Goodrich ISR Systems

Magnetometer Integration Guide

October 12, 2011

Authors:

Marius Niculescu / Bill Vaglienti

2621 Wasco Street / PO Box 1500 / Hood River, OR 97031

(541) 387-2120 phone / (541) 387-2030 fax

www.cloudcaptech.com / sales@cloudcaptech.com / support@cloudcaptech.com

Cloud Cap Technology, a Goodrich Company

Table of Contents

---

*The Piccolo Autopilot avionics system and all of its versions (such as Piccolo, Piccolo Plus, Piccolo II, Piccolo LT, and Piccolo SL) were designed for use **only** on un-manned aircraft. **USE OF THESE PICCOLO AUTOPILOT PRODUCTS IN AIRCRAFT WITH HUMAN OCCUPANTS IS PROHIBITED BY THE FEDERAL AVIATION ADMINISTRATION.** Cloud Cap Technology, Inc. is not permitted to sell the Piccolo Autopilot to any customer that intends to use the product on aircraft with human occupants.*

Piccolo Magnetometer Integration Guide Change Log

February 8, 2011

- Section 3.3: Updated Position Change screen capture.

December 21, 2009

- Section 3.2 Calibration Procedure: Updated Calibration Procedure
- Section 3.3 Manual Calibration Procedure: Updated Manual Calibration Procedure

1 Overview

Piccolo Autopilots can be configured to connect to the Honeywell HMR2300 or the HMR3400 magnetometer to enhance its navigation solution. Magnetometers sense the local magnetic field in three axes by comparing the sensed magnetic field with the expected Earth magnetic field. This is most useful for operation in GPS denied environments where they allow dead reckoning of the aircraft position and velocity.

The Honeywell HMR2300 Magnetometer with RS232 interface and the HMR3400 Digital Compass are available at Digikey (www.digikey.com)

- Digikey p/n 342-1014-ND - HMR2300 no enclosure (bare board)
- Digikey p/n 342-1015-ND - HMR2300 flush mount enclosure
- Digikey p/n 342-1016-ND - HMR2300 extended enclosure (easiest to mount)
- Digikey p/n 342-1057-ND - HMR3400 no enclosure (bare board)

2 Installation

2.1.1 Orientation

IMPORTANT! For the navigation solution to function correctly the magnetometer must be mounted in the correct orientation.

- The orientation is relative to the vehicle coordinate axis. The magnetometer must be level in pitch and roll with respect to the vehicle.
- The connector of the magnetometer should be pointing toward the direction of flight and mounted inside the fuselage (see **Figure 1)**.
- The HMR2300 should be mounted with the label facing up.

