AHRS400 Series Installation and Troubleshooting Guide

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This application note describes installation and calibration of the Crossbow Attitude Heading Reference System (AHRS400 Series). It includes checkout, installation, calibration, and troubleshooting procedures.

Pre-installation Software Checkout

The GyroView software will be required to checkout the installation and calibrate the AHRS400. It is recommended to install the software on the computer to be used for checkout and calibration before starting the procedure. A laptop computer running Microsoft Windows is recommended. The AHRS400 is shipped with an I/O cable to connect the unit to a PC communications port.

1. Connect the 15-pin end of the calibration cable to the port on the AHRS400.
2. Connect the 9-pin end of the cable to the serial port of your computer.
3. The additional black and red wires on the cable supply power to the AHRS400. Match red to (+) power and black to (-) ground. The input voltage can range from 9 - 30 VDC at 275 mA for the AHRS400.

   💣 WARNING

   Do not reverse the power leads! Applying the wrong power to the AHRS.
4. With the AHRS400 connected to your PC serial port and powered, open the GyroView software.
5. GyroView should automatically detect the AHRS400 and display the serial number and firmware version if it is connected.
6. Let the AHRS400 warm up under still (motionless) conditions for at least 60 seconds when first turned on. This allows the Kalman filter to estimate the rate sensor biases and zero them out.
7. Slowly move the AHRS400 around each axis and notice that the rates in the GyroView graph display are changing.
8. You can verify the functionality of accelerometers by changing the orientation of different axes aligned with the gravity axis.

Installation Location Selection

The AHRS400 case is not weatherproof. You should protect the device from moisture and dust.

Mechanical and Vibration

The AHRS400 must be installed in a location that is rigid to alleviate potential vibration errors induced from normal airframe vibration sources. The mounting plate must be stiff enough to rigidly follow the aircraft motions without inducing low frequency motions relative to the aircraft. Larger vibration will make the accelerometer readings noisy and therefore can affect the angle calculations. In addition, if the magnitude of the vibration exceeds the range of the accelerometer, the accelerometer output can saturate. This can cause errors in the accelerometer output.

Magnetic Environment

The AHRS400 uses a set of sensitive magnetometers inside its housing to measure Earth's weak magnetic field to determine heading. As a result, small amounts of moving magnetic material near the AHRS400 can have large effects on the heading measurement. The AHRS400 should be isolated from magnetic material as much as possible. Magnetic material will distort the magnetic field near the AHRS400, which can affect its accuracy as a heading sensor.
Materials to avoid include anything that will stick to a magnet: iron, carbon steel, some stainless steels, nickel and cobalt. Use a magnet to test materials that will be near the AHRS400. AHRS400 can correct for the effect of these magnetic fields by using the hard and soft iron calibration routine as long as the material is stationary.

Materials that will not affect the magnetic heading performance include brass, plastic, titanium, wood, and aluminum. Again, if in doubt, try to stick a magnet on the material. If the magnet doesn't stick, you are working with a material that will not affect the heading.
Stationary ferrous objects will be compensated for by the calibration procedure. Moving ferrous objects within 24 inches cannot be fully compensated by the calibration. The AHRS400 must not be located within 24 inches of any large moving ferrous metal objects such as landing gear components, electric motors, control linkages, etc. Ferrous metal objects that may change position during flight operations, such as landing gear, flap actuators, and control linkages must not be within 24 inches of the AHRS400.
The AHRS400 should not be located close to high current DC power cables or 400 cycle AC power cables and their associated magnetic fields.

IMPORTANT

DO NOT stick a magnet to the AHRS400. This could permanently magnetize internal components of the AHRS400 and degrade its magnetic heading accuracy.

AHRS400 Alignment if installed in the aircraft

The AHRS400 should be mounted as close to the center of gravity (CG) of your system as possible. This will minimize any “lever effect.” If it is not mounted at the center of gravity, then rotations around the center of gravity will cause the AHRS400 accelerometers to measure an acceleration proportional to the product of the angular rate squared and the distance between the AHRS400 and the aircraft CG.
The AHRS400 must be level on the yaw and roll planes of rotation when the plane is in straight and level flight. The pitch axis must be set parallel to the wing angle of incidence.
The AHRS400 will measure rotations around the axes of its sensors. The AHRS400 sensors are aligned with the base plate. The base plate references are noted in the installation drawing and are used as reference surfaces for aligning the AHRS400 sensor axes with the aircraft. The AHRS400 should be aligned as closely as possible with the axes you define in your system. Errors in alignment will contribute directly to errors in measured acceleration and rotation relative to your system axes.

