

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,671,648 B2

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

NINTENDO CO., LTD., and
NINTENDO OF AMERICA INC.
Petitioners

v.

AMERICAN GNC CORPORATION
Patent Owner

Case IPR2024-00668
U.S. Patent No. 6,671,648 B2
Issue Date: December 30, 2003

Title: MICRO INERTIAL MEASUREMENT UNIT

DECLARATION OF DARRIN YOUNG, PH.D.

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I, Darrin Young, Ph.D., declare as follows:

I. INTRODUCTION AND QUALIFICATIONS

1. My name is Darrin Young. I have prepared this declaration as an expert witness on behalf of Petitioner Nintendo Co., Ltd., and Nintendo of America Inc. In this declaration, I will give my opinion as to whether claims 1 and 4 of U.S. Patent No. 6,671,648 (“the ’648 patent”) (**EX1001**) are valid. I also provide herein the technical bases for these opinions, as appropriate.

2. This declaration contains statements of my opinions formed to date, and the bases and rationale for these opinions. I may offer additional opinions based on further review of materials in this case, including opinions and/or testimony of other expert witnesses.

3. For my efforts in connection with the preparation of this declaration, I have been compensated at my usual and customary rate for this type of consulting activity. My compensation is in no way contingent on the results of these or any other proceedings related to the ’648 patent.

A. Qualifications / Professional Background

4. My qualifications generally are set forth in my Curriculum Vitae, which is attached as **Appendix A**. Appendix A also includes a list of the publications I have authored and a list of the other cases in which I have testified during the last

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five years.

5. I am a Utah Science Technology and Research Initiative (USTAR) Associate Professor of the Electrical and Computer Engineering Department at the University of Utah.

6. I received a Bachelor of Science degree in 1991, a Master of Science degree in 1993, and a Ph.D. in 1999, all in Electrical Engineering and Computer Sciences from the University of California, Berkeley.

7. I joined the University of Utah in 2009. Prior to joining the University of Utah, I was an Assistant and Associate Professor in the Electrical Engineering and Computer Science Department at Case Western Reserve University for ten years. Prior to joining the Case Western Reserve University, I was a participating researcher at the Lawrence Livermore National Laboratory in Livermore, California for two years, where I worked on the design, fabrication, and testing of MEMS-based 3D high-Q coil inductors. My research has focused on electronic circuits design, electrical interface design for micro-electro-mechanical systems (“MEMS”), and integrated microsystem technology development for industrial, wireless, and navigation applications. I have designed, fabricated, and tested MEMS sensors including accelerometers, gyroscopes, strain gauge sensors, and pressure sensors.

8. I have served as a technical program committee member and session

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chair for a number of international conferences. Since 2015, I have been serving as an editor for the IEEE Transactions on Electron Devices with a focus on sensors and actuators. I was an associate editor of the IEEE Journal of Solid-State Circuits from 2006 to 2011, and served as the chair of the Micro-Electro-Mechanical Systems committee under the IEEE Electron Devices Society between 2010 and 2014. I have served on the IEEE Sensors Council as an administrative committee member as well as a representative from the IEEE Solid-State Circuits Society between 2002 and 2016.

9. I am an author of over 100 peer-reviewed publications including refereed journals and conferences, in the field of sensors, MEMS, MEMS hardware including capacitors, inductors, microsystem packaging, and interface circuits design. I am the invited author of multiple book chapters in the field of MEMS. I have also given numerous presentations and speeches around the world on similar topics including sensors, MEMS, MEMS hardware including capacitors, inductors, microsystem packaging, and interface circuits design. I am the inventor of two patents, both in the field of sensors.

10. I have been retained by counsel for Petitioners to provide my expert opinion in connection with the above-captioned proceeding as set forth herein.

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B. Materials Considered

11. The analysis that I provide in this Declaration is based on my education, research, and experience, as well as the documents I have considered. In forming my opinions, I have read and considered U.S. Patent No. 6,671,648 B2 (**EX1001**) and its prosecution history. I have cited to the following documents in my analysis below:

Exhibit No.	Description of Document
1001	U.S. Patent No. 6,671,648 B2 to Hiram McCall, et al. (filed Oct. 22, 2001, issued Dec. 30, 2003) (“’648” or “’648 patent”)
1003	U.S. Patent No. 4,675,820 to Jeffrey T. Smith, et al. (filed Apr. June 14, 1984, issued June 23, 1987) (“Smith”)
1004	U.S. Patent No. 4,424,038 to Paul Tingleff, et al. (filed Apr. Jan. 31, 1980, issued Jan. 3, 1984) (“Tingleff”)
1005	U.S. Patent No. 6,058,778 to Tsiu Chiu Chan (filed October 24, 1997, issued May 9, 2000) (“Chan”)
1006	U.S. Patent No. 5,203,208 to Jonathan J. Bernstein (filed April 29, 1992, issued April 20, 1993) (“Bernstein”)
1007	Excerpts from J. David Irwin et al., <i>Introduction to Electrical Engineering</i> (1995) (“Irwin”)
1008	Excerpts from Shmuel Merhav, <i>Aerospace Sensor Systems and Applications</i> (1996) (“Merhav”)
1009	Japanese Patent Application JPH07313649A to Yuichiro Yamawaki et al. (filed May 27, 1994, published December 5, 1995)
1010	Certified English Translation of Exhibit 1009

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Exhibit No.	Description of Document
1011	U.S. Patent No. 4,820,953 to Malcolm Saubolle et al. (filed November 23, 1987, issued April 19, 1989) (“Saubolle”)
1012	Excerpts from <i>IEEE Standard Dictionary of Electrical and Electronics Terms</i> (1996)
1013	U.S. Patent No. 5,396,797 to Rand H. Hulsing, II (filed December 8, 1992, issued March 14, 1995) (“Hulsing”)
1014	U.S. Patent No. 5,841,537 to James H. Doty (filed August 11, 1997, issued November 24, 1998) (“Doty”)
1015	Prosecution history of U.S. Patent No. 6,671,648 B2
1016	Affidavit of Service of Summons and Complaint, Mar. 23, 2023, <i>American GNC Corp. v. Nintendo Co., Ltd.</i> , 2:23-cv-00302-TL (W.D.Wash.)
1017	Order on Motion to Dismiss, Jan. 10, 2024, <i>American GNC Corp. v. Nintendo Co., Ltd.</i> , 2:23-cv-00302-TL (W.D.Wash.), Dkt. 38.
1018	AGNC’s Opening Claim Construction Brief, Feb. 21, 2018, <i>American GNC Corp. v. ZTE (USA) Inc., et al</i> , 4:17-cv-00620-ALM-KPJ (E.D. Tex), Dkt. 111.
1019	AGNC’s Opening Claim Construction Brief, Mar. 2, 2021, <i>American GNC Corp. v. Oneplus Tech. (Shenzhen) Co. Ltd., et al</i> , 6:20-cv-00171-ADA (W.D. Tex), Dkt. 55.
1020	AGNC’s Opening Claim Construction Brief, Feb. 21, 2018, <i>American GNC Corp. v. LG Electronics Inc., et al</i> , 3:17-cv-01090-BAS-BLM (S.D. Cal.), Dkt. 92.
1022	Additional pages from J. David Irwin et al., <i>Introduction to Electrical Engineering</i> (1995) (not included with EX1007)
1023	Additional pages from Shmuel Merhav, <i>Aerospace Sensor Systems and Applications</i> (1996) (not included with EX1008)

II. PERSON OF ORDINARY SKILL IN THE ART

12. I understand that, under the patent laws in effect before the America

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Invents Act (“AIA”) of 2011, an assessment of claims of a patent filed before the AIA took effect should be undertaken from the perspective of a person of ordinary skill in the art as of the earliest claimed priority date (i.e., the “time the invention was made”). I have preliminarily for purposes of my Declaration only assumed that date to be January 4, 2000, the earliest patent application to which the ’648 patent claims priority.¹

13. I have also been advised that to determine the appropriate level of a person having ordinary skill in the art, the following factors may be considered: (1) the types of problems encountered by those working in the field and prior art solutions thereto; (2) the sophistication of the technology in question, and the rapidity with which innovations occur in the field; (3) the educational level of active workers in the field; and (4) the educational level of the inventor.

14. In my opinion, a person of ordinary skill (“POSITA” or “reasonably skilled artisan”) would have possessed a bachelor’s degree in electrical engineering or similar degree, with two to three years of practical experience designing and/or

¹ I understand that in the pending litigation, the Patent Owner has claimed that the ’648 patent is entitled to an invention date of May 1999. I express no opinion on whether the ’648 patent is entitled to such an invention date. This issue is not relevant here because all the prior art references relied upon predate that date. Moreover, none of my opinions would change if the date of invention of the ’648 patent was prior to January 4, 2000, such as an earlier date in 1999.

implementing systems that include sensors for measuring movement, such as acceleration and rotational position. The '648 patent specification confirms that various types of IMUs, including platform IMUs, strapdown IMUs, and MEMS IMUs, using accelerometers and gyroscopes, were well-known prior to the alleged invention. ('648, 1:11-2:35.) A person could also have qualified as a person of ordinary skill in the art with a combination of (1) more formal education (such as a Master of Science degree) and less technical experience, or (2) less formal education and more technical or professional experience.

15. Although my qualifications and experience exceed those of the hypothetical person having ordinary skill in the art defined above, my analysis and opinions regarding the '648 patent have been based on the perspective of a person of ordinary skill in the art as of January 2000.

III. STATEMENT OF LEGAL PRINCIPLES

A. Claim Construction

16. I understand that a purpose of claim construction is to determine what a person of ordinary skill in the art would have understood the claim terms to mean. Claim terms are generally given their ordinary and customary meaning, which is the meaning that the term would have to a person of ordinary skill in the art in question as of the effective filing date.

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17. I understand that the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification. I understand that the patent specification, under the legal principles, has been described as the single best guide to the meaning of a claim term, and is thus highly relevant to the interpretation of claim terms. And I understand for terms that do not have a customary meaning within the art, the specification usually supplies the best context of understanding the meaning of those terms.

18. I further understand that other claims of the patent in question, both asserted and unasserted, can be valuable sources of information as to the meaning of a claim term. Because the claim terms are normally used consistently throughout the patent, the usage of a term in one claim can often illuminate the meaning of the same term in other claims. Differences among claims can also be a useful guide in understanding the meaning of particular claim terms.

19. I understand that the prosecution history can further inform the meaning of the claim language by demonstrating how the inventors understood the invention and whether the inventors limited the invention in the course of prosecution, making the claim scope narrower than it otherwise would be. Extrinsic evidence, such as dictionaries, may also be consulted in construing the claim terms.

20. I understand that, in *Inter Partes* Review (IPR) proceedings, a claim of a patent shall be construed using the same claim construction standard that would be used to construe the claim in a civil action filed in a U.S. district court (which I understand is called the “*Phillips*” claim construction standard), including construing the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

21. I have been instructed by counsel to apply the “*Phillips*” claim construction standard for purposes of interpreting the claims in this proceeding, to the extent they require an explicit construction. The description of the legal principles set forth above thus provides my understanding of the “*Phillips*” standard as provided to me by counsel.

22. I understand that certain terms appearing in the challenged claims have been the subject of dispute in the district court litigation. For purposes of my analysis here, I do not believe express claim constructions are necessary because the prior art renders the claim obvious under the claim constructions proposed by either party in the district court litigation.

B. Obviousness

23. I understand that a patent claim is obvious if, as of the effective filing

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date, it would have been obvious to a person having ordinary skill in the field of the technology (the “art”) to which the claimed subject matter belongs.

24. I understand that the following factors should be considered in analyzing obviousness: (1) the scope and content of the prior art; (2) the differences between the prior art and the claims; and (3) the level of ordinary skill in the pertinent art. I also understand that certain other facts known as “secondary considerations” such as commercial success, unexplained results, long felt but unsolved need, industry acclaim, simultaneous invention, copying by others, skepticism by experts in the field, and failure of others may be utilized as indicia of nonobviousness. I understand, however, that secondary considerations should be connected, or have a “nexus,” with the invention claimed in the patent at issue.

25. I understand that a reference qualifies as prior art for obviousness purposes when it is analogous to the claimed invention. The test for determining what art is analogous is: (1) whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the inventor’s endeavor, whether the reference still is reasonably pertinent to the particular problem with which the inventor is involved.

26. I understand that a person of ordinary skill in the art is assumed to have knowledge of all prior art. I understand that one skilled in the art can combine

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various prior art references based on the teachings of those prior art references, the general knowledge present in the art, or common sense. I understand that a motivation to combine references may be implicit in the prior art, and there is no requirement that there be an actual or explicit teaching to combine two references. Thus, one may take into account the inferences and creative steps that a person of ordinary skill in the art would employ to combine the known elements in the prior art in the manner claimed by the patent at issue. I understand that one should avoid “hindsight bias” and ex post reasoning in performing an obviousness analysis. But this does not mean that a person of ordinary skill in the art for purposes of the obviousness inquiry does not have recourse to common sense.

27. I understand that when determining whether a patent claim is obvious in light of the prior art, neither the particular motivation for the patent nor the stated purpose of the patentee is controlling. The primary inquiry has to do with the objective reach of the claims, and that if those claims extend to something that is obvious, then the entire patent claim is invalid.

28. I understand one way that a patent can be found obvious is if there existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent’s claims. I understand that a motivation to combine various prior art references to solve a particular problem may come from a

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variety of sources, including market demand or scientific literature. I understand that a need or problem known in the field at the time of the invention can also provide a reason to combine prior art references and render a patent claim invalid for obviousness. I understand that familiar items may have obvious uses beyond their primary purpose, and that a person of ordinary skill in the art will be able to fit the teachings of multiple prior art references together like the pieces of a puzzle. I understand that a person of ordinary skill is also a person of at least ordinary creativity. I understand when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp. If this finite number of predictable solutions leads to the anticipated success, I understand that the invention is likely the product of ordinary skill and common sense, and not of any sort of innovation. I understand that the fact that a combination was obvious to try might also show that it was obvious, and hence invalid, under the patent laws. I understand that if a patent claims a combination of familiar elements according to known methods, the combination is likely to be obvious when it does not more than yield predictable results. Thus, if a person of ordinary skill in the art can implement a predictable variation, an invention is likely obvious. I understand that combining embodiments disclosed near each other in a

prior art reference would not ordinarily require a leap of inventiveness.

29. I understand that obviousness may be shown by demonstrating that it would have been obvious to modify what is taught in a single piece of prior art to create the patented invention. Obviousness may also be shown by demonstrating that it would have been obvious to combine the teachings of more than one item of prior art. I understand that a claimed invention may be obvious if some teaching, suggestion, or motivation exists that would have led a person of ordinary skill in the art to combine the invalidating references. I also understand that this suggestion or motivation may come from the knowledge of a person having ordinary skill in the art, or from sources such as explicit statements in the prior art. I understand that when there is a design need or market pressure, and there are a finite number of predictable solutions, a person of ordinary skill may be motivated to apply common sense and his skill to combine the known options in order to solve the problem.

30. I understand the following are examples of approaches and rationales that may be considered in determining whether a piece of prior art could have been combined with other prior art or with other information within the knowledge of a person having ordinary skill in the art:

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- (1) Some teaching, motivation, or suggestion in the prior art that would have led a person of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention;
- (2) Known work in one field of endeavor may prompt variations of it for use in the same field or a different field based on design incentives or other market forces if the variations would have been predictable to a person of ordinary skill in the art;
- (3) Combining prior art elements according to known methods to yield predictable results;
- (4) Applying a known technique to a known device, method, or product ready for improvement to yield predictable results;
- (5) Applying a technique or approach that would have been “obvious to try” (choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success);
- (6) Simple substitution of one known element for another to obtain predictable results; or
- (7) Use of a known technique to improve similar products, devices, or methods in the same way.

31. I understand that, when determining whether a claimed combination is

obvious, the correct analysis is not whether one of ordinary skill in the art, writing on a blank slate, would have chosen the particular combination of elements described in the claim. Instead, I understand the correct analysis considers whether one of ordinary skill, facing the wide range of needs created by developments in the field of endeavor, would have seen a benefit to selecting the combination claimed.

32. I understand that the test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference. The test for obviousness, in other words, is not whether the references could be physically combined but whether the claimed inventions are rendered obvious by the teachings of the prior art as a whole.

IV. THE '648 PATENT

A. Overview of the Specification

33. The '648 patent indicates that 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[.]” ('648, 1:11-16.)

1. Admitted Prior Art

34. The '648 patent states that “[g]enerally, an inertial measurement unit (IMU) is employed to determine the motion of a carrier” by relying on “three

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orthogonally mounted inertial angular rate producers and three orthogonally mounted acceleration producers to obtain three-axis angular rate and acceleration measurement signals.” (’648, 1:18-23.) The ’648 patent further teaches that three inertial angular rate producers and three acceleration producers with mechanical support and electric devices are “conventionally called” an IMU. (’648, 1:23-29.)

35. The ’648 patent further provides examples of “conventional IMUs,” such as the Platform IMU and Strapdown IMU. (’648, 1:28-29.) Both types of IMUs are used to obtain the attitude and attitude rate measurements by employing the angular rate producers and acceleration producers. (*Id.*, 1:30-44.)

36. The ’648 patent discloses that “[a] conventional IMU uses a variety of inertial angular rate producers and acceleration producers.” (’648, 1:45-46.) The ’648 patent provides several examples of “[c]onventional inertial angular rate producers,” including “optical gyros,” “Ring Laser Gyros (RLG),” among many others. (*Id.*, 1:46-52.) The ’648 patent also provides several examples of “conventional acceleration producers,” including “Pulsed Integrating Pendulous Accelerometer (PIPA), Pendulous Integrating Gyro Accelerometer (PIGA).” (*Id.*, 1:52-54.) The ’648 patent also discloses that there is a variety of “type[s] of gyros and accelerometers employed in the IMUs.” (*Id.*, 1:55-58.)

37. The ’648 patent states that Micro Electronic Mechanical System

(“MEMS”) inertial sensors are “the next logical step in the silicon revolution,” and were opening up “[n]ew horizons . . . for inertial sensor device technologies.” (’648, 2:10-11.) The ’648 patent discloses that “[p]rolific MEMS angular rate sensor approaches have been developed[.]” (*Id.*, 2:25-26.) It also provides two examples of micromechanical accelerometers from Draper and Analog Devices. (*Id.*, 2:35-45.) MEMS sensors, according to the ’648 patent, offer “tremendous cost, size, and reliability improvements for guidance, navigation, and control systems, compared with conventional inertial sensors.” (*Id.*, 2:11-15.)

2. Disclosure of Embodiments

38. Referring to Figure 1, the disclosed micro IMU “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 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.” (’648, 6:61-7:3.) Figure 1 is reproduced below:

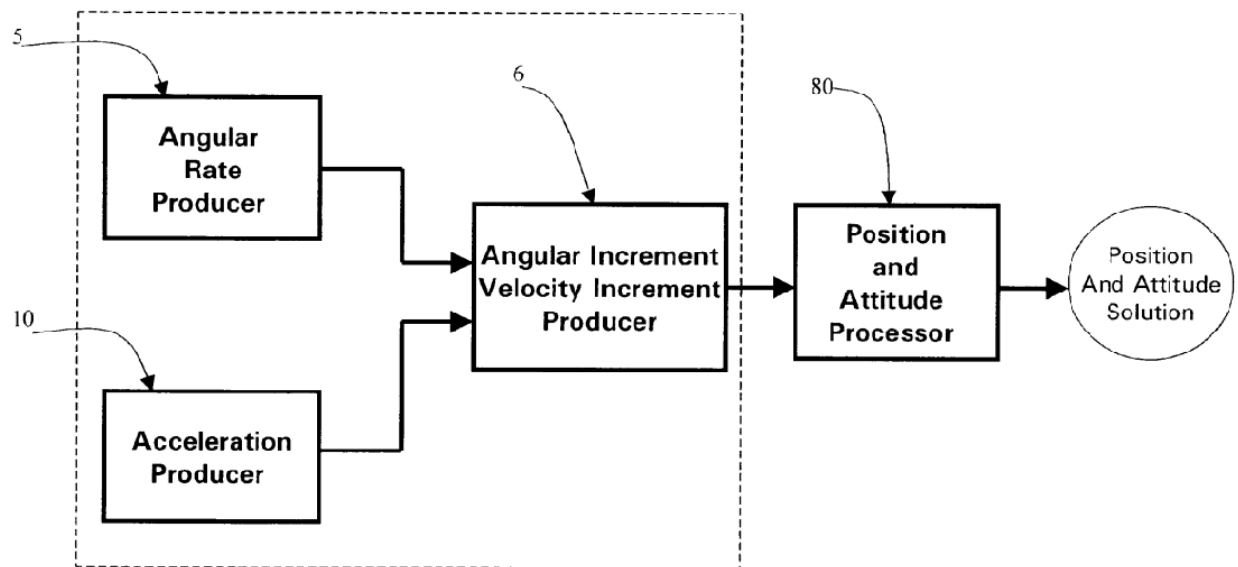


Figure 1

(*Id.*, Fig. 1.) The '648 patent discloses that “the output of the angular rate producer **5** and the acceleration producer **10** are analog voltage signals.” (*Id.*, 8:11-13.) Furthermore, “[t]he three-axis analog angular rate 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.” (*Id.*, 8:13-18.)

39. Figure 4 discloses that the angular increment and velocity increment producer **6** 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**.” ('648, 8:29-33.) Figure 4 is reproduced below:

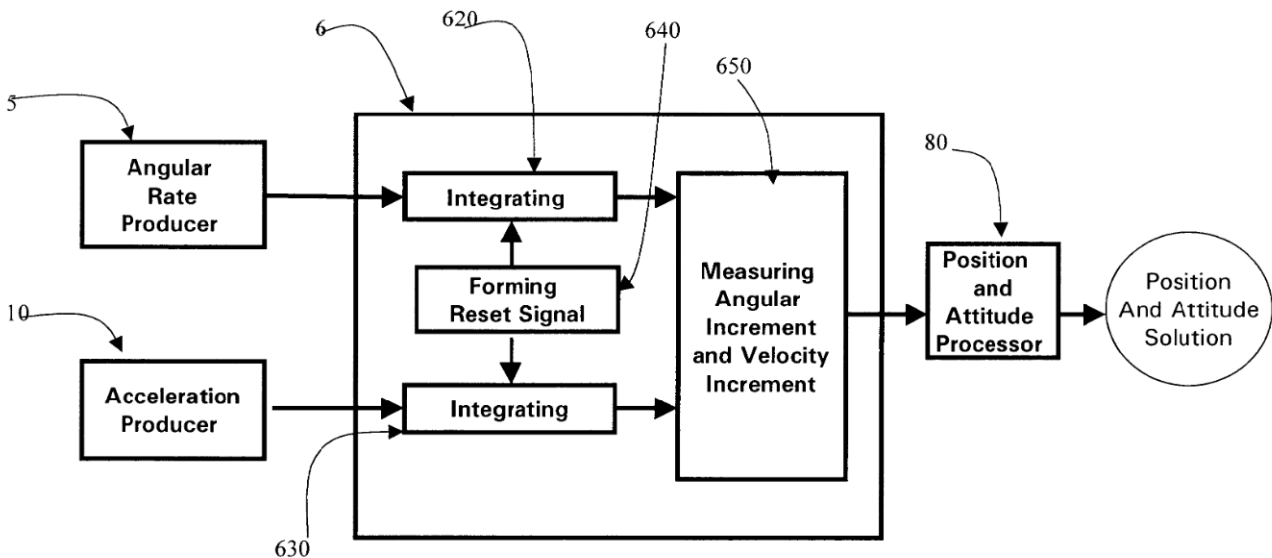


Figure 4

(*Id.*, Fig. 4.) The angular integrating means **620** and the acceleration integrating means **630** integrate “the three-axis analog angular rate voltage signals and the three-axis analog acceleration voltage signals,” respectively. (*Id.*, 8:34-37.) The signals are integrated “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.” (*Id.*, 8:37-44.)

40. “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[.]” (’648, 8:44-48.) Therefore, the produced “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.” (*Id.*, 8:51-54.)

41. The angular increment and velocity increment measurement means **650** measures “the voltage values of the three-axis accumulated angular increments and the three-axis accumulated velocity increments . . . to acquire angular increment counts and velocity increment counts as a digital form” of the respective increments. (’648, 8:60-66.)

B. The Challenged Claims

42. This Declaration addresses claims 1 and 4 of the ’648 patent. Independent claim 1 is representative and recites:

1. A micro inertial measurement unit, comprising:
 - [a]** 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;
 - [b]** 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

- [c] 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 into² digital angular increments and digital velocity increments respectively.

(’648, 23:43-24:21 (Claim 1; bracketed notation (e.g., [a]) added).)

43. Claim 4 recites:

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

² I understand that the word “are” after “converted into” was deleted by a correction issued on March 21, 2017.

said vehicle.

(’648, 24:36-44 (Claim 4).)

44. I address the claims further in my detailed analysis in **Part V** below.

V. APPLICATION OF THE PRIOR ART TO CHALLENGED CLAIMS

45. I have reviewed and analyzed the prior art references and materials listed in **Part I.B** above. In my opinion the claims of the ’648 patent would have been obvious to a person of ordinary skill in the art based on the following combinations of the prior art.

Ground	Claims	Basis for Challenge Under § 103
1	1	Smith in view of Chan and Bernstein
2	4	Ground 1 Prior Art + Irwin and Merhav
3	1, 4	Tingleff in view of Chan and Bernstein
4	1, 4	Yamawaki in view of Chan, Bernstein, and Saubolle

46. I am informed by counsel that each of the references cited in the grounds above qualifies as prior art to the challenged claims because each reference was filed or published before the filing of the earliest patent application to which the ’648 patent claims priority (January 2000).

A. Brief Summary and Overview of the Prior Art

1. Smith (EX1003)

47. **Smith**, U.S. Patent No. 4,675,820 (filed June 14, 1984, issued June 23,

1987), is titled “Inertial Reference System.” Smith discloses an inertial sensor assembly (ISA) that “includes a cluster of three ring laser gyros, each gyro producing an output signal having a pulse repetition rate representative of the rate of angular deviation of the ISA about one of three coordinate axes X, Y, and Z.” (Smith, Abstract.) I am informed that Smith qualifies as prior art because it was issued on June 23, 1987, more than one year before the filing date of the earliest patent application to which the ’648 patent claims priority.

48. Smith explains that “[i]nertial reference systems are commonly employed in aircraft and other vehicular guidance systems.” (Smith, 1:20-21.) “Sensors within the system detect both attitude and velocity changes with respect to three mutually perpendicular axes. These positional signals are then processed to produce output signals corresponding to positional changes of the vehicle with respect to a fixed, reference position.” (*Id.*, 1:24-29.)

49. Smith purports to disclose an improved inertial reference system that “may be constructed in a small enclosure and is designed to minimize the use of expensive components, thereby reducing overall cost.” (Smith, 2:55-59.) Smith further explains that, as was well-known in the prior art, an inertial reference system includes gyroscopes and accelerometers for determining changes in angular position and velocity along the X, Y, and Z axes:

Briefly, according to the invention, an inertial reference system comprises an inertial sensor assembly. The inertial sensor assembly includes gyros for producing asynchronous output signals $\Delta\theta_x$, $\Delta\theta_y$, and $\Delta\theta_z$ representative of the change in angular position of the inertial sensor assembly with respect to three mutually orthogonal coordinate axes X, Y, and Z, respectively. Also provided in the inertial sensor assembly are accelerometers for producing output signals ΔV_x , ΔV_y , and ΔV_z representative of the change in velocity of the inertial sensor assembly in the X, Y, and Z coordinate axes, respectively.

(*Id.*, 3:7-18.) Figure 1 of Smith shows an overall diagram of the disclosed inertial measurement system:

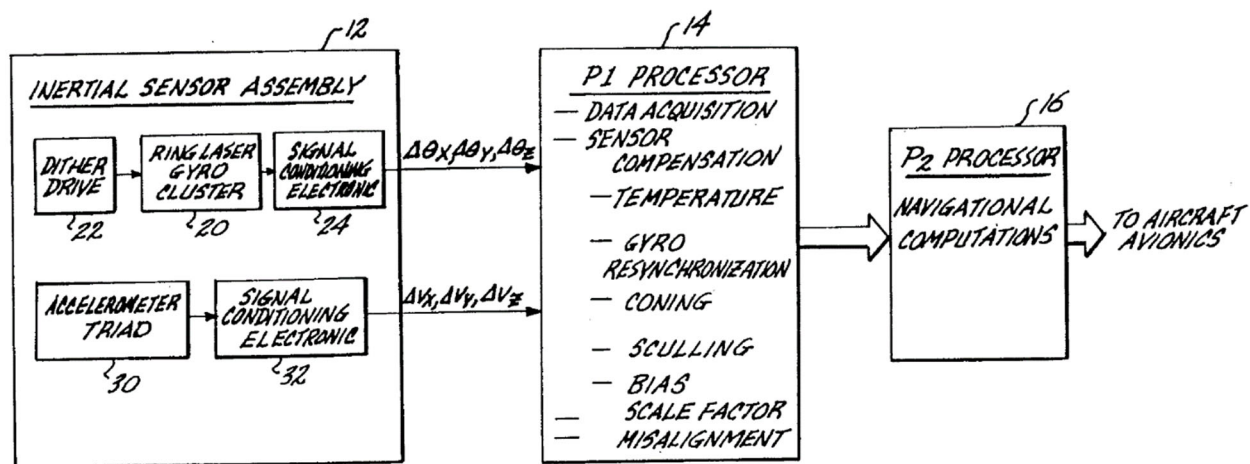


Fig. 1.

(*Id.*, Fig. 1.) Figure 1 shows, from left-to-right, inertial sensor assembly (ISA) 12, P1 processor 14, and P2 processor 16. (*Id.*, 5:55-59.)

50. ISA 12 on the left “contains the positional sensors,” which include “a

cluster of three ring laser gyros **20**,” each of which is “mounted with its sensitive axis normal to one of three mutually orthogonal coordinate axes X, Y, and Z.” (Smith, 5:60-65.) “The output from each gyro is a digital signal having a pulse repetition rate proportional to the rate of angular displacement of the ISA **12** about the gyro’s sensitive axis.” (*Id.*, 5:65-68.)

51. ISA **12** also includes “accelerometer triad **30**,” which includes “three accelerometers, each having its sensitive axis aligned with one of the three mutually orthogonal coordinate axes X, Y, and Z. Preferably, each accelerometer in accelerometer triad **30** is comprised of a digital accelerometer, having an output pulse repetition rate related to the rate of change of velocity of each gyro along its sensitive axis.” (Smith, 6:15-21.) Smith explains that conventional accelerometers can be used. (*Id.*, 10:2-4 (“Preferably, a ‘Q-FLEX’ type accelerometer, available from Sundstrand Data Control of Redmond, Wash., is used.”).)

