Low-Power Real Time Clock

INTRODUCTION

This application note implements a low-power real time clock using the Timer1 module of the PIC16CXX family of processors. Timer1 can operate from its own crystal source, which allows the timer to increment while the device is in sleep mode. The device is placed into sleep to minimize the current consumption. Only the events that require processing will wake the device from sleep. These are a key input and a Timer1 overflow.

OPERATION

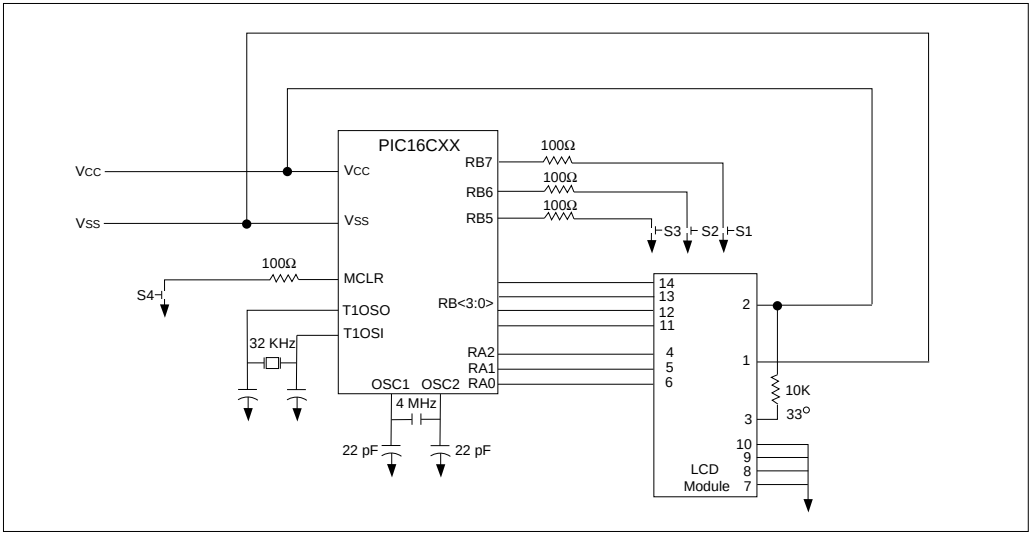
Upon power-up, the device goes into an initial state. This state sets the display to 12:00 PM and waits for Timer1 to generate an interrupt (every second). The Timer1 overflow interrupt wakes the device from sleep This causes the time registers (HRS, MIN, SECS) to be updated. If the SECS register contains an even value (SECS<0> = 0), the colon (":") is not displayed. This gives a visual indication for each second.

There are three keys for the setting of the clock. The SELECT_UNITS Key (S1) selects which units are to be modified (hours, minutes, off). The selected units are blanked for a second then flashed for one second. The INC Key (S2) increments the selected units. While incrementing, the selected units are displayed. After a key has not been depressed for more then one second, the selected units will begin to flash. The CLR_MIN Key (S3) clears the minutes and seconds. CLR_MIN is useful for exactly setting the time to the “top of the hour” as announced in radio broadcasts. After the INC or SELECT_UNITS keys are depressed, the user has ten seconds to depress the next key. After no key has been depressed for ten seconds, the unit returns to the clock mode.

To simplify the design time, a standard Hitachi LCD display module is used. In most applications requiring a LCD display, a custom LCD display is used. The LCD interface software would need to be modified to suit the specific LCD display driver being used.

Figure 1 is a block diagram of the design. RA<2:0> are the control signals to the LCD display, RB<3:0> is the 4-bit data bus, and RB<7:5> is the input switches. The OSC1 pin is connected to an RC network, which generates approximately a 4 MHz device frequency. The device frequency does not need to be stable, since the Timer1 module operates asynchronously. This allows the device's oscillaor to be configures for RC mode. This oscillator mode is the least expensive and has the quickest start-up time. Timer1 is where the accurate frequency is required. This crystal is connected to the T1OSI and T1OSO pins. A good choice for a crystal is a 32.786 KHz (watch) crystal. Table 1 is a list of the components and their part number.

FIGURE 1: CLOCK BLOCK DIAGRAM



Relative to most microelectronics, the LCD's are slow devices. A good portion of the time spent in the Interrupt Service Routine, is talking to and updating the LCD module. To minimize power consumption, the device should be in the sleep mode as much as possible.

By using the conditional assemble, if a flag (called Debug) is true, the total time spent in the subroutine can be seen on the PORTD<0> pin (the high time). Measuring this time on an oscilloscope displayed a typical time of 800 uS that the device is awake. This 800 uS operation is out of the 1 second time that the device needs to service the interrupt (a TMR1 overflow).

The accuracy of a real time clock using Timer1 depends on the accuracy of the crystal being used. The more accurate the crystal, the higher the cost. So as always there is a cost / performance trade-off to be made. A crystal rated with an accuracy of 20 PPM (parts per million), could cause an error of about 1.7 seconds per day. For many applications, this should be adequate (said from someone who doesn't wear a watch).

The program presented here shows one method for a real time clock. Trade-offs between code size, current consumption and desired operation have been made. Some possible alternative implementations are:

1. When displaying the time, update only the characters that changed.
2. Turn off the display during sleep
3. LCD module data interface of 8-bits, not the 4-bit interface.

Alternative 1 can reduce the time awake, by keeping track of which characters need to be updated. The majority of the time it will be only the position which contains either the ":" or the " ". Next would be the ones place of the minutes, then the tens place of the minutes, etc. The display would only need to be completely updated 2 times every 24 hrs. This would reduce the amount of time talking with the LCD display at the cost of some program / data memory.

Depending on the requirements of the application and the characteristics of the display, alternative 2 could be implemented by turning the power off and on (at a given rate) to the display. This technique may lead to a lower system current consumption. Evaluation upon the desired display / display driver is recommended.

Alternative 3 uses the LCD module in an 8-bit mode, will reduce the size of the display routines (save about 20 words of program memory) at the cost of four additional I/O lines. For some applications this may be a good trade off to get the additional program memory space. The percentage of operating time saved is slight and should not give substantial power savings.

TABLE 1: LIST OF COMPONENTS†

Description	Part Number	Manufacturer	Quantity
LCD Module (2 x 20 Characteristics)	LM032L	Hitachi	1
Switches	EVQPADO4M	Panasonic	4
Microcontroller	PIC16C64 / 74	Microchip	1
32.768 KHz Crystal	NC26 / NC38	FOX	1
4 MHz Crystal	ECS-40-20-1	ECS	1

† Most components available from DigiKey.

CONCLUSION

The Timer1 module allows many applications to include a real time clock at minimal system cost. This time function can be useful in consumer applications (display time) as well as in industrial applications (data time stamp). The accuracy of the time is strictly dependent on the accuracy of the crystal. Table 2 shows the program resource requirements.

TABLE 2: PROGRAM RESOURCE REQUIREMENTS

Resource			Words / Bytes	Cycles
Program Memory	Initialization		61	61
	Clock Operation	Increment Time W.C.	106	35 + Display
		Key Input W.C.		35 + Display Time
Data Memory	Display‡		208	526†
	Variables		5	N.A.
	Scratch RAM		4	N.A.

† Dependent on LCD Module (re: BUSY_CHECK subroutine)

‡ Assumes worst case numbers and best case response from LCD module.

