

Using COP800 Devices to Control DC Stepper Motors

National Semiconductor
Application Note 714
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INTRODUCTION

COP800 devices can be used to control DC stepper motors with limited effort. This application note describes the use of a COP820 to control the speed, direction and rotation angle of a stepper motor. In addition to the COP820, this application requires a quad high current peripheral driver (DS3658) to meet the high current needs of the stepper motor.

DC STEPPER MOTOR

A DC stepper motor translates current pulses into rotor movement. A typical motor contains four winding coils labeled red, yellow/white, red/white, and yellow. Applying current to these windings forces the motor to step. For normal operation, two windings are activated (pulsed) concurrently. The motor moves clockwise one step per change in windings activated with the following activation sequence: red and yellow, yellow and red/white, red/white and yellow/white, yellow/white and red, repeat. Half-steps may be generated by altering the sequence to: red and yellow, yellow, yellow and red/white, red/white, red/white and yellow/white, yellow/white, yellow/white and red, red, repeat. The motor runs in a counterclockwise direction if either sequence is applied in reverse order. The speed of rotation (number of steps/second) is controlled by the frequency of the pulses.

COP820 CONTROL OF STEPPER MOTOR

The COP820 controls the stepper motor by sending pulse sequences to the motor windings in response to control commands. Commands executed by the code in this application include: single step the motor in a clockwise or counterclockwise direction (i.e. rotate the rotor through a certain number of degrees), run the motor continuously at one of four speeds in a clockwise or counterclockwise direction, and stop the motor.

Note: Half-stepping is not implemented in this example.

During continuous mode operation, the 16-bit timer of the COP820 is used to control the speed of the stepper motor. The timer is set up with a value that causes an underflow once every x seconds or at a frequency of 1/x. Each underflow of the timer interrupts the microcontroller. In response to the timer interrupt, the microcontroller generates a new pulse and causes a single step of the motor. Thus the motor steps at the frequency of the timer underflows. This application sets up the timer to generate interrupts at four different frequencies. These frequencies produce the following motor speeds: 25 steps/second, 100 steps/second, 200 steps/second, and 400 steps/second.

The determination of which windings to activate and deactivate to step the motor is performed by a single subroutine in this example. A block of memory is allocated to store a step pointer and the four possible stepper drive values are shown in Table I (9,C,6,3). Consecutive memory locations are used to store the stepper drive values so that applying the value from location X and then location X+1 (or X-1) causes the motor to step once. The motor drive subroutine increments or decrements the pointer to the current drive value based on the selection of a clockwise or counterclockwise direction. Writing the value from the newly selected location to the motor causes a single step of the motor in the appropriate direction.

During single step operation, the microcontroller steps the motor the exact number of times requested in the control command. Each step corresponds to 1.8 degrees of rotor movement. Therefore, a request to perform 200 steps will rotate the rotor through one complete revolution (360 degrees) at a fixed speed.

A block diagram of the application is shown in Figure 1. A flowchart of the code used to control the motor is given in Figure 2. The complete code is given at the end.

TABLE I. Stepper Motor Drive Sequence

Step	Yellow	Red/White	Yellow/White	Red	Hex Value
0	ON	OFF	OFF	ON	9
1	ON	ON	OFF	OFF	C
2	OFF	ON	ON	OFF	6
3	OFF	OFF	ON	ON	3
4	ON	OFF	OFF	ON	9

