Approaching the Final Frontier

# Near Space

## Temperature Sensors for the Hobo Data Logger

There are times when you would like to record temperatures. A data logger like the HOBO makes a great platform for this purpose. Onset — the manufacturer of the HOBO — even produces a line of sensors for recording temperature data. The directions that follow are for those who wish to make a temperature sensor for their HOBO data logger, rather than purchase one.

### Goals

This month, we are going to make one (or more) temperature sensors for a HOBO data logger with external channels. The work doesn't end there, however. To turn the data our sensor records into the readings we require, we'll need to determine the equation that calculates the temperature from recorded voltage readings. From there, we will produce a chart of temperatures versus elapsed time.

### Required Materials

- HOBO data logger with external channels

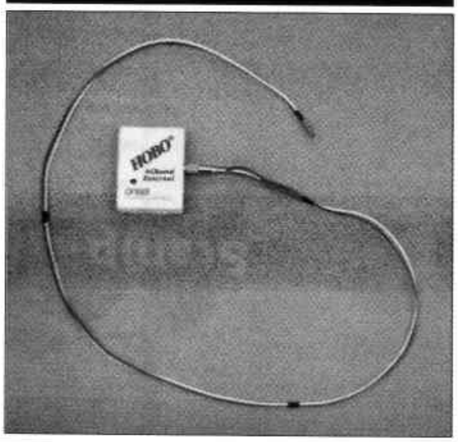

Figure 1. HOBO and sensor.

- 3/32" (2.5mm) stereo jack
- #24 AWG stranded wire (red, green, and white are the three suggested colors)
- A 51K resistor (1/8 or 1/4 watt) DMM
- A 10K thermistor (RadioShack part number 271-110A)
- Small diameter heat shrink tubing (1/8" and 1/4" are recommended)
- MS Excel spreadsheet or one of similar capabilities

## About This Project

Like a photocell, a thermistor is a variable resistor. In the case of the thermistor, however, its resistance varies according to its temperature, as opposed to light intensity, as is the case for the photocell. For a typical near space (NS) mission, the thermistor described in this project will vary its resistance from 8.3K at 30° C (86° F) to 320.2K at -50° C (-58° F). The circuit used in this project is a voltage divider (two or more resistors in series).

The HOBO provides the supply voltage (2.5 V) for the input side of the voltage divider. The ground is located at the opposite end of the fixed resistor. The voltage measured between the thermistor and the fixed resistor indicates the temperature of the thermistor. It's the voltage drop across the thermistor that is being recorded by the HOBO.

In choosing the value of the fixed resistor, I wanted to maximize the range of the voltage drop across the thermistor for the typical temperature range experienced on an NS mission. I entered several temperatures and thermistor values into a spreadsheet. Then, I created a column for calculating the voltage drop across the thermistor based on a fixed resistor under test.

A final column indicated the amount of variation in voltage drops between the warmest and coldest temperatures expected. The range maxed out with a fixed resistor of 50K. The reduction in voltage range was minimal with resistors a few kΩ more or less than 50K. The 51K resistor is the closest standard resistor value, so I selected it for the circuit. The procedure we will follow is to, first, make and test the temperature sensor and, second, determine the temperature equation particular to your sensor.

### Making the 3/32" Stereo Jack

These directions will make a single temperature sensor. Repeat them for any additional sensors.

Of course, we will first have to determine how far from the HOBO the temperature sensor must reach. In an NS application where the HOBO resides inside the NS craft and the thermistor may be placed outside, a length of two feet should suffice. Then, cut a two-foot length of green and white wire and a shorter, three-inch length of red wire. The red wire is much shorter because the 51K resistor will remain inside the NS craft and close to the HOBO. Now, strip about 1/8" of insulation from one end of each wire and lightly tin each stripped end.

Open the housing on the 3/32" stereo jack. Notice that the stereo jack has three solder pads. They are for the tip, ring, and base sections of the jack. Be sure you can identify which solder pad is for which section of the jack. Lightly tin each solder pad of the stereo jack and solder the wires to the following pads: white to the jack, white to the tip, red to the ring, and green to the base. You may want to slide some small diameter heat shrink tubing over the white wire where it is soldered to the jack tip.

At this point, it's a good idea to take a break and do some Quality Assurance. When you've done this, make sure the connections are good (mechanically strong and electrically conducting). Tug on each wire to make sure they don't pull off too easily. Then, strip a little insulation from the free ends of each wire and use a DMM in the continuity setting to measure for continuity between the end of each wire and the 3/32" jack.

You'll need to make sure there are no shorts between the wires soldered to the solder pads of the jack.

