



## **BNO080/BNO085 Sensor Calibration Procedure**

Document Number: 1000-4044  
Document Revision: 1.3  
Date: July 2019

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## 1.0 Introduction

The BNO080/BNO085 contains MEMS sensors which need to be calibrated for best performance. Each individual sensor is different, so each unique device must be calibrated individually. Additionally, the sensor parameters that need to be calibrated can change after the sensor has been placed on the board so calibration within the final assembled device is essential.

Hillcrest has created “dynamic calibration” algorithms which can calibrate the sensor simply by moving the device in specific motions. During normal AR/VR application use, Hillcrest recommends that dynamic calibration for the gyroscope and magnetometer be disabled to avoid new calibrations being created during gameplay which can cause unwanted motion artifacts. The gyroscope is automatically calibrated when the device is stable, and the magnetometer calibration is not likely to change significantly if the user uses the device in the same general environment.

It is recommended that a first time calibration is performed in the factory using the calibration tool discussed below. The calibration results are saved in flash on the BNO080/BNO085 in a file known as the Dynamic Calibration Data (DCD) file. This document discusses these calibration procedures.

### 1.1 Special Note about Magnetometer Calibration

The magnetometer is most important when using the Rotation Vector BNO080/BNO085 output (which aligns the quaternion output to magnetic north). When using the Game Rotation Vector output (which aligns the quaternion output to an arbitrary orientation and is not affected by magnetic perturbations), accurate calibration of the magnetometer is less important.

The magnetometer calibration process will calibrate for the unique magnetic field affecting the environment in which the calibration process takes place. This includes components that affect the magnetic field in the headset itself (soft iron effects) like batteries, and objects that affect the magnetic field around the user (hard iron effects) like metallic furniture or speakers. For best performance, it is recommended that the end-user performs a similar magnetic calibration procedure when they start using the device in their home and any time that they significantly change their environment (e.g. after moving the device to a new room) if Rotation Vector is used by the applications.

## 2.0 Factory Calibration

This section discusses the calibration methods that should be used in factory production.

### 2.1 Testing Environment Recommendations for Factory Calibration

Ideally the calibration process would be performed several feet away from high magnetic interferers like tables with magnetic components, desktop PC towers, monitors, etc. If this guideline is not followed then the magnetometer calibration saved to the device will include compensation factors for those environmental interferers.

For consultation on this topic contact Hillcrest Labs.

### 2.2 Factory Calibration Procedure

The following procedure is an example calibration process for the BNO080/BNO085. Hillcrest can consult on specific factory requirements or questions.

#### BNO080/BNO085 Configuration

- Enable dynamic calibration for accelerometer, gyroscope, and magnetometer
  - o Use the Configure ME Calibration Command in the BNO080/BNO085 API. Refer to the SH-2 Reference Manual [1] for more details.
- Enable Game Rotation Vector output
- Enable Magnetic Field output (the magnetometer requires 50Hz report rate to get proper calibration)
  - o Ensure the Status bit is exposed to the application. This bit indicates the accuracy of the sensor and will be used to track the progress of the calibration (0-3 scale with 0 = Unreliable, 3 = Accuracy High)

#### Calibration Procedure

1. Position the device in a relatively clean magnetic environment (see Section 2.1)
2. Begin observing the Status bit of the Magnetic Field output (it can be displayed in the application)
3. Perform the accelerometer calibration motions. The accelerometer will be calibrated after the device is moved into 4-6 unique orientations and held in each orientation for ~1 second. One way to think about this is the “cube” method described below:
  - a. Imagine that the device is a standard cube with 6 faces (Front, Back, Left, Right, Top, Bottom). See Figure 2 for visualization.

