AN557

Four Channel Digital Voltmeter with Display and Keyboard

Author: *Stan D'Souza*
Microchip Technology Inc.

INTRODUCTION

The PIC16C71 is a member of the mid-range family of 8-bit, high-speed microcontrollers, namely the PIC16CXXX. The salient features of the PIC16C71 are:

- Improved and enhanced instruction set
- 14-bit instruction word
- Interrupt capability
- On-chip four channel, 8-bit A/D converter

This application note demonstrates the capability of the PIC16C71. This application note has been broken down into four subsections:

Multiplexing Four 7-Segment LED Displays

Multiplexing Four 7-Segment LED Displays and Scanning a 4x4 Keypad

Multiplexing Four 7-Segment LED Displays and the A/D Channel0

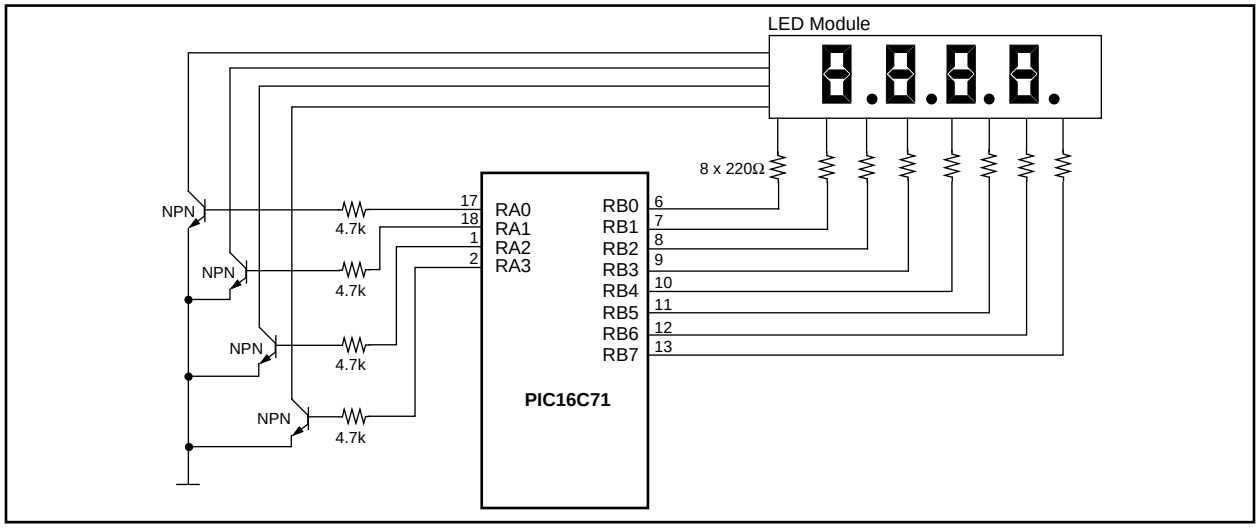
Multiplexing Four 7-Segment LED Displays with a 4x4 Keypad and 4 A/D Channels

MULTIPLEXING FOUR 7-SEGMENT LED DISPLAYS

Hardware

The PIC16C71's I/O ports have an improved sink/source specification. Each I/O pin can sink up to 25 mA and source 20 mA, in addition total PORTB source current is 100 mA and sink current is 150 mA. PORTA is rated for 50 mA source current and 80 mA sink current. This makes the PIC16C71 ideal for driving 7-segment LEDs. Since the total number of I/O pins is limited to 13, the 8-bit PORTB is used to drive the 4 LEDs, while external sink transistors or MOSFETs are used to sink the digit current (Figure 1). Another alternative is to use ULN2003 open collector sink current drivers, which are available in 16-pin DIP or very small SO-16 packages. Each transistor on the ULN2003 can sink a maximum of 500 mA and the base drive can be directly driven from the PORTA pins.

FIGURE 1: MULTIPLEXING FOUR 7-SEGMENTS LEDS



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Software

The multiplexing is achieved by turning on each LED for a 5 μs duration every 20 μs. This gives an update rate of 50 Hz, which is quite acceptable to the human eye as a steady display. The 5 μs time-base is generated by dividing the 4.096 MHz oscillator clock. The internal prescaler is configured to be a divide by 32 and assigned to Timer0. TMR0 is pre-loaded with a value = 96. TMR0 will increment to FFh and then roll over to 00h after a period =
(256-96)•(32•4/4096000) = 5 μs.

When TMR0 rolls over, flag bit T0IF flag is set, and because bits T0IE and GIE are enabled, an interrupt is generated.

The software implements a simple timer which increments at a 1 second rate. Every second, the 4 nibble (two 8-bit registers MsdTime and LsdTime) are incremented in a BCD format. The lower 4 bits of LsdTime correspond to the least significant digit (LSD) on the display. The high 4 bits of LsdTime correspond to the second significant digit of the display and so on. Depending on which display is turned on, the corresponding 4-bit BCD value is extracted from either MsdTime or LsdTime, and decoded to a 7-segment display. The TMR0 interrupt is generated at a steady rate of 5 μs and given an instruction time of 1 μs. The entire display update program can reside in the interrupt service routine with no chance of getting an interrupt within an interrupt. The Code Listing for this section is in Appendix A.

MULTIPLEXING FOUR 7-SEGMENT LED DISPLAYS AND SCANNING A 4x4 KEYPAD

Hardware

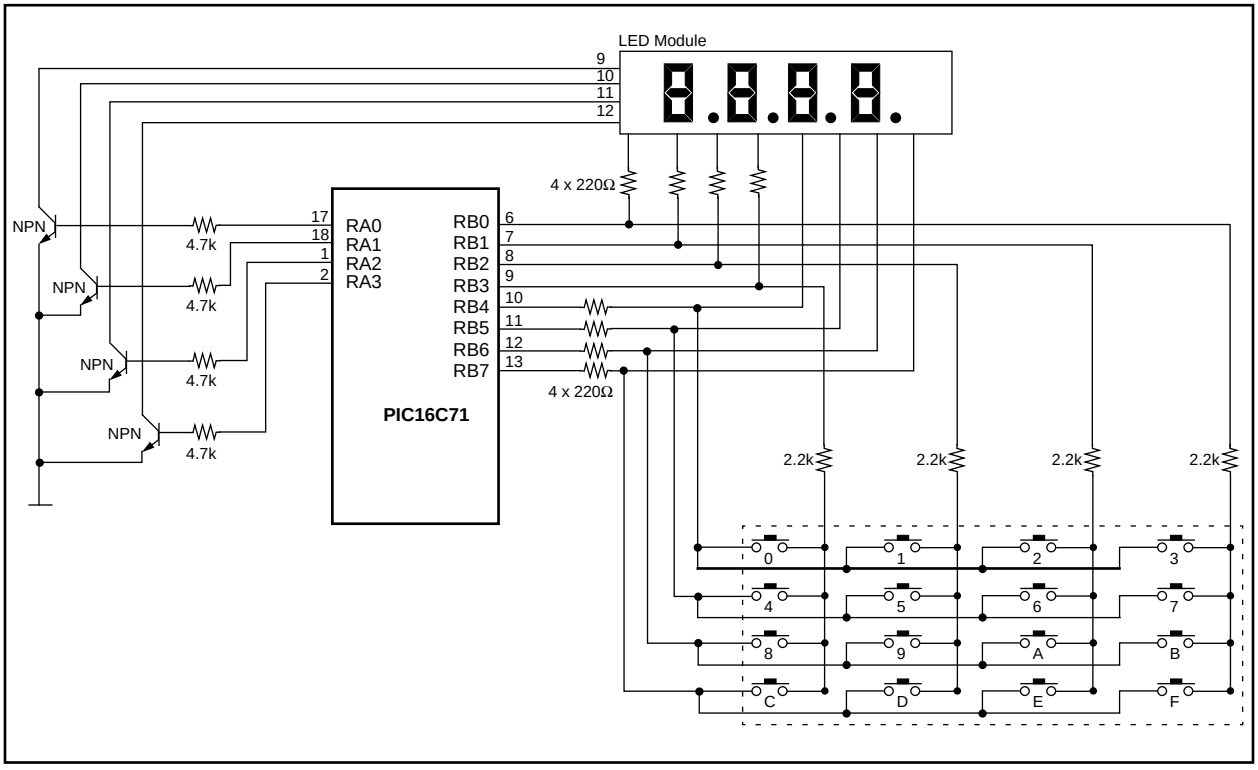
A 4x4 keypad can be very easily interfaced to the PIC16C71's PORTB (Figure 2). Internal pull-ups on pins RB7:RB4 can be enabled/disabled by clearing/setting bit $\overline{\text{RBPU}}$ (OPTION<7>). The internal pull-ups have a value of 20k at 5V (typical). In order to sense a low level at the input, the switch is “connected” to ground through a 2.2 kΩ resistor. A key hit normally lasts anywhere from 50 ms to as long as a person holds the key down. In order not to miss any key hits, the keypad is sampled every 20 μs (just after the update of the MSD).

Software

To sample the keypad, the digit sinks are first disabled. PORTB is then configured with RB7:RB4 as inputs and RB3:RB0 as outputs driven high. The pull-ups on RB7:RB4 are enabled. Sequentially RB3:RB0 are made low while RB7:RB4 are checked for a key hit (a low level). One key hit per scan is demonstrated in this program. Multiple key hits per scan can very easily be implemented. Once the key hit is sensed, a 40 ms debounce period elapses before key sampling is resumed. No more key hits are sensed until the present key is released. This prevents erroneous key inputs.

The program basically inputs the key hit and displays its value as a hexadecimal character on the multiplexed 7- segment LEDs. The Code Listing for this section is in Appendix B.

FIGURE 2: MULTIPLEXING FOUR 7-SEGMENT LEDS WITH A 4X4 KEYPAD



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MULTIPLEXING FOUR 7-SEGMENT LED DISPLAYS AND THE A/D CHANNEL0

Hardware

The four analog channels are connected to RA3:RA0. If any of these pins are used normally as digital I/O, they can momentarily be used as analog inputs. In order to avoid interference from the analog source, it is advisable to buffer the analog input through a voltage follower op-amp, however, it is not always necessary. Figure 3 and Figure 4 show some typical configurations. In this application, the analog input is a potentiometer whose wiper is connected through an RC network to Channel0. The RC is necessary in order to smooth out the analog voltage. The RC does contribute to a delay in the sampling time, however the stability of the analog reading is greatly improved.

Software

The analog input is sampled every 20 ms. The digit sinks and the drivers are turned off (i.e., PORTA is configured as an input and PORTB outputs are made low). A 1 ms settling time is allowed for the external RC network connected to the analog input to settle and then the A/D conversion is started. The result is read then converted from an 8-bit binary value to a 3-digit Binary Code Decimal (BCD) value which is then displayed on the 7-segment LEDs. The Code Listing for this section is in Appendix C.

