape capstan is to be driven by a stepper motor. The frictional drag torque (T_F) is 8.6 mNm and the Inertia of the capstan is 8×10^{-4} g.m². The capstan must rotate in 7.5 increments at a rate of 170 steps per second.

Solution:

Since a torque greater than 8.6 mNm at 170 steps per second is needed, consider a K82402 motor.
The Total Inertia = Motor Rotor Inertia + Load Inertia.

$$J_T = J_R + J_L$$

$$= (10 \times 10^{-4} + 8 \times 10^{-4}) \text{ g.m}^2$$

$$= 18 \times 10^{-4} \text{ g.m}^2$$

1. Since there is no acceleration ramping, use the equation:

$$T_J = J_T \times \frac{v^2}{2} \times K \qquad (K = .13)$$

$$T_J = 18 \times 10^{-4} \times \frac{170^2}{2} \times .13$$

$$T_J = 3.4 \text{ mNm}$$

2. Total Torque $= T_F + T_J$

$$= 8.6 + 3.4$$

$$= 12 \text{ mNm}$$

3. Refer to the running curve Fig. 9, at 170 steps per second, the available torque is 15 mNm. Therefore, the K82402 motor can be used with a safety factor.

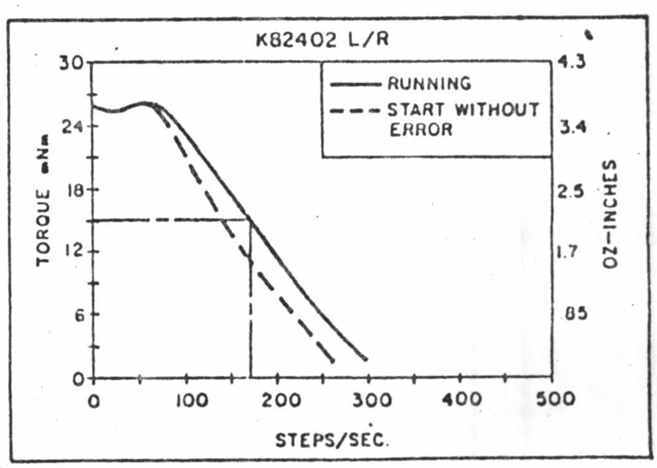


Fig. 9 Speed/Torque — Friction Plus Inertia.

STEP FUNCTION — SINGLE STEP

When a single step of a motor is made, a typical response is as shown in Figure 10.

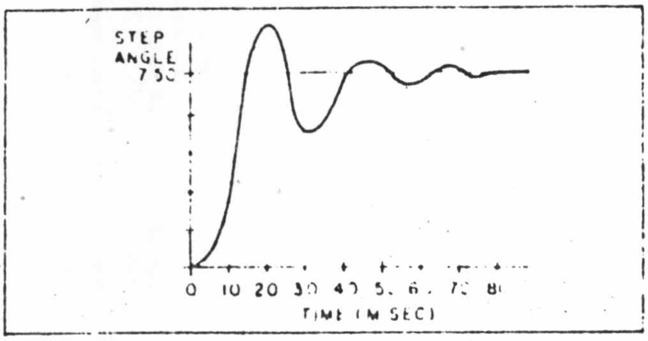


Fig. 10 Single Step Response.

The actual response for a given motor is a function of the power input provided by the drive and the load. Increasing the frictional load or adding external damping can thus modify this response if it is required.

Mechanical dampers such as slip pads or plates, or devices such as a fluid coupled flywheel can be used but add to system cost and complexity. Electronic damping can also be accomplished. A first time delay and a reverse pulse and then a second time delay and forward pulse is added to every move pulse or to the last pulse in a movement. Delaying the final pulse of an incremental movement can also be used to effect damping.

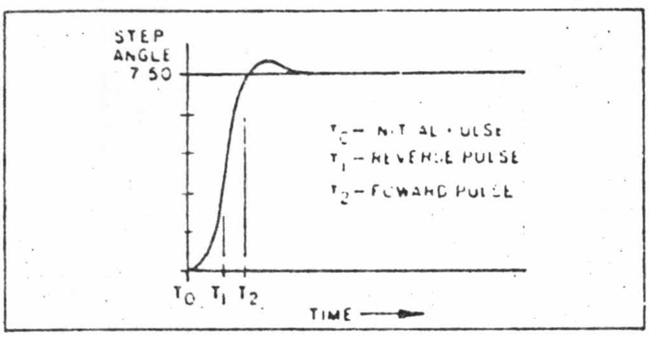


Fig. 11 Electronically Damped Response.

STEP FUNCTION — MULTIPLE STEPPING

Multiple stepping can offer several alternatives. A 7.5° motor moving 12 steps or a 15° motor moving 6 steps to give a 90° output move would have less overshoot, be stiffer, and relatively more accurate than a motor with a 90° step angle. Also, the pulses can be timed to shape the velocity of the motion; slow during start, accelerate to maximum velocity, then decelerate to stop with minimum ringing.

RESONANCE

If a stepper motor is operated no-load over the entire frequency range, one or more natural oscillating resonance points may be detected either audibly or by vibration sensors. Some applications may be such that operation at these frequencies should be avoided or external damping, added inertia, or a softer drive used. A permanent magnet stepper motor, however, will not exhibit the instability and loss of steps often found in variable reluctance stepper motors since the PM has a higher rotor inertia and a stronger detent torque.

