

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,508,122 B1

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 IPR2024-00667
U.S. Patent No. 6,508,122 B1
Issue Date: January 21, 2003

Title: MICROELECTROMECHANICAL SYSTEM FOR MEASURING
ANGULAR RATE

DECLARATION OF DARRIN YOUNG, PH.D.

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I, Darrin Young, 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 3 of U.S. Patent No. 6,508,122 (“the ’122 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 ’122 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. 6,508,122 B1 (**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. 6,508,122 B1 to Hiram McCall, et al. (filed Sept. 15, 2000, issued Jan. 21, 2003) (“122” or “122 patent”)
1003	U.S. Patent No. 5,945,599 A to Motohiro Fujiyoshi, et al. (filed Dec. 12, 1997, issued Aug. 31, 1999) (“Fujiyoshi”)
1004	International Patent Publication No. WO 99/14,557 to Kevin Townsend (filed Sept. 17, 1998, published March 25, 1999) (“Townsend”)
1005	U.S. Patent No. 5,604,311 to Lalit Kumar, et al. (filed June 7, 1995, issued February 18, 1997) (“Kumar”)
1006	U.S. Patent No. 3,838,346 to Donald Clyde Cox (filed Nov. 1, 1973, issued Sept. 24, 1974) (“Cox”)
1007	Japanese Patent Application Publication No. 9[1997]-42973 (filed Aug. 1, 1995, published Feb. 14, 1997) (“Mitamura”)
1008	Excerpts from Shmuel Merhav, <i>Aerospace Sensor Systems and Applications</i> (1996)
1009	Certified English Translation of Exhibit 1007

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Exhibit No.	Description of Document
1010	Excerpts from Ljubisa Ristic (ed.), <i>Sensor Technology and Devices</i> (1994)
1011	Excerpts from J.M. Slater, <i>Inertial Guidance Sensors</i> (1964)
1012	Excerpts from Myron Kayton, <i>Avionics Navigation Systems</i> (2d Ed. 1997)
1013	Excerpts from David Irwin, <i>The Industrial Electronics Handbook</i> (1997)
1014	Excerpts from Anthony Lawrence, <i>Modern Inertial Technology</i> (1993)
1015	Excerpts from Connie L. McClure, <i>Theory of Inertial Guidance</i> (1960)
1016	Declaration of Ingrid Hsieh-Yee, Ph.D. (with exhibits)
1017	Proof of Service of Summons and Complaint, ECF No. 10, dated March 8, 2023, filed in <i>American GNC Corp. v. Nintendo Co., Ltd., et al</i> , Case No. 2:23-cv-00302-TL (W.D. Wash.)
1018	Patent Owner's Opening Claim Construction Brief, ECF No. 55, dated March 2, 2021, filed in <i>American GNC Corp. v. OnePlus Tech. (Shenzhen) Co., Ltd.</i> , Case No. 6:20-cv-00171-ADA (W.D. Tex.)
1019	Patent Owner's Reply Claim Construction Brief, ECF No. 57, dated April 6, 2021, filed in <i>American GNC Corp. v. OnePlus Tech. (Shenzhen) Co., Ltd.</i> , No. 6:20-cv-00171-ADA (W.D. Tex.)
1020	Patent Owner's Opening Claim Construction Brief, ECF No. 92, dated January 30, 2018, filed in <i>American GNC Corp. v. LG Electronics Inc., et al</i> , No. 3:17-CV-1090-BAS-BLM (S.D. Cal.)
1021	Patent Owner's Responsive Claim Construction Brief, ECF No. 97, dated February 13, 2018, filed in <i>American GNC Corp. v. LG Electronics Inc., et al</i> , No. 3:17-CV-1090-BAS-BLM (S.D. Cal.)

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Exhibit No.	Description of Document
1022	Patent Owner’s Opening Claim Construction Brief, ECF No. 111, dated February 21, 2018, filed in <i>American GNC Corp. v. ZTE (USA) Inc., et al</i> , Case No. 4:17-cv-00620-ALM-KPJ (E.D. Tex.)
1023	Patent Owner’s Reply Claim Construction Brief, ECF No. 122, dated March 14, 2018, filed in <i>American GNC Corp. v. ZTE (USA) Inc., et al</i> , No. 4:17-cv-00620-ALM-KPJ (E.D. Tex.)
1024	File history for U.S. Patent No. 6,508,122 B1
1025	Additional pages from Shmuel Merhav, <i>Aerospace Sensor Systems and Applications</i> (1996) (not included with EX1008)
1026	Petitioner’s Preliminary Claim Constructions and Extrinsic Evidence, dated January 29, 2024, in <i>American GNC Corp. v. Nintendo Co., Ltd.</i> , No. 2:23-cv-00302-TL (W.D. Wash.)

II. PERSON OF ORDINARY SKILL IN THE ART

12. I understand that, under the patent laws in effect before the America 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 September 16, 1999, the priority date AGNC is asserting in the district

court litigation.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 implementing systems that include sensors for measuring movement, such as acceleration and rotational position. The ’122 patent specification confirms that various types of angular rate sensors, including “ring laser gyros and Interferometric Fiber-Optic Gyros,” were well-known prior to the alleged invention. (’122, 1:23-32.) A person could also have qualified as a person of ordinary skill in the art

¹ I understand that in the pending litigation, the Patent Owner has claimed that the ’122 patent is entitled to an invention date of May 1999. I express no opinion on whether the ’122 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 ’122 patent was prior to September 16, 1999, such as an earlier date in 1999.

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 '122 patent have been based on the perspective of a person of ordinary skill in the art as of September 1999.

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.

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 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

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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 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 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

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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:

- (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;

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- (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. TECHNOLOGY BACKGROUND

33. A POSITA would have understood the concept of *navigation* as the determination of the position and velocity of a moving device. (Kayton at 1.) A POSITA would have also understood the concept of *deduced reckoning* (otherwise known as “dead reckoning”). (Lawrence at 4-5.) A POSITA would have understood that deduced reckoning refers to the process of determining the starting point of an object and tracking its motion for a known time to determine its new position relative to the initial position. (*Id.*; Kayton at 2-3)

34. A POSITA would have understood the concept of an *inertial sensor*. An inertial sensor is a sensor that uses the inertial properties of matter (or of light) for their operation. (Lawrence at 6, 8.) A POSITA would have further understood that *inertial navigation* is performing dead reckoning using inertial sensors. (*Id.*) In particular, it would have been obvious to a POSITA that an inertial navigation system determines a moving vehicle’s position and velocity by measuring its acceleration. (Kayton at 313.)

35. A POSITA would have understood that sensors, in general, are

composed of three elements: 1) the sensitive component, 2) the force balancing component, and 3) the output. (Merhav (**EX1025**) at 6.) The sensitive component “translat[es] a change in the measured physical variable . . . into another readily measurable quantity, such as a linear or rotational displacement, a voltage, or a current.” (*Id.* at 8.)

36. A POSITA would have understood the concept of “pickoff.” A pickoff is an output device that represents a displacement in the sensitive element of the sensor. (Merhav at 8.)

37. A POSITA would have understood that an *inertial measurement unit* (IMU) uses a set of gyroscopes and accelerometers that can measure angular rate and acceleration of a moving vehicle, respectively. (Kayton at 313, 324; Lawrence at 6, 8). A POSITA also would have understood that an accelerometer is a device that measures the force required to accelerate a proof mass; thus, it measures the acceleration of the vehicle containing the accelerometer. (Kayton at 317.)

38. A POSITA would have been familiar with the concept of a micro-machined (silicon) accelerometer and a flexure-pivot accelerometer, commonly used in aircrafts. (Kayton at 319.) A POSITA would have understood that a flexure-pivot accelerometer is composed of three elements of a sensor: 1) pendulum with a torque coil and a pickoff supported by a flexure as the sensitive element; 2) the torque or

coils as the force balancing component that restores the pendulum to null, thus measuring the acceleration, and 3) the pickoff measuring the displacement of the pendulum from null. (*Id.*; *see also* Merhav at 35-36; McClure at 120-21.)

39. A POSITA would have been familiar with the concept of *dither* in attempting to solve the problem of “lock-in” of low frequency gyros. A POSITA would have understood that a dither is a sinusoidal motion that is externally applied to the gyro. (Kayton at 330-31.)

V. THE '122 PATENT

A. Overview of the Specification

40. The '122 patent indicates that “[t]he present invention relates to a microelectromechanical system (MEMS), more particularly, relates to a microelectromechanical system (MEMS) to measure angular rate of a carrier.” ('122, 1:14-17.)

1. Disclosed Prior Art

41. The '122 patent discloses that “[v]arious 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.” ('122, 1:57-60.) The '122 patent provides examples of “[s]ingle input axis MEMS angular rate sensors,” which are based on either (1) “translational resonance, such as tuning forks” or (2) “structural mode resonance, such as vibrating rings.” (*Id.*,

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1:60-63.) Further, the '122 patent indicates that “dual input axis MEMS angular rate sensors may be based on angular resonance of a rotating rigid rotor suspended by torsional springs.” (*Id.*, 1:63-65.)

42. MEMS “is a very well developed technology” according to the '122 patent. ('122, 1:46-47.) “Example MEMS devices include inkjet-printer cartridges, accelerometers that deploy car airbags, and miniature robots.” (*Id.*, 1:43-45.) The “integrated circuit industry” has developed “process technology” for micromachining to “fabricate tiny sensors and actuators on silicon chips.” (*Id.*, 1:48-50.) This process “shrink[s] the sensor size by several orders of magnitude” and allows for “integrated electronics” to be added to a chip, “creating an entire system on a chip.” (*Id.*, 1:50-53.) Such technology “will result in, not only the redesign of conventional military products, but also new commercial applications that could not have existed without small, inexpensive inertial sensors.” (*Id.*, 1:53-56.)

43. The '122 patent also discloses that many conventional angular rate sensor designs exist. The '122 patent discloses that a “conventional gyro” can measure angular rate. ('122, 1:23-24.) “Many types of approaches based on various sensing principles used to achieve an angular rate sensor have been invented”—and the '122 patent discloses that more will be invented “as the market for angular rate sensors continues to expand.” (*Id.*, 1:24-28.) The '122 patent discloses that

“[c]onventional angular rate sensors have been commonly used in a wide variety of applications.” (*Id.*, 1:33-34.) Two examples of existing approaches to angular rate measurement that the ’122 patent provides are “conventional spinning mass gyros . . . based principally on the Law of the Gyroscope” and “ring laser gyros and Interferometric Fiber-Optic Gyros [] dependant [sic] on the Sagnac Effects.” (*Id.*, 1:28-32.) The ’122 patent discloses that such “conventional angular rate sensors” are limited by “cost, size, and power.” (*Id.*, 1:34-36.)

2. Disclosure of Embodiments

44. Referring to Figure 1, the ’122 patent discloses that “the system of the present invention includes an angular rate sensor unit **10**, a central circuitry **20**, and a digital signal processing system **30**, which are fabricated into one chip[.]” (’122, 4:25-29.) Figure 1 is reproduced below:

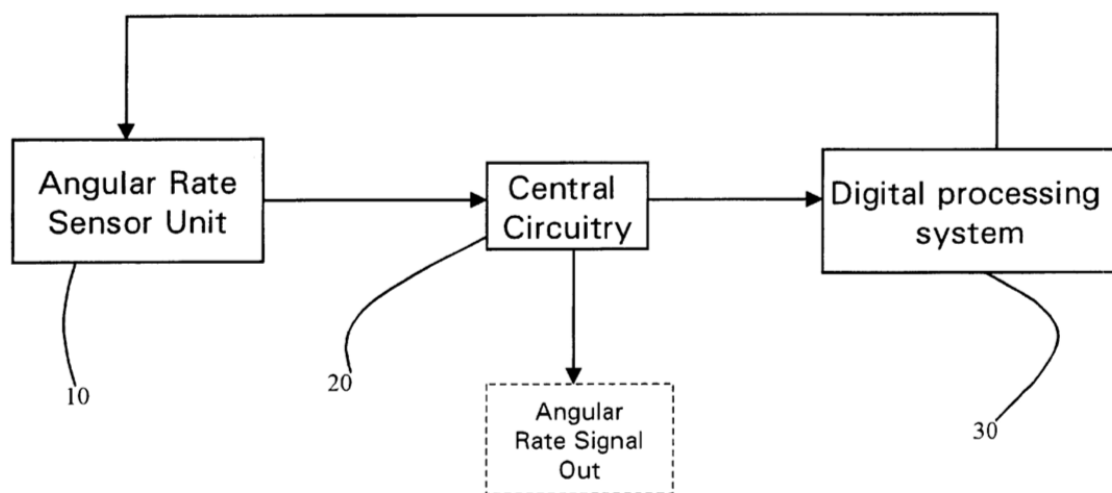


Figure 1

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(*Id.*, Fig. 1.) The '122 patent discloses that the angular rate sensor unit “can be a micromachined sensor unit.” (*Id.*, 4:49-50.) Further, the '122 patent discloses that the system can “incorporate with MEMS technology that employs a dynamic theory, Coriolis effect” using a “tuning fork that uses closed-loop capacitive sensing,” where “[t]he Coriolis effect can be seen that when [sic] an angular rate is applied to a translating body and a Coriolis force is generated.” (*Id.*, 4:50-56.) Angular rate is measured “by picking-off a signal generated by an oscillating micromachined mass as it deviates from its plane of oscillation under the Coriolis force effect when the oscillating micromachined mass is submitted to a rotation about an axis perpendicular to the plane of oscillation.” (*Id.*, 4:57-62.)

45. Figure 2 of the '122 patent, reproduced below, “illustrates the configuration of the micromachined sensor unit.” ('122 patent, 4:63-64.)

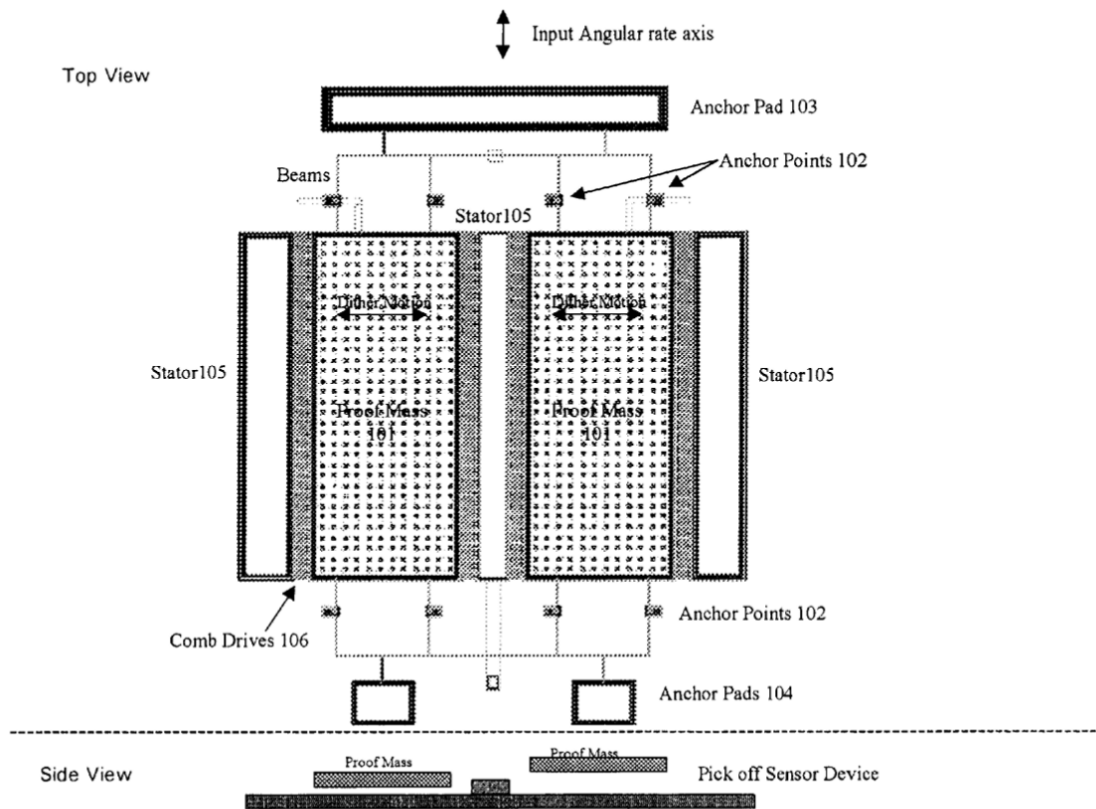


Figure 2

(*Id.*, Fig. 2.) Two proof masses **101** are shown. (*Id.*, 5:50-52.) The '122 patent describes their operation as follows:

The vibrating (dither) proof masses are driven in opposite directions by electrostatic comb drive motors to maintain lateral in-plane oscillation. The dither motion is in the plane of the wafer. When an angular rate is applied to the MEMS device about the input axis (which is in the plane of the tines), the proof masses are caused to oscillate out of plane by a Coriolis force due to the Coriolis effect. The resulting out-of-plane up and down oscillation motion amplitude, proportional to the input angular rate, is detected and measured by capacitive pickoff plates

underneath the proof masses. The comb drives move the masses out of phase with respect to each other. The masses will then respond in opposite directions to the Coriolis [sic] force.

(*Id.*, 5:7-20.) The displacement of the proof masses due to the Coriolis force is measured via a change in capacitance, which is “determined by measuring the current flow from a high frequency signal[.]” (*Id.*, 5:34-37.) “Two capacitors are formed by two pair of proof masses and sensor electrodes,” such that when a proof mass moves, the capacitance changes. (*Id.*, 6:8-14.)

46. Figure 6—reproduced below—shows a block diagram of the '122 patent system, including central circuitry **20** that “comprises a dither motion control circuitry **21** and an angle signal loop circuitry **22**.” ('122, 7:61-63.)

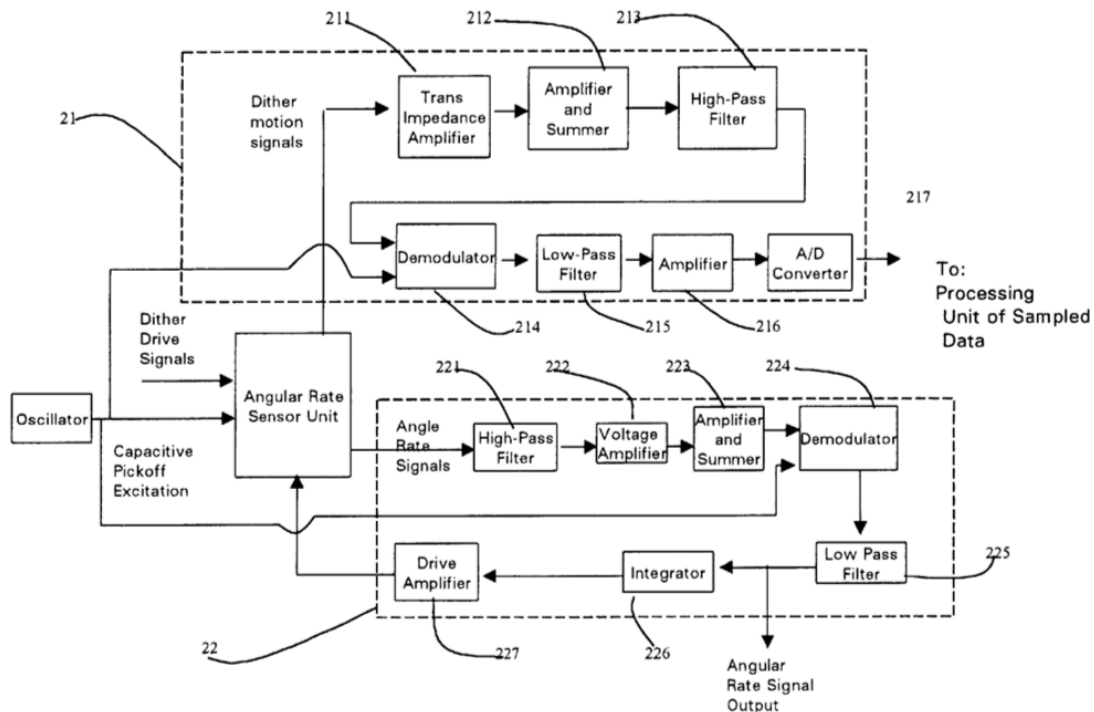


Figure 6

(*Id.*, Fig. 6.) The angular rate sensor unit is shown outputting dither motion signals to the dither motion control circuitry **21**, which includes a low-pass filter **215** that “remov[es] high frequency noise from the inertial element displacement signal input to form a low frequency inertial element displacement signal with bandwidth less than 3000 Hz[.]” (*Id.*, 8:27-31.) “Analog/digital converter **217**” at the output of dither motion control circuitry **21** “convert[s] the low frequency inertial element displacement signal that is an analog signal to produce a digitized low frequency inertial element displacement signal as a digital sampled signal.” (*Id.*, 8:35-39.)

47. Angle rate signal loop circuitry **22** is shown in Figure 6 to receive angle rate signals, which are processed and form an “angular rate signal” at the output of

low-pass filter **225**. ('122, 8:61-64.) The angle rate signal loop circuitry **22** also outputs a “displacement restoring signal,” shown in Figure 6 at the output of module **226**. (*Id.*, 8:65-9:4.)

48. Figure 7 of the '122 patent, which is reproduced below, shows digital signal processing system **30**, which receives digital low frequency inertial element displacement from the dither motion control circuitry **21** and outputs dither driver signals to the angular rate sensor unit. ('122, 9:7-12, 9:34-37.)

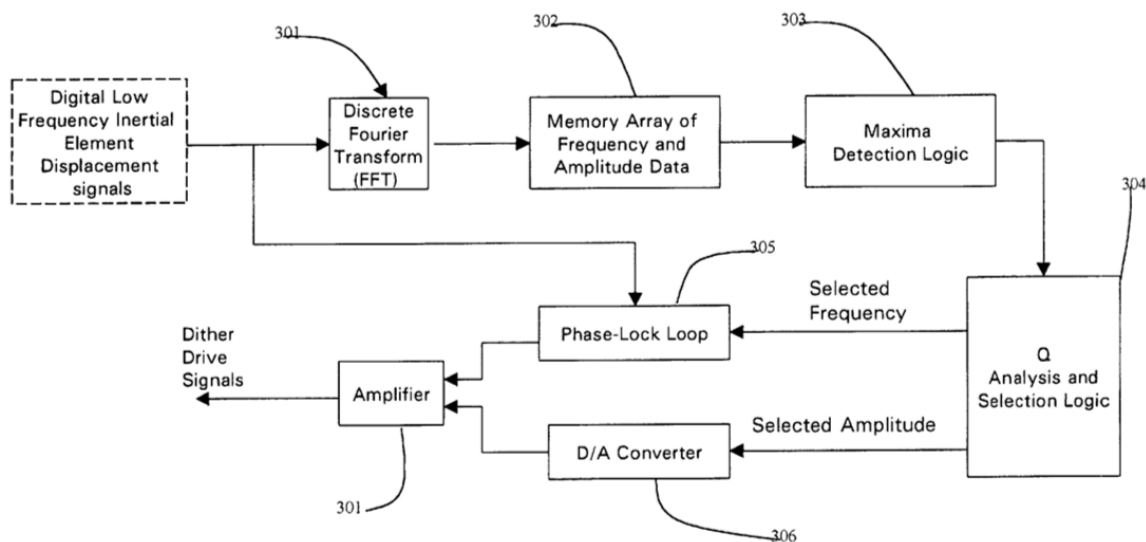


Figure 7

(*Id.*, Fig. 7.)

B. The Challenged Claims

49. This Declaration addresses claims 1 and 3 of the '122 patent. Independent claim 1 is representative and recites:

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,508,122 B1

1. A microelectromechanical system (MEMS) for measuring angular rate of a carrier, comprising:
 - [a] an angular rate sensor unit receiving dither driver signals, capacitive pickoff excitation signals and a displacement restoring signal and outputting angle rate signals in response to motion of said carrier and dither motion signals;
 - [b] a central circuitry receiving said angle rate signals in response to said motion of said carrier and said dither motion signals and outputting angular rate signals and digital low frequency inertial element displacement signals; and
 - [c] a digital signal processing system analyzing said digital low frequency inertial element displacement signals and feeding back said dither driver signals to said angular rate sensor unit.

(’122, 9:39-55 (Claim 1; bracketed notation (e.g., [a]) added).)

50. Claim 3 recites:

The microelectromechanical system, as recited in claim 1, wherein said central circuitry comprises a dither motion control circuitry and an angle rate signal loop circuitry.

(’122, 10:13-15 (Claim 3).)

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

VI. APPLICATION OF THE PRIOR ART TO CHALLENGED CLAIMS

52. I have reviewed and analyzed the prior art references and materials listed in **Part I.B** above. In my opinion the claims of the '122 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 and 3	Fujiyoshi and Townsend and/or Cox and Kumar
2	1 and 3	Mitamura and Townsend

53. 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 '122 patent claims priority (September 1999).

A. Brief Summary and Overview of the Prior Art

1. Fujiyoshi (EX1003)

54. Fujiyoshi (U.S. Patent No. 5,945,599; filed December 12, 1997; granted August 31, 1999) relates to “an angular velocity sensor for detecting an angular velocity acting on a vehicle such as an automobile, airplane, or an electronic equipment.” (Fujiyoshi, 1:7-9.) “More particularly, the present invention relates to a resonance type angular velocity sensor which excites a mass portion corresponding

to an inertia mass, and detects an angular velocity on the basis of a displacement of the mass portion due to a Coriolis force generated in a direction perpendicular to both directions of an exciting direction of the mass portion and a rotating axis direction of the angular velocity sensor.” (*Id.*, 1:9-16.)

(a) Description of prior art

55. In describing the prior art, Fujiyoshi discloses a “resonance type vibrating component” for a “conventional angular velocity sensor” manufactured by “micro machining techniques” shown in Figures 1A, 1B, and 1C:

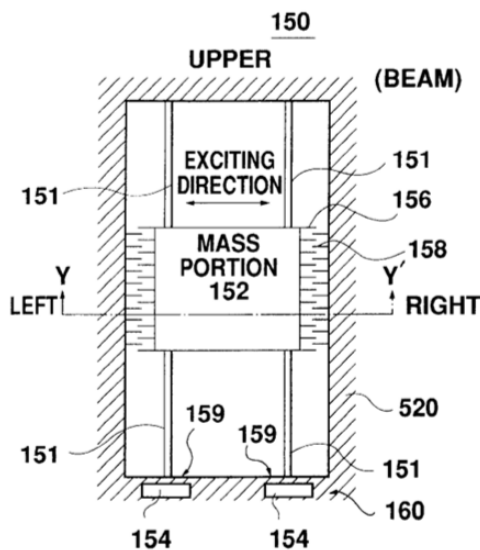


**Fig. 1A
PRIOR ART**

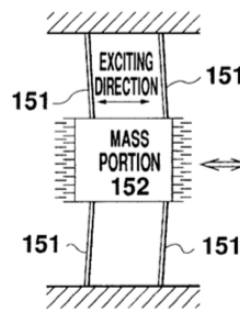


**Fig. 1B
PRIOR ART**

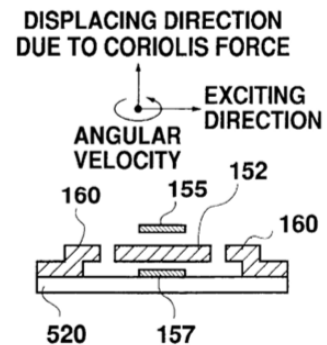


**Fig. 1C
PRIOR ART**

(Fujiyoshi, Figs. 1A-C, 1:18-20, 3:5-8, 2:11-13 (describing manufacture via “a semiconductor process technique for fine processing”), 3:3-13.) This component

includes a “vibrating component **150**,” which has a “mass portion **152** corresponding to an inertia mass” and is supported by “two beams **151** having an end fixed to a frame portion **160** of a silicon substrate **520**.” (*Id.*, 1:20-24.) “Comb electrodes” **156** and **158** are connected to an “exciting conductive layer” (not shown in Figure 1A-C) that provides alternating voltage, generating an electrostatic force that causes the mass portion **152** to vibrate in the lateral direction shown in Figure 1B. (*Id.*, 1:24:36.) While mass portion **152** vibrates, angular velocity of the system causes Coriolis force generated in a direction perpendicular to the side-to-side motion of the mass portion **152** and the rotating axis direction, causing the mass portion **152** to displace (e.g., upward in Figure 1C). (*Id.*, 1:38-45.) This displacement is measured via detecting electrodes **155** and **157** “by, for example, a capacity detecting method or the like”—generating signals “in response to a magnitude of an amplitude of a vibration of the mass portion **152** due to the Coriolis force[.]” (*Id.*, 1:52-59.)

56. Fujiyoshi describes certain limitations with the beams used to support the vibrating mass portion in a conventional angular velocity sensor as shown in Figures 1A-C. (Fujiyoshi, 1:60-3:18.)

(b) Description of embodiments

(1) Embodiment 1

57. Figure 3 shows an angular velocity sensor in accordance with

Fujiyoshi's "embodiment 1." (Fujiyoshi, 11:51-56.) This sensor is "a fine angular velocity sensor manufactured using a micro machine technology for silicon." (*Id.*, 11:57-59; *see also id.*, Figs. 6A-E, 13:57-14:40.) Figure 3 is reproduced below:

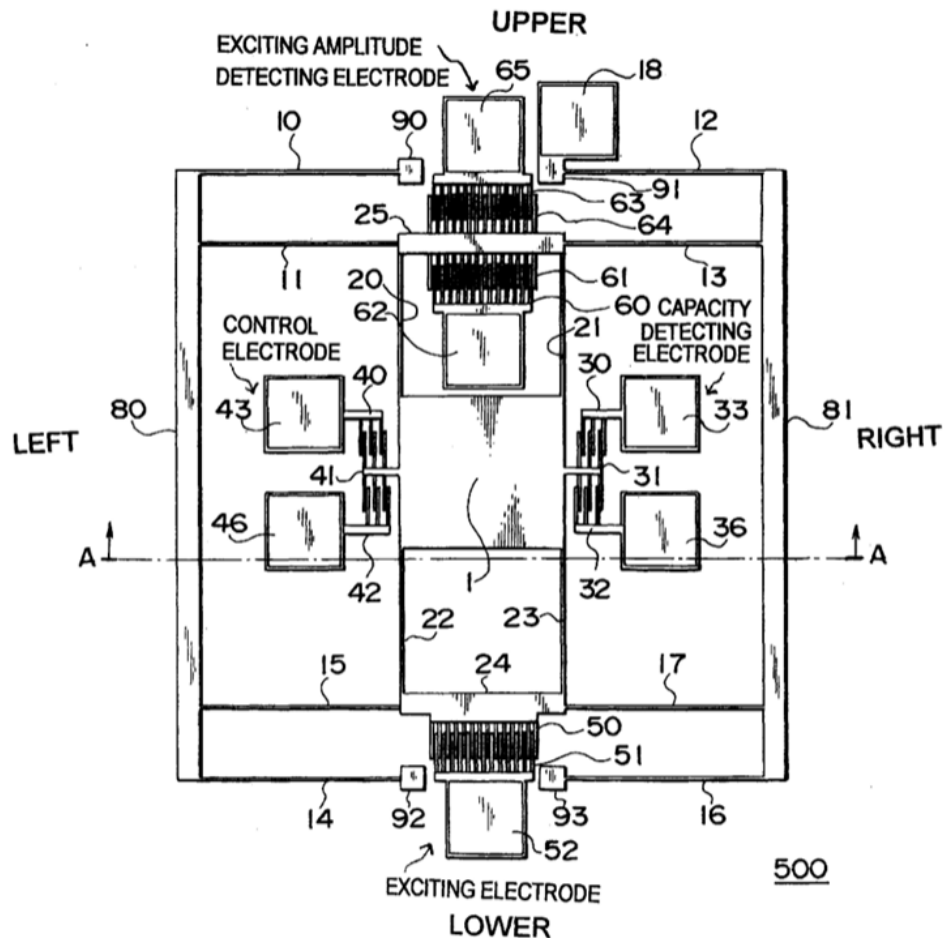


Fig. 3

(*Id.*, Fig. 3.)

58. Figure 3 shows angular velocity sensor **500**, which includes proof mass **1**. (Fujiyoshi, 11:59-62.) An alternating voltage is applied to comb exciting

electrode **51** and comb electrode **50**, causing an electrostatic force that vibrates mass portion **1** up and down vertically from the perspective shown in Figure 3. (*Id.*, 12:29-44.)

59. Comb detecting electrodes **60** and **63** detect an amplitude of the vertical vibration of mass portion **1** based on a change in the capacitance between comb electrodes **61** and **64** and comb detecting electrodes **60** and **63**, respectively. (Fujiyoshi, 12:45-64.)

60. When the Figure 3 sensor undergoes angular velocity, the mass portion **1** moves horizontally (from the perspective shown in Figure 3) due to the Coriolis force. (Fujiyoshi, 12:65-13:5.) Capacity detecting electrodes **30** and **32** detect the displacement caused by the Coriolis force based on the differential output of the changing capacitance of capacitors formed by electrodes **30** and **32** and projecting electrode **31**. (*Id.*, 13:9-13, 13:25-30.)

61. An alternating voltage is applied through control electrodes **40** and **42**, which creates an electrostatic force between electrodes **40** and **42** and projecting electrode **41** that causes the detected displacement of mass portion **1** due to the Coriolis force to be zero. (Fujiyoshi, 13:13-21.) The displacement amount of mass portion **1** is calculated based on the control amount necessary for making the displacement of the mass portion **1** zero. (*Id.*, 13:21-24.) “[T]he feedback loop is

formed so that the motion of the mass portion **1** is restricted to the adjacent portion of the zero point.” (*Id.*, 16:33-36.)

(a) Embodiment 2

62. Fujiyoshi’s “embodiment 2” is shown in Figure 8, reproduced below. (Fujiyoshi, 17:34-43.) The second embodiment of Fujiyoshi is substantially the same as the first embodiment discussed above. (*Id.*, 17:45-49.) The main difference between the two embodiments is Fujiyoshi’s second embodiment enables adjusting the frequency difference between the exciting frequency of the mass portion **1** and the vibrating frequency in the Coriolis force detecting direction via additional electrodes **70-77** incorporated into Fujiyoshi’s first embodiment. (*Id.*, 17:35-49, 18:63-19:9.)

