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 and has been broken down into four subsections:

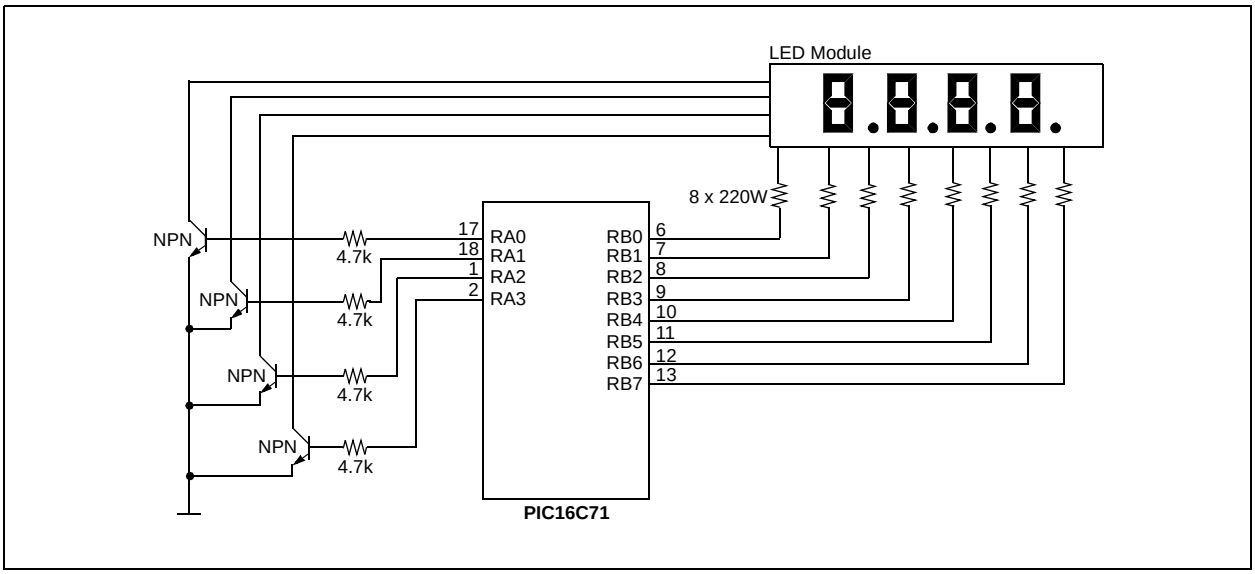
- Multiplexing Four 7-Segment LED Displays
- Multiplexing Four 7-Segment LED Displays and Scanning a 4x4 Keypad
- Multiplexing Four 7-Segment LED Displays and the A/D Channel 0
- Multiplexing Four 7-Segment LED Displays with a 4x4 Keypad and 4 A/D Channels

MULTIPLEXING FOUR 7-SEGMENT LED DISPLAYS

Hardware

The PIC16C71 device'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 a 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 16-pin SOIC 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-SEGMENT LEDS



Software

The multiplexing is achieved by turning on each LED for a 5 ms duration every 20 ms. This gives an update rate of 50 Hz, which is quite acceptable to the human eye as a steady display. The 5 ms 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 preloaded with a value = 96. TMR0 will increment to FFh and then roll over to 00h after a period = (256 – 96) • (32 • 4/4096000) = 5 ms.

When TMR0 rolls over, the T0IF flag bit 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 nibbles (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 ms 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: "MPLX.ASM"**.

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

Hardware

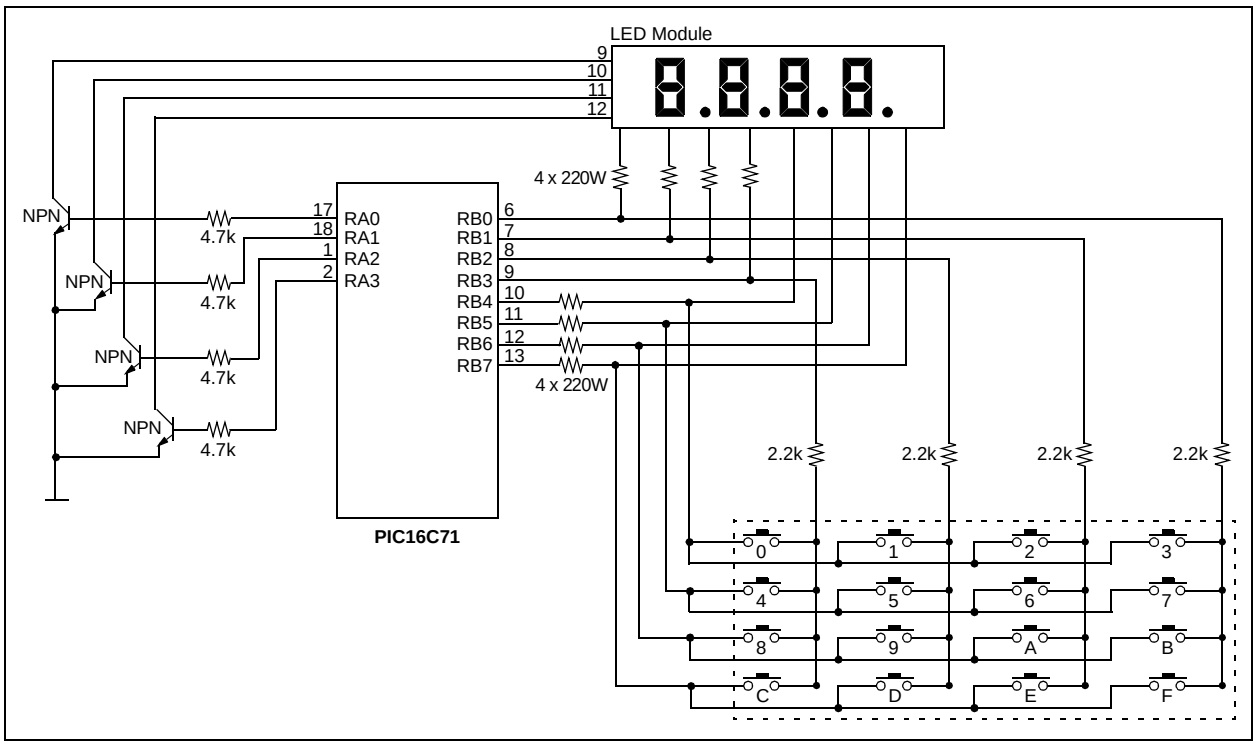
A 4x4 keypad can very easily be interfaced to the PIC16C71 device's PORTB (Figure 2). Internal pull-ups on pins RB7:RB4 can be enabled/disabled by clearing/setting bit $\overline{\text{RBPU}}$ (OPTION<7>). The internal pull-ups have a value of 20k at 5V (typical). In order to sense a low level at the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

