AN557

Four Channel Digital Voltmeter with Display and Keyboard

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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

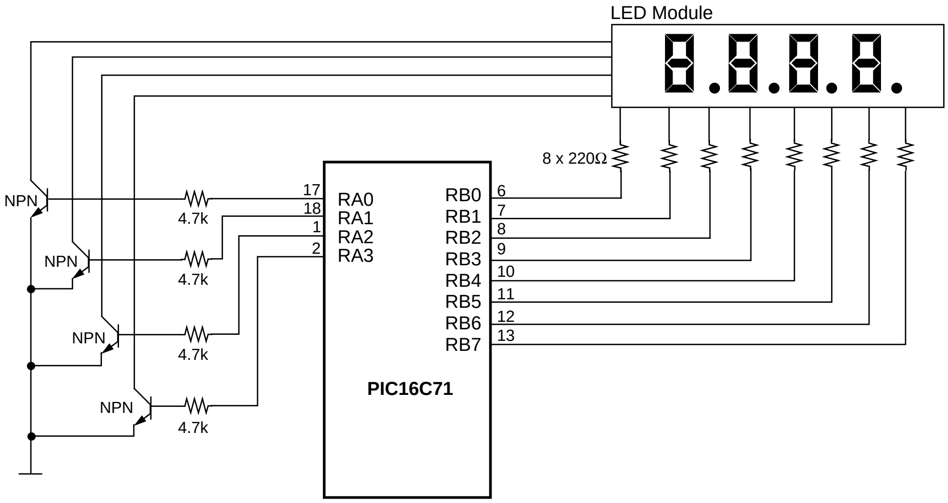
Multiplexing Four 7-Segment LED Displays with a 4x4 Keypad and 4 A/D Channels

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



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

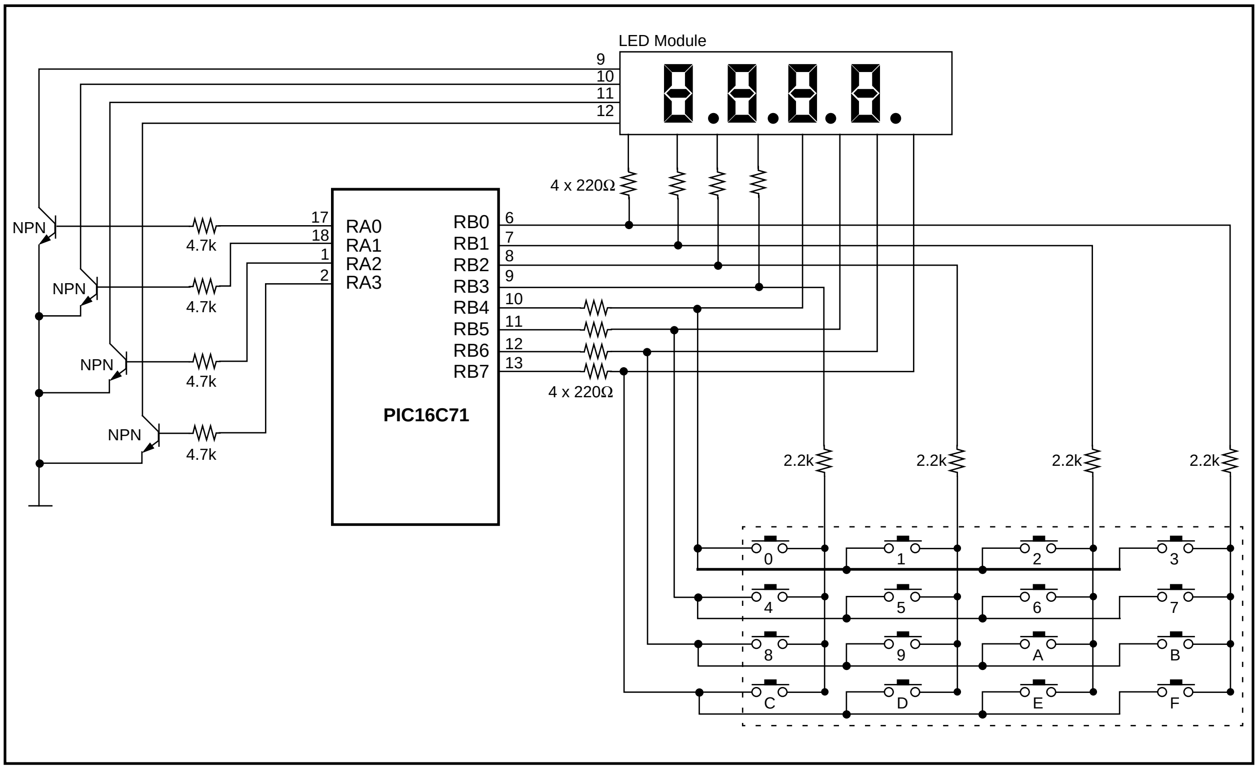
A 4x4 keypad can be very easily interfaced to the PIC16C71's PORTB (Figure 2). Internal pull-ups on pins RB7:RB4 can be enabled/disabled by clearing/setting bit $\overline{\text{RBPU}}$ (OPTION<7>). The internal pull-ups have a value of 20k at 5V (typical). In order to sense a low level at the input, 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