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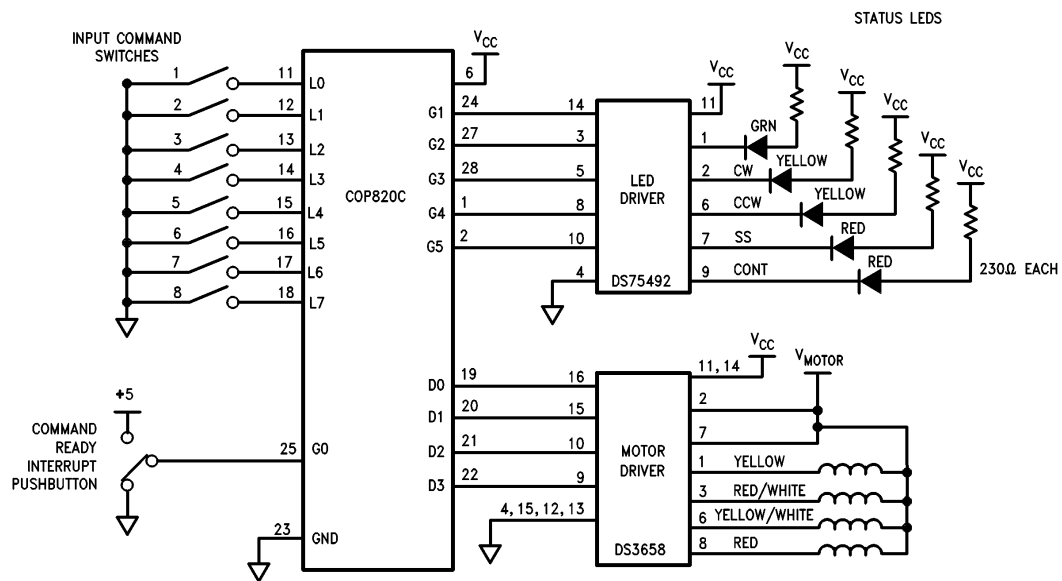
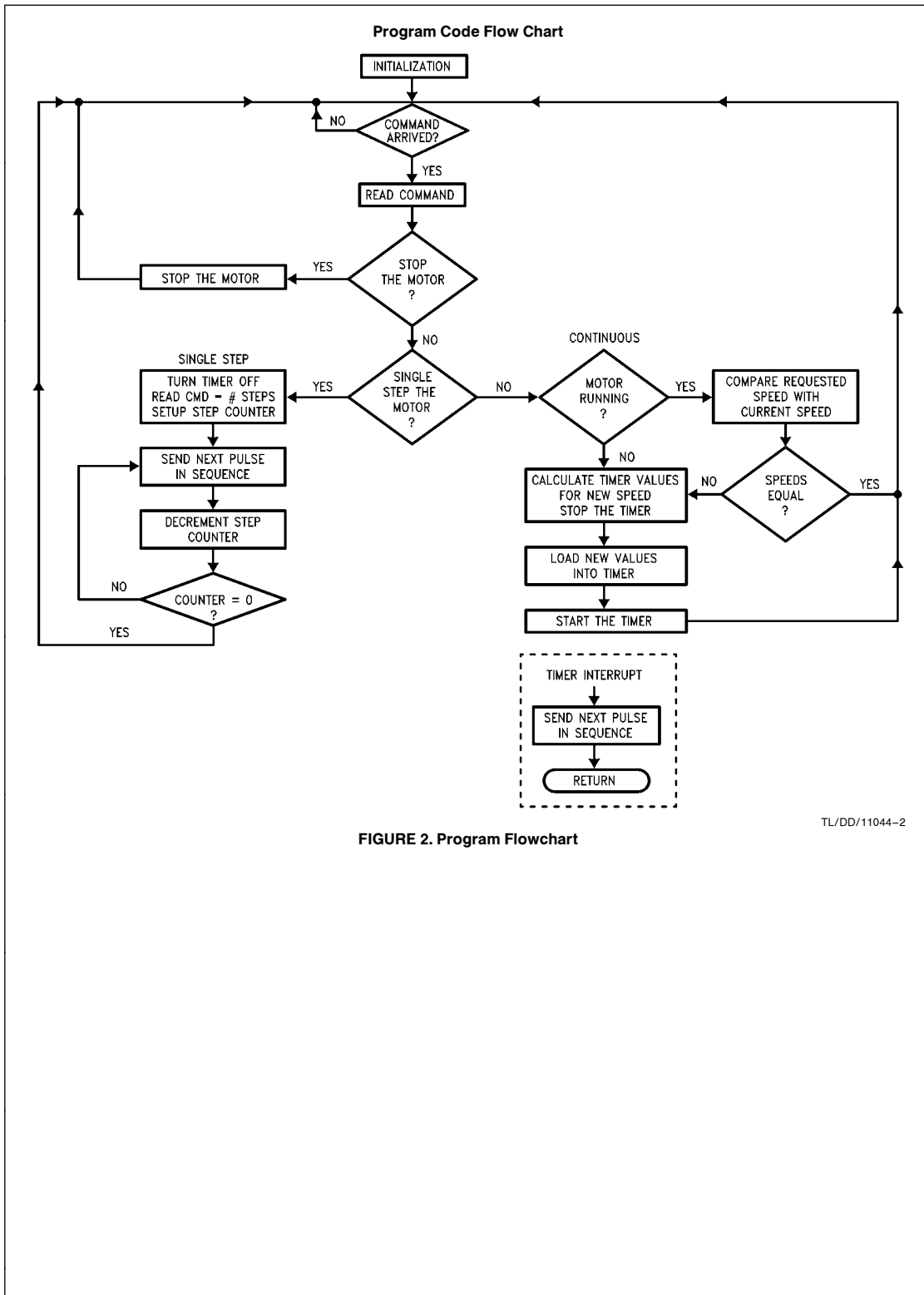