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



MULTIPLEXING FOUR 7-SEGMENT LED DISPLAYS AND THE A/D CHANNEL 0

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 Channel 0. 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: "MPLXCH0.ASM"**.

FIGURE 3: TYPICAL CONNECTION FOR ANALOG/DIGITAL INPUT

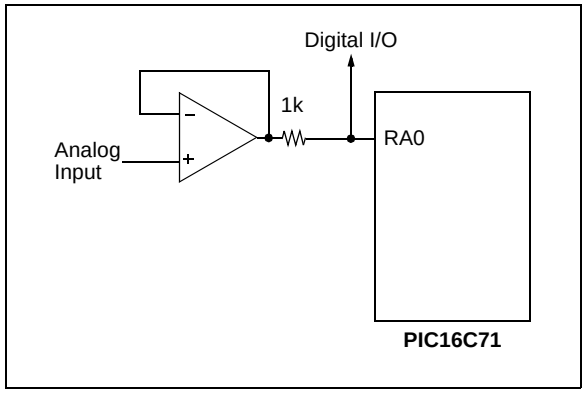
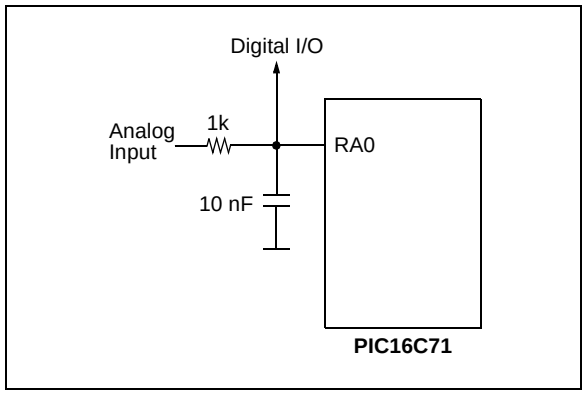


FIGURE 4: TYPICAL CONNECTION FOR ANALOG/DIGITAL INPUT



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 ms if required. The keypad sampling need not be any faster than once every 20 ms.

Software

The program samples the analog inputs and saves the result in four consecutive locations, starting at "ADVALUE", with Channel 0 saved at the first location and so on:

KEY 0 → Channel 0

or

KEY 1 → Channel 0

Key hits greater than 3 are ignored. The code listing for this section is in **Appendix D: "MPLXAD.ASM"**D.