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

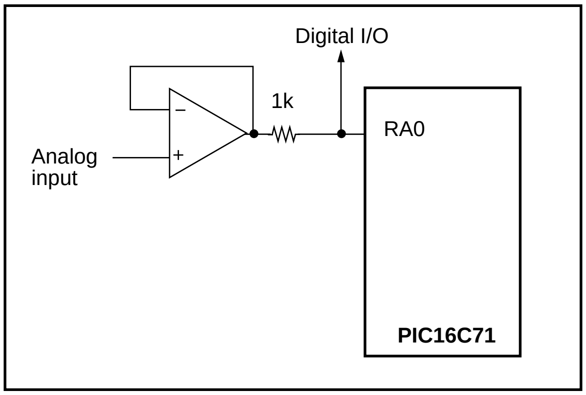
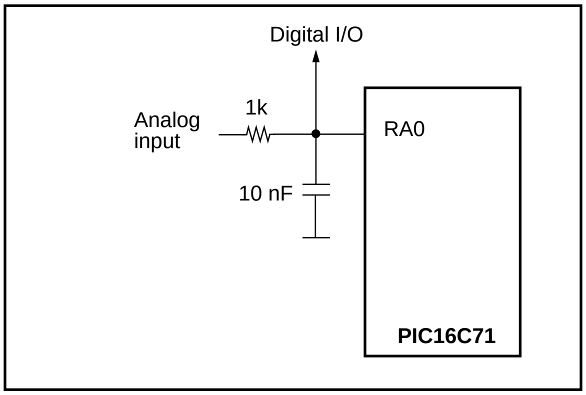


FIGURE 4: TYPICAL CONNECTION FOR ANALOG/DIGITAL INPUT



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.