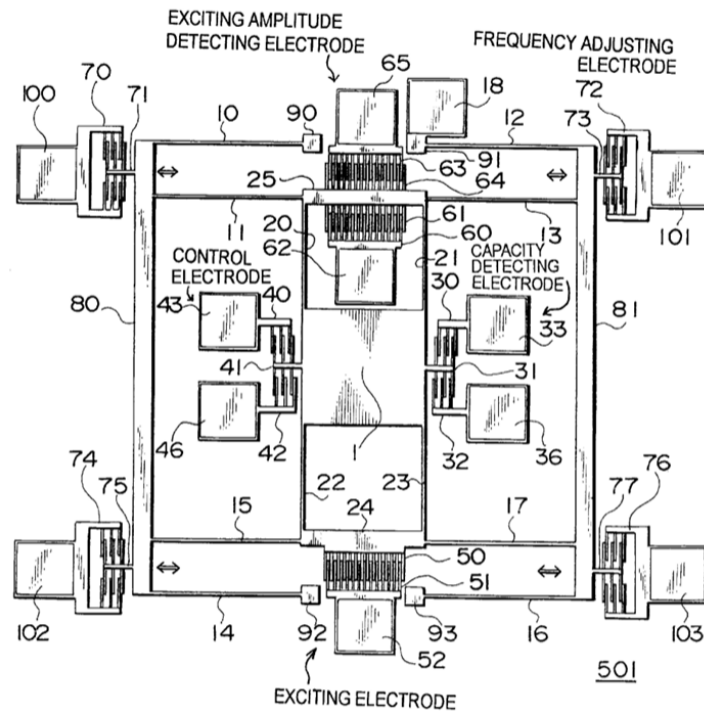
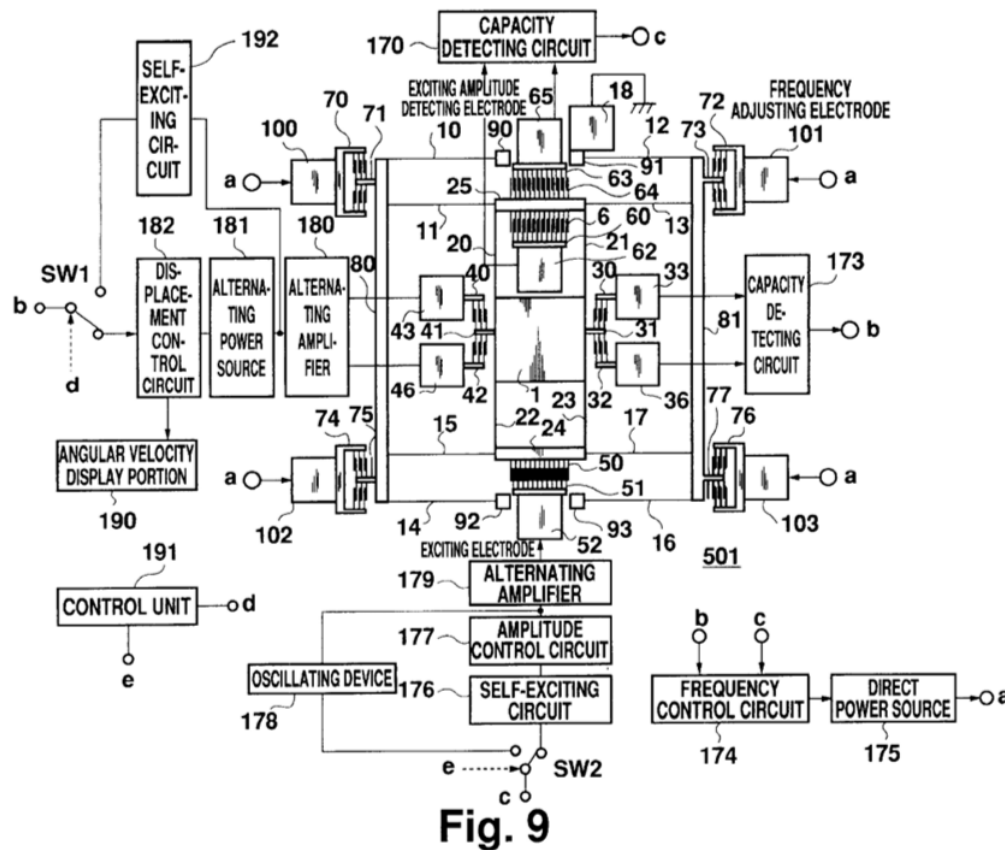


Fig. 8

(*Id.*, Fig. 8.)

63. A circuit structure for Fujiyoshi's second embodiment is shown in Figure 9, reproduced below:



(Fujiyoshi, Fig. 9, 19:55-58.)

64. In Fujiyoshi's Figure 9 circuit, an alternating voltage is supplied through self-exciting circuit **176**, amplitude control circuit **177**, and alternating amplifier **179** to exciting electrode **51**, such that mass portion **1** is vibrated in the "exciting direction"—i.e., vertically up and down from the perspective of Figure 9. (Fujiyoshi, 19:63-67.) The vibration of the mass portion is detected by capacity detecting circuit **170** via exciting amplitude detecting electrodes **60** and **63**. (*Id.*, 19:67-20:4.) Capacity detecting circuit **170** then outputs signals to self-exciting circuit **176** (through node "c" in Figure 9), "which generates a self-exciting signal

on the basis of the above detected output and further the amplitude control circuit **177** controls in such a manner as to make the amplitude of the vibration constant on the basis of the excitation control signal.” (*Id.*, 20:4-8.) Thus, a “feedback loop is formed in such a manner that the mass portion **1** always vibrates to the exciting direction with an appropriate frequency and an appropriate amplitude.” (*Id.*, 20:8-11.)

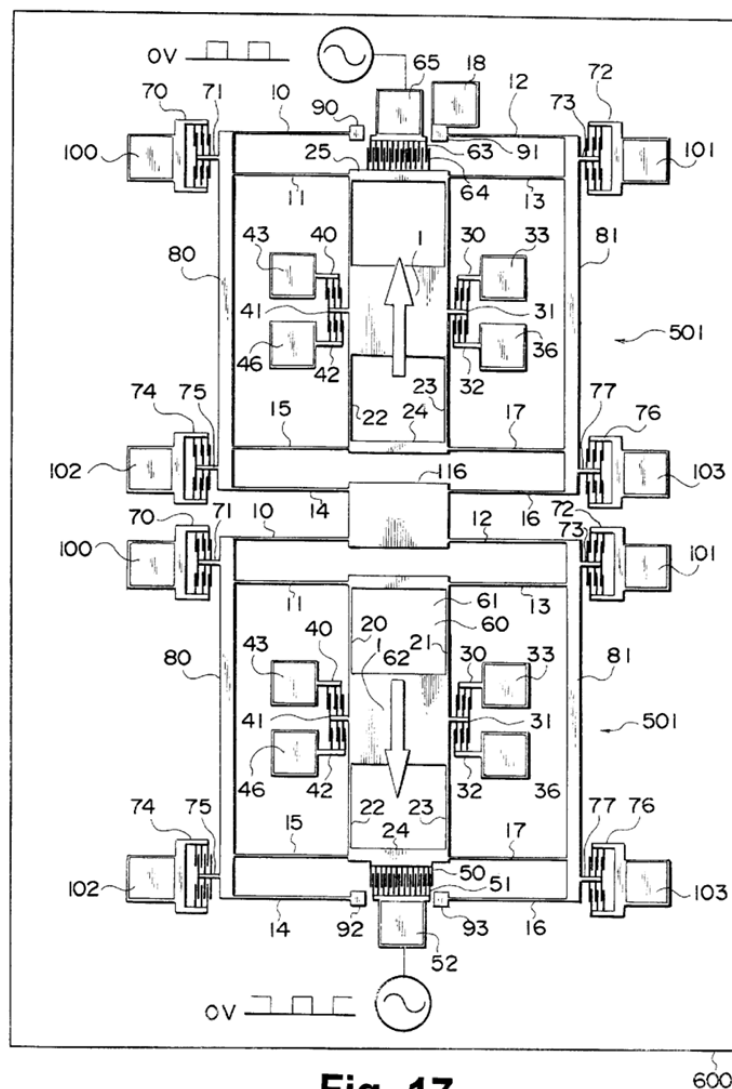
65. Further, when the mass portion **1** displaces in the “detecting direction” due to the Coriolis force caused by angular velocity, this vibration is detected by capacity detecting circuit **173** through capacity detecting electrodes **30** and **32** as a change in capacitance. (Fujiyoshi, 20:12-19.) Capacity detecting circuit **173** provides an output to displacement control circuit **182** (through node “b” in Figure 9), which “controls the alternating power source **181** in such a manner as to make the displacement of the mass portion **1** zero on the basis of the detected output, so that the corresponding control voltage is applied to the control electrodes **40** and **42** through the alternating amplifier **180**.” (*Id.*, 20:20-27.)

66. Fujiyoshi discloses that the displacement control circuit **182** also “determines the Coriolis force acting on the mass portion **1** on the basis of the control signal necessary for making the displacement of the mass portion **1** zero, and is then able to calculate the corresponding angular velocity,” which is output to the angular

velocity display portion **190** for display. (Fujiyoshi, 20:28-34.)

(b) Embodiment 7

67. Fujiyoshi's seventh embodiment—shown in Figure 17, reproduced below—discloses the use of two angular velocity sensors **501** as shown in Fujiyoshi's second embodiment (discussed above), which are connected via connecting portion **116** and “disposed within one package.” (Fujiyoshi, 24:33-42.)



(*Id.*, Fig. 17.) In the respective mass portions **1** of the two angular velocity sensors **501**, “the exciting vibration thereof is excited in a state that the phases thereof are shifted 180 degrees.” (*Id.*, 24:42-44.) Accordingly, “the Coriolis force generated by the angular velocity acts on the two mass portions **1** in the inverted direction to each other.” (*Id.*, 24:47-50.) However, any applied acceleration causes the two mass portions **1** to displace in the *same* direction. (*Id.*, 24:52-54.) If the difference of the output from the two angular velocity sensors **501** is taken, the displacement caused by acceleration is subtracted out and only the displacement caused by angular velocity remains. (*Id.*, 24:54-57.)

68. A POSITA would recognize the circuit in Fujiyoshi’s seventh embodiment to be a differential configuration. In addition to being able to separate angular rate from acceleration, Fujiyoshi discloses that in this differential configuration, “little energy of the vibration leaks outward,” so “vibration Q value” is improved, leading to a sensor with a “high sensibility.” (Fujiyoshi, 24:58-63.)

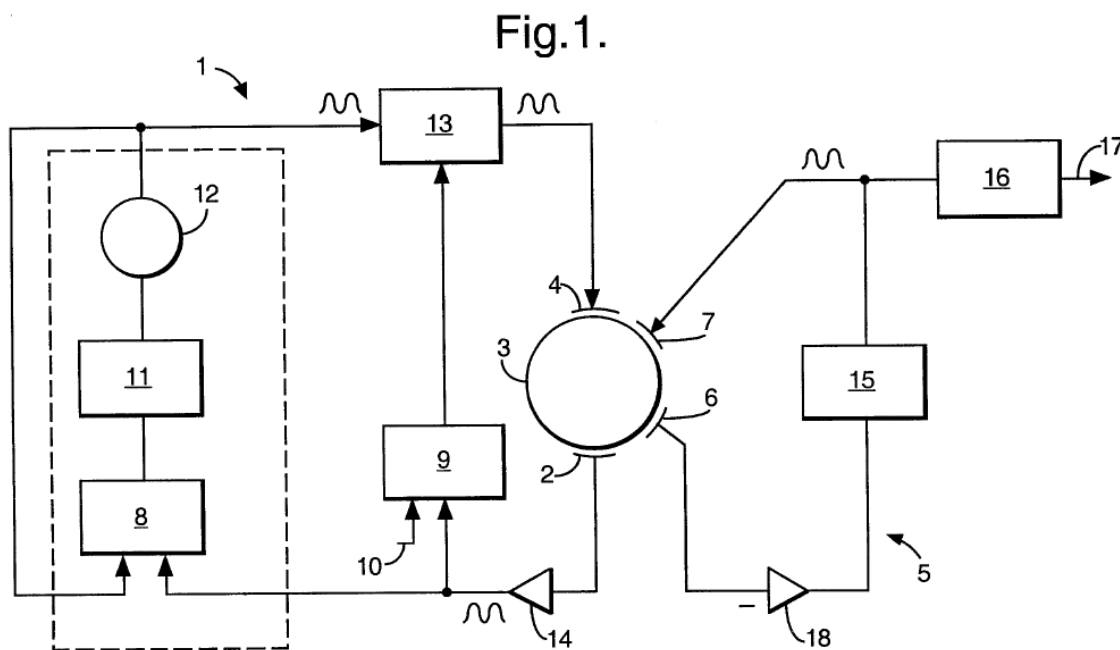
2. Townsend (EX1004)

69. Townsend (International Publication Number WO 99/14,557; filed September 17, 1998; published March 25, 1999) discloses “a digital control system for a vibrating structure gyroscope of the kind having a vibrating structure, primary and secondary drive means for putting and maintaining the vibrating structure in

vibratory resonance and primary and secondary pick-off means for detecting vibration of the vibrating structure.” (Townsend at 1.)

70. Townsend discloses that “known vibrating structure gyroscopes” include “beams, tuning forks, cylinders, hemispherical shells and rings.” (Townsend at 1.) “A common feature in all these known systems is that they are required to maintain a resonance carrier mode oscillation at a natural frequency determined by the mechanical vibratory structure” to “provide[] the linear momentum which produces Coriolis force when the gyro is rotated around the appropriate axis.” (*Id.*)

71. Townsend discloses an example of a “typical conventional analogue closed loop control system for a shell like vibrating structure 3,” as shown in Figure 1, which is reproduced below:



(Townsend, Fig. 1; *id.* at 1.)

72. The prior art system consists of two “ideally independent” control loops. (*Id.* at 1-2.) First, the “primary or excitation loop 1” is “between a primary pick-off means 2 which acts as a motion detector output from the vibrating structure 3, and a primary drive means 4 which acts as a forcing input creating vibration in the structure 3.” (*Id.*) “The primary loop 1 is required to excite the vibrating structure 3 at its natural resonant frequency . . . and to control the amplitude of the resultant signal at the primary pick off means 2 which in effect is the amplitude of the resultant vibration” using “a reference level 10[.]” (*Id.* at 2.) The primary loop 1 includes “filter 11, a voltage controlled oscillator (VCO) 12, a gain control 13 and an amplifier 14.” (*Id.* at 3.)

73. Second, “[a] secondary or damping loop 5 is provided between secondary pick off means 6 and a secondary drive means 7.” (Townsend at 2.) “The secondary loop 5 is shown in a typical force feedback configuration to provide damping for the high Q rate response in order to achieve the required system performance.” (*Id.*) The secondary loop includes “an amplifier 18, a filter 15, and a demodulator 16 from which issues a direct current output signal 17 proportional to the applied angular rate.” (*Id.* at 3-4.)

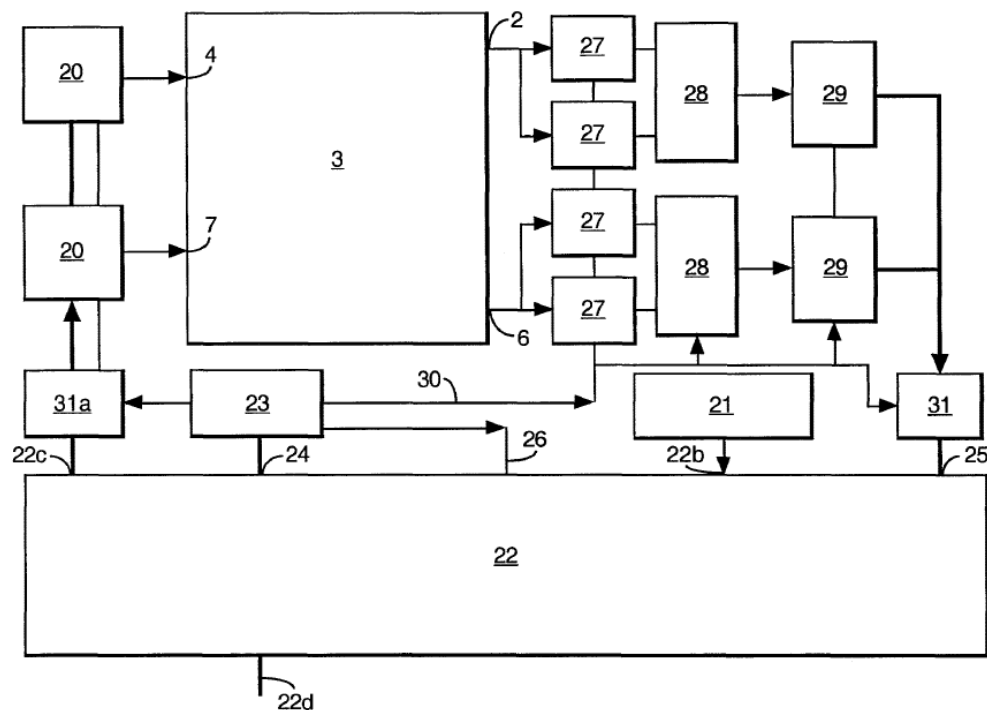
74. Townsend teaches that the conventional analog implementations of

control circuitry for prior art vibrating sensors have limitations. “[P]recision analogue electronic circuits” like those required for these sensors “are notoriously difficult to specify, design and integrate into small low cost systems (i.e. ASICS).” (Townsend at 3.) Further, Townsend teaches it is “difficult to apply calibrations and compensations to systems based on analogue circuits.” (*Id.*) Additionally, Townsend teaches that “modern systems require the sensor outputs to be available in digital format to simplify system integration and enable further compensations to be applied to enhance performance.” (*Id.*)

75. Given the limitations of analog implementations, Townsend teaches that “[t]here is . . . a need for a digital electronic based implementation of the loops 1 and 5 in order to facilitate ASIC development, system integration and provide a route to higher performance by enabling more complex and ‘in loop’ compensations to be applied.” (Townsend at 4.)

76. Figure 4 of Townsend depicts an embodiment of Townsend’s digital implementation of the control loops for vibrating structure gyroscopes. Figure 4 is reproduced below:

Fig.4.



(Townsend, Fig. 4.)

77. In Figure 4, vibrating structure **3** outputs signals from primary pickoff means **2** and secondary pickoff means **6**. (Townsend at 4, 10, 11.) These signals are output to sample and hold devices **27**. (*Id.* at 12.) These sample and hold devices “provide a high degree of noise rejection” by “averag[ing] or integrat[ing] the input waveform over the sample period.” (*Id.* at 18.) The signals from sample and hold devices **27** are output to multiplexers **28**, which “select the appropriate quarter sample for conversion” and outputs it to digital converters **29** to convert the analog signals to digital. (*Id.* at 12-13.) These signals are stored in buffer **31** and input to digital processing unit **22** via data input **25**. (*Id.* at 13.) Then, data is output from

the digital processing unit **22** via output **22c**, stored in buffer **31a**, and converted to analog signals via digital to analog converters **20**. (*Id.*) These signals are fed back into vibrating structure gyro **3** via primary drive means **4** (to drive vibration) and secondary drive means **7** (for damping). (*Id.* at 3.)

3. Kumar (EX1005)

78. Kumar (U.S. Patent No. 5,604,311; filed June 7, 1995; granted February 18, 1997) discloses embodiments of a Coriolis effect rotation rate sensor and method.

79. Kumar discloses a rotation sensor that “can be manufactured in bulk using inexpensive photolithographic techniques and that utilizes fewer individual components than prior rotation sensors.” (Kumar, 1:56-59.)

80. In a preferred embodiment, Kumar discloses “three members with substantially equal resonance frequencies are mechanically coupled to form an ‘I’-shaped structure.” (Kumar, 2:3-5.)

81. Kumar discloses a vibrating gyro system that has control loop circuitry for both the driven vibrating motion and sensing motion caused by the Coriolis force. (*See, e.g.*, Kumar, Fig. 2a, 3:50-4:45.)

82. Kumar senses such motion of an inertial element by measuring a capacitance change as the distance between a “central member” (the vibrating

inertial element) and a “pickoff electrode” that forms a “parallel plate capacitor” with the central member. (Kumar, 3:62-65.)

83. Kumar discloses that “[s]ince a DC bias voltage is present on the central member’s electrically conductive layer **47**, the varying capacitance,” due to the distance between the central member and the pickoff electrode changing, “causes a variation in the electrical signal” that gets output as a motion sensing signal. (*Id.*, 3:62-4:2, 4:19-25.)

84. Further, Kumar discloses that “other types [of] oscillation sensors may be employed, such as high frequency carrier signal capacitive pickoffs (which operate without a DC bias voltage).” (*Id.*, 6:29-34.)

85. An embodiment of Kumar’s rotation sensor is reproduced below:

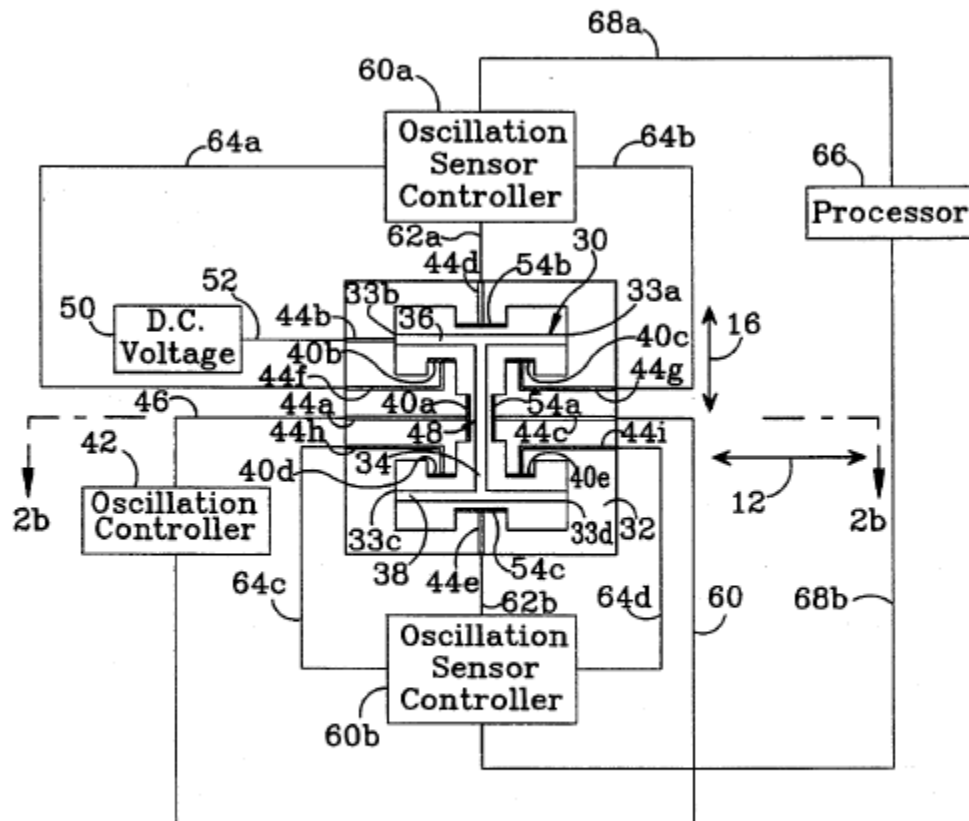


FIG. 2a

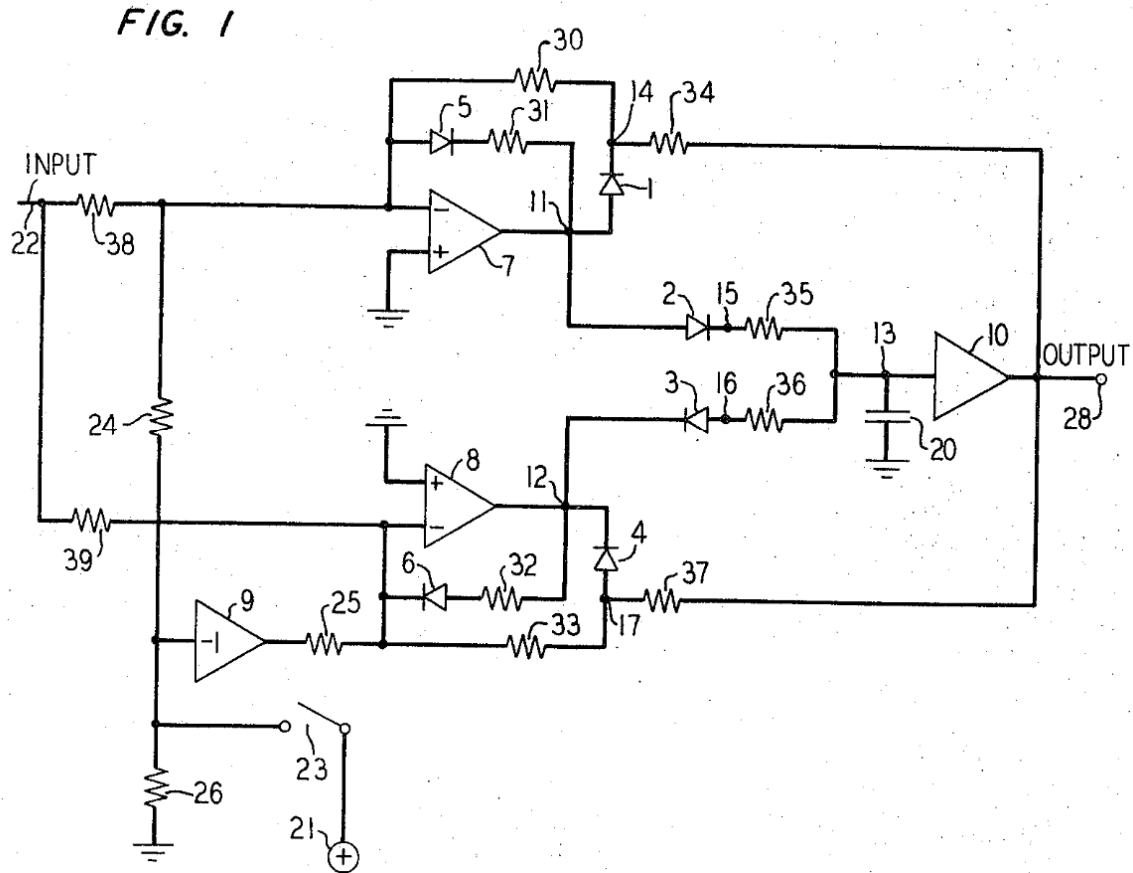
(Kumar, Fig. 2a.)

4. Cox (EX1006)

86. Cox (U.S. Patent No. 3,838,346; filed November 1, 1973; granted September 24, 1974) discloses a “sample and hold circuit” incorporating a low-pass filter via “a resistive arrangement in association with the holding capacitor.” (Cox, Abstract, 1:27-30, 3:50-4:8.).

87. Figure 1 below is a diagram of the sample and hold circuit disclosed by

Cox:



(Cox, Fig. 1.) In Cox’s circuit, the “current passes from node 11 through diodes 1 and 2 to node 13 and capacitor 20 tending to discharge capacitor 20, thereby making the voltage of capacitor 20 more positive and approaching zero.” (*Id.*, 2:41-45.) Once the voltage at node 13 has caught up to the voltage at node 11, “no current flows through diodes 1, 2, 3, or 4.” (*Id.*, 2:60-63.) As the signal continues to move, nodes 11 and 12 become slightly negative with respect to node 13. (*Id.*, 2:63-68.) Capacitor 20 tracks the voltage at node 12. (*Id.*, 3:1-3.) The capacitor 20 continues

to change polarity as the signal moves. (*Id.*, 3:4-7.)

88. In Cox’s circuit, resistors **35** and **36** and the holding capacitor **20** “are arranged to function as a low-pass RC filter.” (Cox, 3:50-52.) “These two resistors may be set equal to zero without interfering with either the tracking or the hold modes of operation.” (*Id.*, 3:52-54.)

89. Cox explains that “[w]hile filtering is not always necessary in conjunction with a sample and hold circuit, it is desirable for certain applications.” (*Id.*, 3:54-56.) Specifically, Cox explains that filtering is desirable in a “closed feedback loop of a phase-locked loop where the phase-locked loop is used as a bandpass filter” and is, in fact, “needed in analog-to-digital converters to restrict the bandwidth of a sampled input signal.” (Cox, 3:57-65.)

90. Finally, Cox teaches that it is “convenient to incorporate the RC low-pass filter into the sample and hold circuit”:

[T]he capacitor performs the two functions of holding the sampled signal and serving as a component of the RC low-pass filter. If low-pass filtering were not so incorporated, then separate provision would have to be made external to the sample and hold circuit for such filtering. The incorporation of low-pass filtering into the sample and hold circuit obviously minimizes the total number of components needed.

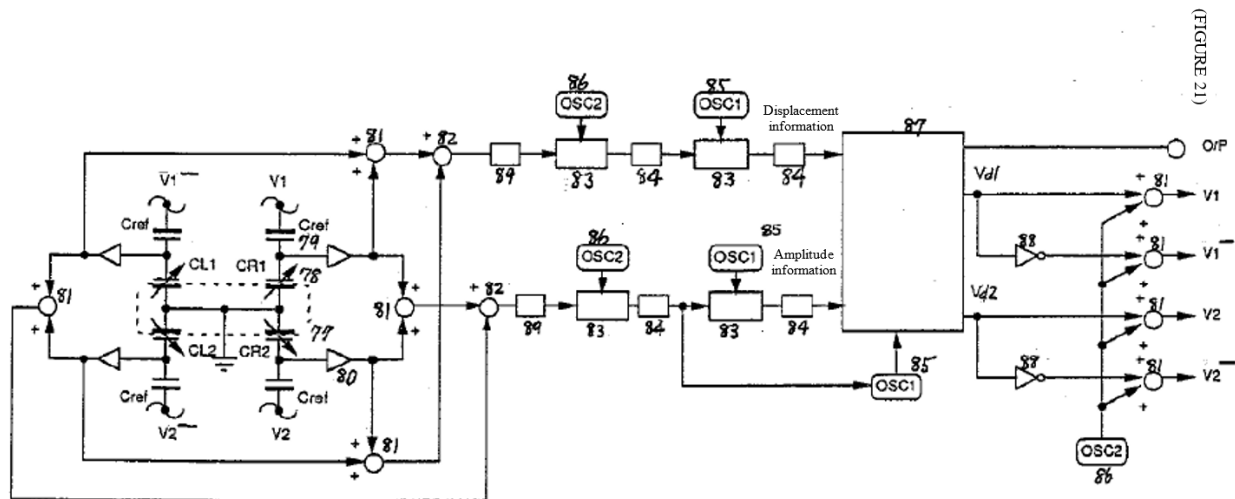
(Cox, 3:64-4:8.)

5. Mitamura (EX1007)

91. Mitamura (Japanese Patent Application Publication No. 9[1997]-42973; filed August 1, 1995; published February 14, 1997) discloses embodiments of an “angular velocity sensor, which is lightweight, mass-producible, and highly accurate.” (Mitamura, [0001].)

92. Mitamura discloses a third embodiment, shown below:

[FIGURE 21]

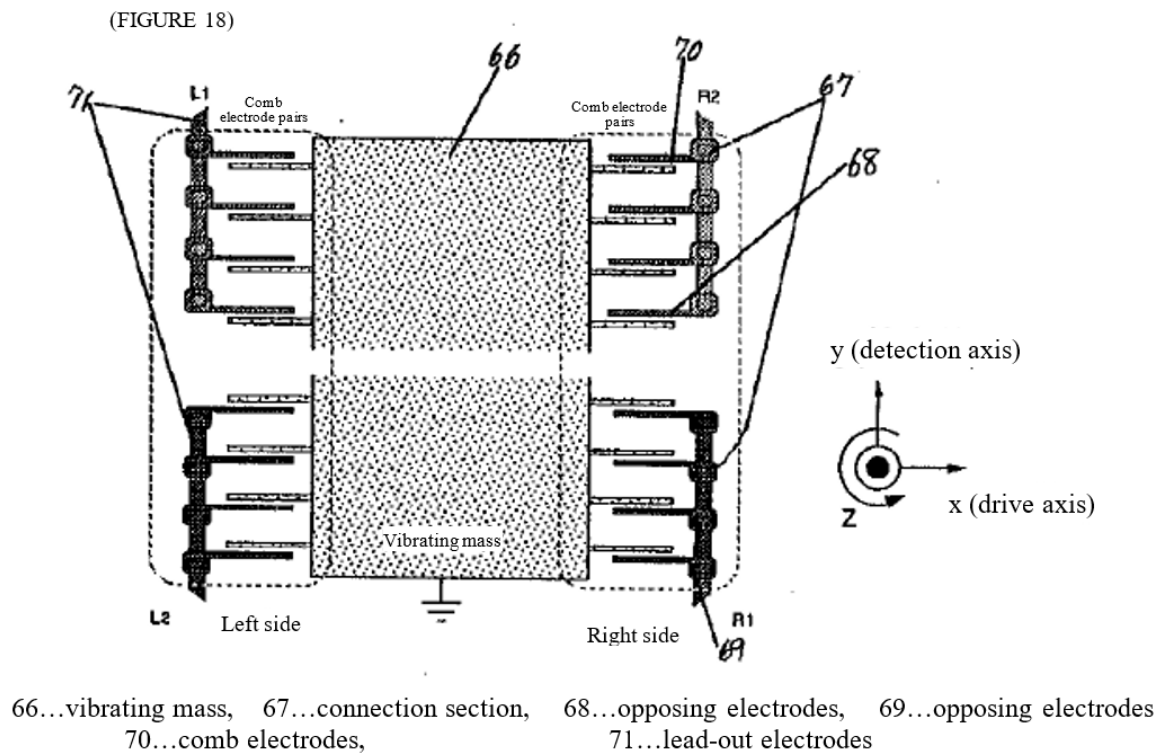


77...vibrating mass, 78...detection capacitance, 79...reference capacitance Cref, 80...buffers, 81...adder
82...subtractor, 83...demodulator, 84...low-pass filter, 85...oscillator OSC1, 86...oscillator OSC2
87...control circuit, 88...inverter, 89...high-pass filter

(Mitamura, Fig. 21, [0044].)

93. Figure 21 shows circuitry for detection and control related to a vibrating mass sensor shown below:

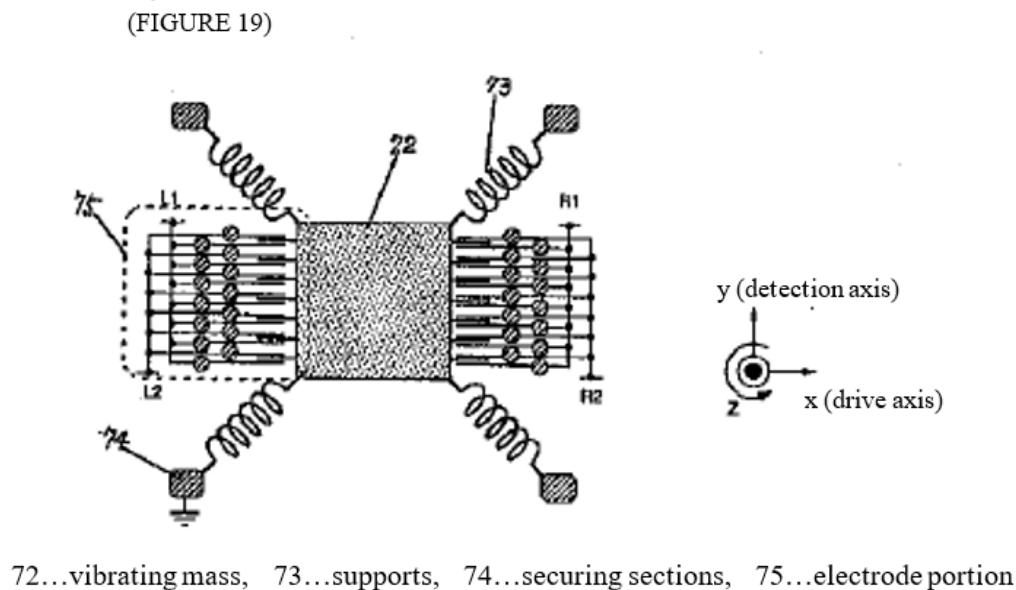
[FIGURE 18]



(*Id.*, Fig. 18, [0042].)

94. Another view of Mitamura's vibrating mass sensor is shown below:

[FIGURE 19]



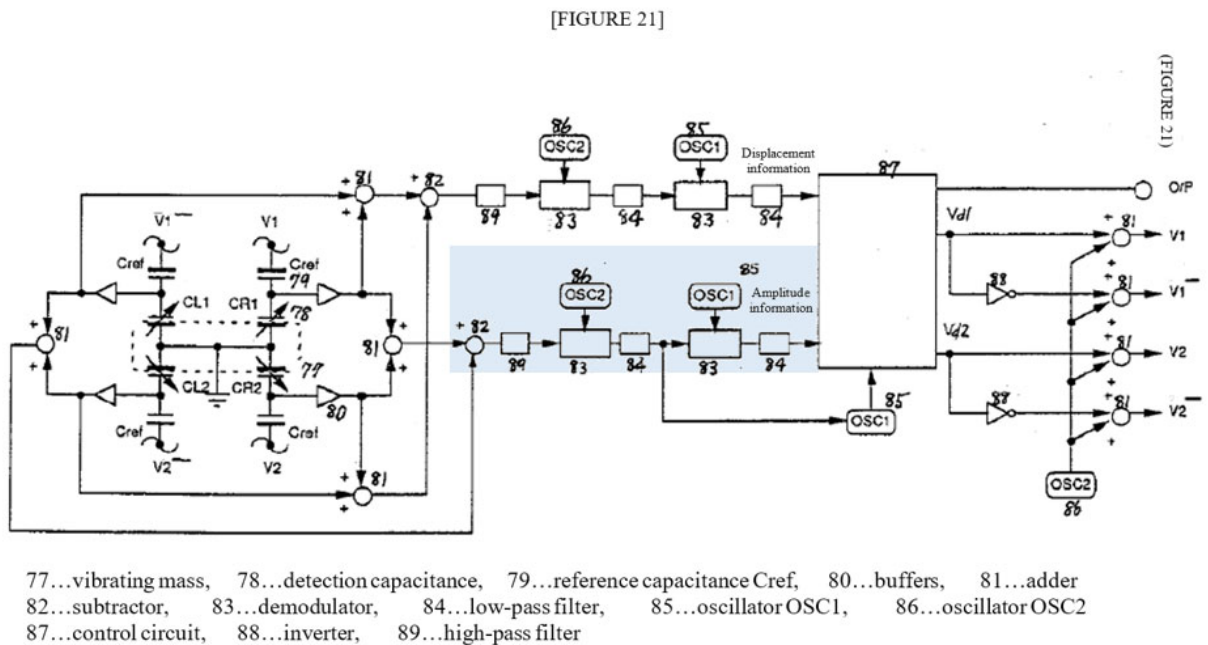
(*Id.*, Fig. 19, [0043].)