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APPENDIX A: SOURCE CODE LISTING (CLOCK_01.LST)

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MPASM 01.01 Released     CLOCK.ASM   5-13-1994  13:11:9               PAGE  1


LOC  OBJECT CODE     LINE SOURCE TEXT

                     0001         LIST    P = 16C74,  F = INHX8M, n = 66
                     0002 ;
                     0003 ;*****************************************************************************
                     0004 ;
                     0005 ; This program implements a real time clock using the TMR1 module of the
                     0006 ; PIC16Cxx family. A LCD display module is used to display (update) the
                     0007 ; time every second. Three keys are used to set the time.
                     0008 ;
                     0009 ;       Program = CLOCK.ASM
                     0010 ;       Revision Date:   5-15-94
                     0011 ;
                     0012 ;*****************************************************************************
                     0013 ;
                     0014 ;
                     0015 ; HARDWARE SETUP
                     0016 ;   LCD Control Lines
                     0017 ;       RA0 = E     (Enable)
                     0018 ;       RA1 = R_W   (Read/Write)
                     0019 ;       RA2 = RS    (Register Select)
                     0020 ;   LCD Data Lines
                     0021 ;       RB<3:0>
                     0022 ;   Switch Inputs
                     0023 ;       RB7 = Select Hour / Minute / Off
                     0024 ;       RB6 = Increment Hour / Minute
                     0025 ;       RB5 = Reset Minutes to 00
                     0026 ;
                     0027             INCLUDE <C74_reg.h>
                     0233
                     0027
                     0028             INCLUDE <CLOCK.h>
                     0028
                     0029 ;
0006                 0030 LCD_DATA        EQU     PORTB       ; The LCD data is on the lower 4-bits
0086                 0031 LCD_DATA_TRIS   EQU     TRISB       ; The TRIS register for the LCD data
0005                 0032 LCD_CNTL        EQU     PORTA       ; Three control lines
                     0033 ;
0000                 0034 PICMaster       EQU     FALSE        ; A Debugging Flag
0000                 0035 Debug           EQU     FALSE        ; A Debugging Flag
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0001                    0036 Debug_PU        EQU     TRUE         ; A Debugging Flag
                        0037 ;
                        0038 ;
                        0039 ; Reset address. Determine type of RESET
                        0040 ;
                        0041         org     RESET_V              ; RESET vector location
0000 1683               0042 RESET       BSF     STATUS, RP0      ; Bank 1
0001 188E               0043             BTFSC   PCON, POR        ; Power-up reset?
0002 290C               0044             GOTO    START            ; YES
0003 295F               0045             GOTO    OTHER_RESET      ; NO, a WDT or MCLR reset
                        0046 ;
                        0047 ; This is the Peripheral Interrupt routine. Need to determine the type
                        0048 ; of interrupt that occurred. The following interrupts are enabled:
                        0049 ;   1.  PORTB Change (RBIF)
                        0050 ;   2.  TMR1 Overflow Interrupt (T1IF)
                        0051 ;
                        0053         org     ISR_V                ; Interrupt vector location
                        0054 PER_INT_V
                        0055         if ( Debug )
                        0056             bsf     PORTD, 0         ; Set high, use to measure total
                        0057         endif                        ;    time in Int Service Routine
                        0058 ;
0004 1283               0059             BCF     STATUS, RP0      ; Bank 0
0005 180C               0060             BTFSC   PIR1, TMR1IF     ; Timer 1 overflowed?
0006 2843               0061             GOTO    T1_OVRFL         ; YES, Service the Timer1 Overflow Interrupt
0007 1C0B               0062             BTFSS   INTCON, RBIF     ; NO, Did PORTB change?
0008 28D0               0063             GOTO    ERROR1           ; NO, Error Condition - Unknown Interrupt
                        0064 ;
                        0065 PORTB_FLAG                          ; Are any of PORTB's inputs active?
0009 0806               0066             MOVF    PORTB, W         ;
000A 39E0               0067             ANDLW   0xE0             ; Keep only the 3 switch values
000B 00B5               0068 DEBOUNCE    MOVWF   TEMP             ;
000C 3002               0069             MOVLW   DB_HI_BYTE       ; This is the debounce delay
000D 08B3               0070             MOVF    MSD              ;
000E 01B4               0071             CLRF    LSD              ;
000F 0BB4               0072 KB_D_LP1    DECFSZ  LSD              ;
0010 280F               0073             GOTO    KB_D_LP1         ;
0011 0BB3               0074             DECFSZ  MSD              ;
0012 280F               0075             GOTO    KB_D_LP1         ;
0013 0806               0076 END_DELAY   MOVF    PORTB, W         ;
0014 39E0               0077             ANDLW   0xE0             ; Keep only the 3 switch values
0015 02B5               0078             SUBWF   TEMP, F          ;
0016 1D03               0079             BTFSS   STATUS, Z        ; Is the Zero bit set?
                        0080                                      ;   (switches were the same on 2 reads)
0017 280B               0081             GOTO    DEBOUNCE         ; NO, Try another read
0018 00B5               0082 KEY_MATCH   MOVWF   TEMP             ; YES, need to see which is depressed.
                        0083 ;
0019 3080               0084             MOVLW   0x80             ; Since doing key inputs, clear TMR1
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001A 008F           0085             MOVWF   TMR1H          ;   for 1 sec overflow.
001B 018E           0086             CLRF    TMR1L          ;
001C 100C           0087             BCF     PIR1, TMR1IF   ; Clear Timer 1 Interrupt Flag
                    0088
001D 1FB5           0089             BTFSS   TEMP, HR_MIN_SW   ; Is the hour-min-off switch depressed?
001E 2826           0090             GOTO    SELECT_UNITS      ; YES, specify the units selected
001F 1F35           0091             BTFSS   TEMP, INC_SW      ; Is the inc switch depressed?
0020 282B           0092             GOTO    INC_UNIT          ; YES, Increment the selected Units
0021 1EB5           0093             BTFSS   TEMP, CLR_MIN_SW  ; Is the clear minute switch depressed?
0022 2835           0094             GOTO    CLR_MIN           ; YES, clear the minutes.
                    0095 ;
                    0096 ; No key match occured, or finished with PortB interrupt and need to clear interrupt condition.
                    0097 ;
                    0098 CLR_RB                        ; No RB<7:5> keys are depressed (rising edge Int.)
0023 0886           0099             MOVF    PORTB, F       ; Clear the PORTB mismatch condition
0024 100B           0100             BCF     INTCON, RBIF   ; Clear the PORTB Int Flag
                    0101         if ( Debug )
                    0102             bcf     PORTD, 0    ; Set low, use to measure total
                    0103         endif                   ;   time in Int Service Routine
0025 0009           0104             RETFIE              ; Return / Enable Global Interrupts
                    0105 ;
                    0107 SELECT_UNITS
0026 30FF           0108             MOVLW   0xFF               ;
0027 00C0           0109             MOVWF   WAIT_CNTR          ; WAIT_CNTR has LSb set after each SELECT UNIT key press.
0028 0AA0           0110             INCF    FLAG_REG, F        ; Increment the pointer to the MIN_UNIT:HR_UNIT
0029 1620           0111             BSF     FLAG_REG, KEY_INPUT ;
002A 2875           0112             GOTO    DISPLAY            ; Flash the Display of the selected unit
                    0113 ;
                    0114 INC_UNIT
