APPLICATION NOTE

Accelerometer for AHRS application

30N.AHRS.B.05.11

The MS9010, ideal product for AHRS application

Features

- ±5g to ±15g range
- Excellent bias stability (less than 0.05% of full scale)
- Low temperature coefficient without T calibration
- Extra small 20 pin LCC ceramic package with hermetic sealing (8.9mm x 8.9mm)
- Low power
- Brown out protected
- RoHS compliant suitable for lead free soldering process and SMD mounting

Introduction

Inertial navigation is the process of calculating the position and velocity of a body (such as an aircraft) from self-contained accelerometers and gyroscopes. Attitude and Heading Reference Systems, better known as AHRS, are multi-axis sensors that provide heading, attitude and yaw information for aircraft or any subject moving in free space.

Fig. 1: AHRS

AHRS are designed to replace traditional mechanical gyroscopic flight instruments and provide superior reliability and accuracy. They consist of either solid-state or MEMS gyroscopes, accelerometers and magnetometers on all three axes. Some AHRS use GPS receivers to improve long-term stability of the gyroscopes. A Kalman filter is typically used to compute the solution from these multiple sources.

Constituent parts function

Strap down inertial navigation systems require an initialization process that establishes the relationship between the aircraft body frame and the local geographic reference. This process called alignment generally requires the device to remain stationary for some period of time in order to establish this initial state. To initialize, the inertial reference system goes through a self alignment process to align the vertical axis of the local level coordinate frame with sensed acceleration (leveling) and to measure the horizontal earth rate to determine the initial azimuth (gyro-compassing). If the initial attitude of the vehicle could be known, and if the gyros provided perfect readings, then the attitude processor would be sufficient. However, the initial attitude is seldom known, and gyros typically provide corrupted data due to bias drift and turn-on instability.

Both gyros and accelerometers suffer from bias and bias drift terms, misalignment errors, acceleration errors (g-sensitive), nonlinear effects (second order term or VRE), and scale factor errors. The magnetometers are also susceptible to magnetic disturbances, which corrupt their measurement of the Earth's magnetic field. These errors are calibrated out once the system is installed in its final mounting position.

The largest error in AHRS is associated with the gyro bias terms. Without a filter structure and separate independent measurements from the accelerometers, gyros and magnetometers, the attitude processor would diverge from the true trajectory.

The Kalman filter attitude correction component provides an on-the-fly calibration for the gyros by providing corrections to the attitude processor trajectory and a characterization of the gyro bias state. The accelerometers provide an attitude reference using gravity, and the magnetometers provide a heading reference using the Earth's magnetic field vector.

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Accelerometer function in AHRS

In general, the role of accelerometer in an AHRS application is to provide with initial attitude reference (leveling) and provide attitude corrections during the flight required to correct the gyro drift.

Various types of AHRS solutions in the market place today:

- The high accuracy systems use Ring Laser Gyro (RLG) or Fiber Optic Gyro (FOG). They need to be very accurate since they are used in the automatic flight mode and have to be accurate enough to prevent the collision of large aircraft wings to the ground during take-off and landing especially under fog and extreme weather conditions. For this type of applications usually accelerometers with bias stability of better than 2 mg over all conditions including temperature range, linearity, second order effects and axis misalignment are required.
- The lower classes of AHRS available are used as general assistance to the pilots' sight or as backup systems and do not require such high performance. This type of AHRS is very often used in the small civilian airplanes and some UAVs. In these cases, lower end MEMS accelerometer and MEMS gyros are used.

Example of AHRS system (Courtesy SAGEM DEFENCE SECURITE)

The accelerometer range depends on the application. For high-end and medium AHRS performance usually 10g to 15g range are required as for lower end solutions 5g sensors are used.

COLIBRYS accelerometer for AHRS

The main parameters essential to optimum AHRS performance are bias stability (1), scale factor stability, axis misalignment and its stability and second order linearity effects or VRE (vibration rectification error). The initial deviation of the majority of these parameters from their expected value can be easily calibrated. However, the main issue is their repeatability and stability over time, temperature, post shock and vibration. These events could cause unpredictable drifts, which will in turn determine the classification of the accelerometer.

