



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.

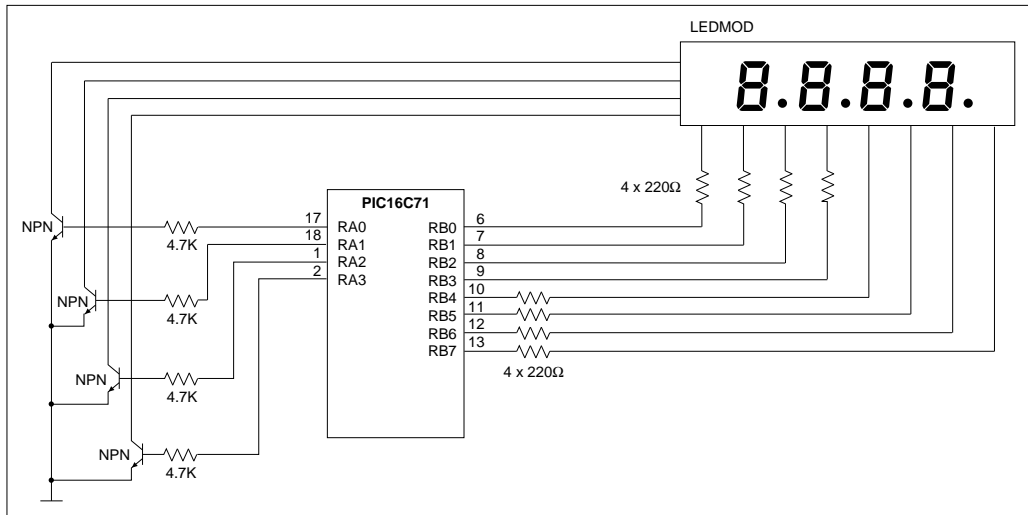
IMPLEMENTATION

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



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Software

The multiplexing is achieved by turning on each LED for a 5 msec duration every 20µs. This gives an update rate of 50 Hz, which is quite acceptable 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 = $(256-96) \times (32 \times 4/4096000) = 5 \mu\text{s}$. 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

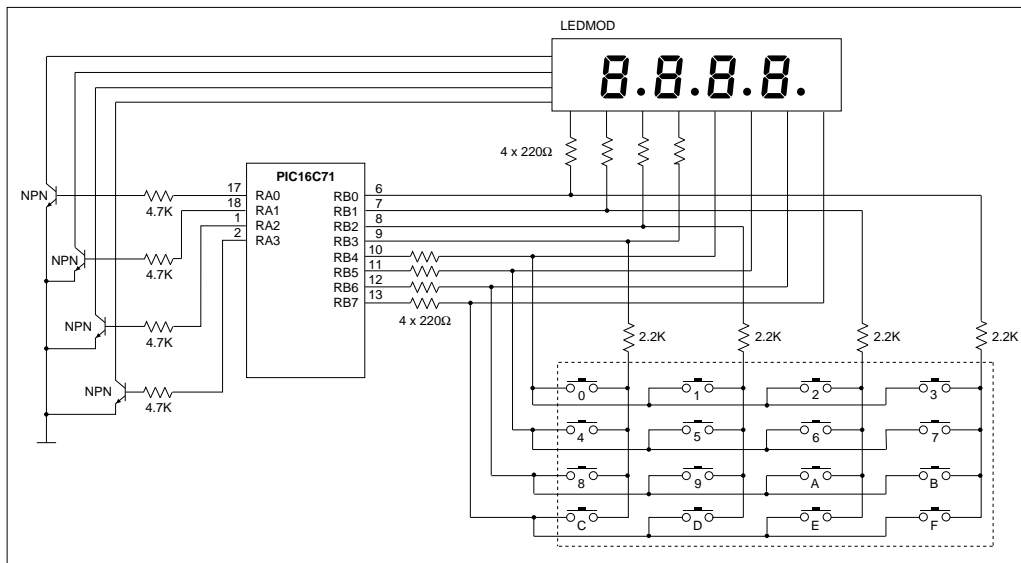
A 4x4 keypad can be very easily interfaced to the PIC16C71's Port B (see Figure 2). Internal pull-ups on pins RB4 to RB7 can be enabled and disabled by setting the RBPU bit in the OPTION register. The internal pull-ups have a value of 20K at 5V (typical). In order to sense a low level at the input, the 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