002B 01C0           0115             CLRF    WAIT_CNTR          ; WAIT_CNTR is cleared to zero after each key press.
002C 1820           0116             BTFSC   FLAG_REG, HR_UNIT  ; Are the hour units selected?
002D 285C           0117             GOTO    INC_HRS            ; YES, Increment the hour units
002E 1CA0           0118             BTFSS   FLAG_REG, MIN_UNIT ; Are the minute units selected?
002F 2823           0119             GOTO    CLR_RB             ; NO, Not a valid key. Clear flags
                    0120 ;
0030 0AB1           0121             INCF    MIN, F             ; YES, Increment the minute units
0031 303C           0122             MOVLW   0x3C               ; This is Decimal 60
0032 0231           0123             SUBWF   MIN, W             ; MIN - 60 = ?
0033 1D03           0124             BTFSS   STATUS, Z          ; MIN = 60?
0034 2875           0125             GOTO    DISPLAY            ; NO, display time
                    0126                                        ; YES, MIN = 0 (use code from CLR_MIN)
0035 01B1           0127 CLR_MIN     CLRF    MIN                ; MIN = 0
0036 3004           0128             MOVLW   0x04               ; Clear the seconds
0037 00B2           0129             MOVWF   SECS               ; Initial Second count = 4
0038 3080           0130             MOVLW   0x80               ; Clear Timer 1, for 1 sec overflow
0039 008F           0131             MOVWF   TMR1H              ;
003A 018E           0132             CLRF    TMR1L              ;
003B 100C           0133             BCF     PIR1, TMR1IF       ; Clear the TMR1 overflow interrupt.
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003C 01C0    0134             CLRF    WAIT_CNTR           ; WAIT_CNTR is cleared to zero after each key press.
003D 1AB5    0135             BTFSC   TEMP, CLR_MIN_SW    ; Is the clear minute switch depressed?
003E 2875    0136             GOTO    DISPLAY             ; NO. Rollover from increment key
003F 10A0    0137             BCF     FLAG_REG, MIN_UNIT  ; YES, Clear ALL relevant flags
0040 1020    0138             BCF     FLAG_REG, HR_UNIT   ;
0041 1220    0139             BCF     FLAG_REG, KEY_INPUT ;
0042 2875    0140             GOTO    DISPLAY             ;
             0141 ;
             0143 ;
             0144 T1_OVRFL
0043 100C    0145             BCF     PIR1, TMR1IF          ; Clear Timer 1 Interrupt Flag
0044 1E20    0146             BTFSS   FLAG_REG, KEY_INPUT   ; Are we using the key inputs?
0045 284F    0147             GOTO    INC_TIME              ; NO, Need to Increment the time
0046 0AC0    0148             INCF    WAIT_CNTR, F          ; YES,
0047 300A    0149             MOVLW   0x0A                  ; 10 counts x 1 seconds
0048 0240    0150             SUBWF   WAIT_CNTR, W          ; Has the 10 Sec wait for key expired?
0049 1D03    0151             BTFSS   STATUS, Z             ; Is the result 0?
004A 2875    0152             GOTO    DISPLAY               ; NO, Display value
004B 01C0    0153             CLRF    WAIT_CNTR             ; YES, Clear WAIT_CNTR
004C 1220    0154             BCF     FLAG_REG, KEY_INPUT   ;
004D 1020    0155             BCF     FLAG_REG, HR_UNIT     ;
004E 10A0    0156             BCF     FLAG_REG, MIN_UNIT    ;
             0157 ;
             0158 ;
004F 3080    0159 INC_TIME    MOVLW   0x80            ;
0050 008F    0160             MOVWF   TMR1H           ; 1 Second Overflow
0051 0AB2    0161             INCF    SECS, F         ;
0052 1F32    0162             BTFSS   SECS, 6         ;
0053 2875    0163             GOTO    DISPLAY         ;
0054 3004    0164             MOVLW   0x04            ;
0055 00B2    0165             MOVWF   SECS            ;
0056 0AB1    0166             INCF    MIN, F          ;
0057 303C    0167             MOVLW   0x3C            ; W = 60d
0058 0231    0168             SUBWF   MIN, W          ;
0059 1D03    0169             BTFSS   STATUS, Z       ;
005A 2875    0170             GOTO    DISPLAY         ;
005B 01B1    0171             CLRF    MIN             ;
005C 0AB0    0172 INC_HRS     INCF    HRS, F          ;
005D 300C    0173             MOVLW   0x0C            ; It is now 12:00, Toggle AM / PM
005E 0230    0174             SUBWF   HRS, W          ;
005F 1D03    0175             BTFSS   STATUS, Z       ;
0060 2867    0176             GOTO    CK_13           ; Need to check if HRS = 13
0061 1FA0    0177             BTFSS   FLAG_REG, AM    ; Was it AM or PM
0062 2865    0178             GOTO    SET_AM          ; Was PM, Needs to be AM
0063 13A0    0179             BCF     FLAG_REG, AM    ; It is PM
0064 2875    0180             GOTO    DISPLAY         ;
0065 17A0    0181 SET_AM      BSF     FLAG_REG, AM    ; It is AM
0066 2875    0182             GOTO    DISPLAY         ;
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                        0183 ;
0067 300D               0184 CK_13       MOVLW   0x0D            ; Check if HRS = 13
0068 0230               0185             SUBWF   HRS, W          ;
0069 1D03               0186             BTFSS   STATUS, Z       ;
006A 2875               0187             GOTO    DISPLAY         ;
006B 01B0               0188             CLRF    HRS             ;
006C 0AB0               0189             INCF    HRS, F          ;
006D 2875               0190             GOTO    DISPLAY         ;
                        0191 ;
                        0193 INIT_DISPLAY
006E 300C               0194             MOVLW   DISP_ON         ; Display On, Cursor On
006F 20E3               0195             CALL    SEND_CMD        ; Send This command to the Display Module
0070 3001               0196             MOVLW   CLR_DISP        ; Clear the Display
0071 20E3               0197             CALL    SEND_CMD        ; Send This command to the Display Module
0072 3006               0198             MOVLW   ENTRY_INC       ; Set Entry Mode Inc., No shift
0073 20E3               0199             CALL    SEND_CMD        ; Send This command to the Display Module
0074 0008               0200             RETURN
                        0201 ;
                        0202 DISPLAY
0075 3080               0203             MOVLW   DD_RAM_ADDR     ;
0076 20E3               0204             CALL    SEND_CMD        ;
                        0205 ;
0077 1A20               0206             BTFSC   FLAG_REG, KEY_INPUT ; Do we need to flash the selectected units?
0078 287D               0207             GOTO    FLASH_UNITS         ; YES, we need to flash selected units
0079 20A4               0208             CALL    LOAD_HRS            ; NO, do a normal display
007A 20AD               0209             CALL    LOAD_COLON          ;
007B 20B2               0210             CALL    LOAD_MIN            ;
007C 28BB               0211             GOTO    LOAD_AM             ;
                        0212 ;
                        0213 FLASH_UNITS
007D 018A               0214             CLRF    PCLATH              ; This clears PCLATH, This table in 1st
007E 0820               0215             MOVF    FLAG_REG, W         ;    256 bytes of program memory
007F 3903               0216             ANDLW   0x03                ; only HR_UNIT and MIN_UNIT bit can be non-zero
                        0217 UNIT_TBL
0080 0782               0218             ADDWF   PCL                 ; HR_UNIT:MIN_UNIT
0081 289F               0219             GOTO    NO_UNITS            ;    0 0  - Display everything.
0082 2887               0220             GOTO    HR_UNITS            ;    0 1  - Flash the hour units
0083 2893               0221             GOTO    MIN_UNITS           ;    1 0  - Flash the minute units
                        0222 UNIT_TBL_END
0084 30FC               0223             MOVLW   0xFC                ;    1 1  - Need to clear FLAG_REG
0085 05A0               0224             ANDWF   FLAG_REG, F         ;                  <HR_UNIT:MIN_UNIT>
0086 289F               0225             GOTO    NO_UNITS            ;    0 0  - Display everything.
                        0226 ;
                        0227     if ( (UNIT_TBL & 0x0FF) >= (UNIT_TBL_END & 0x0FF) )
                        0228        MESSG   "Warning: Table UNIT_TBL crosses page boundry in computed jump"
                        0229     endif
                        0230 ;
                        0231 ;
```