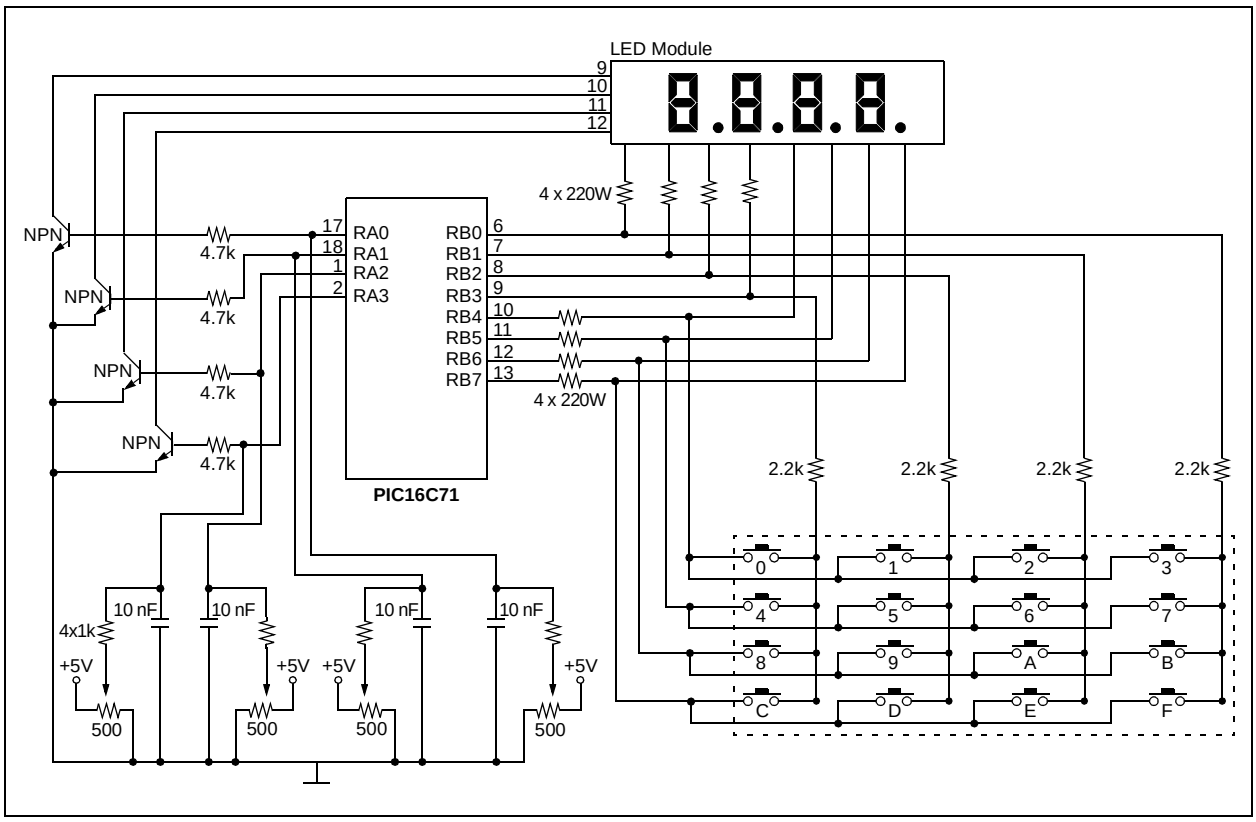
Code Size

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



APPENDIX A: MPLX.ASM

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

LOC  OBJECT CODE     LINE SOURCE TEXT
  VALUE

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

```
0008 1683          00045         bsf      STATUS, RP0       ;select Bank1
0009 3003          00046         movlw    3                 ;make RA0-3 digital I/O
000A 0088          00047         movwf    ADCON1            ;       /
000B 0185          00048         clrf     TRISA             ;make RA0-4 outputs
000C 0186          00049         clrf     TRISB             ;make RB0-7 outputs
000D 1283          00050         bcf      STATUS, RP0       ;select Bank0
000E 0185          00051         clrf     PORTA             ;make all outputs low
000F 0186          00052         clrf     PORTB             ;       /
0010 1585          00053         bsf      PORTA, 3          ;enable MSB digit sink
0011 0008          00054         return
                   00055 ;
                   00056 ;
                   00057 ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                   00058 ;the TMR0 will be incremented every 31.25uS. If TMR0 is preloaded
                   00059 ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                   00060 ;end result is that we get a TMR0 interrupt every 5mS.
0012               00061 InitTimers
0012 0190          00062         clrf     MsdTime           ;clr timers
0013 0191          00063         clrf     LsdTime           ;       /
0014 1683          00064         bsf      STATUS, RP0       ;select Bank1
0015 3084          00065         movlw    B'10000100'       ;assign ps to TMR0
0016 0081          00066         movwf    OptionReg         ;ps = 32
0017 1283          00067         bcf      STATUS, RP0       ;select Bank0
0018 3020          00068         movlw    B'00100000'       ;enable TMR0 interrupt
0019 008B          00069         movwf    INTCON            ;
001A 3060          00070         movlw    .96               ;preload TMR0
001B 0081          00071         movwf    TMR0              ;start counter
001C 0009          00072         retfie
                   00073 ;
001D               00074 ServiceInterrupts
001D 190B          00075         btfsc    INTCON, T0IF      ;TMR0 interrupt?
001E 2822          00076         goto     ServiceTMR0       ;yes then service
001F 3020          00077         movlw    B'00100000'       ;else clr rest
0020 008B          00078         movwf    INTCON
0021 0009          00079         retfie
                   00080 ;
0022               00081 ServiceTMR0
0022 3060          00082         movlw    .96               ;initialize TMR0
0023 0081          00083         movwf    TMR0
0024 110B          00084         bcf      INTCON, T0IF      ;clr int flag
0025 2028          00085         call     IncTimer          ;inc timer
0026 2050          00086         call     UpdateDisplay     ;update display
0027 0009          00087         retfie
                   00088 ;
                   00089 ;The display is incremented every 200*5mS = 1 Sec.
0028               00090 IncTimer
0028 0A0F          00091         incf     Count, W          ;inc count
0029 3AC8          00092         xorlw    .200              ;= 200?
002A 1903          00093         btfsc    STATUS, Z         ;no then skip
002B 282E          00094         goto     DoIncTime         ;else inc time
002C 0A8F          00095         incf     Count, F
002D 0008          00096         return
002E               00097 DoIncTime
002E 018F          00098         clrf     Count             ;clr count
002F 0A11          00099         incf     LsdTime, W        ;get lsd
0030 390F          00100         andlw    0x0F              ;mask high nibble
0031 3A0A          00101         xorlw    0x0a              ; = 10?
0032 1903          00102         btfsc    STATUS, Z         ;no then skip
0033 2836          00103         goto     IncSecondLsd      ;inc next lsd
0034 0A91          00104         incf     LsdTime, F        ;else inc timer
0035 0008          00105         return
```

```
0036                    00106 IncSecondLsd
0036 0E11               00107         swapf     LsdTime, W      ;get hi in low nibble
0037 390F               00108         andlw     0x0F            ;mask hi nibble
0038 3E01               00109         addlw     1               ;inc it
0039 0091               00110         movwf     LsdTime         ;restore back
003A 0E91               00111         swapf     LsdTime, F      ;       /
003B 3A0A               00112         xorlw     0x0a            ; = 10?
003C 1903               00113         btfsc     STATUS, Z       ;no then skip
003D 283F               00114         goto      IncThirdLsd     ;else inc next lsd