Use the DMM to verify that there are no shorts between the wires. You may want to squirt a little (very little) hot glue over the soldered jack. Finally, slide the jack cover over the 3/32" jack.

## Finishing the Sensor

Okay, back to work. We'll finish the sensor by first stripping 1/4" of insulation from the free end of the red wire and tinning it. Then, cut both leads of the fixed resistor to 1/4" and tin them. Slide a 1/2" long piece of 1/8" heat shrink tubing over the red wire and place one lead of the resistor in contact with the tinned red wire. Now, heat the two wires with a tinned soldering iron and solder the two together.

After the joint cools, slide the heat shrink over the soldered connection and shrink. Next, lay the resistor against the white wire and mark where the remaining lead of the resistor lays against the insulation of the white wire. Carefully strip insulation from the white wire at the marked locations. Now, twist the lead of the resistor once around the white wire and solder them together. Of course, slide 3/32" diameter heat shrink over the soldered resistor and white wire.

Now, trim the white and green wires to the same length and strip 1/4" of insulation from the ends of the white and green wires before tinning the ends of the white and green wires. Cut several short pieces of 1/4" or 3/32" heat shrink tubing and slide the heat shrink over both the white and green wires. This heat shrink consolidates the green and white wires into a cable.

Cut two pieces of 1/8" diameter heat shrink tubing to a length of 1/2" and slide it over the white and green wires now — before you forget and solder the thermistor to the wires — then trim and tin the leads of the thermistor to 1/4" long. Place a lead of the thermistor against the tinned white wire and heat the point of contact with a tinned soldering iron and solder the thermistor to the white wire.

Repeat this process with the green wire and the other lead of the thermistor. Again, slide the heat shrink over the solder thermistor leads and all wires and shrink them. Be sure to double-check your work.

With a DMM, you should measure the following resistances: base to ring — about 62K; base to tip — about 10K; and ring to tip — about 50K. The values vary, based on the temperature of the thermistor. Be sure to record the actual resistance between the ring and tip, as this is the actual resistance of the 50K resistor; this value is needed for the spreadsheet.

I have found that an easy way to label each temperature sensor is to print a small label and wrap it around the 3/32" jack housing. Then, cover the label with clear heat shrink. The heat shrink will protect the label and keep it from peeling off. After doing this (if you choose to), complete your remaining temperature sensors using the same steps.

## Determining the Temperature Equation

This procedure is required for each temperature sensor, so repeat it for each one.

First, we'll need to start a spreadsheet. Create a new spreadsheet and enter the following labels: data and equations. Label the first column Temperature (C). In the column, enter the following temperatures:

-50, -45, -40, -35, -30, -25, -20, -15, -10, -5, 0, 5, 10, 15, 20, 25, 30

Label the second column Thermistor Resistance (k). In the column, enter the resistances listed below:

320.2, 247.5, 188.4, 144, 111.3, 86.4, 67.7, 53.4, 42.5, 33.9, 27.3, 22.1, 18.0, 14.7, 12.1, 10.0, 8.3

Be sure to line up the values so that -50° C is in the same row as 320.2 K. Note that I have rounded the resistances to only one decimal place.

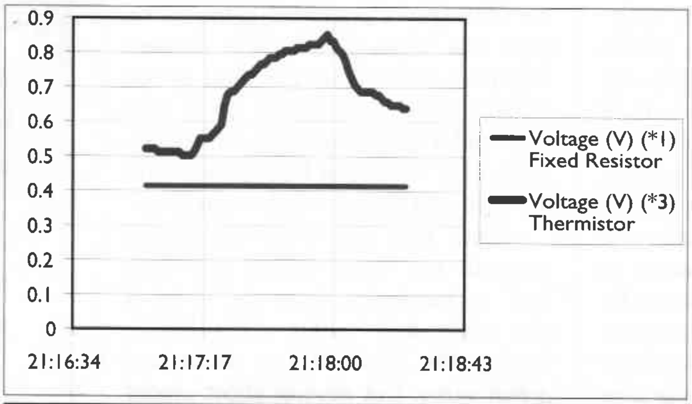


***Figure 2.*** Graphed data from a cold, outdoor test.

Label the third column Temperature (F). Enter the following equation (I'm assuming you're using Excel and your data begins in row number two):

= ((+A2+40)*1.8)-40

Copy and paste this equation into the entire column. Label the fourth column Voltage (V) and enter the following equation:

= 2.5*(C3/(C3+51.1))

Note: The value 51.1 is the actual resistance of my 51K resistor. Change the equation to match your 51K resistor's actual resistance.