FIGURE 3: TYPICAL CONNECTION FOR ANALOG/DIGITAL INPUT

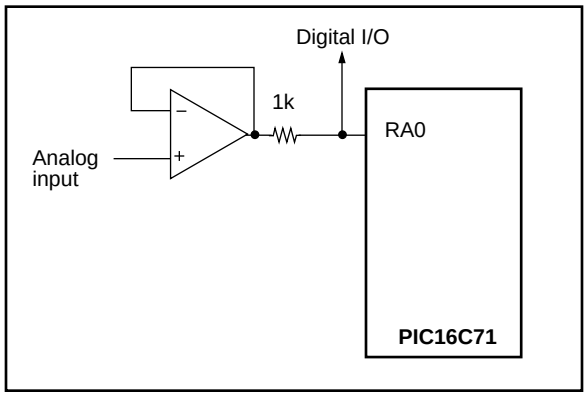
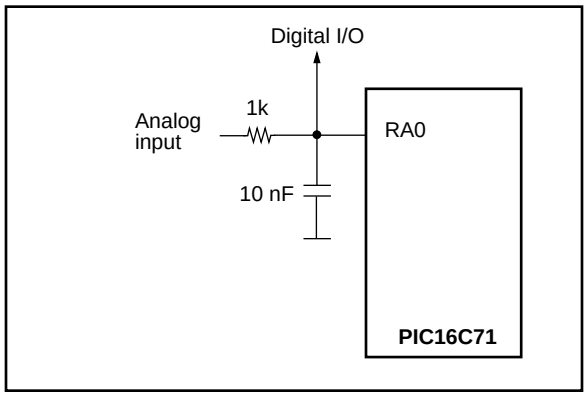


FIGURE 4: TYPICAL CONNECTION FOR ANALOG/DIGITAL INPUT



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MULTIPLEXING FOUR 7-SEGMENT LED DISPLAYS WITH A 4x4 KEYPAD AND 4 A/D CHANNELS

Hardware

This section essentially incorporates the previous three sections to give a complete four channel voltmeter. Figure 5 shows a typical configuration. The analog channels are connected through individual potentiometers to their respective analog inputs and are sampled every 20 ms in a round robin fashion. The sampling rate can be increased to as fast as once every 5 µs if required. The keypad sampling need not be any faster than once every 20 µs.

Software

The program samples the analog inputs and saves the result in four consecutive locations starting at "ADVALUE", with Channel0 saved at the first location and so on.

KEY 0 → Channel0

or

KEY 1 → Channel0

Key hits greater than 3 are ignored. The code listing for this section is in Appendix D.

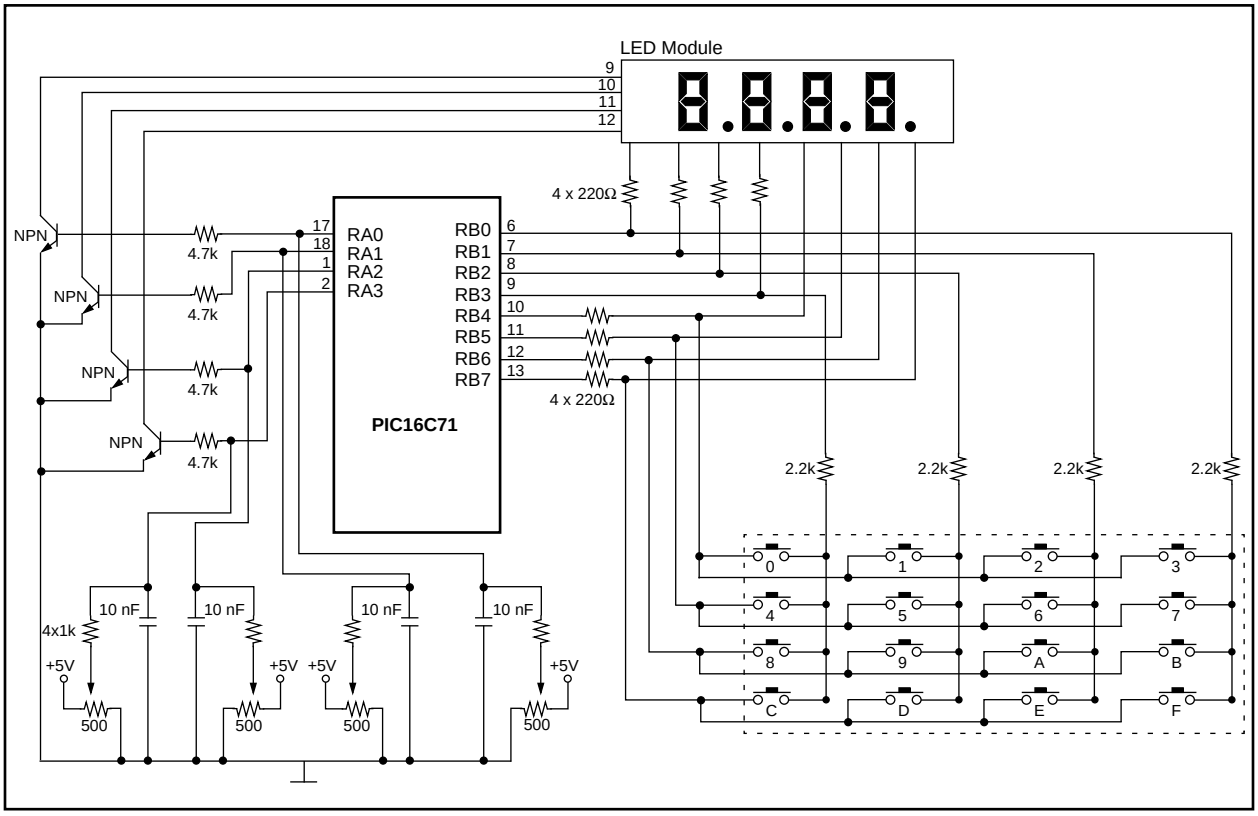
Code Size

Four 7-segment LEDs	Program Memory:	139
	Data Memory:	6
Four 7-segment LEDs and 4x4 keypad sampling	Program Memory:	207
	Data Memory:	13
Four 7-segment LEDs and A/D	Program Memory:	207
	Data Memory:	11
Four 7-segment LEDs, 4x4 keypad sampling, and A/D	Program Memory:	207
	Data Memory:	13

CONCLUSION

The four A/D channels on the PIC16C71 can be multiplexed with digital I/O, thus reducing overall pin counts and improving I/O pin usage in an analog application.

FIGURE 5: FOUR CHANNEL VOLTMETER WITH DISPLAY AND KEYPAD



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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 A: MPLX.ASM

```
MPASM 01.40 Released            MPLX.ASM   1-16-1997  16:20:47         PAGE  1

LOC  OBJECT CODE     LINE SOURCE TEXT
  VALUE

                     00001 ;*******************************************************************
                     00002 ;This program demonstrates how to multiplex four 7 segment LED
                     00003 ;digits using a PIC16C71. The four digits will start at 0000 and
                     00004 ;increment at a 1 sec rate up to 9999.
                     00005 ;The LEDs are updated every 5 mS, for a multiplexing rate of 20 mS.
                     00006 ;The TMR0 timer is used in internal interrupt mode to generate the
                     00007 ;5 mS.
                     00008 ;
                     00009 ;                                        Stan D'Souza 5/8/93
                     00010 ;
                     00011 ;       Program:          MPLX.ASM
                     00012 ;       Revision Date:
                     00013 ;                         1-15-97      Compatibility with MPASMWIN 1.40
                     00014 ;
                     00015 ;*******************************************************************
                     00016         LIST P=16C71
                     00017         ERRORLEVEL  -302
                     00018 ;
                     00019         include   <p16c71.inc>
                     00001         LIST
                     00002 ; P16C71.INC  Standard Header File, Version 1.00  Microchip Technology
                     00142         LIST
                     00020 ;
  0000000C           00021 TempC   equ     0x0c            ;temp general purpose regs
  0000000D           00022 TempD   equ     0x0d
  0000000E           00023 TempE   equ     0x0e
  0000000F           00024 Count   equ     0x0f            ;count
  00000010           00025 MsdTime equ     0x10            ;most significant Timer
  00000011           00026 LsdTime equ     0x11            ;Least significant Timer
  00000001           00027 OptionReg equ   1
  00000002           00028 PCL     equ     2
  00000026           00029 BcdMsd  equ     26
  00000027           00030 Bcd     equ     27
                     00031 ;
0000                 00032         org     0
0000 2805            00033         goto    Start           ;skip over interrupt vector
                     00034 ;
0004                 00035         org     4
0004 281D            00036         goto    ServiceInterrupts
                     00037 ;
0005                 00038 Start
0005 2008            00039         call    InitPorts
0006 2012            00040         call    InitTimers
0007                 00041 loop
0007 2807            00042         goto    loop
                     00043 ;
0008                 00044 InitPorts
0008 1683            00045         bsf     STATUS,RP0      ;select Bank1
0009 3003            00046         movlw   3               ;make RA0-3 digital I/O
000A 0088            00047         movwf   ADCON1          ;       /
000B 0185            00048         clrf    TRISA           ;make RA0-4 outputs
000C 0186            00049         clrf    TRISB           ;make RB0-7 outputs
000D 1283            00050         bcf     STATUS,RP0      ;select Bank0
000E 0185            00051         clrf    PORTA           ;make all outputs low
000F 0186            00052         clrf    PORTB           ;       /
```

```
0010 1585           00053         bsf     PORTA,3         ;enable MSB digit sink
0011 0008           00054         return
                    00055 ;
                    00056 ;
                    00057 ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                    00058 ;the TMR0 will be incremented every 31.25uS. If TMR0 is preloaded
                    00059 ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                    00060 ;end result is that we get a TMR0 interrupt every 5mS.
0012                00061 InitTimers
0012 0190           00062         clrf    MsdTime                 ;clr timers
0013 0191           00063         clrf    LsdTime                 ;       /
0014 1683           00064         bsf     STATUS,RP0              ;select Bank1
0015 3084           00065         movlw   B'10000100'             ;assign ps to TMR0
0016 0081           00066         movwf   OptionReg               ;ps = 32
0017 1283           00067         bcf     STATUS,RP0              ;select Bank0
0018 3020           00068         movlw   B'00100000'             ;enable TMR0 interrupt
0019 008B           00069         movwf   INTCON                  ;
001A 3060           00070         movlw   .96                     ;preload TMR0
001B 0081           00071         movwf   TMR0                    ;start counter
001C 0009           00072         retfie
                    00073 ;
001D                00074 ServiceInterrupts
001D 190B           00075         btfsc   INTCON,T0IF             ;TMR0 interrupt?
001E 2822           00076         goto    ServiceTMR0             ;yes then service
001F 3020           00077         movlw   B'00100000'             ;else clr rest
0020 008B           00078         movwf   INTCON
0021 0009           00079         retfie
                    00080 ;
0022                00081 ServiceTMR0
0022 3060           00082         movlw   .96                     ;initialize TMR0
0023 0081           00083         movwf   TMR0
0024 110B           00084         bcf     INTCON,T0IF             ;clr int flag
0025 2028           00085         call    IncTimer                ;inc timer
0026 2050           00086         call    UpdateDisplay           ;update display
0027 0009           00087         retfie
                    00088 ;
                    00089 ;The display is incremented every 200*5mS = 1 Sec.
0028                00090 IncTimer
0028 0A0F           00091         incf    Count,W                 ;inc count
0029 3AC8           00092         xorlw   .200                    ;= 200?
002A 1903           00093         btfsc   STATUS,Z                ;no then skip
002B 282E           00094         goto    DoIncTime               ;else inc time
002C 0A8F           00095         incf    Count, F
002D 0008           00096         return
002E                00097 DoIncTime
002E 018F           00098         clrf    Count                   ;clr count
002F 0A11           00099         incf    LsdTime,W               ;get lsd
0030 390F           00100         andlw   0x0F                    ;mask high nibble
0031 3A0A           00101         xorlw   0x0a                    ; = 10?
0032 1903           00102         btfsc   STATUS,Z                ;no then skip
0033 2836           00103         goto    IncSecondLsd            ;inc next lsd
0034 0A91           00104         incf    LsdTime, F              ;else inc timer
0035 0008           00105         return
0036                00106 IncSecondLsd
0036 0E11           00107         swapf   LsdTime,W               ;get hi in low nibble
0037 390F           00108         andlw   0x0F                    ;mask hi nibble
0038 3E01           00109         addlw   1                       ;inc it
0039 0091           00110         movwf   LsdTime                 ;restore back
003A 0E91           00111         swapf   LsdTime, F              ;       /
003B 3A0A           00112         xorlw   0x0a                    ; = 10?
003C 1903           00113         btfsc   STATUS,Z                ;no then skip
003D 283F           00114         goto    IncThirdLsd             ;else inc next lsd
003E 0008           00115         return
003F                00116 IncThirdLsd
003F 0191           00117         clrf    LsdTime
0040 0A10           00118         incf    MsdTime,W               ;get 3rd lsd
```