FIGURE 1. Schematic Diagram

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1          ;STEPPER MOTOR CONTROL PROGRAM
2          ;MAY 1990
3          ;
4          ;This program controls the speed, direction, and degree of rotation of
5          ;a DC stepper motor.
6          ;
7          ;
8          ; Memory Map
9          ; RAM CONTENTS
10         ; 00 (MS0) step motor drive value 09H (two windings active per pulse)
11         ; 01 (MS1) step motor drive value 0CH
12         ; 02 (MS2) step motor drive value 06H
13         ; 03 (MS3) step motor drive value 03H
14         ; 04 (CMD) control command
15         ; bit7 - bit4 = motor speed or upper nibble of # single steps
16         ; bit 3 = unused
17         ; bit 2 = (MODE) single step or continuous mode select (1 = ss)
18         ; bit 1 = (DIR) cw or ccw direction select (1 = cw)
19         ; bit 0 = (GO) motor go or motor stop select (1 = stop)
20         ; 05 (STEPS) lower byte of number of single steps
21         ; 07 (FLGREG) flag register
22         ; bit 0 = (INT) ready to read in cmd (ext int occurred)
23         ; bit1 - bit7 = unused
24         ; 14 (TVAL0) value to load in lower byte of timer for speed X
25         ; 15 (TVAL1) value to load in upper byte of timer for speed X
26         ; D2 (PORTLP) port L input pins used for incoming commands
27         ; D4 (PORTGD) port G data pins used to drive status LEDs
28         ; DC (PORTD) port D data pins used to output pulses to the stepper motor
29         ; F0 (CREG0) step counter register zero
30         ; F1 (CREG1) step counter register one
31         ; F2 (STPPTR) pointer to current step motor drive value (RAM 00 - 03)
32         ;REGISTER AND CONSTANT DEFINITIONS
33         ;
34         ;COMMAND BITS
35         0000 GO = 0 ;GO COMMAND BIT
36         ; 1 = STOP 0 = GO
37         0001 DIR = 1 ;DIRECTION COMMAND BIT
38         ; 1 = CW 0 = CCW
39         0002 MODE = 2 ;MODE COMMAND BIT
40         ; 1 = SINGLE STEP 0 = CONTINUOUS
41         ;
42         ;PORTG BITS
43         0000 INT = 0 ;FLAG BIT (SET IF EXTINT OCCURS)
44         0001 READY = 1 ;READY LED
45         0002 CW = 2 ;CLOCKWISE LED
46         0003 CCW = 3 ;COUNTER CLOCKWISE LED
47         0004 SS = 4 ;SINGLE STEP LED
48         0005 NS = 5 ;CONTINUOUS (NON-STOP) LED
49         ;
50         ;REGISTERS
51         0004 CMD = 04 ;INPUT COMMAND STORAGE REGISTER

