AN557

Four Channel Digital Voltmeter with Display and Keyboard

INTRODUCTION

The PIC16C71 is a member of a new family of 8-bit microcontrollers, namely the PIC16CXX. 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. To make this application note easier for the end user, it has been broken down into four sub-sections:

Section 1:	Implements the multiplexing of four 7 segment LEDs with the PIC16C71.
Section 2:	Implements the multiplexing of four 7 segment LEDs as well as the sampling of a 4x4 Keypad.
Section 3:	Implements the multiplexing of four 7 segment LEDs as well as the sampling of one A/D channel.
Section 4:	Implements the multiplexing of four 7 segment LEDs, sampling a 4x4 keypad and four A/D channels.

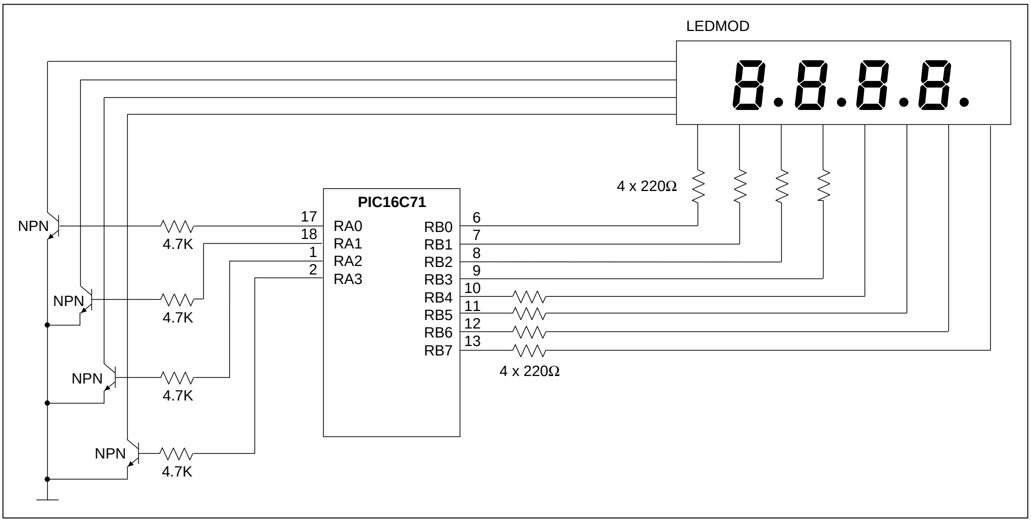
IMPLEMENTATION

SECTION 1: MULTIPLEXING FOUR 7 SEGMENT LED DISPLAYS

Hardware

The PIC16C71's I/O ports have an improved sink/source specification. Each I/O pin can sink up to 25 mA and source 20 mA, in addition total Port B source current is 100 mA and sink current is 150 mA. Port A is rated for 50 mA source current and 80 mA sink current. This makes the PIC16C71 ideal for driving 7 segment LEDs. Since the total number of I/O is limited to 13, the 8-bit Port B is used to drive the 8 LEDs, while external sink transistors or MOSFETs are used to sink the digit current (See Figure 1). Another alternative is to use ULN2003 open collector sink current drivers, which are available in 16 pin DIP or very small S0-16 packages. Each transistor on the ULN2003 can sink a maximum of 500 mA and the base drive can be directly driven from the Port A pins.

FIGURE 1 - MULTIPLEXING FOUR 7 SEGMENT LEDS



Software

The multiplexing is achieved by turning on each LED for a 5 msec duration every 20 µs. This gives an update rate of 50 Hz, which is quite exceptable to the human eye as a steady display. The 5 msec 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 the RTCC. The RTCC is pre-loaded with a value = 96. The RTCC will increment to FF and then roll over to 00 after a period = (256-96)*(32*4/4096000) = 5 µs. When the RTCC rolls over, the RTIF flag is set and since the RTIE and GIE bits are enabled, an interrupt is generated.

The software implements a simple timer which increments at a 1 second rate. Every second, the 4 nibble (two 8-bit registers MsdTime and LsdTime) are incremented in a BCD format. The lower 4 bits of LsdTime correspond to the least significant digit (LSD) on the display. The high 4 bits of LsdTime correspond to the second significant digit of the display and so on. Depending on which display is turned on, the corresponding 4 bit BCD value is extracted from either MsdTime or LsdTime, and decoded to a 7 segment display. The RTCC interrupt is generated at a steady rate of 5 µs and given an instruction time of 1 us. 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 Section 1 is in Appendix A.

SECTION 2: MULTIPLEXING FOUR 7 SEGMENT LED DISPLAYS AND SCANNING A 4X4 KEYPAD

Hardware

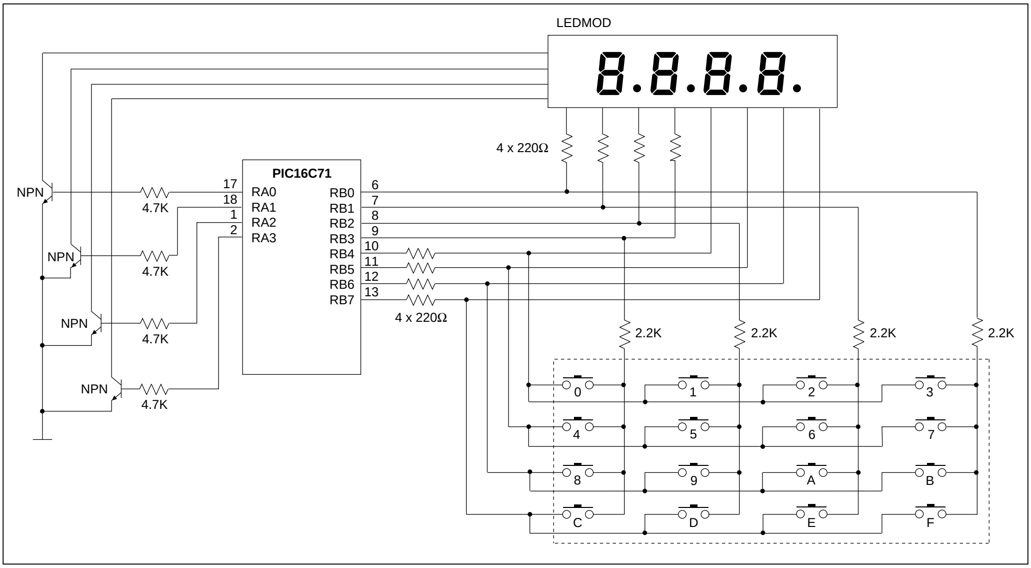
A 4x4 keypad can be very easily interfaced to the PIC16C71's Port B (see Figure 2). Internal pull-ups on pins RB4 to RB7 can be enabled and disabled by setting the RBPU bit in the OPTION register. The internal pull-ups have a value of 20K at 5V (typical). In order to sense a low level at the input, the switch is "connected" to ground through a 2.2K resistor. A key hit normally lasts from 50 msec to as long as a person holds the key down. In order not to miss any key hits, the keypad is sampled every 20 µs (just after the update of the MSD).

Software

To sample the keypad, the digit sinks are first disabled. Port B is then configured with RB4-RB7 as inputs and RB0 -RB3 as outputs driven high. The pull-ups on RB4-RB7 are enabled. Sequentially RB0 to RB3 are made low while RB4 to RB7 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 msec 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 Section 2 is in Appendix B.

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



SECTION 3: MULTIPLEXING FOUR 7 SEGMENT LED DISPLAYS AND THE A/D CHANNEL 0

Hardware

The four analog channels are connected to RA0-RA3. 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 3A and 3B 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 msec. The digit sinks and the drivers are turned off i.e. Port A is configured as an input and Port B outputs are made low. A 1msec 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 BCD value which is then displayed on the 7 Segment LEDs. The Code Listing for Section 3 is in Appendix C.

FIGURE 3A - TYPICAL CONNECTION FOR ANALOG/DIGITAL INPUT

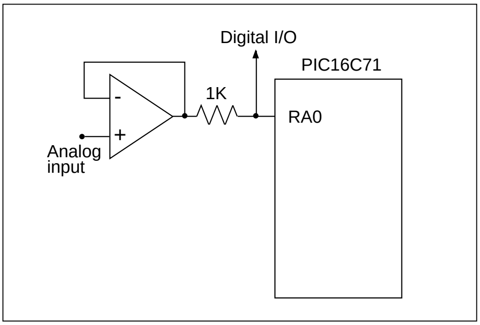
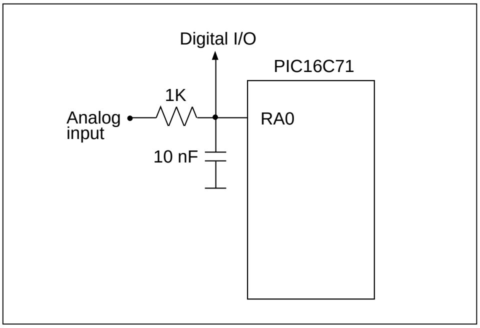


FIGURE 3B - TYPICAL CONNECTION FOR ANALOG/DIGITAL INPUT



SECTION 4: MULTIPLEXING FOUR 7 SEGMENT LED DISPLAYS WITH A 4X4 KEYPAD AND 4 A/D CHANNELS

Hardware

This section essentially incorporated Sections 1, 2 and 3 to give a complete four channel voltmeter. Figure 4 shows a typical configuration. The analog channels are connected through individual potentiometers to their respective analog inputs and are sampled every 20 msec in a round robin format. The sampling rate can be increased to as fast as once every 5 µs if required. The keypad sampling need not be any faster than once every 20 µs.