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0041 390F           00119         andlw   0x0F                  ;mask hi nibble
0042 3A0A           00120         xorlw   0x0a                  ;= 10?
0043 1903           00121         btfsc   STATUS,Z              ;no then skip
0044 2847           00122         goto    IncMsd                ;else Msd
0045 0A90           00123         incf    MsdTime, F            ;else inc timer
0046 0008           00124         return
0047                00125 IncMsd
0047 0E10           00126         swapf   MsdTime,W             ;get hi in lo nibble
0048 390F           00127         andlw   0x0F                  ;mask hi nibble
0049 3E01           00128         addlw   1                     ;inc timer
004A 0090           00129         movwf   MsdTime               ;restore back
004B 0E90           00130         swapf   MsdTime, F            ;       /
004C 3A0A           00131         xorlw   0x0a                  ;= 10?
004D 1903           00132         btfsc   STATUS,Z              ;no then skip
004E 0190           00133         clrf    MsdTime               ;clr msd
004F 0008           00134         return
                    00135 ;
                    00136 ;
0050                00137 UpdateDisplay
0050 0805           00138         movf    PORTA,W             ;present sink value in w
0051 0185           00139         clrf    PORTA               ;disable all digits sinks
0052 390F           00140         andlw   0x0f
0053 008C           00141         movwf   TempC               ;save sink value in tempC
0054 160C           00142         bsf     TempC,4             ;preset for lsd sink
0055 0C8C           00143         rrf     TempC, F            ;determine next sink value
0056 1C03           00144         btfss   STATUS,C            ;c=1?
0057 118C           00145         bcf     TempC,3             ;no then reset LSD sink
0058 180C           00146         btfsc   TempC,0             ;else see if Msd
0059 286B           00147         goto    UpdateMsd           ;yes then do Msd
005A 188C           00148         btfsc   TempC,1             ;see if 3rdLsd
005B 2866           00149         goto    Update3rdLsd        ;yes then do 3rd Lsd
005C 190C           00150         btfsc   TempC,2             ;see if 2nd Lsd
005D 2861           00151         goto    Update2ndLsd        ;yes then do 2nd lsd
005E                00152 UpdateLsd
005E 0811           00153         movf    LsdTime,W           ;get Lsd in w
005F 390F           00154         andlw   0x0f                ;       /
0060 286F           00155         goto    DisplayOut          ;enable display
0061                00156 Update2ndLsd
0061 2080           00157         call    Chk2LsdZero         ;msd = 0 & 2 lsd 0?
0062 1D03           00158         btfss   STATUS,Z            ;yes then skip
0063 0E11           00159         swapf   LsdTime,W           ;get 2nd Lsd in w
0064 390F           00160         andlw   0x0f                ;mask rest
0065 286F           00161         goto    DisplayOut          ;enable display
0066                00162 Update3rdLsd
0066 2088           00163         call    ChkMsdZero          ;msd = 0?
0067 1D03           00164         btfss   STATUS,Z            ;yes then skip
0068 0810           00165         movf    MsdTime,W           ;get 3rd Lsd in w
0069 390F           00166         andlw   0x0f                ;mask low nibble
006A 286F           00167         goto    DisplayOut          ;enable display
006B                00168 UpdateMsd
006B 0E10           00169         swapf   MsdTime,W           ;get Msd in w
006C 390F           00170         andlw   0x0f                ;mask rest
006D 1903           00171         btfsc   STATUS,Z            ;msd != 0 then skip
006E 300A           00172         movlw   0x0a
006F                00173 DisplayOut
006F 2074           00174         call    LedTable            ;get digit output
0070 0086           00175         movwf   PORTB               ;drive leds
0071 080C           00176         movf    TempC,W             ;get sink value in w
0072 0085           00177         movwf   PORTA
0073 0008           00178         return
                    00179 ;
                    00180 ;
0074                00181 LedTable
0074 0782           00182         addwf   PCL, F               ;add to PC low
0075 343F           00183         retlw   B'00111111'          ;led drive for 0
0076 3406           00184         retlw   B'00000110'          ;led drive for 1
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0077 345B           00185         retlw   B'01011011'             ;led drive for 2
0078 344F           00186         retlw   B'01001111'             ;led drive for 3
0079 3466           00187         retlw   B'01100110'             ;led drive for 4
007A 346D           00188         retlw   B'01101101'             ;led drive for 5
007B 347D           00189         retlw   B'01111101'             ;led drive for 6
007C 3407           00190         retlw   B'00000111'             ;led drive for 7
007D 347F           00191         retlw   B'01111111'             ;led drive for 8
007E 3467           00192         retlw   B'01100111'             ;led drive for 9
007F 3400           00193         retlw   B'00000000'             ;blank led drive
                    00194 ;
                    00195 ;
0080                00196 Chk2LsdZero
0080 2088           00197         call    ChkMsdZero              ;msd = 0?
0081 1D03           00198         btfss   STATUS,Z                ;yes then skip
0082 0008           00199         return                          ;else return
0083 0E11           00200         swapf   LsdTime,W               ;get 2nd lsd
0084 390F           00201         andlw   0x0f                    ;mask of LSD
0085 1D03           00202         btfss   STATUS,Z                ;0? then skip
0086 0008           00203         return
0087 340A           00204         retlw   .10                     ;else return with 10
                    00205 ;
0088                00206 ChkMsdZero
0088 0810           00207         movf    MsdTime,W               ;get Msd in w
0089 1D03           00208         btfss   STATUS,Z                ;= 0? skip
008A 0008           00209         return                          ;else return
008B 340A           00210         retlw   .10                     ;ret with 10
                    00211 ;
                    00212
                    00213         end

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

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

All other memory blocks unused.

Program Memory Words Used:   137
Program Memory Words Free:   887
Errors   :     0
Warnings :     0 reported,     0 suppressed
Messages :     0 reported,     3 suppressed
```


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APPENDIX B: MPLXKEY.ASM

```
MPASM 01.40 Released          MPLXKEY.ASM   1-16-1997  16:24:40         PAGE  1


LOC  OBJECT CODE     LINE SOURCE TEXT
  VALUE

                     00001 ;*******************************************************************
                     00002 ;This program is to demonstrate how to multiplex four 7 segment LED
                     00003 ;digits and a 4x4 keypad using a PIC16C71.
                     00004 ;The four digits will start as '0000' and when a key is hit
                     00005 ;it is displayed on the 7 segment leds as a hex value 0 to F. The last
                     00006 ;digit hit is always displayed on the right most led with the rest of
                     00007 ;the digits shifted to the left. The left most digit is deleted.
                     00008 ;The LEDs are updated every 20mS, the keypad is scanned at a rate of 20
                     00009 ;mS. The TMR0 timer is used in internal interrupt mode to generate the
                     00010 ;5 mS.
                     00011 ;
                     00012 ;                                        Stan D'Souza 5/8/93
                     00013 ;
                     00014 ;       Program:          MPLXKEY.ASM
                     00015 ;       Revision Date:
                     00016 ;                         1-15-97      Compatibility with MPASMWIN 1.40
                     00017 ;
                     00018 ;*******************************************************************
                     00019         LIST P=16C71
                     00020         ERRORLEVEL  -302
                     00021 ;
                     00022         include     <p16c71.inc>
                     00001         LIST
                     00002 ; P16C71.INC Standard Header File,Ver. 1.00 Microchip Technology, Inc.
                     00142         LIST
                     00023 ;
  0000000C           00024 TempC   equ     0x0c            ;temp general purpose regs
  0000000D           00025 TempD   equ     0x0d
  0000000E           00026 TempE   equ     0x0e
  00000020           00027 PABuf   equ     0x20
  00000021           00028 PBBuf   equ     0x21
  0000000F           00029 Count   equ     0x0f            ;count
  00000010           00030 MsdTime equ     0x10            ;most significant Timer
  00000011           00031 LsdTime equ     0x11            ;Least significant Timer
  00000012           00032 KeyFlag equ     0x12            ;flags related to key pad
  00000000           00033 keyhit  equ     0               ;bit 0 --> key-press on
  00000001           00034 DebnceOn equ    1               ;bit 1 --> debounce on
  00000002           00035 noentry equ     2               ;no key entry = 0
  00000003           00036 ServKey equ     3               ;bit 3 --> service key
  00000013           00037 Debnce  equ     0x13            ;debounce counter
  00000014           00038 NewKey  equ     0x14
  0000002F           00039 WBuffer equ     0x2f
  0000002E           00040 StatBuffer equ  0x2e
  00000001           00041 OptionReg equ   1
  00000002           00042 PCL     equ     2
                     00043 ;
                     00044 ;
                     00045 push    macro
                     00046         movwf   WBuffer         ;save w reg in Buffer
                     00047         swapf   WBuffer, F      ;swap it
                     00048         swapf   STATUS,W        ;get status
                     00049         movwf   StatBuffer      ;save it
                     00050         endm
                     00051 ;
```

