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PATENT NUMBER and
ISSUE DATE
6671648

U.S. UTILITY Patent Application

APPL NUM	FILING DATE	CLASS	SUBCLASS	GAU	EXAMINER
10017310	10/22/2001	702	1411	2857	<i>[Signature]</i>

**APPLICANTS: McCall Hiram; Lin Ching-Fang; 2863

**CONTINUING DATA VERIFIED:

THIS APPLICATION IS A DIV OF 09/477,151 01/04/2000

Certificate
MAR 21 2017
of Correction

** FOREIGN APPLICATIONS VERIFIED:

NOTE-DISCLAIMER
The term of this patent shall not extend
beyond the expiration date
of Pat. No. 6,456,939

PG-PUB DO NOT PUBLISH ☐	RESCIND ☐
Foreign priority claimed ☐ yes ☒ no	ATTORNEY DOCKET NO
35 USC 119 conditions met ☐ yes ☒ no	USDP1699A-GNC
Verified and Acknowledged Examiners's initials	
TITLE : Micro inertial measurement unit	

U.S. DEPT. OF COMM./PAT & TM-PTO-436L (Rev. 12-04)

NOTICE OF ALLOWANCE MAILED 7/14/03		CLAIMS ALLOWED Total Claims 4 Print Claim for O.G. 1	
ISSUE FEE Amount Due \$950 Date Paid 10/13/03		DRAWING Sheets Drwg. 26 Figs. Drwg. 26 Print Fig. 1	
☒ TERMINAL DISCLAIMER ISSUE FEE IN FILE		BRYAN BUI PRIMARY EXAMINER <i>[Signature]</i> Primary Examiner PREPARED FOR ISSUE Application Examiner <i>[Signature]</i>	
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0-101-100-1
10017310

JCS58 U.S. PAT
10/017310
10/22/01

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INITIALS _____

CONTENTS

	Date Received (incl. C. of M.) or Date Mailed	Date Received (incl. C. of M.) or Date Mailed
1. Application <u>26</u> papers.		
2. <u>Pre-Auth A</u>	<u>2-12-02</u>	
3. <u>Rejection (3 nos)</u>	<u>03/17/03</u>	
4. <u>Response</u> <u>6-16-03</u>	<u>6-18-03</u>	
5. <u>Terminal Disclaimer</u>	<u>6-18-2003</u>	
6. <u>Alliance</u>	<u>7-14-03</u>	
7. <u>Chp of cddr</u>	<u>10/3/03</u>	
8. <u>Request Gr Life</u>	<u>12/19/2016</u>	
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PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

12/20/2001 VTRUDNG1 00000019 10017310

01 FC:201 370.00 DP

PTO-1556
(5/87)

*U.S. GPO: 1999-450-062/19144



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Bib Data Sheet

CONFIRMATION NO. 7211

SERIAL NUMBER 10/017,310	FILING OR 371(c) DATE 10/22/2001 RULE	CLASS 702	GROUP ART UNIT 2863	ATTORNEY DOCKET NO. USDP1699A-GNC
APPLICANTS Hiram McCall, Chatsworth, CA; Ching-Fang Lin, Chatsworth, CA;				
** CONTINUING DATA ***** This application is a DIV of 09/477,151 01/04/2000 PAT 6,456,939				
** FOREIGN APPLICATIONS *****				
IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** ** SMALL ENTITY ** 01/17/2002				
Foreign Priority claimed ☐ yes ☐ no 35 USC 119 (a-d) conditions ☐ yes ☐ no ☐ Met after met Allowance Verified and Acknowledged Examiner's Signature _____ Initials _____	STATE OR COUNTRY CA	SHEETS DRAWING 26	TOTAL CLAIMS 4	INDEPENDENT CLAIMS 1
ADDRESS David and Raymond Patent Group 108 N. Ynez Ave., Suite 128 Monterey Park, CA 91754				
TITLE MICRO INERTIAL MEASUREMENT UNIT				
FILING FEE RECEIVED 670	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:			
		☐ All Fees		
		☐ 1.16 Fees (Filing)		
		☐ 1.17 Fees (Processing Ext. of time)		
		☐ 1.18 Fees (Issue)		
		☐ Other _____		
		☐ Credit		



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Bib Data Sheet

CONFIRMATION NO. 7211

SERIAL NUMBER 10/017,310	FILING DATE 10/22/2001 RULE	CLASS 702	GROUP ART UNIT 2857 2863	ATTORNEY DOCKET NO. USDP1699A-GNC	
APPLICANTS Hiram McCall, Chatsworth, CA; Ching-Fang Lin, Chatsworth, CA;					
** CONTINUING DATA ***** THIS APPLICATION IS A DIV OF 09/477,151 01/04/2000					
** FOREIGN APPLICATIONS *****					
IF REQUIRED, FOREIGN FILING LICENSE GRANTED** SMALL ENTITY ** ** 01/17/2002					
Foreign Priority claimed ☐ yes ☒ no 35 USC 119 (a-d) conditions ☐ yes ☒ no ☐ Met after Allowance? Verified and Acknowledged <i>[Signature]</i> Examiner's Signature Initials		STATE OR COUNTRY CA	SHEETS DRAWING 26	TOTAL CLAIMS 4	INDEPENDENT CLAIMS 1
ADDRESS Raymond Y. C. Chan 1050 Oakdale Lane Arcadia, CA 91006					
TITLE Micro inertial measurement unit					
FILING FEE RECEIVED 370	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

10/22/01



PTO/SB/05 (03-01)
Approved for use through 10/31/2002. OMB 0651-0032
U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. USDP1699A-GNC

First Inventor Hiram McCall et al.

Title Micro Inertial Measurement Unit

Express Mail Label No. EL 745708005 US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☒ Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original and a duplicate for fee processing)
2. ☒ Applicant claims small entity status.
See 37 CFR 1.27.
3. ☒ Specification (preferred arrangement set forth below) [Total Pages 47]
 - Descriptive title of the invention
 - Cross Reference to Related Applications
 - Statement Regarding Fed sponsored R & D
 - Reference to sequence listing, a table, or a computer program listing appendix
 - Background of the invention
 - Brief Summary of the invention
 - Brief Description of the Drawings (if filed)
 - Detailed Description
 - Claim(s)
 - Abstract of the Disclosure
4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 26]
5. ☒ Oath or Declaration [Total Pages 1]
 - a. ☐ Newly executed (original or copy)
 - b. ☒ Copy from a prior application (37 CFR 1.63 (d))
(for continuation/divisional with Box 18 completed)
 - i. ☐ DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s)
named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☐ Application Data Sheet. See 37 CFR 1.76

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

7. ☐ CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix)
8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
 - a. ☐ Computer Readable Form (CRF)
 - b. Specification Sequence Listing on:
 - i. ☐ CD-ROM or CD-R (2 copies); or
 - ii. ☐ paper
 - c. ☐ Statements verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

9. ☐ Assignment Papers (cover sheet & document(s))
10. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney
11. ☐ English Translation Document (if applicable)
12. ☐ Information Disclosure Statement (IDS/PTO-1449) ☐ Copies of IDS Citations
13. ☐ Preliminary Amendment
14. ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
15. ☐ Certified Copy of Priority Document(s)
(if foreign priority is claimed)
16. ☐ Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. ☐ Other: _____

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:

☐ Continuation ☒ Divisional ☐ Continuation-in-part (CIP) of prior application No. 09, 477,151

Prior application information: Examiner Gertrude Arthur Group Art Unit: 3661

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

☐ Customer Number or Bar Code Label (PRINT Customer No. or Attach bar code label here) or ☒ Correspondence address below

Name	Raymond Y. C. Chan				
Address	1050 Oakdale Lane				
City	Arcadia	State	CA	Zip Code	91006
Country	USA	Telephone	626-571-9812	Fax	626-571-9813

Name (Print/Type)	Raymond Y. C. Chan	Registration No. (Attorney/Agent)	37,484
Signature		Date	10/22/01

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FEE TRANSMITTAL for FY 2002

Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT (\$)

370.00

Complete if Known

Application Number	
Filing Date	
First Named Inventor	Hiram McCall et al.
Examiner Name	
Group Art Unit	
Attorney Docket No.	USDP1699A-GNC

METHOD OF PAYMENT

1. ☐ The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number

Deposit Account Name

☐ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

☒ Applicant claims small entity status. See 37 CFR 1.27

2. ☒ Payment Enclosed:

☒ Check ☐ Credit card ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE				
Large Entity		Small Entity		Fee Description
Fee Code (\$)	Fee Code (\$)	Fee Code (\$)	Fee Code (\$)	Fee Description
101	740	201	370	Utility filing fee
106	330	206	165	Design filing fee
107	510	207	255	Plant filing fee
108	740	208	370	Reissue filing fee
114	160	214	80	Provisional filing fee

SUBTOTAL (1) (\$)

370.00

2. EXTRA CLAIM FEES

Extra Claims

Total Claims -20** = X =

Independent Claims -3** = X =

Multiple Dependent =

Large Entity Small Entity				Fee Description
Fee Code (\$)	Fee Code (\$)	Fee Code (\$)	Fee Code (\$)	Fee Description
103	18	203	9	Claims in excess of 20
102	84	202	42	Independent claims in excess of 3
104	280	204	140	Multiple dependent claim, if not paid
109	84	209	42	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) (\$)

0.00

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES				
Large Entity		Small Entity		Fee Description
Fee Code (\$)	Fee Code (\$)	Fee Code (\$)	Fee Code (\$)	Fee Description
105	130	205	65	Surcharge - late filing fee or oath
127	50	227	25	Surcharge - late provisional filing fee or cover sheet
139	130	139	130	Non-English specification
147	2,520	147	2,520	For filing a request for <i>ex parte</i> reexamination
112	920*	112	920*	Requesting publication of SIR prior to Examiner action
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action
115	110	215	55	Extension for reply within first month
116	400	216	200	Extension for reply within second month
117	920	217	460	Extension for reply within third month
118	1,440	218	720	Extension for reply within fourth month
128	1,960	228	980	Extension for reply within fifth month
119	320	219	160	Notice of Appeal
120	320	220	160	Filing a brief in support of an appeal
121	280	221	140	Request for oral hearing
138	1,510	138	1,510	Petition to institute a public use proceeding
140	110	240	55	Petition to revive - unavoidable
141	1,280	241	640	Petition to revive - unintentional
142	1,280	242	640	Utility issue fee (or reissue)
143	460	243	230	Design issue fee
144	620	244	310	Plant issue fee
122	130	122	130	Petitions to the Commissioner
123	50	123	50	Processing fee under 37 CFR 1.17(q)
126	180	126	180	Submission of Information Disclosure Stmt
581	40	581	40	Recording each patent assignment per property (times number of properties)
146	740	246	370	Filing a submission after final rejection (37 CFR § 1.129(a))
149	740	249	370	For each additional invention to be examined (37 CFR § 1.129(b))
179	740	279	370	Request for Continued Examination (RCE)
169	900	169	900	Request for expedited examination of a design application

Other fee (specify)

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) (\$)

0.00

SUBMITTED BY

Name (Print/Type)	Raymond Y. C. Chan	Registration No. (Attorney/Agent)	37,484	Telephone	626-571-9812
Signature		Date	10/22/2001		

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12-18-01

A



In the United States Patent and Trademark Office

Commissioner of Patents and Trademarks
Washington, District of Columbia 20231

Mailed: October 22, 2001
Attorney Docket: USDP1699A-GNC

Sir:

Please file the following enclosed patent application papers:

Applicant #1, Name: Hiram McCall

Applicant #2, Name: Ching-Fang Lin

Title: Micro Inertial Measurement Unit (Divisional appl. of 09/477,151 filed on 01/04/2000)

☒ Specification, Claims, and Abstract: Nr. Of Sheets 47

☒ Declaration: Date Signed: 12/29/1999

☒ Drawing(s): Nr. Of Sheets Enc.: (In Triplicate): Formal: 26 Informal: _____

☒ The applicant claims small entity status. See 37 CFR 1.27

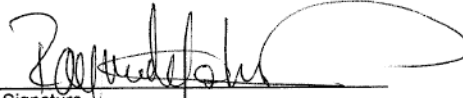
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Raymond Y. C. Chan
Reg. Nr. : 37,484

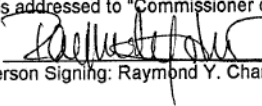
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Signature:  Date: 10/22/2001
Name of Person Signing: Raymond Y. Chan

Title

Micro Inertial Measurement Unit

Inv
dl

Background of the Present Invention

Field of the Present Invention

5 The present invention relates to motion measurement, and more particularly to a motion inertial measurement unit in micro size that can produce highly accurate, digital angular increments, velocity increments, position, velocity, attitude, and heading measurements of a carrier under dynamic environments.

Description of Related Arts

10 Generally, an inertial measurement unit (IMU) is employed to determine the motion of a carrier. In principle, an inertial measurement unit relies on three orthogonally mounted inertial angular rate producers and three orthogonally mounted acceleration producers to obtain three-axis angular rate and acceleration measurement signals. The three orthogonally mounted inertial angular rate producers and three orthogonally
15 mounted acceleration producers with additional supporting mechanical structure and **electronic** devices are conventionally called an Inertial Measurement Unit (IMU). The conventional IMUs may be cataloged into Platform IMU and Strapdown IMU.

 In the platform IMU, angular rate producers and acceleration producers are installed on a stabilized platform. Attitude measurements can be directly picked off from
20 the platform structure. But attitude rate measurements can not be directly obtained from the platform. Moreover, there are highly accurate feedback control loops associated with the platform.

Compared with the platform IMU, in the strapdown IMU, angular rate producers and acceleration producers are directly strapped down with the carrier and move with the carrier. The output signals of the strapdown rate producers and acceleration producers are expressed in the carrier body frame. The attitude and attitude
5 rate measurements can be obtained by means of a series of computations.

A conventional IMU uses a variety of inertial angular rate producers and acceleration producers. Conventional inertial angular rate producers include iron spinning wheel gyros and optical gyros, such as Floated Integrating Gyros (FIG), Dynamically Tuned Gyros (DTG), Ring Laser Gyros (RLG), Fiber-Optic Gyros (FOG), Electrostatic
10 Gyros (ESG), Josephson Junction Gyros (JJG), Hemispherical Resonating Gyros (HRG), etc. Conventional acceleration producers include Pulsed Integrating Pendulous Accelerometer (PIPA), Pendulous Integrating Gyro Accelerometer (PIGA), etc.

The processing method, mechanical supporting structures, and electronic circuitry of conventional IMUs vary with the type of gyros and accelerometers employed
15 in the IMUs. Because conventional gyros and accelerometers have a large size, high power consumption, and moving mass, complex feedback control loops are required to obtain stable motion measurements. For example, dynamic-tuned gyros and accelerometers need force-rebalance loops to create a moving mass idle position. There are often pulse modulation force-rebalance circuits associated with dynamic-tuned gyros
20 and accelerometer based IMUs. Therefore, conventional IMUs commonly have the following features:

- High cost,
- Large bulk (volume, mass, large weight),
- High power consumption,
- 25 ▪ Limited lifetime, and

- Long turn-on time.

These present deficiencies of conventional IMUs prohibit them from use in the emerging commercial applications, such as phased array antennas for mobile communications, automotive navigation, and handheld equipment.

5 New horizons are opening up for inertial sensor device technologies. MEMS (MicroElectronicMechanicalSystem) inertial sensors offer tremendous cost, size, and reliability improvements for guidance, navigation, and control systems, compared with conventional inertial sensors.

10 MEMS, or, as stated more simply, micromachines, are considered as the next logical step in the silicon revolution. It is believed that this coming step will be different, and more important than simply packing more transistors onto silicon. The hallmark of the next thirty years of the silicon revolution will be the incorporation of new types of functionality onto the chip structures, which will enable the chip to, not only think, but to sense, act, and communicate as well.

15 Prolific MEMS angular rate sensor approaches 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
20 angular resonance of a rotating rigid rotor suspended by torsional springs. Current MEMS angular rate sensors are primarily based on an electronically-driven tuning fork method.

25 More accurate MEMS accelerometers are the force rebalance type that use closed-loop capacitive sensing and electrostatic forcing. Draper's micromechanical accelerometer is a typical example, where the accelerometer is a monolithic silicon structure consisting of a torsional pendulum with capacitive readout and electrostatic torquer. Analog Device's MEMS accelerometer has an integrated polysilicon capacitive

structure fabricated with on-chip BiMOS process to include a precision voltage reference, local oscillators, amplifiers, demodulators, force rebalance loop and self-test functions.

Although the MEMS angular rate sensors and MEMS accelerometers are available commercially and have achieved micro chip-size and low power consumption, however, there is not yet available high performance, small size, and low power consumption IMUs.

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Summary of the Present Invention

A main objective of the present invention is to provide a micro inertial measurement unit, which can produce digital highly accurate angular increment and velocity increment measurements of a carrier from voltage signals output from the specific angular rate and acceleration producers thereof, so as to obtain highly accurate, position, velocity, attitude, and heading measurements of the carrier under dynamic environments.

Another objective of the present invention is to provide a micro inertial measurement unit (IMU) which successfully incorporates the MEMS technology.

Another objective of the present invention is to provide a micro inertial measurement unit, wherein output signals of angular rate producer and acceleration producer are exploited, and are preferably emerging MEMS (MicroElectronicMechanicalSystem) angular rate sensor arrays and acceleration sensor arrays. These outputs are proportional to rotation and translational motion of the carrier, respectively. Compared with a conventional IMU, the present invention utilizes a feedforward open-loop signal processing scheme to obtain highly accurate motion measurements by means of signal integration, digitizing, temperature control and compensation, sensor error and misalignment calibrations, and dramatically shrinks the size of mechanical and electronic hardware and power consumption, meanwhile, obtains highly accurate motion measurements.

Although the present invention can use existing angular rate devices and acceleration devices, the present invention specifically selects MEMS angular rate devices and acceleration devices to assemble a micro IMU, wherein the micro IMU 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) Shock resistant and vibration tolerant.

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

Another objective of the present invention is to provide a micro IMU rendering into an integrated micro land navigator that has the following unique features:

(1) Miniature, light weight, low power, and 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 for the micro IMU to function as aircraft inertial avionics, which has the following unique features:

(1) Rate Gyro

(2) Vertical Gyro

(3) Directional Gyro

(4) AHRS

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

Another objective of the present invention is to provide a micro IMU to function as 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, that have the following unique features:

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

Another objective of the present invention is to provide a micro IMU to form 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) Low Cost, Light Weight, High Reliability

5 Another objective of the present invention is to provide a micro IMU to be used in a micro pointing and stabilization mechanism that has the following unique features:

- (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.
- 10 (3) Vehicle motion, vibration, and other interference rejected by a stabilized platform.
- (4) Variable pointing angle for tracker implementations.
- (5) Typical applications include miniature antenna pointing and tracking control, laser beam pointing for optical communications, telescopic pointing for imaging,
15 airborne laser pointing control for targeting, vehicle control and guidance.

Brief Description of the Drawings

Figure 1 is a block diagram illustrating the processing module for a micro inertial measurement unit according to a preferred embodiment of the present invention.

5 Figure 2 is a block diagram illustrating the processing modules with thermal control processing for the micro inertial measurement unit according to the above preferred embodiment of the present invention.

Figure 3 is a block diagram illustrating the processing modules with thermal compensation processing for the micro inertial measurement unit according to the above preferred embodiment of the present invention.

10 Figure 4 is a block diagram illustrating an angular increment and velocity increment producer for outputting voltage signals of the angular rate producer and acceleration producer for the micro inertial measurement unit according to the above preferred embodiment of the present invention.

15 Figure 5 is a block diagram illustrating another angular increment and velocity increment producer for outputting voltage signals of angular rate producer and acceleration producer for the micro inertial measurement unit according to the above preferred embodiment of the present invention.

20 Figure 6 is a block diagram illustrating another angular increment and velocity increment producer for outputting voltage signals of an angular rate producer and acceleration producer for the micro inertial measurement unit according to the above preferred embodiment of the present invention.

Figure 7 is a block diagram illustrating another angular increment and velocity increment producer for outputting voltage signals of an angular rate producer and acceleration

producer for the micro inertial measurement unit according to the above preferred embodiment of the present invention.

Figure 8 is a block diagram illustrating a thermal processor for outputting analog voltage signals of the thermal sensing producer according to the above preferred embodiment of
5 the present invention.

Figure 9 is a block diagram illustrating another thermal processor for outputting analog voltage signals of the thermal sensing producer according to the above preferred embodiment of the present invention.

FIG. 10
10 Figure 10 is a block diagram illustrating another thermal processor for outputting analog voltage signals of the thermal sensing producer according to the above preferred embodiment of the present invention.

Figure 11 is a block diagram illustrating a processing module for the micro inertial measurement unit according to the above preferred embodiment of the present invention.

FIG. 12
15 Figure 12 is a block diagram illustrating a temperature digitizer for outputting analog voltage signals of the thermal sensing producer according to the above preferred embodiment of the present invention.

Figure 13 is a block diagram illustrating a temperature digitizer for outputting analog voltage signals of the thermal sensing producer according to the above preferred embodiment of the present invention.

20 Figure 14 is a block diagram illustrating a processing module with thermal compensation processing for the micro inertial measurement unit according to the above preferred embodiment of the present invention.

Figure 15 is a block diagram illustrating the attitude and heading processing module according to the above preferred embodiment of the present invention.

Figure 16 is a functional block diagram illustrating the position velocity attitude and heading module according to the above preferred embodiment of the present invention.

Figure 17 is a perspective view illustrating the inside mechanical structure and circuit board deployment in the micro IMU according to the above preferred embodiment of the present invention.

Figure 18 is a sectional side view of the micro IMU according to the above preferred embodiment of the present invention.

Figure 19 is a block diagram illustrating the connection among the four circuit boards inside the micro IMU according to the above preferred embodiment of the present invention.

10 Figure 20 is a block diagram of the front-end circuit in each of the first, second, and fourth circuit boards of the micro IMU according to the above preferred embodiment of the present invention.

Figure 21 is a block diagram of the ASIC chip in the third circuit board of the micro IMU according to the above preferred embodiment of the present invention.

15 Figure 22 is a block diagram of processing modules running in the DSP chipset in the third circuit board of the micro IMU according to the above preferred embodiment of the present invention.

20 Figure 23 is a block diagram of the angle signal loop circuitry of the ASIC chip in the third circuit board of the micro IMU according to the above preferred embodiment of the present invention.

Figure 24 is block diagram of the dither motion control circuitry of the ASIC chip in the third circuit board of the micro IMU according to the above preferred embodiment of the present invention.