Software

The program samples the analog inputs and saves the result in four consecutive locations starting at "ADVALUE", with channel 0 saved at the first location and so on. By default, channel 0 is displayed. If Key 1 is pressed, channel 1 is displayed and so on. Key hits > 3 are ignored. The Code Listing for Section 4 is in Appendix D.

Code Size

Section 1:	Program Memory:	139
	Data Memory:	6
Section 2:	Program Memory:	207
	Data Memory:	13
Section 3:	Program Memory:	207
	Data Memory:	17
Section 4:	Program Memory:	
	Data Memory:	

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.

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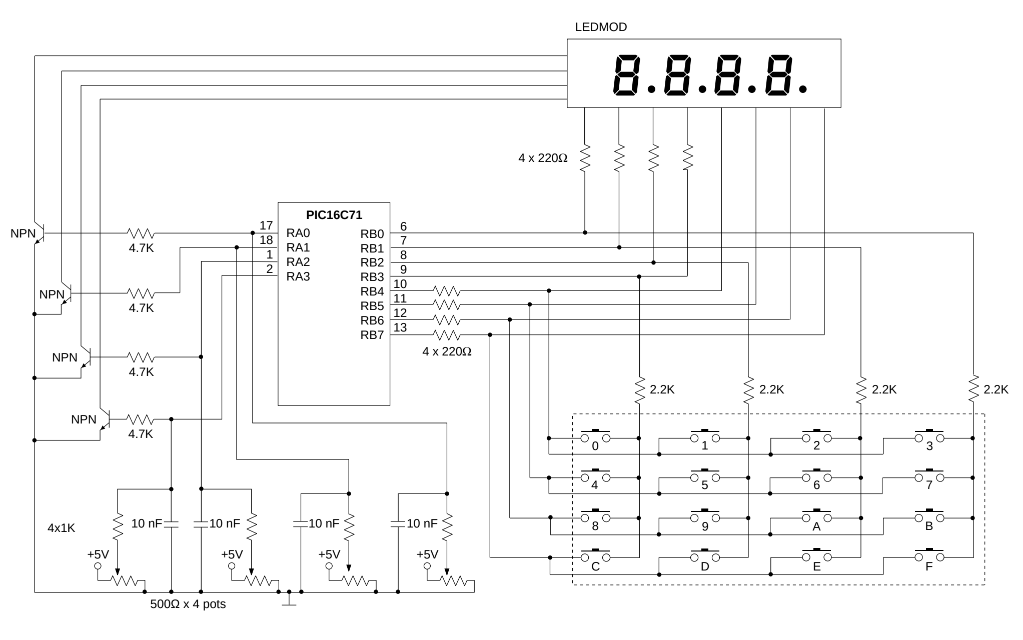
FIGURE 4 - FOUR CHANNEL VOLTMETER WITH DISPLAY AND KEYPAD



APPENDIX A

```
MPASM B0.50                                                             PAGE  1



                      ;**********************************************************************
                      ;This program is to demonstrate how to multiplex four 7 segment LED
                      ;digits using a PIC16C71. The four digits will start at 0000 and
                      ;increment at a 1 sec rate up to 9999.
                      ;The LEDs are updated every 5 msec, for a multiplexing rate of 20 msec.
                      ;The RTCC timer is used in internal interrupt mode to generate the 5 msec.
                      ;
                      ;                                       Stan D'Souza 5/8/93
                      ;**********************************************************************
                             LIST P=16C71, F=INHX8M
                      ;
                             include "picreg.equ"



                      ;
000C                  TempC          equ    0x0c           ;temp general purpose regs
000D                  TempD          equ    0x0d
000E                  TempE          equ    0x0e
000F                  Count          equ    0x0f           ;count
0010                  MsdTime        equ    0x10           ;most significant Timer
0011                  LsdTime        equ    0x11           ;Least significant Timer
0001                  OptionReg      equ    1
0002                  PCL            equ    2
0026                  BcdMsd         equ    26
0027                  Bcd            equ    27
                      ;
                                     org    0
0000 2805                            goto   Start          ;skip over interrupt vector
                      ;
                                     org    4
0004 281D                            goto   ServiceInterrupts
                      ;
                      Start
0005 2008                            call   InitPorts
0006 2012                            call   InitTimers
                      loop
0007 2807                            goto   loop
                      ;
                      InitPorts
0008 1683                            bsf    STATUS,RP0     ;select pg 1
0009 3003                            movlw  3              ;make RA0-3 digital I/O
000A 0108                            movwf  ADCON1         ;       /
000B 0205                            clrf   TRISA          ;make RA0-4 outputs
000C 0206                            clrf   TRISB          ;make RB0-7 outputs
000D 1283                            bcf    STATUS,RP0     ;select page 0
000E 0185                            clrf   PORT_A         ;make all outputs low
000F 0186                            clrf   PORT_B         ;       /
0010 1585                            bsf    PORT_A,3       ;enable MSB digit sink
0011 0008                            return
                      ;
                      ;
                      ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                      ;the rtcc will be incremented every 31.25uS. If rtcc is preloaded
                      ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5msec. So the
                      ;end result is that we get a rtcc interrupt every 5msec.
                      InitTimers
0012 0190                            clrf   MsdTime        ;clr timers
0013 0191                            clrf   LsdTime        ;       /
0014 1683                            bsf    STATUS,RP0     ;select pg 1
0015 3084                            movlw  B'10000100'    ;assign ps to rtcc
```

```
0016 0081                    movwf  OptionReg              ;ps = 32
0017 1283                    bcf    STATUS,RP0             ;select pg 0
0018 3020                    movlw  B'00100000'            ;enable rtcc interrupt
0019 008B                    movwf  INTCON                 ;
001A 3060                    movlw  .96                    ;preload rtcc
001B 0081                    movwf  RTCC                   ;start counter
001C 0009                    retfie
                      ;
                      ServiceInterrupts
001D 190B                    btfsc  INTCON,RTIF            ;rtcc interrupt?
001E 2822                    goto   ServiceRTCC            ;yes then service
001F 3020                    movlw  B'00100000'            ;else clr rest
0020 008B                    movwf  INTCON
0021 0009                    retfie
                      ;
                      ServiceRTCC
0022 3060                    movlw  .96                    ;initialize rtcc
0023 0081                    movwf  RTCC
0024 110B                    bcf    INTCON,RTIF            ;clr int flag
0025 2028                    call   IncTimer               ;inc timer
0026 2050                    call   UpdateDisplay          ;update display
0027 0009                    retfie
                      ;
                      ;The display is incremented every 200*5msec = 1 Sec.
                      IncTimer
0028 0A0F                    incf   Count,w                ;inc count
0029 3AC8                    xorlw  .200                   ;= 200?
002A 1903                    btfsc  STATUS,Z               ;no then skip
002B 282E                    goto   DoIncTime              ;else inc time
002C 0A8F                    incf   Count
002D 0008                    return
                      DoIncTime
002E 018F                    clrf   Count                  ;clr count
002F 0A11                    incf   LsdTime,w              ;get lsd
0030 390F                    andlw  0x0F                   ;mask high nibble
0031 3A0A                    xorlw  0x0a                   ; = 10?
0032 1903                    btfsc  STATUS,Z               ;no then skip
0033 2836                    goto   IncSecondLsd           ;inc next lsd
0034 0A91                    incf   LsdTime                ;else inc timer
0035 0008                    return
                      IncSecondLsd
0036 0E11                    swapf  LsdTime,w              ;get hi in low nibble
0037 390F                    andlw  0x0F                   ;mask hi nibble
0038 3E01                    addlw  1                      ;inc it
0039 0091                    movwf  LsdTime                ;restore back
003A 0E91                    swapf  LsdTime                ;       /
003B 3A0A                    xorlw  0x0a                   ; = 10?
003C 1903                    btfsc  STATUS,Z               ;no then skip
003D 283F                    goto   IncThirdLsd            ;else inc next lsd
003E 0008                    return
                      IncThirdLsd
003F 0191                    clrf   LsdTime
0040 0A10                    incf   MsdTime,w              ;get 3rd lsd
0041 390F                    andlw  0x0F                   ;mask hi nibble
0042 3A0A                    xorlw  0x0a                   ;= 10?
0043 1903                    btfsc  STATUS,Z               ;no then skip
0044 2847                    goto   IncMsd                 ;else Msd
0045 0A90                    incf   MsdTime                ;else inc timer
0046 0008                    return
                      IncMsd
0047 0E10                    swapf  MsdTime,w              ;get hi in lo nibble
0048 390F                    andlw  0x0F                   ;mask hi nibble
0049 3E01                    addlw  1                      ;inc timer
004A 0090                    movwf  MsdTime                ;restore back
004B 0E90                    swapf  MsdTime                ;       /
004C 3A0A                    xorlw  0x0a                   ;= 10?
004D 1903                    btfsc  STATUS,Z               ;no then skip
004E 0190                    clrf   MsdTime                ;clr msd
004F 0008                    return
```

```
                     ;
                     ;
                     UpdateDisplay
0050 0805                    movf   PORT_A,w               ;present sink value in w
0051 0185                    clrf   PORT_A                 ;disable all digits sinks
0052 390F                    andlw  0x0f
0053 008C                    movwf  TempC                  ;save sink value in tempC
0054 160C                    bsf    TempC,4                ;preset for lsd sink
0055 0C8C                    rrf    TempC                  ;determine next sink value
0056 1C03                    btfss  STATUS,CARRY           ;c=1?
0057 118C                    bcf    TempC,3                ;no then reset LSD sink
0058 180C                    btfsc  TempC,0                ;else see if Msd
0059 286B                    goto   UpdateMsd              ;yes then do Msd
005A 188C                    btfsc  TempC,1                ;see if 3rdLsd
005B 2866                    goto   Update3rdLsd           ;yes then do 3rd Lsd
005C 190C                    btfsc  TempC,2                ;see if 2nd Lsd
005D 2861                    goto   Update2ndLsd           ;yes then do 2nd lsd
                     UpdateLsd
005E 0811                    movf   LsdTime,w              ;get Lsd in w
005F 390F                    andlw  0x0f                   ;       /
0060 286F                    goto   DisplayOut             ;enable display
                     Update2ndLsd
0061 2080                    call   Chk2LsdZero            ;msd = 0 & 2 lsd 0?
0062 1D03                    btfss  STATUS,Z               ;yes then skip
0063 0E11                    swapf  LsdTime,w              ;get 2nd Lsd in w
0064 390F                    andlw  0x0f                   ;mask rest
0065 286F                    goto   DisplayOut             ;enable display
                     Update3rdLsd
0066 2088                    call   ChkMsdZero             ;msd = 0?
0067 1D03                    btfss  STATUS,Z               ;yes then skip
0068 0810                    movf   MsdTime,w              ;get 3rd Lsd in w
0069 390F                    andlw  0x0f                   ;mask low nibble
006A 286F                    goto   DisplayOut             ;enable display
                     UpdateMsd
006B 0E10                    swapf  MsdTime,w              ;get Msd in w
006C 390F                    andlw  0x0f                   ;mask rest
006D 1903                    btfsc  STATUS,Z               ;msd != 0 then skip
006E 300A                    movlw  0x0a
                     DisplayOut
006F 2074                    call   LedTable               ;get digit output
0070 0086                    movwf  PORT_B                 ;drive leds
0071 080C                    movf   TempC,w                ;get sink value in w
0072 0085                    movwf  PORT_A
0073 0008                    return
                     ;
                     ;
                     LedTable
0074 0782                    addwf  PCL                    ;add to PC low
0075 343F                    retlw  B'00111111'            ;led drive for 0
0076 3406                    retlw  B'00000110'            ;led drive for 1
0077 345B                    retlw  B'01011011'            ;led drive for 2
0078 344F                    retlw  B'01001111'            ;led drive for 3
0079 3466                    retlw  B'01100110'            ;led drive for 4
007A 346D                    retlw  B'01101101'            ;led drive for 5
007B 347D                    retlw  B'01111101'            ;led drive for 6
007C 3407                    retlw  B'00000111'            ;led drive for 7
007D 347F                    retlw  B'01111111'            ;led drive for 8
007E 3467                    retlw  B'01100111'            ;led drive for 9
007F 3400                    retlw  B'00000000'            ;blank led drive
                     ;
                     ;
                     Chk2LsdZero
0080 2088                    call   ChkMsdZero             ;msd = 0?
0081 1D03                    btfss  STATUS,Z               ;yes then skip
0082 0008                    return                        ;else return
0083 0E11                    swapf  LsdTime,w              ;get 2nd lsd
0084 390F                    andlw  0x0f                   ;mask of LSD
0085 1D03                    btfss  STATUS,Z               ;0? then skip
0086 0008                    return
```

```
0087 340A                      retlw   10                    ;else return with 10
                        ;
                        ChkMsdZero
0088 0810                      movf    MsdTime,w             ;get Msd in w
0089 1D03                      btfss   STATUS,Z              ;= 0? skip
008A 0008                      return                        ;else return
008B 340A                      retlw   .10                   ;ret with 10
                        ;

                               end
                        ;
```