Hard/Soft Iron Calibration

The AHRS400 will need to be calibrated for hard and soft iron compensation before being used with the system. The AHRS400 series uses magnetic sensors to compute heading. Ideally, the magnetic sensors would be measuring only earth's magnetic field to compute the heading angle. In the real world, however, residual magnetism in the AHRS400 itself and in your system will add to the magnetic field measured by the AHRS400.
The extra magnetic field can create errors in the heading measurement if they are not compensated. These extra magnetic fields are called hard iron magnetic fields. In addition, magnetic material can change the direction of the magnetic field as a function of the input magnetic field. This dependence of the local magnetic field on input direction is called the soft iron effect. The AHRS400 measures any extra constant magnetic field that is associated with the AHRS400 or your system and corrects for it during the calibration procedure. The AHRS400 can also make a correction for some soft iron effects. The process of measuring these non-ideal effects and correcting for them is called hard iron and soft iron calibration. Calibration will help correct for magnetic fields that are fixed with respect to the AHRS400. It cannot compensate for time varying fields, or fields created by parts that move with respect to the AHRS400.
The AHRS400 accounts for the extra magnetic field by making a series of measurements. The AHRS400 uses these measurements to model the hard iron and soft iron environment in your system.

AHRS400 Hard and Soft Iron Calibration Procedure

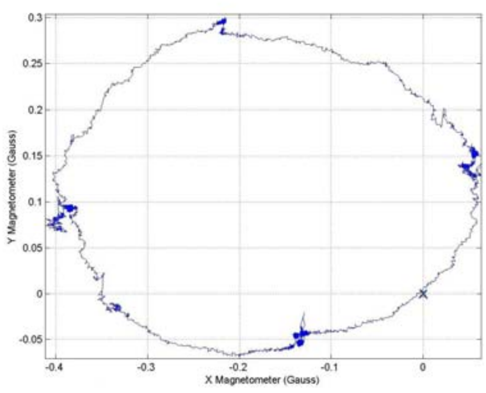
The hard and soft iron calibration procedure is performed with the AHRS400 mounted in your system using the I/O cable, a portable PC running Windows, and GyroView software provided by Crossbow Technology, Inc. For best accuracy, you should do the calibration process with the AHRS400 installed in your system. If you do the calibration process with the AHRS400 by itself, you will only correct for the magnetism internal to the AHRS400. If you then install the AHRS400 in a system and the magnetic environment is different, you will still see errors arising from the magnetism of the aircraft environment.

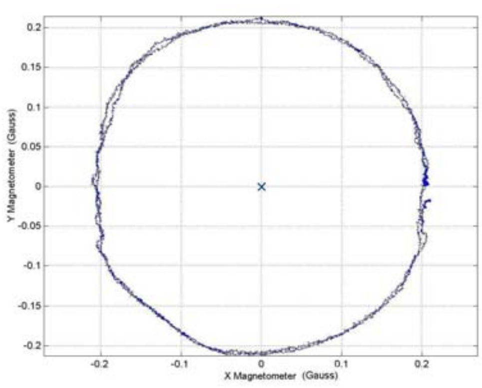
1. Power up the AHRS400 and start GyroView as explained in the pre-installation checkout procedure.
2. With the unit still and level in the system, click on the “CLEAR CAL” button of GyroView. This clears the hard and soft iron calibration by sending 'h' and 't' commands as explained in the manual.
3. Then click on “START CAL” button commanding the unit to enter the hard iron calibration process. The system will then need to be rotated through a complete circle(s). The system does not have to be perfectly level, as the algorithm will compensate for any angle offsets, but running the test with the aircraft as close to level as possible will ease the process.
4. When done, click on “STOP CAL” to end the calibration.
5. Allow at least 1 min. for the algorithm to initialize by keeping the system still and motionless.

Evaluating and Testing Calibration Data

The heading calibration can be tested by comparing the heading output of the AHRS400 against a known reference (compass or compass markers). In other words, you can rotate your system at 90 degree intervals of compass rose and then stop and see if you notice any drift in heading. If there is any drift this means that the rate sensors and the magnetometers are not in complete agreement with each other and there is still some additional hard iron effect for which compensation is needed.
Align the system along an ordinal heading of North, South, East or West. Make sure the AHRS400 has completed the 60 second initialization period. Observe the heading reading and make sure heading reading agrees within 3^0 of the reference. Rotate the system along an ordinal heading of North, South, East or West that is 90 degrees from the previous position. Observe the heading reading and make sure that this agrees within 3^0 from the reference. A good calibration will not display more than a 3^0 heading change once the turning is stopped. Repeat this test for all the four ordinal heading directions.