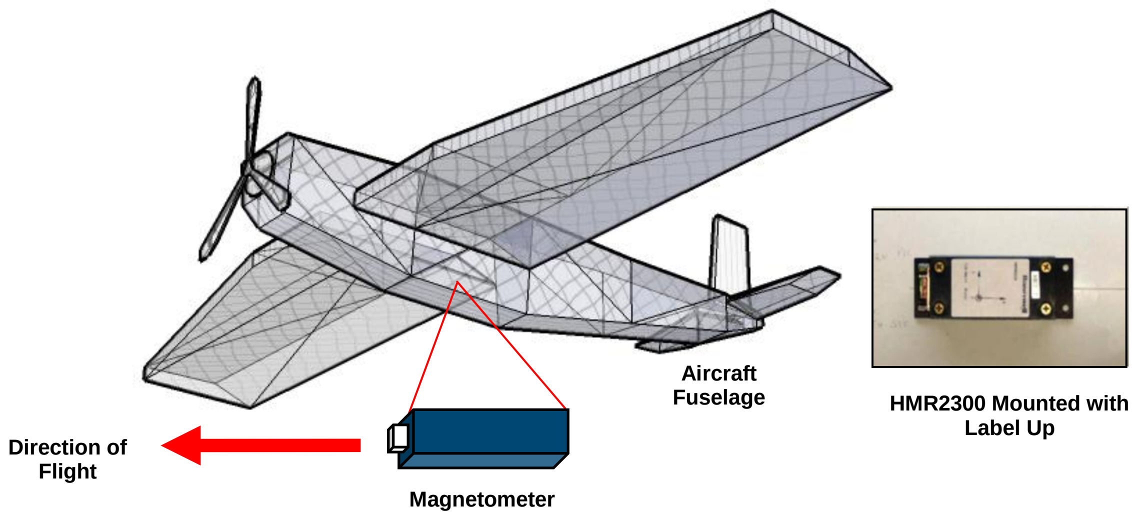

Figure 1 - Magnetometer Orientation

2.2 Connections

2.2.1 HMR2300 Connections

The HMR2300 can be connected to any of the Piccolo's external serial ports. An interface pigtail cable is available through Cloud Cap Technology. Users will need to configure the appropriate port on the **`Payload Com Settings`** window in the Piccolo Command Center to activate the magnetometer.

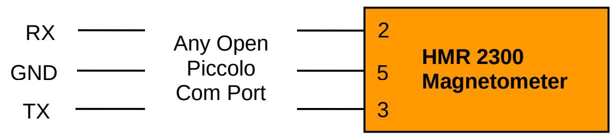

Table 1 – Piccolo Magnetometer Connections

PIN	NAME	Type	LEVEL	FUNCTION
Piccolo Plus, Piccolo II				
34	TXD_RS232	0	RS232	COM1 TX - Payload 1 - TPU_B[0]
33	RXD_RS232	I	RS232	COM1 RX - Payload 1 - TPU_B[1]
4	GND			Ground
32	SCI_2_TX_232	O	RS232	COM2 TX - ExtCom/Program Port
31	SCI_2_RX_232	I	RS232	COM2 RX - ExtCom/Program Port
3	GND			Ground
Piccolo II Secondary Connector				
7	TXD1_232	O	RS232	COM4 TX – Iridium Comm.
6	RXD1_232	I	RS232	COM4 RX – Iridium Comm.
16	GND			Ground
5	TXD2_232	O	RS232	COM5 TX – Iridium DTR
4	RXD2_232	I	RS232	COM5 RX – Iridium CD
14	GND			Ground
3	TXD3_232	I/O	RS232	COM3 TX – Payload 2 – TPU_B4
2	RXD3_232	I/O	RS232	COM3 RX – Payload 2 – TPU_B5
1	GND			Ground
Piccolo LT				
27	TXD_RS232	0	232	COM1 TX - Payload 1 - TPU_B[0]
26	RXD_RS232	I	232	COM1 RX - Payload 1 - TPU_B[1]
25	GND			Ground
7	SCI_2_TX_232	O	RS232	COM2 TX - ExtCom/Program Port
6	SCI_2_RX_232	I	RS232	COM2 RX - ExtCom/Program Port
5	GND			Ground
Piccolo SL				
33	TXD1_RS232	O	RS232	COM1 TX – Payload 1 – TPU_B[0]
50	RXD1_RS232	I	RS232	COM1 RX – Payload 1 – TPU_B[1]
15	GND		*	Ground
49	SCI_2_TXD_232	O	RS232	COM2 Serial TX - Program/User
32	SCI_2_RXD2_232	I	RS232	COM2 Serial RX - Program/User
14	GND		*	Ground

29	TXD3_RS232/Spare2	O	RS232	COM3 - Serial TX from Piccolo SL (Spare)
46	RXD3_RS232/Spare1	I	RS232	COM3 - Serial RX to Piccolo SL (Spare)
11	GND		*	Ground

2.2.2 HMR3400 Connections

The Piccolo II, Piccolo LT, and Piccolo SL autopilot come standard from the factory with RS-232. Since the HMR3400 is a RS232/TTL (Transistor-Transistor Logic) connected device, it can only be used with a Piccolo II, Piccolo LT, or Piccolo SL autopilot that has been configured at the factory for a TTL connection. The Piccolo Plus does NOT support the HMR3400 magnetometer.