Appendix B

```
MPASM B0.50                                                             PAGE  1

                       ;*********************************************************************
                       ;This program is to demonstrate how to multiplex four 7 segment LED
                       ;digits and a 4X4 keypad using a PIC16C71.
                       ;The four digits will start as ‘0000’ and when a key is hit
                       ;it is displayed on the 7 segment leds as a hex value 0 to F. The last
                       ;digit hit is always displayed on the right most led with the rest of
                       ;the digits shifted to the left. The left most digit is deleted.
                       ;The LEDs are updated every 20msec, the keypad is scanned at a rate of 20
msec.
                       ;The RTCC timer is used in internal interrupt mode to generate the 5 msec.
                       ;
                       ;                                       Stan D’Souza 5/8/93
                       ;**********************************************************************
                              LIST P=16C71, F=INHX8M
                       ;
                              include “picreg.equ”


                       ;
000C                   TempC          equ    0x0c           ;temp general purpose regs
000D                   TempD          equ    0x0d
000E                   TempE          equ    0x0e
0020                   PABuf          equ    0x20
0021                   PBBuf          equ    0x21
000F                   Count          equ    0x0f           ;count
0010                   MsdTime        equ    0x10           ;most significant Timer
0011                   LsdTime        equ    0x11           ;Least significant Timer
0012                   KeyFlag        equ    0x12           ;flags related to key pad
0000                   keyhit         equ    0              ;bit 0 —> key-press on
0001                   DebnceOn       equ    1              ;bit 1 —> debounce on
0002                   noentry        equ    2              ;no key entry = 0
0003                   ServKey        equ    3              ;bit 3 —> service key
0013                   Debnce         equ    0x13           ;debounce counter
0014                   NewKey         equ    0x14
002F                   WBuffer        equ    0x2f
002E                   StatBuffer     equ    0x2e
0001                   OptionReg      equ    1
0002                   PCL            equ    2
                       ;
                       ;
                       push           macro
                                      movwf  WBuffer        ;save w reg in Buffer
                                      swapf  WBuffer        ;swap it
                                      swapf  STATUS,w       ;get status
                                      movwf  StatBuffer     ;save it
                                      endm
                       ;
                       pop            macro
                                      swapf  StatBuffer,w   ;restore status
                                      movwf  STATUS         ;       /
                                      swapf  WBuffer,w      ;restore W reg
                                      endm
                       ;
                                      org    0
0000 280D                             goto   Start          ;skip over interrupt vector
                       ;
                                      org    4
                       ;It is always a good practice to save and restore the w reg,
                       ;and the status reg during a interrupt.
                                      push
0004 00AF                             movwf  WBuffer        ;save w reg in Buffer
0005 0EAF                             swapf  WBuffer        ;swap it
0006 0E03                             swapf  STATUS,w       ;get status
0007 00AE                             movwf  StatBuffer     ;save it
0008 2036                             call   ServiceInterrupts
```

```
                              pop
0009 0E2E                     swapf   StatBuffer,w          ;restore status
000A 0083                     movwf   STATUS                ;       /
000B 0E2F                     swapf   WBuffer,w             ;restore W reg

000C 0009                     retfie
                      ;
                      Start
000D 2020                     call    InitPorts
000E 202A                     call    InitTimers
                      loop
000F 1992                     btfsc   KeyFlag,ServKey       ;key service pending
0010 2012                     call    ServiceKey            ;yes then service
0011 280F                     goto    loop
                      ;
                      ;ServiceKey, does the software service for a keyhit. After a key service,
                      ;the ServKey flag is reset, to denote a completed operation.
                      ServiceKey
0012 0814                     movf    NewKey,w              ;get key value
0013 008E                     movwf   TempE                 ;save in TempE
0014 0E10                     swapf   MsdTime,w             ;move MSD out
0015 39F0                     andlw   B’11110000'           ;clr lo nibble
0016 0090                     movwf   MsdTime               ;save back
0017 0E11                     swapf   LsdTime,w             ;get Lsd
0018 390F                     andlw   B’00001111'           ;mask off lsd
0019 0490                     iorwf   MsdTime               ;and left shift 3rd
001A 0E11                     swapf   LsdTime,w             ;get Lsd again
001B 39F0                     andlw   B’11110000'           ;mask off 2nd
001C 040E                     iorwf   TempE,w               ;or with new lsd
001D 0091                     movwf   LsdTime               ;make Lsd
001E 1192                     bcf     KeyFlag,ServKey       ;reset service flag
001F 0008                     return
                      ;
                      InitPorts
0020 1683                     bsf     STATUS,RP0            ;select pg 1
0021 3003                     movlw   3                     ;make RA0-3 digital I/O
0022 0108                     movwf   ADCON1                ;       /
0023 0205                     clrf    TRISA                 ;make RA0-4 outputs
0024 0206                     clrf    TRISB                 ;make RB0-7 outputs
0025 1283                     bcf     STATUS,RP0            ;select page 0
0026 0185                     clrf    PORT_A                ;make all outputs low
0027 0186                     clrf    PORT_B                ;       /
0028 1585                     bsf     PORT_A,3              ;enable MSB digit sink
0029 0008                     return
                      ;
                      ;
                      ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                      ;the rtcc will be incremented every 31.25uS. If rtcc is preloaded
                      ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5msec. So the
                      ;end result is that we get a rtcc interrupt every 5msec.
                      InitTimers
002A 0190                     clrf    MsdTime               ;clr timers
002B 0191                     clrf    LsdTime               ;       /
002C 0192                     clrf    KeyFlag               ;clr all flags
002D 1683                     bsf     STATUS,RP0            ;select pg 1
002E 3084                     movlw   B’10000100'           ;assign ps to rtcc
002F 0081                     movwf   OptionReg             ;ps = 32
0030 1283                     bcf     STATUS,RP0            ;select pg 0
0031 3020                     movlw   B’00100000'           ;enable rtcc interrupt
0032 008B                     movwf   INTCON                ;
0033 3060                     movlw   .96                   ;preload rtcc
0034 0081                     movwf   RTCC                  ;start counter
0035 0009                     retfie
                      ;
                      ServiceInterrupts
0036 190B                     btfsc   INTCON,RTIF           ;rtcc interrupt?
0037 283B                     goto    ServiceRTCC           ;yes then service
0038 018B                     clrf    INTCON                ;else clr all int
0039 168B                     bsf     INTCON,RTIE
```

```
003A 0008                      return
                       ;
                       ServiceRTCC
003B 3060                      movlw  .96                    ;initialize rtcc
003C 0081                      movwf  RTCC
003D 110B                      bcf    INTCON,RTIF            ;clr int flag
003E 1805                      btfsc  PORT_A,0               ;if msb on then do
003F 2042                      call   ScanKeys               ;do a quick key scan
0040 20A1                      call   UpdateDisplay          ;update display
0041 0008                      return
                       ;
                       ;
                       ;ScanKeys, scans the 4X4 keypad matrix and returns a key value in
                       ;NewKey (0 - F) if a key is pressed, if not it clears the keyhit flag.
                       ;Debounce for a given keyhit is also taken care of.
                       ;The rate of key scan is 20msec with a 4.096Mhz clock.
                       ScanKeys
0042 1C92                      btfss  KeyFlag,DebnceOn       ;debounce on?
0043 2848                      goto   Scan1                  ;no then scan keypad
0044 0B93                      decfsz Debnce                 ;else dec debounce time
0045 0008                      return                        ;not over then return
0046 1092                      bcf    KeyFlag,DebnceOn       ;over, clr debounce flag
0047 0008                      return                        ;and return
                       Scan1
0048 208A                      call   SavePorts              ;save port values
0049 30EF                      movlw  B’11101111'            ;init TempD
004A 008D                      movwf  TempD
                       ScanNext