003E 0008               00115         return
003F                    00116 IncThirdLsd
003F 0191               00117         clrf      LsdTime
0040 0A10               00118         incf      MsdTime, W      ;get 3rd lsd
0041 390F               00119         andlw     0x0F            ;mask hi nibble
0042 3A0A               00120         xorlw     0x0a            ;= 10?
0043 1903               00121         btfsc     STATUS, Z       ;no then skip
0044 2847               00122         goto      IncMsd          ;else Msd
0045 0A90               00123         incf      MsdTime, F      ;else inc timer
0046 0008               00124         return
0047                    00125 IncMsd
0047 0E10               00126         swapf     MsdTime, W      ;get hi in lo nibble
0048 390F               00127         andlw     0x0F            ;mask hi nibble
0049 3E01               00128         addlw     1               ;inc timer
004A 0090               00129         movwf     MsdTime         ;restore back
004B 0E90               00130         swapf     MsdTime, F      ;       /
004C 3A0A               00131         xorlw     0x0a            ;= 10?
004D 1903               00132         btfsc     STATUS, Z       ;no then skip
004E 0190               00133         clrf      MsdTime         ;clr msd
004F 0008               00134         return
                        00135 ;
                        00136 ;
0050                    00137 UpdateDisplay
0050 0805               00138         movf      PORTA, W        ;present sink value in w
0051 0185               00139         clrf      PORTA           ;disable all digits sinks
0052 390F               00140         andlw     0x0f
0053 008C               00141         movwf     TempC           ;save sink value in tempC
0054 160C               00142         bsf       TempC, 4        ;preset for lsd sink
0055 0C8C               00143         rrf       TempC, F        ;determine next sink value
0056 1C03               00144         btfss     STATUS, C       ;c=1?
0057 118C               00145         bcf       TempC, 3        ;no then reset LSD sink
0058 180C               00146         btfsc     TempC, 0        ;else see if Msd
0059 286B               00147         goto      UpdateMsd       ;yes then do Msd
005A 188C               00148         btfsc     TempC, 1        ;see if 3rdLsd
005B 2866               00149         goto      Update3rdLsd    ;yes then do 3rd Lsd
005C 190C               00150         btfsc     TempC, 2        ;see if 2nd Lsd
005D 2861               00151         goto      Update2ndLsd    ;yes then do 2nd lsd
005E                    00152 UpdateLsd
005E 0811               00153         movf      LsdTime, W      ;get Lsd in w
005F 390F               00154         andlw     0x0f            ;       /
0060 286F               00155         goto      DisplayOut      ;enable display
0061                    00156 Update2ndLsd
0061 2080               00157         call      Chk2LsdZero     ;msd = 0 & 2 lsd 0?
0062 1D03               00158         btfss     STATUS, Z       ;yes then skip
0063 0E11               00159         swapf     LsdTime, W      ;get 2nd Lsd in w
0064 390F               00160         andlw     0x0f            ;mask rest
0065 286F               00161         goto      DisplayOut      ;enable display
0066                    00162 Update3rdLsd
0066 2088               00163         call      ChkMsdZero      ;msd = 0?
0067 1D03               00164         btfss     STATUS, Z       ;yes then skip
0068 0810               00165         movf      MsdTime, W      ;get 3rd Lsd in w
0069 390F               00166         andlw     0x0f            ;mask low nibble
006A 286F               00167         goto      DisplayOut      ;enable display
```

```
006B                00168 UpdateMsd
006B 0E10           00169         swapf     MsdTime, W       ;get Msd in w
006C 390F           00170         andlw     0x0f             ;mask rest
006D 1903           00171         btfsc     STATUS, Z        ;msd != 0 then skip
006E 300A           00172         movlw     0x0a
006F                00173 DisplayOut
006F 2074           00174         call      LedTable         ;get digit output
0070 0086           00175         movwf     PORTB            ;drive leds
0071 080C           00176         movf      TempC, W         ;get sink value in w
0072 0085           00177         movwf     PORTA
0073 0008           00178         return
                    00179 ;
                    00180 ;
0074                00181 LedTable
0074 0782           00182         addwf     PCL, F           ;add to PC low
0075 343F           00183         retlw     B'00111111'      ;led drive for 0
0076 3406           00184         retlw     B'00000110'      ;led drive for 1
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
```