52. The middle of Figure 1 shows P1 processor **14** that performs a number of different functions. As shown, P1 processor **14** receives signals (represented by arrows) from ring gyro cluster **20** and accelerometer triad **30** that represent the change in the angular position and velocity, respectively, along the X, Y, and Z axes. As Smith explains: “The three ring laser gyro cluster **20** signals $\Delta\theta_x$, $\Delta\theta_y$, and $\Delta\theta_z$, as well as the three accelerometer **30** signals ΔV_x , ΔV_y , and ΔV_z are passed to the

inputs of the P1 processor 14.” (Smith, 6:29-32.) “The functions of the P1 processor 14 are to acquire and store, as well as provide compensation for the sensor data. Inasmuch as the gyro and accelerometer-produced signals are digital in nature, the data acquisition function of the P1 processor 14 involves the accumulation and storage of the input pulses over periodic cycles.” (*Id.*, 6:33-38.) P1 processor 14 includes gyro and accelerometer counters that accumulate and count $\Delta\theta$ and ΔV output values obtained from the inertial sensor assembly 12 over a period of time. (*Id.*, e.g., 3:48-58, 4:29-37, 13:3-12, 13:26-39.) P1 processor 14 also “provides bias, scale factor and misalignment correction for both the gyro cluster 20 and the accelerometer triad 30.” (*Id.*, 7:16-18.)

53. At the right side of Figure 1 is P2 processor 16. As Smith explains, “[t]he fully compensated and resynchronized gyro signals, as well as the compensated acceleration signals are then passed [from P1 processor 14] to the P2 processor 16.” (Smith, 7:34-36.) “The function of the P2 processor 16 is to process the attitude rate and linear acceleration signals through navigational computations to produce output positional data.” (*Id.*, 7:36-39.)

2. Tingleff (EX1004)

54. **Tingleff**, U.S. Patent No. 4,424,038 (filed January 31, 1980; granted January 3, 1984), is titled “Inflight aircraft training system.” Tingleff describes an

inflight military aircraft training systems that “sense[s] the aircraft altitude and includes inertial navigation equipment to sense the location and attitude of the aircraft,” yielding information that can be used in the simulation and in analyzing a pilot’s performance subsequent to the training flight. (Tingleff, 2:24-43, Abstract.)

I am informed that Tingleff qualifies as prior art because it was filed and published before the earliest filing date for the ’648 patent.

55. Tingleff discloses improving on prior art ground-based aircraft training simulators (*i.e.*, simulators that never left the ground) by disclosing a flight simulation system that can be operated inflight (*i.e.*, while flying an aircraft—*e.g.*, over a military base). (Tingleff, 1:10-50.) Tingleff’s simulator is “relatively small and self-contained” to accommodate the need for an inflight simulator. (*Id.*, 3:11-13.)

56. Tingleff’s simulator contains an inertial navigation system, an altimeter, and a processor. “The inertial navigation system indicates the position of the aircraft with respect to the earth to the processor. The altimeter indicates the altitude of the aircraft to the processor. The processor relates the present position of the aircraft to the position of simulator initialization point and checks the scenario file.” (Tingleff, 4:24-30.)

57. Figure 1, reproduced below is a block diagram of the disclosed

simulator. The disclosed simulator comprises “data processing system **10**, inertial guidance unit **11**, and driver and interface circuit **12** which are physically all contained within a single housing.” (Tingleff, 6:2-5.)

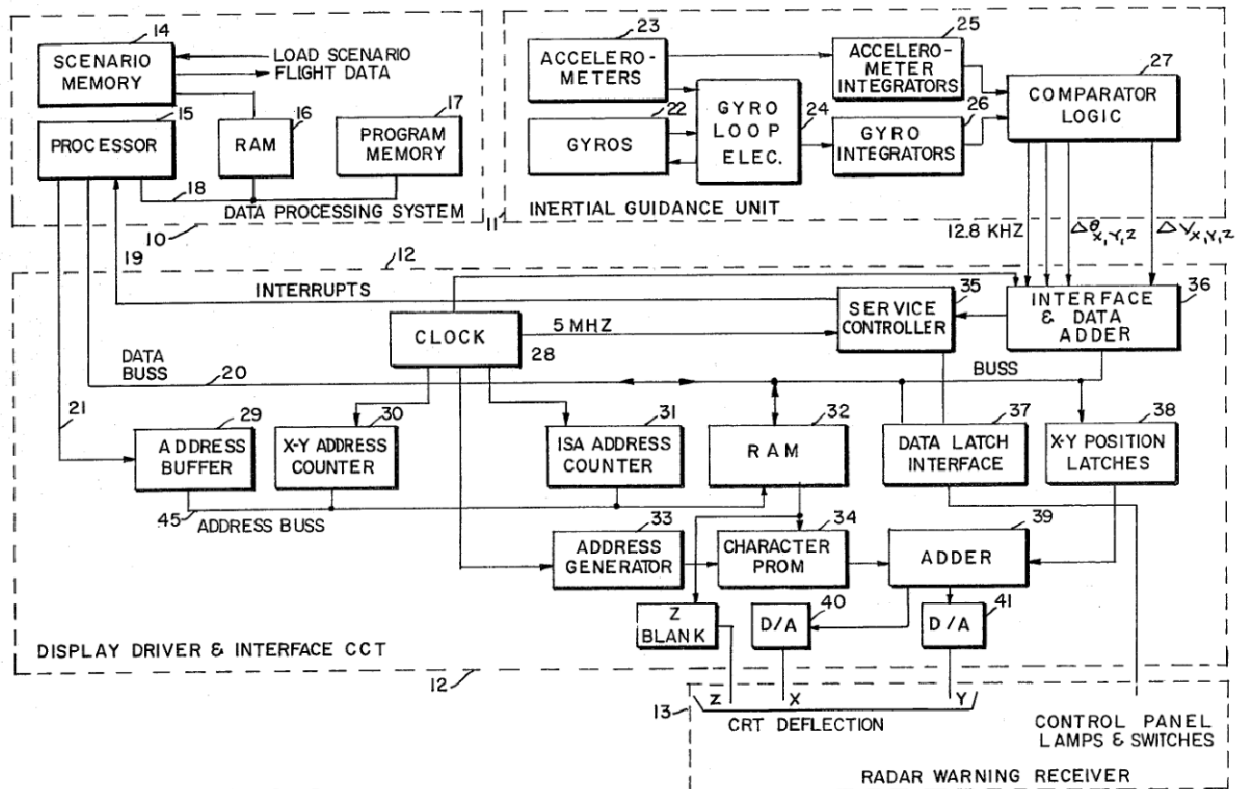


FIG. 1.

(*Id.*, Fig. 1.)

58. “Inertial guidance unit **11** is a commercially available unit containing standard apparatus and provides outputs indicating change in aircraft attitude ($\delta\theta_{x,y,z}$) and change in aircraft velocity ($\delta V_{x,y,z}$).” (Tingleff, 6:50-53.) Inertial guidance unit **11** further includes “three sets of gyros **22** and accelerometers **23** that sense angular rates and acceleration about the X, Y and Z Cartesian coordinates.”

(*Id.*, 6:67-7:2.) Tingleff explains that the “the error signals from gyros **22** and accelerometers **23** are applied to gyro-loop electronics **24** which attempts to hold the accelerometer pendulum and gyro gimbal nulled[.]” (*Id.*, 7:3-6.)

59. The analog signals from accelerometers **23** and from gyro-loop electronics **24** are then converted into digital pulse trains by accelerometer integrator **25** and gyro integrator **26**, respectively. (Tingleff, 7:8-11.) These digital signals are inputted to comparator logic **27**, which adds the received pulse trains to a 12.8 KHz reference signal. (*Id.*, 7:11-13.) “These pulse trains then represent the incremental changes in attitude $\delta\theta_{X,Y,Z}$ and incremental changes in velocity $\delta V_{X,Y,Z}$ experienced by the inertial guidance platform.” (*Id.*, 7:15-18.)

3. Yamawaki (EX1009/1010)

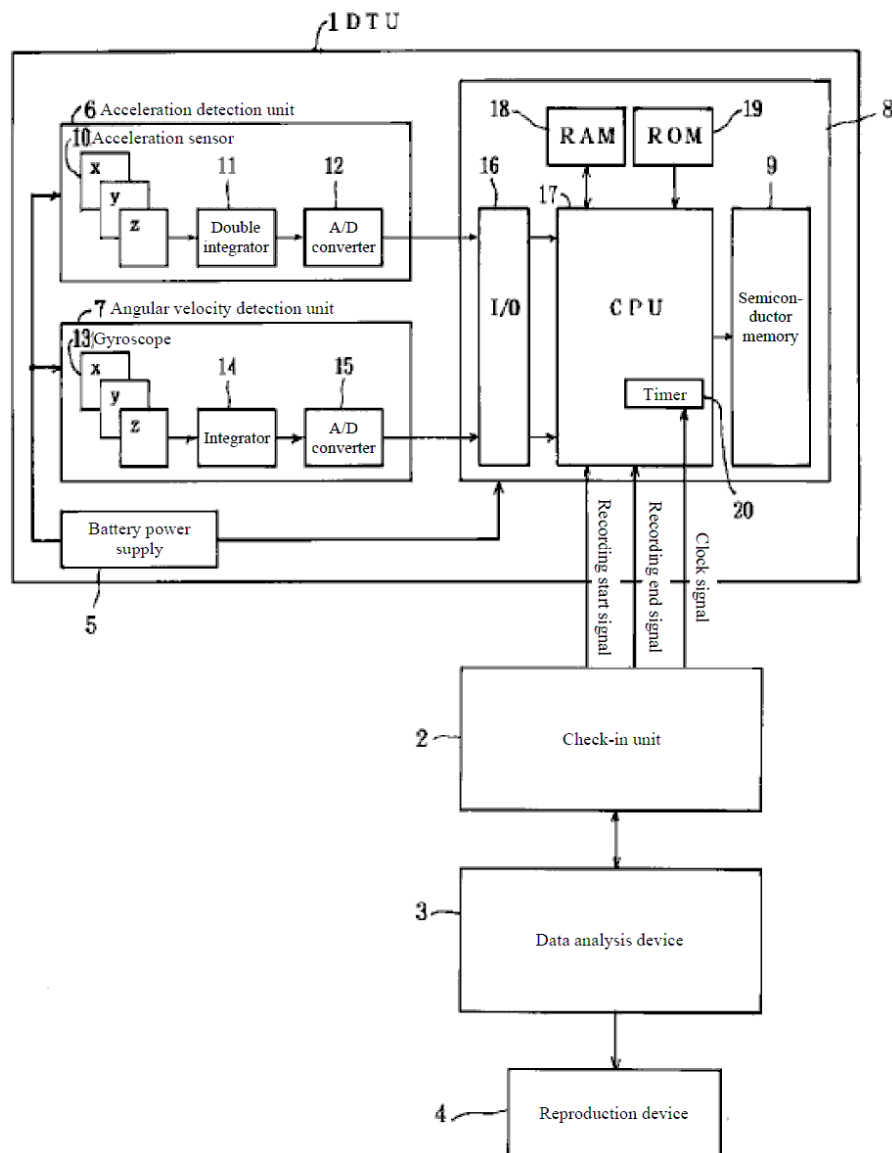
60. **Yamawaki** is a Japanese published patent application entitled “Mobile Data Collection Device for Underwater Moving Body and Diving Training System Comprising Said Device.” The Yamawaki application was written in Japanese, and as such, counsel has provided me with a certified English translation (**EX1010**). All citations to Yamawaki in my Declaration, therefore, will refer to the certified translation. I am informed that Yamawaki qualifies as prior art because it was published before the earliest filing date for the ’648 patent.

61. Yamawaki states that it relates to “a data collection device for recording

the movement path of an underwater moving body as electrical data, and to a diving training system, which includes a mobile data collection device for an underwater moving body that is capable of accurately plotting a diver's swimming path as recorded by the device on a background screen represented by a nautical chart or computer graphics.” (Yamawaki, ¶[0001].) Yamawaki explains that diving “has become popular, but divers engage in underwater diving which always entails danger due to the effects of ocean currents and water depth, thus making it essential for beginners to receive training.” (*Id.*, ¶[0002].) Yamawaki further explains that when carrying out training, “it is important to accurately identify the diver's swimming path in order to maximize the effectiveness of the training.” (*Id.*, ¶[0003].) Yamawaki seeks to address these issues with “a portable, user-friendly, and inexpensive mobile data collection device for an underwater moving body and a diving training system capable of accurately reproducing a movement path by analyzing data with a computer after a dive.” (*Id.*, ¶[0005].)

62. The overall system of Yamawaki is shown in Figure 1:

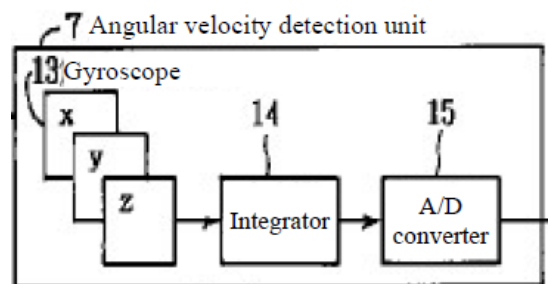
[FIGURE 1]



(Yamawaki, Fig. 1; *see id.*, ¶[0012] (“Figure 1 is a block diagram of an overall configuration of the diving training system according to this embodiment.”).) Figure 1 shows Diver Tracking Unit (DTU) 1, which “is a portable device in which a device body 1a, which makes up an outer housing thereof, is configured to have a relatively high degree of watertightness, with all components compactly accommodated in the

device body 1a, which can be worn in an appropriate place on the diver's body and can be removed, and detects the movement distance and movement direction of the diver." (*Id.*, ¶[0014].) The key components of DTU 1, for purposes of my Declaration, are the acceleration detection unit 6 and the angular velocity detection unit 7, both shown in Figure 1 above. (*Id.* ¶[0015].) As shown below, these units contain the same components as the inertial measurements in Smith and Tingleff, *i.e.*, three gyroscopes and three acceleration detectors for measuring, respectively, changes in angular rate and velocity.

63. Starting with the angular velocity detection unit 7 of Figure 1 (shown at right, partial figure), it includes a 3D gyroscope 13 that "comprises a gyro sensor and detects the rotational velocity of the diver during underwater movement." (*Id.*, ¶[0016].)



Angular velocity detection unit 7 also includes an integrator 14 and an analog-to-digital (A/D) converter 15. (*Id.*) Yamawaki explains that "[o]utput from the gyroscope 13 is obtained for rotation relative to the previous position, subjected to A/D conversion at a fixed sampling period, and imported into the CPU as a digital value to calculate the change in the diver's movement direction." (*Id.*, ¶[0029].) As Yamawaki further explains:

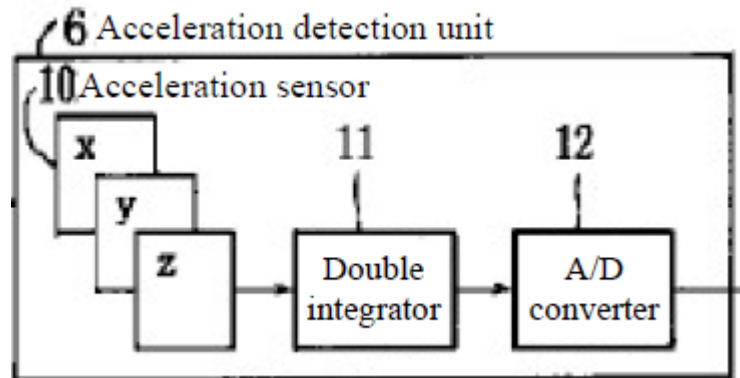
Assuming that the diver rotates underwater $\Delta\theta_{xy}$ in the X-Y plane during the time Δt , the angular rate $\Delta\omega_{xy}$ in the X-Y plane is expressed as

$$\Delta\omega_{xy} = \Delta\theta/\Delta t.$$

Therefore, the angle of rotation (change in movement direction) can be calculated by using with the integrator 14 to integrate the data obtained chronologically from the gyroscope over time.

(*Id.*, ¶[0030].)

64. Now moving to the acceleration detection unit 6 of Figure 1 (shown at right, partial figure), it contains a “3D acceleration sensor 10 which comprises a gyro sensor and detects acceleration during underwater.” (*Id.*, ¶[0016].)



Acceleration detection unit 6 also includes a double integrator 11 and an analog-to-digital (A/D) converter 15. (*Id.*) Yamawaki explains that “[o]utput from the acceleration sensor 10 is obtained of changes in movement speed or acceleration in the movement direction relative to the immediately preceding position and is then passed through the double integrator 11, subjected to A/D conversion by the A/D converter 12, acquired at a fixed sampling period, and recorded in the memory with the relative time from the starting point added.” (*Id.*, ¶[0023].) “This data indicates

the distance moved from the position at the previous unit of time.” (*Id.*) Using Figure 4 as an example (shown at right):

[W]hen the diver is at point P in an underwater 3D coordinate system at time t_0 and moves a very small distance ΔL to reach point Q at time t_1 after a minute of time Δt has elapsed, looking at the X-direction component Δx of the movement distance ΔL , the elapsed time Δt is defined as

[FIGURE 4]

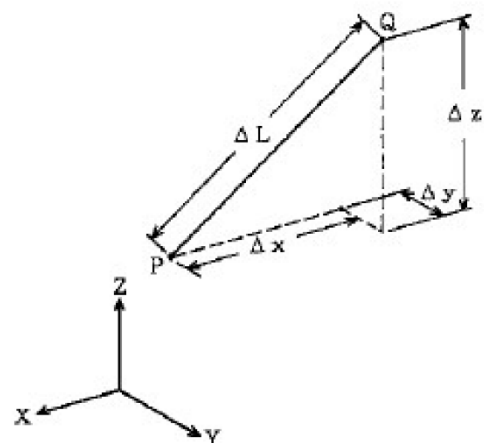
$$\Delta t = t_1 - t_0$$

the amount of change in speed in X direction ΔV_x is expressed as

$$\Delta V_x = \Delta x / \Delta t$$

and the acceleration α_x in the X direction is expressed as

$$\alpha_x = \Delta V_x / \Delta t$$



(*Id.*, ¶[0026].) “Therefore, by integrating the data

obtained chronologically from the acceleration sensor, the change in speed can be calculated, and by integrating this over time, the movement distance can be calculated.” (*Id.*, ¶[0028].) Although this particular example from Yamawaki only shows “movement components in the X-direction,” the “same process can be used to calculate the components in Y- and Z-directions as well.” (*Id.*)

65. I will provide more detail about Yamawaki in my analysis below.

4. Chan (EX1005)

66. **Chan**, U.S. Patent No. 6,058,778 (filed October 24, 1997, issued May 9, 2000), is titled “Integrated Sensor Having Plurality of Released Beams for Sensing Acceleration.” Chan discloses a micromechanical accelerometer that can sense acceleration in a predetermined direction. (Chan, Abstract.) I am informed that Chan qualifies as prior art because it was filed on October 24, 1997, before the filing date of earliest patent application to which the ’648 patent claims priority.

67. My Declaration cites Chan to confirm that microelectromechanical (MEMS) sensors such as accelerometers were well-known to persons of ordinary skill in the art before the earliest filing date of the ’648 patent. I have cited Chan in the event the preamble of claim 1, “[a] **micro inertial measurement unit**,” is deemed to be a claim limitation. My analysis relies primarily on the Background disclosures in Chan, which acknowledge:

Over the years, various microelectromechanical systems (“MEMS”) have arisen which require the necessity to sense temperature, pressure, strain, acceleration, rotation, infrared radiation, chemical properties of liquids and gases, and other physical inputs. Accordingly, various types of microsensors have been developed which receive analog and digital electrical inputs and also sense or measure these other physical inputs, e.g., acceleration, pressure, temperature, strain.

(Chan, 1:12-20.) Chan further explains that:

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,671,648 B2

Examples of applications for microsensors for acceleration or accelerometers include air bag systems, anti-lock braking systems, and ride suspension systems for automobiles and in-flight aircraft monitoring systems for aircraft. Each of these applications requires small, inexpensive, and reliable acceleration devices.

Many of the known accelerometers for these applications, for example, are analog and measure or sense an electrical current that varies with frequency or amplitude of acceleration. In other words, in essence, many of these sensors convert mechanical parameters to other energy domains and then sense or measure directly.

(*Id.*, 1:33-44.)

68. Chan goes on to disclose an improved sensor capable of “sensing acceleration in a predetermined direction.” (Chan, 3:14-16.) Nevertheless, my Declaration does not rely on the particular details of the allegedly inventive accelerometer disclosed in Chan, but on his general disclosure of the availability of MEMS-based sensors for sensing acceleration. As I will explain below, Chan confirms that it would have been obvious to modify the inertial measurement units in Smith and Tingleff to provide for MEMS-based motion sensors, such as MEMS-based accelerometers.

69. I will provide more detail about Chan in my discussion of the claim limitations below.

5. Bernstein (EX1006)

70. **Bernstein**, U.S. Patent No. 5,203,208 (filed April 29, 1991, issued April 20, 1993), is titled “Symmetrical Micromechanical Gyroscope.” Bernstein discloses a micromechanical gyroscope that “includes an inertial mass symmetrically supported about both drive and sense axes, for detecting rotational movement about an input axis.” (Bernstein, Abstract.) I am informed that Bernstein qualifies as prior art because it was issued on April 20, 1993, more than one year before the filing date of earliest patent application to which the ’648 patent claims priority.

71. Bernstein describes micromechanical gyroscopes for measuring angular position along a particular axis. The Background of Bernstein states that “[m]icromechanical gyroscopes which are micromachined from a single silicon substrate are now well known in the art.” (Bernstein, 1:11-13.) “Such devices typically have a gimbaled structure which includes an inner gimbal ring having a set of flexures coupled to a mass. The inner gimbal ring serves as the sense axis.” (*Id.*, 1:13-16.) The gimbaled structure also includes an outer ring which “serves as the drive axis and is coupled to a gyroscope frame by an outer set of flexures.” (*Id.*, 1:17-19.) Bernstein purports to improve micromachined gyroscopes by disclosing “a micromechanical gyroscope including a mass symmetrically supported about

both drive and sense axes, for detecting rotational movement about an input axis.”
(*Id.*, 1:48-51.)

72. As with Chan, my Declaration does not rely on the particular details of the allegedly inventive gyroscope disclosed in Bernstein, but on his general disclosure of the availability of MEMS-based sensors for measuring angular position. As I will explain below, Bernstein confirms that it would have been obvious to modify the inertial measurement units in Smith and Tingleff to provide for MEMS-based motion sensors, such as MEMS-based gyroscopes. I will provide more detail about Bernstein in my discussion of the claim limitations below.

6. Irwin (EX1007)

73. **Irwin** is a textbook entitled *Introduction to Electrical Engineering* (1995). As its title implies, “[t]his book is intended to serve as a text for an introductory course sequence in electrical engineering.” (EX1022, Preface, at xiii.) “It is a broad and comprehensive introduction to the field designed to provide students with an understanding of the fundamental concepts and a practical working knowledge of the application of these basic principles to real-world, up-to-date problems.” (*Id.*) I am informed that Irwin qualifies as prior art because it was published before the filing date of earliest patent application to which the ’648 patent claims priority.

74. My Declaration cites Irwin for **Ground 2** and **Ground 3** in connection with dependent claim 4, which recites that the angular rate electrical signals and acceleration electrical signals of claim 1 are “**voltage signals**,” that are “**directly proportional**” to the angular rate or acceleration they measure. Irwin confirms that these characteristics would have been basic and background knowledge of a person of ordinary skill in the art. Irwin confirms that is elementary knowledge that an analog signal is a signal whose amplitude (measured by its voltage) represents the information the signal is intended to convey. As explained in J. David Irwin et al., *Introduction to Electrical Engineering* (1995), in an analog signal, “the amplitude of the signal represents the information at every point in time.” (EX1007 (“Irwin”), § 7.3, p. 240.) As Irwin further explains:

Almost all observable nature is analog, with continuously varying parameters such as temperature, pressure, light intensity, etc. Therefore, many systems receive as their input an analog signal representing an analog parameter. The electronic signal generally originates from a sensor or transducer which provides an analog signal proportional to the parameter it’s designed to measure. Table 7.1 provides a partial list of analog parameters that various types of electronic sensors can measure.

(Irwin, § 7.3, p. 242 (emphasis added).) Among the examples listed in Table 7.1, referenced above, include “[a]cceleration” and “[r]otation.” (*Id.*, Table 7.1, p. 241.)

As noted, although Irwin uses “amplitude” when discussing the information carried by an analog signal, it was well-known that the amplitude of an analog signal is measured in volts. (*Id.*, e.g., EX1022, pp. xviii-xix; EX1007, 242-243; *see also*, e.g., *id.*, p. 243 (“Assume the voltage signal from an electric guitar is 20 millivolts in amplitude....”) .)

75. I will provide more detail about Irwin in my discussion of claim 4 below.

7. Merhav (EX1008)

76. **Merhav** is a book entitled *Aerospace Sensor Systems and Applications* (1996), which as its name implies, describes sensor systems for (among other things) aircraft aviation systems. (EX1008 (“Merhav”), *see also* EX1023, § 1.0, p. 5.) I am informed that Merhav qualifies as prior art because it was published before the filing date of earliest patent application to which the ’648 patent claims priority.

77. My Declaration cites Merhav in combination with Smith for purposes of **Ground 2**, which addresses dependent claim 4. Smith states that the three gyroscopes of its inertial measurement unit are ring laser gyroscopes that produce a digital output signal. (Smith, e.g., 2:13-15 (“The signal produced by a ring laser gyro is digital in nature, having a pulse repetition rate corresponding to the rate of gyro angular displacement.”).) I cite Merhav to show that it would have been

obvious that a ring laser gyro as disclosed in Smith would have produced an analog signal, as recited in claim 4.

78. Merhav describes the ring laser gyroscope (RLG) as “one of the most revolutionary twentieth century developments in the aerospace sensor field,” which “appeared on the scene in the early 1960s and since then has matured as a dominant product in the aerospace industry, having accumulated millions of successful operational flight hours in military and commercial aircraft.” (Merhav, § 8.0, p. 377.) Merhav explains that, in a ring laser gyroscope, angular rate is measured based on the interaction between “a pair of colocated, closed path clockwise and counterclockwise light beams.” (*Id.*) “Their interaction causes interference, which manifests itself as fringes resulting from the corresponding changes of the wavelengths and oscillating frequencies. These changes are proportional to the inertial angular rate.” (*Id.*) Merhav further explains that “[t]he intrinsic readout is by counting the pulses due to the fringes,” which “constitutes a natural interface with the digital processor and computer.” (*Id.*)

79. But Merhav further explains that, before these pulses are output by a ring laser gyroscope, an analog signal, *e.g.*, a sinusoidal signal, is generated:

As the intensity fringes cross a diode, a corresponding sinusoidal signal is generated. Two diodes are required in order to determine whether Ω is clockwise or counter-clockwise. The diodes are placed at 90° with

respect to each other in the coordinates of the fringe angle ζ . With this arrangement, it is possible to determine which of the two diodes precedes the other. Digital pulse conditioning and logic convert the sinusoidal outputs into a train of pulses whose frequency is directly proportional to Ω and whose accumulated count represents the angle θ .

(Merhav, p. 381 (emphasis added).) A person of ordinary skill in the art would have understood that the sinusoidal signal generated by the ring laser circuitry constitutes an analog signal. Merhav therefore confirms that it would have been obvious that a ring laser gyroscope, such as the ones used in Smith, would have generated an analog signal relating to a detected angular rate.

80. I will provide more detail about Merhav in my discussion of **Ground 2** below.

8. Saubolle (EX1011)

81. Saubolle, U.S. Patent No. 4,820,953 (filed November 23, 1987, issued April 11, 1989), is titled “Rate of Ascent Monitor Using Piezoelectric Transducer.” Saubolle “relates to a device for monitoring the rate of ascent of divers or similar applications.” (Saubolle, 1:5-6.) I am informed that Saubolle qualifies as prior art because it was issued on April 11, 1989, more than one year before the filing date of the earliest patent application to which the ’648 patent claims priority.

82. I have cited Saubolle for **Ground 4** in combination with Yamawaki

(EX1009/1010), which as explained in **Part V.A.3** above, discloses a data collection device for recording the movement of a diver underwater. (Yamawaki, ¶[0001].) Yamawaki discloses a system that uses accelerometers to measure a change of velocity of a diver along the X, Y, and Z axes, but it is unclear if Yamawaki converts change of velocity information to digital form and retains it for storage. (Yamawaki, ¶¶[0023], [0026]-[0028].) I have thus cited Saubolle to provide a motivation to convert the change of velocity information into digital format, and to retain the data in storage.

83. Saubolle explains that “[d]ivers using underwater breathing apparatus for diving must control their rate of ascent towards the water surface,” because if they fail to do so, they may “suffer dangerous, unpleasant and possibly fatal decompression effects, commonly referred to as the ‘bends’.” (Saubolle, 1:7-11.) Saubolle goes on to describe various prior art references that attempt to solve this problem, and goes on to describe “a rate of ascent or descent monitor which is inexpensive to manufacture and simple to use, thus rendering it suitable for widespread use and fulfilling a need for such a device at a sufficiently low price to be attractive to recreational divers.” (Saubolle, 1:66-2:3.)

84. My Declaration does not rely on the particular details of the allegedly inventive ascent/descent rate monitoring system in Saubolle, but on his general

disclosure of the need to carefully monitor the rate of ascent or descent in a diving scenario. As I will explain below, Saubolle confirms that it would have been obvious to adapt the data collection device of Yamawaki to obtain and collect digital information about the speed of travel.

85. I will provide more detail about Saubolle in my discussion of **Ground 4** below.

B. Ground 1: Claim 1 Is Obvious Over Smith in view of Chan and Bernstein

1. Independent Claim 1

86. For reference, claim 1 recites:

1. A micro inertial measurement unit, comprising:
 - [a]** 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;
 - [b]** 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
 - [c]** 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 digital angular increments and digital velocity increments respectively.

(’648, 23:43-24:21 (Claim 1; bracketed notations (*e.g.*, [a]) added).)

**(a) “A micro inertial measurement unit, comprising:”
(Claim 1[p])**

87. The preamble of claim 1 recites “[a] **micro inertial measurement unit.**” I understand from counsel that, under the patent laws, the preamble of a claim is generally not limiting if the limitations in the body of the claim that follow the preamble define a structurally complete invention, and the preamble states only a purpose of intended use of the invention. In my opinion, the preamble is not limiting under these principles because the claim limitations that follow, *i.e.*, limitations 1[a] through 1[c], define a structurally complete invention comprising, respectively, an “**angular rate producer,**” “**acceleration producer,**” and “**angular increment and velocity increment producer,**” each describing their respective components and purposes without relying on anything recited in the preamble.

88. The claim limitations in the body do not rely on the preamble for antecedent basis with respect to any claim element. Turning to the preamble itself, *i.e.* “[a] **micro inertial measurement unit**,” it merely recites the intended purpose or use of the invention recited in the claim limitations of the body of the claim. If the patentee had written the preamble to simply recite “[a] **unit comprising**,” or “[a] **system comprising**,” this would not have made the invention recited in the body of the claim any less complete, nor would have impacted the operation of any of the components or functions recited in the claim limitations.