```
                  00052 pop     macro
                  00053         swapf   StatBuffer,W    ;restore status
                  00054         movwf   STATUS          ;       /
                  00055         swapf   WBuffer,W       ;restore W reg
                  00056         endm
                  00057 ;
0000              00058         org     0
0000 280D         00059         goto    Start           ;skip over interrupt vector
                  00060 ;
0004              00061         org     4
                  00062 ;It is always a good practice to save and restore the w reg,
                  00063 ;and the status reg during an interrupt.
                  00064         push
0004 00AF             M         movwf   WBuffer         ;save w reg in Buffer
0005 0EAF             M         swapf   WBuffer, F      ;swap it
0006 0E03             M         swapf   STATUS,W        ;get status
0007 00AE             M         movwf   StatBuffer      ;save it
0008 2036         00065         call    ServiceInterrupts
                  00066         pop
0009 0E2E             M         swapf   StatBuffer,W    ;restore status
000A 0083             M         movwf   STATUS          ;       /
000B 0E2F             M         swapf   WBuffer,W       ;restore W reg
000C 0009         00067         retfie
                  00068 ;
000D              00069 Start
000D 2020         00070         call    InitPorts
000E 202A         00071         call    InitTimers
000F              00072 loop
000F 1992         00073         btfsc   KeyFlag,ServKey ;key service pending
0010 2012         00074         call    ServiceKey      ;yes then service
0011 280F         00075         goto    loop
                  00076 ;
                  00077 ;ServiceKey, does the software service for a keyhit. After a key
                  00078 ;service, the ServKey flag is reset, to denote a completed operation.
0012              00079 ServiceKey
0012 0814         00080         movf    NewKey,W        ;get key value
0013 008E         00081         movwf   TempE           ;save in TempE
0014 0E10         00082         swapf   MsdTime,W       ;move MSD out
0015 39F0         00083         andlw   B'11110000'     ;clr lo nibble
0016 0090         00084         movwf   MsdTime         ;save back
0017 0E11         00085         swapf   LsdTime,W       ;get Lsd
0018 390F         00086         andlw   B'00001111'     ;mask off lsd
0019 0490         00087         iorwf   MsdTime, F      ;and left shift 3rd
001A 0E11         00088         swapf   LsdTime,W       ;get Lsd again
001B 39F0         00089         andlw   B'11110000'     ;mask off 2nd
001C 040E         00090         iorwf   TempE,W         ;or with new lsd
001D 0091         00091         movwf   LsdTime         ;make Lsd
001E 1192         00092         bcf     KeyFlag,ServKey ;reset service flag
001F 0008         00093         return
                  00094
                  00095 ;
0020              00096 InitPorts
0020 1683         00097         bsf     STATUS,RP0      ;select Bank1
0021 3003         00098         movlw   3               ;make RA0-3 digital I/O
0022 0088         00099         movwf   ADCON1          ;       /
0023 0185         00100         clrf    TRISA           ;make RA0-4 outputs
0024 0186         00101         clrf    TRISB           ;make RB0-7 outputs
0025 1283         00102         bcf     STATUS,RP0      ;select Bank0
0026 0185         00103         clrf    PORTA           ;make all outputs low
0027 0186         00104         clrf    PORTB           ;       /
0028 1585         00105         bsf     PORTA,3         ;enable MSB digit sink
0029 0008         00106         return
                  00107 ;
                  00108 ;
                  00109 ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                  00110 ;the TMR0 will be incremented every 31.25uS. If TMR0 is preloaded
```


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```
                 00111 ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                 00112 ;end result is that we get a TMR0 interrupt every 5mS.
002A             00113 InitTimers
002A 0190        00114         clrf    MsdTime         ;clr timers
002B 0191        00115         clrf    LsdTime         ;       /
002C 0192        00116         clrf    KeyFlag         ;clr all flags
002D 1683        00117         bsf     STATUS,RP0      ;select Bank1
002E 3084        00118         movlw   B'10000100'     ;assign ps to TMR0
002F 0081        00119         movwf   OptionReg       ;ps = 32
0030 1283        00120         bcf     STATUS,RP0      ;select Bank0
0031 3020        00121         movlw   B'00100000'     ;enable TMR0 interrupt
0032 008B        00122         movwf   INTCON          ;
0033 3060        00123         movlw   .96             ;preload TMR0
0034 0081        00124         movwf   TMR0            ;start counter
0035 0009        00125         retfie
                 00126 ;
0036             00127 ServiceInterrupts
0036 190B        00128         btfsc   INTCON,T0IF     ;TMR0 interrupt?
0037 283B        00129         goto    ServiceTMR0     ;yes then service
0038 018B        00130         clrf    INTCON          ;else clr all int
0039 168B        00131         bsf     INTCON,T0IE
003A 0008        00132         return
                 00133 ;
003B             00134 ServiceTMR0
003B 3060        00135         movlw   .96             ;initialize TMR0
003C 0081        00136         movwf   TMR0
003D 110B        00137         bcf     INTCON,T0IF     ;clr int flag
003E 1805        00138         btfsc   PORTA,0         ;if msb on then do
003F 2042        00139         call    ScanKeys        ;do a quick key scan
0040 20A1        00140         call    UpdateDisplay   ;update display
0041 0008        00141         return
                 00142 ;
                 00143 ;
                 00144 ;ScanKeys, scans the 4X4 keypad matrix and returns a key value in
                 00145 ;NewKey (0 - F) if a key is pressed, if not it clears the keyhit flag.
                 00146 ;Debounce for a given keyhit is also taken care of.
                 00147 ;The rate of key scan is 20mS with a 4.096Mhz clock.
0042             00148 ScanKeys
0042 1C92        00149         btfss   KeyFlag,DebnceOn ;debounce on?
0043 2848        00150         goto    Scan1            ;no then scan keypad
0044 0B93        00151         decfsz  Debnce, F        ;else dec debounce time
0045 0008        00152         return                   ;not over then return
0046 1092        00153         bcf     KeyFlag,DebnceOn ;over, clr debounce flag
0047 0008        00154         return                   ;and return
0048             00155 Scan1
0048 208A        00156         call    SavePorts        ;save port values
0049 30EF        00157         movlw   B'11101111'      ;init TempD
004A 008D        00158         movwf   TempD
004B             00159 ScanNext
004B 0806        00160         movf    PORTB,W          ;read to init port
004C 100B        00161         bcf     INTCON,RBIF      ;clr flag
004D 0C8D        00162         rrf     TempD, F         ;get correct column
004E 1C03        00163         btfss   STATUS,C         ;if carry set?
004F 2862        00164         goto    NoKey            ;no then end
0050 080D        00165         movf    TempD,W          ;else output
0051 0086        00166         movwf   PORTB            ;low column scan line
0052 0000        00167         nop
0053 1C0B        00168         btfss   INTCON,RBIF      ;flag set?
0054 284B        00169         goto    ScanNext         ;no then next
0055 1812        00170         btfsc   KeyFlag,keyhit   ;last key released?
0056 2860        00171         goto    SKreturn         ;no then exit
0057 1412        00172         bsf     KeyFlag,keyhit   ;set new key hit
0058 0E06        00173         swapf   PORTB,W          ;read port
0059 008E        00174         movwf   TempE            ;save in TempE
005A 2064        00175         call    GetKeyValue      ;get key value 0 - F
005B 0094        00176         movwf   NewKey           ;save as New key
```

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```
005C 1592          00177         bsf     KeyFlag,ServKey  ;set service flag
005D 1492          00178         bsf     KeyFlag,DebnceOn ;set flag
005E 3004          00179         movlw   4
005F 0093          00180         movwf   Debnce           ;load debounce time
0060               00181 SKreturn
0060 2097          00182         call    RestorePorts     ;restore ports
0061 0008          00183         return
                   00184 ;
0062               00185 NoKey
0062 1012          00186         bcf     KeyFlag,keyhit   ;clr flag
0063 2860          00187         goto    SKreturn
                   00188 ;
                   00189 ;GetKeyValue gets the key as per the following layout
                   00190 ;
                   00191 ;                  Col1    Col2    Col3    Col4
                   00192 ;                  (RB3)   (RB2)   (RB1)   (RB0)
                   00193 ;
                   00194 ;Row1(RB4)           0       1       2       3
                   00195 ;
                   00196 ;Row2(RB5)           4       5       6       7
                   00197 ;
                   00198 ;Row3(RB6)           8       9       A       B
                   00199 ;
                   00200 ;Row4(RB7)           C       D       E       F
                   00201 ;
0064               00202 GetKeyValue
0064 018C          00203         clrf    TempC
0065 1D8D          00204         btfss   TempD,3          ;first column
0066 286E          00205         goto    RowValEnd
0067 0A8C          00206         incf    TempC, F
0068 1D0D          00207         btfss   TempD,2          ;second col.
0069 286E          00208         goto    RowValEnd
006A 0A8C          00209         incf    TempC, F
006B 1C8D          00210         btfss   TempD,1          ;3rd col.
006C 286E          00211         goto    RowValEnd
006D 0A8C          00212         incf    TempC, F         ;last col.
006E               00213 RowValEnd
006E 1C0E          00214         btfss   TempE,0          ;top row?
006F 2878          00215         goto    GetValCom        ;yes then get 0,1,2&3
0070 1C8E          00216         btfss   TempE,1          ;2nd row?
0071 2877          00217         goto    Get4567          ;yes the get 4,5,6&7
0072 1D0E          00218         btfss   TempE,2          ;3rd row?
0073 2875          00219         goto    Get89ab          ;yes then get 8,9,a&b
0074               00220 Getcdef
0074 150C          00221         bsf     TempC,2          ;set msb bits
0075               00222 Get89ab
0075 158C          00223         bsf     TempC,3          ;       /
0076 2878          00224         goto    GetValCom        ;do common part
0077               00225 Get4567
0077 150C          00226         bsf     TempC,2
0078               00227 GetValCom
0078 080C          00228         movf    TempC,W
0079 0782          00229         addwf   PCL, F
007A 3400          00230         retlw   0
007B 3401          00231         retlw   1
007C 3402          00232         retlw   2
007D 3403          00233         retlw   3
007E 3404          00234         retlw   4
007F 3405          00235         retlw   5
0080 3406          00236         retlw   6
0081 3407          00237         retlw   7
0082 3408          00238         retlw   8
0083 3409          00239         retlw   9
0084 340A          00240         retlw   0a
0085 340B          00241         retlw   0b
0086 340C          00242         retlw   0c
```


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```
0087 340D           00243         retlw   0d
0088 340E           00244         retlw   0e
0089 340F           00245         retlw   0f
                    00246 ;
                    00247 ;SavePorts, saves the porta and portb condition during a key scan
                    00248 ;operation.
008A                00249 SavePorts
008A 0805           00250         movf    PORTA,W         ;Get sink value
008B 00A0           00251         movwf   PABuf           ;save in buffer
008C 0185           00252         clrf    PORTA           ;disable all sinks
008D 0806           00253         movf    PORTB,W         ;get port b
008E 00A1           00254         movwf   PBBuf           ;save in buffer
008F 30FF           00255         movlw   0xff            ;make all high
0090 0086           00256         movwf   PORTB           ;on port b
0091 1683           00257         bsf     STATUS,RP0      ;select Bank1
0092 1381           00258         bcf     OptionReg,7     ;enable pull ups
0093 30F0           00259         movlw   B'11110000'     ;port b hi nibble inputs
0094 0086           00260         movwf   TRISB           ;lo nibble outputs
0095 1283           00261         bcf     STATUS,RP0      ;Bank0
0096 0008           00262         return
                    00263 ;
                    00264 ;RestorePorts, restores the condition of porta and portb after a
                    00265 ;key scan operation.
0097                00266 RestorePorts
0097 0821           00267         movf    PBBuf,W         ;get port b
0098 0086           00268         movwf   PORTB
0099 0820           00269         movf    PABuf,W         ;get port a value
009A 0085           00270         movwf   PORTA
009B 1683           00271         bsf     STATUS,RP0      ;select Bank1
009C 1781           00272         bsf     OptionReg,7     ;disable pull ups
009D 0185           00273         clrf    TRISA           ;make port a outputs
009E 0186           00274         clrf    TRISB           ;as well as PORTB
009F 1283           00275         bcf     STATUS,RP0      ;Bank0
00A0 0008           00276         return
                    00277 ;
                    00278 ;
00A1                00279 UpdateDisplay
00A1 0805           00280         movf    PORTA,W         ;present sink value in w
00A2 0185           00281         clrf    PORTA           ;disable all digits sinks
00A3 390F           00282         andlw   0x0f
00A4 008C           00283         movwf   TempC           ;save sink value in tempC
00A5 160C           00284         bsf     TempC,4         ;preset for lsd sink
00A6 0C8C           00285         rrf     TempC, F        ;determine next sink value
00A7 1C03           00286         btfss   STATUS,C        ;c=1?
00A8 118C           00287         bcf     TempC,3         ;no then reset LSD sink
00A9 180C           00288         btfsc   TempC,0         ;else see if Msd
00AA 28B8           00289         goto    UpdateMsd       ;yes then do Msd
00AB 188C           00290         btfsc   TempC,1         ;see if 3rdLsd
00AC 28B5           00291         goto    Update3rdLsd    ;yes then do 3rd Lsd
00AD 190C           00292         btfsc   TempC,2         ;see if 2nd Lsd
00AE 28B2           00293         goto    Update2ndLsd    ;yes then do 2nd lsd
00AF                00294 UpdateLsd
00AF 0811           00295         movf    LsdTime,W       ;get Lsd in w
00B0 390F           00296         andlw   0x0f            ;       /
00B1 28BA           00297         goto    DisplayOut
00B2                00298 Update2ndLsd
00B2 0E11           00299         swapf   LsdTime,W       ;get 2nd Lsd in w
00B3 390F           00300         andlw   0x0f            ;mask rest
00B4 28BA           00301         goto    DisplayOut      ;enable display
00B5                00302 Update3rdLsd
00B5 0810           00303         movf    MsdTime,W       ;get 3rd Lsd in w
00B6 390F           00304         andlw   0x0f            ;mask low nibble
00B7 28BA           00305         goto    DisplayOut      ;enable display
00B8                00306 UpdateMsd
00B8 0E10           00307         swapf   MsdTime,W       ;get Msd in w
00B9 390F           00308         andlw   0x0f            ;mask rest
```

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```
00BA                00309 DisplayOut
00BA 20BF           00310         call    LedTable        ;get digit output
00BB 0086           00311         movwf   PORTB           ;drive leds
00BC 080C           00312         movf    TempC,W         ;get sink value in w
00BD 0085           00313         movwf   PORTA
00BE 0008           00314         return
                    00315 ;
                    00316 ;
00BF                00317 LedTable
00BF 0782           00318         addwf   PCL, F          ;add to PC low
00C0 343F           00319         retlw   B'00111111'     ;led drive for 0
00C1 3406           00320         retlw   B'00000110'     ;led drive for 1
00C2 345B           00321         retlw   B'01011011'     ;led drive for 2
00C3 344F           00322         retlw   B'01001111'     ;led drive for 3
00C4 3466           00323         retlw   B'01100110'     ;led drive for 4
00C5 346D           00324         retlw   B'01101101'     ;led drive for 5
00C6 347D           00325         retlw   B'01111101'     ;led drive for 6
00C7 3407           00326         retlw   B'00000111'     ;led drive for 7
00C8 347F           00327         retlw   B'01111111'     ;led drive for 8
00C9 3467           00328         retlw   B'01100111'     ;led drive for 9
00CA 3477           00329         retlw   B'01110111'     ;led drive for A
00CB 347C           00330         retlw   B'01111100'     ;led drive for b
00CC 3439           00331         retlw   B'00111001'     ;led drive for C
00CD 345E           00332         retlw   B'01011110'     ;led drive for d
00CE 3479           00333         retlw   B'01111001'     ;led drive for E
00CF 3471           00334         retlw   B'01110001'     ;led drive for F
                    00335
                    00336                                 ;
                    00337                                 ;
                    00338
                    00339         end

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

0000 : X---XXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0080 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
00C0 : XXXXXXXXXXXXXXXX ---------------- ---------------- ----------------

All other memory blocks unused.