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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

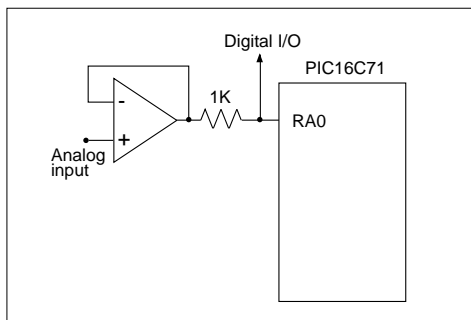
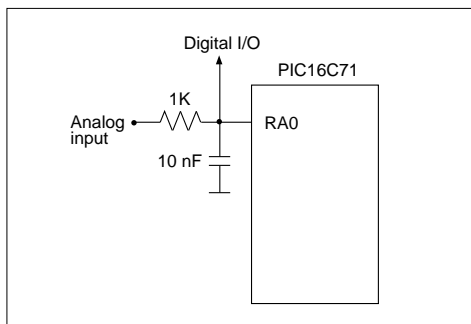


FIGURE 3B - TYPICAL CONNECTION FOR ANALOG/DIGITAL INPUT



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

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

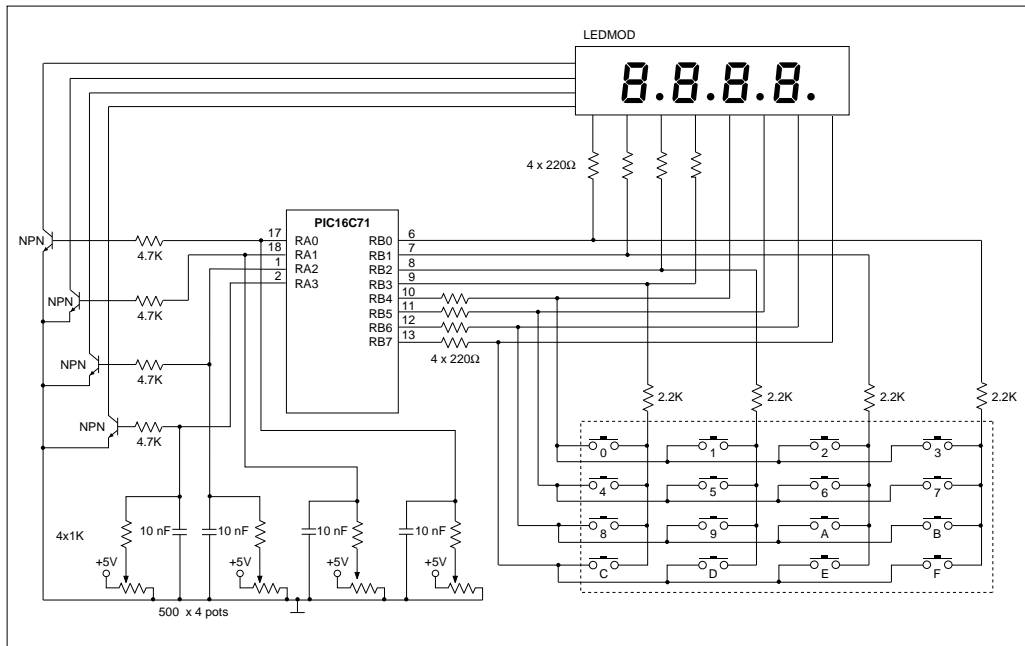
Section 1:	Program Memory:	139
	Data Memory:	6
Section 2:	Program Memory:	207
	Data Memory:	13
Section 3:	Program Memory:	207
	Data Memory:	17
Section 4:	Program Memory:	
	Data Memory:	