89. Nevertheless, even if it is determined that the preamble of claim 1 imposes a limitation on the claim, it is rendered obvious over the prior art. Smith discloses an “**inertial measurement unit**” which includes at least the inertial sensor assembly (ISA) 12 and P1 processor 14, in Figure 1:

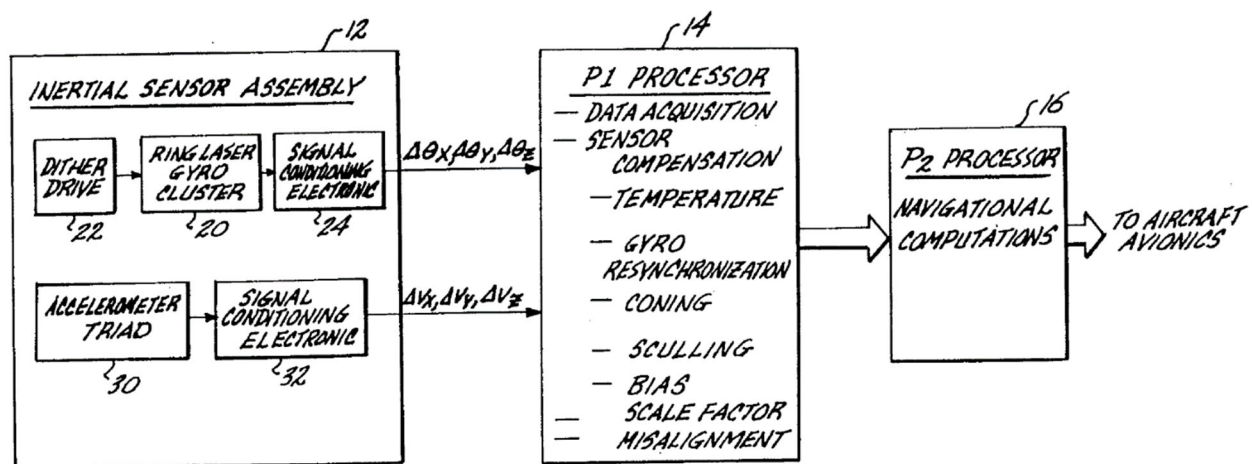


Fig. 1.

(Smith, Fig. 1.)

90. ISA **12** shown on the left of Figure 1 “contains the positional sensors,” which include “a cluster of three ring laser gyros **20**,” each of which is “mounted with its sensitive axis normal to one of three mutually orthogonal coordinate axes X, Y, and Z.” (Smith, 5:60-65.) “The output from each gyro is a digital signal having a pulse repetition rate proportional to the rate of angular displacement of the ISA **12** about the gyro’s sensitive axis.” (*Id.*, 5:65-68.) ISA **12** also includes “accelerometer triad **30**,” which includes “three accelerometers, each having its sensitive axis aligned with one of the three mutually orthogonal coordinate axes X, Y, and Z. Preferably, each accelerometer in accelerometer triad **30** is comprised of a digital accelerometer, having an output pulse repetition rate related to the rate of change of velocity of each gyro along its sensitive axis.” (*Id.*, 6:15-21.)

91. Smith explains that the purpose of the ISA is to measure and output the changes in angular position and velocity along the X, Y, and Z axes:

Briefly, according to the invention, an inertial reference system comprises an inertial sensor assembly. The inertial sensor assembly includes gyros for producing asynchronous output signals $\Delta\theta_x$, $\Delta\theta_y$, and $\Delta\theta_z$ representative of the change in angular position of the inertial sensor assembly with respect to three mutually orthogonal coordinate axes X, Y, and Z, respectively. Also provided in the inertial sensor assembly are accelerometers for producing output signals ΔV_x , ΔV_y ,

and ΔV_z representative of the change in velocity of the inertial sensor assembly in the X, Y, and Z coordinate axes, respectively.

(Smith, 3:7-18.) The above-mentioned signals output from inertial sensor assembly **12** are then provided to the **P1** processor **14**, shown in the middle of Figure 1 above.

(Smith, 3:19-20 (“A first processor, P1, predeterminedly accesses and processes the $\Delta\theta_x$, $\Delta\theta_y$, $\Delta\theta_z$, ΔV_x , ΔV_y and ΔV_z signals [from the initial sensor assembly].”).) **P1** processor **14**, as explained in more detail in the discussion of claim limitation 1[c] below, includes gyro and accelerometer counters that accumulate and count $\Delta\theta$ and ΔV output values obtained from the inertial sensor assembly **12** over a period of time. (Smith, *e.g.*, 3:48-58, 4:29-37, 13:3-12, 13:26-39.)

92. Smith thus discloses an “**inertial measurement unit.**” I note that Smith’s description mirrors the ’648 patent specification’s description of inertial measurement units. The ’648 patent discloses that “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.” (’648, 1:20-24; *see also* 1:24-28 (“three orthogonally mounted inertial angular rate producers and three orthogonally mounted acceleration producers with additional supporting mechanical structure and electronic devices are conventionally called an Inertial Measurement Unit (IMU)”).) Further, the ’648 specification discloses that “an inertial

measurement unit (IMU) is employed to determine the motion of a carrier.” (*Id.*, 1:18-19.) This closely corresponds to the description in Smith as discussed above, which includes three gyros and accelerometers, mounted orthogonally along the X, Y, and Z axes, that determine the motion of a carrier (*e.g.*, an aircraft). (Smith, 5:62-65 (“Each ring laser gyro... is mounted with its sensitive axis normal to one of three mutually orthogonal coordinate axes X, Y, and Z.”), 6:15-18 (“An accelerometer triad **30** includes three accelerometers, each having its sensitive axis aligned with one of the three mutually orthogonal coordinate axes X, Y, and Z.”).)

“Micro” Inertial Measurement Unit

93. I note that the preamble further recites a “**micro inertial measurement unit.**” Smith discloses that his inertial measurement unit “may be constructed in a small enclosure” (Smith, 2:57-58), but does not expressly disclose that the inertial measurement system uses micromachined or micromechanical components.

94. Although the ’648 patent does not expressly define the word “**micro**,” the patent refers to known MEMS techniques. MEMS, which stands for Micro Electro Mechanical Systems, generally refers to a category of sensors and other components that are miniaturized using microfabrication techniques similar to those used to construct silicon-based integrated circuits such as microchips. The ’648 patent explains that “MEMS, or, as stated more simply, micromachines, are

considered as the next logical step in the silicon revolution.” (’648, 2:15-16.) The ’648 patent nevertheless acknowledges that microchip-sized angular rate sensors and accelerometers were already known in the art and commercially available. (’648, 2:25-51.) Nevertheless, to the extent the preamble of claim 1 is deemed to be limiting, a “**micro inertial measurement unit**” would have been obvious over Smith in view of **Chan** and **Bernstein**.

95. I have cited Chan and Bernstein, respectively, for examples of prior art references disclosing micromachined accelerometers and gyroscopes. As noted, MEMS accelerometers and gyroscopes are admitted prior art in the ’648 patent, a fact further confirmed by Chan and Bernstein.

96. Turning first to Chan, it explains:

Over the years, various microelectromechanical systems (“MEMS”) have arisen which require the necessity to sense temperature, pressure, strain, acceleration, rotation, infrared radiation, chemical properties of liquids and gases, and other physical inputs. Accordingly, various types of microsensors have been developed which receive analog and digital electrical inputs and also sense or measure these other physical inputs, e.g., acceleration, pressure, temperature, strain.

(Chan, 1:12-20.) Chan further confirms that MEMS-based accelerometers were already well-known and had been used commercially:

Examples of applications for microsensors for acceleration or

accelerometers include air bag systems, anti-lock braking systems, and ride suspension systems for automobiles and in-flight aircraft monitoring systems for aircraft. Each of these applications requires small, inexpensive, and reliable acceleration devices.

Many of the known accelerometers for these applications, for example, are analog and measure or sense an electrical current that varies with frequency or amplitude of acceleration. In other words, in essence, many of these sensors convert mechanical parameters to other energy domains and then sense or measure directly.

(Chan, 1:33-44.) Chan goes on to disclose an improved sensor capable of “sensing acceleration in a predetermined direction.” (*Id.*, 3:14-16.)

97. Turning next to gyroscopes, Bernstein describes micromechanical gyroscopes for measuring angular position along a particular axis. The Background of Bernstein states that “[m]icromechanical gyroscopes which are micromachined from a single silicon substrate are now well known in the art.” (Bernstein, 1:11-13.) “Such devices typically have a gimbaled structure which includes an inner gimbal ring having a set of flexures coupled to a mass. The inner gimbal ring serves as the sense axis.” (*Id.*, 1:13-16.) The gimbaled structure also includes an outer ring which “serves as the drive axis and is coupled to a gyroscope frame by an outer set of flexures.” (*Id.*, 1:16-19.) Bernstein purports to improve micromachined gyroscopes by disclosing “a micromechanical gyroscope including a mass symmetrically

supported about both drive and sense axes, for detecting rotational movement about an input axis.” (*Id.*, 1:48-51.) It would have been apparent and obvious to a POSITA that Bernstein discloses a “**micro**,” *e.g.*, MEMS-based, gyroscope.

98. ***Rationale and Motivation to Combine (Smith with Chan and Bernstein)***: It would have been obvious to combine Smith with Chan and Bernstein, predictably resulting in the inertial measurement unit in Smith further adapted to use micromechanical (MEMS-based) accelerometers and gyroscopes. The proposed combination would thus have rendered obvious a “**micro**” inertial measurement unit, with the Smith inertial sensor assembly constructed using micromechanical accelerometers and gyroscopes, for example, mounted on a printed circuit board using conventional techniques.

99. The proposed combination could have been implemented in a number of straightforward ways. In one implementation, the three accelerometers and gyroscopes in Smith would have been replaced with corresponding micromachined accelerometers and gyroscopes. As I noted in **Part V.A.4** and **Part V.A.5**, my obviousness analysis does not rely on the particular details of the allegedly inventive accelerometer in Chan, or the allegedly inventive gyroscope in Bernstein, but on Chan’s and Bernstein’s general disclosures of the availability of MEMS-based sensors for sensing acceleration and angular rotation. Chan and Bernstein, as well

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as the '648 patent itself (*e.g.*, '648, 2:25-51), all confirm that these MEMS-based components were known and commercially available. Under the proposed combination, the inertial measurement unit in Smith would have produced angular and velocity increments, in response to signals obtained from micromechanical gyroscopes and accelerometers, respectively. This combination would have been straightforward because the micromechanical accelerometers and gyroscopes are, after all, accelerometers and gyroscopes that serve the same purposes and provide the same types of velocity and angular position information as their non-micromechanical counterparts. And although the use of micromechanical components would have required a change in the manufacturing processes of the IMU in Smith, and may have required a change to the signal conditioning electronics to interface the signals provided by the micromechanical replacement gyros and accelerometers, this would have been regarded as a routine implementation well within the skill of a POSITA. As the '648 patent itself acknowledges, "MEMS angular rate sensors and MEMS accelerometers are available commercially and have achieved micro chip-size and low power consumption[.]" ('648, 2:47-51.) This is confirmed by Chan and Bernstein, which confirm (as part of their general backgrounds) the existence of micromechanical accelerometers and gyroscopes, as noted.

100. Smith, Chan and Bernstein are analogous references in the same field as the '648 patent of devices for measuring motion such as velocity and angular position. These prior art references would also have been reasonably pertinent to problems facing the inventor in implementing an inertial measurement unit to measure changes in velocity and angular position along the X, Y, and Z axes, using accelerometer and gyroscope devices. Chan and Bernstein would further have been pertinent to a problem facing the inventor in using MEMS accelerometers and gyroscopes in constructing the inertial measurement unit.

101. A POSITA would have been amply motivated to combine Smith, Chan and Bernstein. An ordinarily skilled artisan would have appreciated that micromechanical accelerometers and gyroscopes would have offered reduced size, reduced weight, and reduced power consumption when compared to larger (non-micromechanical) components. By the time of the filing date of the '648 patent, moreover, micromachined accelerometers and gyroscopes had been commercially available for several years, thus providing a potential cost savings. This motivation is further supported by Smith, which explains that one objective of his invention was to provide an “improved inertial reference system may be constructed in a small enclosure and is designed to minimize the use of expensive components, thereby reducing overall cost.” (Smith, 2:56-59; *see also id.*, 22:35-39 (“It has also been

found that the present organization lends itself to construction of the IRS [inertial reference system] within a small chassis, thereby making the present IRS suitable for application in smaller vehicles, such as privately owned aircraft.”).) The use of micromechanical accelerometers and gyroscopes would have furthered Smith’s objectives of making a small and reduced-cost inertial measurement unit. This motivation is further supported by Chan, which explains that “[e]xamples of applications for microsensors for acceleration or accelerometers include... in-flight aircraft monitoring systems for aircraft,” which Chan identifies as an example of application that requires “small, inexpensive, and reliable acceleration devices.” (Chan, 1:33-38 (emphasis added).) This provides a further motivation to use MEMS-based sensors to improve an IMU used in the context of aircraft.

102. This is further supported by the Background of the ’648 patent, which acknowledges that it was known that “MEMS (MicroElectronicMechanicalSystem) inertial sensors offer tremendous cost, size, and reliability improvements for guidance, navigation, and control systems, compared with conventional inertial sensors.” (’648, 2:11-14.) This is supported by other more modern references, published in the 1990s, that disclose use of micromachined accelerometers and gyroscopes in the context of aviation, which I have cited to confirm the knowledge of a skilled artisan. For example, U.S. Patent No. 5,396,797 to Rand Hulsing

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(**EX1013**), which was issued on March 14, 1995, discloses “micromachined devices used for measuring angular rate and acceleration.” (Hulsing, 1:10-11.) Hulsing explains that “[i]nertial measurement units (IMUs) are critical to the proper operation of inertial navigation and guidance systems,” and “are used on ships, aircraft, spacecraft, etc.” (Hulsing, 1:36-39.) Hulsing discloses placing micromachined devices on a single substrate, with “the input axes **38** of the accelerometers **32a** and **b**... precisely oriented with respect to the vehicle or aircraft carrying the sensor **10** of this invention.” (Hulsing, 8:48-50.) As another example, U.S. Patent No. 5,841,537 to James H. Doty (**EX1014**), which was issued on November 24, 1998, explains in its Background that “[g]yroscopes and accelerometers have been utilized in avionics inertial navigation systems to provide information concerning the orientation of the airplane with respect to a reference plane, typically the local level ground coordinates.” (Doty, 1:15-18.) Doty explains that information about movement of an aircraft is provided to an “attitude heading reference system (AHRS),” which typically “utilize precision solid state inertial sensors to measure rotation rates,” including among other examples, “silicon micromachined accelerometers” and “micromachined quartz gyros, which are also commercially available.” (Doty, 1:18-36.) A skilled artisan would thus have acknowledged that the benefits of MEMS-based sensors would have been fully

applicable to use in navigation systems for aircraft.

103. As noted, the Background of the '648 patent acknowledges the known benefits of MEMS sensors by admitting that they “offer tremendous cost, size, and reliability improvements for guidance, navigation, and control systems, compared with conventional inertial sensors.” ('648, 2:12-15.) The Background explains that “[p]rolific 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.” ('648, 2:25-28.) These admitted benefits were known before the application for the '648 patent was filed.

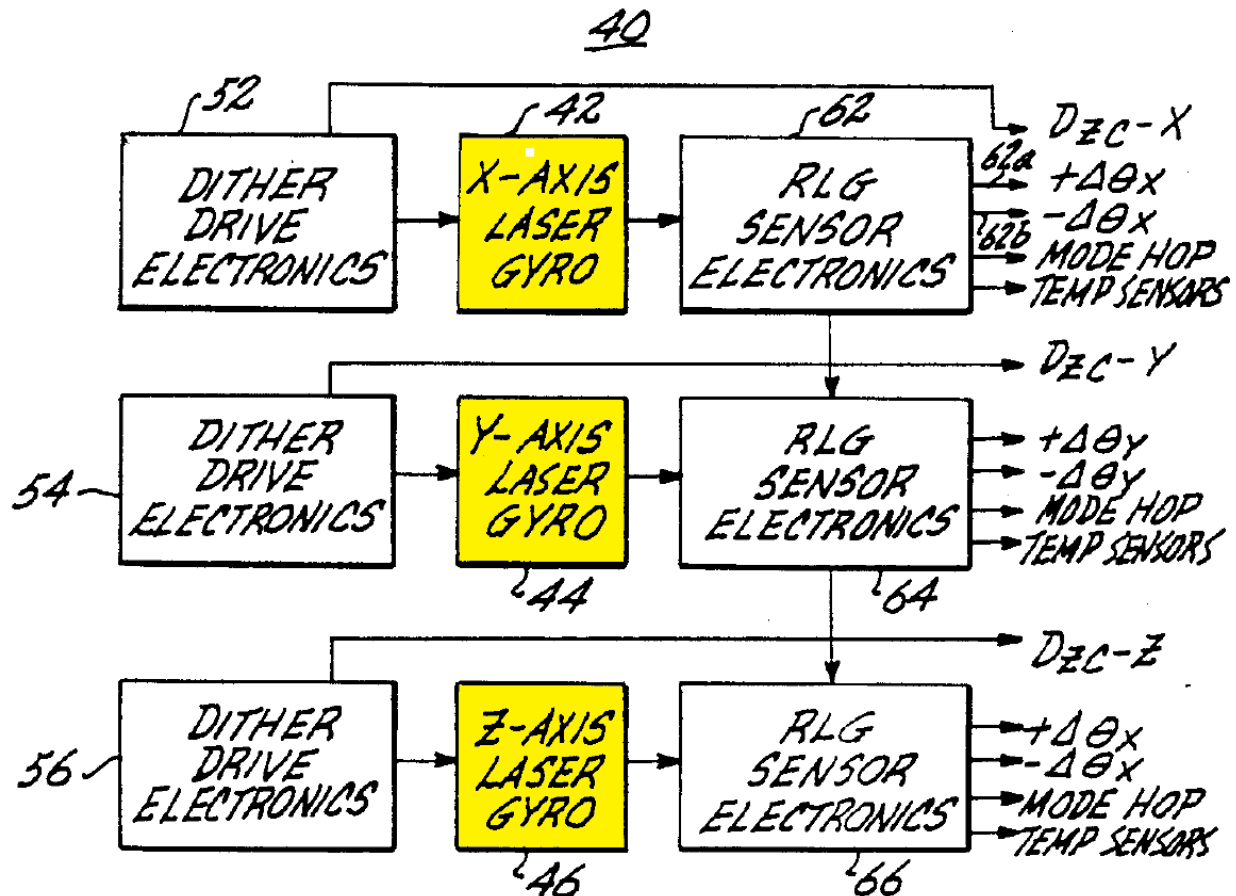
104. An ordinarily skilled artisan would have had more than a reasonable expectation of success and could have implemented the proposed combination using conventional techniques without undue experimentation. As noted above, the '648 patent itself acknowledges that micromechanical sensors such as accelerometers and gyroscopes were already commercially available. ('648, 2:25-46.) The proposed combination would have involved nothing more than the use of prior art devices according to known techniques.

105. Accordingly, to the extent the preamble is limiting, it would have been obvious to provide “[a] **micro inertial measurement unit.**”

- (b) **“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;”**
(Claim 1[a])

106. Smith discloses **“an angular rate producer”** in the form of a set of three gyroscopes, each of which detects the angular position of the inertial measurement unit along one of three axes and produces an electrical signal. These gyroscopes are shown in Figure 2:

Fig. 2.



(Smith, Fig. 2 (partial figure; highlighting added).)

107. As explained in Smith, Figure 2 shows “a cluster, indicated generally at 40, of three ring laser gyros 42, 44, 46, each having its sensitive axis aligned with one of three mutually orthogonal coordinate axes X, Y, and Z, respectively.” (Smith, 7:58-62 (highlighting added).) “Each ring laser gyro 42, 44, and 46 produces an output digital signal having a pulse repetition rate proportional to the rate of angular displacement of each gyro 42, 44, and 46 about its coordinate axis.” (*Id.*, 8:3-6

(highlighting added).)

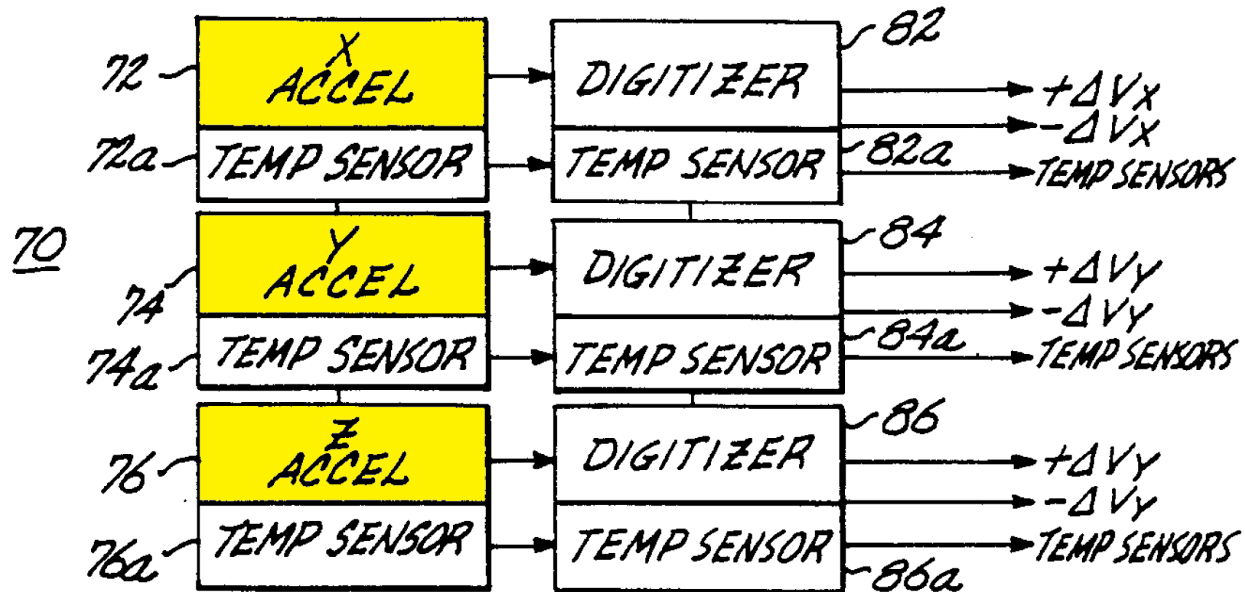
108. Smith thus discloses “**an angular rate producer,**” which includes the three gyroscopes shown above, thus “**comprising a X axis angular rate detecting unit which produces a X axis angular rate electrical signal, a Y axis angular rate detecting unit which produces a Y axis angular rate electrical signal, and a Z axis angular rate detecting unit which produces a Z axis angular rate electrical signal,**” *i.e.*, respectively, gyros 42, 44, and 46, each of which detects angular displacement along the X, Y and Z axes, respectively, and generates an electrical signal proportional to the rate of angular displacement along the corresponding axis. The claimed electrical signals are shown, in Figure 2 above, as the signals transmitted by gyros 42, 44, and 46 to RLG sensor electronics 62, 64, and 66, respectively. This is also consistent with the specification of the '648 patent, which confirms that “[c]onventional inertial angular rate producers include... Ring Laser Gyros (RLG)” ('648, 1:46-52), which are the type of gyros disclosed in Smith.

109. And moreover, to the extent the word “**micro**” in the preamble is limiting, it would also have been obvious for the ring laser gyros in Smith to have been replaced with micromechanical gyroscopes which were well-known in the art, each of which would have produced an angular rate electrical signal. I provided a full explanation of the rationale and motivation to make this change in my discussion

of the preamble, above. As noted, Bernstein explains in describing one example of a micromechanical gyro, “[c]omputation electronics **53**, responsive to the drive and sense electronics, are provided to compute the amount of angular rotation about the input axis which is sensed by the gyroscope.” (Bernstein, 3:59-62.) In any case, it would have been obvious to a person of ordinary skill in the art that a micromechanical gyroscope – as with other types of electronic sensor components – would have produced an electrical signal, in the case of a gyroscope, a signal relating to the detected angular rate or rotation. As explained in my discussion of the preamble, therefore, it would have been obvious for the **“angular rate producer”** (as well as the claimed inertial measurement unit) to be constructed from micromechanical components, to the extent this is determined to be a limitation of claim 1.

- (c) **“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” (Claim 1[b])**

110. Smith also discloses **“an acceleration producer”** in the form of a set of three accelerometers, each of which detects acceleration of the inertial measurement unit along one of three axes and produces an electrical signal. These accelerometers are shown in the bottom half of Figure 2:



(Smith, Fig. 2 (partial figure; highlighting added).)

111. As explained in Smith, Figure 2 shows “an accelerometer triad, indicated generally at 70,” which “is comprised of three analog accelerometers 72, 74, 76, each having its sensitive axis aligned with one of the three mutually orthogonal coordinate axes X, Y, and Z, respectively.” (Smith, 8:43-48 (highlighting added).) “The analog accelerometers 72, 74, and 76 produce analog output signals corresponding to the rate of change of velocity of each accelerometer along its sensitive axis.” (*Id.*, 8:48-51 (highlighting added).)

112. Smith thus discloses “an acceleration producer,” which includes the three accelerometers shown above, thus “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,” i.e., respectively, accelerometers **72**, **74**, and **76**, each of which detects acceleration along the X, Y and Z axes, respectively, and generates an analog electrical signal corresponding to the acceleration along that axis. The claimed electrical signals are shown, in Figure 2 above, as the signals transmitted by accelerometers **72**, **74**, and **76** to digitizers **82**, **84**, and **86**, respectively.

113. And moreover, to the extent the word “**micro**” in the preamble is limiting, it would also have been obvious for the accelerometers in Smith to have been micromechanical accelerometers which were well-known in the art, each of which would have produced an acceleration electrical signal. I provided a full explanation of the rationale and motivation to make this change in my discussion of the preamble, above. Smith does not limit the type of accelerometer used, but states that “[p]referably, a ‘Q-FLEX’ type accelerometer, available from Sundstrand Data Control of Redmond, Wash., is used” (Smith, 10:2-4), which indicates that commercially-available accelerometers could have been used. Chan explains that many known MEMS-based accelerometers “are analog and measure or sense an electrical current that varies with frequency or amplitude of acceleration.” (Chan, 1:40-43.) It therefore would have been obvious to a person of ordinary skill in the art that a micromechanical accelerometer – as with any other type of electronic

sensor component – would have produced an electrical signal, in the case of an accelerometer, reflecting the detected acceleration. As explained in my discussion of the preamble, it would have been obvious for the “**acceleration producer**” (as well as the claimed inertial measurement unit) to have been constructed from micromechanical components, to the extent this is determined to be a requirement of claim 1.

- (d) “**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 digital angular increments and digital velocity increments respectively.**” (Claim 1[c])

114. Smith also discloses “**an angular increment and velocity increment producer,**” in the form of the components and circuitry in Smith that receive and process the electrical signals from the gyroscopes and accelerometers (discussed for claim limitations 1[a]-1[b] above), to convert them into the claimed digital increments. These components are shown in Figure 1:

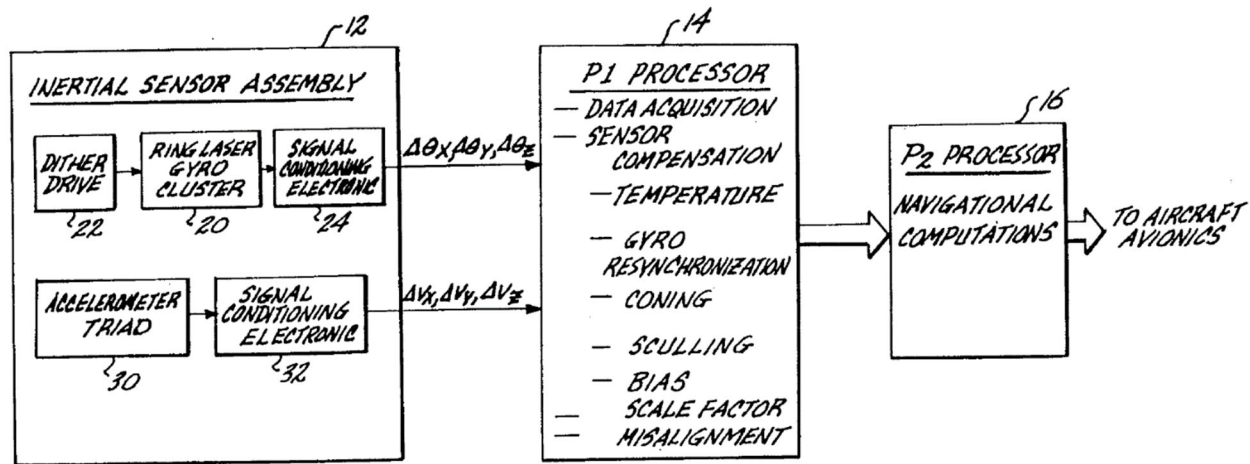


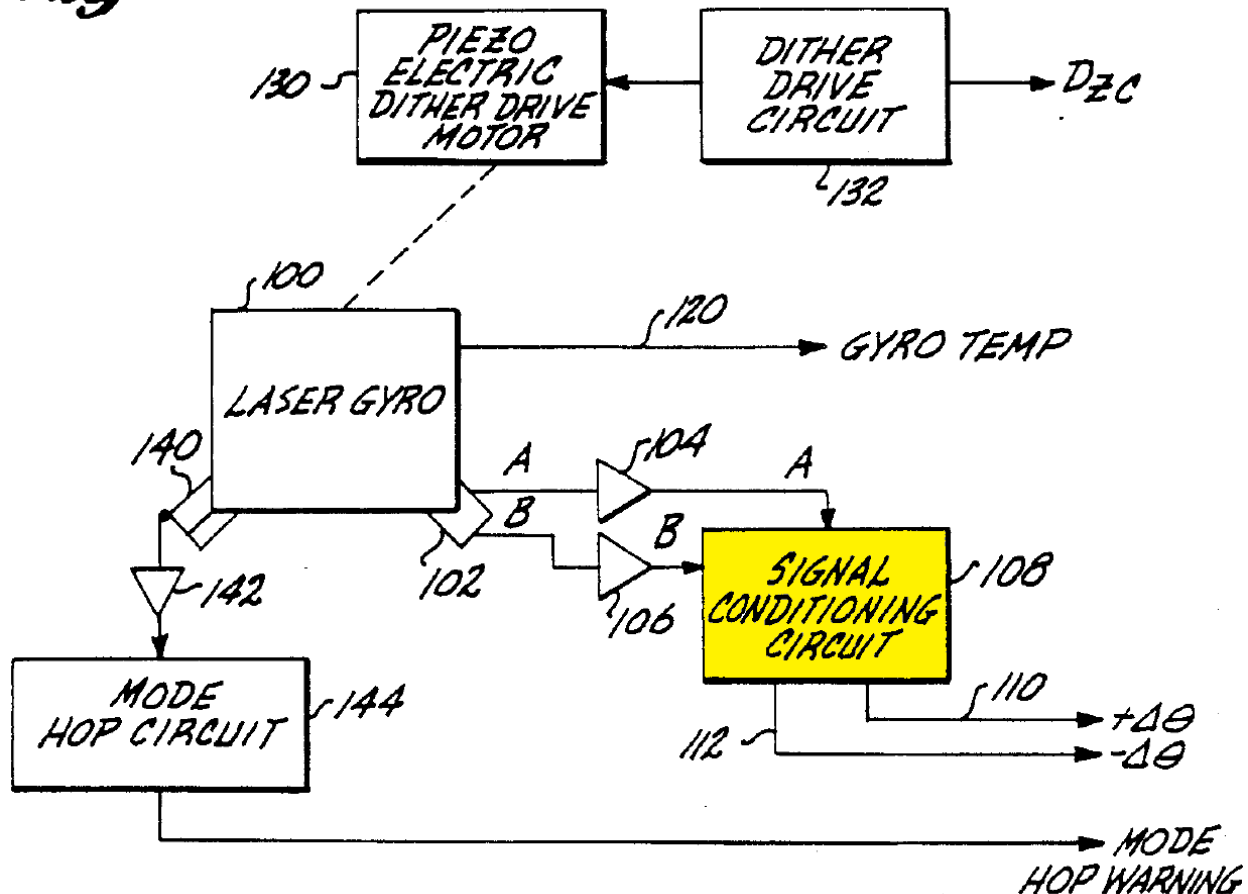
Fig. 1.