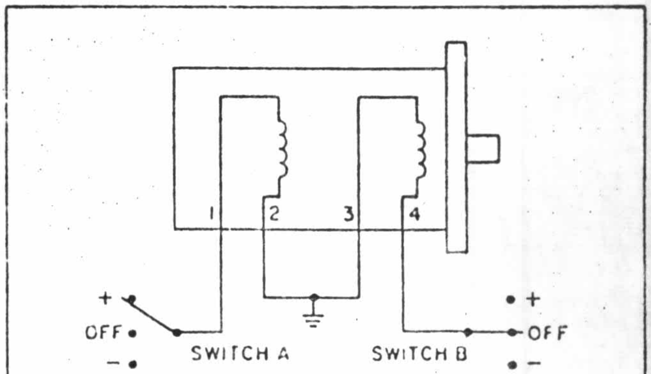
DRIVE METHODS

The normal drive method, as previously stated, is the 4-step sequence shown in Fig. 2; however, the following methods are also possible.

WAVE DRIVE

Energizing only one winding at a time, as is indicated in Fig. 12 is called Wave Excitation. It produces the same increment as the four-step sequence.

Since only one winding is on, the hold and running torque with rated voltage applied will be reduced 30%. Within limits, the voltage can be increased to bring output power back to near rated torque value. The advantage of this type of drive is increased efficiency while the disadvantage is decreased step accuracy.



CW ROTATION ↓ / CCW ROTATION ↑

STEP	COIL A	COIL B
1	+	OFF
2	OFF	+
3	−	OFF
4	OFF	−
1	+	OFF

Fig. 12 Schematic — Wave Drive Switching Sequence.

HALF STEP

It is also possible to step the motor according to an eight step sequence to obtain a half step — such as a 3.75° step from a 7.5° motor.

Applications utilizing this should be aware of the fact that the holding torque will vary for every other step since only one winding will be energized for a step position but on the next step two windings are energized. This gives the effect of a strong step and a weak step. Also, since the winding and flux conditions are not similar for each step when ½ stepping, accuracy will not be as good as when full stepping.

CW ROTATION ↓ / CCW ROTATION ↑

STEP	COIL A	COIL B
1	+	+
2	+	OFF
3	+	−
4	OFF	−
5	−	−
6	−	OFF
7	−	+
8	OFF	+
1	+	+

Fig. 13 Half Step or 8 Step Switching Sequence.

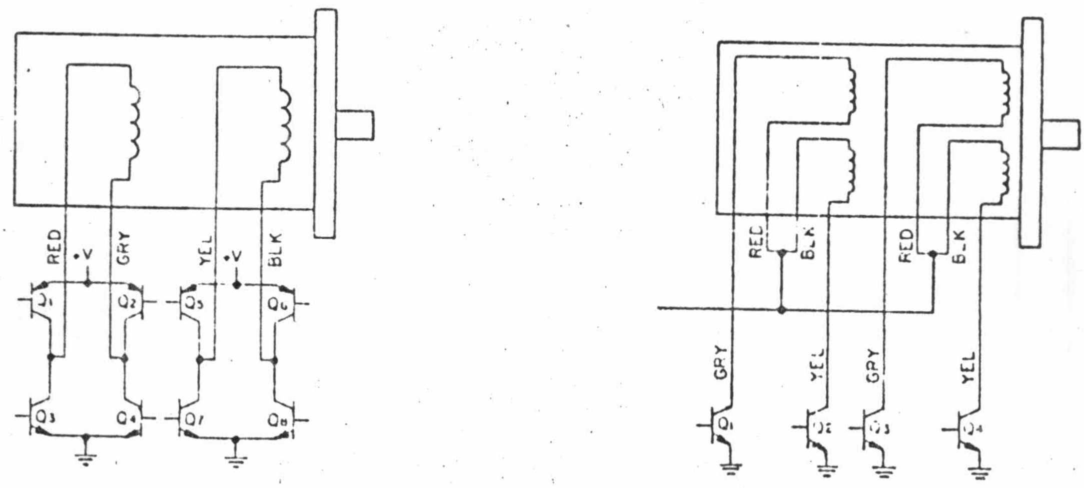
BIPOLAR AND UNIPOLAR OPERATION

All NAPCC stepper motors are available with either 2 coil bipolar, or 4 coil unipolar windings.

The stator flux with a BIPOLAR winding is reversed by reversing the current in the winding. It requires a push-pull bipolar drive as shown in Fig. 14. Care must be taken to design the circuit so that the transistors in series do not short the power supply by coming on at the same time. Properly operated, the bipolar winding gives the optimum motor performance at low to medium step rates.

A UNIPOLAR winding has 2 coils wound on the same bobbin per stator half. Flux is reversed by energizing one coil or the other coil from a single power supply. The use of a unipolar winding, sometimes called a bifilar winding, allows the drive circuit to be simplified. Not only are half as many power switches required (4 vs. 8), but the timing is not as critical to prevent a current short through two transistors as is possible with a bipolar drive.

For a unipolar motor to have the same number of turns per winding as a bipolar motor, the wire diameter must be decreased and therefore the resistance increased. As a result unipolar motors have 30% less torque at low step rates. However, at higher rates the torque outputs are equivalent.