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52      0005      STEPS = 05      ;INPUT #STEPS/SPEED REGISTER
53      00F0      CREG0 = 0F0     ;COUNTER REGISTER
54      00F1      CREG1 = 0F1     ;COUNTER REGISTER
55      0007      FLGREG = 07      ;FLAG REGISTER (FLAG BITS)
56      00F2      STPPTR = 0F2     ;CURRENT MOTOR STEP POINTER
57      0014      TVAL0 = 014      ;MOTOR SPEED LOAD VALUES
58      0015      TVAL1 = 015
59      0000      MS0 = 00         ;STEPPER MOTOR DRIVE VALUES
60      0001      MS1 = 01
61      0002      MS2 = 02
62      0003      MS3 = 03
63
64      ;ASSIGNMENTS FOR COP820
65
66      00D5      PORTGC = 0D5
67      00D4      PORTGD = 0D4
68      00D6      PORTGP = 0D6
69      00D1      PORTLC = 0D1
70      00D0      PORTLD = 0D0
71      00D2      PORTLP = 0D2
72      00DC      PORTD = 0DC
73      00D7      PORTI = 0D7
74      00E9      SIOR = 0E9
75      00EA      TMRLO = 0EA
76      00EB      TMRHI = 0EB
77      00EC      TAULO = 0EC
78      00ED      TAUHI = 0ED
79      00EE      CNTRL = 0EE
80      00EF      PSW = 0EF
81
82
83      0000      GIE = 0
84      0001      ENI = 1
85      0002      BUSY = 2
86      0003      IPND = 3
87      0004      ENTI = 4
88      0005      TPND = 5
89
90      0002      IEDG = 2
91      0003      MSEL = 3
92      0004      TRUN = 4
93      0005      TC3 = 5
94      0006      TC2 = 6
95      0007      TC1 = 7
96
97
98      .CHIP 820
99
100     ;INITIALIZATION OF REGISTERS      ;*****
101 0000 DD2F      LD      SP,#02F
102 0002 BCCE80    LD      CNTRL,#080

```

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103 0005 BCEF03          LD      PSW,#003          ;GLOBAL INT ENABLE/EXTINT ENABLE
104 0008 BCD401          LD      PORTGD,#01
105 000B BCD53E          LD      PORTGC,#03E        ;CONFIG PORTG FOR OUTPUTS
106 000E BCD0C9          LD      PORTD,#09          ;START MOTOR DRIVE VALUE
107 0011 BCD100          LD      PORTLC,#00        ;CONFIG PORTL FOR INPUTS
108 0014 BCD0FF          LD      PORTLD,#0FF        ;CONFIG PORTL FOR WEAK PULL-UPS
109 0017 5F              LD      B,#MS0            ;SETUP MOTOR DRIVE VALUES
110 0018 9A09            LD      [B+],#09
111 001A 9A0C            LD      [B+],#0C
112 001C 9A06            LD      [B+],#06
113 001E 9E03            LD      [B],#03
114 0020 D200            LD      STPPTR,#00          ;INIT STEP POINTER
115 0022 BC0700          LD      FLGREG,#00          ;INIT FLAG REGISTER
116
117
118                      ;READ, DECODE, AND EXECUTE COMMAND
119
120 0025 BDD479          TOP:    SBIT    READY,PORTGD          ;*****
121 0028 3081            JSR      WAIT                        ;TURN ON READY FOR NEXT CMD LED
122 002A BDD469          RBIT    READY,PORTGD          ;WAIT FOR CMD AND READ CMD
123 002D 9C04            X        A,CMD                  ;TURN OFF READY FOR NEXT CMD LED
124 002F BD0470          IFBIT   GO,CMD                  ;STORE IN CMD REGISTER
125 0032 08             JP      STOP                      ;IF STOP BIT SET
126 0033 BD0472          IFBIT   MODE,CMD                ;THEN STOP MOTOR
127 0036 3041            JSR      SSTEP                    ;ELSE CHEK MODE
128 0038 305F            JSR      CONT                    ;IF MODE SET THEN GO SINGLE STEP
129 003A EA             JP      TOP                      ;ELSE GO CONTINUOUS
130                      ;GO WAIT FOR NEXT COMMAND
131 003B 308E            JSR      TMRSET                    ;STOP THE MOTOR
