Yet Another Clock Featuring the PIC16C924

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INTRODUCTION

Once again, because of its universal familiarity and range of functionality, the clock is used to convey the use of the PIC16C92X microcontrollers. In this case we have added a twist to the clock with the addition of a thermometer. The LCD panel has a two digit temperature readout.

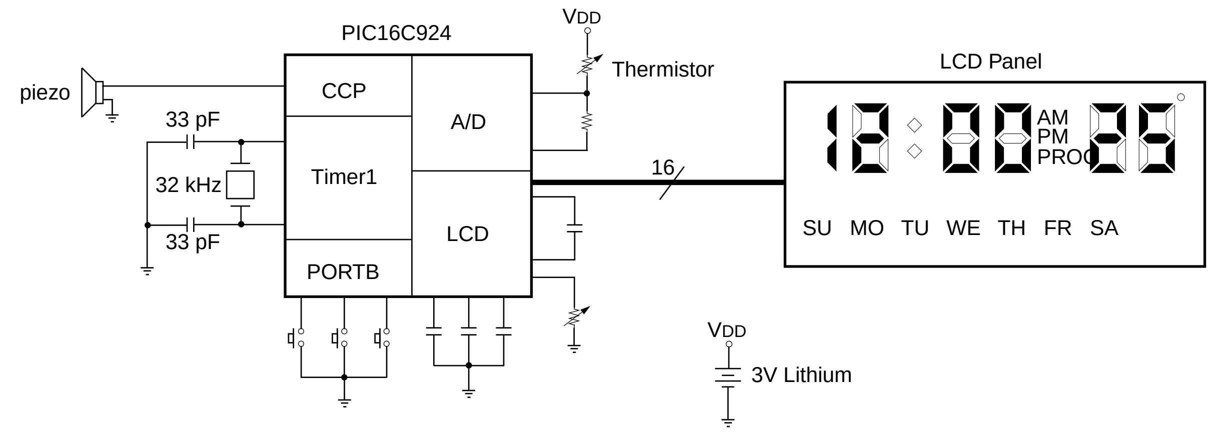
This application note will discuss the use of the following peripherals used to implement the clock: Timer1, PORTB, CCP, A/D converter, and the LCD Module. All source code and examples are written in C and compiled using Microchip's MPLAB-C compiler.

The features of the PIC16C924 are:

- 4K x 14 EPROM program memory
- 176 x 8 SRAM data memory
- DC - 8 MHz operating speed
- Timer0, Timer1, and Timer2
- One CCP pin
- SSP Module with SPI and I^{2}C capability
- 8-bit, 5 channel A/D converter
- LCD Module
  - Multiple LCD timing sources
  - LCD can be driven while in SLEEP
  - Static, 1/2, 1/3 and 1/4 multiplex modes
  - Static and 1/3 bias capability
  - Up to 32 segments, up to 4 commons

    1 COM x 32 SEGs = 32 pixels
    2 COMs x 31 SEGs = 62 pixels
    3 COMs x 30 SEGs = 90 pixels
    4 COMs x 29 SEGs = 116 pixels
- Available in DIE form, 68-pin PLCC, and 64-pin TQFP packages

FIGURE 1: SIMPLIFIED BLOCK DIAGRAM

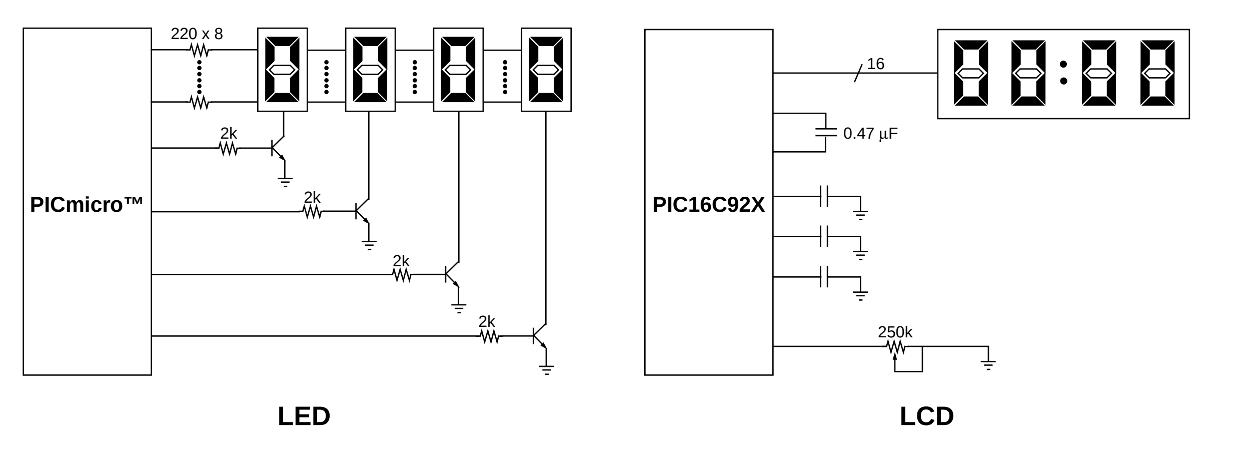


LCD panels offer many advantages over LED type displays such as; lower cost, lower power consumption, and better display quality. Figure 2 shows typical examples of an LED and an LCD application. Table 1 further describes each application according to components, cost, power consumption, etc.

TABLE 1: LED vs. LCD

	LED	LCD
Cost (1000 units)	$7.05	$5.42
# Components	20	6
Power Consumption	~ 10 mA	~ 50 µA
Hardware	Timer, 12 I/O pins	LCD Module
Signal Generation	Firmware	LCD Module

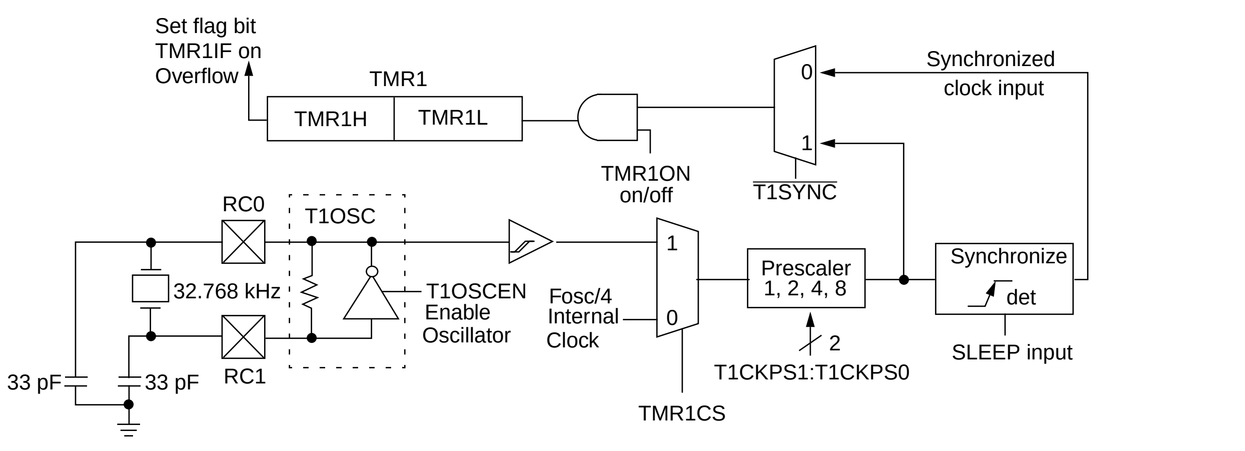
FIGURE 2: EXAMPLE LED AND LCD APPLICATIONS



TIMER1

Currently, the Timer1 module exists in all the PIC16CXXX devices with 28 or more pins. This module can be used to easily implement a real-time clock. Instead of an external real-time clock device, an inexpensive 32.768 kHz watch crystal and two 33 pF capacitors are used to complete the circuit. Figure 3 shows the block diagram for Timer1.

FIGURE 3: TIMER1 BLOCK DIAGRAM



In this application, Timer1 is clocked by an external crystal connected across RC0 and RC1. The following is some sample code to initialize Timer1.

```
TMR1H = 0x80;
TMR1L = 0x00;
T1CON = 0b00001111;
PIR1.TMR1IF = 0;
PIE1.TMR1IE = 1;
```

The first step in initializing Timer1 is to preset TMR1H:TMR1L to 0x8000. Since Timer1 is a 16-bit timer, the 32.768 kHz crystal will cause Timer1 to overflow every two seconds or 65536 counts. For this reason, Timer1 is initialized to 0x8000 so that every overflow relates to one second. The second step is to configure Timer1. For this mode, the Timer1 oscillator must be enabled via T1CON<T1OSCEN>. This bit enables the internal oscillator, which is functionally equivalent to the LP oscillator of the microcontroller. The clock source for Timer1 is selected to be the external input using the T1CON<TMR1CS> bit. The prescaler is set to 1:1 using the T1CKPS1:T1CKPS0 bits of the T1CON register. Since the timer is to operate during SLEEP, it is not synchronized to the internal Fosc clock. Synchronization is controlled by the $\overline{\text{T1SYNC}}$ bit of the T1CON register. Finally, the clock source is enabled to clock TMR1H:TMR1L using the TMR1ON bit of T1CON.

In this mode of operation, Timer1 can operate during SLEEP while consuming a minimal amount of current (≈20 μA). The last two lines of code clear the Timer1 Overflow flag and enable the Timer1 Overflow interrupt. This interrupt will wake up the processor from SLEEP at a predetermined rate for updating the clock, in this case once each second. The following is a sample interrupt service routine for Timer1 Overflow:

```
if(PIR1.TMR1IF)
{
   Seconds++;          //Increment seconds
   if(Seconds > 59)    //60 seconds?
   {
      Seconds = 0;
      Minutes++;
   }
   if(Minutes > 59)    //60 minutes?
   {
      Minutes = 0;
      Hours++;
   }
   if(Hours > 12)      //Do not use 24hr
      Hours = 1;       //military time

   TMR1H |= 0x80;      //Reset timer1
   PIR1.TMR1IF = 0;    //Clear flag
}
```

First, register PIR1 is checked to verify that the Timer1 Overflow interrupt occurred. Next the variable Seconds is incremented every time a Timer1 overflow occurs. Once Seconds reaches 60, the Minutes variable is incremented and Seconds is cleared thus implementing 60 seconds per minute. If Minutes reaches 60, then the Hours variable is incremented and Minutes is cleared which implements 60 minutes per hour. For civilian time, if Hours is greater than 12, Hours is reset to 1. Military time uses 24 hours a day, so that when Hours reaches 24 it is reset to 1.

Since it takes a finite amount of time to enter the interrupt service routine and execute it, the program adds 0x80 to TMR1H so that the next Timer1 Overflow interrupt occurs exactly in one second. If the program simply cleared TMR1L and set TMR1H to 0x80, the real-time clock would now be off by the finite amount of time previously described. Finally, the Timer1 Overflow interrupt flag is reset.

PORTB

The wake-up on change feature of PORTB was specifically designed to interface keys or a keypad directly to the microcontroller. Internal weak pull-up resistors are provided to reduce external parts count, while adding only a small amount of current. This feature allows the microcontroller to remain in the low-power SLEEP mode until a key is pressed. The device will wake-up from SLEEP when the key is pressed. The interrupt service routine will process the key input. The following example routine shows how to initialize the PORTB wake-up on change interrupt.

```
OPTION.RBPU = 0;
Temp = PORTB;
INTCON.RBIF = 0;
INTCON.RBIE = 1;
```

Whenever the state of the RB7:RB4 pins change, a mismatch condition occurs inside the microcontroller. The only way to clear the mismatch condition is to read PORTB, which also allows the RBIF interrupt flag to be cleared. In the previous code, the first line enables the internal weak pull-up resistors. The second line of the code resets the mismatch condition. Then the following lines clear the interrupt flag and enable the interrupt. A sample interrupt service routine is given below.

```
   if(INTCON.RBIF)
   {
      Temp = PORTB;
      Delay_Ms_4MHz(16);  //key debounce
      if(Temp!=0xf0 && Temp==PORTB)
      {
         StartBEEP(); //key press starts
beep

         if(!Temp.SET)       //SET key
            Flags.SET = 1;
         if(!Temp.UP)        //UP key
            Flags.UP = 1;
         if(!Temp.SOUND)     //SOUND key
         {
            if(Flags.SOUND_STATE)
               Flags.SOUND_STATE = 0;
            else
               Flags.SOUND_STATE = 1;
         }
      }
      INTCON.RBIF = 0;       //clear flag
   }
```

The first line of the above example is used to verify that a change on PORTB interrupt has occurred. The next line is a 5 ms delay followed by a read of PORTB. This resets the mismatch condition. The following 20 ms delay is used in conjunction with the previous 5 ms delay for switch debouncing. The value of `Temp` and PORTB are compared and if equal a key press has been detected. The if statement also checks to see if the mismatch condition is from a key press or when the key is released. The key inputs are processed only when a key is pressed. When a key is pressed, it grounds the respective input pin. The nested if statements check each of the individual keys to see which have been pressed. If the SOUND key has been pressed, it merely toggles whether the hourly beep is enabled. Finally, the RBIF interrupt flag is cleared.

