AN587

Interfacing PICmicros™ to an LCD Module

Author: *Mark Palmer*
Code: *Mark Palmer/Scott Fink*
Microchip Technology Inc.

INTRODUCTION

This application note interfaces a micrange PICmicro device to a Hitachi® LM032L LCD character display module, with a two line by twenty character display. LCD modules are useful for displaying text information from a system. In large volume applications, the use of custom LCD displays becomes economical. The routines provided should be a good starting point for users whose applications implement a custom LCD. This source code should be compatible with the PIC16C5X devices, after modifications for the special function register initialization, but has not been verified on those devices.

OPERATION

The Hitachi LM032L LCD character display module can operate in one of two modes. The first (and default) mode is the 4-bit data interface mode. The second is the 8-bit data interface mode. When operating in 4-bit mode, two transfers per character / command are required. 8-bit mode, though easier to implement (less program memory) requires four additional I/O lines. The use of 8-bit mode is strictly a program memory size vs. I/O trade-off. The three most common data interfaces from the microcontroller are:

1. An 8-bit interface.
2. A 4-bit interface, with data transfers on the high nibble of the port.
3. A 4-bit interface, with data transfers on the low nibble of the port.

The LCD module also has three control signals, Enable (E), Read/Write (R_W), and Register Select (RS). The function of each control signal is shown in Table 1.

TABLE 1: CONTROL SIGNAL FUNCTIONS

Control SIgnal	Function
E	Causes data/control state to be latched Rising Edge = Latches control state (RS and R_W) Falling Edge = Latches data
RS	Register Select Control 1 = LCD in data mode 0 = LCD in command mode
R_W	Read / Write control 1 = LCD to write data 0 = LCD to read data

A single source file, with conditional assembly is used to generate each of these three options. This requires two flags. The flags and their results are shown in Table 2.

TABLE 2: CONDITIONAL ASSEMBLY FLAGS

Flags		
`Four_bit`	`Data_HI`	Result
1	0	4-bit mode. Data transferred on the low nibble of the port.
1	1	4-bit mode. Data transferred on the high nibble of the port.
0	x	8-bit mode.

Figure 1, Figure 2, and Figure 3 show the block diagrams for the three different data interfaces. The LCD_CNTL and LCD_DATA lines are user definable to their port assignment. This is accomplished with EQUate statements in the source code. See Appendices B, C, and D.

FIGURE 1: 8-BIT DATA INTERFACE

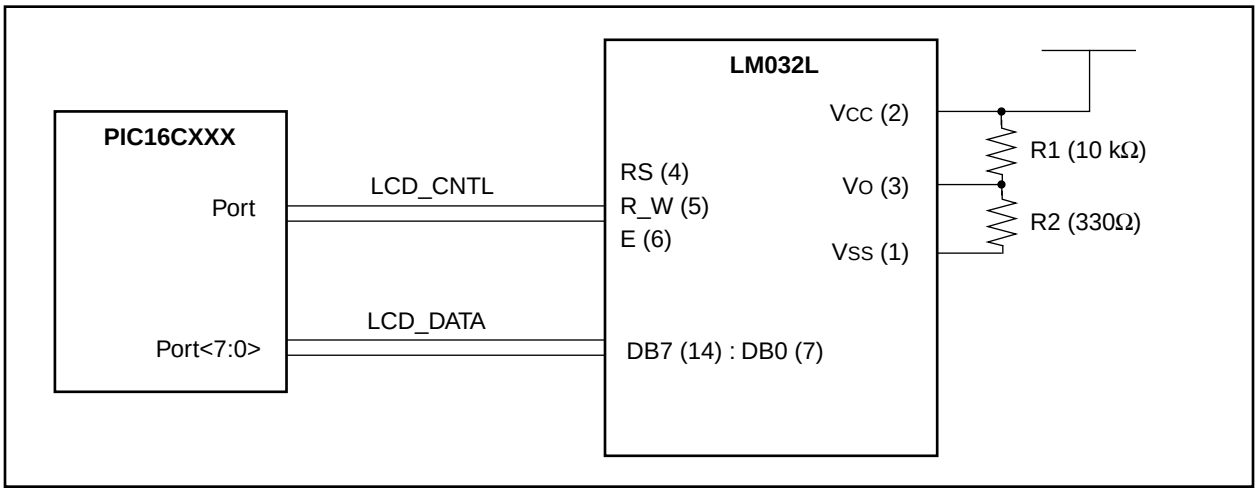


FIGURE 2: 4-BIT MODE; DATA TRANSFERRED ON THE HIGH NIBBLE OF THE PORT

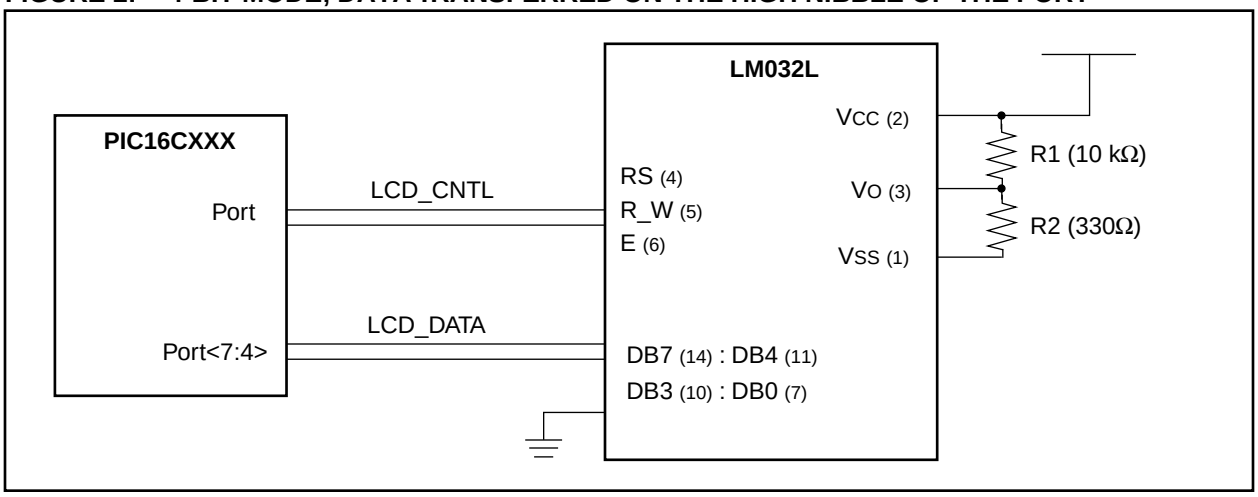
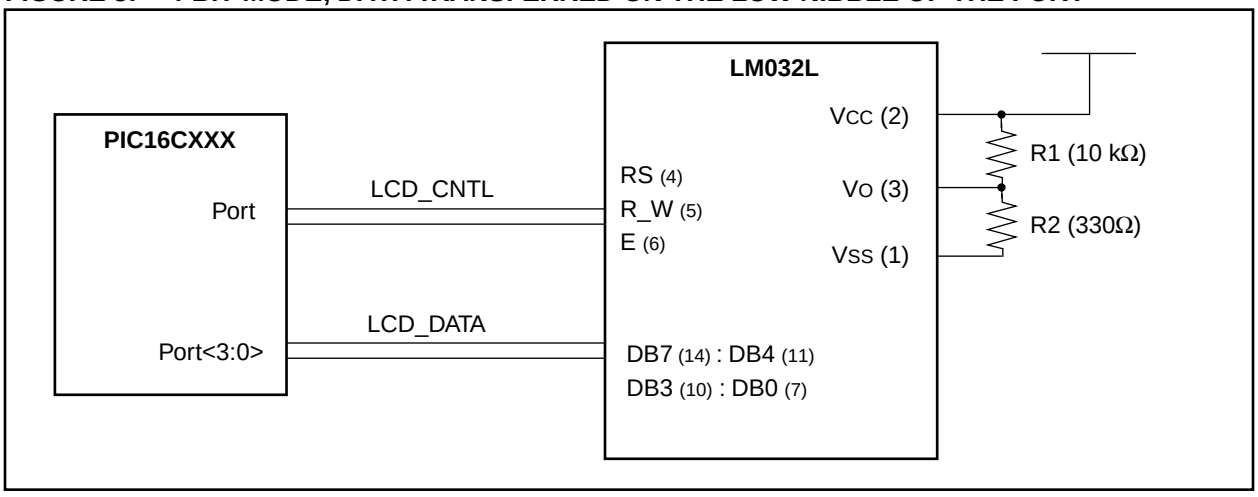