132 003D BCD401          LD      PORTGD,#01              ;STOP THE TIMER
133 0040 E4             JP      TOP                      ;TURN OFF ALL LEDS
134                      ;GO WAIT FOR NEXT CMD
135
136                      ;SINGLE STEP THE MOTOR (SS)
137
138                      SSTEP:
139 0041 308E            JSR      TMRSET                    ;*****
140 0043 BCD410          LD      PORTGD,#010              ;STOP TIMER
141 0046 3081            JSR      WAIT                        ;TURN ON SS LED (RST ALL OTHER LEDS)
142 0048 8A             INC      A                        ;WAIT FOR CMD BYTE 2 (# STEPS)
143 0049 9CF0            X        A,CREG0                ;ADD 1 TO CORRECT FOR LOOP
144 004B 9D04            LD      A,CMD                  ;STORE #STEPS IN LOBYTE COUNT REG
145 004D 65             SWAP     A                        ;LOAD HIBYTE # STEPS
146 004E 950F            AND      A,#0F                  ;MOVE TO LOWER NIBBLE
147 0050 8A             INC      A                        ;GET RID OF UPPER BITS
148 0051 9CF1            X        A,CREG1                ;ADD 1 TO CORRECT FOR LOOP
149 0053 C0             DRSZ     CREG0                    ;MOVE TO HIBYTE OF COUNT REG
150 0054 05             JP      DO                        ;DECR LOBYTE AND IF NOT ZERO
151 0055 C1             DRSZ     CREG1                    ;THEN GO DO A STEP
152 0056 01             JP      DO2                      ;ELSE DECR HIBYTE AND IF NOT ZERO
153 0057 8D             RETSK                             ;THEN GO DO A STEP AND RST LO COUNT
                                           ;ELSE END OF LOOP    RETURN

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154 0058 D0FF          DO2:  LD      CREG0,#0FF          ;RESET LOBYTE OF COUNTER
155 005A 3098          DO:   JSR     NXTVAL              ;STEP THE MOTOR
156 005C 3158          JSR     DELAY                    ;SLOW THE STEPPING
157 005E F4           JP      TP2                      ;GO TO TOP OF LOOP
158
159
160
161
162
163 005F BDEE74          ;RUN THE MOTOR CONTINUOUSLY (NS = NON-STOP = CONTINUOUSLY)
164 0062 01          CONT:  IFBIT   TRUN,CNTRL          ;*****
165 0063 03          JP      CHKSPD                    ;IF MOTOR ALREADY RUNNING NS
166 0064 3148          CHKSPD: JSR     SPEED              ;THEN CHECK THE CURRENT SPEED
167 0066 8E          RET                                ;ELSE GO START THE MOTOR
168 0067 308E          SETGO: JSR     TMRSET              ;COMPARE INPUT WITH ACTUAL SPD
169 0069 BCD420          LD      PORTGD,#020            ;IF EQUAL RET ELSE RESTART MOTOR
170 006C 3126          JSR     TIMVAL                    ;STOP THE TIMER
171 006E AE          LD      A,[B]                      ;TURN ON CONTINUOUS LED
172 006F 9CEB          X       A,TMRHI                  ;CALCULATE TIMER (SPEED) VALUE
173 0071 AB          LD      A,[B-]                    ;LOAD A WITH TVAL1
174 0072 9CED          X       A,TAUHI                  ;MOVE SPEED VAL INTO TIMER
175 0074 AE          LD      A,[B]                      ;LOAD A WITH TVAL1 POINT TO TVAL0
176 0075 9CEA          X       A,TMRLO                  ;MOVE SPEED VAL INTO AUTORELOAD REG
177 0077 AE          LD      A,[B]                      ;LOAD A WITH TVAL0
178 0078 9CEC          X       A,TAULO                  ;LOAD A WITH TVAL0
179 007A BDEF7C          SBIT    ENT1,PSW                ;ENABLE TIMER INTERRUPT
180 007D BDEF7C          SBIT    TRUN,CNTRL              ;START THE TIMER
