By Michael Simpson

Important

Requires ZeusPro
V1.70 or later

Environmental Sensors
as seen in
March 2007 of Nuts & Volts Magazine

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Last month I introduced you to various anemometers that could be used in building your own weather station. In this article I want to show you how to use additional sensors, but first I want to delve a little deeper into the 1-Wire interface.

1-Wire Chips

A few years ago Dallas Semiconductor (now owned by Maxim) invented a protocol that would allow them to connect multiple chips to a host using a minimal pin count. That is how 1-Wire was born. The chips shown in Figure 2 are just a small sampling of the 1-Wire chips available. Notice the different form factors. The small speck just below the two surface mount chips is a DS2401 chip.

One of the chips we will be using throughout the series is the DS18s20 digital thermometer. This chip comes in both a surface mount and TO92 format, which makes it perfect for the hobbyist.

1-Wire Protocol

Before I jump into the techno babble I want to assure you that whether you use a PC or a microcontroller, low level routines have been provided to handle the 1-Wire protocol. The protocol information presented here is for the sole purpose of satisfying your inner geek.

The protocol is called 1-Wire because it uses a single wire for both transmission and reception of data. In reality two wires are needed, as a return wire is also required but the data itself is carried on the data lead. The protocol uses time slots to determine the presence or lack of a single bit in said time slot. Multiple bit time slots are used to transmit and receive bytes or words. There are no external timing pulses so the protocol is considered asynchronous in nature and has very stringent timing guidelines.

The protocol allows multiple chips or devices to be placed on the same two wires, which is sometimes called a bus. This bus has a single master and one

Figure 2

or more slaves. The bus is held high by a pull-up resistor or some other means. This is normally done on the master end of the bus. The master can provide a hard pull-up when needed to provide power to the chips in parasite mode, which we will get into a little later. A slave chip or device can only pull the line low. During a single bit time slot, a slave will let the bus float thus signaling a 1, or pull it low signaling a 0.

In order to communicate with individual devices on the bus each 1-Wire device has a unique 64-bit registration number that allows that chip to be targeted for communications. The first 8-bits in this registration number is the family code. This code is used to identify the device type. The next 48-bits (6 bytes) represent the serial number for the slave. The last 8-bits are a CRC of the first 56-bits.

The 1-Wire protocol also specifies a search algorithm for identifying all the slaves on a bus. By using the family code we can actually display the serial number and chip type of each chip connected to the bus. I used this feature last month in the test applications and will be using it in this article as well. I have included a small application called RomSearchForm.exe that will allow you to display all the chips connected to your DS9097U adapter.

1-Wire Network

Once we start adding chips to the bus it becomes a network. Dallas calls this a MicroLAN. A network requires one master and at least one slave to operate. As previously mentioned the protocol is written so that you can place as many slaves on the network as you wish, but in practice once you get more than twenty or so slaves on the network loading and other issues can start to cause communications issues.

The length and type of cable used for the network will determine how many devices you can actually place on the network. For short distances of under ten feet just about any cable will work. Unfortunately we are building a weather station so long cable lengths are a fact of life. In most cases you will have a cable longer than 100' The best cable for running longer lengths is CAT5 or CAT5e. In a pinch you can use CAT3 but I don't recommend it in lengths longer than 200'. In many of my current configurations I run a CAT3 cable 200' to my various weather poles and it works just fine but I am pushing it. I have taken special care to make sure the network cable does not cross any power lines or equipment that can cause interference. You probably know what CAT5 cable is. This is the network cable used to connect your PC to the internet or other computers. CAT3 cable is simply twisted pair telephone cable. You can purchase both of these cables at your local home center or Radio Shack.

CAT5 cable has eight wires. In our weather station we will use only two of these wires. In most cases it will be the blue and blue/white wire. For CAT3 there are four or six wires and we will use the red and green wires. The reason we are using particular colors is that the wires in the cable are twisted in pairs. This twist helps alleviate unwanted interference in the cable. Many companies like Hobby Board use RJ connectors on their 1-Wire boards. The colors we have chosen map out to the center pins on those connectors (most of the time).

When building 1-Wire network cables it is absolutely essential that you keep the cables lengths at a minimum. Do yourself a favor and purchase a modular plug crimper. You can pick up a light weight crimper for under $10 from Radio Shack. The heavy duty metal crimper shown in Figure 3 was purchased from my local home center for $20. It will crimp RJ11/12 and RJ45 modular plugs. It also cuts and strips both round and flat data cables.

Figure 3

On my weather pole I mounted an outdoor receptacle box. It can be purchased from most home centers along with a sealed waterproof cover. I oriented the access hole on the bottom of the box and ran all my wires that way. This makes for a nice water resistant box, but air can still get inside for the humidity sensor. Using a modular splice I connected my main cable to a 5-way junction box like the one shown in Figure 4. This allows me to create small jumpers that run to each sensor.