Figure 25 is a block diagram of the thermal control circuit of the ASIC chip in the third circuit board of the micro IMU according to the above preferred embodiment of the present invention.

Figure 26 is a block diagram of the dither motion processing module running in the DSP
5 chipset of the third circuit board of the micro IMU according to the above preferred embodiment of the present invention.

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Detail Description of the Preferred Embodiment

Currently, MEMS exploits the existing microelectronics infrastructure to create complex machines with micron feature sizes. These machines can have many functions, including sensing, communication, and actuation. Extensive applications for these devices exist in a wide variety of commercial systems.

The difficulties for building a micro IMU is the achievement of the following hallmark using existing low cost and low accuracy angular rate sensors and accelerometers:

- Low cost,
- Micro size
- Lightweight
- Low power consumption
- No wear/extended lifetime
- Instant turn-on
- Large dynamic range
- High sensitivity
- High stability
- High accuracy

To achieve the high degree of performance mentioned above, a number of problems need to be addressed:

(1) Micro-size angular rate sensors and accelerometers need to be obtained.

5 Currently, the best candidate angular rate sensor and accelerometer to meet the micro size are MEMS angular rate sensors and MEMS accelerometers.

(2) Associated mechanical structures need to be designed.

(3) Associated electronic circuitry needs to be designed.

(4) Associated thermal requirements design need to be met to compensate MEMS sensor's thermal effects.

10 (5) The size and power of the associated electronic circuitry need to be shrunk.

15 The micro inertial measurement unit of the present invention is preferred to employ with the angular rate producer, such as MEMS angular rate device array or gyro array, that provides three-axis angular rate measurement signals of a carrier, and the acceleration producer, such as MEMS acceleration device array or accelerometer array, that provides three-axis acceleration measurement signals of the carrier, wherein the motion measurements of the carrier, such as attitude and heading angles, are achieved by means of processing procedures of the three-axis angular rate measurement signals from the angular rate producer and the three-axis acceleration measurement signals from the acceleration producer.

20 In the present invention, output signals of the angular rate producer and acceleration producer are processed to obtain digital highly accurate angular rate increment and velocity increment measurements of the carrier, and are further processed to obtain highly accurate position, velocity, attitude and heading measurements of the carrier under dynamic environments.

Referring to Figure 1, the micro inertial measurement unit of the present invention comprises an angular rate producer 5 for producing three-axis (X axis, Y axis and Z axis) angular rate signals; an acceleration producer 10 for producing three-axis (X-axis, Y axis and Z axis) acceleration signals; and an angular increment and velocity
5 . increment producer 6 for converting the three-axis angular rate signals into digital angular increments and for converting the input three-axis acceleration signals into digital velocity increments.

Moreover, a position and attitude processor 80 is adapted to further connect with the micro IMU of the present invention to compute position, attitude and heading
10 angle measurements using the three-axis digital angular increments and three-axis velocity increments to provide a user with a rich motion measurement to meet diverse needs.

The position, attitude and heading processor 80 further comprises two optional running modules:

- 15
- (1) Attitude and Heading Module 81, producing attitude and heading angle only; and
 - (2) Position, Velocity, Attitude, and Heading Module 82, producing position, velocity, and attitude angles.

In general, the angular rate producer 5 and the acceleration producer 10 are very
20 sensitive to a variety of temperature environments. In order to improve measurement accuracy, referring to Figure 2, the present invention further comprises a thermal controlling means for maintaining a predetermined operating temperature of the angular rate producer 5, the acceleration producer 10 and the angular increment and velocity increment producer 6. It is worth to mention that if the angular rate producer 5, the
25 acceleration producer 10 and the angular increment and velocity increment producer 6 are operated in an environment under perfect and constant thermal control, the thermal controlling means can be omitted.

According to the preferred embodiment of the present invention, as shown in Figs. 2, the thermal controlling means comprises a thermal sensing producer device 15, a heater device 20 and a thermal processor 30.

5 The thermal sensing producer device 15, which produces temperature signals, is processed in parallel with the angular rate producer 5 and the acceleration producer 10 for maintaining a predetermined operating temperature of the angular rate producer 5 and the acceleration producer 10 and angular increment and velocity increment producer 6 of the micro IMU, wherein the predetermined operating temperature is a constant designated temperature selected between 150°F and 185°F, preferable 176°F ($\pm 0.1^\circ\text{F}$).

10 The temperature signals produced from the thermal sensing producer device 15 are inputted to the thermal processor 30 for computing temperature control commands using the temperature signals, a temperature scale factor, and a predetermined operating temperature of the angular rate producer 5 and the acceleration producer 10, and produce driving signals to the heater device 20 using the temperature control commands for
15 controlling the heater device 20 to provide adequate heat for maintaining the predetermined operating temperature in the micro IMU.

Temperature characteristic parameters of the angular rate producer 5 and the acceleration producer 10 can be determined during a series of the angular rate producer and acceleration producer temperature characteristic calibrations.

20 Referring to Figure 3, when the above thermal processor 30 and the heater device 20 are not provided, in order to compensate the angular rate producer and acceleration producer measurement errors induced by a variety of temperature environments, the micro IMU of the present invention can alternatively comprise a temperature digitizer 18 for receiving the temperature signals produced from the thermal
25 sensing producer device 15 and outputting a digital temperature value to the position, attitude, and heading processor 80. As shown in Fig. 12, the temperature digitizer 18 can be embodied to comprise an analog/digital converter 182.

Moreover, the position, attitude, and heading processor 80 is adapted for accessing temperature characteristic parameters of the angular rate producer and the acceleration producer using a current temperature of the angular rate producer and the acceleration producer from the temperature digitizer 18, and compensating the errors
5 induced by thermal effects in the input digital angular and velocity increments and computing attitude and heading angle measurements using the three-axis digital angular increments and three-axis velocity increments in the attitude and heading processor 80.

In most applications, the output of the angular rate producer 5 and the acceleration producer 10 are analog voltage signals. The three-axis analog angular rate
10 voltage signals produced from the angular producer 5 are directly proportional to carrier angular rates, and the three-axis analog acceleration voltage signals produced from the acceleration producer 10 are directly proportional to carrier accelerations.

When the outputting analog voltage signals of the angular rate producer 5 and the acceleration producer 10 are too weak for the angular increment and velocity
15 increment producer 6 to read, the angular increment and velocity increment producer 6 may employ amplifying means 660 and 665 for amplifying the analog voltage signals input from the angular rate producer 5 and the acceleration producer 10 and suppress noise signals residing within the analog voltage signals input from the angular rate producer 5 and the acceleration producer 10, as shown in Figs. 5 and 6.

Referring to Figure 4, the angular increment and velocity increment producer 6
20 comprises an angular integrating means 620, an acceleration integrating means 630, a resetting means 640, and an angular increment and velocity increment measurement means 650.

The angular integrating means 620 and the acceleration integrating means 630
25 are adapted for respectively integrating the three-axis analog angular rate voltage signals and the three-axis analog acceleration voltage signals for a predetermined time interval to accumulate the three-axis analog angular rate voltage signals and the three-axis analog acceleration voltage signals as an uncompensated three-axis angular increment and an

uncompensated three-axis velocity increment for the predetermined time interval to achieve accumulated angular increments and accumulated velocity increments. The integration is performed to remove noise signals that are non-directly proportional to the carrier angular rate and acceleration within the three-axis analog angular rate voltage signals and the three-axis analog acceleration voltage signals, to improve signal-to-noise ratio, and to remove the high frequency signals in the three-axis analog angular rate voltage signals and the three-axis analog acceleration voltage signals. The signals are directly proportional to the carrier angular rate and acceleration within the three-axis analog angular rate voltage signals and the three-axis analog acceleration voltage signals.

10 The resetting means forms an angular reset voltage pulse and a velocity reset voltage pulse as an angular scale and a velocity scale which are input into the angular integrating means 620 and the acceleration integrating means 630 respectively.

15 The angular increment and velocity increment measurement means 650 is adapted for measuring the voltage values of the three-axis accumulated angular increments and the three-axis accumulated velocity increments with the angular reset voltage pulse and the velocity reset voltage pulse respectively to acquire angular increment counts and velocity increment counts as a digital form of the angular increment and velocity increment measurements respectively.

20 In order to output real three-angular increment and velocity increment values as an optional output format to substitute the voltage values of the three-axis accumulated angular increments and velocity increments, the angular increment and velocity increment measurement means 650 also scales the voltage values of the three-axis accumulated angular and velocity increments into real three-axis angular and velocity increment voltage values.

25 In the angular integrating means 620 and the acceleration integrating means 630, the three-axis analog angular voltage signals and the three-axis analog acceleration voltage signals are each reset to accumulate from a zero value at an initial point of every predetermined time interval.

As shown in Fig. 6, in general, the resetting means 640 can be an oscillator 66, so that the angular reset voltage pulse and the velocity reset voltage pulse are implemented by producing a timing pulse by the oscillator 66. In applications, the oscillator 66 can be built with circuits, such as Application Specific Integrated Circuits (ASIC) chip and a printed circuit board.

As shown in Fig. 7, the angular increment and velocity increment measurement means 650, which is adapted for measuring the voltage values of the three-axis accumulated angular and velocity increments, is embodied as an analog/digital converter 650. In other words, the analog/digital converter 650 substantially digitizes the raw three-axis angular increment and velocity increment voltage values into digital three-axis angular increment and velocity increments.

Referring to Figs. 7 and 11, the amplifying means 660 and 665 of the angular increment and velocity increment producer 6 are embodied by an angular amplifier circuit 61 and an acceleration amplifier circuit 67 respectively to amplify the three-axis analog angular rate voltage signals and the three-axis analog acceleration voltage signals to form amplified three-axis analog angular rate signals and amplified three-axis analog acceleration signals respectively.

The angular integrating means 620 and the acceleration integrating means 630 of the angular increment and velocity increment producer 6 are respectively embodied as an angular integrator circuit 62 and an acceleration integrator circuit 68 for receiving the amplified three-axis analog angular rate signals and the amplified three-axis analog acceleration signals from the angular and acceleration amplifier circuits 61, 67 which are integrated to form the accumulated angular increments and the accumulated velocity increments respectively.

The analog/digital converter 650 of the angular increment and velocity increment producer 6 further includes an angular analog/digital converter 63, a velocity analog/digital converter 69 and an input/output interface circuit 65.

The accumulated angular increments output from the angular integrator circuit 62 and the accumulated velocity increments output from the acceleration integrator circuit are input into the angular analog/digital converter 63 and the velocity analog/digital converter 69 respectively.

5 The accumulated angular increments are digitized by the angular analog/digital converter 63 by measuring the accumulated angular increments with the angular reset voltage pulse to form digital angular measurements of voltage in terms of the angular increment counts which are output to the input/output interface circuit 65 to generate digital three-axis angular increment voltage values.

10 The accumulated velocity increments are digitized by the velocity analog/digital converter 69 by measuring the accumulated velocity increments with the velocity reset voltage pulse to form digital velocity measurements of voltage in terms of the velocity increment counts which are output to the input/output interface circuit 65 to generate digital three-axis velocity increment voltage values.

15 Referring to Figs. 2 and 8, in order to achieve flexible adjustment of the thermal processor 30 for the thermal sensing producer device 15 with analog voltage output and the heater device 20 with analog input, the thermal processor 30 can be implemented in a digital feedback controlling loop as shown in Figure 8.

20 The thermal processor 30, as shown in Fig. 8, comprises an analog/digital converter 304 connected to the thermal sensing producer device 15, a digital/analog converter 303 connected to the heater device 20, and a temperature controller 306 connected with both the analog/digital converter 304 and the digital/analog converter 303. The analog/digital converter 304 inputs the temperature voltage signals produced by the thermal sensing producer device 15, wherein the temperature voltage signals are
25 sampled in the analog/digital converter 304 to sampled temperature voltage signals which are further digitized to digital signals and output to the temperature controller 306.

The temperature controller 306 computes digital temperature commands using the input digital signals from the analog/digital converter 304, a temperature sensor scale factor, and a pre-determined operating temperature of the angular rate producer and acceleration producer, wherein the digital temperature commands are fed back to the
5 digital/analog converter 303.

The digital/analog converter 303 converts the digital temperature commands input from the temperature controller 306 into analog signals which are output to the heater device 20 to provide adequate heat for maintaining the predetermined operating temperature of the micro IMU of the present invention.

10 Moreover, as shown in Fig. 9, if the voltage signals produced by the thermal sensing producer device 15 are too weak for the analog/digital converter 304 to read, the thermal processor 30 further comprises a first amplifier circuit 301 between the thermal sensing producer device 15 and the digital/analog converter 303, wherein the voltage
15 signals from the thermal sensing producer device 15 is first input into the first amplifier circuit 301 for amplifying the signals and suppressing the noise residing in the voltage signals and improving the signal-to-noise ratio, wherein the amplified voltage signals are then output to the analog/digital converter 304.

The heater device 20 requires a specific driving current signal. In this case, referring to Figure 10, the thermal processor 30 can further comprise a second amplifier
20 circuit 302 between the digital/analog converter 303 and heater device 20 for amplifying the input analog signals from the digital/analog converter 303 for driving the heater device 20.

In other words, the digital temperature commands input from the temperature controller 306 are converted in the digital/analog converter 303 into analog signals which
25 are then output to the amplifier circuit 302.

Referring to Fig. 11, an input/output interface circuit 305 is required to connect the analog/digital converter 304 and digital/analog converter 303 with the temperature

controller 306. In this case, as shown in Figure 11, the voltage signals are sampled in the analog/digital converter 304 to form sampled voltage signals that are digitized into digital signals. The digital signals are output to the input/output interface circuit 305.

As mentioned above, the temperature controller 306 is adapted to compute the
5 digital temperature commands using the input digital temperature voltage signals from the input/output interface circuit 305, the temperature sensor scale factor, and the predetermined operating temperature of the angular rate producer and acceleration producer, wherein the digital temperature commands are fed back to the input/output interface circuit 305. Moreover, the digital/analog converter 303 further converts the digital
10 temperature commands input from the input/output interface circuit 305 into analog signals which are output to the heater device 20 to provide adequate heat for maintaining the predetermined operating temperature of the micro IMU.

Referring to Figure 12, as mentioned above, the thermal processor 30 and the heater device 20 as disclosed in Figs. 2, 8, 9, 10, and 11 can alternatively be replaced by
15 the analog/digital converter 182 connected to the thermal sensing producer device 15 to receive the analog voltage output from the thermal sensing producer device 15. If the voltage signals produced by the thermal sensing producer device 15 are too weak for the analog/digital converter 182 to read, referring to Figure 13, an additional amplifier circuit 181 can be connected between the thermal sensing producer device 15 and the
20 digital/analog converter 182 for amplifying the analog voltage signals and suppressing the noise residing in the voltage signals and improving the voltage signal-to-noise ratio, wherein the amplified voltage signals are output to the analog/digital converter 182 and sampled to form sampled voltage signals that are further digitized in the analog/digital converters 182 to form digital signals **connected to** the attitude and heading processor 80.

25 Alternatively, an input/output interface circuit 183 can be connected between the analog/digital converter 182 and the attitude and heading processor 80. In this case, referring to Figure 14, the input amplified voltage signals are sampled to form sampled voltage signals that are further digitized in the analog/digital converters to form digital

signals **connected to** the input/output interface circuit 183 before inputting into the attitude and heading processor 80.

Referring to Figure 1, the digital three-axis angular increment voltage values or real values and three-axis digital velocity increment voltage values or real values are produced and outputted from the angular increment and velocity increment producer 6.

In order to adapt to digital three-axis angular increment voltage value and three-axis digital velocity increment voltage values from the angular increment and velocity increment producer 6, the attitude and heading module 81, as shown in Fig. 15, comprises a coning correction module 811, wherein digital three-axis angular increment voltage values from the input/output interface circuit 65 of the angular increment and velocity increment producer 6 and coarse angular rate bias obtained from an angular rate producer and acceleration producer calibration procedure at a high data rate (short interval) are input into the coning correction module 801, which computes coning effect errors by using the input digital three-axis angular increment voltage values and coarse angular rate bias, and outputs three-axis coning effect terms and three-axis angular increment voltage values at a reduced data rate (long interval), which are called three-axis long-interval angular increment voltage values.

The attitude and heading module 81 further comprises an angular rate compensation module 812 and an alignment rotation vector computation module 815. In the angular rate compensation module 812, the coning effect errors and three-axis long-interval angular increment voltage values from the coning correction module 811 and angular rate device misalignment parameters, fine angular rate bias, angular rate device scale factor, and coning correction scale factor from the angular rate producer and acceleration producer calibration procedure are connected to the angular rate compensation module 812 for compensating definite errors in the three-axis long-interval angular increment voltage values using the coning effect errors, angular rate device misalignment parameters, fine angular rate bias, and coning correction scale factor, and transforming the compensated three-axis long-interval angular increment voltage values to real three-axis long-interval angular increments using the angular rate device scale

factor. Moreover, the real three-axis angular increments are output to the alignment rotation vector computation module 815.

The attitude and heading module 81 further comprises an accelerometer compensation module 813 and a level acceleration computation module 814, wherein the
5 three-axis velocity increment voltage values from the angular increment and velocity increment producer 6 and acceleration device misalignment, acceleration device bias, and acceleration device scale factor from the angular rate producer and acceleration producer calibration procedure are connected to the accelerometer compensation module 813 for transforming the three-axis velocity increment voltage values into real three-axis velocity
10 increments using the acceleration device scale factor, and compensating the definite errors in three-axis velocity increments using the acceleration device misalignment, accelerometer bias, wherein the compensated three-axis velocity increments are connected to the level acceleration computation module 814.

By using the compensated three-axis angular increments from the angular rate
15 compensation module 812, an east damping rate increment from an east damping rate computation module 8110, a north damping rate increment from a north damping rate computation module 819, and vertical damping rate increment from a vertical damping rate computation module 818, a quaternion, which is a vector representing rotation angle of the carrier, is updated, and the updated quaternion is connected to a direction cosine
20 matrix computation module 816 for computing the direction cosine matrix, by using the updated quaternion.

The computed direction cosine matrix is connected to the level acceleration computation module 814 and an attitude and heading angle extract module 817 for extracting attitude and heading angle using the direction cosine matrix from the direction
25 cosine matrix computation module 816.

The compensated three-axis velocity increments are connected to the level acceleration computation module 814 for computing level velocity increments using the compensated three-axis velocity increments from the acceleration compensation module

814 and the direction cosine matrix from the direction cosine matrix computation module 816.

5 The level velocity increments are connected to the east damping rate computation module 8110 for computing east damping rate increments using the north velocity increment of the input level velocity increments from the level acceleration computation module 814.

10 The level velocity increments are connected to the north damping rate computation module 819 for computing north damping rate increments using the east velocity increment of the level velocity increments from the level acceleration computation module 814.

The heading angle from the attitude and heading angle extract module 817 and a measured heading angle from the external heading sensor 90 are connected to the vertical damping rate computation module 818 for computing vertical damping rate increments.

15 The east damping rate increments, north damping rate increments, and vertical damping rate are fed back to the alignment rotation vector computation module 815 to damp the drift of errors of the attitude and heading angles.

20 Alternatively, in order to adapt real digital three-axis angular increment values and real three-axis digital velocity increment values from the angular increment and velocity increment producer 6, referring to Figure 15, the real digital three-axis angular increment values from the angular increment and velocity increment producer 6 and coarse angular rate bias obtained from an angular rate producer and acceleration producer calibration procedure at a high data rate (short interval) are connected to the coning correction module 811 for computing coning effect errors in the coning correction module 811 using the digital three-axis angular increment values and coarse angular rate bias and outputting three-axis coning effect terms and three-axis angular increment values at reduced data rate (long interval), which are called three-axis long-interval angular increment values, into the angular rate compensation module 802.

The coning effect errors and three-axis long-interval angular increment values from the coning correction module 811 and angular rate device misalignment parameters and fine angular rate bias from the angular rate producer and acceleration producer calibration procedure are connected to the angular rate compensation module 812 for compensating definite errors in the three-axis long-interval angular increment values using the coning effect errors, angular rate device misalignment parameters, fine angular rate bias, and coning correction scale factor, and outputting the real three-axis angular increments to the alignment rotation vector computation module 815.

The three-axis velocity increment values from the angular increment and velocity increment producer 6 and acceleration device misalignment, and acceleration device bias from the angular rate producer and acceleration producer calibration procedure are connected into the accelerometer compensation module 813 for compensating the definite errors in three-axis velocity increments using the acceleration device misalignment, and accelerometer bias; outputting the compensated three-axis velocity increments to the level acceleration computation module 814.

It is identical to the above mentioned processing that the following modules use the compensated three-axis angular increments from the angular rate compensation module 812 and compensated three-axis velocity increments from the acceleration compensation module 813 to produce attitude and heading angle.

Referring to Figure 3, 14, and 15, which use the temperature compensation method by means of the temperature digitizer 18, in order to adapt to digital three-axis angular increment voltage value and three-axis digital velocity increment voltage values from the angular increment and velocity increment producer 6, the digital three-axis angular increment voltage values from the angular increment and velocity increment producer 6 and coarse angular rate bias obtained from an angular rate producer and acceleration producer calibration procedure at a high data rate (short interval) are connected to the coning correction module 811 for computing coning effect errors in the coning correction module 811 using the digital three-axis angular increment voltage values and coarse angular rate bias, and outputting three-axis coning effect terms and

three-axis angular increment voltage values at a reduced data rate (long interval), which are called three-axis long-interval angular increment voltage values, into the angular rate compensation module 812.

5 The coning effect errors and three-axis long-interval angular increment voltage values from the coning correction module 811 and angular rate device misalignment parameters, fine angular rate bias, angular rate device scale factor, coning correction scale factor from the angular rate producer and acceleration producer calibration procedure, the digital temperature signals from input/output interface circuit 183, and temperature sensor scale factor are connected to the angular rate compensation module 10 812 for computing current temperature of the angular rate producer, accessing angular rate producer temperature characteristic parameters using the current temperature of the angular rate producer, compensating definite errors in the three-axis long-interval angular increment voltage values using the coning effect errors, angular rate device misalignment parameters, fine angular rate bias, and coning correction scale factor, transforming the compensated three-axis long-interval angular increment voltage values to real three-axis 15 long-interval angular increments, compensating temperature-induced errors in the real three-axis long-interval angular increments using the angular rate producer temperature characteristic parameters, and outputting the real three-axis angular increments to the alignment rotation vector computation module 805.