BIPOLAR / **UNIPOLAR**

Normal 4 Step Sequence (CW ROTATION ↓ / CCW ROTATION ↑)

BIPOLAR:

Step	Q.-Q	Q.-Q	Q.-Q	Q.-Q
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

UNIPOLAR:

Step	Q.	Q.	Q.	Q.
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

½ Step 8 Step Sequence (CW ROTATION ↓ / CCW ROTATION ↑)

BIPOLAR:

1	ON	OFF	ON	OFF
2	ON	OFF	OFF	OFF
3	ON	OFF	OFF	ON
4	OFF	OFF	OFF	ON
5	OFF	ON	OFF	ON
6	OFF	ON	OFF	OFF
7	OFF	ON	ON	OFF
8	OFF	OFF	ON	OFF
1	ON	OFF	ON	OFF

UNIPOLAR:

1	ON	OFF	ON	OFF
2	ON	OFF	OFF	OFF
3	ON	OFF	OFF	ON
4	OFF	OFF	OFF	ON
5	OFF	ON	OFF	ON
6	OFF	ON	OFF	OFF
7	OFF	ON	ON	OFF
8	OFF	OFF	ON	OFF
1	ON	OFF	ON	OFF

Wave Drive 4 Step Sequence (CW ROTATION / CCW ROTATION)

BIPOLAR:

1	ON	OFF	OFF	OFF
2	OFF	OFF	OFF	ON
3	OFF	ON	OFF	OFF
4	OFF	OFF	ON	OFF
1	ON	OFF	OFF	OFF

UNIPOLAR:

1	ON	OFF	OFF	OFF
2	OFF	OFF	OFF	ON
3	OFF	ON	OFF	OFF
4	OFF	OFF	ON	OFF
1	ON	OFF	OFF	OFF

Fig. 14 Schematic Bipolar and Unipolar Switching Sequence.

HIGHER PERFORMANCE

A motor operated at a fixed rated voltage has a decreasing torque curve as the frequency or step rate increases. This is due to the fact that the rise time of the coil limits the percentage of power actually delivered to the motor. This effect is governed by the inductance to resistance ratio of the circuit (L/R).

Compensation for this effect can be by either increasing the power supply voltage to maintain a constant current as the frequency increases, or by raising the power supply voltage and adding a series resistor as is shown below in the L/4R drive circuit. Note that as the L/R is changed, more total power is used by the system.

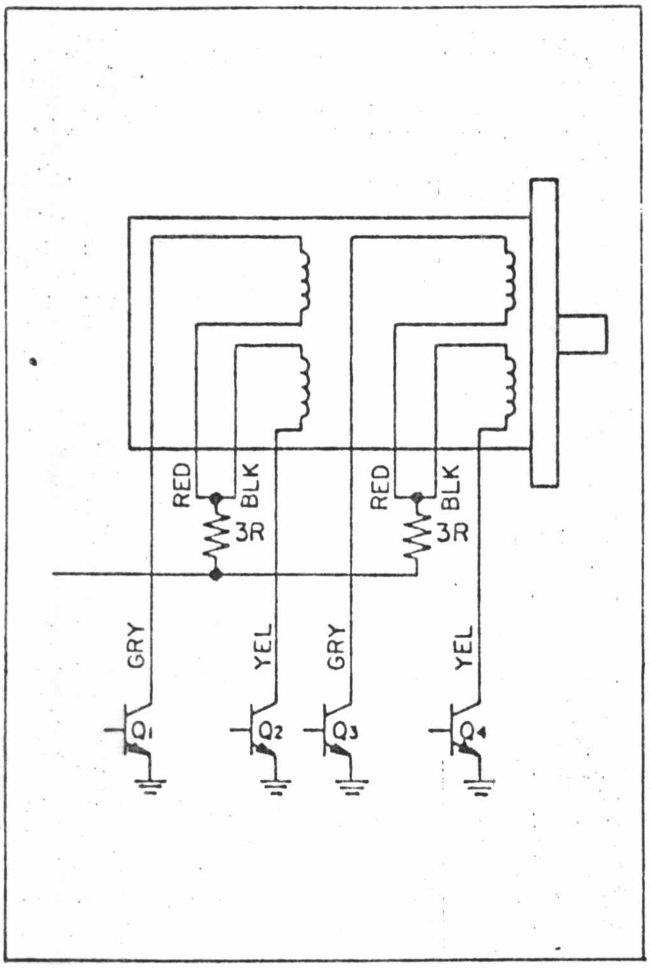


Fig. 15 L/4R Drive

The series resistors, R, are selected for the L/R ratio desired. For L/4R they are selected to be 3 times the motor winding resistance with a

watts rating = (current per winding)^2 x R.

The power supply voltage is increased to 4 times motor rated voltage so as to maintain rated current to the motor. The power supplied will thus be 4 times that of a L/R drive.

Note, the unipolar motor which has a higher coil resistance thus has a better L/R ratio than a bipolar motor.

To minimize power consumption various devices such as a bi-level power supply, or chopper may be used.

BI-LEVEL DRIVE

The bi-level drive allows the motor at zero step/sec to hold at a lower than rated voltage, and when stepping to run at a higher than rated voltage. It is most efficient when operated at a fixed stepping rate. The high voltage may be switched on through the use of a current sensing resistor or by a circuit as shown below which uses the inductively generated turnoff current spikes to control the voltage.