FIGURE 3: 4-BIT MODE; DATA TRANSFERRED ON THE LOW NIBBLE OF THE PORT



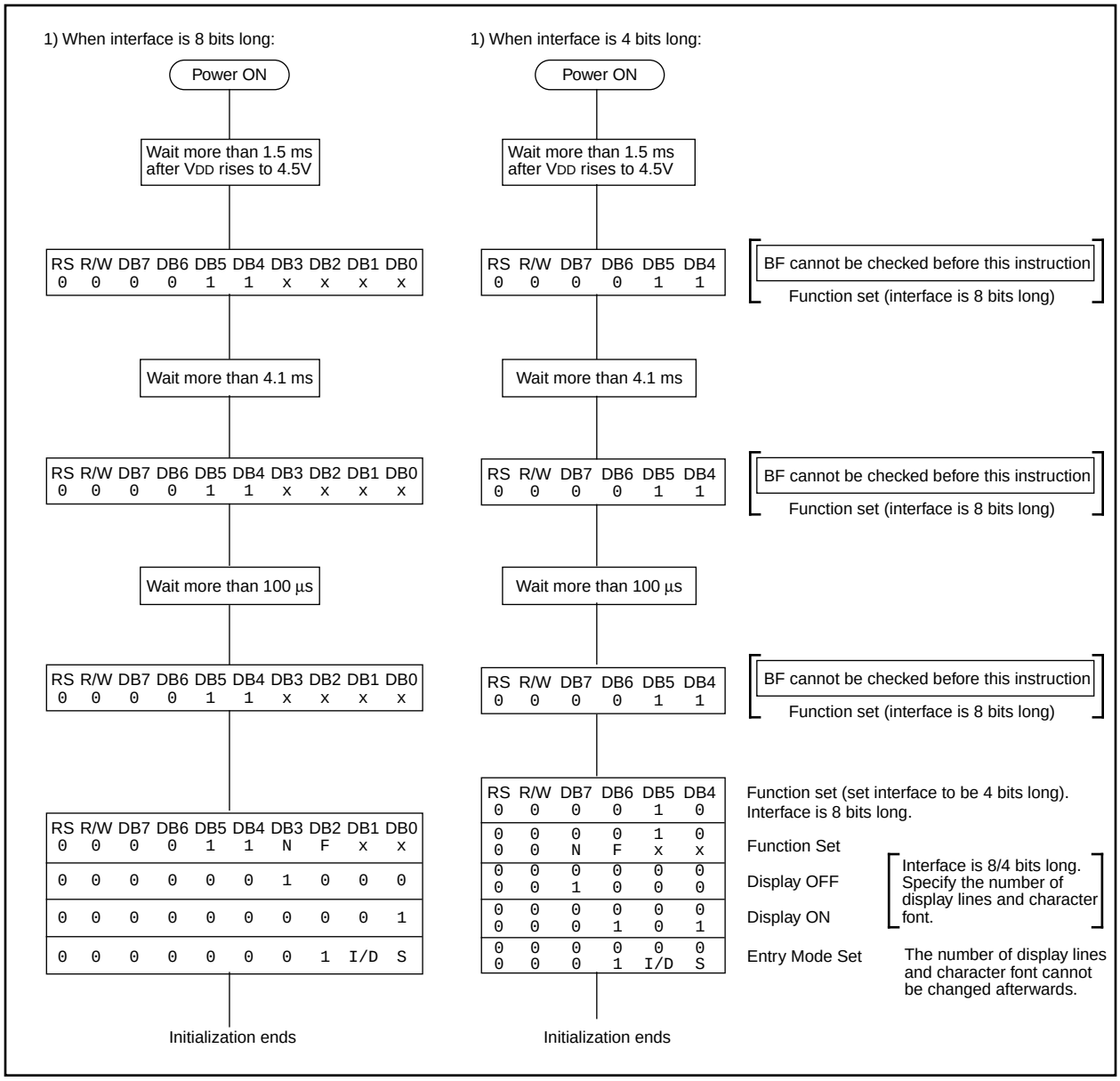
LCD's (drivers) are slow devices when compared to microcontrollers. Care must be taken from having communication occur too quickly. The software will need to control communicaton speed and timing to ensure the slow LCD and fast microcontroller can stay synchronized. The timing requirements of the LM032L are shown in Appendix A. We recommend that the complete specifications of the LM032L be acquired from Hitachi or a Hitachi distributor. The literature numbers are CE-E613Q and M24T013 for a LM032L display driver.

When the module powers up, the default data transfer mode is 8-bit. The initialization sequence only requires commands that are 4-bit in length. The last initialization command needs to specify the data transfer width (4-or 8-bit). Then a delay of 4.6 ms must be executed before the LCD module can be initialized. Some of the LCD module commands are:

- 1 or 2 lines of characters
- Display on /off
- Clear display
- Increment / do not increment character address pointer after each character
- Load character address pointer

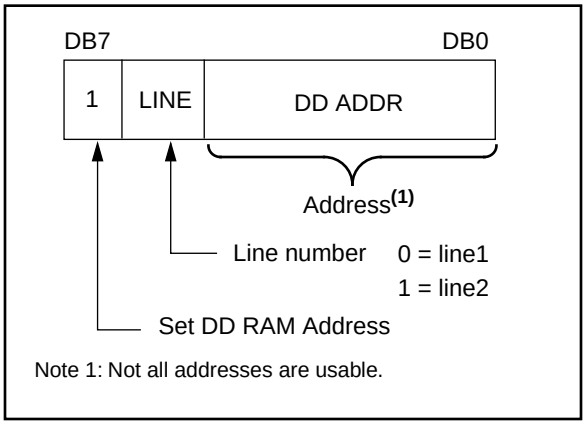
The initialization flow for the module is shown in Figure 4.

FIGURE 4: INITIALIZATION FLOW FOR LCD MODULE



After initialization, each character address is individually addressable. Figure 5 shows the structure of the command to specify the character address.

FIGURE 5: CHARACTER ADDRESS COMMAND FORMAT



The Hitachi Display Drive (HD44780A) has 80 bytes of RAM. The LM032L modules only use 40 bytes of the available RAM (2 x 20 characters). It is possible to use the remaining RAM locations for storage of other information.

Figure 6 shows the display data positions supported by the display driver as well as the characters actually displayed by the module (the non-shaded addresses).

The program example implemented here uses the character auto increment feature. This automatically increments the character address pointer after each character is written to the display.

CONCLUSION

The Hitachi LM032L character display module is well suited for displaying information. The selection of 4-bit or 8-bit data transfer mode is strictly a program memory size vs. I/O resource trade-off. The supplied code is easily used in any of three common data interfaces. The source is easily modifiable to a designers specific application needs. Other display modules/drivers maybe implemented with the appropriate modifications. Table 3 shows the resource requirements for the three subroutines `SEND_CHAR`, `SEND_COMMAND`, and `BUSY_CHECK` in the various data interface modes.

FIGURE 6: DISPLAY DRIVER (DD) RAM LOCATIONS

digit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	- - - -	33	34	35	36	37	38	39	40	← Display position
line-1	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	10	11	12	13	14	- - - -	20	21	22	23	24	25	26	27	← DD RAM address (Hexadecimal)
line-2	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	- - - -	60	61	62	63	64	65	66	67	

Note: Shaded locations are not displayed on the LM032L display module.

TABLE 3: RESOURCE REQUIREMENTS

Mode	Program Memory	Data Memory	Verified On
8-bit	32	3	PICDEM-2(1)
4-bit, Data transferred on the high nibble of the port.	53	3	PICDEM-2(1)
4-bit, Data transferred on the high nibble of the port.	53	3	Low-Power Real-Time Clock Board (AN582)

Note 1: Jumper J6 must be removed.

APPENDIX A: LM032L TIMING REQUIREMENTS

TABLE A-1: TIMING CHARACTERISTICS

Parameter #	Symbol	Characteristics	Min.	Typ.	Max.	Unit
1	TCYC	Enable cycle time	1.0	—	—	µs
2	PWEH	Enable pulse width	450	—	—	µs
3	TER, TEF	Enable rise / fall time	—	—	25	µs
4	TAS	RS, R/W set-up time	140	—	—	µs
5	TDDR	Data delay time	—	—	320	µs
6	TDSU	Data setup time	195	—	—	µs
7	TH	Hold time	20	—	—	µs

FIGURE A-1: DATA WRITE INTERFACE TIMING

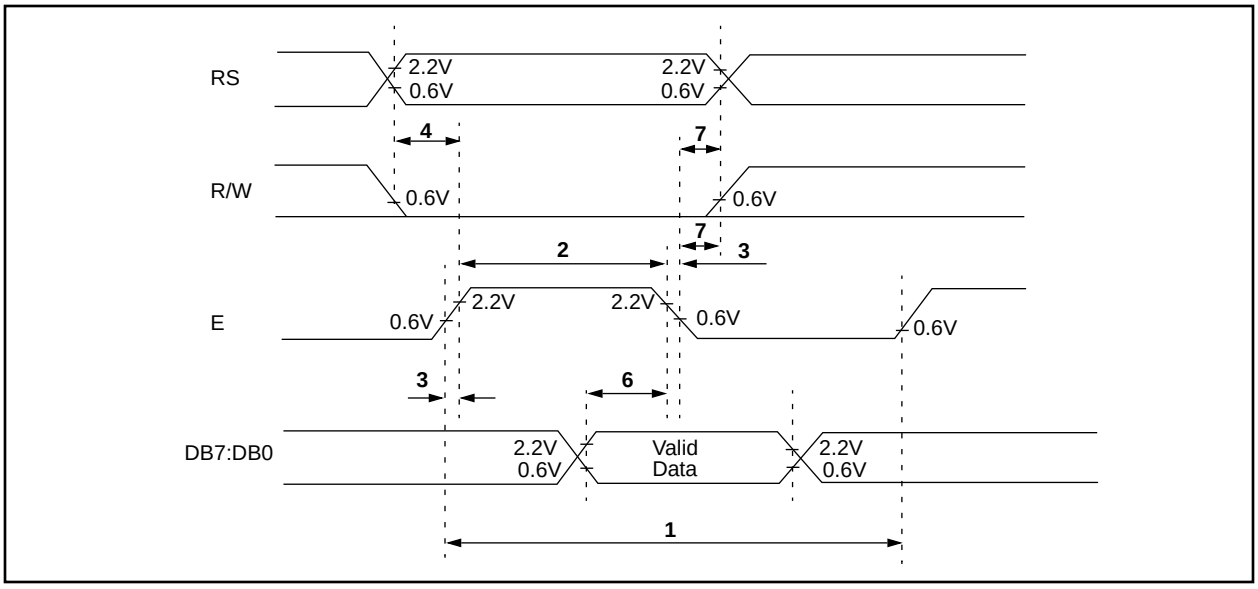
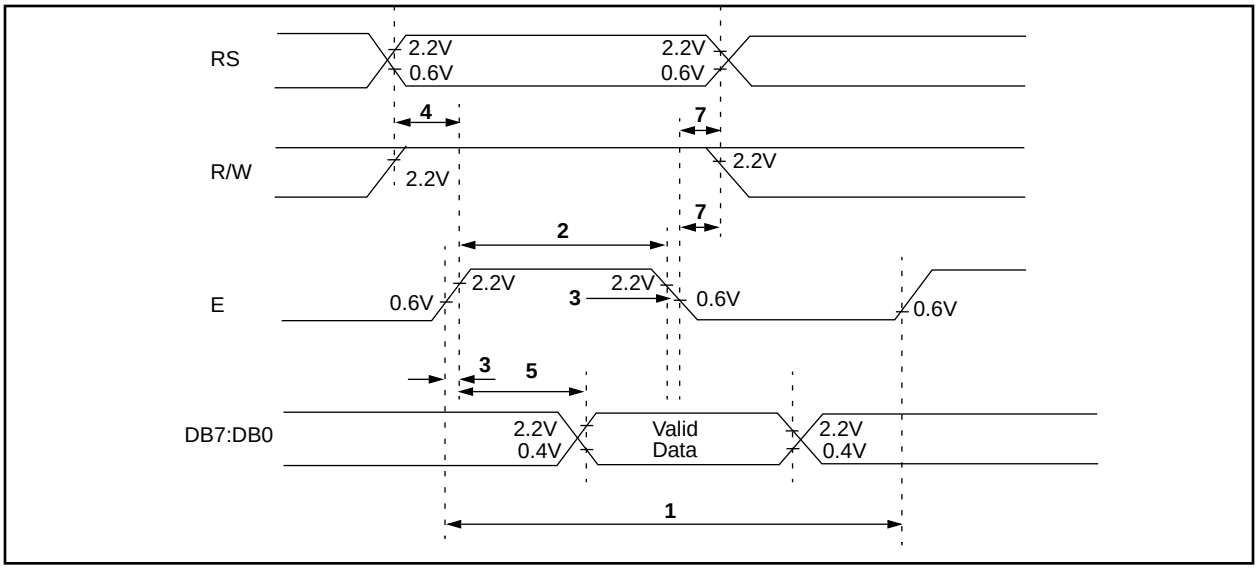


FIGURE A-2: DATA READ INTERFACE TIMING



Note: Refer to Hitachi documentation for the most current timing specifications.

