

DALLAS SEMICONDUCTOR

Application Note 105 High Resolution Temperature Measurement with Dallas Direct-to-Digital Temperature Sensors

INTRODUCTION

This application note describes the principle of operation of Dallas Semiconductor's line of direct-to-digital temperature sensors, and outlines a method of achieving high (<math><0.05^{\circ}\text{C}</math>) resolution with these devices. An example C code listing is given for use with the DS1620.

DIRECT-TO-DIGITAL TEMPERATURE SENSOR PRINCIPLE OF OPERATION

The Dallas Direct-to-Digital Temperature Sensors measure temperature through the use of an onboard proprietary temperature measurement technique. A block diagram of the temperature measurement circuitry is shown in Figure 1.

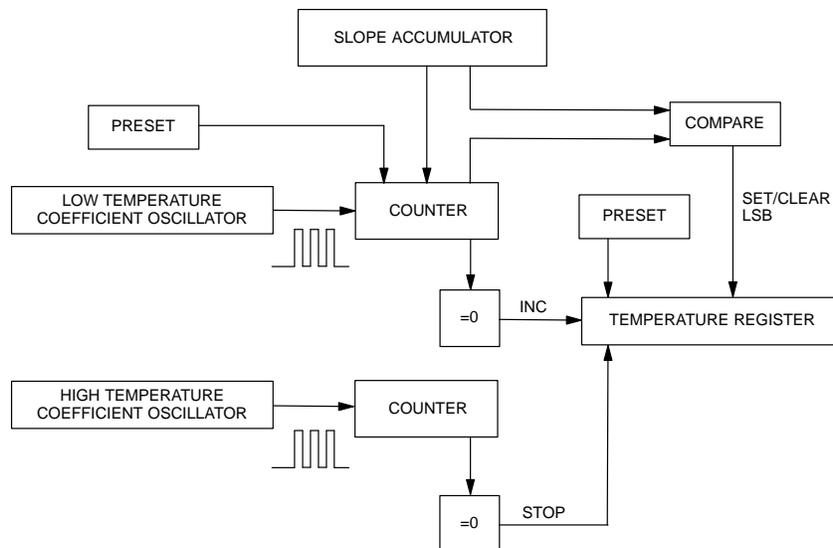
Each temperature sensor measures temperature by counting the number of clock cycles that an oscillator with a low temperature coefficient goes through during a gate period determined by a high temperature coefficient oscillator. The counter is preset with a base count that corresponds to -55°C . If the counter reaches zero

before the gate period is over, the temperature register, which is also preset to the -55°C value, is incremented, indicating that the temperature is higher than -55°C .

At the same time, the counter is then preset with a value determined by the slope accumulator circuitry. This circuitry is needed to compensate for the parabolic behavior of the oscillators over temperature. The counter is then clocked again until it reaches zero. If the gate period is still not finished, then this process repeats.

The slope accumulator is used to compensate for the nonlinear behavior of the oscillators over temperature, yielding a high resolution temperature measurement (0.5°C for almost all the products). This is done by changing the number of counts necessary for the counter to go through for each incremental degree in temperature. To obtain the desired resolution, therefore, both the value of the counter and the number of counts per degree C (the value of the slope accumulator) at a given temperature must be known.

TEMPERATURE MEASUREMENT CIRCUITRY Figure 1



INCREASING TEMPERATURE RESOLUTION

Most of Dallas' direct-to-digital temperature sensors provide 0.5°C resolution directly. This is accomplished by the device determining whether to set or clear the least significant bit (LSB), based on the actual temperature. The device attempts to keep errors within $\frac{1}{2}$ LSB, by quantizing different readings into the LSB step size. For example, a part which is ramping up in temperature from 25°C to +26°C, or down in temperature from -10°C to -11°C, would exhibit this behavior:

ACTUAL TEMPERATURE	SET/CLEAR LSB	DIRECT READING
25	Clear	25
25.1	Clear	25
25.2	Clear	25
25.3	Set	25.5
25.4	Set	25.5
25.5	Set	25.5
25.6	Set	25.5
25.7	Set	25.5
25.8	Clear	26
25.9	Clear	26
26	Clear	26
-10	Clear	-10
-10.1	Clear	-10
-10.2	Clear	-10
-10.3	Set	-10.5
-10.4	Set	-10.5
-10.5	Set	-10.5
-10.6	Set	-10.5
-10.7	Set	-10.5
-10.8	Clear	-11
-10.9	Clear	-11
-11	Clear	-11

This example shows then that every reading is rounded up (in absolute value) by $\frac{1}{2}$ LSB. For most parts, this is

0.25°C. This is important to remember, since in doing calculations to achieve higher resolutions, this rounding factor must be taken into account.