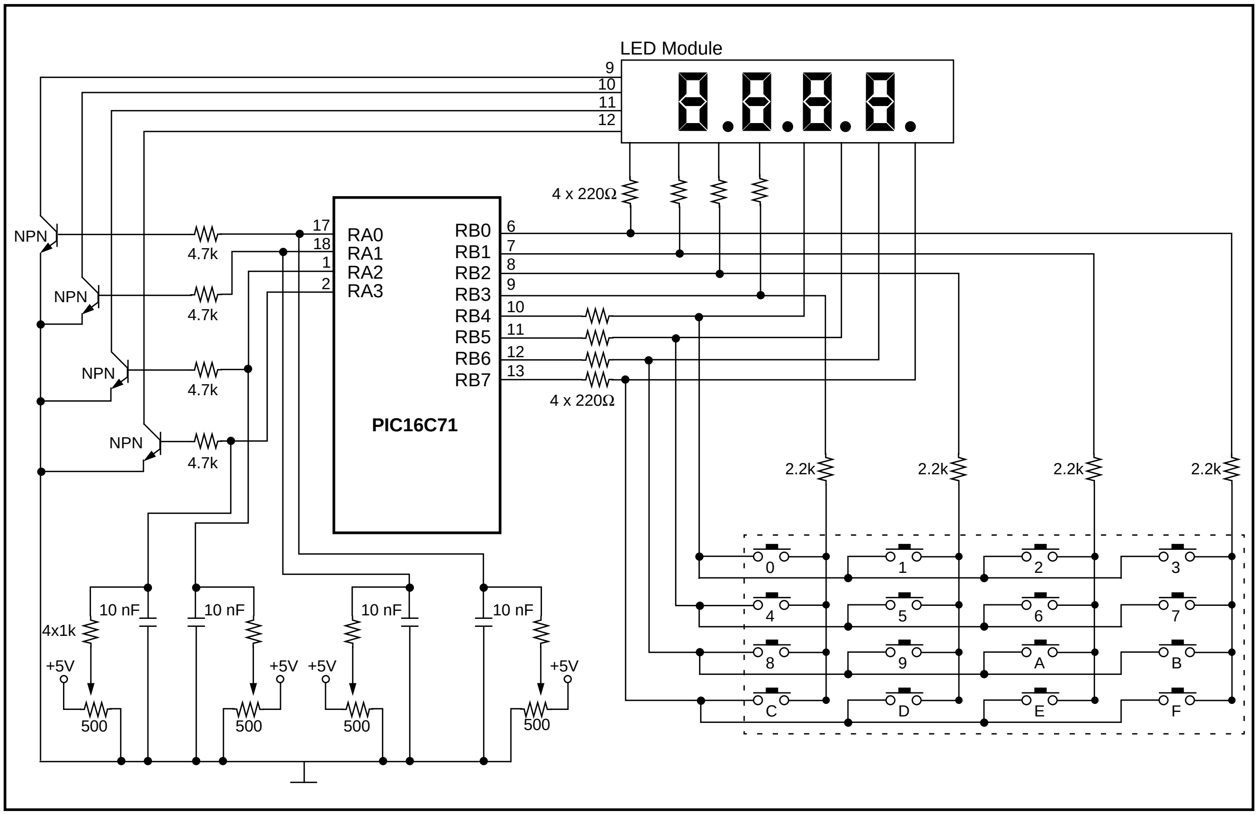
Code Size

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



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                   bsf     PORTA,3         ;enable MSB digit sink
0011 0008                   return
                    ;
                    ;
                    ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                    ;the TMR0 will be incremented every 31.25uS. If TMR0 is preloaded
                    ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                    ;end result is that we get a TMR0 interrupt every 5mS.
0012                InitTimers
0012 0190                   clrf    MsdTime                 ;clr timers
0013 0191                   clrf    LsdTime                 ;       /
0014 1683                   bsf     STATUS,RP0              ;select Bank1
0015 3084                   movlw   B'10000100'             ;assign ps to TMR0
0016 0081                   movwf   OptionReg               ;ps = 32
0017 1283                   bcf     STATUS,RP0              ;select Bank0
0018 3020                   movlw   B'00100000'             ;enable TMR0 interrupt
0019 008B                   movwf   INTCON                  ;
001A 3060                   movlw   .96                     ;preload TMR0
001B 0081                   movwf   TMR0                    ;start counter
001C 0009                   retfie
                    ;
001D                ServiceInterrupts
001D 190B                   btfsc   INTCON,T0IF             ;TMR0 interrupt?
001E 2822                   goto    ServiceTMR0             ;yes then service
001F 3020                   movlw   B'00100000'             ;else clr rest
0020 008B                   movwf   INTCON
0021 0009                   retfie
                    ;
0022                ServiceTMR0
0022 3060                   movlw   .96                     ;initialize TMR0
0023 0081                   movwf   TMR0
0024 110B                   bcf     INTCON,T0IF             ;clr int flag
0025 2028                   call    IncTimer                ;inc timer
0026 2050                   call    UpdateDisplay           ;update display
0027 0009                   retfie
                    ;
                    ;The display is incremented every 200*5mS = 1 Sec.
0028                IncTimer
0028 0A0F                   incf    Count,W                 ;inc count
0029 3AC8                   xorlw   .200                    ;= 200?
002A 1903                   btfsc   STATUS,Z                ;no then skip
002B 282E                   goto    DoIncTime               ;else inc time
002C 0A8F                   incf    Count, F
002D 0008                   return
002E                DoIncTime
002E 018F                   clrf    Count                   ;clr count
002F 0A11                   incf    LsdTime,W               ;get lsd
0030 390F                   andlw   0x0F                    ;mask high nibble
0031 3A0A                   xorlw   0x0a                    ; = 10?
0032 1903                   btfsc   STATUS,Z                ;no then skip
0033 2836                   goto    IncSecondLsd            ;inc next lsd
0034 0A91                   incf    LsdTime, F              ;else inc timer
0035 0008                   return
0036                IncSecondLsd
0036 0E11                   swapf   LsdTime,W               ;get hi in low nibble
0037 390F                   andlw   0x0F                    ;mask hi nibble
0038 3E01                   addlw   1                       ;inc it
0039 0091                   movwf   LsdTime                 ;restore back
003A 0E91                   swapf   LsdTime, F              ;       /
003B 3A0A                   xorlw   0x0a                    ; = 10?
003C 1903                   btfsc   STATUS,Z                ;no then skip
003D 283F                   goto    IncThirdLsd             ;else inc next lsd
003E 0008                   return
003F                IncThirdLsd
003F 0191                   clrf    LsdTime
0040 0A10                   incf    MsdTime,W               ;get 3rd lsd
```