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



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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

```

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```

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      btfscc 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      btfscc STATUS,Z          ;no then skip
002B 282E      goto   DoIncTime        ;else inc time
002C 0A8F      incf   Count          ;
002D 0008      return

DoIncTime
002E 018F      clrfs  Count          ;clr count
002F 0A11      incf   LsdTime,w        ;get lsd
0030 390F      andlw  0x0F          ;mask high nibble
0031 3A0A      xorlw  0x0a          ; = 10?
0032 1903      btfscc 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      btfscc STATUS,Z          ;no then skip
003D 283F      goto   IncThirdLsd     ;else inc next lsd
003E 0008      return

IncThirdLsd
003F 0191      clrfs  LsdTime        ;
0040 0A10      incf   MsdTime,w        ;get 3rd lsd
0041 390F      andlw  0x0F          ;mask hi nibble
0042 3A0A      xorlw  0x0a          ;= 10?
0043 1903      btfscc 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      btfscc STATUS,Z          ;no then skip
004E 0190      clrfs  MsdTime        ;clr msd
004F 0008      return

```

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```

;
;
UpdateDisplay
0050 0805      movf    PORT_A,w           ;present sink value in w
0051 0185      clrfs   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      btfs   STATUS,CARRY       ;c=1?
0057 118C      bcf     TempC,3         ;no then reset LSD sink
0058 180C      btfs   TempC,0         ;else see if Msd
0059 286B      goto    UpdateMsd        ;yes then do Msd
005A 188C      btfs   TempC,1         ;see if 3rdLsd
005B 2866      goto    Update3rdLsd      ;yes then do 3rd Lsd
005C 190C      btfs   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      btfs   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      btfs   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      btfs   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      btfs   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      btfs   STATUS,Z           ;0? then skip
0086 0008      return

```

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```
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
;
```


Four Channel Digital Voltmeter with Display and Keyboard

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
```

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```

                                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      btfs   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      btfs   INTCON,RTIF            ;rtcc interrupt?
0037 283B      goto   ServiceRTCC          ;yes then service
0038 018B      clrf  INTCON                ;else clr all int
0039 168B      bsf   INTCON,RTIE          ;enable rtcc interrupt

```

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```
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                decfsw 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
```

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Four Channel Digital Voltmeter with Display and Keyboard

```

;
GetKeyValue
0064 018C          clrfs TempC
0065 1D8D          btfs TempD,3      ;first column
0066 286E          goto RowValEnd
0067 0A8C          incf TempC
0068 1D0D          btfs TempD,2      ;second col.
0069 286E          goto RowValEnd
006A 0A8C          incf TempC
006B 1C8D          btfs TempD,1      ;3rd col.
006C 286E          goto RowValEnd
006D 0A8C          incf TempC      ;last col.
RowValEnd
006E 1C0E          btfs TempE,0      ;top row?
006F 2878          goto GetValCom    ;yes then get 0,1,2&3
0070 1C8E          btfs TempE,1      ;2nd row?
0071 2877          goto Get4567      ;yes the get 4,5,6&7
0072 1D0E          btfs 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          clrfs 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
```

Four Channel Digital Voltmeter with Display and Keyboard

```

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
;

```

Four Channel Digital Voltmeter with Display and Keyboard

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        ;
;
```

Four Channel Digital Voltmeter with Display and Keyboard

```

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

;

```

Four Channel Digital Voltmeter with Display and Keyboard

```

;
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.

```


Four Channel Digital Voltmeter with Display and Keyboard

```

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

```

Four Channel Digital Voltmeter with Display and Keyboard

```

00A0 3400          retlw      B'00000000'    ;blank led drive
;
;
      Chk2LsdZero
00A1 20A9          call       ChkMsdZero    ;msd = 0?
00A2 1D03          btfs     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          btfs     STATUS,Z    ;0? then skip
00A7 0008          return     ;else return with 10
00A8 340A          retlw      .10
;
      ChkMsdZero
00A9 0810          movf     MsdTime,w    ;get Msd in w
00AA 1D03          btfs     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          clr     R0
00B1 01A3          clr     R1
00B2 01A4          clr     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
;
adjDEC 00BB 3024          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
;
adjBCD 00C5 3003          movlw   3
00C6 0700          addwf  0,W
00C7 00A7          movwf  temp
00C8 19A7          btfs   temp,3           ; test if result > 7
00C9 0080          movwf  0
00CA 3030          movlw  30
00CB 0700          addwf  0,W
00CC 00A7          movwf  temp