Program Memory Words Used:   205
Program Memory Words Free:   819


Errors   :     0
Warnings :     0 reported,     0 suppressed
Messages :     0 reported,     6 suppressed
```


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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: MPLXCH0.ASM

```
MPASM 01.40 Released          MPLXCH0.ASM   1-16-1997  16:24:14         PAGE  1


LOC  OBJECT CODE     LINE SOURCE TEXT
  VALUE

                     00001 ;***************************************************************************
                     00002 ;This program is to demonstrate how to multiplex four 7 segment LED
                     00003 ;and sample ch0 of the a/d in a PIC16C71. The a/d value is displayed
                     00004 ;as a 3 digit decimal value of the a/d input (0 - 255).
                     00005 ;The LEDs are updated every 20mS, the a/d is sampled every 20 mS.
                     00006 ;The TIMER0 timer is used in internal interrupt mode to generate the
                     00007 ;5 mS.
                     00008 ;
                     00009 ;                                        Stan D'Souza 5/8/93
                     00010 ;
                     00011 ;
                     00012 ;
                     00013 ;       Program:          MPLXCH0.ASM
                     00014 ;       Revision Date:
                     00015 ;                         1-15-97      Compatibility with MPASMWIN 1.40
                     00016 ;
                     00017 ;***************************************************************************
                     00018         LIST P=16C71
                     00019         ERRORLEVEL  -302
                     00020 ;
                     00021         include     <p16c71.inc>
                     00001         LIST
                     00002 ; P16C71.INC Standard Header File, Ver. 1.00 Microchip Technology, Inc.
                     00142         LIST
                     00022 ;
  00000026           00023 BcdMsd  equ     26
  00000027           00024 Bcd     equ     27
  0000000C           00025 TempC   equ     0x0c            ;temp general purpose regs
  0000000D           00026 TempD   equ     0x0d
  0000000E           00027 TempE   equ     0x0e
  00000020           00028 PABuf   equ     0x20
  00000021           00029 PBBuf   equ     0x21
  0000000F           00030 Count   equ     0x0f            ;count
  00000010           00031 MsdTime equ     0x10            ;most significant Timer
  00000011           00032 LsdTime equ     0x11            ;Least significant Timer
  00000012           00033 ADFlag  equ     0x12            ;flags related to key pad
  00000005           00034 ADOver  equ     5               ;bit 5 --> a/d over
  0000002F           00035 WBuffer equ     0x2f
  0000002E           00036 StatBuffer equ  0x2e
  00000001           00037 OptionReg equ   1
  00000002           00038 PCL     equ     2
                     00039 ;
                     00040 push    macro
                     00041         movwf   WBuffer         ;save w reg in Buffer
                     00042         swapf   WBuffer, F      ;swap it
                     00043         swapf   STATUS,W        ;get status
                     00044         movwf   StatBuffer      ;save it
                     00045         endm
                     00046 ;
                     00047 pop     macro
                     00048         swapf   StatBuffer,W    ;restore status
                     00049         movwf   STATUS          ;       /
                     00050         swapf   WBuffer,W       ;restore W reg
                     00051         endm
```

```
                  00052 ;
0000              00053         org     0
0000 280D         00054         goto    Start           ;skip over interrupt vector
                  00055 ;
0004              00056         org     4
                  00057 ;It is always a good practice to save and restore the w reg,
                  00058 ;and the status reg during an interrupt.
                  00059         push
0004 00AF             M         movwf   WBuffer         ;save w reg in Buffer
0005 0EAF             M         swapf   WBuffer, F      ;swap it
0006 0E03             M         swapf   STATUS,W        ;get status
0007 00AE             M         movwf   StatBuffer      ;save it
0008 2039         00060         call    ServiceInterrupts
                  00061         pop
0009 0E2E             M         swapf   StatBuffer,W    ;restore status
000A 0083             M         movwf   STATUS          ;       /
000B 0E2F             M         swapf   WBuffer,W       ;restore W reg
000C 0009         00062         retfie
                  00063 ;
000D              00064 Start
000D 2021         00065         call    InitPorts
000E 202B         00066         call    InitTimers
000F 2036         00067         call    InitAd
0010              00068 loop
0010 1A92         00069         btfsc   ADFlag,ADOver   ;a/d over?
0011 2013         00070         call    UpdateAd        ;yes then update
0012 2810         00071         goto    loop
                  00072 ;
0013              00073 UpdateAd
0013 1C88         00074         btfss   ADCON0,ADIF     ;a/d done?
0014 0008         00075         return                  ;no then leave
0015 0809         00076         movf    ADRES,W         ;get a/d value
0016 00A1         00077         movwf   L_byte
0017 01A0         00078         clrf    H_byte
0018 20AD         00079         call    B2_BCD
0019 0824         00080         movf    R2,W            ;get LSd
001A 0091         00081         movwf   LsdTime         ;save in LSD
001B 0823         00082         movf    R1,W            ;get Msd
001C 0090         00083         movwf   MsdTime         ;save in Msd
001D 1088         00084         bcf     ADCON0,ADIF     ;clr interrupt flag
001E 1008         00085         bcf     ADCON0,ADON     ;turn off a/d
001F 1292         00086         bcf     ADFlag,ADOver   ;clr flag
0020 0008         00087         return
                  00088 ;
                  00089 ;
                  00090 ;
0021              00091 InitPorts
0021 1683         00092         bsf     STATUS,RP0      ;select Bank1
0022 3003         00093         movlw   3               ;make RA0-3 digital I/O
0023 0088         00094         movwf   ADCON1          ;       /
0024 0185         00095         clrf    TRISA           ;make RA0-4 outputs
0025 0186         00096         clrf    TRISB           ;make RB0-7 outputs
0026 1283         00097         bcf     STATUS,RP0      ;select Bank0
0027 0185         00098         clrf    PORTA           ;make all outputs low
0028 0186         00099         clrf    PORTB           ;       /
0029 1585         00100         bsf     PORTA,3         ;enable MSB digit sink
002A 0008         00101         return
                  00102 ;
                  00103 ;
                  00104 ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                  00105 ;the TMR0 will be incremented every 31.25uS. If TMR0 is preloaded
                  00106 ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                  00107 ;end result is that we get a TMR0 interrupt every 5mS.
002B              00108 InitTimers
002B 0190         00109         clrf    MsdTime         ;clr timers
002C 0191         00110         clrf    LsdTime         ;       /
```


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```
002D 1683          00111         bsf     STATUS,RP0      ;select Bank1
002E 3084          00112         movlw   B'10000100'     ;assign ps to TMR0
002F 0081          00113         movwf   OptionReg       ;ps = 32
0030 1283          00114         bcf     STATUS,RP0      ;select Bank0
0031 3020          00115         movlw   B'00100000'     ;enable TMR0 interrupt
0032 008B          00116         movwf   INTCON          ;
0033 3060          00117         movlw   .96             ;preload TMR0
0034 0081          00118         movwf   TMR0            ;start counter
0035 0009          00119         retfie
                   00120 ;
                   00121 ;
0036               00122 InitAd
0036 30C0          00123         movlw   B'11000000'     ;rc osc, ch 0 for a/d
0037 0088          00124         movwf   ADCON0
0038 0008          00125         return
                   00126 ;
                   00127 ;
0039               00128 ServiceInterrupts
0039 190B          00129         btfsc   INTCON,T0IF     ;TMR0 interrupt?
003A 283E          00130         goto    ServiceTMR0     ;yes then service
003B 018B          00131         clrf    INTCON
003C 168B          00132         bsf     INTCON,T0IE
003D 0008          00133         return
                   00134 ;
003E               00135 ServiceTMR0
003E 3060          00136         movlw   .96             ;initialize TMR0
003F 0081          00137         movwf   TMR0
0040 110B          00138         bcf     INTCON,T0IF     ;clr int flag
0041 1C05          00139         btfss   PORTA,0         ;last digit?
0042 2045          00140         call    SampleAd        ;then sample a/d
0043 2071          00141         call    UpdateDisplay   ;else update display
0044 0008          00142         return
                   00143 ;
                   00144 ;
0045               00145 SampleAd
0045 205A          00146         call    SavePorts
0046 204C          00147         call    DoAd            ;do a ad conversion
0047               00148 AdDone
0047 1908          00149         btfsc   ADCON0,GO       ;ad done?
0048 2847          00150         goto    AdDone          ;no then loop
0049 1692          00151         bsf     ADFlag,ADOver   ;set a/d over flag
004A 2067          00152         call    RestorePorts    ;restore ports
004B 0008          00153         return
                   00154 ;
                   00155 ;
004C               00156 DoAd
004C 0186          00157         clrf    PORTB           ;turn off leds
004D 1683          00158         bsf     STATUS,RP0      ;select Bank1
004E 300F          00159         movlw   0x0f            ;make port a hi-Z
004F 0085          00160         movwf   TRISA           ;       /
0050 1283          00161         bcf     STATUS,RP0      ;select Bank0
0051 1408          00162         bsf     ADCON0,ADON     ;start a/d
0052 307D          00163         movlw   .125
0053 2056          00164         call    Wait
0054 1508          00165         bsf     ADCON0,GO       ;start conversion
0055 0008          00166         return
                   00167 ;
                   00168 ;
0056               00169 Wait
0056 008C          00170         movwf   TempC           ;store in temp
0057               00171 Next
0057 0B8C          00172         decfsz  TempC, F
0058 2857          00173         goto    Next
0059 0008          00174         return
                   00175
                   00176 ;
```

```
                  00177 ;SavePorts, saves the porta and portb condition during a key scan
                  00178 ;operation.
005A              00179 SavePorts
005A 0805         00180         movf    PORTA,W         ;Get sink value
005B 00A0         00181         movwf   PABuf           ;save in buffer
005C 0185         00182         clrf    PORTA           ;disable all sinks
005D 0806         00183         movf    PORTB,W         ;get port b
005E 00A1         00184         movwf   PBBuf           ;save in buffer
005F 30FF         00185         movlw   0xff            ;make all high
0060 0086         00186         movwf   PORTB           ;on port b
0061 1683         00187         bsf     STATUS,RP0      ;select Bank1
0062 1381         00188         bcf     OptionReg,7     ;enable pull ups
0063 30F0         00189         movlw   B'11110000'     ;port b hi nibble inputs
0064 0086         00190         movwf   TRISB           ;lo nibble outputs
0065 1283         00191         bcf     STATUS,RP0      ;Bank0
0066 0008         00192         return
                  00193 ;
                  00194 ;RestorePorts, restores the condition of porta and portb after a
                  00195 ;key scan operation.
0067              00196 RestorePorts
0067 0821         00197         movf    PBBuf,W         ;get port n
0068 0086         00198         movwf   PORTB
0069 0820         00199         movf    PABuf,W         ;get port a value
006A 0085         00200         movwf   PORTA
006B 1683         00201         bsf     STATUS,RP0      ;select Bank1
006C 1781         00202         bsf     OptionReg,7     ;disable pull ups
006D 0185         00203         clrf    TRISA           ;make port a outputs
006E 0186         00204         clrf    TRISB           ;as well as PORTB
006F 1283         00205         bcf     STATUS,RP0      ;Bank0
0070 0008         00206         return
                  00207 ;
                  00208 ;
0071              00209 UpdateDisplay
0071 0805         00210         movf    PORTA,W         ;present sink value in w
0072 0185         00211         clrf    PORTA           ;disable all digits sinks
0073 390F         00212         andlw   0x0f
0074 008C         00213         movwf   TempC           ;save sink value in tempC
0075 160C         00214         bsf     TempC,4         ;preset for lsd sink
0076 0C8C         00215         rrf     TempC, F        ;determine next sink value
0077 1C03         00216         btfss   STATUS,C        ;c=1?
0078 118C         00217         bcf     TempC,3         ;no then reset LSD sink
0079 180C         00218         btfsc   TempC,0         ;else see if Msd
007A 288C         00219         goto    UpdateMsd       ;yes then do Msd
007B 188C         00220         btfsc   TempC,1         ;see if 3rdLsd
007C 2887         00221         goto    Update3rdLsd    ;yes then do 3rd Lsd
007D 190C         00222         btfsc   TempC,2         ;see if 2nd Lsd
007E 2882         00223         goto    Update2ndLsd    ;yes then do 2nd lsd
007F              00224 UpdateLsd
007F 0811         00225         movf    LsdTime,W       ;get Lsd in w
0080 390F         00226         andlw   0x0f            ;       /
0081 2890         00227         goto    DisplayOut      ;enable display
0082              00228 Update2ndLsd
0082 20A1         00229         call    Chk2LsdZero     ;msd = 0 & 2 lsd 0?
0083 1D03         00230         btfss   STATUS,Z        ;yes then skip
0084 0E11         00231         swapf   LsdTime,W       ;get 2nd Lsd in w
0085 390F         00232         andlw   0x0f            ;mask rest
0086 2890         00233         goto    DisplayOut      ;enable display
0087              00234 Update3rdLsd
0087 20A9         00235         call    ChkMsdZero      ;msd = 0?
0088 1D03         00236         btfss   STATUS,Z        ;yes then skip
0089 0810         00237         movf    MsdTime,W       ;get 3rd Lsd in w
008A 390F         00238         andlw   0x0f            ;mask low nibble
008B 2890         00239         goto    DisplayOut      ;enable display
008C              00240 UpdateMsd
008C 0E10         00241         swapf   MsdTime,W       ;get Msd in w
008D 390F         00242         andlw   0x0f            ;mask rest
```