At zero steps/sec the windings are energized with the low voltage. As the windings are switched according to the 4 step sequence, the suppression diodes D_1, D_2, D_3 and D_4 are used to turn on the high voltage supply transistors S_1 and S_2.

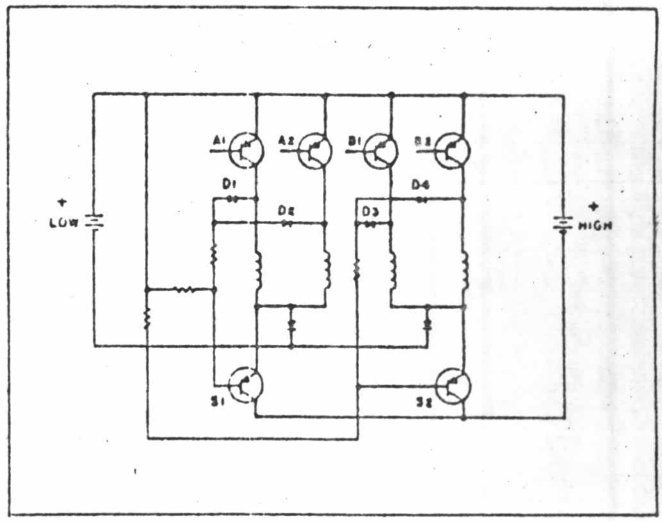


Fig. 16 Unipolar Bi-Level Drive.

CHOPPER DRIVE

A chopper drive maintains an average current level through the use of a current sensor which turns on a high voltage supply until an upper current value is reached. It then turns off the voltage until a low level limit is sensed where it turns on again. A chopper is best for fast acceleration and variable frequency applications. It is more efficient than a constant current amplifier regulated supply. The V+ in the chopper shown in Fig. 17 typically would be five to ten times the motor voltage rating.

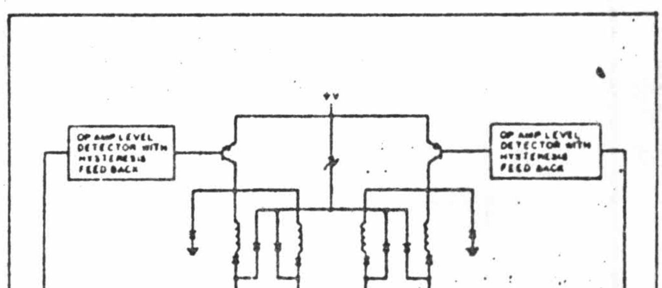


Fig. 17 Unipolar Chopper Drive.

VOLTAGE SUPPRESSION

Whenever winding current is turned off, a high voltage inductive spike will be generated which could damage the drive circuit. The normal method used to suppress these spikes is to put a diode across each winding. This, however, will reduce the torque output of the motor unless the voltage across the switching transistors is allowed to build up to at least twice the supply voltage. The higher this voltage the faster the induced field and current will collapse, and thus the better performance. For this reason, a zener diode or series resistor is usually added as shown in Figure 18.

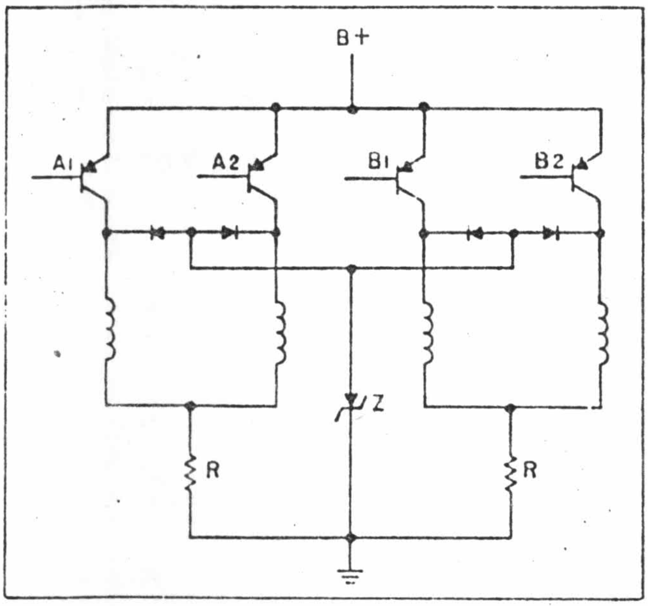


Fig. 18 Voltage Suppression Circuit.

PERFORMANCE LIMITATIONS

Increasing the voltage to a stepper motor at standstill or low stepping rates will produce a proportionally higher torque until the magnetic flux paths within the motor saturate. As the motor nears saturation, it becomes less efficient and thus does not justify the additional power input.

The maximum speed a stepper motor can be driven is limited by hysteresis and eddy current losses. At some rate, the heating effects of these losses limits any further effort to get more speed or torque output by driving the motor harder.

MOTOR HEATING AND TEMPERATURE RISE

Operating continuous duty at rated voltage and current will give an approximate 40°C motor winding temperature rise. If the motor is mounted on a substantial heat sink, however, more power may be put into the windings. If it is desired to push the motor harder, a maximum motor winding temperature of 100°C should be the upper limit. Motor construction can be upgraded to allow for a winding temperature of 120°C.

