

09/16/99



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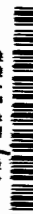
PROVISIONAL APPLICATION FOR PATENT COVER SHEET
(Small Entity)

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (b)(2).

Docket Number		USP9952A-GNC		Type a plus sign (+) inside this box →		+	
INVENTOR(s)/APPLICANT(s)							
LAST NAME		FIRST NAME		MIDDLE INITIAL		RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)	
McCall LIN		Hiram Ching		Fang		Chatsworth, California Chatsworth, California	
TITLE OF THE INVENTION (280 characters max)							
MicroElectroMechanical System for measuring Angular Rate							
CORRESPONDENCE ADDRESS							
108 N. Ynez Ave., Suite 128 Monterey Park							
STATE		CA		ZIP CODE		91754	
COUNTRY		United States					
ENCLOSED APPLICATION PARTS (check all that apply)							
☒ Specification		Number of Pages		17		☒ Small Entity Statement	
☒ Drawing(s)		Number of Sheets		6		☐ Other (specify) _____	
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT (check one)							
☒ A check or money order is enclosed to cover the filing fees						FILING FEE AMOUNT	
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60/154700



09/16/99

The invention was made by an agency of the United States Government or under a contract with an agency of the United States

☒ No.☐ Yes, the name of the U.S. Government agency and the Government contract number _____

Respectfully submitted,

SIGNATURE

Date

09/17/1999

TYPED or PRINTED NAME Raymond Y. Chan

REGISTRATION NO.
(if appropriate)

37,484

☐ Additional inventors are being named on separately numbered sheets attached hereto**USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT**

SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, DC 20231

In the United States Patent and Trademark Office

Mailed 1999 Sep 18

Commissioner of Patents and Trademarks
Washington, District of Columbia 20231

Sir:

Please file the following enclosed provisional patent application papers:

Applicant #1 Name: HiramMcCall

Applicant #2 Name: Ching-Fang Lin

Title: MicroElectromechanical System for Measuring Angular Rate

☒ Specification, Claims, and Abstract: No. of Sheets 17

☐ Declaration: Date Signed _____

☒ Drawing(s): Nr. Of Sheets Enc.: (In Triplicate): Formal: _____ Informal: 6

☒ Small Entity Declaration of Inventor(s) SED of Non-Inventor/Assignee/Licensee

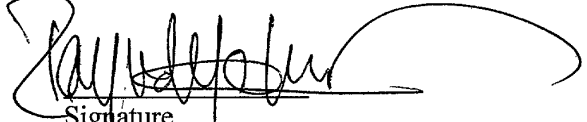
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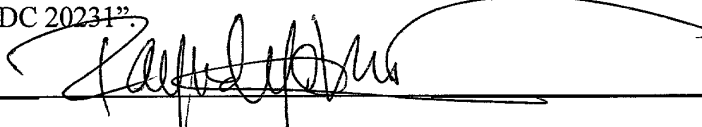
Very respectfully,


Signature
Raymond Y.C. Chan
Reg. Nr.: 37,484

516 San Luis Rey Road
Arcadia, CA 91007

Express Mail Label # EJ754294576US ; **Date of Deposit** 09/18/1999

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Serial or Patent No.: _____ Docket No.: USP9952A-GNC
Filed or Issued: _____
For: _____

**VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY
STATUS (37 CFR 1.9 (f) and 1.27 (b)) – INDEPENDENT INVENTOR**

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9 (c) for purposes of paying reduced fees under section 41 (a) and (b) of Title 35, United States Code, to the Patent and Trademark Office with regard to the invention entitled:
MicroElectroMechanical System for Measuring Angular Rate described in:

- ☒ the specification filed herewith
☐ application serial no. _____, filed _____
☐ patent no. _____, issued _____

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who could not be classified as an independent inventor under 37 CFR 1.9 (c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9 (d) or a non profit organization under 37 CFR 1.9 (e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

- ☐ no such person, concern, or organization
☒ person, concern or organizations listed below*

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

FULL NAME American GNC Corporation
ADDRESS 9131 Mason Ave., Chatsworth, CA 91311
☐ INDIVIDUAL ☒ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

FULL NAME _____
ADDRESS _____
☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

FULL NAME _____
ADDRESS _____
☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28 (b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statements is directed.

Hiram McCall Ching-Fang Lin
NAME OF INVENTOR NAME OF INVENTOR NAME OF INVENTOR

Hiram McCall Ching-Fang Lin
Signature of Inventor Signature of Inventor Signature of Inventor

Sept 18, 1999 Sept 18, 1999
Date Date Date

Title

A MicroElectroMechanical System for Measuring Angular Rate

Background of the Present Invention

5 Field of the Present Invention

10 The present invention relates to a microelectromechanical system (MEMS), more particularly, relates to a microelectromechanical system (MEMS) to measure angular rate. The system of the present invention includes an angular rate sensor unit, microeleronic circuitry, and signal processing to obtain highly accurate, sensitive, stable angular rate measurement under dynamic environments.

