

Temperature Sensor Eludes Analog Interfacing

Are you in need of a thermostat that is analog-free? Follow Jeff's lead as he introduces you to Dallas's DS1620 Thermometer and Thermostat. The name of the game is solid state with the help of an EEPROM.

FROM THE BENCH

Jeff Bachiochi



As I write this, I am enjoying the best time of year to go hiking in New

England. The peak of the foliage season yields a terrain of patchwork colors. If you are fortunate enough to catch this view from atop a mountain or even a high hill, you know how inspiring it can be. Add to this picture a crisp blue sky scattered with wisps of cottony clouds and an autumn sunset as it slowly unfolds into a psychedelic overload for your eyes.

As the last bits of summer fall from the trees, we rake the pleasant memories of warmer weather into small piles. Oil delivery trucks have come out of summer's hibernation, which can only mean the heating season has started. Thermostats are being turned up all across the forty-first parallel.

Conventional thermostats are simple devices. A mercury-filled tilt switch is rocked back and forth by the expansion and contraction of a bimetallic coil. When the coil contracts because of cooling temperatures, it tilts the mercury toward awaiting

Photo 1--Temperature measurement and control is possible using Dallas Semiconductor's DS1620 thermometer/thermostat chip. A two-digit display and other features may be added by including a small, dedicated microcontroller.

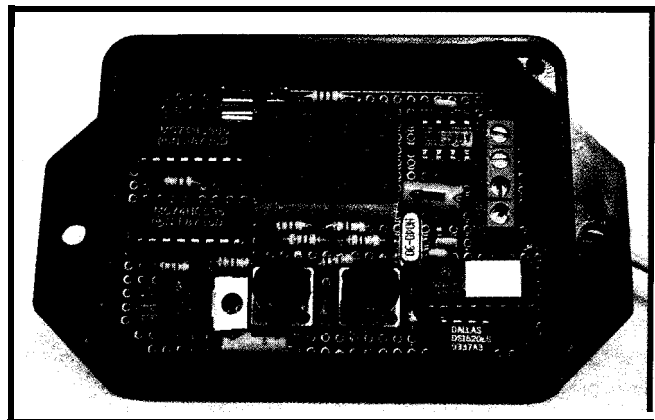
contacts, completing a circuit which requests heat from the furnace. Simple and dependable, but certainly has no place in today's Intelligent House.

I bought one of those digital thermostats years ago. I threw it away years ago. I didn't like it. I needed the instruction book every time I wanted to change the setpoints. The backup battery lasted five minutes less than the duration of every power outage. And twice a year, at Daylight Saving Time/Standard Time changes, it had to be reprogrammed. This all took place before I added on to our cozy little cape. Now I have three zones of heating. I'm considering breaking these three into a few more individually controlled zones for the selective comfort of each family member. Along with each added zone comes the necessity for an additional thermostat.

Up to this point if you wanted to measure temperature electronically, it required biasing and gain circuitry designed to match the sensor's analog output to an A/D converter. The digitized data could then be used to calculate the actual temperature. This is all changing, and Dallas Semiconductor is providing the instrument of change: the DS 1620.

TEMPERA-DIGITATION

Dallas has packed a solid-state temperature sensor with an EEPROM and some comparators into a single package to form a stand-alone, solid-state thermostat. A 3-wire interface allows both high and low setpoints to be programmed into the internal EEPROM. Temperatures above the high setpoint turn on the T_{HIGH} output, while temperatures below the low



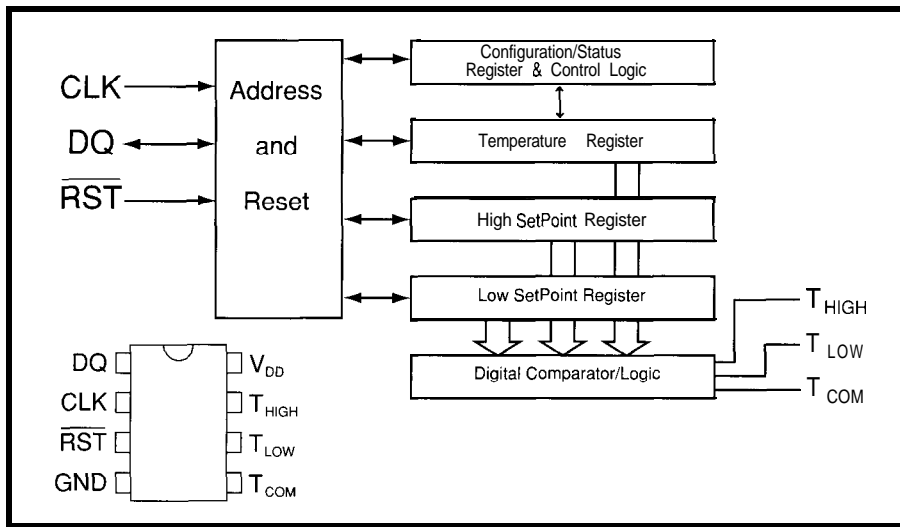


Figure 1—Three registers in the DS1620 determine the mode of operation and establish the temperature at which an action will take place when compared to an ambient temperature.