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
                  00111 ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                  00112 ;end result is that we get a TMR0 interrupt every 5mS.
002A              00113 InitTimers
```

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

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, R P0         ;select Bank0
0031 3020          00115            movlw   B'00100000'          ;enable TMR0 interrupt
0032 008B          00116            movwf   INTCON               ;
0033 3060          00117            movlw   .96                  ;preload TMR0
0034 0081          00118            movwf   TMR0                 ;start counter
0035 0009          00119            retfie
                   00120 ;
                   00121 ;
0036               00122 InitAd
0036 30C0          00123            movlw   B'11000000'          ;rc osc, ch 0 for a/d
0037 0088          00124            movwf   ADCON0
0038 0008          00125            return
                   00126 ;
                   00127 ;
0039               00128 ServiceInterrupts
0039 190B          00129            btfsc   INTCON, T0IF         ;TMR0 interrupt?
003A 283E          00130            goto    ServiceTMR0          ;yes then service
003B 018B          00131            clrf    INTCON
003C 168B          00132            bsf     INTCON, T0IE
003D 0008          00133            return
                   00134 ;
003E               00135 ServiceTMR0
003E 3060          00136            movlw   .96                  ;initialize TMR0
003F 0081          00137            movwf   TMR0
0040 110B          00138            bcf     INTCON, T0IF         ;clr int flag
0041 1C05          00139            btfss   PORTA, 0             ;last digit?
0042 2045          00140            call    SampleAd             ;then sample a/d
0043 2071          00141            call    UpdateDisplay        ;else update display
0044 0008          00142            return
                   00143 ;
                   00144 ;
0045               00145 SampleAd
0045 205A          00146            call    SavePorts
0046 204C          00147            call    DoAd                 ;do a ad conversion
0047               00148 AdDone
0047 1908          00149            btfsc   ADCON0, GO           ;ad done?
0048 2847          00150            goto    AdDone               ;no then loop
0049 1692          00151            bsf     ADFlag, ADOver       ;set a/d over flag
004A 2067          00152            call    RestorePorts         ;restore ports
004B 0008          00153            return
                   00154 ;
                   00155 ;
004C               00156 DoAd
004C 0186          00157            clrf    PORTB                ;turn off leds
004D 1683          00158            bsf     STATUS, RP0          ;select Bank1
004E 300F          00159            movlw   0x0f                 ;make port a hi-Z
004F 0085          00160            movwf   TRISA                ;       /
0050 1283          00161            bcf     STATUS, RP0          ;select Bank0
0051 1408          00162            bsf     ADCON0, ADON         ;start a/d
0052 307D          00163            movlw   .125
0053 2056          00164            call    Wait
0054 1508          00165            bsf     ADCON0, GO           ;start conversion
0055 0008          00166            return
                   00167 ;
                   00168 ;
0056               00169 Wait
0056 008C          00170            movwf   TempC                ;store in temp
0057               00171 Next
0057 0B8C          00172            decfsz  TempC, F
0058 2857          00173            goto    Next
0059 0008          00174            return
                   00175
                   00176 ;
                   00177 ;SavePorts, saves the porta and portb condition during a key scan
                   00178 ;operation.
005A               00179 SavePorts
```

```
005A 0805          00180            movf    PORTA, W            ;Get sink value
005B 00A0          00181            movwf   PABuf               ;save in buffer
005C 0185          00182            clrf    PORTA               ;disable all sinks
005D 0806          00183            movf    PORTB, W            ;get port b
005E 00A1          00184            movwf   PBBuf               ;save in buffer
005F 30FF          00185            movlw   0xff                ;make all high
0060 0086          00186            movwf   PORTB               ;on port b
0061 1683          00187            bsf     STATUS, RP0         ;select Bank1
0062 1381          00188            bcf     OptionReg, 7        ;enable pull ups
0063 30F0          00189            movlw   B'11110000'         ;port b hi nibble inputs
0064 0086          00190            movwf   TRISB               ;lo nibble outputs
0065 1283          00191            bcf     STATUS, RP0         ;Bank0
0066 0008          00192            return
                   00193 ;
                   00194 ;RestorePorts, restores the condition of porta and portb after a
                   00195 ;key scan operation.
0067               00196 RestorePorts
0067 0821          00197            movf    PBBuf, W            ;get port n
0068 0086          00198            movwf   PORTB
0069 0820          00199            movf    PABuf, W            ;get port a value
006A 0085          00200            movwf   PORTA
006B 1683          00201            bsf     STATUS, RP0         ;select Bank1
006C 1781          00202            bsf     OptionReg, 7        ;disable pull ups
006D 0185          00203            clrf    TRISA               ;make port a outputs
006E 0186          00204            clrf    TRISB               ;as well as PORTB
006F 1283          00205            bcf     STATUS, RP0         ;Bank0
0070 0008          00206            return
                   00207 ;
                   00208 ;
0071               00209 UpdateDisplay
0071 0805          00210            movf    PORTA, W            ;present sink value in w
0072 0185          00211            clrf    PORTA               ;disable all digits sinks
0073 390F          00212            andlw   0x0f
0074 008C          00213            movwf   TempC               ;save sink value in tempC