Description of Related Arts

15 It can obtain angular rate measurement to employ a conventional gyro. Many types of approaches based on various sensing principles used to achieve a angular rate sensor have been invented in the past decades, are currently being invented, and will continue to be invented as the market for angular rate sensors continues to expand. For example, conventional spinning mass gyros are principally based on the Law of the Gyroscopic. Existing ring laser gyros and Interferometric Fiber-Optic Gyros are dependant on the Sagnac Effects.

20 Angular rate sensors have been commonly used in wide variety of applications, their cost, size, and power prohibits them from emerging commercial applications.

 "MEMS" stands for "MicroElectroMechanical Systems", or small electrical/mechanical devices. MEMS devices involve creating controllable mechanical and movable structures using IC (Integrated Circuit) technologies. MEMS includes the

concepts of Microelectronics and Micromachining. Example MEMS devices include inkjet-printer cartridges, accelerometers that deploy car airbags, and miniature robots.

Microelectronics, the development of electronic circuitry on silicon chips, is a very well developed technology. Micromachining utilizes process technology developed by the integrated circuit industry to fabricate tiny sensors and actuators on silicon chips. In addition to shrinking the sensor size by several orders of magnitude, integrated electronics can be added to the same chip, creating an entire system on a chip. This instrument will result in, not only the redesign of conventional military products, but also new commercial applications that could not have existed without small, inexpensive inertial sensors.

Some MEMS angular rate sensors approach have been developed to meet the need for inexpensive yet reliable angular rate sensors in fields ranging from automotive to consumer electronics. Single input axis MEMS angular rate sensors are based on either translational resonance, such as tuning forks, or structural mode resonance, such as vibrating rings. Moreover, dual input axis MEMS angular rate sensors may be based on angular resonance of a rotating rigid rotor suspended by torsional springs. The inherent symmetry of the circular design allows angular rate measurement about two axes simultaneously.

However, it is still very challenging work to design and manufacture a MEMS angular rate sensor with high accuracy, keen sensitivity, wide dynamic range, and high stability.

Summary of the Present Invention

5 A main objective of the present invention is to provide a system to measure angular rate, wherein angular rate sensor unit, microelectronic circuitry, and signal processing are fabricated into one silicon chip with surface micromachining layers of polysilicon and Integrated circuitry (IC) technology to obtain highly accurate, sensitive, stable angular rate measurement under dynamic environments.

Compared with existing MEMS angular rate sensor, the MEMS angular rate sensor of the present invention has several unique features that are described as follows:

- 10 1. Hinge to minimize number of resonance modes.
2. Mass distribution for resonance mode linearity.
3. Resonance mode locking circuitry.
4. Displacement regulation for scale factor stability.
5. Temperature stabilization for scale factor and bias stability.
- 15 6. Low mechanical damping through moderate vacuum.
7. Pickoff circuitry to minimize bias and scale factor shift.
8. The same driver comb used for both excitation and dither pickoff.
9. Closed loop design for scale factor linearity.

20 Another objective of the present invention is to provide a microelectromechanical system to measure angular rate. The present invention enables the core micro IMU, which has the following unique features:

- (1) Attitude Heading Reference System (AHRS) Capable Core Sensor Module.

(2) Miniaturized (Length/Width/Height) and Light Weight.

(3) High Performance and Low Cost.

(4) Low Power Dissipation.

(5) Dramatic Improvement In Reliability (microelectromechanical systems -MEMS).

5 Another objective of the present invention is to provide a microelectromechanical system to measure angular rate. The present invention enables the core micro IMU to be into an integrated micro land navigator, which has the following unique features:

(1) Miniature, light weight, low power, low cost.

10 (2) AHRS, odometer, integrated GPS chipset and flux valve.

(3) Integration filter for sensor data fusion and zero velocity updating.

(4) Typical applications: automobiles, railway vehicles, miniature land vehicles, robots, unmanned ground vehicles, personal navigators, and military land vehicles.

15 Another objective of the present invention is to provide a microelectromechanical system to measure angular rate. The present invention enables the core micro IMU to function as aircraft inertial avionics, which has the following unique features:

(1) Rate Gyro

20 (2) Vertical Gyro

(3) Directional Gyro

(4) AHRS

- (5) IMU
- (6) Inertial Navigation System
- (7) Fully-Coupled GPS/MEMS IMU Integrated System
- (8) Fully-Coupled GPS/IMU/Radar Altimeter Integrated System
- 5 (9) Universal vehicle navigation and control box.