This application takes advantage of the wake-up on change and internal pull-up resistors to implement the SET, ▲, and SOUND keys. The SET key puts the clock in program mode and the PROG icon appears on the LCD. Program mode allows the user to set the time, AM or PM, and day of the week (see LCD Module for details on the LCD). Once in program mode, the hours digits flash. Pressing the ▲ key increments `Hours` from 12 to 11 AM and then from 12 to 11 PM. At any point the SET key can be pressed to advance to the minutes digits. The minutes digits are incremented using the ▲ key. `Minutes` can be incremented from 0 to 59. Pressing the SET key again flashes the day of the week. Using the ▲ key increments the day of the week from SU to SA. Finally, pressing the SET key takes the user out of program mode. If no key presses are detected for five seconds the program exits program mode.

CCP

The CCP module is used in Pulse Width Modulation (PWM) mode. The PWM signal is used to drive a piezo alarm circuit. The operation of PWM mode will not be discussed since it has been explained in great depth in application notes AN531, AN538, AN539, AN564, and AN594.

An example of configuring the CCP as a PWM output is shown below.

```
CCP1CON = 0x0f;     //Set CCP to PWM
PR2 = 122;          //period of 2048 Hz
CCPR1L = 5;         //Duty Cycle very low
TRISC.RC2 = 0;      //PWM pin output
T2CON = 0b01111101; //Enable timer2
PIR1.TMR2IF = 0;    //Clear flag
PIE1.TMR2IE = 1;    //Enable interrupt
```

The CCP1CON register is set to 0x0F which puts the CCP into PWM mode. The period or frequency of the PWM output is set using the PR2 register. The following formula is used to calculate the value in PR2.

$$\text{PWM period} = [\ (\text{PR2}) + 1\ ] \bullet 4 \bullet \text{Tosc} \bullet (\text{TMR2 prescale value})\ ]$$

Another step in configuring the CCP is to set the value of the T2CON register. In the case above, a value of 0x7D configures the Timer2 output postscaler to 1:16, enables Timer2, and sets the Timer2 clock prescaler to 4. Using PR2 = 122, Tosc = 250 ns, and TMR2 prescale = 4, the resultant PWM period is approximately 500 µs or 2 kHz. This is the resonant frequency of the piezo alarm. The duty cycle, or more specifically the time the PWM output stays high, of the PWM output is set by the value of CCPR1L and bits CCP1CON<5:4>. The following formula uses the 10-bit value of CCPR1L:CCP1CON<5:4> to calculate the duty cycle.

$$\text{PWM duty cycle} = [\ (\text{CCPR1L:CCP1CON}<5:4>) \bullet \text{Tosc} \bullet (\text{TMR2 prescale value})\ ]$$

Using 0x014 as the value of CCPR1L:CCP1CON<5:4>, Tosc = 250 ns, and a TMR2 prescale = 4, the PWM duty cycle is calculated to be 20 µs or 4% duty cycle. The TRISC register must also be configured such that the PWM pin is setup as an output.

The Timer2 Overflow interrupt is used to turn off the PWM output. This produces a “beep” when the keys are pressed or an hourly alarm. The Timer2 postscaler waits for 16 PWM periods before the interrupt occurs. The following interrupt service routine is an example of how to generate a “beep”.

```
if(PIR1.TMR2IF)
{
   Count--;
   if(!Count)
   {
      CCP1CON = 0;      //Disable CCP, and
      T2CON = 0;        //Timer2 and TMR2
      PIE1.TMR2IE = 0;  //interrupts
      CCPR1L = 0;
   }
   PIR1.TMR2IF = 0;     //Clear flag
}
```

The first line of code detects if a Timer2 Overflow interrupt has occurred. The variable `Count` is used to vary the length of the beep. `Count` is set previous to enabling the PWM. If `Count` reaches zero the following occurs:

- The PWM is disabled by clearing the CCP1CON register
- Timer2 is disabled by clearing the T2CON register
- The Timer2 Overflow interrupt is disabled by clearing the TMR2IE bit of the register PIE1
- The duty cycle register is cleared

Before exiting the service routine, the TMR2IF interrupt flag is cleared.

A/D CONVERTER

Since the PIC16C924 has a five channel, 8-bit A/D converter and the LCD has a ° (degree) symbol and two digits, the application circuit has a thermistor for measuring temperature. Thermistors typically take hundreds of milliseconds to stabilize at a particular temperature and therefore the A/D converter is ideal for temperature measurements. Another feature of the A/D converter is the on-chip RC oscillator that can be used as the conversion clock. This feature allows the A/D to operate in SLEEP. The following code segment is used to initialize the A/D converter.

```
ADCON0 = 0b11000001;  //Enable A/D
ADCON1 = 0b00000100;  //Configure D/A I/O
PIR1.ADIF = 0;        //Clear flag
PIE1.ADIE = 1;        //Enable interrupt
```

The first line enables the internal RC for conversion clock, channel 0, and enables the A/D converter. The second line makes PORTA<1:0> analog inputs and PORTA<5,3:2> as digital I/O. The following lines clear the A/D conversion complete interrupt flag and enable the interrupt. The application uses the Timer1 Overflow interrupt to start a conversion every second using the GO bit of the ADCON0 register. The A/D conversion complete interrupt then processes the result of the conversion. The following is an example of the service routine.

```
if(PIR1.ADIF)
{
   TempC = ThermTable[ADRES];
   PIR1.ADIF = 0;
}
```

The first line checks for the ADIF interrupt flag. A lookup table, ThermTable, is used to convert the A/D result into a temperature reading. This table was created using calibration data from the thermistor. Finally, the ADIF interrupt flag is cleared.

The following code was added to the Timer1 interrupt service routine to start the A/D conversion.

```
TRISA.THERM_GND = 0;
DELAY_10_µs_4MHz(4);
ADCON0.GO = 1
NOP();
NOP();
TRISA.THERM_GND = 1;
```

The first line of code grounds the I/O pin connected to resistor R1. The 40 µs delay is provided so the A/D converter can sample the input signal. The A/D converter is then instructed to convert by setting the GO bit. A two cycle delay is added so that the sampling capacitor is disconnected from the input. Finally the I/O pin connected to R1 is made an input. This scheme only powers the thermistor when sampling, to reduce power consumption.

LCD MODULE

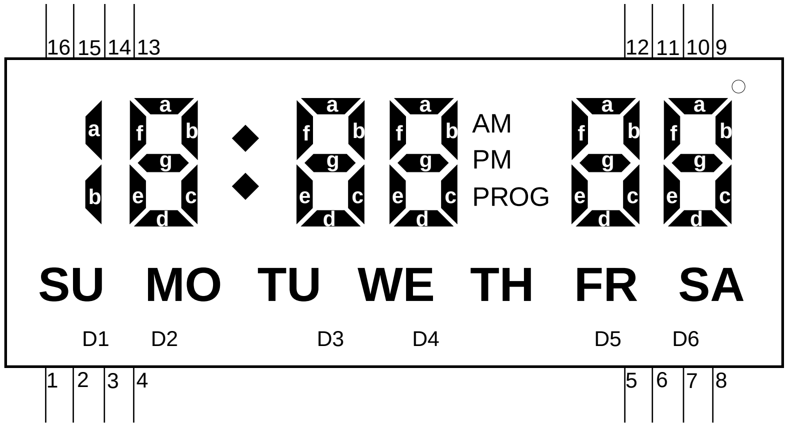
The LCD Module has a wealth of features typically found on more expensive dedicated LCD driver devices. The following is a detailed list of features:

- LCD Timing Sources
  - Fosc/256 (internal system clock)
  - Timer1 oscillator
  - Internal RC oscillator
- LCD Voltage Generation
  - Internal charge pump
  - External resistor ladder
- Bias
  - Static
  - 1/3
- Multiplex
  - Static
  - 1/2
  - 1/3
  - 1/4
- Operation during SLEEP
  - Only with internal RC or Timer1 clock sources
- Capable of up to 4 commons and 32 segments
  - 1 COM x 32 SEGs, total of 32 pixels
  - 2 COMs x 31 SEGs, total of 62 pixels
  - 3 COMs x 30 SEGs, total of 90 pixels
  - 4 COMs x 29 SEGs, total of 116 pixels
- 16 x 8 LCD data registers

The LCD Module is ideal for systems that use one controller board that has several applications with different displays. Microchip's OTP technology means that the controller board can be assembled with blank microcontrollers, and at final test the device can be programmed depending on the display type. This helps to reduce overhead and creates one board to track in inventory.

The particular LCD panel that was selected for this application is shown in Figure 2. It has four common electrodes and 12 segment electrodes. The panel provides 3 1/2 digits, colon, and AM/PM icons for time display. The panel also has day of the week icons (SU,MO,TU,WE,TH,FR,SA). This was the basis of another clock design using the PIC16C924.

FIGURE 4: LCD PINOUT



	COM0, pin 1	COM1, pin 8	COM2, pin 9	COM3, pin 16
SEG0, pin 2	SU	D2.e	D2.f	D1
SEG1, pin 3	MO	D3.e	:	D2.b
SEG2, pin 4	TU	D3.c	D3.b	D4.f
SEG3, pin 5	WE	D4.c	D4.b	AM
SEG4, pin 6	FR	D5.c	D6.f	D5.b
SEG5, pin 7	SA	D6.c	D6.b	°
SEG6, pin 10	D6.d	D6.e	D6.g	D6.a
SEG7, pin 11	D5.d	D5.e	D5.g	D5.a
SEG8, pin 12	TH	PROG	PM	D5.f
SEG9, pin 13	D4.d	D4.e	D4.g	D4.a
SEG10, pin 14	D3.d	D3.g	D3.f	D3.a
SEG11, pin 15	D2.d	D2.c	D2.g	D2.a

The LCD Module is initialized by the following code:

```
STATUS.RP1 = 1;       //Change to Bank 2
LCDPS = 6;            //Frame freq to 37Hz
LCDSE = 0xff;         //All LCD I/O as LCD
LCDCON = 0b00010111; //1/4 MUX charge pump
LCDD00 = 0;           //Clear all LCD
LCDD01 = 0;           //data RAM
LCDD02 = 0;
LCDD03 = 0;
LCDD04 = 0;
LCDD05 = 0;
LCDD06 = 0;
LCDD07 = 0;
LCDD08 = 0;
LCDD09 = 0;
LCDD10 = 0;
LCDD11 = 0;
LCDD12 = 0;
LCDD13 = 0;
LCDD14 = 0;
LCDD15 = 0;
LCDCON.LCDEN = 1;       //Enable LCD module
STATUS.RP1 = 0;         //Back to Bank 0
PIR1.LCDIF = 0;         //Clear flag
PIE1.LCDIE = 1;         //Enable interrupt
```

Note: At the time when this application note was generated, four banks of data memory were not supported by the MPC or MPLAB-C compilers.

The PIC16C924 starts a new page in Microchip history with four banks of data memory for the PIC16CXXX mid-range products. The first line of code switches to the second set of banks. The second line of code sets a frame frequency of approximately 37 Hz using the Timer1 oscillator. This frequency can be calculated by using the following formula:

$$\text{Clock source} / (128 \bullet (\text{LP3:LP0} + 1))$$

Using 32.768 kHz as the clock source and LP3:LP0 = 6 the resultant frame frequency is 36.57 Hz. Setting LCDSE to 0xFF configures ports D,E,F, and G as LCD drivers. Setting LCDCON to 0x17 configures the LCD Module for 1/4 MUX, 1/3 Bias, Timer1 clock source, charge pump enabled, and the LCD module will continue to drive during SLEEP. The LCD data registers LCDD00 - LCDD15 are all cleared, which turns off all pixels on the LCD panel. Any unused bits in the LCD data registers can be used as general purpose RAM. The PIC16C924 Clock can use the upper 4-bits of registers LCDD01, LCDD05, LCDD09, LCDD13 and all of LCDD02, LCDD03, LCDD06, LCDD07, LCDD10, LCDD11, LCDD14, LCDD15. This is a result of not using segments 13 through 28. The LCD Module is then enabled by setting the LCDEN bit in the LCDCON register. Finally the LCD interrupt flag is cleared and the interrupt is enabled.

The following is an example of the LCD interrupt service routine.