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```
008E 1903           00243         btfsc   STATUS,Z        ;msd != 0 then skip
008F 300A           00244         movlw   0x0a
0090                00245 DisplayOut
0090 2095           00246         call    LedTable        ;get digit output
0091 0086           00247         movwf   PORTB           ;drive leds
0092 080C           00248         movf    TempC,W         ;get sink value in w
0093 0085           00249         movwf   PORTA
0094 0008           00250         return
                    00251 ;
                    00252 ;
0095                00253 LedTable
0095 0782           00254         addwf   PCL, F           ;add to PC low
0096 343F           00255         retlw   B'00111111'      ;led drive for 0
0097 3406           00256         retlw   B'00000110'      ;led drive for 1
0098 345B           00257         retlw   B'01011011'      ;led drive for 2
0099 344F           00258         retlw   B'01001111'      ;led drive for 3
009A 3466           00259         retlw   B'01100110'      ;led drive for 4
009B 346D           00260         retlw   B'01101101'      ;led drive for 5
009C 347D           00261         retlw   B'01111101'      ;led drive for 6
009D 3407           00262         retlw   B'00000111'      ;led drive for 7
009E 347F           00263         retlw   B'01111111'      ;led drive for 8
009F 3467           00264         retlw   B'01100111'      ;led drive for 9
00A0 3400           00265         retlw   B'00000000'      ;blank led drive
                    00266 ;
                    00267 ;
00A1                00268 Chk2LsdZero
00A1 20A9           00269         call    ChkMsdZero       ;msd = 0?
00A2 1D03           00270         btfss   STATUS,Z         ;yes then skip
00A3 0008           00271         return                   ;else return
00A4 0E11           00272         swapf   LsdTime,W        ;get 2nd lsd
00A5 390F           00273         andlw   0x0f             ;mask of LSD
00A6 1D03           00274         btfss   STATUS,Z         ;0? then skip
00A7 0008           00275         return
00A8 340A           00276         retlw   .10              ;else return with 10
                    00277 ;
00A9                00278 ChkMsdZero
00A9 0810           00279         movf    MsdTime,W        ;get Msd in w
00AA 1D03           00280         btfss   STATUS,Z         ;= 0? skip
00AB 0008           00281         return                   ;else return
00AC 340A           00282         retlw   .10              ;ret with 10
                    00283 ;
                    00284 ;
                    00285 ;
  00000026          00286 count  equ      26
  00000027          00287 temp   equ      27
                    00288 ;
  00000020          00289 H_byte  equ     20
  00000021          00290 L_byte  equ     21
  00000022          00291 R0      equ     22               ; RAM Assignments
  00000023          00292 R1      equ     23
  00000024          00293 R2      equ     24
                    00294 ;
                    00295 ;
00AD 1003           00296 B2_BCD  bcf     STATUS,0         ; clear the carry bit
00AE 3010           00297         movlw   .16
00AF 00A6           00298         movwf   count
00B0 01A2           00299         clrf    R0
00B1 01A3           00300         clrf    R1
00B2 01A4           00301         clrf    R2
00B3 0DA1           00302 loop16  rlf     L_byte, F
00B4 0DA0           00303         rlf     H_byte, F
00B5 0DA4           00304         rlf     R2, F
00B6 0DA3           00305         rlf     R1, F
00B7 0DA2           00306         rlf     R0, F
                    00307 ;
00B8 0BA6           00308         decfsz  count, F
```

```
00B9 28BB           00309         goto    adjDEC
00BA 3400           00310         RETLW   0
                    00311 ;
00BB 3024           00312 adjDEC  movlw   R2
00BC 0084           00313         movwf   FSR
00BD 20C5           00314         call    adjBCD
                    00315 ;
00BE 3023           00316         movlw   R1
00BF 0084           00317         movwf   FSR
00C0 20C5           00318         call    adjBCD
                    00319 ;
00C1 3022           00320         movlw   R0
00C2 0084           00321         movwf   FSR
00C3 20C5           00322         call    adjBCD
                    00323 ;
00C4 28B3           00324         goto    loop16
                    00325 ;
00C5 3003           00326 adjBCD  movlw   3
00C6 0700           00327         addwf   0,W
00C7 00A7           00328         movwf   temp
00C8 19A7           00329         btfsc   temp,3          ; test if result > 7
00C9 0080           00330         movwf   0
00CA 3030           00331         movlw   30
00CB 0700           00332         addwf   0,W
00CC 00A7           00333         movwf   temp
00CD 1BA7           00334         btfsc   temp,7          ; test if result > 7
00CE 0080           00335         movwf   0               ; save as MSD
00CF 3400           00336         RETLW   0
                    00337 ;
                    00338 ;
                    00339
                    00340         end

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

0000 : X---XXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0080 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
00C0 : XXXXXXXXXXXXXXXX ---------------- ---------------- ----------------

All other memory blocks unused.

Program Memory Words Used:   205
Program Memory Words Free:   819


Errors   :     0
Warnings :     0 reported,     0 suppressed
Messages :     0 reported,     7 suppressed
```


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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 D: MPLXAD.ASM

```
MPASM 01.40 Released           MPLXAD.ASM   1-16-1997  16:23:40         PAGE  1


LOC  OBJECT CODE     LINE SOURCE TEXT
  VALUE

                     00001 ;***********************************************************************
                     00002 ;This program demonstrates how to multiplex four 7 segment LED
                     00003 ;digits and a 4X4 keypad along with 4 A/D inputs using a PIC16C71.
                     00004 ;The four digits will first display the decimal a/d value of ch0.
                     00005 ;When keys from 0 - 3 are hit the corresponding channel's a/d value
                     00006 ;is displayed in decimal.
                     00007 ;The LEDs are updated every 20mS, the keypad is scanned at a rate of 20
                     00008 ;mS. All 4 channels are scanned at 20mS rate, so each channel gets
                     00009 ;scanned every 80mS. A faster rate of scanning is possible as required
                     00010 ;by the users application.
                     00011 ;Timer0 is used in internal interrupt mode to generate the
                     00012 ;5 mS.
                     00013 ;
                     00014 ;                                        Stan D'Souza 5/8/93
                     00015 ;
                     00016 ;Corrected error in display routine.
                     00017 ;                                        Stan D'Souza 2/27/94
                     00018 ;
                     00019 ;       Program:          MPLXAD.ASM
                     00020 ;       Revision Date:
                     00021 ;                         1-15-97      Compatibility with MPASMWIN 1.40
                     00022 ;
                     00023 ;***********************************************************************
                     00024         LIST P=16C71
                     00025         ERRORLEVEL  -302
                     00026 ;
                     00027         include      <p16c71.inc>
                     00001         LIST
                     00002 ; P16C71.INC Standard Header File, Ver. 1.00 Microchip Technology, Inc.
                     00142         LIST
                     00028 ;
  0000000C           00029 TempC   equ       0x0c            ;temp general purpose regs
  0000000D           00030 TempD   equ       0x0d
  0000000E           00031 TempE   equ       0x0e
  00000020           00032 PABuf   equ       0x20
  00000021           00033 PBBuf   equ       0x21
  0000000F           00034 Count   equ       0x0f            ;count
  00000010           00035 MsdTime equ       0x10            ;most significant Timer
  00000011           00036 LsdTime equ       0x11            ;Least significant Timer
                     00037 ;
  00000012           00038 Flag    equ       0x12            ;general purpose flag reg
                     00039 #define keyhit    Flag,0          ;bit 0 --> key-press on
                     00040 #define DebnceOn  Flag,1          ;bit 1 -> debounce on
                     00041 #define noentry   Flag,2          ;no key entry = 0
                     00042 #define ServKey   Flag,3          ;bit 3 --> service key
                     00043 #define ADOver    Flag,4          ;bit 4 --> a/d conv. over
                     00044 ;
  00000013           00045 Debnce  equ       0x13            ;debounce counter
  00000014           00046 NewKey  equ       0x14
  00000015           00047 DisplayCh equ     0x15            ;channel to be displayed
                     00048 ;
  00000016           00049 ADTABLE equ       0x16            ;4 locations are reserved here
                     00050                                   ;from 0x16 to 0x19
                     00051 ;
```