TORQUE MEASUREMENT

The output torque of a stepper motor and drive can best be measured by using a bridge type strain gage coupled to a magnetic particle brake load. A simple pulley and pull spring scale can also be used, but is difficult to read at low and high step rates.

SUMMARY OF KEY TORQUE EVALUATIONS

The speed-torque characteristic curves are the key to selecting the right motor and the control drive method for a specific application.

Define your application load.

Use the Start Without Error curve if the control circuit provides no acceleration and the load is frictional only.

Use the Running curve, in conjunction with a Torque = Inertia x Acceleration equation ($T = J\alpha$), when the load is inertial and/or acceleration control is provided.

When acceleration ramping control is provided, use the running curve and this torque equation.

$$T_J \text{ (Torque mNm)} = J_T \times \frac{\Delta V}{\Delta t} \times K$$

When no acceleration ramping control is provided, use the Running curve and this torque equation.

$$T \text{ (Torque mNm)} = J_T \times \frac{V^2}{2} \times K$$

STANDARD MOTOR DRIVES

North American Philips offers two unipolar type drives for pulse to step control of 4 coil two phase stepper motors. Both operate as pulse input, 4 step sequences, square wave output devices.

SAA 1027 DRIVER

The SAA is a 16-pin dual-in-line plastic package complete IC pulse to step drive. It is capable of driving a motor winding load of 375 ma per phase. Pulses are supplied to a single input. Direction of rotation is controlled by a voltage level applied to a gate input. A single 12Vdc power supply can operate the IC driver and motor.

ELECTRICAL REQUIREMENTS

Supply voltage - V_S	9.5 - 18V (12V Typ)
System Current - I_S	800 ma (max)
Motor Current per phase	375 ma (max)
Bias Current to pin 4 (see Fig. 2)	50 ma (max)
Control Current to pin 14	4.5 ma (typ)

Output drivers (pins 6, 8, 9, 11) are open collectors. The breakdown voltage is 18Vdc. Do not exceed.

Temperature	Storage	—40°C to +125°C
	Operating Ambient	—20°C to + 70°C

INPUTS

The three inputs are controlled by applying High or Low voltage levels to the terminals.

The High voltage level can be between 7.5Vdc and 18Vdc (12 typ). It is normally equal to, but not greater than the voltage on pin 14. High current per input 1uA (typ).

The Low voltage level can be between 0 and 4.5Vdc max. Low level current per input -30uA (typ.)

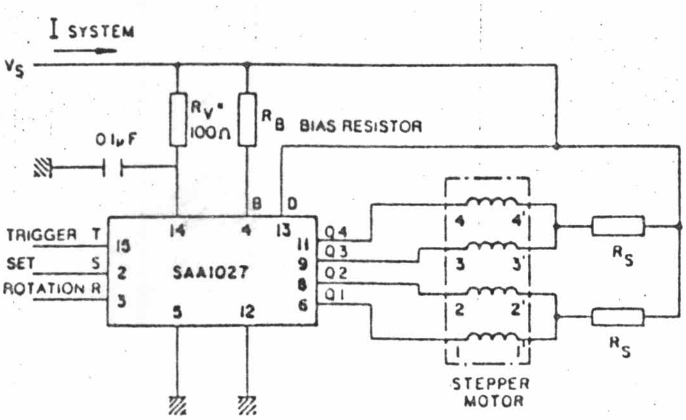


Fig. 1 Drive System Diagram.

TRIGGER INPUT T

The voltage on T, pin 15, is normally High when not being pulsed or stepped. A change from High to Low and back to High will trigger the IC. The motor steps on the positive going edge, Low to High, of the pulse.

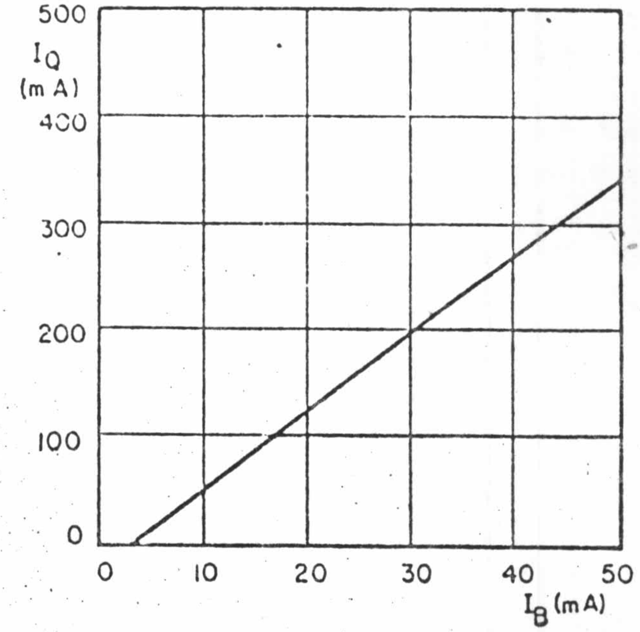


Fig. 2 Relationship between output current and bias current.

SET INPUT S

The motor can be set to a logic state of Q1 Low (winding on), Q2 High (winding off), Q3 Low (winding on), Q4 High (winding off) by momentarily applying a Low level to pin 2 when T, pin 15, is held High.