```
0041 390F                   andlw   0x0F                    ;mask hi nibble
0042 3A0A                   xorlw   0x0a                    ;= 10?
0043 1903                   btfsc   STATUS,Z                ;no then skip
0044 2847                   goto    IncMsd                  ;else Msd
0045 0A90                   incf    MsdTime, F              ;else inc timer
0046 0008                   return
0047                IncMsd
0047 0E10                   swapf   MsdTime,W               ;get hi in lo nibble
0048 390F                   andlw   0x0F                    ;mask hi nibble
0049 3E01                   addlw   1                       ;inc timer
004A 0090                   movwf   MsdTime                 ;restore back
004B 0E90                   swapf   MsdTime, F              ;       /
004C 3A0A                   xorlw   0x0a                    ;= 10?
004D 1903                   btfsc   STATUS,Z                ;no then skip
004E 0190                   clrf    MsdTime                 ;clr msd
004F 0008                   return
                    ;
                    ;
0050                UpdateDisplay
0050 0805                   movf    PORTA,W                ;present sink value in w
0051 0185                   clrf    PORTA                  ;disable all digits sinks
0052 390F                   andlw   0x0f
0053 008C                   movwf   TempC                  ;save sink value in tempC
0054 160C                   bsf     TempC,4                ;preset for lsd sink
0055 0C8C                   rrf     TempC, F               ;determine next sink value
0056 1C03                   btfss   STATUS,C               ;c=1?
0057 118C                   bcf     TempC,3                ;no then reset LSD sink
0058 180C                   btfsc   TempC,0                ;else see if Msd
0059 286B                   goto    UpdateMsd              ;yes then do Msd
005A 188C                   btfsc   TempC,1                ;see if 3rdLsd
005B 2866                   goto    Update3rdLsd           ;yes then do 3rd Lsd
005C 190C                   btfsc   TempC,2                ;see if 2nd Lsd
005D 2861                   goto    Update2ndLsd           ;yes then do 2nd lsd
005E                UpdateLsd
005E 0811                   movf    LsdTime,W              ;get Lsd in w
005F 390F                   andlw   0x0f                   ;       /
0060 286F                   goto    DisplayOut             ;enable display
0061                Update2ndLsd
0061 2080                   call    Chk2LsdZero            ;msd = 0 & 2 lsd 0?
0062 1D03                   btfss   STATUS,Z               ;yes then skip
0063 0E11                   swapf   LsdTime,W              ;get 2nd Lsd in w
0064 390F                   andlw   0x0f                   ;mask rest
0065 286F                   goto    DisplayOut             ;enable display
0066                Update3rdLsd
0066 2088                   call    ChkMsdZero             ;msd = 0?
0067 1D03                   btfss   STATUS,Z               ;yes then skip
0068 0810                   movf    MsdTime,W              ;get 3rd Lsd in w
0069 390F                   andlw   0x0f                   ;mask low nibble
006A 286F                   goto    DisplayOut             ;enable display
006B                UpdateMsd
006B 0E10                   swapf   MsdTime,W              ;get Msd in w
006C 390F                   andlw   0x0f                   ;mask rest
006D 1903                   btfsc   STATUS,Z               ;msd != 0 then skip
006E 300A                   movlw   0x0a
006F                DisplayOut
006F 2074                   call    LedTable               ;get digit output
0070 0086                   movwf   PORTB                  ;drive leds
0071 080C                   movf    TempC,W                ;get sink value in w
0072 0085                   movwf   PORTA
0073 0008                   return
                    ;
                    ;
0074                LedTable
0074 0782                   addwf   PCL, F                  ;add to PC low
0075 343F                   retlw   B'00111111'             ;led drive for 0
0076 3406                   retlw   B'00000110'             ;led drive for 1
```