```

Four Channel Digital Voltmeter with Display and Keyboard

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

Four Channel Digital Voltmeter with Display and Keyboard

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"
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
0012      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
0013      0038 ;
0013      0039 Debnce equ 0x13        ;debounce counter
0014      0040 NewKey equ 0x14
0015      0041 DisplayCh equ 0x15      ;channel to be displayed
0016      0042 ;
0016      0043 ADTABLE equ 0x16       ;4 locations are reserved here
0016      0044                               ;from 0x16 to 0x19
0016      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 ;
```

Four Channel Digital Voltmeter with Display and Keyboard

```

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      btfs   ServKey      ;key service pending
0011 2015    0082      call   ServiceKey   ;yes then service
0012 1A12    0083      btfs   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      btfs   STATUS,C     ;no then skip
0019 0008    0094      return  ;else ignore key
001A 0814    0095      movf   NewKey,w     ;get key value
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 routine 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     ;      /

```

Four Channel Digital Voltmeter with Display and Keyboard

```
002C 1A88      0121      btfsc  ADCON0,5      ;if <= ch3
002D 30C1      0122      movlw  B'11000001'  ;select ch0
002E 0088      0123      movwf  ADCON0
                                0124      ;now load adres in the table
002F 3016      0125      movlw  ADTABLE
0030 0084      0126      movwf  FSR           ;load FSR with top
0031 0C8C      0127      rrf    TempC
0032 0C8C      0128      rrf    TempC
0033 0C0C      0129      rrf    TempC,w      ;get in w reg
0034 3903      0130      andlw  3             ;mask off all but last 2
0035 0784      0131      addwf  FSR           ;add offset to table
0036 0809      0132      movf  ADRES,w       ;get a/d value
0037 0080      0133      movwf  0             ;load indirectly
0038 1212      0134      bcf    ADOVer       ;clear flag
0039 201C      0135      call  LoadAD        ;load a/d value in display reg.
003A 0008      0136      return
                                0137
                                0138
                                0139
                                0140 ;
                                0141 InitPorts
003B 1683      0142      bsf    STATUS,RP0   ;select pg 1
003C 3003      0143      movlw  3             ;make RA0-3 digital I/O
003D 0088      0144      movwf  ADCON1       ;
                                /
003E 0185      0145      clrf  TRISA         ;make RA0-4 outputs
003F 0186      0146      clrf  TRISB         ;make RB0-7 outputs
0040 1283      0147      bcf    STATUS,RP0   ;select page 0
0041 0185      0148      clrf  PORT_A        ;make all outputs low
0042 0186      0149      clrf  PORT_B        ;
                                /
0043 1585      0150      bsf    PORT_A,3     ;enable MSB digit sink
0044 0008      0151      return
                                0152 ;
                                0153 ;
0154 ;The clock speed is 4.096Mhz. Dividing internal clk. by a 32 prescaler,
0155 ;the rtcc will be incremented every 31.25uS. If rtcc is preloaded
0156 ;with 96, it will take (256-96)*31.25uS to overflow i.e. 5mS. So the
0157 ;end result is that we get a rtcc interrupt every 5mS.
0158 InitTimers
0045 0190      0159      clrf  MsdTime       ;clr timers
0046 0191      0160      clrf  LsdTime       ;
                                /
0047 0195      0161      clrf  DisplayCh     ;show channel 0
0048 0192      0162      clrf  Flag          ;clr all flags
0049 1683      0163      bsf    STATUS,RP0   ;select pg 1
004A 3084      0164      movlw  B'10000100'  ;assign ps to rtcc
004B 0081      0165      movwf  OptionReg    ;ps = 32
004C 1283      0166      bcf    STATUS,RP0   ;select pg 0
004D 3020      0167      movlw  B'00100000'  ;enable rtcc interrupt
004E 008B      0168      movwf  INTCON       ;
                                ;
004F 3060      0169      movlw  .96           ;preload rtcc
0050 0081      0170      movwf  RTCC         ;start counter
0051 0009      0171      retfie
                                0172 ;
                                0173 ServiceInterrupts
0052 190B      0174      btfsc  INTCON,RTIF  ;rtcc interrupt?
0053 2857      0175      goto  ServiceRTCC  ;yes then service
0054 018B      0176      clrf  INTCON        ;else clr all int
0055 168B      0177      bsf    INTCON,RTIE
0056 0008      0178      return
                                0179 ;
                                0180 ServiceRTCC
0057 3060      0181      movlw  .96           ;initialize rtcc
0058 0081      0182      movwf  RTCC
0059 110B      0183      bcf    INTCON,RTIF  ;clr int flag
005A 1805      0184      btfsc  PORT_A,0     ;scan keys every 20 mS
005B 2060      0185      call  ScanKeys      ;when digit 1 is on
005C 1985      0186      btfsc  PORT_A,3     ;scan a/d every 20mS
005D 20F1      0187      call  SampleAd      ;when digit 4 is on
005E 20BF      0188      call  UpdateDisplay ;update display
005F 0008      0189      return
```

Four Channel Digital Voltmeter with Display and Keyboard