Another objective of the present invention is to provide a microelectromechanical system to measure angular rate. The present invention enables the core micro IMU to be a Spaceborne MEMS IMU Attitude Determination System and a Spaceborne Fully-Coupled GPS/MEMS IMU Integrated system for orbit determination, attitude control, payload pointing, and formation flight, which has the following unique features:

- (1) Shock resistant and vibration tolerant
- (2) High anti-jamming
- (3) High dynamic performance
- 15 (4) Broad operating range of temperatures
- (5) High resolution
- (6) Compact, low power and light weight unit
- (7) Flexible hardware and software architecture

Another objective of the present invention is to provide a microelectromechanical system to measure angular rate. The present invention enables the core micro IMU to be a marine INS with embedded GPS, which has the following unique features:

- (1) Micro MEMS IMU AHRS with Embedded GPS
- (2) Built-in CDU (Control Display Unit)
- (3) Optional DGPS (Differential GPS)
- (4) Flexible Hardware and Software System Architecture
- 5 (5) Low Cost, Light Weight, High Reliability

Another objective of the present invention is to provide a microelectromechanical system to measure angular rate. The present invention enables the core micro IMU to be used in a micro pointing and stabilization mechanism, which has the following unique features:

- 10 (1) Micro MEMS IMU AHRS utilized for platform stabilization.
- (2) MEMS IMU integrated with the electrical and mechanical design of the pointing and stabilization mechanism.
- (3) Vehicle motion, vibration, and other interference cancelled by a stabilized platform.
- 15 (4) Variable pointing angle for tracker implementations.
- (5) Micro MEMS IMU utilized for a micro fire control system for sniper rifles.

Typical applications: miniature antenna pointing and tracking control, laser beam pointing for optical communications, telescopic pointing for imaging, airborne laser pointing control for targeting, vehicle control and guidance.

- 20 The present invention can be used as a motion measurement device for both commercial and government systems require phased array antenna systems for communication on-the-move. Specific applications include pointing control systems for mobile satellite reception for truckers and radiotelephone and direct broadcast satellite

reception. The development of a low cost attitude and heading reference system is critical to wide deployment of these systems in the commercial arena.

SECRET

Brief Description of the Drawings

Figure 1 shows the functional structure of the present invention.

Figure 2 shows the configuration of a Micromachined sensor unit.

Figure 3 shows variable capacitive signal picking off point connection design.

5 Figure 4 shows a picture of the packaged MEMS angular rate sensor.

Figure 5 illustrates cross sectional view showing layers of the surface machined fabrication process of a MEMS.

Figure 6 shows the diagram of the central circuitry.

Figure 7 shows the diagram of digital processing system

10

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Patent Application No. 2024/00667

Detailed description of the Preferred Embodiment

The present invention will be described as it applies to its preferred embodiment. It is not intended that the present invention be limited to the described
5 embodiment. It is intended that the invention cover all alternatives, modifications, and equivalences which may be included within the spirit and scope of the invention.

The present invention relates to a microelectromechanical system (MEMS), more particularly, relates to a microelectromechanical system (MEMS) to measure angular rate.

10 Referring to Figure 1, the system of the present invention includes an angular rate sensor unit 10, a central circuitry 20, and a digital signal processing system 30, which are fabricated into one chip using standard surface machining technology to obtain highly accurate, sensitive, stable angular rate measurement under dynamic environments.

15 The angular rate sensor unit can be a micromachined sensor unit. In principle, the present invention may incorporate with MEMS technology that employs a dynamic theory, Coriolis effect. The Coriolis effect is that when an angular rate is applied to a translating body, a Coriolis force is generated. Its principle of operation and construction feature is tuning fork type that uses closed-loop capacitive sensing.

20 The MEMS of the present invention measures angular rate by picking-off a signal generated by an oscillating micromachined mass as it deviates from its plane of oscillation under the Coriolis force effect when the oscillating micromachined mass is submitted to a rotation about an axis perpendicular to the plane of oscillation.

Referring to Figure 2, which illustrates the configuration of the micromachined sensor unit.

25 The micromachined sensor unit 10 consists of two vibration devices which have opposite dither motion directions, thus a pair of differential measurements are formed to

eliminate the effect of the gravity and acceleration induced interference force. The proof masses are suspended by eight beams which also provide the plastic force for the vibration at the same time. The beam are attached to the substrate by anchors on the middle of the beams.

5 Two vibrating proof masses are attached by springs to each other and to the surrounding stationary material. The vibrating (dither) proof masses are driven in opposite directions by electrostatic comb drive motors to maintain lateral in-plane oscillation. The dither motion is in the plane of the wafer. When an angular rate is applied to the MEMS device about the input axis (which is in the plane of the tines), the proof
10 masses are caused to oscillate out of plane by a Coriolis force due to Coriolis effect. The resulting out-of-plane up and down oscillation motion amplitude, proportional to the input angular rate, is detected and measured by capacitive pickoff plates underneath the proof masses. The comb drives move the masses out of phase with respect to each other. The masses will then respond in opposite directions to the Coriolis force.