TABLE A-2: LM032L PIN CONNECTION

Pin No.	Symbol	Level	Function	
1	V_{SS}	—	0V	Ground
2	V_{DD}	—	+5V	Power Supply(+)
3	V_O	—	—	Ground
4	RS	H/L	L: Instruction Code Input H: Data Input	
5	R/W	H/L	H: Data Read (LCD module→MPU) L: Data Write (LCD module←MPU)	
6	E	H,H→L	Enable Signal	
7	DB0	H/L		
8	DB1	H/L		
9	DB2	H/L		
10	DB3	H/L	Data Bus Line	
11	DB4	H/L	Note (1), (2)	
12	DB5	H/L		
13	DB6	H/L		
14	DB7	H/L		

In the HD44780, the data can be sent in either two 4-bit operations or one 8-bit operation, This flexibility allows an interface to both 4- and 8-bit MPUs.

Note 1: When interface data is 4-bits long, data is transferred using only 4 lines of DB7:DB4 (DB3:DB0 are not used). Data transfer between the HD44780 and the MPU completes when 4-bits of data is transferred twice. Data of the higher order 4 bits (contents of DB7:DB4 when interface data is 8-bits long) is transferred first and then lower order 4 bits (contents of DB3:DB0 when interface data is 8-bits long).

2: When interface data is 8-bits long, data is transferred using 8 data lines of DB7:DB0.

Please check the Microchip BBS for the latest version of the source code. Microchip's Worldwide Web Address: www.microchip.com; Bulletin Board Support: MCHIPBBS using CompuServe® (CompuServe membership not required).