```
  0000002F          00052 WBuffer equ     0x2f
  0000002E          00053 StatBuffer equ  0x2e
  00000001          00054 OptionReg equ   1
  00000002          00055 PCL     equ     2
                    00056 ;
                    00057 ;
                    00058 push    macro
                    00059         movwf   WBuffer         ;save w reg in Buffer
                    00060         swapf   WBuffer, F      ;swap it
                    00061         swapf   STATUS,W        ;get status
                    00062         movwf   StatBuffer      ;save it
                    00063         endm
                    00064 ;
                    00065 pop     macro
                    00066         swapf   StatBuffer,W    ;restore status
                    00067         movwf   STATUS          ;       /
                    00068         swapf   WBuffer,W       ;restore W reg
                    00069         endm
                    00070 ;
0000                00071         org     0
0000 280D           00072         goto    Start           ;skip over interrupt vector
                    00073 ;
0004                00074         org     4
                    00075 ;It is always a good practice to save and restore the w reg,
                    00076 ;and the status reg during a interrupt.
                    00077         push
0004 00AF               M         movwf   WBuffer         ;save w reg in Buffer
0005 0EAF               M         swapf   WBuffer, F      ;swap it
0006 0E03               M         swapf   STATUS,W        ;get status
0007 00AE               M         movwf   StatBuffer      ;save it
0008 2052           00078         call    ServiceInterrupts
                    00079         pop
0009 0E2E               M         swapf   StatBuffer,W    ;restore status
000A 0083               M         movwf   STATUS          ;       /
000B 0E2F               M         swapf   WBuffer,W       ;restore W reg
000C 0009           00080         retfie
                    00081 ;
000D                00082 Start
000D 203B           00083         call    InitPorts
000E 20EE           00084         call    InitAd
000F 2045           00085         call    InitTimers
0010                00086 loop
0010 1992           00087         btfsc   ServKey         ;key service pending
0011 2015           00088         call    ServiceKey      ;yes then service
0012 1A12           00089         btfsc   ADOver          ;a/d pending?
0013 2028           00090         call    ServiceAD       ;yes the service a/d
0014 2810           00091         goto    loop
                    00092 ;
                    00093 ;ServiceKey, does the software service for a keyhit. After a key
                    00094 ;service, the ServKey flag is reset, to denote a completed operation.
0015                00095 ServiceKey
0015 1192           00096         bcf     ServKey         ;reset service flag
0016 0814           00097         movf    NewKey,W        ;get key value
0017 3C03           00098         sublw   3               ;key > 3?
0018 1C03           00099         btfss   STATUS,C        ;no then skip
0019 0008           00100         return                  ;else ignore key
001A 0814           00101         movf    NewKey,W
001B 0095           00102         movwf   DisplayCh       ;load new channel
                    00103 ;
001C                00104 LoadAD
001C 3016           00105         movlw   ADTABLE         ;get top of table
001D 0715           00106         addwf   DisplayCh,W     ;add offset
001E 0084           00107         movwf   FSR             ;init FSR
001F 0800           00108         movf    0,W             ;get a/d value
0020 00A1           00109         movwf   L_byte
0021 01A0           00110         clrf    H_byte
```


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```
0022 2106           00111         call    B2_BCD
0023 0824           00112         movf    R2,W            ;get LSd
0024 0091           00113         movwf   LsdTime         ;save in LSD
0025 0823           00114         movf    R1,W            ;get Msd
0026 0090           00115         movwf   MsdTime         ;save in Msd
0027 0008           00116         return
                    00117 ;
                    00118 ;This routine essentially loads the ADRES value in the table location
                    00119 ;determined by the channel offset. If channel 0 then ADRES is saved
                    00120 ;in location ADTABLE. If channel 1 then ADRES is saved at ADTABLE + 1.
                    00121 ;and so on.
0028                00122 ServiceAD
0028 0808           00123         movf    ADCON0,W        ;get adcon0
0029 008C           00124         movwf   TempC           ;save in temp
002A 3008           00125         movlw   B'00001000'     ;select next channel
002B 0708           00126         addwf   ADCON0,W        ;       /
002C 1A88           00127         btfsc   ADCON0,5        ;if <= ch3
002D 30C1           00128         movlw   B'11000001'     ;select ch0
002E 0088           00129         movwf   ADCON0
                    00130 ;now load adres in the table
002F 3016           00131         movlw   ADTABLE
0030 0084           00132         movwf   FSR             ;load FSR with top
0031 0C8C           00133         rrf     TempC, F
0032 0C8C           00134         rrf     TempC, F
0033 0C0C           00135         rrf     TempC,W         ;get in w reg
0034 3903           00136         andlw   3               ;mask off all but last 2
0035 0784           00137         addwf   FSR, F          ;add offset to table
0036 0809           00138         movf    ADRES,W         ;get a/d value
0037 0080           00139         movwf   0               ;load indirectly
0038 1212           00140         bcf     ADOver          ;clear flag
0039 201C           00141         call    LoadAD          ;load a/d value in display reg.
003A 0008           00142         return
                    00143
                    00144
                    00145
                    00146 ;
003B                00147 InitPorts
003B 1683           00148         bsf     STATUS,RP0      ;select Bank1
003C 3003           00149         movlw   3               ;make RA0-3 digital I/O
003D 0088           00150         movwf   ADCON1          ;       /
003E 0185           00151         clrf    TRISA           ;make RA0-4 outputs
003F 0186           00152         clrf    TRISB           ;make RB0-7 outputs
0040 1283           00153         bcf     STATUS,RP0      ;select Bank0
0041 0185           00154         clrf    PORTA           ;make all outputs low
0042 0186           00155         clrf    PORTB           ;       /
0043 1585           00156         bsf     PORTA,3         ;enable MSB digit sink
0044 0008           00157         return
                    00158 ;
                    00159 ;
                    00160 ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                    00161 ;the TMR0 will be incremented every 31.25uS. If TMR0 is preloaded
                    00162 ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                    00163 ;end result is that we get a TMR0 interrupt every 5mS.
0045                00164 InitTimers
0045 0190           00165         clrf    MsdTime         ;clr timers
0046 0191           00166         clrf    LsdTime         ;       /
0047 0195           00167         clrf    DisplayCh       ;show channel 0
0048 0192           00168         clrf    Flag            ;clr all flags
0049 1683           00169         bsf     STATUS,RP0      ;select Bank1
004A 3084           00170         movlw   B'10000100'     ;assign ps to TMR0
004B 0081           00171         movwf   OptionReg       ;ps = 32
004C 1283           00172         bcf     STATUS,RP0      ;select Bank0
004D 3020           00173         movlw   B'00100000'     ;enable TMR0 interrupt
004E 008B           00174         movwf   INTCON          ;
004F 3060           00175         movlw   .96             ;preload TMR0
0050 0081           00176         movwf   TMR0            ;start counter
```

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```
0051 0009           00177         retfie
                    00178 ;
0052                00179 ServiceInterrupts
0052 190B           00180         btfsc   INTCON,T0IF     ;TMR0 interrupt?
0053 2857           00181         goto    ServiceTMR0     ;yes then service
0054 018B           00182         clrf    INTCON          ;else clr all int
0055 168B           00183         bsf     INTCON,T0IE
0056 0008           00184         return
                    00185 ;
0057                00186 ServiceTMR0
0057 3060           00187         movlw   .96             ;initialize TMR0
0058 0081           00188         movwf   TMR0
0059 110B           00189         bcf     INTCON,T0IF     ;clr int flag
005A 1805           00190         btfsc   PORTA,0         ;scan keys every 20 mS
005B 2060           00191         call    ScanKeys        ;when digit 1 is on
005C 1985           00192         btfsc   PORTA,3         ;scan a/d every 20mS
005D 20F1           00193         call    SampleAd        ;when digit 4 is on
005E 20BF           00194         call    UpdateDisplay   ;update display
005F 0008           00195         return
                    00196 ;
                    00197 ;
                    00198 ;ScanKeys, scans the 4x4 keypad matrix and returns a key value in
                    00199 ;NewKey (0 - F) if a key is pressed, if not it clears the keyhit flag.
                    00200 ;Debounce for a given keyhit is also taken care of.
                    00201 ;The rate of key scan is 20mS with a 4.096Mhz clock.
0060                00202 ScanKeys
0060 1C92           00203         btfss   DebnceOn        ;debounce on?
0061 2866           00204         goto    Scan1           ;no then scan keypad
0062 0B93           00205         decfsz  Debnce, F       ;else dec debounce time
0063 0008           00206         return                  ;not over then return
0064 1092           00207         bcf     DebnceOn        ;over, clr debounce flag
0065 0008           00208         return                  ;and return
0066                00209 Scan1
0066 20A8           00210         call    SavePorts       ;save port values
0067 30EF           00211         movlw   B'11101111'     ;init TempD
0068 008D           00212         movwf   TempD
0069                00213 ScanNext
0069 0806           00214         movf    PORTB,W         ;read to init port
006A 100B           00215         bcf     INTCON,RBIF     ;clr flag
006B 0C8D           00216         rrf     TempD, F        ;get correct column
006C 1C03           00217         btfss   STATUS,C        ;if carry set?
006D 2880           00218         goto    NoKey           ;no then end
006E 080D           00219         movf    TempD,W         ;else output
006F 0086           00220         movwf   PORTB           ;low column scan line
0070 0000           00221         nop
0071 1C0B           00222         btfss   INTCON,RBIF     ;flag set?
0072 2869           00223         goto    ScanNext        ;no then next
0073 1812           00224         btfsc   keyhit          ;last key released?
0074 287E           00225         goto    SKreturn        ;no then exit
0075 1412           00226         bsf     keyhit          ;set new key hit
0076 0E06           00227         swapf   PORTB,W         ;read port
0077 008E           00228         movwf   TempE           ;save in TempE
0078 2082           00229         call    GetKeyValue     ;get key value 0 - F
0079 0094           00230         movwf   NewKey          ;save as New key
007A 1592           00231         bsf     ServKey         ;set service flag
007B 1492           00232         bsf     DebnceOn        ;set flag
007C 3004           00233         movlw   4
007D 0093           00234         movwf   Debnce          ;load debounce time
007E                00235 SKreturn
007E 20B5           00236         call    RestorePorts    ;restore ports
007F 0008           00237         return
                    00238 ;
0080                00239 NoKey
0080 1012           00240         bcf     keyhit          ;clr flag
0081 287E           00241         goto    SKreturn
                    00242 ;
```


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```
                  00243 ;GetKeyValue gets the key as per the following layout
                  00244 ;
                  00245 ;                 Col1    Col2    Col3    Col4
                  00246 ;                 (RB3)   (RB2)   (RB1)   (RB0)
                  00247 ;
                  00248 ;Row1(RB4)          0       1       2       3
                  00249 ;
                  00250 ;Row2(RB5)          4       5       6       7
                  00251 ;
                  00252 ;Row3(RB6)          8       9       A       B
                  00253 ;
                  00254 ;Row4(RB7)          C       D       E       F
                  00255 ;
0082              00256 GetKeyValue
0082 018C         00257         clrf    TempC
0083 1D8D         00258         btfss   TempD,3         ;first column
0084 288C         00259         goto    RowValEnd
0085 0A8C         00260         incf    TempC, F
0086 1D0D         00261         btfss   TempD,2         ;second col.
0087 288C         00262         goto    RowValEnd
0088 0A8C         00263         incf    TempC, F
0089 1C8D         00264         btfss   TempD,1         ;3rd col.
008A 288C         00265         goto    RowValEnd
008B 0A8C         00266         incf    TempC, F        ;last col.
008C              00267 RowValEnd
008C 1C0E         00268         btfss   TempE,0         ;top row?
008D 2896         00269         goto    GetValCom       ;yes then get 0,1,2&3
008E 1C8E         00270         btfss   TempE,1         ;2nd row?
008F 2895         00271         goto    Get4567         ;yes the get 4,5,6&7
0090 1D0E         00272         btfss   TempE,2         ;3rd row?
0091 2893         00273         goto    Get89ab         ;yes then get 8,9,a&b
0092              00274 Getcdef
0092 150C         00275         bsf     TempC,2         ;set msb bits
0093              00276 Get89ab
0093 158C         00277         bsf     TempC,3         ;       /
0094 2896         00278         goto    GetValCom       ;do common part
0095              00279 Get4567
0095 150C         00280         bsf     TempC,2
0096              00281 GetValCom
0096 080C         00282         movf    TempC,W
0097 0782         00283         addwf   PCL, F
0098 3400         00284         retlw   0
0099 3401         00285         retlw   1
009A 3402         00286         retlw   2
009B 3403         00287         retlw   3
009C 3404         00288         retlw   4
009D 3405         00289         retlw   5
009E 3406         00290         retlw   6
009F 3407         00291         retlw   7
00A0 3408         00292         retlw   8
00A1 3409         00293         retlw   9
00A2 340A         00294         retlw   0a
00A3 340B         00295         retlw   0b
00A4 340C         00296         retlw   0c
00A5 340D         00297         retlw   0d
00A6 340E         00298         retlw   0e
00A7 340F         00299         retlw   0f
                  00300 ;
                  00301 ;SavePorts, saves the porta and portb condition during a key scan
                  00302 ;operation.
00A8              00303 SavePorts
00A8 0805         00304         movf    PORTA,W         ;Get sink value
00A9 00A0         00305         movwf   PABuf           ;save in buffer
00AA 0185         00306         clrf    PORTA           ;disable all sinks
00AB 0806         00307         movf    PORTB,W         ;get port b
00AC 00A1         00308         movwf   PBBuf           ;save in buffer
```

```
00AD 30FF           00309         movlw   0xff           ;make all high
00AE 0086           00310         movwf   PORTB          ;on port b
00AF 1683           00311         bsf     STATUS,RP0     ;select Bank1
00B0 1381           00312         bcf     OptionReg,7    ;enable pull ups
00B1 30F0           00313         movlw   B'11110000'    ;port b hi nibble inputs
00B2 0086           00314         movwf   TRISB          ;lo nibble outputs
00B3 1283           00315         bcf     STATUS,RP0     ;Bank0
00B4 0008           00316         return
                    00317 ;
                    00318 ;RestorePorts, restores the condition of porta and portb after a
                    00319 ;key scan operation.
00B5                00320 RestorePorts
00B5 0821           00321         movf    PBBuf,W        ;get port b
00B6 0086           00322         movwf   PORTB
00B7 0820           00323         movf    PABuf,W        ;get port a value
00B8 0085           00324         movwf   PORTA
00B9 1683           00325         bsf     STATUS,RP0     ;select Bank1
00BA 1781           00326         bsf     OptionReg,7    ;disable pull ups
00BB 0185           00327         clrf    TRISA          ;make port a outputs
00BC 0186           00328         clrf    TRISB          ;as well as PORTB
00BD 1283           00329         bcf     STATUS,RP0     ;Bank0
00BE 0008           00330         return
                    00331 ;
                    00332 ;
00BF                00333 UpdateDisplay
00BF 0805           00334         movf    PORTA,W        ;present sink value in w
00C0 0185           00335         clrf    PORTA          ;disable all digits sinks
00C1 390F           00336         andlw   0x0f
00C2 008C           00337         movwf   TempC          ;save sink value in tempC
00C3 160C           00338         bsf     TempC,4        ;preset for lsd sink
00C4 0C8C           00339         rrf     TempC, F       ;determine next sink value
00C5 1C03           00340         btfss   STATUS,C       ;c=1?
00C6 118C           00341         bcf     TempC,3        ;no then reset LSD sink
00C7 180C           00342         btfsc   TempC,0        ;else see if Msd
00C8 28D6           00343         goto    UpdateMsd      ;yes then do Msd
00C9 188C           00344         btfsc   TempC,1        ;see if 3rdLsd
00CA 28D3           00345         goto    Update3rdLsd   ;yes then do 3rd Lsd
00CB 190C           00346         btfsc   TempC,2        ;see if 2nd Lsd
00CC 28D0           00347         goto    Update2ndLsd   ;yes then do 2nd lsd
00CD                00348 UpdateLsd
00CD 0811           00349         movf    LsdTime,W      ;get Lsd in w
00CE 390F           00350         andlw   0x0f           ;       /
00CF 28D8           00351         goto    DisplayOut
00D0                00352 Update2ndLsd
00D0 0E11           00353         swapf   LsdTime,W      ;get 2nd Lsd in w
00D1 390F           00354         andlw   0x0f           ;mask rest
00D2 28D8           00355         goto    DisplayOut     ;enable display
00D3                00356 Update3rdLsd
00D3 0810           00357         movf    MsdTime,W      ;get 3rd Lsd in w
00D4 390F           00358         andlw   0x0f           ;mask low nibble
00D5 28D8           00359         goto    DisplayOut     ;enable display
00D6                00360 UpdateMsd
00D6 0E10           00361         swapf   MsdTime,W      ;get Msd in w
00D7 390F           00362         andlw   0x0f           ;mask rest
00D8                00363 DisplayOut
00D8 20DD           00364         call    LedTable       ;get digit output
00D9 0086           00365         movwf   PORTB          ;drive leds
00DA 080C           00366         movf    TempC,W        ;get sink value in w
00DB 0085           00367         movwf   PORTA
00DC 0008           00368         return
                    00369 ;
                    00370 ;
00DD                00371 LedTable
00DD 0782           00372         addwf   PCL, F         ;add to PC low
00DE 343F           00373         retlw   B'00111111'    ;led drive for 0
00DF 3406           00374         retlw   B'00000110'    ;led drive for 1
```