0075 160C          00214            bsf     TempC, 4            ;preset for lsd sink
0076 0C8C          00215            rrf     TempC, F            ;determine next sink value
0077 1C03          00216            btfss   STATUS, C           ;c=1?
0078 118C          00217            bcf     TempC, 3            ;no then reset LSD sink
0079 180C          00218            btfsc   TempC, 0            ;else see if Msd
007A 288C          00219            goto    UpdateMsd           ;yes then do Msd
007B 188C          00220            btfsc   TempC, 1            ;see if 3rdLsd
007C 2887          00221            goto    Update3rdLsd        ;yes then do 3rd Lsd
007D 190C          00222            btfsc   TempC, 2            ;see if 2nd Lsd
007E 2882          00223            goto    Update2ndLsd        ;yes then do 2nd lsd
007F               00224 UpdateLsd
007F 0811          00225            movf    LsdTime, W          ;get Lsd in w
0080 390F          00226            andlw   0x0f                ;       /
0081 2890          00227            goto    DisplayOut          ;enable display
0082               00228 Update2ndLsd
0082 20A1          00229            call    Chk2LsdZero         ;msd = 0 & 2 lsd 0?
0083 1D03          00230            btfss   STATUS, Z           ;yes then skip
0084 0E11          00231            swapf   LsdTime, W          ;get 2nd Lsd in w
0085 390F          00232            andlw   0x0f                ;mask rest
0086 2890          00233            goto    DisplayOut          ;enable display
0087               00234 Update3rdLsd
0087 20A9          00235            call    ChkMsdZero          ;msd = 0?
0088 1D03          00236            btfss   STATUS, Z           ;yes then skip
0089 0810          00237            movf    MsdTime, W          ;get 3rd Lsd in w
008A 390F          00238            andlw   0x0f                ;mask low nibble
008B 2890          00239            goto    DisplayOut          ;enable display
008C               00240 UpdateMsd
008C 0E10          00241            swapf   MsdTime, W          ;get Msd in w
008D 390F          00242            andlw   0x0f                ;mask rest
008E 1903          00243            btfsc   STATUS, Z           ;msd != 0 then skip
008F 300A          00244            movlw   0x0a
```

```
0090                00245 DisplayOut
0090 2095           00246             call    LedTable            ;get digit output
0091 0086           00247             movwf   PORTB               ;drive leds
0092 080C           00248             movf    TempC, W            ;get sink value in w
0093 0085           00249             movwf   PORTA
0094 0008           00250             return
                    00251 ;
                    00252 ;
0095                00253 LedTable
0095 0782           00254             addwf   PCL, F              ;add to PC low
0096 343F           00255             retlw   B'00111111'         ;led drive for 0
0097 3406           00256             retlw   B'00000110'         ;led drive for 1
0098 345B           00257             retlw   B'01011011'         ;led drive for 2
0099 344F           00258             retlw   B'01001111'         ;led drive for 3
009A 3466           00259             retlw   B'01100110'         ;led drive for 4
009B 346D           00260             retlw   B'01101101'         ;led drive for 5
009C 347D           00261             retlw   B'01111101'         ;led drive for 6
009D 3407           00262             retlw   B'00000111'         ;led drive for 7
009E 347F           00263             retlw   B'01111111'         ;led drive for 8
009F 3467           00264             retlw   B'01100111'         ;led drive for 9
00A0 3400           00265             retlw   B'00000000'         ;blank led drive
                    00266 ;
                    00267 ;
00A1                00268 Chk2LsdZero
00A1 20A9           00269             call    ChkMsdZero          ;msd = 0?
00A2 1D03           00270             btfss   STATUS, Z           ;yes then skip
00A3 0008           00271             return                      ;else return
00A4 0E11           00272             swapf   LsdTime, W          ;get 2nd lsd
00A5 390F           00273             andlw   0x0f                ;mask of LSD
00A6 1D03           00274             btfss   STATUS, Z           ;0? then skip
00A7 0008           00275             return
00A8 340A           00276             retlw   .10                 ;else return with 10
                    00277 ;
00A9                00278 ChkMsdZero
00A9 0810           00279             movf    MsdTime, W          ;get Msd in w
00AA 1D03           00280             btfss   STATUS, Z           ;= 0? skip
00AB 0008           00281             return                      ;else return
00AC 340A           00282             retlw   .10                 ;ret with 10
                    00283 ;
                    00284 ;
                    00285 ;
  00000026          00286 count       equ      26
  00000027          00287 temp        equ      27
                    00288 ;
  00000020          00289 H_byte      equ     20
  00000021          00290 L_byte      equ     21
  00000022          00291 R0          equ     22                ; RAM Assignments
  00000023          00292 R1          equ     23
  00000024          00293 R2          equ     24
                    00294 ;
                    00295 ;
00AD 1003           00296 B2_BCD      bcf     STATUS, 0         ; clear the carry bit
00AE 3010           00297             movlw   .16
00AF 00A6           00298             movwf   count
00B0 01A2           00299             clrf    R0
00B1 01A3           00300             clrf    R1
00B2 01A4           00301             clrf    R2
00B3 0DA1           00302 loop16      rlf     L_byte, F
00B4 0DA0           00303             rlf     H_byte, F
00B5 0DA4           00304             rlf     R2, F
00B6 0DA3           00305             rlf     R1, F
00B7 0DA2           00306             rlf     R0, F
                    00307 ;
00B8 0BA6           00308             decfsz  count, F
00B9 28BB           00309             goto    adjDEC
00BA 3400           00310             RETLW   0
```