004B 0806                      movf   PORT_B,w               ;read to init port
004C 100B                      bcf    INTCON,RBIF            ;clr flag
004D 0C8D                      rrf    TempD                  ;get correct column
004E 1C03                      btfss  STATUS,C               ;if carry set?
004F 2862                      goto   NoKey                  ;no then end
0050 080D                      movf   TempD,w                ;else output
0051 0086                      movwf  PORT_B                 ;low column scan line
0052 0000                      nop
0053 1C0B                      btfss  INTCON,RBIF            ;flag set?
0054 284B                      goto   ScanNext               ;no then next
0055 1812                      btfsc  KeyFlag,keyhit         ;last key released?
0056 2860                      goto   SKreturn               ;no then exit
0057 1412                      bsf    KeyFlag,keyhit         ;set new key hit
0058 0E06                      swapf  PORT_B,w               ;read port
0059 008E                      movwf  TempE                  ;save in TempE
005A 2064                      call   GetKeyValue            ;get key value 0 - F
005B 0094                      movwf  NewKey                 ;save as New key
005C 1592                      bsf    KeyFlag,ServKey        ;set service flag
005D 1492                      bsf    KeyFlag,DebnceOn       ;set flag
005E 3004                      movlw  4
005F 0093                      movwf  Debnce                 ;load debounce time
                       SKreturn
0060 2097                      call   RestorePorts           ;restore ports
0061 0008                      return
                       ;
                       NoKey
0062 1012                      bcf    KeyFlag,keyhit         ;clr flag
0063 2860                      goto   SKreturn
                       ;
                       ;GetKeyValue gets the key as per the following layout
                       ;
                       ;                  Col1    Col2    Col3    Col3
                       ;                  (RB3)   (RB2)   (RB1)   (RB0)
                       ;
                       ;Row1(RB4)           0       1       2       3
                       ;
                       ;Row2(RB5)           4       5       6       7
                       ;
                       ;Row3(RB6)           8       9       A       B
                       ;
                       ;Row4(RB7)           C       D       E       F
                       ;
                       GetKeyValue
0064 018C                     clrf    TempC
0065 1D8D                     btfss   TempD,3        ;first column
0066 286E                     goto    RowValEnd
0067 0A8C                     incf    TempC
0068 1D0D                     btfss   TempD,2        ;second col.
0069 286E                     goto    RowValEnd
006A 0A8C                     incf    TempC
006B 1C8D                     btfss   TempD,1        ;3rd col.
006C 286E                     goto    RowValEnd
006D 0A8C                     incf    TempC          ;last col.
                       RowValEnd
006E 1C0E                     btfss   TempE,0        ;top row?
006F 2878                     goto    GetValCom      ;yes then get 0,1,2&3
0070 1C8E                     btfss   TempE,1        ;2nd row?
0071 2877                     goto    Get4567        ;yes the get 4,5,6&7
0072 1D0E                     btfss   TempE,2        ;3rd row?
0073 2875                     goto    Get89ab        ;yes then get 8,9,a&b
                       Getcdef
0074 150C                     bsf     TempC,2        ;set msb bits
                       Get89ab
0075 158C                     bsf     TempC,3        ;       /
0076 2878                     goto    GetValCom      ;do common part
                       Get4567
0077 150C                     bsf     TempC,2
                       GetValCom
0078 080C                     movf    TempC,w
0079 0782                     addwf   PCL
007A 3400                     retlw   0
007B 3401                     retlw   1
007C 3402                     retlw   2
007D 3403                     retlw   3
007E 3404                     retlw   4
007F 3405                     retlw   5
0080 3406                     retlw   6
0081 3407                     retlw   7
0082 3408                     retlw   8
0083 3409                     retlw   9
0084 340A                     retlw   0a
0085 340B                     retlw   0b
0086 340C                     retlw   0c
0087 340D                     retlw   0d
0088 340E                     retlw   0e
0089 340F                     retlw   0f
                       ;
                       ;SavePorts, saves the porta and portb condition during a key scan
                       ;operation.
                       SavePorts
008A 0805                     movf    PORT_A,w       ;Get sink value
008B 00A0                     movwf   PABuf          ;save in buffer
008C 0185                     clrf    PORT_A         ;disable all sinks
008D 0806                     movf    PORT_B,w       ;get port b
008E 00A1                     movwf   PBBuf          ;save in buffer
008F 30FF                     movlw   0xff           ;make all high
0090 0086                     movwf   PORT_B         ;on port b
0091 1683                     bsf     STATUS,RP0     ;select page 1
0092 1381                     bcf     OptionReg,7    ;enable pull ups
0093 30F0                     movlw   B’11110000'    ;port b hi nibble inputs
0094 0106                     movwf   TRISB          ;lo nibble outputs
0095 1283                     bcf     STATUS,RP0     ;page 0
0096 0008                     return
                       ;
                       ;RestorePorts, restores the condition of porta and portb after a
                       ;key scan operation.
                       RestorePorts
0097 0821                     movf    PBBuf,w        ;get port n
0098 0086                     movwf   PORT_B
0099 0820                     movf    PABuf,w        ;get port a value
```

```
009A 0085                     movwf   PORT_A
009B 1683                     bsf     STATUS,RP0     ;select page 1
009C 1781                     bsf     OptionReg,7    ;disable pull ups
009D 0205                     clrf    TRISA          ;make port a outputs
009E 0206                     clrf    TRISB          ;as well as PORTB
009F 1283                     bcf     STATUS,RP0     ;page 0
00A0 0008                     return
                       ;
                       ;
                       UpdateDisplay
00A1 0805                     movf    PORT_A,w       ;present sink value in w
00A2 0185                     clrf    PORT_A         ;disable all digits sinks
00A3 390F                     andlw   0x0f
00A4 008C                     movwf   TempC          ;save sink value in tempC
00A5 160C                     bsf     TempC,4        ;preset for lsd sink
00A6 0C8C                     rrf     TempC          ;determine next sink value
00A7 1C03                     btfss   STATUS,CARRY   ;c=1?
00A8 118C                     bcf     TempC,3        ;no then reset LSD sink
00A9 180C                     btfsc   TempC,0        ;else see if Msd
00AA 28B8                     goto    UpdateMsd      ;yes then do Msd
00AB 188C                     btfsc   TempC,1        ;see if 3rdLsd
00AC 28B5                     goto    Update3rdLsd   ;yes then do 3rd Lsd
00AD 190C                     btfsc   TempC,2        ;see if 2nd Lsd
00AE 28B2                     goto    Update2ndLsd   ;yes then do 2nd lsd
                       UpdateLsd
00AF 0811                     movf    LsdTime,w      ;get Lsd in w
00B0 390F                     andlw   0x0f           ;       /
00B1 28BA                     goto    DisplayOut
                       Update2ndLsd
00B2 0E11                     swapf   LsdTime,w      ;get 2nd Lsd in w
00B3 390F                     andlw   0x0f           ;mask rest
00B4 28BA                     goto    DisplayOut     ;enable display
                       Update3rdLsd
00B5 0810                     movf    MsdTime,w      ;get 3rd Lsd in w
00B6 390F                     andlw   0x0f           ;mask low nibble
00B7 28BA                     goto    DisplayOut     ;enable display
                       UpdateMsd
00B8 0E10                     swapf   MsdTime,w      ;get Msd in w
00B9 390F                     andlw   0x0f           ;mask rest
                       DisplayOut
00BA 20BF                     call    LedTable       ;get digit output
00BB 0086                     movwf   PORT_B         ;drive leds
00BC 080C                     movf    TempC,w        ;get sink value in w
00BD 0085                     movwf   PORT_A
00BE 0008                     return
                       ;
                       ;
                       LedTable
00BF 0782                     addwf   PCL            ;add to PC low
00C0 343F                     retlw   B’00111111'    ;led drive for 0
00C1 3406                     retlw   B’00000110'    ;led drive for 1
00C2 345B                     retlw   B’01011011'    ;led drive for 2
00C3 344F                     retlw   B’01001111'    ;led drive for 3
00C4 3466                     retlw   B’01100110'    ;led drive for 4
00C5 346D                     retlw   B’01101101'    ;led drive for 5
00C6 347D                     retlw   B’01111101'    ;led drive for 6
00C7 3407                     retlw   B’00000111'    ;led drive for 7
00C8 347F                     retlw   B’01111111'    ;led drive for 8
00C9 3467                     retlw   B’01100111'    ;led drive for 9
00CA 3477                     retlw   B’01110111'    ;led drive for A
00CB 347C                     retlw   B’01111100'    ;led drive for b
00CC 3439                     retlw   B’00111001'    ;led drive for C
00CD 345E                     retlw   B’01011110'    ;led drive for d
00CE 3479                     retlw   B’01111001'    ;led drive for E
00CF 3471                     retlw   B’01110001'    ;led drive for F
                       ;
                       ;
                              end
                       ;
```