setpoint turn on the T_{LOW} output. A third output, T_{COM} , turns on when temperatures drop below the low setpoint but remains on until temperatures rise above the high setpoint. Here, the upper and lower setpoints act like an adjustable hysteresis band. The EEPROM retains the setpoints

Temp	Binary Value	Hex
+125°C	00000000 11111010	00 FA
+25°C	00000000 00110010	00 32
+0.5°C	00000000 00000001	00 01
0°C	00000000 00000000	00 00
-0.5°C	00000001 11111111	01 FF
-25°C	00000001 11001110	01 CE
-55°C	00000001 10010010	01 92
	MSB LSB MSB LSB	
	MSByte LSByte	

Table 1—The DS1620 puts out 8-bit conversion values plus a ninth sign bit.

even in the event of power failure. Figure 1 shows a block diagram and pinout of the device.

Temperature is presented in a two-byte format. The most-significant byte holds the sign bit (actually only the low bit of that byte is used) and the least-significant byte holds the digital value of the actual temperature. The output resolution of this device is in 0.5°C increments from -55°C to +125°C. If the sign bit is set, then the temperature is negative and the least-significant byte's value is presented as the two's complement. For Fahrenheit measurements, you can use a lookup table or crunch the samples through the ever-popular $(\%C) + 32$ conversion

factor. Table 1 shows a sampling of temperature readings along with the data generated by the DS1620.

The DS1620 has three EEPROM registers, a configuration/status register, and two setpoint registers. The two setpoint registers (High and Low) establish the temperature at which some action will take place when compared with the ambient temperature. The setpoint temperature in each of these two-byte registers takes the same form as the two-byte temperature values above.

The configuration/status register determines the mode of operation. Only the two least-significant bits of the byte-wide status register are used to set the mode, however an additional two bits are used to reset flags. Some of the particulars of this register are shown in Table 2. When the status register is read, it returns the current mode of operation and a few extra bits of information.

STAND-ALONE MODE

The DS 1620 can free run, continuously converting and compar-

ing the temperature while only drawing 1 mA at 5 volts. In one-shot mode, after a conversion is complete, current consumption dips to 1 μ A until the next conversion is initiated by dropping the CLK/*CONV line. As long as power is applied and the THF and TLF flags are not reset through the configuration register, the contents of these two flags will continue to indicate if the temperature has ever passed either of the setpoints. This makes an excellent yet simple temperature limit exception logger.

Once the initial setpoints are programmed (through the 3-wire communication bus), the DS 1620 will post vigil as a full-time thermostat and only needs a relay (mechanical or solid state) to control a fan, valve, or furnace.

3-WIRE COMMUNICATION MODE

Although the "set it and forget it" mode has many applications, most of us would find this a bit inflexible for use with our home heating system. The 3-wire communication mode allows control over the device through just 3 bits. The bidirectional bit (DQ) provides a data path in both directions

Write Configuration Byte (x=don't care)							
Bit	Position	7	6	5	4	3	2 1 0
		x	THF	TLF	x	x	CPU 1Shot
THF=0 (reset High Temperature Flag)							
TLF=0 (reset Low Temperature Flag)							
CPU=1 (using 3-wire comm mode DQ, CLK, *RST)							
CPU=0 (when ● RST=0, CLK=0 initiates conversion[s])							
1Shot=1 (perform single conversion)							
1Shot=0 (perform continuous conversions)							
Read Configuration Byte (x=don't care)							
Bit	Position	7	6	5	4	3	2 1 0
		Done	THF	TLF	x	x	CPU 1Shot
Done=1 (Conversion complete)							
Done=0 (Conversion in progress)							
THF=1 (Temperature exceeds High Setpoint)							
THF=0 (Temperature does not exceed High Setpoint)							
TLF=1 (Temperature below Low Setpoint)							
TLF=0 (Temperature is not below Low Setpoint)							
CPU reflects last value written							
1 Shot reflects last value written							

Table 2—The configuration/status register determines the mode of operation of the DS1620. Bit positions 0 and 1 are used to set the mode while bit positions 5 and 6 are used to reset flags.

and remains tristated whenever the

- RST input is low. Taking 'RST high initiates a transfer in which the DS1620 accepts data on the first eight rising CLK cycles it sees. This first byte of data sent to the DS1620 will determine what happens next. There are nine possible command bytes, as shown in Table 3. You can examine this along with the 3-wire protocol that is illustrated in Figure 2.

Table 3—The first byte of data sent to the DS1620 determines what happens next. The part supports a total of nine commands.

Cmd Byte	Next Action
01H	Next 9 bits received go to TH registers
02H	Next 9 bits received go to TL registers
0CH	Next 8 bits received go to configuration register
22H	Stop conversion; registers are transmitted
A1H	Next 9 bits come from TH registers and are transmitted
A2H	Next 9 bits come from TL registers and are transmitted
AAH	Next 9 bits come from temp conv and are transmitted
ACH	Next 8 bits come from config register and are transmitted
EEH	Start conversion

TEMPERATURE CONVERSION

A single temperature conversion requires about one second. If one-shot

conversion is being used, the status register must be checked to assure the conversion has completed before requesting the converted temperature.