With the exception of devices intended for battery management (DS2434 and DS2435), the temperature sensors can measure temperature over the range of -55°C to +125°C in 0.5°C increments. For Fahrenheit usage, a lookup table or conversion factor must be used.

Higher resolutions may be obtained by reading the temperature and truncating the least significant bit from the read value. From the example above, it should be apparent that this must be done on the raw, 9-bit number, in two's-complement arithmetic, in order for the correct reading to result. After the truncation, the number can then be converted into a signed integer. This value is referred to below as `temp_read`. The value left in the counter can then be read by issuing a special command protocol to the sensor. This value is the count remaining (`count_remain`) after the gate period has ceased. Reading the value of the slope accumulator (by using another command protocol or set of protocols, as outlined below) yields the number of counts per degree C (`count_per_degree`) at that temperature. Once these parameters are all known, the actual temperature can be calculated from the following equation:

$$TEMPERATURE = temp_read - \frac{1}{2}LSB + \frac{count_per_degree - count_remain}{count_per_degree}$$

A simple routine in C, called `CalcHiResTemp`, is given in the listing of Figure 7.

PROCEDURES FOR READING COUNTER VALUES AND CALCULATING HIGH RESOLUTION TEMPERATURE READINGS

The following is a list of procedures for performing high resolution temperature readings from various digital thermometers. For all parts, conversions must be done in oneshot mode (if applicable). `XXh` refers to the protocol to send to the part; if two protocols are listed together (e.g., 84h A0h), both protocols should be sent in the given order, without resetting the part between protocols. A variable name `XXX` is designated as "named `XXX`."

NOTE:

The high-resolution temperature equation is slightly different for the DS1821 as compared to the DS1620, DS1623, DS1625, DS2434, and DS2435.

DS1620, DS1623, and DS1625

1. Issue Start Convert protocol (EEh).
2. When conversion is finished, read 9-bit temperature value (AAh).
3. Truncate half-degree bit from reading.
4. Convert truncated value from 2's complement to signed integer (named temp_read).
5. Read 9-bit counter value (A0h; named count_remain).
6. Send undocumented Load Counter protocol (41h).
7. Read 9-bit counter value (A0h; named count_per_degree).
8. Calculate high-resolution temperature using the high resolution temperature equation given in the previous section. $1/2 \text{ LSB} = 0.25$.

DS1621, DS1624, and DS1820

The procedure to find the high resolution temperature parameters and the calculation to use are given in the respective product data sheets for these products. Note that since the DS1624 already provides a 13-bit number with 0.03125°C resolution, no further processing is possible to achieve any higher temperature resolution.

DS1821

1. Issue Start Convert protocol (EEh).
2. When conversion is finished, read 8-bit temperature value (AAh).
3. Convert value from 2's complement to signed integer (named temp_read).
4. Read 9-bit counter value (A0h; named count_remain).
5. Send undocumented Load Counter protocol (41h).
6. Read 9-bit counter value (A0h; named count_per_degree).
7. Calculate high-resolution temperature using the high resolution temperature equation given in the previous section. Note that for the DS1821, $1/2 \text{ LSB} = 0.5$.

DS2434 and DS2435

1. Issue Start Convert protocol (D2h).
2. When conversion is finished, read 8-bit temperature value (B2h 61h).
3. Convert temperature value from 2's complement to signed integer (named temp_read).
4. Read 9-bit counter value (84h A0h; named count_remain).
5. Send undocumented Load Counter protocol (84h 41h).
6. Read 9-bit counter value (84h A0h; named count_per_degree).
7. Calculate high-resolution temperature using the high resolution temperature equation given in the previous section. $1/2 \text{ LSB} = 0.25$.