(1) One year stability defined according to IEEE 528-2001: switch on / switch on, storage at -55°C and 85°C, -40°C to 125°C T cycling, -55°C to 85°C unpowered harass, vibration and shock.

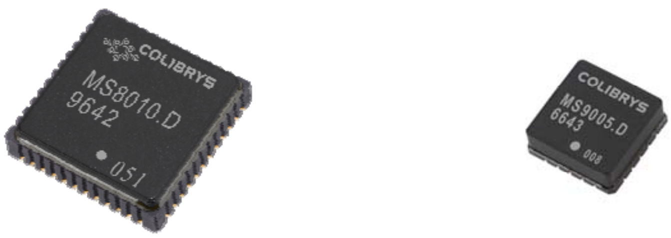

Fig. 2: MS8010 and MS9005 Colibrys accelerometers

Colibrys is one of the only MEMS accelerometer suppliers committing to the Mil / Aerospace market and specifying a large number of these parameters. The MS9000.D family is currently the latest generation of products and a further improvement of Colibrys' flagship accelerometer MS8000 product.

MS9000 is offered in a new smaller LCC20 package with essentially the same performance as MS8000 but in a smaller form factor. MS9010.D has a long term bias stability of 4.5 mg (1σ) and a scale factor of better than 400 ppm. This product is available for AHRS with acceleration ranges of 2g, 5g and 10g and 15g on demand.

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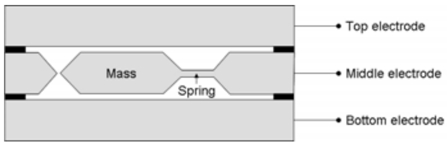
Product description

The MS Colibrys product is a MEMS capacitive accelerometer based on a bulk micro-machined silicon element specifically designed for high stability, a low power ASIC for signal conditioning, a micro-controller for storage of compensation values and a temperature sensor. The product is low power, fully calibrated, robust and stable. It operates from a single power supply voltage (between 2.5V and 5.5V) with low current consumption (< 0.5mA at 5V). The output is a ratiometric analog voltage that varies between 0.5V and 4.5V for the full-scale acceleration range at a voltage supply of 5V. The sensor is fully self-contained and packaged in a 20-pin LCC ceramic housing, thus insuring a full hermeticity. It operates over temperature range of –55°C-to-125°C and can withstand shocks up to 6000g. Long-term stability of bias and scale factor, inherited from the inertial products from Colibrys is typically less than 0.1% of full-scale range.

Principle of operation

The core of the accelerometer is the capacitive bulk micro machined silicon sensor. The fundamental technology for the manufacturing of Colibrys accelerometers is based on the structuring of three silicon wafers:

- The center wafer supports the proof mass through a spring
- This inertial mass is also the center electrode of the capacitive sensor
- Upper and lower wafers constitute the external fixed electrodes of the sensor



The three wafers are bounded together by Silicon Fusion Bonding (SFB). This bonding process insures not only a perfect balance between the three wafers of the system but also allows building a hermetic sealed cavity for the spring–mass system. The bonding process is done at high temperature (>1000°C) and at low pressure to ensure an optimal gas damping and bandwidth control. This also allows to avoid any surface contaminant like water molecules in particular and to relax all surface stresses that could be present in the material prior bonding.

The measurement range of the “spring – mass” system is adaptable. Variations of open loop measurement ranges are obtained by modifying the thickness of the spring. Under acceleration or tilt the mass moves between the upper and lower electrodes and changes the values of the capacitors. This differential variation of the sensing capacitors is measured through the interface circuit, which uses a self-balancing capacitor bridge to translate the signal into a calibrated voltage output.

Conclusion

Colibrys is offering one of the best MEMS capacitive accelerometer for AHRS. Colibrys is continuously working on new products and new solutions. Thanks to the evolution of manufacturing techniques, the MEMS sensor element but also the assembly techniques and associated electronics are continuously improved specifically for optimizing bias stability (“in run” and “run to run” stability) required by numerous AHRS suppliers.

Key words

- AHRS: Attitude and Heading Reference Systems
- Stability: One year bias stability as small as few mg for a 10g sensor
- VRE: Vibration Rectification Error participating to overall bias stability
- T range: Wide temperature range from -55°C to 125°C
- Low power: Current consumption of 400µA at 5V

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