20 The three-axis velocity increment voltage values from the angular increment and velocity increment producer 6 and acceleration device misalignment, acceleration bias, acceleration device scale factor from the angular rate producer and acceleration producer calibration procedure, the digital temperature signals from the input/output interface circuit 183 of the temperature digitizer 18, and temperature sensor scale factor 25 are connected to the acceleration compensation module 813 for computing current temperature of the acceleration producer, accessing acceleration producer temperature characteristic parameters using the current temperature of the acceleration producer, transforming the three-axis velocity increment voltage values into real three-axis velocity increments using the acceleration device scale factor, compensating the definite errors in

the three-axis velocity increments using the acceleration device misalignment and acceleration bias, compensating temperature-induced errors in the real three-axis velocity increments using the acceleration producer temperature characteristic parameters, and outputting the compensated three-axis velocity increments to the level acceleration
5 computation module 814.

It is identical to the above mentioned processing that the following modules use the compensated three-axis angular increments from the angular rate compensation module 812 and compensated three-axis velocity increments from the acceleration compensation module 813 to produce the attitude and heading angles.

10 Alternatively, referring to Figs. 3, 14, and 15, which use the temperature compensation method, in order to adapt real digital three-axis angular increment values and real three-axis digital velocity increment values from the angular increment and velocity increment producer 6, the attitude and heading module 81 can be further modified to accept the digital three-axis angular increment values from the angular
15 increment and velocity increment producer 6 and coarse angular rate bias obtained from an angular rate producer and acceleration producer calibration procedure at a high data rate (short interval) into the coning correction module 811 for computing coning effect errors in the coning correction module 811 using the input digital three-axis angular increment values and coarse angular rate bias, and outputting three-axis coning effect
20 data and three-axis angular increment data at a reduced data rate (long interval), which are called three-axis long-interval angular increment values, into the angular rate compensation module 812.

The coning effect errors and three-axis long-interval angular increment values from the coning correction module 811 and angular rate device misalignment parameters
25 and fine angular rate bias from the angular rate producer and acceleration producer calibration procedure, the digital temperature signals from the input/output interface circuit 183 and temperature sensor scale factor are connected to the angular rate compensation module 812 for computing current temperature of the angular rate producer, accessing angular rate producer temperature characteristic parameters using the

current temperature of the angular rate producer, compensating definite errors in the three-axis long-interval angular increment values using the coning effect errors, angular rate device misalignment parameters, fine angular rate bias, and coning correction scale factor, compensating temperature-induced errors in the real three-axis long-interval angular increments using the angular rate producer temperature characteristic parameters, and outputting the real three-axis angular increments to an alignment rotation vector computation module 815.

The three-axis velocity increment values from the input/output interface circuit 65 and acceleration device misalignment and acceleration bias from the angular rate producer and acceleration producer calibration procedure, the digital temperature signals from the input/output interface circuit 183 and temperature sensor scale factor are input into the acceleration compensation module 803 for computing current temperature of the acceleration producer, accessing the acceleration producer temperature characteristic parameters using the current temperature of the acceleration producer, compensating the definite errors in the three-axis velocity increments using the input acceleration device misalignment, acceleration bias, compensating temperature-induced errors in the real three-axis velocity increments using the acceleration producer temperature characteristic parameters, and outputting the compensated three-axis velocity increments to the level acceleration computation module 804.

It is identical to the above mentioned processing that the following modules use the compensated three-axis angular increments from the angular rate compensation module 812 and compensated three-axis velocity increments from the acceleration compensation module 813 to produce the attitude and heading angles.

Referring to Fig. 16, the Position, velocity, and attitude Module 82 comprises:

a coning correction module 8201, which is same as the coning correction module 811 of the attitude and heading module 81;

an angular rate compensation module 8202, which is same as the angular rate compensation module 812 of the attitude and heading module 81;

an alignment rotation vector computation module 8205, which is same as the alignment rotation vector computation module 815 of the attitude and heading module
5 81;

a direction cosine matrix computation module 8206, which is same as the Direction cosine matrix computation module 816 of the attitude and heading module 81;

an acceleration compensation module 8203, which is same as the acceleration compensation module 813 of the attitude and heading module 81;

10 a level acceleration computation module 8204, which is same as the acceleration compensation module 814 of the attitude and heading module 81; and

an attitude and heading angle extract module 8209, which is same as the attitude and heading angle extract module 817 of the attitude and heading module 81.

15 A position and velocity update module 8208 accepts the level velocity increments from the level acceleration computation module 8204 and computes position and velocity solution.

20 An earth and carrier rate computation module 8207 accepts the position and velocity solution from the position and velocity update module 8208 and computes the rotation rate vector of the local navigation frame (n frame) of the carrier relative to the inertial frame (i frame), which is connected to the alignment rotation vector computation module 8205.

25 In order to meet the diverse requirements of application systems, referring to Figs. 11 and 14, the digital three-axis angular increment voltage values, the digital three-axis velocity increment, and digital temperature signals in the input/output interface circuit 65 and the input/output interface circuit 305 can be ordered with a specific format

required by an external user system, such as RS-232 serial communication standard, RS-422 serial communication standard, the popular PCI/ISA bus standard, and 1553 bus standard, etc.

5 In order to meet diverse requirements of application systems, referring to Figures 1, 11 and 14, the digital three-axis angular increment values, the digital three-axis velocity increment, and attitude and heading data in the input/output interface circuit 85 are ordered with a specific format required by an external user system, such as RS-232 serial communication standard, RS-422 serial communication standard, PCI/ISA bus standard, and 1553 bus standard, etc.

10 As mentioned above, one of the key technologies of the present invention to achieve the micro IMU with a high degree of performance is to utilize a micro size angular rate producer, wherein the micro-size angular rate producer with MEMS technologies and associated mechanical supporting structure and circuitry board deployment of the micro IMU of the present invention are disclosed in the following
15 description.

Another of the key technologies of the present invention to achieve the micro IMU with low power consumption is to design a micro size circuitry with small power consumption, wherein the conventional AISC (Application Specific Integrated Circuit) technologies can be utilized to shrink a complex circuitry into a silicon chip.

20 Existing MEMS technologies, which are employed into the micro size angular rate producer, use vibrating inertial elements (a micromachine) to sense vehicle angular rate via the Coriolis Effect. The angular rate sensing principle of Coriolis Effect is the inspiration behind the practical vibrating angular rate sensors.

The Coriolis Effect can be explained by saying that when an angular rate is
25 applied to a translating or vibrating inertial element, a Coriolis force is generated. When this angular rate is applied to the axis of an oscillating inertial element, its tines receive a

Coriolis force, which then produces torsional forces about the sensor axis. These forces are proportional to the applied angular rate, which then can be measured.

The force (or acceleration), Coriolis force (or Coriolis acceleration) or Coriolis effect, is originally named from a French physicist and mathematician, Gaspard de Coriolis (1792-1843), who postulated his acceleration in 1835 as a correction for the earth's rotation in ballistic trajectory calculations. The Coriolis acceleration acts on a body that is moving around a point with a fixed angular velocity and moving radially as well.

The basic equation defining Coriolis force is expressed as follows:

$$\vec{F}_{Coriolis} = m\vec{a}_{Coriolis} = 2m(\vec{\omega} \times \vec{V}_{Oscillation})$$

where $\vec{F}_{Coriolis}$ is the detected Coriolis force;

m is the mass of the inertial element;

$\vec{a}_{Coriolis}$ is the generated Coriolis acceleration;

$\vec{\omega}$ is the applied (input) angular rotation rate;

$\vec{V}_{Oscillation}$ is the oscillation velocity in a rotating frame.

The Coriolis force produced is proportional to the product of the mass of the inertial element, the input rotation rate, and the oscillation velocity of the inertial element that is perpendicular to the input rotation rate.

The major problems with micromachined vibrating type angular rate producer are insufficient accuracy, sensitivity, and stability. Unlike MEMS acceleration producers that are passive devices, micromachined vibrating type angular rate producer are active devices. Therefore, associated high performance electronics and control should be invented to effectively use hands-on micromachined vibrating type angular rate producers

to achieve high performance angular rate measurements in order to meet the requirement of the micro IMU.

Therefore, in order to obtain angular rate sensing signals from a vibrating type angular rate detecting unit, a dither drive signal or energy must be fed first into the vibrating type angular rate detecting unit to drive and maintain the oscillation of the inertial elements with a constant momentum. The performance of the dither drive signals is critical for the whole performance of a MEMS angular rate producer.

As shown in Fig. 17 and Fig. 18, which are a perspective view and a sectional view of the micro IMU of the present invention as shown in the block diagram of Fig.1., the micro IMU comprises a first circuit board 2, a second circuit board 4, a third circuit board 7, and a control circuit board 9 arranged inside a metal cubic case 1.

The first circuit board 2 is connected with the third circuit board 7 for producing X axis angular sensing signal and Y axis acceleration sensing signal to the control circuit board 9.

The second circuit board 4 is connected with the third circuit board 7 for producing Y axis angular sensing signal and X axis acceleration sensing signal to the control circuit board 9.

The third circuit board 7 is connected with the control circuit board 9 for producing Z axis angular sensing signal and Z axis acceleration sensing signals to the control circuit board 9.

The control circuit board 9 is connected with the first circuit board 2 and then the second circuit board 4 through the third circuit board 7 for processing the X axis, Y axis and Z axis angular sensing signals and the X axis, Y axis and Z axis acceleration sensing signals from the first, second and control circuit board to produce digital angular increments and velocity increments, position, velocity, and attitude solution.

As shown in Fig. 19, the angular producer 5 of the preferred embodiment of the present invention comprises:

a X axis vibrating type angular rate detecting unit 21 and a first front-end circuit 23 connected on the first circuit board 2;

5 a Y axis vibrating type angular rate detecting unit 41 and a second front-end circuit 43 connected on the second circuit board 4;

a Z axis vibrating type angular rate detecting unit 71 and a third front-end circuit 73 connected on the third circuit board 7;

10 three angular signal loop circuitries 921, which are provided in a ASIC chip 92 connected on the control circuit board 9, for the first, second and third circuit boards 2, 4, 7 respectively;

three dither motion control circuitries 922, which are provided in the ASIC chip 92 connected on the control circuit board 9, for the first, second and third circuit boards 2, 4, 7 respectively;

15 an oscillator 925 adapted for providing reference pickoff signals for the X axis vibrating type angular rate detecting unit 21, the Y axis vibrating type angular rate detecting unit 41, the Z axis vibrating type angular rate detecting unit 71, the angle signal loop circuitry 921, and the dither motion control circuitry 922; and

20 three dither motion processing modules 912, which run in a DSP (Digital Signal Processor) chipset 91 connected on the control circuit board 9, for the first, second and third circuit boards 2, 4, 7 respectively.

The first, second and third front-end circuits 23, 43, 73, each of which is structurally identical, are used to condition the output signal of the X axis, Y axis and Z

axis vibrating type angular rate detecting units 21, 41, 71 respectively and each further comprises:

5 a trans impedance amplifier circuit 231, 431, 731, which is connected to the respective X axis, Y axis or Z axis vibrating type angular rate detecting unit 21, 41, 71 for changing the 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. The two dither displacement signals are output to the dither motion control circuitry 922; and

10 a high-pass filter circuit 232, 432, 732, which is connected with the respective X axis, Y axis or Z axis vibrating type angular rate detecting units 21, 41, 71 for removing residual dither drive signals and noise from the dither displacement differential signal to form a filtered dither displacement differential signal to the angular signal loop circuitry 921.

15 Each of the X axis, Y axis and Z axis angular rate detecting units 21, 41, and 71 is structurally identical except that sensing axis of each angular rate detecting unit is placed in an orthogonal direction. The X axis angular rate detecting unit 21 is adapted to detect the angular rate of the vehicle along X axis. The Y axis angular rate detecting unit 21 is adapted to detect the angular rate of the vehicle along Y axis. The Z axis angular rate detecting unit 21 is adapted to detect the angular rate of the vehicle along Z axis.

Each of the X axis, Y axis and Z axis angular rate detecting units 21, 41 and 71 is a vibratory device, which comprises at least one set of vibrating inertial elements, including tuning forks, and associated supporting structures and means, including capacitive readout means, and uses Coriolis effects to detect vehicle angular rate.

25 Each of the X axis, Y axis and Z axis vibrating type angular rate detecting units 21, 41, 71 receives signals as follows:

1) dither drive signals from the respective dither motion control circuitry 922, keeping the inertial elements oscillating; and

2) carrier reference oscillation signals from the oscillator 925, including capacitive pickoff excitation signals.

5 Each of the X axis, Y axis and Z axis vibrating type angular rate detecting units 21, 41, 71 detects the angular motion in X axis, Y axis and Z axis respectively of a vehicle in accordance with the dynamic theory (Coriolis force), and outputs signals as follows:

10 1) angular motion-induced signals, including rate displacement signals which may be modulated carrier reference oscillation signals to a trans Impedance amplifier circuit 231, 431, 731 of the first, second, and third front-end circuit 23; and

2) its inertial element dither motion signals, including dither displacement signals, to the high-pass filter 232, 432, 732 of the first, second, and third front-end circuit 23.

15 The three dither motion control circuitries 922 receive the inertial element dither motion signals from the X axis, Y axis and Z axis vibrating type angular rate detecting units 21, 41, 71 respectively, reference pickoff signals from the oscillator 925, and produce digital inertial element displacement signals with known phase.

20 In order to convert the inertial element dither motion signals from the X axis, Y axis and Z axis vibrating type angular rate detecting units 21, 41, 71 to processible inertial element dither motion signals, referring to Fig. 24, each of the dither motion control circuitries 922 comprises:

an amplifier and summer circuit 9221 connected to the trans impedance amplifier circuit 231, 431, 731 of the respective first, second or third front-end circuit 23, 25 43, 73 for amplifying the two dither displacement signals for more than ten times 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 signal;

a high-pass filter circuit 9222 connected to the amplifier and summer circuit 9221 for removing residual dither drive signals and noise from the dither displacement differential signal to form a filtered dither displacement differential signal;

a demodulator circuit 9223 connected to the high-pass filter circuit 9222 for receiving the capacitive pickoff excitation signals as phase reference signals from the oscillator 925 and the filtered dither displacement differential signal from the high-pass filter 9222 and extracting the in-phase portion of the filtered dither displacement differential signal to produce an inertial element displacement signal with known phase;

a low-pass filter 9225 connected to the demodulator circuit 9223 for removing high frequency noise from the inertial element displacement signal input thereto to form a low frequency inertial element displacement signal;

an analog/digital converter 9224 connected to the low-pass filter 9225 for converting the low frequency inertial element displacement analog signal to produce a digitized low frequency inertial element displacement signal to the dither motion processing module 912 (disclosed in the following text) running the DSP chipset 91;

a digital/analog converter 9226 processing the selected amplitude from the dither motion processing module 912 to form a dither drive signal with the correct amplitude; and

an amplifier 9227 which generates and amplifies the dither drive signal to the respective X axis, Y axis or Z axis vibrating type angular rate detecting unit 21, 41, 71 based on the dither drive signal with the selected frequency and correct amplitude.

The oscillation of the inertial elements residing inside each of the X axis, Y axis and Z axis vibrating type angular rate detecting units 21, 41, 71 is generally driven by a high frequency sinusoidal signal with precise amplitude. It is critical to provide the X axis, Y axis and Z axis vibrating type angular rate detecting units 21, 41, 71 with high

performance dither drive signals to achieve keen sensitivity and stability of X-axis, Y-axis and Z axis angular rate measurements.

The dither motion processing module 912 receives digital inertial element displacement signals with known phase from the analog/digital converter 9224 of the
5 dither motion control circuitry 922 for:

(1) finding the frequencies which have the highest Quality Factor (Q) Values,

(2) locking the frequency, and

(3) locking the amplitude to produce a dither drive signal, including high frequency sinusoidal signals with a precise amplitude, to the respective X axis, Y axis or
10 Z axis vibrating type angular rate detecting unit 21, 41, 71 to keep the inertial elements oscillating at the pre-determined resonant frequency.

The three dither motion processing modules 912 is to search and lock the vibrating frequency and amplitude of the inertial elements of the respective X axis, Y axis or Z axis vibrating type angular rate detecting unit 21, 41, 71. Therefore, the
15 digitized low frequency inertial element displacement signal is first represented in terms of its spectral content by using discrete Fast Fourier Transform (FFT).

Discrete Fast Fourier Transform (FFT) is an efficient algorithm for computing discrete Fourier transform (DFT), which dramatically reduces the computation load imposed by the DFT. The DFT is used to approximate the Fourier transform of a discrete
20 signal. The Fourier transform, or spectrum, of a continuous signal is defined as:

$$X(j\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t} dt$$

The DFT of N samples of a discrete signals X(nT) is given by:

$$X_s(k\omega) = \sum_{n=0}^{N-1} x(nT)e^{-j\omega Tnk}$$

where $\omega = 2\pi / NT$, T is the inter-sample time interval. The basic property of FFT is its ability to distinguish waves of different frequencies that have been additively combined.

After the digitized low frequency inertial element displacement signals are
5 represented in terms of their spectral content by using discrete Fast Fourier Transform (FFT), Q (Quality Factor) Analysis is applied to their spectral content to determine the frequency with global maximal Q value. The vibration of the inertial elements of the respective X axis, Y axis or Z axis vibrating type angular rate detecting unit 21, 41, 71 at the frequency with global maximal Q value can result in minimal power consumption and
10 cancel many of the terms that affect the excited mode. The Q value is a function of basic geometry, material properties, and ambient operating conditions.

A phase-locked loop and digital/analog converter is further used to control and stabilize the selected frequency and amplitude.

Referring to Figure 26, the dither motion processing module 912 further
15 includes a discrete Fast Fourier Transform (FFT) module 9121, a memory array of frequency and amplitude data module 9122, a maxima detection logic module 9123, and a Q analysis and selection logic module 9124 to find the frequencies which have the highest Quality Factor (Q) Values.

The discrete Fast Fourier Transform (FFT) module 9121 is arranged for
20 transforming the digitized low frequency inertial element displacement signal from the analog/digital converter 9224 of the dither motion control circuitry 922 to form amplitude data with the frequency spectrum of the input inertial element displacement signal.

The memory array of frequency and amplitude data module 9122 receives the amplitude data with frequency spectrum to form an array of amplitude data with
25 frequency spectrum.

The maxima detection logic module 9123 is adapted for partitioning the frequency spectrum from the array of the amplitude data with frequency into plural

spectrum segments, and choosing those frequencies with the largest amplitudes in the local segments of the frequency spectrum.

The Q analysis and selection logic module 9124 is adapted for performing Q analysis on the chosen frequencies to select frequency and amplitude by computing the ratio of amplitude/bandwidth, wherein the range for computing bandwidth is between $\pm 1/2$ of the peak for each maximum frequency point.

Moreover, the dither motion processing module 912 further includes a phase-lock loop 9125 to reject noise of the selected frequency to form a dither drive signal with the selected frequency, which serves as a very narrow bandpass filter, locking the frequency.

The three angle signal loop circuitries 921 receive the angular motion-induced signals from the X axis, Y axis and Z axis vibrating type angular rate detecting units 21, 41, 71 respectively, reference pickoff signals from the oscillator 925, and transform the angular motion-induced signals into angular rate signals. Referring to Fig. 23, each of the angle signal loop circuitries 921 for the respective first, second or third circuit board 2, 4, 7 comprises:

a voltage amplifier circuit 9211, which amplifies the filtered angular motion-induced signals from the high-pass filter circuit 232 of the respective first, second or third front-end circuit 23, 43, 73 to an extent of at least 100 milivolts to form amplified angular motion-induced signals;

an amplifier and summer circuit 9212, which subtracts the difference between the angle rates of the amplified angular motion-induced signals to produce a differential angle rate signal;

a demodulator 9213, which is connected to the amplifier and summer circuit 9212, extracting the amplitude of the in-phase differential angle rate signal from the differential angle rate signal and the capacitive pickoff excitation signals from the oscillator 925;

a low-pass filter 9214, which is connected to the demodulator 9213, removing the high frequency noise of the amplitude signal of the in-phase differential angle rate signal to form the angular rate signal output to the angular increment and velocity increment producer 6.

5 Referring to Figs. 17 to 19, the acceleration producer 10 of the preferred embodiment of the present invention comprises:

a X axis accelerometer 42, which is provided on the second circuit board 4 and connected with the angular increment and velocity increment producer 6 provided in the AISC chip 92 of the control circuit board 9;

10 a Y axis accelerometer 22, which is provided on the first circuit board 2 and connected with angular increment and velocity increment producer 6 provided in the AISC chip 92 of the control circuit board 9; and

15 a Z axis accelerometer 72, which is provided on the third circuit board 7 and connected with angular increment and velocity increment producer 6 provided in the AISC chip 92 of the control circuit board 9.

Referring to Fig. 2, 18 and Fig. 19, thermal sensing producer device 15 of the preferred embodiment of the present invention further comprises:

a first thermal sensing producing unit 24 for sensing the temperature of the X axis angular rate detecting unit 21 and the Y axis accelerometer 22;

20 a second thermal sensing producer 44 for sensing the temperature of the Y axis angular rate detecting unit 41 and the X axis accelerometer 42; and

a third thermal sensing producer 74 for sensing the temperature of the Z axis angular rate detecting unit 71 and the Z axis accelerometer 72.

Referring to Fig. 2 and 19, the heater device 20 of the preferred embodiment of the present invention further comprises:

a first heater 25, which is connected to the X axis angular rate detecting unit 21, the Y axis accelerometer 22, and the first front-end circuit 23, for maintaining the
5 . predetermined operational temperature of the X axis angular rate detecting unit 21, the Y axis accelerometer 22, and the first front-end circuit 23;

a second heater 45, which is connected to the Y axis angular rate detecting unit 41, the X axis accelerometer 42, and the second front-end circuit 43, for maintaining the
10 predetermined operational temperature of the X axis angular rate detecting unit 41, the X axis accelerometer 42, and the second front-end circuit 43; and

a third heater 75, which is connected to the Z axis angular rate detecting unit 71, the Z axis accelerometer 72, and the third front-end circuit 73, for maintaining the
predetermined operational temperature of the Z axis angular rate detecting unit 71, the Z axis accelerometer 72, and the third front-end circuit 73.

15 Referred to Figs. 2, 18, 19, 21, and 25, the thermal processor 30 of the preferred embodiment of the present invention further comprises three identical thermal control circuitries 923 and the thermal control computation modules 911 running the DSP chipset 91.