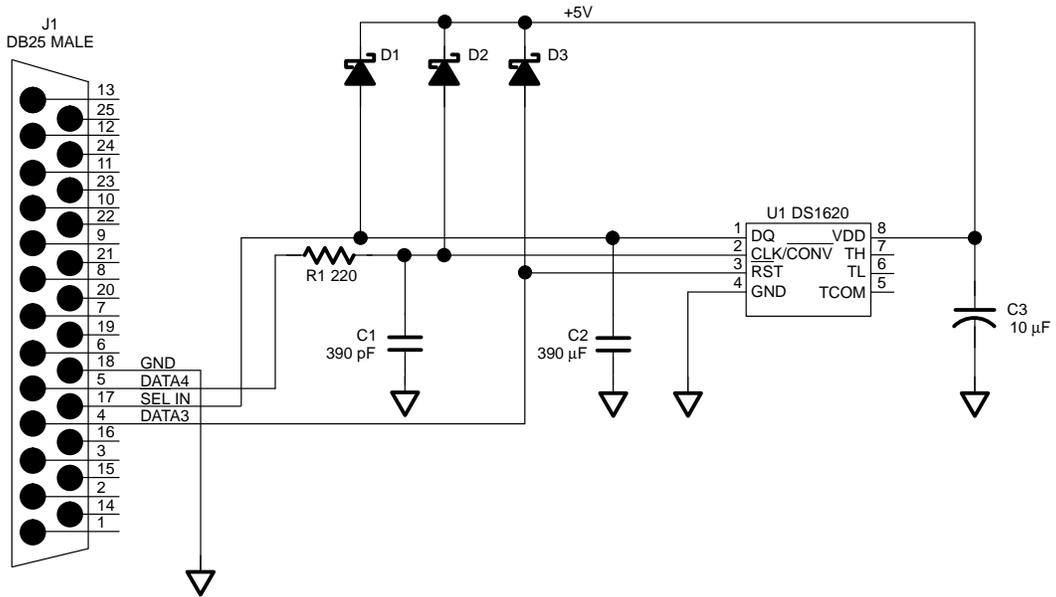
EXAMPLE C CODE

The following example is a simple exerciser for the DS1620 from an IBM-PC compatible computer. It reads temperature and displays it in both the normal 0.5°C resolution and in high resolution. The DS1620 is interfaced to the parallel port of the PC using the circuit shown in Figure 2, which is the schematic of the DS1620K demo kit.

The hardware for the DS1620K demo kit "steals" power from a parallel port using D1, D2, D3, and C3. Not all PC parallel ports are able to supply sufficient current to make this hardware work, so be advised that if this circuit does not work, try connecting a +5V power source to the +5V line in this circuit and try again. R1 and C1 serve to filter the CLK line and prevent negative undershoots. Likewise, C2 helps prevent negative undershoot on the DQ line.

The code is written in an attempt to make it easy to adapt to any of the digital temperature sensors. All that need be done to use it with other devices is to change the command header file to account for the protocols and resolution of the device being used, and change the files which manipulate the hardware interface to the device to account for either 1, 2 or 3-wire interfaces.

DS1620K HARDWARE SCHEMATIC Figure 2



THREEWIR.H C CODE LISTING Figure 3

```
/* THREEWIR.H
This file defines the method for setting the 3-wire interface lines from an IBM-PC
compatible computer. The interface is through the parallel port. The parallel
port lines used are as follows:
```

```
/SELIN      pin 17  DQ
Data4       pin 5   CLK
Data3       pin 4   /RST
GND         pin 18  GND
```

```
The inportb, outportb, and delay functions are defined in most PC-based C compilers in dos.h
```

```
*/
```

```
#include <dos.h>
```

```
#define CLK_HI      p_data|= 0x08; outportb(p_addr,p_data); delay(1);
#define CLK_LOW     p_data&=~0x08; outportb(p_addr,p_data); delay(1);
#define RSTB_HI     p_data|= 0x04; outportb(p_addr,p_data); delay(1);
#define RSTB_LOW    p_data&=~0x04; outportb(p_addr,p_data); delay(1);
#define DQ_HI       outportb(p_addr+2,0x02); delay(1);
#define DQ_LOW      outportb(p_addr+2,0x0A); delay(1);
#define READ_BACK   -((inportb(p_addr+2) & 0x08) >> 3)+1
```

```
#define p_addr peek(0,0x0408) /* Finds the address of the parallel port */
```

```
char  p_data = 0xFF;
```