Alternatively, the quality of hard iron calibration can be assessed by plotting the magnetometer outputs. If you slowly rotate the system about z-axis through one complete turn while logging the data using GyroView and then plot the X-Mag vs. Y-Mag, in a successful hard iron calibration you should notice a perfect circle centered around the origin. Additionally, the total magnetic field (calculated as $\sqrt{M_x{}^2 + M_y{}^2 + M_z{}^2}$) should be constant during the complete rotation of the system. If the circle is not circular or the center of the circle has an offset, there is still scope for improvement of the calibration. To improve the calibration, you can repeat the calibration procedure as explained in the previous section without clearing the existing calibration. This helps to build on to the existing calibration thereby refining the quality of calibration.





Before Hard Iron Calibration **After Hard Iron Calibration**

Usually a successful calibration may not be achieved after the first turn, unless the magnetic environment is extremely clean. Repeat the calibration procedure as described above, making another complete turn circle with the system. Always turn the system the same direction as the first turn. In this way, the calibration algorithm continues to refine itself until it achieves a successful calibration. After every calibration routine, it is a good idea to verify the quality of calibration using the plotting procedure described above.

IMPORTANT

If you happen to terminate the calibration process before a circle is complete, it is a good idea to clear the existing calibration before doing another calibration.
Note that the hard iron calibration is a one-time operation and once you have a successful calibration, you won't have to repeat the procedure unless you change the unit mounting or the iron content of the system.

Troubleshooting Tips:

Are the supply voltage and connections okay?

The AHRS400 needs at least 9V power supply for proper operation. Verify that your power supply is regulated and not current limited. Ensure that the supply does not fall below 9V or go above 30V. Make sure that all the connections are intact.

Are you providing the enough initialization time (>1 min)?

You need to let the AHRS400 warm up for at least 60 seconds when first turned on or upon completion of hard iron calibration. This allows the Kalman filter to estimate the rate sensor biases. The AHRS400 needs to be held stationary during this initialization process. Any rate inputs during this process may cause a constant offset on the rate sensors and in turn a drift in calculated angles.

Is the AHRS400 mounting orientation okay?

The Pitch and Roll angles corresponding to 90 degree orientation are singularity points for the Kalman filter algorithm and you should not let the unit sit in this position for extended periods of time. As a result, the angles start drifting if you stay at these singularities for long time. The longer you keep the unit in a singularity position, the longer it will take for the unit to stabilize upon recovery.

Are you exceeding the range of rate sensors, causing the outputs to over range?

Whenever the maximum range of the rate sensors is exceeded, the Kalman filter goes into re-initialization mode and saturates the outputs. When recovered from this over-ranged condition, the AHRS400 resets itself and needs to be steady and level. The recovery time may vary from 30-60 second depending on the nature of the preceding maneuvers. It is recommended that whenever the rate sensors are over-ranged, the system is brought back to level and held still for at least 60 seconds before doing any further testing.

Do you have constant maneuvers close to the maximum range of rate sensors?

Although the AHRS400 is rated to operate at 100 or 200 deg/sec, constant maneuvers close to the range should be avoided. Prolonged rates close to the maximum range may result in continuous drift due to bias on the rate sensors resulting from temperature, vibration, EMI etc.

Do you have heavy EMI interference in the environment?

Heavy EMI interference can cause a bias shift of the rate sensors and magnetometers and hence continuous drift in calculated angles. Before you install the AHRS400 in the system, by closely watching the magnetometer and rate sensor outputs, you can test the effect of different potential EMI contributors (strobe lights, microwave transmitters, alternators, radio modems, controllers etc), by actually operating them. Move the AHRS400 to a location where effects of such interferences are within the acceptable accuracy.

Is the vibration isolation adequate?

Large amounts of vibration will make the accelerometer readings noisy and thereby may affect the anglular calculations. In addition, if the magnitude of the vibration exceeds the range of the accelerometer, the accelerometer output can saturate. This can cause errors in the accelerometer output and in turn the estimated angles. The AHRS400 must be installed in a location that is rigid to alleviate potential vibration errors induced from normal airframe vibration sources. You can use vibration isolators if needed to dampen out the unwanted vibrations.

Has the hard iron calibration been successful?

A successful hard iron calibration is the key to obtaining good heading accuracy. Verify that the hard iron calibration has been successful before proceeding with further tests. Note that the hard iron calibration is a one-time operation and once you have a successful calibration, you don't have to worry about it again unless you change the mounting or the iron content of the system.