95. “The thickness of the vibrating mass and opposing electrodes is typically in the range of a few micrometers.” (*Id.*, [0042].) Further, the vibrating mass is “formed from a thin-film structural material.” (*Id.*, [0043].)

96. The sensor operates by using the electrostatic force generated by voltage applied to the comb electrodes to vibrate the mass in the “drive axis”—*i.e.*, left and right in the above figures. (*Id.*, [0048]-[0056].) The amplitude of this driven vibration is detected by the circuitry shown in Figure 21. (*Id.*, [0045].) This amplitude information is then used via control circuit 87 and subsequent circuitry to generate the driving signals for the left/right vibration in a feedback loop. (*Id.*,

[0045], [0048]-[0056].)

97. The path in Figure 21 involved in detecting and driving the motion in the left/right vibration axis is the lower, “[a]mplitude information” path, shown in blue highlighting below:

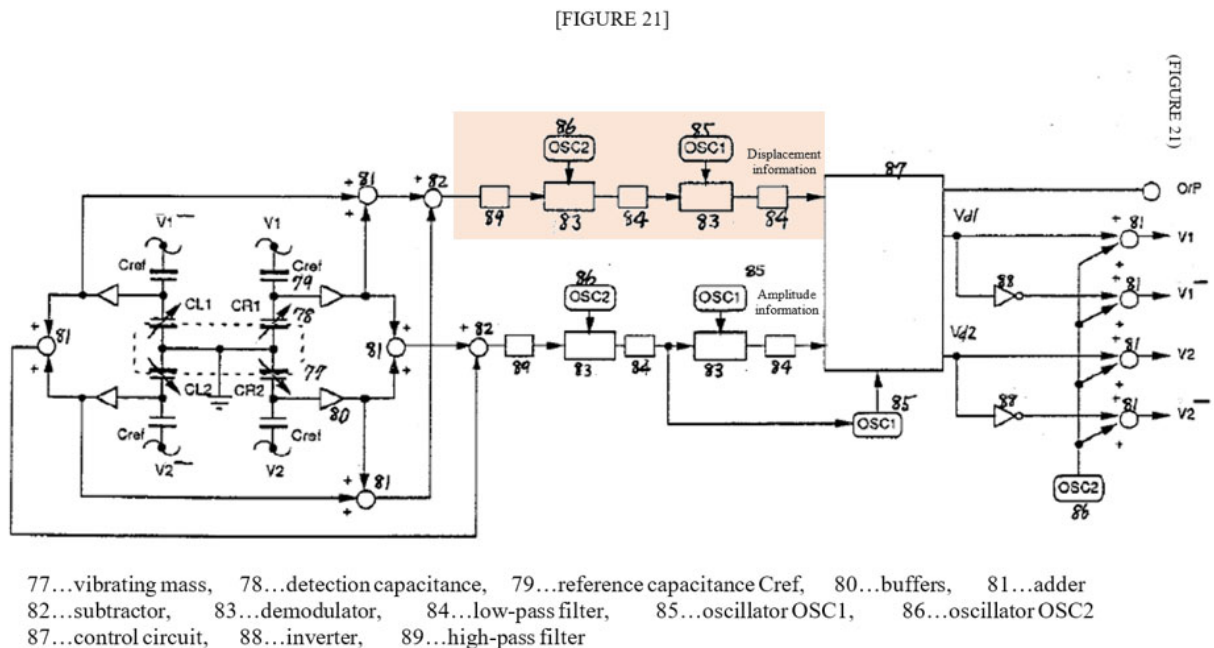


(Mitamura, Fig. 21 (highlighting added).)

98. Further, when the mass is vibrating and the system undergoes rotation around the “z” rotation axis shown in the figures above, a Coriolis force is exerted on the proof mass, causing it to move in the “y” direction (i.e., up and down in the above figures). (*Id.*, [0057]-[0063].) Based on this information, “[o]utput proportional to the angular velocity is output by the control circuit 87”—shown at the top right (“O/P”) of Figure 21. (*Id.*, [0045].) The Coriolis force information is

also fed back into the system through control circuit 87 and subsequent circuitry to generate the driving signals for compensating for the Coriolis force. (*Id.*, [0057].)

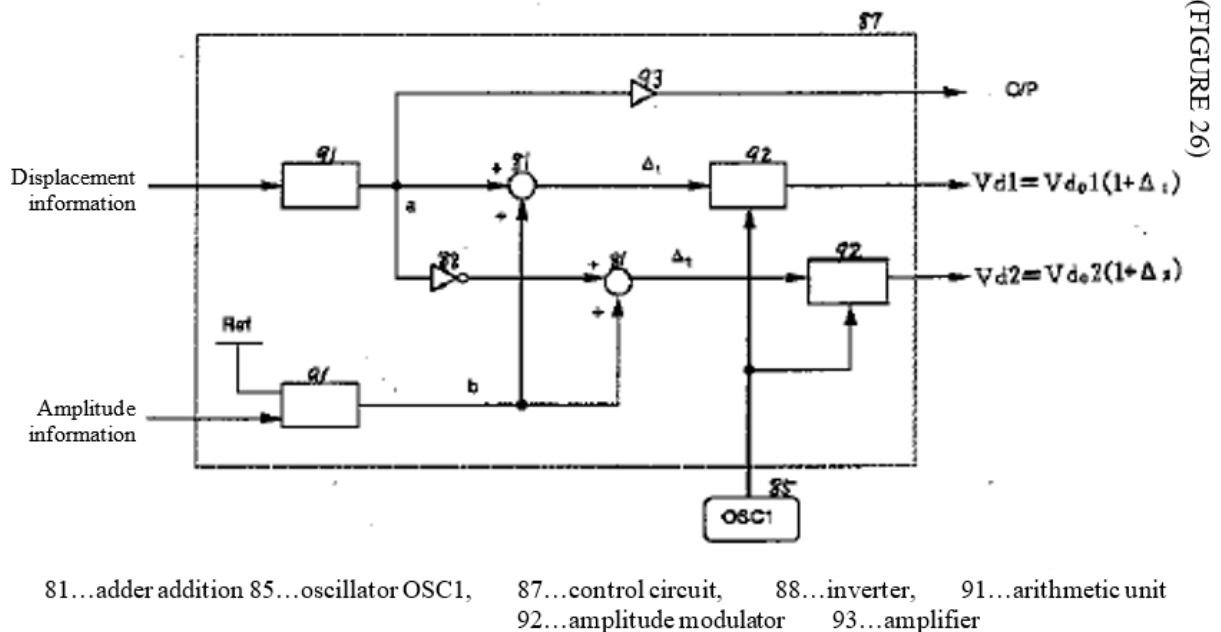
99. The path in Figure 21 involved in detecting and driving the motion in the up/down Coriolis force displacement axis (the “detection axis”) is the upper, “[d]isplacement information” path, shown in red highlighting below:



(*Id.*, Fig. 21 (highlighting added).)

100. An “example configuration” of control circuit 87 shown in Figure 21 is provided in Figure 26, shown below:

[FIGURE 26]



(*Id.*, Fig. 26, [0046].)

101. Figure 26 shows that the amplitude information signals (related to the left/right vibrating motion of the mass on the lower path) enters an arithmetic unit 91, where the amplitude information is “calculated as modulation amounts of the drive voltage . . . based on a deviation from a set reference level for the amplitude information.” (*Id.*, [0046].) The output of arithmetic unit 91 is labeled “b.”

102. Figure 26 also shows that displacement information signals (related to the up/down Coriolis force motion of the mass on the upper path) yields the signals labeled “a.” (*Id.*, [0046].) This is amplified via amplifier 93 and output (“O/P”) from the system. (*Id.*, [0045].) Further, “a” is used in generating the driving signals

105. Based on the processes discussed above, Mitamura discloses feeding back driving signals V1, V1-, V2, and V2-, which constitute a combination of signals formed in control circuit 87 based on the left/right vibration and up/down Coriolis force motion information, plus an oscillator signal OSC2 from oscillator 86. (*Id.*, Fig. 21, [0050]-[0056].)

B. Ground 1: Claims 1 and 3 Are Obvious Over Fujiyoshi in View of Kumar, Cox, and Townsend

1. Independent Claim 1

106. For reference, claim 1 recites:

1. A microelectromechanical system (MEMS) for measuring angular rate of a carrier, comprising:
 - [a] an angular rate sensor unit receiving dither driver signals, capacitive pickoff excitation signals and a displacement restoring signal and outputting angle rate signals in response to motion of said carrier and dither motion signals;
 - [b] a central circuitry receiving said angle rate signals in response to said motion of said carrier and said dither motion signals and outputting angular rate signals and digital low frequency inertial element displacement signals; and
 - [c] a digital signal processing system analyzing said digital low frequency inertial element displacement signals and feeding back said dither driver signals to said angular rate sensor unit.

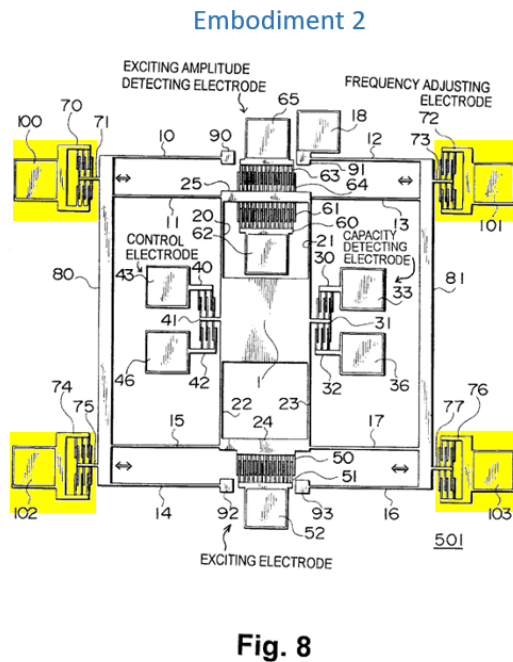
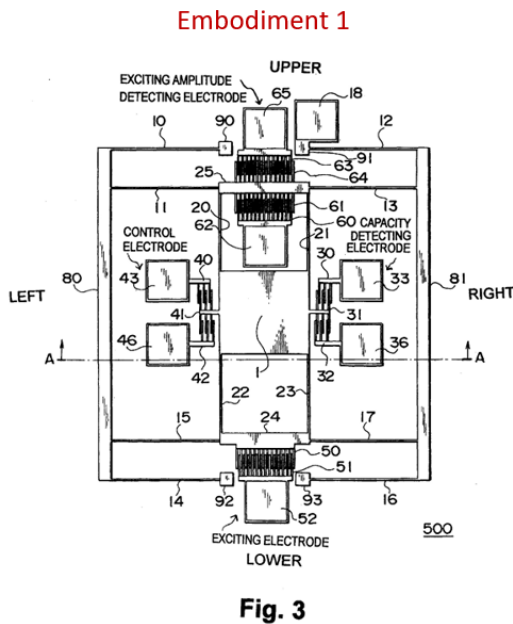
(’122, 9:39-55 (Claim 1; bracketed notation (e.g., [a]) added).)

107. As discussed below, it is my opinion that all requirements of claim 1 are satisfied or rendered obvious by Fujiyoshi’s *second* embodiment. Further, it is my opinion that all requirements of claim 1 are satisfied or rendered obvious by Fujiyoshi’s *seventh* embodiment—which is a differential configuration using two instances of Fujiyoshi’s *second* embodiment. (Fujiyoshi, 24:33-63.) Additionally, I refer in my analysis to some of the descriptions in Fujiyoshi’s *first* embodiment, which (as I describe below) is very similar to Fujiyoshi’s *second* embodiment, including in that both are microelectromechanical (MEMS) systems.

108. Since Fujiyoshi explicitly discloses that its seventh embodiment is nothing more than “two angular velocity sensors **501** as shown in the **embodiment 2**” connected via connecting portion **116**, it is my opinion that Fujiyoshi’s teachings regarding the second embodiment are equally applicable to the seventh embodiment. (Fujiyoshi, 24:38-42 (emphasis added).) To the extent my analysis combines disclosures from Fujiyoshi’s second and seventh embodiments to meet the claim limitations, it is my opinion that it would have been natural and obvious to combine these disclosures about Fujiyoshi’s second and seventh embodiments. For example, it would have been obvious to a POSITA to have implemented Fujiyoshi’s seventh embodiment using the circuitry and components in Fujiyoshi’s second embodiment

shown in Figure 9. For example, Fujiyoshi expressly teaches that its seventh embodiment contains “two angular velocity sensors 501 as shown in the embodiment 2[.]” (Fujiyoshi, 24:38-42 (emphasis added).) In other words, Fujiyoshi discloses that its seventh embodiment is just a combination of two instances of its second embodiment. It would have been obvious to a POSITA that Fujiyoshi’s seventh embodiment would have used the same circuitry and components as its second embodiment, with circuitry and components duplicated to serve each of the respective instances of the second embodiment.

109. Further, it is my opinion that a POSITA would have considered Fujiyoshi’s teachings related to its first embodiment to apply to its second and seventh embodiments. To the extent any obviousness analysis is necessary, it is also my opinion that it would have been obvious to a POSITA to combine Fujiyoshi’s teachings about its first embodiment with disclosures about its second and seventh embodiments. Fujiyoshi’s first embodiment is very similar to the second embodiment, with the only difference being the addition of electrodes in the second embodiment that allow for frequency adjustment of beams supporting the sensor hardware. (Fujiyoshi, 17:45-49.) This is shown in the below side-by-side comparison of Fujiyoshi’s Figures 3 and 8, where differences between the two embodiments are highlighted:



(*Id.*, Figs. 3, 8 (highlighting and colored annotations added).) As Figures 3 and 8 also indicate, there are many common and commonly numbered elements between Fujiyoshi's first and second embodiments. For these elements a POSITA would have understood that Fujiyoshi's descriptions regarding its first embodiment would have been applicable to its second (and therefore seventh) embodiments. A POSITA would have understood that the commonly numbered elements function the same or substantially the same in both embodiments, so Fujiyoshi's descriptions for the first embodiment are equally applicable to the second embodiment.

(a) **A microelectromechanical system (MEMS) for measuring angular rate of a carrier, comprising (Claim 1[p]):**

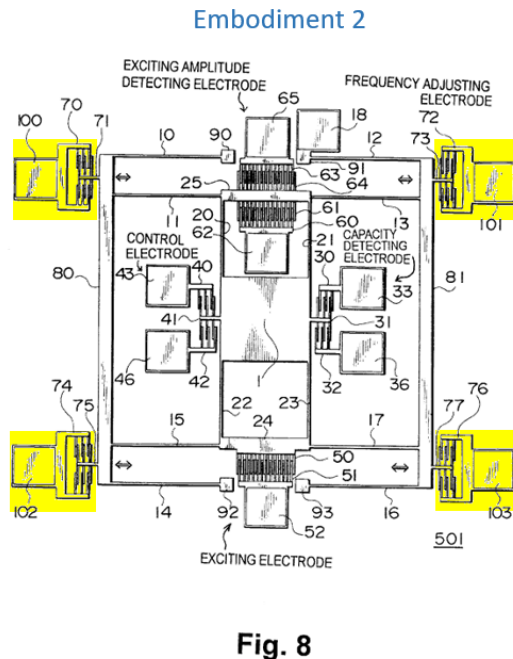
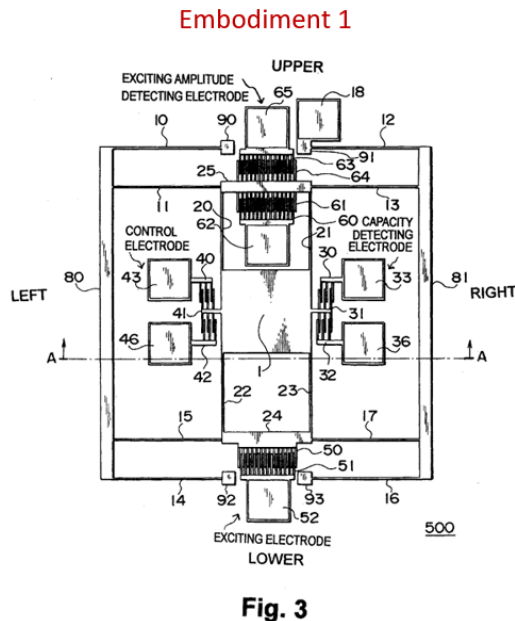
110. Fujiyoshi discloses **a microelectromechanical system (MEMS) for**

measuring angular rate of a carrier.

111. Further, it is my opinion that Fujiyoshi discloses a **microelectromechanical system (MEMS)**. Fujiyoshi describes its first embodiment shown in Figure 3 as “a fine angular velocity sensor manufactured using a micro machine technology for silicon.” (Fujiyoshi, 11:57-59.) The ’122 patent indicates that micromechanical systems are constructed via micromachining. (’122, 6:15-17, 1:41-43, 1:46-50.) Specifically, the ’122 patent indicates that “surface micromachining”—in which the “sensor element is built onto the surface of a silicon wafer”—is the “preferred MEMS fabrication” process. (’122, 6:15-20, 6:24-25.) Similarly, Fujiyoshi discloses fabricating its embodiments “using a micro machine technology for silicon” in which its sensor architecture “float[s] on a substrate surface.” (Fujiyoshi, 11:57-62; *see also id.*, Figs. 6A-E, 13:57-14:40.)

112. Fujiyoshi’s other embodiments, including its second and seventh embodiments, are also **microelectromechanical systems (MEMS)**. As I discussed above, the only difference between Fujiyoshi’s first embodiment shown in Figure 3 and its second embodiment shown in Figure 8 is the addition of electrodes in the second embodiment that allow for frequency adjustment of beams supporting the sensor hardware. (Fujiyoshi, 17:45-49.) This is shown in the below side-by-side comparison of Fujiyoshi’s Figures 3 and 8, where differences between the two

embodiments are highlighted:



(*Id.*, Figs. 3, 8 (highlighting and colored annotations added).) A POSITA would have understood that the system in Fujiyoshi's embodiment 2 is a MEMS sensor, given that there are only minor differences between embodiment 2 and embodiment 1. A POSITA would have also considered Fujiyoshi's embodiment 7 shown in Figure 17 to be a MEMS, since it merely combines two of Fujiyoshi's embodiment 2 sensors in a single differential sensor design. (*Id.*, 24:38-42; *see also* '122, Fig. 2, 6:12-14 (describing as MEMS a differential, two-mass vibrating sensor design).)

113. Fujiyoshi also discloses that one of the objectives for the patent is to overcome limitations in MEMS prior art. (Fujiyoshi, 3:3-13.) Fujiyoshi discloses:

[A]s shown in FIGS. 1A, 1B, and 1C, in recent fine vibrating sensors

manufactured by micro machining techniques using a material such as a silicon or the like, it is extremely difficult to fine adjust the frequency using a trimming process because the spot diameter of the laser beam is 10 or some tens of μm larger than the area to be trimmed in the vibrating type sensor, which may be as small as a few μm or less.

(*Id.*, 3:3-13.) All of Fujiyoshi's embodiments—including embodiments 1, 2, and 7—are “resonance type,” micromachined sensors that purport to improve upon the sensors shown in Figure 1A, 1B, and 1C. (*See, e.g., id.*, 1:9-20, 3:3-25.) Further, embodiments 2 and 7 provide a means for electrically adjusting the frequency of support beams for their disclosed system—directly addressing the issue with MEMS prior art disclosed by Fujiyoshi as quoted above. (*Id.*, 17:61-18:46, 24:38-42.)

114. Fujiyoshi, entitled “Resonance Type Angular Velocity Sensor,” is directed to embodiments of a sensor **for measuring angular rate**. For example, Fujiyoshi discloses a second embodiment that is an “angular velocity sensor.” (Fujiyoshi, Fig. 8, 17:42-44; *see also* Fig. 9, 20:28-34 (describing outputting “angular velocity”).) Fujiyoshi also discloses a seventh embodiment—which contains two instances of Fujiyoshi's second embodiment in a differential arrangement—that outputs “angular velocity.” (Fujiyoshi, 24:54-57.) It is my opinion that a POSITA would have understood “angular velocity” to be the same as “angular rate.”

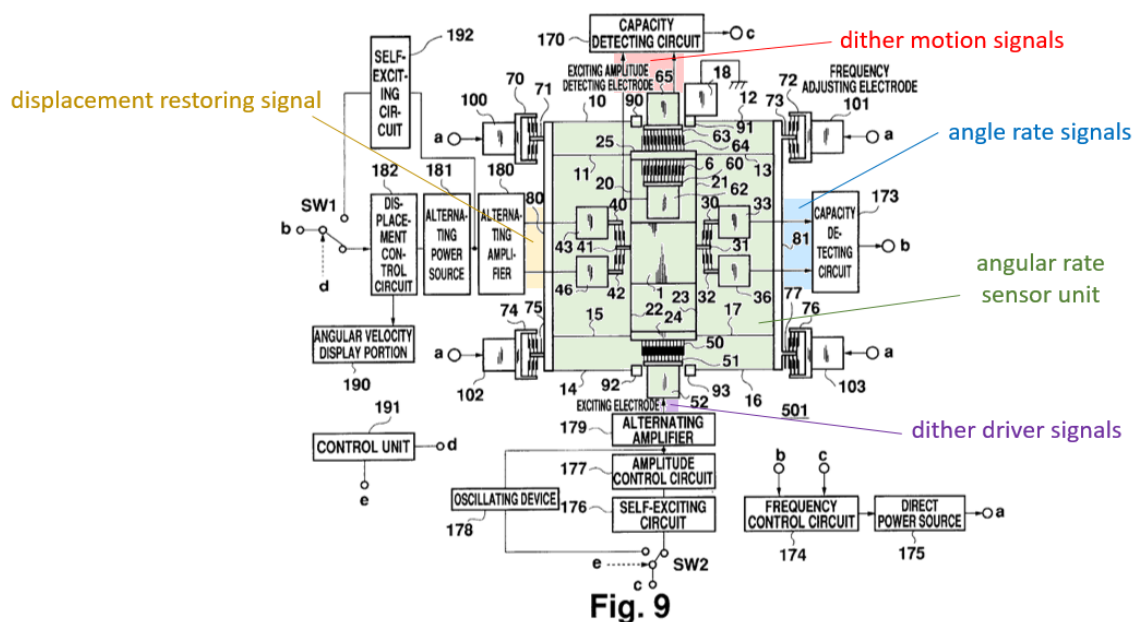
115. Fujiyoshi further discloses that these angular rate measurements are of a **carrier**, including a vehicle. Fujiyoshi discloses that “[t]he present invention relates to an angular velocity sensor for detecting an angular velocity acting on a vehicle such as an automobile, airplane, or an electronic equipment.” (Fujiyoshi, 1:7-9.) Fujiyoshi discloses that its second embodiment is particularly well suited for being mounted on a vehicle, since (1) sensor stability of the second embodiment “can be maintained for a long time,” which a vehicle use case demands, and (2) the sensor can be used in variable temperatures, which “varies widely” for a vehicle. (*Id.*, 18:10-27.) The examples of carriers disclosed by Fujiyoshi are consistent with those disclosed by the ’122 patent, which indicates that typical applications for its sensors are “automobiles, railway vehicles, miniature land vehicles, robots, unmanned ground vehicles, personal navigators, and military land vehicles.” (’122, 2:54-57.)

116. Accordingly, it is my opinion that Fujiyoshi discloses a **microelectromechanical system (MEMS) for measuring angular rate of a carrier**.

- (b) an angular rate sensor unit receiving dither driver signals, capacitive pickoff excitation signals and a displacement restoring signal and outputting angle rate signals in response to motion of said carrier and dither motion signals (Claim 1[a]);

117. It is my opinion that an angular rate sensor unit receiving dither driver signals, capacitive pickoff excitation signals and a displacement restoring signal and outputting angle rate signals in response to motion of said carrier and dither motion signals would have been obvious to a POSITA based on Fujiyoshi alone or in light of Kumar.

118. The following annotated version of Fujiyoshi's Figure 9 circuit shows how Fujiyoshi's second embodiment discloses limitations of claim 1[a]:



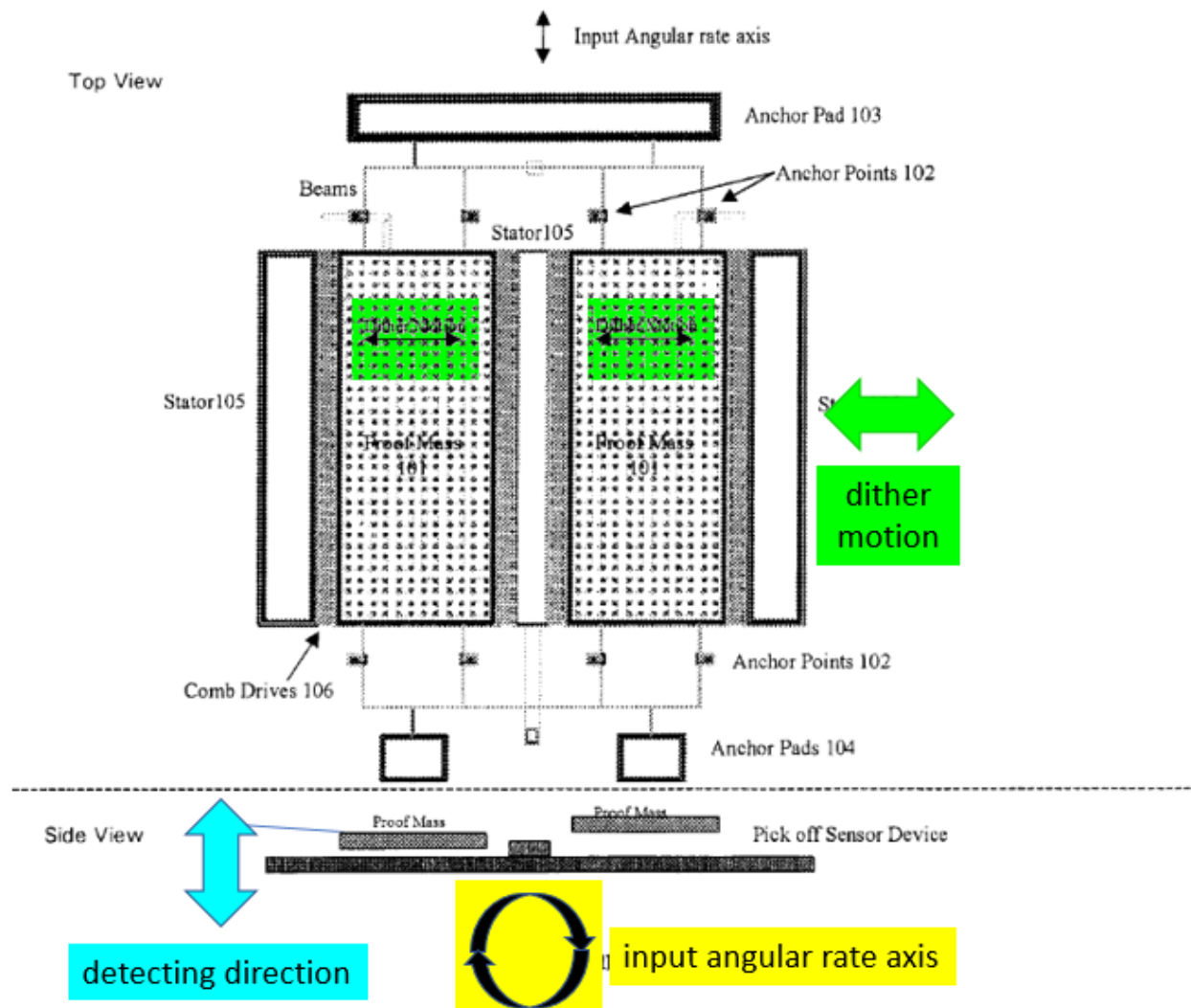
(Fujiyoshi, Fig. 9 (highlighting and colored annotations added).)

119. Fujiyoshi discloses an **angular rate sensor unit**. As discussed above, Fujiyoshi discloses embodiments—including its first, second, and seventh embodiments—for measuring angular rate. (Fujiyoshi, 17:42-44; *see also* Figs. 9, 17; 20:28-34, 24:38-57.) This angular rate sensing is performed by the green-highlighted hardware shown in Figure 9, which vibrates mass portion 1 in the vertical direction, leading to a Coriolis force that displaces the mass portion 1 in the horizontal direction when the system undergoes an angular rotation along an axis that is perpendicular to the surface plane of mass portion 1. (*Id.*, 19:63-20:34.) Measurement of the magnitude of the displacement of the mass portion 1 allows for sensing of the angular rate. (*Id.*, 20:28-34.) Accordingly, the green-highlighted components in Figure 9 constitute an **angular rate sensor unit**.

120. Fujiyoshi discloses an angular rate sensor unit that **receiv[es] dither driver signals**. The '122 patent indicates that “dither” motion is vibration back and forth of an inertial element in one axis such that when the system undergoes angular rotation, the Coriolis force will move the inertial element in a *different* axis. ('122, Fig. 2, 5:6-20 (“vibrating (dither)”), 4:65-66.) This effect is shown in Figure 2 of the '122 patent, reproduced below in an annotated version. The proof masses 101 are vibrated back and forth (right and left in Figure 2) in “Dither Motion,” shown in green highlighting. When angular rotation occurs along the “Input Angular rate

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Petition for *Inter Partes* Review of
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axis” (shown in yellow highlighting), the proof masses have a tendency (due to inertia) to continue traveling in a straight line either to the right or left of Figure 2 based on the dither motion. But the whole device has rotated, so traveling in a straight line based on the *previous* orientation of the device leads to motion along a different axis perpendicular to the left-right dither motion axis with respect to the *new* orientation of the device, leading the proof mass to move three-dimensionally, from the perspective of the top view in Figure 2 below, in and out of the page (as shown in blue at the bottom of Figure 2):

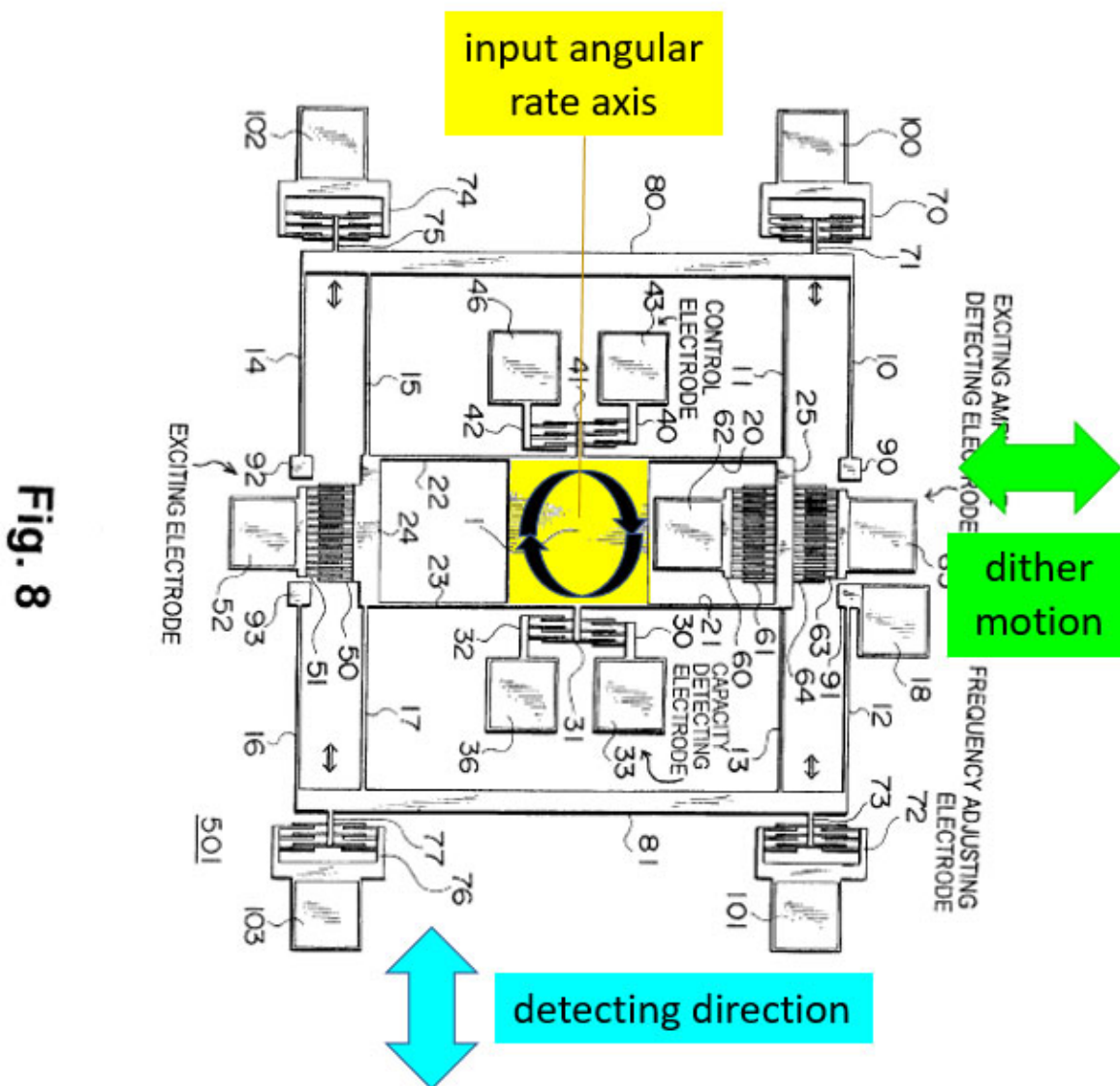


(’122, Fig. 2 (colored annotations and highlighting added), 5:6-20, 4:65-66.)² The ’122 patent indicates that the dither motion is “driven” by “electrostatic comb drive motors[.]” (’122, 5:7-10, 5:17-18, 5:25-30.) While the ’122 patent does not

² I note that the blue-highlighted detecting direction and yellow-highlighted input angular rate axis in the annotated ’122 Figure 2 above pertain to the side view of the device shown underneath the dotted line, while the green-highlighted dither motion axis relates to the top view shown above the dotted line.

explicitly define what constitutes the dither driver signals in the Figure 2 embodiment, a POSITA would have understood it to be the control signals input to the electrostatic comb drive motors to cause the dither motion in the left-right axis. (*Id.*)