```
                        0232 HR_UNITS
0087 1C40               0233            BTFSS   WAIT_CNTR, 0    ; If WAIT_CNTR is odd,
                        0234                                    ;    hour digits are displayed as blank
0088 288D               0235            GOTO    SKIP_BLK_HRS    ;
0089 3020               0236            MOVLW   ' '             ;
008A 20D4               0237            CALL    SEND_CHAR       ;
008B 3020               0238            MOVLW   ' '             ;
008C 20D4               0239            CALL    SEND_CHAR       ;
                        0240 SKIP_BLK_HRS
008D 1C40               0241            BTFSS   WAIT_CNTR, 0    ; WAIT_CNTR was even, display hour digits
008E 20A4               0242            CALL    LOAD_HRS        ;
                        0243 ;
008F 303A               0244            MOVLW   ':'             ; : always on, display all other character
0090 20D4               0245            CALL    SEND_CHAR       ;
0091 20B2               0246            CALL    LOAD_MIN        ;
0092 28BB               0247            GOTO    LOAD_AM         ;
                        0248 ;
                        0250 MIN_UNITS
0093 20A4               0251            CALL    LOAD_HRS        ; Display hours
0094 303A               0252            MOVLW   ':'             ; : always on
0095 20D4               0253            CALL    SEND_CHAR       ;
0096 1C40               0254            BTFSS   WAIT_CNTR, 0    ; If WAIT_CNTR is odd,
                        0255                                    ;   minute digits are displayed as blank
0097 289C               0256            GOTO    SKIP_BLK_MIN    ;
0098 3020               0257            MOVLW   ' '             ;
0099 20D4               0258            CALL    SEND_CHAR       ;
009A 3020               0259            MOVLW   ' '             ;
009B 20D4               0260            CALL    SEND_CHAR       ;
                        0261 SKIP_BLK_MIN
009C 1C40               0262            BTFSS   WAIT_CNTR, 0    ; WAIT_CNTR was even, display minute digits
009D 20B2               0263            CALL    LOAD_MIN        ;
009E 28BB               0264            GOTO    LOAD_AM         ;
                        0265 ;
                        0266 NO_UNITS
009F 20A4               0267            CALL    LOAD_HRS        ; Display all character
00A0 303A               0268            MOVLW   ':'             ;
00A1 20D4               0269            CALL    SEND_CHAR       ;
00A2 20B2               0270            CALL    LOAD_MIN        ;
00A3 28BB               0271            GOTO    LOAD_AM         ;
                        0272 ;
                        0273 LOAD_HRS
00A4 0830               0274            MOVF    HRS, W          ; Load the Wreg with the value
00A5 20C7               0275            CALL    BIN_2_BCD       ;   to convert to BCD
00A6 0833               0276            MOVF    MSD, W          ; Load the MSD value into the Wreg
00A7 2400               0277            CALL    NUM_TABLE       ; Get the ASCII code
00A8 20D4               0278            CALL    SEND_CHAR       ; Send this Character to the Display
                        0279 ;
00A9 0834               0280            MOVF    LSD, W          ; Load the LSD value into the Wreg
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00AA 2400           0281            CALL    NUM_TABLE       ; Get the ASCII code
00AB 20D4           0282            CALL    SEND_CHAR       ; Send this Character to the Display
00AC 0008           0283            RETURN
                    0284 ;
00AD 3020           0285 LOAD_COLON  MOVLW   ' '             ; ASCII value for a Blank space
00AE 1832           0286            BTFSC   SECS, 0         ; Is it an EVEN or ODD second
00AF 3E1A           0287            ADDLW   ':' - ' '       ; Is ODD, Second colon is ON.
                    0288                                    ;   Add delta offset of ASCII Characters
00B0 20D4           0289            CALL    SEND_CHAR       ; Send this Character to the Display
00B1 0008           0290            RETURN
                    0291 ;
                    0292 LOAD_MIN
00B2 0831           0293            MOVF    MIN, W          ; Load the Wreg with the value
00B3 20C7           0294            CALL    BIN_2_BCD       ;   to convert to BCD
00B4 0833           0295            MOVF    MSD, W          ; Load the MSD value into the Wreg
00B5 2400           0296            CALL    NUM_TABLE       ; Get the ASCII code
00B6 20D4           0297            CALL    SEND_CHAR       ; Send this Character to the Display
                    0298 ;
00B7 0834           0299            MOVF    LSD, W          ; Load the LSD value into the Wreg
00B8 2400           0300            CALL    NUM_TABLE       ; Get the ASCII code
00B9 20D4           0301            CALL    SEND_CHAR       ; Send this Character to the Display
00BA 0008           0302            RETURN
                    0303 ;
00BB 3020           0305 LOAD_AM     MOVLW   ' '             ; ASCII value for a Blank space
00BC 20D4           0306            CALL    SEND_CHAR       ; Send this Character to the Display
00BD 3041           0307            MOVLW   'A'             ; ASCII value for a Blank space
00BE 1FA0           0308            BTFSS   FLAG_REG, AM    ; Is it AM or PM
00BF 3E0F           0309            ADDLW   'P' - 'A'       ; Is PM, Add delta offset of ASCII Characters
00C0 20D4           0310            CALL    SEND_CHAR       ; Send this Character to the Display
00C1 304D           0311            MOVLW   'M'
00C2 20D4           0312            CALL    SEND_CHAR       ; Send this Character to the Display
                    0313 ;
00C3 1683           0314            BSF     STATUS, RP0     ; Bank 1
00C4 1381           0315            BCF     OPTION_R, RBPU  ; Turn on PORTB Pull-up
00C5 1283           0316            BCF     STATUS, RP0     ; Bank 0
00C6 2823           0317            GOTO    CLR_RB          ; You've displayed the time, Clear RBIF
                    0318 ;
                    0319 ;
                    0320 ;*****************************************************************************
                    0321 ; The BIN_2_BCD routine converts the binary number, in the W register, to a
                    0322 ; binary coded decimal (BCD) munber. This BCD number is stored MSD:LSD. This
                    0323 ; routine is used by the DISPLAY subroutine, to convert the time values.
                    0324 ;*****************************************************************************
                    0325 ;
00C7 01B3           0326 BIN_2_BCD   CLRF    MSD             ; This value contain the 10's digit value
00C8 00B4           0327            MOVWF   LSD             ; This value contain the 1's digit value
00C9 300A           0328 TENS_SUB    MOVLW   .10             ; A decimal 10
00CA 0234           0329            SUBWF   LSD, W          ;
00CB 1C03           0330            BTFSS   STATUS, C       ; Did this subtract cause a Negative Result?
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00CC 3400           0331            RETLW   0           ; YES, Return from this Routine
00CD 00B4           0332            MOVWF   LSD         ; No, move the result into LSD
00CE 0AB3           0333            INCF    MSD, F      ; Increment the most significat digit
00CF 28C9           0334            GOTO    TENS_SUB    ;
                    0335 ;
                    0336 ;
                    0337 ; Should NEVER get here
                    0338 ;
00D0 1283           0339 ERROR1     BCF     STATUS, RP0         ; Bank 0
                    0340 ;
                    0341        if ( Debug )
                    0342            bsf     PORTD, 1
                    0343            bcf     PORTD, 1
                    0344        else
00D1 1407           0345            BSF     PORTC, 0
00D2 1007           0346            BCF     PORTC, 0
                    0347        endif
00D3 28D0           0348            GOTO    ERROR1
                    0349 ;
                    0351 ;
                    0352 ;*****************************************************************
                    0353 ;* SendChar - Sends character to LCD                             *
                    0354 ;* This routine splits the character into the upper and lower    *
                    0355 ;* nibbles and sends them to the LCD, upper nibble first.        *
                    0356 ;* The data is transmitted on the PORT<3:0> pins                 *
                    0357 ;*****************************************************************
                    0358
                    0359 SEND_CHAR
00D4 00B6           0360            MOVWF   CHAR            ; Character to be sent is in W
00D5 20F2           0361            CALL    BUSY_CHECK      ; Wait for LCD to be ready
00D6 0E36           0362            SWAPF   CHAR, W
00D7 390F           0363            ANDLW   0x0F            ; Get upper nibble
00D8 0086           0364            MOVWF   LCD_DATA        ; Send data to LCD
00D9 1085           0365            BCF     LCD_CNTL, R_W   ; Set LCD to read
00DA 1505           0366            BSF     LCD_CNTL, RS    ; Set LCD to data mode
00DB 1405           0367            BSF     LCD_CNTL, E     ; toggle E for LCD
00DC 1005           0368            BCF     LCD_CNTL, E
00DD 0836           0369            MOVF    CHAR, W
00DE 390F           0370            ANDLW   0x0F            ; Get lower nibble
00DF 0086           0371            MOVWF   LCD_DATA        ; Send data to LCD
00E0 1405           0372            BSF     LCD_CNTL, E     ; toggle E for LCD
00E1 1005           0373            BCF     LCD_CNTL, E
00E2 0008           0374            RETURN
                    0375
                    0376 ;*****************************************************************
```