Appendix C

```
MPASM B0.50                                                             PAGE  1



                      ;*********************************************************************
                      ;This program is to demonstrate how to multiplex four 7 segment LED
                      ;and sample ch0 of the a/d in a PIC16C71. The a/d value is displayed
                      ;as a 3 digit decimal value of the a/d input (0 - 255).
                      ;The LEDs are updated every 20msec, the a/d is sampled every 20 msec.
                      ;The RTCC timer is used in internal interrupt mode to generate the 5 msec.
                      ;
                      ;                                       Stan D’Souza 5/8/93
                      ;**********************************************************************
                              LIST P=16C71, F=INHX8M
                      ;
                              include “picreg.equ”



                      ;
0026                  BcdMsd         equ     26
0027                  Bcd            equ     27
000C                  TempC          equ     0x0c           ;temp general purpose regs
000D                  TempD          equ     0x0d
000E                  TempE          equ     0x0e
0020                  PABuf          equ     0x20
0021                  PBBuf          equ     0x21
000F                  Count          equ     0x0f           ;count
0010                  MsdTime        equ     0x10           ;most significant Timer
0011                  LsdTime        equ     0x11           ;Least significant Timer
0012                  ADFlag         equ     0x12           ;flags related to key pad
0005                  ADOver         equ     5              ;bit 5 —> a/d over
002F                  WBuffer        equ     0x2f
002E                  StatBuffer     equ     0x2e
0001                  OptionReg      equ     1
0002                  PCL            equ     2
                      ;
                      push           macro
                      movwf          WBuffer                ;save w reg in Buffer
                      swapf          WBuffer                ;swap it
                      swapf          STATUS,w               ;get status
                      movwf          StatBuffer             ;save it
                      endm
                      ;
                      pop            macro
                      swapf          StatBuffer,w           ;restore status
                      movwf          STATUS                 ;       /
                      swapf          WBuffer,w              ;restore W reg
                      endm
                      ;
                      org            0
0000 280D             goto           Start                  ;skip over interrupt vector
                      ;
                      org            4
                      ;It is always a good practice to save and restore the w reg,
                      ;and the status reg during a interrupt.
                      push
0004 00AF             movwf          WBuffer                ;save w reg in Buffer
0005 0EAF             swapf          WBuffer                ;swap it
0006 0E03             swapf          STATUS,w               ;get status
0007 00AE      `      movwf          StatBuffer             ;save it

0008 2039             call           ServiceInterrupts
                      pop
0009 0E2E             swapf          StatBuffer,w           ;restore status
000A 0083                   movwf   STATUS          ;       /
```

```
000B 0E2F                     swapf  WBuffer,w              ;restore W reg

000C 0009                     retfie
                      ;
                      Start
000D 2021                     call   InitPorts
000E 202B                     call   InitTimers
000F 2036                     call   InitAd
                      loop
0010 1A92                     btfsc  ADFlag,ADOver          ;a/d over?
0011 2013                     call   UpdateAd               ;yes then update
0012 2810                     goto   loop
                      ;
                      UpdateAd
0013 1C88                     btfss  ADCON0,ADIF            ;a/d done?
0014 0008                     return                        ;no then leave
0015 0809                     movf   ADRES,W                ;get a/d value
0016 00A1                     movwf  L_byte
0017 01A0                     clrf   H_byte
0018 20AD                     call   B2_BCD
0019 0824                     movf   R2,W                   ;get LSd
001A 0091                     movwf  LsdTime                ;save in LSD
001B 0823                     movf   R1,W                   ;get Msd
001C 0090                     movwf  MsdTime                ;save in Msd
001D 1088                     bcf    ADCON0,ADIF            ;clr interrupt flag
001E 1008                     bcf    ADCON0,ADON            ;turn off a/d
001F 1292                     bcf    ADFlag,ADOver          ;clr flag
0020 0008                     return
                      ;
                      ;
                      ;
                      InitPorts
0021 1683                     bsf    STATUS,RP0             ;select pg 1
0022 3003                     movlw  3                      ;make RA0-3 digital I/O
0023 0108                     movwf  ADCON1                 ;       /
0024 0205                     clrf   TRISA                  ;make RA0-4 outputs
0025 0206                     clrf   TRISB                  ;make RB0-7 outputs
0026 1283                     bcf    STATUS,RP0             ;select page 0
0027 0185                     clrf   PORT_A                 ;make all outputs low
0028 0186                     clrf   PORT_B                 ;       /
0029 1585                     bsf    PORT_A,3               ;enable MSB digit sink
002A 0008                     return
                      ;
                      ;
                      ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                      ;the rtcc will be incremented every 31.25uS. If rtcc is preloaded
                      ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5msec. So the
                      ;end result is that we get a rtcc interrupt every 5msec.
                      InitTimers
002B 0190                     clrf   MsdTime                ;clr timers
002C 0191                     clrf   LsdTime                ;       /
002D 1683                     bsf    STATUS,RP0             ;select pg 1
002E 3084                     movlw  B’10000100'            ;assign ps to rtcc
002F 0081                     movwf  OptionReg              ;ps = 32
0030 1283                     bcf    STATUS,RP0             ;select pg 0
0031 3020                     movlw  B’00100000'            ;enable rtcc interrupt
0032 008B                     movwf  INTCON                 ;
0033 3060                     movlw  .96                    ;preload rtcc
0034 0081                     movwf  RTCC                   ;start counter
0035 0009                     retfie
                      ;
                      ;
                      InitAd
0036 30C8                     movlw  B’11001000'            ;init a/d
0037 0088                     movwf  ADCON0
0038 0008                     return
                      ;
                      ;
                      ServiceInterrupts
0039 190B                     btfsc  INTCON,RTIF            ;rtcc interrupt?
003A 283E                     goto   ServiceRTCC            ;yes then service
003B 018B                     clrf   INTCON
003C 168B                     bsf    INTCON,RTIE
003D 0008                     return
                      ;
                      ServiceRTCC
003E 3060                     movlw  .96                    ;initialize rtcc
003F 0081                     movwf  RTCC
0040 110B                     bcf    INTCON,RTIF            ;clr int flag
0041 1C05                     btfss  PORT_A,0               ;last digit?
0042 2045                     call   SampleAd               ;then sample a/d
0043 2071                     call   UpdateDisplay          ;else update display
0044 0008                     return
                      ;
                      ;
                      SampleAd
0045 205A                     call   SavePorts
0046 204C                     call   DoAd                   ;do a ad conversion
                      AdDone
0047 1908                     btfsc  ADCON0,GO              ;ad done?
0048 2847                     goto   AdDone                 ;no then loop
0049 1692                     bsf    ADFlag,ADOver          ;set a/d over flag
004A 2067                     call   RestorePorts           ;restore ports
004B 0008                     return
                      ;
                      ;
                      DoAd
004C 0186                     clrf   PORT_B                 ;turn off leds
004D 1683                     bsf    STATUS,RP0             ;select pg 1
004E 300F                     movlw  0x0f                   ;make port a hi-Z
004F 0105                     movwf  TRISA                  ;       /
0050 1283                     bcf    STATUS,RP0             ;select pg 0
0051 1408                     bsf    ADCON0,ADON            ;start a/d