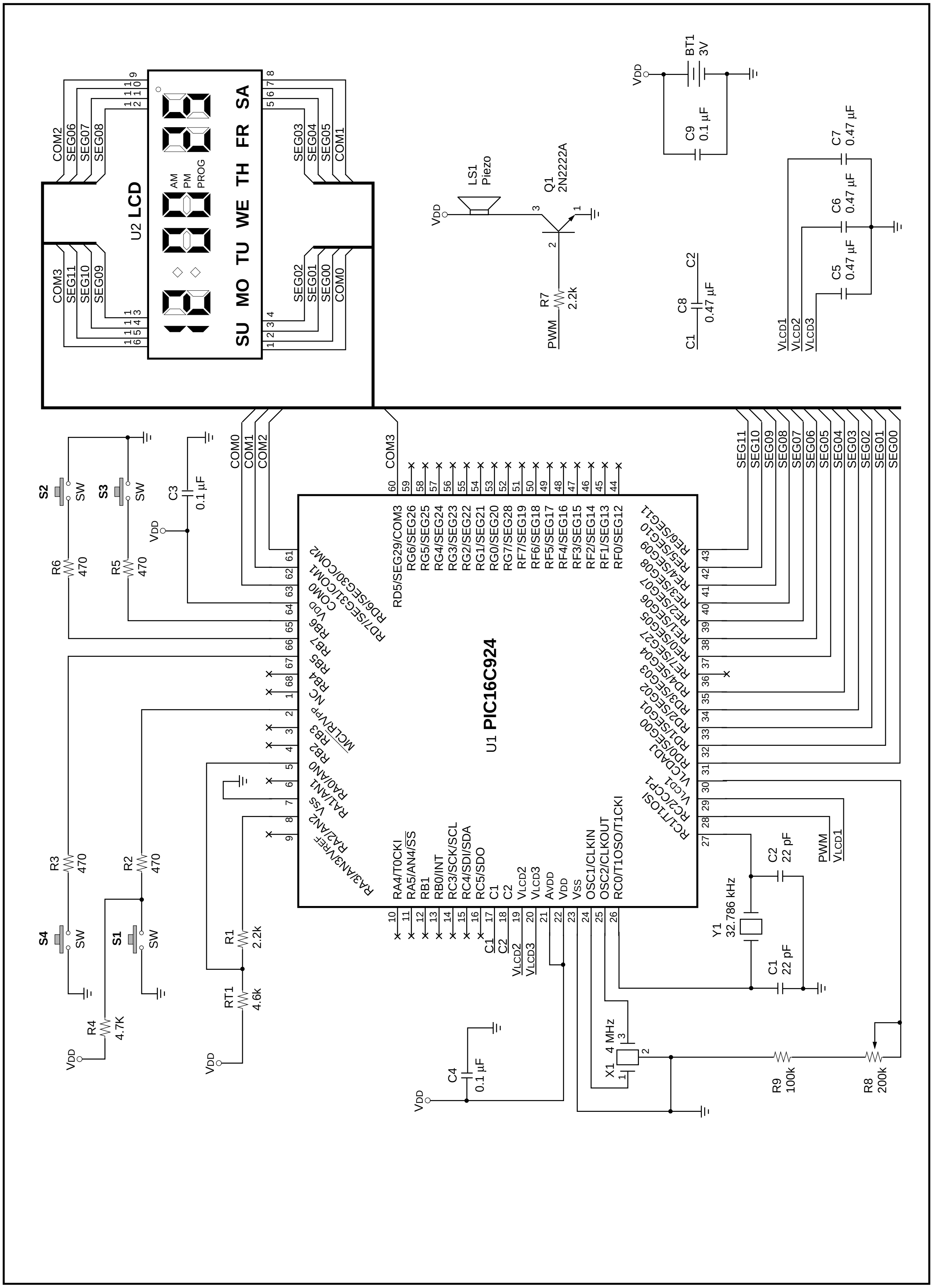
```
if(PIR1.LCDIF)
{
   Flags.FRAME = 1;
   PIR1.LCDIF = 0;
}
```

In this application, the LCD interrupt is used to signal the main routine that the LCD data registers can be updated without causing any flicker on the panel. Finally, as in any interrupt service routine, the interrupt flag is cleared.

CONCLUSION

The PIC16C924 is ideally suited towards battery applications such as thermostats or meters. It can extend battery life while maintaining a rich feature set such as A/D converter, SPI/I^{2}C module, and CCP module. All of the peripherals that have been previously described can operate during SLEEP, thus lowering the average current consumption. If the 8-bit A/D converter is not sufficient or not used in your design, Microchip also offers the PIC16C923 which has all the features of the PIC16C924 without the A/D converter. This device can use an external higher resolution A/D converter that can be interfaced to the SSP module, specifically the SPI port.