Troubleshooting 1-Wire Network Problems

Because all the 1-Wire devices are connected in parallel, the only way to troubleshoot a faulty network is to systematically remove devices to determine where the problem is located. The 5-way junction box makes it very easy. I use the small test plug shown in Figure 5 and Schematic 1. Plug the test plug into the network and load the RomSearchForm program.

Test Plug Test Results

- If the network cable is wired backward (Red and Green wires reversed) the program will report a network short.
- If the LED blinks but the search reports no devices the voltages may be too low at the test point.
- If the LED does not blink and no devices are found you probably have a broken or miss-wired connection.
- If the LED blinks and the DS2401 is identified the current network segment is wired correctly and working.

Figure 4

Figure 5

Parasite Mode

1-Wire chips have the option of running in what is called parasite mode. When operated this way they get their power from the 1-Wire bus. There are both advantages and disadvantages of running the slaves in parasite mode.

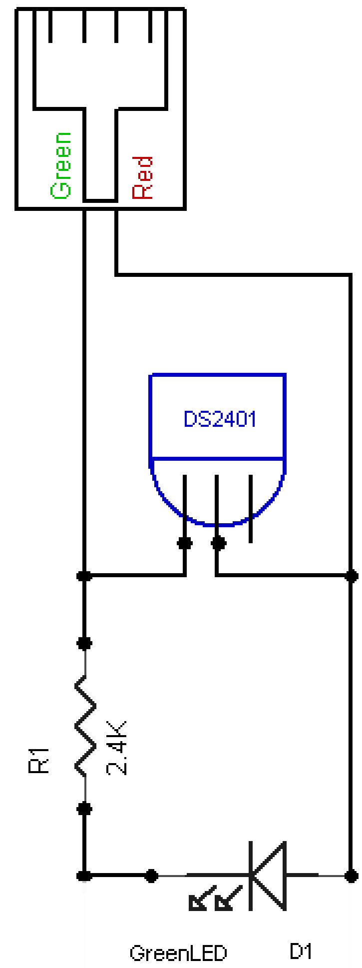
Disadvantages

- When doing AtoD or temperature conversions the master must place a hard pull-up on the data line in order to power the slave during this conversion. This tends to add more delays to the interface process. Also during this process the master is unable to talk to other slaves.
- Some slaves will lose data when power is removed. This means the chip must be periodically reconfigured. This introduces even more delays and even worse, can cause bad readings until the proper configuration is restored.
- Some slaves will lose counter data so battery backup at the chips location may be needed.
- There are times when the sensors that 1-Wire chips are connected to must be powered.

Advantages

- Since we are only supplying two leads, cable configurations are much simpler.
- If you connect a device incorrectly there is little chance of damage.
- Only a single pair in the cable can be used. This allows us to use longer cable runs. If we have to add power to the cable via a second pair this adds unwanted characteristics to the cable and can affect communications.
- We can reset a chips counter or configuration by simply pulling the data line low for a period of time. This is important for remote configurations like a weather station. I have had slave devices simply lockup and the only way I could regain access was to remove the power. Not a problem in parasite mode.

Most of our outdoor 1-Wire devices will be powered via parasite mode. If you decide to power the devices and chips normally only minor changes need to be made. But you should run the power using a different cable. This is especially true of longer cable lengths.



Schematic 1

iButtons

Dallas has placed several of their chips in small stainless steel cans. These devices resemble a small battery as shown in Figure 6 and are parasitically powered. This makes them very resistant to harsh environments. While we won't be using any of these devices in our weather station you should take a look at the iButton Website at:
http://www.maxim-ic.com/products/ibutton/

Figure 6

Connecting Your PC to a 1-Wire Network

There are a couple of ways to get your PC connected to a 1-Wire network. Dallas makes two adapters. The DS9097U shown in Figure 7 is a RS232 to 1-Wire adapter. The DS9490R shown in Figure 8 is a USB to 1-Wire Adapter. There are other adapters but they are mostly variants of the DS9097U.

Figure 7

Figure 8

Dallas has made several device drivers available on their web site but I am sorry to say I found them problematic to install. There were just too many moving parts associated with the drivers.

In order to add 1-Wire support to the Zeus Language I wrote my own low level 1-Wire interface routines to access the DS9097U directly. This means you don't need to install any of the drivers. I have also added several high level 1-Wire chip libraries as well.