20 As shown in Figs. 19 and 25, each of the thermal control circuitries 923 further comprises:

a first amplifier circuit 9231, which is connected with the respective X axis, Y axis or Z axis thermal sensing producer 24, 44, 74, for amplifying the signals and suppressing the noise residing in the temperature voltage signals from the respective X axis, Y axis or Z axis thermal sensing producer 24, 44, 74 and improving the signal-to-
25 noise ratio;

an analog/digital converter 9232, which is connected with the amplifier circuit 9231, for sampling the temperature voltage signals and digitizing the sampled temperature voltage signals to digital signals, which are output to the thermal control computation module 911;

5 a digital/analog converter 9233 which converts the digital temperature commands input from the thermal control computation module 911 into analog signals; and

a second amplifier circuit 9234, which receives the analog signals from the digital/analog converter 9233, amplifying the input analog signals from the digital/analog
10 converter 9233 for driving the respective first, second or third heater 25, 45, 75; and closing the temperature controlling loop.

The thermal control computation module 911 computes digital temperature commands using the digital temperature voltage signals from the analog/digital converter 9232, the temperature sensor scale factor, and the pre-determined operating temperature
15 of the angular rate producer and acceleration producer, wherein the digital temperature commands are connected to the digital/analog converter 9233.

In order to achieve a high degree of full functional performance for the micro IMU, a specific package of the first circuit board 2, the second circuit board 4, the third circuit board 7, and the control circuit board 9 of the preferred embodiment of the present
20 invention is provided and disclosed as follows:

In the preferred embodiment of the present invention, as shown in Fig. 17, 18, and 19, the third circuit board 7 is bonded to a supporting structure by means of a conductive epoxy, and the first circuit board 2, the second circuit board 4, and the control circuit board 9 are arranged parallelly to bond to the third circuit board 7 perpendicularly
25 by a non conductive epoxy.

In other words, the first circuit board 2, the second circuit board 4, and the control circuit board 9 are soldered to the third circuit board 7 in such a way as to use the third circuit board 7 as an interconnect board, thereby avoiding the necessity to provide interconnect wiring, so as to minimize the small size.

5 The first, second, third, and control circuit boards 2, 4, 7, and 9 are constructed using ground planes which are brought out to the perimeter of each circuit board 2, 4, 7, 9, so that the conductive epoxy can form a continuous ground plane with the supporting structure. In this way the electrical noise levels are minimized and the thermal gradients are reduced. Moreover, the bonding process also reduces the change in misalignments
10 due to structural bending caused by acceleration of the IMU.

10017310-105201

What is Claimed is:

1. A micro inertial measurement unit, comprising:

an angular rate producer comprising a X axis angular rate detecting unit which produces a X axis angular rate electrical signal, a Y axis angular rate detecting unit which produces a Y axis angular rate electrical signal, and a Z axis angular rate detecting unit which produces a Z axis angular rate electrical signal;

an acceleration producer comprising a X axis accelerometer which produces a X axis acceleration electrical signal, a Y axis accelerometer which produces a Y axis acceleration electrical signal, and a Z axis accelerometer which produces a Z axis acceleration electrical signal; and

an angular increment and velocity increment producer, which is electrically connected with said X axis, Y axis and Z axis angular rate detecting units and said X axis, Y axis and Z axis accelerometers, receiving said X axis, Y axis and Z axis angular rate electrical signals and said X axis, Y axis and Z axis acceleration electrical signals from said angular rate producer and said acceleration producer respectively, wherein said X axis, Y axis and Z axis angular rate electrical signals and said X axis, Y axis and Z axis acceleration electrical signals are converted into are digital angular increments and digital velocity increments respectively.

2. The micro inertial measurement unit, as recited in claim 1, further comprising a thermal controlling means for maintaining a predetermined operating temperature of said angular rate producer, said acceleration producer and said angular increment and velocity increment producer.

4. A micro inertial measurement unit, as recited in claim 1, wherein said X axis, Y axis and Z axis angular rate electrical signals produced from said angular producer are analog angular rate voltage signals directly proportional to angular rates of a carrier carrying said micro inertial measurement unit, and said X axis, Y axis and Z axis

acceleration electrical signals produced from said acceleration producer are analog acceleration voltage signals directly proportional to accelerations of said vehicle.

- 3A. A micro inertial measurement unit, as recited in claim 2, wherein said X axis, Y axis and Z axis angular rate electrical signals produced from said angular
5 producer are analog angular rate voltage signals directly proportional to angular rates of a carrier carrying said micro inertial measurement unit, and said X axis, Y axis and Z axis acceleration electrical signals produced from said acceleration producer are analog acceleration voltage signals directly proportional to accelerations of said vehicle.

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Micro Inertial Measurement Unit

Abstract of the Disclosure

5 A micro inertial measurement unit, which is adapted to apply to output signals proportional to rotation and translational motion of a carrier, respectively from angular rate sensors and acceleration sensors, is employed with MEMS rate and acceleration sensors. Compared with a conventional IMU, the processing method utilizes a feedforward open-loop signal processing scheme to obtain highly accurate motion measurements by means of signal digitizing, temperature control and compensation, sensor error and misalignment calibrations, attitude updating, and damping control loops, and dramatically shrinks the size of mechanical and electronic hardware and power consumption, meanwhile, obtains highly accurate motion measurements.

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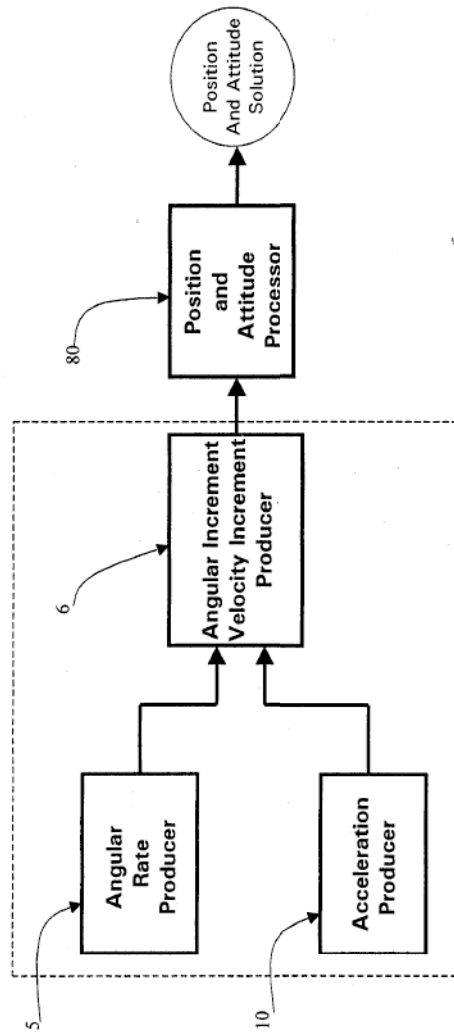


Figure 1

102301-01E-2-001

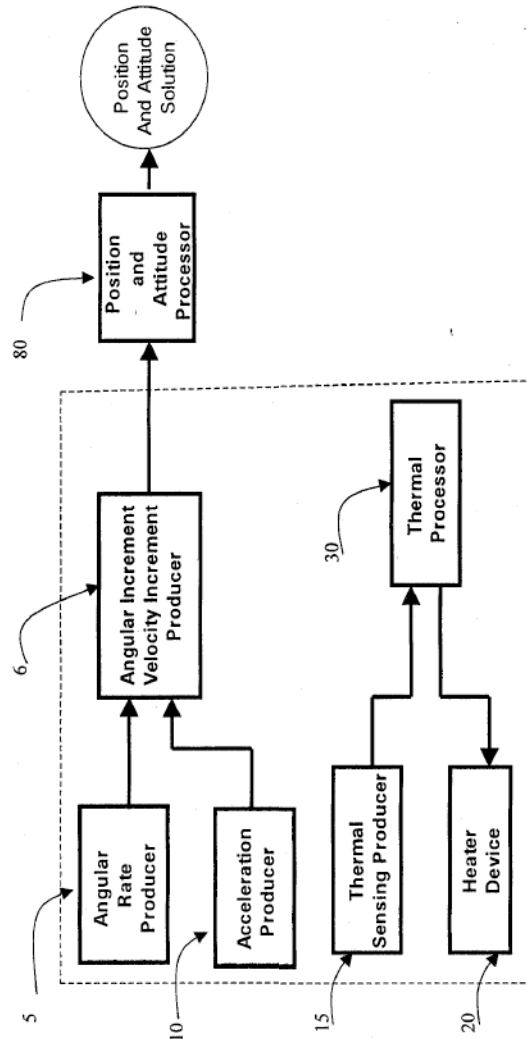


Figure 2

FIG. 3

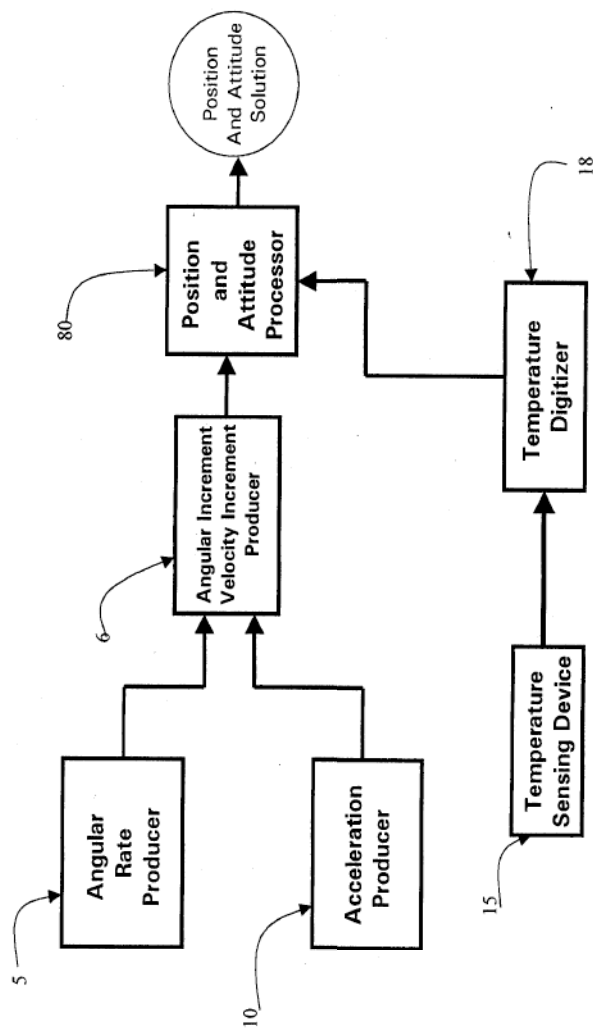


Figure 3

102201-01241001

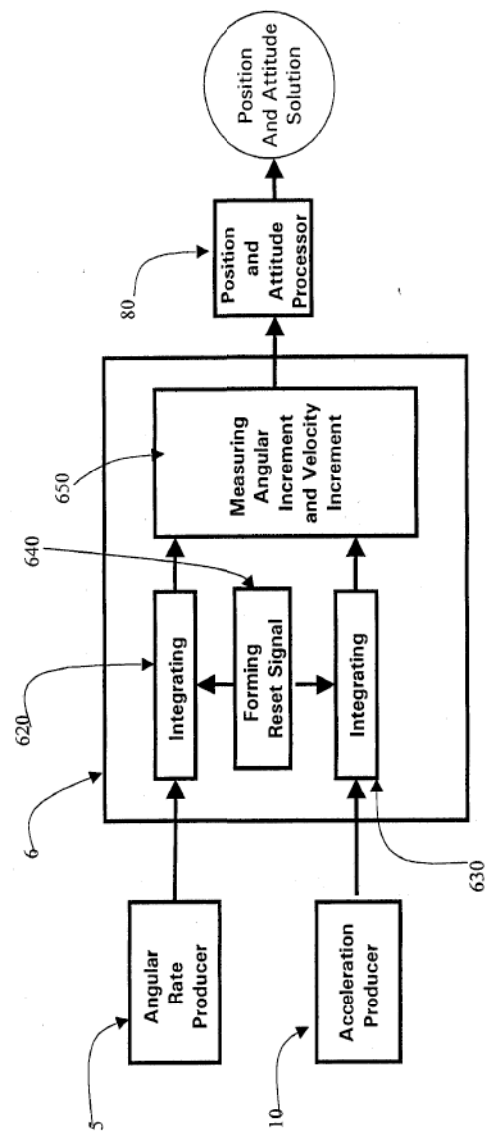


Figure 4

102201-01E21001

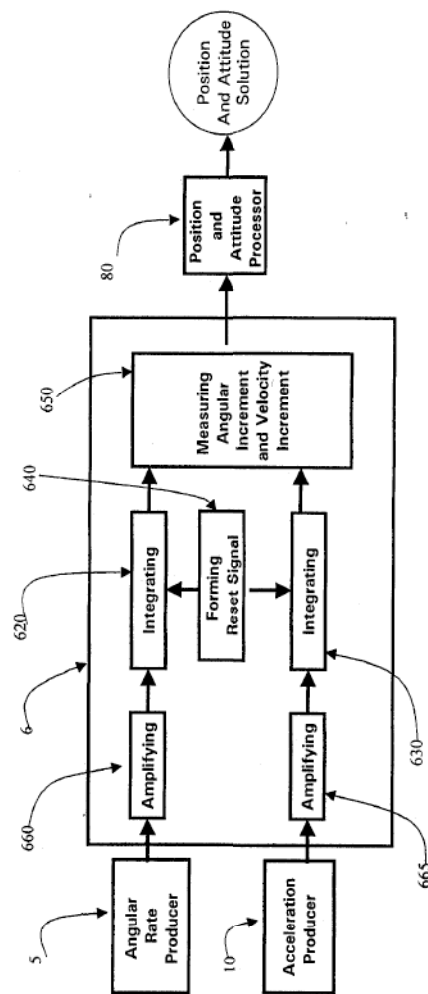


Figure 5

102201-01221001

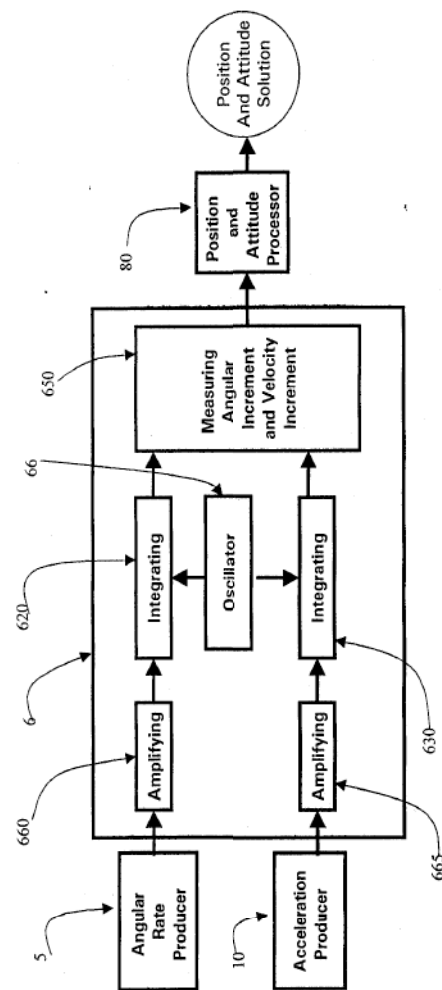


Figure 6

102201-01E21001

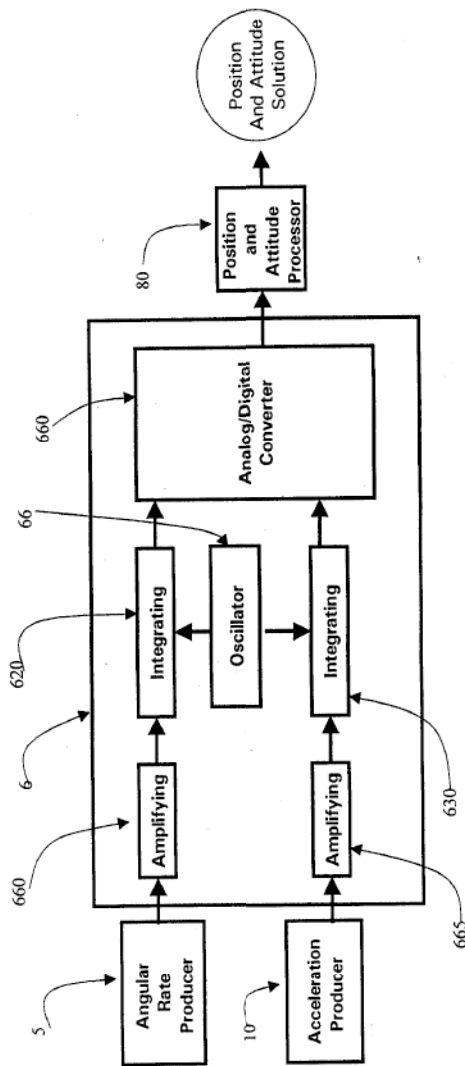


Figure 7

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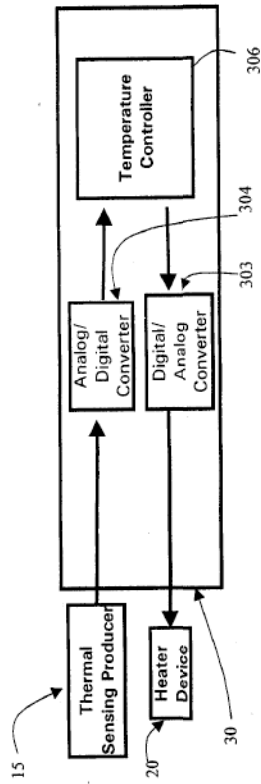