15 The circuitry detects this perpendicular motion by measuring the change in capacitance. The sensitivity of the device is dependent on the amplitude of the dither motion, the frequency of the oscillation, the mass of the device and the detection method. The sensitivity is proportional to the product of the velocity of the device and the angular rate. Maximizing the amplitude and frequency of oscillation increases the sensitivity. To
20 increase the amplitude of oscillation, the device is run at the resonant frequency of the supporting springs. This minimizes the energy required to drive the device. If the resonant frequency is too high (stiff springs) the perpendicular motion of the device is decreased. Typical resonant frequencies are 1000 –3000 Hz. Some error can occur in the device if the dither motion is not truly linear.

25 The change in capacitance caused by the motion of the mass in response to a coriolis force is determined by measuring the current flow from a high frequency signal (100 kHz to 1 MHz). The capacitance is on the order of 0.5 pf with changes in capacitance on the order of 1 ff. In order to achieve the greatest sensitivity, the design of the present invention places the electronics as close as possible to the pickoff electrodes

on the device. In the MEMS of the present invention, this is done by either integrating the electronics on the same wafer as the micromachined sensor unit or by placing the electronics as close as possible to the sensor package. On chip electronics can detect changes in motion on the order of angstroms.

5 Referring to Figure 2, the micromachined sensor unit 10 comprises:

1. two proof masses, which are attached with beam spring to eight anchor points and driven by the three stators to oscillate to sense Coriolis force.
2. Eight anchor points, which are scattered both sides of the two proof masses and connected with the silicon substrate and to support the two proof masses
10 through beam strings.
3. A big anchor pad, which is connected with the silicon substrate and is connected with the four anchor points through beam strings to improve and stabilize the oscillating of the two proof masses.
4. Two small anchor pads, which are connected with the silicon substrate and are connected with the four anchor points through beam strings to improve
15 and stabilize the oscillating of the two proof masses.
5. Three stators, which are connected with the silicon substrate and drive the two proof masses through the comb drives.

20 When an angular rate is applied about the angular rate input axis of the micromachined sensor unit, the changed-capacitive signal can be picked up.

Referring to Figure 3, totally, six capacitors are formed by the micromachined sensor unit structure. Among them, four capacitors are formed by the two proof masses and three stators to construct four pair of drive combs for the vibration drive mechanism. Two capacitors are formed by two pair of proof masses and sensor electrodes. When
25 there is an angular rate in the gyro input axis, one proof mass will move towards its electrode and the other moves away from its electrode under the Coriolis force. Thus the two sensor capacitors can be used to form a differential measurement circuit.

Two techniques are presently employed to fabricate MEMS devices; bulk micromachining and surface micromachining. The preferred MEMS fabrication of the present patent is the surface micromachining process. Surface micromachined devices are typically a few microns to 10 microns thick. Angular rate sensors created with surface machining have very low masses. The advantage of surface machining is the low cost and the ease of incorporating the electronics close to the sensor.

In surface micromachining, the sensor element is built onto the surface of a silicon wafer. To build a surface micromachined sensor, a few μm thick layer of sacrificial oxide is deposited on the passivation layer of a silicon wafer, in which n^+ wells have been previously diffused. Openings are then etched through both insulators to the diffused areas in the substrate. A thick layer of polysilicon is subsequently deposited over the entire sensor area, filling the openings and establishing both a mechanical and electrical bond with the n^+ diffused areas. The sensing elements are then etched into the layer of "floating" polysilicon. The sacrificial oxide is subsequently removed from under the polysilicon through further etching, leaving the polysilicon layer essentially suspended in mid-air, yet still attached to the substrate via the anchor posts, or pedestals, formed at the points of diffusion.

Surface micromachining starts with a wafer of material. In surface micromachining the wafer is the substrate --- the working surface --- on which multiple, alternating layers of structural and sacrificial material are deposited and etched. A typical cycle in a surface micromachining process begins with a deposition of either the sacrificial material, a material which will be completely removed in the final step of the fabrication process, or structural material, a material from which the functional components of the MEMS will be constructed. The layer is then masked with a desired pattern which is typically transferred using a photolithographic process, usually the exposure of a photosensitive material and development of the exposed photoresist. Next, the underlying material, not protected by the masking pattern, is etched, typically by reactive ion etching, a sort of sand blasting with ions, to transfer the mask pattern to that particular material layer. The deposition-masking-etching cycle is repeated on all laminated layers of structural and sacrificial materials until the MEMS angular rate

sensor is complete. The final step in surface micromachining is the release of the structural material from the laminations by etching or removing the underlying and surrounding sacrificial materials.

The most commonly used surface micromachining processes starts with silicon wafers of the same grade and type used in microelectronics fabrication and uses layers of silicon dioxide as the sacrificial material and layers of polysilicon, a deposited, less crystalline form of silicon, as the structural material. Other deposited materials such as silicon nitride, polyimides, and aluminum are also used to provide electrically insulating materials, conducting materials, etchant masks, and additional structural materials. All of these materials are extensively used and available in standard microelectronics fabrication.