```
                     0377 ;* SendCmd - Sends command to LCD                                *
                     0378 ;* This routine splits the command into the upper and lower       *
                     0379 ;* nibbles and sends them to the LCD, upper nibble first.         *
                     0380 ;* The data is transmitted on the PORT<3:0> pins                  *
                     0381 ;*********************************************************************
                     0382
                     0383 SEND_CMD
00E3 00B6            0384             MOVWF   CHAR            ; Character to be sent is in W
00E4 20F2            0385             CALL    BUSY_CHECK      ; Wait for LCD to be ready
00E5 0E36            0386             SWAPF   CHAR, W
00E6 390F            0387             ANDLW   0x0F            ; Get upper nibble
00E7 0086            0388             MOVWF   LCD_DATA        ; Send data to LCD
00E8 1085            0389             BCF     LCD_CNTL, R_W   ; Set LCD to read
00E9 1105            0390             BCF     LCD_CNTL, RS    ; Set LCD to command mode
00EA 1405            0391             BSF     LCD_CNTL, E     ; toggle E for LCD
00EB 1005            0392             BCF     LCD_CNTL, E
00EC 0836            0393             MOVF    CHAR, W
00ED 390F            0394             ANDLW   0x0F            ; Get lower nibble
00EE 0086            0395             MOVWF   LCD_DATA        ; Send data to LCD
00EF 1405            0396             BSF     LCD_CNTL, E     ; toggle E for LCD
00F0 1005            0397             BCF     LCD_CNTL, E
00F1 0008            0398             RETURN
                     0400 ;*********************************************************************
                     0401 ;* This routine checks the busy flag, returns when not busy         *
                     0402 ;*  Affects:                                                        *
                     0403 ;*      TEMP - Returned with busy/address                           *
                     0404 ;*********************************************************************
                     0405
                     0406 BUSY_CHECK
                     0407 ;
                     0408         if ( Debug )
                     0409             bsf     PORTD, 3
                     0410             bcf     PORTD, 3
                     0411         endif
00F2 0186            0412             CLRF    LCD_DATA        ;** Have PORTB<3:0> output low
00F3 1683            0413             BSF     STATUS, RP0     ; Bank 1
00F4 1781            0414             BSF     OPTION_R, RBPU  ; Turn off PORTB Pull-up
00F5 30FF            0415             MOVLW   0xFF            ; Set PortB for input
00F6 0086            0416             MOVWF   LCD_DATA_TRIS
00F7 1283            0417             BCF     STATUS, RP0     ; Bank 0
00F8 1105            0418             BCF     LCD_CNTL, RS    ; Set LCD for Command mode
00F9 1485            0419             BSF     LCD_CNTL, R_W   ; Setup to read busy flag
00FA 1405            0420             BSF     LCD_CNTL, E     ; Set E high
00FB 1005            0421             BCF     LCD_CNTL, E     ; Set E low
00FC 0E06            0422             SWAPF   LCD_DATA, W     ; Read upper nibble busy flag, DDRam address
```