0052 307D                     movlw  .125
0053 2056                     call   Wait
0054 1508                     bsf    ADCON0,GO              ;start conversion
0055 0008                     return
                      ;
                      ;
                      Wait
0056 008C                     movwf  TempC                  ;store in temp
                      Next
0057 0B8C                     decfsz TempC
0058 2857                     goto   Next
0059 0008                     return

                      ;
                      ;SavePorts, saves the porta and portb condition during a key scan
                      ;operation.
                      SavePorts
005A 0805                     movf   PORT_A,w               ;Get sink value
005B 00A0                     movwf  PABuf                  ;save in buffer
005C 0185                     clrf   PORT_A                 ;disable all sinks
005D 0806                     movf   PORT_B,w               ;get port b
005E 00A1                     movwf  PBBuf                  ;save in buffer
005F 30FF                     movlw  0xff                   ;make all high
0060 0086                     movwf  PORT_B                 ;on port b
0061 1683                     bsf    STATUS,RP0             ;select page 1
0062 1381                     bcf    OptionReg,7            ;enable pull ups
0063 30F0                     movlw  B’11110000'            ;port b hi nibble inputs
0064 0106                     movwf  TRISB                  ;lo nibble outputs
0065 1283                     bcf    STATUS,RP0             ;page 0
0066 0008                     return
                      ;
                      ;RestorePorts, restores the condition of porta and portb after a
                      ;key scan operation.
                      RestorePorts
0067 0821                     movf   PBBuf,w        ;get port n
0068 0086                     movwf  PORT_B
0069 0820                     movf   PABuf,w        ;get port a value
006A 0085                     movwf  PORT_A
006B 1683                     bsf    STATUS,RP0     ;select page 1
006C 1781                     bsf    OptionReg,7    ;disable pull ups
006D 0205                     clrf   TRISA          ;make port a outputs
006E 0206                     clrf   TRISB          ;as well as PORTB
006F 1283                     bcf    STATUS,RP0     ;page 0
0070 0008                     return
                      ;
                      ;
                      UpdateDisplay
0071 0805                     movf   PORT_A,w       ;present sink value in w
0072 0185                     clrf   PORT_A         ;disable all digits sinks
0073 390F                     andlw  0x0f
0074 008C                     movwf  TempC          ;save sink value in tempC
0075 160C                     bsf    TempC,4        ;preset for lsd sink
0076 0C8C                     rrf    TempC          ;determine next sink value
0077 1C03                     btfss  STATUS,CARRY   ;c=1?
0078 118C                     bcf    TempC,3        ;no then reset LSD sink
0079 180C                     btfsc  TempC,0        ;else see if Msd
007A 288C                     goto   UpdateMsd      ;yes then do Msd
007B 188C                     btfsc  TempC,1        ;see if 3rdLsd
007C 2887                     goto   Update3rdLsd   ;yes then do 3rd Lsd
007D 190C                     btfsc  TempC,2        ;see if 2nd Lsd
007E 2882                     goto   Update2ndLsd   ;yes then do 2nd lsd
                      UpdateLsd
007F 0811                     movf   LsdTime,w      ;get Lsd in w
0080 390F                     andlw  0x0f           ;       /
0081 2890                     goto   DisplayOut     ;enable display
                      Update2ndLsd
0082 20A1                     call   Chk2LsdZero    ;msd = 0 & 2 lsd 0?
0083 1D03                     btfss  STATUS,Z       ;yes then skip
0084 0E11                     swapf  LsdTime,w      ;get 2nd Lsd in w
0085 390F                     andlw  0x0f           ;mask rest
0086 2890                     goto   DisplayOut     ;enable display
                      Update3rdLsd
0087 20A9                     call   ChkMsdZero     ;msd = 0?
0088 1D03                     btfss  STATUS,Z       ;yes then skip
0089 0810                     movf   MsdTime,w      ;get 3rd Lsd in w
008A 390F                     andlw  0x0f           ;mask low nibble
008B 2890                     goto   DisplayOut     ;enable display
                      UpdateMsd
008C 0E10                     swapf  MsdTime,w      ;get Msd in w
008D 390F                     andlw  0x0f           ;mask rest
008E 1903                     btfsc  STATUS,Z       ;msd != 0 then skip
008F 300A                     movlw  0x0a
                      DisplayOut
0090 2095                     call   LedTable       ;get digit output
0091 0086                     movwf  PORT_B         ;drive leds
0092 080C                     movf   TempC,w        ;get sink value in w
0093 0085                     movwf  PORT_A
0094 0008                     return
                      ;
                      ;
                      LedTable
0095 0782                     addwf  PCL            ;add to PC low
0096 343F                     retlw  B’00111111'    ;led drive for 0
0097 3406                     retlw  B’00000110'    ;led drive for 1
0098 345B                     retlw  B’01011011'    ;led drive for 2
0099 344F                     retlw  B’01001111'    ;led drive for 3
009A 3466                     retlw  B’01100110'    ;led drive for 4
009B 346D                     retlw  B’01101101'    ;led drive for 5
009C 347D                     retlw  B’01111101'    ;led drive for 6
009D 3407                     retlw  B’00000111'    ;led drive for 7
009E 347F                     retlw  B’01111111'    ;led drive for 8
009F 3467                     retlw  B’01100111'    ;led drive for 9
```

```
00A0 3400                     retlw          B’00000000'    ;blank led drive
                      ;
                      ;
                      Chk2LsdZero
00A1 20A9                     call           ChkMsdZero     ;msd = 0?
00A2 1D03                     btfss          STATUS,Z       ;yes then skip
00A3 0008                     return                        ;else return
00A4 0E11                     swapf          LsdTime,w      ;get 2nd lsd
00A5 390F                     andlw          0x0f           ;mask of LSD
00A6 1D03                     btfss          STATUS,Z       ;0? then skip
00A7 0008                     return
00A8 340A                     retlw          .10            ;else return with 10
                      ;
                      ChkMsdZero
00A9 0810                     movf           MsdTime,w      ;get Msd in w
00AA 1D03                     btfss          STATUS,Z       ;= 0? skip
00AB 0008                     return                        ;else return
00AC 340A                     retlw          .10            ;ret with 10
                      ;
                      ;
                      ;
0026                  count   equ    26
0027                  temp    equ    27
                      ;
0020                  H_byte  equ    20
0021                  L_byte  equ    21
0022                  R0      equ    22                     ; RAM Assignments
0023                  R1      equ    23
0024                  R2      equ    24
                      ;
                      ;
00AD 1003             B2_BCD  bcf    STATUS,0               ; clear the carry bit
00AE 3010                     movlw  .16
00AF 00A6                     movwf  count
00B0 01A2                     clrf   R0
00B1 01A3                     clrf   R1
00B2 01A4                     clrf   R2
00B3 0DA1             loop16  rlf    L_byte
00B4 0DA0                     rlf    H_byte
00B5 0DA4                     rlf    R2
00B6 0DA3                     rlf    R1
00B7 0DA2                     rlf    R0
                      ;
00B8 0BA6                     decfsz count
00B9 28BB                     goto   adjDEC
00BA 3400                     RETLW  0
                      ;
00BB 3024             adjDEC  movlw  R2
00BC 0084                     movwf  FSR
00BD 20C5                     call   adjBCD
                      ;
00BE 3023                     movlw  R1
00BF 0084                     movwf  FSR
00C0 20C5                     call   adjBCD
                      ;
00C1 3022                     movlw  R0
00C2 0084                     movwf  FSR
00C3 20C5                     call   adjBCD
                      ;
00C4 28B3                     goto   loop16
                      ;
00C5 3003             adjBCD  movlw  3
00C6 0700                     addwf  0,W
00C7 00A7                     movwf  temp
00C8 19A7                     btfsc  temp,3                 ; test if result > 7
00C9 0080                     movwf  0
00CA 3030                     movlw  30
00CB 0700                     addwf  0,W
00CC 00A7                     movwf  temp
```

```
00CD 1BA7                      btfsc   temp,7         ; test if result > 7
00CE 0080                      movwf   0              ; save as MSD
00CF 3400                      RETLW   0
                       ;
                       ;

                               end
                       ;
```