APPENDIX B: 8-BIT DATA INTERFACE LISTING

```
MPASM 01.40.01 Intermediate    LM032L.ASM   4-7-1997  9:43:02         PAGE  1


LOC  OBJECT CODE     LINE SOURCE TEXT
  VALUE

                     00001         LIST P=16C64
                     00002         ERRORLEVEL  -302
                     00003 ;
                     00004 ; This program interfaces to a Hitachi (LM032L) 2 line by 20 character display
                     00005 ; module. The program assembles for either 4-bit or 8-bit data interface, depending
                     00006 ; on the value of the 4bit flag. LCD_DATA is the port which supplies the data to
                     00007 ; the LM032L, while LCD_CNTL is the port that has the control lines ( E, RS, RW ).
                     00008 ; In 4-bit mode the data is transfer on the high nibble of the port ( PORT<7:4> ).
                     00009 ;
                     00010 ;       Program = LM032L.ASM
                     00011 ;       Revision Date:   5-10-94
                     00012 ;                        1-22-97    Compatibility with MPASMWIN 1.40
                     00013 ;
                     00014 ;
                     00015        include <p16c64.inc>
                     00001         LIST
                     00002 ; P16C64.INC Standard Header File, Version 1.01 Microchip Technology, Inc.
                     00238         LIST
                     00016
  0000009F           00017 ADCON1           EQU  9F
                     00018
  00000000           00019 FALSE            EQU  0
  00000001           00020 TRUE             EQU  1
                     00021
                     00022        include <lm032l.h>
                     00069         list
                     00023 ;
  00000001           00024 Four_bit         EQU  TRUE              ; Selects 4- or 8-bit data transfers
  00000000           00025 Data_HI          EQU  FALSE             ; If 4-bit transfers, Hi or Low nibble of PORT
                     00026 ;
                     00027 ;
                     00028     if ( Four_bit && !Data_HI )
                     00029 ;
  00000006           00030 LCD_DATA         EQU  PORTB
  00000086           00031 LCD_DATA_TRIS    EQU  TRISB
```

```
                    00032 ;
                    00033     else
                    00034 ;
                    00035 LCD_DATA         EQU  PORTD
                    00036 LCD_DATA_TRIS    EQU  TRISD
                    00037 ;
                    00038     endif
                    00039 ;
  00000005          00040 LCD_CNTL         EQU  PORTA
                    00041 ;
                    00042 ;
                    00043 ;
                    00044 ; LCD Display Commands and Control Signal names.
                    00045 ;
                    00046     if ( Four_bit && !Data_HI )
                    00047 ;
  00000000          00048 E                EQU  0                  ; LCD Enable control line
  00000001          00049 RW               EQU  1                  ; LCD Read/Write control line
  00000002          00050 RS               EQU  2                  ; LCD Register Select control line
                    00051 ;
                    00052     else
                    00053 ;
                    00054 E                EQU  3                  ; LCD Enable control line
                    00055 RW               EQU  2                  ; LCD Read/Write control line
                    00056 RS               EQU  1                  ; LCD Register Select control line
                    00057 ;
                    00058     endif
                    00059 ;
                    00060 ;
  00000030          00061 TEMP1            EQU  0x030
                    00062 ;
0000                00063        org       RESET_V                 ; RESET vector location
0000 2808           00064 RESET       GOTO    START                 ;
                    00065 ;
                    00066 ; This is the Periperal Interrupt routine. Should NOT get here
                    00067 ;
                    00068     page
0004                00069         org      ISR_V                   ; Interrupt vector location
0004                00070 PER_INT_V
0004 1283           00071 ERROR1           BCF  STATUS, RP0        ; Bank 0
0005 1407           00072                  BSF  PORTC, 0
0006 1007           00073                  BCF  PORTC, 0
0007 2804           00074                  GOTO ERROR1
                    00075 ;
                    00076 ;
                    00077 ;
0008                00078 START                                    ; POWER_ON Reset (Beginning of program)
```

```
0008 0183           00079             CLRF   STATUS               ; Do initialization (Bank 0)
0009 018B           00080             CLRF   INTCON
000A 018C           00081             CLRF    PIR1
000B 1683           00082             BSF     STATUS, RP0          ; Bank 1
000C 3000           00083             MOVLW   0x00                 ; The LCD module does not like to work w/ weak pull-ups
000D 0081           00084             MOVWF   OPTION_REG           ;
000E 018C           00085             CLRF    PIE1                 ; Disable all peripheral interrupts
                    00086 ;***
                    00087 ;***   If using device with A/D, these two instructions are required.
                    00088 ;***
                    00089 ;           MOVLW   0xFF                 ;
                    00090 ;           MOVWF   ADCON1               ; Port A is Digital.
                    00091 ;
                    00092 ;
000F 1283           00093             BCF     STATUS, RP0          ; Bank 0
0010 0185           00094             CLRF    PORTA                ; ALL PORT output should output Low.
0011 0186           00095             CLRF    PORTB
0012 0187           00096             CLRF    PORTC
0013 0188           00097             CLRF    PORTD
0014 0189           00098             CLRF    PORTE
0015 1010           00099             BCF     T1CON, TMR1ON        ; Timer 1 is NOT incrementing
                    00100 ;
0016 1683           00101             BSF     STATUS, RP0          ; Select Bank 1
0017 0185           00102             CLRF    TRISA                ; RA5 -  0 outputs
0018 30F0           00103             MOVLW   0xF0                 ;
0019 0086           00104             MOVWF   TRISB                ; RB7 - 4 inputs, RB3 - 0 outputs
001A 0187           00105             CLRF    TRISC                ; RC Port are outputs
001B 1407           00106             BSF     TRISC, T1OSO         ; RC0 needs to be input for the oscillator to function
001C 0188           00107             CLRF    TRISD                ; RD Port are outputs
001D 0189           00108             CLRF    TRISE                ; RE Port are outputs
001E 140C           00109             BSF     PIE1, TMR1IE         ; Enable TMR1 Interrupt
001F 1781           00110             BSF     OPTION_REG,NOT_RBPU  ; Disable PORTB pull-ups
0020 1283           00111             BCF     STATUS, RP0          ; Select Bank 0
                    00112 ;
                    00113     page
                    00114 ;
                    00115 ; Initialize the LCD Display Module
                    00116 ;
0021 0185           00117             CLRF    LCD_CNTL             ; ALL PORT output should output Low.
                    00118
0022                00119 DISPLAY_INIT
                    00120     if ( Four_bit && !Data_HI )
0022 3002           00121             MOVLW   0x02                 ; Command for 4-bit interface low nibble
                    00122     endif
                    00123 ;
                    00124     if ( Four_bit && Data_HI )
                    00125             MOVLW   0x020                ; Command for 4-bit interface high nibble
```

```
                    00126     endif
                    00127 ;
                    00128     if ( !Four_bit )
                    00129             MOVLW   0x038               ; Command for 8-bit interface
                    00130     endif
                    00131 ;
0023 0086           00132             MOVWF   LCD_DATA            ;
0024 1405           00133             BSF     LCD_CNTL, E         ;
0025 1005           00134             BCF     LCD_CNTL, E         ;
                    00135 ;
                    00136 ; This routine takes the calculated times that the delay loop needs to
                    00137 ; be executed, based on the LCD_INIT_DELAY EQUate that includes the
                    00138 ; frequency of operation. These uses registers before they are needed to
                    00139 ; store the time.
                    00140 ;
0026 3006           00141 LCD_DELAY   MOVLW   LCD_INIT_DELAY      ;
0027 00B3           00142             MOVWF   MSD                 ; Use MSD and LSD Registers to Initialize LCD
0028 01B4           00143             CLRF    LSD                 ;
0029 0BB4           00144 LOOP2       DECFSZ  LSD, F              ; Delay time = MSD * ((3 * 256) + 3) * Tcy
002A 2829           00145             GOTO    LOOP2               ;
002B 0BB3           00146             DECFSZ  MSD, F              ;
002C                00147 END_LCD_DELAY
002C 2829           00148             GOTO    LOOP2               ;
                    00149 ;
                    00150 ; Command sequence for 2 lines of 5x7 characters
                    00151 ;
002D                00152 CMD_SEQ
                    00153 ;
                    00154     if ( Four_bit )
                    00155         if ( !Data_HI )
002D 3002           00156             MOVLW   0X02                ; 4-bit low nibble xfer
                    00157         else
                    00158             MOVLW   0X020               ; 4-bit high nibble xfer
                    00159         endif
                    00160 ;
                    00161     else                                ; 8-bit mode
                    00162             MOVLW   0X038
                    00163     endif
                    00164 ;
002E 0086           00165             MOVWF   LCD_DATA            ; This code for both 4-bit and 8-bit modes
002F 1405           00166             BSF     LCD_CNTL, E         ;
0030 1005           00167             BCF     LCD_CNTL, E         ;
                    00168 ;
                    00169     if ( Four_bit )                     ; This code for only 4-bit mode (2nd xfer)
                    00170         if ( !Data_HI )
0031 3008           00171             MOVLW   0x08                ; 4-bit low nibble xfer
                    00172         else
```

```
                    00173             MOVLW   0x080               ; 4-bit high nibble xfer
                    00174         endif
0032 0086           00175             MOVWF   LCD_DATA            ;
0033 1405           00176             BSF     LCD_CNTL, E         ;
0034 1005           00177             BCF     LCD_CNTL, E         ;
                    00178     endif
                    00179 ;
                    00180 ; Busy Flag should be valid after this point
                    00181 ;
0035 300C           00182             MOVLW   DISP_ON             ;
0036 2072           00183             CALL    SEND_CMD            ;
0037 3001           00184             MOVLW   CLR_DISP            ;
0038 2072           00185             CALL    SEND_CMD            ;
0039 3006           00186             MOVLW   ENTRY_INC           ;
003A 2072           00187             CALL    SEND_CMD            ;
003B 3080           00188             MOVLW   DD_RAM_ADDR         ;
003C 2072           00189             CALL    SEND_CMD            ;
                    00190 ;
                    00191     page
                    00192 ;
                    00193 ;Send a message the hard way
003D 304D           00194             movlw   'M'
003E 2063           00195             call    SEND_CHAR
003F 3069           00196             movlw   'i'
0040 2063           00197             call    SEND_CHAR
0041 3063           00198             movlw   'c'
0042 2063           00199             call    SEND_CHAR
0043 3072           00200             movlw   'r'
0044 2063           00201             call    SEND_CHAR
0045 306F           00202             movlw   'o'
0046 2063           00203             call    SEND_CHAR
0047 3063           00204             movlw   'c'
0048 2063           00205             call    SEND_CHAR
0049 3068           00206             movlw   'h'
004A 2063           00207             call    SEND_CHAR
004B 3069           00208             movlw   'i'
004C 2063           00209             call    SEND_CHAR
004D 3070           00210             movlw   'p'
004E 2063           00211             call    SEND_CHAR
                    00212
004F 30C0           00213             movlw   B'11000000'         ;Address DDRam first character, second line
0050 2072           00214             call    SEND_CMD
                    00215
                    00216                                         ;Demonstration of the use of a table to output a message
0051 3000           00217             movlw   0                   ;Table address of start of message
0052                00218 dispmsg
0052 00B0           00219             movwf   TEMP1               ;TEMP1 holds start of message address
```

```
0053 2099           00220             call    Table
0054 39FF           00221             andlw   0FFh                ;Check if at end of message (zero
0055 1903           00222             btfsc   STATUS,Z            ;returned at end)
0056 285B           00223             goto    out
0057 2063           00224             call    SEND_CHAR          ;Display character
0058 0830           00225             movf    TEMP1,w            ;Point to next character
0059 3E01           00226             addlw   1
005A 2852           00227             goto    dispmsg
005B                00228 out
005B                00229 loop
005B 285B           00230             goto    loop               ;Stay here forever
                    00231 ;
                    00232 ;
005C                00233 INIT_DISPLAY
005C 300C           00234             MOVLW   DISP_ON            ; Display On, Cursor On
005D 2072           00235             CALL    SEND_CMD           ; Send This command to the Display Module
005E 3001           00236             MOVLW   CLR_DISP           ; Clear the Display
005F 2072           00237             CALL    SEND_CMD           ; Send This command to the Display Module
0060 3006           00238             MOVLW   ENTRY_INC          ; Set Entry Mode Inc., No shift
0061 2072           00239             CALL    SEND_CMD           ; Send This command to the Display Module
0062 0008           00240             RETURN
                    00241 ;
                    00242     page
                    00243 ;
                    00244 ;*****************************************************************
                    00245 ;* The LCD Module Subroutines                                    *
                    00246 ;*****************************************************************
                    00247 ;
                    00248     if ( Four_bit )      ; 4-bit Data transfers?
                    00249 ;
                    00250         if ( Data_HI )   ; 4-bit transfers on the high nibble of the PORT
                    00251 ;
                    00252 ;*****************************************************************
                    00253 ;*SendChar - Sends character to LCD                            *
                    00254 ;*This routine splits the character into the upper and lower    *
                    00255 ;*nibbles and sends them to the LCD, upper nibble first.       *
                    00256 ;*****************************************************************
                    00257 ;
                    00258 SEND_CHAR
                    00259             MOVWF   CHAR               ;Character to be sent is in W
                    00260             CALL    BUSY_CHECK         ;Wait for LCD to be ready
                    00261             MOVF    CHAR, w
                    00262             ANDLW   0xF0               ;Get upper nibble
                    00263             MOVWF   LCD_DATA           ;Send data to LCD
                    00264             BCF     LCD_CNTL, RW       ;Set LCD to read
                    00265             BSF     LCD_CNTL, RS       ;Set LCD to data mode
                    00266             BSF     LCD_CNTL, E        ;toggle E for LCD
```

```
                00267             BCF     LCD_CNTL, E
                00268             SWAPF   CHAR, w
                00269             ANDLW   0xF0            ;Get lower nibble
                00270             MOVWF   LCD_DATA        ;Send data to LCD
                00271             BSF     LCD_CNTL, E     ;toggle E for LCD
                00272             BCF     LCD_CNTL, E
                00273             RETURN
                00274 ;
                00275         else            ; 4-bit transfers on the low nibble of the PORT