(Smith, Fig. 1.) As explained in detail below, the claimed “**angular increment and velocity increment producer**” corresponds in Smith to signal conditioning electronics **24** and **32** for the gyroscopes and accelerometers (shown within inertial sensor assembly **12** above), and further includes P1 processor **14** that accumulates and stores angular and velocity increments ($\Delta\theta$ and ΔV) for the X, Y, and Z axes. Claim 1 recites conversion of the electrical signals from the gyroscopes and accelerometers into “**digital angular increments**” and “**digital velocity increments**,” respectively, and I will address each of these below.

115. Starting with “**digital angular increments**”, Figure 1 above shows ring laser gyro cluster **20**, as discussed extensively for limitation 1[a], which includes “**said X axis, Y axis and Z axis angular rate detecting units.**” Figure 1 shows gyro cluster **20** electronically connected to signal conditioning electronics **24**.

(Smith, 6:9-11.) The signal conditioning electronics are also shown in Figure 3:

Fig. 3.

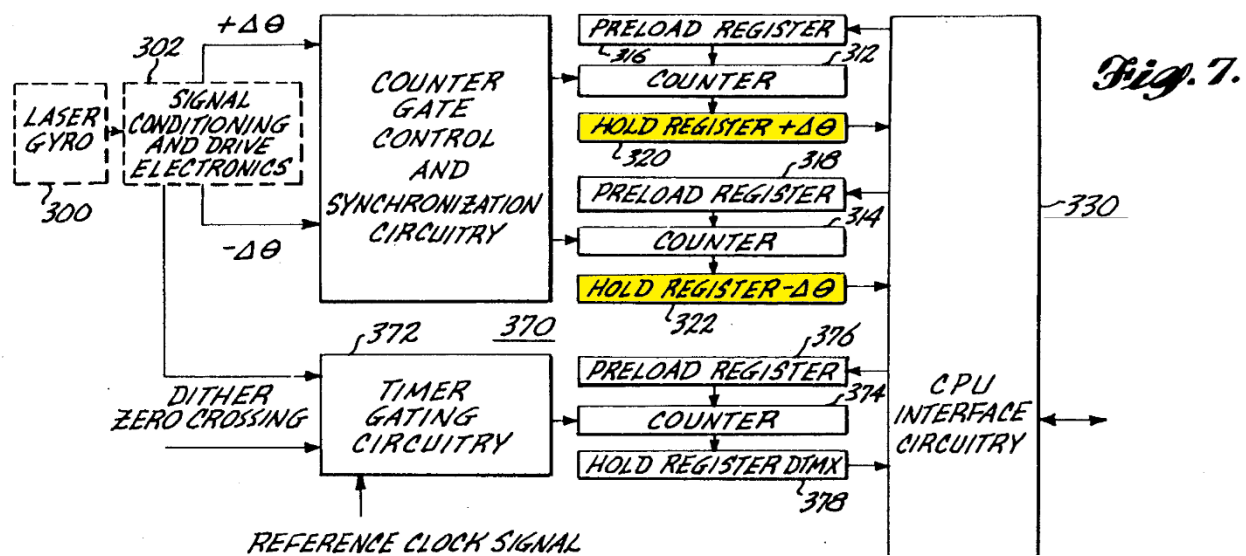


(Smith, Fig. 3 (highlighting added).)

116. Figure 3 shows “a detailed block diagram illustrating a ring laser gyro and its associated dither drive and output processing circuits.” (Smith, 9:7-9.) The gyro, as shown, produces “output signal A representative of clockwise rotation of the laser gyro, and an output signal B representative of counterclockwise laser gyro rotation.” (*Id.*, 9:19-22.) “Signal-conditioning circuit **108** processes the A and B input signals to produce, on a first output line **110**, a signal $+\Delta\theta$ having a pulse

repetition rate proportional to the clockwise angular rotation rate of the laser gyro 10 [sic; 100] in its sensitive axis. On a second line 112, the signal-conditioning circuit 108 produces an output signal $-\Delta\theta$ having a pulse repetition rate proportional to the counterclockwise angular rotation rate of the laser gyro 100 in its sensitive axis.” (*Id.*, 9:25-33.) Although Figure 3 shows signal-conditioning electronics for a single gyroscope 100, Smith makes clear these electronics are provided for each of the three gyroscopes, resulting in three sets of $+\Delta\theta$ and $-\Delta\theta$ signals for the X, Y, and Z axes, *i.e.*, $+\Delta\theta_x$, $-\Delta\theta_x$, $+\Delta\theta_y$, $-\Delta\theta_y$, $+\Delta\theta_z$ and $-\Delta\theta_z$. (*Id.*, 8:3-28, Figs. 1-2.)

117. Figure 7 of Smith, reproduced in relevant part below, shows these $+\Delta\theta$ and $-\Delta\theta$ signals (with respect to a single gyroscope 300) output to P1 processor 14, where they are then accumulated over a period of time to produce and store counts of the $+\Delta\theta$ and $-\Delta\theta$ signals:

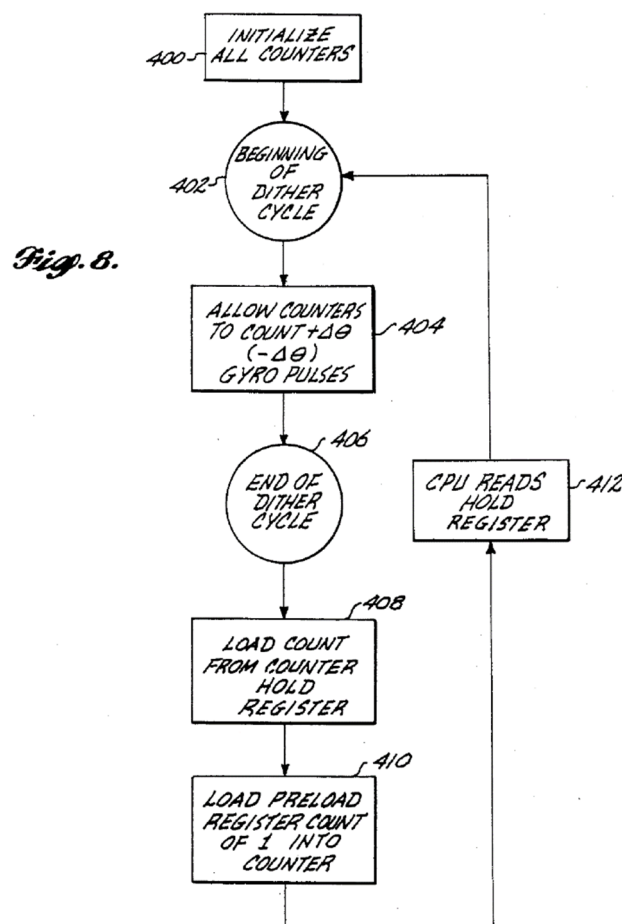


(Smith, Fig. 7 (partial figure shown; highlighting added).) Figure 7 shows the $+\Delta\theta$ and $-\Delta\theta$ signals from the signal conditioning electronics **302** for a gyro **300** (at the top left) output to counter gate control and synchronization circuitry which are further sent to the counters. The counter gate control and synchronization circuitry and the counters are part of P1 processor **14**. (*Id.*, 3:46-47, 10:36-38 (“The inputs to the P1 processor are the above-described outputs from the inertial sensor assembly.”).)

118. The purpose of this counter is conceptually straightforward. The term “counter” in electronics, as its name implies, generally refers to logic circuits for counting how many signals of a particular type are received during a period of time. In this case, the $+\Delta\theta$ and $-\Delta\theta$ signals received from the signal conditioning electronics **302** represent the rate of angular displacement information from the gyroscope *at a particular point in time*. To further determine the change of angular displacement *over time*, the counters in Figure 7 count the number of pulses in the $+\Delta\theta$ and $-\Delta\theta$ signals that are received, over a predetermined time interval, and then store the accumulated counts in hold registers **320** and **322** as shown above. (Smith, 3:48-54, 6:35-38 (“Inasmuch as the gyro and accelerometer-produced signals are digital in nature, the data acquisition function of the P1 processor **14** involves the accumulation and storage of the input pulses over periodic cycles.”).) Using the

example in Figure 7 above, hold register 320 holds the accumulated counts of the $+\Delta\theta$ signals, and hold register 322 holds the accumulated counts of the $-\Delta\theta$ signals, received during the predetermined time interval. These stored accumulated counts can then be accessed by the CPU via CPU interface circuitry 330, as also shown in Figure 7 above. (*Id.*, 13:14-16.) As explained above and below, these accumulated counts of the $+\Delta\theta$ and $-\Delta\theta$ signals qualify as “**digital angular increments.**”

119. Figure 8 provides a more detailed description of how the counters perform the process of accumulating $+\Delta\theta$ and $-\Delta\theta$ signals:



(Smith, Fig. 8.)

120. As Figure 8 shows, the accumulation of $+\Delta\theta$ and $-\Delta\theta$ signals takes place during beginning **402** and end **406** of a dither cycle. (Smith, *e.g.*, 2:15-18 (“To eliminate the dither signal from the produced gyro signal, the count of the gyro pulse output is accumulated over one full dither cycle, and measured at dither zero crossings.”), 3:48-52, 14:7-13.) During this period of time, “the counters, such as counters **312**, **314** [in Figure 7 above] are allowed to count their corresponding $+\Delta\theta$ and $-\Delta\theta$, respectively, gyro pulses at block **404**.” (*Id.*, 14:7-11 (emphasis added).) At the end of dither cycle **406**, “the accumulated counts in the counters **312**, **314** are loaded into the corresponding hold registers **320**, **322**, respectively, at block **408**.” (*Id.*, 14:13-16 (emphasis added).)

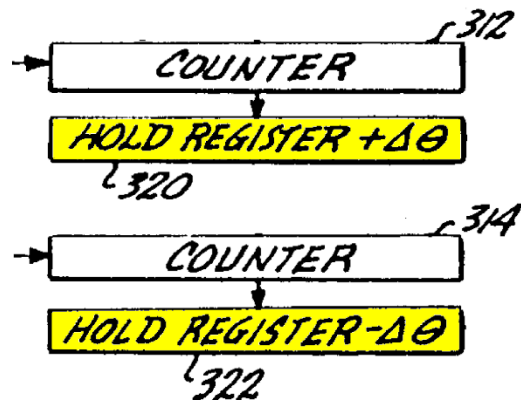
121. In other words and using simple terms, the process in Figure 8 counts the number of pulses of the $+\Delta\theta$ signal and the number of pulses of the $-\Delta\theta$ signal received over a predetermined time period (*i.e.* dither cycle), and then stores those accumulated counts in hold registers **320** and **322**, respectively. This accumulation takes place with respect to all three gyros, and thus, generates $+\Delta\theta$ and $-\Delta\theta$ counts for the X, Y, and Z axes. (Smith, *e.g.*, 10:39-54, Fig. 5 (**202** (X axis), **204** (Y axis), **206** (Z axis)).)

122. Smith thus discloses “**an angular increment ... producer, which is electrically connected with said X axis, Y axis and Z axis angular rate detecting**

units... receiving said X axis, Y axis and Z axis angular rate electrical signals... from said angular rate producer,” *i.e.*, the signals received from the three gyroscopes from the X, Y, and Z axes as discussed above, which are “converted into... digital angular increments,” *i.e.*, the accumulated $+\Delta\theta$ and $-\Delta\theta$ counts for each of the X, Y, and Z axes produced by the counters as discussed above.

123. These accumulated counts qualify as “digital angular increments,” as claimed. I understand that in prior litigation involving the ’648 patent, Patent Owner has argued that the phrase, “digital angular increments” should take its plain and ordinary meaning or, if construed, means “changes in angle expressed digitally.” (EX1019, p. 26 (emphasis added).) I understand that defendants in those prior litigations (not Petitioner) argued that this phrase refers to “accumulated changes in angle over a predetermined time interval expressed in digital form.” (*Id.* (emphasis in original)) Smith easily satisfies both constructions.

124. This is because the accumulated counts of the $+\Delta\theta$ and $-\Delta\theta$ signals, for example stored in registers 320 and 322 (shown partially at right), represent changes in the angular position of the inertial measurement unit. This is clear from the $\Delta\theta$ notation used in Smith, with delta (Δ) being a



standard symbol representing change, and theta (θ) a standard symbol representing angle, consistent with disclosures in Smith. (Smith, *e.g.*, 3:8-13 (“... signals $\Delta\theta_x$, $\Delta\theta_y$, and $\Delta\theta_z$ [are] representative of the change in angular position of the inertial sensor assembly with respect to three mutually orthogonal coordinate axes X, Y, and Z, respectively.”) (emphasis added).) The $+\Delta\theta$ and $-\Delta\theta$ accumulated counts stored in registers **320** and **322** therefore represent the change in angle of a gyroscope during the predetermined time interval. For example, Smith explains that a “net” $\Delta\theta$ value, which the P1 processor can readily compute by simply subtracting the accumulated $+\Delta\theta$ count in **320** from the accumulated $-\Delta\theta$ count in **322** as discussed above, “represents change of displacement rates for each gyro at a different point in time.” (*Id.*, 15:10-13 (emphasis added); *see also id.*, 15:1-7 (“[A] simple subtraction of the count in hold register **322** from that in hold register **320** by the CPU produces a count proportional to the rate of angular displacement of the particular gyro...”); *see also id.*, 14:65-15:1 (identifying the “CPU” as P1 processor).) “Displacement” in the context of the gyro here refers to angular displacement. (*Id.*, 2:13-15 (“The signal produced by a ring laser gyro... correspond[s] to the rate of gyro angular displacement.”) (emphasis added).) Smith thus discloses “**angular increments**” under either proposed construction, as the $+\Delta\theta$ and $-\Delta\theta$ accumulated counts represent changes in angular displacement over a predetermined time interval. In

my opinion, alternatively, the claimed “**angular increments**” can be mapped to the “net” $\Delta\theta$ value determined by a subtraction involving the $+\Delta\theta$ and $-\Delta\theta$ counts, which the P1 processor CPU can determine as discussed above. (*Id.*, 14:65-15:13.) In my opinion, therefore, the claimed angular increments can be satisfied by either (1) the $+\Delta\theta$ and $-\Delta\theta$ accumulated counts, or (2) the “net” $\Delta\theta$, discussed above.

125. These angular increments are also “**digital**” because, as noted, the signals from the gyros are digital, and the accumulated counts are stored in memory (*i.e.* hold registers) accessible by the CPU. (Smith, 6:35-38 (“Inasmuch as the gyro and accelerometer-produced signals are digital in nature, the data acquisition function of the P1 processor 14 involves the accumulation and storage of the input pulses over periodic cycles.”) (emphasis added), 13:8-16.) It therefore would have been obvious to person of ordinary skill in the art that the “**angular increments**” in Smith are expressed digitally.

126. A substantially similar analysis applies to the claimed “**digital velocity increments**.” Figure 1 of Smith above shows the accelerometer triad 30, which was discussed extensively for limitation 1[b], includes “**said X axis, Y axis and Z axis accelerometers**.” Figure 1 also shows accelerometer triad 30 electronically connected to signal conditioning electronics 32, which generate a digital output signal. (Smith, 6:24-26, 10:5-17.) More specifically, “[t]he analog accelerometers

72, 74, and 76 produce analog output signals corresponding to the rate of change of velocity of each accelerometer along its sensitive axis,” which are “converted to digital signals by corresponding digitizers 82, 84, and 86.” (*Id.*, 8:48-53.) This is shown in Figure 4, which shows a more detailed view of the signal conditioning electronics for a particular accelerometer 150, which include digitizer:

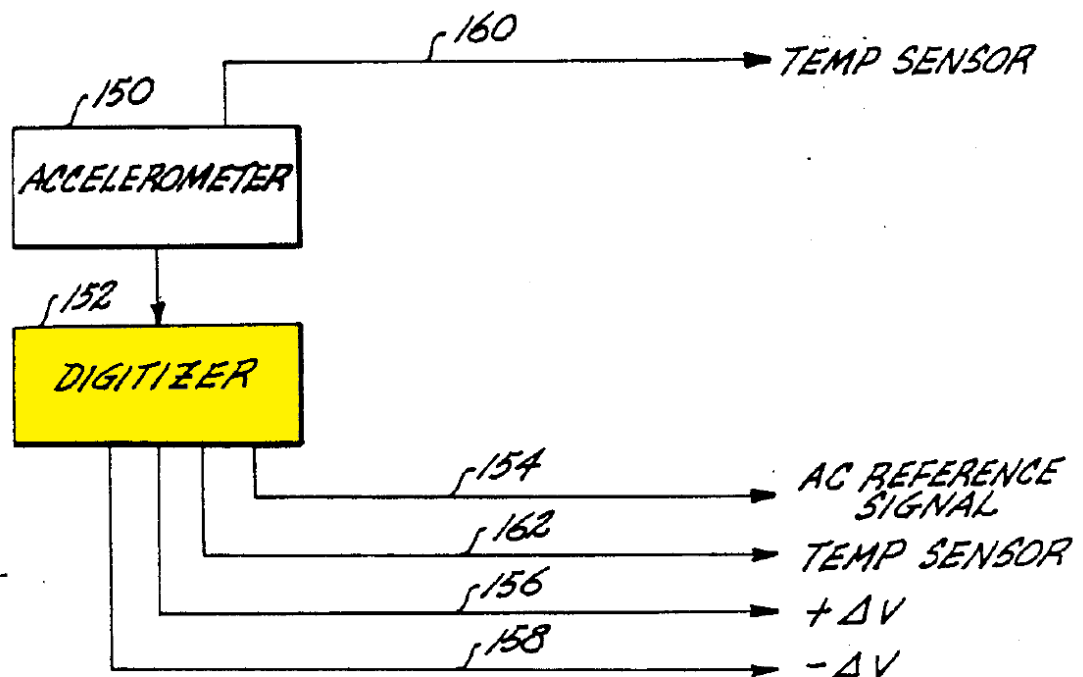


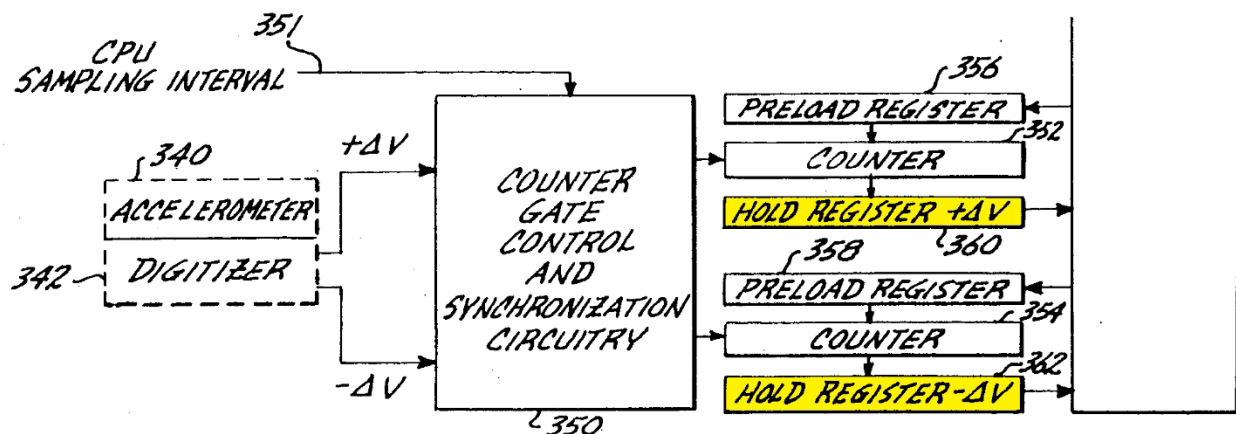
Fig. 4.

(Smith, Fig. 4 (highlighting added).)

127. Figure 4 shows an analog accelerometer 150 and digitizer 152. “The digitizer 152 processes the analog output signal from the accelerometer 50 [sic; 150], as well as an input AC reference signal on a line 154, to produce a pair of output signals +ΔV, -ΔV.” (Smith, 10:6-9 (highlighting added).) “The +ΔV signal is a

digital signal having a pulse repetition rate proportional to acceleration of the accelerometer **150** in a reference positive direction along its sensitive axis. The $-\Delta V$ signal has a pulse repetition rate proportional to acceleration of the accelerometer **150** in a reference negative direction along its sensitive axis.” (*Id.*, 10:10-15.) This process takes place for all three accelerometers, resulting in output of three sets of $+\Delta V$ and $-\Delta V$ signals for the X, Y, and Z axes, *i.e.*, $+\Delta V_x$, $-\Delta V_x$, $+\Delta V_y$, $-\Delta V_y$, $+\Delta V_z$ and $-\Delta V_z$. (*Id.*, 8:54-64, Figs. 1-2.)

128. And similar to the process for the gyroscopes discussed above, the bottom half of Figure 7 shows that these digitized $+\Delta V$ and $-\Delta V$ signals (with respect to one accelerometer) are output to P1 processor **14**, which are accumulated over a period of time to store digital $+\Delta V$ and $-\Delta V$ increment signals:



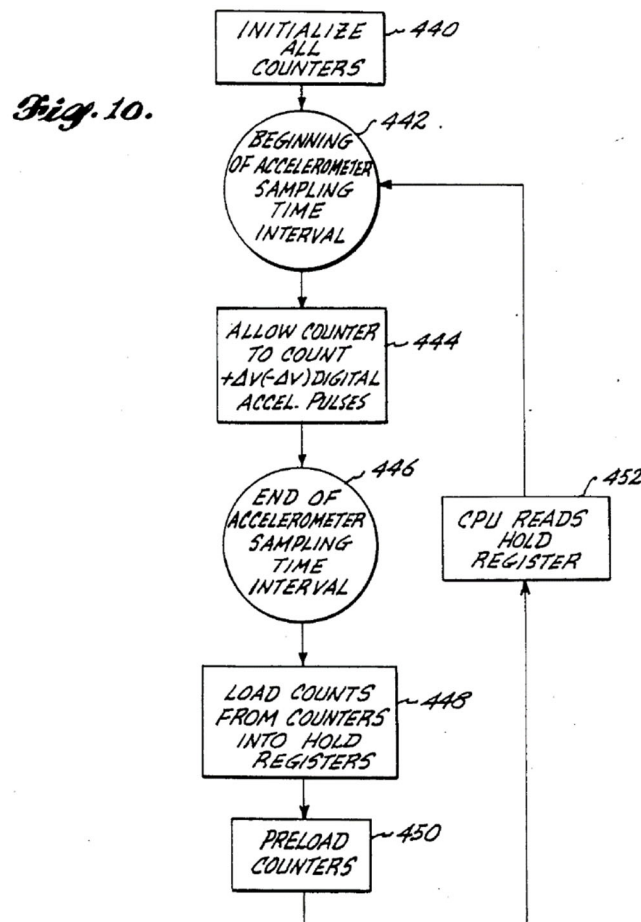
(Smith, Fig. 7 (partial figure; highlighting added).)

129. Figure 7 shows the $+\Delta V$ and $-\Delta V$ signals from the digitizer **342** for a particular accelerometer **340** (at left) output to counter gate control and

synchronization circuitry, followed by the counters, which are part of P1 processor

14. (Smith, 13:26-29, 10:36-38 (“The inputs to the P1 processor are the above-described outputs from the inertial sensor assembly.”).) The purpose of the counters is substantially the same as the counters discussed above for the gyroscopes. The $+\Delta V$ and $-\Delta V$ signals received from the digitizer 342 represent acceleration from the accelerometer at a *particular point in time*. To determine the change of velocity *over time*, the counters shown in Figure 7 receive and count the number of pulses of the $+\Delta V$ and $-\Delta V$ signals, over a period of time, and then store the accumulated counts in hold registers 360 and 362 as shown above. (*Id.*, 4:29-35 (“The P1 processor includes an accelerometer counter for accumulating the pulse count of each accelerometer-produced output signal over a period of time. Accelerometer storage is provided for storing the accumulated pulse counts for each of the accelerometer output signals over each of the predetermined periodic intervals.”), 13:27-45.) These stored signals can then be accessed by the CPU via CPU interface circuitry 330. (*Id.*, 13:43-45.)

130. Figure 10 provides a more detailed description of how the counters perform the process of accumulating $+\Delta V$ and $-\Delta V$ signals:



(Smith, Fig. 10.)

131. As Figure 10 shows, the accumulation of $+\Delta V$ and $-\Delta V$ signals takes place during beginning 442 and end 446 of a sampling time interval. (Smith, *e.g.*, 14:53-59.) During this period of time, “the counters 352, 354 [in Figure 7 above] are allowed to count the $+\Delta V$, $-\Delta V$ digital accelerometer pulses, respectively, at block 444.” (*Id.*, 14:53-56 (emphasis added).) “At the end of the accelerometer sampling time interval, at 446, the accumulated counts in the counters 352, 354 are loaded into the corresponding hold registers 360, 358 [sic; 362] at block 448.” (*Id.*,

14:56-59 (highlighting and emphasis added).)

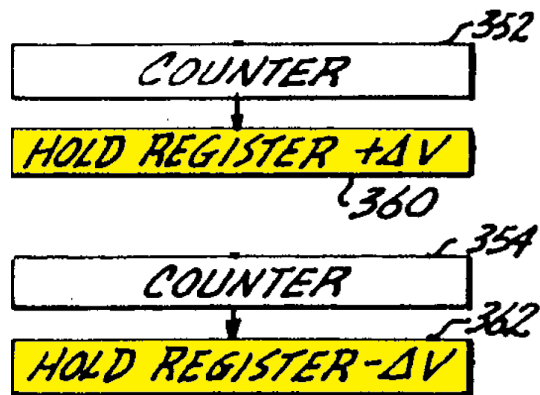
132. In other words and using simple terms, the accumulation process in Figure 10 counts the number of pulses of the $+\Delta V$ signal and the number of pulses of the $-\Delta V$ signal received over a predetermined time period (*i.e.*, sampling interval), and then stores those accumulated counts in hold registers **360** and **362**, respectively. And like the gyroscopes discussed above, the accumulation of $+\Delta V$ and $-\Delta V$ signals takes place with respect to all three accelerometers, and thus, for the X, Y, and Z axes, generates $+\Delta V$ and $-\Delta V$ accumulated counts for the X, Y, and Z axes. (Smith, *e.g.*, 10:39-54, Fig. 5 (**202** (X axis), **204** (Y axis), **206** (Z axis))).)

133. Smith thus discloses “**a velocity increment producer, which is electrically connected to ... said X axis, Y axis and Z axis accelerometers, receiving... said X axis, Y axis and Z axis acceleration electrical signals from... said acceleration producer,**” *i.e.*, the analog signals received from the three accelerometers with respect to the X, Y, and Z axes discussed above, which are “**converted into... digital velocity increments,**” *i.e.*, the accumulated $+\Delta V$ and $-\Delta V$ counts for each of the X, Y, and Z axes produced by the counters as discussed above.

134. These digital signals $+\Delta V$ and $-\Delta V$ for each of the X, Y, and Z axes qualify as “**digital velocity increments,**” as claimed. I understand that in prior

litigations involving the '648 patent, Patent Owner has argued that the phrase, “**digital velocity increments**” should take its plain and ordinary meaning or, if construed, mean “*changes in velocity expressed digitally.*” (EX1019, p. 26 (emphasis added).) I also understand that defendants in those prior litigations (not Petitioner) argued that this phrase refers to “*accumulated changes in velocity over a predetermined time interval expressed in digital form.*” (*Id.* (emphasis in original)) Smith satisfies either of these proposed constructions.

135. This is because the accumulated signals $+\Delta V$ and $-\Delta V$, for example stored in registers 360 and 362 (shown partially at right), represent changes in the velocity of the inertial measurement unit. This is clear from the ΔV notation used in Smith, with delta (Δ) being a standard symbol representing change, and V representing velocity, consistent with disclosures in Smith.



(Smith, *e.g.*, 3:13-18 (“... signals ΔV_x , ΔV_y , and ΔV_z [are] representative of the change in velocity of the inertial sensor assembly in the X, Y, and Z coordinate axes, respectively.”) (emphasis added).) Smith further explains that a net ΔV value, which a CPU can compute based on the difference between the accumulated $+\Delta V$ count in hold register 360 from and the accumulated $-\Delta V$ count in hold register 362,

“produces a resultant acceleration count ΔV .” (*Id.*, 20:67-21:2.) Smith thus discloses “**velocity increments**” under either proposed construction, as the accumulated $+\Delta V$ and $-\Delta V$ counts represent changes in velocity over a predetermined time interval. In my opinion, alternatively, the claimed “**velocity increments**” can be mapped to the net ΔV value determined by a subtraction involving the $+\Delta V$ and $-\Delta V$ counts, which the P1 processor CPU can determine as discussed above. (*Id.*, 20:65-21:2.) In my opinion, therefore, the claimed velocity increments can be satisfied by either (1) the $+\Delta V$ and $-\Delta V$ accumulated counts, or (2) the net ΔV , discussed above.

136. These velocity increments are also “**digital**” because, as noted, the signals from the accelerometer digitizers are digital and the accumulated counts are stored in memory (*i.e.* hold registers) accessible by the CPU. (*Id.*, 6:35-38 (“Inasmuch as the gyro and accelerometer-produced signals are digital in nature, the data acquisition function of the P1 processor 14 involves the accumulation and storage of the input pulses over periodic cycles.”) (emphasis added), 13:34-45.) It therefore would have been obvious to person of ordinary skill in the art that the “**velocity increments**” in Smith are expressed digitally.

137. The claimed “**angular increment and velocity increment producer**” thus corresponds to the signal conditioning electronics for the three gyroscopes and

the three accelerometers (discussed for limitation 1[a]-1[b] above), as well as the counter gate control and synchronization circuitry and counters of P1 processor 14 for the gyroscopes and accelerometers as described above. I note that my mapping of distinct electronics in Smith for producing *angular* and *velocity* increments is entirely consistent with the '648 patent, which similarly discloses an angular increment and velocity increment producer that includes (among other components) angular integrating means 620 and a separate acceleration integrating means 630. ('648, 8:29-33.) The combination of the signal conditioning electronics, counter gate control and synchronization circuitry, and the counters for the three gyroscopes and the three accelerometers thus discloses the claimed “**angular increment and velocity increment producer.**”

138. Additionally, to the extent the word “**micro**” in the preamble is limiting, as discussed extensively above, it would also have been obvious for the gyroscopes and accelerometers in Smith to have been replaced with micromechanical gyroscopes and accelerometers as explained for limitation 1[a]-[b], which were well-known in the art as discussed. Under the proposed combination, therefore, the IMU in Smith would have been adapted to receive and process signals from MEMS gyroscopes and accelerometers to produce the claimed digital angular and velocity increments. Adapting Smith to use MEMS gyroscopes and accelerometers may have

required a change to the signal conditioning electronics and the counter gate control and synchronization circuitry and the counters in Smith, depending on the type and content of the signals output by the selected micromechanical gyros and accelerometers, but this would have been regarded as a routine implementation well within the ability of a skilled artisan.

C. Ground 2: Claim 4 Is Obvious Over Ground 1 Prior Art, in Further View of Irwin and Merhav

1. Dependent Claim 4

139. For reference, claim 4 recites:

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.

('648, 24:36-44 (Claim 4).)