APPENDIX A: PIC16C924 CLOCK SCHEMATIC



APPENDIX B: PIC16C924 CLOCK FIRMWARE LISTING

```
                 /*****************************************************************************
                  *  Filename: CLK.C
                  *****************************************************************************
                  *   Author:     Rodger Richey
                  *   Company:  Microchip Technology Incorporated
                  *   Revision: A3
                  *   Date:     12-17-96
                  *   Compiled using MPLAB-C Version 00.00.14
                  *****************************************************************************
                  *   Include files:
                  *   16C924.h   Rev 1.00
                  *   MUSIC.C    Rev A2
                  *   LCD.C      Rev A1
                  *   TIME.C     Rev A1
                  *****************************************************************************
                  *   Peripheral Modules Used:
                  *     Timer0   : Used by the music generation program for timing notes
                  *                and durations
                  *     Timer1   : Used as a real time clock using an external 32.768KHz
                  *                crystal and (2) 33pF capacitors
                  *     Timer2   : Used in conjunction with the PWM
                  *     CCP      : Used in PWM mode, for driving the piezo alarm
                  *     PORTB    : Used to decode key presses
                  *     A/D      : Used to measure temperature via a thermistor on RA0
                  *     LCD      : Used to display time, temperature, day of week
                  *****************************************************************************
                  *   External Clock Frequency   : 4MHz
                  *   Timer1 OSC Frequency       : 32.768KHz
                  *   Configuration Bit Settings : XT Oscillator
                  *                              : Watchdog Timer OFF
                  *                              : Code Protect OFF
                  *                              : Power-Up Timer ON
                  *   Program Memory Usage       : 1095 words
                  *   Data Memory Usage          : 19 bytes
                  *****************************************************************************
                  *   Revision History
                  *   A1 - First Release
                  *   A2 - Added code to clear CCPR1L after PWM has finished
                  *      - Set No sleep flag in StartMusic
                  *   A3 - Changed __INT interrupt service routine.
                  *   Added INTCON.T0IE to check for Timer0 interrupt
                  *****************************************************************************
                  *   Note: Make sure that the temporary variables in the 16c924.h file
                  *         have been changed to locations 0x7a to 0x7f
                  ****************************************************************************/
                  #include <16c924.h>
                  #include <delay14.h>

                  // PORTA pin defines
0002              #define THERM_GND 2

                  // PORTB key defines
0004              #define EXTRA 4
0005              #define SOUND 5
0006              #define UP 6
0007              #define SET 7

                  // Variable declarations
0026              bits Flags;                  // Contains flag bits for various events
0027              bits Temp;                   // Temporary storage
0028              bits Count;                  // Number of Timer2 Interrupts to count
0029              bits Ticks;                  // Counts seconds will in program mode
0078              bits Mode @ 0x78;            // Contains flag bits to turn on LCD pixels
002A              unsigned char FrameCnt;      // Count LCD frames
```

```
                 // Bit defines for Flags
0000             #define UPDATE 0
0001             #define FRAME 1
0003             #define PROGRAM 3
0004             #define SOUND_STATE 4
0005             #define SLEEP_STATE 5

                 // Time variables
0070             unsigned char Seconds @ 0x70;   // Holds number of seconds
0071             unsigned char Minutes @ 0x71;   // Holds number of minutes
0072             unsigned char Hours @ 0x72;     // Holds number of hours
0073             bits LStatus @ 0x73;            // bit 7 -> 0=AM, 1=PM
                                                 // bits 0-3 -> 0000=SUN
0074             bits DayOfWeek @0x74;           //  0001=MON
                                                 //  0010=TUE
                                                 //  0011=WED
                                                 //  0100=THU
                                                 //  0101=FRI
                                                 //  0110=SAT

                 // Bit defines for LStatus
0007             #define AMPM 7

                 // Temperature Variable
0075             unsigned char TempC @ 0x75;

000C             #define FRAME_COUNT 12          // Number of frames in blink in prgm mode
0004             #define BEEP_COUNT 4            // PWM duty cycle value for “beep”

                 // Thermistor calibration table, 0C to 99C
                 const unsigned int ThermTable[] =
            {
               0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,
               0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,
               0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x01,0x02,0x03,0x04,
               0x05,0x06,0x06,0x07,0x08,0x09,0x09,0x10,0x11,0x11,0x12,0x12,0x13,0x13,0x14,0x14,
               0x15,0x15,0x16,0x16,0x17,0x17,0x18,0x18,0x19,0x19,0x20,0x20,0x21,0x21,0x22,0x22,
               0x23,0x23,0x24,0x24,0x25,0x25,0x25,0x26,0x26,0x27,0x27,0x28,0x28,0x28,0x29,0x29,
               0x30,0x30,0x30,0x31,0x31,0x32,0x32,0x32,0x33,0x33,0x33,0x34,0x34,0x35,0x35,0x35,
               0x36,0x36,0x37,0x37,0x38,0x38,0x38,0x39,0x39,0x40,0x40,0x40,0x41,0x41,0x42,0x42,
               0x43,0x43,0x43,0x44,0x44,0x45,0x45,0x45,0x46,0x46,0x47,0x47,0x48,0x48,0x48,0x49,
               0x49,0x50,0x50,0x50,0x51,0x51,0x52,0x52,0x53,0x53,0x54,0x54,0x55,0x55,0x56,0x56,
               0x57,0x57,0x58,0x58,0x59,0x59,0x60,0x60,0x61,0x61,0x62,0x62,0x63,0x63,0x64,0x64,
               0x65,0x65,0x66,0x66,0x67,0x67,0x68,0x68,0x69,0x69,0x70,0x71,0x71,0x72,0x73,0x73,
               0x74,0x74,0x75,0x76,0x76,0x77,0x78,0x78,0x79,0x79,0x80,0x81,0x81,0x82,0x83,0x84,
               0x84,0x85,0x86,0x87,0x88,0x89,0x90,0x91,0x92,0x93,0x94,0x95,0x96,0x97,0x98,0x99,
               0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,
               0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99,0x99
            };
0005 0782    ADDWF  02
0006 3400    RETLW  00h
0007 3400    RETLW  00h
0008 3400    RETLW  00h
0009 3400    RETLW  00h
000A 3400    RETLW  00h
000B 3400    RETLW  00h
000C 3400    RETLW  00h
000D 3400    RETLW  00h
000E 3400    RETLW  00h
000F 3400    RETLW  00h
0010 3400    RETLW  00h
0011 3400    RETLW  00h
0012 3400    RETLW  00h
0013 3400    RETLW  00h
0014 3400    RETLW  00h
```

```
0015 3400    RETLW  00h
0016 3400    RETLW  00h
0017 3400    RETLW  00h
0018 3400    RETLW  00h
0019 3400    RETLW  00h
001A 3400    RETLW  00h
001B 3400    RETLW  00h
001C 3400    RETLW  00h
001D 3400    RETLW  00h
001E 3400    RETLW  00h
001F 3400    RETLW  00h
0020 3400    RETLW  00h
0021 3400    RETLW  00h
0022 3400    RETLW  00h
0023 3400    RETLW  00h
0024 3400    RETLW  00h
0025 3400    RETLW  00h
0026 3400    RETLW  00h
0027 3400    RETLW  00h
0028 3400    RETLW  00h
0029 3400    RETLW  00h
002A 3400    RETLW  00h
002B 3400    RETLW  00h
002C 3400    RETLW  00h
002D 3400    RETLW  00h
002E 3400    RETLW  00h
002F 3400    RETLW  00h
0030 3400    RETLW  00h
0031 3400    RETLW  00h
0032 3401    RETLW  01h
0033 3402    RETLW  02h
0034 3403    RETLW  03h
0035 3404    RETLW  04h
0036 3405    RETLW  05h
0037 3406    RETLW  06h
0038 3406    RETLW  06h
0039 3407    RETLW  07h
003A 3408    RETLW  08h
003B 3409    RETLW  09h
003C 3409    RETLW  09h
003D 3410    RETLW  10h
003E 3411    RETLW  11h
003F 3411    RETLW  11h
0040 3412    RETLW  12h
0041 3412    RETLW  12h
0042 3413    RETLW  13h
0043 3413    RETLW  13h
0044 3414    RETLW  14h
0045 3414    RETLW  14h
0046 3415    RETLW  15h
0047 3415    RETLW  15h
0048 3416    RETLW  16h
0049 3416    RETLW  16h
004A 3417    RETLW  17h
004B 3417    RETLW  17h
004C 3418    RETLW  18h
004D 3418    RETLW  18h
004E 3419    RETLW  19h
004F 3419    RETLW  19h
0050 3420    RETLW  20h
0051 3420    RETLW  20h
0052 3421    RETLW  21h
0053 3421    RETLW  21h
0054 3422    RETLW  22h
0055 3422    RETLW  22h
0056 3423    RETLW  23h
```

```
0057 3423    RETLW  23h
0058 3424    RETLW  24h
0059 3424    RETLW  24h
005A 3425    RETLW  25h
005B 3425    RETLW  25h
005C 3425    RETLW  25h
005D 3426    RETLW  26h
005E 3426    RETLW  26h
005F 3427    RETLW  27h
0060 3427    RETLW  27h
0061 3428    RETLW  28h
0062 3428    RETLW  28h
0063 3428    RETLW  28h
0064 3429    RETLW  29h
0065 3429    RETLW  29h
0066 3430    RETLW  30h
0067 3430    RETLW  30h
0068 3430    RETLW  30h
0069 3431    RETLW  31h
006A 3431    RETLW  31h
006B 3432    RETLW  32h
006C 3432    RETLW  32h
006D 3432    RETLW  32h
006E 3433    RETLW  33h
006F 3433    RETLW  33h
0070 3433    RETLW  33h
0071 3434    RETLW  34h
0072 3434    RETLW  34h
0073 3435    RETLW  35h
0074 3435    RETLW  35h
0075 3435    RETLW  35h
0076 3436    RETLW  36h
0077 3436    RETLW  36h
0078 3437    RETLW  37h
0079 3437    RETLW  37h
007A 3438    RETLW  38h
007B 3438    RETLW  38h
007C 3438    RETLW  38h
007D 3439    RETLW  39h
007E 3439    RETLW  39h
007F 3440    RETLW  40h
0080 3440    RETLW  40h
0081 3440    RETLW  40h
0082 3441    RETLW  41h
0083 3441    RETLW  41h
0084 3442    RETLW  42h
0085 3442    RETLW  42h
0086 3443    RETLW  43h
0087 3443    RETLW  43h
0088 3443    RETLW  43h
0089 3444    RETLW  44h
008A 3444    RETLW  44h
008B 3445    RETLW  45h
008C 3445    RETLW  45h
008D 3445    RETLW  45h
008E 3446    RETLW  46h
008F 3446    RETLW  46h
0090 3447    RETLW  47h
0091 3447    RETLW  47h
0092 3448    RETLW  48h
0093 3448    RETLW  48h
0094 3448    RETLW  48h
0095 3449    RETLW  49h
0096 3449    RETLW  49h
0097 3450    RETLW  50h
0098 3450    RETLW  50h
```

```
0099 3450    RETLW  50h
009A 3451    RETLW  51h
009B 3451    RETLW  51h
009C 3452    RETLW  52h
009D 3452    RETLW  52h
009E 3453    RETLW  53h
009F 3453    RETLW  53h
00A0 3454    RETLW  54h
00A1 3454    RETLW  54h
00A2 3455    RETLW  55h
00A3 3455    RETLW  55h
00A4 3456    RETLW  56h
00A5 3456    RETLW  56h
00A6 3457    RETLW  57h
00A7 3457    RETLW  57h
00A8 3458    RETLW  58h
00A9 3458    RETLW  58h
00AA 3459    RETLW  59h
00AB 3459    RETLW  59h
00AC 3460    RETLW  60h
00AD 3460    RETLW  60h
00AE 3461    RETLW  61h
00AF 3461    RETLW  61h
00B0 3462    RETLW  62h
00B1 3462    RETLW  62h
00B2 3463    RETLW  63h
00B3 3463    RETLW  63h
00B4 3464    RETLW  64h
00B5 3464    RETLW  64h
00B6 3465    RETLW  65h
00B7 3465    RETLW  65h
00B8 3466    RETLW  66h
00B9 3466    RETLW  66h
00BA 3467    RETLW  67h
00BB 3467    RETLW  67h
00BC 3468    RETLW  68h
00BD 3468    RETLW  68h
00BE 3469    RETLW  69h
00BF 3469    RETLW  69h
00C0 3470    RETLW  70h
00C1 3471    RETLW  71h
00C2 3471    RETLW  71h
00C3 3472    RETLW  72h
00C4 3473    RETLW  73h
00C5 3473    RETLW  73h
00C6 3474    RETLW  74h
00C7 3474    RETLW  74h
00C8 3475    RETLW  75h
00C9 3476    RETLW  76h
00CA 3476    RETLW  76h
00CB 3477    RETLW  77h
00CC 3478    RETLW  78h
00CD 3478    RETLW  78h
00CE 3479    RETLW  79h
00CF 3479    RETLW  79h
00D0 3480    RETLW  80h
00D1 3481    RETLW  81h
00D2 3481    RETLW  81h
00D3 3482    RETLW  82h
00D4 3483    RETLW  83h
00D5 3484    RETLW  84h
00D6 3484    RETLW  84h
00D7 3485    RETLW  85h
00D8 3486    RETLW  86h
00D9 3487    RETLW  87h
00DA 3488    RETLW  88h
```

```
00DB 3489    RETLW  89h
00DC 3490    RETLW  90h
00DD 3491    RETLW  91h
00DE 3492    RETLW  92h
00DF 3493    RETLW  93h
00E0 3494    RETLW  94h
00E1 3495    RETLW  95h
00E2 3496    RETLW  96h
00E3 3497    RETLW  97h
00E4 3498    RETLW  98h
00E5 3499    RETLW  99h
00E6 3499    RETLW  99h
00E7 3499    RETLW  99h
00E8 3499    RETLW  99h
00E9 3499    RETLW  99h
00EA 3499    RETLW  99h
00EB 3499    RETLW  99h
00EC 3499    RETLW  99h
00ED 3499    RETLW  99h
00EE 3499    RETLW  99h
00EF 3499    RETLW  99h
00F0 3499    RETLW  99h
00F1 3499    RETLW  99h
00F2 3499    RETLW  99h
00F3 3499    RETLW  99h
00F4 3499    RETLW  99h
00F5 3499    RETLW  99h
00F6 3499    RETLW  99h
00F7 3499    RETLW  99h
00F8 3499    RETLW  99h
00F9 3499    RETLW  99h
00FA 3499    RETLW  99h
00FB 3499    RETLW  99h
00FC 3499    RETLW  99h
00FD 3499    RETLW  99h
00FE 3499    RETLW  99h
00FF 3499    RETLW  99h

                  /****************************************************************************
                   *   StartBEEP
                   *   Function: This routine configures the necessary hardware to emit a
                   *             beep from the piezo
                   ****************************************************************************/
                                  void StartBEEP(void)
                                  {
0100 1283    BCF    03,5              Flags.SLEEP_STATE = 1; // Don’t let the 924 go to sleep
0101 16A6    BSF    26,5
0102 3004    MOVLW  04h               Count = BEEP_COUNT;    // Set Count for length of beep
0103 00A8    MOVWF  28
0104 300F    MOVLW  0Fh               CCP1CON = 0x0f;        // Set the CCP module to PWM
0105 0097    MOVWF  17
0106 307A    MOVLW  7Ah               PR2 = 122;             // Set the period to 2048Hz
0107 1683    BSF    03,5
0108 0092    MOVWF  12
0109 3003    MOVLW  03h               CCPR1L = 3;            // Set the duty cycle very low
010A 1283    BCF    03,5
010B 0095    MOVWF  15
010C 307D    MOVLW  7Dh               T2CON = 0b01111101;    // Enable Timer2
010D 0092    MOVWF  12
010E 108C    BCF    0C,1              PIR1.TMR2IF = 0;       // Clear the Timer2 Interrupt flag
010F 1683    BSF    03,5              PIE1.TMR2IE = 1;       // Enable the Timer2 Interrupt
0110 148C    BSF    0C,1