```

0190 ;
0191 ;
0192 ;ScanKeys, scans the 4X4 keypad matrix and returns a key value in
0193 ;NewKey (0 - F) if a key is pressed, if not it clears the keyhit flag.
0194 ;Debounce for a given keyhit is also taken care of.
0195 ;The rate of key scan is 20mS with a 4.096Mhz clock.
0196 ScanKeys
0060 1C92      0197      btfsz   DebnceOn      ;debounce on?
0061 2866      0198      goto    Scan1         ;no then scan keypad
0062 0B93      0199      decfsz  Debnce       ;else dec debounce time
0063 0008      0200      return  ;not over then return
0064 1092      0201      bcf     DebnceOn     ;over, clr debounce flag
0065 0008      0202      return  ;and return
0203 Scan1
0066 20A8      0204      call   SavePorts     ;save port values
0067 30EF      0205      movlw  B'11101111'  ;init TempD
0068 008D      0206      movwf  TempD
0207 ScanNext
0069 0806      0208      movf   PORT_B,w     ;read to init port
006A 100B      0209      bcf    INTCON,RBIF  ;clr flag
006B 0C8D      0210      rrf    TempD        ;get correct column
006C 1C03      0211      btfsz  STATUS,C     ;if carry set?
006D 2880      0212      goto   NoKey        ;no then end
006E 080D      0213      movf   TempD,w     ;else output
006F 0086      0214      movwf  PORT_B      ;low column scan line
0070 0000      0215      nop
0071 1C0B      0216      btfsz  INTCON,RBIF  ;flag set?
0072 2869      0217      goto   ScanNext    ;no then next
0073 1812      0218      btfsz  keyhit       ;last key released?
0074 287E      0219      goto   SKreturn    ;no then exit
0075 1412      0220      bsf    keyhit       ;set new key hit
0076 0E06      0221      swapf  PORT_B,w    ;read port
0077 008E      0222      movwf  TempE       ;save in TempE
0078 2082      0223      call  GetKeyValue  ;get key value 0 - F
0079 0094      0224      movwf  NewKey      ;save as New key
007A 1592      0225      bsf    ServKey     ;set service flag
007B 1492      0226      bsf    DebnceOn    ;set flag
007C 3004      0227      movlw  4
007D 0093      0228      movwf  Debnce      ;load debounce time
0229 SKreturn
007E 20B5      0230      call  RestorePorts ;restore ports
007F 0008      0231      return
0232 ;
0233 NoKey
0080 1012      0234      bcf    keyhit      ;clr flag
0081 287E      0235      goto   SKreturn
0236 ;
0237 ;GetKeyValue gets the key as per the following layout
0238 ;
0239 ;
0240 ;
0241 ;
0242 ;Row1 (RB4)      0      1      2      3
0243 ;
0244 ;Row2 (RB5)      4      5      6      7
0245 ;
0246 ;Row3 (RB6)      8      9      A      B
0247 ;
0248 ;Row4 (RB7)      C      D      E      F
0249 ;
0250 GetKeyValue
0082 018C      0251      clr    TempC
0083 1D8D      0252      btfsz  TempD,3     ;first column
0084 288C      0253      goto   RowValEnd
0085 0A8C      0254      incf   TempC
0086 1D0D      0255      btfsz  TempD,2     ;second col.
0087 288C      0256      goto   RowValEnd
0088 0A8C      0257      incf   TempC

```

Four Channel Digital Voltmeter with Display and Keyboard