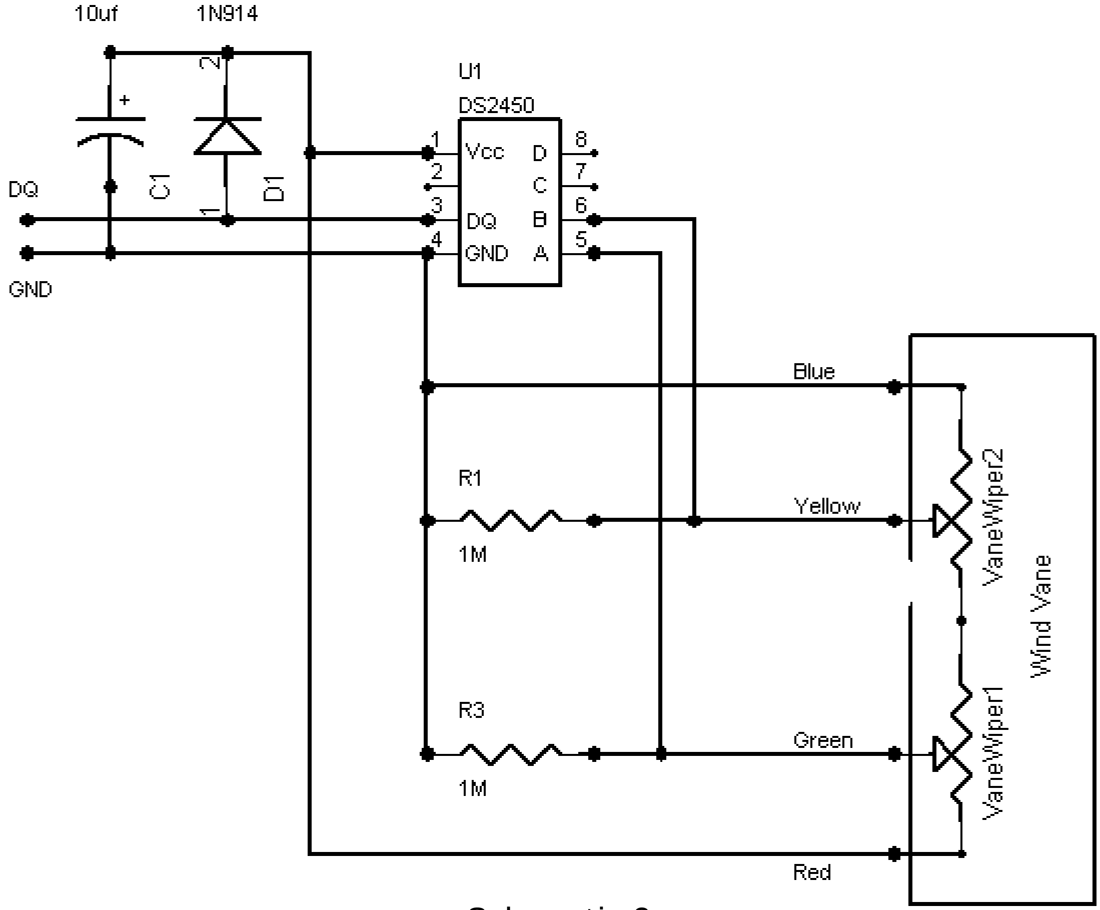
1-Wire Example

Let's take a real world example and see what it takes to connect an analog device to a 1-Wire network. Fascinating Electronics sells a wind vane kit that uses a special dual potentiometer as a sensor. The kit shown in Figure 9 is one of the nicest wind vanes I have had the opportunity to work with. With a price tag of only $49 you can't go wrong.

In this first example we will be connecting the wind vane to a DS2450 1-Wire IC chip as shown in Schematic 1. In order to parasitically power the analog circuit I have added a Diode (D1) and a capacitor (C1). These allow us to keep power applied to the wind vane potentiometer in parasite mode while we take our readings. I also added two 1 Meg resistors across the wipers and GND. This keeps the voltage level from floating when the wiper is in its dead zone.

Figure 9

Figure 10



Schematic 2

Notice that we are only using two of the four AtoD ports. This leaves us two that we can use later on other sensors. We could easily add a CDS cell to use as a light sensor or a couple of probes to measure moisture.

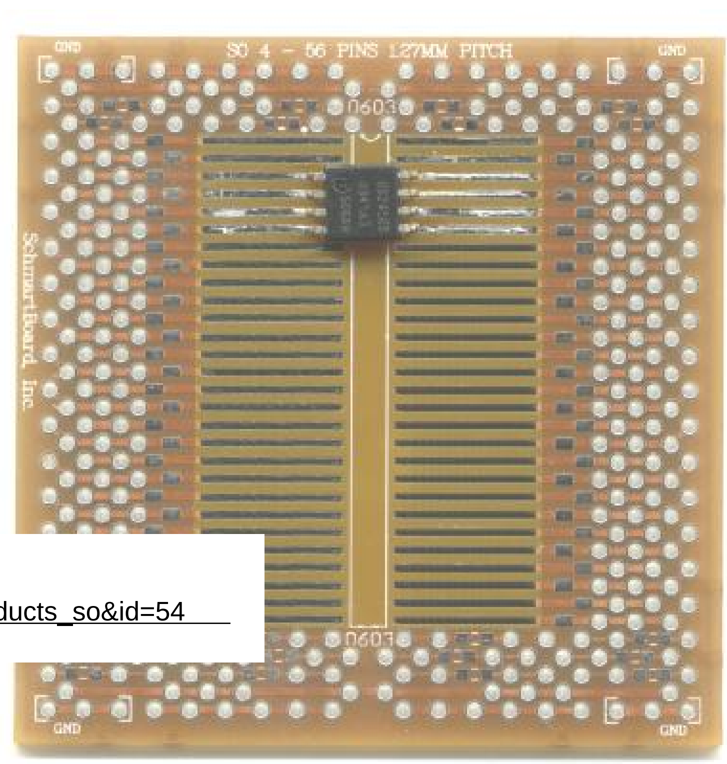


Figure 11

Pick one of these boards up up here:

http://www.schmartboard.com/index.asp?a=11&page=a_products_so&id=54

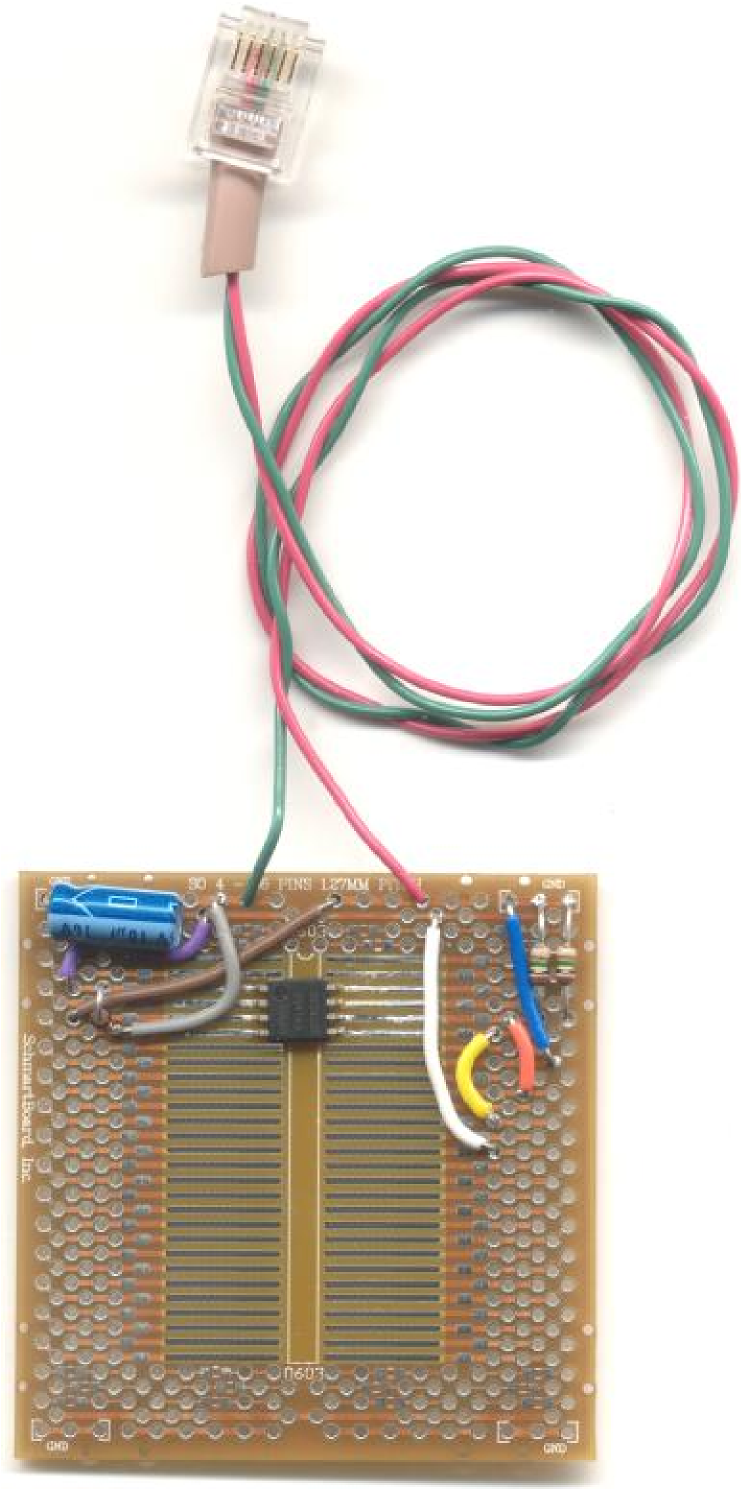


Figure 12

One of the reasons I have shied away from using Dallas 1-Wire chips is that many are only available in surface mount form factors. The DS2450 is no exception and is only available in SOIC form. This is no longer an issue since a company called SchmartBoard has solved our surface mount blues. The model 202-0004-01 is perfect to use with the Dallas 1-Wire SOIC chips. The chip simply sits in a small groove and using your soldering iron you simply place the tip in the groove furthest from the chip and move the tip toward the chip. This moves the solder that's already in the groove to the point where the chip is in contact with the groove as shown in Figure 11. This works pretty well but make sure you use your multi-meter to make sure you have a good solder joint. What I did was to place a very small dab of soldering paste on the tip of the SOIC pin that was being soldered. A small needle works perfect for this.