```
00FD 39F0           0423            ANDLW   0xF0            ; Mask out lower nibble
00FE 00B5           0424            MOVWF   TEMP            ;
00FF 1405           0425            BSF     LCD_CNTL, E     ; Toggle E to get lower nibble
0100 1005           0426            BCF     LCD_CNTL, E
0101 0806           0427            MOVF    LCD_DATA, W     ; Read lower nibble busy flag, DDRam address
0102 390F           0428            ANDLW   0x0F            ; Mask out upper nibble
0103 04B5           0429            IORWF   TEMP, F         ; Combine nibbles
0104 1BB5           0430            BTFSC   TEMP, 7         ; Check busy flag, high = busy
0105 28F2           0431            GOTO    BUSY_CHECK      ; If busy, check again
0106 1085           0432            BCF     LCD_CNTL, R_W
0107 1683           0433            BSF     STATUS, RP0     ; Bank 1
0108 30F0           0434            MOVLW   0xF0            ;
0109 0086           0435            MOVWF   LCD_DATA_TRIS   ; RB7 - 4 = inputs, RB3 - 0 = output
010A 1283           0436            BCF     STATUS, RP0     ; Bank 0
010B 0008           0437            RETURN
                    0438 ;
                    0440 ;
                    0441 ;*******************************************************************************
                    0442 ;*****      Start program here, Power-On Reset occurred.
                    0443 ;*******************************************************************************
                    0444 ;
                    0445 START                              ; POWER_ON Reset (Beginning of program)
010C 1283           0446            BCF     STATUS, RP0     ; Bank 0
010D 300C           0447            MOVLW   0x0C            ; Decimal 12
010E 00B0           0448            MOVWF   HRS             ; HOURS = 12
010F 01B1           0449            CLRF    MIN             ; MIN   = 00
0110 3000           0450            MOVLW   0x00            ;
0111 00A0           0451            MOVWF   FLAG_REG        ; PM light is on
0112 3004           0452            MOVLW   0x04            ; Initial value of seconds (64d - 60d)
0113 00B2           0453            MOVWF   SECS            ; This allows a simple bit test to see if 60
                    0454                                    ;   secs has elapsed.
0114 3080           0455            MOVLW   0x80            ; TIM1H:TMR1L = 0x8000 gives 1 second
0115 008F           0456            MOVWF   TMR1H           ;   overflow, at 32 KHz.
0116 018E           0457            CLRF    TMR1L           ;
                    0458 ;
                    0459 MCLR_RESET                         ; A Master Clear Reset
0117 1283           0460            BCF     STATUS, RP0     ; Bank 0
0118 0183           0461            CLRF    STATUS          ; Do initialization (Bank 0)
0119 018B           0462            CLRF    INTCON
011A 018C           0463            CLRF    PIR1
011B 1683           0464            BSF     STATUS, RP0     ; Bank 1
011C 3000           0465            MOVLW   0x00            ; The LCD module does not like to work w/ weak pull-ups
011D 0081           0466            MOVWF   OPTION_R        ;
011E 018C           0467            CLRF    PIE1            ; Disable all peripheral interrupts
011F 30FF           0468            MOVLW   0xFF            ;
0120 009F           0469            MOVWF   ADCON1          ; Port A is Digital.
                    0470 ;
                    0471 ;
```

```
0121 1283           0472            BCF     STATUS, RP0     ; Bank 0
0122 0185           0473            CLRF    PORTA           ; ALL PORT output should output Low.
0123 0186           0474            CLRF    PORTB
0124 0187           0475            CLRF    PORTC
0125 0188           0476            CLRF    PORTD
0126 0189           0477            CLRF    PORTE
0127 1010           0478            BCF     T1CON, TMR1ON   ; Timer 1 is NOT incrementing
                    0479 ;
0128 1683           0480            BSF     STATUS, RP0     ; Select Bank 1
0129 0185           0481            CLRF    TRISA           ; RA5 -  0 outputs
012A 30F0           0482            MOVLW   0xF0            ;
012B 0086           0483            MOVWF   TRISB           ; RB7 - 4 inputs, RB3 - 0 outputs
012C 0187           0484            CLRF    TRISC           ; RC Port are outputs
012D 1407           0485            BSF     TRISC, T1OSO    ; RC0 needs to be input for the oscillator to function
012E 0188           0486            CLRF    TRISD           ; RD Port are outputs
012F 0189           0487            CLRF    TRISE           ; RE Port are outputs
0130 140C           0488            BSF     PIE1, TMR1IE    ; Enable TMR1 Interrupt
0131 1381           0489            BCF     OPTION_R, RBPU  ; Enable PORTB pull-ups
0132 1283           0490            BCF     STATUS, RP0     ; Select Bank 0
0133 0886           0491            MOVF    PORTB, F        ; Need to clear 1st RBIF, due to
0134 100B           0492            BCF     INTCON, RBIF    ;    set up of PORTB
                    0493 ;
                    0495 ;
                    0496 ; Initilize the LCD Display Module
                    0497 ;
0135 0185           0498            CLRF    LCD_CNTL        ; ALL PORT output should output Low.
                    0499
                    0500 DISPLAY_INIT
0136 3002           0501            MOVLW   0x02            ; Command for 4-bit interface
0137 0086           0502            MOVWF   LCD_DATA        ;
0138 1405           0503            BSF     LCD_CNTL, E     ;
0139 1005           0504            BCF     LCD_CNTL, E     ;
                    0505 ;
                    0506 ; This routine takes the calculated times that the delay loop needs to
                    0507 ; be executed, based on the LCD_INIT_DELAY EQUate that includes the
                    0508 ; frequency of operation. These uses registers before they are needed to
                    0509 ; store the time.
                    0510 ;
013A 3006           0511 LCD_DELAY  MOVLW   LCD_INIT_DELAY  ;
013B 00B3           0512            MOVWF   MSD             ; Use MSD and LSD Registers to Initilize LCD
013C 01B4           0513            CLRF    LSD             ;
013D 0BB4           0514 LOOP2      DECFSZ  LSD             ; Delay time = MSD * ((3 * 256) + 3) * Tcy
013E 293D           0515            GOTO    LOOP2           ;
013F 0BB3           0516            DECFSZ  MSD             ;
                    0517 END_LCD_DELAY
0140 293D           0518            GOTO    LOOP2           ;
                    0519 ;
                    0520 ; Command sequence for 2 lines of 5x7 characters
```

```
                    0521 ;
0141 3002           0522 CMD_SEQ     MOVLW   0X02
0142 0086           0523             MOVWF   LCD_DATA
0143 1405           0524             BSF     LCD_CNTL, E     ;
0144 1005           0525             BCF     LCD_CNTL, E     ;
0145 3008           0526             MOVLW   0x08            ;
0146 0086           0527             MOVWF   LCD_DATA        ;
0147 1405           0528             BSF     LCD_CNTL, E     ;
0148 1005           0529             BCF     LCD_CNTL, E     ;
                    0530 ;
                    0531 ; Busy Flag should be valid after this point
                    0532 ;
0149 300C           0533             MOVLW   DISP_ON         ;
014A 20E3           0534             CALL    SEND_CMD        ;
014B 3001           0535             MOVLW   CLR_DISP        ;
014C 20E3           0536             CALL    SEND_CMD        ;
014D 3006           0537             MOVLW   ENTRY_INC       ;
014E 20E3           0538             CALL    SEND_CMD        ;
014F 3080           0539             MOVLW   DD_RAM_ADDR     ;
0150 20E3           0540             CALL    SEND_CMD        ;
                    0541 ;
                    0543 ;
                    0544 ; Initialize the Special Function Registers (SFR) interrupts
                    0545 ;
0151 018C           0546             CLRF    PIR1            ;
0152 300E           0547             MOVLW   0x0E
0153 0090           0548             MOVWF   T1CON           ; RC1 is overridden by TCKO
0154 170B           0549             BSF     INTCON, PEIE    ; Enable Peripheral Interrupts
0155 158B           0550             BSF     INTCON, RBIE    ; Disable PORTB<7:4> Change Interrupts
0156 178B           0551             BSF     INTCON, GIE     ; Enable all Interrupts
                    0552 ;
0157 206E           0553             CALL    INIT_DISPLAY    ;
0158 2075           0554             CALL    DISPLAY         ;
                    0555 ;
0159 300E           0556             MOVLW   0x0E
015A 0090           0557             MOVWF   T1CON           ; Enable T1 Oscillator, Ext Clock, Async, prescaler = 1
015B 1410           0558             BSF     T1CON, TMR1ON   ; Turn Timer 1 ON
                    0559 ;
                    0560         if ( PICMaster )
                    0561 lzz         goto    lzz             ; Loop waiting for interrupts (for use with PICMASTER)
                    0562         else
                    0563 ;
015C 0063           0564 SLEEP_LP    SLEEP                   ; Wait for Change on PORTB interrupt. or TMR1 timeout
015D 0000           0565             NOP                     ;
015E 295C           0566             GOTO    SLEEP_LP        ;
                    0567 ;
                    0568         endif
                    0569 ;
```