APPENDIX D

```
MPASM 1.00 Released    MPLXAD.ASM   7-15-1994  13:43:14                 PAGE  1


LOC  OBJECT CODE     LINE SOURCE TEXT

                     0001 ;*********************************************************************
                     0002 ;This program is to demonstrate how to multiplex four 7 segment LED
                     0003 ;digits and a 4X4 keypad along with 4 A/D inputs using a PIC16C71.
                     0004 ;The four digits will first display the decimal a/d value of ch0.
                     0005 ;When keys from 0 - 3 are hit the corresponding channel’s a/d value
                     0006 ;is displayed in decimal.
                     0007 ;The LEDs are updated every 20mS, the keypad is scanned at a rate of 20 mS.
                     0008 ;All 4 channels are scanned at 20mS rate, so each channel gets scanned
                     0009 ;every 80mS. A faster rate of scanning is possible as required by
                     0010 ;the users application.
                     0011 ;The RTCC timer is used in internal interrupt mode to generate the
                     0012 ;5 mS.
                     0013 ;
                     0014 ;                                       Stan D’Souza 5/8/93
                     0015 ;
                     0016 ;Corrected error in display routine.
                     0017 ;                                       Stan D’Souza 2/27/94
                     0018 ;**********************************************************************
                     0019         LIST P=16C71, F=INHX8M
                     0020 ;
                     0021         include “picreg.equ”
                     0083
                     0084
                     0021
                     0022 ;
000C                 0023 TempC   equ     0x0c            ;temp general purpose regs
000D                 0024 TempD   equ     0x0d
000E                 0025 TempE   equ     0x0e
0020                 0026 PABuf   equ     0x20
0021                 0027 PBBuf   equ     0x21
000F                 0028 Count   equ     0x0f           ;count
0010                 0029 MsdTime equ     0x10            ;most significant Timer
0011                 0030 LsdTime equ     0x11            ;Least significant Timer
                     0031 ;
0012                 0032 Flag    equ     0x12            ;general purpose flag reg
0001                 0033  #define keyhit  Flag,0         ;bit 0 —> key-press on
0002                 0034  #define DebnceOn Flag,1        ;bit 1 -> debounce on
0003                 0035  #define noentry Flag,2         ;no key entry = 0
0004                 0036  #define ServKey Flag,3         ;bit 3 —> service key
0005                 0037  #define ADOver  Flag,4         ;bit 4 —> a/d conv. over
                     0038 ;
0013                 0039 Debnce  equ     0x13            ;debounce counter
0014                 0040 NewKey  equ     0x14
0015                 0041 DisplayCh equ   0x15            ;channel to be displayed
                     0042 ;
0016                 0043 ADTABLE equ     0x16            ;4 locations are reserved here
                     0044                                 ;from 0x16 to 0x19
                     0045 ;
002F                 0046 WBuffer equ     0x2f
002E                 0047 StatBuffer equ  0x2e
0001                 0048 OptionReg equ   1
0002                 0049 PCL     equ     2
                     0050 ;
                     0051 ;
                     0052 push    macro
                     0053         movwf   WBuffer         ;save w reg in Buffer
                     0054         swapf   WBuffer         ;swap it
                     0055         swapf   STATUS,w        ;get status
                     0056         movwf   StatBuffer      ;save it
                     0057         endm
                     0058 ;
                     0059 pop     macro
                     0060         swapf   StatBuffer,w    ;restore status
                     0061         movwf   STATUS          ;       /
                     0062         swapf   WBuffer,w       ;restore W reg
                     0063         endm
                     0064 ;
                     0065         org     0
0000 280D            0066         goto    Start           ;skip over interrupt vector
                     0067 ;
                     0068         org     4
                     0069 ;It is always a good practice to save and restore the w reg,
                     0070 ;and the status reg during a interrupt.
                     0071         push
0004 00AF               M         movwf   WBuffer         ;save w reg in Buffer
0005 0EAF               M         swapf   WBuffer         ;swap it
0006 0E03               M         swapf   STATUS,w        ;get status
0007 00AE               M         movwf   StatBuffer      ;save it
0008 2052            0072         call    ServiceInterrupts
                     0073         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            0074         retfie
                     0075 ;
                     0076 Start
000D 203B            0077         call    InitPorts
000E 20EE            0078         call    InitAd
000F 2045            0079         call    InitTimers
                     0080 loop
0010 1992            0081         btfsc   ServKey         ;key service pending
0011 2015            0082         call    ServiceKey      ;yes then service
0012 1A12            0083         btfsc   ADOver          ;a/d pending?
0013 2028            0084         call    ServiceAD       ;yes the service a/d
0014 2810            0085         goto    loop
                     0086 ;
                     0087 ;ServiceKey, does the software service for a keyhit. After a key service,
                     0088 ;the ServKey flag is reset, to denote a completed operation.
                     0089 ServiceKey
0015 1192            0090         bcf     ServKey         ;reset service flag
0016 0814            0091         movf    NewKey,w        ;get key value
0017 3C03            0092         sublw   3               ;key > 3?
0018 1C03            0093         btfss   STATUS,C        ;no then skip
0019 0008            0094         return                  ;else ignore key
001A 0814            0095         movf    NewKey,w
001B 0095            0096         movwf   DisplayCh       ;load new channel
                     0097 ;
                     0098 LoadAD
001C 3016            0099         movlw   ADTABLE         ;get top of table
001D 0715            0100         addwf   DisplayCh,w     ;add offset
001E 0084            0101         movwf   FSR             ;init FSR
001F 0800            0102         movf    0,w             ;get a/d value
0020 00A1            0103         movwf   L_byte
0021 01A0            0104         clrf    H_byte
0022 2106            0105         call    B2_BCD
0023 0824            0106         movf    R2,W            ;get LSd
0024 0091            0107         movwf   LsdTime         ;save in LSD
0025 0823            0108         movf    R1,W            ;get Msd
0026 0090            0109         movwf   MsdTime         ;save in Msd
0027 0008            0110         return
                     0111 ;
                     0112 ;This rountine essentially loads the ADRES value in the table location
                     0113 ;determined by the channel offset. If channel 0 then ADRES is saved
                     0114 ;in location ADTABLE. If channel 1 then ADRES is saved at ADTABLE + 1.
                     0115 ;and so on.
                     0116 ServiceAD
0028 0808            0117         movf    ADCON0,w        ;get adcon0
0029 008C            0118         movwf   TempC           ;save in temp
002A 3008            0119         movlw   B’00001000'     ;select next channel
002B 0708            0120         addwf   ADCON0,w        ;       /
```

```
002C 1A88                  btfsc   ADCON0,5        ;if <= ch3
002D 30C1                  movlw   B’11000001'     ;select ch0
002E 0088                  movwf   ADCON0
                           ;now load adres in the table
002F 3016                  movlw   ADTABLE
0030 0084                  movwf   FSR             ;load FSR with top
0031 0C8C                  rrf     TempC
0032 0C8C                  rrf     TempC
0033 0C0C                  rrf     TempC,w         ;get in w reg
0034 3903                  andlw   3               ;mask off all but last 2
0035 0784                  addwf   FSR             ;add offset to table
0036 0809                  movf    ADRES,w         ;get a/d value
0037 0080                  movwf   0               ;load indirectly
0038 1212                  bcf     ADOver          ;clear flag
0039 201C                  call    LoadAD          ;load a/d value in display reg.
003A 0008                  return



                   ;
                   InitPorts
003B 1683                  bsf     STATUS,RP0      ;select pg 1
003C 3003                  movlw   3               ;make RA0-3 digital I/O
003D 0088                  movwf   ADCON1          ;       /
003E 0185                  clrf    TRISA           ;make RA0-4 outputs
003F 0186                  clrf    TRISB           ;make RB0-7 outputs
0040 1283                  bcf     STATUS,RP0      ;select page 0
0041 0185                  clrf    PORT_A          ;make all outputs low
0042 0186                  clrf    PORT_B          ;       /
0043 1585                  bsf     PORT_A,3        ;enable MSB digit sink
0044 0008                  return
                   ;
                   ;
                   ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
                   ;the rtcc will be incremented every 31.25uS. If rtcc is preloaded
                   ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
                   ;end result is that we get a rtcc interrupt every 5mS.
                   InitTimers
0045 0190                  clrf    MsdTime         ;clr timers
0046 0191                  clrf    LsdTime         ;       /
0047 0195                  clrf    DisplayCh       ;show channel 0
0048 0192                  clrf    Flag            ;clr all flags
0049 1683                  bsf     STATUS,RP0      ;select pg 1
004A 3084                  movlw   B’10000100'     ;assign ps to rtcc
004B 0081                  movwf   OptionReg       ;ps = 32
004C 1283                  bcf     STATUS,RP0      ;select pg 0
004D 3020                  movlw   B’00100000'     ;enable rtcc interrupt
004E 008B                  movwf   INTCON          ;
004F 3060                  movlw   .96             ;preload rtcc
0050 0081                  movwf   RTCC            ;start counter
0051 0009                  retfie
                   ;
                   ServiceInterrupts
0052 190B                  btfsc   INTCON,RTIF     ;rtcc interrupt?
0053 2857                  goto    ServiceRTCC     ;yes then service
0054 018B                  clrf    INTCON          ;else clr all int
0055 168B                  bsf     INTCON,RTIE
0056 0008                  return
                   ;
                   ServiceRTCC
0057 3060                  movlw   .96             ;initialize rtcc
0058 0081                  movwf   RTCC
0059 110B                  bcf     INTCON,RTIF     ;clr int flag
005A 1805                  btfsc   PORT_A,0        ;scan keys every 20 mS
005B 2060                  call    ScanKeys        ;when digit 1 is on
005C 1985                  btfsc   PORT_A,3        ;scan a/d every 20mS
005D 20F1                  call    SampleAd        ;when digit 4 is on
005E 20BF                  call    UpdateDisplay   ;update display
005F 0008                  return
```

```
                     ;
                     ;
                     ;ScanKeys, scans the 4X4 keypad matrix and returns a key value in
                     ;NewKey (0 - F) if a key is pressed, if not it clears the keyhit flag.
                     ;Debounce for a given keyhit is also taken care of.
                     ;The rate of key scan is 20mS with a 4.096Mhz clock.
                     ScanKeys
0060 1C92                    btfss   DebnceOn        ;debounce on?
0061 2866                    goto    Scan1           ;no then scan keypad
0062 0B93                    decfsz  Debnce          ;else dec debounce time
0063 0008                    return                  ;not over then return
0064 1092                    bcf     DebnceOn        ;over, clr debounce flag
0065 0008                    return                  ;and return
                     Scan1
0066 20A8                    call    SavePorts       ;save port values
0067 30EF                    movlw   B’11101111'     ;init TempD
0068 008D                    movwf   TempD
                     ScanNext
0069 0806                    movf    PORT_B,w        ;read to init port
006A 100B                    bcf     INTCON,RBIF     ;clr flag
006B 0C8D                    rrf     TempD           ;get correct column
006C 1C03                    btfss   STATUS,C        ;if carry set?
006D 2880                    goto    NoKey           ;no then end
006E 080D                    movf    TempD,w         ;else output
006F 0086                    movwf   PORT_B          ;low column scan line
0070 0000                    nop
0071 1C0B                    btfss   INTCON,RBIF     ;flag set?