```
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---XXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0080 : XXXXXXXXXXXX---- ---------------- ---------------- ----------------

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
```

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

APPENDIX B: 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
                    ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                    ;end result is that we get a TMR0 interrupt every 5mS.
002A                InitTimers
002A 0190                   clrf    MsdTime         ;clr timers
002B 0191                   clrf    LsdTime         ;       /
002C 0192                   clrf    KeyFlag         ;clr all flags
002D 1683                   bsf     STATUS,RP0      ;select Bank1
002E 3084                   movlw   B'10000100'     ;assign ps to TMR0
002F 0081                   movwf   OptionReg       ;ps = 32
0030 1283                   bcf     STATUS,RP0      ;select Bank0
0031 3020                   movlw   B'00100000'     ;enable TMR0 interrupt
0032 008B                   movwf   INTCON          ;
0033 3060                   movlw   .96             ;preload TMR0
0034 0081                   movwf   TMR0            ;start counter
0035 0009                   retfie
                    ;
0036                ServiceInterrupts
0036 190B                   btfsc   INTCON,T0IF     ;TMR0 interrupt?
0037 283B                   goto    ServiceTMR0     ;yes then service
0038 018B                   clrf    INTCON          ;else clr all int
0039 168B                   bsf     INTCON,T0IE
003A 0008                   return
                    ;
003B                ServiceTMR0
003B 3060                   movlw   .96             ;initialize TMR0
003C 0081                   movwf   TMR0
003D 110B                   bcf     INTCON,T0IF     ;clr int flag
003E 1805                   btfsc   PORTA,0         ;if msb on then do
003F 2042                   call    ScanKeys        ;do a quick key scan
0040 20A1                   call    UpdateDisplay   ;update display
0041 0008                   return
                    ;
                    ;
                    ;ScanKeys, scans the 4X4 keypad matrix and returns a key value in
                    ;NewKey (0 - F) if a key is pressed, if not it clears the keyhit flag.
                    ;Debounce for a given keyhit is also taken care of.
                    ;The rate of key scan is 20mS with a 4.096Mhz clock.
0042                ScanKeys
0042 1C92                   btfss   KeyFlag,DebnceOn ;debounce on?
0043 2848                   goto    Scan1            ;no then scan keypad
0044 0B93                   decfsz  Debnce, F        ;else dec debounce time
0045 0008                   return                   ;not over then return
0046 1092                   bcf     KeyFlag,DebnceOn ;over, clr debounce flag
0047 0008                   return                   ;and return
0048                Scan1
0048 208A                   call    SavePorts        ;save port values
0049 30EF                   movlw   B'11101111'      ;init TempD
004A 008D                   movwf   TempD
004B                ScanNext
004B 0806                   movf    PORTB,W          ;read to init port
004C 100B                   bcf     INTCON,RBIF      ;clr flag
004D 0C8D                   rrf     TempD, F         ;get correct column
004E 1C03                   btfss   STATUS,C         ;if carry set?
004F 2862                   goto    NoKey            ;no then end
0050 080D                   movf    TempD,W          ;else output
0051 0086                   movwf   PORTB            ;low column scan line
0052 0000                   nop
0053 1C0B                   btfss   INTCON,RBIF      ;flag set?
0054 284B                   goto    ScanNext         ;no then next
0055 1812                   btfsc   KeyFlag,keyhit   ;last key released?
0056 2860                   goto    SKreturn         ;no then exit
0057 1412                   bsf     KeyFlag,keyhit   ;set new key hit
0058 0E06                   swapf   PORTB,W          ;read port
0059 008E                   movwf   TempE            ;save in TempE
005A 2064                   call    GetKeyValue      ;get key value 0 - F
005B 0094                   movwf   NewKey           ;save as New key
```

```
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
```

```
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
```

```
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
```