DS3WIRE.C C CODE LISTING Figure 4

```
/* DS3wire.C
These routines handle a Dallas 3-wire interface. Methods of changing the individual bit states in the hardware need to be defined in "threewir.h".
*/

#include "threewir.h"

/*
Bit level drivers, used in routines for handling the protocol and data interface to a 3-wire device.
*/

/* Drives RSTB signal high (state=1) or low (state=0) */

void rb3w( int state )
{
    if (state==0) {RSTB_LOW;}
    else {RSTB_HI}
}

/* Drives CLK signal high (state=1) or low (state=0) */

void c3w( int state )
{
    if (state==0) {CLK_LOW}
    else {CLK_HI}
}

/* Drives DQ signal high (state=1) or low (state=0) */

void dq3w( int state )
{
    if (state==0) {DQ_LOW}
    else {DQ_HI}
}

/* Reads data back from port */

int rd_back()
{
    char i;
    i=READ_BACK;
    return( i );
}
```

```
/* Writes a 0 (w_bit=0) or a 1 (w_bit=1) to a three wire device. */

void write_bit( int w_bit )
{
    if ( w_bit == 0 ) dq3w( 0 );
    else dq3w( 1 );
    c3w( 0 );
    c3w( 1 );
    dq3w( 1 );
}

/* Reads a 0 (return 0) or a 1 (return 1) from a three wire device. */

int read_bit()
{
    int i;

    c3w( 0 );
    i=rd_back();
    c3w( 1 );

    return(i);
}

/*
Routines to read and write a Dallas 3-wire part. The three wire interface typi-
cally requires that the part be sent an eight-bit protocol, followed by data. The
exception to this are the digital potentiometers, which use no protocols but send
only data. All transfers are LSB first.

If writing, the data must follow the protocol immediately, but there is no fixed
number of bits that may be data.

If reading, the part must be written with an eight bit protocol; the DQ pin must
then be changed to READ back data. As with writing, there is no fixed number of
bits that may be data.

These routines are set up to handle an arbitrary data length UP TO the size of an
int (which is typically 16 bits for most C compilers).
*/
```

```
/* write_part
Write a command and data to a 3-wire part. param is the integer value of the data
to be written after the write protocol. n_bits is the number of bits to transfer
in param.
*/

void write_part(int protocol, int param, int n_bits)
{
int index,data;

rb3w(1); /* Raise the /RST line */
for (index = 0; index<8; index++) /* protocol is 8 bits */
{
data = protocol>>index;
data &= 0x01;
write_bit(data);
}
for (index = 0; index<n_bits; index++) /* Write out data */
{
data = param>>index;
data &= 0x01;
write_bit(data);
}
rb3w(0); /* Drop /RST line */
}

/* read_part
Reads data from a 3-wire part. protocol is command to be written to the part,
and n_bits is number of bits to read after the protocol is sent. Returns int value
of reading.
*/

int read_part(int protocol, int n_bits)
{
int index,data;
int r_data = 0;

rb3w(1); /* Raise the /RST line */
for (index = 0; index<8; index++) /* protocol is 8 bits */
{
data = protocol>>index;
data &= 0x01;
write_bit(data);
}

for (index = 0; index<n_bits; index++) /* Read in data */
{
r_data |= read_bit()<<index;
}
rb3w(0);
return(r_data);
}
```

DS1620CMD.H Figure 5

```
/* 1620CMD.H
This file defines the protocols and bit masks needed for a specific device: the
DS1620.
*/

/* protocols */
#define Read_Temp          0xAA
#define Start_Convert     0xEE
#define Stop_Convert      0x22
#define Write_TH          0x01
#define Write_TL          0x02
#define Read_TH           0xA1
#define Read_TL           0xA2
#define Write_Config      0x0C
#define Read_Config       0xAC
#define Read_Counter      0xA0
#define Load_Counter      0x41

/* masks for configuration/status register */
#define mode_mask         0x03 /* masks off all but CPU and 1SHOT
bits */
#define nvb_mask          0x10 /* masks off all but NVB bit */
#define done_mask         0x80 /* masks off all but DONE bit */
#define flags_mask        0x60 /* masks off all but THF and TLF flag
bits */
#define flag_offset       5 /* number of right shifts to
right-justify flags */

#define res               (int)(1.0/LSB)
/* resolution factor, used in
application to calculate
actual temperatures from raw
data */

float LSB = 0.5; /* The value of a LSB on the
DS1620 in degrees C */
```

