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MEMS Rate Sensors for Space

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ABSTRACT

Micromachined Electro Mechanical System (MEMS) Rate Sensors offer many advantages that make them attractive for space use. They are smaller, consume less power, and cost less than the systems currently available. MEMS Rate Sensors however, have not been optimized for use on spacecraft. This paper describes an approach to developing MEMS Rate Sensors systems for space use.

INTRODUCTION

Spacecraft designers are striving to replace traditional heavy, power-hungry mechanical gyro systems with lightweight and extremely reliable solid state rate sensing systems. One such system is the micromachined gyroscope. These systems offer extremely small size (about 8 in^3), low weight (less than 3 lbs.), low power (3 watts), and much lower cost then the existing technology gyros used in space applications.

Many satellites of the future will be much smaller than those currently being produced. Hundreds of "nano-satellites" launched and released into various orbits for space and earth science missions have been proposed. The mass and power budgets for these satellites will be less than what a single ACS component now consumes. The potential for small size and low cost of the MEMS rate sensor make it an attractive option for these future satellites.

Currently, MEMS Rate Sensor systems are being produced for terrestrial and missile applications. Therefore they have relatively coarse performance, a large rate range (up to 1000 deg/sec), and are not radiation hardened. Before this technology can be used for attitude control on spacecraft, design issues must be addressed.

To address these design issues, a program has been initiated at the GSFC that seeks to optimize the MEMS Rate Sensor for space use and develop a MEMS based Inertial Reference Unit (IRU) for space use. This paper will summarize the results to date of the optimization effort and describe two approaches for development of an IRU.

MEMS GYROS

Advances in micromachining have enabled the fabrication of very small, low cost inertial sensors. These MEMS "Gyros" sense angular rates by measuring coriolis forces acting on a vibrating mass. This vibrating mass or sensing element is typically etched in silicon or quartz which is driven electrostatically into oscillation. When a rate is applied to the sensor, the deflection of the sensing element due to coriolis forces is capacitively sensed. This deflection signal is proportional to the angular input rate of the sensor.

SYSTEMS AVAILABLE TODAY:

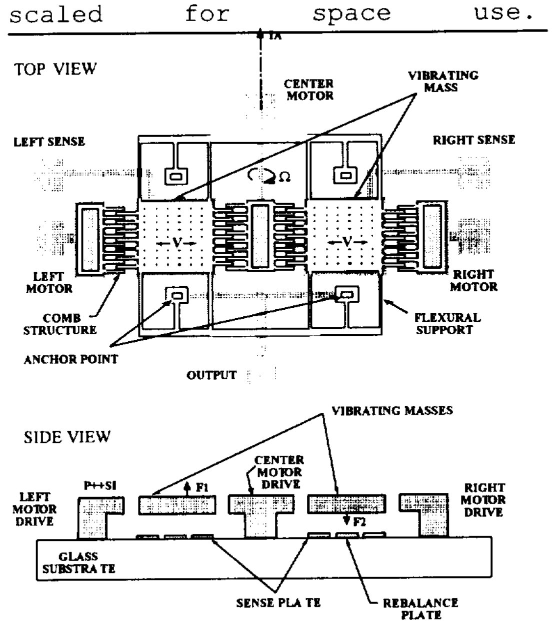
There are several microgyro based IRU systems available commercially. They combine microgyros, accelerometers, and some even include GPS navigation to provide position information. The size of these systems is on the order of 25 to 40 in^3. Their power consumption is less than 10 watts.

Several off the shelf units were obtained for testing and evaluation at the GSFC. One of the units obtained was the Systron Donner Motion Pak IMU. This unit combines three quartz tuning fork gyros with three quartz accelerometers. Also obtained was a Boeing Digital Quartz IMU (DQI) [1]. This unit uses quartz gyros built by Systron Donner that have better performance than those used in the Motion Pak IMU.

The most recent acquisition was that of the Boeing Beta Rate Sensor. It uses a silicon micromachined gyro developed by Draper Laboratory [2][3]. These gyros which are packaged individually, promise good performance and flexibility. Also, Draper continues to downsize and improve the performance of these units which will be used to produce a micro Inertial Measurement Unit (IMU).

The performance of microgyros is very coarse when compared to systems currently used for space applications. The market is driven by military and automotive customers where ultra low noise performance is not of prime concern. This low market demand and high performance requirement explains why few microgyro manufacturers have sought to provide space units.

As a result, the GSFC has sought to develop space microgyros by encouraging organizations who show interest in this area. Two manufacturers that have shown interest in developing space microgyros are Draper Laboratory and Kearfott Corp. Both have extensive experience in designing, building, and testing gyro systems for space and both are working with NASA/GSFC to produce microgyro systems for space. Draper is studying ways to optimize sensors for space while Kearfott is constructing a single axis sensor package with a dynamic range and bandwidth scaled for space use.



Draper Microgyro

MICROGYRO OPTIMIZATION FOR SPACE

Most of the Microgyro systems currently being produced are designed for automobiles and ballistic missiles. They have very high dynamic ranges (up to 1000 deg/sec) and high bandwidths (greater than 50 Hz). Spacecraft on the other hand, typically require a relatively low dynamic range (5 to 10 deg/sec) and can live with lower bandwidths (less than 10 Hz). Also, the performance of currently available units makes them useable in very limited applications.