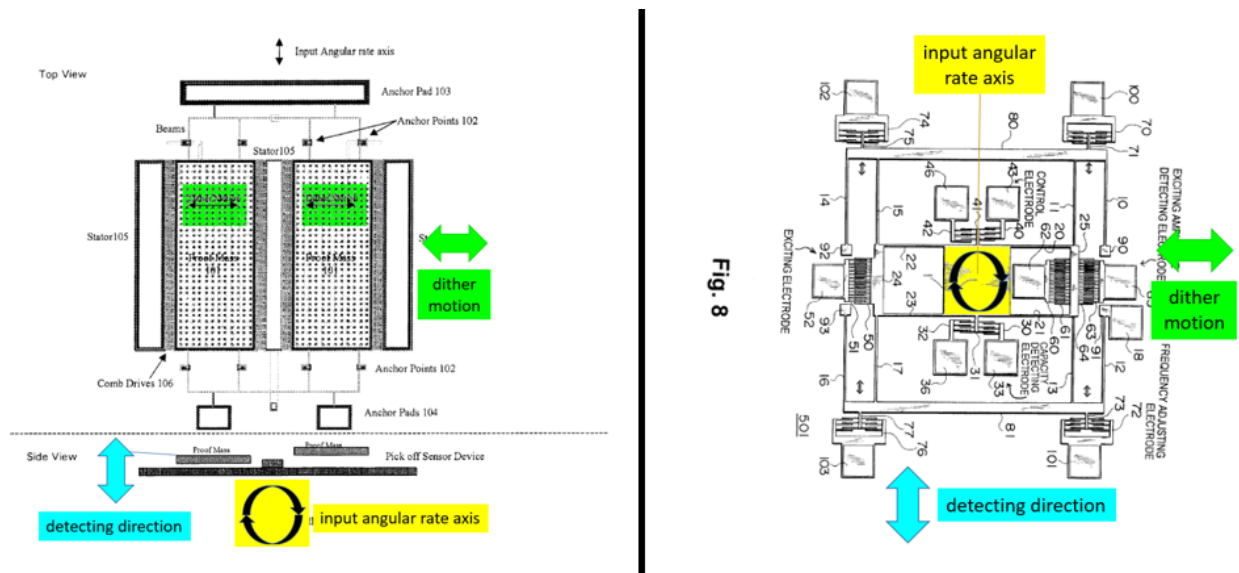
121. Similar to the '122 patent, Fujiyoshi discloses that its second and seventh embodiments contain inertial elements (mass portions **1**) that are vibrated back-and-forth along one axis (the “exciting direction”) so that when the system undergoes angular rotation, the inertial elements are displaced along a different axis (the “detecting direction”) by the Coriolis force. (Fujiyoshi, 19:63-20:19.) The same three axes shown above for Figure 2 of the '122 patent—dither motion (right-left), Coriolis force or “sensing” motion (up-down), and input angular rate axis (clockwise-counterclockwise)—are shown in the following annotated version of Fujiyoshi’s Figure 8 (second embodiment), which I have rotated so that the direction of dither motion is the same as the '122 patent’s Figure 2:



(Fujiyoshi, Fig. 8 (rotated; colored annotations and highlighting added).)³ The

³ I note that unlike the annotated '122 Figure 2 above, the yellow, blue, and green-highlighted axes in annotated Fujiyoshi Figure 8 all relate to the top view (*i.e.*, none relate to a side view, like with the annotated '122 Figure 2 above.) This difference does not impact my analysis that the '122 patent and Fujiyoshi devices operate

annotated '122 and Fujiyoshi figures are shown alongside each other below for comparison:



('122, Fig. 2 (colored annotations and highlighting added); Fujiyoshi, Fig. 8 (rotated; colored annotations and highlighting added).) While the axes of Fujiyoshi's Figure 8 are different than the '122 patent's Figure 2 (the axis of rotation and Coriolis force direction are flipped), the fundamental operation is the same. Fujiyoshi's mass portion 1 is dithered back-and-forth in one axis, so when the system undergoes angular rotation around a second axis, a Coriolis force will be detected in a third

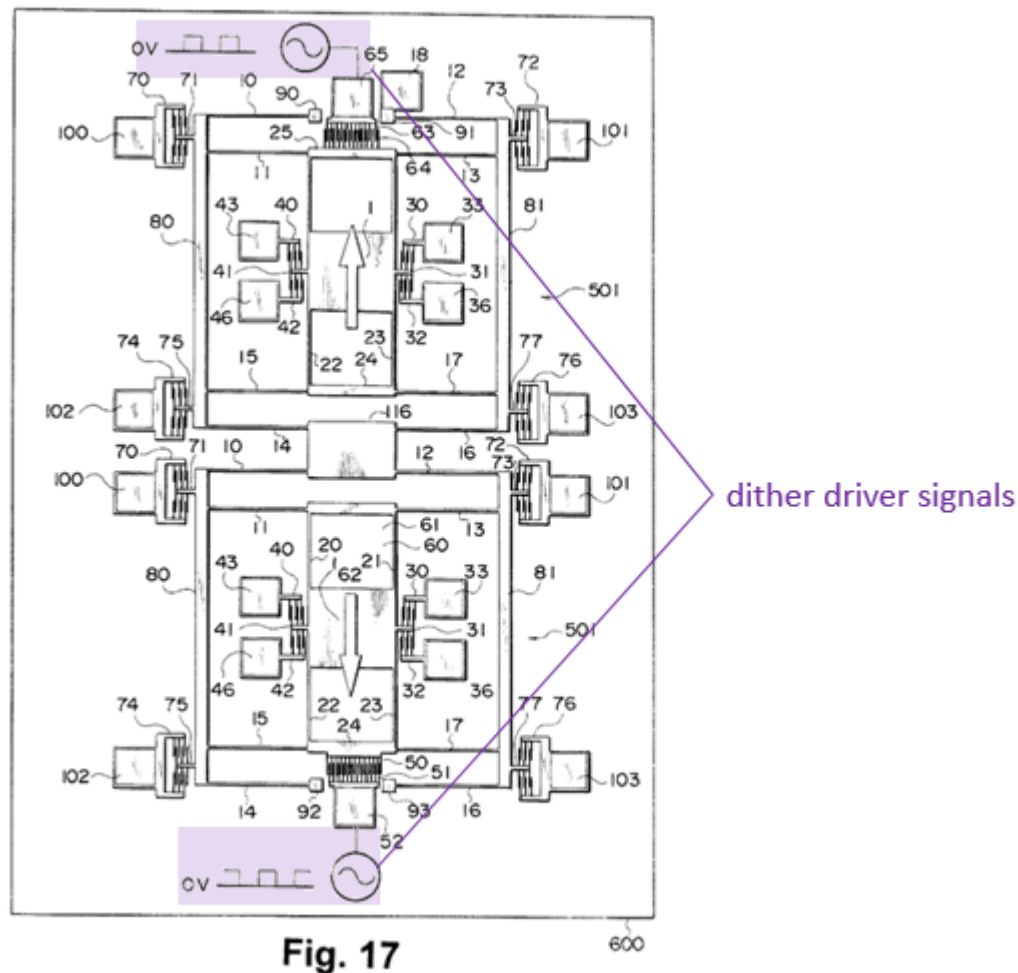
similarly, with orthogonal dither, detecting, and rotation axes. This interrelationship between the dither, detecting, and rotation axes is present in both the '122 Figure 2 device and the Fujiyoshi Figure 8 device, regardless of the directions each specific axis points in.

axis.

122. The angular rate sensor unit in Fujiyoshi's second and seventh embodiments **receiv[es] dither driver signals** to drive the dither motion of mass portion **1**. The dither vibration of the mass portion **1** in Fujiyoshi's Figure 9 circuit is controlled by "[a]lternating voltage supplied through an amplitude control circuit **177** and an alternating amplifier **179** from the self-exciting circuit **176** . . . applied to the exciting electrode **51**, so that the mass portion **1** is vibrated to the exciting direction." (Fujiyoshi, 19:63-67, 12:35-44 (describing vibrating drive mechanism), 21:29-33.) The dither vibration is controlled via an alternating voltage (the **dither driver signals**) "applied to the exciting electrode **52**," as highlighted in purple in annotated Figure 9 above. (*Id.*, 21:29-33.) Fujiyoshi describes the alternating voltage as controlling the "[d]rive" of the angular velocity sensor, so a POSITA would have understood the alternating voltage applied to exciting electrode **52** to be **driver signals**. (*Id.*, 19:55-59, 10:49-52, 24:47-50.) Since exciting electrodes **51** and **52** are part of the angular rate sensor unit in Fujiyoshi's second and seventh embodiments (as shown in the green-highlighted components in annotated Figure 9 above), the **angular rate sensor unit receiv[es] dither drive signals**. (See, e.g., *id.*, Fig. 8 (including exciting electrode **52**), 10:32-34 (describing Fig. 8 as "view which shows a resonance type angular velocity sensor").)

123. To the extent there is any argument that claim 1 of the '122 patent requires plural “dither driver signals,” it is my opinion that Fujiyoshi’s second embodiment satisfies this requirement. The alternating voltage applied to electrode **52** changes over time in response to the dither motion of mass portion **1** “in such a manner as to make the amplitude of the vibration constant on the basis of the excitation control signal.” (Fujiyoshi, 20:4-11.) Accordingly, a POSITA would have understood that the alternating voltage applied to electrode **52** comprises plural dither driver **signals**, because when considered over time, that alternating voltage constitutes a set of alternating voltage signals with different characteristics.

124. Further, to the extent there is any dispute that the alternating voltage applied to electrode **52** in Fujiyoshi’s *second* embodiment comprises plural dither driver signals, it is my opinion that Fujiyoshi’s *seventh* embodiment includes plural dither driver signals. Fujiyoshi’s seventh embodiment is a differential implementation of Fujiyoshi’s second embodiment, where two of Fujiyoshi’s second embodiment circuits are used together in a differential arrangement, which together form an **angular rate sensor unit**. (Fujiyoshi, 24:33-63.) Each of the two second embodiment circuits in the seventh embodiment circuit has its own alternating voltage applied to the exciting electrode for each respective mass portion **1**, as shown in the annotated Figure 17 (showing Fujiyoshi’s seventh embodiment) below:



(*Id.*, Fig. 17 (highlighting and colored annotations added).)

125. Patent Owner's prior representations regarding the claim language "dither driver signals" further supports that the alternating voltage applied to exciting electrode **52** in Fujiyoshi's second and seventh embodiments satisfies this claim limitation. While I understand that the claims of the '122 patent have not been construed by a Court, I also understand that Patent Owner has proposed constructions for certain claim terms in prior district court litigations. For example,

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U.S. Patent No. 6,508,122 B1

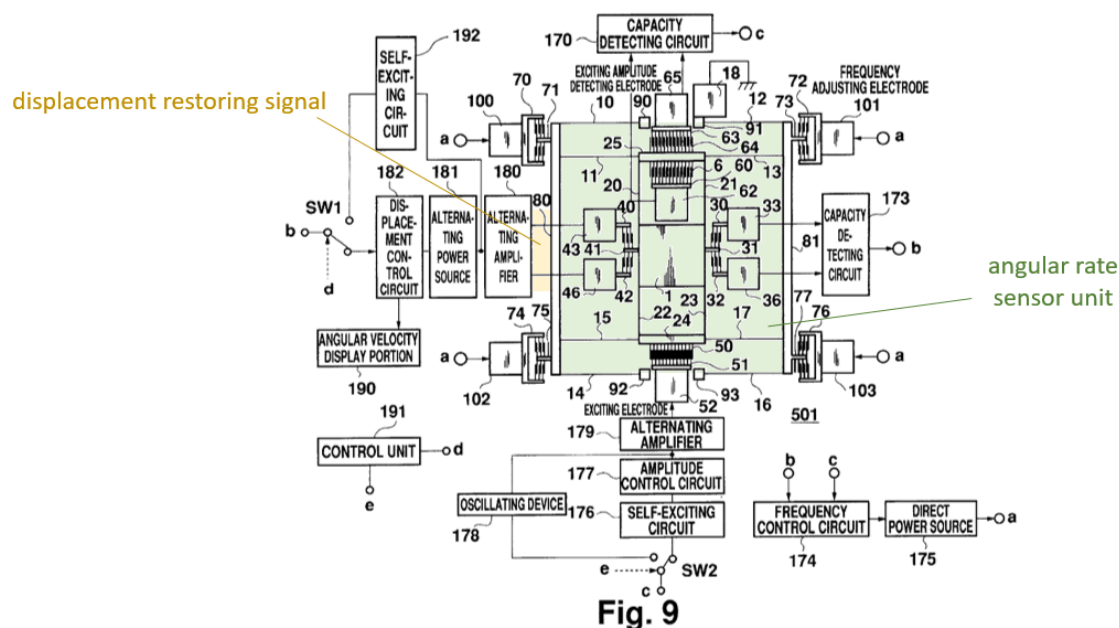
I understand that in multiple district court cases, Patent Owner proposed that the term “dither driver signals” should be construed as “signals used to oscillate, or vibrate, an inertial element in the angular rate sensor unit.” (**EX1018** at 5-8; **EX1019** at 4-5; **EX1020** at 24-25; **EX1021** at 10-12; **EX1022** at 29-30; **EX1023** at 8-9.) The alternating voltage applied to the exciting electrodes in Fujiyoshi’s second and seventh embodiments constitute “signals used to oscillate, or vibrate, an inertial element in the angular rate sensor unit.” A POSITA would have understood the mass portion **1** in Fujiyoshi’s second and seventh embodiments is an “inertial element.” The ’122 patent discloses that its “proof masses,” which dither and are displaced by the Coriolis force, are “inertial elements.” (’122, 8:3-6, 10:25-28, 11:3-6; *see also id.*, Figs. 2, 2:58-3:6, 5:6-20, 5:47-67.) Accordingly, it is consistent with the ’122 patent to understand Fujiyoshi’s mass portion **1**, which also dithers and is displaced by the Coriolis force, as an “inertial element.” Further, as I discuss above, the alternating voltage applied to exciting electrode **52** in Fujiyoshi’s second and seventh embodiments comprises “signals used to oscillate, or vibrate” mass portion **1**.

126. It is further my opinion that Fujiyoshi discloses an **angular rate sensor unit that receiv[es] a displacement restoring signal**. The ’122 patent indicates that a displacement restoring signal is derived from the signals indicating the

displacement of an inertial element caused by the Coriolis force and is used to drive the inertial element. ('122, 8:40-9:4.) While the '122 patent does not explicitly define the term displacement restoring signal, a POSITA would have understood that a **displacement restoring signal** is a signal used to restore the position of an inertial element to its approximate original (*i.e.*, pre-Coriolis force) location following the displacement of the inertial element by the Coriolis force.

127. It is my opinion that Fujiyoshi's second and seventh embodiments include an angular rate sensor that receives a **displacement restoring signal** per the '122 patent's disclosures and a POSITA's understanding of the term. The angular rate sensor unit in Fujiyoshi's second and seventh embodiments receives a "control voltage" from alternating amplifier **180** that "make[s] the displacement of the mass portion **1** zero on the basis of the detected output" from the capacity detecting circuit **173** (discussed further below). (Fujiyoshi, 20:20-27; *see also id.*, 13:21-24.) This control voltage is the displacement restoring signal for Fujiyoshi's second and seventh embodiments. The influence of the control voltage on the displacement of mass portion **1** is discussed further for the similar first embodiment, indicating that "the motion of the mass portion **1** is restricted to the adjacent portion of the zero point" for mass portion **1**. (*Id.*, 16:33-36.) A POSITA would have understood based on Fujiyoshi's disclosures that the mass portion **1** would move due to the Coriolis

force and, as a result, a feedback force would be generated to counteract the movement. In a practical system, due to finite system loop gain, the mass portion **1** would be restored approximately to its original position. A POSITA would have understood this process as “nulling.” This control voltage from alternating amplifier **180** constitutes a **displacement restoring signal**, since it restores mass portion **1** to its original position—after displacement of mass portion **1** by the Coriolis force. Fujiyoshi’s displacement restoring signal is shown in the annotated Figure 9 below:



(Fujiyoshi, Fig. 9 (highlighting and annotations added).)

128. Also, similar to the '122 patent's disclosures regarding the displacement restoring signal, the yellow-highlighted signal in annotated Figure 9 above is derived from the displacement of the inertial element (mass portion **1**)

caused by the Coriolis force. The control voltage from alternating amplifier **180** restores mass portion **1** to its original location “on the basis of the detected output” from capacity detecting circuit **173**, which detects “the vibration to the detecting direction of the mass portion **1**” based on “the Coriolis force due to the angular velocity[.]” (Fujiyoshi, 20:12-27.) The ’122 patent discusses the generation of the displacement restoring signal in similar terms. (’122, 8:40-9:4.)

129. The displacement restoring signal in Fujiyoshi’s second and seventh embodiments is further **receiv[ed]** by the **angular rate sensor unit**, which is shown in **green** highlighting in the annotated Figure 9 above. The control voltage from alternating amplifier **180** is received by electrode pads **43** and **46**, which are part of the angular rate sensor unit as shown by the **green** highlighting in the annotated Figure 9 above. (See Fujiyoshi, Fig. 8 (including elements **40-43**), 10:32-34 (describing Fig. 8 as a “view which shows a resonance type angular velocity sensor”), 20:20-27, 13:13-21.)

130. To the extent there is any question that Fujiyoshi’s second embodiment receives **a displacement restoring signal**—since Fujiyoshi’s Figure 9 shows two signals supplied by alternating amplifier **180** to the angular rate sensor unit—it is my opinion that either of these signals could be considered **a displacement restoring signal**.

131. It is also my opinion that Fujiyoshi's seventh embodiment satisfies the **displacement restoring signal** limitation. The angular rate sensor consisting of the differential configuration of two sensors according to Fujiyoshi's second embodiment receives a **displacement restoring signal** in that the control voltage from alternating amplifier **180** in either of the constituent sensors could be considered a **displacement restoring signal**. (Fujiyoshi, Fig. 17.)

132. To the extent there is any argument that the control voltage from alternating amplifier **180** is not a displacement restoring force because it cancels out the Coriolis force, I disagree. A POSITA would have understood that the design of Fujiyoshi's system requires the Coriolis force to move mass portion **1** before the control voltage from alternating amplifier **180** can counteract that force and move the vibrating mass approximately to its original position along the sensing axis. A POSITA would have understood that some motion along the sensing axis would be necessary before the Coriolis force can be counteracted—otherwise, no motion could be detected to start the counteracting process in the first place.

133. I understand that Patent Owner has proposed that the term “displacement restoring signal” should be construed as “signal that is used to restore displacement of the inertial element(s)” in multiple district court cases. (**EX1018** at 19-22; **EX1020** at 10-12; **EX1021** at 28-30; **EX1022** at 12; **EX1023** at 33-35;

EX1024 at 10.) It is my opinion that the control voltage from alternating amplifier **180** in Fujiyoshi's second and seventh embodiments is a "signal that is used to restore displacement of the inertial element(s)," since the control voltage restores mass portion **1** to its original position—after displacement of mass portion **1** by the Coriolis force. (Fujiyoshi, 20:12-19.)

134. I also understand that in Patent Owner's pending district court litigation against Nintendo, Petitioners have proposed that the term "displacement restoring signal" should be construed as "electrical signal used to oppose displacement of inertial element(s) caused by angular rotation." (**EX1026**.) It is my opinion that the control voltage from alternating amplifier **180** in Fujiyoshi's second and seventh embodiments constitutes a "displacement restoring signal" under Petitioners' proposed construction. The control voltage from alternating amplifier **180** is an electrical signal (voltage) used to oppose displacement of mass portion **1** caused by angular rotation, since it restores mass portion **1** to its original position—after displacement of mass portion **1** by the Coriolis force. (Fujiyoshi, 20:12-19.)

135. It is my opinion that Fujiyoshi teaches or renders obvious **an angular rate sensor unit that receiv[es] capacitive pickoff excitation signals**. The concept of "capacitive pickoff excitation signals" was not an invention of the '122 patent, but well-known in the field of angular rate sensors such as gyroscopes. The '122

patent discloses that in an embodiment, “capacitive pickoff plates” sit underneath the inertial elements and their capacitance changes when the inertial elements move based on the Coriolis force. (’122, 5:10-17, 5:35-38.) The ’122 patent discloses that this capacitance change can be output as “phase reference signals from an oscillator” or “current flow from a high frequency signal.” (*Id.*, 8:20-22, 5:35-38.) A POSITA would understand from these disclosures that capacitive pickoff excitation signals can include oscillator signals provided to variable capacitors to measure how the capacitance changes over time. For example, the textbook J.M. Slater, *Inertial Guidance Sensors* (1964) (“Slater”, **EX1011**), in a chapter entitled “Gyros,” teaches that “[c]apacitor pick-off systems typically include as the sensing element a differential-type capacitor of variable effective area or (and more usually) variable gap.” (Slater at 72.)

136. Fujiyoshi does not explicitly use the term “capacitive pickoff excitation signals” in describing signals received by the **angular rate sensor unit**. But these signals would have been obvious based on Fujiyoshi’s disclosures about its capacitive sensing mechanism. Fujiyoshi teaches that the angular rate sensor units in its second and seventh embodiments include capacity detecting electrodes **30, 32, 33, and 36**. (*See* Fujiyoshi, Figs. 8, 17; 20:42-45.) In Figure 5, Fujiyoshi provides a close-up view of an implementation of such capacity detecting electrodes for its

first embodiment—which a POSITA would have understood to also apply to its second and seventh embodiments, which have the same capacity detecting electrode configuration. (*Id.*, Figs. 3, 8, 17.) Figure 5 is reproduced below:

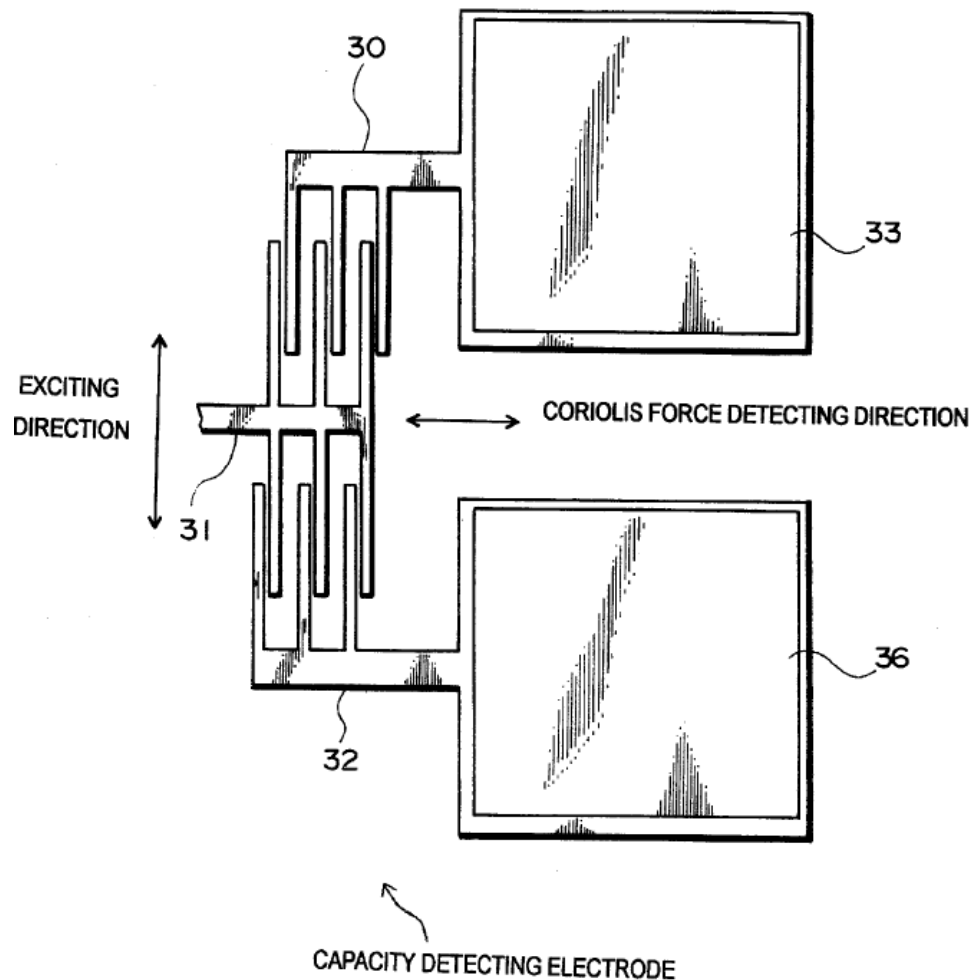


Fig. 5

(*Id.*, Fig. 5.) Fujiyoshi discloses that the capacitance of these electrodes is detected via a capacity detecting circuit as the capacitance changes over time due to the

providing a high frequency signal to electrodes **30** and **32** that would get modulated by the change in capacitance. A POSITA would have known that measuring this modulated signal would have indicated the change in capacitance—and therefore the motion of mass portion **1**—over time.

138. As noted above, Slater’s textbook from 1964 teaches that “[c]apacitor pick-off systems typically include as the sensing element a differential-type capacitor of variable effective area or (and more usually) variable gap.” (Slater at 72.) Further, Slater teaches “[t]he carrier voltage excitation for the pick-off may be either in the audio- or radio-frequency range.” (*Id.* at 73; Fig. 3.6 (showing “representative capacitor pick-off circuits”).) Slater shows that it was well-established as early as the 1960s to implement a capacitive sensor like Fujiyoshi discloses by providing an oscillating signal to the capacitive sensor. Slater further shows that it would have long been familiar to a POSITA that capacitive sensing like Fujiyoshi discloses is referred to as a “pick-off” system and high frequency signals provided to it are “excitation” signals. (*Id.* at 73.)

139. Similarly, the textbook Ljubisa Ristic (ed.), *Sensor Technology and Devices* (1994) (“Ristic,” **EX1010**) indicates that “[a]ny of the capacitive sensing techniques used in a micromachined structure require an ac voltage across the capacitor being measured.” (Ristic at 429.) Ristic discloses the following examples

of capacitive sensing circuits, each with an AC signal provided to the variable capacitor to measure the capacitance change over time, highlighted below:

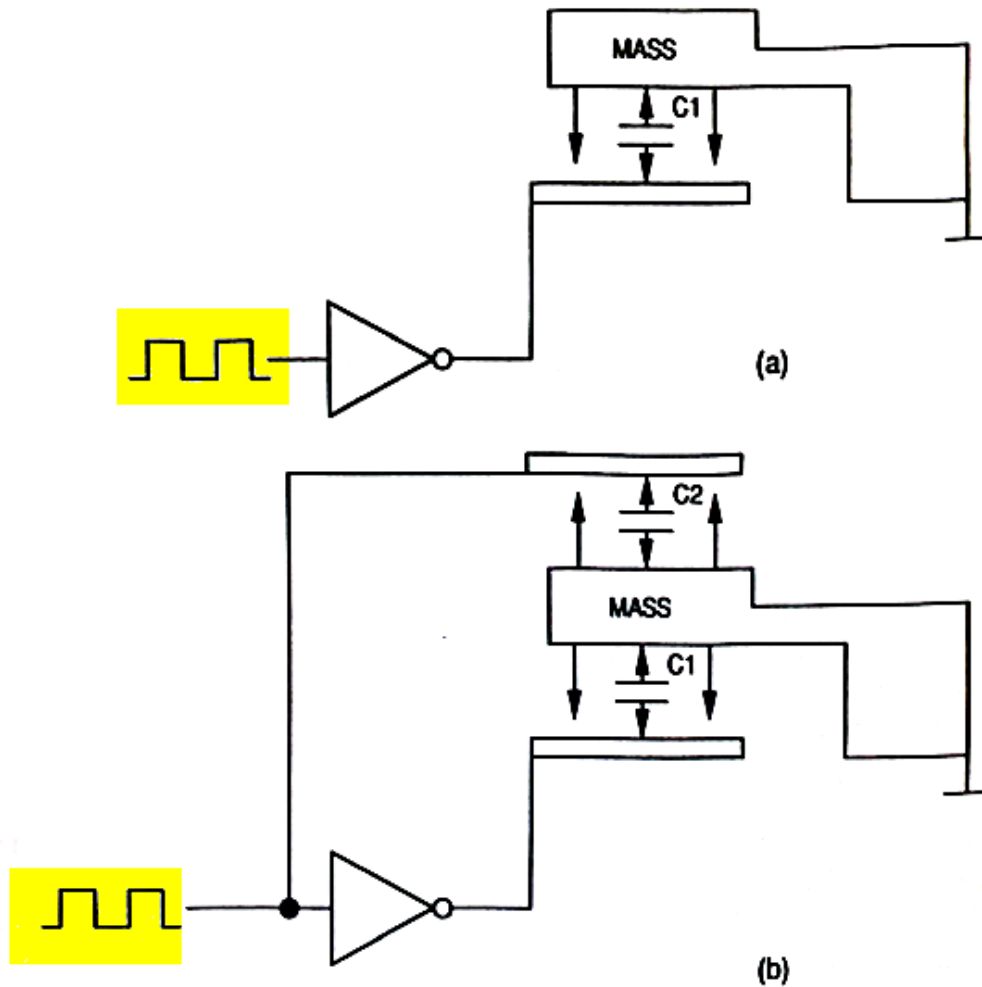


Figure 12.7 Capacitive sensing with electrostatic forces: (a) single-sided capacitive cantilever structure; (b) a movable plate between two fixed plates.

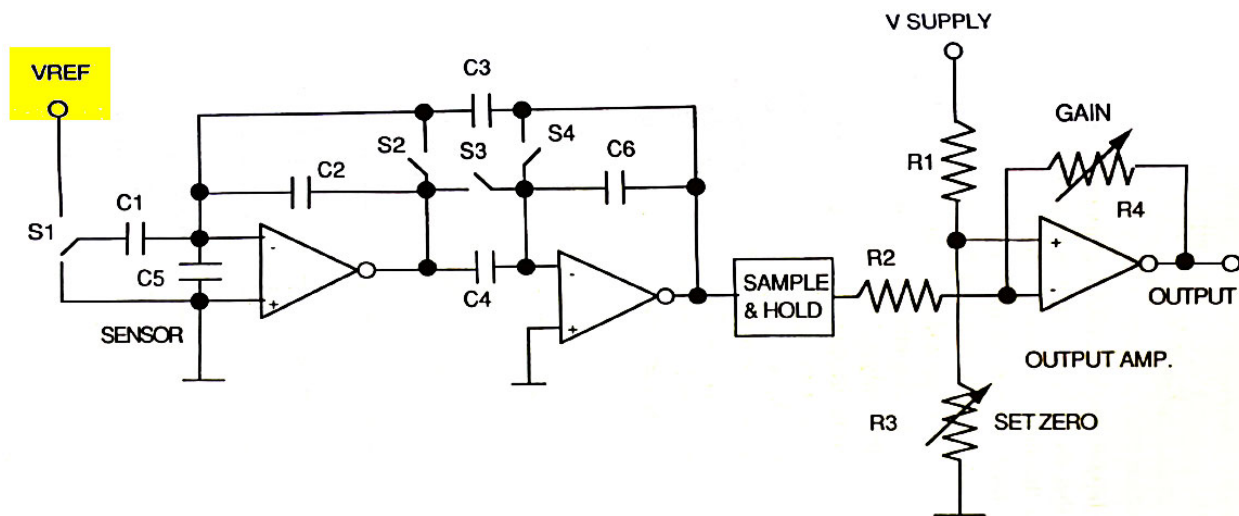


Figure 12.8 Single capacitor sensing block diagram.

(*Id.* at 430-31 (highlighting added).)

140. A POSITA would have known that a change in capacitance in Fujiyoshi's second and seventh embodiments would have been measured by applying AC signals to electrodes **30** and **32**. Based on the disclosures of the '122 patent, such signals constitute **capacitive pickoff excitation signals**. ('122 patent, 8:20-22, 5:35-38.) A POSITA would have understood the capacitive pickoff excitation signals would modulate (i.e., excite) the capacity change signal to a higher frequency, thus achieving an improved signal-to-noise ratio from the capacitive detection circuit **173**, and therefore a more accurate detection of the angular rate signals. It is my opinion that the alternating-current signals provided over time to electrodes **30** and **32** to detect a change in capacitance are **capacitive pickoff excitation signals**, since they relate to a change in capacitance, they excite the

capacitors formed by mass portion **1** and electrodes **30** and **32**, and they serve to “pick off” or sense the capacitance at electrodes **30** and **32** with respect to the mass portion **1** at a given point in time.

141. To the extent there is any question that a POSITA would have understood that Fujiyoshi’s vibration motion and Coriolis force sensing would have involved **capacitive pickoff excitation signals**, it would have been obvious to use such signals in Fujiyoshi’s system based on Kumar.

142. Kumar discloses a vibrating gyro system that has control loop circuitry for both the driven vibrating motion and sensing motion caused by the Coriolis force—similar to Fujiyoshi. (*See, e.g.*, Kumar, Fig. 2a, 3:50-4:45.) Like Fujiyoshi, Kumar senses such motion of an inertial element by measuring a capacitance change as the distance between a “central member” (the vibrating inertial element) and a “pickoff electrode” that forms a “parallel plate capacitor” with the central member. (*Id.*, 3:62-65.) Kumar discloses that “[s]ince a DC bias voltage is present on the central member’s electrically conductive layer **47**, the varying capacitance,” due to the distance between the central member and the pickoff electrode changing, “causes a variation in the electrical signal” that gets output as a motion sensing signal. (*Id.*, 3:62-4:2, 4:19-25.) Further, Kumar discloses that “other types of oscillation sensors may be employed, such as high frequency carrier signal capacitive pickoffs (which

operate without a DC bias voltage)[.]” (*Id.*, 6:29-34.) In light of Kumar, it would have been obvious to a POSITA to implement Fujiyoshi’s capacity detecting circuits 170 and 173 using a DC bias voltage or AC carrier signal provided to the angular rate sensor unit in Fujiyoshi’s second and seventh embodiments. The Fujiyoshi-Kumar combination renders obvious **an angular rate sensor unit receiving capacitive pickoff excitation signals.**

143. **Rationale and Motivation to Combine (Fujiyoshi with Kumar):** A POSITA would have been motivated to combine Fujiyoshi with Kumar, in the manner described above, predictably resulting in the angular rate sensor unit of Fujiyoshi receiving capacitive excitation pickoff signals, as described in Kumar.

144. Fujiyoshi and Kumar are analogous references. Both are in the same field as the ’122 patent. Like Fujiyoshi, Kumar relates to the design of vibrating gyroscopes and associated control circuitry. (Kumar, 1:7-9, 3:50-4:45.)

145. A POSITA would have been motivated to combine Fujiyoshi with Kumar in order to implement Fujiyoshi’s capacitive sensing systems using a method disclosed by Kumar as effective to detect inertial element movement in a sensor design that is highly similar to Fujiyoshi’s. Fujiyoshi only provides high-level disclosures related to how its capacitive sensing systems work—disclosing “capacity detecting circuit[s],” but not explicitly disclosing how these circuits work at a

granular level. (Fujiyoshi, Fig. 9, 20:12-19.) Kumar provides further detail for how a POSITA would have been motivated to implement capacity detecting circuits to detect the motion of an inertial element. (Kumar, 3:62-4:2.) A skilled artisan would thus have found the disclosures in Kumar helpful in understanding how to implement Fujiyoshi's capacitive sensing systems.

146. To the extent there is any argument that claim 1 of the '122 patent requires plural capacitive pickoff excitation signals, it is my opinion that a POSITA would have considered Fujiyoshi's seventh embodiment in combination with Kumar to have plural capacitive pickoff excitation signals, because each of the two mass portions 1 (in the two constituent instances of Fujiyoshi's second embodiment) would have received separate capacitive pickoff excitation signals.

147. Further, it is my opinion that a POSITA would have considered an AC carrier signal supplied over time to Fujiyoshi's angular rate sensor unit to be plural capacitive pickoff excitation signals in Fujiyoshi's second and seventh embodiments. A POSITA would have understood that a "high frequency carrier signal" like Kumar discloses varies over time—and therefore constitutes capacitive pickoff excitation *signals*. A POSITA would have been motivated to use Kumar's AC carrier signal—rather than a DC bias—for Fujiyoshi's capacitive pickoff excitation signals. A POSITA would have understood that the use of an AC carrier

signal allows for better elimination of noise than a DC carrier signal. (*See, e.g.,* Ristic at 429-31; Slater at 72-73.) To the extent there is any argument that an AC signal does not constitute multiple signals when considered over time, Fujiyoshi discloses two separate capacity detecting circuits **170** and **173**. (*See, e.g.,* Fig. 9.) Based on my discussion above, a POSITA would have understood that *each* of these capacity detecting circuits would provide a *separate* capacitive pickoff excitation signal to the angular rate sensor unit—which would comprise multiple **capacitive pickoff excitation signals** in Fujiyoshi’s second and seventh embodiments.