0111 0008    RETURN                   return;
                                  }

                                  // Include source files
                   #include “lcd.c”          // Contains programs that control the LCD
                  /****************************************************************************
                   *  Filename: LCD.C
                   *****************************************************************************
                   *   Author:     Rodger Richey
                   *   Company:  Microchip Technology Incorporated
                   *   Revision: A0
                   *   Date:     6-14-96
                   *   Compiled using MPLAB-C Version 00.00.14
                   ****************************************************************************
                   *   This file contains routines to output time, day of week, AM/PM, and
                   *   temperature.  It also contains routines to blink the different groupings
                   *   of numbers, i.e. hours,seconds,day of the week.  Finally, the last
                   *   routine displays the state of the hourly beep.
                   ***************************************************************************/

                   // Bit defines for the Mode variable, tells the UpdateLCD routine which
                   // groups of numbers to display
0000               #define HOURS 0
0001               #define MINUTES 1
0002               #define DAYOFWEEK 2
0005               #define PROG 5           // PROG icon
0006               #define COLON 6          // colon, :, for the hours/seconds time display
0007               #define DEGREES 7        // degrees symbol for temperature

                  /****************************************************************************
                   *   UpdateLCD
                   *   Function: This function updates the LCD display based on the Mode
                   *          variable.
                   ***************************************************************************/
                   void UpdateLCD(void)
                   {
                      // Array of 7-segment numbers
                                                            //   gfedcba
                      const unsigned char SevenSegTable[16]={ 0b00111111, // Zero
                                                              0b00000110, // One
                                                              0b01011011, // Two
                                                              0b01001111, // Three
                                                              0b01100110, // Four
                                                              0b01101101, // Five
                                                              0b01111101, // Six
                                                              0b00000111, // Seven
                                                              0b01111111, // Eight
                                                              0b01101111, // Nine
                                                              0b01110111, // Ten
                                                              0b01111100, // Eleven
                                                              0b01011000, // Twelve
                                                              0b01011110, // Thirteen
                                                              0b01111001, // Fourteen
0112 2924    GOTO   0124h                                     0b01110001};// Fifteen
0113 0782    ADDWF  02
0114 343F    RETLW  3Fh
0115 3406    RETLW  06h
0116 345B    RETLW  5Bh
0117 344F    RETLW  4Fh
0118 3466    RETLW  66h
0119 346D    RETLW  6Dh
011A 347D    RETLW  7Dh
011B 3407    RETLW  07h
011C 347F    RETLW  7Fh
011D 346F    RETLW  6Fh
011E 3477    RETLW  77h
011F 347C    RETLW  7Ch
0120 3458    RETLW  58h
0121 345E    RETLW  5Eh
0122 3479    RETLW  79h
```

```
0123 3471    RETLW  71h

                                         // Temporary variables in common RAM locations
0076                                      bits segment @ 0x76;
0077                                      unsigned char index @ 0x77;

                                         // Change to Bank 2, and clear all LCD data RAM
0124 1703    BSF    03,6                  STATUS.RP1 = 1;
0125 1283    BCF    03,5                  LCDD00 = 0;
0126 0190    CLRF   10
0127 0191    CLRF   11                    LCDD01 = 0;
0128 0194    CLRF   14                    LCDD04 = 0;
0129 0195    CLRF   15                    LCDD05 = 0;
012A 0198    CLRF   18                    LCDD08 = 0;
012B 0199    CLRF   19                    LCDD09 = 0;
012C 019C    CLRF   1C                    LCDD12 = 0;
012D 019D    CLRF   1D                    LCDD13 = 0;

                                         // Update day of the week if enabled
012E 1D78    BTFSS  78,2                  if(Mode.DAYOFWEEK)
012F 2965    GOTO   0165h
0130                                      {
                                              // Update Day of the Week
0130 08F4    MOVF   74                        if(DayOfWeek == 0)             // Sunday
0131 1D03    BTFSS  03,2
0132 2936    GOTO   0136h
0133 1283    BCF    03,5                          LCDD00.0 = 1;
0134 1410    BSF    10,0
0135 2965    GOTO   0165h                     else if(DayOfWeek == 1)        // Monday
0136 3001    MOVLW  01h                           LCDD00.1 = 1;
0137 1283    BCF    03,5
0138 0274    SUBWF  74,W
0139 1D03    BTFSS  03,2
013A 293E    GOTO   013Eh
013B 1283    BCF    03,5
013C 1490    BSF    10,1
013D 2965    GOTO   0165h                     else if(DayOfWeek == 2)        // Tuesday
013E 3002    MOVLW  02h                           LCDD00.2 = 1;
013F 1283    BCF    03,5
0140 0274    SUBWF  74,W
0141 1D03    BTFSS  03,2
0142 2946    GOTO   0146h
0143 1283    BCF    03,5
0144 1510    BSF    10,2
0145 2965    GOTO   0165h                     else if(DayOfWeek == 3)        // Wednesday
0146 3003    MOVLW  03h                           LCDD00.3 = 1;
0147 1283    BCF    03,5
0148 0274    SUBWF  74,W
0149 1D03    BTFSS  03,2
014A 294E    GOTO   014Eh
014B 1283    BCF    03,5
014C 1590    BSF    10,3
014D 2965    GOTO   0165h                     else if(DayOfWeek == 4)        // Thursday
014E 3004    MOVLW  04h                           LCDD01.0 = 1;
014F 1283    BCF    03,5
0150 0274    SUBWF  74,W
0151 1D03    BTFSS  03,2
0152 2956    GOTO   0156h
0153 1283    BCF    03,5
0154 1411    BSF    11,0
0155 2965    GOTO   0165h                     else if(DayOfWeek == 5)        // Friday
0156 3005    MOVLW  05h                           LCDD00.4 = 1;
0157 1283    BCF    03,5
0158 0274    SUBWF  74,W
0159 1D03    BTFSS  03,2
015A 295E    GOTO   015Eh
```

```
015B 1283    BCF    03,5
015C 1610    BSF    10,4
015D 2965    GOTO   0165h                     else if(DayOfWeek == 6)        // Saturday
015E 3006    MOVLW  06h                           LCDD00.5 = 1;
015F 1283    BCF    03,5
0160 0274    SUBWF  74,W
0161 1D03    BTFSS  03,2
0162 2965    GOTO   0165h
0163 1283    BCF    03,5
0164 1690    BSF    10,5
                                          }

                                          // Update Time if enabled
0165 1283    BCF    03,5                  if(Mode.HOURS)
0166 1C78    BTFSS  78,0
0167 2988    GOTO   0188h
0168                                      {
                                              // Update AM/PM icons
0168 1FF3    BTFSS  73,7                      if(LStatus.AMPM)
0169 296C    GOTO   016Ch
016A 1419    BSF    19,0                              LCDD09.0 = 1;
016B 296D    GOTO   016Dh                     else
016C 159C    BSF    1C,3                              LCDD12.3 = 1;

                                              // Digit 1
016D 1A72    BTFSC  72,4                      if(Hours&0x10)
016E 141C    BSF    1C,0                          LCDD12.0 = 1;

                                              // Digit 2
016F 300F    MOVLW  0Fh                       index = Hours & 0x0f;
0170 0572    ANDWF  72,W
0171 00F7    MOVWF  77
0172 00FB    MOVWF  7B                        segment = SevenSegTable[index];
0173 3001    MOVLW  01h
0174 008A    MOVWF  0A
0175 08FB    MOVF   7B
0176 0877    MOVF   77,W
0177 2113    CALL   0113h
0178 1283    BCF    03,5
0179 00F6    MOVWF  76
017A 1876    BTFSC  76,0                      if(segment.0)                      // D2.a
017B 159D    BSF    1D,3                          LCDD13.3 = 1;
017C 18F6    BTFSC  76,1                      if(segment.1)                      // D2.b
017D 149C    BSF    1C,1                          LCDD12.1 = 1;
017E 1976    BTFSC  76,2                      if(segment.2)                      // D2.c
017F 1595    BSF    15,3                          LCDD05.3 = 1;
0180 19F6    BTFSC  76,3                      if(segment.3)                      // D2.d
0181 1591    BSF    11,3                          LCDD01.3 = 1;
0182 1A76    BTFSC  76,4                      if(segment.4)                      // D2.e
0183 1414    BSF    14,0                          LCDD04.0 = 1;
0184 1AF6    BTFSC  76,5                      if(segment.5)                      // D2.f
0185 1418    BSF    18,0                          LCDD08.0 = 1;
0186 1B76    BTFSC  76,6                      if(segment.6)                      // D2.g
0187 1599    BSF    19,3                          LCDD09.3 = 1;
                                          }

                                         // Update Minutes if enabled
0188 1CF8    BTFSS  78,1                  if(Mode.MINUTES)
0189 29C6    GOTO   01C6h
018A                                      {
                                              // Digit 3
018A 30F0    MOVLW  F0h                       index = Minutes & 0xf0;
018B 0571    ANDWF  71,W
018C 00F7    MOVWF  77
018D 1003    BCF    03,0                      index >>= 4;
018E 0CF7    RRF    77
```

```
018F 1003    BCF    03,0
0190 0CF7    RRF    77
0191 1003    BCF    03,0
0192 0CF7    RRF    77
0193 1003    BCF    03,0
0194 0CF7    RRF    77
0195 00FB    MOVWF  7B                        segment = SevenSegTable[index];
0196 3001    MOVLW  01h
0197 008A    MOVWF  0A
0198 08FB    MOVF   7B
0199 0877    MOVF   77,W
019A 2113    CALL   0113h
019B 1283    BCF    03,5
019C 00F6    MOVWF  76
019D 1876    BTFSC  76,0                      if(segment.0)                      // D3.a
019E 151D    BSF    1D,2                          LCDD13.2 = 1;
019F 18F6    BTFSC  76,1                      if(segment.1)                      // D3.b
01A0 1518    BSF    18,2                          LCDD08.2 = 1;
01A1 1976    BTFSC  76,2                      if(segment.2)                      // D3.c
01A2 1514    BSF    14,2                          LCDD04.2 = 1;
01A3 19F6    BTFSC  76,3                      if(segment.3)                      // D3.d
01A4 1511    BSF    11,2                          LCDD01.2 = 1;
01A5 1A76    BTFSC  76,4                      if(segment.4)                      // D3.e
01A6 1494    BSF    14,1                          LCDD04.1 = 1;
01A7 1AF6    BTFSC  76,5                      if(segment.5)                      // D3.f
01A8 1519    BSF    19,2                          LCDD09.2 = 1;
01A9 1B76    BTFSC  76,6                      if(segment.6)                      // D3.g
01AA 1515    BSF    15,2                          LCDD05.2 = 1;

                                              // Digit 4
01AB 300F    MOVLW  0Fh                       index = Minutes & 0x0f;
01AC 0571    ANDWF  71,W
01AD 00F7    MOVWF  77
01AE 00FB    MOVWF  7B                        segment = SevenSegTable[index];
01AF 3001    MOVLW  01h
01B0 008A    MOVWF  0A
01B1 08FB    MOVF   7B
01B2 0877    MOVF   77,W
01B3 118A    BCF    0A,3
01B4 2113    CALL   0113h
01B5 118A    BCF    0A,3
01B6 1283    BCF    03,5
01B7 00F6    MOVWF  76
01B8 1876    BTFSC  76,0                      if(segment.0)                      // D4.a
01B9 149D    BSF    1D,1                          LCDD13.1 = 1;
01BA 18F6    BTFSC  76,1                      if(segment.1)                      // D4.b
01BB 1598    BSF    18,3                          LCDD08.3 = 1;
01BC 1976    BTFSC  76,2                      if(segment.2)                      // D4.c
01BD 1594    BSF    14,3                          LCDD04.3 = 1;
01BE 19F6    BTFSC  76,3                      if(segment.3)                      // D4.d
01BF 1491    BSF    11,1                          LCDD01.1 = 1;
01C0 1A76    BTFSC  76,4                      if(segment.4)                      // D4.e
01C1 1495    BSF    15,1                          LCDD05.1 = 1;
01C2 1AF6    BTFSC  76,5                      if(segment.5)                      // D4.f
01C3 151C    BSF    1C,2                          LCDD12.2 = 1;
01C4 1B76    BTFSC  76,6                      if(segment.6)                      // D4.g
01C5 1499    BSF    19,1                          LCDD09.1 = 1;
                                          }

                                         // Update Temperature
                                         // Digit 5
01C6 30F0    MOVLW  F0h                   index = TempC&0xf0;
01C7 0575    ANDWF  75,W
01C8 00F7    MOVWF  77
01C9 1003    BCF    03,0                  index >>= 4;
01CA 0CF7    RRF    77
```

```
01CB 1003    BCF    03,0
01CC 0CF7    RRF    77
01CD 1003    BCF    03,0
01CE 0CF7    RRF    77
01CF 1003    BCF    03,0
01D0 0CF7    RRF    77
01D1 00FB    MOVWF  7B                    segment = SevenSegTable[index];
01D2 3001    MOVLW  01h
01D3 008A    MOVWF  0A
01D4 08FB    MOVF   7B
01D5 0877    MOVF   77,W
01D6 2113    CALL   0113h
01D7 1283    BCF    03,5
01D8 00F6    MOVWF  76
01D9 1876    BTFSC  76,0                  if(segment.0)                           // D5.a
01DA 179C    BSF    1C,7                          LCDD12.7 = 1;
01DB 18F6    BTFSC  76,1                  if(segment.1)                           // D5.b
01DC 161C    BSF    1C,4                          LCDD12.4 = 1;
01DD 1976    BTFSC  76,2                  if(segment.2)                           // D5.c
01DE 1614    BSF    14,4                          LCDD04.4 = 1;
01DF 19F6    BTFSC  76,3                  if(segment.3)                           // D5.d
01E0 1790    BSF    10,7                          LCDD00.7 = 1;