Because of the laminated structural and sacrificial material layers and the etching of material done by a process that is insensitive to crystalline structure, either because of the etch or because the material itself is non-crystalline, surface micromachining enables the fabrication of free form, complex, and multi-component integrated MEMS structures, liberating the MEMS designer to envision and build devices and systems that are impossible to realize with bulk process. Surface micromachining also frees the process developer and device designer to choose any material system that has complementary structural and sacrificial materials. It is this freedom to fabricate devices and systems without constraints on materials, geometry, assembly and interconnections that is the source for the richness and depth of MEMS applications that cut across so many areas.

The major problem with angular rate sensors is reliably moving the masses. Unlike accelerometers that are passive devices, rate sensors are active devices. All actuation is done with electrostatic forces. These forces are very weak so something can impede the motion of the masses. Problems can occur from dust or from the device not being properly cleaned. The surface machined device is made by separating all moving parts with a sacrificial oxide. The final step in the processing is the removal of this oxide. Once the oxide is removed the etching solution has to be completely removed with

water and then the water has to be removed with alcohol. The alcohol then has to be removed completely by drying the device. If the solutions are not properly removed than stiction occurs impeding the motion of the device making it unusable. The device can also be susceptible to the squeeze-film effect. If the device is run in atmosphere the movement of the device can be impeded by the inability of the trapped gas to move when the device moves. Many of these devices are packaged in a vacuum environment. Getters are usually employed in the package to maintain the quality of the vacuum. The use of a vacuum can degrade the device's resistance to shock though. Air damping increases shock resistance.

10 The MEMS gyro prototypes of the present invention was fabricated through the MCNC MUMPS program. The program fabricates a device according to per submitted drawings, release the device, and package the sensor. The program also can integrate the device with their ASIC in a flip chip assembly. MCNC also serves as a foundry for the MEMS community. The MUMPs process is a three-layer polysilicon surface micromachining process derived from work performed at the Berkeley Sensors and
15 Actuators Center (BSAC) at the University of California. Several modifications and enhancements have been made to increase the flexibility and versatility of the process for the multi-user environment.

Figure 4 shows a picture of the packaged MEMS angular sensor of the present
20 invention.

Referring to Figure 5, which is a cross section of the three-layer polysilicon surface micromachining MUMPs process. This process has the general features of a standard surface micromachining process: (1) polysilicon is used as the structural material, (2) deposited oxide (PSG) is used as the sacrificial layer, and silicon nitride is used as electrical isolation between the polysilicon and the substrate. The process is
25 different from most customized surface micromachining processes in that it is designed to be as general as possible, and to be capable of supporting many different designs on a single silicon wafer. Since the process was not optimized with the purpose of fabricating any one specific device, the thickness of the structural and sacrificial layers were chosen

to suit most users, and the layout design rules were chosen conservatively to guarantee the highest yield possible.

Referring to Figure 1, the MEMS angular rate sensor of the present invention comprises an angular rate sensor unit 10, a central circuitry 20, and a digital signal processing system 30.

Referring to Figure 6, the central circuitry 20 comprises a dither motion control circuitry 21 and an angle signal loop circuitry 22.

Referring to Figure 6, the dither motion control circuitry 21 comprises:

a trans impedance amplifier circuit, connected to the Angular rate sensor unit 10, for changing an output impedance of the dither motion signals from a very high level, greater than 100 million ohms, to a low level, less than 100 ohms to achieve two dither displacement signals which are A/C voltage signals representing the displacement between the inertial elements and the anchor combs ;

a first amplifier and summer circuit, connected to the trans impedance amplifier circuit, for more than ten times amplifying the two dither displacement signals and enhancing the sensitivity for combining the two dither displacement signals to achieve a dither displacement differential signal by subtracting a center anchor comb signal with a side anchor comb signals;

a first high-pass filter circuit, connected to the first amplifier and summer circuit, for removing residual dither drive signals and noise from the dither displacement differential signal to a filtered dither displacement differential signal;

a demodulator circuit, connected to the high-pass filter circuit, for receiving the capacitive pickoff excitation signals as phase reference signals from an oscillator and the filter dither displacement differential signal from the first high-pass filter, and extracting the in-phase portion of the filtered dither displacement differential signal to produce an inertial element displacement signal with known phase;

a first low-pass filter, connected to the demodulator circuit, for removing high frequency noise from the inertial element displacement signal input thereto to form a low frequency inertial element displacement signal, such as less than 3000 Hz; and

an analog/digital converter, connected to the first low-pass filter, for converting the low frequency inertial element displacement signal that is an analog signal to produce a digitized low frequency inertial element displacement signal as a digital sampled signal.