If you have an existing autopilot and would like us to configure it for a TTL connection, contact us for an RMA number.

If you would like to have a TTL connection in a new Piccolo II, Piccolo LT, or Piccolo SL autopilot, please contact us. A TTL connection can be added to the autopilot prior to shipment.

The Payload 2 port is the only port that can be configured for TTL. Please see the Piccolo Micro-Dot Connector Pin-Out tables in the *Piccolo User's Guide* for connection information.

Note: *Refer to the HMR2300 manual and data sheets for power supply requirements.*

2.3 Power Requirements

The HMR2300 must be supplied with 6.5 - 15 volts DC. The HMR3400 must be supplied with 4.8 - 5.2 volts DC.

Caution must be used when connecting to a freshly charged 12-volt battery. Some 12-volt batteries can have terminal voltages of more than 15 volts immediately after charge and cause the magnetometer to fail.

Refer to the HMR2300 and HMR3400 manual and data sheets for power supply requirements. Data sheets can be found at:

- http://www.ssec.honeywell.com/magnetic/datasheets/hmr2300.pdf
- http://www.ssec.honeywell.com/magnetic/datasheets/hmr3400.pdf

2.4 Software Setup

Go to **`Window`** » **`Preflight`** » **`Payload Com Settings`** in the Piccolo Command Center. Select the Piccolo external serial port that the magnetometer is connected to. Under **`Protocol`**, select the Magnetometer you are using for that that serial port.

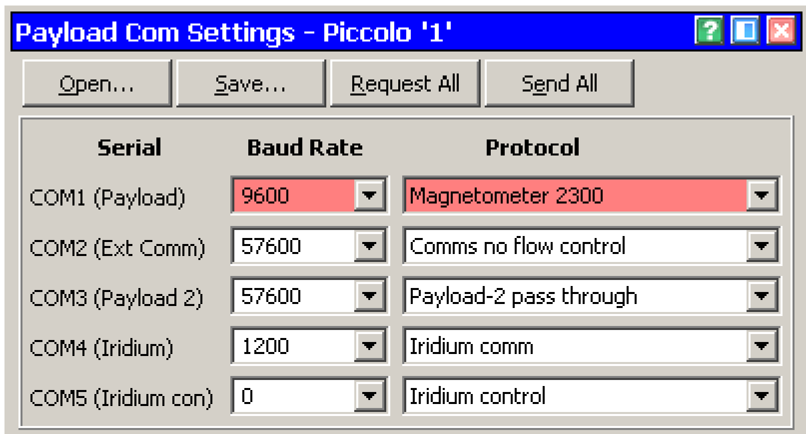

Figure 2 - Payload Com Settings Window

Note: *The serial port that is connected to the magnetometer must be configured for the magnetometer protocol at 9600 baud. It can be determined that the magnetometer is working by looking at the compass heading value on the telemetry page and verifying that it moves as the aircraft changes heading.*

3 Magnetometer Calibration

Using the magnetometer for attitude and navigation aiding requires that any magnetic fields that are not caused by the Earth be accounted for. A calibration process is used to remove "hard iron" errors. Hard Iron errors are constant changes in the magnetic field produced by the aircraft systems. Another type of error is called "soft iron". These are changes in the magnetic field that vary in time, i.e., with a payload being turned on and off. Soft iron effects cannot be calibrated out and must be minimized in the aircraft design.

3.1 Calibration Fundamentals

The magnetometer calibration interface is located under **`Window`** » **`Advanced Windows`** » **`Sensors Configuration`** in the Piccolo Command Center.