                00276 ;
                00277 ;*********************************************************************
                00278 ;* SEND_CHAR - Sends character to LCD                                *
                00279 ;* This routine splits the character into the upper and lower       *
                00280 ;* nibbles and sends them to the LCD, upper nibble first.           *
                00281 ;* The data is transmitted on the PORT<3:0> pins                    *
                00282 ;*********************************************************************
                00283 ;
0063            00284 SEND_CHAR
0063 00B6       00285             MOVWF   CHAR            ; Character to be sent is in W
0064 2081       00286             CALL    BUSY_CHECK      ; Wait for LCD to be ready
0065 0E36       00287             SWAPF   CHAR, W
0066 390F       00288             ANDLW   0x0F            ; Get upper nibble
0067 0086       00289             MOVWF   LCD_DATA        ; Send data to LCD
0068 1085       00290             BCF     LCD_CNTL, RW    ; Set LCD to read
0069 1505       00291             BSF     LCD_CNTL, RS    ; Set LCD to data mode
006A 1405       00292             BSF     LCD_CNTL, E     ; toggle E for LCD
006B 1005       00293             BCF     LCD_CNTL, E
006C 0836       00294             MOVF    CHAR, W
006D 390F       00295             ANDLW   0x0F            ; Get lower nibble
006E 0086       00296             MOVWF   LCD_DATA        ; Send data to LCD
006F 1405       00297             BSF     LCD_CNTL, E     ; toggle E for LCD
0070 1005       00298             BCF     LCD_CNTL, E
0071 0008       00299             RETURN
                00300 ;
                00301         endif
                00302     else
                00303 ;
                00304 ;*********************************************************************
                00305 ;* SEND_CHAR - Sends character contained in register W to LCD    *
                00306 ;* This routine sends the entire character to the PORT           *
                00307 ;* The data is transmitted on the PORT<7:0> pins                 *
                00308 ;*********************************************************************
                00309 ;
                00310 SEND_CHAR
                00311             MOVWF   CHAR            ; Character to be sent is in W
                00312             CALL    BUSY_CHECK      ; Wait for LCD to be ready
                00313             MOVF    CHAR, w
```

```
00314             MOVWF   LCD_DATA        ; Send data to LCD
00315             BCF     LCD_CNTL, RW    ; Set LCD in read mode
00316             BSF     LCD_CNTL, RS    ; Set LCD in data mode
00317             BSF     LCD_CNTL, E     ; toggle E for LCD
00318             BCF     LCD_CNTL, E
00319             RETURN
00320 ;
00321     endif
00322 ;
00323     page
00324 ;
00325 ;*****************************************************************
00326 ;* SendCmd - Sends command to LCD                                *
00327 ;* This routine splits the command into the upper and lower       *
00328 ;* nibbles and sends them to the LCD, upper nibble first.         *
00329 ;* The data is transmitted on the PORT<3:0> pins                  *
00330 ;*****************************************************************
00331 ;
00332     if ( Four_bit )      ; 4-bit Data transfers?
00333 ;
00334         if ( Data_HI )   ; 4-bit transfers on the high nibble of the PORT
00335 ;
00336 ;*****************************************************************
00337 ;* SEND_CMD - Sends command to LCD                               *
00338 ;* This routine splits the command into the upper and lower       *
00339 ;* nibbles and sends them to the LCD, upper nibble first.         *
00340 ;*****************************************************************
00341
00342 SEND_CMD
00343             MOVWF   CHAR            ; Character to be sent is in W
00344             CALL    BUSY_CHECK      ; Wait for LCD to be ready
00345             MOVF    CHAR,w
00346             ANDLW   0xF0            ; Get upper nibble
00347             MOVWF   LCD_DATA        ; Send data to LCD
00348             BCF     LCD_CNTL,RW     ; Set LCD to read
00349             BCF     LCD_CNTL,RS     ; Set LCD to command mode
00350             BSF     LCD_CNTL,E      ; toggle E for LCD
00351             BCF     LCD_CNTL,E
00352             SWAPF   CHAR,w
00353             ANDLW   0xF0            ; Get lower nibble
00354             MOVWF   LCD_DATA        ; Send data to LCD
00355             BSF     LCD_CNTL,E      ; toggle E for LCD
00356             BCF     LCD_CNTL,E
00357             RETURN
00358 ;
00359         else             ; 4-bit transfers on the low nibble of the PORT
00360 ;
```

```
0072                    00361 SEND_CMD
0072 00B6               00362             MOVWF   CHAR            ; Character to be sent is in W
0073 2081               00363             CALL    BUSY_CHECK      ; Wait for LCD to be ready
0074 0E36               00364             SWAPF   CHAR, W
0075 390F               00365             ANDLW   0x0F            ; Get upper nibble
0076 0086               00366             MOVWF   LCD_DATA        ; Send data to LCD
0077 1085               00367             BCF     LCD_CNTL, RW    ; Set LCD to read
0078 1105               00368             BCF     LCD_CNTL, RS    ; Set LCD to command mode
0079 1405               00369             BSF     LCD_CNTL, E     ; toggle E for LCD
007A 1005               00370             BCF     LCD_CNTL, E
007B 0836               00371             MOVF    CHAR, W
007C 390F               00372             ANDLW   0x0F            ; Get lower nibble
007D 0086               00373             MOVWF   LCD_DATA        ; Send data to LCD
007E 1405               00374             BSF     LCD_CNTL, E     ; toggle E for LCD
007F 1005               00375             BCF     LCD_CNTL, E
0080 0008               00376             RETURN
                        00377 ;
                        00378         endif
                        00379     else
                        00380 ;
                        00381 ;*****************************************************************
                        00382 ;* SEND_CND - Sends command contained in register W to LCD    *
                        00383 ;* This routine sends the entire character to the PORT        *
                        00384 ;* The data is transmitted on the PORT<7:0> pins              *
                        00385 ;*****************************************************************
                        00386
                        00387 SEND_CMD
                        00388             MOVWF   CHAR            ; Command to be sent is in W
                        00389             CALL    BUSY_CHECK      ; Wait for LCD to be ready
                        00390             MOVF    CHAR, w
                        00391             MOVWF   LCD_DATA        ; Send data to LCD
                        00392             BCF     LCD_CNTL, RW    ; Set LCD in read mode
                        00393             BCF     LCD_CNTL, RS    ; Set LCD in command mode
                        00394             BSF     LCD_CNTL, E     ; toggle E for LCD
                        00395             BCF     LCD_CNTL, E
                        00396             RETURN
                        00397 ;
                        00398     endif
                        00399 ;
                        00400     page
                        00401 ;
                        00402     if ( Four_bit )               ; 4-bit Data transfers?
                        00403 ;
                        00404         if ( Data_HI )            ; 4-bit transfers on the high nibble of the PORT
                        00405 ;
                        00406 ;*****************************************************************
                        00407 ;* This routine checks the busy flag, returns when not busy       *
```

```
                        00408 ;*  Affects:                                                  *
                        00409 ;*      TEMP - Returned with busy/address                    *
                        00410 ;***************************************************************
                        00411 ;
                        00412 BUSY_CHECK
                        00413             BSF     STATUS, RP0     ; Select Register Bank1
                        00414             MOVLW   0xFF            ; Set Port_D for input
                        00415             MOVWF   LCD_DATA_TRIS
                        00416             BCF     STATUS, RP0     ; Select Register Bank0
                        00417             BCF     LCD_CNTL, RS    ; Set LCD for Command mode
                        00418             BSF     LCD_CNTL, RW    ; Setup to read busy flag
                        00419             BSF     LCD_CNTL, E     ; Set E high
                        00420             BCF     LCD_CNTL, E     ; Set E low
                        00421             MOVF    LCD_DATA, W     ; Read upper nibble busy flag, DDRam address
                        00422             ANDLW   0xF0            ; Mask out lower nibble
                        00423             MOVWF   TEMP
                        00424             BSF     LCD_CNTL, E     ; Toggle E to get lower nibble
                        00425             BCF     LCD_CNTL, E
                        00426             SWAPF   LCD_DATA, w     ; Read lower nibble busy flag, DDRam address
                        00427             ANDLW   0x0F            ; Mask out upper nibble
                        00428             IORWF   TEMP            ; Combine nibbles
                        00429             BTFSC   TEMP, 7         ; Check busy flag, high = busy
                        00430             GOTO    BUSY_CHECK      ; If busy, check again
                        00431             BCF     LCD_CNTL, RW
                        00432             BSF     STATUS, RP0     ; Select Register Bank1
                        00433             MOVLW   0x0F
                        00434             MOVWF   LCD_DATA_TRIS   ; Set Port_D for output
                        00435             BCF     STATUS, RP0     ; Select Register Bank0
                        00436             RETURN
                        00437 ;
                        00438         else                        ; 4-bit transfers on the low nibble of the PORT
                        00439 ;
                        00440 ;***************************************************************
                        00441 ;* This routine checks the busy flag, returns when not busy    *
                        00442 ;*  Affects:                                                    *
                        00443 ;*      TEMP - Returned with busy/address                      *
                        00444 ;***************************************************************
                        00445 ;
0081                    00446 BUSY_CHECK
0081 1683               00447             BSF     STATUS, RP0     ; Bank 1
0082 30FF               00448             MOVLW   0xFF            ; Set PortB for input
0083 0086               00449             MOVWF   LCD_DATA_TRIS
0084 1283               00450             BCF     STATUS, RP0     ; Bank 0
0085 1105               00451             BCF     LCD_CNTL, RS    ; Set LCD for Command mode
0086 1485               00452             BSF     LCD_CNTL, RW    ; Setup to read busy flag
0087 1405               00453             BSF     LCD_CNTL, E     ; Set E high
0088 1005               00454             BCF     LCD_CNTL, E     ; Set E low
```

```
0089 0E06          00455             SWAPF   LCD_DATA, W     ; Read upper nibble busy flag, DDRam address
008A 39F0          00456             ANDLW   0xF0            ; Mask out lower nibble
008B 00B5          00457             MOVWF   TEMP            ;
008C 1405          00458             BSF     LCD_CNTL, E     ; Toggle E to get lower nibble
008D 1005          00459             BCF     LCD_CNTL, E
008E 0806          00460             MOVF    LCD_DATA, W     ; Read lower nibble busy flag, DDRam address
008F 390F          00461             ANDLW   0x0F            ; Mask out upper nibble
0090 04B5          00462             IORWF   TEMP, F         ; Combine nibbles
0091 1BB5          00463             BTFSC   TEMP, 7         ; Check busy flag, high = busy
0092 2881          00464             GOTO    BUSY_CHECK      ; If busy, check again
0093 1085          00465             BCF     LCD_CNTL, RW
0094 1683          00466             BSF     STATUS, RP0     ; Bank 1
0095 30F0          00467             MOVLW   0xF0            ;
0096 0086          00468             MOVWF   LCD_DATA_TRIS   ; RB7 - 4 = inputs, RB3 - 0 = output
0097 1283          00469             BCF     STATUS, RP0     ; Bank 0
0098 0008          00470             RETURN
                   00471 ;
                   00472         endif
                   00473     else
                   00474 ;
                   00475 ;*************************************************************
                   00476 ;* This routine checks the busy flag, returns when not busy   *
                   00477 ;*  Affects:                                                  *
                   00478 ;*      TEMP - Returned with busy/address                     *
                   00479 ;*************************************************************
                   00480 ;
                   00481 BUSY_CHECK
                   00482             BSF     STATUS,RP0      ; Select Register Bank1
                   00483             MOVLW   0xFF            ; Set port_D for input
                   00484             MOVWF   LCD_DATA_TRIS
                   00485             BCF     STATUS, RP0     ; Select Register Bank0
                   00486             BCF     LCD_CNTL, RS    ; Set LCD for command mode
                   00487             BSF     LCD_CNTL, RW    ; Setup to read busy flag
                   00488             BSF     LCD_CNTL, E     ; Set E high
                   00489             BCF     LCD_CNTL, E     ; Set E low
                   00490             MOVF    LCD_DATA, w     ; Read busy flag, DDram address
                   00491             MOVWF   TEMP
                   00492             BTFSC   TEMP, 7         ; Check busy flag, high=busy
                   00493             GOTO    BUSY_CHECK
                   00494             BCF     LCD_CNTL, RW
                   00495             BSF     STATUS, RP0     ; Select Register Bank1
                   00496             MOVLW   0x00
                   00497             MOVWF   LCD_DATA_TRIS   ; Set port_D for output
                   00498             BCF     STATUS, RP0     ; Select Register Bank0
                   00499             RETURN
                   00500 ;
                   00501     endif
```

```
                    00502     page
                    00503 ;
0099                00504 Table
0099 0782           00505             addwf   PCL, F          ;Jump to char pointed to in W reg
009A 344D           00506             retlw   'M'
009B 3469           00507             retlw   'i'
009C 3463           00508             retlw   'c'
009D 3472           00509             retlw   'r'
009E 346F           00510             retlw   'o'
009F 3463           00511             retlw   'c'
00A0 3468           00512             retlw   'h'
00A1 3469           00513             retlw   'i'
00A2 3470           00514             retlw   'p'
00A3 3420           00515             retlw   ' '
00A4 3454           00516             retlw   'T'
00A5 3465           00517             retlw   'e'
00A6 3463           00518             retlw   'c'
00A7 3468           00519             retlw   'h'
00A8 346E           00520             retlw   'n'
00A9 346F           00521             retlw   'o'
00AA 346C           00522             retlw   'l'
00AB 346F           00523             retlw   'o'
00AC 3467           00524             retlw   'g'
00AD 3479           00525             retlw   'y'
00AE                00526 Table_End
00AE 3400           00527             retlw   0
                    00528 ;
                    00529         if ( (Table & 0x0FF) >= (Table_End & 0x0FF) )
                    00530        MESSG   "Warning - User Definded: Table Table crosses page boundry in computed jump"
                    00531     endif
                    00532 ;
                    00533
                    00534
                    00535
                    00536     end
MEMORY USAGE MAP ('X' = Used,  '-' = Unused)


0000 : X---XXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0080 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXX- ----------------

All other memory blocks unused.

Program Memory Words Used:   172
Program Memory Words Free:  1876
```

```
Errors   :     0
Warnings :     0 reported,     0 suppressed
Messages :     0 reported,    12 suppressed
```