```
0089 1C8D      0258      btfss   TempD,1      ;3rd col.
008A 288C      0259      goto    RowValEnd
008B 0A8C      0260      incf    TempC      ;last col.
                0261      RowValEnd
008C 1C0E      0262      btfss   TempE,0      ;top row?
008D 2896      0263      goto    GetValCom    ;yes then get 0,1,2&3
008E 1C8E      0264      btfss   TempE,1      ;2nd row?
008F 2895      0265      goto    Get4567      ;yes the get 4,5,6&7
0090 1D0E      0266      btfss   TempE,2      ;3rd row?
0091 2893      0267      goto    Get89ab      ;yes then get 8,9,a&b
                0268      Getcdef
0092 150C      0269      bsf     TempC,2      ;set msb bits
                0270      Get89ab
0093 158C      0271      bsf     TempC,3      ;
0094 2896      0272      goto    GetValCom    ;do common part
                0273      Get4567
0095 150C      0274      bsf     TempC,2
                0275      GetValCom
0096 080C      0276      movf    TempC,w
0097 0782      0277      addwf   PCL
0098 3400      0278      retlw   0
0099 3401      0279      retlw   1
009A 3402      0280      retlw   2
009B 3403      0281      retlw   3
009C 3404      0282      retlw   4
009D 3405      0283      retlw   5
009E 3406      0284      retlw   6
009F 3407      0285      retlw   7
00A0 3408      0286      retlw   8
00A1 3409      0287      retlw   9
00A2 340A      0288      retlw   0a
00A3 340B      0289      retlw   0b
00A4 340C      0290      retlw   0c
00A5 340D      0291      retlw   0d
00A6 340E      0292      retlw   0e
00A7 340F      0293      retlw   0f
                0294      ;
0295 ;SavePorts, saves the porta and portb condition during a key scan
0296 ;operation.
0297 SavePorts
00A8 0805      0298      movf    PORT_A,w      ;Get sink value
00A9 00A0      0299      movwf   PABuf         ;save in buffer
00AA 0185      0300      clrf    PORT_A        ;disable all sinks
00AB 0806      0301      movf    PORT_B,w      ;get port b
00AC 00A1      0302      movwf   PBBuf         ;save in buffer
00AD 30FF      0303      movlw   0xff          ;make all high
00AE 0086      0304      movwf   PORT_B        ;on port b
00AF 1683      0305      bsf     STATUS,RP0    ;select page 1
00B0 1381      0306      bcf     OptionReg,7   ;enable pull ups
00B1 30F0      0307      movlw   B'11110000'   ;port b hi nibble inputs
00B2 0086      0308      movwf   TRISB         ;lo nibble outputs
00B3 1283      0309      bcf     STATUS,RP0    ;page 0
00B4 0008      0310      return
                0311      ;
0312 ;RestorePorts, restores the condition of porta and portb after a
0313 ;key scan operation.
0314 RestorePorts
00B5 0821      0315      movf    PBBuf,w      ;get port b
00B6 0086      0316      movwf   PORT_B
00B7 0820      0317      movf    PABuf,w      ;get port a value
00B8 0085      0318      movwf   PORT_A
00B9 1683      0319      bsf     STATUS,RP0    ;select page 1
00BA 1781      0320      bsf     OptionReg,7   ;disable pull ups
00BB 0185      0321      clrf    TRISA         ;make port a outputs
00BC 0186      0322      clrf    TRISB         ;as well as PORTB
00BD 1283      0323      bcf     STATUS,RP0    ;page 0
00BE 0008      0324      return
                0325      ;
                0326      ;
```


Four Channel Digital Voltmeter with Display and Keyboard