140. The limitations in claim 4 would have been well-known to persons of ordinary skill in the art. It is basic knowledge to a POSITA that an analog signal is a signal whose amplitude (typically measured by its voltage) represents the information the signal is intended to convey. As explained in J. David Irwin et al., *Introduction to Electrical Engineering* (1995) (EX1007), in an analog signal, “the

amplitude of the signal represents the information at every point in time.” (*Id.*, § 7.3, p. 240.) As Irwin further explains:

Almost all observable nature is analog, with continuously varying parameters such as temperature, pressure, light intensity, etc. Therefore, many systems receive as their input an analog signal representing an analog parameter. The electronic signal generally originates from a sensor or transducer which provides an analog signal proportional to the parameter it’s designed to measure. Table 7.1 provides a partial list of analog parameters that various types of electronic sensors can measure.

(Irwin, § 7.3, p. 242 (emphasis added).) Among the examples listed in Table 7.1, referenced above, include “[a]cceleration” and “[r]otation.” (*Id.*, Table 7.1, p. 241.) Although Irwin uses “amplitude” when discussing the information carried by an analog signal, it was well-known that the amplitude of an analog signal is measured in volts. (*Id.*, e.g., EX1022, pp. xviii-xix, EX1007, p. 242-243; *see also*, e.g., *id.*, p. 243 (“Assume the voltage signal from an electric guitar is 20 millivolts in amplitude....”) (emphasis added).) Irwin therefore confirms, as was known to persons of ordinary skill in the art, that an acceleration or rotation sensor provides an analog voltage signal proportional to the measured acceleration or rotation.

141. It therefore would have been obvious, based on basic principles of analog signals known to ordinarily skilled artisans, that the “**electrical signals**”

produced from the angular producer and the acceleration producer in the prior art would have included “**analog voltage signals directly proportional to,**” respectively, the angular rotation and acceleration measured by the gyroscopes and accelerometers. As Irwin confirms above, sensors generate analog electrical signals “proportional to the parameter” they are designed to measure, in this case, “[a]cceleration” and “[r]otation” (Irwin, pp. 241-242).

142. This is further supported by the disclosures in Smith. With respect to the accelerometers, Smith states that “[t]he analog accelerometers **72, 74, and 76** produce analog output signals corresponding to the rate of change of velocity of each accelerometer along its sensitive axis.” (Smith, 8:48-51 (emphasis added).) Smith further confirms, in describing the digital signals output after analog-to-digital conversion, that “[t]he $+\Delta V$ signal is a digital signal having a pulse repetition rate proportional to acceleration of the accelerometer **150** in a reference positive direction along its sensitive axis. The $-\Delta V$ signal has a pulse repetition rate proportional to acceleration of the accelerometer **150** in a reference negative direction along its sensitive axis.” (*Id.*, 10:10-15 (emphasis added).) It therefore would have been obvious that the analog signals provided by the accelerometers in Smith, which are directly used to generate the “proportional” digital ΔV signals, would also have been proportional to the measured acceleration.

143. With respect to the gyroscopes, Smith states that “[e]ach ring laser gyro produces a first output signal $+\Delta\theta_x$, $+\Delta\theta_y$, $+\Delta\theta_z$ having a pulse repetition rate proportional to the rate of angular displacement of the ring laser gyro in a reference clockwise direction and a second output signal $-\Delta\theta_x$, $-\Delta\theta_y$, $-\Delta\theta_z$ having a pulse repetition rate proportional to the rate of angular displacement of the ring laser gyro in a reference counterclockwise direction.” (Smith, 3:37-44 (emphasis added).)

144. Although Smith states the signals output by the ring laser gyroscopes are digital, this does not present a non-obvious distinction for purposes of claim 4. Merhav explains, as explained in **Part V.A.7** above, that ring laser gyroscopes generate analog signals (*e.g.* sinusoidal outputs) prior to the generation of pulse signals. Merhav explains that, in a ring laser gyroscope, angular rate is measured based on the interaction between “a pair of collocated, closed path clockwise and counterclockwise light beams.” (Merhav, § 8.0, p. 377.) “Their interaction causes interference, which manifests itself as fringes resulting from the corresponding changes of the wavelengths and oscillating frequencies. These changes are proportional to the inertial angular rate.” (*Id.*) Merhav further explains that “[t]he intrinsic readout is by counting the pulses due to the fringes,” which “constitutes a natural interface with the digital processor and computer.” (*Id.*)

145. Merhav further explains that, before these pulses are output by a ring

laser gyroscope, an analog signal, *e.g.*, a sinusoidal signal, is generated:

As the intensity fringes cross a diode, a corresponding sinusoidal signal is generated. Two diodes are required in order to determine whether Ω is clockwise or counter-clockwise. The diodes are placed at 90° with respect to each other in the coordinates of the fringe angle ζ . With this arrangement, it is possible to determine which of the two diodes precedes the other. Digital pulse conditioning and logic convert the sinusoidal outputs into a train of pulses whose frequency is directly proportional to Ω and whose accumulated count represents the angle θ .

(Merhav, p. 381 (emphasis added).) A person of ordinary skill in the art would have understood that the sinusoidal signal generated by the ring laser circuitry constitutes an analog signal. Merhav therefore confirms that it would have been obvious that a ring laser gyroscope, such as the ones used in Smith, would have generated an analog signal relating to a detected angular rate. This is further supported by the presence of photopreamps **104** and **106** in Figure 3 of Smith, which are used to amplify the signals from the photodetectors **102**, which is consistent with signals having analog behavior with small amplitudes.

146. It therefore would have been obvious for the ring laser gyroscope in Smith to have produced an analog signal. As Irwin explains, “[a]lmost all observable nature is analog,” such that an “electronic signal generally originates from a sensor or transducer which provides an analog signal proportional to the

parameter,” which as Irwin notes, includes the “[r]otation” parameter. (Irwin, § 7.3, pp. 241-42 (emphasis added).) Additionally, gyroscopes that generate analog output were common; for example Tingleff discussed for **Ground 3** uses gyroscopes that produce analog signals and require other components to perform analog-to-digital conversion. The decision between a gyroscope that outputs a digital or analog signal would have been nothing more than a routine implementation detail to a skilled artisan.

147. ***Rationale and Motivation to Combine (Ground 1 Prior Art with Irwin and Merhav):*** It would have been obvious based on the disclosures of Irwin and Merhav for the gyroscope in Smith to have produced an analog signal as claimed. It therefore would have been obvious that, for purposes of claim 4, the “**angular rate electrical signals**” produced by the angular producer in Smith would have included analog signals generated by the gyroscopes, which would have been proportional to the measured rotation. The conversion of these analog signals into digital would have been performed, under the proposed combination, as part of the function of the angular increment producer of limitation 1 [c] above, for example, using digital pulse conditioning logic described in Merhav. (Merhav, p. 381.) Irwin and Merhav are analogous references in the field of the ’648 patent of sensor technology for detecting movement such as acceleration and rotation, and would have been reasonably

pertinent to problems facing the inventors including understanding the operation of movement sensors and the nature of the signals they output.

148. With respect to **both** the accelerometers and gyroscopes, an ordinarily skilled artisan would have been motivated to implement Smith in order to provide analog voltage signals that are “**directly proportional**” to the measured acceleration and rotation. I note that adverb “**directly**” in the claim language does not impose a requirement not already disclosed by the “proportional” signals discussed above. This is because the word “proportional” as used in Irwin and Smith describes a linear relationship in which the voltage signal varies based on a constant ratio to the measured acceleration or angular rate. (See *IEEE Standard Dictionary of Electrical and Electronics Terms* (1996) (EX1012), pp. 830 (“**proportionally** See: linearity.”), 584 (“**linearity (1) (analog computer)** A property of a component describing a constant ratio of incremental cause and effect. *Proportionality* is a special case of linearity in which the straight line passes through the origin.”) (emphasis in original).) It thus would have been obvious to provide analog voltage signals that are directly proportional to the measured acceleration and angular rate, in order to provide more accurate information. Because the signals from the accelerometers and gyroscopes are foundational to the angular and velocity increments in Smith (discussed for claim limitation 1[c]), a skilled artisan would have been motivated to

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,671,648 B2

provide signals that were directly proportional to the measured acceleration and angular rate. In fact, conversely if the analog voltage signals were not directly proportional to the measured acceleration and angular rate, the system would likely have generated less accurate (and thus less useful) values in response to movement of the inertial measurement unit.

149. I note that claim 4 ends with “**said vehicle**,” which has no antecedent basis in claim 4 or claim 1 from which it depends. I understand that in pending litigation involving the ’648 patent, Patent Owner has taken the position that “said vehicle” in claim 4 refers to “*said carrier*”. I understand that in prior litigation involving the ’648 patent, Patent Owner took the position that “said vehicle” in claim 4 refers to “*a carrier: a means of carrying or transporting something.*” (**EX1018**, p. 7; **EX1020**, p. 7 (emphasis added).) I also understand that Petitioner has proposed “*a device or structure for transporting persons or things.*”

150. Smith discloses either construction because the inertial measurement unit is mounted to the device or vehicle with which it is associated. With respect to Patent Owner’s current and prior construction, Smith’s IMU measures the acceleration and angular rate of an aircraft that is carrying it. (Smith, 7:39-41, 22:19-23, 22:35-39.) Further, Smith also satisfies Petitioner’s proposed construction because an aircraft is plainly “a device or structure for transporting persons or

things” (e.g., the aircraft’s pilot or passengers, the aircraft’s cargo, etc.).

D. Ground 3: Claims 1 and 4 Are Obvious Over Tingleff in View of Chan and Bernstein

1. Independent Claim 1

151. For reference, claim 1 recites:

1. A micro inertial measurement unit, comprising:
 - [a] 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;
 - [b] 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
 - [c] 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 digital angular increments and digital velocity increments respectively.

(’648, 23:43-24:21 (Claim 1; bracketed notations (*e.g.*, [a]) added).)

**(a) “A micro inertial measurement unit, comprising:”
(Claim 1[p])**

152. The preamble of claim 1 recites “[a] **micro inertial measurement unit.**” As I explained for **Ground 1**, the preamble of claim 1 is not limiting, but even if it was, it is rendered obvious by the prior art.

153. Tingleff discloses an “**inertial measurement unit.**” Tingleff discloses “inertial guidance unit **11**,” shown in the annotated version of Tingleff’s Figure 1 below.

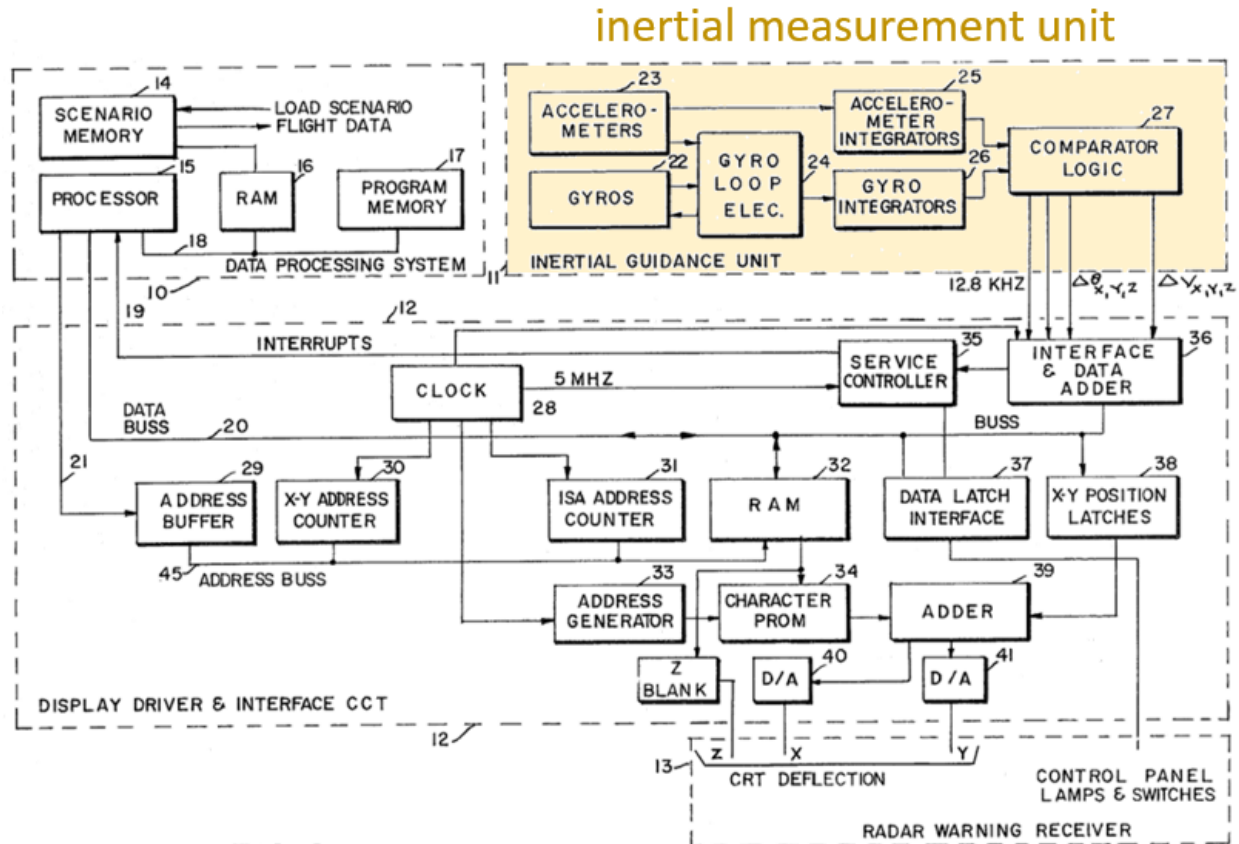


FIG. 1.

(Tingleff, Fig. 1, 6:2-5 (highlighting and annotations added).)

154. Inertial guidance unit **11** (in yellow) contains “three sets of gyros **22** and accelerometers **23** that sense angular rates and acceleration about the X, Y and Z Cartesian coordinates.” (Tingleff, 6:67-7:2; 4:24-26 (“The inertial navigation system indicates the position of the aircraft with respect to the earth to the processor.”).) In other words, Tingleff discloses an inertial unit that “sense[s]” (*i.e.*, measures) angular rate and acceleration. Accordingly, Tingleff discloses an “**inertial measurement unit.**”

155. The '648 specification supports that the inertial guidance unit **11** in

Tingleff is an “**inertial measurement unit.**” The ’648 patent discloses that “[i]n 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.” (’648, 1:20-24; *see also* 1:24-28 (“three orthogonally mounted inertial angular rate producers and three orthogonally mounted acceleration producers with additional supporting mechanical structure and electronic devices are conventionally called an Inertial Measurement Unit (IMU)”)). Further, the ’648 specification discloses that “an inertial measurement unit (IMU) is employed to determine the motion of a carrier.” (*Id.*, 1:18-19.) The inertial guidance unit **11** in Tingleff contains three gyros and three accelerometers that determine the motion of a carrier (*e.g.*, an aircraft). A POSITA would have understood these sensors to be “orthogonally mounted,” since Tingleff discloses that they measure “angular rates and acceleration about the X, Y and Z Cartesian coordinates.” (Tingleff, 6:67-7:2.) Accordingly, the disclosures of Tingleff are consistent with the disclosure of an “**inertial measurement unit**” provided by the ’648 patent specification.

156. As explained for **Ground 1**, it would have been obvious based on Tingleff in light of Chan and Bernstein to use a “**micro**” inertial measurement unit, to the extent the preamble is found to be limiting. My analysis from **Ground 1**

applies with full force here. Under the proposed combination, a person of ordinary skill in the art would have been motivated to combine Tingleff with Chan and Bernstein to incorporate micromechanical accelerometers and gyros into Tingleff's IMU. Tingleff itself discloses that its simulation system is "relatively small and self-contained." (Tingleff, 3:11-13.) Additionally, "[t]he preprogrammed RWR simulator is quickly and easily exchanged for the plug-in processor module of the RWR equipment within the aircraft." (*Id.*, 3:19-21.) Accordingly, a skilled artisan would have been motivated based on Tingleff to use components, including sensors, that are as small as possible—since Tingleff clearly teaches that devices with a small size are advantageous in the context of its system. This motivation is further supported by Chan, which explains that "[e]xamples of applications for microsensors for acceleration or accelerometers include... in-flight aircraft monitoring systems for aircraft," which Chan identifies as an example of application that requires "small, inexpensive, and reliable acceleration devices." (Chan, 1:33-38 (emphasis added).) All of the motivations that I provided for **Ground 1**, including the reduced size, reduced weight, reduced power consumption, and reduced cost, apply here.

157. Further, the motivation behind Tingleff's invention was to provide an inflight aircraft training simulator to overcome the disadvantages of ground-based

aircraft training simulators. (Tingleff, 1:9-24.) Furthermore, Tingleff's invention is contemplated to be used in a "military combat aircraft," an instrument generally manufactured just big enough for one or two people. (*Id.*, 1:52, 2:58.) The application context of inflight training would have motivated a POSITA to implement Tingleff's simulator system with as small of a form factor as possible. A skilled artisan would have recognized that weight and size are of paramount importance in the design of a system intended to be used on an airborne aircraft. Accordingly, a skilled artisan would have been motivated to use MEMS sensors in the interest of keeping Tingleff's simulator system as light and small as possible.

(b) **"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;"**
(Claim 1[a])

158. Tingleff discloses an **"angular rate producer"** comprising three **"angular rate detecting unit[s],"** which each produces an **"angular rate electrical signal"** for the **"X axis," "Y axis,"** and **"Z axis,"** respectively. The **"gyros 22"** block in Tingleff's Figure 1 contains "three sets of gyros . . . that sense angular rates . . . about the X, Y and Z Cartesian coordinates." (Tingleff, 6:67-7:2.) These three sets of gyros—corresponding to the X, Y, and Z axis—are shown in the below annotated

version of Tingleff's Figure 1:

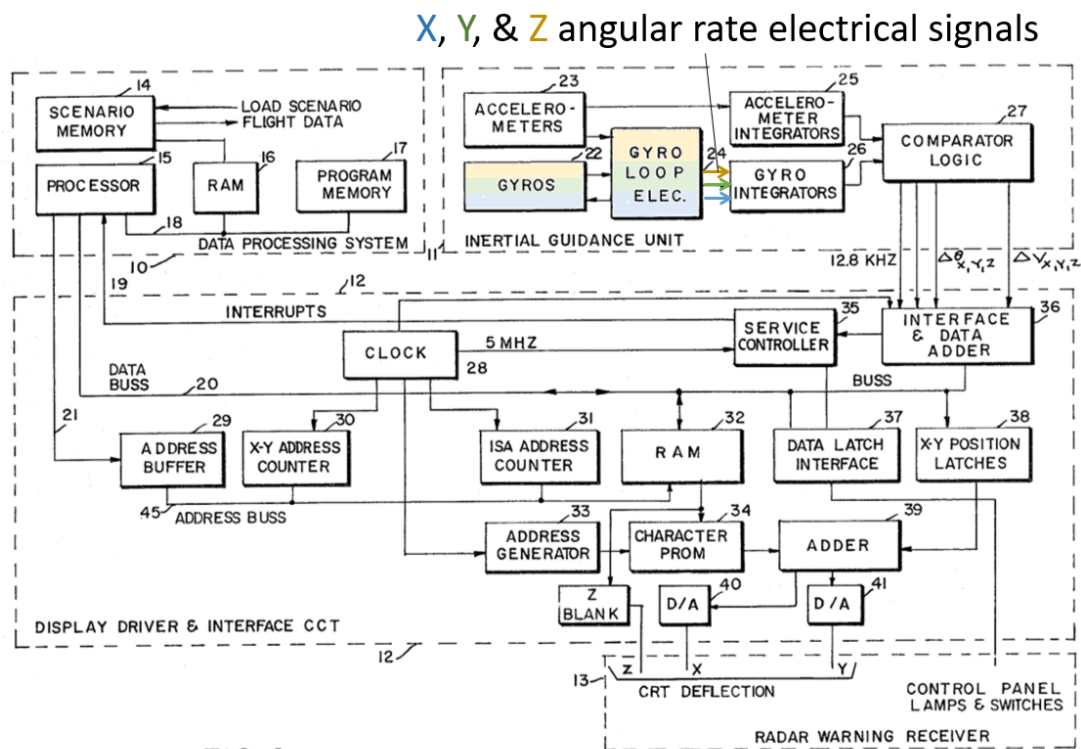


FIG. 1.

(Tingleff, Fig. 1 (annotations and highlighting added). “As motion of the aircraft is sensed by the inertial guidance unit 11, the error signal from gyros 22 and accelerometers 23” are output to gyro loop electronics 24. (*Id.*, 7:2-5.) Using these error signals, the gyro-loop electronics 24 “attempts to hold the accelerometer pendulum and gyro gimbal nulled.” (*Id.*, 7:5-7.) “These signals are also used as the analog rate signals within unit 11.” (*Id.*, 7:7-8.) Gyro loop electronics 24 then outputs the analog signals to the gyro integrators 26 that converts the angular rate electrical signal to digital pulse trains. (*Id.*, 7:8-11.) Each of the three sets of gyros

and associated circuitry in the gyro loop electronics **24** constitutes an “**angular rate detecting unit**” that produces an analog electrical signal indicating X, Y, and Z-axis angular rate, respectively.

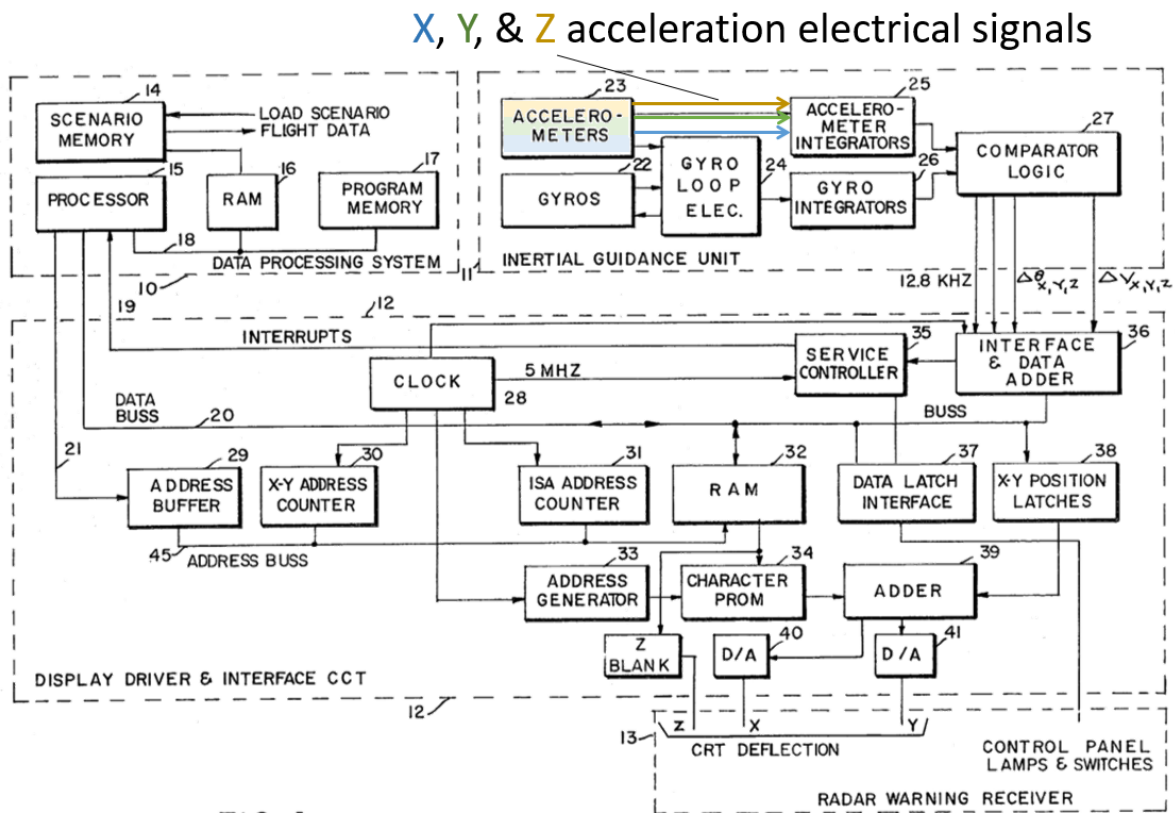
159. A POSITA would have understood an “angular rate *error signal*” to be a signal output due to the angular rotation of the moving object. The term “error signal” in this context refers to a signal that represents the difference between a sensing signal and a constant or reference. (*See IEEE Standard Dictionary of Electrical and Electronics Terms* (1996) (**EX1012**), p. 371 (“**error signal (1)**... In a control system the error signal is the difference between a sensing signal and a constant reference signal.”) (emphasis in original).) In the context of Tingleff, therefore, the “angular rate error signal” represents the difference between the current position of a gyro gimbal and its original (null) position.

160. A skilled artisan would therefore have understood that Tingleff’s “angular rate error signal” as a signal resulting from rotation that causes a displacement in a gyro gimbal, which is fed back to the gyro **22** to hold the gimbal at its original (null) position. Tingleff accordingly discloses that the error signals entering the gyro-loop electronic **24** “are also used as the analog rate signals within unit **11**.” (Tingleff, 7:7-8.) For the gyro, the analog rate signal represents the angular rate signal.

161. Moreover, to the extent the word “**micro**” in the preamble is limiting, as I fully explained for the preamble and in connection with **Ground 1**, it would also have been obvious for the gyros in Tingleff to have been replaced with micromechanical gyroscopes which were well-known in the art, each of which would have produced an angular rate electrical signal. I provided a full explanation of the rationale and motivation to provide MEMS-based gyroscopes in the discussion of the preamble above and for **Ground 1**.

- (c) “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**” (Claim 1[b])

162. Tingleff discloses an “**acceleration producer**” comprising three “**accelerometer[s]**,” which each produces an “**acceleration electrical signal**” for the “**X axis**,” “**Y axis**,” and “**Z axis**,” respectively. The “**accelerometers 23**” block in Tingleff’s Figure 1 contains “three sets of . . . accelerometers . . . that sense . . . acceleration about the X, Y and Z Cartesian coordinates.” (Tingleff, 6:67-7:2.) These three sets of accelerometers—corresponding to the X, Y, and Z axis—are shown in the below annotated version of Tingleff’s Figure 1:



(*Id.*, Fig. 1 (annotations and highlighting added). “As motion of the aircraft is sensed by the inertial guidance unit 11, the error signal from gyros 22 and accelerometers 23” are output to gyro loop electronics 24. (*Id.*, 7:2-5 (emphasis added).) Using these error signals, the gyro-loop electronics 24 “attempts to hold the *accelerometer pendulum* and gyro gimbal *nulled*.” (*Id.*, 7:5-7 (emphasis added).) “These signals are also used as the analog rate signals within unit 11.” (*Id.*, 7:7-8.) Accelerometers 23 then output the analog signals to the accelerometer integrator 25 that converts the acceleration electrical signal to digital pulse trains. (*Id.*, 7:8-11.)

163. A POSITA would have understood that an “acceleration error signal”

is caused by the acceleration of the moving object. As noted, “error signal” in this context refers to a signal that represents the difference between a sensing signal and a constant or reference. (*See IEEE Standard Dictionary of Electrical and Electronics Terms* (1996) (**EX1012**), p. 371 (“**error signal (1)**... In a control system the error signal is the difference between a sensing signal and a constant reference signal.”) (emphasis in original).) In the context of Tingleff, therefore, the “acceleration error signal” represents the difference between the current position of the accelerometer pendulum and its original (null) position. A skilled artisan would therefore have understood that Tingleff’s “acceleration error signal” as a signal resulting from an acceleration that causes a displacement in the accelerometer pendulum, which is processed by the gyro loop electronics **24** to hold the pendulum to its original (null) position. A POSITA would have understood that each accelerometer produces an analog electrical signal indicating X, Y, and Z-axis acceleration, respectively.

164. Moreover, to the extent the word “**micro**” in the preamble is limiting, as I fully explained for the preamble and in connection with **Ground 1**, it would also have been obvious for the accelerometers in Tingleff to have been replaced with micromechanical accelerometers which were well-known in the art, each of which would have produced an acceleration electrical signal. I provided a full explanation

of the rationale and motivation to provide MEMS-based accelerometers in the discussion of the preamble.

165. Accordingly, it is my opinion that Tingleff teaches claim 1 [b].

- (d) **“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 digital angular increments and digital velocity increments respectively.” (Claim 1[c])**

166. Tingleff discloses an **angular increment and velocity increment producer**, as shown in the annotated version of Tingleff’s Figure 1 circuit below:

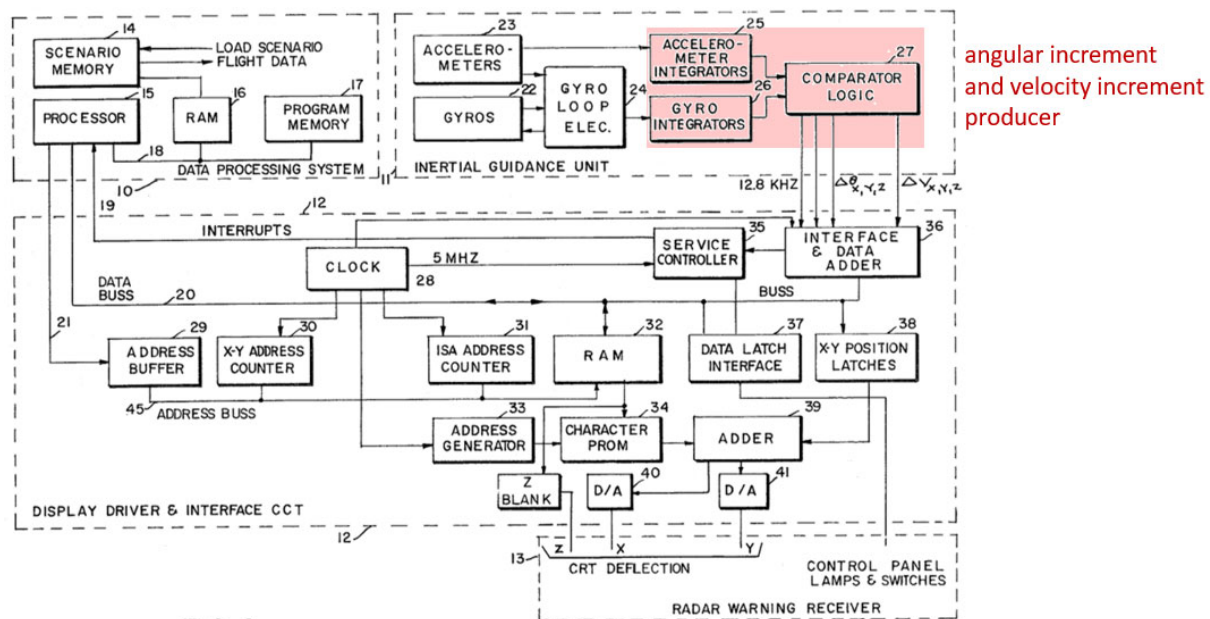


FIG. 1.

(Tingleff, Fig. 1 (highlighting and annotations added).)

167. The identified angular increment and velocity increment producer circuitry in Tingleff 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.**” As discussed above for claim limitations 1[a] and 1[b], blocks 22-24 in Figure 1 comprise said X axis, Y axis and Z axis angular rate detecting units and said X axis, Y axis and Z axis accelerometers. The block diagram in Figure 1 shows that blocks 22-24 are electrically connected to blocks 25-27—*i.e.*, the angular increment and velocity increment producer. (See also Tingleff, 7:8-11.)