Figure 8

102201-0122001

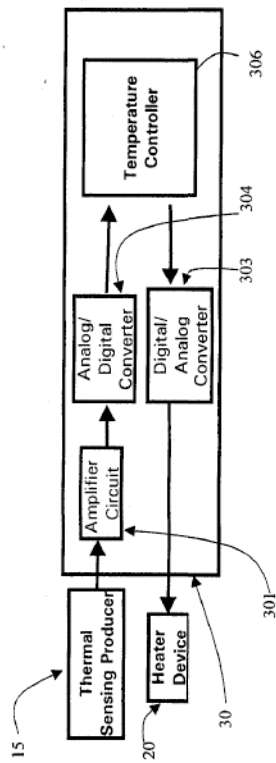


Figure 9

102201-01E/100F

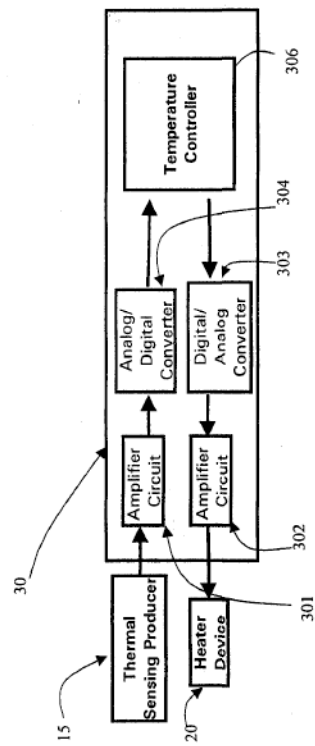


Figure 10

102201-01221001

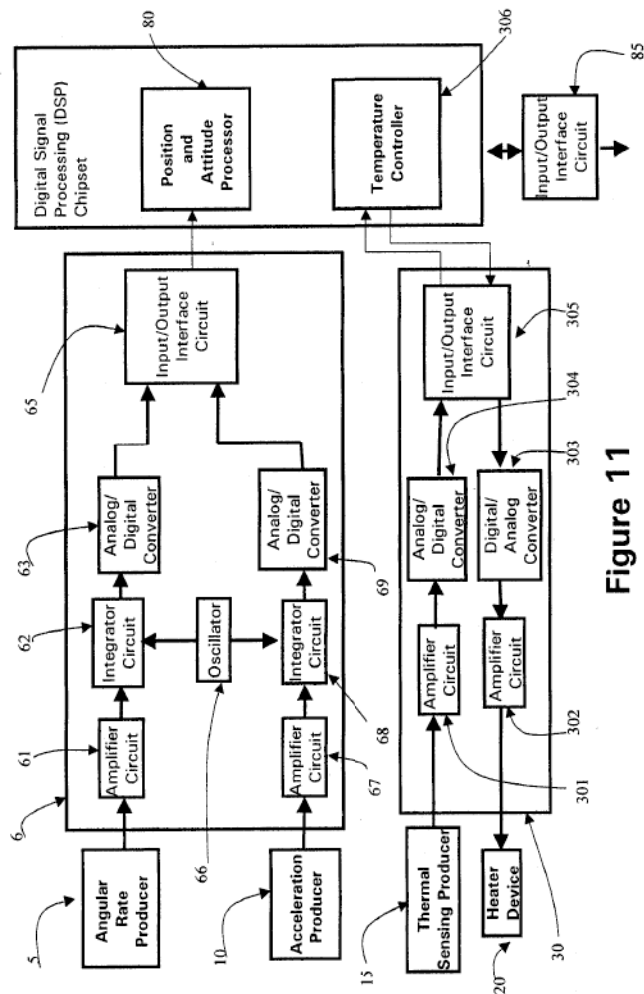


Figure 11

102201.0YE/T001

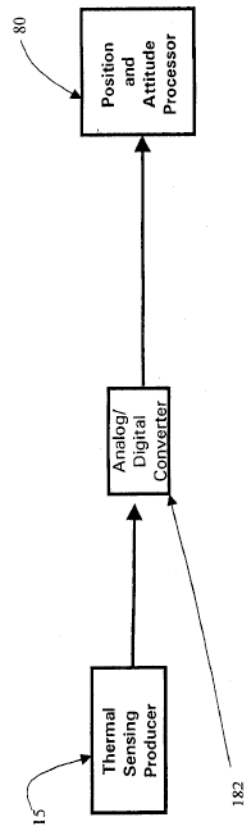


Figure 12

102201.01E4T001

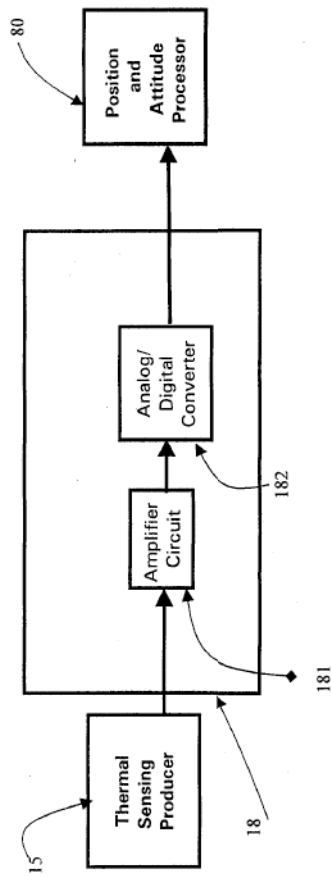


Figure 13

102201-0121001

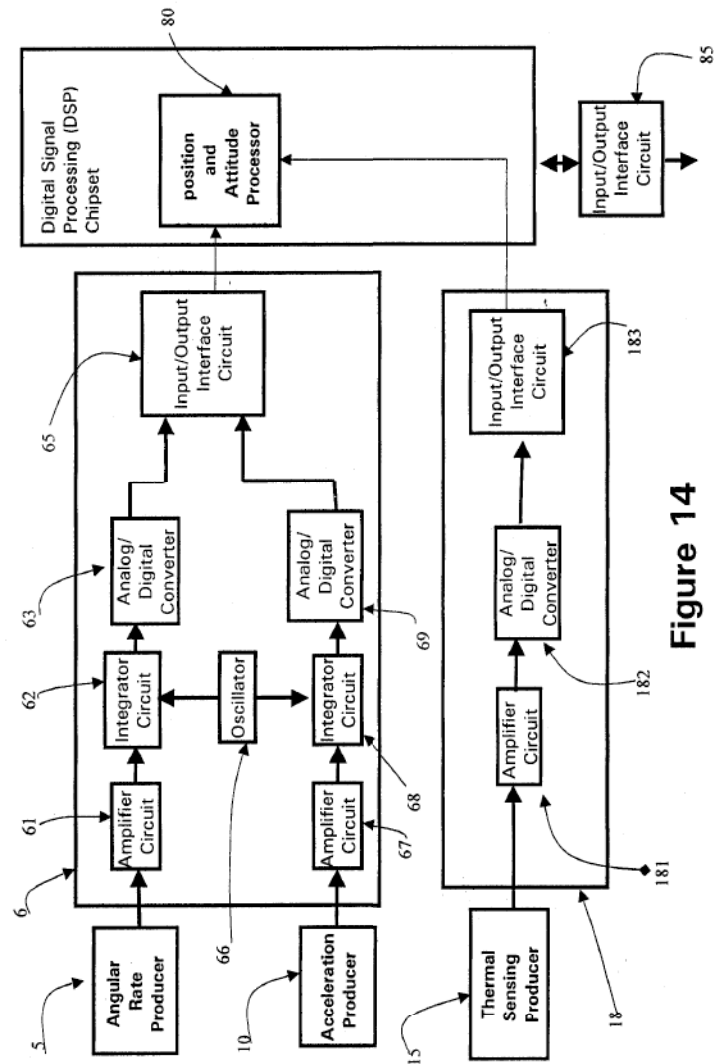


Figure 14

102201-0121001

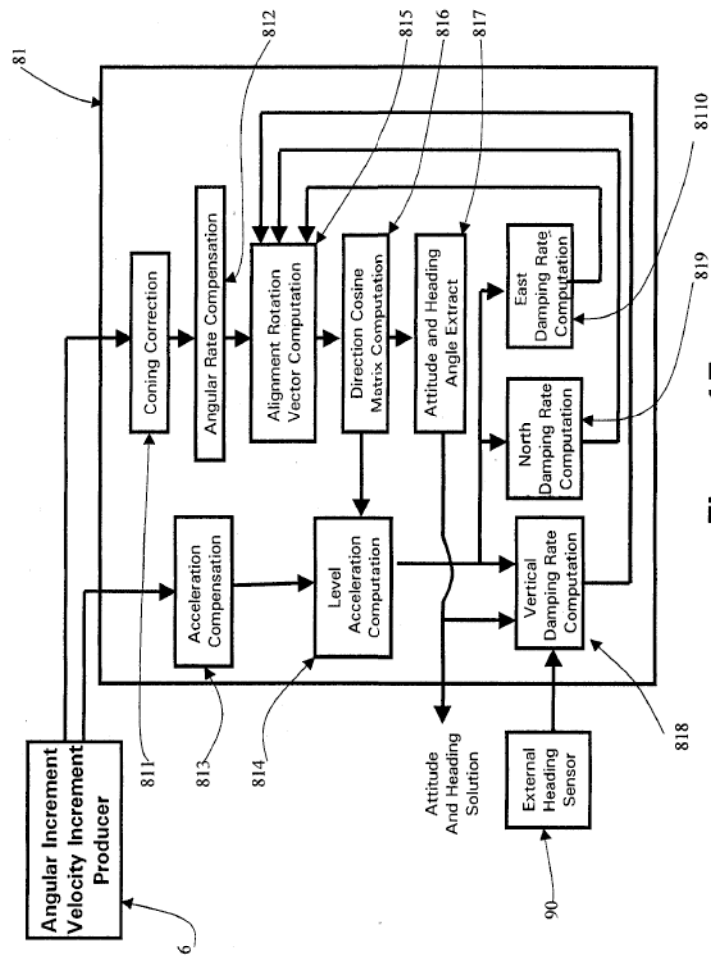


Figure 15

102201-01221001

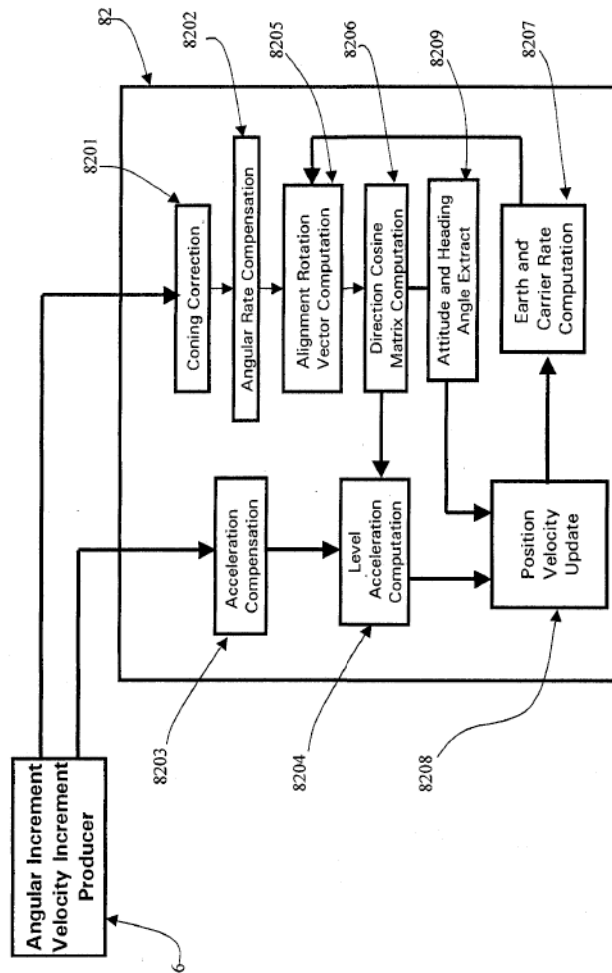


Figure 16

102201.01E2T001

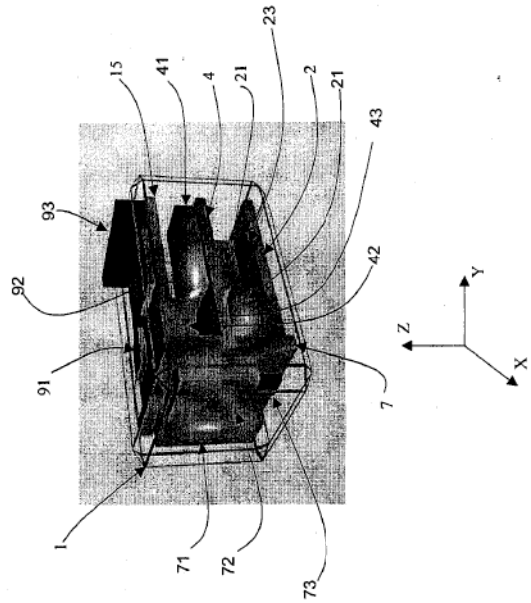


Figure 17

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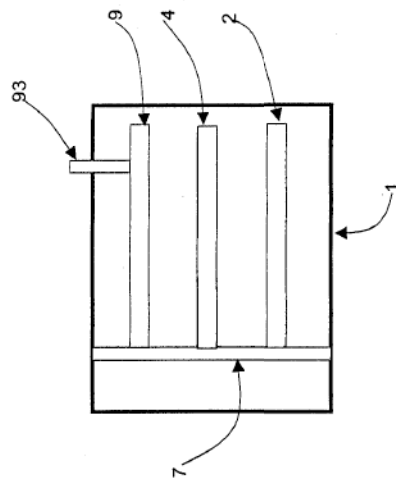


Figure 18

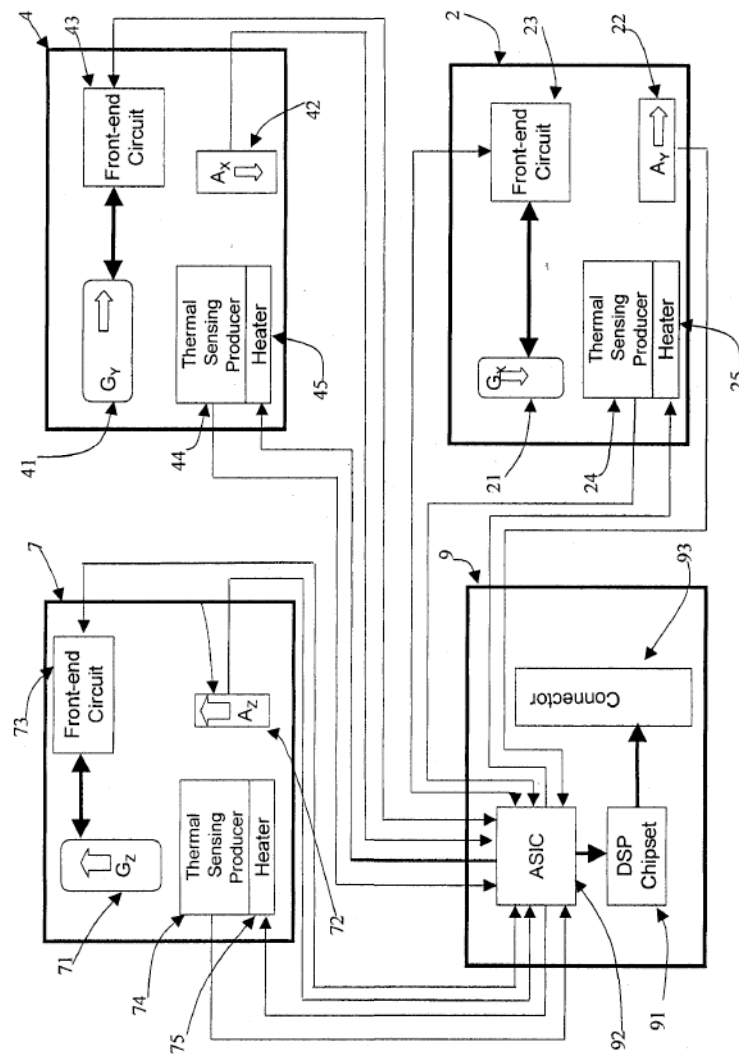


Figure 19

1002201-01E/1001

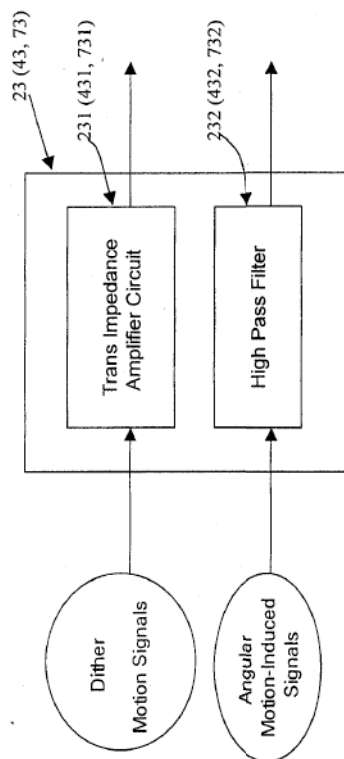


Figure 20

102201-01E21001

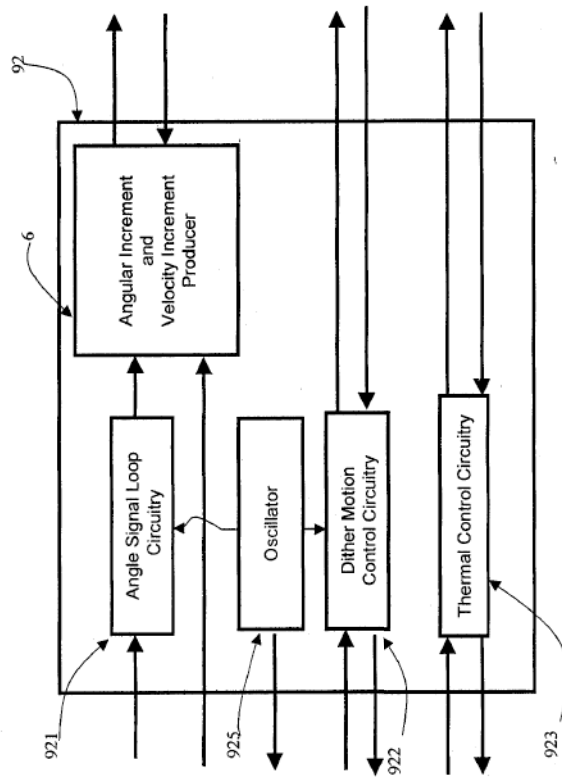


Figure 21

102201-012-1001

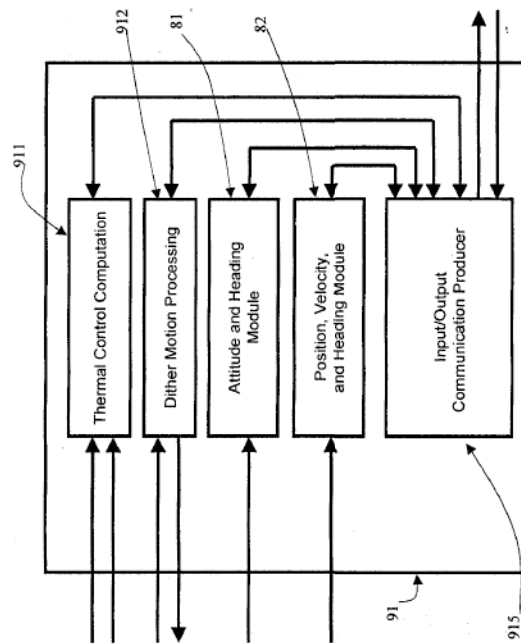


Figure 22

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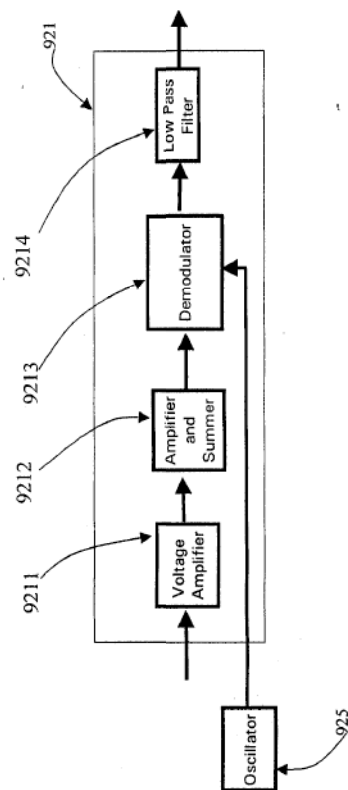