Referring to Figure 6, the angle rate signal loop circuitry 22 comprises:

5 a second high-pass filter circuit, connected to the Angular rate sensor unit, for removing low frequency noise of the angle rate signals which are voltage singals output from the Angular rate sensor unit thereto to form filtered angle rate signals;

a voltage amplifier circuit, connected to the second high-pass filter circuit, for amplifying the filtered angle rate signals to an extent of at least 100 milivolts to form
10 amplified angle rate signals;

an amplifier and summer circuit, connected to the voltage amplifier circuit, for subtracting the difference between the angle rates of the amplified angle rate signals to produce a differential angle rate signal;

a demodulator, connected to the amplifier and summer circuit, for extracting the
15 amplitude of the in-phase differential angle rate signal from the differential angle rate signal and the reference signal from the oscillator.

a low-pass filter, connected to the demodulator, for removing the high frequency noises of the amplitude signal of the in-phase differential angle rate signal to forms angular rate signal output.

20 an integrator, connected with the low-pass filter, for integrating the angular rate signal to forms a displace restoring signal without an offset.

a driver amplifier, connected the integrator, for amplifying the displace restoring signal without an offset to forms a driving signal to the Angular rate sensor unit.

Referring to Figure 7, the digital signal processing system 30 comprises:

a discrete Fast Fourier Transform (FFT) module, receiving the digitized low frequency inertial element displacement signal from the analog/digital converter of dither motion control circuitry 21 to form amplitude data with the frequency spectrum of the input inertial element displacement signal.

- 5 a memory array of frequency and amplitude data module, receiving the amplitude data with frequency spectrum to form an array of amplitude data with frequency spectrum.

- 10 a maxima detection logic module to process the array of the amplitude data with frequency spectrum to choose those frequencies with the largest amplitudes in the local segment of the frequency spectrum from the array of the amplitude data with frequency spectrum.

- 15 a Q analysis and selection logic module to perform Q analysis on the chosen frequencies to select frequency and amplitude by computing the ratio of amplitude/area. The range for computing area is between $\pm 1/2$ of the peak for each maximum frequency point.

a phase-lock loop to serve as a very narrow bandpass filter to reject noise of the selected frequency, to form a dither drive signal with the selected frequency.

a D/A converter to process the selected amplitude to form a dither drive signal with correct amplitude.

- 20 an amplifier to generate and amplify the dither drive signal to the Angular rate sensor unit based on the dither drive signal with the selected frequency and correct amplitude.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Hiram McCall and Ching-Fang Lin

Filing Date: _____

Serial No.: _____

Examiner: _____

Art Unit: _____

Title: MicroElectroMechanical System for Measuring Angular Rate

To: The Commissioner of
Patents and Trademarks
Washington, D.C. 20231

POWER OF ATTORNEY BY INVENTOR

As a named inventor of the above identified application, I hereby appoint the following attorney(s) and/or agent(s) to prosecute and transact all business in the Patent and trademark Office connected with the above application:

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Hiram McCall
Name of Person Signing: Hiram McCall