Please check the Microchip BBS for the latest version of the source code. Microchip's Worldwide Web Address: www.microchip.com; Bulletin Board Support: MCHIPBBS using CompuServe® (CompuServe membership not required).

APPENDIX C: 4-BIT DATA INTERFACE, HIGH NIBBLE LISTING

```
MPASM 01.40.01 Intermediate    LM032L.ASM   4-7-1997  9:50:32         PAGE  1


LOC  OBJECT CODE     LINE SOURCE TEXT
  VALUE

                     00001         LIST P=16C64
                     00002         ERRORLEVEL  -302
                     00003 ;
                     00004 ; This program interfaces to a Hitachi (LM032L) 2 line by 20 character display
                     00005 ; module. The program assembles for either 4-bit or 8-bit data interface, depending
                     00006 ; on the value of the 4bit flag. LCD_DATA is the port which supplies the data to
                     00007 ; the LM032L, while LCD_CNTL is the port that has the control lines ( E, RS, RW ).
                     00008 ; In 4-bit mode the data is transfer on the high nibble of the port ( PORT<7:4> ).
                     00009 ;
                     00010 ;       Program = LM032L.ASM
                     00011 ;       Revision Date:   5-10-94
                     00012 ;                        1-22-97    Compatibility with MPASMWIN 1.40
                     00013 ;
                     00014 ;
                     00015        include <p16c64.inc>
                     00001         LIST
                     00002 ; P16C64.INC  Standard Header File, Version 1.01    Microchip Technology, Inc.
                     00238         LIST
                     00016
  0000009F           00017 ADCON1           EQU     9F
                     00018
  00000000           00019 FALSE            EQU     0
  00000001           00020 TRUE             EQU     1
                     00021
                     00022        include <lm032l.h>
                     00069         list
                     00023 ;
  00000000           00024 Four_bit         EQU     FALSE           ; Selects 4- or 8-bit data transfers
  00000001           00025 Data_HI          EQU     TRUE            ; If 4-bit transfers, Hi or Low nibble of PORT
                     00026 ;
                     00027 ;
                     00028     if ( Four_bit && !Data_HI )
                     00029 ;
                     00030 LCD_DATA         EQU     PORTB
                     00031 LCD_DATA_TRIS    EQU     TRISB
```

```
                    00032 ;
                    00033     else
                    00034 ;
  00000008          00035 LCD_DATA          EQU     PORTD
  00000088          00036 LCD_DATA_TRIS     EQU     TRISD
                    00037 ;
                    00038     endif
                    00039 ;
  00000005          00040 LCD_CNTL          EQU     PORTA
                    00041 ;
                    00042 ;
                    00043 ;
                    00044 ; LCD Display Commands and Control Signal names.
                    00045 ;
                    00046     if ( Four_bit && !Data_HI )
                    00047 ;
                    00048 E                 EQU     0               ; LCD Enable control line
                    00049 RW                EQU     1               ; LCD Read/Write control line
                    00050 RS                EQU     2               ; LCD Register Select control line
                    00051 ;
                    00052     else
                    00053 ;
  00000003          00054 E                 EQU     3               ; LCD Enable control line
  00000002          00055 RW                EQU     2               ; LCD Read/Write control line
  00000001          00056 RS                EQU     1               ; LCD Register Select control line
                    00057 ;
                    00058     endif
                    00059 ;
                    00060 ;
  00000030          00061 TEMP1             EQU     0x030
                    00062 ;
0000                00063         org       RESET_V                  ; RESET vector location
0000 2808           00064 RESET             GOTO    START             ;
                    00065 ;
                    00066 ; This is the Periperal Interrupt routine. Should NOT get here
                    00067 ;
                    00068     page
0004                00069          org      ISR_V                    ; Interrupt vector location
0004                00070 PER_INT_V
0004 1283           00071 ERROR1            BCF     STATUS, RP0      ; Bank 0
0005 1407           00072                   BSF     PORTC, 0
0006 1007           00073                   BCF     PORTC, 0
0007 2804           00074                   GOTO    ERROR1
                    00075 ;
                    00076 ;
                    00077 ;
0008                00078 START                                      ; POWER_ON Reset (Beginning of program)
```

```
0008 0183           00079             CLRF    STATUS              ; Do initialization (Bank 0)
0009 018B           00080             CLRF    INTCON
000A 018C           00081             CLRF    PIR1
000B 1683           00082             BSF     STATUS, RP0         ; Bank 1
000C 3000           00083             MOVLW   0x00                ; The LCD module does not like to work w/ weak pull-ups
000D 0081           00084             MOVWF   OPTION_REG          ;
000E 018C           00085             CLRF    PIE1                ; Disable all peripheral interrupts
                    00086 ;***
                    00087 ;***   If using device with A/D, these two instructions are required.
                    00088 ;***
                    00089 ;            MOVLW   0xFF               ;
                    00090 ;            MOVWF   ADCON1             ; Port A is Digital.
                    00091 ;
                    00092 ;
000F 1283           00093             BCF     STATUS, RP0         ; Bank 0
0010 0185           00094             CLRF    PORTA               ; ALL PORT output should output Low.
0011 0186           00095             CLRF    PORTB
0012 0187           00096             CLRF    PORTC
0013 0188           00097             CLRF    PORTD
0014 0189           00098             CLRF    PORTE
0015 1010           00099             BCF     T1CON, TMR1ON       ; Timer 1 is NOT incrementing
                    00100 ;
0016 1683           00101             BSF     STATUS, RP0         ; Select Bank 1
0017 0185           00102             CLRF    TRISA               ; RA5 -  0 outputs
0018 30F0           00103             MOVLW   0xF0                ;
0019 0086           00104             MOVWF   TRISB               ; RB7 - 4 inputs, RB3 - 0 outputs
001A 0187           00105             CLRF    TRISC               ; RC Port are outputs
001B 1407           00106             BSF     TRISC, T1OSO        ; RC0 needs to be input for the oscillator to function
001C 0188           00107             CLRF    TRISD               ; RD Port are outputs
001D 0189           00108             CLRF    TRISE               ; RE Port are outputs
001E 140C           00109             BSF     PIE1, TMR1IE        ; Enable TMR1 Interrupt
001F 1781           00110             BSF     OPTION_REG,NOT_RBPU ; Disable PORTB pull-ups
0020 1283           00111             BCF     STATUS, RP0         ; Select Bank 0
                    00112 ;
                    00113     page
                    00114 ;
                    00115 ; Initilize the LCD Display Module
                    00116 ;
0021 0185           00117             CLRF    LCD_CNTL            ; ALL PORT output should output Low.
                    00118
0022                00119 DISPLAY_INIT
                    00120     if ( Four_bit && !Data_HI )
                    00121             MOVLW   0x02                ; Command for 4-bit interface low nibble
                    00122     endif
                    00123 ;
                    00124     if ( Four_bit && Data_HI )
                    00125             MOVLW   0x020               ; Command for 4-bit interface high nibble
```

```
                    00126     endif
                    00127 ;
                    00128     if ( !Four_bit )
0022 3038           00129             MOVLW   0x038               ; Command for 8-bit interface
                    00130     endif
                    00131 ;
0023 0088           00132             MOVWF   LCD_DATA            ;
0024 1585           00133             BSF     LCD_CNTL, E         ;
0025 1185           00134             BCF     LCD_CNTL, E         ;
                    00135 ;
                    00136 ; This routine takes the calculated times that the delay loop needs to
                    00137 ; be executed, based on the LCD_INIT_DELAY EQUate that includes the
                    00138 ; frequency of operation. These use registers before they are needed to
                    00139 ; store the time.
                    00140 ;
0026 3006           00141 LCD_DELAY   MOVLW   LCD_INIT_DELAY      ;
0027 00B3           00142             MOVWF   MSD                 ; Use MSD and LSD Registers to Initilize LCD
0028 01B4           00143             CLRF    LSD                 ;
0029 0BB4           00144 LOOP2       DECFSZ  LSD, F              ; Delay time = MSD * ((3 * 256) + 3) * Tcy
002A 2829           00145             GOTO    LOOP2               ;
002B 0BB3           00146             DECFSZ  MSD, F              ;
002C                00147 END_LCD_DELAY
002C 2829           00148             GOTO    LOOP2               ;
                    00149 ;
                    00150 ; Command sequence for 2 lines of 5x7 characters
                    00151 ;
002D                00152 CMD_SEQ
                    00153 ;
                    00154     if ( Four_bit )
                    00155         if ( !Data_HI )
                    00156             MOVLW   0X02                ; 4-bit low nibble xfer
                    00157         else
                    00158             MOVLW   0X020               ; 4-bit high nibble xfer
                    00159         endif
                    00160 ;
                    00161     else                                ; 8-bit mode
002D 3038           00162             MOVLW   0X038
                    00163     endif
                    00164 ;
002E 0088           00165             MOVWF   LCD_DATA            ; This code for both 4-bit and 8-bit modes
002F 1585           00166             BSF     LCD_CNTL, E         ;
0030 1185           00167             BCF     LCD_CNTL, E         ;
                    00168 ;
                    00169     if ( Four_bit )                     ; This code for only 4-bit mode (2nd xfer)
                    00170         if ( !Data_HI )
                    00171             MOVLW   0x08                ; 4-bit low nibble xfer
                    00172         else
```

```
                    00173             MOVLW   0x080               ; 4-bit high nibble xfer
                    00174         endif
                    00175             MOVWF   LCD_DATA           ;
                    00176             BSF     LCD_CNTL, E        ;
                    00177             BCF     LCD_CNTL, E        ;
                    00178     endif
                    00179 ;
                    00180 ; Busy Flag should be valid after this point
                    00181 ;
0031 300C           00182             MOVLW   DISP_ON            ;
0032 2068           00183             CALL    SEND_CMD           ;
0033 3001           00184             MOVLW   CLR_DISP           ;
0034 2068           00185             CALL    SEND_CMD           ;
0035 3006           00186             MOVLW   ENTRY_INC          ;
0036 2068           00187             CALL    SEND_CMD           ;
0037 3080           00188             MOVLW   DD_RAM_ADDR        ;
0038 2068           00189             CALL    SEND_CMD           ;
                    00190 ;
                    00191     page
                    00192 ;
                    00193 ;Send a message the hard way
0039 304D           00194             movlw   'M'
003A 205F           00195             call    SEND_CHAR
003B 3069           00196             movlw   'i'
003C 205F           00197             call    SEND_CHAR
003D 3063           00198             movlw   'c'
003E 205F           00199             call    SEND_CHAR
003F 3072           00200             movlw   'r'
0040 205F           00201             call    SEND_CHAR
0041 306F           00202             movlw   'o'
0042 205F           00203             call    SEND_CHAR
0043 3063           00204             movlw   'c'
0044 205F           00205             call    SEND_CHAR
0045 3068           00206             movlw   'h'
0046 205F           00207             call    SEND_CHAR
0047 3069           00208             movlw   'i'
0048 205F           00209             call    SEND_CHAR
0049 3070           00210             movlw   'p'
004A 205F           00211             call    SEND_CHAR
                    00212
004B 30C0           00213             movlw   B'11000000'        ;Address DDRam first character, second line
004C 2068           00214             call    SEND_CMD
                    00215
                    00216                                        ;Demonstration of the use of a table to output a message
004D 3000           00217             movlw   0                  ;Table address of start of message
004E                00218 dispmsg
004E 00B0           00219             movwf   TEMP1              ;TEMP1 holds start of message address
```

```
004F 2083                 call    Table
0050 39FF                 andlw   0FFh                ;Check if at end of message (zero
0051 1903                 btfsc   STATUS,Z            ;returned at end)
0052 2857                 goto    out
0053 205F                 call    SEND_CHAR           ;Display character
0054 0830                 movf    TEMP1,w             ;Point to next character
0055 3E01                 addlw   1
0056 284E                 goto    dispmsg
0057            out
0057            loop
0057 2857                 goto    loop                ;Stay here forever
                ;
                ;
0058            INIT_DISPLAY
0058 300C                 MOVLW   DISP_ON             ; Display On, Cursor On
0059 2068                 CALL    SEND_CMD            ; Send This command to the Display Module
005A 3001                 MOVLW   CLR_DISP            ; Clear the Display
005B 2068                 CALL    SEND_CMD            ; Send This command to the Display Module
005C 3006                 MOVLW   ENTRY_INC           ; Set Entry Mode Inc., No shift
005D 2068                 CALL    SEND_CMD            ; Send This command to the Display Module
005E 0008                 RETURN
                ;
                    page
                ;
                ;*******************************************************************
                ;* The LCD Module Subroutines                                      *
                ;*******************************************************************
                ;
                    if ( Four_bit )      ; 4-bit Data transfers?
                ;
                        if ( Data_HI )   ; 4-bit transfers on the high nibble of the PORT
                ;
                ;*******************************************************************
                ;*SendChar - Sends character to LCD                                *
                ;*This routine splits the character into the upper and lower       *
                ;*nibbles and sends them to the LCD, upper nibble first.           *
                ;*******************************************************************
                ;
                SEND_CHAR
                          MOVWF   CHAR                ;Character to be sent is in W
                          CALL    BUSY_CHECK          ;Wait for LCD to be ready
                          MOVF    CHAR, w
                          ANDLW   0xF0                ;Get upper nibble
                          MOVWF   LCD_DATA            ;Send data to LCD
                          BCF     LCD_CNTL, RW        ;Set LCD to read
                          BSF     LCD_CNTL, RS        ;Set LCD to data mode
                          BSF     LCD_CNTL, E         ;toggle E for LCD
```

```
                  00267             BCF     LCD_CNTL, E
                  00268             SWAPF   CHAR, w
                  00269             ANDLW   0xF0                ; Get lower nibble
                  00270             MOVWF   LCD_DATA            ; Send data to LCD
                  00271             BSF     LCD_CNTL, E         ; toggle E for LCD
                  00272             BCF     LCD_CNTL, E
                  00273             RETURN
                  00274 ;
