# Adjusting Calibrations using Vernier Sensor Calibrations.txt
(Revised 3/25/09)

The file Vernier Sensor Calibrations.txt, which is in the Vernier Sensor folder you downloaded, is a simple text file with a structure like this:

| Number | Sensor Name | | Intercept | Slope | Units | Round | Short | Min | Max | Installed |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Accelerometer | 5g | -5620000 | 11800 | m/s^2 | 1 | Accel | -50 | 50 | 1 |
| 1 | Accelerometer | 25g | -28500000 | 60000 | m/s^2 | 1 | Accel | -250 | 250 | 1 |
| 2 | Barometer | | 8048000 | 3824 | kPa | 2 | Baro | 80 | 110 | 1 |

Each Vernier sensor that works with the NXT adapter has at least one row in the file. In a few cases, a sensor has more than one range, and it has a row for each range; examples include the Dual-Range Force Sensor and Magnetic Field Sensor. The STS and TMP temperature probes support temperature measurement using the Fahrenheit scale, with a separate row in the file. The sensor name (with switch setting, if there is more than one calibration), the units, and the number of digits to the right of the decimal to be displayed when the readings are displayed are all listed. Two other numbers, the slope and intercept used in calibration, are also listed. For all Vernier sensors that work with the NXT adapter, except the Stainless Steel Temperature Probe (TMP-BTA) and the Surface Temperature Probe (STS-BTA), the calibration is linear. This means that the relationship between the raw count from the NXT and the reading of the sensor is linear. These values are related by this equation:

$$\text{Sensor Reading} = (\text{Raw Count} * \text{Slope} + \text{Intercept})/100{,}000$$

The 100,000 factor is included because the NXT does not have a floating-point processor. We want to work with large integers and to avoid decimal numbers when doing calibration calculations. Basically, we do all the calculations and come up with sensor readings 100,000 times the correct reading. Before displaying the readings as a number, we convert by dividing by 100,000 so the proper reading is displayed. Before we display the Sensor Reading (Text) string, we use string operations to display the value correctly on the data hub.

We have carefully set the values of the slope and intercept for each of the sensors in the Vernier Sensor calibrations.txt file, which is found in the Vernier Sensor folder of the Vernier Sensor Block download. If you want to adjust calibrations, you can open the Vernier Sensor calibrations.txt file with a word processor or spreadsheet program, edit the values and resave it. Note: you should make a backup of the whole Vernier Sensor folder before you make changes.

Here are some tips on adjusting the slope and intercept for linear calibrations. This applies to all sensors except the two thermistor temperature probes. (TMP-BTA and STS-BTA).

- If all readings are off by a similar amount, change the intercept. Increasing the intercept by 100,000 will increase all readings by 1.
- If the readings are off in a proportional way, that is, larger reading are off by more than smaller readings, adjust the slope.
- If you want to start over and do a completely new calibration, see the section below for an example of how that is done.

**An Example of Adjusting a Calibration By Changing the Vernier Sensor Calibration.txt file**

In this example we will be testing and adjusting the calibration of a Vernier 5-*g* Accelerometer (LGA-BTA). This sensor, like most Vernier sensors, has a linear calibration. The first step is to test the current calibration of the sensor. There is an easy way to test the calibration of an accelerometer. An accelerometer senses its orientation, as well as acceleration, so if you point a Vernier accelerometer so that the arrow on the casing points straight up, it should read the acceleration due to gravity, or 9.8 m/s$^2$. Similarly, if you orient the accelerometer with the arrow pointed straight down, it should read –9.8 m/s$^2$. If you point the arrow horizontally, the sensor should read 0.0 m/s$^2$. If you notice that these readings are a little off, you might decide to recalibrate by changing the file.

To perform a recalibration, you need to come up with data on the raw count from the sensor in two or more different known conditions. In this case, it is easy to provide known conditions of 9.8, –9.8 and 0.0 m/s$^2$ for the accelerometer by simply orienting the arrow properly. An easy way to read the raw count at these known conditions is to place a Vernier Sensor Block in NXT 2.0 Programming and select Raw Count from the Sensor pull-down list in the configuration panel. Connect the acceleration sensor to the NXT via the Vernier NXT Adapter. If the NXT is turned on and connected, you will see the raw count displayed in the digital display in the lower-left corner of the configuration panel. Using this readout and orienting the arrow on the LGA-BTA sensor, you can build a table like this.

| Orientation | Expected Reading (m/s$^2$) | Raw Count |
|---|---|---|
| Arrow Up | 9.8 | 561 |
| Arrow Down | –9.8 | 386 |
| Arrow Horizontal | 0 | 469 |