- **Req. Cal** - Requests the current magnetometer calibration parameters from the avionics.
- **Send Cal** - Sends the magnetometer calibration parameters from the PCC to the avionics.
- **Cal 2D** - Updates the X and Y biases and scale factors.
- **Cal 3D** -Updates all X, Y, Z parameters.
- **Save** - Saves the current magnetometer calibration parameters into an XML file.
- **Load…** - Loads the magnetometer calibration parameters from an XML file into the Piccolo Command Center.

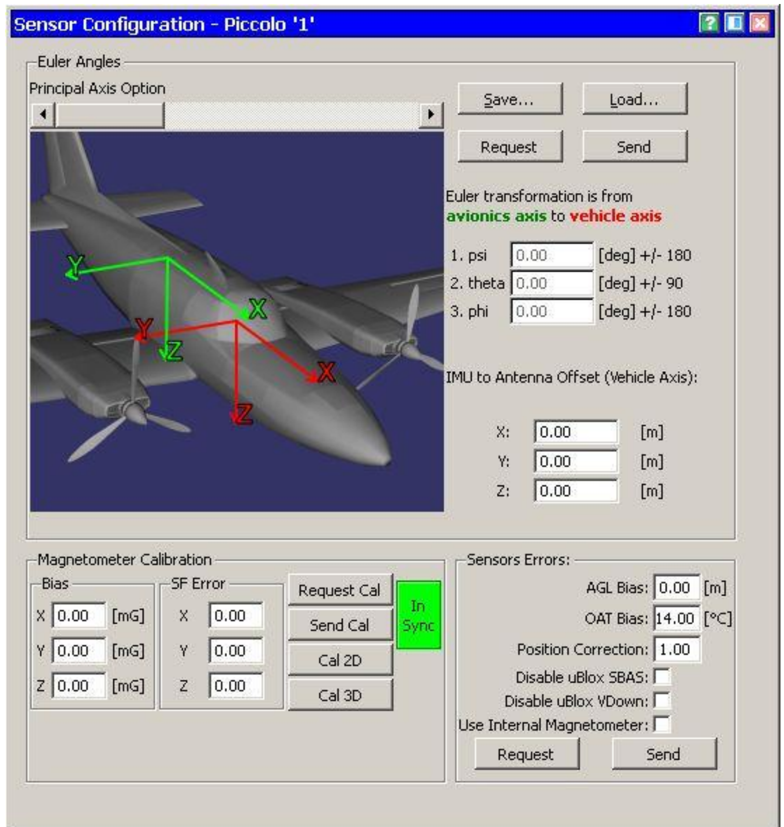

Figure 3 - Sensor Configuration Window

The central part of the **`Magnetometer Calibration`** interface contains the six calibration parameters (a bias and a scale factor error for each of the three magnetometer axes). The biases, also known as hard iron errors, are specified in magnetic field units (milliGuaus [mG]) and the scale factor errors are given as fractions of 1. The magnetic field correction performed in the avionics for each axis uses the following formula:

$$H_{correct} = \frac{H_{measured} - Bias}{1 + SF_{error}}$$

The **Magnetometer Calibration** section also a status light indicator. The status light indicator displays one of the following states:

Table 2 - Magnetometer Calibration Status

Status	Description
In Synch (green)	Calibration settings displayed match the ones that are stored in the avionics.
In Synch (red)	Calibration settings displayed are different than the ones that are stored in the avionics.
19 (yellow)	Magnetometer calibration is in progress. The indicator will also display the estimated remaining time (in seconds) for the calibration.

During the calibration process, the avionics collects magnetic field measurements four times per second. After the avionics has collected 100 magnetic field samples it will run the calibration procedure and compute the biases and scale factor errors for the appropriate axes depending on which calibration procedure was selected [1].