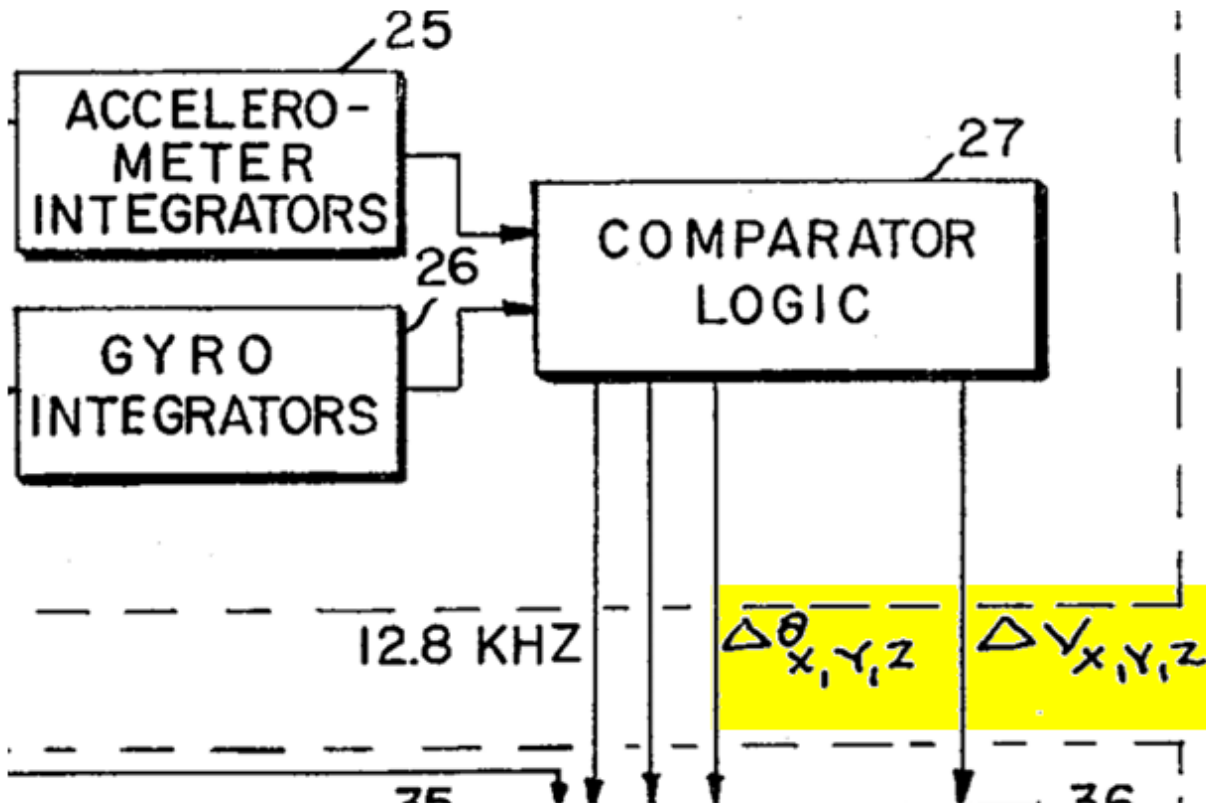
168. Tingleff discloses that the identified angular increment and velocity increment producer circuitry “**receiv[es] said X axis, Y axis and Z axis angular**

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.” Tingleff discloses that analog signals are “input” to “[a]ccelerometer integrator **25** and gyro integrator **26**” from “units **23** and **24**.” (Tingleff, 7:8-11.)

169. Tingleff further teaches that “**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 digital angular increments and digital velocity increments respectively.**” Tingleff discloses that “[a]ccelerometer integrator **25** and gyro integrator **26** convert the respective analog signals input thereto from units **23** and **24** into digital pulse trains that are input to comparator logic **27**.” (Tingleff, 7:8-11.) Tingleff further discloses that following the addition of a reference signal by comparator logic circuit **27**, the outputted pulse trains “represent the **incremental changes in attitude** $\delta\theta_{X, Y, Z}$ and **incremental changes in velocity** $\delta V_{X, Y, Z}$ experienced by the inertial guidance platform.”³ (*Id.*, 7:15-18 (emphasis added).) Figure 1 of Tingleff confirms that the digital outputs of comparator logic circuit **27** are digital angular increments and digital velocity increments, labeling the signals

³ A POSITA would have understood “angular increments,” “incremental changes in attitude,” “ $\delta\theta_{X, Y, Z}$,” and “ $\Delta\theta_{X, Y, Z}$ ” to be synonymous—in each case, referring to increments to three-dimensional orientation (pitch, yaw, and/or roll).

as shown in the zoomed-in subpart of Figure 1 below:



(*Id.*, Fig. 1 (subpart; highlighting added).) It is my opinion that the pulse trains output by comparator logic circuit 27 are **digital angular increments and digital velocity increments**.

170. As I explained for **Ground 1**, I understand that in prior litigation involving the '648 patent, Patent Owner has argued that the phrase, “**digital angular increments**” should take its plain and ordinary meaning or, if construed, mean “*changes in angle expressed digitally.*” (**EX1019**, p. 26 (emphasis added).) Tingleff

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,671,648 B2

discloses this limitation under this construction because Tingleff discloses “incremental **changes** in attitude $\delta\theta_{x,y,z}$ and incremental **changes** in velocity $\delta V_{x,y,z}$ experienced by the inertial guidance platform.” (*Id.*, 7:15-18 (emphasis added).) These changes, as noted, are expressed digitally.

171. As also explained for **Ground 1**, I understand that defendants in prior litigations involving the '648 patent (not Petitioner) argued that this phrase refers to “*accumulated changes in angle over a predetermined time interval expressed in digital form.*” (**EX1019**, p. 26 (emphasis in original).) It would have been obvious that Tingleff also satisfies this construction because determining the incremental change in rotation and velocity would have required a sampling of signals from the accelerometers and gyroscopes over a period of time. Indeed, Tingleff states that comparator logic **27** relies on a 12.8 KHz signal, among other things, “to provide an accurate time base for the data sampling interval.” (Tingleff, 7:13-15.)

172. Additionally, to the extent the word “**micro**” in the preamble is limiting, as discussed extensively above, it would also have been obvious for the gyroscopes and accelerometers in Tingleff to have been substituted with micromechanical gyroscopes and accelerometers as explained for limitation 1**[a]**-**[b]**, which were well-known in the art as discussed. Under the proposed combination, therefore, the IMU in Tingleff would have been adapted to receive and process signals from

MEMS gyroscopes and accelerometers to produce the claimed digital angular and velocity increments. Adapting Tingleff to use MEMS gyroscopes and accelerometers may have required a change to the integrator and comparator in Tingleff, depending on the type and content of the signals output by the selected micromechanical gyros and accelerometers, but this would have been regarded as a routine implementation well within the ability of a skilled artisan.

2. Dependent Claim 4

173. For reference, claim 4 recites:

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.

('648, 24:36-44 (Claim 4).)

174. As fully explained for **Ground 2**, claim 4 would have been obvious based on Tingleff and the knowledge of a person of ordinary skill in the art. In my opinion, claim 4 does not recite anything beyond and well-known characteristics of analog signals, as I fully explained above.

175. Tingleff discloses that the **angular rate electrical signals** and **acceleration electrical signals** in the Figure 1 circuit are **analog** signals. (See

Tingleff, 7:3-8 (“[T]he error signals from gyros **22** and accelerometers **23**... are also used as the **analog** rate signals within unit **11**.”) (emphasis added); Tingleff, 7:8-11 (“Accelerometer integrator **25** and gyro integrator **26** convert the respective **analog** signals input thereto from units **23** and **24** into digital pulse trains that are input to comparator logic **27**.”) (emphasis added).)

176. Tingleff does not explicitly disclose that the angular rate electrical signals and acceleration electrical signals are “**voltage signals**,” or that they are “**directly proportional**” to the angular rate or acceleration they measure. But these are basic concepts of analog signals that would have been well-known to persons of ordinary skill in the art. It is elementary knowledge that an analog signal is a signal whose amplitude (typically measured by its voltage) represents the information the signal is intended to convey. As explained in J. David Irwin et al., *Introduction to Electrical Engineering* (1995) (**EX1007**), in an analog signal, “the amplitude of the signal represents the information at every point in time.” (*Id.*, § 7.3, p. 240.) As Irwin further explains:

Almost all observable nature is analog, with continuously varying parameters such as temperature, pressure, light intensity, etc. Therefore, many systems receive as their input an analog signal representing an analog parameter. The electronic signal generally originates from a sensor or transducer which provides an analog signal

proportional to the parameter it's designed to measure. Table 7.1 provides a partial list of analog parameters that various types of electronic sensors can measure.

(Irwin, § 7.3, p. 242 (emphasis added).) Among the examples listed in Table 7.1, referenced above, include “[a]cceleration” and “[r]otation.” (*Id.*, Table 7.1, p. 241.) Although Irwin uses “amplitude” when discussing the information carried by an analog signal, it was well-known that the amplitude of an analog signal is typically measured in volts. (*Id.*, e.g., EX1022, pp. xviii-xix; EX1007, pp. 242-243; *see also*, e.g., *id.*, p. 243 (“Assume the voltage signal from an electric guitar is 20 millivolts in amplitude....”) (emphasis added).) Irwin therefore confirms, as was known to persons of ordinary skill in the art, that an acceleration or rotation sensor provides an analog voltage signal proportional to the measured acceleration or rotation.

177. It therefore would have been obvious, based on basic principles of analog signals known to ordinarily skilled artisans, that the “**electrical signals**” produced from the angular rate producer and the acceleration producer in Tingleff would have included “**analog voltage signals directly proportional to,**” respectively, the angular rate and acceleration measured by the gyroscopes and accelerometers. As Irwin confirms above, sensors generate analog electrical signals “proportional to the parameter” they are designed to measure, in this case, “[a]cceleration” and “[r]otation” (Irwin, pp. 241-242.)

178. For the same reasons I provided for claim 4 in **Ground 2**, an ordinarily skilled artisan would have been motivated to implement Tingleff to provide analog voltage signals that are “**directly proportional**” to the measured acceleration and angular rate. As noted, the adverb “**directly**” does not impose a requirement not already disclosed by the “proportional” signals discussed above. This is because the word “proportional” as used in Irwin describes a linear relationship in which the voltage signal varies based on a constant ratio to the measured acceleration or rotation. (See *IEEE Standard Dictionary of Electrical and Electronics Terms* (1996) (EX1012), pp. 830 (“**proportionally** See: linearity.”), 584 (“**linearity** (1) (**analog computer**) A property of a component describing a constant ratio of incremental cause and effect. *Proportionality* is a special case of linearity in which the straight line passes through the origin.”) (emphasis in original).) It thus would have been obvious to provide analog voltage signals that are directly proportional to the measured acceleration and angular rate, in order to provide more accurate information. Because the signals from the accelerometers and gyroscopes are foundational to the angular and velocity increments in Tingleff (discussed for claim limitation 1[c]), a skilled artisan would have been motivated to provide signals that were directly proportional to the measured acceleration and rotation. In fact, conversely if the analog voltage signals were not directly proportional, the system

would likely have generated less accurate (and thus less useful) values in response to movement of the inertial measurement unit.

179. I note that claim 4 ends with “**said vehicle**,” which has no antecedent basis in claim 4 or claim 1 from which it depends. I understand that in pending litigation involving the ’648 patent, Patent Owner has taken the position that “said vehicle” in claim 4 refers to “*said carrier*”. I understand that in prior litigation involving the ’648 patent, Patent Owner took the position that “said vehicle” in claim 4 refers to “*a carrier: a means of carrying or transporting something.*” (EX1018, p. 7; EX1020, p. 7 (emphasis added).) I also understand that Petitioner has proposed “*a device or structure for transporting persons or things.*” (*Id.* (emphasis added))

180. Tingleff discloses either construction because the inertial measurement unit is mounted to the device or vehicle with which it is associated. With respect to Patent Owner’s construction, Tingleff’s IMU measures the acceleration and angular rate of an aircraft that is carrying it. (Tingleff, 7:2-5.) Further, Tingleff also satisfied Petitioner’s proposed construction because an aircraft is plainly “a device or structure for transporting persons or things” (*e.g.*, the aircraft’s pilot or passengers, the aircraft’s cargo, etc.).

E. Ground 4: Claims 1 and 4 Are Obvious Over Yamawaki in View of Chan, Bernstein and Saubolle

1. Independent Claim 1

181. For reference, claim 1 recites:

1. A micro inertial measurement unit, comprising:
 - [a] 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;
 - [b] 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
 - [c] 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 digital angular increments and digital velocity

increments respectively.

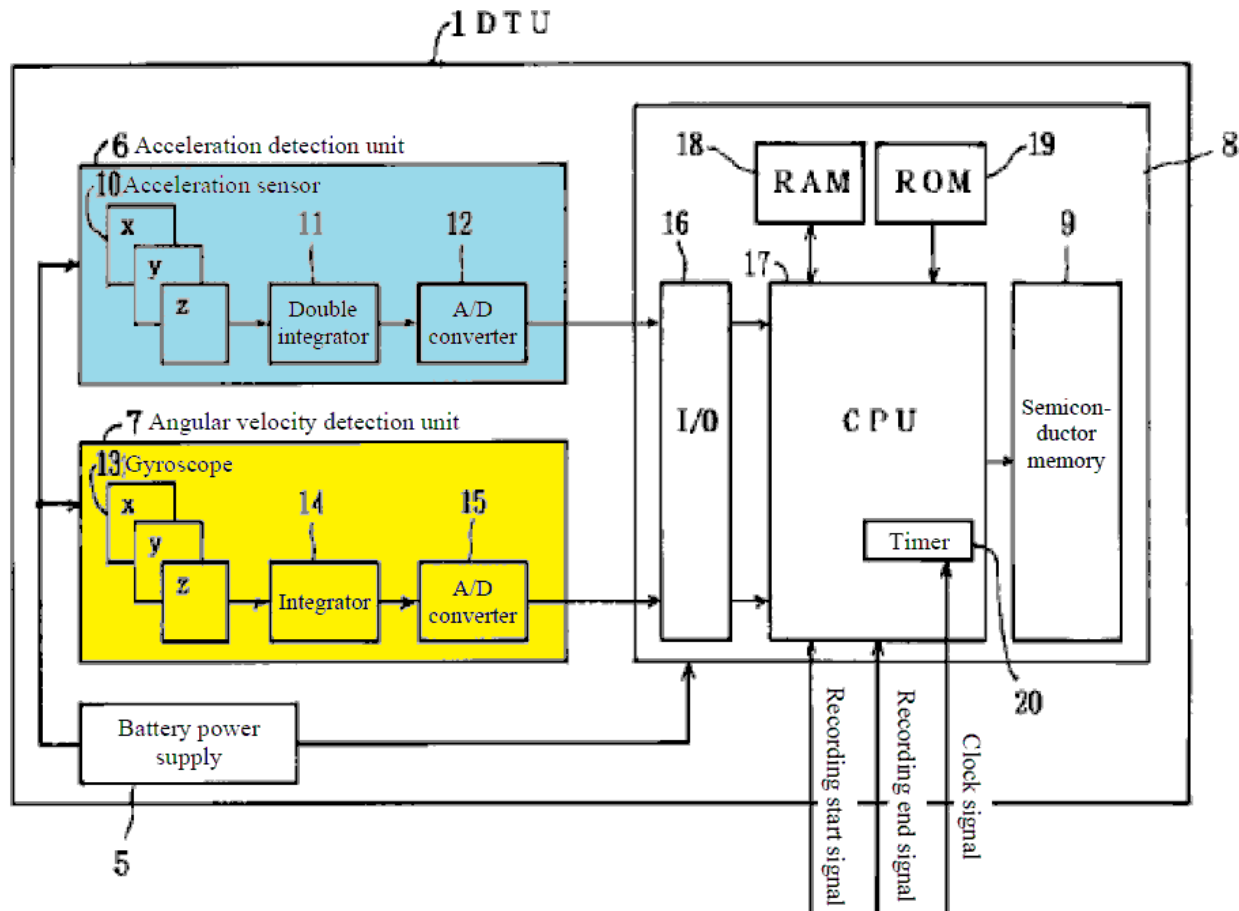
(’648, 23:43-24:21 (Claim 1; bracketed notations (*e.g.*, [a]) added).)

**(a) “A micro inertial measurement unit, comprising:”
(Claim 1[p])**

182. The preamble of claim 1 recites “[a] **micro inertial measurement unit.**” As I explained for **Ground 1**, the preamble of claim 1 is not limiting, but even if it was, it is rendered obvious by the prior art.

183. Yamawaki discloses an “**inertial measurement unit,**” which is shown in Figure 1 below:

[FIGURE 1]



(Yamawaki, Fig. 1 (partial figure; highlighting added).) The claimed “**inertial measurement unit**” in Yamawaki includes the **acceleration detection unit 6** and **angular velocity detection unit 7**.

184. With respect to **angular velocity detection unit 7**, it includes a 3D gyroscope 13 that “comprises a gyro sensor and detects the rotational velocity of the diver during underwater movement.” (Yamawaki, ¶[0016].) Angular velocity detection unit 7 also includes an integrator 14 and an analog-to-digital (A/D)

converter 15. (*Id.*) Yamawaki explains that “[o]utput from the gyroscope 13 is obtained for rotation relative to the previous position, subjected to A/D conversion at a fixed sampling period, and imported into the CPU as a digital value to calculate the change in the diver’s movement direction.” (*Id.*, ¶[0029].)

185. Moving to **acceleration detection unit** 6, it contains a “3D acceleration sensor 10 which comprises a gyro sensor and detects acceleration during underwater movement of the diver as a moving body.” (Yamawaki, ¶[0016].) Acceleration detection unit 6 also includes a double integrator 11 and an analog-to-digital (A/D) converter 12. (*Id.*) Yamawaki further explains that “[o]utput from the acceleration sensor 10 is obtained of changes in movement speed or acceleration in the movement direction relative to the immediately preceding position and is then passed through the double integrator 11, subjected to A/D conversion by the A/D converter 12, acquired at a fixed sampling period, and recorded in the memory with the relative time from the starting point added.” (*Id.*, ¶[0023].) “This data indicates the distance moved from the position at the previous unit of time.” (*Id.*)

186. Yamawaki therefore discloses an inertial unit that measures angular rate and acceleration, and thus, discloses an “**inertial measurement unit.**” This is supported by the ’648 specification. As explained previously, the ’648 patent discloses that “[i]n 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.” (’648, 1:20-24; *see also* 1:24-29 (“three orthogonally mounted inertial angular rate producers and three orthogonally mounted acceleration producers with additional supporting mechanical structure and electronic devices are conventionally called an Inertial Measurement Unit (IMU)”)).) Further, the ’648 specification discloses that “an inertial measurement unit (IMU) is employed to determine the motion of a carrier.” (*Id.*, 1:18-19.) Similarly, the inertial guidance unit in Yamawaki contains three gyros and three acceleration detectors that determine the motion of a carrier (*e.g.*, an underwater body). A POSITA would have understood these sensors to be “orthogonally mounted,” since Yamawaki discloses that they measure angular rates and acceleration about the X, Y and Z axes. (Yamawaki, Fig. 4.) Accordingly, the disclosures of Yamawaki are consistent with the disclosure of an “**inertial measurement unit**” provided by the ’648 patent specification.

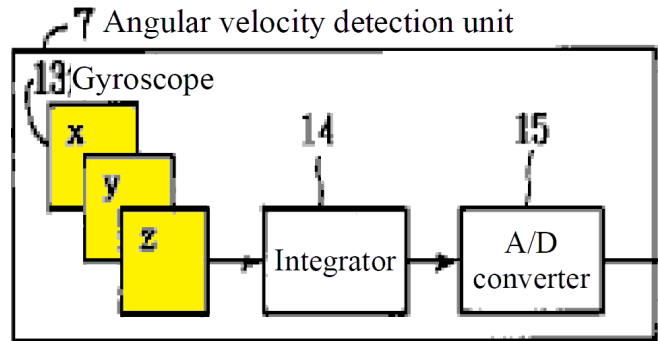
187. As explained for **Ground 1**, it would have been obvious based on Yamawaki in light of Chan and Bernstein to use a “**micro**” inertial measurement unit, to the extent the preamble is found to be limiting. My analysis from **Ground 1** applies with full force here. Under the proposed combination, a person of ordinary

skill in the art would have been motivated to combine Yamawaki with Chan and Bernstein to incorporate micromechanical accelerometers and gyros into Yamawaki's IMU. Yamawaki itself discloses that its mobile data collection device is "portable" and "inexpensive," with components "compactly accommodated in the device body[.]" (Yamawaki, ¶¶[0005], [0014].) Accordingly, in light of the small form factor of the mobile data collection device in Yamawaki, a skilled artisan would have been motivated to use components, including sensors, that are as small as possible. All of the motivations that I provided for **Ground 1**, including the reduced size, reduced weight, reduced power consumption, and reduced cost, apply here. Accordingly, a skilled artisan would have been motivated to use MEMS sensors in the interest of keeping Yamawaki's mobile data collection device as light, small and energy-efficient as possible.

- (b) **"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;"**
(Claim 1[a])

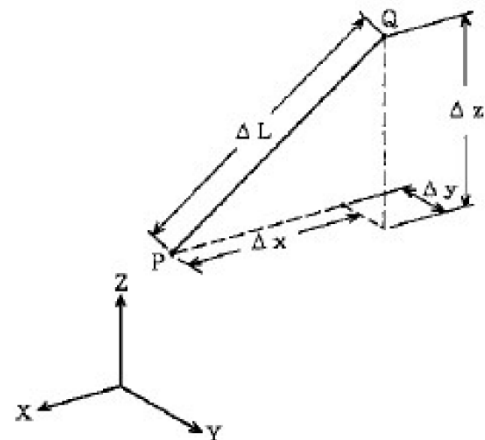
188. The claimed **"angular rate producer"** in Yamawaki comprises **3D**

gyroscope 13 of the angular velocity detection unit 7 of Figure 1 (shown at right, partial figure). 3D gyroscope 13, according to Yamawaki, “detects the rotational velocity of the diver during underwater movement.” (Yamawaki, ¶[0016].)



189. It would have been obvious to a skilled artisan that 3D gyroscope 13 in Yamawaki comprises “X axis,” “Y axis,” and “Z axis,” angular rate detecting units producing, respectively, an X, Y, and Z axis “angular rate electrical signals.” The claimed signals are shown in Figure 1 showing output from 3D gyroscope 13 to integrator 14. (Yamawaki, ¶[0029] (“Output from the gyroscope 13 is obtained for rotation relative to the previous position...”).) As shown in Figure 1, 3D gyroscope 13 is expressly shown as providing information

for X, Y, and Z axes – consistent with Yamawaki’s repeated reference to gyroscope as “3D gyroscope.” (Yamawaki, e.g., ¶¶[0006], [0016], [0037].) This is also consistent with Figure 4 (shown at right), which shows an



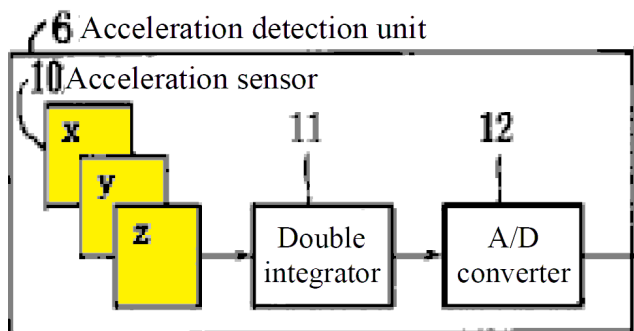
example in which a diver can move from point P to point Q, potentially resulting in

movement changes in the X, Y, and Z axes. It therefore would have been obvious that the 3D gyroscope 13 in Yamawaki provides angular rate detecting units and angular rate electrical signals across the X, Y, and Z axes.

190. Moreover, to the extent the word “**micro**” in the preamble is limiting, as fully explained for the preamble and in connection with **Ground 1**, it would also have been obvious for the gyros in Yamawaki to have been micromechanical gyroscopes which were well-known in the art, each of which would have produced an angular rate electrical signal. I provided a full explanation of the rationale and motivation to provide MEMS-based gyroscopes in the discussion of the preamble above and for **Ground 1**.

- (c) “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” (Claim 1[b])

191. The claimed “**acceleration producer**” in Yamawaki comprises **3D acceleration sensor 10** within acceleration detection unit 6 (shown at right, partial figure). Yamawaki explains that “3D acceleration sensor 10 which comprises a gyro sensor and detects acceleration during underwater movement of the

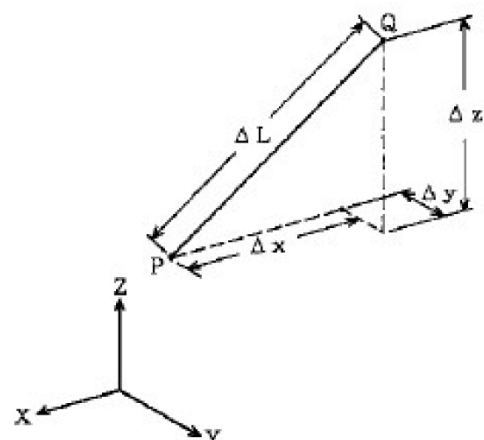


diver as a moving body.” (Yamawaki, ¶[0016].) Acceleration detection unit 6 also includes a double integrator 11 and an analog-to-digital (A/D) converter 12. (*Id.*) Yamawaki explains that “[o]utput from the acceleration sensor 10 is obtained of changes in movement speed or acceleration in the movement direction relative to the immediately preceding position and is then passed through the double integrator 11, subjected to A/D conversion by the A/D converter 12, acquired at a fixed sampling period, and recorded in the memory with the relative time from the starting point added.” (*Id.*, ¶[0023]).)

192. It would have been obvious to a skilled artisan that the acceleration sensor 10 Yamawaki comprises “**X axis**,” “**Y axis**,” and “**Z axis**,” accelerometers producing, respectively, an X, Y, and Z axis “**acceleration electrical signals**.” The claimed signals are shown in Figure 1, above showing output from acceleration sensor 10 to double integrator 11. (Yamawaki, ¶[0023].) As shown in Figure 1, acceleration sensor is expressly shown as

[FIGURE 4]

providing information for X, Y, and Z axes – consistent with Yamawaki’s repeated reference to acceleration sensor 10 as “**3D** acceleration sensor.” (*Id.*, e.g., ¶¶[0006], [0016], [0037].) This is also consistent with Figure 4 discussed

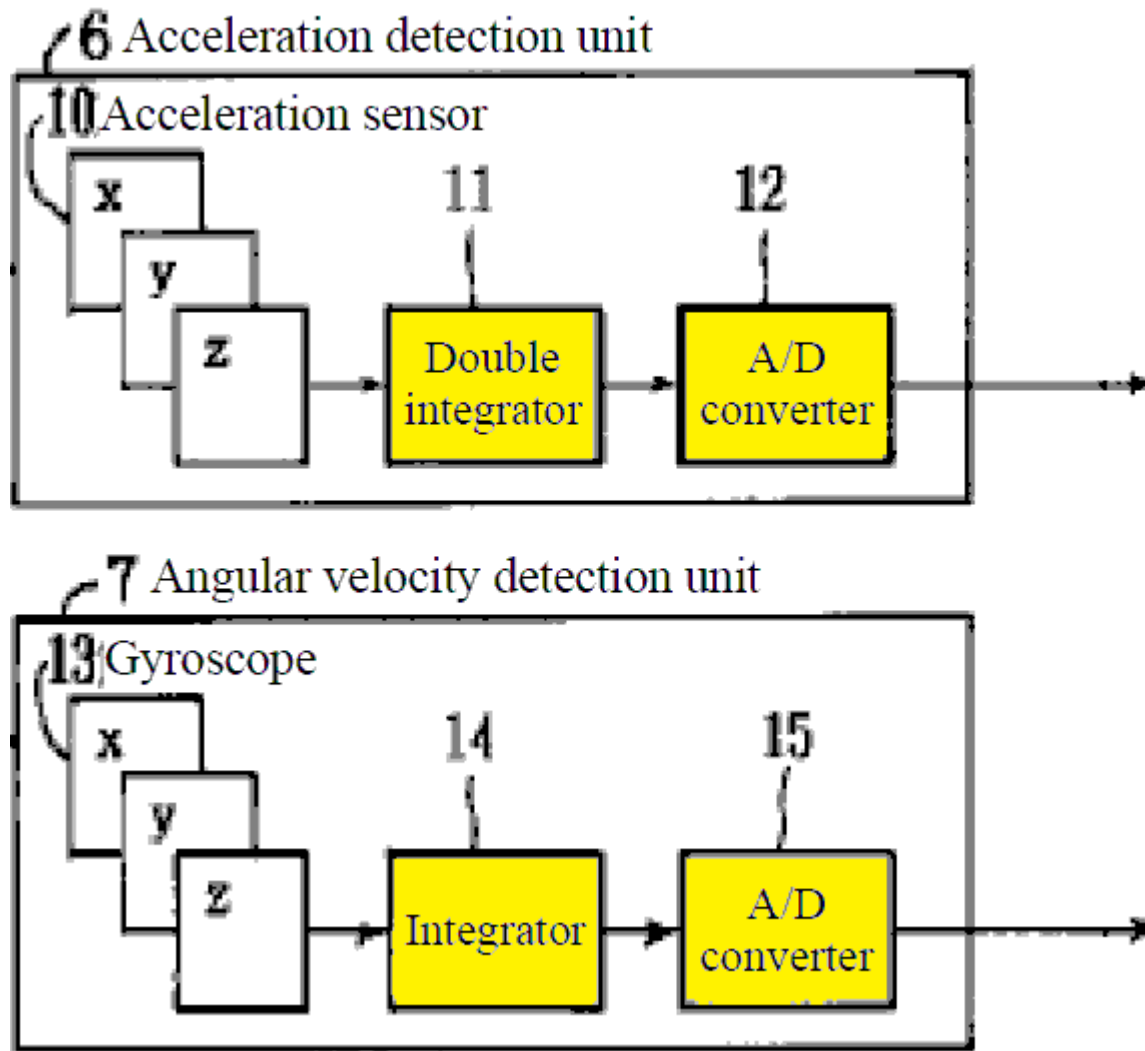


above (shown at right), which shows an example in which a diver can move from point P to point Q, potentially resulting in movement changes in the X, Y, and Z axes. It therefore would have been obvious that the acceleration sensor in Yamawaki provides accelerometers and acceleration electrical signals across the X, Y, and Z axes. (*Id.*, ¶[0028] (showing processing of acceleration sensors for X-direction by explaining that “the same process can be used to calculate the components in Y- and Z-directions as well.”).) It would also have been obvious that each of the X, Y, and Z acceleration sensors in Yamawaki is an “**accelerometer**,” as each device is designed to detect acceleration in a particular direction. Yamawaki expressly uses the term “accelerometer” in describing an example of how output from these devices is processed. (*Id.*, ¶[0027], Table 1 (“Output of accelerometer”) (emphasis added).)

193. Moreover, to the extent the word “**micro**” in the preamble is limiting, as fully explained for the preamble and in connection with **Ground 1**, it would also have been obvious for the acceleration sensors in Yamawaki to have been replaced with micromechanical accelerometers which were well-known in the art, each of which would have produced an acceleration electrical signal. I provided a full explanation of the rationale and motivation to provide MEMS-based accelerometers in the discussion of the preamble.