Figure 23

102201-01E21001

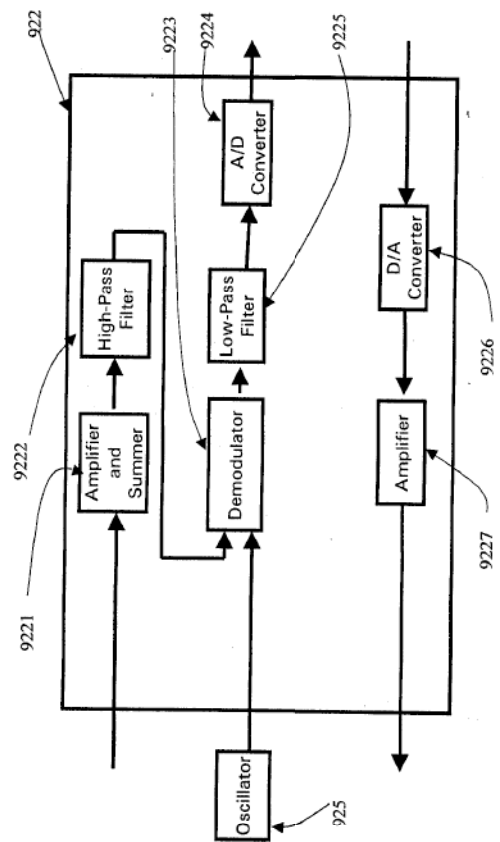


Figure 24

102201-01E/1001

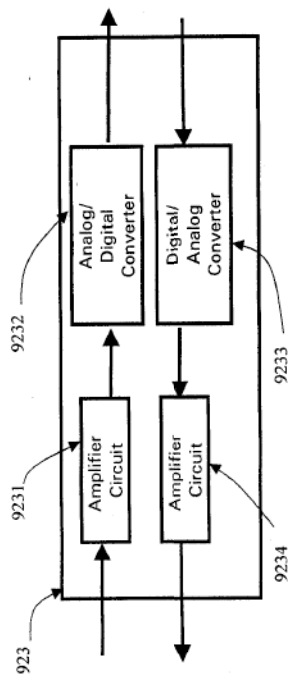


Figure 25

102201-01E/1001

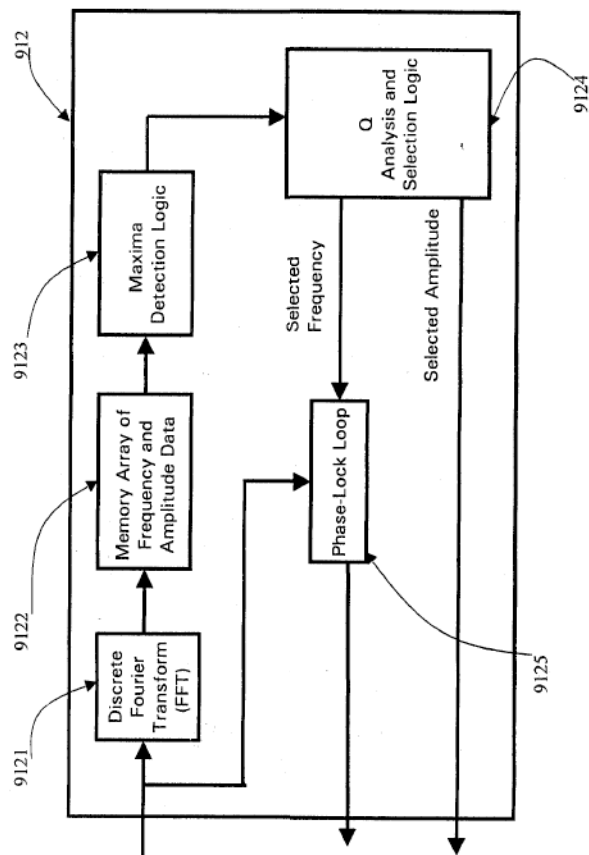


Figure 26

Hidden

702
141

FIG. 1

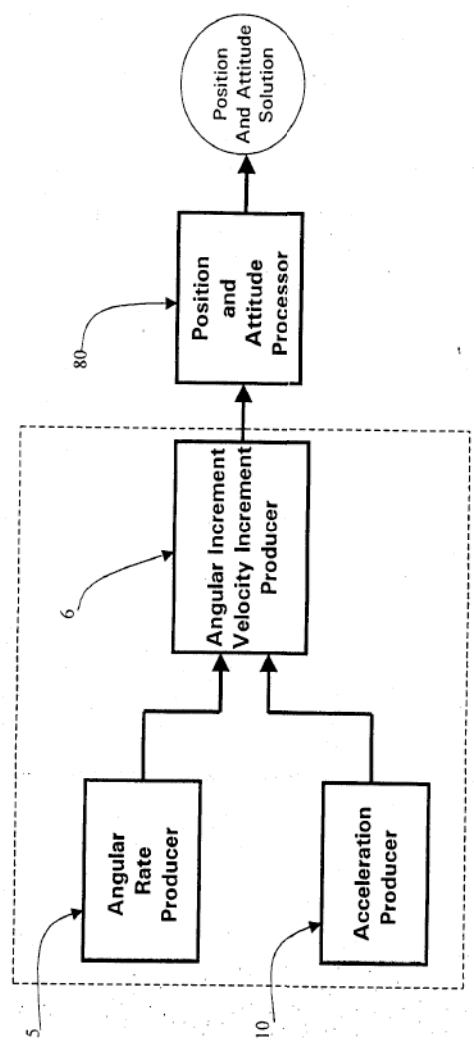


Figure 1

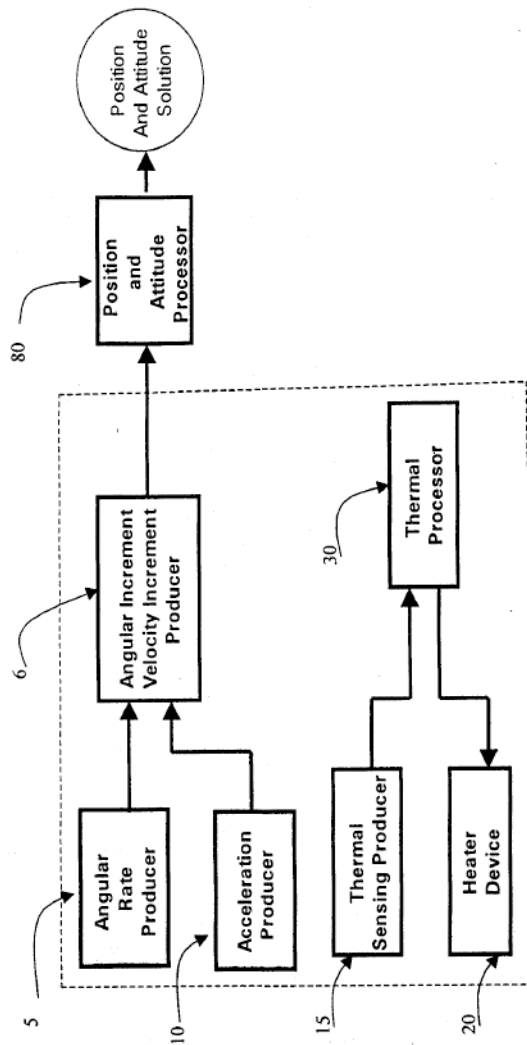


Figure 2

FIG. 3

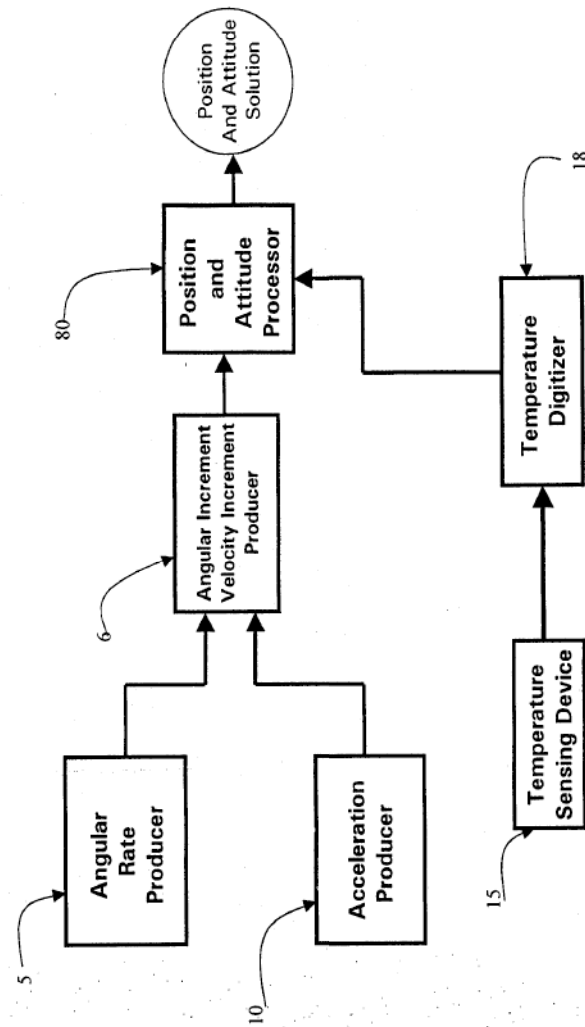


Figure 3

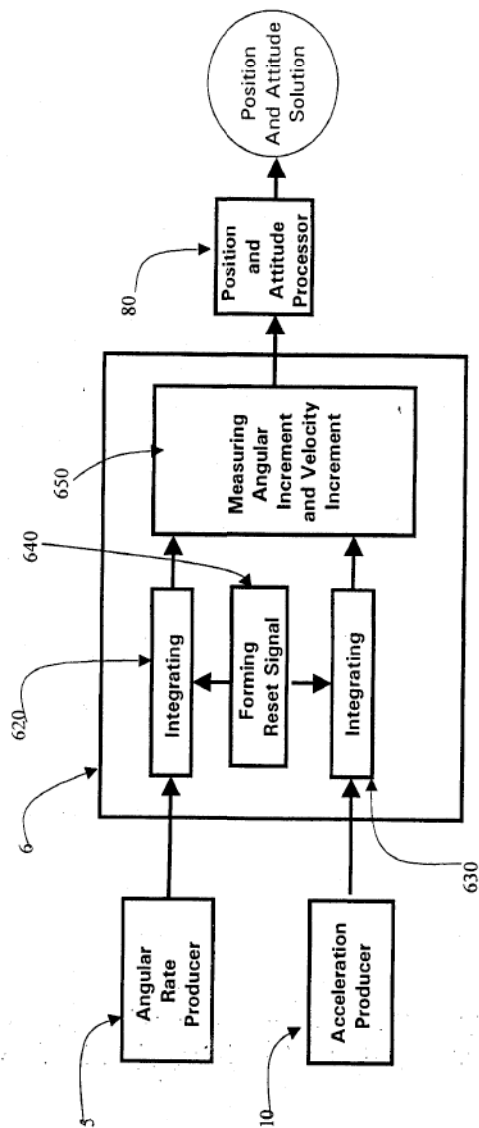


Figure 4

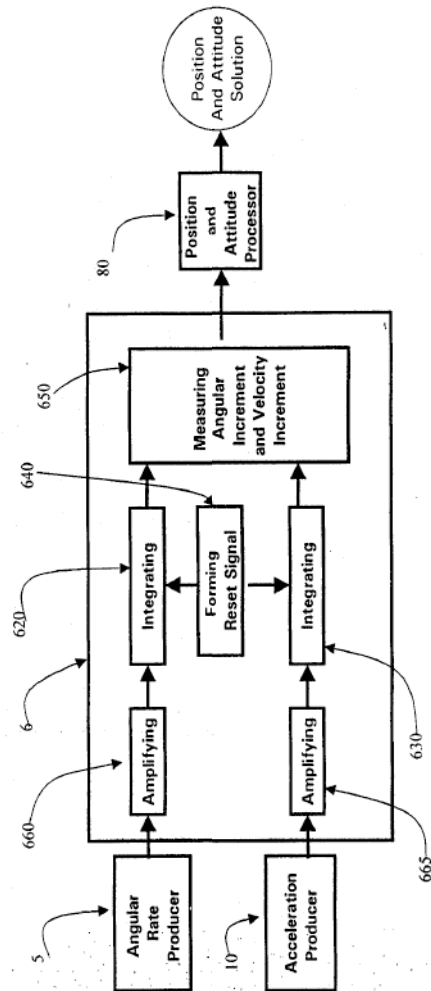


Figure 5

102201-0127001

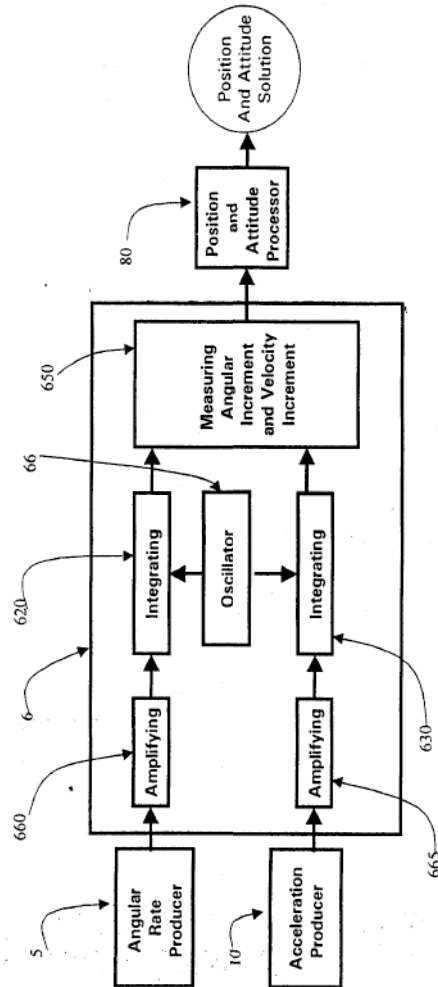


Figure 6

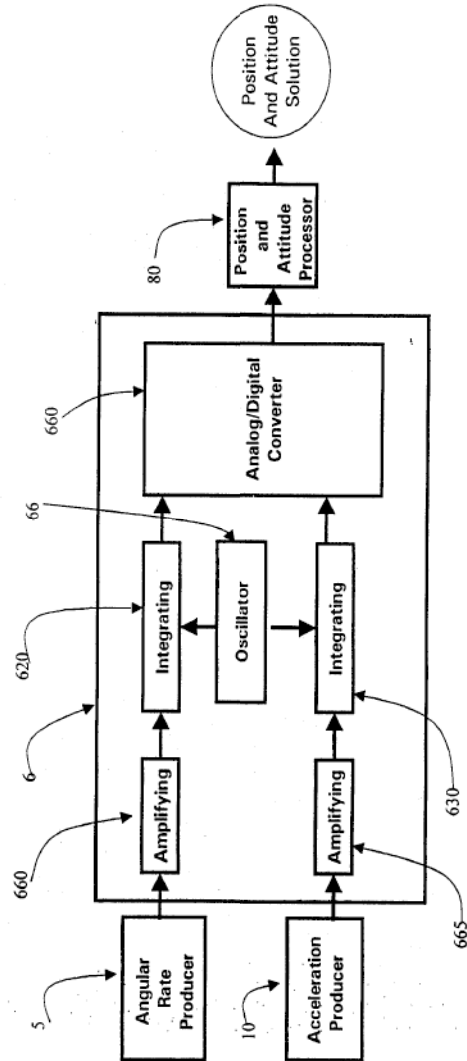


Figure 7

FILED "012400"

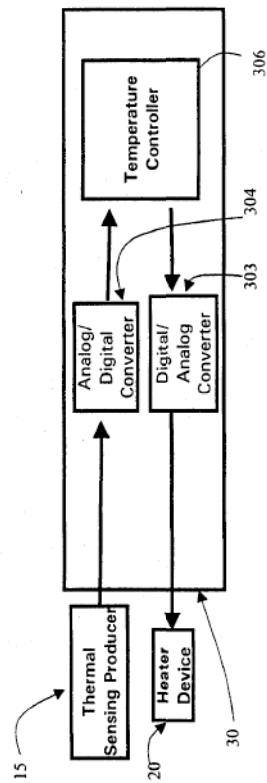


Figure 8

1002201-01E21001

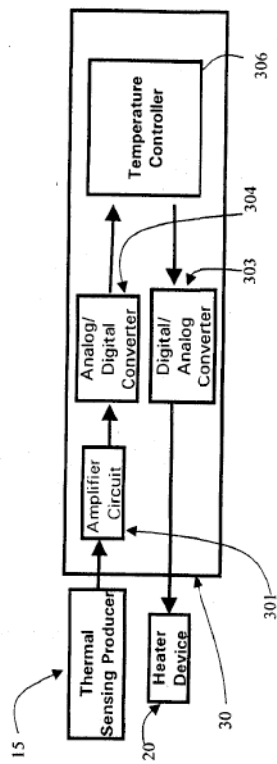
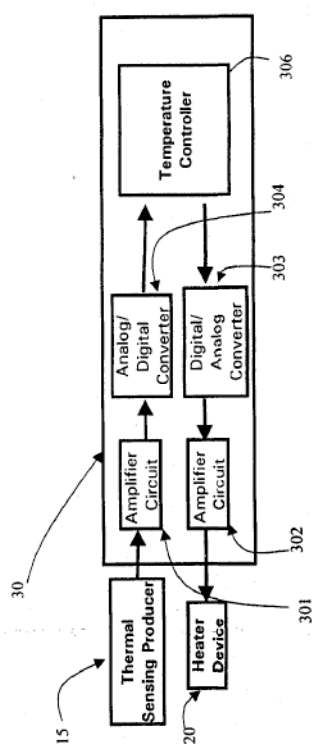