```
                    0570 ; Here is where you do things depending on the type of RESET (Not a Power-On Reset).
                    0571 ;
015F 1E03           0572 OTHER_RESET   BTFSS  STATUS, TO     ; WDT Time-out?
0160 28D0           0573 WDT_TIMEOUT   GOTO   ERROR1         ; YES, This is error condition
                    0574         if ( Debug_PU )
0161 290C           0575             goto   START           ; MCLR reset, Goto START
                    0576         else
                    0577             GOTO   MCLR_RESET      ; MCLR reset, Goto MCLR_RESET
                    0578         endif
                    0579 ;
                    0580         if (Debug )
                    0581 END_START     NOP                  ; END lable for debug
                    0582         endif
                    0583 ;
                    0585 ;
                    0586     org     TABLE_ADDR
                    0587 ;
0400 00B5           0588 NUM_TABLE       MOVWF   TEMP               ; Store value to TEMP register
0401 3004           0589                 MOVLW   HIGH (TABLE_ADDR)  ; Ensure that the PCLATH high has the
0402 008A           0590                 MOVWF   PCLATH             ;   correct value
0403 0835           0591                 MOVF    TEMP, W            ; Value into table
0404 390F           0592                 ANDLW   0x0F               ; Mask to 4-bits (00 - 0Fh)
0405 0782           0593 NUM_TBL         ADDWF   PCL, F             ; Determine Offset into table
0406 3430           0594                 RETLW   '0'                ; ASCII value of "0" in W register
0407 3431           0595                 RETLW   '1'                ; ASCII value of "1" in W register
0408 3432           0596                 RETLW   '2'                ; ASCII value of "2" in W register
0409 3433           0597                 RETLW   '3'                ; ASCII value of "3" in W register
040A 3434           0598                 RETLW   '4'                ; ASCII value of "4" in W register
040B 3435           0599                 RETLW   '5'                ; ASCII value of "5" in W register
040C 3436           0600                 RETLW   '6'                ; ASCII value of "6" in W register
040D 3437           0601                 RETLW   '7'                ; ASCII value of "7" in W register
040E 3438           0602                 RETLW   '8'                ; ASCII value of "8" in W register
040F 3439           0603                 RETLW   '9'                ; ASCII value of "9" in W register
                    0604                                            ; Any enter after is in error (Display an E)
0410 3445           0605                 RETLW   'E'                ; ASCII value of "E" in W register
0411 3445           0606                 RETLW   'E'                ; ASCII value of "E" in W register
0412 3445           0607                 RETLW   'E'                ; ASCII value of "E" in W register
0413 3445           0608                 RETLW   'E'                ; ASCII value of "E" in W register
0414 3445           0609                 RETLW   'E'                ; ASCII value of "E" in W register
0415 3445           0610 NUM_TBL_END     RETLW   'E'                ; ASCII value of "E" in W register
                    0611 ;
                    0612     if ( (NUM_TBL & 0x0FF) >= (NUM_TBL_END & 0x0FF) )
                    0613        MESSG   "Warning: Table NUM_TBL crosses page boundry in computed jump"
                    0614     endif
                    0615 ;
                    0616 ;
                    0617     org     PMEM_END            ; End of Program Memory
07FF 28D0           0618             GOTO    ERROR1          ; If you get here your program was lost
```

```
                    0619
                    0620     end
                    0621
                    0622


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

0000 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0040 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX

0080 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
00C0 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX

0100 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX
0140 : XXXXXXXXXXXXXXXX XXXXXXXXXXXXXXXX XX-------- --------

0400 : XXXXXXXXXXXXXXXX XXXXXX------ -------- --------
0440 : -------- -------- -------- --------

0780 : -------- -------- -------- --------
07C0 : -------- -------- -------- -------X

All other memory blocks unused.


Errors   :    0
Warnings :   16
```

NOTE: Special Function Register data memory locations in Bank 1, are specified by their true address in the file C74_REG.H. The use of the MPASM assembler will generate a warning message, when these lables are used with direct addressing.

APPENDIX B: CLOCK_01.H INCLUDE FILE

```
       nolist
;*****************************************************************************
;
;  This is the custom Header File for the real time clock application note
;       PROGRAM:       CLOCK_01.H
;       Revision:      5-04-94
;
;*****************************************************************************
; This is used for the ASSEMBLER to recalculate certain frequency
; dependant variables. The value of Dev_Freq must be changed to
; reflect the frequency that the device actually operates at.
;
Dev_Freq               EQU     D'4000000'     ; Device Frequency is 4 MHz
DB_HI_BYTE             EQU     (HIGH ((( Dev_Freq / 4 ) * 1 / D'1000' ) / 3 ) ) + 1
LCD_INIT_DELAY         EQU     (HIGH ((( Dev_Freq / 4 ) * D'46' / D'10000' ) / 3 ) ) + 1
INNER_CNTR             EQU     40             ; RAM Location
OUTER_CNTR             EQU     41             ; RAM Location
;
T1OSO                  EQU     0              ; The RC0 / T1OSO / T1CKI
;
RESET_V                EQU     0x0000         ; Address of RESET Vector
ISR_V                  EQU     0x0004         ; Address of Interrupt Vector
PMEM_END               EQU     0x07FF         ; Last address in Program Memory
TABLE_ADDR             EQU     0x0400         ; Address where to start Tables
;
HR_MIN_SW              EQU     0x7            ; The switch to select the units
INC_SW                 EQU     0x6            ; The switch to increment the selected units
CLR_MIN_SW             EQU     0x5            ; The switch to clear the minutes and seconds
;
FLAG_REG               EQU     0x020          ; Register which contains flag bits
;
;  +------+-----+-----+-------------+-----+-----+-----------+----------+
;  |  AM  |  -  |  -  | KEY_INPUT |  -  |  -  | MIN_UNIT | HR_UNIT |
;  +------+-----+-----+-------------+-----+-----+-----------+----------+
;
AM                     EQU     0x07           ; Flag to specify if AM or PM
;
KEY_INPUT              EQU     0x04           ; Flag to specify if doing key inputs
;
MIN_UNIT               EQU     0x01           ; Flags to specify which units to operate on
HR_UNIT                EQU     0x00           ;  (HRS, MIN, or none)
;
HRS                    EQU     0x030          ; Holds counter value for HOURS
MIN                    EQU     0x031          ; Holds counter value for MINUTES
SECS                   EQU     0x032          ; Holds counter value for SECONDS
MSD                    EQU     0x033          ; Temp. register, Holds Most Significant
                                              ;   Digit of BIN to BCD conversion
LSD                    EQU     0x034          ; Temporary register, Holds Least Significant
                                              ;   Digit of BIN to BCD conversion
TEMP                   EQU     0x035          ; Temporary register
CHAR                   EQU     0x036          ; Temporary register,
                                              ;  Holds value to send to LCD module.
;
WAIT_CNTR              EQU     0x040          ; Counter that holds wait time for key inputs
;
; LCD Display Commands and Control Signal names.
;
E                      EQU     0              ; LCD Enable control line
R_W                    EQU     1              ; LCD Read/Write control line
RS                     EQU     2              ; LCD Register Select control line
;
; LCD Module commands
;
DISP_ON                EQU     0x00C          ; Display on
DISP_ON_C              EQU     0x00E          ; Display on, Cursor on
DISP_ON_B              EQU     0x00F          ; Display on, Cursor on, Blink cursor
```