01E1 1A76    BTFSC  76,4                  if(segment.4)                           // D5.e
01E2 1794    BSF    14,7                          LCDD04.7 = 1;
01E3 1AF6    BTFSC  76,5                  if(segment.5)                           // D5.f
01E4 141D    BSF    1D,0                          LCDD13.0 = 1;
01E5 1B76    BTFSC  76,6                  if(segment.6)                           // D5.g
01E6 1798    BSF    18,7                          LCDD08.7 = 1;

                                          // Digit 6
01E7 300F    MOVLW  0Fh                   index = TempC&0x0f;
01E8 0575    ANDWF  75,W
01E9 00F7    MOVWF  77
01EA 00FB    MOVWF  7B                    segment = SevenSegTable[index];
01EB 3001    MOVLW  01h
01EC 008A    MOVWF  0A
01ED 08FB    MOVF   7B
01EE 0877    MOVF   77,W
01EF 118A    BCF    0A,3
01F0 2113    CALL   0113h
01F1 118A    BCF    0A,3
01F2 1283    BCF    03,5
01F3 00F6    MOVWF  76
01F4 1876    BTFSC  76,0                  if(segment.0)                           // D6.a
01F5 171C    BSF    1C,6                          LCDD12.6 = 1;
01F6 18F6    BTFSC  76,1                  if(segment.1)                           // D6.b
01F7 1698    BSF    18,5                          LCDD08.5 = 1;
01F8 1976    BTFSC  76,2                  if(segment.2)                           // D6.c
01F9 1694    BSF    14,5                          LCDD04.5 = 1;
01FA 19F6    BTFSC  76,3                  if(segment.3)                           // D6.d
01FB 1710    BSF    10,6                          LCDD00.6 = 1;
01FC 1A76    BTFSC  76,4                  if(segment.4)                           // D6.e
01FD 1714    BSF    14,6                          LCDD04.6 = 1;
01FE 1AF6    BTFSC  76,5                  if(segment.5)                           // D6.f
01FF 1618    BSF    18,4                          LCDD08.4 = 1;
0200 1B76    BTFSC  76,6                  if(segment.6)                           // D6.g
0201 1718    BSF    18,6                          LCDD08.6 = 1;

                                          // Turn on : if enabled
0202 1B78    BTFSC  78,6                  if(Mode.COLON)
0203 1498    BSF    18,1                          LCDD08.1 = 1;

                                          // Turn on degrees symbol if enabled
0204 1BF8    BTFSC  78,7                  if(Mode.DEGREES)
0205 169C    BSF    1C,5                          LCDD12.5 = 1;
```

```
                                          // Turn on PROG symbol if enabled
0206 1AF8    BTFSC  78,5                  if(Mode.PROG)
0207 1415    BSF    15,0                          LCDD05.0 = 1;

                                          // Make copies of the LCD data registers
0208 0810    MOVF   10,W                  LCDD02 = LCDD00;
0209 0092    MOVWF  12
020A 0811    MOVF   11,W                  LCDD03 = LCDD01;
020B 0093    MOVWF  13
020C 0814    MOVF   14,W                  LCDD06 = LCDD04;
020D 0096    MOVWF  16
020E 0815    MOVF   15,W                  LCDD07 = LCDD05;
020F 0097    MOVWF  17
0210 0818    MOVF   18,W                  LCDD10 = LCDD08;
0211 009A    MOVWF  1A
0212 0819    MOVF   19,W                  LCDD11 = LCDD09;
0213 009B    MOVWF  1B
0214 081C    MOVF   1C,W                  LCDD14 = LCDD12;
0215 009E    MOVWF  1E
0216 081D    MOVF   1D,W                  LCDD15 = LCDD13;
0217 009F    MOVWF  1F

0218 1303    BCF    03,6                  STATUS.RP1 = 0;          // Return to Bank 0
0219 0008    RETURN                       return;
                                  }

                  /****************************************************************************
                   *   BlinkLCD
                   *   Function: This function is used in program mode to blink hours, minutes
                   *             or day of the week depending on the current status.
                   ***************************************************************************/
                                  void BlinkLCD(bits which)
002B                              {
021A 1283    BCF    03,5
021B 00AB    MOVWF  2B
021C 1C26    BTFSS  26,0              if(Flags.UPDATE)     // If UPDATE flag is set, blank the
021D 2A3C    GOTO   023Ch
021E                                  {                             // corresponding group
021E 1026    BCF    26,0                  Flags.UPDATE = 0;         // Clear UPDATE flag
021F 3001    MOVLW  01h                   if(which==0x01)           // Blank Hours
0220 022B    SUBWF  2B,W
0221 1D03    BTFSS  03,2
0222 2A28    GOTO   0228h
0223                                      {
0223 30E6    MOVLW  E6h                       Mode = 0b11100110;
0224 1283    BCF    03,5
0225 00F8    MOVWF  78
0226 2112    CALL   0112h                     UpdateLCD();
                                          }
0227 2A3B    GOTO   023Bh                 else if(which == 0x02)   // Blank Minutes
0228 3002    MOVLW  02h                   {
0229 1283    BCF    03,5
022A 022B    SUBWF  2B,W
022B 1D03    BTFSS  03,2
022C 2A32    GOTO   0232h
022D 30E5    MOVLW  E5h                       Mode = 0b11100101;
022E 1283    BCF    03,5
022F 00F8    MOVWF  78
0230 2112    CALL   0112h                     UpdateLCD();
                                          }
0231 2A3B    GOTO   023Bh                 else if(which == 0x04)   // Blank day of the week
0232 3004    MOVLW  04h                   {
0233 1283    BCF    03,5
0234 022B    SUBWF  2B,W
0235 1D03    BTFSS  03,2
0236 2A3B    GOTO   023Bh
0237 30E3    MOVLW  E3h                       Mode = 0b11100011;
0238 1283    BCF    03,5
0239 00F8    MOVWF  78
023A 2112    CALL   0112h                     UpdateLCD();
                                          }
                                      }
023B 2A40    GOTO   0240h             else                   // Turn on all groups if UPDATE
flag is
                                      {                      // cleared
023C 1426    BSF    26,0                  Flags.UPDATE = 1;  // Set the UPDATE flag
023D 30E7    MOVLW  E7h                   Mode = 0b11100111; // Set bits in Mode to turn all on
023E 00F8    MOVWF  78
023F 2112    CALL   0112h                 UpdateLCD();
                                      }
0240 0008    RETURN                   return;
                                  }

                  /****************************************************************************
                   *   DisplaySoundState
                   *   Function: When the SOUND button is pressed the state of the hourly beep
                   *          is toggle between on and off.  This routine displays to the
                                  *          user the state, Snd OF or Snd On.
                   ****************************************************************************/
                                  void DisplaySoundState(void)
                                  {
002C                                  unsigned char frames;  // Frame count variable

0241 300C    MOVLW  0Ch               frames = FRAME_COUNT;  // Initialize the frame counter
0242 1283    BCF    03,5
0243 00AC    MOVWF  2C

0244 1283    BCF    03,5              while(!Flags.FRAME);   // Wait for next frame to occur
0245 1CA6    BTFSS  26,1
0246 2A44    GOTO   0244h
0247 1283    BCF    03,5              Flags.FRAME = 0;       // Clear FRAME flag
0248 10A6    BCF    26,1

0249 1703    BSF    03,6              STATUS.RP1 = 1;        // Change to Bank 2
024A 3080    MOVLW  80h               LCDD00 = 0b10000000;   // Write data common to both
024B 0090    MOVWF  10
024C 300A    MOVLW  0Ah               LCDD01 = 0b00001010;   // Snd On and Snd OF
024D 0091    MOVWF  11
024E 300E    MOVLW  0Eh               LCDD05 = 0b00001110;
024F 0095    MOVWF  15
0250 300A    MOVLW  0Ah               LCDD09 = 0b00001010;
0251 0099    MOVWF  19
0252 3009    MOVLW  09h               LCDD13 = 0b00001001;
0253 009D    MOVWF  1D
0254 1303    BCF    03,6              STATUS.RP1 = 0;        // Change to Bank 0

0255 1E26    BTFSS  26,4              if(Flags.SOUND_STATE)  // Sound on
0256 2A5F    GOTO   025Fh
0257                                  {
0257 1703    BSF    03,6                  STATUS.RP1 = 1;    // Change to Bank 2
0258 30FE    MOVLW  FEh                   LCDD04 = 0b11111110; // Write data specific to Snd On
0259 0094    MOVWF  14
025A 3049    MOVLW  49h                   LCDD08 = 0b01001001;
025B 0098    MOVWF  18
025C 3090    MOVLW  90h                   LCDD12 = 0b10010000;
025D 009C    MOVWF  1C
                                      }
025E 2A66    GOTO   0266h             else                   // Sound off
                                      {
025F 1703    BSF    03,6                  STATUS.RP1 = 1;    // Change to Bank 2
0260 30DE    MOVLW  DEh                   LCDD04 = 0b11011110;// Write data specific to Snd OFF
0261 0094    MOVWF  14
```

```
0262 3059    MOVLW  59h                   LCDD08 = 0b01011001;
0263 0098    MOVWF  18
0264 30D0    MOVLW  D0h                   LCDD12 = 0b11010000;
0265 009C    MOVWF  1C
                                      }
0266 1303    BCF    03,6              STATUS.RP1 = 0;          // Change to Bank 0

                                      while(frames)    // Delay a specific number of frames so
                                      {                        // the user can see the message
0267 1283    BCF    03,5
0268 08AC    MOVF   2C
0269 1903    BTFSC  03,2
026A 2A71    GOTO   0271h
026B                                      if(Flags.FRAME)      // Decrement frames until 0
026B 1283    BCF    03,5                  {
026C 1CA6    BTFSS  26,1
026D 2A70    GOTO   0270h
026E 10A6    BCF    26,1                      Flags.FRAME = 0;
026F 03AC    DECF   2C                        frames--;
                                          }
0270 2A67    GOTO   0267h             }
0271 0008    RETURN                   return;
                                  }

                                  #include “time.c”       // Contains programs for timekeeping
                  /****************************************************************************
                   *  Filename: TIME.C
                   ****************************************************************************
                   *   Author:     Rodger Richey
                   *   Company:  Microchip Technology Incorporated
                   *   Revision: A0
                   *   Date:     6-14-96
                   *   Compiled using MPLAB-C Version 00.00.14
                   *****************************************************************************
                   *   This file contains the routines to increment time and set the time in
                   *   program mode.
                   ****************************************************************************/

                  /****************************************************************************
                   *   IncMinutes
                   *   Function: Increments minutes and performs checks.  Minutes is in BCD.
                   ****************************************************************************/
                                  void IncMinutes(void)
                                  {
0272 1283    BCF    03,5              Seconds = 0;               // Clear Seconds
0273 01F0    CLRF   70
0274 0AF1    INCF   71                Minutes++;                 // Increment Minutes
0275 300F    MOVLW  0Fh               if( (Minutes&0x0f) > 0x09) // Check for BCD overflow
0276 0571    ANDWF  71,W
0277 00FB    MOVWF  7B
0278 3009    MOVLW  09h
0279 027B    SUBWF  7B,W
027A 1D03    BTFSS  03,2
027B 1C03    BTFSS  03,0
027C 2A82    GOTO   0282h
027D                                  {
027D 30F0    MOVLW  F0h                  Minutes &= 0xf0;
027E 1283    BCF    03,5
027F 05F1    ANDWF  71
0280 3010    MOVLW  10h                  Minutes += 0x10;
0281 07F1    ADDWF  71
                                      }
0282 0008    RETURN                   return;
                                  }

                  /****************************************************************************
```

```
                   *   IncHours
                   *   Function: Increments hours and performs checks.  Hours is in BCD.
                   ****************************************************************************/
                                  void IncHours(void)
                                  {
0283 1283    BCF    03,5              if(!Flags.PROGRAM) // If program mode, do not clear Minutes
0284 1DA6    BTFSS  26,3
0285 01F1    CLRF   71                   Minutes = 0;
0286 0AF2    INCF   72                Hours++;                   // Increment Hours
0287 300F    MOVLW  0Fh               if( (Hours&0x0f) > 0x09)   // Check for BCD overflow
0288 0572    ANDWF  72,W
0289 00FB    MOVWF  7B
028A 3009    MOVLW  09h
028B 027B    SUBWF  7B,W
028C 1D03    BTFSS  03,2
028D 1C03    BTFSS  03,0
028E 2A94    GOTO   0294h
028F                                  {
028F 30F0    MOVLW  F0h                  Hours &= 0xf0;
0290 1283    BCF    03,5
0291 05F2    ANDWF  72
0292 3010    MOVLW  10h                  Hours += 0x10;
0293 07F2    ADDWF  72
                                      }
0294 3012    MOVLW  12h               if(Hours == 0x12)     // If hours = 12 then change AM/PM
0295 1283    BCF    03,5
0296 0272    SUBWF  72,W
0297 1D03    BTFSS  03,2
0298 2AA8    GOTO   02A8h
0299                                  {                     //  and day of the week accordingly
0299 1283    BCF    03,5                 if(LStatus.AMPM)   // If PM
029A 1FF3    BTFSS  73,7
029B 2AA7    GOTO   02A7h
029C                                     {
029C 13F3    BCF    73,7                   LStatus.AMPM = 0;  // change to AM
029D 19A6    BTFSC  26,3                   if(!Flags.PROGRAM)  // If not prog mode, increment day
029E 2AA6    GOTO   02A6h
029F                                       {             // of the week and check for overflow
029F 0AF4    INCF   74                      DayOfWeek++;
02A0 3007    MOVLW  07h                     if(DayOfWeek == 0x07)
02A1 0274    SUBWF  74,W
02A2 1D03    BTFSS  03,2
02A3 2AA6    GOTO   02A6h
02A4 1283    BCF    03,5                        DayOfWeek = 0;
02A5 01F4    CLRF   74
                                           }
                                         }