Figure 9



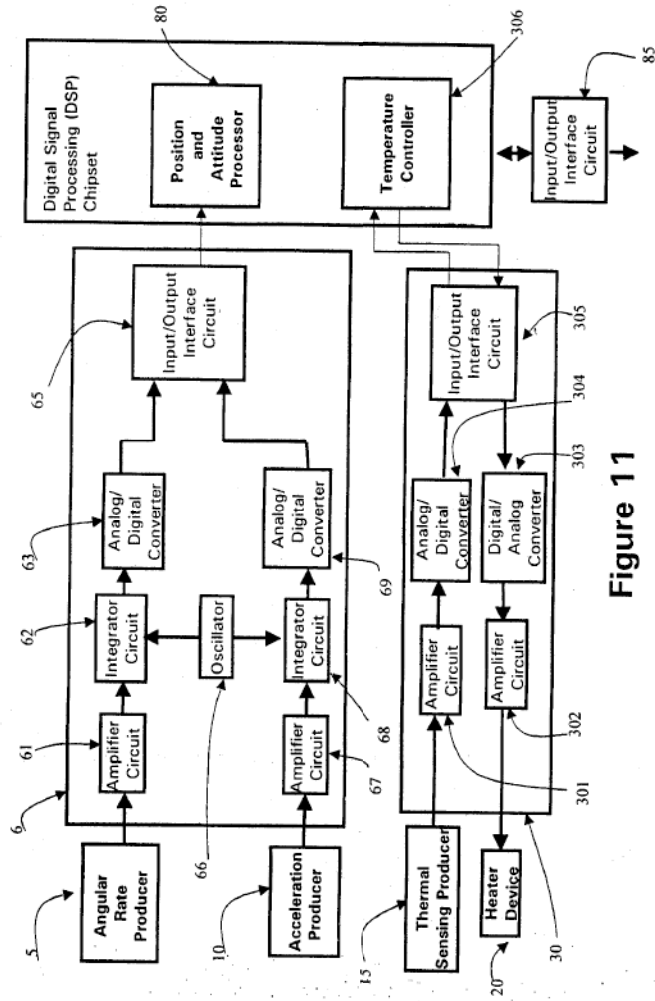


Figure 11

PRINT OF DRAWINGS
AS ORIGINALLY FILED

FIG. 12

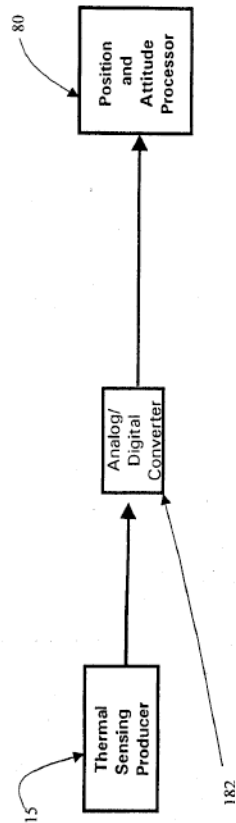


Figure 12

102201 0122001

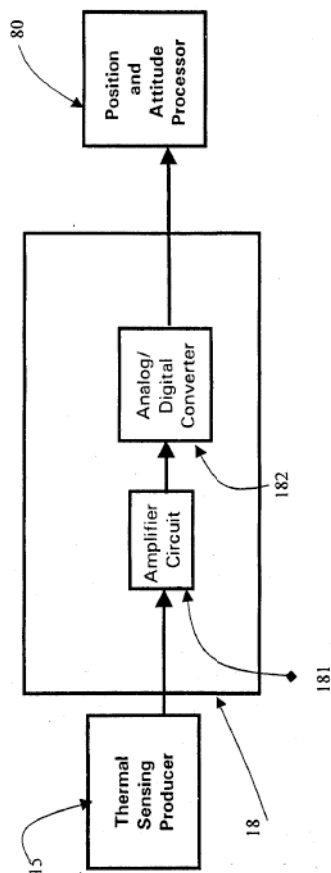


Figure 13

FIG. 14

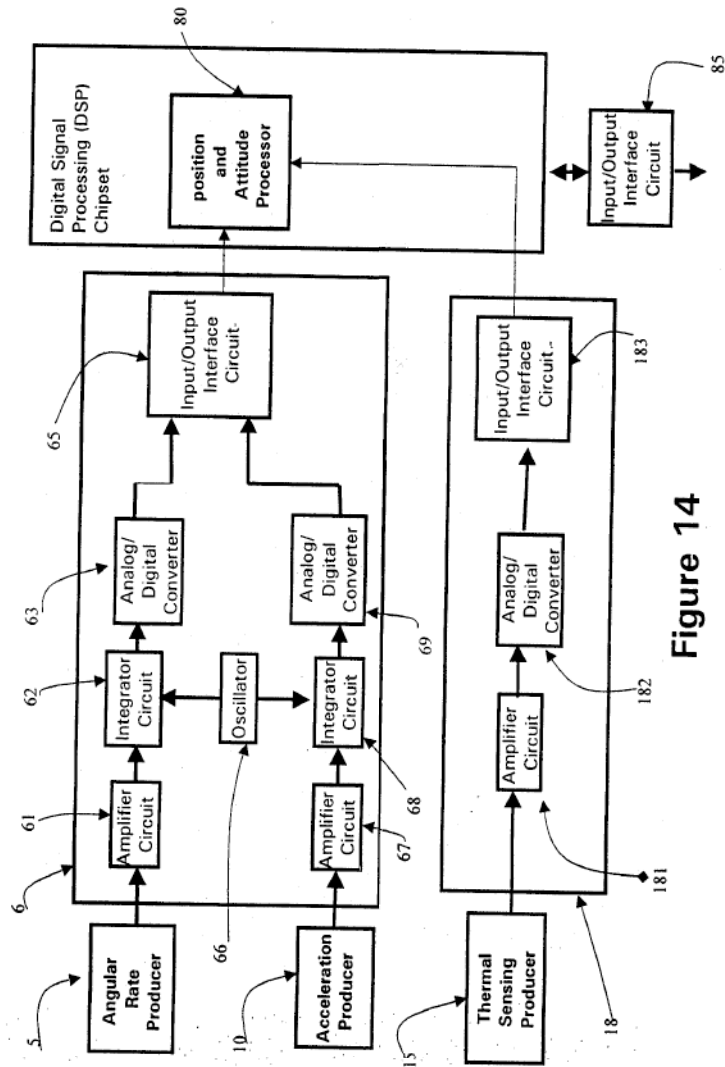


Figure 14

FIG. 15

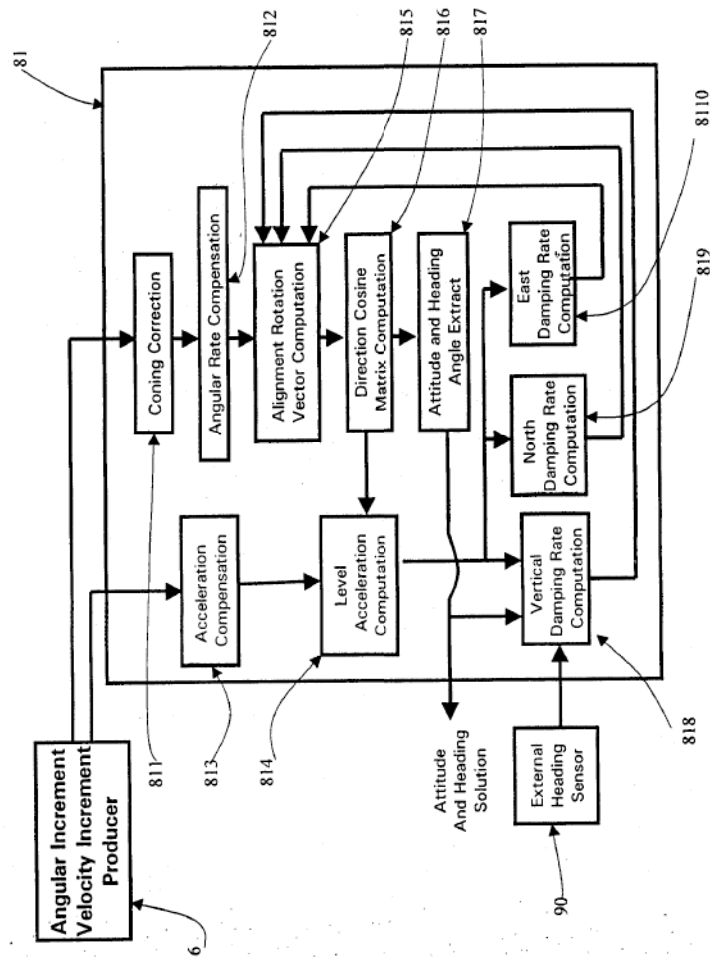


Figure 15

102201-01E21001

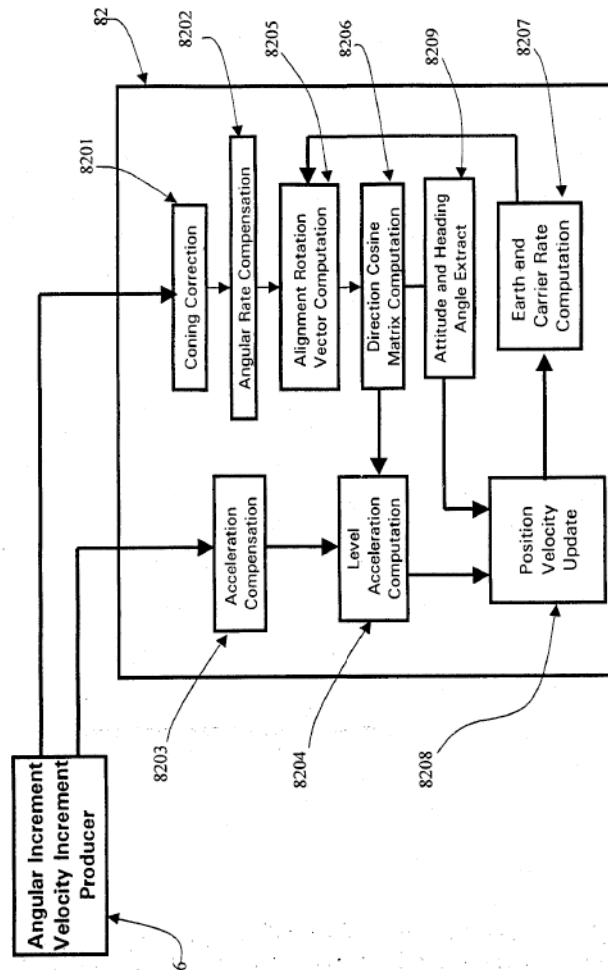


Figure 16

PRINT OF DRAWINGS
AS ORIGINALLY ID

FIGURE 17

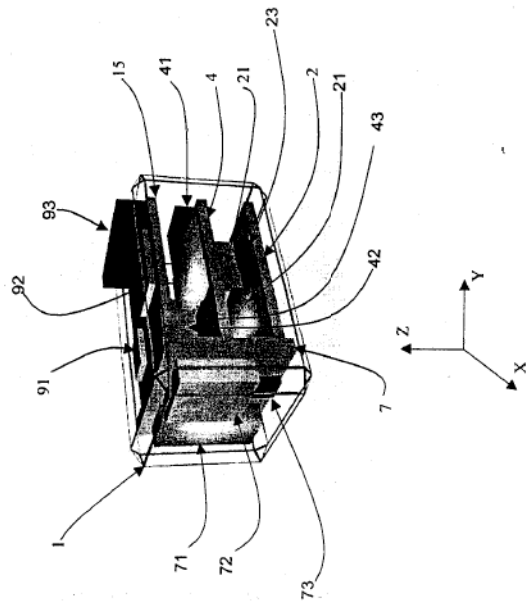


Figure 17

PRINT OF DRAWINGS
AS ORIGINALLY FILED

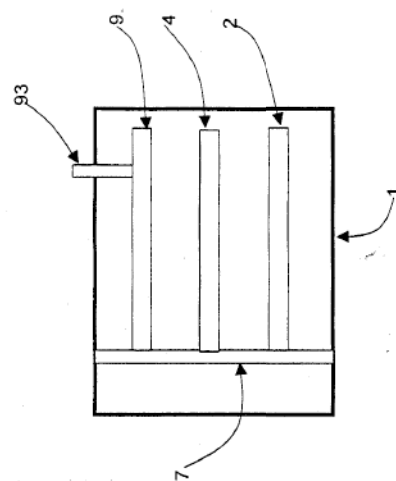


Figure 18

PRINT OF DRAWINGS
AS ORIGINALLY FILED

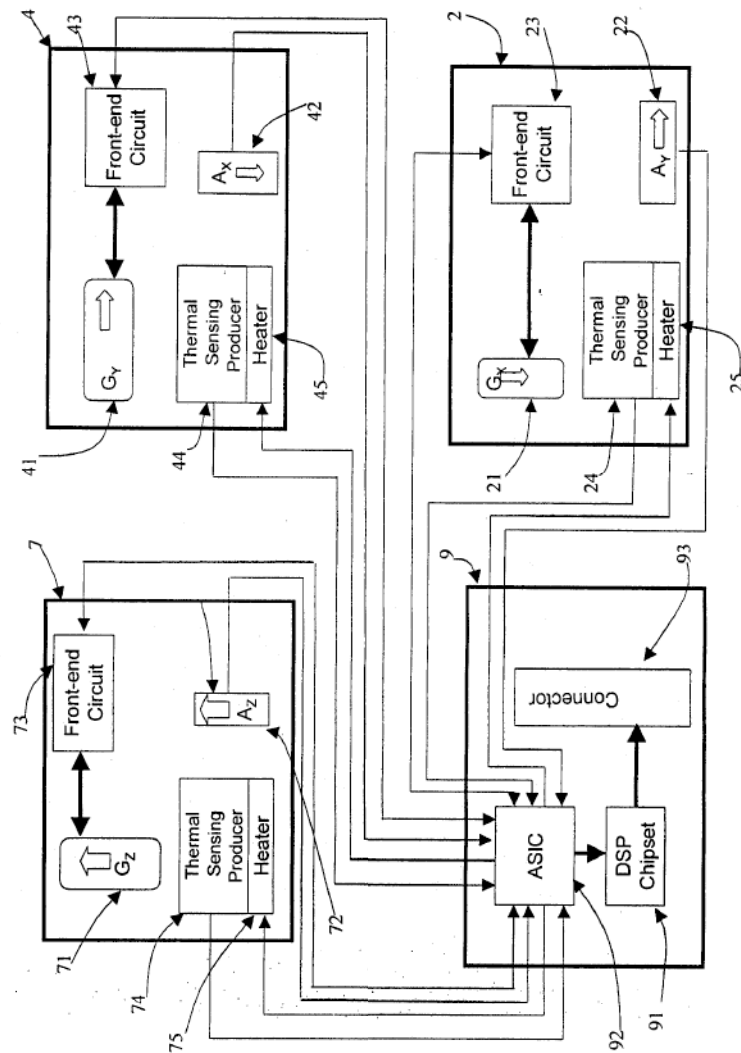


Figure 19

FIG. 20

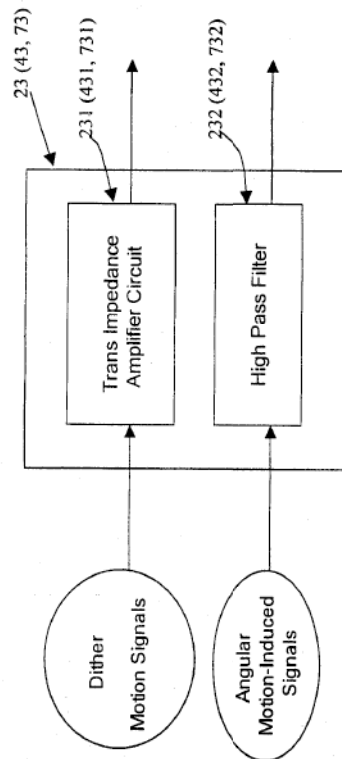


Figure 20

PRINT OF DRAWINGS
AS ORIGINALLY FILED

FIG. 21

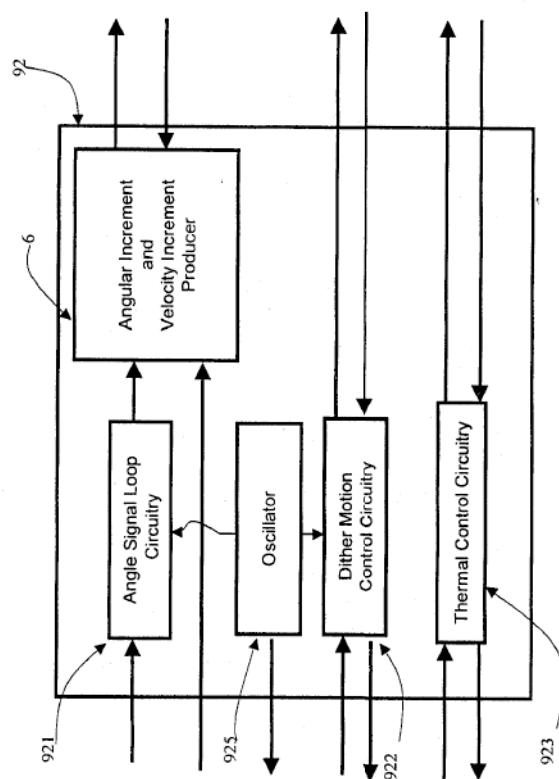


Figure 21

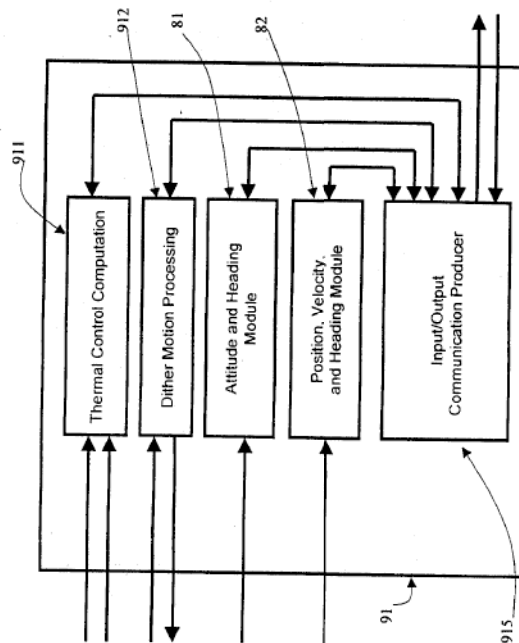


Figure 22

PRINT OF DRAWINGS
AS ORIGINALLY FILED

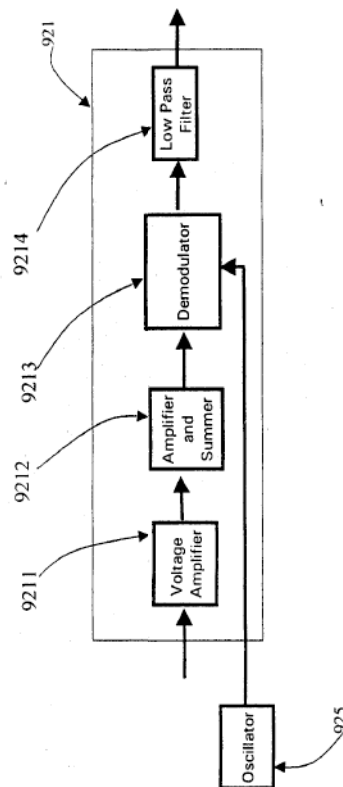


Figure 23

FIGURE 24

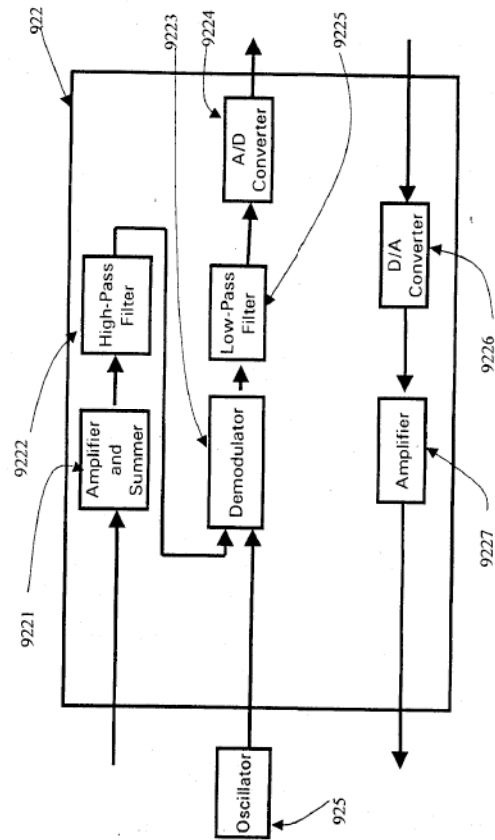


Figure 24

102201-01E21001

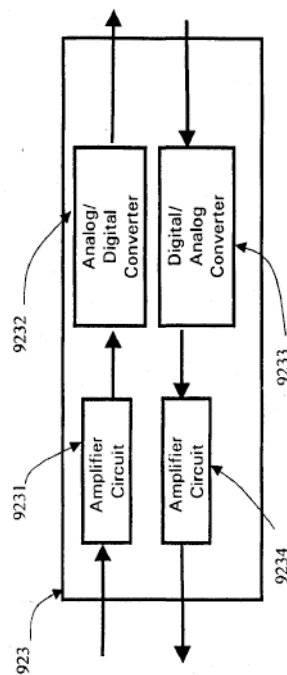


Figure 25

FIG. 26

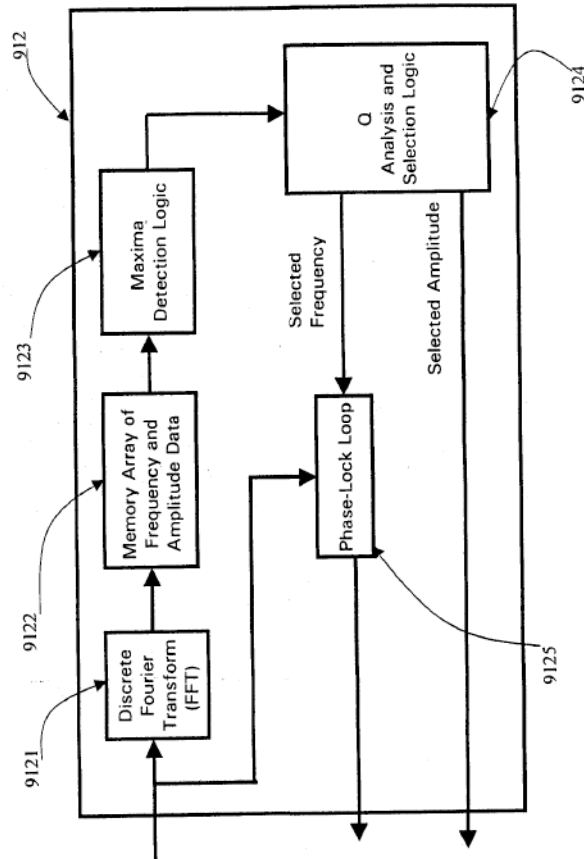


Figure 26

Attorney/Docket No: USP1048A-GNC

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Micro Inertial Measurement Unit

the specification of which is attached hereto unless the following box is checked:

☐ was filed on _____ as United States Application Number or PCT International Application Number _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 USC 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

(Number)	(Country)	(Day/Month/Year Filed)	Priority Claimed ☐ Yes ☐ No
_____	_____	_____	☐ Yes ☐ No
_____	_____	_____	☐ Yes ☐ No
_____	_____	_____	☐ Yes ☐ No

I hereby claimed the benefit under 35 USC 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 USC 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

(Application Number)	(Filing Date)	(Status-patented, pending, abandoned)
_____	_____	_____
_____	_____	_____

I hereby appoint the following attorney(s) and/or agent(s), with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Raymond Yat Chiu Chan, Reg. No. 37,484

Address all correspondence to: 516 San Luis Rey Road, Arcadia, CA 91007

Telephone Calls to: (626) 571-9812

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 or any patent issued thereon.

Full name of sole or first inventor (given name, family name) Hiram McCall

Inventor's signature Hiram McCall Date December 29, 1999
Residence 9131 Mason Ave., Chatsworth CA 91311 Citizenship U.S.A.
Post Office Address 9131 Mason Ave., Chatsworth CA 91311

Full name of second joint inventor, if any (given name, family name) Ching-Fang Lin

Second Inventor's signature Ching-Fang Lin Date December 29, 1999
Residence 9131 Mason Ave., Chatsworth CA 91311 Citizenship U.S.A.
Post Office Address 9131 Mason Ave., Chatsworth CA 91311

☐ Additional inventors are being named on separately numbered sheets attached hereto.

Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Applicant or Patentee: _____ A _____y's
Serial or Patent No.: _____ Docket No.: USP1048A-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:
Micro Inertial Measurement Unit 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 Avenue, Chatsworth CA 91311, USA
☐ 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
<u>Hiram McCall</u>	<u>Ching-Fang Lin</u>	
Signature of Inventor	Signature of Inventor	Signature of Inventor
<u>December 29, 1999</u>	<u>December 29, 1999</u>	
Date	Date	Date



COPY OF PAPERS
ORIGINALLY FILED

4-23-02 PB
[Signature]
2857

In The United States Patent and Trademark Office

Application Number: 10/017310
Applicants: Hiram McCall et al
Filing Date: 01/04/2000
Title: Micro Inertial Measurement Unit

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Examiner:
Group 1
TECHNOLOGY CENTER 2800

Date: January 17, 2002

PRELIMINARY AMENDMENT

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

Please amend the above identified divisional application as follows.

IN THE SPECIFICATION:

Kindly insert a section entitled "Cross Reference of Related Application" in page 1, after the section entitled "Title" and before the section "Background of the Present Invention" of the originally filed specification with the section as follows.

ai
Cross Reference of Related Application

This is a divisional application of a non-provisional application having an application number of 09/477,151 and a filing date of January 04, 2000.

VERSION WITH MARKINGS TO SHOW CHANGES MADE IN THE SPECIFICATION

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FEB 19 2002
TECHNOLOGY CENTER 2000

The changes after the section entitled "Title" and before the section entitled "Background of the Present Invention" in page 1 of the specification are marked up as follows.

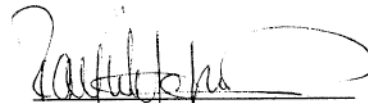
Cross Reference of Related Application

This is a divisional application of a non-provisional application having an application number of 09/477,151 and a filing date of January 04, 2000.

REMARKS-General

Upon review of the original specification, the applicant has amended the original specification to include the section entitled "Cross Reference of Related Application", which is deemed to more clearly and distinctly describe the subject matter of the instant invention. No new matter has been included in the specification.

Respectfully submitted,

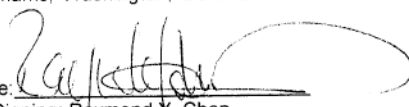


Raymond Y. C. Chan
Reg. Nr.: 37,484
1050 Oakdale Ave.
Arcadia, CA 91006-2222
Tel.: 1-626-571-9812
Fax.: 1-626-571-9813

CERTIFICATE OF MAILING

I hereby certify that this corresponding is being deposited with the United States Postal Service by First Class Mail, with sufficient postage, in an envelope addressed to "Box Amendments, Commissioner of Patents and Trademarks, Washington, DC 20231" on the date below.

Date: 01/17/2002

Signature: 
Person Signing: Raymond Y. Chan



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
ADDRESS: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/017,310	10/22/2001	Hiram McCall	USDP1699A-GNC	7211

7590 03/17/2003
Raymond Y. C. Chan
1050 Oakdale Lane
Arcadia, CA 91006

EXAMINER

BUI, BRYAN

ART UNIT

PAPER NUMBER

2863

DATE MAILED: 03/17/2003

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)	
	10/017,310	MCCALL ET AL.	
	Examiner	Art Unit	
	Bryan Bui	2863	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) ☒ Responsive to communication(s) filed on 22 October 2001.

2a) ☐ This action is FINAL. 2b) ☒ This action is non-final.

3) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4) ☒ Claim(s) 1-4 is/are pending in the application.

 4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5) ☐ Claim(s) _____ is/are allowed.

6) ☒ Claim(s) 1-4 is/are rejected.

7) ☐ Claim(s) _____ is/are objected to.

8) ☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9) ☐ The specification is objected to by the Examiner.

10) ☐ The drawing(s) filed on _____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

11) ☐ The proposed drawing correction filed on _____ is: a) ☐ approved b) ☐ disapproved by the Examiner.

If approved, corrected drawings are required in reply to this Office action.

12) ☐ The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. §§ 119 and 120

13) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a) ☐ All b) ☐ Some * c) ☐ None of:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. _____.

3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

14) ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).

a) ☐ The translation of the foreign language provisional application has been received.

15) ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892) 2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) 3) ☐ Information Disclosure Statement(s) (PTO-1449) Paper No(s) _____	4) ☐ Interview Summary (PTO-413) Paper No(s) _____ 5) ☐ Notice of Informal Patent Application (PTO-152) 6) ☐ Other: _____
---	--

DETAILED ACTION

Double Patenting

1. The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. See *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and, *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent is shown to be commonly owned with this application. See 37 CFR 1.130(b).

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

2. Claims 1-4 are rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1-2 of U.S. Patent No. 6,456,939. Although the conflicting claims are not identical, they are not patentably distinct from each other because the claims 1-2 of the reference 6,456,939 disclose all the specific features of the instant application to have the same results, especially when an angular rate producer/an acceleration producer for producing X axis, Y axis and Z axis angular rate electrical signals/X axis, Y axis and Z axis acceleration electrical signals as recited in claim 1 (6,456,939) are commonly well-known in the art to include X, Y and Z axes angular rate detecting units/X, Y, Z axes accelerometers to produce the respectively axis angular rate electrical signals/to produce the respectively axis acceleration electrical signals. Even though the claims of the reference (6,456,939) does not mention

the phrase of the connection between devices as recites in the limitation of the instant application "**electrically connected**" in an angular increment and velocity producer with the X, Y, and Z axes angular rate detecting units and X, Y, and Z axes accelerometers, it would be obvious in the art to modify the proceeding technique to include the "electrically connected" between devices to convert the X, Y, and X axes angular rate electrical signals/ X, Y, and Z axes acceleration electrical signals into digital angular increment/ digital velocity increment that having the same results as discloses in the claimed reference.

Conclusion

3. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

The reference of McNie et al. (U.S. Patent No. 6,276,205) discloses a Micro-machining.

The reference of Matthews et al. (U.S. Patent No. 5,033,854) discloses a multiplexed fiber-optic Gyro control.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Bryan Bui whose telephone number is 703-305-4490. The examiner can normally be reached on M-Th from 7am-4pm, and Alternate Fridays.

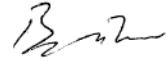
If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, John E Barlow can be reached on 703-308-3126. The fax phone numbers

Application/Control Number: 10/017,310
Art Unit: 2863

Page 4

for the organization where this application or proceeding is assigned are 703-308-7722
for regular communications and 703-308-7724 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or
proceeding should be directed to the receptionist whose telephone number is 703-308-
0956.



BRYAN BUI
PRIMARY EXAMINER

BB
March 7, 2003

Notice of References Cited	Application/Control No. 10/017,310	Applicant(s)/Patent Under Reexamination MCCALL ET AL.	
	Examiner Bryan Bui	Art Unit 2863	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-6,456,939	09-2002	McCall et al.	701/220
	B	US-6,276,205	08-2001	McNie et al.	73/504.13
	C	US-5,033,854	07-1991	Matthews et al.	356/462
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(i).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

U.S. Patent and Trademark Office
PTO-892 (Rev. 01-2001)

Notice of References Cited

Part of Paper No. 3



In The United States Patent and Trademark Office

Application Number: 10/017,310
Applicants: Ching-Fang Lin et al
Filing Date: 10/22/2001
Title: Micro Inertial Measurement Unit

Examiner: Bryan Bui
Group Art Unit: 2863

Date: 06/16/2003

Gp/2863-8
4/Response
P. Walker
6-26-03

RESPONSE

Honorable Commissioner for Patents,
P.O. Box 1450,
Alexandria, VA 22313-1450

Sir:

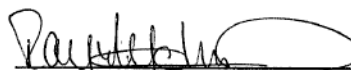
In response to the Office Action mailed 03/17/2003, the applicant respectfully submits as follows.

1. The applicant submits a terminal disclaimer herewith, in compliance with 37CFR1.321(c), to disclaim the terminal part of the statutory term of any patent granted on instant application which would extend beyond the expiration date of the full statutory term defined in 35 U.S.C. 154 to 156 and 173, as presently shortened by any terminal disclaimer, of prior Patent No. 6,456,939, in order to overcome the rejection of the claims 1-4 under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1-2 of the U.S. Patent No. 6,456,939.
2. The cited but not relied upon references have been studied and are greatly appreciated, but are deemed to be less relevant than the relied upon references.
3. A check in an amount of US\$55.00 is submitted herewith to pay the terminal disclaimer fee. This amount is believed to be correct; however, the Commissioner is hereby authorized to charge any deficiency or credit any overpayment to Deposit Account No. 502111.
4. In view of the above, it is submitted that the claims are in condition for allowance. Reconsideration and withdrawal of the rejection are requested. Allowance of claims 1-4 at an early date is solicited.

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JUN 23 2003
TECHNOLOGY CENTER 2800

5. Should the Examiner believe that anything further is needed in order to place the application in condition for allowance, he is requested to contact the undersigned at the telephone number listed below.

Respectfully submitted,

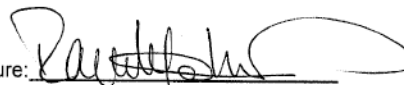


Raymond Y. Chan
Reg. Nr.: 37,484
108 N. Ynez Ave.
Suite 128
Monterey Park, CA 91754
Tel.: 1-626-571-9812
Fax.: 1-626-571-9813

CERTIFICATE OF MAILING

I hereby certify that this corresponding is being deposited with the United States Postal Service by First Class Mail, with sufficient postage, in an envelope addressed to "Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450" on the date below.

Date: June 16, 2003

Signature: 
Person Signing: Raymond Y. Chan



Docket Number: USDP1699A-GNC

#5
R. Preston
7/8/2003

**TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION
OVER A PRIOR PATENT**

**TERMINAL DISCLAIMER
APPROVED**

In re Application of:
Application No.: 10/017,310
Filed: 10/22/2001
For: Micro Inertial Measurement Unit

JUL 08 2003

**TECHNOLOGY CENTER 2800
SPECIAL PROGRAM CENTER**

The owner*, Ching-Fang Lin and Hiram McCall, of one hundred percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on instant application which would extend beyond the expiration date of the full statutory term defined in 35 U.S.C. 154 to 156 and 173, as presently shortened by any terminal disclaimer, of prior Patent No. 6,456,939. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the prior patent are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term as defined in 35 U.S.C. 154 to 156 and 173 of the prior patent, as presently shortened by any terminal disclaimer, in the event that it later: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued or is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

Check either box 1 or 2 below, if appropriate.