DIRECTION INPUT R

Applying a High level to pin 3 will cause the motor to be stepped CCW. A Low level to pin 3 will cause the motor to step CW. For maximum noise immunity, this input must not be left open. It should be always held High or Low.

The chart shown below lists the various stepper motors recommended for use with IC driver SAA 1027 showing the bias resistor R_B and motor series resistors R_S required with a 12Vdc (V_S) power supply.

Unipolar torque versus step rate characteristic curves using the SAA 1027 chip listed in this handbook were derived by utilizing the values shown below.

Selection of resistor R_B

Motor Series	R_B Value Ω	*R_S Value Ω	1 System (mA)-Nominal
K82201-P1	220 1 W	33Ω 2 W	520
K82101-P2	390 ½ W	0	320
K82201-P2	560 ½ W	0	210
K82301-P1	220 1 W	33Ω 2 W	520
K82301-P2	560 ½ W	0	210
K82401-P1	150 1 W	25Ω 5 W	750
K82401-P2	390 ½ W	0	330
K82501-P1	150 1 W	25Ω 5 W	740
K82501-P2	390 ½ W	0	315
K82601-P2	180 1 W	0	660
K82701-P2	150 1 W	0	800
K83701-P2	150 1 W	0	800
K82801-P2	180 1 W	0	675
K83801-P1	180 1 W	25Ω 5 W	680
K83801-P2	560 ½ W	0	250

*R_S used to operate motors rated at 5 Volts.

HIGH PERFORMANCE DRIVE

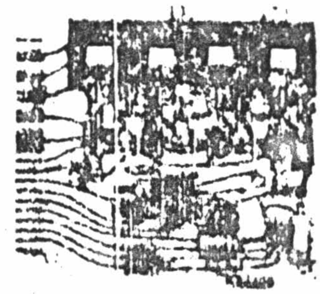
The K33504 is a complete pulse to step printed circuit board drive capable of switching motor loads up to 2 amp per winding with a power supply voltage up to 40Vdc. As with the SAA1027, it is designed to drive a two phase unipolar stepper motor according to the 4 step sequence.

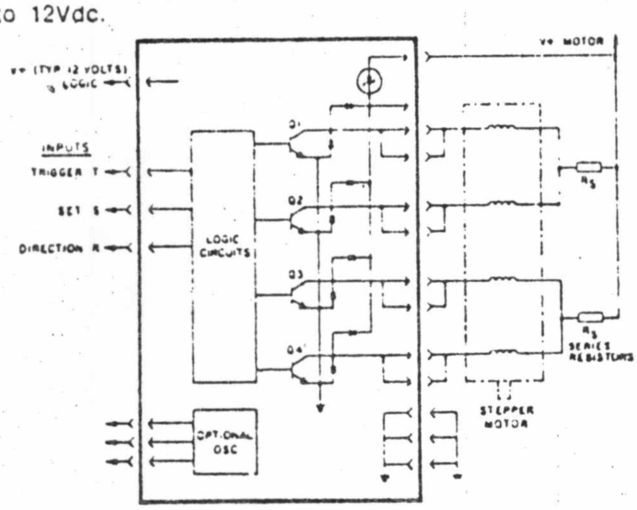
The circuit is essentially a SAA1027 driving 4 silicon power transistors. The input requirements are thus the same as for the SAA1027.

POWER SUPPLY REQUIREMENTS

The V+ motor voltage is determined by the motor rating and dropping resistor R_S. For example, if a 5 volt stepper motor is to be driven L/4R, then R_S would equal 3 x (motor winding resistance) and the V+ motor would be 20 volts. Current required would be 2 x (rated motor winding current).

The V+ logic requirement is 12Vdc. .025 amps. If a single power supply is used and V+ motor is higher than 12Vdc, then a dropping resistor and a filter capacitor must be used to bring the voltage for the V+ logic down to 12Vdc.

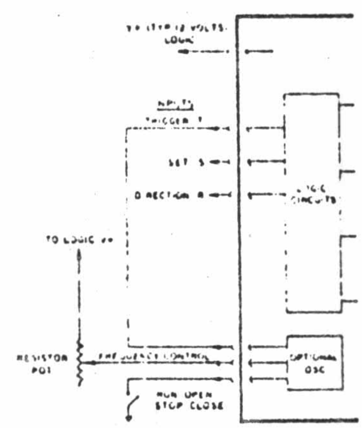




OPTIONAL OSCILLATOR

The K33505, illustrated above, contains the added feature of a built-in oscillator. The pulser/step frequency of the oscillator is set by an external resistor or potentiometer. If the oscillator pulse output is connected to the trigger input terminal, opening the control circuit will cause the drive to step to the motor at the preset frequency.

The control circuit could be a gate with open collector output controlled by a counter monitoring the pulse output to give a precise number of motor steps.



All unipolar L/R and L/4R torque versus step rate curves in this handbook, except those using the SAA1027 chip, were obtained by utilizing the K33505 High Performance Drive.