0072 2869                    goto    ScanNext        ;no then next
0073 1812                    btfsc   keyhit          ;last key released?
0074 287E                    goto    SKreturn        ;no then exit
0075 1412                    bsf     keyhit          ;set new key hit
0076 0E06                    swapf   PORT_B,w        ;read port
0077 008E                    movwf   TempE           ;save in TempE
0078 2082                    call    GetKeyValue     ;get key value 0 - F
0079 0094                    movwf   NewKey          ;save as New key
007A 1592                    bsf     ServKey         ;set service flag
007B 1492                    bsf     DebnceOn        ;set flag
007C 3004                    movlw   4
007D 0093                    movwf   Debnce          ;load debounce time
                     SKreturn
007E 20B5                    call    RestorePorts    ;restore ports
007F 0008                    return
                     ;
                     NoKey
0080 1012                    bcf     keyhit          ;clr flag
0081 287E                    goto    SKreturn
                     ;
                     ;GetKeyValue gets the key as per the following layout
                     ;
                     ;                  Col1    Col2    Col3    Col3
                     ;                  (RB3)   (RB2)   (RB1)   (RB0)
                     ;
                     ;Row1(RB4)           0       1       2       3
                     ;
                     ;Row2(RB5)           4       5       6       7
                     ;
                     ;Row3(RB6)           8       9       A       B
                     ;
                     ;Row4(RB7)           C       D       E       F
                     ;
                     GetKeyValue
0082 018C                    clrf    TempC
0083 1D8D                    btfss   TempD,3         ;first column
0084 288C                    goto    RowValEnd
0085 0A8C                    incf    TempC
0086 1D0D                    btfss   TempD,2         ;second col.
0087 288C                    goto    RowValEnd
0088 0A8C                    incf    TempC
```

```
0089 1C8D                   btfss   TempD,1         ;3rd col.
008A 288C                   goto    RowValEnd
008B 0A8C                   incf    TempC           ;last col.
                     RowValEnd
008C 1C0E                   btfss   TempE,0         ;top row?
008D 2896                   goto    GetValCom       ;yes then get 0,1,2&3
008E 1C8E                   btfss   TempE,1         ;2nd row?
008F 2895                   goto    Get4567         ;yes the get 4,5,6&7
0090 1D0E                   btfss   TempE,2         ;3rd row?
0091 2893                   goto    Get89ab         ;yes then get 8,9,a&b
                     Getcdef
0092 150C                   bsf     TempC,2         ;set msb bits
                     Get89ab
0093 158C                   bsf     TempC,3         ;       /
0094 2896                   goto    GetValCom       ;do common part
                     Get4567
0095 150C                   bsf     TempC,2
                     GetValCom
0096 080C                   movf    TempC,w
0097 0782                   addwf   PCL
0098 3400                   retlw   0
0099 3401                   retlw   1
009A 3402                   retlw   2
009B 3403                   retlw   3
009C 3404                   retlw   4
009D 3405                   retlw   5
009E 3406                   retlw   6
009F 3407                   retlw   7
00A0 3408                   retlw   8
00A1 3409                   retlw   9
00A2 340A                   retlw   0a
00A3 340B                   retlw   0b
00A4 340C                   retlw   0c
00A5 340D                   retlw   0d
00A6 340E                   retlw   0e
00A7 340F                   retlw   0f
                     ;
                     ;SavePorts, saves the porta and portb condition during a key scan
                     ;operation.
                     SavePorts
00A8 0805                   movf    PORT_A,w        ;Get sink value
00A9 00A0                   movwf   PABuf           ;save in buffer
00AA 0185                   clrf    PORT_A          ;disable all sinks
00AB 0806                   movf    PORT_B,w        ;get port b
00AC 00A1                   movwf   PBBuf           ;save in buffer
00AD 30FF                   movlw   0xff            ;make all high
00AE 0086                   movwf   PORT_B          ;on port b
00AF 1683                   bsf     STATUS,RP0      ;select page 1
00B0 1381                   bcf     OptionReg,7     ;enable pull ups
00B1 30F0                   movlw   B’11110000'     ;port b hi nibble inputs
00B2 0086                   movwf   TRISB           ;lo nibble outputs
00B3 1283                   bcf     STATUS,RP0      ;page 0
00B4 0008                   return
                     ;
                     ;RestorePorts, restores the condition of porta and portb after a
                     ;key scan operation.
                     RestorePorts
00B5 0821                   movf    PBBuf,w         ;get port b
00B6 0086                   movwf   PORT_B
00B7 0820                   movf    PABuf,w         ;get port a value
00B8 0085                   movwf   PORT_A
00B9 1683                   bsf     STATUS,RP0      ;select page 1
00BA 1781                   bsf     OptionReg,7     ;disable pull ups
00BB 0185                   clrf    TRISA           ;make port a outputs
00BC 0186                   clrf    TRISB           ;as well as PORTB
00BD 1283                   bcf     STATUS,RP0      ;page 0
00BE 0008                   return
                     ;
                     ;
```

```
               UpdateDisplay
00BF 0805              movf    PORT_A,w        ;present sink value in w
00C0 0185              clrf    PORT_A          ;disable all digits sinks
00C1 390F              andlw   0x0f
00C2 008C              movwf   TempC           ;save sink value in tempC
00C3 160C              bsf     TempC,4         ;preset for lsd sink
00C4 0C8C              rrf     TempC           ;determine next sink value
00C5 1C03              btfss   STATUS,CARRY    ;c=1?
00C6 118C              bcf     TempC,3         ;no then reset LSD sink
00C7 180C              btfsc   TempC,0         ;else see if Msd
00C8 28D6              goto    UpdateMsd       ;yes then do Msd
00C9 188C              btfsc   TempC,1         ;see if 3rdLsd
00CA 28D3              goto    Update3rdLsd    ;yes then do 3rd Lsd
00CB 190C              btfsc   TempC,2         ;see if 2nd Lsd
00CC 28D0              goto    Update2ndLsd    ;yes then do 2nd lsd
               UpdateLsd
00CD 0811              movf    LsdTime,w       ;get Lsd in w
00CE 390F              andlw   0x0f            ;       /
00CF 28D8              goto    DisplayOut
               Update2ndLsd
00D0 0E11              swapf   LsdTime,w       ;get 2nd Lsd in w
00D1 390F              andlw   0x0f            ;mask rest
00D2 28D8              goto    DisplayOut      ;enable display
               Update3rdLsd
00D3 0810              movf    MsdTime,w       ;get 3rd Lsd in w
00D4 390F              andlw   0x0f            ;mask low nibble
00D5 28D8              goto    DisplayOut      ;enable display
               UpdateMsd
00D6 0E10              swapf   MsdTime,w       ;get Msd in w
00D7 390F              andlw   0x0f            ;mask rest
               DisplayOut
00D8 20DD              call    LedTable        ;get digit output
00D9 0086              movwf   PORT_B          ;drive leds
00DA 080C              movf    TempC,w         ;get sink value in w
00DB 0085              movwf   PORT_A
00DC 0008              return
               ;
               ;
               LedTable
00DD 0782              addwf   PCL             ;add to PC low
00DE 343F              retlw   B’00111111'     ;led drive for 0
00DF 3406              retlw   B’00000110'     ;led drive for 1
00E0 345B              retlw   B’01011011'     ;led drive for 2
00E1 344F              retlw   B’01001111'     ;led drive for 3
00E2 3466              retlw   B’01100110'     ;led drive for 4
00E3 346D              retlw   B’01101101'     ;led drive for 5
00E4 347D              retlw   B’01111101'     ;led drive for 6
00E5 3407              retlw   B’00000111'     ;led drive for 7
00E6 347F              retlw   B’01111111'     ;led drive for 8
00E7 3467              retlw   B’01100111'     ;led drive for 9
00E8 3477              retlw   B’01110111'     ;led drive for A
00E9 347C              retlw   B’01111100'     ;led drive for b
00EA 3439              retlw   B’00111001'     ;led drive for C
00EB 345E              retlw   B’01011110'     ;led drive for d
00EC 3479              retlw   B’01111001'     ;led drive for E
00ED 3471              retlw   B’01110001'     ;led drive for F

               ;
               ;
               InitAd
00EE 30C0              movlw   B’11000000'     ;internal rc for tad
00EF 0088              movwf   ADCON0          ;       /
                       ;note that adcon1 is set in InitPorts
00F0 0008              return
               ;
               SampleAd
00F1 20A8              call    SavePorts
00F2 20F8              call    DoAd                    ;do a ad conversion
               AdDone
```

```
00F3 1908                    btfsc   ADCON0,GO               ;ad done?
00F4 28F3                    goto    AdDone                  ;no then loop
00F5 1612                    bsf     ADOver                  ;set a/d over flag
00F6 20B5                    call    RestorePorts            ;restore ports
00F7 0008                    return
                     ;
                     ;
                     DoAd
00F8 0186                    clrf    PORT_B                  ;turn off leds
00F9 1683                    bsf     STATUS,RP0              ;select pg 1
00FA 300F                    movlw   0x0f                    ;make port a hi-Z
00FB 0085                    movwf   TRISA                   ;       /
00FC 1283                    bcf     STATUS,RP0              ;select pg 0
00FD 1408                    bsf     ADCON0,ADON             ;start a/d
00FE 307D                    movlw   .125
00FF 2102                    call    Wait
0100 1508                    bsf     ADCON0,GO               ;start conversion
0101 0008                    return
                     ;
                     ;
                     Wait
0102 008C                    movwf   TempC                   ;store in temp
                     Next
0103 0B8C                    decfsz  TempC
0104 2903                    goto    Next
0105 0008                    return

                     ;
                     ;
0026                 count  equ      26
0027                 temp   equ      27
                     ;
0020                 H_byte  equ     20
0021                 L_byte  equ     21
0022                 R0      equ     22              ; RAM Assignments
0023                 R1      equ     23
0024                 R2      equ     24
                     ;
                     ;
0106 1003            B2_BCD  bcf     STATUS,0                ; clear the carry bit
0107 3010                    movlw   .16
0108 00A6                    movwf   count
0109 01A2                    clrf    R0
010A 01A3                    clrf    R1
010B 01A4                    clrf    R2
010C 0DA1            loop16  rlf     L_byte
010D 0DA0                    rlf     H_byte
010E 0DA4                    rlf     R2
010F 0DA3                    rlf     R1
0110 0DA2                    rlf     R0
                     ;
0111 0BA6                    decfsz  count
0112 2914                    goto    adjDEC
0113 3400                    RETLW   0
                     ;
0114 3024            adjDEC  movlw   R2
0115 0084                    movwf   FSR
0116 211E                    call    adjBCD
                     ;
0117 3023                    movlw   R1
0118 0084                    movwf   FSR
0119 211E                    call    adjBCD
                     ;
011A 3022                    movlw   R0
011B 0084                    movwf   FSR
011C 211E                    call    adjBCD
                     ;
011D 290C                    goto    loop16
```

```
                     0464 ;
011E 3003            0465 adjBCD  movlw   3
011F 0700            0466         addwf   0,W
0120 00A7            0467         movwf   temp
0121 19A7            0468         btfsc   temp,3          ; test if result > 7
0122 0080            0469         movwf   0
0123 3030            0470         movlw   30
0124 0700            0471         addwf   0,W
0125 00A7            0472         movwf   temp
0126 1BA7            0473         btfsc   temp,7          ; test if result > 7
0127 0080            0474         movwf   0               ; save as MSD
0128 3400            0475         RETLW   0
                     0476 ;
                     0477 ;
                     0478 ;
                     0479 ;
                     0480
                     0481         end
                     0482 ;
                     0483
                     0484
                     0485


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——— ————————
0140 : ———————— ———————— ———————— ————————

All other memory blocks unused.


Errors   :    0
Warnings :    0
```

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