1. ☐ For submissions on behalf of an organization (e.g., corporation, partnership, university, government agency, etc.), the undersigned is empowered to act on behalf of the organization.

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 or any patent issued thereon.

2. ☒ The undersigned is an attorney or agent of record.

RENEE PRESTON
PARALEGAL SPECIALIST
TECHNOLOGY CENTER 2800

RECEIVED

JUL 07 2003

**OFFICE OF THE SPECIAL
PROGRAMS EXAMINER**

Signature
Raymond Y. Chan
Reg. No. 37,484

Date
JUL 16, 2003

- ☒ Terminal disclaimer fee under 37 CFR 1.20(d) included.

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).

06/26/2003 EMAIL: 00000001 10017310

01 JUL 2003

55.00 DP

Serial Number 	Application No.	Applicant(s)	
	10/017,310	LIN, CHING-FANG et al.	

TERMINAL DISCLAIMER		☒ APPROVED		☐ DISAPPROVED	
The term of this patent shall not extend beyond the expiration date of U.S. Patent No:	6,456,939				
The term of this patent subsequent to the adjacent date has been disclaimed.					
INTERNAL DOCUMENT - DO NOT MAIL				Document Code - DISQ	

U.S. Patent and Trademark Office

Notice of Allowability	Application No.	Applicant(s)	
	10/017,310	MCCALL ET AL.	
	Examiner	Art Unit	
	Bryan Bui	2863	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office of upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to 8/18/2003.
2. ☒ The allowed claim(s) is/are 1-4.
3. ☒ The drawings filed on 22 October 2001 are accepted by the Examiner.
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
 - a) ☐ All b) ☐ Some* c) ☐ None of the:
 1. ☐ Certified copies of the priority documents have been received.
 2. ☐ Certified copies of the priority documents have been received in Application No. _____.
 3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

5. ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).
 - (a) ☐ The translation of the foreign language provisional application has been received.
6. ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application. **THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

7. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
8. ☐ CORRECTED DRAWINGS must be submitted.
 - (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
 - 1) ☐ hereto or 2) ☐ to Paper No. _____.
 - (b) ☐ including changes required by the proposed drawing correction filed _____, which has been approved by the Examiner.
 - (c) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No. _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet.

9. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1 ☐ Notice of References Cited (PTO-892) 3 ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948) 5 ☐ Information Disclosure Statements (PTO-1449), Paper No. _____ 7 ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material	2 ☐ Notice of Informal Patent Application (PTO-152) 4 ☐ Interview Summary (PTO-413), Paper No. _____ 6 ☐ Examiner's Amendment/Comment 8 ☒ Examiner's Statement of Reasons for Allowance 9 ☐ Other
--	---

DETAILED ACTION

Notice to applicants

1. Applicants' papers filed on 6/18/2003 have been received and entered. Claims 1-4 are pending in the application.
2. The terminal disclaimer filed on 6/18/2003 disclaiming the terminal portion of any patent granted on this application which would extend beyond the expiration date of prior patent No. 6,456,939 has been reviewed and is accepted. The terminal disclaimer has been recorded.

Allowable Subject Matter

3. The following is an examiner's statement of reasons for allowance:

Claims 1-4 are allowable over the prior art of record because none of the prior art whether taken singularly or in combination to teach the claimed combination to include the relationship between an angular increment and velocity increment producer between x, y, and z axes angular rate electrical signals and x, y, and z axes acceleration electrical signals in which x, y, and z axes angular rate electrical signals and x, y, and z axes acceleration electrical signals are converted into digital angular increments and digital velocity increments respectively, except the patent No. 6,456,939 that applicants already filed terminal disclaimer.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Application/Control Number: 10/017,310
Art Unit: 2863

Page 3

Conclusion

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Bryan Bui whose telephone number is 703-305-4490. The examiner can normally be reached on M-Th from 7am-4pm, and Alternate Fridays.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, John E Barlow can be reached on 703-308-3126. The fax phone numbers for the organization where this application or proceeding is assigned are 703-308-7722 for regular communications and 703-308-7724 for After Final communications.

Correspondence in patent-related matters must be addressed to:

Commissioner for Patents

P.O. Box 1450

Alexandria, VA 22313-1450

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0956.



**BRYAN BUI
PRIMARY EXAMINER**

BB
July 10, 2003



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address COMMISSIONER FOR PATENTS
P.O. Box 1419
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

7590 07/14/2003
Raymond Y. C. Chan
1050 Oakdale Lane
Arcadia, CA 91006

EXAMINER

BUI, BRYAN

ART UNIT CLASS-SUBCLASS

2863

702-141000

DATE MAILED: 07/14/2003

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/017,310	10/22/2001	Hiram McCall	USDP1699A-GNC	7211

TITLE OF INVENTION: MICRO INERTIAL MEASUREMENT UNIT

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	\$650	\$300	\$950	10/14/2003

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status is changed, pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above and notify the United States Patent and Trademark Office of the change in status, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check the box below and enclose the PUBLICATION FEE and 1/2 the ISSUE FEE shown above.

☐ Applicant claims SMALL ENTITY status.
See 37 CFR 1.27.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Box ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail Stop ISSUE FEE**
Commissioner for Patents
Alexandria, Virginia 22313-1450
Fax (703)746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (NOTE: Legibly write-up with any correction one of the Block 1)

7590 07/14/2003

Raymond Y. C. Chan
1050 Oakdale Lane
Arcadia, CA 91006

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Box Issue Fee address above, or being facsimile transmitted to the USPTO, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/017,310	10/22/2001	Hiram McCall	USDP1699A-GNC	7211

TITLE OF INVENTION: MICRO INERTIAL MEASUREMENT UNIT

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	\$650	\$300	\$950	10/14/2003

EXAMINER	ART UNIT	CLASS-SUBCLASS
BUI, BRYAN	2863	702-141000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363). ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached. ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.	2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 1 _____ 2 _____ 3 _____
--	---

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) ☐ individual ☐ corporation or other private group entity ☐ government

4a. The following fee(s) are enclosed: ☐ Issue Fee ☐ Publication Fee ☐ Advance Order - # of Copies _____	4b. Payment of Fee(s): ☐ A check in the amount of the fee(s) is enclosed. ☐ Payment by credit card. Form PTO-2038 is attached. ☐ The Commissioner is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).
---	---

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) (Date) NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office. This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.	TRANSMIT THIS FORM WITH FEE(S)
---	---------------------------------------



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/017,310	10/22/2001	Hiram McCall	USDP1699A-GNC	7211
EXAMINER				
BUL, BRYAN				
ART UNIT			PAPER NUMBER	
2863				

DATE MAILED: 07/14/2003

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The patent term adjustment to date is 84 days. If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the term adjustment will be 84 days.

If a continued prosecution application (CPA) was filed in the above-identified application, the filing date that determines patent term adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) system. (<http://pair.uspto.gov>)

Any questions regarding the patent term extension or adjustment determination should be directed to the Office of Patent Legal Administration at (703)305-1383.



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/017,310	10/22/2001	Hiram McCall	USDP1699A-GNC	7211
EXAMINER				
BUI, BRYAN				
ART UNIT		PAPER NUMBER		
2863				

DATE MAILED: 07/14/2003

Notice of Fee Increase on January 1, 2003

If a reply to a "Notice of Allowance and Fee(s) Due" is filed in the Office on or after January 1, 2003, then the amount due will be higher than that set forth in the "Notice of Allowance and Fee(s) Due" since there will be an increase in fees effective on January 1, 2003. See Revision of Patent and Trademark Fees for Fiscal Year 2003: Final Rule, 67 Fed. Reg. 70847, 70849 (November 27, 2002).

The current fee schedule is accessible from: <http://www.uspto.gov/main/howtofees.htm>.

If the issue fee paid is the amount shown on the "Notice of Allowance and Fee(s) Due," but not the correct amount in view of the fee increase, a "Notice to Pay Balance of Issue Fee" will be mailed to applicant. In order to avoid processing delays associated with mailing of a "Notice to Pay Balance of Issue Fee," if the response to the Notice of Allowance and Fee(s) due form is to be filed on or after January 1, 2003 (or mailed with a certificate of mailing on or after January 1, 2003), the issue fee paid should be the fee that is required at the time the fee is paid. If the issue fee was previously paid, and the response to the "Notice of Allowance and Fee(s) Due" includes a request to apply a previously-paid issue fee to the issue fee now due, then the difference between the issue fee amount at the time the response is filed and the previously paid issue fee should be paid. See Manual of Patent Examining Procedure, Section 1308.01 (Eighth Edition, August 2001).

Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (703) 305-8283.



In The United States Patent and Trademark Office

Serial Number: 10/017,310
Applicants: Hiram McCALL
Filing Date: 10/22/2001
Title: Micro Inertial Measurement Unit

Examiner: Bui, Bryan
Group Art Unit: 2863

Date: August 21, 2003

**Submission of Issue Fee Payment, Publication Fee, and
Change of Correspondence Address,**

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In response to the Notice of Allowance and Fees Due dated 07/14/2003, the applicant respectfully submits a check in the amount of US\$950.00 for payment of the Issue Fee and Publication Fee.

Furthermore, applicant also encloses herewith corrected a change of correspondence address. Please send all future correspondence to the new correspondence address.

Thank you for your assistance.

Respectfully submitted,

Raymond Y. Chan
Reg. Nr.: 37,484
c/o 108 N. Ynez Ave, Suite 128
Monterey Park, CA 91754

Certification of Mailing

I certify that this correspondence will be deposited with the United States Postal Service as First Class mail with proper postage affixed in an envelope addressed to: "Mail Stop Issue Fee, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450" on the date below.

Date: 09/30/2003

Signature:
Name of Person Signing: Raymond Y. Chan

B
\$



#7
11/4/03
OCA

**CHANGE OF
CORRESPONDENCE ADDRESS
Application**

Address to:
Assistant Commissioner for Patents
Washington, D.C. 20231

PTO/SB/122 (10-01)
Approved for use through 10/31/2002, OMB 0651-0035
U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Application Number	10/017,310
Filing Date	10/22/2001
First Named Inventor	Hiram McCALL
Art Unit	2863
Examiner Name	Bui, Bryan
Attorney Docket Number	USDP1699A-GNC

Please change the Correspondence Address for the above-identified application to:

☐ Customer Number →
Type Customer Number here

Place Customer
Number Bar Code
Label here

OR

☒ Firm or Individual Name	David and Raymond Patent Group		
Address	108 N. Ynez Ave., Suite 128		
Address			
City	Monterey Park	State	CA
		ZIP	91754
Country	United States of America		
Telephone	626-571-9812	Fax	626-571-9813

This form cannot be used to change the data associated with a Customer Number. To change the data associated with an existing Customer Number use "Request for Customer Number Data Change" (PTO/SB/124).

I am the :

- ☐ Applicant/Inventor.
- ☐ Assignee of record of the entire interest.
Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96).
- ☒ Attorney or Agent of record.
- ☐ Registered practitioner named in the application transmittal letter in an application without an executed oath or declaration. See 37 CFR 1.33(a)(1). Registration Number _____

Typed or Printed Name	Raymond Y. Chan
Signature	
Date	09/30/2007

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below.

☒ Total of 1 forms are submitted.

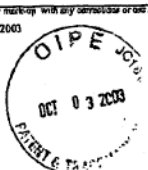
Burden Hour Statement: This form is estimated to take 3 minutes to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail Stop ISSUE FEE**
Commissioner for Patents
Alexandria, Virginia 22313-1450
Fax (703)746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Name): Legibly mark-up with any corrections or use block 1)
 7590 07/14/2003
 Raymond Y. C. Chan
 1050 Oakdale Lane
 Arcadia, CA 91006



Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Box Issue Fee address above, or being facsimile transmitted to the USPTO, on the date indicated below.

RAYMOND Y. CHAN (Depositor's name)
Raymond Y. Chan (Signature)
 07/14/2003 (Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10017310	10/22/2001	Hiram McCall	USDP1699A-GNC	7211

TITLE OF INVENTION: MICRO INERTIAL MEASUREMENT UNIT

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	\$650	\$300	\$950	10/14/2003

EXAMINER	ART UNIT	CLASS-SUBCLASS
BUI, BRYAN	2863	702-141000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

RAYMOND Y. CHAN
DAVID AND RAYMOND
PATENT GROUP

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

AMERICAN GNC CORPORATION

(B) RESIDENCE: (CITY AND STATE OR COUNTRY)

SIMI VALLEY, CA

Please check the appropriate assignee category or categories (will not be printed on the patent) ☐ individual ☒ corporation or other private group entity ☐ government

4a. The following fee(s) are enclosed:

☒ Issue Fee
☒ Publication Fee
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s):

☒ A check in the amount of the fee(s) is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☒ The Commissioner is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number **523111** (enclose an extra copy of this form).

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) *Raymond Y. Chan* (Date) **Aug 18 2003**
NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant, a registered attorney or agent, or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMIT THIS FORM WITH FEE(S)

PTOL-85 (REV. 05-03) Approved for use through 04/30/2004. OMB 0651-0033

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

10/09/2003 WABDLR3 00000135 10017310

01 FC:2501
 02 FC:1504

650.00 BP
 300.00 BP



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	FILE WRAPPER LOCATION
10/017,310	6671648	2863	9200R100811009103



0000000032564918

Correspondence Address/Fee Address Change

The following fields have been set to Customer Number 30265 on 09/30/2008

- Correspondence Address
- Maintenance Fee Address
- Power of Attorney Address

The address of record for Customer Number 30265 is:

30265
DAVID AND RAYMOND PATENT FIRM
108 N. YNEZ AVE., SUITE 128
MONTEREY PARK, CA 91754



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application Number: 10,017,310
First Named Inventor: Hiram McCall
Filing Date: 10/22/2001
Examiner: Bui, Bryan
Title: Micro Inertial Measurement Unit

Patent Number: 6,671,648
Issue Date: 12/30/2003
Group Art Unit: 2863
Atty's Docket No.: USDP1699A-GNC

Date: December 12, 2016

Request for Certificate of Correction under 37 CFR 1.323

Commissioner for Patents
Office of Patent Publication
Certificate of Corrections Branch
P.O. Box 1450, Alexandria, VA 22313-1450.

The applicant respectfully requests for the correction of the typo for the Claim. The Letters Patent is required to be corrected as shown below.

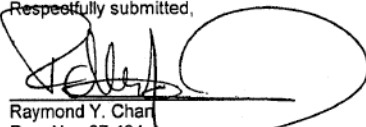
Claim 1, column 24, line 20 "verted into are digital angular increments and digital" should be amended to delete "are" and corrected to read as "verted into digital angular increments and digital".

The applicant hereby enclosed the followings for the correction:

1. Form PTO/SB44
2. A mark-up copy of the Certificate.
3. Payment of US\$100.00 for the Certificate of Correction. The fee submitted is believed to be correct. However, the Director is hereby authorized to charge the additional required fee(s) or credit any overpayment to Deposit Account Number 502111 in the name of David and Raymond Patent Firm.

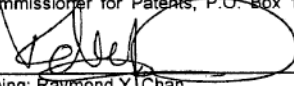
Please accept the above documents and payment and issue the Certificate of Correction for this immediate application. Thank you for your assistance.

Respectfully submitted,


Raymond Y. Chan
Reg. No.: 37,484
108 N. Ynez Avenue, Suite 128,
Monterey Park, CA 91754.
Tel.: (626) 571-9812/ Fax: (626) 571-9813

Certification of Mailing

I certify that this correspondence will be deposited with the United States Postal Service as first class mail with proper postage affixed in an envelope addressed to: "Certificate of Corrections Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450." on the date below.

Signature: 
Person Signing: Raymond Y. Chan

Date: 12/14/2016

12/20/2016 COMM. 00000021 6671648
91 FC:1611 102.00 00

**UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION**

Page 1 of 1

PATENT NO. : 6,671,648 B2
APPLICATION NO.: 10/017,310
ISSUE DATE : December 30, 2003
INVENTOR(S) : Hiram McCall, Ching-Fang Lin

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims
Claim 1, column 24, line 20, between "into" and "digital" delete "are".

MAILING ADDRESS OF SENDER (Please do not use customer number below):

This collection of information is required by 37 CFR 1.322, 1.323, and 1.324. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1.0 hour to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Attention Certificate of Corrections Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,671,648 B2
APPLICATION NO. : 10/017310
DATED : December 30, 2003
INVENTOR(S) : Hiram McCall and Ching-Fang Lin

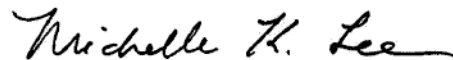
Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Claim 1, Column 24, Line 20, between "into" and "digital" delete "are".

Signed and Sealed this
Twenty-first Day of March, 2017



Michelle K. Lee
Director of the United States Patent and Trademark Office

AO 120 (Rev. 08/10)

TO: Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
---	---

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been
filed in the U.S. District Court **FOR THE EASTERN DISTRICT OF TEXAS** on the following

☐ Trademarks or ☒ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO. 2:17-cv-107	DATE FILED 2/3/2017	U.S. DISTRICT COURT FOR THE EASTERN DISTRICT OF TEXAS
PLAINTIFF American GNC Corporation		DEFENDANT ZTE Corporation, ZTE (USA) Inc., and ZTE (TX) Inc.
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1 6,311,555	11/6/2001	American GNC Corporation
2 6,415,227	7/2/2002	American GNC Corporation
3 6,508,122	1/21/2003	American GNC Corporation
4 6,516,283	2/4/2003	American GNC Corporation
5 6,671,648	12/30/2003	American GNC Corporation

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1		
2		
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In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT		
CLERK	(BY) DEPUTY CLERK	DATE

Copy 1—Upon initiation of action, mail this copy to Director Copy 3—Upon termination of action, mail this copy to Director
Copy 2—Upon filing document adding patent(s), mail this copy to Director Copy 4—Case file copy

AO 120 (Rev. 08/10)

TO: Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
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In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court **FOR THE EASTERN DISTRICT OF TEXAS** on the following

☐ Trademarks or ☒ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO. 2:17-cv-00119	DATE FILED 2/9/2017	U.S. DISTRICT COURT FOR THE EASTERN DISTRICT OF TEXAS
PLAINTIFF American GNC Corporation		DEFENDANT LG Electronics Inc., LG Electronics USA, Inc., LG Electronics Mobilecomm USA, Inc., and LG Electronics Mobile Research USA, LLC
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1 6,311,555	11/6/2001	American GNC Corporation
2 6,415,227	7/2/2002	American GNC Corporation
3 6,508,122	1/21/2003	American GNC Corporation
4 6,516,283	2/4/2003	American GNC Corporation
5 6,671,648	12/30/2003	American GNC Corporation

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY	☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
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In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT		
CLERK	(BY) DEPUTY CLERK	DATE

Copy 1—Upon initiation of action, mail this copy to Director Copy 3—Upon termination of action, mail this copy to Director
 Copy 2—Upon filing document adding patent(s), mail this copy to Director Copy 4—Case file copy

13 CLAIMS ONLY							SERIAL NO. 10017310		FILING DATE 10-22-01				
							APPLICANT(S)						
CLAIMS													
	AS FILED		AFTER 1st AMENDMENT		AFTER 2nd AMENDMENT			*		*		*	
	IND.	DEP.	IND.	DEP.	IND.	DEP.		IND.	DEP.	IND.	DEP.	IND.	DEP.
1							51						
2							52						
3							53						
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48							98						
49							99						
50							100						
TOTAL IND.							TOTAL IND.						
TOTAL DEP.							TOTAL DEP.						
TOTAL CLAIMS							TOTAL CLAIMS						

* MAY BE USED FOR ADDITIONAL CLAIMS OR ADMENDMENTS

FORM PTO-2022 (1-98)

U.S. DEPARTMENT OF COMMERCE
 Patent and Trademark Office

PATENT APPLICATION FEE DETERMINATION RECORD Effective October 1, 2001					Application or Docket Number USDP 1699A-GNC		
CLAIMS AS FILED - PART I							
		(Column 1)	(Column 2)				
TOTAL CLAIMS		4					
FOR		NUMBER FILED	NUMBER EXTRA				
TOTAL CHARGEABLE CLAIMS		4	minus 20=		*		
INDEPENDENT CLAIMS		1	minus 3 =		*		
MULTIPLE DEPENDENT CLAIM PRESENT		☐					
* If the difference in column 1 is less than zero, enter "0" in column 2							
CLAIMS AS AMENDED - PART II							
		(Column 1)	(Column 2)	(Column 3)			
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR		PRESENT EXTRA		
	Total	*	4	Minus	**	20	
	Independent	*	1	Minus	***	3	
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM						☐
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR		PRESENT EXTRA		
	Total	*		Minus	**	=	
	Independent	*		Minus	***	=	
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM						☐
AMENDMENT C	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR		PRESENT EXTRA		
	Total	*		Minus	**	=	
	Independent	*		Minus	***	=	
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM						☐
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20." *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3." The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.							

SMALL ENTITY TYPE ☒		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	370.00	OR	BASIC FEE	740.00
X\$ 9=		OR	X\$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL	370	OR	TOTAL	~~740~~

SMALL ENTITY TYPE ☒		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X\$ 9=		OR	X\$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

SMALL ENTITY TYPE ☒		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X\$ 9=		OR	X\$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

ISSUE SLIP STAPLE AREA (for additional cross-references)

ISSUING CLASSIFICATION			
ORIGINAL		CROSS REFERENCE(S)	
CLASS	SUBCLASS	CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)
702	141	702	145
INTERNATIONAL CLASSIFICATION			
G01P	5100		
G01P	15100		
	1		
	1		
	1		

^ Continued on Issue Slip Inside File Jacket

INDEX OF CLAIMS

☒ Rejected - (Through numeral) ... Canceled N Non-elected A Appeal
☐ Allowed + ... Restricted I Interference O Objected

Claim	Date	Claim	Date	Claim	Date
1		51		101	
2		52		102	
3		53		103	
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48		98		148	
49		99		149	
50		100		150	

If more than 150 claims or 9 actions staple additional sheet here

SEARCH

Class	Sub.	Date	Exmr.
702	127	3/5/03	B7
	141		
	142		
	145		
	151		
701	216		
	217		
	220		
	221	3/5/03	B7
Updated Record has as above		7/9/03	B7

INTERFERENCE SEARCHED

Class	Sub.	Date	Exmr.
702	141	7/10/03	B7
	145	7/14/03	B7

SEARCH NOTES

(List databases searched. Attach search strategy inside.)

	Date	Exmr.
East Searcher (H. H. Schuch)	5/5/03	B7