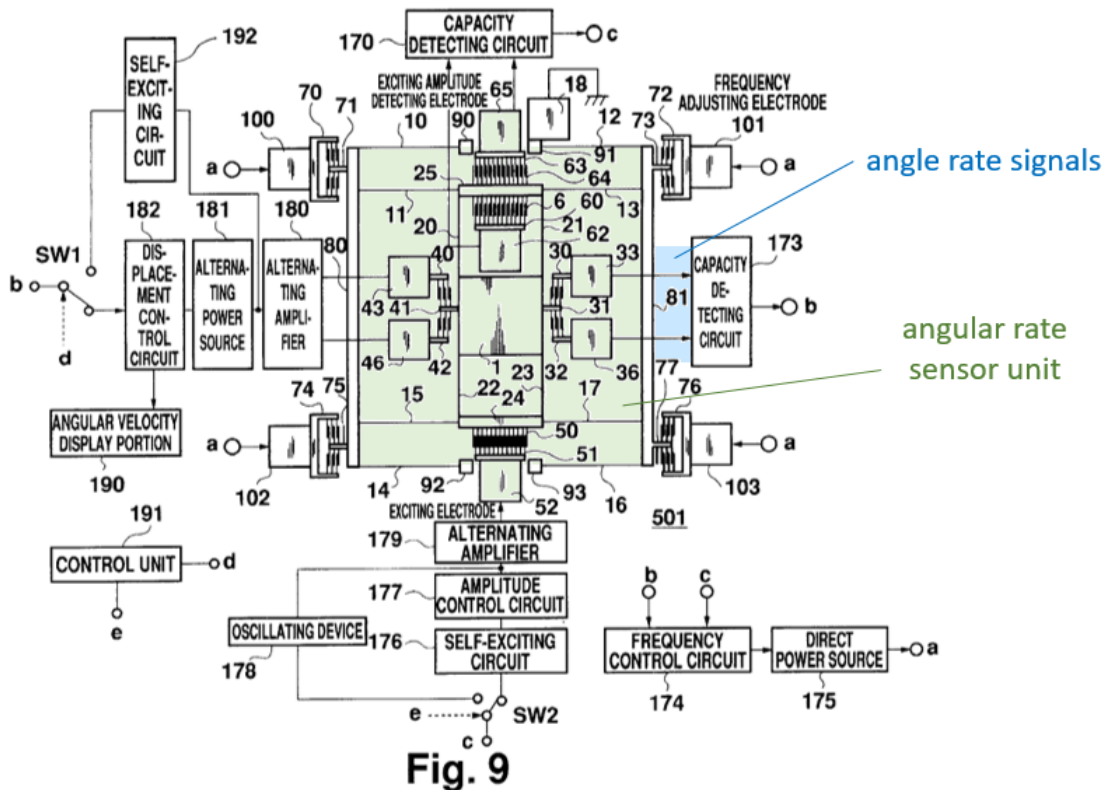
148. I understand that Patent Owner proposed in prior litigation that the term “capacitive pickoff excitation signals” should be construed as “electrical signals that provide electrical energy (i.e. excitation) into the angular rate sensor unit’s pickoff capacitors.” (**EX1018** at 15-19; **EX1019** at 8-10; **EX1020** at 26-28; **EX1021** at 12; **EX1022** at 31-33; **EX2023** at 9-10.) This proposed construction supports my understanding that a POSITA would have understood Fujiyoshi’s second and seventh embodiments to provide **capacitive pickoff excitation signals** to electrodes **30** and **32** or mass portion(s) **1**. These signals provide electrical energy into the capacitors formed by comb electrodes **30**, **31**, and **32**.

149. Continuing on with my analysis, Fujiyoshi further discloses an **angular rate sensor unit** that **output[s] angle rate signals in response to motion of said**

carrier. The '122 patent indicates that angle rate signals are part of the circuit loop that outputs angular rate information—meaning they reflect or are derived from the displacement of the inertial element due to the Coriolis force when the carrier undergoes angular rotation motion. (Fujiyoshi, 4:57-62, 5:10-18.) The '122 patent also indicates that angle rate signals are a preliminary form of angular rate signals, which are derived from the angle rate signals. (*Id.*, 8:40-9:4.)

150. Similar to the disclosures of the '122 patent, Fujiyoshi teaches that its **angular rate sensor unit output[s] angle rate signals**, which reflect the displacement of an inertial element (mass portion **1**) due to the Coriolis force and which are used to derive angular rate signals. Fujiyoshi discloses that in its second and seventh embodiments, the Coriolis force causes vibration of mass portion **1** in the lateral “detecting” direction (i.e., horizontally side-to-side from the perspective of Fujiyoshi’s Figure 9) when the sensor unit undergoes an angular rotation along an axis that is perpendicular to the surface plane of mass portion **1**. (Fujiyoshi, 20:12-19.) Fujiyoshi further teaches that “the vibration to the detecting direction of the mass portion **1** is transmitted to the capacity detecting circuit **173** through the capacity detecting electrodes **30** and **32** as a capacity change and the change thereof is detected.” (*Id.*) The signals transmitting a capacity change from capacity detecting electrodes **30** and **32** to capacity detecting circuit **173** in Fujiyoshi’s Figure

9 circuit are **angle rate signals in response to motion of said carrier**, since they indicate the rate at which the angle of the carrier is changing. The angle rate signals are identified in the annotated version of Fujiyoshi's Figure 9 below:



(Fujiyoshi, Fig. 9 (highlighting and annotations added).)

151. Further, similar to the '122 patent's disclosures that angle rate signals are used to derive angular rate signals, the signals output by capacity detecting electrodes **30** and **32** in Fujiyoshi's second and seventh embodiments become angular rate signals (discussed further below), as shown in the annotated version of Fujiyoshi's Figure 9 below:

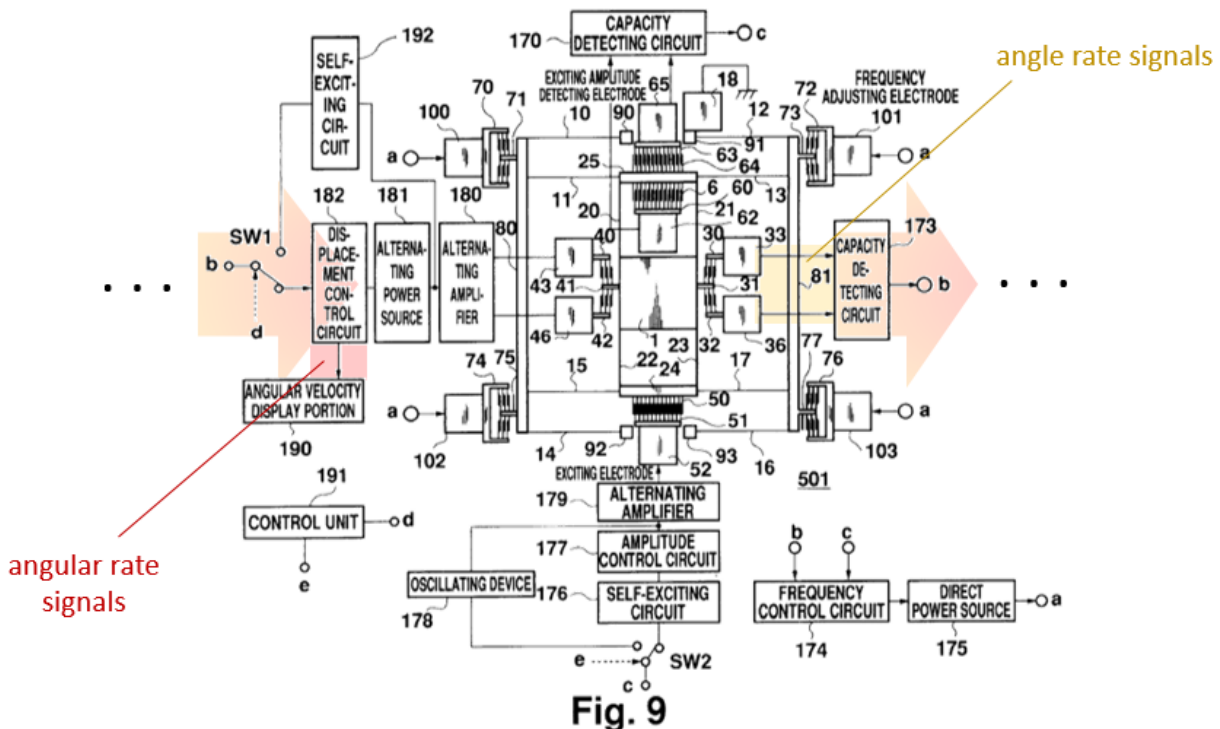
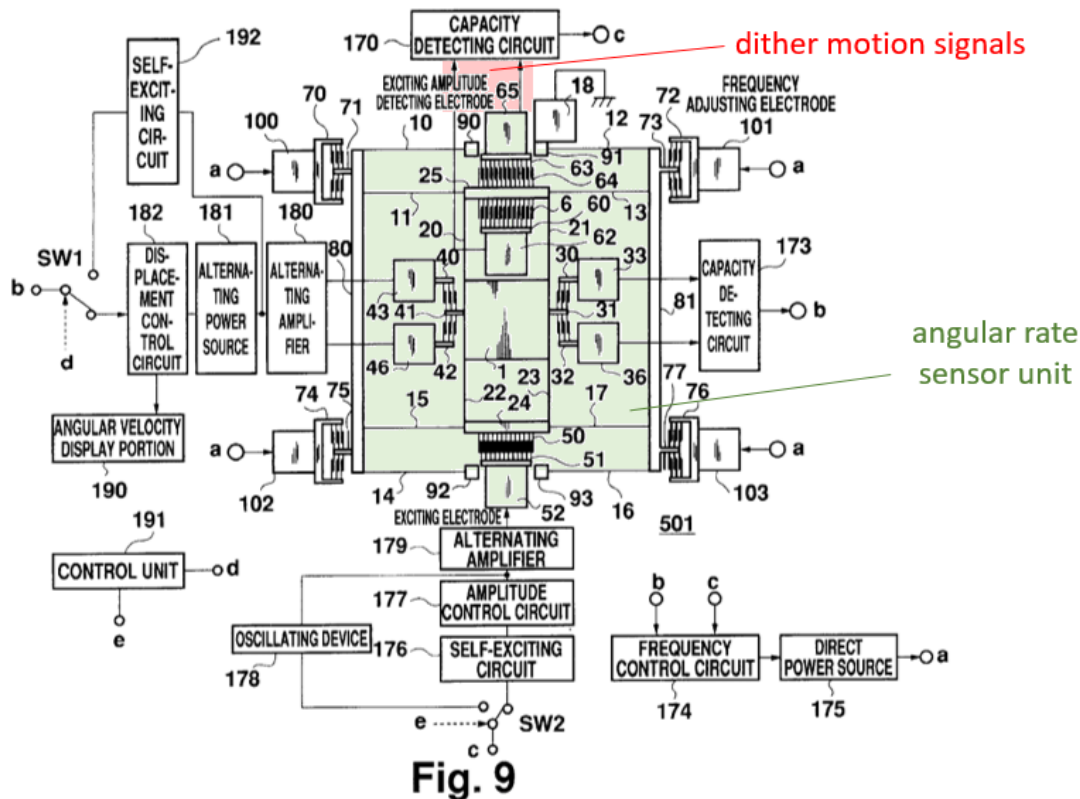


Fig. 9

(Fujiyoshi, Fig. 9 (highlighting and colored annotations added), 20:20-27.)

152. I also note that Fujiyoshi’s **angle rate signals** are **output[] in response to motion of said carrier**. Fujiyoshi indicates that angle rate signals are output based on “the Coriolis force due to the angular velocity.” (Fujiyoshi, 20:12-19.) Fujiyoshi’s angle rate signals are output in response to the rotation motion of the sensor system, which varies based on the rotation motion of the carrier—e.g., the vehicle on which the sensor system is mounted.

153. It is also my opinion that Fujiyoshi teaches an **angular rate sensor unit** that **output[s] dither motion signals**, as shown in the annotated version of Fujiyoshi’s Figure 9 below:



(Fujiyoshi, Fig. 9 (highlighting and annotations added).) In Fujiyoshi’s second and seventh embodiments, vibration in the “exciting direction” (i.e., vertically up and down from the perspective of Figure 9) is “detected by a capacity detecting circuit 170 through the exciting amplitude detecting electrodes 60 and 63[.]” (*Id.*, 19:67-20:2.) Accordingly, the signals provided from electrodes 60 and 63 are **dither motion signals**, since they reflect the dither (i.e., vibration) motion of mass portion 1. This information is then fed back into the circuitry for generating the dither driver signals “in such a manner as to make the amplitude of the vibration constant on the basis of the excitation control signal.” (*Id.*, 20:4-11.)

154. Based on the above analysis, it is my opinion that Fujiyoshi alone or in combination with Kumar would have rendered obvious to a POSITA **an angular rate sensor unit receiving dither driver signals, capacitive pickoff excitation signals and a displacement restoring signal and outputting angle rate signals in response to motion of said carrier and dither motion signals.**

- (c) **a central circuitry receiving said angle rate signals in response to said motion of said carrier and said dither motion signals and outputting angular rate signals and digital low frequency inertial element displacement signals (Claim 1[b]);**

155. It is my opinion that a POSITA would have found **a central circuitry receiving said angle rate signals in response to said motion of said carrier and said dither motion signals and outputting angular rate signals and digital low frequency inertial element displacement signals** obvious based on Fujiyoshi in light of Townsend.

156. Fujiyoshi discloses **a central circuitry receiving said angle rate signals in response to said motion of said carrier and said dither motion signals.** The '122 patent indicates that the central circuitry consists of two distinct circuit blocks—one related to dither motion and the other related to motion due to the Coriolis force. These two blocks are shown in the annotated version of Figure 6 shown below, where example central circuitry is shown in the dotted lines:

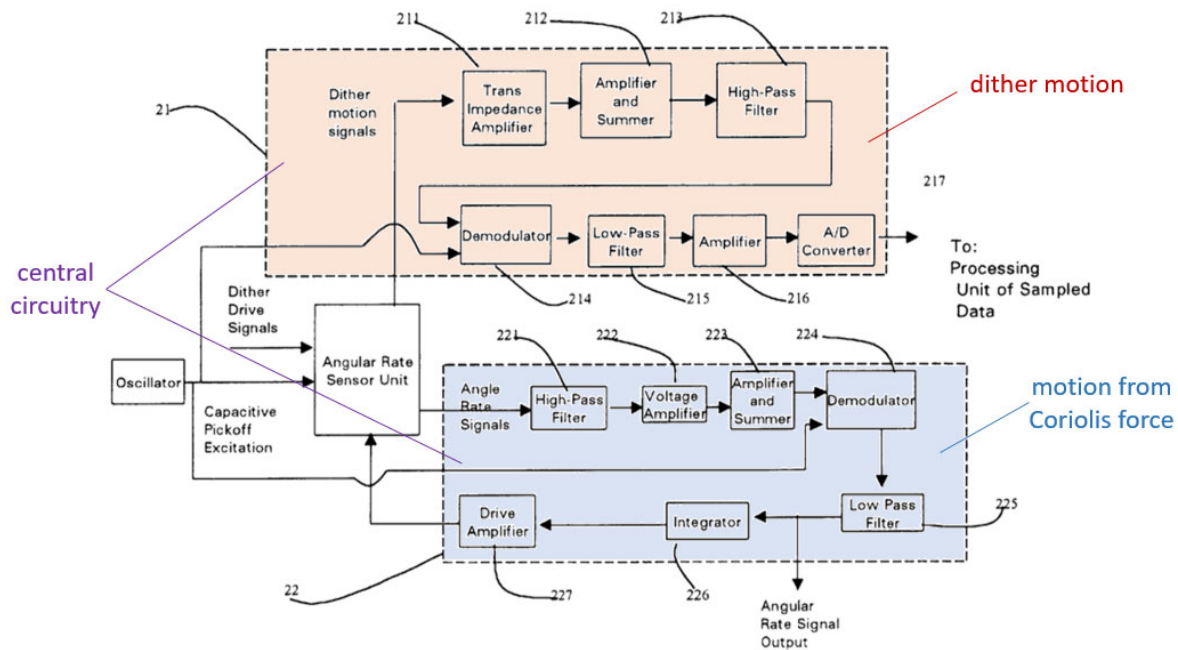
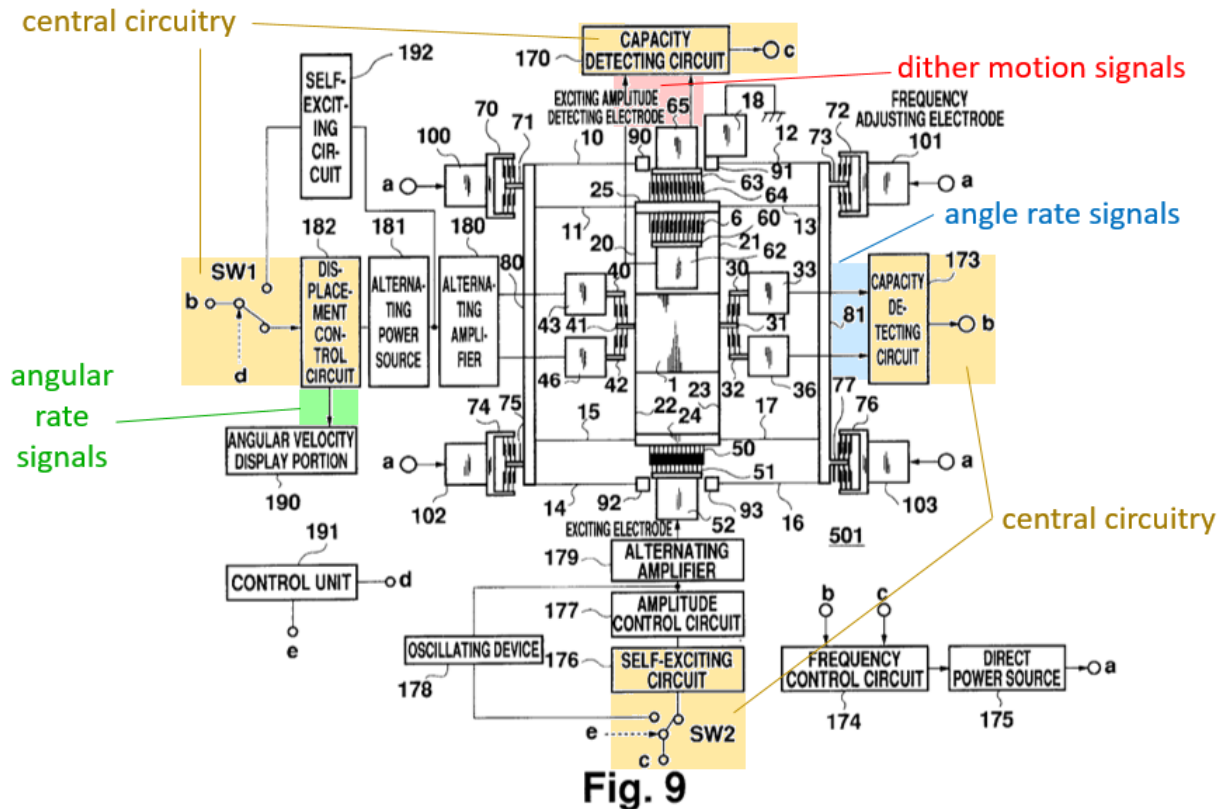


Figure 6

(’122, Fig. 6 (colored annotations and highlighting added), 7:61-63.) Based on the ’122 patent, the above-highlighted circuitry appears to correspond to the “central” circuitry because, on the **dither motion** side, the central circuitry is centrally located between the angular rate sensor unit and the digital signal processing system (not pictured to the right of Figure 6). On the **Coriolis force motion** side, the central circuitry is centrally located between the angular rate sensor unit and the angular rate signal output.

157. Similar to the disclosures of the ’122 patent regarding central circuitry, Fujiyoshi discloses two blocks of **central circuitry**—one related to dither motion (the **orange**-highlighted boxes at the top and bottom of annotated Figure 9 below,

which are connected at node “c”) and one related to Coriolis force motion (the orange-highlighted boxes on the right and left of annotated Figure 9 below, which are connected at node “b”):



(Fujiyoshi, Fig. 9 (highlighting and colored annotations added), 19:67-20:8, 20:12-19.) Further, just like in the '122 patent, the central circuitry related to dither motion (top and bottom of the above Figure 9) is centrally located between the angular rate sensor and the **digital signal processing unit** (discussed for claim 1[c] below), and the central circuitry related to Coriolis force motion is centrally located between the angular rate sensor and the **angular rate signals** output (shown in green highlighting

above).

158. My reasoning for why it is my opinion that the labeled signals in Figure 9 constitute **dither motion signals** and **angle rate signals** is provided above for claim 1[a]. Fujiyoshi also discloses that these signals are received by components of the **central circuitry** highlighted in orange in the above annotated figure. (Fujiyoshi, 19:67-20:8, 20:12-19.)

159. It is my opinion that Fujiyoshi teaches a **central circuitry** that **output[s] angular rate signals**. Fujiyoshi discloses that displacement control circuit **182** in its second and seventh embodiments “determines the Coriolis force acting on the mass portion **1** on the basis of the control signal necessary for making the displacement of the mass portion **1** zero, and is then able to calculate the corresponding angular velocity.” (Fujiyoshi, 20:28-32.) This calculated angular velocity is then “output to the angular velocity display portion **190** and a desired display is performed.” (*Id.*, 20:32-34.) In my opinion, the angular velocity output from displacement control circuit **182** to display portion **190** comprises **angular rate signals**.

160. As I discuss above for the **angle rate signals** claim language in claim 1[a], my understanding of what constitutes **angle rate signals** and **angular rate signals** in Fujiyoshi’s second and seventh embodiments is consistent with the ’122

patent's disclosures. The '122 patent discloses that angle rate signals are processed to form angular rate signals. ('122, Fig. 6, 8:40-64.) The same is true of the angle rate signals and angular rate signals I identify in Fujiyoshi's second and seventh embodiments. (Fujiyoshi, 20:20-27.)

161. To the extent there is any argument that plural **angular rate signals** are required to be output from the **central circuitry**, it is my opinion that the angular velocity output from displacement control circuit **182** in Fujiyoshi's second embodiment constitutes plural angular rate signals. Fujiyoshi's second embodiment measures angular rate as it changes over time. (*See, e.g.*, Fujiyoshi, 18:10-18, 3:44-62.) Accordingly, as angular rate changes, the output of Fujiyoshi's displacement control circuit **182** changes—yielding different signals in real time. In this sense, a POSITA would have understood that Fujiyoshi's displacement control circuit **182** outputs plural **angular rate signals** when considered over time.

162. To the extent there is any dispute that Fujiyoshi's second embodiment teaches central circuitry that outputs plural angular rate signals, Fujiyoshi's seventh embodiment—which is a differential configuration combining two instances of Fujiyoshi's second embodiment circuit—has central circuitry that outputs plural angular rate signals. Each of the two constituent sensors according to Fujiyoshi's second embodiment outputs its own angular rate signal in Fujiyoshi's seventh

embodiment. (Fujiyoshi, 24:54-57 (“[T]he difference of the output from the two angular velocity sensors **501** is taken[.]”).) These two angular rate signals comprise plural **angular rate signals**, to the extent there is any argument that is required by claim 1.

163. It would have been obvious to a POSITA that the **central circuitry** in Fujiyoshi’s second and seventh embodiments would output **digital low frequency inertial element displacement signals** in light of Townsend and Cox.

164. I provide my analysis for the Fujiyoshi-Townsend combination below in connection with claim 1[c]. As I explain there, it would have been obvious to a POSITA—and a POSITA would have been motivated—to incorporate a digital signal processing system into Fujiyoshi’s system to process signals in the dither motion control loop. As I also explain below, a POSITA would have been motivated to include sample-and-hold device(s) in Fujiyoshi’s system in order to decrease noise and improve sensor performance.

165. It is my opinion that the sample-and-hold devices in the Fujiyoshi-Townsend combination would have generated **low frequency inertial element displacement signals**. Townsend discloses that sample-and-hold devices “average or integrate the input waveform over the sample period,” providing “a high degree of noise rejection.” (Townsend at 18; *see also id.*, Fig. 4, 12-13.) As I discuss below,

the Fujiyoshi-Townsend combination would have involved outputting Fujiyoshi's dither motion signals into sample-and-hold devices. Based on the disclosures of Townsend, a POSITA would have understood that such sample-and-hold devices would have output a low frequency form of those dither motion signals, because the "averag[ing] or integrat[ing]" operation of the sample-and-hold devices would have led to the removal of high-frequency noise. (*Id.* at 18; *see also id.*, Fig. 4, 12-13.) Understanding dither motion signals from which high-frequency information has been removed as "low frequency inertial element displacement signals" is consistent with the disclosures of the '122 specification. (*See* '122, Fig. 6, 8:27-34.) Further, it is my opinion that the Fujiyoshi-Townsend combination would satisfy Petitioners' proposed construction for "inertial element displacement signals" in the pending district court litigation: "electrical signals reflecting dither motion of inertial element(s)." (**EX1026**.) The signals I have identified are electrical signals derived from the dither motion signals, so they satisfy Petitioners' construction in my opinion.

166. To the extent there is any dispute that inputting Fujiyoshi's dither motion signals into sample-and-hold devices would have resulted in **low frequency inertial element displacement signals**, it would have been obvious to incorporate a low-pass filter into the sample-and-hold devices of the Fujiyoshi-Townsend

combination in light of Cox.

167. Cox discloses a “sample and hold circuit” incorporating a low-pass filter via “a resistive arrangement in association with the holding capacitor.” (Cox, Abstract, 1:27-30, 3:50-4:8.) It would have been obvious to a POSITA to implement the sample-and-hold devices in the Fujiyoshi-Townsend combination according to Cox’s disclosures, such that they would also function as low-pass filters. In the resulting combination, the result of Fujiyoshi’s dither motion signals passing through Cox’s sample-and-hold devices/low-pass filters would constitute **low frequency inertial elements displacement signals**. (See ’122, Fig. 6, 8:27-31.)

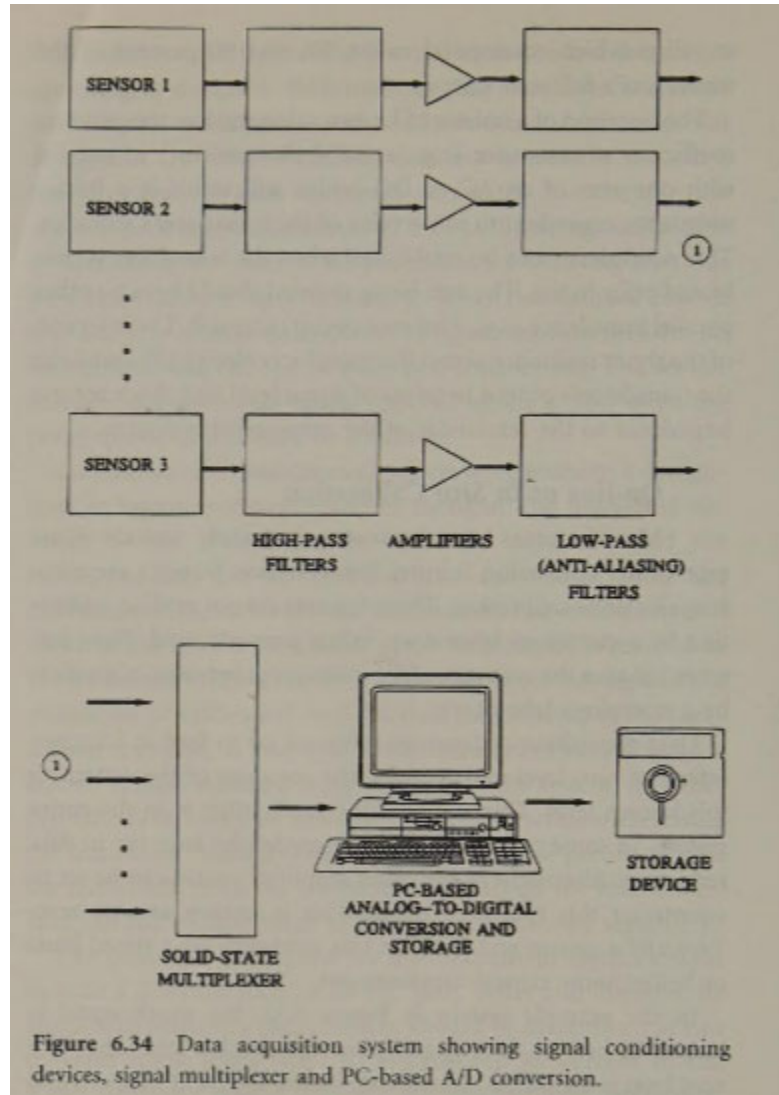
168. ***Rationale and Motivation to Combine (Fujiyoshi with Townsend and Cox)***: A POSITA would have been motivated to combine Fujiyoshi and Townsend with Cox, in the manner described above. As I will explain for limitation 1[c] below, like Fujiyoshi, Townsend is also an analogous reference.

169. Fujiyoshi and Cox are analogous references. Both are in the same field as the ’122 patent. Like Fujiyoshi, Cox discloses circuitry for manipulating and detecting AC signals, including by using capacitors and feedback loops. (E.g., Cox, Figs, 1-2, 2:14-25, 3:19-28.)

170. A POSITA would have been motivated to implement the sample-and-hold devices in the Fujiyoshi-Townsend combination to function as low-pass filters

according to Cox's disclosures in order to eliminate more noise from the system. Both Fujiyoshi and Townsend indicate that reduction of noise is important for sensor performance. (Townsend at 18; Fujiyoshi, 6:50-53; 12:60-64.) A POSITA would have understood that adding low-pass filtering functionality to the sample-and-hold devices would have further reduced noise and improved sensor performance.

171. A POSITA would have been further motivated to incorporate Cox's low-pass filter functionality into the Fujiyoshi-Townsend combination's sample-and-hold devices to reduce aliasing by the analog-to-digital converters. For example, the textbook David Irwin, *The Industrial Electronics Handbook* (1997) ("Irwin"; **EX1013**.) indicates that "[a] low-pass filter is also referred to as an anti-aliasing filter" in the context of analog-to-digital conversion, because "LP filtering removes unnecessary higher frequency components and enables us to choose a sampling rate that avoids any 'distortions' in the digitized signal." (Irwin at 139.) Further, Irwin shows a diagram of a low-pass filter preceding an analog-to-digital converter:



(Irwin at 138.)

172. A POSITA would have been motivated to use Cox's design of a sample-and-hold device combined with a low-pass filter in the interest of minimizing the number of components in the system. Cox discloses:

[T]he capacitor performs the two functions of holding the sampled signal and serving as a component of the RC low-pass filter. If low-pass

filtering were not so incorporated, then separate provision would have to be made external to the sample and hold circuit for such filtering. The incorporation of low-pass filtering into the sample and hold circuit obviously minimizes the total number of components needed.

(Cox, 3:68-4:8.) A POSITA would have been motivated to minimize the total number of components needed, for example, to reduce system cost.

173. Accordingly, it is my opinion that **a central circuitry outputting low frequency inertial element displacement signals** would have been obvious based on Fujiyoshi in light of Townsend. In the alternative, it is my opinion that this limitation would have been obvious based on Fujiyoshi in light of Townsend and Cox.

174. It is also my opinion that **a central circuitry outputting *digital* low frequency inertial element displacement signals** would have been obvious based on Fujiyoshi in light of Townsend (or, in the alternative, Fujiyoshi in light of Townsend and Cox). As I discuss below, it would have been obvious to a POSITA that, in the Fujiyoshi-Townsend combination, an analog-to-digital converter would convert the analog low frequency inertial element displacement signals into *digital* signals.

175. Accordingly, it is my opinion that, based on Fujiyoshi in light of Townsend and Cox, a POSITA would have found obvious **a central circuitry**

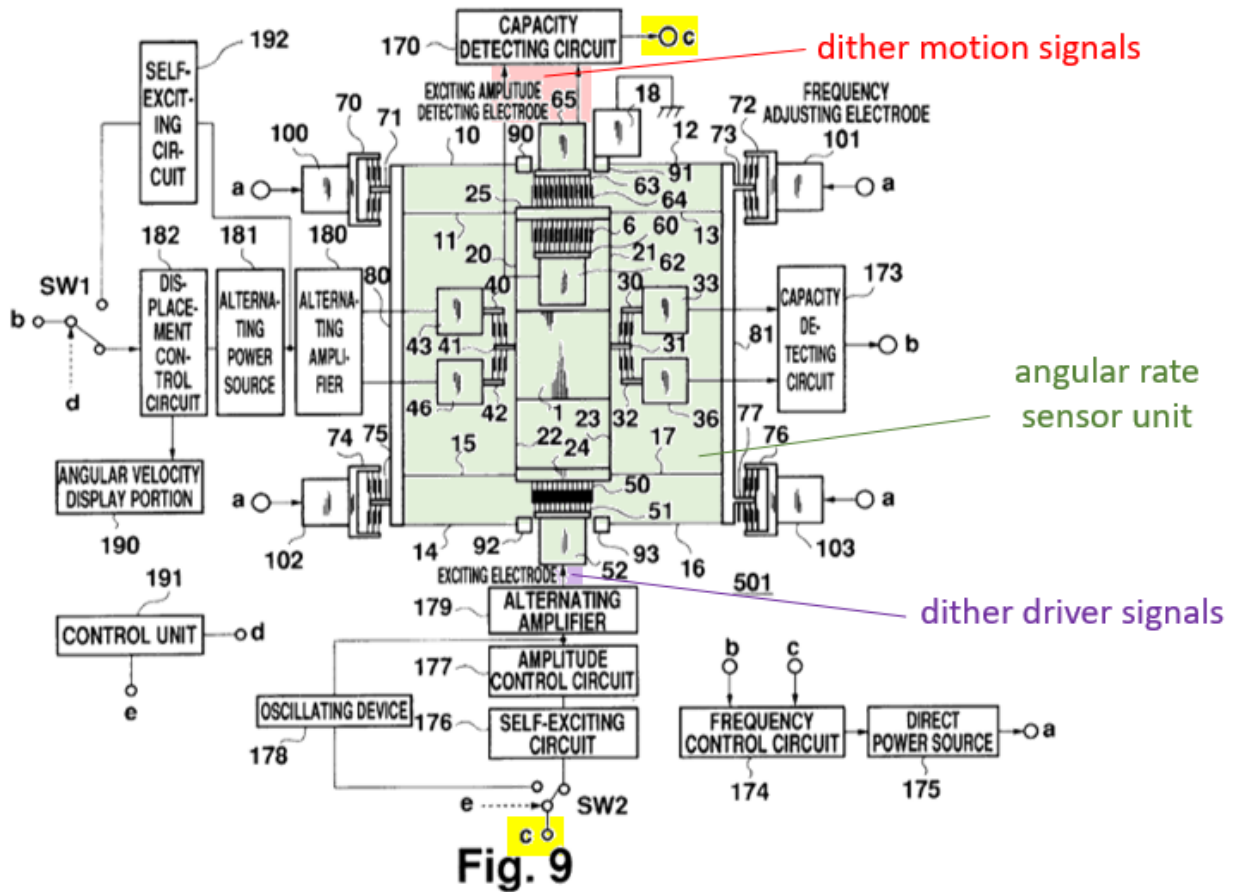
receiving said angle rate signals in response to said motion of said carrier and said dither motion signals and outputting angular rate signals and digital low frequency inertial element displacement signals.

- (d) a digital signal processing system analyzing said digital low frequency inertial element displacement signals and feeding back said dither driver signals to said angular rate sensor unit. (Claim 1[c]).**

176. The final limitation recites **a digital signal processing system analyzing said digital low frequency inertial element displacement signals and feeding back said dither driver signals to said angular rate sensor unit.** This limitation would have been obvious to a POSITA based on Fujiyoshi in light of Townsend.