3.2 Calibration Procedure

The following the steps calibrate the magnetometer using the calibration buttons in the **Magnetometer Calibration** section:

1. Install and setup the magnetometer as described in section *2 Installation*
2. Move the vehicle to a location where it will not be affected by neighboring magnetic fields (i.e. away from power systems, generators, buildings, etc.)
3. Turn on any payloads and/or electrical systems on the aircraft that may cause local magnetic fields.
4. In the **Sensors Configuration** window, click **Cal 2D** or **Cal 3D**.

   In **Cal 2D** rotate the vehicle through a full 360° of heading around the Z axis. The rotation should be smooth (roughly 15 deg/sec) and the vehicle must remain at zero pitch and roll during the rotation. In **Cal 3D**, rotate the vehicle a full 360° (if possible) around all three axes (**Figure 4**). Your progress will be displayed in PCC as a percentage from 0% to 100%.

[1] If the aircraft is too large it may not be practical to rotate the aircraft through the vertical plane in the Cal 3D mode. See Section 3.3 Manual Calibration Procedure for more information.

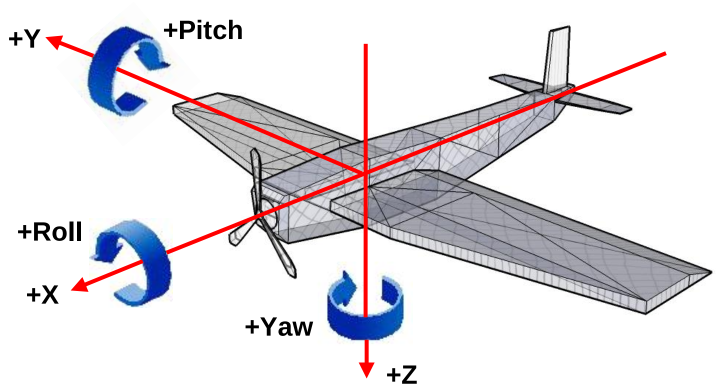

Figure 4 - X, Y, Z Axes

5. When the magnetic calibration is complete, the avionics will automatically send the new calibration parameters to the ground station. The PCC will display the new parameters and the status indicator will turn green to show that the calibration is complete. If the biases are greater than 50 mG or the scale factor errors are greater than 0.1, then the calibration may be faulty or the vehicle may have strong local magnetic fields.

Once calibration is complete it should be validated. This can be done by aligning the vehicle with a known heading and comparing this to the compass heading reading on the telemetry page. The compass reading is the true heading, corrected for the difference between the Earth's field and true North.

Note: *A valid GPS is required for the correction to be accurate (corrections depend on time and location). Reverse the vehicle heading and validate the direction. Typical errors should be less than 5 degrees.*

3.3 Manual Calibration Procedure

Manual calibration is for calibrating the magnetometer in an aircraft where it is not practical to physically rotate the aircraft through the vertical plane (3D cal) or if there is a greater probability of human error during the automated calibration process.

Before starting the manual calibration procedure it is important to obtain the magnetic model field readings for your area.

3.3.1 Obtaining Magnetic Field Readings

1. Start the Simulator application. Enter your local latitude, longitude and altitude values in the Position Change section.

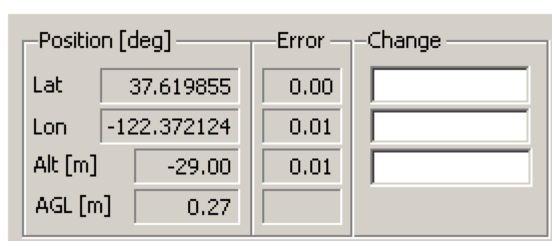

Figure 5 - Position Change

2. Enter “0” for roll, pitch, and yaw angles.

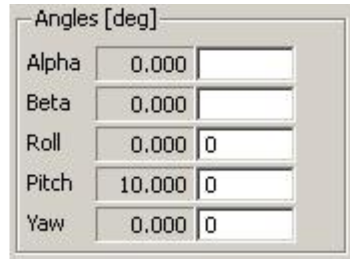

Figure 6 - Angles

3. Click **`Apply Slew`**. Write down the magnetic field values that are displayed in the **`Mag`** section.

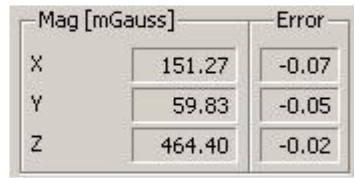

Figure 7 - Mag

Note: *It is also helpful, to use the calculator available at the [National Geophysical Data Center (NGDC)] for computing magnetic field values.*