181 0080 8E          RET                                ;RET TO MAIN AND WAIT FOR TMRINT
182
183
184
185
186
187
188 0081 BD0770          ;SUPPORT ROUTINES *****
189 0084 01          WAIT:  ;WAIT FOR AN EXTERNAL INTERRUPT TO SIGNAL AN INCOMING COMMAND
190 0085 FB          ;READ THE INCOMING COMMAND FROM PORT L
191 0086 BD0768          IFBIT   INT,FLGREG              ;IF EXTERNAL INTERRUPT OCCURED
192 0089 9DD2          JP      OUT                        ;THEN JUMP OUT OF LOOP
193 008B 96FF          OUT:   RBIT    INT,FLGREG          ;ELSE CONTINUE TO WAIT
194 008D 8E          LD      A,PORTLP                    ;RESET EXTERNAL INTERRUPT FLAG
195
196
197
198
199 008E BDEE6C          XOR     A,#0FF                  ;READ INCOMING COMMAND
200 0091 BDEF6D          RET                                ;COMPLEMENT INCOMING COMMAND
201 0094 BDEF6C          ;RETURN COMMAND IN ACC
202 0097 8E
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205          NXTVAL:                                     ;*****
206          ;SEND THE NEXT DRIVE VALUE TO STEP THE MOTOR ONE STEP IN THE
207          ;APPROPRIATE DIRECTION (CW OR CCW)
208 0098 9DF2      LD      A,STPPTR                     ;LOAD STEP VALUE POINTER
209 009A DED4      LD      B,#PORTGD                   ;POINT TO PORT G
210 009C BD0471    IFBIT   DIR,CMD                     ;IF CLOCKWISE
211 009F 11        JP      IPTR                         ;THEN GO INCREMENT POINTER
212 00A0 6A        DPTR:  RBIT   CW,[B]                 ;ELSE RST CW LED
213 00A1 7B        SBIT   CCW,[B]                     ;TURN ON CCW LED
214 00A2 8B        DEC     A                             ;AND DECREMENT POINTER
215 00A3 92FF      IFEQ    A,#0FF                      ;IF OFF BOTTOM OF STEPS
216 00A5 9803      LD      A,#03                       ;THEN LOOP TO TOP OF STEPS
217 00A7 9CF2      WRVAL:  X      A,STPPTR              ;A -> STPPTR (SAVE NEW STPPTR)
218 00A9 9DF2      LD      A,STPPTR                    ;[STPPTR] -> PORTD (LOOKUP VAL)
219 00AB 9CFE      X      A,B
220 00AD AE        LD      A,[B]
221 00AE 9CDC      X      A,PORTD                      ;WRITE STEP VALUE TO MOTOR
222 00B0 8E        RET
223 00B1 6B        IPTR:  RBIT   CCW,[B]                ;TURN OFF CCW LED
224 00B2 7A        SBIT   CW,[B]                      ;TURN ON CW LED
225 00B3 8A        INC     A                             ;INCREMENT THE STEP POINTER
226 00B4 9204      IFEQ    A,#04                       ;IF OFF TOP OF STEPS
227 00B6 64        CLR     A                             ;THEN LOOP TO BOTTOM OF STEPS
228 00B7 EF        JP      WRVAL                      ;GO WRITE VALUE TO MOTOR
229
230
231          ; INTERRUPT HANDLERS
232 00FF          . = 0FF                                ;*****
233          ;BRANCH TO THE APPROPRIATE INTERRUPT HANDLER
234 00FF BDEF75    IFBIT   TPND,PSW                     ;TIMER UNDERFLOW
235 0102 08        JP      TMRINT
236 0103 BDEF73    IFBIT   IPND,PSW                     ;EXTERNAL INTERRUPT
237 0106 16        JP      EXTINT
238 0107 BDEF78    SBIT   GIE,PSW                      ;SOFTWARE TRAP
239 010A 8D        RETSK
240
241          TMRINT:                                     ;*****
242          ;RESET THE TIMER INTERRUPT PENDING BIT AND STEP THE MOTOR
243 010B 9CF9      X      A,0F9                          ;CONTEXT SAVE ROUTINE
244 010D 9DFE      LD      A,B
245 010F 9CFA      X      A,0FA
246 0111 BDEF6D    RBIT   TPND,PSW                     ;RESET PENDING BIT