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         ;       /
```

```
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 ;
```

```
           ;SavePorts, saves the porta and portb condition during a key scan
           ;operation.
005A       SavePorts
005A 0805          movf    PORTA,W         ;Get sink value
005B 00A0          movwf   PABuf           ;save in buffer
005C 0185          clrf    PORTA           ;disable all sinks
005D 0806          movf    PORTB,W         ;get port b
005E 00A1          movwf   PBBuf           ;save in buffer
005F 30FF          movlw   0xff            ;make all high
0060 0086          movwf   PORTB           ;on port b
0061 1683          bsf     STATUS,RP0      ;select Bank1
0062 1381          bcf     OptionReg,7     ;enable pull ups
0063 30F0          movlw   B'11110000'     ;port b hi nibble inputs
0064 0086          movwf   TRISB           ;lo nibble outputs
0065 1283          bcf     STATUS,RP0      ;Bank0
0066 0008          return
           ;
           ;RestorePorts, restores the condition of porta and portb after a
           ;key scan operation.
0067       RestorePorts
0067 0821          movf    PBBuf,W         ;get port n
0068 0086          movwf   PORTB
0069 0820          movf    PABuf,W         ;get port a value
006A 0085          movwf   PORTA
006B 1683          bsf     STATUS,RP0      ;select Bank1
006C 1781          bsf     OptionReg,7     ;disable pull ups
006D 0185          clrf    TRISA           ;make port a outputs
006E 0186          clrf    TRISB           ;as well as PORTB
006F 1283          bcf     STATUS,RP0      ;Bank0
0070 0008          return
           ;
           ;
0071       UpdateDisplay
0071 0805          movf    PORTA,W         ;present sink value in w
0072 0185          clrf    PORTA           ;disable all digits sinks
0073 390F          andlw   0x0f
0074 008C          movwf   TempC           ;save sink value in tempC
0075 160C          bsf     TempC,4         ;preset for lsd sink
0076 0C8C          rrf     TempC, F        ;determine next sink value
0077 1C03          btfss   STATUS,C        ;c=1?
0078 118C          bcf     TempC,3         ;no then reset LSD sink
0079 180C          btfsc   TempC,0         ;else see if Msd
007A 288C          goto    UpdateMsd       ;yes then do Msd
007B 188C          btfsc   TempC,1         ;see if 3rdLsd
007C 2887          goto    Update3rdLsd    ;yes then do 3rd Lsd
007D 190C          btfsc   TempC,2         ;see if 2nd Lsd
007E 2882          goto    Update2ndLsd    ;yes then do 2nd lsd
007F       UpdateLsd
007F 0811          movf    LsdTime,W       ;get Lsd in w
0080 390F          andlw   0x0f            ;       /
0081 2890          goto    DisplayOut      ;enable display
0082       Update2ndLsd
0082 20A1          call    Chk2LsdZero     ;msd = 0 & 2 lsd 0?
0083 1D03          btfss   STATUS,Z        ;yes then skip
0084 0E11          swapf   LsdTime,W       ;get 2nd Lsd in w
0085 390F          andlw   0x0f            ;mask rest
0086 2890          goto    DisplayOut      ;enable display
0087       Update3rdLsd
0087 20A9          call    ChkMsdZero      ;msd = 0?
0088 1D03          btfss   STATUS,Z        ;yes then skip
0089 0810          movf    MsdTime,W       ;get 3rd Lsd in w
008A 390F          andlw   0x0f            ;mask low nibble
008B 2890          goto    DisplayOut      ;enable display
008C       UpdateMsd
008C 0E10          swapf   MsdTime,W       ;get Msd in w
008D 390F          andlw   0x0f            ;mask rest
```