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

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

0000 : X---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
```

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         00111             call      B2_BCD
0023 0824         00112             movf      R2, W             ;get LSd
0024 0091         00113             movwf     LsdTime           ;save in LSD
0025 0823         00114             movf      R1, W             ;get Msd
```

```
0026 0090           00115            movwf   MsdTime             ;save in Msd
0027 0008           00116            return
                    00117 ;
                    00118 ;This routine essentially loads the ADRES value in the table location
                    00119 ;determined by the channel offset. If channel 0 then ADRES is saved
                    00120 ;in location ADTABLE. If channel 1 then ADRES is saved at ADTABLE + 1.
                    00121 ;and so on.
0028                00122 ServiceAD
0028 0808           00123            movf    ADCON0, W           ;get adcon0
0029 008C           00124            movwf   TempC               ;save in temp
002A 3008           00125            movlw   B'00001000'         ;select next channel
002B 0708           00126            addwf   ADCON0, W           ;       /
002C 1A88           00127            btfsc   ADCON0, 5           ;if <= ch3
002D 30C1           00128            movlw   B'11000001'         ;select ch0
002E 0088           00129            movwf   ADCON0
                    00130 ;now load adres in the table
002F 3016           00131            movlw   ADTABLE
0030 0084           00132            movwf   FSR                 ;load FSR with top
0031 0C8C           00133            rrf     TempC, F
0032 0C8C           00134            rrf     TempC, F
0033 0C0C           00135            rrf     TempC, W            ;get in w reg
0034 3903           00136            andlw   3                   ;mask off all but last 2
0035 0784           00137            addwf   FSR, F              ;add offset to table
0036 0809           00138            movf    ADRES, W            ;get a/d value
0037 0080           00139            movwf   0                   ;load indirectly
0038 1212           00140            bcf     ADOver              ;clear flag
0039 201C           00141            call    LoadAD              ;load a/d value in display reg.
003A 0008           00142            return
                    00143
                    00144
                    00145
                    00146 ;
003B                00147 InitPorts
003B 1683           00148            bsf     STATUS, RP0         ;select Bank1
003C 3003           00149            movlw   3                   ;make RA0-3 digital I/O
003D 0088           00150            movwf   ADCON1              ;       /
003E 0185           00151            clrf    TRISA               ;make RA0-4 outputs
003F 0186           00152            clrf    TRISB               ;make RB0-7 outputs
0040 1283           00153            bcf     STATUS, RP0         ;select Bank0
0041 0185           00154            clrf    PORTA               ;make all outputs low
0042 0186           00155            clrf    PORTB               ;       /
0043 1585           00156            bsf     PORTA, 3            ;enable MSB digit sink
0044 0008           00157            return
                    00158 ;
                    00159 ;
                    00160 ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                    00161 ;the TMR0 will be incremented every 31.25uS. If TMR0 is preloaded
                    00162 ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                    00163 ;end result is that we get a TMR0 interrupt every 5mS.
0045                00164 InitTimers
0045 0190           00165            clrf    MsdTime             ;clr timers
0046 0191           00166            clrf    LsdTime             ;       /
0047 0195           00167            clrf    DisplayCh           ;show channel 0
0048 0192           00168            clrf    Flag                ;clr all flags
0049 1683           00169            bsf     STATUS, RP0         ;select Bank1
004A 3084           00170            movlw   B'10000100'         ;assign ps to TMR0
004B 0081           00171            movwf   OptionReg           ;ps = 32
004C 1283           00172            bcf     STATUS, RP0         ;select Bank0
004D 3020           00173            movlw   B'00100000'         ;enable TMR0 interrupt
004E 008B           00174            movwf   INTCON              ;
004F 3060           00175            movlw   .96                 ;preload TMR0
0050 0081           00176            movwf   TMR0                ;start counter
0051 0009           00177            retfie
                    00178 ;
```

```
0052                00179 ServiceInterrupts
0052 190B           00180             btfsc   INTCON, T0IF        ;TMR0 interrupt?
0053 2857           00181             goto    ServiceTMR0         ;yes then service
0054 018B           00182             clrf    INTCON              ;else clr all int
0055 168B           00183             bsf     INTCON, T0IE
0056 0008           00184             return
                    00185 ;
0057                00186 ServiceTMR0
0057 3060           00187             movlw   .96                 ;initialize TMR0
0058 0081           00188             movwf   TMR0
0059 110B           00189             bcf     INTCON, T0IF        ;clr int flag
005A 1805           00190             btfsc   PORTA, 0            ;scan keys every 20 mS
005B 2060           00191             call    ScanKeys            ;when digit 1 is on
005C 1985           00192             btfsc   PORTA, 3            ;scan a/d every 20mS
005D 20F1           00193             call    SampleAd            ;when digit 4 is on
005E 20BF           00194             call    UpdateDisplay       ;update display
005F 0008           00195             return
                    00196 ;
                    00197 ;
                    00198 ;ScanKeys, scans the 4x4 keypad matrix and returns a key value in
                    00199 ;NewKey (0 - F) if a key is pressed, if not it clears the keyhit flag.
                    00200 ;Debounce for a given keyhit is also taken care of.
                    00201 ;The rate of key scan is 20mS with a 4.096Mhz clock.
0060                00202 ScanKeys
0060 1C92           00203             btfss   DebnceOn            ;debounce on?
0061 2866           00204             goto    Scan1               ;no then scan keypad