DEVFUNC.C C CODE LISTING Figure 6

```
/* Device Specific Functions
These are device specific functions for all 3-wire Dallas Temperature Sensors,
supporting all documented functions of the parts, including high resolution tem-
perature measurements.

Since these routines may be used with many different devices, no attempt is made
in these routines to interpret the data written or read; the application program
which uses these routines must assure that the data written or read is in the
appropriate format for use by these routines and by the application.
*/

/*
Place device-appropriate include file here for specific device commands.
*/
#include <stdio.h>
#include "1620cmd.h" /* This example for DS1620 */

/*prototypes*/

extern void write_part();
extern int read_part();

/* StartTempConvert
This routine issues the Start Convert command. No further data is required and no
data is read back.
*/
void StartTempConvert(void)
{
    write_part(Start_Convert,0,0);
}

/* StopTempConvert
This routine issues the Stop Convert command. No further data is required and no
data is read back.
*/
void StopTempConvert(void)
{
    write_part(Stop_Convert,0,0);
}
```

```
/* ReadTemp
This routine reads back the value of the converted temperature reading and returns
that value. num_bits is the number of bits to read back (up to size of int (16)).
Remember that this only returns the raw data; the calling program must know how to
interpret the data (for example, this routine will return an int with 9 bits when
called as ReadTemp(9); the user must then know that the LSB is 0.5°C, and make the
appropriate data conversion. Likewise, interpreting the sign of the returned tem-
perature is up to the calling program.)
*/
int ReadTemp (int num_bits)
{
    int    temperature;
    temperature = read_part(Read_Temp,num_bits);
    return(temperature);
}

/* WriteTempHigh
This routine writes to the TH thermostat register. Param is value to place in TH,
and should be 9 bits wide. As with ReadTemp, the calling program must assure that
the data sent here is in the appropriate device-specific data form to be used
properly (is LSB 0.5°C or 1°C?, etc).
*/
void WriteTempHigh (int param, int num_bits)
{
    write_part(Write_TH,param,num_bits);
}

/* WriteTempLo
This routine writes to the TL thermostat register. Param is value to place in TL,
and should be num_bits bits wide. As with ReadTemp, the calling program must
assure that the data sent here is in the appropriate device-specific data form to
be used properly (is LSB 0.5°C or 1°C?, etc).
*/
void WriteTempLo (int param, int num_bits)
{
    write_part(Write_TL, param, num_bits);
}

/* ReadTempHigh
This routine reads back from the part the value stored in the TH thermostat regis-
ter and returns that value. num_bits is the number of bits to read back (up to
size of int (16)). Remember that this only returns the raw data; the calling pro-
gram must know how to interpret the data (for example, this routine will return an
int with 9 bits when called as ReadTempHigh(9); the user must then know that the
LSB is 0.5°C, and make the appropriate data conversion. Likewise, interpreting the
sign of the returned temperature is up to the calling program.)
*/
int ReadTempHigh (int num_bits)
{
```

```
    int tHigh;

    tHigh = read_part(Read_TH,num_bits);

    return(tHigh);
}

/* ReadTempLo
This routine reads back from the part the value stored in the TL thermostat register and returns that value. num_bits is the number of bits to read back (up to size of int (16)). See the caveat for ReadTempHigh regarding returned data.
*/
int ReadTempLo (int num_bits)
{
    int tLow;

    tLow = read_part(Read_TL,num_bits);

    return(tLow);
}

/* LoadCounter
This routine sends the Load Counter command. No further data is required and no data is read back.
*/
void LoadCounter (void)
{
    write_part(Load_Counter,0,0);
}

/* ReadCounter
This routine reads back from the part the value in the temp sensor count register and returns that value. num_bits is the number of bits to read back (up to size of int (16)).
*/
int ReadCounter (int num_bits)
{
    int count;

    count = read_part(Read_Counter,num_bits);

    return(count);
}
```

```
/* WriteConfig
This routine writes to the configuration register. Param is the byte to be written
into the configuration register, and it is always 8 bits wide.
*/
void WriteConfig (int param)
{
    write_part(Write_Config,param,8);
}

/* ReadConfig
This routine reads back the value of the configuration byte and returns that
value. It always returns 8 bits.
*/
int ReadConfig(void)
{
    int regvalue;

    regvalue = read_part(Read_Config,8);
    return(regvalue);
}

/* CheckIfBusy
This routine will check to see if the device is busy and cannot process further
writes to EEPROM. It checks the NVB flag in the configuration register. If the
device is busy, the function returns a 1; if it is not busy, the function will
return a 0.
*/
int CheckIfBusy(void)
{
    if ((ReadConfig() & nvb_mask) == nvb_mask)
        return(1);
    else
        return(0);
}

/* CheckIfDone
This routine will check to see if the device has completed a temperature conver-
sion. It checks the DONE flag in the configuration register. If the device is
busy, the function returns a 1; if it is not busy, the function will return a 0.
NOTE: If the mode is set so that the temp sensor is doing continuous conversions,
DONE will NEVER be set, so make sure you know what mode you're in if you use this
check routine.
*/
int CheckIfDone(void)
{
    if ((ReadConfig() & done_mask) == done_mask)
        return(0);
    else
        return(1);
}
```

```
/* SetMode
```