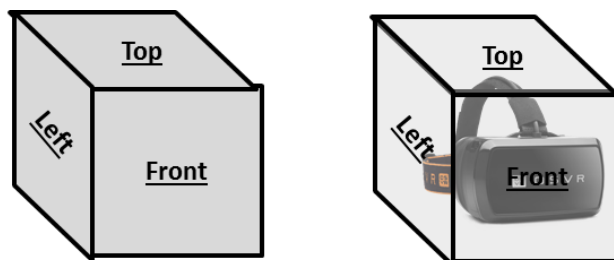
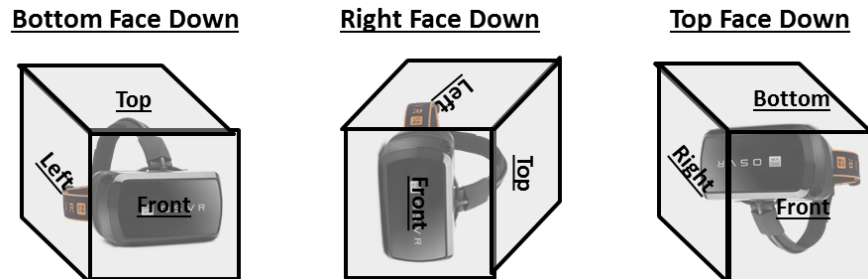


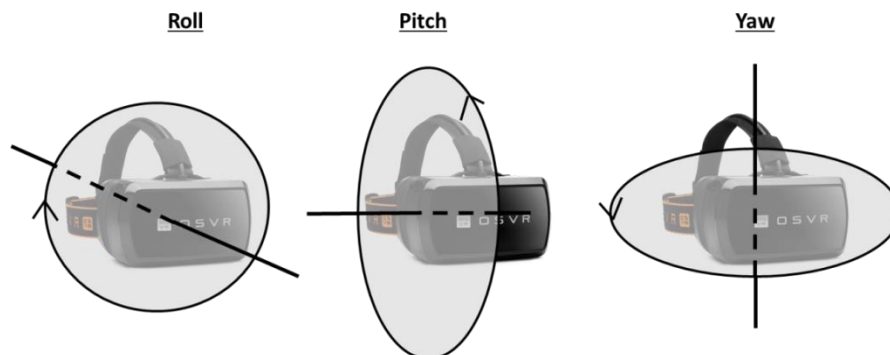
Figure 2: Headset Cube Face Visualization

- b. Orient the device so that it is sitting on each face of the cube sequentially. For example, start with the device positioned normally (bottom face of the cube down). Then orient it so that the right side of the cube is facing down. Then continue through the rest of the faces of the cube. See Figure 3 for an example.



**Figure 3: Headset Orientation Example**

- c. Hold the device in each position for 1 second
- d. Notes about the accelerometer calibration motions:
- If one of the faces is difficult to position the device, you do not need to do all 6 faces (e.g. if cables or straps are in the way). Four or five orientations should be sufficient.
  - The positions do not need to be perfectly aligned with the cube faces. The important part is that you position the device into 4-6 unique orientations. The cube is merely a way to visualize the type of motions required.
  - It does not matter which order the cube face positions are moved into
4. Perform the gyroscope calibration
- Set the device down on a stationary surface for ~2-3 seconds to calibrate the gyroscope
5. Perform the magnetometer calibration motions
- Rotate the device ~180° and back to the beginning position in each axis (roll, pitch, yaw) as shown in Figure 1
    - The speed of the rotation should be approximately ~2 seconds per axis but it does not need to be perfect



**Figure 1: Headset Rotation Axes**

- b. Observe the Status bit of the magnetic field output
  - c. Continue rotations until the Magnetic Field Status bit reads 2 or 3 (medium or high accuracy)
6. When finished with the calibration motions, run the Save DCD Now command, which will save this calibration data into flash

## 3.0 User Calibration

For best performance, a calibration utility should be created so that users can perform similar calibration steps during a first time setup configuration mode. This calibration routine should be performed at the following times:

1. First Time Setup when the user first uses the device in their home
2. Any time the user significantly changes their environment (i.e. when they move the device to another room)

This will ensure that the calibration is optimal in the user's environment. Additionally, this calibration utility can be repeated by the user if there are any performance issues during the lifespan of the device.

The motions and BNO080/BNO085 settings for User Calibration are the same as Factory Calibration. For further questions, contact Hillcrest Labs.

## 4.0 References

1. 1000-3625 SH-2 Reference Manual, Hillcrest Labs

## 5.0 Notices

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