                  00275         else                            ; 4-bit transfers on the low nibble of the PORT
                  00276 ;
                  00277 ;*********************************************************************
                  00278 ;* SEND_CHAR - Sends character to LCD                                *
                  00279 ;* This routine splits the character into the upper and lower        *
                  00280 ;* nibbles and sends them to the LCD, upper nibble first.            *
                  00281 ;* The data is transmitted on the PORT<3:0> pins                     *
                  00282 ;*********************************************************************
                  00283 ;
                  00284 SEND_CHAR
                  00285             MOVWF   CHAR                ; Character to be sent is in W
                  00286             CALL    BUSY_CHECK          ; Wait for LCD to be ready
                  00287             SWAPF   CHAR, W
                  00288             ANDLW   0x0F                ; Get upper nibble
                  00289             MOVWF   LCD_DATA            ; Send data to LCD
                  00290             BCF     LCD_CNTL, RW        ; Set LCD to read
                  00291             BSF     LCD_CNTL, RS        ; Set LCD to data mode
                  00292             BSF     LCD_CNTL, E         ; toggle E for LCD
                  00293             BCF     LCD_CNTL, E
                  00294             MOVF    CHAR, W
                  00295             ANDLW   0x0F                ; Get lower nibble
                  00296             MOVWF   LCD_DATA            ; Send data to LCD
                  00297             BSF     LCD_CNTL, E         ; toggle E for LCD
                  00298             BCF     LCD_CNTL, E
                  00299             RETURN
                  00300 ;
                  00301         endif
                  00302     else
                  00303 ;
                  00304 ;*********************************************************************
                  00305 ;* SEND_CHAR - Sends character contained in register W to LCD    *
                  00306 ;* This routine sends the entire character to the PORT           *
                  00307 ;* The data is transmitted on the PORT<7:0> pins                 *
                  00308 ;*********************************************************************
                  00309 ;
005F              00310 SEND_CHAR
005F 00B6         00311             MOVWF   CHAR                ; Character to be sent is in W
0060 2071         00312             CALL    BUSY_CHECK          ; Wait for LCD to be ready
0061 0836         00313             MOVF    CHAR, w
```

```
0062 0088           00314             MOVWF   LCD_DATA          ; Send data to LCD
0063 1105           00315             BCF     LCD_CNTL, RW      ; Set LCD in read mode
0064 1485           00316             BSF     LCD_CNTL, RS      ; Set LCD in data mode
0065 1585           00317             BSF     LCD_CNTL, E       ; toggle E for LCD
0066 1185           00318             BCF     LCD_CNTL, E
0067 0008           00319             RETURN
                    00320 ;
                    00321     endif
                    00322 ;
                    00323     page
                    00324 ;
                    00325 ;*****************************************************************
                    00326 ;* SendCmd - Sends command to LCD                                *
                    00327 ;* This routine splits the command into the upper and lower      *
                    00328 ;* nibbles and sends them to the LCD, upper nibble first.        *
                    00329 ;* The data is transmitted on the PORT<3:0> pins                 *
                    00330 ;*****************************************************************
                    00331 ;
                    00332     if ( Four_bit )                   ; 4-bit Data transfers?
                    00333 ;
                    00334         if ( Data_HI )                ; 4-bit transfers on the high nibble of the PORT
                    00335 ;
                    00336 ;*****************************************************************
                    00337 ;* SEND_CMD - Sends command to LCD                               *
                    00338 ;* This routine splits the command into the upper and lower      *
                    00339 ;* nibbles and sends them to the LCD, upper nibble first.        *
                    00340 ;*****************************************************************
                    00341
                    00342 SEND_CMD
                    00343             MOVWF   CHAR              ; Character to be sent is in W
                    00344             CALL    BUSY_CHECK        ; Wait for LCD to be ready
                    00345             MOVF    CHAR,w
                    00346             ANDLW   0xF0              ; Get upper nibble
                    00347             MOVWF   LCD_DATA          ; Send data to LCD
                    00348             BCF     LCD_CNTL,RW       ; Set LCD to read
                    00349             BCF     LCD_CNTL,RS       ; Set LCD to command mode
                    00350             BSF     LCD_CNTL,E        ; toggle E for LCD
                    00351             BCF     LCD_CNTL,E
                    00352             SWAPF   CHAR,w
                    00353             ANDLW   0xF0              ; Get lower nibble
                    00354             MOVWF   LCD_DATA          ; Send data to LCD
                    00355             BSF     LCD_CNTL,E        ; toggle E for LCD
                    00356             BCF     LCD_CNTL,E
                    00357             RETURN
                    00358 ;
                    00359         else                          ; 4-bit transfers on the low nibble of the PORT
                    00360 ;
```

```
                    00361 SEND_CMD
                    00362             MOVWF   CHAR              ; Character to be sent is in W
                    00363             CALL    BUSY_CHECK        ; Wait for LCD to be ready
                    00364             SWAPF   CHAR, W
                    00365             ANDLW   0x0F              ; Get upper nibble
                    00366             MOVWF   LCD_DATA          ; Send data to LCD
                    00367             BCF     LCD_CNTL, RW      ; Set LCD to read
                    00368             BCF     LCD_CNTL, RS      ; Set LCD to command mode
                    00369             BSF     LCD_CNTL, E       ; toggle E for LCD
                    00370             BCF     LCD_CNTL, E
                    00371             MOVF    CHAR, W
                    00372             ANDLW   0x0F              ; Get lower nibble
                    00373             MOVWF   LCD_DATA          ; Send data to LCD
                    00374             BSF     LCD_CNTL, E       ; toggle E for LCD
                    00375             BCF     LCD_CNTL, E
                    00376             RETURN
                    00377 ;
                    00378         endif
                    00379     else
                    00380 ;
                    00381 ;*****************************************************************
                    00382 ;* SEND_CND - Sends command contained in register W to LCD    *
                    00383 ;* This routine sends the entire character to the PORT        *
                    00384 ;* The data is transmitted on the PORT<7:0> pins              *
                    00385 ;*****************************************************************
                    00386
0068                00387 SEND_CMD
0068 00B6           00388             MOVWF   CHAR              ; Command to be sent is in W
0069 2071           00389             CALL    BUSY_CHECK        ; Wait for LCD to be ready
006A 0836           00390             MOVF    CHAR, w
006B 0088           00391             MOVWF   LCD_DATA          ; Send data to LCD
006C 1105           00392             BCF     LCD_CNTL, RW      ; Set LCD in read mode
006D 1085           00393             BCF     LCD_CNTL, RS      ; Set LCD in command mode
006E 1585           00394             BSF     LCD_CNTL, E       ; toggle E for LCD
006F 1185           00395             BCF     LCD_CNTL, E
0070 0008           00396             RETURN
                    00397 ;
                    00398     endif
                    00399 ;
                    00400     page
                    00401 ;
                    00402     if ( Four_bit )                   ; 4-bit Data transfers?
                    00403 ;
                    00404         if ( Data_HI )                ; 4-bit transfers on the high nibble of the PORT
                    00405 ;
                    00406 ;*****************************************************************
                    00407 ;* This routine checks the busy flag, returns when not busy        *
```

```
00408 ;*  Affects:                                                        *
00409 ;*      TEMP - Returned with busy/address                          *
00410 ;*******************************************************************
00411 ;
00412 BUSY_CHECK
00413             BSF     STATUS, RP0         ; Select Register Bank1
00414             MOVLW   0xFF                ; Set Port_D for input
00415             MOVWF   LCD_DATA_TRIS
00416             BCF     STATUS, RP0         ; Select Register Bank0
00417             BCF     LCD_CNTL, RS        ; Set LCD for Command mode
00418             BSF     LCD_CNTL, RW        ; Setup to read busy flag
00419             BSF     LCD_CNTL, E         ; Set E high
00420             BCF     LCD_CNTL, E         ; Set E low
00421             MOVF    LCD_DATA, W         ; Read upper nibble busy flag, DDRam address
00422             ANDLW   0xF0                ; Mask out lower nibble
00423             MOVWF   TEMP
00424             BSF     LCD_CNTL, E         ; Toggle E to get lower nibble
00425             BCF     LCD_CNTL, E
00426             SWAPF   LCD_DATA, w         ; Read lower nibble busy flag, DDRam address
00427             ANDLW   0x0F                ; Mask out upper nibble
00428             IORWF   TEMP, F             ; Combine nibbles
00429             BTFSC   TEMP, 7             ; Check busy flag, high = busy
00430             GOTO    BUSY_CHECK          ; If busy, check again
00431             BCF     LCD_CNTL, RW
00432             BSF     STATUS, RP0         ; Select Register Bank1
00433             MOVLW   0x0F
00434             MOVWF   LCD_DATA_TRIS       ; Set Port_D for output
00435             BCF     STATUS, RP0         ; Select Register Bank0
00436             RETURN
00437 ;
00438         else                            ; 4-bit transfers on the low nibble of the PORT
00439 ;
00440 ;*******************************************************************
00441 ;* This routine checks the busy flag, returns when not busy        *
00442 ;*  Affects:                                                       *
00443 ;*      TEMP - Returned with busy/address                          *
00444 ;*******************************************************************
00445 ;
00446 BUSY_CHECK
00447             BSF     STATUS, RP0         ; Bank 1
00448             MOVLW   0xFF                ; Set PortB for input
00449             MOVWF   LCD_DATA_TRIS
00450             BCF     STATUS, RP0         ; Bank 0
00451             BCF     LCD_CNTL, RS        ; Set LCD for Command mode
00452             BSF     LCD_CNTL, RW        ; Setup to read busy flag
00453             BSF     LCD_CNTL, E         ; Set E high
00454             BCF     LCD_CNTL, E         ; Set E low
```

```
                    00455             SWAPF   LCD_DATA, W       ; Read upper nibble busy flag, DDRam address
                    00456             ANDLW   0xF0              ; Mask out lower nibble
                    00457             MOVWF   TEMP              ;
                    00458             BSF     LCD_CNTL, E       ; Toggle E to get lower nibble
                    00459             BCF     LCD_CNTL, E
                    00460             MOVF    LCD_DATA, W       ; Read lower nibble busy flag, DDRam address
                    00461             ANDLW   0x0F              ; Mask out upper nibble
                    00462             IORWF   TEMP, F           ; Combine nibbles
                    00463             BTFSC   TEMP, 7           ; Check busy flag, high = busy
                    00464             GOTO    BUSY_CHECK        ; If busy, check again
                    00465             BCF     LCD_CNTL, RW
                    00466             BSF     STATUS, RP0       ; Bank 1
                    00467             MOVLW   0xF0              ;
                    00468             MOVWF   LCD_DATA_TRIS     ; RB7 - 4 = inputs, RB3 - 0 = output
                    00469             BCF     STATUS, RP0       ; Bank 0
                    00470             RETURN
                    00471 ;
                    00472         endif
                    00473     else
                    00474 ;
                    00475 ;*************************************************************
                    00476 ;* This routine checks the busy flag, returns when not busy   *
                    00477 ;*  Affects:                                                   *
                    00478 ;*      TEMP - Returned with busy/address                     *
                    00479 ;*************************************************************
                    00480 ;
0071                00481 BUSY_CHECK
0071 1683           00482             BSF     STATUS,RP0        ; Select Register Bank1
0072 30FF           00483             MOVLW   0xFF              ; Set port_D for input
0073 0088           00484             MOVWF   LCD_DATA_TRIS
0074 1283           00485             BCF     STATUS, RP0       ; Select Register Bank0
0075 1085           00486             BCF     LCD_CNTL, RS      ; Set LCD for command mode
0076 1505           00487             BSF     LCD_CNTL, RW      ; Setup to read busy flag
0077 1585           00488             BSF     LCD_CNTL, E       ; Set E high
0078 1185           00489             BCF     LCD_CNTL, E       ; Set E low
0079 0808           00490             MOVF    LCD_DATA, w       ; Read busy flag, DDram address
007A 00B5           00491             MOVWF   TEMP
007B 1BB5           00492             BTFSC   TEMP, 7           ; Check busy flag, high=busy
007C 2871           00493             GOTO    BUSY_CHECK
007D 1105           00494             BCF     LCD_CNTL, RW
007E 1683           00495             BSF     STATUS, RP0       ; Select Register Bank1
007F 3000           00496             MOVLW   0x00
0080 0088           00497             MOVWF   LCD_DATA_TRIS     ; Set port_D for output
0081 1283           00498             BCF     STATUS, RP0       ; Select Register Bank0
0082 0008           00499             RETURN
                    00500 ;
                    00501     endif
```

```
                     page
                   ;
0083               Table
0083 0782                  addwf   PCL, F          ; Jump to char pointed to in W reg
0084 344D                  retlw   'M'
0085 3469                  retlw   'i'
0086 3463                  retlw   'c'
0087 3472                  retlw   'r'
0088 346F                  retlw   'o'
0089 3463                  retlw   'c'
008A 3468                  retlw   'h'
008B 3469                  retlw   'i'
008C 3470                  retlw   'p'
008D 3420                  retlw   ' '
008E 3454                  retlw   'T'
008F 3465                  retlw   'e'
0090 3463                  retlw   'c'
0091 3468                  retlw   'h'
0092 346E                  retlw   'n'
0093 346F                  retlw   'o'
0094 346C                  retlw   'l'
0095 346F                  retlw   'o'
0096 3467                  retlw   'g'
0097 3479                  retlw   'y'
0098               Table_End
0098 3400                  retlw   0
                   ;
                       if ( (Table & 0x0FF) >= (Table_End & 0x0FF) )
                      MESSG   "Warning - User Definded: Table Table crosses page boundry in computed jump"
                     endif
                   ;



                     end
```

```
MEMORY USAGE MAP ('X' = Used,  '-' = Unused)


0000 : X---XXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0080 : XXXXXXXXXXXXXXXX XXXXXXXXX------- ---------------- ----------------

All other memory blocks unused.

Program Memory Words Used:   150
Program Memory Words Free:  1898


Errors   :     0
Warnings :     0 reported,     0 suppressed
Messages :     0 reported,    12 suppressed
```