```
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  equu      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---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,     7 suppressed
```

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

APPENDIX 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
```

```
0022 2106                   call    B2_BCD
0023 0824                   movf    R2,W            ;get LSd
0024 0091                   movwf   LsdTime         ;save in LSD
0025 0823                   movf    R1,W            ;get Msd
0026 0090                   movwf   MsdTime         ;save in Msd
0027 0008                   return
                    ;
                    ;This routine essentially loads the ADRES value in the table location
                    ;determined by the channel offset. If channel 0 then ADRES is saved
                    ;in location ADTABLE. If channel 1 then ADRES is saved at ADTABLE + 1.
                    ;and so on.
0028                ServiceAD
0028 0808                   movf    ADCON0,W        ;get adcon0
0029 008C                   movwf   TempC           ;save in temp
002A 3008                   movlw   B'00001000'     ;select next channel
002B 0708                   addwf   ADCON0,W        ;       /
002C 1A88                   btfsc   ADCON0,5        ;if <= ch3
002D 30C1                   movlw   B'11000001'     ;select ch0
002E 0088                   movwf   ADCON0
                    ;now load adres in the table
002F 3016                   movlw   ADTABLE
0030 0084                   movwf   FSR             ;load FSR with top
0031 0C8C                   rrf     TempC, F
0032 0C8C                   rrf     TempC, F
0033 0C0C                   rrf     TempC,W         ;get in w reg
0034 3903                   andlw   3               ;mask off all but last 2
0035 0784                   addwf   FSR, F          ;add offset to table
0036 0809                   movf    ADRES,W         ;get a/d value
0037 0080                   movwf   0               ;load indirectly
0038 1212                   bcf     ADOver          ;clear flag
0039 201C                   call    LoadAD          ;load a/d value in display reg.
003A 0008                   return



                    ;
003B                InitPorts
003B 1683                   bsf     STATUS,RP0      ;select Bank1
003C 3003                   movlw   3               ;make RA0-3 digital I/O
003D 0088                   movwf   ADCON1          ;       /
003E 0185                   clrf    TRISA           ;make RA0-4 outputs
003F 0186                   clrf    TRISB           ;make RB0-7 outputs
0040 1283                   bcf     STATUS,RP0      ;select Bank0
0041 0185                   clrf    PORTA           ;make all outputs low
0042 0186                   clrf    PORTB           ;       /
0043 1585                   bsf     PORTA,3         ;enable MSB digit sink
0044 0008                   return
                    ;
                    ;
                    ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                    ;the TMR0 will be incremented every 31.25uS. If TMR0 is preloaded
                    ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                    ;end result is that we get a TMR0 interrupt every 5mS.
0045                InitTimers
0045 0190                   clrf    MsdTime         ;clr timers
0046 0191                   clrf    LsdTime         ;       /
0047 0195                   clrf    DisplayCh       ;show channel 0
0048 0192                   clrf    Flag            ;clr all flags
0049 1683                   bsf     STATUS,RP0      ;select Bank1
004A 3084                   movlw   B'10000100'     ;assign ps to TMR0
004B 0081                   movwf   OptionReg       ;ps = 32
004C 1283                   bcf     STATUS,RP0      ;select Bank0
004D 3020                   movlw   B'00100000'     ;enable TMR0 interrupt
004E 008B                   movwf   INTCON          ;
004F 3060                   movlw   .96             ;preload TMR0
0050 0081                   movwf   TMR0            ;start counter
```

```
0051 0009                   retfie
                    ;
0052                ServiceInterrupts
0052 190B                   btfsc   INTCON,T0IF     ;TMR0 interrupt?
0053 2857                   goto    ServiceTMR0     ;yes then service
0054 018B                   clrf    INTCON          ;else clr all int
0055 168B                   bsf     INTCON,T0IE
0056 0008                   return
                    ;
0057                ServiceTMR0
0057 3060                   movlw   .96             ;initialize TMR0
0058 0081                   movwf   TMR0
0059 110B                   bcf     INTCON,T0IF     ;clr int flag
005A 1805                   btfsc   PORTA,0         ;scan keys every 20 mS
005B 2060                   call    ScanKeys        ;when digit 1 is on
005C 1985                   btfsc   PORTA,3         ;scan a/d every 20mS
005D 20F1                   call    SampleAd        ;when digit 4 is on
005E 20BF                   call    UpdateDisplay   ;update display
005F 0008                   return
                    ;
                    ;
                    ;ScanKeys, scans the 4x4 keypad matrix and returns a key value in
                    ;NewKey (0 - F) if a key is pressed, if not it clears the keyhit flag.
                    ;Debounce for a given keyhit is also taken care of.