```

0327 UpdateDisplay
00BF 0805      0328      movf    PORT_A,w      ;present sink value in w
00C0 0185      0329      clrf    PORT_A      ;disable all digits sinks
00C1 390F      0330      andlw  0x0f
00C2 008C      0331      movwf  TempC      ;save sink value in tempC
00C3 160C      0332      bsf    TempC,4    ;preset for lsd sink
00C4 0C8C      0333      rrf    TempC      ;determine next sink value
00C5 1C03      0334      btfsz  STATUS,CARRY ;c=1?
00C6 118C      0335      bcf    TempC,3    ;no then reset LSD sink
00C7 180C      0336      btfsz  TempC,0    ;else see if Msd
00C8 28D6      0337      goto   UpdateMsd  ;yes then do Msd
00C9 188C      0338      btfsz  TempC,1    ;see if 3rdLsd
00CA 28D3      0339      goto   Update3rdLsd ;yes then do 3rd Lsd
00CB 190C      0340      btfsz  TempC,2    ;see if 2nd Lsd
00CC 28D0      0341      goto   Update2ndLsd ;yes then do 2nd lsd
                                0342 UpdateLsd
00CD 0811      0343      movf    LsdTime,w  ;get Lsd in w
00CE 390F      0344      andlw  0x0f      ;
00CF 28D8      0345      goto   DisplayOut
                                0346 Update2ndLsd
00D0 0E11      0347      swapf  LsdTime,w  ;get 2nd Lsd in w
00D1 390F      0348      andlw  0x0f      ;mask rest
00D2 28D8      0349      goto   DisplayOut ;enable display
                                0350 Update3rdLsd
00D3 0810      0351      movf    MsdTime,w  ;get 3rd Lsd in w
00D4 390F      0352      andlw  0x0f      ;mask low nibble
00D5 28D8      0353      goto   DisplayOut ;enable display
                                0354 UpdateMsd
00D6 0E10      0355      swapf  MsdTime,w  ;get Msd in w
00D7 390F      0356      andlw  0x0f      ;mask rest
                                0357 DisplayOut
00D8 20DD      0358      call   LedTable   ;get digit output
00D9 0086      0359      movwf  PORT_B     ;drive leds
00DA 080C      0360      movf    TempC,w   ;get sink value in w
00DB 0085      0361      movwf  PORT_A
00DC 0008      0362      return
                                0363 ;
                                0364 ;
                                0365 LedTable
00DD 0782      0366      addwf  PCL        ;add to PC low
00DE 343F      0367      retlw  B'00111111' ;led drive for 0
00DF 3406      0368      retlw  B'00000110' ;led drive for 1
00E0 345B      0369      retlw  B'01011011' ;led drive for 2
00E1 344F      0370      retlw  B'01001111' ;led drive for 3
00E2 3466      0371      retlw  B'01100110' ;led drive for 4
00E3 346D      0372      retlw  B'01101101' ;led drive for 5
00E4 347D      0373      retlw  B'01111101' ;led drive for 6
00E5 3407      0374      retlw  B'00000111' ;led drive for 7
00E6 347F      0375      retlw  B'01111111' ;led drive for 8
00E7 3467      0376      retlw  B'01100111' ;led drive for 9
00E8 3477      0377      retlw  B'01110111' ;led drive for A
00E9 347C      0378      retlw  B'01111100' ;led drive for b
00EA 3439      0379      retlw  B'00111001' ;led drive for C
00EB 345E      0380      retlw  B'01011110' ;led drive for d
00EC 3479      0381      retlw  B'01111001' ;led drive for E
00ED 3471      0382      retlw  B'01110001' ;led drive for F
                                0383
                                0384 ;
                                0385 ;
                                0386 InitAd
00EE 30C0      0387      movlw  B'11000000' ;internal rc for tad
00EF 0088      0388      movwf  ADCON0     ;
                                0389 ;note that adcon1 is set in InitPorts
00F0 0008      0390      return
                                0391 ;
                                0392 SampleAd
00F1 20A8      0393      call   SavePorts
00F2 20F8      0394      call   DoAd      ;do a ad conversion
                                0395 AdDone

```

Four Channel Digital Voltmeter with Display and Keyboard