247 0114 3098      JSR     NXTVAL                       ;STEP THE MOTOR
248 0116 9DFA      LD      A,0FA                       ;CONTEXT RESTORE ROUTINE
249 0118 9CFE      X      A,B
250 011A 9DF9      LD      A,0F9
251 011C 8F        RETI
252
253          EXTINT:                                     ;*****
254 011D BD0778    SBIT   INT,FLGREG                     ;SET INTERRUPT OCCURED FLAG
255 0120 3158      JSR     DELAY                        ;WAIT

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256 0122 BDEF6B          RBIT    IPND,PSW          ;RESET PENDING BIT
257 0125 8F             RETI
258
259                     ;SUPPORT ROUTINES CONTINUED
260
261         TIMVAL:      ;*****
262                     ;During continuous operation, the motor is stepped once every
263                     ;timer underflow. Therefore, a timer value is calculated that will
264                     ;produce timer underflows every X microseconds causing the motor
265                     ;to step Xsteps/second.
266                     ;For example: To step 100 times per second.
267                     ;      microseconds/step = 1000000uS/sec x 1sec/100steps = 10000
268                     ;      10000uS/step = 02718Hex uS/step
269                     ;      1uS = one count down of the timer
270                     ; Therefore, load the timer with 02718H for 100 steps/sec.
271
272 0126 DE14             LD        B,#TVAL0          ;POINT TO STORAGE FOR TIMVAL
273 0128 BD0474          IFBIT    4,CMD             ;IF LOWEST SPEED BIT SET
274 012B 17             JP        SLOWER           ;THEN USE SLOWEST SPEED
275 012C BD0475          IFBIT    5,CMD             ;IF SECOND LOWEST SPD BIT SET
276 012F 0E             JP        SLOW             ;THEN USE SLOW SPEED
277 0130 BD0476          IFBIT    6,CMD             ;IF SECOND HIGHEST SPD BIT SET
278 0133 05             JP        FAST             ;THEN USE FAST SPEED
279 0134 9A02           FASTER: LD        [B+],#02    ;ELSE USE FASTEST SPEED
280 0136 9E08           LD        [B],#08           ;400steps/sec = 2rev/sec
281 0138 8E             RET
282 0139 9A88           FAST:   LD        [B+],#088    ;200steps/sec = 1rev/sec
283 013B 8E13           LD        [B],#013
284 013D 8E             RET
285 013E 9A18           SLOW:   LD        [B+],#018    ;100steps/sec = .5rev/sec
286 0140 8E27           LD        [B],#027
287 0142 8E             RET
288 0143 9A54           SLOWER: LD        [B+],#054    ;25steps/sec = .125rev/sec
289 0145 8E9C           LD        [B],#09C
290 0147 8E             RET
291
292
293         SPEED:      ;*****
294                     ;COMPARE CURRENT MOTOR SPEED WITH DESIRED MOTOR SPEED
295 0148 3126           JSR        TIMVAL            ;CALCULATED DESIRED SPEED VAL
296 014A 8D14           LD        A,TVAL0
297 014C BDEC82         IFEQ      A,TAULO           ;IF DESIRED LBYTE EQUALS CURRENT LBYTE
298 014F 01             JP        TSTHI            ;THEN GO TEST HI-BYTE
299 0150 8D             RETSK                      ;ELSE NOT EQUAL RETURN AND SKIP
300 0151 8D15           TSTHI: LD        A,TVAL1
301 0153 BDED82         IFEQ      A,TAUHI           ;IF HI-BYTE EQUALS CURRENT HI-BYTE
302 0156 8E             RET                      ;THEN DESIRED = CURRENT RETURN
303 0157 8D             RETSK                      ;ELSE DESIRED != CURRENT RET & SKIP
304
305         DELAY:      ;*****
306                     ;INSERT A DELAY