177. Fujiyoshi discloses **feeding back said dither driver signals to said angular rate sensor unit.** Fujiyoshi discloses that its dither motion control system involves a “feedback loop,” where “the detected output from the capacity detecting circuit **170** [based on the dither motion signals] is supplied to the self-exciting circuit **176**, which generates a self-exciting signal on the basis of the above detected output and further the amplitude control circuit **177** controls in such a manner as to make the amplitude of the vibration constant on the basis of the excitation control signal [the dither driver signals].” (Fujiyoshi, 20:2-11.) This is shown in the annotated version of Fujiyoshi’s Figure 9 below, which demonstrates that dither motion signals

connect to the circuitry for generating dither driver signals through node “c”:

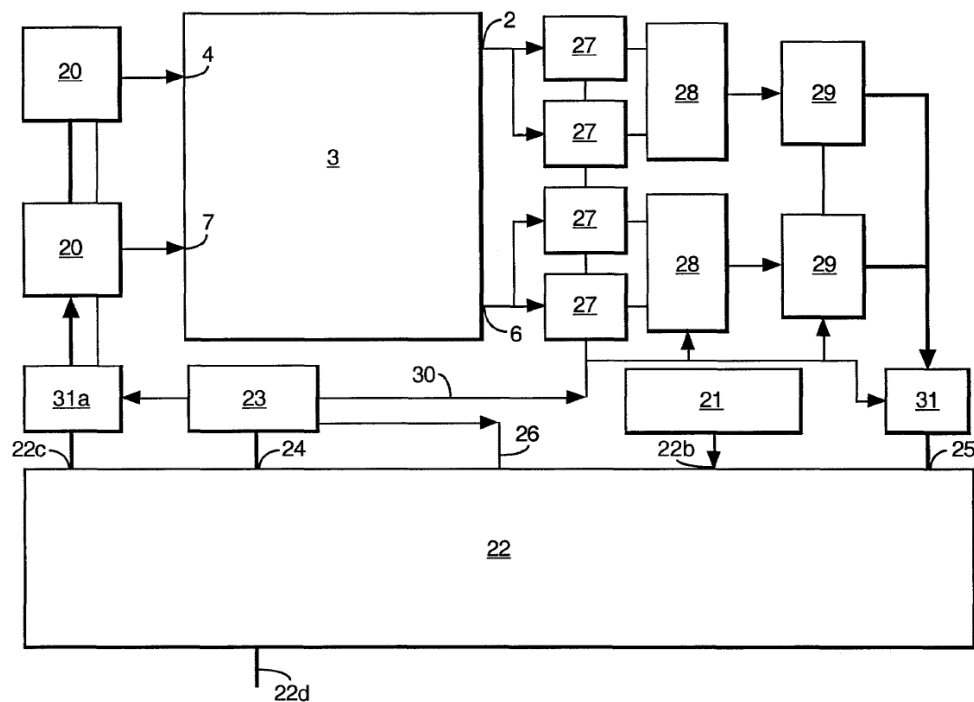


(*Id.*, Fig. 9 (highlighting and colored annotations added).) Accordingly, it is my opinion that Fujiyoshi discloses that **dither driver signals** are f[ed] back to said **angular rate sensor unit**.

178. **Townsend** discloses a digital control system for a vibrating structure gyroscope—which Townsend discloses can include a variety of different structures including “beams, tuning forks, cylinders, hemispherical shells and rings” for detecting Coriolis forces exerted on a vibrating element. (Townsend at 1.)

Townsend discloses that such vibrating structure gyroscopes are conventionally designed with two circuit loops: (1) a primary loop for exciting the vibrating structure and maintaining its vibration at a “natural frequency determined by the mechanical vibratory structure” and (2) a secondary loop “to provide damping for the high Q rate response in order to achieve the required system performance.” (*Id.* at 1-2.) While Townsend teaches that these loops are traditionally implemented using precision analog circuits, Townsend indicates that such implementations come with various drawbacks, including difficulty with specification, design, and integration into small low cost systems; difficulty with calibration and compensation; and the requirement of “modern systems” for outputs available in digital format. (*Id.* at 3.) Accordingly, Townsend discloses embodiments using a digital processing unit in the primary and secondary circuit loops for vibrating structure gyroscope control, including the embodiment shown in Figure 4:

Fig.4.

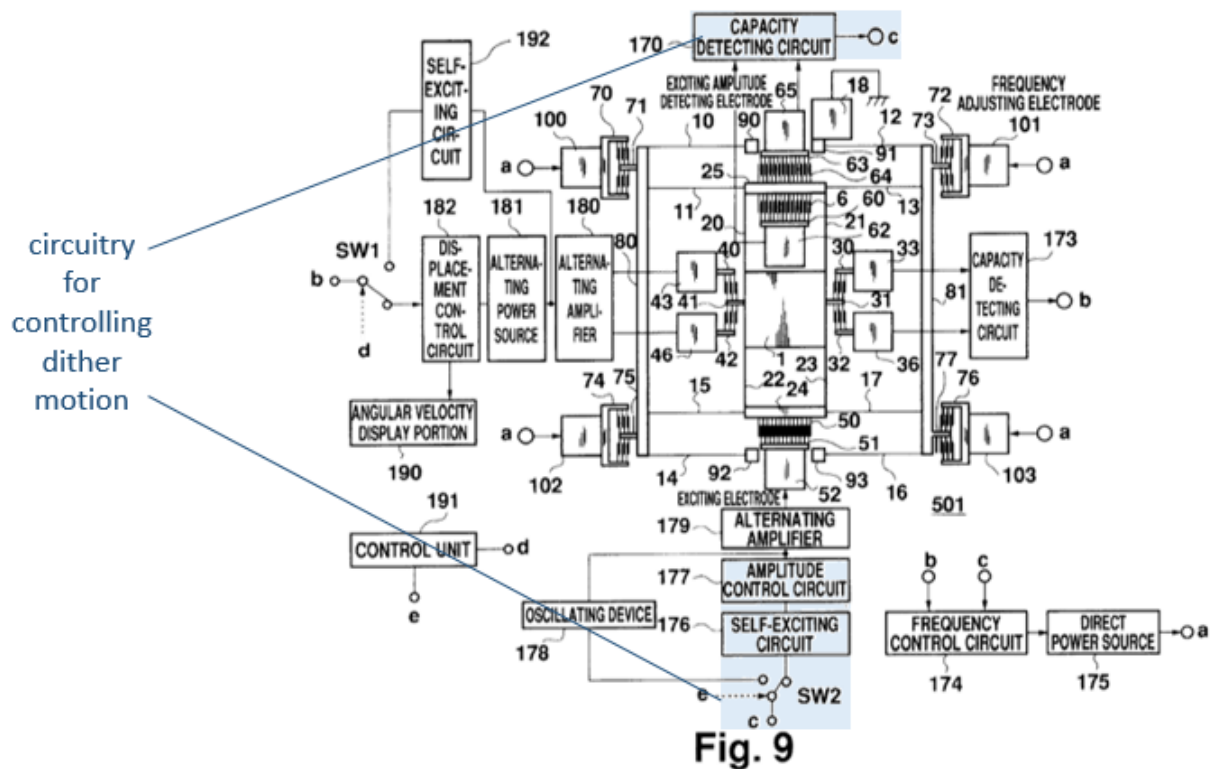


(Townsend, Fig. 4.) Vibrating structure 3 is vibrated at its resonant frequency via primary loop 1. (*Id.* at 2-3.) Primary pickoff means 2 outputs a signal reflecting “the amplitude of the resultant vibration.” (*Id.* at 2.) Secondary pickoff means 6 outputs a signal “proportional to the applied angular rate,” which is used in a “damping loop” for “providing damping for the high Q rate response in order to achieve the required system performance.” (*Id.* at 2, 4) These analog signals pass through sample and hold devices 27, are converted to digital signals via analog-to-digital converters 29, are stored in buffer 31, and input to digital processing unit 22 via data input 25. (*Id.* at 12-13.) Data processing unit 22 outputs signals via output 22c, which are stored in buffer 31a, converted to analog signals via digital-to-analog

converters 20, and fed back into vibrating structure 3 via primary drive means 4 (to drive vibration) and secondary drive means 7 (for damping). (*Id.* at 3.)

179. It would have been obvious to a POSITA to incorporate a digital signal processing system—e.g., the data processing unit and related circuitry (e.g., analog-to-digital and digital-to-analog converters, sample-and-hold devices) disclosed by Townsend—into Fujiyoshi’s system for controlling the dither motion and sensing (Coriolis force) motion of Fujiyoshi’s mass portion(s) in its second and seventh embodiments. Accordingly, a POSITA would have found it obvious based on Fujiyoshi in light of Townsend to incorporate **a digital signal processing system analyzing said digital low frequency inertial element displacement signals and feeding back said dither driver signals to said angular rate sensor unit.**

180. A POSITA would have been motivated to connect the dither motion control circuitry in Fujiyoshi’s second and seventh embodiments to a digital signal processing system like Townsend teaches. The annotated version of Fujiyoshi’s Figure 9 below shows the circuitry for controlling dither motion in Fujiyoshi’s second and seventh embodiments:



(Fujiyoshi, Fig. 9 (highlighting and annotations added).) It would have been obvious to connect the highlighted dither motion control circuitry in the above annotated version of Fujiyoshi's Figure 9 to a digital signal processing system like that disclosed by Townsend.

181. For example, a POSITA would have also been motivated to connect node "c" at the top of Fujiyoshi's Figure 9 system in the circuitry for controlling dither motion to a sample-and-hold device, analog-to-digital converter, buffer, and digital processing unit as disclosed by Townsend. Further, the digital processing unit would, in one example, have been connected to node "c" at the bottom of

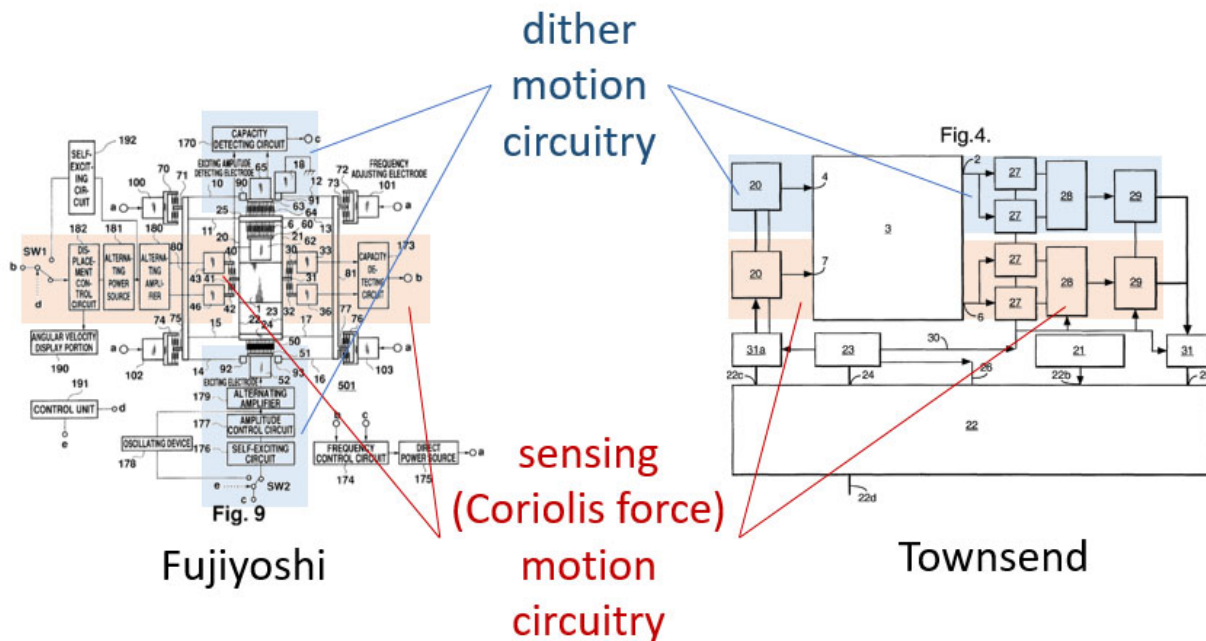
Fujiyoshi's Figure 9 circuit through a buffer and digital-to-analog converter as disclosed by Townsend. Alternatively, a POSITA would have found it obvious that amplitude control circuit 177 disclosed in Fujiyoshi's Figure 9 circuit would have contained some or all of the digital signal processing system like that disclosed by Townsend.

182. **Rationale and Motivation to Combine (Fujiyoshi with Townsend):** A POSITA would have been motivated to combine Fujiyoshi with Townsend, in the manner described above. The combination would have predictably resulted in Fujiyoshi's circuitry for controlling dither motion incorporating a digital processor and circuitry (e.g., sample-and-hold devices, analog-to-digital converters, and digital-to-analog converters) for converting between analog signals used in Fujiyoshi's circuits and digital signals input to or output from digital processor.

183. Fujiyoshi and Townsend are analogous references. Both are in the same field as the '122 patent. Like Fujiyoshi, Townsend relates to the design of vibrating gyroscopes and associated control circuitry. (E.g., Townsend at 1-2.) Townsend discloses that its systems can be used with "[k]nown vibrating structure gyroscopes" using a "variety of different mechanical vibratory structure," including "beams, tuning forks, cylinders, hemispherical shells and rings." (*Id.* at 1.) A POSITA would have considered Fujiyoshi's vibrating mass system within as

belonging to the set of “vibrating structure gyroscopes” Townsend’s systems could be used with. (*See, e.g.*, Fujiyoshi, 24:58-60 (describing Fujiyoshi’s seventh embodiment as a “tuning fork”); 19:63-20:19.) Fujiyoshi also indicates that some of its functionality involves calculating values, which suggests the use of digital processing circuitry like what Townsend discloses. (*Id.*, 16:28-33, 6:4-11.)

184. A POSITA would have been motivated to combine Fujiyoshi with Townsend because Fujiyoshi describes embodiments of a vibrating structure gyroscope and circuit loops for (1) controlling vibration of the vibrating element and (2) controlling motion caused by the Coriolis force when the system undergoes an angular rotation. (Fujiyoshi, 19:63-20:34.) Townsend describes analogous circuit loops in the form of its (1) “primary or excitation loop” (which “excite[s] the vibrating structure 3 at its natural resonant frequency”) and (2) its “secondary or damping loop” (which involves a “signal . . . proportional to the applied angular rate” and which “provide[s] damping for the high Q rate response” of the vibrating structure gyroscope. (Townsend at 1-2, 4.) A POSITA would have understood that the circuit loops of Fujiyoshi and Townsend correspond as shown in the diagram below:



Accordingly, a POSITA would have understood that the teachings of Townsend are applicable to the control circuit loops of Fujiyoshi.

185. A POSITA would have been motivated to combine Townsend with Fujiyoshi because Townsend describes digital implementations of vibrating structure gyroscope circuitry that improve upon prior art analog approaches. Townsend discloses that analog circuitry has drawbacks when used for the control loops of vibrating structure gyroscope circuitry, because such circuitry is “notoriously difficult to specify, design and integrate into small low cost systems (i.e. ASICS)”; it is “difficult to apply calibrations and compensations to systems based on analogue circuits”; and “modern systems require the sensor outputs to be

available in digital format to simplify system integration and enable further compensations to be applied to enhance performance.” (Townsend at 3.) Faced with Townsend’s teachings about the limitations of analog circuitry when used for control circuit loops for vibrating structure sensors, a POSITA would have looked to Townsend’s digital implementation for Fujiyoshi’s control circuitry.

186. In addition to incorporating a digital signal processor from Townsend into Fujiyoshi’s second and seventh embodiments, a POSITA would have been motivated to incorporate other circuitry from Townsend used in converting between analog and digital signals. A POSITA would have been motivated to incorporate digital-to-analog and analog-to-digital converters into Fujiyoshi’s circuit, since Townsend discloses that these are necessary for converting between analog signals input to/output from the vibrating structure sensor and digital signals input to/output from the digital processor. (Townsend at 12-13.) Further, a POSITA would have been motivated to incorporate sample and hold devices into Fujiyoshi’s second and seventh embodiments, because Townsend indicates that sample and hold devices “provide a high degree of noise rejection” by “averag[ing] or integrat[ing] the input waveform over the sample period.” (*Id.* at 18.) A POSITA would have been motivated based on Fujiyoshi’s disclosures to incorporate circuitry for rejecting noise. For example, Fujiyoshi discloses mechanisms for “lower[ing] noise (cross-

talk)” such that “sensor resolution can be improved.” (Fujiyoshi, 6:50-53; 12:60-64.) A POSITA would look for further means for reducing noise in Fujiyoshi’s second and seventh embodiment—like the sample and hold devices disclosed by Townsend—so as to further improve sensor performance.

2. Dependent Claim 3

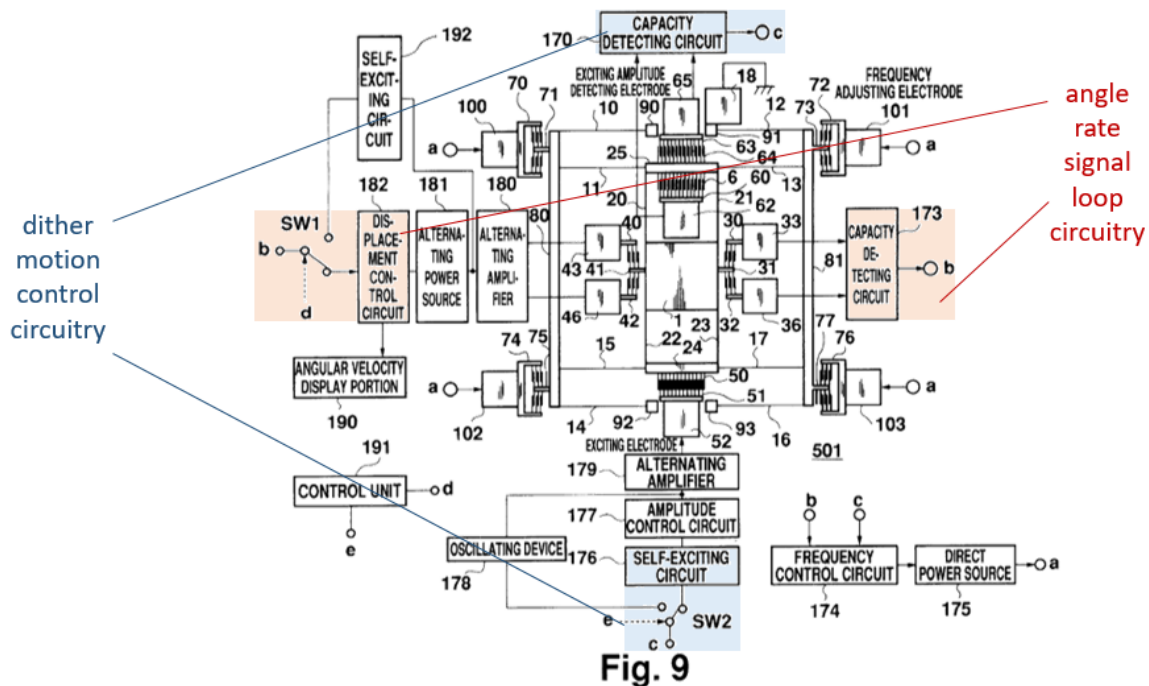
187. For reference, claim 3 recites:

3. The microelectromechanical system, as recited in claim 1, wherein said central circuitry comprises a dither motion control circuitry and an angle rate signal loop circuitry.

188. It is my opinion that Fujiyoshi discloses a **microelectromechanical system, as recited in claim 1, wherein said central circuitry comprises a dither motion control circuitry and an angle rate signal loop circuitry.**

189. I provide my analysis for why Fujiyoshi discloses a **microelectromechanical system, as recited in claim 1**, in the above analysis related to claim 1.

190. As shown in the annotated version of Fujiyoshi’s Figure 9 below, the central circuitry I identify above for claim 1[b] can be divided between **dither motion control circuitry and angle rate signal loop circuitry:**



(Fujiyoshi, Fig. 9 (highlighting and colored annotations added).) The blue-highlighted circuitry in the above diagram is **dither motion control circuitry**, because it is involved in detecting dither motion of mass portion 1 and generating dither driver signals to vibrate mass portion 1. (*Id.*, 19:63-20:11.) The red-highlighted circuitry in the above diagram is **angle rate signal loop circuitry**, because it is involved in detecting lateral displacement of mass portion 1 caused by angle rate of the system. (*Id.*, 20:12-34.) This circuitry is also a **loop**, because the angle rate signals are used to generate displacement control signals, which are fed back into the system in the circuitry on the left side of Figure 9. (*Id.*, 20:20-27.)

191. Accordingly, it is my opinion that Fujiyoshi discloses a **microelectromechanical system wherein said central circuitry comprises a**

dither motion control circuitry and an angle rate signal loop circuitry.

**C. Ground 2: Claims 1 and 3 are Obvious Over Mitamura and
Townsend**

1. Independent Claim 1

**(a) A microelectromechanical system (MEMS) for
measuring angular rate of a carrier, comprising
(Claim 1[p]):**

192. It is my opinion that Mitamura discloses **a microelectromechanical
system (MEMS) for measuring angular rate of a carrier.**

193. Mitamura teaches **a microelectromechanical system (MEMS)**. The
'122 patent indicates that microelectromechanical systems are “small
electrical/mechanical devices.” ('122, 1:38-39.) Mitamura discloses that its third
embodiment contains a “vibrating mass” (a mechanical component) and “opposing
electrodes” (electrical components) with a thickness “in the range of a few
micrometers.” (Mitamura, [0042]; *see also id.*, [0043] (describing the third
embodiment as containing an “angular velocity sensor formed from a thin-film
structural material”), [0012] (describing the invention as “an angular velocity sensor
that is compact and lightweight”).) A POSITA would have understood Mitamura’s
third embodiment to be sufficiently “small” to be a microelectromechanical
system—particularly since a device made of components as small as a few
micrometers is clearly a **micro**electromechanical system.

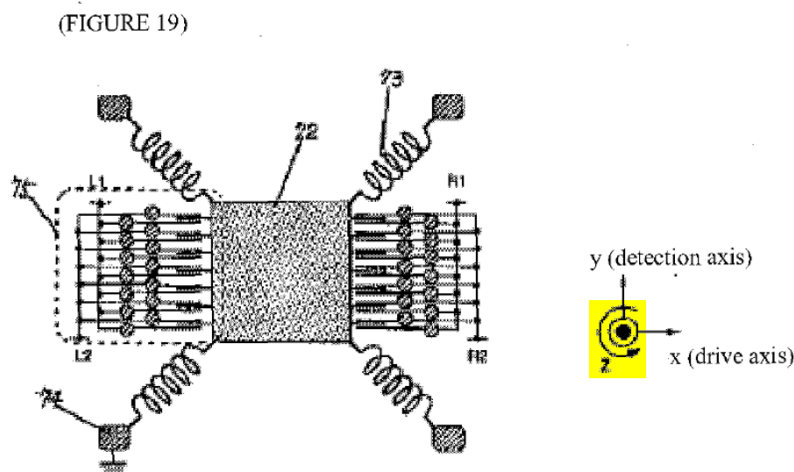
194. The '122 patent further indicates that MEMS involves “Microelectronics”—the “development of electronic circuitry on silicon chips”—and “Micromachining”—the “fabricat[ion of] tiny sensors and actuators on silicon chips.” ('122, 1:41-43, 1:46-50.) Similarly, Mitamura discloses that its third embodiment “can be fabricated using a known technique and monocrystalline or polycrystalline silicon.” (Mitamura, [0042].) Mitamura further describes various processes for fabricating its embodiments on silicon chips. (Mitamura, Figs. 8-10, [0019]-[0022]; *see also id.*, [0041] (describing relationship of Mitamura’s third embodiment to other embodiments).) Mitamura’s disclosures regarding the fabrication of its third embodiment on silicon chips—similar to the '122 patent’s teachings of the microelectronics and micromachining techniques that MEMS involves—provide further support that Mitamura’s third embodiment is a microelectromechanical system (MEMS).

195. Mitamura teaches that its third embodiment is **for measuring angular rate**. Mitamura describes its third embodiment as an “angular velocity sensor.” (Mitamura, [0042], p. 25 (discussing “angular velocity detection circuit in the third embodiment”).) Mitamura further discloses that the “detection circuit” for its third embodiment provides “[o]utput proportional to the angular velocity.” (*Id.*, [0045].) A POSITA would have understood that “angular rate” and “angular velocity” are the

same—since both refer to the change in angular rotation over time.

196. Mitamura further teaches that when the vibrating mass in its sensor embodiments “is rotated” around a particular axis, the “angular velocity” around that axis is measured. (Mitamura, [0013]; *see also id.*, [0001], [0012], Title (“Angular Velocity Sensor”).) For example, Figure 19 (which shows a sensor according to Mitamura’s third embodiment) shows a circular “z” axis representing the direction in which it measures angular rate:

[FIGURE 19]



(Mitamura, Fig. 19 (highlighting added), p. 24 (indicating that Figure 19 relates to third embodiment), [0043]; *see also id.*, [0027] (discussing z-axis).)

197. Mitamura further teaches that its third embodiment is for measuring angular rate **of a carrier**. Mitamura teaches that its vibrating mass 72 is “connected

to supports 73,” which are “secured to the substrate by securing sections 74.” (Mitamura, [0043].) The substrate thus serves as a carrier for vibrating mass 72, since vibrating mass 72 is supported or carried by the substrate. Since rotation of the carrier substrate causes vibrating mass 72 to rotate, and Mitamura discloses that angular rate is measured when the vibrating mass “is rotated,” a POSITA would have understood that its third embodiment measures angular rate of a carrier. (Mitamura, [0013].)

198. To the extent there is any question as to whether the substrate in Mitamura’s third embodiment is a carrier, it is my opinion that it would have been obvious to a POSITA to mount a sensor according to Mitamura’s third embodiment to a carrier like an automobile or an aircraft. A POSITA would have understood that an angular rate sensor like Mitamura discloses is for measuring the angular rate of *something on which it is mounted*—not the angular rate sensor on its own. (*See, e.g.,* Mitamura, Abstract (discussing when the sensor “is rotated”).) A POSITA would have been motivated to mount Mitamura’s sensor on a carrier like an automobile or an aircraft in order to measure the angular rate of the carrier—e.g., for safety, control, or tracking purposes. For example, the applicant on the Mitamura application is Nissan Motor Co., Ltd., which a POSITA would have recognized as a manufacturer of vehicles including automobiles. (Mitamura, Cover.) A POSITA would have been

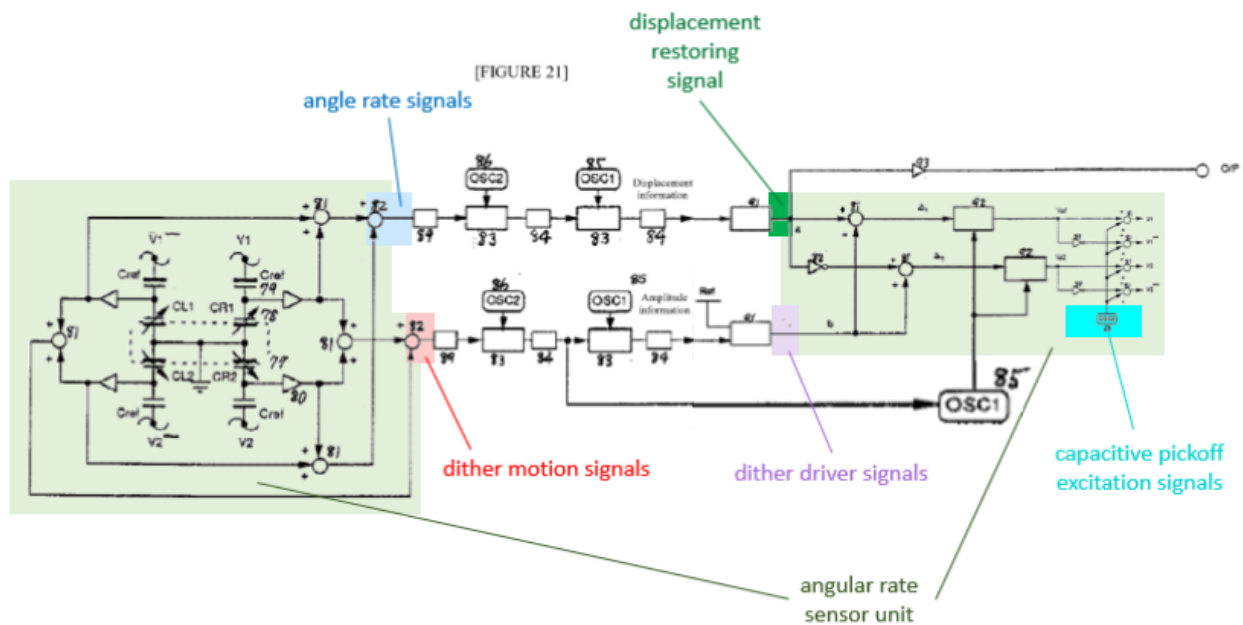
particularly motivated to mount a sensor according to Mitamura's third embodiment on an automobile or aircraft given Mitamura's disclosures regarding how "compact and lightweight" its sensors are. (Mitamura, [0071].) The '122 supports that measuring angular rate of vehicles like automobiles and aircraft is a "[t]ypical application[]" for micro IMUs. ('122, 2:44-57.)

199. Accordingly, it is my opinion that Mitamura teaches or renders obvious **a microelectromechanical system (MEMS) for measuring angular rate of a carrier**, to the extent it is considered to be a limitation of claim 1 of the '122 patent.

(b) an angular rate sensor unit receiving dither driver signals, capacitive pickoff excitation signals and a displacement restoring signal and outputting angle rate signals in response to motion of said carrier and dither motion signals (Claim 1[a]);

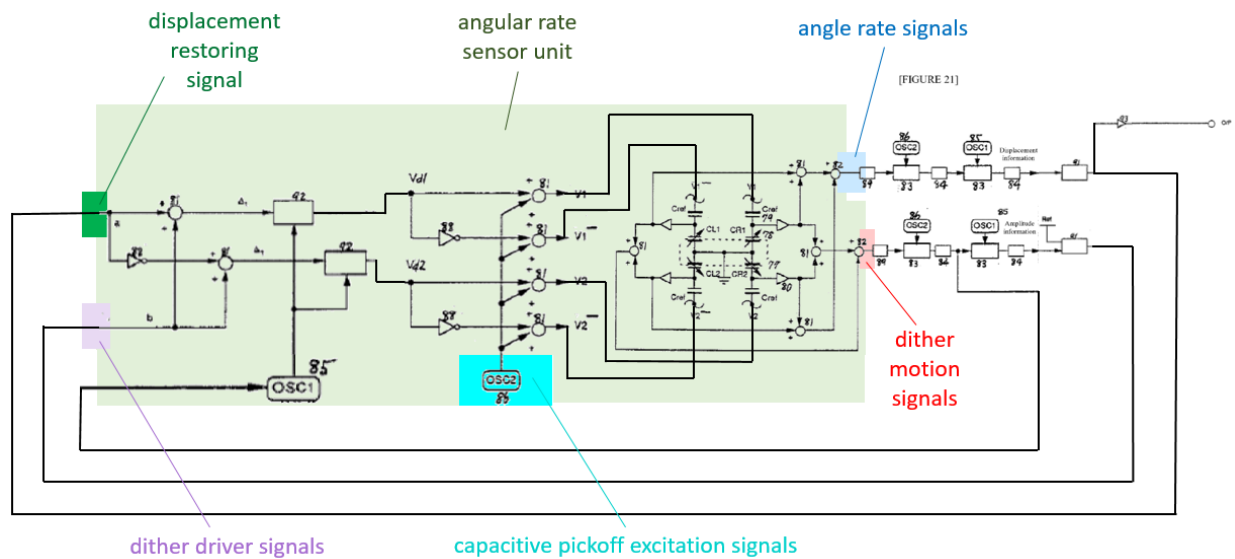
200. It is my opinion that Mitamura discloses **an angular rate sensor unit receiving dither driver signals, capacitive pickoff excitation signals and a displacement restoring signal and outputting angle rate signals in response to motion of said carrier and dither motion signals.**

201. The below annotated version of Mitamura's Figure 21 circuit (which replaces Mitamura's control circuit 87 with the example implementation disclosed in Mitamura's Figure 26) identifies the elements of Claim 1[a] in Mitamura's third embodiment.



(Mitamura, Figs. 21, 26 (colored annotations and highlighting added).) Figure 26 shows an “example configuration of a control circuit used in the angular velocity detection circuit shown in Figure 21.” (Mitamura at 25; *see also id.*, Fig. 21 (indicating control circuit 87), Fig. 26 (indicating control circuit 87).) For convenience, another view of the Mitamura Figure 21 circuit with the angular rate sensor unit components consolidated is shown below:

Declaration of Darrin Young, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 6,508,122 B1



(*Id.*, Figs. 21, 26 (annotations and highlighting added).)

202. Mitamura discloses that the green-highlighted circuitry in the annotated Figure 21 shown above combined with the example control circuitry of Figure 26 constitutes an **angular rate sensor**. Mitamura discloses that the green-highlighted components and circuitry on the left side of the first annotated Figure 21 above includes a vibrating mass driven to vibrate using electrostatic forces generated by comb electrodes, which can sense Coriolis forces (along a perpendicular axis from the dither vibrations) using those same comb electrodes when the system undergoes angular rotation. (Mitamura, Fig. 21, [0041]-[0042].) The green-highlighted circuitry on the right side of the first annotated Figure 21 above is part of control circuitry 87 that provides signals for controlling the motion of vibrating mass 72 through the comb electrodes, which is necessary for its sensing functionality. (*Id.*,

Fig. 26, [0046].) A POSITA would have understood that a vibrating mass sensor like Mitamura discloses can only sense if it is vibrating (*i.e.*, dithering), so a POSITA would have considered the green-highlighted motion control circuitry on the right side of the first annotated Figure 21 above to be an integral part of the angular rate sensor unit. (*See, e.g., id.*, [0057] (“The Coriolis force which is produced is proportional to the vibration velocity of the vibrating mass[.]”).) The ’122 patent similarly discloses drive and sensing electronics as part of the angular rate sensor unit. (’122, Figs. 2-4, 6:1-14.)

203. Mitamura discloses that the **angular rate sensor unit receiv[es] dither driver signals**. The ’122 patent discusses dither motion as the vibration of inertial elements in one plane such that when angular rotation occurs over a particular axis, the inertial element is caused to move in a perpendicular plane by the Coriolis force. (’122, 5:6-17.) Based on the ’122 patent’s disclosures, dither driver signals are signals used in driving the dither motion of an inertial element. Mitamura discloses such dither motion signals in its third embodiment. Mitamura indicates that the green-highlighted angular rate sensor unit receives the purple-highlighted signals from arithmetic unit 91. Mitamura refers to the magnitude of these signals as “b.” (Mitamura, Fig. 26, [0046].) These signals are summed and used to modulate other signals before being input into the comb electrodes for controlling the motion of

vibrating mass 72. (*Id.*, Fig. 26, [0046].) Ultimately, Mitamura indicates that the following equation indicates the vibrating force generated on vibrating mass 72 using the electrostatic force:

$$F_d \cong \epsilon_0 m t \cdot (CV^0)^2 / d \cdot (1 + 2b)$$

(Mitamura, [0063] (reformatted for clarity).) This equation shows that the magnitude of the force exerted on vibrating mass 72 to cause that mass to vibrate (dither) depends on the magnitude of “b”—the purple-highlighted signals from arithmetic unit 91. In other words, the purple-highlighted signals from arithmetic unit 91 are **dither driver signals receiv[ed] by the angular rate sensor unit**.

204. It is also my opinion that “b” output by arithmetic unit 91 constitutes plural **dither driver signals** to the extent that is considered to be a requirement of claim 1. The “b” output by arithmetic unit 91 changes over time, including when the device undergoes acceleration that impacts the dither amplitude. Accordingly, it is my opinion that “b” comprises plural signals when considered over time.

205. Patent Owner’s prior representations regarding the claim language “dither driver signals” further supports that “b” output by arithmetic unit 91 satisfies this claim language. While I understand that the claims of the ’122 patent have not been construed by a Court, I also understand that Patent Owner has proposed constructions for certain claim terms in prior district court litigations. For example,

I understand that in multiple district court cases, Patent Owner proposed that the term “dither driver signals” should be construed as “signals used to oscillate, or vibrate, an inertial element in the angular rate sensor unit.” (**EX1018** at 5-8; **EX1019** at 4-5; **EX1020** at 24-25; **EX1021** at 10-12; **EX1022** at 29-30; **EX1023** at 8-9.) As I discuss above, the “b” output by arithmetic unit 91 is used to oscillate, or vibrate, vibrating mass 72 in Mitamura’s angular rate sensor unit, including because it appears as a term in the equation that describes the vibrating force applied to vibrating mass 72. (Mitamura, [0063].)