3.3.2 2D Manual Calibration

1. Close the simulator and establish communications with the avionics.
2. Zero the magnetometer calibration in the aircraft.
3. Set the aircraft at zero pitch and roll, away from magnetic disturbances (metal, rocks, etc.)
4. Turn on all relevant aircraft systems.
5. In PCC, go to **`Window`** » **`Status Windows`** » **`Sensor Telemetry`**. Write down the measured magnetic field values (*x*, *y*, *z*) from the Magnetometer section.

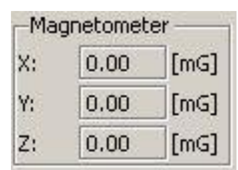

Figure 8 - Magnetometer

There is a label error for magnetic field units in all software versions v.2.1.0 and below. All magnetic field units displayed and entered in PCC should be in [mG] milliGauss not [nT] nanoTesla.

6. Rotate the aircraft exactly 180° in heading. Record the new magnetic field values. This a "paired reading", i.e. two readings exactly 180° apart.
7. Compute the average reading for *x* and *y* (i.e. *x*avg = (*x*1 + *x*2)/2). These are the *x* and *y* bias terms.
8. Compute the measured Horizontal Field Strength (Shm) for the first and second reading (i.e. ((*x*1 - *x*bias)^2 + (*y*1 - *y*bias)^2)^0.5. Take the average of these two readings.

9. Compute the horizontal field strength from the magnetic model (Shs). You may take the Horizontal Intensity value from the NGDC web site (note 1 milliGauss = 100 nT), or use the magnitude of the horizontal magnetic components from the simulator, i.e. (xsim^2 + ysim^2)^0.5.
10. Compute the scale factor error *s* = (Shm/Shs) - 1. This is the scale factor error for all three terms, ideally it should be close to zero.
11. Calculate *z*-bias as *z*-bias = *z*1 - *z*fieldfromsim*(1 + *s*).
12. Input the corrections in the **`Magnetometer Calibration`** fields of the **`Sensor Configuration`** window in PCC.
13. Enter the x, y, z, bias terms from step 7 and step 11.
14. Enter the same scale factor error from step 10 into the x, y, z fields.
15. Click **`Send Cal.`**
16. Test the calibration.

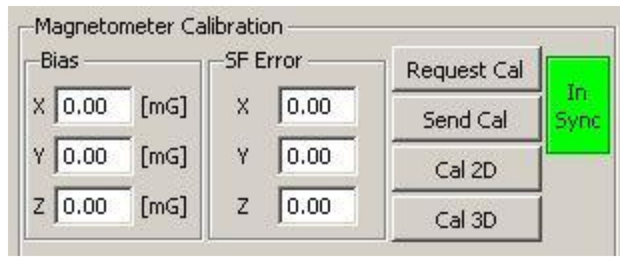

Figure 9 - Magnetometer Calibration

Note: *Taking multiple paired readings will improve your statistics.*

3.3.3 3D Manual Calibration

Calibration can also be extended to a 3D calibration (*x*, *y*, *z*) by performing the following additional steps:

1. Take a pair of readings with the vehicle upright and inverted.
2. Compute the *z*-bias as (*z*1 + *z*2)/2.
3. Compute the scale factor error using the ratios of the measured field magnitude to modeled field magnitude, using all three terms (*x*, *y*, *z*).