02A6 2AA8    GOTO   02A8h                else                // Otherwise change to PM
02A7 17F3    BSF    73,7                   LStatus.AMPM = 1;
                                      }
02A8 1283    BCF    03,5              if(Flags.SOUND_STATE) // Start hourly beep if enabled
02A9 1E26    BTFSS  26,4
02AA 2AAC    GOTO   02ACh
02AB 2100    CALL   0100h                StartBEEP();

02AC 3013    MOVLW  13h               if(Hours == 0x13)    // If hours has overflowed, set to 1
02AD 1283    BCF    03,5
02AE 0272    SUBWF  72,W
02AF 1D03    BTFSS  03,2
02B0 2AB4    GOTO   02B4h
02B1 3001    MOVLW  01h                  Hours = 0x01;
02B2 1283    BCF    03,5
02B3 00F2    MOVWF  72

02B4 0008    RETURN                   return;
                                  }
```

```
                  /*****************************************************************************
                   *   SetTime
                   *   Function: This routine sets the time in program mode.  Allows hours,
                   *          minutes and day of the week to be configured.
                   *****************************************************************************/
                                  void SetTime(void)
                                  {
02B5 300C    MOVLW  0Ch               FrameCnt = FRAME_COUNT; // Initialize the frame counter
02B6 1283    BCF    03,5
02B7 00AA    MOVWF  2A
                                      while(!Flags.SET)   // Wait for the SET button to be
02B8 1283    BCF    03,5              {                   // hit before advancing to minutes
02B9 1BA6    BTFSC  26,7
02BA 2AD2    GOTO   02D2h
02BB                                     if(Flags.UP)     // If UP button pressed, inc Minutes
02BB 1F26    BTFSS  26,6                 {
02BC 2ABF    GOTO   02BFh
02BD 1326    BCF    26,6                   Flags.UP = 0;
02BE 2283    CALL   0283h                  IncHours();
                                         }
02BF 1283    BCF    03,5                 if(Flags.FRAME)  // Toggle display state (blink) every
02C0 1CA6    BTFSS  26,1
02C1 2ACC    GOTO   02CCh
02C2                                     {                // FRAME_COUNT frames
02C2 10A6    BCF    26,1                   Flags.FRAME = 0;
02C3 03AA    DECF   2A                     FrameCnt--;
02C4 08AA    MOVF   2A                     if(!FrameCnt)  // If frame count = zero, toggle state
02C5 1D03    BTFSS  03,2
02C6 2ACC    GOTO   02CCh
02C7                                       {
02C7 300C    MOVLW  0Ch                     FrameCnt = FRAME_COUNT;
02C8 1283    BCF    03,5
02C9 00AA    MOVWF  2A
02CA 3001    MOVLW  01h                     BlinkLCD(0x01);
02CB 221A    CALL   021Ah
                                           }
                                         }
02CC 3005    MOVLW  05h                  if(Ticks == 5)       // If no button pressed in 5 secs
02CD 1283    BCF    03,5
02CE 0229    SUBWF  29,W
02CF 1903    BTFSC  03,2
02D0 0008    RETURN                        return;             // exit program mode
02D1 2AB8    GOTO   02B8h             }
02D2 1283    BCF    03,5              Flags.SET = 0;
02D3 13A6    BCF    26,7

02D4 300C    MOVLW  0Ch               FrameCnt = FRAME_COUNT; // Initialize the frame counter
02D5 00AA    MOVWF  2A
                                      while(!Flags.SET)    // Wait for the SET button to be hit
02D6 1283    BCF    03,5              {                 // before advancing to day of the week
02D7 1BA6    BTFSC  26,7
02D8 2AF7    GOTO   02F7h
02D9                                     if(Flags.UP)  // If the UP button is hit, inc Minutes
02D9 1F26    BTFSS  26,6                 {
02DA 2AE4    GOTO   02E4h
02DB 1326    BCF    26,6                   Flags.UP = 0;
02DC 2272    CALL   0272h                  IncMinutes();
02DD 3060    MOVLW  60h                    if(Minutes >= 0x60)     // Check for upper limit
02DE 1283    BCF    03,5
02DF 0271    SUBWF  71,W
02E0 1C03    BTFSS  03,0
02E1 2AE4    GOTO   02E4h
02E2 1283    BCF    03,5                    Minutes = 0;
02E3 01F1    CLRF   71
                                         }
```

```
02E4 1283    BCF    03,5                 if(Flags.FRAME)    // Toggle the display state (blink)
02E5 1CA6    BTFSS  26,1
02E6 2AF1    GOTO   02F1h
02E7                                     {                      // every FRAME_COUNT frames
02E7 10A6    BCF    26,1                   Flags.FRAME = 0;
02E8 03AA    DECF   2A                     FrameCnt--;
02E9 08AA    MOVF   2A                     if(!FrameCnt)    // If FRAME_COUNT=zero, toggle state
02EA 1D03    BTFSS  03,2
02EB 2AF1    GOTO   02F1h
02EC                                       {
02EC 300C    MOVLW  0Ch                     FrameCnt = FRAME_COUNT;
02ED 1283    BCF    03,5
02EE 00AA    MOVWF  2A
02EF 3002    MOVLW  02h                     BlinkLCD(0x02);
02F0 221A    CALL   021Ah
                                           }
                                         }
02F1 3005    MOVLW  05h                  if(Ticks == 5)     // If no button pressed in 5 secs
02F2 1283    BCF    03,5
02F3 0229    SUBWF  29,W
02F4 1903    BTFSC  03,2
02F5 0008    RETURN                        return;              // exit program mode
02F6 2AD6    GOTO   02D6h             }
02F7 1283    BCF    03,5              Flags.SET = 0;
02F8 13A6    BCF    26,7

02F9 300C    MOVLW  0Ch               FrameCnt = FRAME_COUNT;  // Initialize the frame counter
02FA 00AA    MOVWF  2A
                                      while(!Flags.SET)        // Wait for SET button to be hit
02FB 1283    BCF    03,5              {                        // before exiting program mode
02FC 1BA6    BTFSC  26,7
02FD 2B1B    GOTO   031Bh
02FE                                     if(Flags.UP)          // If the UP key is pressed, inc
02FE 1F26    BTFSS  26,6                 {                     // inc. day of week
02FF 2B08    GOTO   0308h
0300 1326    BCF    26,6                   Flags.UP = 0;
0301 0AF4    INCF   74                     DayOfWeek++;
0302 3007    MOVLW  07h                    if(DayOfWeek == 0x07) // Check for overflow
0303 0274    SUBWF  74,W
0304 1D03    BTFSS  03,2
0305 2B08    GOTO   0308h
0306 1283    BCF    03,5                    DayOfWeek = 0;
0307 01F4    CLRF   74
                                         }
0308 1283    BCF    03,5                 if(Flags.FRAME)       // Toggle display state every
0309 1CA6    BTFSS  26,1
030A 2B15    GOTO   0315h
030B                                     {                     // every FRAME_COUNT frames
030B 10A6    BCF    26,1                   Flags.FRAME = 0;
030C 03AA    DECF   2A                     FrameCnt--;
030D 08AA    MOVF   2A                     if(!FrameCnt)
030E 1D03    BTFSS  03,2
030F 2B15    GOTO   0315h
0310                                       {
0310 300C    MOVLW  0Ch                     FrameCnt = FRAME_COUNT;
0311 1283    BCF    03,5
0312 00AA    MOVWF  2A
0313 3004    MOVLW  04h                     BlinkLCD(0x04);
0314 221A    CALL   021Ah
                                           }
                                         }
0315 3005    MOVLW  05h                  if(Ticks == 5)         // If no button pressed in 5 secs
0316 1283    BCF    03,5
0317 0229    SUBWF  29,W
0318 1903    BTFSC  03,2
0319 0008    RETURN                        return;          // exit program mode
```

```
031A 2AFB    GOTO   02FBh             }
031B 1283    BCF    03,5              Flags.SET = 0;
031C 13A6    BCF    26,7
031D 0008    RETURN                   return;
                                   }

                  /****************************************************************************
                   *   Init924
                   *   Function: This routine initializes the peripherals and CPU of the
                   *          PIC16C924.
                   ***************************************************************************/
                                 void Init924(void)
                                 {
031E 1283    BCF    03,5   STATUS.RP0 = 0;       // Change to Bank 0
031F 1303    BCF    03,6   STATUS.RP1 = 0;
0320 3053    MOVLW  53h    OPTION = 0b01010011;  // Pull-ups on,T0 int clk source,
0321 1683    BSF    03,5
0322 0081    MOVWF  01
                                                 // Prescaler assigned to T0, 1:16
0323 30C1    MOVLW  C1h    ADCON0 = 0b11000001;  // Internal RC clk src, Ch0, A/D on
0324 1283    BCF    03,5
0325 009F    MOVWF  1F
0326 0185    CLRF   05     PORTA = 0;            // Clear ports A,B,C
0327 0186    CLRF   06     PORTB = 0;
0328 0187    CLRF   07     PORTC = 0;
0329 3007    MOVLW  07h    TRISA = 0b00000111;   // RAZ:RA1> digi outputs
032A 1683    BSF    03,5
032B 0085    MOVWF  05
032C 30F0    MOVLW  F0h    TRISB = 0xf0;         // Upper 4 pins are inputs for keys
032D 0086    MOVWF  06
032E 3003    MOVLW  03h    TRISC = 0x03;         // RC<0:1> used for Timer1
032F 0087    MOVWF  07                           // external crystal
0330 3004    MOVLW  04h    ADCON1 = 0b00000100;  // RA<0:1,3> are analog
0331 009F    MOVWF  1F
0332 1283    BCF    03,5   PIR1.ADIF = 0;        // Clear A/D interrupt flag
0333 130C    BCF    0C,6
0334 1683    BSF    03,5   PIE1.ADIE = 1;        // Enable A/D interrupt
0335 170C    BSF    0C,6

0336 1283    BCF    03,5   Temp = PORTB;         // Clear mismatch condition
0337 0806    MOVF   06,W                         // on PORTB
0338 00A7    MOVWF  27
0339 100B    BCF    0B,0   INTCON.RBIF = 0;      // Clear PORTB interrupt flag
033A 158B    BSF    0B,3   INTCON.RBIE = 1;      // Enable PORTB interrupt

033B 3080    MOVLW  80h    TMR1H = 0x80;         // Initialize Timer1 to 0x8000
033C 008F    MOVWF  0F
033D 018E    CLRF   0E     TMR1L = 0x00;
033E 300F    MOVLW  0Fh    T1CON = 0b00001111;   // Timer1 1:1 prescale, Osc
033F 0090    MOVWF  10                           // enabled, no sync, external
                                                 // clock source, Timer1 on
0340 100C    BCF    0C,0   PIR1.TMR1IF = 0;      // Clear Timer1 Overflow int flag
0341 1683    BSF    03,5   PIE1.TMR1IE = 1;      // Enable T1 Overflow interrupt
0342 140C    BSF    0C,0

0343 1703    BSF    03,6   STATUS.RP1 = 1;       // Go to Bank 2
0344 3006    MOVLW  06h    LCDPS = 6;            // Set LCD frame freq to 37 Hz,
0345 1283    BCF    03,5                         // Timer1 clk source
0346 008E    MOVWF  0E
0347 30FF    MOVLW  FFh    LCDSE = 0xff;         // Ports D,E,F,G are all LCD pins
0348 008D    MOVWF  0D
0349 3017    MOVLW  17h    LCDCON = 0b00010111;  // Drive in SLEEP,charge pump on,Timer1 clk src
034A 008F    MOVWF  0F                           // Timer1 clk src 1/4 mux, 1/3 bias
034B 0190    CLRF   10     LCDD00 = 0;           // Clear all LCD data registers
034C 0191    CLRF   11     LCDD01 = 0;
```

```
034D 0192    CLRF   12                LCDD02 = 0;
034E 0193    CLRF   13                LCDD03 = 0;
034F 0194    CLRF   14                LCDD04 = 0;
0350 0195    CLRF   15                LCDD05 = 0;
0351 0196    CLRF   16                LCDD06 = 0;
0352 0197    CLRF   17                LCDD07 = 0;
0353 0198    CLRF   18                LCDD08 = 0;
0354 0199    CLRF   19                LCDD09 = 0;
0355 019A    CLRF   1A                LCDD10 = 0;
0356 019B    CLRF   1B                LCDD11 = 0;
0357 019C    CLRF   1C                LCDD12 = 0;
0358 019D    CLRF   1D                LCDD13 = 0;
0359 019E    CLRF   1E                LCDD14 = 0;
035A 019F    CLRF   1F                LCDD15 = 0;
035B 178F    BSF    0F,7              LCDCON.LCDEN = 1;   // Enable the LCD Module
035C 1303    BCF    03,6              STATUS.RP1 = 0;     // Go to Bank 0
035D 138C    BCF    0C,7              PIR1.LCDIF = 0;     // Clear LCD interrupt flag
035E 1683    BSF    03,5              PIE1.LCDIE = 1;     // Enable LCD interrupt
035F 178C    BSF    0C,7

0360 1283    BCF    03,5              Seconds = 0;        // Initialize data variables
0361 01F0    CLRF   70
0362 01F1    CLRF   71                Minutes = 0;
0363 3012    MOVLW  12h               Hours = 0x12;       // Set time to 12:00AM Sunday
0364 00F2    MOVWF  72
0365 01F3    CLRF   73                LStatus = 0;
0366 01F4    CLRF   74                DayOfWeek = 0;
0367 3011    MOVLW  11h               Flags = 0b00010001;
0368 00A6    MOVWF  26
0369 01F5    CLRF   75                TempC = 0;
036A 01A9    CLRF   29                Ticks = 0;
036B 3004    MOVLW  04h               Count = BEEP_COUNT;
036C 00A8    MOVWF  28
036D 30C7    MOVLW  C7h               Mode = 0b11000111;  // Turn on :,degrees,hours,
036E 00F8    MOVWF  78                                    // minutes, day of week

036F 170B    BSF    0B,6              INTCON.PEIE = 1;    // Enable peripheral interrupts
0370 178B    BSF    0B,7              INTCON.GIE = 1;     // Enable global interrupts
0371 0008    RETURN                   return;
                                  }

                  /****************************************************************************
                   *   main
                   *   Function: Controls the clock.  Calls routines to update the LCD panel,
                   *             play music, program mode, and display state of sound.
                   ****************************************************************************/
                                  void main(void)
                                  {
0372 231E    CALL   031Eh             Init924();          // Initialize the PIC16C924

                                      while(1)
                                      {
0373 1283    BCF    03,5                 if(Flags.UPDATE&&Flags.FRAME) // Refresh the LCD
0374 1C26    BTFSS  26,0                                               // data registers
0375 2B7D    GOTO   037Dh
0376 1CA6    BTFSS  26,1
0377 2B7D    GOTO   037Dh
0378                                     {                // based on new data
0378 1283    BCF    03,5                   Flags.UPDATE = 0;       // Clear the UPDATE flag
0379 1026    BCF    26,0
037A 10A6    BCF    26,1                   Flags.FRAME = 0;        // Clear the FRAME flag
037B 2112    CALL   0112h                  UpdateLCD();            // Update LCD data regs
                                         }
037C 2B84    GOTO   0384h                else if(!Flags.UPDATE&&Flags.FRAME)  // Clear FRAME