```
DISP_OFF              EQU     0x008          ; Display off
CLR_DISP              EQU     0x001          ; Clear the Display
ENTRY_INC             EQU     0x006          ;
ENTRY_INC_S           EQU     0x007          ;
ENTRY_DEC             EQU     0x004          ;
ENTRY_DEC_S           EQU     0x005          ;
DD_RAM_ADDR           EQU     0x080          ; Least Significant 7-bit are for address
DD_RAM_UL             EQU     0x080          ; Upper Left coner of the Display
;
        list
```

APPENDIX C: C74_REG.H INCLUDE FILE

```
    nolist
;
;   File =   C64_reg.h
;   Rev. History:     08-04-93 by MP
;                     10-18-93 by MP to make Page ok
;                     11-15-93 by MP to have correct pages for SFR
;
; EQUates for Special Function Registers
;
;
INDF                  EQU           00
RTCC                  EQU           01
OPTION_R              EQU           81
PCL                   EQU           02
STATUS                EQU           03
FSR                   EQU           04
PORTA                 EQU           05
TRISA                 EQU           85
PORTB                 EQU           06
TRISB                 EQU           86
PORTC                 EQU           07
TRISC                 EQU           87
PORTD                 EQU           08
TRISD                 EQU           88
PORTE                 EQU           09
TRISE                 EQU           89
PCLATH                EQU           0A
INTCON                EQU           0B
PIR1                  EQU           0C
PIE1                  EQU           8C
TMR1L                 EQU           0E
PCON                  EQU           8E
TMR1H                 EQU           0F
T1CON                 EQU           10
TMR2                  EQU           11
T2CON                 EQU           12
PR2                   EQU           92
SSPBUF                EQU           13
SSPADD                EQU           93
SSPCON                EQU           14
SSPSTAT               EQU           94
CCPR1L                EQU           15
CCPR1H                EQU           16
CCP1CON               EQU           17
RCSTA                 EQU           18
TXSTA                 EQU           98
TXREG                 EQU           19
SPBRG                 EQU           99
RCREG                 EQU           1A
CCPR2L                EQU           1B
CCPR2H                EQU           1C
CCP2CON               EQU           1D
ADRES                 EQU           1E
ADCON0                EQU           1F
ADCON1                EQU           9F

;
;*******************************************
;************   Bit Deffinitions   ************
;*******************************************
;
; STATUS register (Address 03/83)
;
IRP                   EQU           7
RP1                   EQU           6
RP0                   EQU           5
```

```
TO                  EQU             4
PD                  EQU             3
Z                   EQU             2
DC                  EQU             1
C                   EQU             0
;
; INTCON register (Address 0B/8B)
;
GIE                 EQU             7
PEIE                EQU             6
RTIE                EQU             5
INTE                EQU             4
RBIE                EQU             3
RTIF                EQU             2
INTF                EQU             1
RBIF                EQU             0
;
; PIR1 register (Address 0C)
;
PSPIF               EQU             7
SSPIF               EQU             3
CCP1IF              EQU             2
TMR2IF              EQU             1
TMR1IF              EQU             0
;
; PIE1 register (Address 8C)
;
PSPIE               EQU             7
SSPIE               EQU             3
CCP1IE              EQU             2
TMR2IE              EQU             1
TMR1IE              EQU             0
;
; OPTION register (Address 81)
;
RBPU                EQU             7
INTEDG              EQU             6
RTS                 EQU             5
RTE                 EQU             4
PSA                 EQU             3
PS2                 EQU             2
PS1                 EQU             1
PS0                 EQU             0
;
; PCON register (Address 8E)
;
POR                 EQU             1
;
; TRISE register (Address 89)
;
IBF                 EQU             7
OBF                 EQU             6
IBOV                EQU             5
PSPMODE             EQU             4
TRISE2              EQU             2
TRISE1              EQU             1
TRISE0              EQU             0

;
; T1CON register (Address 10)
;
T1CKPS1             EQU             5
T1CKPS0             EQU             4
T1OSCEN             EQU             3
T1INSYNC            EQU             2
TMR1CS              EQU             1
TMR1ON              EQU             0
;
```

```
; T2CON register (Address 12)
;
TOUTPS3                 EQU             6
TOUTPS2                 EQU             5
TOUTPS1                 EQU             4
TOUTPS0                 EQU             3
TMR2ON                  EQU             2
T2CKPS1                 EQU             1
T2CKPS0                 EQU             0
;
; SSPCON register (Address 14)
;
WCOL                    EQU             7
SSPOV                   EQU             6
SSPEN                   EQU             5
CKP                     EQU             4
SSPM3                   EQU             3
SSPM2                   EQU             2
SSPM1                   EQU             1
SSPM0                   EQU             0
;
; SSPSTAT register (Address 94)
;
DA                      EQU             5
P                       EQU             4
S                       EQU             3
RW                      EQU             2
UA                      EQU             1
BF                      EQU             0
;
; CCP1CON register (Address 17)
;
CCP1X                   EQU             5
CCP1Y                   EQU             4
CCP1M3                  EQU             3
CCP1M2                  EQU             2
CCP1M1                  EQU             1
CCP1M0                  EQU             0
;
; RCSTA register (Address 18)
;
SPEN                    EQU             7
RC89                    EQU             6
SREN                    EQU             5
CREN                    EQU             4
FERR                    EQU             2
OERR                    EQU             1
RCD8                    EQU             0
;
; TXSTA register (Address 98)
;
CSRC                    EQU             7
TX89                    EQU             6
TXEN                    EQU             5
SYNC                    EQU             4
BRGH                    EQU             2
TRMT                    EQU             1
TXD8                    EQU             0


;
; CCP2CON register (Address 1D)
;
CCP2X                   EQU             5
CCP2Y                   EQU             4
CCP2M3                  EQU             3
CCP2M2                  EQU             2
CCP2M1                  EQU             1
CCP2M0                  EQU             0
```

```
;
; ADCON0 register (Address 1F)
;
ADCS1                   EQU             7
ADCS0                   EQU             6
CHS2                    EQU             5
CHS1                    EQU             4
CHS0                    EQU             3
GO                              EQU             2
DONE                    EQU             2
ADON                    EQU             0
;
; ADCON1 register (Address 9F)
;
PCFG2                   EQU             2
PCFG1                   EQU             1
PCFG0                   EQU             0
;
;*********************************************
;**** Bits for destination control
;****    W = W register is destination
;****    F = File register is destination
;*********************************************
;
W                       EQU             0
F                       EQU             1
;
FALSE                   EQU             0
TRUE                    EQU             1

    list
```

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