If the DS1620 is in continuous conversion mode, the last temperature converted is sent whenever the temperature is requested.

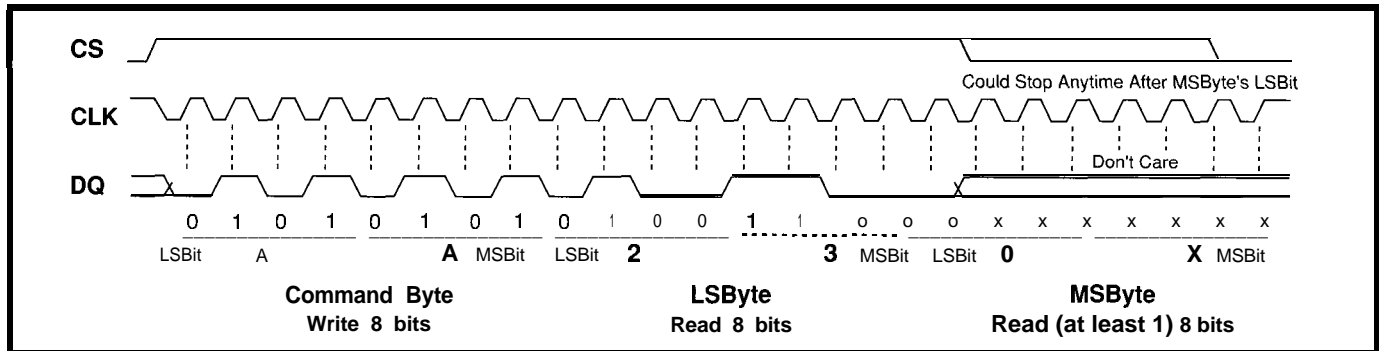


Figure 2—The timing diagram reveals a command byte where the next 9 bits come from Temperature Conversion and are transmitted.

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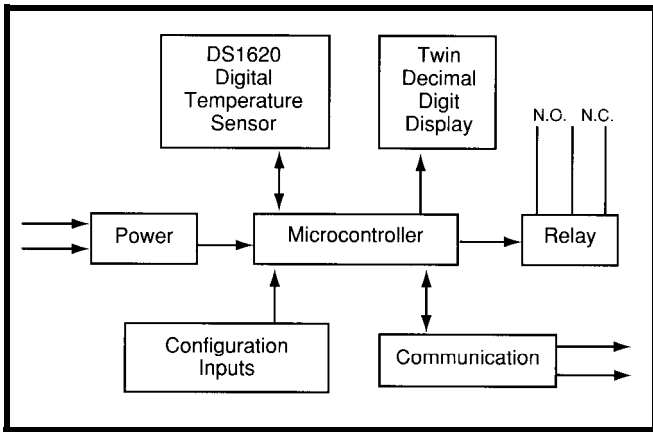


Figure 3—By adding a dedicated microcontroller, the DS1620 can be the basis for a very flexible digital thermostat.

Temperature conversion accuracy is $\pm 0.5^{\circ}\text{C}$ from 0°C to 70°C (32°F to 158°F). The error increases to $\pm 1^{\circ}\text{C}$ down to -40°C (-40°F) and up to 85°C (185°F), and to $\pm 2^{\circ}\text{C}$ down to -55°C (-67°F) and up to 125°C (257°F).

FURNACES UNDER FIRMWARE CONTROL (SORRY, ED)

To satisfy my requirements for a zone thermostat, I want to know what the temperature is and then be able to adjust it up or down from some programmed norm. Since I want the setpoints to be software settable and automatically adjusted by local demand or based on time of day and day of week, this information needs to come from not only the local thermostat control, but also from the central control. The thermostat needs to measure the temperature, display it, and report it when asked. In addition, control inputs will allow local temporary adjustment of the zone's setpoint. For the time being, local adjustments will be canceled at the next automatic setpoint change. However, the software could allow these local changes to permanently alter the active setpoint. This will allow the system to be very flexible. See Figure 3 for the thermostat block diagram.

The local temperature can be displayed in degrees Celsius or Fahrenheit, which means indoor temperatures should not fall below 0°C (32°F) or rise above 37°C (99°F). Using these limits will require only two display digits. Two 74HC595 serial-to-parallel converters will directly drive seven-segment digits to

adequate brightness. Only three output bits are needed for this: data, clock, and register latch enable. This allows the same CLK and DQ lines for DS-1620 communication to be used with the display. Digit data comes from a lookup table and is presented serially through the DDATA bit in least-significant-bit-first format, wherein the unit digit is followed by the ten's digit. The unit digit's data is shifted through the first '595 and into the second. When all 16 bits are clocked in, the double word is latched into the output drivers, which illuminate the proper segments to form the digits.

In an attempt to keep costs down, each local zone monitor must be simple, but sophisticated enough to monitor, display, and communicate. I chose RS-485 for the communication medium because it supports multiple drops, is noise immune, and is capable of long distances.

Next month, I will demonstrate how an inexpensive micro can run the local show, yet still be a slave to your home. \square

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