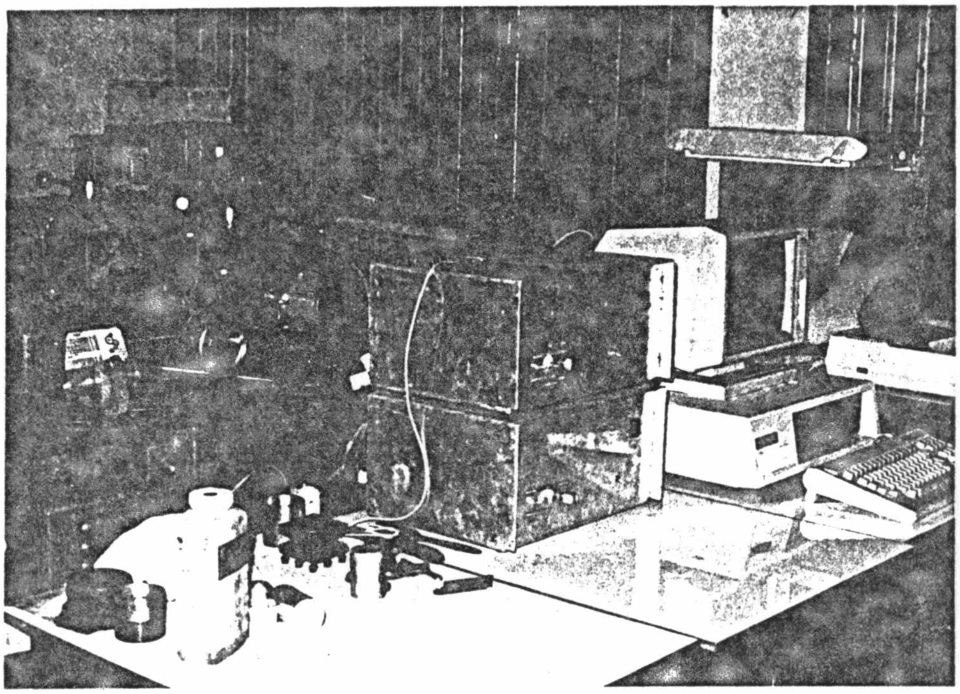
82000 SERIES GEAR REDUCTIONS

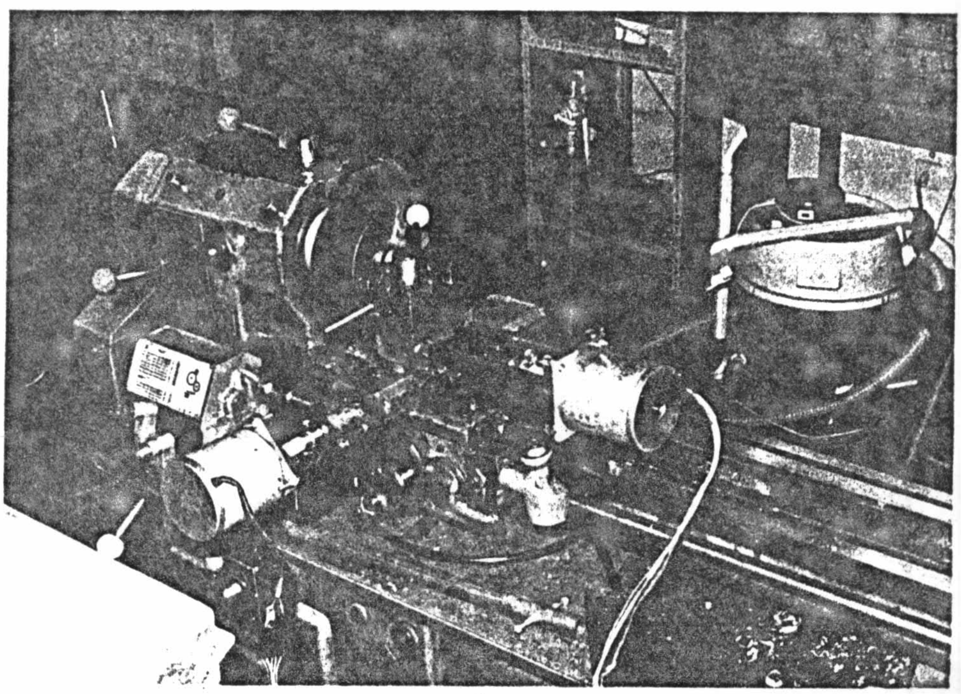
PART NUMBER*	GEAR RATIO	SERIES 82200	SERIES 82400	SERIES 82800	OUTPUT STEP ANGLE	SERIES 82600	OUTPUT STEP ANGLE
K82-01	1:1 DIRECT DRIVE	X	X	X	7.50°	X	15°
K82-11	2:1			X	3.75°	X	7.5°
K82-12	2-1/2:1			X	3.00°	X	6°
K82-13	3:1		X	X	2.50°	X	5°
K82-15	4-1/6:1		X	X	1.80°	X	3.6°
K82-16	5:1		X	X	1.50°	X	3°
K82-17	6:1	X			1.25°		
K82-19	7-1/2:1		X	X	1.00°	X	2°
K82-21	10:1	X	X	X	.75°	X	1.5°
K82-24	15:1		X	X	.50°	X	1°
K82-27	20:1	X			.375°		
K82-30	25:1	X	X	X	.30°	X	.6°
K82-31	30:1	X		X	.25°	X	.5°
K82-36	50:1	X			.15°		
K82-37	60:1	X			.125°		
K82-39	75:1	X	X	X	.10°	X	.2°
K82-45	150:1	X	X	X	.05°	X	.1°
K82-64	1350:1	X			.0055°		

*When ordering fill in correct series digit — Example: 82400 Series Stepper with 3:1 gear ratio K82413. Standard gear reductions are available as shown above. For ratios not listed or for series not marked with "X" — consult factory for availability.