Figure 12 shows how I wired the circuit in Schematic 2. Note that the Blue, Orange, Yellow and White wires attach to a series of holes that could be used to connect your own cable or header. Notice that there is plenty of space left on the board to connect one or two more chips. Once you have all your wires and headers attached I recommend coating the board with liquid electrical tape.

Testing the 1-Wire Wind Vane

I created an application called FEWinidDir2.exe. This program shown in Figure 13 will allow you to set the 1-Wire Rom registration for the DS2450 and test the basic operation of the vane.

The program is very fast and you can see a real-time display of the vane as it moves around. The grey area on the gauge indicates how much the vane has moved since the display was last updated.

Take a look at the source code for this program and you will see a function called FEReadDir. This routine gets the two AtoD readings indicating the two wipers on the potentiometer. This wind vane is unique in the sense that the two wipers in the full rotation potentiometer overlap so there is no dead zone. When one of the wipers is in its dead area the other wiper is used. By using a bit of math we can then calculate a full 360 degrees at a 1 degree resolution.

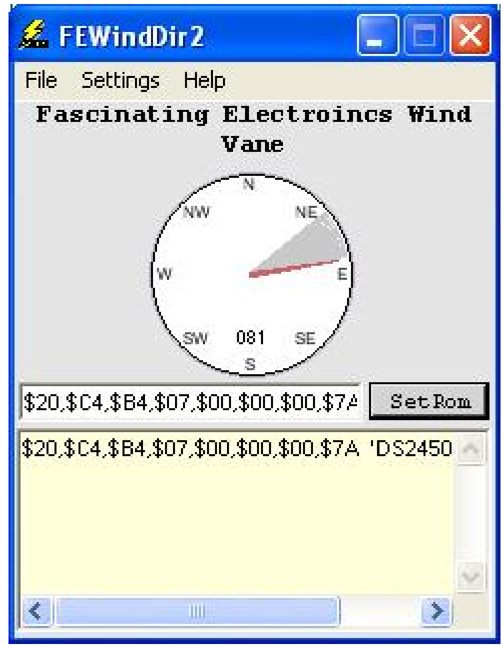


Figure 13

One of the problems I did have was that using parasite power I could not get a full 5v voltage across the wind vane potentiometer. The best I could do was 3.1v. This was enough to take readings but presented a problem. The routines the manufacture supplied are designed for a full 0-5v range. I had to multiply the reading by 6.6 so that the routines would work as is.

This particular example shows how you can create various environmental sensors using 1-Wire chips. The downside is that if you don't like working with surface mount chips you may find it difficult to roll your own sensors. Later in the series we will look at using a microcontroller as our main controller/collector. This approach will allow us to use both 1-Wire and conventional means for taking measurements from various sensors. With a microcontroller we could have simply tied two AtoD lines to the wind vanes potentiometer.

1-Wire Environmental Sensors

Let's take a look at a few more environment modules. I use the term module when a 1-Wire chip is connected to some sort of sensor and placed on a board, but you may also see the terms device or instrument.

Temperature

What would a weather station be without temperature measurements? As a minimum you will need an indoor sensor and an outdoor sensor. You have a couple of choices but I prefer the DS18S20 chip. I have provided chip libraries for the DS18B20, DS18S20 and DS1920 temperature chips. All can be used, but the test routines have been written for the DS18S20. The DS18S20 also has a feature where you can access the internal counter used to calculate the temperature and by a bit of math wizardry we can obtain a much higher precision than just the standard .5C. The high level DS1820ReadTemp function does this automatically for you.

The DS18S20 is actually marked DS1820 and comes in a TO92 form factor shown in Figure 14. In parasite mode the VDD lead is connected to GND. I almost always connect these chips to a length of Cat 3 cable about 4' in length. Once the chip has been connected to the cable I dip it into Liquid Electrical Tape as shown in Figure 15. This allows me to place the actual sensor in just about any location away from external heat sources.

Figure 14

Outdoor sensors must be placed in the shade and must have good air circulation. Last month we looked at the AAG weather instrument. This instrument has a DS18S20 chip installed but when the sun hits the white plastic the inside turns into a solar furnace. The temperature inside this furnace can vary as much as fifteen degrees from the actual outside temperature.

The best way to take outdoor temperature measurements is to build a solar shield in the shape of a pagoda. The pagoda shape is created by stacking a series of bowls or plates so that they overlap. This overlap creates an area inside that is shielded from the sun. You need at least three layers but more are better. The pagoda in Figure 16 was created by using three plastic bowls. I cut a 1-1/2" hole in the center of the two lower bowls for the PVC pipe. The bowls are held together with 3" stainless steel bolts. The sensor is run up through the PCV pipe and extrudes through a small hole in the pipe just under the second layer.

You can buy commercial pagodas but they can run you well over $100. This one cost me about $1 to build. There is a simple pagoda project on the Kronos Robotics website if you want to build one of these.