206. It is also my opinion that Mitamura discloses that the **angular rate sensor unit receiv[es] capacitive pickoff excitation signals**. As discussed above, the ’122 patent indicates that capacitive pickoff excitation signals can be oscillator signals applied to variable capacitors such that they are modulated by the changing capacitance. The oscillator signals provided by OSC2 function similarly to the capacitive pickoff excitation signals discussed by the ’122 patent. OSC2 is added to the outputs of control circuit 87, producing a sum of signals that is applied to comb electrodes R1, R2, L1, and L2 on the vibrating mass 72. (Mitamura, [0045], [0050], [0054], [0056].) Accordingly, like the ’122 patent contemplates, the oscillator signals from OSC2 are applied to variable capacitors on the vibrating mass 72. (*Id.*) Mitamura discusses using OSC2 as a “detection power supply,” which is used in

determining the “y-axis direction displacement due to the Coriolis force[.]” (*Id.*, [0032].) Mitamura further teaches that oscillator 86 (which outputs the OSC2 signals) can be used to “carry[] out synchronous detection . . . using the demodulator 83[.]” (*Id.*, [0045], [0054].) A POSITA would have understood from these disclosures that the OSC2 signals from oscillator 86 is being used as capacitive pickoff excitation signals as the ’122 patent contemplates. The OSC2 signals provide “excitation” to the comb electrode capacitors by providing a high frequency signal. (*Id.*, [0050].) And they conform to a POSITA’s understanding of what “capacitive pickoff” signals are, as discussed above for Ground 1. (*See, e.g.*, Slater at 72.)

207. I understand that in prior litigation, Patent Owner has argued that “capacitive pickoff excitation signals” should be construed as “electrical signals that provide electrical energy (i.e. excitation) into the angular rate sensor unit’s pickoff capacitors.” (**EX1018** at 15-19; **EX1019** at 8-10; **EX1020** at 26-28; **EX1021** at 12; **EX1022** at 31-33; **EX2023** at 9-10.) Mitamura discloses capacitive pickoff excitation signals in accordance with Patent Owner’s prior construction. The OSC2 signals are electrical signals (AC signals) that provide electrical energy into the angular rate sensor unit’s pickoff capacitors, per Patent Owner’s prior construction. A POSITA would have understood Mitamura’s capacitors to be “pickoff

capacitors,” since they detect the motion of an inertial element based on changing capacitance. This understanding is consistent with how publications used the term “pickoff capacitors” in decades-old textbooks. (*See, e.g., EX1011* at 172-73.)

208. Mitamura further discloses that the **angular rate sensor unit receiv[es] a displacement restoring signal**. The '122 patent indicates that a “displacement restoring signal” is a signal that is used to restore a proof mass to approximately its original position on the sensing axis (*i.e.*, perpendicular to the dither axis) when that position is changed due to the Coriolis force caused by angular rotation. ('122, 8:40-9:4.) Similar to the '122 patent discussion, Mitamura indicates that the green-highlighted angular rate sensor unit in the annotated Figure 21 above receives signals “a” from the uppermost arithmetic unit 91 which reflect the displacement of vibrating mass 72 caused by the Coriolis force. (Mitamura, Fig. 26, [0046], [0058].) Mitamura indicates that signals “a” are used to “compensate” for the Coriolis force. (*Id.*, [0060]-[0064].) Mitamura discloses the following equation for the force “Fc” necessary to compensate for the Coriolis force, which includes the magnitude of signals “a” as a term:

$$F_c \equiv \varepsilon_0 m \cdot (CV^0)^2 / d^2 \cdot 2a$$

(Mitamura, [0062] (reformatted for clarity).) This equation indicates that signals “a” are used in generating the force necessary to oppose the Coriolis force and to return

vibrating mass 72 to approximately its original position. Based on the disclosures of the '122 patent, signals “a” are therefore a **displacement restoring signal receiv[ed]** by the **angular rate sensor unit**.

209. To the extent there is any argument that “a” is not a displacement restoring force because it cancels out the Coriolis force, I disagree. A POSITA would have understood that the design of Mitamura’s system requires the Coriolis force to move vibrating mass 72 before the compensating force can counteract that force and move the vibrating mass approximately to its original position in the sensing plane. A POSITA would have understood that some motion in the sensing plane would be necessary before the Coriolis force can be compensated for or counteracted—otherwise, no motion could be detected to start the counteracting process in the first place.

210. I understand that in Patent Owner’s pending district court litigation against Petitioners, Petitioners have proposed that the term “displacement restoring signal” should be construed as “electrical signal used to oppose displacement of inertial element(s) caused by angular rotation.” (EX1018 at 19-22; EX1020 at 10-12; EX1021 at 28-30; EX1022 at 12; EX1023 at 33-35; EX1024 at 10.) It is my opinion that signals “a” at the output of arithmetic unit 91 in Mitamura’s third embodiment are an electrical signal used to oppose displacement of inertial

element(s) caused by angular rotation, because they are electrical signals used to generate the force that compensates for or counteracts the Coriolis force that acts on vibrating mass 72 when the system undergoes angular rotation. (Mitamura, [0060]-[0064].)

211. Further, it is my opinion that Mitamura discloses **an angular rate sensor unit outputting angle rate signals in response to motion of said carrier**. The green-highlighted angular rate sensor in the annotated Figure 21 above outputs the blue-highlighted angle rate signals reflecting the displacement of vibrating mass 72. This is similar to the '122 patent's discussion of the elements in Claim 1[b]. For example, the '122 patent discloses that *angle* rate signals are an intermediate form of angular rate signals prior that are output from the angular rate sensor unit and indicate the motion of proof masses due to the Coriolis force. ('122, Fig. 6, 6:9-12, 8:40-67.)

212. Similar to the disclosures of the '122 patent, Mitamura teaches that the identified **angle rate signals** (shown in annotated Figure 21 of Mitamura above) indicate motion of the vibrating mass in the angular rate sensor unit due to the Coriolis force. Mitamura discloses that in the upper path shown in Figure 21 (labeled "Displacement information"), "[t]he displacement y of the vibrating mass due to the Coriolis force is found[.]" (Mitamura, [0057].) The voltages across the two upper

detecting capacitors (VL1 and VR1) on vibrating mass 72 are summed at 81—and then the sum of the voltages across the two lower detecting capacitors (VL2 and VR2) is subtracted at 82. (*Id.*, [0058].) Mitamura indicates that the result (*i.e.*, the blue-highlighted signals in the annotated version of Figure 21 above) can be represented by equation (20), reproduced below:

$$(VR1 + VL1) - (VR2 + VL2) = 4A / B \cdot y / d \cdot vc$$

(*Id.* (reformatted for clarity).) In this equation, “y” represents the displacement of vibrating mass 72 in the vertical (up-and-down) direction shown in Figure 21, “d” is the distance of the gap between detecting comb electrodes, “A” and “B” are factors related to the settings of various capacitors shown in Figure 21, and “vc” is the output of oscillator 86 (OSC2). (*Id.*, [0051], [0053], [0055].) In other words, the voltage of the blue-highlighted “angle rate signals” in the annotated version of Figure 21 above is representative of (*i.e.*, proportional to) the vertical displacement “y” of vibrating mass 72 caused by the Coriolis force. (*Id.*, [0027] (describing mathematical relationship between Coriolis force in y-axis direction “Fc” and angular rate Ω).) Accordingly, the **angle rate signals** I have identified in Mitamura’s Figure 21 circuit are similar to the angle rate signals discussed in the ’122 patent—*i.e.*, they are signals output by the angular rate sensor unit representing the displacement of an inertial element caused by the Coriolis force, which can then

be processed into angular rate signals.

213. It is also my opinion that the blue-highlighted signals in the annotated version of Figure 21 above are plural **angle rate signals** to the extent that is considered to be a requirement of claim 1. The blue-highlighted signals vary as the angular rotation of the carrier changes—so it comprises plural signals when considered over time.

214. It is further my opinion that Mitamura discloses **an angular rate sensor unit outputting dither motion signals**. The red-highlighted dither motion signals in the annotated version of Mitamura's Figure 21 above reflect the dither motion (*i.e.*, vibrating motion in the horizontal direction in Figure 21) of vibrating mass 72. The identified dither motion signals are similar to the '122 patent's discussion of these signals. The '122 patent indicates that “dither motion” refers to vibration of a proof mass in the plane of the chip wafer (and perpendicular to the Coriolis force) that is driven by “comb drives” controlled by the sensor's electronics. ('122, 5:6-20.) The dither motion signals reflect the motion of a proof mass in the dither axis. (*Id.*, Fig. 6, 7:64-8:6.) These signals then pass through various stages in the central circuitry—for example, high-pass filter 213, demodulator 214, low-pass filter 215, and an A/D converter—before being output as digital low frequency inertial element displacement signals. (*Id.*, Fig. 6, 8:14-39.)

215. Similar to the '122 patent's discussion, Mitamura discloses that the red-highlighted **dither motion signals** in Figure 21 reflect the vibration motion of vibrating mass 72 in the dither axis perpendicular to the Coriolis force sensing axis. Mitamura indicates that the red-highlighted signals result after the voltages VR1 and VR2 (which varies with the capacitance of the rightmost position-sensing capacitors for vibrating mass 72) are added, and the voltages VL1 and VL2 (which varies with the capacitance of the leftmost position-sensing capacitors) are subtracted from the sum. (Mitamura, [0055].) Mitamura teaches that the voltage of the red-highlighted signals varies in accordance with equation (19) reproduced below:

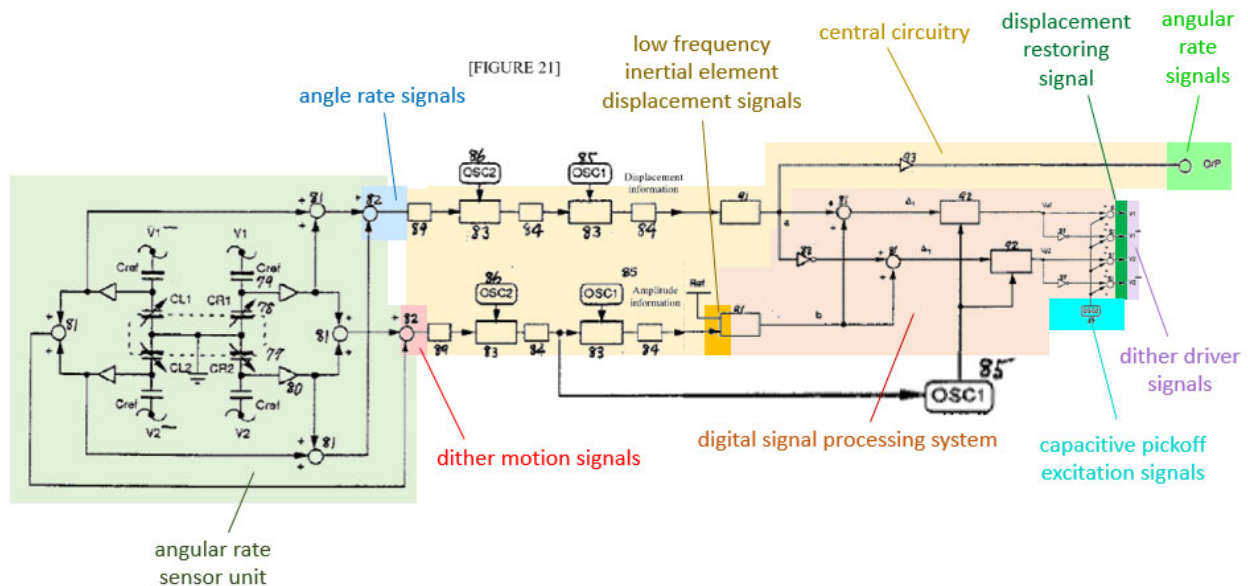
$$(VR1 + VR2) - (VL1 + VL2) = 4 / B \cdot (vd - A \cdot x / L \cdot vc)$$

(Mitamura, [0056] (reformatted for clarity).) In this equation, “x” represents the displacement of vibrating mass 72 in the horizontal (dither) direction shown in Figure 21, “L” indicates the overlap of the sensing comb electrodes when at rest, “A” and “B” are factors related to the settings of various capacitors shown in Figure 21, “vd” is the output of oscillator 85 (OSC1), and “vc” is the output of oscillator 86 (OSC2). (*Id.*, [0051], [0053], [0055], [0056].) In other words, the voltage of the red-highlighted signals in Figure 21 is representative of (*i.e.*, it varies, with an offset, in proportion to) “x”—the horizontal position of vibrating mass 72 in the dither axis. As a result, the red-highlighted signals in Mitamura's Figure 21 is like the dither

motion signals discussed by the '122 patent.

216. It is also my opinion that the red-highlighted signals in the annotated version of Mitamura's Figure 21 above are plural **dither motion signals** to the extent that is considered to be a requirement of claim 1. The red-highlighted signals vary as the amplitude of the vibrating (dither) motion of vibrating mass 72 varies—so it comprises plural signals when considered over time.

217. To the extent there is any argument that “a” and “b” in Mitamura are not the displacement restoring signal and dither driver signals, respectively, because there is additional processing and signal components that determine the signals used to drive the vibrating mass 72, it is my opinion that the Mitamura Figures 21 and 26 circuit could be alternatively split up such that it would meet the requirements of claim 1[a] regardless. I provide an annotated version of Figure 21 below that shows this alternative way of splitting up the Mitamura Figures 21 and 26 circuit:



(Mitamura, Fig. 21 (colored annotations and highlighting added), Fig. 26 (same).)

218. In this alternative understanding of Mitamura's Figure 21 circuit, the **angular rate sensor unit** includes only the vibrating mass 72 and its output circuitry, as shown in green highlighting. (Mitamura, Figs. 17-18, 20, [0042].) Otherwise, the main change from my analysis above for purposes of claim 1[a] is that the **displacement restoring signal** and **dither driver signals** are components of the combination of signals V1, V1-, V2, and V2-, which are input into the angular rate sensor to control the dither drive and displacement compensation. (*Id.*, [0044], [0046]-[0063].) Mitamura discloses that these four signals contain all components for dither driving and Coriolis force compensation. (*Id.*, [0062]-[0063].)

219. I also note that to meet the limitations "displacement restoring signal,"

“dither driver signals,” and “capacitive pickoff excitation signals,” I am identifying different components within the four signals V1, V1-, V2, and V2- of Mitamura. Mitamura separately identifies these components. For example, Mitamura separately identifies the force exerted to compensate for the Coriolis force (Mitamura, [0062]) and the force exerted to dither the vibration mass 72 (*id.*, [0063]).

220. Accordingly, it is my opinion that Mitamura discloses **an angular rate sensor unit receiving dither driver signals, capacitive pickoff excitation signals and a displacement restoring signal and outputting angle rate signals in response to motion of said carrier and dither motion signals.**

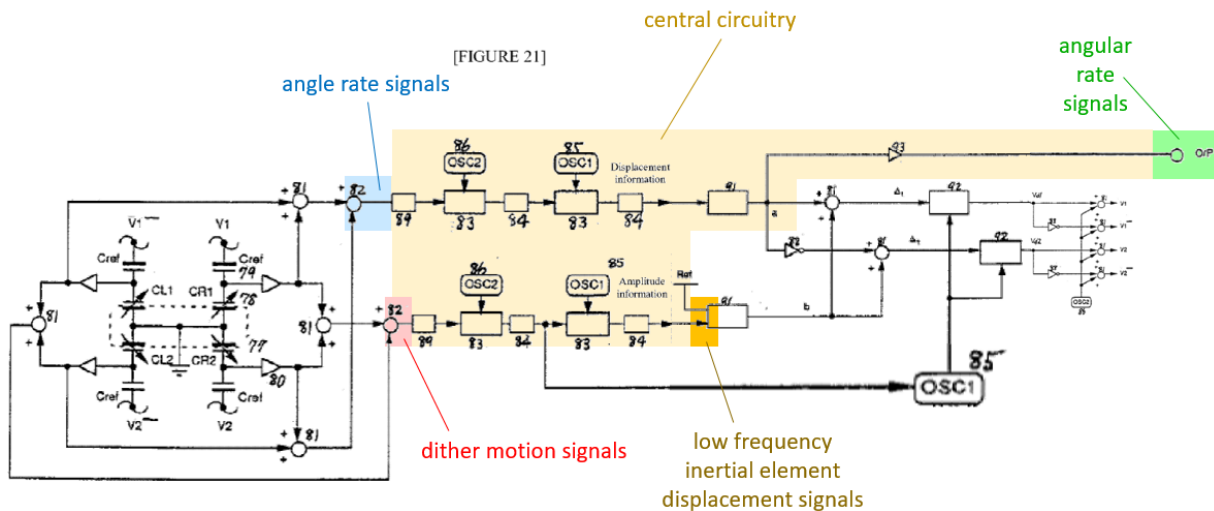
(c) **a central circuitry receiving said angle rate signals in response to said motion of said carrier and said dither motion signals and outputting angular rate signals and digital low frequency inertial element displacement signals (Claim 1[b]);**

221. It is my opinion that Mitamura discloses **a central circuitry receiving said angle rate signals in response to said motion of said carrier and said dither motion signals and outputting angular rate signals and digital low frequency inertial element displacement signals** or a POSITA would have found this limitation obvious based on Mitamura alone or in light of Townsend.

222. In the below annotated version of Mitamura’s Figure 21 circuit in which I have replaced module 87 with the circuitry shown in Figure 26, I identify the

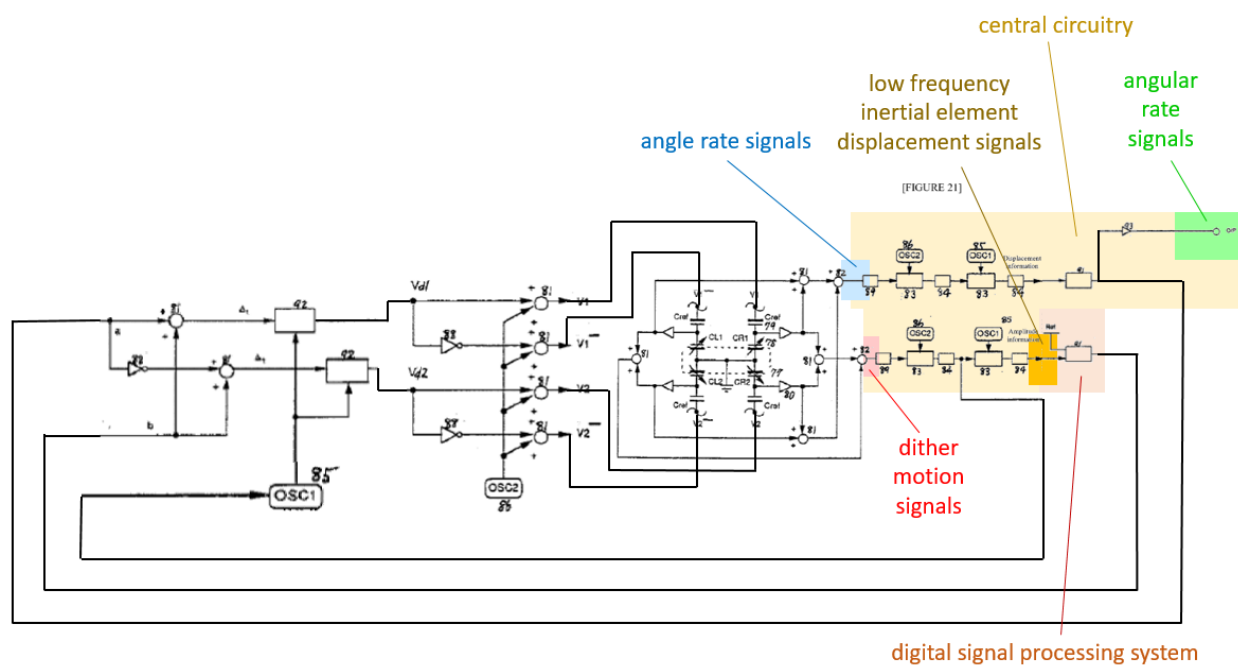
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elements corresponding to the limitations of claim 1[b]:



(Mitamura, Fig. 21 (colored annotations and highlighting added), Fig. 26 (same).)

For convenience, I provide the following annotated version of Figures 21 and 26 where the angular rate sensor unit components are consolidated:



(Mitamura, Fig. 21 (colored annotations and highlighting added), Fig. 26 (same).)

223. Mitamura discloses **central circuitry receiving angle rate signals in response to said motion of said carrier and outputting angular rate signals.**⁴

The yellow-highlighted central circuitry in the annotated Figure 21 above receives the blue-highlighted angle rate signals reflecting the displacement of vibrating mass 72 and processes those signals into the green-highlighted angular rate signals, which are output from the system. (Mitamura, Figs. 21, 26; [0045]-[0046], [0051], [0053], [0055], [0057]-[0058].) This is similar to the '122 patent's discussion of the elements in Claim 1[b]. For example, the '122 patent discloses that angular rate signals are the signals output from the system indicating its rate of angular rotation. ('122, Fig. 6, 8:40-67.) These *angular* rate signals result from processing of *angle* rate signals—which are an intermediate form of angular rate signals prior to processing that are output from the angular rate sensor unit and indicate the motion of proof masses due to the Coriolis force. (*Id.*, Fig. 6, 6:9-12, 8:40-67.) For example,

⁴ I provide my analysis for the “angle rate signals” and “angular rate signals” together, because in my understanding both of these claim limitations pertains to detection of angular rate based on the displacement of an inertial element by the Coriolis force. Similarly, I provide my analysis for the “dither motion signals” and “low frequency inertial element displacement signals” together, because in my understanding, both of these limitations relate to detection of dither motion of an inertial element.

Figure 6 of the '122 patent, which is reproduced below in an annotated version, indicates that *angle* rate signals go through high-pass filter, demodulator, and low-pass filter stages before being output as *angular* rate signals:

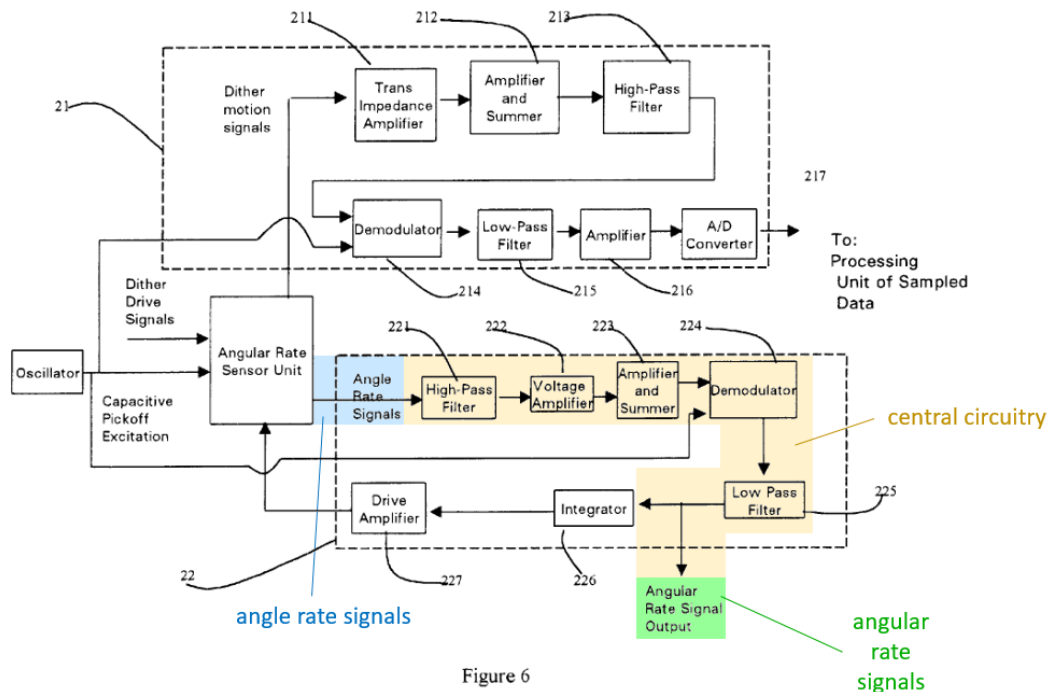


Figure 6

('122, Fig. 6 (colored annotations and highlighting added), 8:40-67).

224. Similar to the disclosures of the '122 patent, Mitamura teaches that the identified **angle rate signals** (shown in annotated Figure 21 of Mitamura above) indicate motion of the vibrating mass in the angular rate sensor unit due to the Coriolis force, and the angle rate signals go through processing stages in the **central circuitry** to result in the outputted **angular rate signals**. Mitamura discloses that in the upper path shown in Figure 21 (labeled "Displacement information"), "[t]he

displacement y of the vibrating mass due to the Coriolis force is found[.]” (Mitamura, [0057].) The voltages across the two upper detecting capacitors (VL1 and VR1) on vibrating mass 72 are summed at 81—and then the sum of the voltages across the two lower detecting capacitors (VL2 and VR2) is subtracted at 82. (*Id.*, [0058].) Mitamura indicates that the result (*i.e.*, the blue-highlighted signals in the annotated version of Figure 21 above) can be represented by equation (20), reproduced below:

$$(VR1 + VL1) - (VR2 + VL2) = 4A / B \cdot y / d \cdot vc$$

(*Id.* (reformatted for clarity).) In this equation, “ y ” represents the displacement of vibrating mass 72 in the vertical (up-and-down) direction shown in Figure 21, “ d ” is the distance of the gap between detecting comb electrodes, “ A ” and “ B ” are factors related to the settings of various capacitors shown in Figure 21, and “ vc ” is the output of oscillator 86 (OSC2). (*Id.*, [0051], [0053], [0055].) In other words, the voltage of the blue-highlighted “angle rate signals” in the annotated version of Figure 21 above is representative of (*i.e.*, proportional to) the vertical displacement “ y ” of vibrating mass 72 caused by the Coriolis force. (*Id.*, [0027] (describing mathematical relationship between Coriolis force in y -axis direction “ F_c ” and angular rate Ω).) Accordingly, the **angle rate signals** I have identified in Mitamura’s Figure 21 circuit are similar to the angle rate signals discussed in the

'122 patent—*i.e.*, they are signals output by the angular rate sensor unit representing the displacement of an inertial element caused by the Coriolis force, which can then be processed into angular rate signals.

225. Mitamura's **angular rate signals** resulting from processing via the **central circuitry** of the **angle rate signals** are also similar to what the '122 patent discloses. The blue-highlighted angle rate signals in annotated Figure 21 are input into high-pass filter 89, demodulators 83, low-pass filters 84, and control circuit 87, which provides the green-highlighted angular velocity output through amplifier 93. (Mitamura, Figs. 21, 26; [0045]-[0046], [0057]-[0058].) Similarly, the '122 patent discloses high-pass filter 221, amplifiers 222 and 223, demodulator 224, and low-pass filter 225 between "angle rate signals" and "angular rate signals" in Figure 6. ('122, Fig. 6, 8:40-67.)

226. To the extent there is any argument that claim 1 of the '122 patent requires plural angle rate signals, it is my opinion that Mitamura satisfies any such requirement. The blue-highlighted signals in annotated Figure 21 change over time as the angular rotation of the system changes. Thus, when considered over time, it is my opinion the blue-highlighted circuit receives multiple angle rate *signals*.

227. To the extent there is any argument that claim 1 of the '122 patent requires outputting plural angular rate signals, it is my opinion that Mitamura

satisfies any such requirement. The green-highlighted signals in annotated Figure 21 change over time as the angular rotation of the system changes. Thus, when considered over time, it is my opinion that the green-highlighted circuit receives multiple angular rate *signals*.

228. It is my opinion that Mitamura also renders obvious **a central circuitry receiving said dither motion signals and outputting digital low frequency inertial element displacement signals**—either based on Mitamura alone or in light of Townsend. The red-highlighted dither motion signals in the annotated version of Mitamura’s Figure 21 above reflect the dither motion (*i.e.*, vibrating motion in the horizontal direction in Figure 21) of vibrating mass 72. Further, these dither motion signals are processed via central circuitry and output as the orange-highlighted digital low frequency inertial element displacement signals.

229. The identified dither motion signals and digital low frequency inertial element displacement signals are similar to the ’122 patent’s discussion of these signals. The ’122 indicates that “dither motion” refers to vibration of a proof mass in the plane of the chip wafer (and perpendicular to the Coriolis force) that is driven by “comb drives” controlled by the sensor’s electronics. (’122, 5:6-20.) The dither motion signals reflect the motion of a proof mass in the dither axis. (*Id.*, Fig. 6, 7:64-8:6.) These signals then pass through various stages in the central circuitry—for

example, high-pass filter 213, demodulator 214, low-pass filter 215, and an A/D converter—before being output as digital low frequency inertial element displacement signals. (*Id.*, Fig. 6, 8:14-39.) The process disclosed by the '122 patent for receiving dither motion signals via central circuitry and outputting digital low frequency inertial element displacement signals is shown in the annotated version of the '122 patent's Figure 6 below:

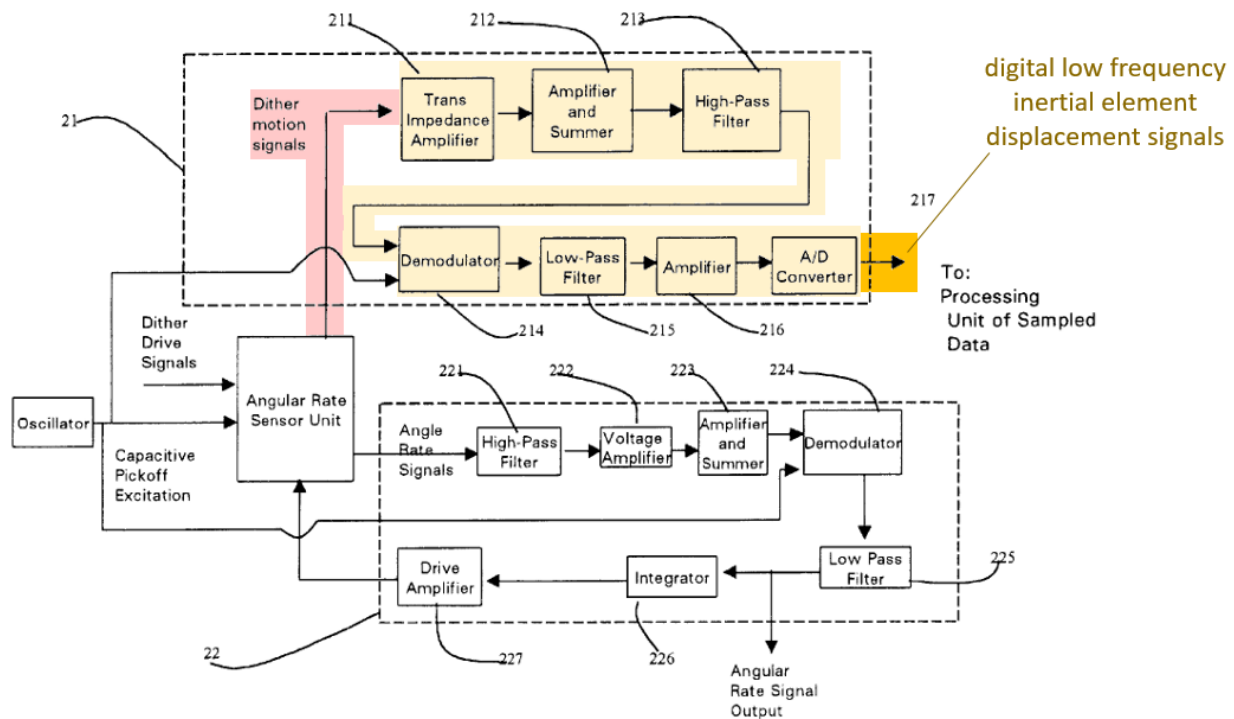


Figure 6

('122, Fig. 6 (colored annotations and highlighting added).) The '122 patent discloses that “inertial element displacement signals” are output following demodulation of dither motion-related signals. (*Id.*, 8:19-26.) The '122 patent further discloses that these signals become “*low frequency* inertial element

displacement signal[s]” once they are passed through a low-pass filter, which “remov[es] high frequency noise from the inertial element displacement signal input to form a low frequency inertial element displacement signal.” (*Id.*, 8:27-31.) Further, the ’122 patent discloses that these signals become “digitized low frequency inertial element displacement signal[s]” once they pass through a A/D converter. (*Id.*, 8:36-39.)

230. Similar to the ’122 patent’s discussion, Mitamura discloses that the red-highlighted **dither motion signals** in Figure 21 reflect the vibration motion of vibrating mass 72 in the dither axis perpendicular to the Coriolis force sensing axis. Mitamura indicates that the red-highlighted signals result after the voltages VR1 and VR2 (which varies with the capacitance of the rightmost position-sensing capacitors for vibrating mass 72) are added, and the voltages VL1 and VL2 (which varies with the capacitance of the leftmost position-sensing capacitors) are subtracted from the sum. (Mitamura, [0055].) Mitamura teaches that the voltage of the red-highlighted signals varies in accordance with equation (19) reproduced below:

$$(VR1 + VR2) - (VL1 + VL2) = 4 / B \cdot (vd - A \cdot x / L \cdot vc)$$

(Mitamura, [0056] (reformatted for clarity).) In this equation, “x” represents the displacement of vibrating mass 72 in the horizontal (dither) direction shown in Figure 21, “L” indicates the overlap of the sensing comb electrodes when at rest,

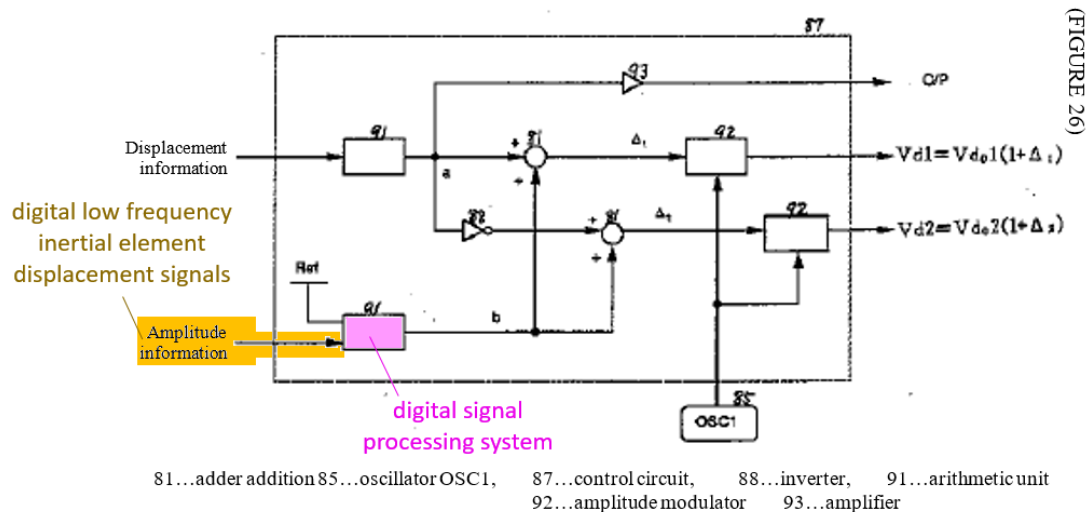
“A” and “B” are factors related to the settings of various capacitors shown in Figure 21, “vd” is the output of oscillator 85 (OSC1), and “vc” is the output of oscillator 86 (OSC2). (*Id.*, [0051], [0053], [0055], [0056].) In other words, the voltage of the red-highlighted signals in Figure 21 is representative of (*i.e.*, it varies, with an offset, in proportion to) “x”—the horizontal position of vibrating mass 72 in the dither axis. As a result, the red-highlighted signals in Mitamura’s Figure 21 is like the dither motion signals discussed by the ’122 patent.

231. Mitamura’s disclosures about the **low frequency inertial element displacement signals** are also similar to what the ’122 patent discloses regarding these signals. Mitamura discloses that the orange-highlighted signals in Figure 21 result from the red-highlighted dither motion signals passing through high-pass filter 89, demodulators 83, and low-pass filters 84 before being output to control circuit 87. (Mitamura, Figs. 21, 26, [0056].) Like the “inertial element displacement signals” discussed by the ’122 patent, the orange-highlighted signals in Figure 21 have been demodulated. (*Id.*; ’122, 8:19-26.) Further, similar to the ’122 patent’s disclosures, the orange-highlighted signals in Figure 21 have passed through low-pass filtering stages, so it comprises “low frequency” signals from which high-frequency noise has been removed. (Mitamura, Fig. 21, [0056]; ’122, 8:27-31.) Also, Mitamura discloses that the orange-highlighted signals in Figure 21 have an

“amplitude is proportional to the drive amplitude of the vibrating mass,” so they are clearly reflective of dither motion, similar to the digital low frequency inertial element displacement signals in the ’122 patent. (Mitamura, Fig. 21, [0056]; ’122, Fig. 6, 7:64-8:39.) Further, these signals satisfy Petitioners’ proposed construction for “inertial element displacement signals” in the pending district court litigation—“electrical signals reflecting dither motion of inertial element(s)”——since they are electrical signals reflective of dither motion. (EX1026.)