0062 0B93           00205             decfsz  Debnce, F           ;else dec debounce time
0063 0008           00206             return                      ;not over then return
0064 1092           00207             bcf     DebnceOn            ;over, clr debounce flag
0065 0008           00208             return                      ;and return
0066                00209 Scan1
0066 20A8           00210             call    SavePorts           ;save port values
0067 30EF           00211             movlw   B'11101111'         ;init TempD
0068 008D           00212             movwf   TempD
0069                00213 ScanNext
0069 0806           00214             movf    PORTB, W            ;read to init port
006A 100B           00215             bcf     INTCON, RBIF        ;clr flag
006B 0C8D           00216             rrf     TempD, F            ;get correct column
006C 1C03           00217             btfss   STATUS, C           ;if carry set?
006D 2880           00218             goto    NoKey               ;no then end
006E 080D           00219             movf    TempD, W            ;else output
006F 0086           00220             movwf   PORTB               ;low column scan line
0070 0000           00221             nop
0071 1C0B           00222             btfss   INTCON, RBIF        ;flag set?
0072 2869           00223             goto    ScanNext            ;no then next
0073 1812           00224             btfsc   keyhit              ;last key released?
0074 287E           00225             goto    SKreturn            ;no then exit
0075 1412           00226             bsf     keyhit              ;set new key hit
0076 0E06           00227             swapf   PORTB,W             ;read port
0077 008E           00228             movwf   TempE               ;save in TempE
0078 2082           00229             call    GetKeyValue         ;get key value 0 - F
0079 0094           00230             movwf   NewKey              ;save as New key
007A 1592           00231             bsf     ServKey             ;set service flag
007B 1492           00232             bsf     DebnceOn            ;set flag
007C 3004           00233             movlw   4
007D 0093           00234             movwf   Debnce              ;load debounce time
007E                00235 SKreturn
007E 20B5           00236             call    RestorePorts        ;restore ports
007F 0008           00237             return
                    00238 ;
0080                00239 NoKey
0080 1012           00240             bcf     keyhit              ;clr flag
0081 287E           00241             goto    SKreturn
                    00242 ;
                    00243 ;GetKeyValue gets the key as per the following layout
                    00244 ;
```

```
                    00245 ;                 Col1    Col2    Col3    Col4
                    00246 ;                 (RB3)   (RB2)   (RB1)   (RB0)
                    00247 ;
                    00248 ;Row1(RB4)          0       1       2       3
                    00249 ;
                    00250 ;Row2(RB5)          4       5       6       7
                    00251 ;
                    00252 ;Row3(RB6)          8       9       A       B
                    00253 ;
                    00254 ;Row4(RB7)          C       D       E       F
                    00255 ;
0082                00256 GetKeyValue
0082 018C           00257           clrf    TempC
0083 1D8D           00258           btfss   TempD, 3            ;first column
0084 288C           00259           goto    RowValEnd
0085 0A8C           00260           incf    TempC, F
0086 1D0D           00261           btfss   TempD, 2            ;second col.
0087 288C           00262           goto    RowValEnd
0088 0A8C           00263           incf    TempC, F
0089 1C8D           00264           btfss   TempD, 1            ;3rd col.
008A 288C           00265           goto    RowValEnd
008B 0A8C           00266           incf    TempC, F            ;last col.
008C                00267 RowValEnd
008C 1C0E           00268           btfss   TempE, 0            ;top row?
008D 2896           00269           goto    GetValCom           ;yes then get 0,1,2&3
008E 1C8E           00270           btfss   TempE, 1            ;2nd row?
008F 2895           00271           goto    Get4567             ;yes the get 4,5,6&7
0090 1D0E           00272           btfss   TempE, 2            ;3rd row?
0091 2893           00273           goto    Get89ab             ;yes then get 8,9,a&b
0092                00274 Getcdef
0092 150C           00275           bsf     TempC, 2            ;set msb bits
0093                00276 Get89ab
0093 158C           00277           bsf     TempC, 3            ;       /
0094 2896           00278           goto    GetValCom           ;do common part
0095                00279 Get4567
0095 150C           00280           bsf     TempC, 2
0096                00281 GetValCom
0096 080C           00282           movf    TempC, W
0097 0782           00283           addwf   PCL, F
0098 3400           00284           retlw   0
0099 3401           00285           retlw   1
009A 3402           00286           retlw   2
009B 3403           00287           retlw   3
009C 3404           00288           retlw   4
009D 3405           00289           retlw   5
009E 3406           00290           retlw   6
009F 3407           00291           retlw   7
00A0 3408           00292           retlw   8
00A1 3409           00293           retlw   9
00A2 340A           00294           retlw   0a
00A3 340B           00295           retlw   0b
00A4 340C           00296           retlw   0c
00A5 340D           00297           retlw   0d
00A6 340E           00298           retlw   0e
00A7 340F           00299           retlw   0f
                    00300 ;
                    00301 ;SavePorts, saves the porta and portb condition during a key scan
                    00302 ;operation.
00A8                00303 SavePorts
00A8 0805           00304           movf    PORTA, W            ;Get sink value
00A9 00A0           00305           movwf   PABuf               ;save in buffer
00AA 0185           00306           clrf    PORTA               ;disable all sinks
00AB 0806           00307           movf    PORTB, W            ;get port b
00AC 00A1           00308           movwf   PBBuf               ;save in buffer
00AD 30FF           00309           movlw   0xff                ;make all high
00AE 0086           00310           movwf   PORTB               ;on port b
```

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