- (d) **“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 digital angular increments and digital velocity increments respectively.” (Claim 1[c])**

194. The claimed **“angular increment and velocity increment producer”** in Yamawaki is shown in Figure 1 as including the components shown in yellow:



(Yamawaki, Fig. 1 (partial figure; highlighting added).) The claimed “**angular increment and velocity increment producer**” in Yamawaki therefore comprises the integrator 14 and A/D converter 15 (of the angular velocity detection unit 7), and the double integrator 11 and A/D converter 12 (of the acceleration detection unit 6). This mapping of components is consistent with the ’648 patent, which similarly discloses an angular increment and velocity increment producer that includes (among other components) angular integrating means **620** and a separate

acceleration integrating means **630**. ('648, 8:29-33.) These components are also **“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,”** as shown by the arrows in Figure 1 and the fact that, as discussed, these components receive signals from 3D gyroscope 13 and 3D acceleration sensor 10. (Yamawaki, ¶¶[0023], [0029].)

195. Yamawaki further discloses that the identified angular increment and velocity increment producer circuitry **“receiv[es] 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.”** As noted, Yamawaki discloses that these signals are **“output”** from 3D gyroscope 13 and 3D acceleration sensor 10.

196. Yamawaki further teaches and renders obvious that **“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 digital angular increments and digital velocity increments respectively.”**

197. Starting with **“digital angular increments,”** these are produced by the integrator 14 and A/D converter 15. Yamawaki explains that **“the angle of rotation (change in movement direction) can be calculated by using with the integrator 14 to integrate the data obtained chronologically from the gyroscope over time.”**

(Yamawaki, ¶[0030] (emphasis added).) As Yamawaki further explains:

Assuming that the diver rotates underwater $\Delta\theta_{xy}$ in the X-Y plane during the time Δt , the angular rate $\Delta\omega_{xy}$ in the X-Y plane is expressed as

$$\Delta\omega_{xy} = \Delta\theta/\Delta t.$$

Therefore, the angle of rotation (change in movement direction) can be calculated by using with the integrator 14 to integrate the data obtained chronologically from the gyroscope over time.

(*Id.*, ¶[0030].) The output is also “subjected to A/D conversion at a fixed sampling period, and imported into the CPU as a digital value to calculate the change in the diver’s movement direction.” (*Id.*, ¶[0029].) Although the example above shows diver movement across the X and Y axes, as explained previously, 3D gyroscope 13 can generate angular rate information across all three axes. It thus would have been obvious that the angular velocity detection unit was capable of measuring change of angular rate with respect to all three axes.

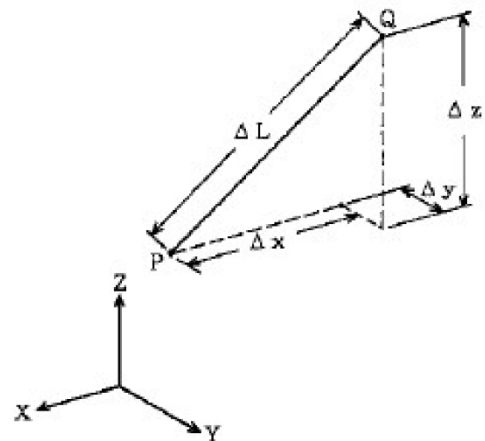
198. Yamawaki thus discloses “**an angular increment ... producer, which is electrically connected with said X axis, Y axis and Z axis angular rate detecting units... receiving said X axis, Y axis and Z axis angular rate electrical signals... from said angular rate producer,**” *i.e.*, the signals received from the 3D gyroscope 13 for the X, Y, and Z axes as discussed above, which are “**converted into... digital angular increments,**” *i.e.*, the change in the angular rate for each of

the X, Y, and Z axes produced by the process as discussed above, that uses integrator 14 and analog-to-digital converter 15.

199. Moving next to “**digital velocity increments**,” similar to the process described above, it would have been obvious for velocity increments to have been produced within the double integrator 11. Yamawaki explains that “[o]utput from the acceleration sensor 10 is obtained of changes in movement speed or acceleration in the movement direction relative to the

[FIGURE 4]

immediately preceding position and is then passed through the double integrator 11, subjected to A/D conversion by the A/D converter 12, acquired at a fixed sampling period, and recorded in the memory with the relative time from the starting point added.” (*Id.*, ¶[0023]) (emphasis added).)



“This data indicates the distance moved from the position at the previous unit of time.” (*Id.*) Using Figure 4 as an example (shown at right):

[W]hen the diver is at point P in an underwater 3D coordinate system at time t_0 and moves a very small distance ΔL to reach point Q at time t_1 after a minute of time Δt has elapsed, looking at the X-direction component Δx of the movement distance ΔL , the elapsed time Δt is defined as

$$\Delta t = t_1 - t_0$$

the amount of change in speed in X direction ΔV_x is expressed as

$$\Delta V_x = \Delta x / \Delta t$$

and the acceleration α_x in the X direction is expressed as

$$\alpha_x = \Delta V_x / \Delta t$$

(*Id.*, ¶[0026] (emphasis added).) “Therefore, by integrating the data obtained chronologically from the acceleration sensor, the change in speed can be calculated, and by integrating this over time, the movement distance can be calculated.” (*Id.*, ¶[0028] (emphasis added).) Although this example only shows “movement components in the X-direction,” the “same process can be used to calculate the components in Y- and Z-directions as well.” (*Id.*)

200. Yamawaki thus discloses “**a velocity increment producer, which is electrically connected to ... said X axis, Y axis and Z axis accelerometers, receiving... said X axis, Y axis and Z axis acceleration electrical signals from... said acceleration producer,**” *i.e.*, the signals received from the 3D acceleration sensor 10 with respect to the X, Y, and Z axes discussed above, which are “**converted into... velocity increments,**” *i.e.*, the amount of the change in speed as discussed above.

201. The claim goes on to require production of “**digital velocity increments,**” and Yamawaki does not expressly state that the computed change of

speed discussed above is actually passed to an A/D converter after the integration of data obtained from acceleration sensor 10. But this would have been obvious in further view of Saubolle.

202. Saubolle “relates to a device for monitoring the rate of ascent of divers or similar applications.” (Saubolle, 1:5-6.) Saubolle explains that “[d]ivers using underwater breathing apparatus for diving must control their rate of ascent towards the water surface,” because if they fail to do so, they may “suffer dangerous, unpleasant and possibly fatal decompression effects, commonly referred to as the ‘bends’.” (Saubolle, 1:7-11.) Saubolle describes “a rate of ascent or descent monitor which is inexpensive to manufacture and simple to use, thus rendering it suitable for widespread use and fulfilling a need for such a device at a sufficiently low price to be attractive to recreational divers.” (Saubolle, 1:66-2:3.)

203. ***Rationale and Motivation to Combine (Yamawaki with Saubolle):*** It would have been obvious to combine Yamawaki with Saubolle, predictably resulting in the mobile data collection device of Yamawaki, adapted such that the acceleration detection unit 6 outputs ***both*** the change in speed of the diver, ***and*** the distance the diver has moved. For example, an additional A/D converter could have been readily provided to convert the change of speed information into digital form, thus resulting in production of “**digital velocity increments**,” as claimed. Under the proposed

combination, therefore, the mobile collection device would have had available, for recording and later analysis, both of these pieces of information. My Declaration does not rely on the particular details of the allegedly inventive ascent/descent rate monitoring system in Saubolle, but on his general disclosure of the need to carefully monitor the rate of ascent or descent in a diving scenario, which as explained below, would have provided a clear motivation to adapt Yamawaki to obtain and record velocity information.

204. Yamawaki and Saubolle are analogous references in the same field of systems for monitoring movement, such as velocity and angular position. These prior art references would also have been reasonably pertinent to problems facing the inventor in implementing an inertial measurement unit to measure changes in movement using known devices. Yamawaki and Saubolle both also share common goals in terms of size and ease of use for divers. For example, Saubolle states that “[a] principal object of the present invention is to provide a rate of ascent or descent monitor which is inexpensive to manufacture and simple to use, thus rendering it suitable for widespread use and fulfilling a need for such a device at a sufficiently low price to be attractive to recreational divers.” (Saubolle, 1:66-2:3.) Yamawaki similarly states that it seeks to provide “a portable, user-friendly, and inexpensive mobile data collection device for an underwater moving body and a diving training

system capable of accurately reproducing a movement path by analyzing data with a computer after a dive.” (Yamawaki, ¶[0005].) Saubolle also would have been reasonably pertinent in understanding some of the practical reasons for why it would be beneficial to measure changes in velocity.

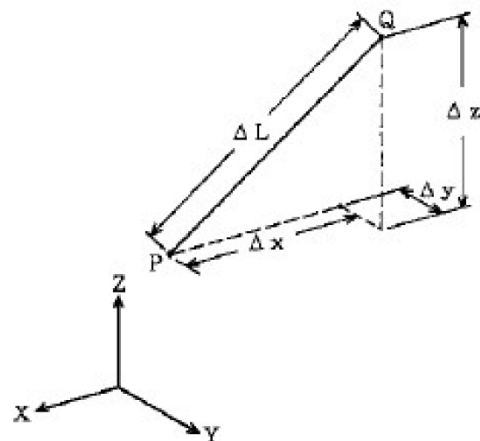
205. A person of ordinary skill in the art would have been amply motivated to adapt Yamawaki to record velocity information. The purpose of Yamawaki, after all, is to record information about the swimmer’s path to allow training of beginning and even more experienced divers. (Yamawaki, *e.g.*, ¶¶[0002]-[0003], [0008], [0010].) After information has been recorded using the mobile data collection device, for example, the information can be displayed on a screen and “a student diver can receive guidance from an instructor while viewing the screen.” (Yamawaki, ¶[0035].) Yamawaki also states that diving entails certain dangers, including “the effects of ocean currents and water depth, thus making it essential for beginners to receive training.” (Yamawaki, ¶[0002] (emphasis added).) But as Saubolle explains, one of the most important things for recreational divers is to “control their rate of ascent towards the water surface, if they are not to suffer dangerous, unpleasant and possibly fatal decompression effects, commonly referred to as the ‘bends’.” (Saubolle, 1:7-11.) It therefore would have been obvious a skilled artisan implementing the mobile collection unit of Yamawaki that information about

the diver's velocity – such as the rate of ascent towards the surface – would have provided exceedingly valuable information to obtain and record for training divers. By monitoring and recording the diver's velocity, for example, a diver can receive training feedback in the event their rate of ascent during a previous dive, *i.e.*, velocity of movement towards the surface, created risks of adverse decompression effects. This information can, accordingly, be used by the training to adjust their behavior in future dives to reduce these risks.

206. Although the need to prevent decompression effects is primarily concerned with the diver's surfacing velocity, *i.e.*,

[FIGURE 4]

speed in the vertical (Z axis) direction towards the surface, it would also have obvious and beneficial to record velocity increments across all three (X, Y, and Z) axes. This is because, as Saubolle explains, “[d]ivers may also become disoriented, and become unaware of whether they are



ascending or descending[.]” (Saubolle, 1:21-22.) In the example shown in Figure 4 (at right), a diver moving from point P to point Q may have moved a distance across an amount across all three axes (Δx , Δy , Δz). The diver in this case may have deliberately increased their speed across the X and Y axes in order to reach an object

of interest, but not realized that that movement may also have resulted in an increase in vertical ascent speed across the Z axis. It therefore would have been obvious and beneficial to capture and record velocity information across all three axes in order to facilitate training, so the diver can better understand how increase in velocity could inadvertently result in a potentially dangerous increase in velocity across the Z axis towards the surface.

207. An ordinarily skilled artisan would have had more than a reasonable expectation of success and could have implemented the proposed combination using conventional techniques without undue experimentation. As noted above, Yamawaki already discloses that the data collection device determines the change in velocity of the diver across all three axes. Yamawaki explains that memory is finite that such that “in order to effectively utilize this limited memory capacity, it is necessary to record the maximum amount of significant data.” (Yamawaki, ¶[0024].) Nevertheless, as explained, a skilled artisan would have found the diver’s change of velocity to be significant data worthy of collection for training.

208. Finally, to the extent the word “**micro**” in the preamble is limiting, as discussed extensively above, it would also have been obvious for the gyroscopes and accelerometers in Yamawaki to have been substituted with micromechanical gyroscopes and accelerometers as explained for limitation 1[a]-[b], which were

well-known in the art as discussed. Under the proposed combination, therefore, the data collection device in Yamawaki would have been adapted to receive and process signals from MEMS gyroscopes and accelerometers to produce the claimed digital angular and velocity increments.

2. Dependent Claim 4

209. For reference, claim 4 recites:

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.

('648, 24:36-44 (Claim 4).)

210. As fully explained for **Ground 2**, claim 4 would have been obvious based on Yamawaki and the knowledge of a person of ordinary skill in the art. In my opinion, claim 4 does not recite anything beyond and well-known characteristics of analog signals, as I fully explained above.

211. It would have been obvious that the **angular rate electrical signals** and **acceleration electrical signals** in Yamawaki are **analog** signals. This is evident by the fact that, as shown in Figure 1, both of these signals (after integration and double-integration) undergo analog-to-digital conversion through A/D converters 15 and 12.

212. Yamawaki does not explicitly disclose that the angular rate electrical signals and acceleration electrical signals are “**voltage signals**,” or that they are “**directly proportional**” to the angular rate or acceleration they measure. But these are basic concepts of analog signals that would have been well-known to persons of ordinary skill in the art. It is elementary knowledge that an analog signal is a signal whose amplitude (typically measured by its voltage) represents the information the signal is intended to convey. As explained in J. David Irwin et al., *Introduction to Electrical Engineering* (1995) (EX1007), in an analog signal, “the amplitude of the signal represents the information at every point in time.” (*Id.*, § 7.3, p. 240.) As Irwin further explains:

Almost all observable nature is analog, with continuously varying parameters such as temperature, pressure, light intensity, etc. Therefore, many systems receive as their input an analog signal representing an analog parameter. The electronic signal generally originates from a sensor or transducer which provides an analog signal proportional to the parameter it’s designed to measure. Table 7.1 provides a partial list of analog parameters that various types of electronic sensors can measure.

(Irwin, § 7.3, p. 242 (emphasis added).) Among the examples listed in Table 7.1, referenced above, include “[a]cceleration” and “[r]otation.” (*Id.*, Table 7.1, p. 241.) Although Irwin uses “amplitude” when discussing the information carried by an

analog signal, it was well-known that the amplitude of an analog signal is typically measured in volts. (*Id.*, e.g., EX1022, pp. xviii-xix, EX1007, pp. 242-243; *see also*, e.g., *id.*, p. 243 (“Assume the voltage signal from an electric guitar is 20 millivolts in amplitude....”) (emphasis added).) Irwin therefore confirms, as was known to persons of ordinary skill in the art, that an acceleration or rotation sensor provides an analog voltage signal proportional to the measured acceleration or rotation.

213. It therefore would have been obvious, based on basic principles of analog signals known to ordinarily skilled artisans, that the “**electrical signals**” produced from the angular rate producer and the acceleration producer in Yamawaki would have included “**analog voltage signals directly proportional to,**” respectively, the angular rate and acceleration measured by the gyroscopes and accelerometers. As Irwin confirms above, sensors generate analog electrical signals “proportional to the parameter” they are designed to measure, in this case, “[a]cceleration” and “[r]otation” (Irwin, pp. 241-242.)

214. For the same reasons I provided for claim 4 in **Ground 2**, an ordinarily skilled artisan would have been motivated to implement Yamawaki to provide analog voltage signals that are “**directly proportional**” to the measured acceleration and angular rate. As noted, the adverb “**directly**” does not impose a requirement not already disclosed by the “proportional” signals discussed above. This is because the

word “proportional” as used in Irwin describes a linear relationship in which the voltage signal varies based on a constant ratio to the measured acceleration or rotation. (See *IEEE Standard Dictionary of Electrical and Electronics Terms* (1996) (EX1012), pp. 830 (“**proportionally** See: linearity.”), 584 (“**linearity** (1) (**analog computer**) A property of a component describing a constant ratio of incremental cause and effect. *Proportionality* is a special case of linearity in which the straight line passes through the origin.”) (emphasis in original).) It thus would have been obvious to provide analog voltage signals that are directly proportional to the measured acceleration and angular rate, in order to provide more accurate information. Because the signals from the accelerometers and gyroscopes are foundational to the angular and velocity increments in Yamawaki (discussed for claim limitation 1[c]), a skilled artisan would have been motivated to provide signals that are directly proportional to the measured acceleration and rotation. In fact, conversely if the analog voltage signals were not directly proportional, the system would likely have generated less accurate (and thus less useful) values in response to movement of the inertial measurement unit.

215. I note that claim 4 ends with “**said vehicle**,” which has no antecedent basis in claim 4 or claim 1 from which it depends. I understand that in pending litigation involving the ’648 patent, Patent Owner has taken the position that “said

vehicle” in claim 4 refers to “*said carrier*”. I understand that in prior litigation involving the ’648 patent, Patent Owner took the position that “said vehicle” in claim 4 refers to “*a carrier: a means of carrying or transporting something.*” (EX1018, p. 7; EX1020, p. 7 (emphasis added).) I also understand that Petitioner has proposed “*a device or structure for transporting persons or things.*”

216. Yamawaki discloses either construction because the data collection device is mounted to the underwater moving body, *e.g.*, worn by a diver. (Yamawaki, ¶[0008].) With respect to Patent Owner’s construction, Yamawaki’s data collection unit measures the acceleration and angular rate of the person that is carrying it. Further, Yamawaki also satisfies Petitioner’s proposed construction because a person is plainly “a device or structure for transporting persons or things,” in this case the mobile data collection unit.

VI. NO SECONDARY CONSIDERATIONS OF NONOBVIOUSNESS

217. As explained in **Part III.B**, I understand that “secondary considerations” may be used as indicia of nonobviousness, provided that there is a nexus to the invention claimed. I understand from counsel, that Patent Owner in the district court litigation has not yet identified any secondary considerations evidence with a nexus to the claimed invention. Nor am I aware of information, such as commercial success, unexplained results, long felt but unsolved need, industry

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,671,648 B2

acclaim, simultaneous invention, copying, skepticism by experts, and failure of others, suggesting that the claims in this Declaration are not obvious. To the extent Patent Owner provides information it claims relates to secondary considerations, I reserve the right to supplement my analysis and opinions to comment on it.

VII. CONCLUSION

218. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in this proceeding. If required, I will appear for cross-examination at the appropriate time. I reserve the right to offer opinions relevant to the invalidity of the challenged claims at issue and/or offer testimony in support of this Declaration.

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,671,648 B2

219. I hereby declare that all statements made herein of my own knowledge are true and that all statements are 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 18 U.S.C. § 1001.

Dated: **3-7-2024**

Respectfully submitted,


Darrin Young

APPENDIX A

Curriculum Vitae

Darrin J. Young

Email: darrin_young@yahoo.com

Phone: 510-282-3638

Education:

University of California at Berkeley

Ph.D. Electrical Engineering and Computer Sciences, May 1999.

University of California at Berkeley

M.S. Electrical Engineering and Computer Sciences, May 1993.

University of California at Berkeley

B.S. Electrical Engineering and Computer Sciences, May 1991.

Research Interests:

Integrated microsystem technologies (based on MEMS device design, fabrication, and integrated circuit design) for industrial sensing, wireless sensing, biomedical implant, wearable health monitoring, environmental sensing, navigation, power and energy scavenging, and RF communication applications.

Professional Experiences:

2009-Present

U-START Associate Professor, Electrical and Computer Engineering Department
The University of Utah, Salt Lake City, Utah.

2013-2020

Associate Chair, Electrical and Computer Engineering Department
The University of Utah, Salt Lake City, Utah.

2005-2009

Associate Professor, Electrical Engineering and Computer Science Department
Case Western Reserve University, Cleveland, Ohio.

1999-2005

Assistant Professor, Electrical Engineering and Computer Science Department
Case Western Reserve University, Cleveland, Ohio.

1991-1999

Research Assistant, Electrical Engineering and Computer Sciences Department
University of California, Berkeley, California.

1997-1999

Participating Researcher, Lawrence Livermore National Laboratory, Livermore,
California.

1997 -1998

Analog RF IC Design Intern, Rockwell Semiconductor Systems, Newport Beach,
California.

1991-1993

Intern, Hewlett-Packard Laboratories, Palo Alto, California.

Honors:

- Recognition and Appreciation of Valued Services and Contributions as IEEE EDS Microelectromechanical Systems Chair, December 2011
- Nomination for 2003 Carl F. Wittke Award at Case Western Reserve University for Excellence in Undergraduate Teaching
- Bachelor of Science Degree with Honors in EECS at U.C. Berkeley, 1991
- Scholastic All American Collegiate Award, 1988

Professional Service:

- Administrative Committee of IEEE Sensors Council, 2002-2016
- Technical Program Session Chair, The 12th International Conference on Solid-State Sensors, Actuators, and Microsystems, Boston, MA, 2003
- MEMS Plenary Session Chair, Emerging Information Technology Conference, Princeton University, Princeton, NJ, 2003
- MEMS Session Chair, Emerging Information Technology Conference, Princeton University, Princeton, NJ, 2004
- Advisor Board, Emerging Information Technology Conference, Princeton University, Princeton, NJ, 2004
- Technical Program Committee for IEEE Sensors Conference, Vienna, Austria, 2004

- Technical Program Committee for International Electron Device Meeting, 2004
- Technical Program Session Chair, International Electron Device Meeting, 2004
- Technical Program Committee for the 1st International Workshop on Networked Sensing Systems, University of Tokyo, Tokyo, Japan, 2004
- Organizing Committee for the 7th International Conference on Solid-State and Integrated-Circuit Technology, Beijing, China, 2004
- Technical Program Session Chair, The 13th International Conference on Solid-State Sensors, Actuators, and Microsystems, Seoul, Korea, 2005
- Conference MEMS Session Chair, Emerging Information Technology Conference, National Taiwan University, Taiwan, R.O.C., 2005
- Advisor Board, Emerging Information Technology Conference, National Taiwan University, Taiwan, R.O.C., 2005
- Technical Program Committee for IEEE Sensors Conference, Irvine, California, USA, 2005
- Technical Program Session Chair, IEEE Sensors Conference, Irvine, California, USA, 2005
- Technical Program Committee for International Electron Device Meeting, Washington, D.C. 2005
- Technical Program Session Chair, International Electron Device Meeting, Washington, D.C. 2005
- Technical Program Committee for the 2nd International Workshop on Networked Sensing Systems, San Diego, California, USA, 2005
- Technical Program Session Chair, International Workshop on Networked Sensing Systems, San Diego, California, USA, 2005
- Technical Program Committee for IEEE International Symposium on Circuits and Systems, Island of Kos, Greece, 2006
- Technical Program Committee for IEEE International Conference on Nano/Micro Engineered and Molecular Systems, Zhuhai, China, 2006
- Program Vice-Chair for the 3rd International Conference on Networked Sensing Systems, Chicago, Illinois, USA, 2006

- Technical Program Committee for IEEE Sensors Conference, Korea, 2006
- Conference MEMS Session Chair, Emerging Information Technology Conference, University of Dallas, Dallas, Texas, 2006
- Advisor Board, Emerging Information Technology Conference, University of Dallas, Dallas, Texas, 2006
- Technical MEMS Program Committee of Electronic Device Society, 2006
- Technical Program Committee for MEMS/MOEMS Technologies and Applications Conference as part of the Photonics Asia Symposium, Beijing, China, 2007
- **Associated Editor for IEEE Journal of Solid-State Circuits, 2006 to 2011**
- IEEE Electron Devices Society MEMS Committee Member, January 2006 to December 2009
- **Chair of the IEEE Electron Devices Society MEMS Committee, January 2010 to 2014**
- Technical Program Committee Member and Conference Publicity Co-Chair for the 4th International Conference on Networked Sensing Systems, Braunschweig, Germany, 2007
- Steering Committee and Technical Program Committee Member the 5th International Conference on Networked Sensing Systems, Kanazawa, Japan, 2008
- Organizing Committee Member and Session Chair for the 9th International Conference on Solid-State and Integrated-Circuit Technology, Beijing, China, 2008
- Steering Committee Member for 2008 Emerging Information Technology Conference
- Technical Program Committee Member and MEMS-Track Co-Chair for the 21st Annual IEEE International SOC Conference, 2008
- Technical Program Committee Member and Industry-Track Co-Chair for the 6th International Conference on Networked Sensing Systems, Pittsburgh, Pennsylvania, 2009
- Technical Program Committee Member for the 22nd Annual IEEE International SOC Conference, 2009
- Medical IC Session Chair, Emerging Information Technology Conference, M.I.T., Cambridge, MA, August 2009

- Technical Program Session Chair, The 5th Annual IEEE International Conference On Nano/Micro Engineered and Molecular Systems, Xiamen, China, 2010
- Steering Committee and Technical Program Committee Member the 7th International Conference on Networked Sensing Systems, Kassel, Germany 2010
- Technical Program Committee Member for the 10th International Conference on Solid-State and Integrated-Circuit Technology, Shanghai, China, 2010
- Technical Program Committee Member of the 22nd Annual IEEE International SOC Conference, 2010
- Technical Program Committee Member and Session Chair of the 24th IEEE International Conference on Micro Electro Mechanical Systems, Cancun, Mexico, 2011
- Technical Program Committee Member and Session Chair of the 25th IEEE International Conference on Micro Electro Mechanical Systems, Paris, France, 2012
- Technical Program Committee Member of the 8th International Conference on Networked Sensing Systems, Penghu, Taiwan, 2011
- Technical Program Session Chair of the 8th International Conference on Networked Sensing Systems, Penghu, Taiwan, 2011
- Technical Program Committee Member of the 9th International Conference on Networked Sensing Systems, Germany, 2012
- Guest Editor for the Special Issue of ACM Journal of Emerging Technologies in Computing Systems (JETC) – Special Issue on Implantable Electronics, Volume 8 Issue 2, June 2012.
- Member of Editorial Board of the Journal of Sensor and Actuator Networks
- Technical Program Committee Member of the 24th Annual IEEE International SOC Conference, 2012.
- Technical Session Chair of the 6th Asia-Pacific Conference on Transducers and Micro/Nano Technologies, Nanjing, China, July 2012
- Technical Track Chair and Session Chair of the 34th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2012
- Technical Program Committee Member and Session Chair of the International Conference on BioElectronics, BioSensors, BioMedical Devices, BioMEMS/NEMS and Applications, Singapore, November 2012.

- Technical Program Committee Member of the 8th IEEE International Conference on Nano/Micro Engineered and Molecular Systems in 2013
- IEEE Sensors Council Meritorious Award Committee Member, 2012-2013
- IEEE Sensors Council Technical Achievement Award Committee Member, 2017-2020
- IEEE Sensors Council Meritorious Award Committee Member, 2020 and 2021
- Technical Session Chair of the IEEE Sensors Conference, Dallas, Texas, 2022
- Technical Session Chair of the IEEE PowerMEMS Conference, Salt Lake City, Utah, 2022
- Member of Awards Committee of the IEEE PowerMEMS Conference, Salt Lake City, Utah, 2022
- **Editor for IEEE Transactions on Electron Devices, 2015 to Present**
- NSF Review Panel for Major Research Instrumentation (MRI) Program, 2004
- NSF Review Panel for Sensor Networks, RF Communications, and VLSI Program, 2004
- NSF Review Panel for SBIR Program, 2003 and 2004
- NSF Review Panel for Sensor Networks, 2005
- NSF CAREER Panel, 2005 and 2008
- NSF Review Panel for Biomedical Engineering / Research to Aid Persons with Disabilities (BME/RAPD) Program, 2006
- NSF Review Panel, 2006
- NSF Review Panel, 2007
- NSF MNS Horizon 2040 Workshop-Health Care Panelist, June 2009
- NSF Biomedical Engineering CAREER Panel, October 2009
- NSF Biomedical Engineering Review Panel, May 2010
- NSF Biomedical Engineering Review Panel, January 2011

- NSF Biomedical Engineering Review Panel, May 2011
- NSF Review Panel, June 2020
- NSF Review Panel, June 2022
- Review for San Francisco State University Faculty Small Grant for Research and Creative Activities, May 2013
- Journal Review for IEEE Journal of MicroElectroMechanical Systems
- Journal Review for IEEE Transactions on Electron Devices
- Journal Review for IEEE Electron Devices Letter
- Journal Review for IEEE Sensors Journal
- Journal Review for Journal of Micromechanics and Microengineering
- Journal Review for IEEE Transaction on Biomedical Engineering
- Journal Review for IEEE Transaction on Biomedical Circuits and Systems
- Journal Review for Sensors & Actuators: A. Physical
- Journal Review for IEEE Transactions on Microwave Theory and Techniques
- Journal Review for Journal of Micromechanics
- Journal Review for Journal of Microelectronics Engineering
- Journal Review for Biosensors
- Journal Review for Journal of Sensors and Sensor Systems
- Journal Review for Microsystems & Nanoengineering

Consulting Service Within Last Five Years

Boston Scientific (2018)
 Expert witness for Boston Scientific
 Boston Scientific v. Nevro
 Patents Infringement Litigation Case & Inter Partes Review Case

Murata Manufacturing Co., Ltd. (2018)
Expert witness for Murata Manufacturing Co., Ltd.
Murata Manufacturing Co., Ltd. v. Inergetic AB
Inter Partes Review Case

Philips North America, LLC and Koninklijke Philips N.V. (2020)
Expert witness for Philips North America, LLC and Koninklijke Philips N.V.
Philips North America, LLC and Koninklijke Philips N.V. v. Fitbit and Garmin
International Trade Commission (ITC) Case & Inter Partes Review Case

Sonova AG (2020)
Expert witness for Sonova AG
MED-EL Elektromedizinische Geräte Ges.m.b.H. v. Sonova AG
Inter Partes Review Case

Momentum Dynamics Corp. (2021)
Expert witness for Momentum Dynamics Corp.
WiTricity v. Momentum Dynamics Corp.
Inter Partes Review Case

Echologics, Inc (2022)
Expert witness for Echologics, Inc,
Echologics v. Orbis Intelligent Systems, Inc.
Patent Infringement Litigation

Masimo Corporation (2023)
Expert witness for Masimo Corporation
Apple, Inc. v. Masimo Corporation
Patent Infringement Litigation

Publications:

Journals

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73. Q. Guo, M. A. Suster, R. Surapaneni, C. Mastrangelo, D. J. Young, "Characterization of Electrical Interferences for Ground Reaction Sensor Cluster," *IEEE Sensors Conference*, Taiwan, R.O.C., 2012, pp. 596-599.
74. Q. Guo, M. A. Suster, R. Surapaneni, C. Mastrangelo, and D. J. Young, "Electronic Sensing System with Flexible Biomechanical Ground Reaction Sensor Array Achieving 100 $\mu\text{m}/\text{Sec}$ Gait Ground Velocity Resolution," *the 17th International Conference on Solid-State Sensors, Actuators and Microsystems*, Barcelona, Spain, June, 2013, pp. 2535-2538.
75. Q. Guo, M. A. Suster, R. Surapaneni, C. H. Mastrangelo and D. J. Young, "Design and Characterization of Electronic Sensing System for a 13 x 13 Biomechanical Ground Reaction Sensor Array," *IEEE Custom Integrated Circuits Conference*, 2013.
76. R. Surapaneni, Q. Guo, D. J. Young and C. H. Mastrangelo and, "A Very High Density Floating-Electrode Flexible Sensor Array for High-Resolution Measurement of Contact Forces," *IEEE Sensors Conference*, 2013, pp. 871-874.
77. Y.-P. Hsu and D. J. Young, "Skin-Surface-Coupled Personal Health Monitoring System," *IEEE Sensors Conference*, 2013, pp. 210-213.
78. Q. Guo, R. Surapaneni, Y.-P. Hsu, C. H. Mastrangelo and D. J. Young, "Electrical Characterization of 26 x 26 Ground Reaction Sensor Array Interfaced with Two Parallel Electronic Detection Channels," *IEEE Sensors Conference*, 2013, pp. 507-510.
79. R. Yang, K. Ladhane, Z. Wang, J. Lee, D. J. Young, and P. X.-L. Feng, "Smart-Cut 6H-Silicon Carbide (SiC) Microdisk Torsional Resonators with Sensitive Photon Radiation Detection", *IEEE 27th International Conference on Micro Electro Mechanical Systems*, 2014.
80. R. Yang, Z. Wang, J. Lee, K. Landhane, D. J. Young, P. X. -L. Feng, "R. Yang, Z. Wang, J. Lee, K. Ladhane, D. J. Young and P. X.-L. Feng, "Temperature Dependence of Torsional and Flexural Modes in 6H-SiC Microdisk Resonators", *IEEE International Frequency Control Symposium*, Taiwan, R.O.C., 2014, pp. 618-620.
81. Q. Guo, C. Mastrangelo and D. J. Young, "Electrical Interference Suppression Technique for 26 x 26 High-Density Ground Reaction Sensor Array", *IEEE Sensors Conference*, 2014, pp. 80-83, 2014.
82. Y. Yu, P. Tathireddy, S. Roundy, and D. J. Young, "Inductive Sensing Characterization for Wireless Implantable Intraluminal Glucose Sensors", *the 4th International Conference on Bio-Sensing Technology*, Lisbon, Portugal, May, 2015.