From these data you need to determine the slope of a graph of acceleration versus raw count. The best way to do this is to use a graphing program, such as Logger *Pro*. You can also use graph paper. If you use a graphing program, enter the data and determine the best linear fit to the data. Here is a sample graph from these data:
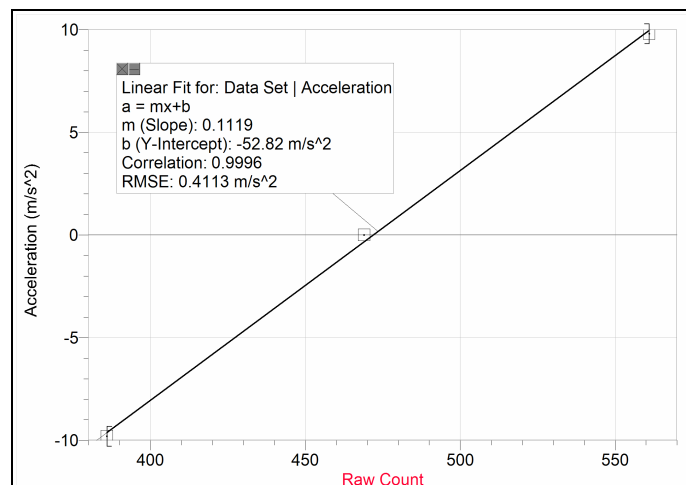


*Calibration Data Graphed with Logger Pro with Linear Fit*

We use the linear curve fit feature of Logger *Pro* to determine the intercept and slope:

Intercept:   –52.82 m/s$^2$

Slope:  0.1119 m/s$^2$/count

If you do not use a computer program, you can determine the slope and intercept as a math exercise. Calculate slope using the change in the expected values divided by the change in the raw count (rise over run).

As mentioned in the discussion above, because the NXT does not have a built-in floating point processor, we choose to store all the values used for calibration in the Vernier Sensor Calibrations.txt file multiplied by a factor of 100000 to avoid problems involving fractions in the calibration math. So, for this example, the numbers to store in the file are:

Intercept as used in Vernier Sensor Calibrations.txt file:  –52.82 * 100000 = –5282000

Slope as used in Vernier Sensor Calibrations.txt file:  0.1119 * 100000 = 11190

We will put these two numbers in for the intercept and slope in the Vernier Sensor Calibrations.txt file. This file is in the Vernier Sensor folder. Before you modify it, you should make a copy of the original file. Open Vernier Sensor Calibrations.txt with a word processor or spreadsheet program. The structure of the file has a structure like this:

```
Number  Sensor Name       Intercept   Slope  Units  Round  Short  Min   Max   Installed
0       Accelerometer  5g  -5620000    11800  m/s^2  1      Accel  -50   50    1
1       Accelerometer  25g -28500000   60000  m/s^2  1      Accel  -250  250   1
2       Barometer          8048000     3824   kPa    2      Baro   80    110   1
```

The first row below the header happens to be for the 5-*g* accelerometer. The third number in the row is the intercept and the fourth is slope. Note that these values are slightly different than the numbers that we calculated in this calibration example, as expected. Change the third and fourth numbers in the row so the top of the file looks like this:

```
Number  Sensor Name       Intercept   Slope  Units  Round  Short  Min   Max   Installed
0       Accelerometer  5g  -5282000    11190  m/s^2  1      Accel  -50   50    1
1       Accelerometer  25g -28500000   60000  m/s^2  1      Accel  -250  250   1
2       Barometer          8048000     3824   kPa    2      Baro   80    110   1
```

Save the Vernier Sensor Calibrations.txt file where it was before. Launch NXT 2.0 Programming and import the Vernier Sensor Block again. Try out the calibration of the 5-*g* Accelerometer and it should be improved.

### Calibration With Stainless Steel and Surface Temperature Probes

Calibration is done in a different way for the Stainless Steel Temperature Probe and the Surface Temperature Probe. These sensors use thermistors and a resistor in a voltage divider circuit. The relationship between raw count and temperature is complex. For these sensors, we use the Steinhart-Hart equation to determine the temperature from the raw count. The Slope and Intercept values in the Vernier Sensor Calibrations.txt file have different uses. To adjust the calibration, follow the procedure below:

**First adjust the readings near 0°C.** If you want to adjust the temperature mostly at low temperatures, you need to adjust the slope number in the Vernier Sensors.txt file. This number is used in a complex way. It is set as negative of the power supply voltage of the NXT (in millivolts). The slope number affects the calibration curve in the area near 0 °C

most strongly. If the slope is reduced in absolute value by 10 mV (e.g. –4911 is changed to –4901), the temperature displayed on the NXT 2.0Programming screen at 0°C will be reduced by approximately 0.2°C

**Next, adjust the values near 100°C**. The Intercept value is 102,800 by default, but it can be changed to add a multiplicative correction. To proportionally increase all the temperature readings, you increase this value. To decrease all the temperature readings, you decrease the intercept. Changing the intercept by 1,000 causes a change of one percent in the 0°C to 100°C Calibration Slope (for example 100°C becomes 101°C and 10°C becomes 10.1°C). Note that this change affects all temperature readings.