                    ;The rate of key scan is 20mS with a 4.096Mhz clock.
0060                ScanKeys
0060 1C92                   btfss   DebnceOn        ;debounce on?
0061 2866                   goto    Scan1           ;no then scan keypad
0062 0B93                   decfsz  Debnce, F       ;else dec debounce time
0063 0008                   return                  ;not over then return
0064 1092                   bcf     DebnceOn        ;over, clr debounce flag
0065 0008                   return                  ;and return
0066                Scan1
0066 20A8                   call    SavePorts       ;save port values
0067 30EF                   movlw   B'11101111'     ;init TempD
0068 008D                   movwf   TempD
0069                ScanNext
0069 0806                   movf    PORTB,W         ;read to init port
006A 100B                   bcf     INTCON,RBIF     ;clr flag
006B 0C8D                   rrf     TempD, F        ;get correct column
006C 1C03                   btfss   STATUS,C        ;if carry set?
006D 2880                   goto    NoKey           ;no then end
006E 080D                   movf    TempD,W         ;else output
006F 0086                   movwf   PORTB           ;low column scan line
0070 0000                   nop
0071 1C0B                   btfss   INTCON,RBIF     ;flag set?
0072 2869                   goto    ScanNext        ;no then next
0073 1812                   btfsc   keyhit          ;last key released?
0074 287E                   goto    SKreturn        ;no then exit
0075 1412                   bsf     keyhit          ;set new key hit
0076 0E06                   swapf   PORTB,W         ;read port
0077 008E                   movwf   TempE           ;save in TempE
0078 2082                   call    GetKeyValue     ;get key value 0 - F
0079 0094                   movwf   NewKey          ;save as New key
007A 1592                   bsf     ServKey         ;set service flag
007B 1492                   bsf     DebnceOn        ;set flag
007C 3004                   movlw   4
007D 0093                   movwf   Debnce          ;load debounce time
007E                SKreturn
007E 20B5                   call    RestorePorts    ;restore ports
007F 0008                   return
                    ;
0080                NoKey
0080 1012                   bcf     keyhit          ;clr flag
0081 287E                   goto    SKreturn
                    ;
```

```
                ;GetKeyValue gets the key as per the following layout
                ;
                ;                  Col1    Col2    Col3    Col4
                ;                  (RB3)   (RB2)   (RB1)   (RB0)
                ;
                ;Row1(RB4)           0       1       2       3
                ;
                ;Row2(RB5)           4       5       6       7
                ;
                ;Row3(RB6)           8       9       A       B
                ;
                ;Row4(RB7)           C       D       E       F
                ;
0082            GetKeyValue
0082 018C               clrf    TempC
0083 1D8D               btfss   TempD,3         ;first column
0084 288C               goto    RowValEnd
0085 0A8C               incf    TempC, F
0086 1D0D               btfss   TempD,2         ;second col.
0087 288C               goto    RowValEnd
0088 0A8C               incf    TempC, F
0089 1C8D               btfss   TempD,1         ;3rd col.
008A 288C               goto    RowValEnd
008B 0A8C               incf    TempC, F        ;last col.
008C            RowValEnd
008C 1C0E               btfss   TempE,0         ;top row?
008D 2896               goto    GetValCom       ;yes then get 0,1,2&3
008E 1C8E               btfss   TempE,1         ;2nd row?
008F 2895               goto    Get4567         ;yes the get 4,5,6&7
0090 1D0E               btfss   TempE,2         ;3rd row?
0091 2893               goto    Get89ab         ;yes then get 8,9,a&b
0092            Getcdef
0092 150C               bsf     TempC,2         ;set msb bits
0093            Get89ab
0093 158C               bsf     TempC,3         ;       /
0094 2896               goto    GetValCom       ;do common part
0095            Get4567
0095 150C               bsf     TempC,2
0096            GetValCom
0096 080C               movf    TempC,W
0097 0782               addwf   PCL, F
0098 3400               retlw   0
0099 3401               retlw   1
009A 3402               retlw   2
009B 3403               retlw   3
009C 3404               retlw   4
009D 3405               retlw   5
009E 3406               retlw   6
009F 3407               retlw   7
00A0 3408               retlw   8
00A1 3409               retlw   9
00A2 340A               retlw   0a
00A3 340B               retlw   0b
00A4 340C               retlw   0c
00A5 340D               retlw   0d
00A6 340E               retlw   0e
00A7 340F               retlw   0f
                ;
                ;SavePorts, saves the porta and portb condition during a key scan
                ;operation.
00A8            SavePorts
00A8 0805               movf    PORTA,W        ;Get sink value
00A9 00A0               movwf   PABuf          ;save in buffer
00AA 0185               clrf    PORTA          ;disable all sinks
00AB 0806               movf    PORTB,W        ;get port b
00AC 00A1               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
```

```
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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