Copy and paste the equation in the entire column. As a sanity check, verify that the voltages are between 0.0 and 2.5 volts.

Now, we will create a chart of the temperature and voltage. First, click the Chart Wizard icon. Under Chart Type, select XY (Scatter); find Chart sub-type and select Scatter with data points connected by lines without markers. Click the NEXT button, then the Series tab. Click the REMOVE button until every series is removed from the Series window, then click the ADD button. Under X Values, select the Voltage column; under Y Values, select the Temperature (F) column, then click the NEXT button.

We don't need to label the chart, as we only want to find the equation describing the line, so click the FINISH button. Right click the line in the new chart and select Add Trendline. Now, click the Polynomial icon and enter 3 for the order. Under the Options tab, click Display Equation, then OKAY. You will notice that the trendline closely matches the original data series.

Write down the equation. It is needed to convert the voltages from the HOBO into temperatures. The equation should look something like this:

y = -24.196x3 + 99.972x2 – 195.64x + 141.23

Repeat this process on the remaining temperature sensors. Make sure to replace the fixed resistance in the Voltage column equation.

Now, you are ready to use your temperature sensor in a HOBO data logger. The cable is long enough that the HOBO can be left inside the warmer NS craft while the thermistor takes the brunt of the cold temperatures in NS. Before programming your HOBO, be sure your PC or laptop time is set accurately according to a GPS receiver. This makes data processing more accurate later. (The HOBO time is set according to the clock on the PC it is programmed on.)

One possible complicating factor for the temperature sensor is that the fixed resistor may change values as it gets cold. To test for this possibility, I built a second voltage divider using just fixed resistors. (I used 10K and 51K resistors to simulate the temperature sensor.) The voltage divider was built following the same design for the temperature sensor, except that a fixed 10K resistor replaced the thermistor.

After connecting it and a real temperature sensor to a HOBO and launching a mission on the logger, I took the HOBO outside into the snow. I kept the 51K resistors in my hand and placed the thermistor and 10K resistor into a snow bank. After a few seconds, I brought the HOBO inside and did a read out of the data. The thermistor indicated the cold temperatures to which it was exposed, while the fixed resistor remained rock steady. Therefore, I concluded that the fixed 51K resistor left inside the NS craft will maintain a near constant resistance. If you are not lucky enough to live where it snows, a bowl of ice cubes will work just as well.

After recovery of the NS craft, read out the HOBO data and save the results into a text file. Start a spreadsheet and open the saved text file. Make sure the file is converted properly (with comma delimiters). (If you aren't sure how to do this, refer back to the "Near Space" column in the May, 2004 issue of *Nuts & Volts*.) The data from the HOBO will have columns for each channel used on the mission and the time.

The HOBO time must be converted into Mission Elapsed Time (MET) or altitude. The voltages must be converted into temperatures. The equation to convert HOBO voltages into temperatures was found when you assembled the temperature and will look something like this:

= -24.196*(B3^3)+99.972*(B3^2)-195.64*B3+141.23

Create a new column for each temperature sensor and enter the appropriate equation for each sensor. Now, process your data.

A question comes up when looking at thermistor data. How much does the resistance of a fixed resistor change as the temperature changes? If the fixed resistor is not truly fixed, then the results from the thermistor will be inaccurate. To address this issue, I created a second voltage divider. In this "temperature sensor," both resistors were fixed.

I placed one resistor (the test resistor) and the thermistor from the real sensor into a snow bank and left the other resistors in my hand. I recorded voltage readings for about 90 seconds. (It was cold outside!) During the second half of the measurements, I removed the test resistor and thermistor from the snow bank. After downloading the data from the HOBO, I graphed the results, which are displayed in Figure 2.

The resistance of the fixed resistor stayed constant throughout the experiment. As a result, I can conclude that temperature variations will not affect the fixed resistor in the temperature sensor. This implies that our results should be as accurate as the thermistor can provide.

## Conclusion

Now, you've learned how to build temperature sensors for your HOBO data logger with external channels. The temperature sensing element is a thermistor — or temperature sensitive resistor. It is combined with a second fixed resistor in series to create a voltage divider. Power to operate the temperature sensor comes from the HOBO data logger, so no additional batteries are needed to record temperature.

The voltage drop across the thermistor is recorded by the HOBO and imported into a spreadsheet after recovery. The necessary equation to convert these voltage readings into temperatures was determined with a spreadsheet when the sensor was created. Any experiment requiring a temperature be recorded can use this temperature sensor.

Onwards and upwards,
Your Near Space Guide **NV**

### Resource

HOBO data logger
Onset **www.onsetcomp.com**