Sept 18, 1999
Date

Ching-Fang Lin
Name of Person Signing: Ching-Fang Lin

Sept 18, 1999
Date

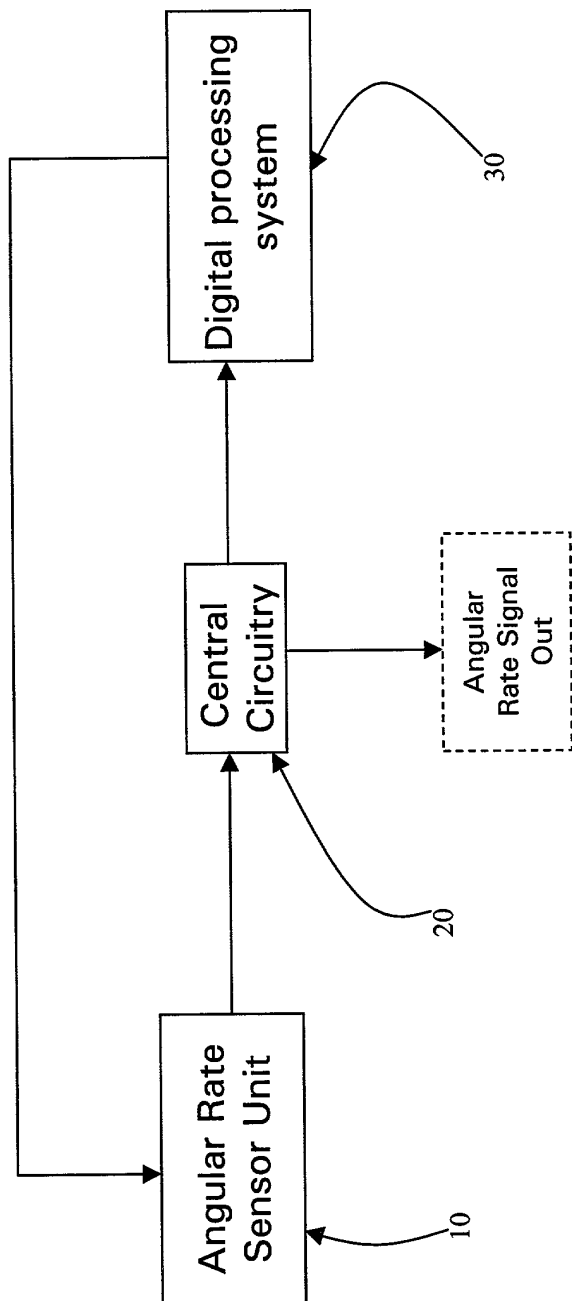


Figure 1

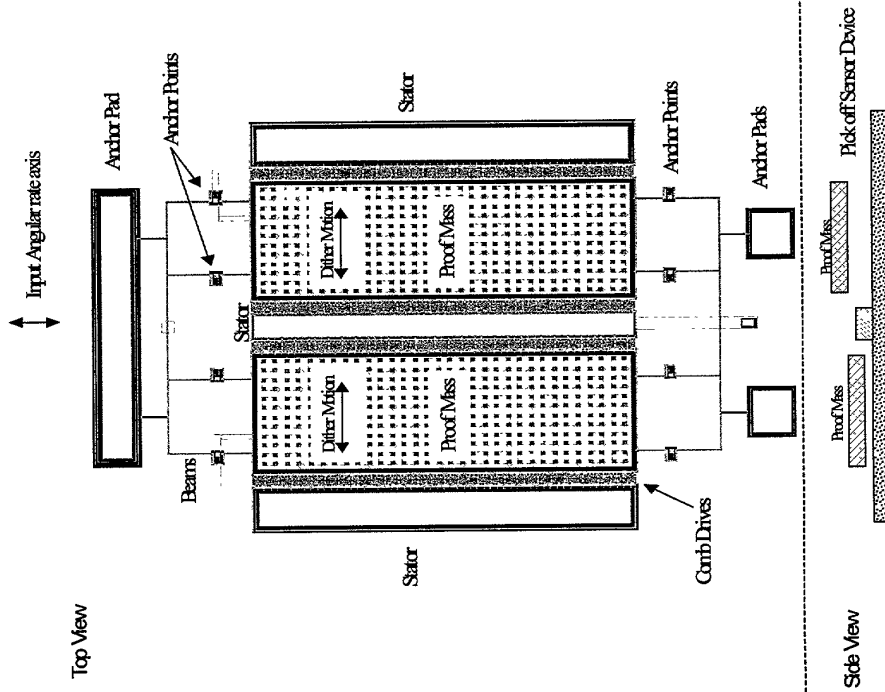


Figure 2