Indoor temperature sensors should be placed away from windows and away from direct sunlight. Also watch out for the heat generated by various appliances such as monitors or other sensors and power supplies. I use a small telephone surface mount box with the sensor attached to the two front Red and Green Wires. Be sure to drill some holes in the cover as shown in Figure 17.

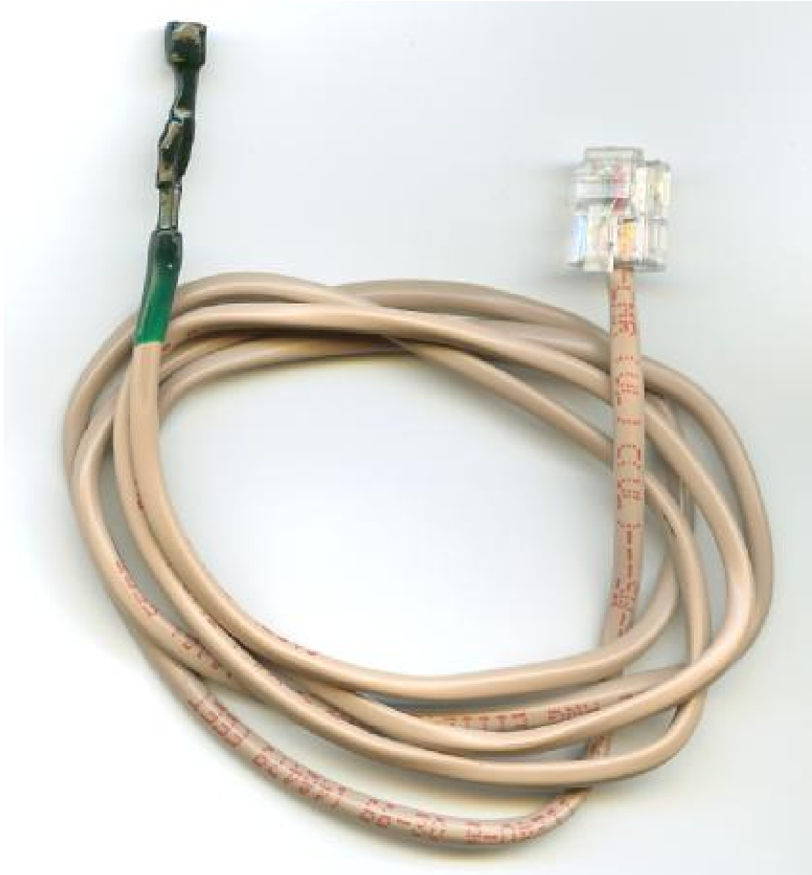


Figure 15

Figure 16

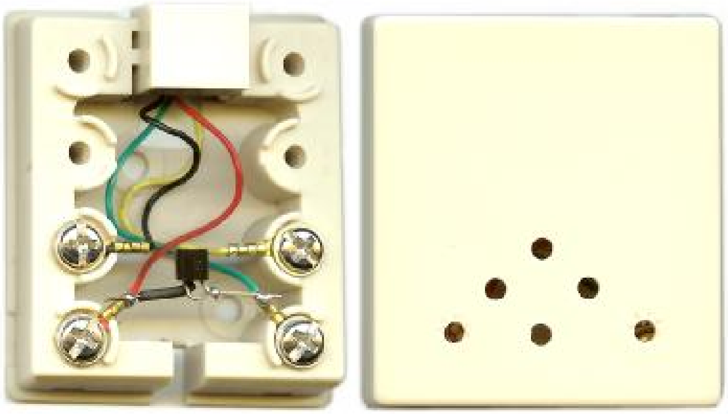


Figure 17

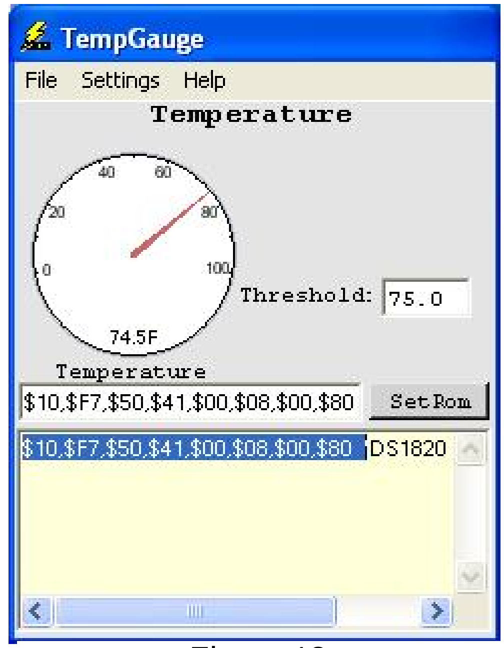


Figure 18

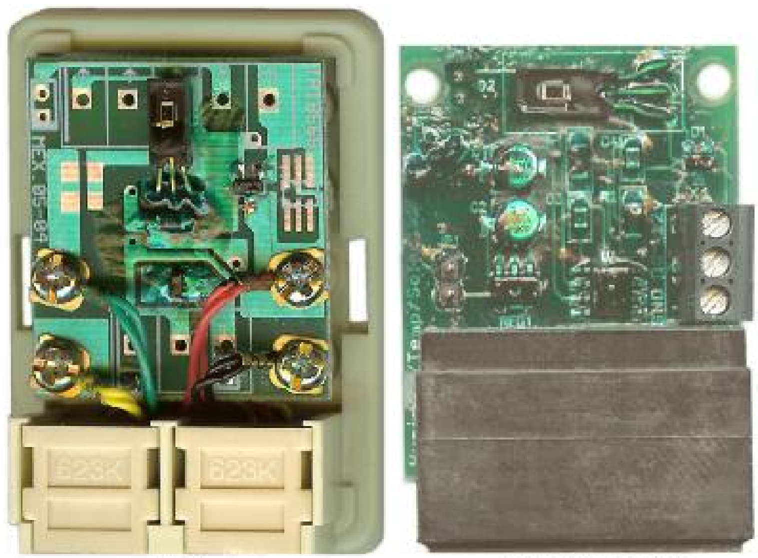
To test your temperature sensor use the TempGuage program shown in Figure 18. As before, do a Rom search then double click the DS1820 entry and hit the SetRom button.

The TempGuage program will take a reading once every 800ms and display the results in Fahrenheit. If you want to display the Celsius values you will have to make a few changes to the source code. Just to show you what you can do with a single DS18S20 chip I added a threshold field. When the temperature is over this value an alarm will sound.

Humidity

You will want your weather station to keep track of both indoor and outdoor humidity. Both AAG and Hobby boards sell a 1-Wire humidity module as shown in Figure 19. They function almost identically and are for the most part interchangeable. Both units utilize a Honeywell HIH-4000 humidity sensor connected to a DS2438 1-Wire chip.

The AAG module comes in only one configuration with the case included. The Hobby Boards module comes in several configurations including kit form. I prefer the Hobby Boards sensor without the case as it has a smaller footprint which makes it easier to mount in most utility boxes. The AAG module with the case was a bit too large for my utility box so it is used as my indoor sensor.



AAG Hobby Boards

Figure 19

The DS2438 used in these modules has the capability to take temperature measurements. As long as the module has plenty of ventilation and is used in parasite mode it is possible to use this portion of the chip as a temperature sensor. The DS18S20 is much more stable so I prefer to use these.