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```
00E0 345B          00375         retlw   B'01011011'    ;led drive for 2
00E1 344F          00376         retlw   B'01001111'    ;led drive for 3
00E2 3466          00377         retlw   B'01100110'    ;led drive for 4
00E3 346D          00378         retlw   B'01101101'    ;led drive for 5
00E4 347D          00379         retlw   B'01111101'    ;led drive for 6
00E5 3407          00380         retlw   B'00000111'    ;led drive for 7
00E6 347F          00381         retlw   B'01111111'    ;led drive for 8
00E7 3467          00382         retlw   B'01100111'    ;led drive for 9
00E8 3477          00383         retlw   B'01110111'    ;led drive for A
00E9 347C          00384         retlw   B'01111100'    ;led drive for b
00EA 3439          00385         retlw   B'00111001'    ;led drive for C
00EB 345E          00386         retlw   B'01011110'    ;led drive for d
00EC 3479          00387         retlw   B'01111001'    ;led drive for E
00ED 3471          00388         retlw   B'01110001'    ;led drive for F
                   00389
                   00390 ;
                   00391 ;
00EE               00392 InitAd
00EE 30C0          00393         movlw   B'11000000'    ;internal rc for tad
00EF 0088          00394         movwf   ADCON0         ;       /
                   00395         ;note that adcon1 is set in InitPorts
00F0 0008          00396         return
                   00397 ;
00F1               00398 SampleAd
00F1 20A8          00399         call    SavePorts
00F2 20F8          00400         call    DoAd           ;do a ad conversion
00F3               00401 AdDone
00F3 1908          00402         btfsc   ADCON0,GO      ;ad done?
00F4 28F3          00403         goto    AdDone         ;no then loop
00F5 1612          00404         bsf     ADOver         ;set a/d over flag
00F6 20B5          00405         call    RestorePorts   ;restore ports
00F7 0008          00406         return
                   00407 ;
                   00408 ;
00F8               00409 DoAd
00F8 0186          00410         clrf    PORTB          ;turn off leds
00F9 1683          00411         bsf     STATUS,RP0     ;select Bank1
00FA 300F          00412         movlw   0x0f           ;make port a hi-Z
00FB 0085          00413         movwf   TRISA          ;       /
00FC 1283          00414         bcf     STATUS,RP0     ;select Bank0
00FD 1408          00415         bsf     ADCON0,ADON    ;start a/d
00FE 307D          00416         movlw   .125
00FF 2102          00417         call    Wait
0100 1508          00418         bsf     ADCON0,GO      ;start conversion
0101 0008          00419         return
                   00420 ;
                   00421 ;
0102               00422 Wait
0102 008C          00423         movwf   TempC          ;store in temp
0103               00424 Next
0103 0B8C          00425         decfsz  TempC, F
0104 2903          00426         goto    Next
0105 0008          00427         return
                   00428
                   00429 ;
                   00430 ;
  00000026         00431 count  equ      26
  00000027         00432 temp   equ      27
                   00433 ;
  00000020         00434 H_byte  equ     20
  00000021         00435 L_byte  equ     21
  00000022         00436 R0      equ     22             ; RAM Assignments
  00000023         00437 R1      equ     23
  00000024         00438 R2      equ     24
                   00439 ;
                   00440 ;
```

```
0106 1003           00441 B2_BCD  bcf     STATUS,0       ; clear the carry bit
0107 3010           00442         movlw   .16
0108 00A6           00443         movwf   count
0109 01A2           00444         clrf    R0
010A 01A3           00445         clrf    R1
010B 01A4           00446         clrf    R2
010C 0DA1           00447 loop16  rlf     L_byte, F
010D 0DA0           00448         rlf     H_byte, F
010E 0DA4           00449         rlf     R2, F
010F 0DA3           00450         rlf     R1, F
0110 0DA2           00451         rlf     R0, F
                    00452 ;
0111 0BA6           00453         decfsz  count, F
0112 2914           00454         goto    adjDEC
0113 3400           00455         RETLW   0
                    00456 ;
0114 3024           00457 adjDEC  movlw   R2
0115 0084           00458         movwf   FSR
0116 211E           00459         call    adjBCD
                    00460 ;
0117 3023           00461         movlw   R1
0118 0084           00462         movwf   FSR
0119 211E           00463         call    adjBCD
                    00464 ;
011A 3022           00465         movlw   R0
011B 0084           00466         movwf   FSR
011C 211E           00467         call    adjBCD
                    00468 ;
011D 290C           00469         goto    loop16
                    00470 ;
011E 3003           00471 adjBCD  movlw   3
011F 0700           00472         addwf   0,W
0120 00A7           00473         movwf   temp
0121 19A7           00474         btfsc   temp,3         ; test if result > 7
0122 0080           00475         movwf   0
0123 3030           00476         movlw   30
0124 0700           00477         addwf   0,W
0125 00A7           00478         movwf   temp
0126 1BA7           00479         btfsc   temp,7         ; test if result > 7
0127 0080           00480         movwf   0              ; save as MSD
0128 3400           00481         RETLW   0
                    00482 ;
                    00483 ;
                    00484 ;
                    00485 ;
                    00486
                    00487         end


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

0000 : X---XXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0080 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
00C0 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0100 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXX------- ----------------

All other memory blocks unused.

Program Memory Words Used:   294
Program Memory Words Free:   730


Errors   :     0
Warnings :     0 reported,     0 suppressed
Messages :     0 reported,     7 suppressed
```


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Corporate Office
2355 West Chandler Blvd.
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Web Address: http://www.microchip.com

Rocky Mountain
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Kokomo, Indiana 46902
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Irvine, CA 92612
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New York
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

Toronto
6285 Northam Drive, Suite 108
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699 Fax: 905-673-6509

ASIA/PACIFIC

Australia
Microchip Technology Australia Pty Ltd
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

China - Beijing
Microchip Technology Consulting (Shanghai) Co., Ltd., Beijing Liaison Office
Unit 915
Bei Hai Wan Tai Bldg.
No. 6 Chaoyangmen Beidajie
Beijing, 100027, No. China
Tel: 86-10-85282100 Fax: 86-10-85282104

China - Chengdu
Microchip Technology Consulting (Shanghai) Co., Ltd., Chengdu Liaison Office
Rm. 2401, 24th Floor,
Ming Xing Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-6766200 Fax: 86-28-6766599

China - Fuzhou
Microchip Technology Consulting (Shanghai) Co., Ltd., Fuzhou Liaison Office
Unit 28F, World Trade Plaza
No. 71 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7503506 Fax: 86-591-7503521

China - Shanghai
Microchip Technology Consulting (Shanghai) Co., Ltd.
Room 701, Bldg. B
Far East International Plaza
No. 317 Xian Xia Road
Shanghai, 200051
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

China - Shenzhen
Microchip Technology Consulting (Shanghai) Co., Ltd., Shenzhen Liaison Office
Rm. 1315, 13/F, Shenzhen Kerry Centre,
Renminnan Lu
Shenzhen 518001, China
Tel: 86-755-2350361 Fax: 86-755-2366086

Hong Kong
Microchip Technology Hongkong Ltd.
Unit 901-6, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200 Fax: 852-2401-3431

India
Microchip Technology Inc.
India Liaison Office
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, O'Shaugnessey Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan
Microchip Technology Japan K.K.
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 135-882
Tel: 82-2-554-7200 Fax: 82-2-558-5934

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

Taiwan
Microchip Technology Taiwan
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

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

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

Italy
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

United Kingdom
Arizona Microchip Technology Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44-118 921-5820

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