This routine sets the operating mode of the digital temperature sensor. Mode is determined by two bits in the configuration register: CPU and 1SHOT. The following modes are possible:

Mode	CPU	1SHOT	
1	0	0	Standalone, continuous conversions (typical for thermostat)
2	0	1	Standalone, one shot (used only if conversions can be started by CONV pin)
3	1	0	CPU, continuous conversion (typical for thermostat with readback)
4	1	1	CPU, one shot (typical for low-power temp readings)

This routine will set the configuration register bits appropriately for the MODE value passed to the routine in mode. It returns no data.

```
*/
```

```
void SetMode(int mode)
{
    WriteConfig (mode-1);
}
```

```
/* ReadFlags
```

This routine will read the state of the two temperature flags, THF and TLF. It returns an integer, t_flag, which is the number of the two bits (0 = 00, 1=01, 2=10, 3=11).

```
*/
```

```
int ReadFlags(void)
{
    int t_flag;

    t_flag =( ReadConfig() & flags_mask) >> flag_offset;
    return(t_flag);
}
```

SIMPLE DS1620 EXERCISER C CODE LISTING Figure 7

```
/* DS1620 Exerciser
Example program to show how to perform various functions of a DS1620 Digital Ther-
mometer. This example is console-driven; that is, it expects input from the user
via a console interface, to set the mode and TH, TL register values.
*/

#include <stdio.h>
#include "devfunc.c"
#include "ds3wire.c"

/*prototypes*/
void StartTempConvert(void);
void StopTempConvert(void);
int ReadTemp(int);
void WriteTempHigh(int,int);
void WriteTempLo(int,int);
int ReadTempHigh(int);
int ReadTempLo(int);
void LoadCounter(void);
int ReadCounter(int);
void WriteConfig(int);
int ReadConfig(void);
int CheckIfBusy(void);
int CheckIfDone(void);
void SetMode(int);
int ReadFlags(void);
void InitTempSensor(void);
void SetThermostat(void);
float CalcHiResTemp(int,int,int);

/* InitTempSensor
This routine will initialize the temperature sensor to a mode specified by the
user.
*/
void InitTempSensor(void)
{
    int mode, test;

    printf("1. Standalone mode, Continuous Conversions\n");
    printf("2. Standalone mode, One Shot\n");
    printf("3. CPU mode, Continuous Conversions\n");
    printf("4. CPU mode, One Shot\n");
    printf("Enter mode desired:");
    scanf("%d",&mode);
    SetMode(mode); /*Write mode bits to Config register */
}
```

```
do                                     /* Wait until EEPROM write
                                     complete                */
{
    test = CheckIfBusy();
    printf("Device Busy");
} while (test);

}

/* SetThermostat
This routine sets the thermostat registers to the high and low values specified by
the user.
*/
void SetThermostat(void)
{
    float    t_hi, t_lo, high_t, low_t;           /* Since TH and TL are 9-bit
                                                    numbers with a 0.5°C
                                                    LSB, they must be of type
                                                    float. This program
                                                    must then assure the data
                                                    passed to the other
                                                    routines is formatted
                                                    properly.                */

    int      hi_t, lo_t, busy;

    printf("Enter a High Temperature Limit:");
    scanf("%f",&t_hi);                            /* Get TH limit          */
    printf("Enter a Low Temperature Limit:");
    scanf("%f",&t_lo);                            /* Get TL limit          */

    hi_t = res*t_hi;                              /* turn into a 9-bit integer -
                                                    note that this routine
                                                    does not check to see if the
                                                    user enters some number that
                                                    can't be used, like 22.635. An
                                                    actual application would
                                                    want to do such error trap
                                                    ping.                    */

    WriteTempHigh(hi_t,9);                       /* Write to TH register*/

do                                     /* Wait until EEPROM write
                                     complete                */
{
    busy = CheckIfBusy();
    printf("Device Busy");
} while (busy);
```

```

    lo_t= res*t_lo;                                /* same comments as for TH
                                                    */
    WriteTempLo(lo_t,9);                          /* Write to TL register
                                                    */

    do                                             /* Wait until EEPROM write
                                                    complete
                                                    */
    {
        busy = CheckIfBusy();
        printf("Device Busy");
    } while (busy);
}

/* CalcHiResTemp
This routine handles the calculation of temperature in high resolution mode.
Requires that the part has provided the values of temperature, count_per_degree,
and count_remain. This routine assumes 9 bit data is read back, and that the user
has defined the value of LSB and res in the appropriate DSXXXXCMD.H file.
*/
float CalcHiResTemp(int temp9, int count_per_degree, int count_remain)
{
    int      temp_read;
    float    frac_deg;

    temp_read = temp9/res;                        /* temp9 is raw data - convert
                                                    for LSB value
                                                    */
    if(temp_read>>8>0)                            /* check to see if MSB set -
                                                    works for 9-bit data.
                                                    */
        temp_read -=256;                          /* convert to negative temper
                                                    ature
                                                    */

    if(count_per_degree !=0)
        frac_deg = (count_per_degree-count_remain)/((float)count_per_degree);
    else
        frac_deg = LSB/2.0;

    return(((float)temp_read-(LSB/2.0))+frac_deg);
}

void main(void)
{
    signed int temperature;
    float    read_temp;
    int      Countrem,CountC;
    float    hires_temp;
    int      busy,key;