```

TL/DD/11044-8

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```

307 0158 D301          LD      0F3,#01          ;FOR SINGLE STEP & EXTINT DEBOUNCE
308 015A D4FF          DLY1:  LD      0F4,#0FF        ;APPROX .256mS X 6
309 015C C4            DLY2:  DRSZ   0F4
310 015D FE            JP      DLY2
311 015E C3            DRSZ   0F3
312 015F FA            JP      DLY1
313 0160 8E            RET
314
315                    .END

```

TL/DD/11044-9

B	00FE	BUSY	0002	*	CCW	0003	CHKSPD	0064
CMD	0004	CNTRL	00EE		CONT	005F	CREG0	00F0
CREG1	00F1	CW	0002		DELAY	0158	DIR	0001
DLY1	015A	DLY2	015C		DO	005A	DO2	0058
DPTR	00A0	ENI	0001	*	ENTI	0004	EXTINT	011D
FAST	0139	FASTER	0134	*	FLGREG	0007	GIE	0000
GO	0000	IEDG	0002	*	INT	0000	IPND	0003
IPTR	00B1	MID	0055	*	MODE	0002	MS0	0000
MS1	0001	MS2	0002	*	MS3	0003	MSEL	0003
NS	0005	NXTVAL	0098		OUT	0086	PORTD	00DC
PORTGC	00D5	PORTGD	00D4		PORTGP	00D6	PORTI	00D7
PORTLC	00D1	PORTLD	00D0		PORTLP	00D2	PSW	00EF
READY	0001	SETGO	0067		SIOR	00E9	SLOW	013E
SLOWER	0143	SP	00FD		SPEED	0148	SS	0004
SSTEP	0041	STEPS	0005	*	STOP	003B	STPPTR	00F2
TAUHI	00ED	TAULO	00EC		TC1	0007	TC2	0006
TC3	0005	TIMVAL	0126		TMRHI	00EB	TMRINT	010B
TMRLO	00EA	TMRSET	008E		TOP	0025	TP2	0053
TPND	0005	TRUN	0004		TSTHI	0151	TVAL0	0014
TVAL1	0015	WAIT	0081		WRVAL	00A7	X	00FC

TL/DD/11044-10

MACRO TABLE

NO WARNING LINES

NO ERROR LINES

282 ROM BYTES USED

SOURCE CHECKSUM = 80C0
OBJECT CHECKSUM = 0520

INPUT FILE C:MOTOR.MAC
LISTING FILE C:MOTOR.PRN
OBJECT FILE C:MOTOR.LM

TL/DD/11044-11

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