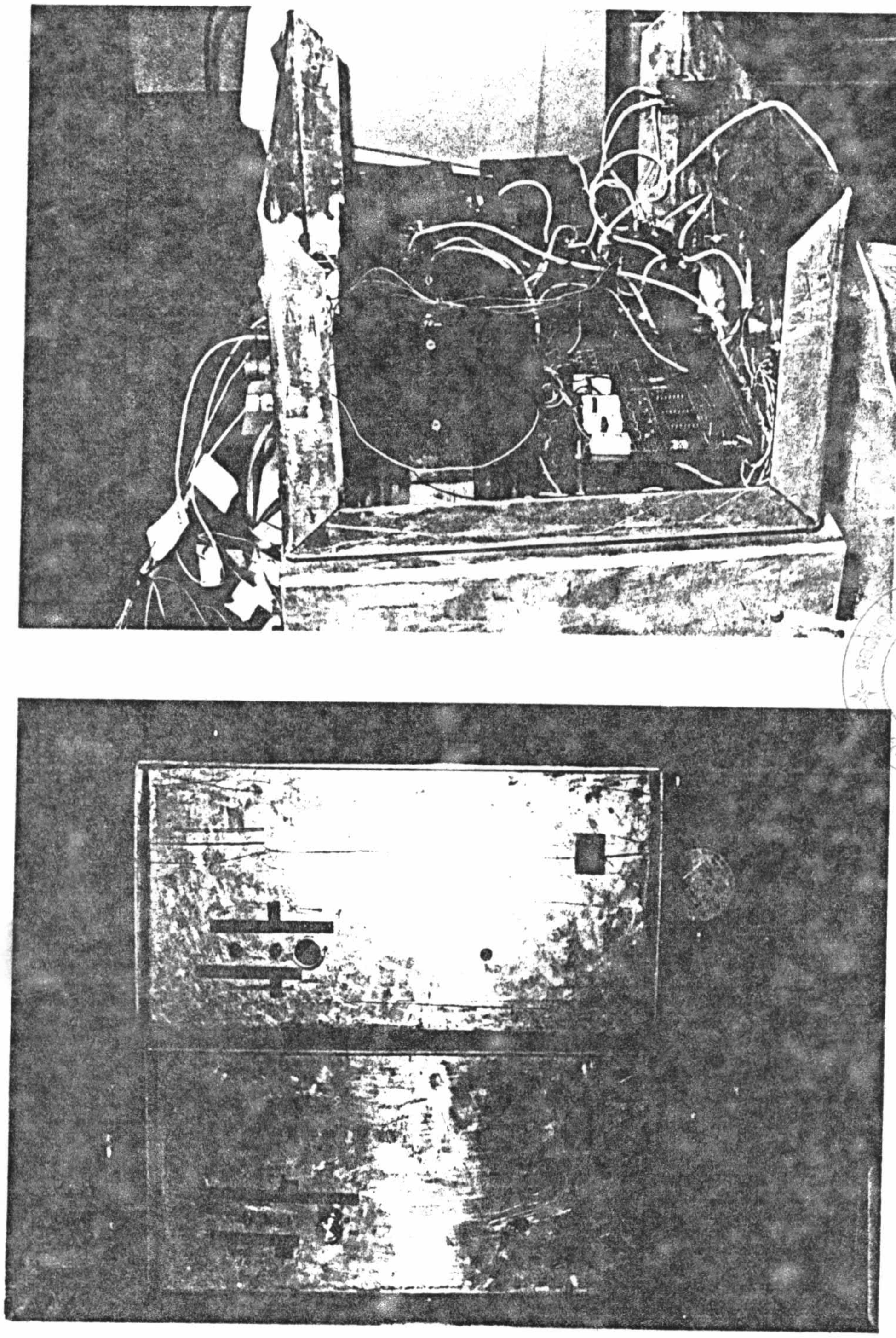
ภาคผนวก ค.

ชุด Interface ระหว่างไมโครคอมพิวเตอร์กับเครื่องกลึง
และ
ชุดเครื่องกลึงอัตโนมัติที่ควบคุมด้วยไมโครคอมพิวเตอร์





ชุดเครื่องกลึงอัตโนมัติที่ควบคุมด้วยไมโครคอมพิวเตอร์



ชุด Interface ระหว่างไมโครคอมพิวเตอร์กับเครื่องกลึง

ประวัติผู้เขียน

นายณัฐพงศ์ อังศุธรารักษ์ เกิดเมื่อวันที่ 1 เมษายน พ.ศ. 2499 ที่อำเภอบัวใหญ่ จังหวัดนครราชสีมา สำเร็จการศึกษาขั้นปริญญาตรีจาก สถาบันเทคโนโลยีพระจอมเกล้า วิทยาเขตพระนครเหนือ สาขาวิชาวิศวกรรมไฟฟ้า (เกียรตินิยมอันดับ 2) เมื่อปีการศึกษา 2522 ปัจจุบันทำงาน บริษัทบางกอกดาต้าเซ็นเตอร์ จำกัด ตำแหน่งวิศวกรคอมพิวเตอร์