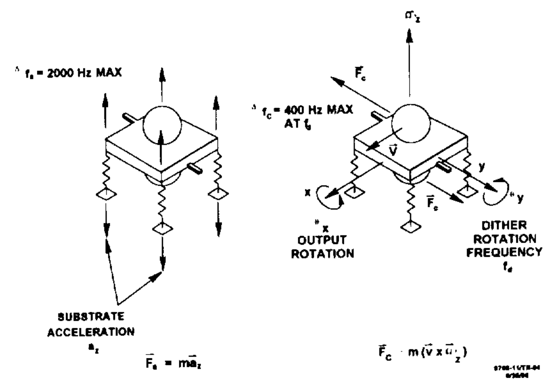
The Microgyro effort at GSFC seeks to improve the performance of Microgyro systems to a level that would be useful for spacecraft missions by optimizing both the gyro sensing element and the electronics. To this end, we have teamed with Kearfott to develop space specific gyro sensors. Also, the GSFC is also exploring ways to improve the performance of "off the shelf" units. Current efforts involve rescaling the dynamic range of existing sensors, optimizing the electronics for low noise, and filtering sensor output.

	Current	Goal
Bandwidth (deg/hr)	> 5Hz	> 5Hz
Angle Random Walk (deg/rt-Hz)	1	0.01
Bias (deg/hr)	40	0.1
Power (watts)	3	0.5

Kearfott is producing an engineering model microgyro scaled to +/- 10 degree/second dynamic range. It is hoped that lowering the dynamic range will improve the noise characteristics of the unit.

In the NASA/GSFC lab, we are experimenting with filtering the gyro output to improve noise performance.

In the future, redesign of the sensing element will be investigated as well as reducing bandwidth in an effort to further increase performance as well as making the unit radiation tolerant.



Kearfott Microgyro

GSFC DEVELOPMENT

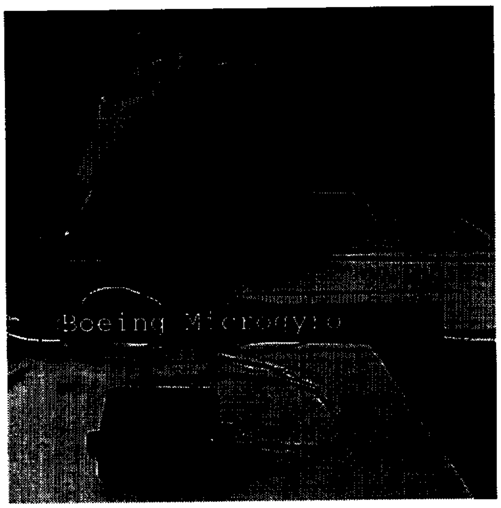
The GSFC is also working to develop an IRU from commercially available sensors. Two approaches for IRU development are presented. First, a 3 axis IRU packaged as a single unit is being assembled from 3 individual Microgyro modules. Second, one or more microgyro modules will be integrated onto an industry standard (compact PCI) board to produce a building block for a modular Attitude Control system (ACS).

MODULAR ACS IRU CARD:

With requirements for systems to be smaller, cheaper, and lower power, spacecraft designers are challenged to come up with innovative approaches to spacecraft systems. One such approach is the Modular ACS. The idea is to construct ACS building blocks using a standard interface. Each board will provide one or more ACS functions. This approach will minimize the amount of redesign necessary for new spacecraft.

MICRO IRU:

A micro Inertial Reference Unit (IRU) will be fabricated from 3 single microgyro modules, a power supply, and interface electronics. The overall size of the IRU will be 27 in^3. The unit will weigh about 1 lb. and consume about 3 watts.



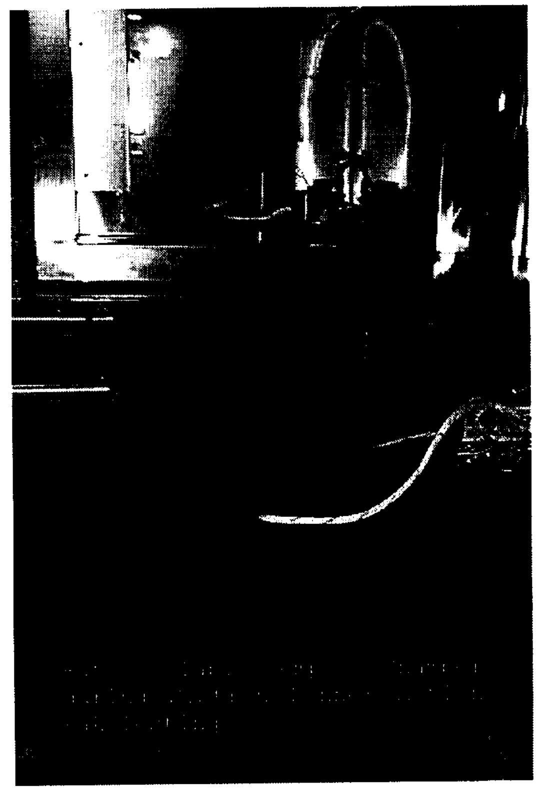
The first prototype IMU will be constructed using gyro modules built by Boeing. These units operate from a single +5 volt supply and provide a voltage output which is linear over the input rate dynamic range. Preliminary testing indicates the need for filtering of this output to reduce high frequency noise.

CONCLUSIONS

Due to low demand and high performance requirements, few vendors are interested in developing microgyro systems for space applications.

The performance of currently available microgyro systems is adequate for only a small number of space applications but the advantages offered by this technology justify further development.

Future work will be done to characterize the effects of reducing dynamic range and bandwidth. Development will continue as advances are made in sensor design.



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