One tip that I can offer is to coat all the electronics used in your sensors with Liquid Electrical tape as shown on the Hobby Boards module in Figure 19. Just don't coat the HIS-4000 sensor.

Right out of the box I found that both these modules delivered an accuracy of 5% which is better than most home gauges I tested delivered. They tracked well with my local weather station.

As before I have provided a test program called HumidityGuage shown in Figure 20. The program updates the display once every 500ms.

Notice that we are reading the temperature sensor from the DS2438 chip. Once we have a temperature reading and a humidity reading we can calculate the DewPoint. The Dew point is the temperature that the air can no longer hold the moisture that it contains. If the temperature drops below the DewPoint the moisture will be released as what we call dew or in some cases fog.

Later we can combine other readings like wind speed and temperature to create a Wind Chill value.

Barometer

What would a weather station be without a barometer? Once you add a barometer to your weather station you have the ability to predict certain weather conditions.

Again both AAG and Hobby Boards offer a barometric pressure module, but unlike the humidity modules they use totally different sensors and 1-Wire interface chips. At the time of the article I had just received the AAG barometer and have not had a chance to create a test or calibration program. Once I do I will publish the results on the Kronos Robotics website.

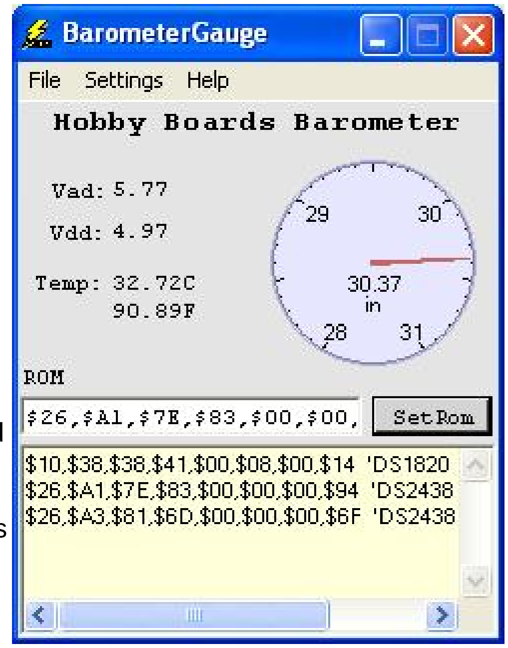


Figure 20

The Hobby Boards pressure gauge shown in Figure 21 will not run in parasite power mode. Due to the MPXA4115A sensor used, a minimum of 14v is needed to power the board. You have a couple of choices in powering the board. You can use a power injector provided by Hobby Boards or you can use an AC adapter. The board has its own regulator for the logic components. The board is available in kit and assembled form, and a PCB and complete schematic is also available for the do-it-yourselfer.