```
00F3 1908      0396      btfsc  ADCON0,GO          ;ad done?
00F4 28F3      0397      goto   AdDone            ;no then loop
00F5 1612      0398      bsf    ADOver            ;set a/d over flag
00F6 20B5      0399      call   RestorePorts      ;restore ports
00F7 0008      0400      return
                0401 ;
                0402 ;
                0403 DoAd
00F8 0186      0404      clrf   PORT_B            ;turn off leds
00F9 1683      0405      bsf    STATUS,RP0        ;select pg 1
00FA 300F      0406      movlw  0x0F              ;make port a hi-Z
00FB 0085      0407      movwf  TRISA              ; /
00FC 1283      0408      bcf    STATUS,RP0        ;select pg 0
00FD 1408      0409      bsf    ADCON0,ADON       ;start a/d
00FE 307D      0410      movlw  .125
00FF 2102      0411      call   Wait
0100 1508      0412      bsf    ADCON0,GO          ;start conversion
0101 0008      0413      return
                0414 ;
                0415 ;
                0416 Wait
0102 008C      0417      movwf  TempC              ;store in temp
                0418 Next
0103 0B8C      0419      decfsz TempC
0104 2903      0420      goto   Next
0105 0008      0421      return
                0422
                0423 ;
                0424 ;
0026          0425 count equ 26
0027          0426 temp equ 27
                0427 ;
0020          0428 H_byte equ 20
0021          0429 L_byte equ 21
0022          0430 R0 equ 22          ; RAM Assignments
0023          0431 R1 equ 23
0024          0432 R2 equ 24
                0433 ;
                0434 ;
0106 1003      0435 B2_BCD bcf STATUS,0          ; clear the carry bit
0107 3010      0436      movlw  .16
0108 00A6      0437      movwf  count
0109 01A2      0438      clrf   R0
010A 01A3      0439      clrf   R1
010B 01A4      0440      clrf   R2
010C 0DA1      0441 loop16 rlf L_byte
010D 0DA0      0442      rlf   H_byte
010E 0DA4      0443      rlf   R2
010F 0DA3      0444      rlf   R1
0110 0DA2      0445      rlf   R0
                0446 ;
0111 0BA6      0447      decfsz count
0112 2914      0448      goto   adjDEC
0113 3400      0449      RETLW 0
                0450 ;
0114 3024      0451 adjDEC movlw R2
0115 0084      0452      movwf  FSR
0116 211E      0453      call   adjBCD
                0454 ;
0117 3023      0455      movlw  R1
0118 0084      0456      movwf  FSR
0119 211E      0457      call   adjBCD
                0458 ;
011A 3022      0459      movlw  R0
011B 0084      0460      movwf  FSR
011C 211E      0461      call   adjBCD
                0462 ;
011D 290C      0463      goto   loop16
```

Four Channel Digital Voltmeter with Display and Keyboard

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

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

```
0000 : X-XXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX

0080 : XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX
00C0 : XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX

0100 : XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXX XXXXXXXXXX- - - - -
0140 : - - - - -
```

All other memory blocks unused.

```
Errors   :    0
Warnings :    0
```



Four Channel Digital Voltmeter with Display and Keyboard

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