```

```
InitTempSensor();           /* Initialize sensor with mode
                             bits                */
SetThermostat();           /* Load in Thermostat values,
                             if used            */
StartTempConvert();        /* Start Temperature
                             Conversion(s)     */

switch(ReadConfig() & mode_mask) /* Checks for conversion done.
                                   This switch is used to
                                   determine what to do depending
                                   upon the mode the
                                   DS1620 is in. If continuous
                                   conversions are going on,
                                   temperature readings should
                                   only be made periodically
                                   based on time. If ONE-SHOT
                                   mode is used, then you can
                                   poll the status register for
                                   the DONE bit to set. */
{
    case 0:                  /* Continuous conversions - so
                               read based on time */

        delay(1000);
        break;

    case 1:                  /* One Shot mode - poll status
                               register for DONE bit */

        do
        {
            busy = CheckIfDone();
            printf("\nConversion in progress");
        } while (busy);
        break;

    case 2:                  /* Continuous conversions - so
                               read based on time */

        delay(1000);
        break;

    case 3:                  /* One Shot mode - poll status
                               register for DONE bit */

        do
        {
            busy = CheckIfDone();
            printf("\nConversion in progress");
        } while (busy);
        break;
} /* end switch */
```

```

read_temp = (float)ReadTemp(9)*LSB;          /* Reads temperature and con
verts for LSB value */
if ((int)read_temp>>7>0)                    /* Check if MSB set
*/
    read_temp -=256;                          /* if it is, correct for it
*/

printf("\nThe temperature is:%5.2f",read_temp);
/* prints temperature on console, to 0.5°C resolution */

StopTempConvert();                          /* In case you were previously
in continuous mode, stop
*/
SetMode(4);                                 /* MUST BE in ONE-SHOT to do
High Res */
StartTempConvert();                          /* Start Temperature
Conversion(s) */

do                                            /* Check to see when conver
sion completes by polling DONE
bit */
{
    busy =CheckIfDone();
    printf("\nConversion in progress");
}while(busy);

read_temp = (float)ReadTemp(9);             /* get raw 9-bit temperature
data */
if ((int)read_temp>>8>0)                    /* Check if MSB set */
    read_temp -=512;                          /* if it is, correct for it -
9 bits now! */

temperature = (signed int) read_temp;        /* make sure temp is now a
signed integer */
Countrem = ReadCounter(9);                  /* reads count remaining
*/
LoadCounter();                              /* Loads counter reg with
counts per degree */
CountC = ReadCounter(9);

hires_temp = CalcHiResTemp(temperature,CountC,Countrem);

printf("\n The temperature is :%5.2f",hires_temp);
/* prints temperature on console, to 0.01°C resolution */
}

```