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AMERICAS

Corporate Office
Microchip Technology Inc.
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-786-7200 Fax: 480-786-7277
Technical Support: 480-786-7627
Web Address: http://www.microchip.com

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Tri-Atria Office Building
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Farmington Hills, MI 48334
Tel: 248-538-2250 Fax: 248-538-2260

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18201 Von Karman, Suite 1090
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Tel: 949-263-1888 Fax: 949-263-1338

New York
Microchip Technology Inc.
150 Motor Parkway, Suite 202
Hauppauge, NY 11788
Tel: 631-273-5305 Fax: 631-273-5335

San Jose
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

AMERICAS (continued)

Toronto
Microchip Technology Inc.
5925 Airport Road, Suite 200
Mississauga, Ontario L4V 1W1, Canada
Tel: 905-405-6279 Fax: 905-405-6253

ASIA/PACIFIC

Hong Kong
Microchip Asia Pacific
Unit 2101, Tower 2
Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2-401-1200 Fax: 852-2-401-3431

Beijing
Microchip Technology, Beijing
Unit 915, 6 Chaoyangmen Bei Dajie
Dong Erhuan Road, Dongcheng District
New China Hong Kong Manhattan Building
Beijing 100027 PRC
Tel: 86-10-85282100 Fax: 86-10-85282104

India
Microchip Technology Inc.
India Liaison Office
No. 6, Legacy, Convent Road
Bangalore 560 025, India
Tel: 91-80-229-0061 Fax: 91-80-229-0062

Japan
Microchip Technology Intl. Inc.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa 222-0033 Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea
Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Shanghai
Microchip Technology
RM 406 Shanghai Golden Bridge Bldg.
2077 Yan'an Road West, Hong Qiao District
Shanghai, PRC 200335
Tel: 86-21-6275-5700 Fax: 86 21-6275-5060

ASIA/PACIFIC (continued)

Singapore
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore 188980
Tel: 65-334-8870 Fax: 65-334-8850

Taiwan, R.O.C
Microchip Technology Taiwan
10F-1C 207
Tung Hua North Road
Taipei, Taiwan, ROC
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

United Kingdom
Arizona Microchip Technology Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5858 Fax: 44-118 921-5835

Denmark
Microchip Technology Denmark ApS
Regus Business Centre
Lautrup hoj 1-3
Ballerup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

France
Arizona Microchip Technology SARL
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - ler Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Arizona Microchip Technology GmbH
Gustav-Heinemann-Ring 125
D-81739 München, Germany
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

Italy
Arizona Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza
Milan, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

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