037D 1283    BCF    03,5                   Flags.FRAME = 0;                // flag if no UPDATE
037E 1826    BTFSC  26,0
037F 2B84    GOTO   0384h
0380 1CA6    BTFSS  26,1
0381 2B84    GOTO   0384h
0382 1283    BCF    03,5
0383 10A6    BCF    26,1

0384 1283    BCF    03,5                 if(Flags.SET)          // Enter program mode
0385 1FA6    BTFSS  26,7
0386 2B9A    GOTO   039Ah
0387                                     {
0387 13A6    BCF    26,7                   Flags.SET = 0;       // Clear the SET, UP flags
0388 1326    BCF    26,6                   Flags.UP = 0;
0389 01A9    CLRF   29                     Ticks = 0;           // Clear the Ticks
038A 15A6    BSF    26,3                   Flags.PROGRAM = 1;   // Change to program mode
038B 1283    BCF    03,5                   while(!Flags.FRAME);  // Wait for next frame to occur
038C 1CA6    BTFSS  26,1
038D 2B8B    GOTO   038Bh
038E 1283    BCF    03,5                   Flags.FRAME = 0;     // Clear FRAME flag
038F 10A6    BCF    26,1
0390 30E7    MOVLW  E7h                    Mode = 0b11100111;   // Enable PROG icon on LCD
0391 00F8    MOVWF  78
0392 2112    CALL   0112h                  UpdateLCD();         // Refresh the LCD

0393 22B5    CALL   02B5h                  SetTime();           // Call program to set time

0394 1283    BCF    03,5                   Flags.PROGRAM = 0;   // Exit program mode
0395 11A6    BCF    26,3
0396 01F0    CLRF   70                     Seconds = 0;         // Clear seconds
0397 1426    BSF    26,0                   Flags.UPDATE = 1;    // Set UPDATE flag
0398 30C7    MOVLW  C7h                    Mode = 0b11000111;   // Reset display mode,
0399 00F8    MOVWF  78                                          // PROG icon off
                                         }

039A 1EF3    BTFSS  73,5                 if(LStatus.SOUND)      // Enable/disable hourly beep
039B 2B9E    GOTO   039Eh
039C                                     {
039C 12F3    BCF    73,5                   LStatus.SOUND = 0;   // Reset SOUND flag
039D 2241    CALL   0241h                  DisplaySoundState(); // Display state of hourly beep
                                         }

039E 1283    BCF    03,5                 if(!Flags.SLEEP_STATE) // If 924 can go to sleep,
039F 1EA6    BTFSS  26,5                                        // go ahead
03A0 0063    SLEEP                         SLEEP();
03A1 2B73    GOTO   0373h             }
03A2 0008    RETURN               }

                  /****************************************************************************
                   *   __INT
                   *   Function: Interrupt service routine for LCD, PORTB, Timer2, Timer1,
                   *          Timer0, and A/D
                   ****************************************************************************/
0004 2BA3    GOTO   03A3h         void __INT(void)
03A3                              {
                                  #asm                          // “push” W and STATUS
03A3 00FA                   movwf   temp_WREG
03A4 0E03                   swapf   STATUS,W
03A5 1283                   bcf     STATUS,RP0
03A6 1303                   bcf     STATUS,RP1
03A7 00FE                   movwf   temp_STATUS
03A8 0804                   movf   FSR,W
03A9 00FF                   movwf  temp_FSR
                                  #endasm

03AA 1283    BCF    03,5              if(PIR1.LCDIF)            // Ok to write to LCD data regs
03AB 1F8C    BTFSS  0C,7
03AC 2BAF    GOTO   03AFh
```

```
03AD                                  {
03AD 14A6    BSF    26,1                 Flags.FRAME = 1;    // Set FRAME flag
03AE 138C    BCF    0C,7                 PIR1.LCDIF = 0;     // Clear LCD interrupt flag
                                      }

03AF 1C0B    BTFSS  0B,0              if(INTCON.RBIF)        // Key press/release detected
03B0 2BD7    GOTO   03D7h
03B1                                  {
03B1 3005    MOVLW  05h                  Delay_Ms_4MHz(5);   // Debounce for 5msec
03B2 2432    CALL   0432h
03B3 1283    BCF    03,5                 Temp = PORTB;       // Read PORTB
03B4 0806    MOVF   06,W
03B5 00A7    MOVWF  27
03B6 3014    MOVLW  14h                  Delay_Ms_4MHz(20);  // Debounce for 20msec more
03B7 2432    CALL   0432h
03B8 30F0    MOVLW  F0h                  if(Temp!=0xf0 && Temp==PORTB) // If same state as
03B9 1283    BCF    03,5                                               // previous read
03BA 0227    SUBWF  27,W
03BB 1903    BTFSC  03,2
03BC 2BD4    GOTO   03D4h
03BD 1283    BCF    03,5
03BE 0827    MOVF   27,W
03BF 0206    SUBWF  06,W
03C0 1D03    BTFSS  03,2
03C1 2BD4    GOTO   03D4h
03C2                                     {                   // and interrupt is not for release
03C2 2100    CALL   0100h                  StartBEEP();      // Beep when key is pressed

03C3 1283    BCF    03,5                   if(!Temp.SET)     // Set the SET flag
03C4 1FA7    BTFSS  27,7
03C5 17A6    BSF    26,7                    Flags.SET = 1;
03C6 1F27    BTFSS  27,6                   if(!Temp.UP)      // Set the UP flag
03C7 1726    BSF    26,6                    Flags.UP = 1;
03C8 118A    BCF    0A,3                   if(!Temp.SOUND&&!Flags.PROGRAM)
03C9 1AA7    BTFSC  27,5
03CA 2BD4    GOTO   03D4h
03CB 19A6    BTFSC  26,3
03CC 2BD4    GOTO   03D4h
03CD                                       {                      // Toggle the SOUND state
03CD 1283    BCF    03,5                      if(Flags.SOUND_STATE)
03CE 1E26    BTFSS  26,4
03CF 2BD2    GOTO   03D2h
03D0 1226    BCF    26,4                        Flags.SOUND_STATE = 0;
03D1 2BD3    GOTO   03D3h                   else
03D2 1626    BSF    26,4                        Flags.SOUND_STATE = 1;
03D3 16F3    BSF    73,5                    LStatus.SOUND = 1;    // Set the SOUND flag
                                           }
                                         }
03D4 1283    BCF    03,5                 Ticks = 0;               // Reset Ticks, because key
03D5 01A9    CLRF   29                                            // was pressed
03D6 100B    BCF    0B,0                 INTCON.RBIF = 0;         // Clear PORTB interrupt flag
                                      }

03D7 1C8C    BTFSS  0C,1              if(PIR1.TMR2IF&&PIE1.TMR2IE)// T2 Overflow used for beep
03D8 2BEE    GOTO   03EEh
03D9 1683    BSF    03,5
03DA 1C8C    BTFSS  0C,1
03DB 2BEE    GOTO   03EEh
03DC                                  {
03DC 1683    BSF    03,5                 if(PIE1.TMR2IE)          // If Timer2 int is enabled
03DD 1C8C    BTFSS  0C,1
03DE 2BEC    GOTO   03ECh
03DF                                     {
03DF 1283    BCF    03,5                   Count--;               // Decrement count
03E0 03A8    DECF   28
03E1 08A8    MOVF   28                     if(!Count)           // If count has reached zero
03E2 1D03    BTFSS  03,2
03E3 2BEC    GOTO   03ECh
03E4                                       {
03E4 1283    BCF    03,5                    CCP1CON = 0;        // Disable CCP module
03E5 0197    CLRF   17
03E6 0192    CLRF   12                      T2CON = 0;          // Disable Timer2
03E7 0195    CLRF   15                      CCPR1L = 0;         // Clear the Duty Cycle
03E8 1683    BSF    03,5                    PIE1.TMR2IE = 0;    // Disable Timer2 Interrupt
03E9 108C    BCF    0C,1
03EA 1283    BCF    03,5                    Flags.SLEEP_STATE = 0;  // Enable 924 to SLEEP
03EB 12A6    BCF    26,5
                                           }
                                         }
03EC 1283    BCF    03,5                 PIR1.TMR2IF = 0;       // Clear Timer2 interrupt flag
03ED 108C    BCF    0C,1
                                      }

03EE 1283    BCF    03,5              if(PIR1.TMR1IF)           // T1 Overflow, once every sec
03EF 1C0C    BTFSS  0C,0
03F0 2C23    GOTO   0423h
03F1                                  {
03F1 19A6    BTFSC  26,3                 if(!Flags.PROGRAM)     // If not in program mode
03F2 2C16    GOTO   0416h
03F3                                     {
03F3 0AF0    INCF   70                     Seconds++;           // Increment seconds
03F4 300F    MOVLW  0Fh                    if( (Seconds&0x0f) > 0x09)   // check for seconds
03F5 0570    ANDWF  70,W                                                // overflow within
03F6 00FB    MOVWF  7B
03F7 3009    MOVLW  09h
03F8 027B    SUBWF  7B,W
03F9 1D03    BTFSS  03,2
03FA 1C03    BTFSS  03,0
03FB 2C01    GOTO   0401h
03FC                                       {                    // seconds
03FC 30F0    MOVLW  F0h                     Seconds &= 0xf0;
03FD 1283    BCF    03,5
03FE 05F0    ANDWF  70
03FF 3010    MOVLW  10h                     Seconds += 0x10;
0400 07F0    ADDWF  70
                                           }
0401 3060    MOVLW  60h                    if(Seconds >= 0x60)  // check for seconds overflow
0402 1283    BCF    03,5
0403 0270    SUBWF  70,W
0404 1C03    BTFSS  03,0
0405 2C07    GOTO   0407h
0406 2272    CALL   0272h                   IncMinutes();       // increment minutes routine
0407 3060    MOVLW  60h                    if(Minutes >= 0x60)  // check for hours overflow
0408 1283    BCF    03,5
0409 0271    SUBWF  71,W
040A 1C03    BTFSS  03,0
040B 2C0D    GOTO   040Dh
040C 2283    CALL   0283h                   IncHours();         // increment hours routine

040D 1283    BCF    03,5                   TMR1H |= 0x80;       // Set Timer1 to 0x8000
040E 178F    BSF    0F,7                                        // + current time
040F 1426    BSF    26,0                   Flags.UPDATE = 1;    // Set UPDATE flag

0410 1F78    BTFSS  78,6                   if(Mode.COLON)       // Toggle whether the colon is
0411 2C14    GOTO   0414h
0412 1378    BCF    78,6                    Mode.COLON = 0;     // on or off every second
0413 2C15    GOTO   0415h                  else
0414 1778    BSF    78,6                    Mode.COLON = 1;
                                         }
0415 2C17    GOTO   0417h                else                   // If in program mode
0416 0AA9    INCF   29                     Ticks++;             // inc Ticks, used for timeout
```

```
0417 1683    BSF    03,5                 TRISA.THERM_GND = 0; // Apply power to thermistor
0418 1105    BCF    05,2
0419 3002    MOVLW  02h                  Delay_10xUs_4MHz(2); // Allow 20us for sampling
041A 243C    CALL   043Ch
041B 1283    BCF    03,5                 ADCON0.GO = 1;       // Start a temp A/D conversion
041C 151F    BSF    1F,2
041D 0000    NOP                         NOP();               // Wait for charging cap to
041E 0000    NOP                         NOP();               // disconnect from pin
041F 1683    BSF    03,5                 TRISA.THERM_GND = 1; // Remove power from thermistor
0420 1505    BSF    05,2
0421 1283    BCF    03,5                 PIR1.TMR1IF = 0;     // Clear Timer1 interrupt flag
0422 100C    BCF    0C,0
                                      }

0423 1F0C    BTFSS  0C,6              if(PIR1.ADIF)           // A/D conversion complete
0424 2C2B    GOTO   042Bh
0425                                  {
0425 018A    CLRF   0A                   TempC = ThermTable[ADRES];// Use converted value
0426 081E    MOVF   1E,W                                          // for table
0427 2005    CALL   0005h
0428 1283    BCF    03,5
0429 00F5    MOVWF  75
042A 130C    BCF    0C,6                 PIR1.ADIF = 0;       // lookup of temperature
                                      }

                                  #asm                        // “pop” W and STATUS
042B 087F                   movf   temp_FSR,W
042C 0084                   movwf  FSR
042D 0E7E                   swapf   temp_STATUS,W
042E 0083                   movwf   STATUS
042F 0EFA                   swapf   temp_WREG,F
0430 0E7A                   swapf   temp_WREG,W
                                  #endasm

0431 0009    RETFIE                   return;
                                  }

                    /*************************************************************************/

                                  void Delay_Ms_4MHz(registerw delay)
                                  /*
                                     Clock Speed = 4MHz
                                     Inst. Clock = 1MHz
                                     Inst. dur.  = 1us  */
0000                              {
                                  #asm
0432 1283                       BCF     STATUS, RP0
0433 00FB                       MOVWF   __WImage
                        DLMS4M1
                                RADIX   DEC
0434 30F9                       MOVLW   249
0435 0084                       MOVWF   FSR
                        DLMS4M2
0436 0000                       NOP
0437 0B84                       DECFSZ  FSR
0438 2C36                       GOTO    DLMS4M2

0439 0BFB                       DECFSZ  __WImage
043A 2C34                       GOTO    DLMS4M1
                                  #endasm
043B 0008    RETURN               }

                    /*************************************************************************/

                                  void Delay_10xUs_4MHz(registerw delay)
                                  /*
```

```
                                     Clock Freq. = 4MHz
                                     Inst. Clock = 1MHz
                                     Inst. dur.  = 1000ns  */
0000                              {
                                  #asm
043C 1283                       BCF     STATUS, RP0
043D 00FB                       MOVWF   __WImage
                        DL10XMS4M
                        DL10XMS4M__  REPT 7
                                NOP
                        ENDM
043E 0000
043F 00 00
0440 00 00
0441 00 00
0442 00 00
0443 00 00
0444 00 00
0445 FB 0B                   DECFSZ  __WImage
0446 3E 2C                   GOTO    DL10XMS4M
                               #endasm
0447 0008    RETURN               }
                    /*************************************************************************/

0000 3003    MOVLW  03h
0001 008A    MOVWF  0A
0002 2B72    GOTO   0372h

ROM USAGE MAP

    0000 to 0002    0004 to 0447
    Total ROM used 0447

Errors             :    0
Warnings           :    0
```

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