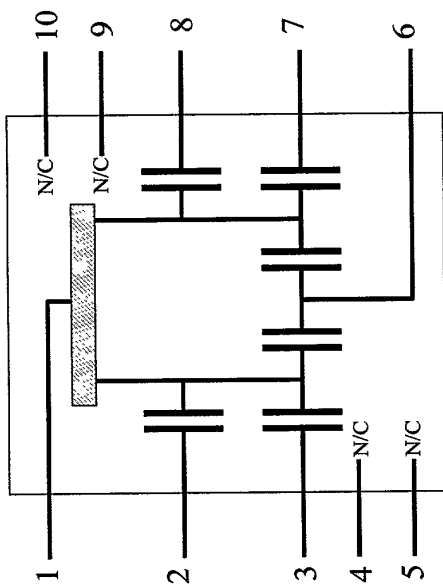


Figure 3

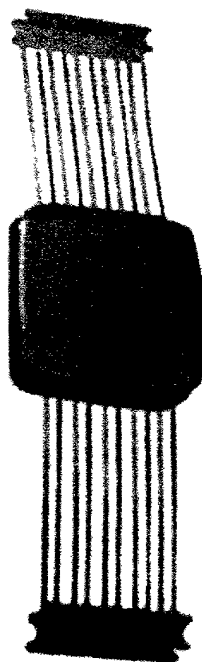


Figure 4

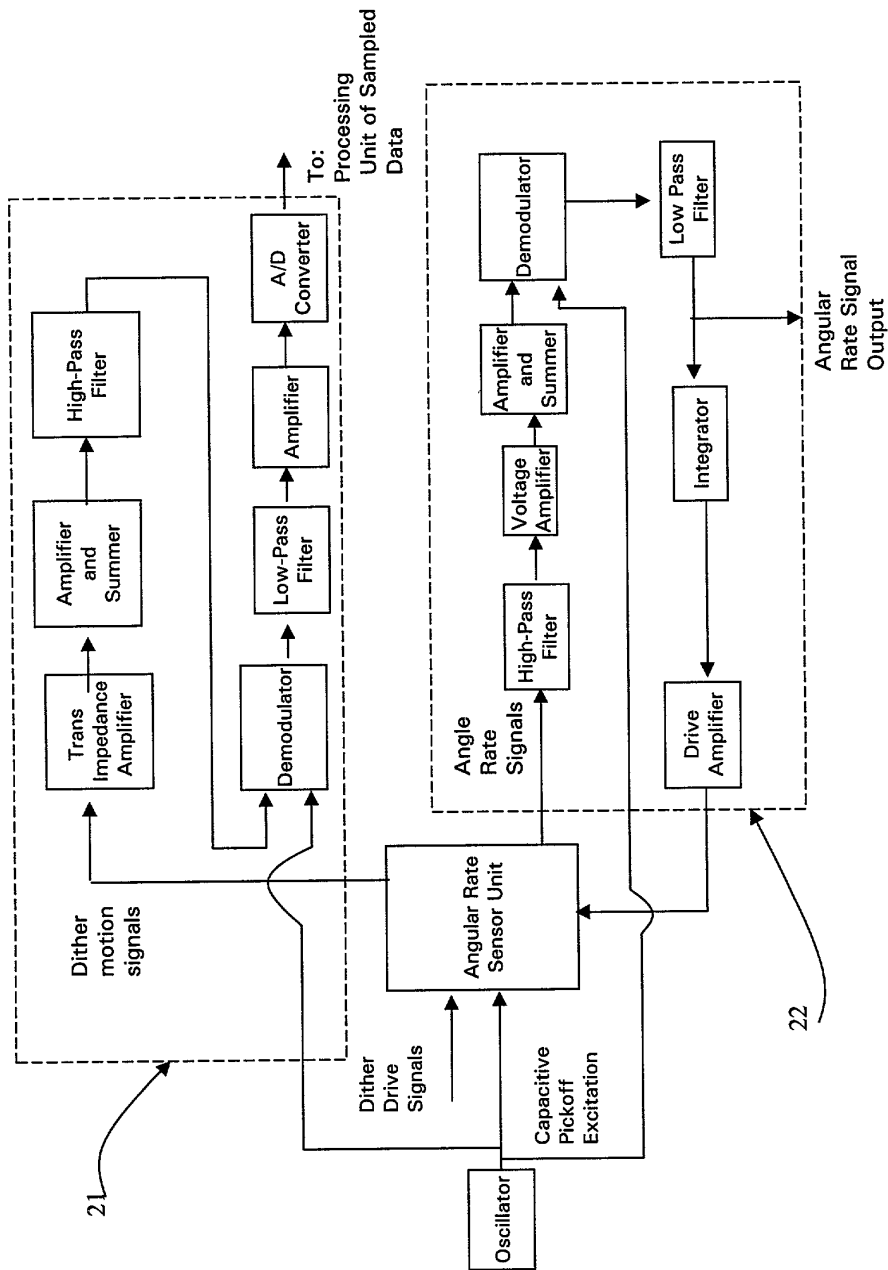


Figure 6

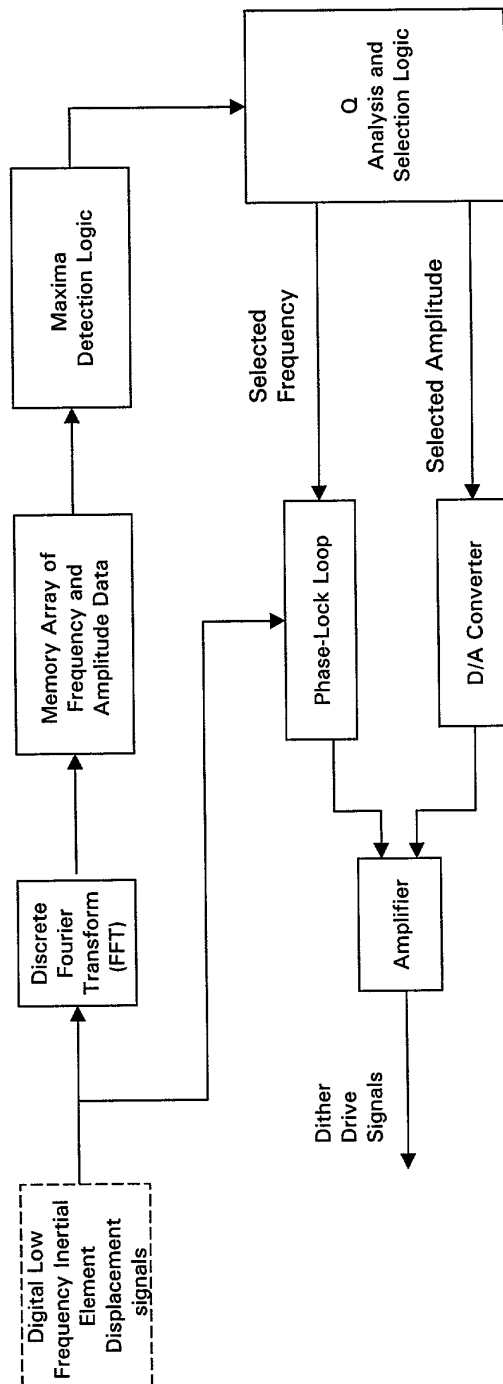


Figure 7