For barometric pressure you can keep the sensor indoors. I have found little or no difference between indoor pressure and outdoor pressure. This is best since most of your outdoor sensors will be used in parasite mode.

I found this module to be very accurate and once calibrated tracks the local weather station readings within 2%. Hobby Boards calibrates the module for you when you place your order but you may need to calibrate the module again once it is installed into your weather station. The test program BarometerGuage shown in Figure 22 has a calibration wizard built-in so calibration is a breeze.

Notice in the test program I am displaying the DS2438 temperature reading. It runs a bit high due to the onboard regulator so I don't recommend using it for anything but monitoring the board temperature.

In order to predict any kind of weather with a barometer you need to keep track of your readings over time. Later in the series as we tie all the sensors to a single program that will do just that.

Figure 21

Other Sensors

There are a myriad of sensors you can add to your weather station. As the series continues we will look at some of these. I will also be writing small application notes for them and place them on the Kronos Robotics weather forum at:
http://www.kronosrobotics.com/forums/

Going Further

You may have noticed that we only talked about individual sensors and not a weather station as a whole. Many of the sensors can work together to give us calculated readings like wind chill and heat index. Near the end of the series we will look at display systems and ways to plot long term data.

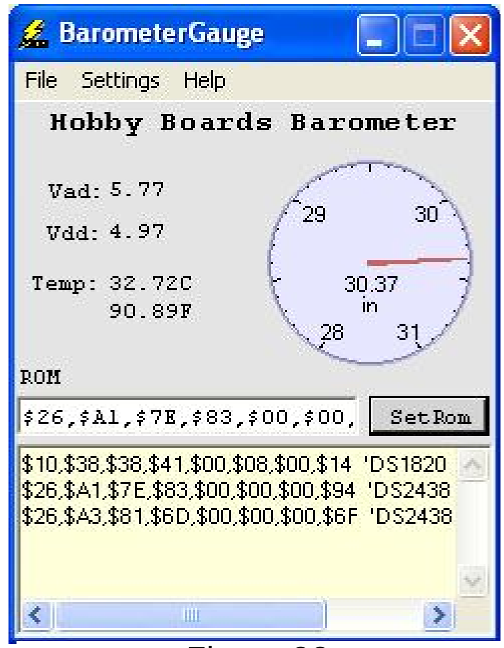


Figure 22

For now it is important that you get the individual sensors working. Later I will show you how to use a microcontroller to collect and display your data. The display system you choose and the collection method will dictate how your weather station is built.

Next month we are going to put our weather station aside and look at home automation. I will show you how to interface to three different X10 controllers. If you decide later to tie the home automation system into your weather station, the type of controller you use as your interface will also play a part in how your station is built.

As you can see there are a lot of variables and no two weather stations are alike. Don't worry. Part of the fun is tearing down the station and rebuilding it in a new and better configuration to suit your needs.

All the example programs as well as the source are available for download at:
http://www.kronosrobotics.com/Projects/esensors.shtml

SchmartBoard

202-0004-01 SO/SOP board
http://www.schmartboard.com/index.asp?a=11&page=a_products_so&id=54

Hobby Boards

1-Wire to Serial Adapter (DS9097U-A)
http://www.hobby-boards.com/catalog/product_info.php?cPath=23&products_id=28

DS2450 1-Wire QuadAtoD
http://www.hobby-boards.com/catalog/product_info.php?cPath=26&products_id=99

DS18S20 1-Wire Temperature Sensor
http://www.hobby-boards.com/catalog/product_info.php?cPath=26&products_id=93

Barometer Module (B1-R1-A)
http://www.hobby-boards.com/catalog/product_info.php?cPath=22&products_id=36

Humidity Module (H3-R1-A)
http://www.hobby-boards.com/catalog/product_info.php?cPath=22&products_id=46

AAG Electronica

Humidity Module (TAI8540D)
Pressure Module (TAI8570)
http://www.aagelectronica.com/aag/en-us/dept_2.html

AAG Weather Instrument (TAI8515)
http://www.aagelectronica.com/aag/en-us/dept_1.html

Fascinating Electronics

Standard Anemometer Kit (WEA-WVKIT)
http://www.fascinatingelectronics.com/weatherinst.html

Other

RJ11 Surface Mount Box
I used a GE TL26101
Can be purchased from most home centers.

Links

SchmartBoard
http://www.schmartboard.com/mscva

Hobby Boards
http://www.hobby-boards.com

Fascinating Electronics
http://www.fascinatingelectronics.com/index.html

AAG Electronica
http://www.aagelectronica.com/aag/

Kronos Robotics
http://www.kronosrobotics.com/xcart/customer/home.php

KRMicros
http://www.krmicros.com/Development/ZeusPro/ZeusPro.htm

iButton
http://www.maxim-ic.com/products/ibutton/