83. Q. Guo, O. Bebek, M. C. Cavusoglu, C. H. Mastrangelo, and D. J. Young, "A Personal Navigation System Using MEMS-Based High-Density Ground Reaction Sensor Array and Inertial Measurement Unit", *the 18th International Conference on Solid-State Sensors, Actuators and Microsystems*, Anchorage, Alaska, U.S.A., June, 2015, pp. 1077-1080.
84. Y. Yu, V. Bhola, P. Tathireddy, S. Roundy, and D. J. Young, "Inductive Sensing Technique For Low Power Implantable Hydrogel-Based Biochemical Sensors", *the IEEE Sensors Conference, Busan, South Korea, October 2015*, pp. 129-133.
85. Q. Guo, C. Mastrangelo, D. J. Young, "High Performance MEMS Tactile Sensor Array with Robustness and Fabrication Simplicity", *the 29th IEEE International Conference on Micro Electro Mechanical Systems*, Shanghai, China, January 2016, pp. 877-880.
86. X. Chen and D. J. Young, "Robust Implantable Blood Pressure Sensor Packaging for Long-Term Laboratory Animals Monitoring", *IEEE Sensors Conference*, Orlando, Florida, October 2016, pp. 1688-1690.
87. Y. Yu, T. Nguyen, P. Tathireddy, S. Roundy, and D. J. Young, "Wireless Hydrogel-Based Glucose Sensor for Future Implantable Applications (Invited)", *IEEE Sensors Conference*, Orlando, Florida, October 2016, pp. 1667-1669.
88. H. Basaeri, D. Christensen, Y. Yu, T. Nguyen, P. Tathireddy, D. J. Young, and S. Roundy, "Ultrasonically Powered Hydrogel-Based Wireless Implantable Glucose Sensor", *IEEE Sensors Conference*, Orlando, Florida, October 2016, pp. 1072-1074.
89. W. Luo, R. Likhite, C. Mastrangelo, D. J. Young, "RF Powering of Micro Coils Array For Wireless Spherical Particle-Based Neural Probes", in *the 19th International Conference on Solid-State Sensors, Actuators and Microsystems*, Kaohsiung, Taiwan, R.O.C., June 2017, pp. 1351-1354.
90. R. Likhite, W. Luo, D. J. Young, C. Mastrangelo, "Fabrication and Inductive Power Transfer in Wireless Spherical Pill Microprobes", in *the 19th International Conference on Solid-State Sensors, Actuators and Microsystems*, Kaohsiung, Taiwan, R.O.C., June 2017, pp. 32-34.
91. Q. Guo, W. Deng, O. Bebek, M. C. Cavusoglu, C. H. Mastrangelo, and D. J. Young, "Personal Inertial Navigation System Employing MEMS Wearable Ground Reaction Sensor Array and Interface ASIC Achieving a Position Accuracy of 5.5 m Over 3 km Walking Distance Without GPS", *IEEE International Solid-State Circuits Conference (ISSCC)*, San Francisco, February, 2018.
92. Y. Yao, C. Xue, P. Wang, D. Young, and D. Xu, "A Novel Method of Acceleration Measurement Base On Tunneling Magnetoresistance," *Asia-Pacific Conference of Transducers and Micro-Nano Technology*, Hong Kong, June, 2018.

93. H. Basaeri, Y. Yu, D. Young, and S. Roundy, "Experimental Study of the Effect of Depth, Orientation, and Alignment for a MEMS Diaphragm Receiver in Acoustic Power Transfer Systems," *The 18th International Conference on Micro and Nanotechnology for Power Generation and Energy Conversion Applications*, Daytona Beach, Florida, USA, December, 2018.
94. W. Luo and D. J. Young, "A Miniature Non-Invasive Wireless Tail-Cuff-Based Heart Rate Sensor With Motion Artifacts Suppression for Real-Time Monitoring of Laboratory Mice," *IEEE Sensors Conference*, October, 2020.
95. W. Luo, R. Goel, S. Roundy, C. Zesiger and D. J. Young, "RF Coils Characterization in Soil for Wireless Soil Sensing Applications," *IEEE Sensors Conference*, October, 2020.
96. W. Luo, V. Sharma, and D. J. Young, "A Comparative Evaluation Of A Wearable MEMS Tactile Sensors Array And A Photoplethysmography Sensor For Atrial Fibrillation Detection Under Sitting Condition," in the *21st International Conference on Solid-State Sensors, Actuators and Microsystems*, June, 2021.
97. W. Luo, A. Jackson, J. Sorensen, A. Dahal, R. Goel, S. Roundy, C. Zesiger, and D. J. Young, "Wireless Power Transfer Through Soil Over a Range of Moisture Level for *In-Situ* Soil Health Monitoring," *IEEE Sensors Conference*, October, 2021.
98. J. Sanchez, A. Dahal, C. Zesiger, R. Goel, D. Young, and S. Roundy, "Design and Characterization of a Low-Power Moisture Sensor from Commercially Available Electronics," *IEEE Sensors Conference*, October, 2021.
99. J. Sanchez, J. Arteaga, C. Zeisiger, D. Young, R. Goel, P. Mitcheson, E. Yeatman, and Shad Roundy, "Integration of a High Frequency Inductive Power Transfer System to Energize Agricultural Sensors Through Soil," *IEEE Wireless Power Week*, Bordeaux, France, July, 2022.
100. B. Young, W. Luo, darnd D. J. Young, "A 3D-Printed Wearable Ring Sensor For Long-Term Accurate Monitoring of Human Cardiovascular Condition", *IEEE Sensors Conference*, 2022.
101. S. Ding, J. Sanchez, A. Jackson, S. Roundy, R. Goel, C. Zesiger, and D. J. Young, "Wireless Power Transfer Through Soil For Energizing An Underground Soil Moisture Sensor", *IEEE Sensors Conference*, 2022.
103. S. Ding, J. Sanchez, S. Roundy, R. Goel, C. Zesiger, and D. J. Young, "Land Vehicle-Based Wireless Power Transfer Through Soil For Enabling Batteryless Underground Soil Moisture Sensing Application", the *21st International Conference on Micro and Nanotechnology for Power Generation and Energy Conversion Applications*, Salt Lake City, Utah, USA, December, 2022.

104. J. Sanchez, J. Arteaga, N. Pucci, P. Mitcheson, E. Yeatman, D. Young, C. Zesiger, and S. Roundy, "Misalignment Parameterization of a 13.56 MHz Inductive Power Transfer System for In-Situ Soil Sensing", the 21st *International Conference on Micro and Nanotechnology for Power Generation and Energy Conversion Applications*, Salt Lake City, Utah, USA, December, 2022.
105. S. Ding, S. Roundy, R. Goel, C. Zesiger, and D. J. Young, "Wireless Battery-Free Sub-mW Underground Soil Moisture Sensing System," *IEEE Sensors Conference*, 2023.
106. S. Ding, S. Roundy, R. Goel, C. Zesiger, and D. J. Young, "Near-Zero-Power Passive Wireless Underground Soil Moisture," *IEEE Sensors Conference*, 2023.

Invited Book Chapters

1. D. J. Young, "Analog Front-End and Telemetry Systems", *Chapter 3 of Bioimplantable Systems: Design Principles and Applications*. Elsevier Inc. 2015.
2. D. J. Young and H. Kim, "Microelectromechanical Systems (MEMS)," *Chapter 18 of Guide to State-of-the-Art Electronic Devices*, Jonh Wiley & Sons Ltd, 2013.
3. C-K Lu and D. J. Young, "Wireless MEMS Accelerometer for Small Laboratory Animal Activity Monitoring," *VDM Verlag Dr. Muller Aktiengesellschaft & Co. KG*, 2000 (ISBN: 978-3-8364-7595-2).
4. D. J. Young, C. A. Zorman, and M. Mehregany, "MEMS/NEMS Devices and Applications," in *The Springer Handbook of Nanotechnology – 2nd Edition*, B. Bhushan, ed., Springer-Verlag, Berlin, 2006.
5. D. J. Young, "MEMS for communication systems," in *Standard Handbook of Electronic Engineering*, Donald Christiansen and Charles K. Alexander, McGraw-Hill, NY, NY, 5th Edition, 2002, Chapter 17.8, pp. 17.144-17.147.
6. S. Rajgopal, C.A. Zorman, D.J. Young, M. Mehregany, "Reliability and MEMS," *The CRC Handbook of Mechanical Engineering*, F. Kreith and D. Y. Goswami, Second Edition, Boca Ration [Fla.]: CRC Press, 2005, pp. 15.68-15.83.
7. P. Cong, W. H. Ko, and D. J. Young, "Integrated Electronic System Design for Implantable Wireless Batteryless Blood Pressure Sensing Microsystem," *IEEE Communications Magazine*, April 2010.
8. D. Young and H. Kim, "A Review of MEMS Innovation." In: Joachim Burghartz (Editors in Chief), *the IEEE EDS Yearbook: 50th Anniversary Review of Electrical Revolutions*, Chapter 18: IEEE, Amsterdam: Elsevier, 2013.

Patents

US 8,634,924 “MEMS Implanted Acoustic Sensor”

US 8,602,999 “Implantable Flat Blood Pressure Sensing Cuff Structure And Implantable Blood Pressure Monitoring Device Using The Cuff Structure”

Presentations

“Smart and Robust Sensing Systems Enabled by MEMS Technology and Low Power Electronics”, presented at the graduate seminar, Electrical and Computer Engineering Department, University of Utah, Salt Lake City, Utah, August 29, 2016.

“MEMS-Based Personal Navigation System Under GPS-Denied Environment”, presented at the Mechanical Engineering Department Seminar, National Taiwan University, Taiwan, R.O.C., June, 6, 2016.

“Smart and Robust Sensing Systems Enabled by MEMS Technology and Low Power Electronics”, presented at Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, May 20, 2016.

“Bionic Human”, panel discussion of Leo After Hours at the Leonardo Museum, Salt Lake City, Utah, March 10, 2016.

“Smart and Robust Sensing Systems Enabled by MEMS Technology and Low Power Electronics” presented at GE HealthCare, Salt Lake City, Utah, February 10, 2016.

“Smart and Robust Sensing Systems Enabled by MEMS Technology and Low Power Electronics” presented at School of Electronics and Information Engineering, Soochow University, January 22, 2016.

“Smart and Robust Sensing Systems Enabled by MEMS Technology and Low Power Electronics” presented at Vimicro Corporation, Beijing, China, December 17, 2015.

“Smart and Robust Sensing Systems Enabled by MEMS Technology and Low Power Electronics” presented at the Institute of Microelectronics, Tsing Hua University, December 16, 2015.

“Smart and Robust Sensing Systems Enabled by MEMS Technology and Low Power Electronics” presented at the institute of Electronics, Chinese Academy of Sciences (IECAS), Beijing, China, December 13, 2015.

“Smart and Robust Sensing Systems Enabled by MEMS Technology and Low Power Electronics” presented at School of Electronics Engineering and Computer Science, Peking University, December 8, 2015.

“Smart Sensing Applications Enabled by Micro-Electro-Mechanical Sensors and Low-Power Integrated Circuits,” presented at the Computer Engineering Students Seminar, University of Utah, November 25, 2014.

“Skin-Coupled Wearable Ambulatory Health Monitoring System Using MEMS Sensors,” presented as an invited talk at the International conference on BioSensors, BioElectronics, BioMedical Devices, BioMEMS/NEMS and Applications 2014 & The 5th Symposium on Green Microsystem Technology, Shanghai, China, November 17, 2014,

“Skin-Coupled Wearable Ambulatory Pulse Wave Velocity Monitoring System Using MEMS Sensors” RF & Wireless Day, University of Utah, September 16, 2014.

“High Performance Microsystems Enabled by MEMS and Integrated Circuits,” presented at the Electrical and Computer Engineering Department Graduate Seminar, University of Utah, September 16, 2013.

“Biomedical Implant System Design Enabled by MEMS and CMOS IC,” presented at the International Conference on BioElectronics, BioSensors, BioMedical Devices, BioMEMS/NEMS and Applications, Singapore, November 20, 2012.

“Wireless Microsystem Technologies and Future Direction”, presented at National Taiwan University, October 31, 2012.

“MEMS-Based Biomedical Implant Research and Commercialization Opportunities”, presented at the 6th Asia-Pacific Conference on Transducers and Micro/Nano Technologies, Nanjing, China, July 10, 2012.

“Wireless Microsystem Technologies for Biomedical Implant Applications”, presented at the Electrical and Computer Engineering Department Graduate Seminar, University of Utah, September 16, 2011.

“MEMS-Based Biomedical Implant Development and Commercialization Opportunity”, presented at the 4th International Workshop on Innovation and Commercialization of Micro & Nano Technology (ICMAN 2010), Shanghai, China, 11-23-2010.

“Low-Interference Sensing Electronics for High-Resolution Error-Correcting Biomechanical Ground Reaction Sensor”, presented at the IEEE Sensors Conference, Big Island, Hawaii, 11-2-2010.

“Wireless Biomedical Microsystems”, presented at the Bioengineering Seminar, University of Utah, 10-6-2010.

“Low-Interference Sensing Electronics for High-Resolution Error-Correcting Biomechanical Ground Reaction Sensor”, presented at the Nanotechnology session of the Emerging Information Technology Conference, Stanford, CA, 8-14-2010.

“A Wireless and Batteryless Blood Pressure Sensor for Laboratory Mice *In Vivo* Real-Time Monitoring”, presented at the CMOS Emerging Technology Workshop, Whistler, British Columbia, Canada, May 20, 2010.

“Interface Electronics for MEMS-Based Wireless Sensing Applications”, presented at the *IEEE International Symposium on VLSI Design, Automation and Test*, Hsinchu, Taiwan, R.O.C., April, 28, 2010.

“Wireless Implantable Microsystem Applications In Animal And Human” presented at Zhe Jiang University, March 25, 2010.

“Wireless Biomedical Microsystems”, presented at the Bioengineering Seminar, University of Utah, February 17, 2010.

“Wireless Batteryless Less-Invasive Blood Pressure Sensing Microsystem for Advanced Biomedical Application,” presented at the 23rd IEEE International Conference on Micro Electro Mechanical Systems, Hong Kong, China, January, 2010

“Wireless Power Recharging for Implantable Bladder Pressure Chronic Monitoring,” presented at the 5th IEEE International Conference on Nano/Micro Engineered and Molecular Systems, Xiamen, China, January 2010.

“Wireless Microsystem Technology For Biomedical Applications,” presented at the Bioengineering Department Seminar, University of Utah, November 20, 2009.

“Development of Wireless Batteryless Implantable Blood Pressure-EKG-Core Body Temperature Sensing Microsystem For Genetically Engineered Mice Real Time Monitoring,” presented at the 3rd IEEE International Conference on Nano/Molecular Medicine and Engineering, Taiwan, R.O.C. October 21, 2009.

“Wireless Microsystem Technology With Focus on Biomedical Applications”, presented at the graduate seminar of Mechanical Engineering Department, National Taiwan University, October 19, 2009.

“Wireless MEMS-Based Strain Sensing Microsystem” presented at the Department of Information and Electronic Engineering, Zhejiang University, Hangzhou, China, 9-22-2009.

“Wireless and Batteryless Biomedical Implant Microsystem” presented at the Shanghai Institute of Microsystem and Information Technology, Shanghai, China, 9-21-2009.

“Wireless MEMS Strain Sensing Technology for Military Applications” presented at the

Workshop on the Research and Evaluation of NEMS/MEMS sponsored by US Army AMRDEC, DARPA, and SMDC, Redstone Arsenal, Alabama, 9-9-2009.

“Wireless Powering and Data Telemetry for Biomedical Implants”, presented in *the 31st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC-2009)*, Minneapolis, Minnesota, 9-4-2009.

“Wireless Batteryless 10-bit Implantable Blood Pressure Sensing Microsystem for Real-Time Genetically Engineered Mice Monitoring”, presented at the Medical IC session of the Emerging Information Technology Conference, Cambridge, MA, 8-6-2009.

“Wireless Microsystem Research”, presented at EECS Department Seminar at Case Western Reserve University, Cleveland, Ohio, 1-20-2009.

“Wireless Microsystem Technology for Biomedical Applications”, presented at the ECE Department Seminar at University of Utah, Salt Lake City, Utah, 12-1-2008.

“Wireless Implantable EMG Sensor for Powered Prosthesis Control”, presented in *the 9th International Conference on Solid-State and Integrated-Circuit Technology*, Beijing, China, 10-22-2008.

“CMOS Cross-Coupled VCO Architecture Comparison at 2GHz and 16GHz”, presented in *the 9th International Conference on Solid-State and Integrated-Circuit Technology*, Beijing, China, 10-22-2008.

“Wireless Microsystem Technology for Biomedical Applications”, presented at State Key Laboratory of Precision Measuring Technology & Instruments, Tianjin University, China, 10-20-2008

“Wireless Microsystem Technology for Biomedical Interface”, presented at the Institute of Electronics, Chinese Academy of Sciences, Beijing, China, 10-16-2008.

“Wireless Microsystem Technology for Biomedical Applications”, presented at the ECE Department graduate seminar, University of Utah, September 23, 2008.

“MEMS Middle Ear Microphone for Fully Implantable Cochlear Prosthesis”, presented at National Chiao Tung University, Taiwan, R.O.C., 6-26-2008.

“Wireless Implantable Less-Invasive Blood Pressure Sensing Microsystem for Small Laboratory Animal Real-Time Monitoring”, presented at the Asia-Pacific Conference on Transducers and Micro-Nano Technology, Taiwan, R.O.C., 6-25-2008.

“Wireless Less-Invasive Blood Pressure Sensing Microsystem for Small Laboratory Animal *In Vivo* Real-Time Monitoring”, presented at the 5th International Conference on Networked Sensing System (INSS 2008), Kanazawa, Japan, 6-18-2008.

“MEMS Middle Ear Microphone for Fully Implantable Cochlear Prosthesis”, presented at Tsinghua University, Beijing, China, 2-26-2008.

“Wireless Less-Invasive Blood Pressure Sensing Microsystem for Small Laboratory Animal *In Vivo* Real-Time Monitoring”, presented at the Institute of Microelectronics, Beijing University, Beijing, China, 2-25-2008.

“Wireless Less-Invasive Blood Pressure Sensing Microsystem for Small Laboratory Animal *In Vivo* Real-Time Monitoring”, presented at Southeast University, Nanjing, China, 2-18-2008.

“Wireless Less-Invasive Long-Term Implantable Blood Pressure Sensing System for Small Animal Real-Time Monitoring”, presented at the 2007 International Electron Devices and Materials Symposia (IEDMS), Taiwan, R.O.C., 11-29-2007.

“Wireless Implantable EMG Sensing Microsystem”, presented at the 2007 Biomedical Engineering Society Annual Fall Meeting, Los Angeles, California, 9-29-2007.

“MEMS Accelerometer with Low Noise Interface Circuits as Middle Ear Microphone for Fully Implantable Cochlear Prosthesis”, presented at the College of Mechanical Engineering, Dalian Technical University, Dalian, China, 10-27-2006.

“Microsystem Technology for Fully Implantable Cochlear Prosthesis”, presented at the 6th Emerging Information Technology Conference, University of Texas at Dallas, Dallas, Texas, 8-11-2006.

“Wireless Strain Sensors”, presented at The Timken Company, Canton, Ohio, 2-28-2006.

“Wireless Strain Sensing Microsystem Technology”, presented at Southeast University, Nanjing, China, 9-6-2005.

“Microsystem Technology for Totally Implantable Cochlear Prosthesis”, presented at National Cheng Kung University, Tainan, Taiwan, R.O.C., 8-18-2005.

“Wireless Strain Sensing Microsystem”, presented as a plenary session talk at the 5th Emerging Information Technology Conference, National Taiwan University, Taipei, Taiwan, R.O.C., 8-18-2005.

“Microsystem Technology for Totally Implantable Cochlear Prosthesis”, presented at Neural Prosthesis Seminar at Case Western Reserve University, Cleveland, Ohio, 7-15-2005

“Strain Sensing Microsystem with Remote RF Powering and Data Telemetry”, presented at ECE Department Seminar, Carnegie Mellon University, Pittsburgh, Pennsylvania, 3-18-2005.

“High-Temperature Wireless Sensing Technology and Its Future Directions”, presented at Beijing University, Beijing, China, 10-21-2004.

“A High-Performance Strain Sensing Microsystem with Remote RF Power Capability,” presented at the 7th International Conference on Solid-State and Integrated-Circuit Technology (ICSICT-2004), Beijing, China, 10-19-2004.

“High-Performance MEMS Capacitive Strain Sensing Microsystem”, presented at Army Research Office MEMS Meeting, Arlington VA. 6-24-2004.

“Single Crystal SiC Capacitive Pressure Sensor at 400 °C”, presented at International Electron Devices Meeting, Washington D.C., 12-10-2003.

“3D-MEMS Approaches to Varactors”, presented at IEEE International Microwave Symposium, Philadelphia, Pennsylvania, 6-9-2003.

“MEMS for RF Applications”, presented at MEMGen Corporation, Burbank, CA, 11-20-2002.

“RF MEMS and Its Applications”, presented at Institute of Microelectronics, TsingHua University, Beijing, China, 7-30-2002.

“Micromachined RF Low Phase Noise Voltage-Controlled Oscillator”, presented at Shanghai Institute of Microsystem and Information Technology, Shanghai, China, 7-15-2002.

“MEMS Technologies for Radio Frequency (RF) and Optical Applications” Short Course Presented at Adriatic Research Institute, Berkeley, California, 4-26-2002.

“Micromachined Low Phase Noise Voltage-Controlled Oscillator”, EE Department Seminar, University of Southern California, Los Angeles, California, 3-19-2002.

“MEMS for RF Communications”, Tutorial Session Presented at Material Research Society (MRS) Fall Meeting, Boston, Massachusetts, 11-26-2001.

“Micromachined Low Phase Noise RF Voltage-Controlled Oscillator”, EECS Department Seminar, University of Michigan, Ann Arbor, Michigan, 11-5-2001.

“MEMS for Wireless Communication”, presented at National Taiwan University, Taipei, Taiwan. R. O. C. on 10-29-2001.

“Key Technology for MEMS”, Short Course Presented at Precision Instrument Development Center, National Science Council, The Executive Yuan, Taiwan, R. O. C., 10-22-2001 to 10-25-2001.

“MEMS & Communications - A Complimentary System” presented at Glennan Microsystem Initiative Meeting, Independence, Ohio on 6- 9-2000.

“RF Voltage-Controlled Oscillator (VCO) with MEMS Capacitors and Inductors” presented at Naval Research Lab workshop on Military Application of RF MEMS, Washington, D.C. on 2-8-2000.

“MEMS for Wireless Communications” presented at Symposium of Micromachine and Microtechnology, Bio-Medical, and Industrial Prospects at Case Western Reserve University, Cleveland, Ohio on 11-12-1999.

“A Low-Noise RF VCO Using On-Chip High-Q 3-D Coil Inductor & Micromachined Variable Capacitor” presented at Solid-State Circuit Technology Committee Workshop, Arlington, Virginia on 11-15-1999.

Research Grants and Contracts:

- “SitS NSF-UKRI: Wireless In-Situ Soil Sensing Network for Future Sustainable Agriculture” (PI)
NSF, January 1, 2020 to December 31, 2023
- “Acoustic Power and Communication Platform for a Deeply Implanted Intraluminal Glucose Sensor” (Co-PI)
NSF, September 2014 to August 2018
- “Implantable Particle-Based Wireless Neurorecording Probes for Minimally-Intrusive 3D Mapping of Brain Signals” (Co-PI)
NSF, September 2015 to August 2017
- “Soldier Navigation via High-Resolution-Gait-Corrected IMUs” (Co-PI)
DARPA, July 2008 to December 2013
- “Robust Design of High Performance MEMS Resonators” (Co-PI)
NSF, September 2008 to August 2011
- “Wireless Implantable Pressure Monitor for Clinical Applications” (Co-PI)
U.S. Department of Veteran Affairs, September 2007 to August 2010
- “Intelligent Sensor Network for In-Vivo Real Time Biological Dynamic Systems” (PI)
NSF, September 2003 to August 2007
- “RF Data Transmitter and Receiver Modules for MEMS Strain Sensors” (PI)
Army Research Office, June 2002 to May 2007
- “Wireless EMG Sensing Microsystem” (PI)
Veteran Affair Medical Center, Cleveland, Ohio, September 2005 to August 2006

- “Harsh Environment MEMS Sensing and Communications” (PI)
NASA, October 1999 to October 2002
- “MEMS Tunable Antennas for Power-Efficient Wireless Communications” (PI)
NASA, October 2001 to March 2003
- “Nerve Reshaping” (Co-PI)
NIH, July 2005 to June 2010
- “Micro Sensor for Cochlear and Middle Ear Implant Systems” (Co-PI)
NIH, December 2003 to November 2005
- “Microfabricated Strain Sensor Module with Interface Circuits” (Co-PI)
Army Research Office, June 2002 to May 2007
- “Fast Bonding Techniques for Attaching Strain Sensors to Steel Substrates” (Co-PI)
Army Research Office, June 2002 to May 2007
- “Multi-Range Pressure Sensor Arrays For Harsh Environment” (Co-PI)
NASA, October 1999 to October 2002

Graduate Research Students Advising:

- Weijie Luo
Ph.D. Dissertation Title: “A Wireless Wearable Atrial Fibrillation Monitoring System Employing A Paper-Based MEMS Tactile Sensors Array And A Low-Power ASIC”
Completion Date: December 2021
- Yuechuan Yu
Ph.D. Dissertation Title: “A Wireless and Battery-less Hermetically Packaged Glucose Sensor Employing Hydrogel-Based Inductive Sensing Scheme and Low-Power ASIC for Future Long-Term Implantable Glucose Monitoring”
Completion Date: March 2020
- Qingbo Guo
Ph.D. Dissertation Title: “Personal Inertial Navigation System Assisted By MEMS Wearable Ground Reaction Sensor Array and Sensing Interface ASIC”
Completion Date: December 2018
- Xing Chen (Post-Doc, 2015-2016)
Packaging Technology for Biomedical Implant Applications
- Michael Suster
Ph.D. Dissertation Title: “Wireless Strain Sensing Microsystem with External RF Powering and Two-Channel Data Telemetry Capability”
Completion Date: July 2011

- Nattapon Chaimanonart
Ph.D. Dissertation Title: “Wireless Implantable Multi-channel Bio-sensing Network with Adaptive RF Power Control for Untethered Laboratory Animal Real-time Monitoring”
Completion Date: July 2009
- Peng Cong
Ph.D. Dissertation Title: “Wireless Less-invasive Implantable Blood Pressure Sensing System for Small Animal Real-time Monitoring”
Completion Date: December 2008
- Kalyan Ladhane
M.S. Project Title: “SiC MEMS”
Completion Date: December 2013
- Bradley Farnsworth
M.S. Thesis Title: “Wireless Implantable EMG Sensor”
Completion Date: May 2010
- Mark Zimmerman
M.S. Thesis Title: “*In Vivo* RF Powering for Advanced Biological Research”
Completion Date: June 2008
- Engin Pehlivanoglu
M.S. Thesis Title: “Silicon Carbide MEMS Oscillator”
Completion Date: January 2008
- Mark Zurcher
M.S. Thesis Title: “Development of a MEMS Middle Ear Acoustic Sensor for a Fully Implantable Cochlear Prosthesis”
Completion Date: November 2007
- Matthew Cross
M.S. Thesis Title: “Architectural Comparison Study for RF and Microwave CMOS Voltage-Controlled Oscillators”
Completion Date: August 2007
- Cheng-Kuan Lu
M.S. Thesis Title: “Wireless MEMS Accelerometer for Real-time Small Laboratory Animal Activity Monitoring”
Completion Date: July 2007
- Steven Mallin
M.S. Thesis Title: “Phase Noise Processes and Suppression Techniques in RF LC Voltage-Controlled Oscillators”
Completion Date: May 2006

- Nattapon Chaimanonart
M.S. Thesis Title: “Remote Radio-Frequency Powering System for Wireless MEMS Strain Sensor”
Completion Date: January 2006
- Jiangang Du
M.S. Thesis Title: “Single Crystal Silicon Carbide Capacitive Pressure Transducer”
Completion Date: May 2005
- Run Wang
M.S. Thesis Title: “Silicon-Carbide-MESFET-Based 400 °C MEMS Sensing and Data Telemetry”
Completion Date: August 2004
- Michael Suster
M.S. Thesis Title: “High-Temperature MEMS Wireless Sensing and Telemetry”
Completion Date: August 2004
- Brian Quach
M.S. Thesis Title: “Micromachined Touch Mode Tunable Capacitor Design and Fabrication for RF Communication Applications”
Completion Date: August 2003

Teaching and Courses Development:

- ECE 4900 Senior Clinic Project (Undergraduate Course)
- ECE 6720 Analog Integrated Circuit Design (Graduate Course)
- ECE 6722 Analog Integrated Circuit Testing (Graduate Course)
- ECE 6226 Electrical Interface for MEMS (Graduate Course)
- ECE 6730 Radio Frequency Integrated Circuits Design (Graduate Course)
- ECE 2280 Fundamentals of Engineering Electronics (Undergraduate Course)
- ECE 3110 Electronic Circuits-II (Undergraduate Course)
- EECS 426 MEMS for Sensing and Communication (Graduate Course)
- EECS 600 Radio-Frequency Integrated Circuits Design (Graduate Course)
- EBME 418 Applied Electronics for Biomedical Engineering (Selected Lectures, Graduate Course in BME)

- EECS 344 Microelectronic Design and Analysis (Undergraduate Course)
- EECS 245 Electronic Circuits (Undergraduate Course)
- ENRG 210 Introduction to Circuits and Instruments (Undergraduate Course)