232. Mitamura further renders obvious that the orange-highlighted signals in Figure 21 are **digital** low frequency inertial element displacement signals. The orange-highlighted signals are “input into the control circuit 87,” where they are provided to arithmetic unit 91 in the example control circuit implementation shown in Figure 26:

[FIGURE 26]



(Mitamura, Fig. 26 (colored annotations and highlighting added).) Based on the disclosures of Mitamura, it would have been obvious to a POSITA to implement arithmetic unit 91 as a digital signal processing system, as I discuss further for Claim 1[c]. Further, while it is not explicitly disclosed, a POSITA would have understood that the low frequency inertial element displacement signals would have to be converted into a digital format in order to be input into the arithmetic unit 91 if it is implemented digitally. Accordingly, it would have been obvious to a POSITA to incorporate an analog-to-digital (A/D) converter at the input of digital signal processing system, which would convert the low frequency inertial element displacement signals into **digital low frequency inertial element displacement signals**. Such an implementation would be similar to how the '122 patent discusses

the process of forming these signals—low frequency inertial element displacement signals are formed, and then they are converted to digital low frequency inertial element displacement signals by passing through an A/D converter. ('122, Fig. 6, 8:27-39.) A POSITA would have been motivated to use an analog-to-digital converter at the input to the pink-highlighted arithmetic unit 91 such that the system would operate. A POSITA would have understood the low frequency inertial element displacement signals at the input to arithmetic unit 91 to be analog signals—and a POSITA would have understood that such analog signals would need to be converted into a digital format before they could be used by arithmetic unit 91 if it is implemented digitally. (Mitamura, [0056] (describing “smooth[ing]” of signal at input of arithmetic unit 91).)

233. To the extent there is any dispute that **a central circuitry outputting digital low frequency inertial element displacement signals** would have been obvious based on Mitamura alone, it would have been obvious to a POSITA to implement arithmetic unit 91 as a digital signal processing system, or to separately incorporate a system into the Mitamura Figure 21 and 26 circuits based on **Townsend**. I provide my obviousness analysis for Townsend for Claim 1[c] below. As I discuss below, in the Mitamura-Townsend combination, it would have been obvious to incorporate an analog-to-digital converter at the input to the digital signal

processing system, yielding digital low frequency inertial element displacement signals.

- (d) **a digital signal processing system analyzing said digital low frequency inertial element displacement signals and feeding back said dither driver signals to said angular rate sensor unit (Claim 1[c]).**

234. It is my opinion that **a digital signal processing system analyzing said digital low frequency inertial element displacement signals and feeding back said dither driver signals to said angular rate sensor unit** would have been obvious based on Mitamura alone or in light of Townsend.

235. Mitamura discloses that a **signal processing system analyzing said low frequency inertial element displacement signals and feeding back said dither driver signals to said angular rate sensor unit**. Mitamura discloses that arithmetic unit 91 outputs a signal that is used for control of the angular rate sensor—in other words, the output signal from arithmetic unit 91 is fed back into the angular rate sensor unit. (Mitamura, Fig. 26, [0046], [0060]-[0062].) Mitamura discloses that arithmetic unit 91 outputs signals “b” that get summed with displacement information “a” on one path and an inverted version of “a” on another path, and a signal from oscillator 85 is modulated using the outputs via amplitude modulators 92 on both paths. (*Id.*, Fig. 26, [0046].) These signals are then each split into two paths (one inverted for each signal), summed with a signal from oscillator 86, and

input into the comb electrodes controlling the motion of vibrating mass 72, where they cause the vibrating (dither) motion of the vibrating mass. (*Id.*, Figs. 21, 26; [0046].) Ultimately, Mitamura discloses that the force with which the vibrating mass 72 is driven “Fd” is determined by the value of “b” output by arithmetic unit 91:

$$F_d \equiv \varepsilon_0 m_t \cdot (CV^0)^2 / d \cdot (1 + 2b)$$

(Mitamura, [0063] (reformatted for clarity).) Accordingly, “b” constitutes **dither driver signals**—since it determines the magnitude of the driving force used to vibrate (dither) mass 72. Further, arithmetic unit 91 **feed[s] back said dither driver signals to said angular rate sensor unit**, since “b” is output to angular rate sensor unit and “b” is derived from the dither motion signals of angular rate sensor unit—leading to a feedback loop. Mitamura discloses the advantages of this feedback loop, indicating that “[b]y inputting the amplitude information of the vibrating mass . . . in the control circuit 87, the drive voltage can be modulated as described above, and the drive amplitude can be equalized . . ., making it possible to achieve high-precision detection with an angular velocity sensor having a simple structure.” (*Id.*, [0063].)

236. It is also my opinion that “b” output by arithmetic unit 91 constitutes plural **dither driver signals** to the extent that is considered to be a requirement of claim 1. The “b” output by arithmetic unit 91 varies as the vibrating (dither)

amplitude of vibrating mass 72 varies—so it comprises plural signals when considered over time.

237. Mitamura discusses inputting the orange-highlighted low frequency inertial element displacement signals in its Figure 21 and 26 circuits into an arithmetic unit 91. It would have been obvious to a POSITA to implement arithmetic unit 91 as a **digital signal processing system analyzing said digital low frequency inertial element displacement signals**. Mitamura discloses that in arithmetic unit 91, “the amplitude information [is] calculated as modulation amounts of the drive voltage, . . . based on a deviation from a set reference level for the amplitude information.” (Mitamura, [0046].) It would have been obvious to a POSITA that a module that performs “calculat[ion]” and has a “set reference level” would be implemented as a digital unit like a processor. (*Id.*) A POSITA would have understood that performing calculations and setting reference levels would have been simpler, less time-consuming, and less expensive via a digital system than an analog one. A POSITA would have further understood that more complex calculations could be feasibly implemented via a digital system than an analog one. Further, a POSITA would have understood that a digital system would have been more flexible to adjustment than an analog system, since digital systems allow for reprogramming, whereas redesigning analog systems tends to involve more time-

consuming, expensive, and difficult physical engineering. Mitamura's reference to a "set reference level" would have particularly motivated a POSITA to implement arithmetic unit 91 as a digital system—which would allow for a simple interface for performing reference level setting—rather than an analog system—which would require more sophisticated engineering to adjust a reference level setting. Accordingly, it is my opinion that it would have been obvious to a POSITA based on Mitamura alone to implement calculating unit 91 as a **digital signal processing system**. In such an implementation, the digital signal processing system would perform "calculat[ion]" of amplitude information as "modulation amounts of the drive voltage, . . . based on a deviation from a set reference level." (*Id.*, [0046].) A POSITA would have understood such calculations to involve **analyzing said digital low frequency inertial element displacement signals**.

238. It would have also been obvious to a POSITA to incorporate circuitry necessary to accommodate a digital signal processing system into Mitamura's Figure 21 and 26 circuits—including an analog-to-digital converter at the input of the processing system and a digital-to-analog converter at the output. A POSITA would have been motivated to make these adjustments to convert signals between the digital signal processing system and the other circuitry of Mitamura, which is implemented in analog circuitry.

239. To the extent there is any dispute that a digital signal processing system would have been obvious to a POSITA based on Mitamura alone, it would have been obvious in light of **Townsend**.

240. I discussed the disclosures of Townsend above for Ground 1, which I incorporate here. Similar to the Fujiyoshi-Townsend combination, it would have been obvious to a POSITA to incorporate a digital signal processing system into the dither motion detection and control circuitry of Mitamura's Figure 21 and 26 circuits (*i.e.*, the lower path shown in Mitamura's Figure 21 and 26 circuits) based on Townsend's Figure 4 block diagram. It would have been obvious to a POSITA to implement Mitamura's arithmetic unit 91 in the dither motion detection and control path as a digital processing unit 22 like Townsend discloses. Further, it would have also been obvious to a POSITA to incorporate a digital processing unit 22 like Townsend discloses elsewhere in Mitamura's circuit—for example, downstream from arithmetic unit 91 in control circuit 87 within the dither motion detection and control path. It would also have been obvious to a POSITA to incorporate other components disclosed in Townsend's Figure 4 circuit—*e.g.*, the sample-and-hold devices, buffers, analog-to-digital converters, and digital-to-analog converters—to incorporate Townsend's digital processing unit 22 into Mitamura's circuit.

241. **Rationale and Motivation to Combine (Mitamura with Townsend)**: A

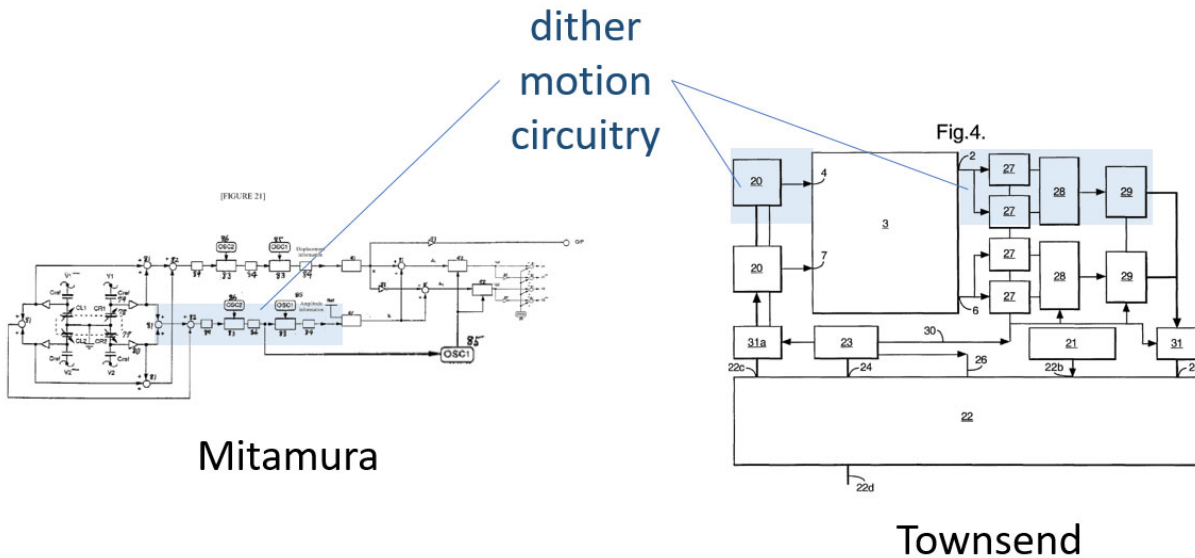
POSITA would have been motivated to combine Mitamura with Townsend, in the manner described above. The combination would have predictably resulted in Mitamura's circuitry for controlling dither motion incorporating a digital processor and circuitry (*e.g.*, sample-and-hold devices, analog-to-digital converters, buffers, and digital-to-analog converters) for converting between analog signals used in Mitamura's circuits and digital signals input to or output from digital processor.

242. Mitamura and Townsend are analogous references. Both are in the same field as the '122 patent. Like Mitamura, Townsend relates to the design of vibrating gyroscopes and associated control circuitry. (*E.g.*, Townsend at 1-2.) Townsend discloses that its systems can be used with "[k]nown vibrating structure gyroscopes" using a "variety of different mechanical vibratory structure," including "beams, tuning forks, cylinders, hemispherical shells and rings." (*Id.* at 1.) A POSITA would have considered Mitamura's vibrating mass system as a "vibrating structure gyroscope[]" compatible with Townsend's systems. (*See, e.g.*, Mitamura, [0040] (describing a vibrating mass in Mitamura's third embodiment).) Mitamura also indicates that its circuitry contains arithmetic units that perform calculations, which suggests the use of digital processing circuitry like what Townsend discloses, as I discuss further above. (*Id.*, [0046].)

243. A POSITA would have been motivated to combine Mitamura with

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Townsend because Mitamura describes embodiments of a vibrating structure gyroscope and circuit loops for (1) controlling vibration of the vibrating element and (2) controlling motion caused by the Coriolis force when the system undergoes an angular rotation. (See, e.g., Mitamura, Fig. 21, [0064].) Townsend describes analogous circuit loops in the form of its (1) “primary or excitation loop” (which “control[s] the amplitude of the resultant signal at the primary pick off means 2 which in effect is the amplitude of the resultant vibration”) and (2) its “secondary or damping loop” (which involves a “signal [] proportional to the applied angular rate” and which “provide[s] damping for the high Q rate response” of the vibrating structure gyroscope). (Townsend at 1-2, 4.) A POSITA would have understood that the circuit loops of Mitamura and Townsend correspond as shown in the diagram below:



(Mitamura, Fig. 21 (annotations and highlighting added); Townsend, Fig. 4 (annotations and highlighting added).) Accordingly, a POSITA would have understood that the teachings of Townsend are applicable to the control circuit loops of Mitamura, including the dither motion control loop.

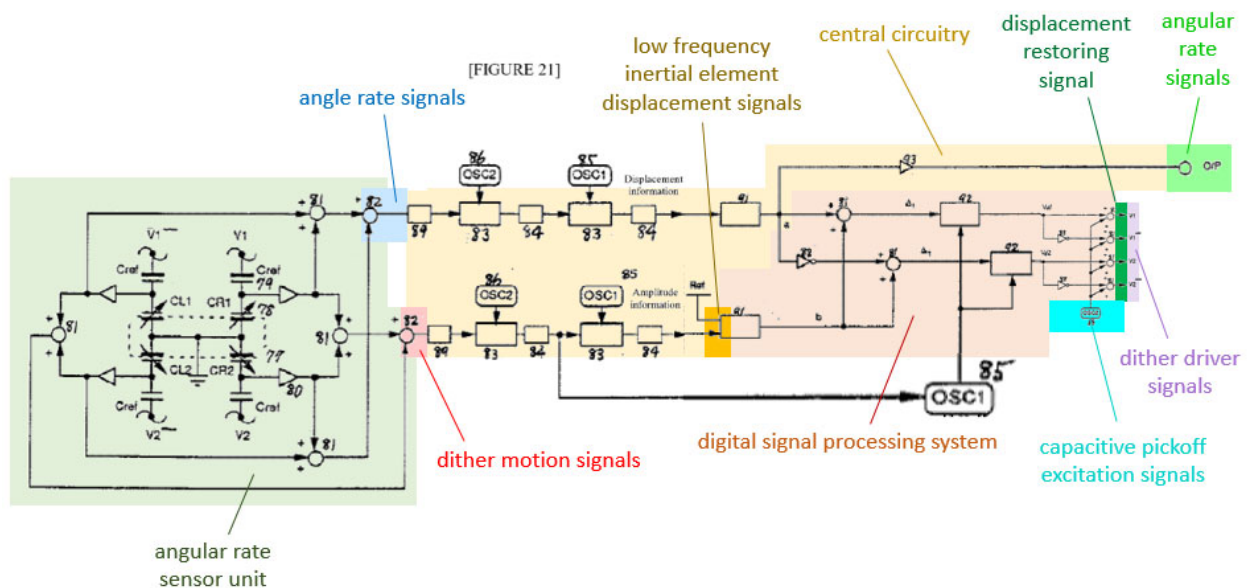
244. A POSITA would have been motivated to combine Townsend with Mitamura because Townsend describes digital implementations of vibrating structure gyroscope circuitry that improve upon prior art analog approaches. Townsend discloses that analog circuitry has drawbacks when used for the control loops of vibrating structure gyroscope circuitry, because such circuitry is “notoriously difficult to specify, design and integrate into small low cost systems (i.e. ASICS)”; it is “difficult to apply calibrations and compensations to systems

based on analogue circuits”; and “modern systems require the sensor outputs to be available in digital format to simplify system integration and enable further compensations to be applied to enhance performance.” (Townsend at 3.) Faced with Townsend’s teachings about the limitations of analog circuitry when used for control circuit loops for vibrating structure sensors, a POSITA would have looked to Townsend’s digital implementation for Mitamura control circuitry.

245. In addition to incorporating a digital processor from Townsend into Mitamura’s third embodiment, a POSITA would have been motivated to incorporate other circuitry from Townsend used in converting between analog and digital signals. A POSITA would have been motivated to incorporate digital-to-analog and analog-to-digital converters into Mitamura’s circuit, since Townsend discloses that these are necessary for converting between analog signals input to/output from the vibrating structure sensor and digital signals input to/output from the digital processor. (Townsend at 12-13.) Further, a POSITA would have been motivated to incorporate sample and hold devices into Mitamura’s third embodiment, because Townsend indicates that sample and hold devices “provide a high degree of noise rejection” by “averag[ing] or integrat[ing] the input waveform over the sample period.” (*Id.* at 18.) A POSITA would look for further means for reducing noise in Mitamura’s third embodiment—which includes filtering—so as to further improve

sensor performance.

246. To the extent there is any argument that “b” in Mitamura does not constitute the dither driver signals, because there is additional processing and signal components that determine the signals used to drive the vibrating mass 72, it is my opinion that the Mitamura Figures 21 and 26 circuit could be alternatively split up such that it would meet the requirements of claim 1[c] regardless. I provide an annotated version of Figure 21 below that shows this alternative way of splitting up the Mitamura Figures 21 and 26 circuit:



(Mitamura, Fig. 21 (colored annotations and highlighting added), Fig. 26 (same).)

247. I outlined my analysis for **dither driver signals** and **displacement restoring signal** above for Claim 1[a]. The main change from the primary mapping

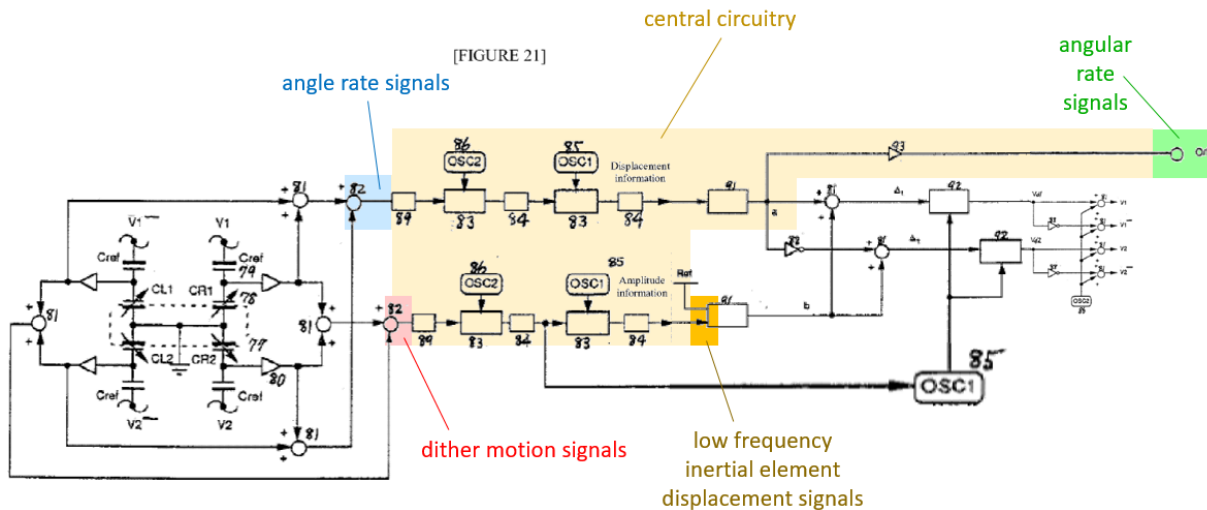
I have discussed for this limitation is that the **digital signal processing system** is expanded to include arithmetic unit 91 and subsequent circuitry that generates signals V1, V1-, V2, and V2-. It is my opinion that this circuitry can be considered part of the digital signal processing system (if arithmetic unit 91 is implemented digitally, as I discuss above). The pink-highlighted circuitry in the above annotated diagram processes signals (including by summing and modulating them) and includes a digital component (arithmetic unit 91, if implemented digitally). (Mitamura, [0048], [0058]-[0061].) Accordingly, the pink-highlighted is a **digital signal processing system**.

2. Dependent Claim 3

248. For reference dependent Claim 3 requires: “The microelectromechanical system, as recited in claim 1, wherein said central circuitry comprises a dither motion control circuitry and an angle rate signal loop circuitry.”

249. It is my opinion that Mitamura discloses a **micromechanical system, as recited in claim 1, wherein said central circuitry comprises a dither motion control circuitry and an angle rate signal loop circuitry**.

250. The following annotated version of Mitamura’s Figure 21 (with control circuit 87 replaced with the example configuration shown in Figure 26), shows the yellow-highlighted central circuitry I identified for Claim 1[b]:



(Mitamura, Fig. 21 (colored annotations and highlighting added); *id.*, Fig. 26.) The upper yellow-highlighted path comprises an **angle rate signal loop circuitry**, because it is part of the circuitry that detects the angular rotation of the carrier and feeds it back (in a feedback loop) into the comb electrode drive circuitry to compensate for the Coriolis force. (*Id.*, Figs. 21, 26; [0045]-[0046], [0057]-[0058].) Further, the lower yellow-highlighted path comprises **dither motion control circuitry**, because it is part of the circuitry that processes signals related to the vibrating (dither) motion of vibrating mass 72. (*Id.*, Figs. 21, 26; [0055]-[0056].)

VII. NO SECONDARY CONSIDERATIONS OF NONOBVIOUSNESS

251. 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 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.

VIII. CONCLUSION

252. 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.

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253. 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,

A handwritten signature in black ink, appearing to read "Darrin Young", written over a horizontal line.

Darrin Young

APPENDIX A

Curriculum Vitae

Darrin J. Young

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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

1. D. J. Young, B. E. Boser, V. Malba, A. F. Bernhardt, "A Micromachined RF Low Phase Noise Voltage-Controlled Oscillator for Wireless Communication," *International Journal of RF and Microwave Computer-Aided Engineering*, pp. 285-300, 2001.
2. J. Du, W. H. Ko, D. J. Young, "Single Crystal Silicon MEMS Fabrication Based On Smart-Cut Technique," *Sensors and Actuators A*, vol. 112, issue 1, pp. 116-121, 2004.
3. M. Suster, W. H. Ko, D. J. Young, "An Optically-Powered Wireless Telemetry Module for High-Temperature MEMS Sensing and Communication," *IEEE Journal of Microelectromechanical Systems*, June, pp. 536-541, 2004.

4. D. J. Young, J. Du, C. A. Zorman, W. H. Ko, "High-Temperature Single Crystal 3C-SiC Capacitive Pressure Sensor," *IEEE Sensors Journal, Special Issue on Microsensors and Microactuators*, August, pp. 464-470, 2004.
5. R. Wang, W. H. Ko, and D. J. Young, "SiC-Carbide-MESFET-Based High-Temperature MEMS Sensing and Data Telemetry Module," *IEEE Sensors Journal*, December, pp. 1389-1394, 2005.
6. Peng Cong and Darrin J. Young, "Single Crystal 6H-SiC MEMS Fabrication Based On Smart-Cut Technique," *Journal of Micromechanics and Microengineering*, 15, pp. 2243-2248, 2005.
7. M. Suster, J. Guo, N. Chaimanonart, W. H. Ko, and D. J. Young, "A High-Performance MEMS Capacitive Strain Sensing Microsystem," *IEEE Journal of Microelectromechanical Systems*, Vol. 15, issue 5, pp. 1069-1077, 2006.
8. N. Chaimanonart and D. J. Young, "Remote RF Powering for Industrial Strain Sensing Microsystem," *IEEE Sensors Journal*, Volume 6, Issue 2, April, pp. 484 – 489, 2006.
9. W. H. Ko, D. J. Young, J. Guo, M. Suster, H-I Kuo, and N. Chaimanonart, "A High-Performance MEMS Capacitive Strain Sensing System," *Sensors and Actuators A*, vol. 133, pp. 272-277, 2007.
10. D. J. Young, M. A. Zurcher, T. Trang, C. A. Megerian, W. H. Ko, "Characterization of Ossicular Chain Vibration at the Umbo: Implications for a Middle Ear Microelectromechanical System Design," *Ear Nose Throat Journal*; 89(1), pp. 21-26, January 2010.
11. P. Cong, W. H. Ko, and D. J. Young, "Wireless Implantable Blood Pressure Sensing Microsystem Design for Small Laboratory Animals Monitoring," *Sensors and Materials*, Vol. 20, Issue 7, pp. 327-340, 2008.
12. P. Cong, N. Chaimanonart, W. H. Ko, and D. J. Young, "A Wireless and Batteryless 10-bit Implantable Blood Pressure Sensing Microsystem with Adaptive RF Powering for Real-time Genetically Engineered Mice Monitoring," *IEEE Journal of Solid-State Circuits*, Vol. 44, No. 12, pp. 3631-3644 (Special Issue), December 2009.
13. W. H. Ko, R. Zhang, P. Huang, J. Guo, X. Ye, D. J. Young, C. A. Megerian, "Studies of MEMS Acoustic Sensors as Implantable Microphones for Totally Implantable Hearing Aid Systems," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 3, no. 5, pp. 277-285, October 2009.
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15. P. Cong, W. H. Ko, and D. J. Young, "Wireless Batteryless Implantable Blood Pressure Monitoring Microsystem for Small Laboratory Animals," *IEEE Sensors Journal*, Vol. 10, No. 2, pp. 243-254, 2010.
16. M. Z. Zurcher, M. Semann, C. A. Megerian, W. H. Ko, D. J. Young, "A MEMS Capacitive Accelerometer Design as Middle Ear Microphone Based on Ossicular Chain Micromechanics Characterization at Umbo for Fully Implantable Cochlear Prosthesis," *Sensors and Materials*, Volume 22, Number 6, pp. 297-312, 2010.
17. N. Chaimanonart, M. A. Suster, and D. J. Young, "Two-Channel Passive Data Telemetry with Remote RF Powering for High-Performance Wireless and Batteryless Strain Sensing Microsystem Applications," *IEEE Sensors Journal*, Volume 10, Issue 8, pp. 1375-1382, 2010.
18. O. Bebek, M. A. Suster, S. Rajgopal, M. J. Fu, X. Huang, M. C. Cavusoglu, D. J. Young, M. Mehregany, A. J. van den Bogert, and C. H. Mastrangelo, "Personal Navigation via High-Resolution-Gait-Corrected Inertial Measurement Units," *IEEE Transactions on Instrumentation and Measurement*, Volume 59, Number 11, pp. 3018-3027, 2010.
19. R. Wang, P. Cheng, F. Xie, D. Young, and Z. Hao, "A Multiple-Beam Tuning-Fork Gyroscope with High Quality Factors," *Sensors and Actuators A* 166, pp. 22-33, 2011.
20. D. J. Young, M. Z. Zurcher, M. Semann, C. A. Megerian, W. H. Ko, "MEMS Capacitive Accelerometer-Based Middle Ear Microphone," *IEEE Transactions On Biomedical Engineering*, Vol. 59, No. 12, pp. 3283-3292, December 2012.
21. Xing Liu, Hui Chen, Qing-An Huang, Darrin J. Young, "A MEMS-Based Intraoperative Monitoring System for Improved Safety in Lumbar Surgery", *IEEE Sensors Journal*, Volume 13, Issue 5, pp. 1541-1548, 2013.
22. R. Surapaneni, Q. Guo, Y. Xie, D. J. Young and C. H. Mastrangelo, "A three-axis high-resolution capacitive tactile imager system based on floating comb electrodes," *Journal of Micromechanics and Microengineering*, Vol. 23, No. 7, 075004, 2013.
23. Q. Guo, M. A. Suster, R. Surapaneni, C. H. Mastrangelo, D. J. Young, "High-Performance Interface Electronic System for a 13 x 13 Flexible Biomechanical Ground Reaction Sensor Array Achieving a Gait Ground Velocity Resolution of 100um/sec," *IEEE Sensors Journal*, Vol. 13, No. 11, pp. 4496-4505, 2013.
24. R. Yang, Z. Wang, J. Lee, K. Ladhane, D. J. Young and P. X.-L. Feng, "6H-SiC microdisk torsional resonators in a "smart-cut" technology," *Applied Physics Letters* 104, 091906, 2014.

25. Y.-P. Hsu and D. J. Young, "Skin-Coupled Personal Wearable Ambulatory Pulse Wave Velocity Monitoring System Using Microelectromechanical Sensors," *IEEE Sensors Journal, Special Issue*, Vol. 14, No. 10, pp. 3490-3497, 2014.
26. D. J. Young, P. Cong, M. A. Suster, M. Damaser, "Implantable Wireless Battery Recharging System for Bladder Pressure Chronic Monitoring," *Lab on a Chip*, DOI: 10.1039/C5LC00821B, 2015, 15, 4338-4347.
27. Q. Guo, W. Deng, O. Bebek, C. Cavusoglu, C. Mastrangelo, and D. Young, "Personal Inertial Navigation System Assisted by MEMS Ground Reaction Sensor Array and Interface ASIC for GPS-Denied Environment," *IEEE Journal of Solid-State Circuits*, Vol. 53, No. 11, pp. 3039-3049 (Special Issue), November 2018.
28. H. Basaeri, Y. Yu, D. Young, and S. Roundy, "A MEMS-Scale Ultrasonic Power Receiver for Biomedical Implants," *IEEE Sensors Letters*, 2019.
29. D. Young and P. Cong, "Wireless Implantable Sensors: From Lab to Technology Breakthrough Ambitions," *Sensors and Actuators A*, 2019.
30. H. Bsaeri, Y. Yu, D. Young, and S. Roundy "Acoustic Power Transfer for Biomedical Implants Using Piezoelectric Receivers: Effects of Misalignment and Misorientation," *Journal of Micromechanics and Microengineering* (Special Issue), 2019.
31. Y. Yu, T. Nguyen, P. Tathireddy, S. Roundy, and D. J. Young, "Wireless Inductive Sensing and Robust Packaging for Future Implantable Hydrogel-based Glucose Monitoring Applications," *IEEE Sensors Journal*, 2020.
32. W. Luo, V. Sharma, and D. J. Young, "A Paper-Based Flexible Tactile Sensor Array for Low-Cost Wearable Human Health Monitoring," *IEEE Journal of Microelectromechanical Systems*, Vol. 29, No. 5, pp. 825-831, 2020.
33. Y. Yu, T. Nguyen, P. Tathireddy, S. Roundy, and D. J. Young, "A Wireless Battery-less and Moisture-Resistant Packaged Glucose Sensing System Employing Hydrogel-based Inductive Sensing Technique and Low-power ASIC for Long-term Glucose Monitoring," *Sensors and Actuators A*, 341 (2022) 113574.
34. J. M. Arteaga, J. Sanchez, F. Elsakloul, M. Marin, C. Zesiger, N. Pucci, G. J. Norton, D. J. Young, D. E. Boyle, E. M. Yeatman, P. D. Hallett, S. Roundy, and P. D. Mitcheson, "High Frequency Inductive Power Transfer Through the Soil for Agricultural Applications", *IEEE Transactions on Power Electronics*, 2023. DOI: 10.1109/TPEL.2023.3305642
35. W. Luo, V. Sharma, and D. J. Young, "A sock-embedded wireless sensing system employing paper-substrate-based MEMS tactile sensors array and low power ASIC for accurate and comfortable AFib monitoring," *IEEE Sensors Journal*, Volume; 23, Issue: 24, December, 2023. DOI: 10.1109/JSEN.2023.3329100

Peer Reviewed Conference Papers

1. D. J. Young, B. E. Boser, "A Micromachined Variable Capacitor for Monolithic Low-Noise VCOs," *Technical Digest, IEEE Solid-State Sensor and Actuator Workshop*, Hilton Head Island, SC. June 1996, pp. 86-89.
2. D. J. Young, B. E. Boser, "A Micromachine-Based RF Low-Noise Voltage-Controlled Oscillator," *Technical Digest, IEEE Custom Integrated Circuits Conference*, Santa Clara, CA. May 1997, pp. 431-434.
3. D. J. Young, V. Malba, J. J. Ou, A. F. Bernhardt, B. E. Boser, "Monolithic High-Performance Three-Dimensional Coil Inductors for Wireless Communication Applications," *Technical Digest, International Electron Devices Meeting*, Washington, D.C. December 1997, pp. 67-70.
4. V. Malba, D. J. Young, J. J. Ou, A. F. Bernhardt, B. E. Boser, "High-performance RF coil inductors on silicon," *48th IEEE Electronic Components & Technology Conference*, 1998, pp. 252-255.
5. D. J. Young, V. Malba, J. J. Ou, A. F. Bernhardt, B. E. Boser, "A Low-Noise RF Voltage-Controlled Oscillator Using On-chip Three-Dimensional Coil Inductor and Micromachined Variable Capacitor," *Technical Digest, IEEE Solid-State Sensor and Actuator Workshop*, Hilton Head Island, SC. June 1998. pp. 128-131.
6. D. J. Young, J. L. Tham, B. E. Boser, "A Micromachine-Based Low Phase-Noise GHz Voltage-Controlled Oscillator for Wireless Communication," *Technical Digest, The 10th International Conference on Solid-State Sensors and Actuators (Transducers '99)*, Sendai, Japan, June 1999. pp. 1386-1389.
7. D. J. Young, "Micromachining for RF Communications," *MRS Bulletin on Microelectromechanical Systems: Technology and Applications*, Volume 26, No. 4, pp.331-332, April 2001.
8. M. Suster, D. J. Young and W. H. Ko, "Micro-Watt Wireless System for MEMS Sensors Network," *IEEE 2001 Microelectromechanical Systems Conference*, Berkeley, CA. August 2001, pp. 25-28.
9. M. Suster, D. J. Young, W. H. Ko, "Micro-Power Wireless Transmitter for High-Temperature MEMS Sensing and Communication Applications," *Technical Digest, The 15th IEEE International Conference on Micro Electro Mechanical Systems*, Las Vegas, Nevada, January, 2002, pp. 641-644.
10. M. Suster, D. J. Young, and W. H. Ko, "Micro-Power Wireless Transmitter with Printed Battery for MEMS Sensing and Communication Applications," *Technical Digest, Solid-State Sensor, Actuator, and Microsystems Workshop*, Hilton Head Island, South Carolina, June 2002. pp. 333-336.

11. J. Du, D. J. Young, and W. H. Ko, "Single Crystal Silicon MEMS Fabrication Technology Using Proton-Implantation Smart-Cut Technique," Technical Digest, *IEEE Sensors 2002*, Orlando, Florida, June 2002, pp. 585-588.
12. D. J. Young, "Micromachined RF Voltage-Controlled Oscillator with Phase Noise Characterization (invited)," Technical Digest, *The 9th IEEE International Conference on Electronics, Circuits and Systems*, Dubrovnik, Croatia, September 2002. pp. 295-298.
13. M. Suster, W. H. Ko, D. J. Young, "Optically-Powered Wireless Transmitter For High-Temperature MEMS Sensing and Communication," *Technical Digest, The 12th International Conference on Solid-State Sensors and Actuators (Transducers'2003)*, Boston, June 2003. pp. 1703-1706.
14. J. Du, D. J. Young, C. A. Zorman, W. H. Ko, "Single Crystal SiC Capacitive Pressure Sensor at 400 °C," *Technical Digest, International Electron Devices Meeting*, Washington, D.C. December 2003, pp. 783-786.
15. J. Guo, H. Kuo, D. J. Young, and W. H. Ko, "Buckled Beam Linear Output Capacitive Strain Sensor," *Technical Digest of Solid-State Sensor, Actuator, and Microsystems Workshop*, Hilton Head Island, South Carolina, June 2004. pp. 344-347.
16. H. Kuo, J. Guo, D. J. Young, and W. H. Ko, "Rapid Bonding of Micro Strain Sensor," *IEEE Sensors Conference*, Vienna, Austria, October 2004. pp. 546-549.
17. N. Chaimanonart, W. H. Ko, and D. J. Young, "Remote RF Powering System for MEMS Industrial Strain Sensing Applications," *IEEE Sensors Conference*, Vienna, Austria, October, 2004. pp. 1522-1525.
18. P. Cong, W. H. Ko, and D. J. Young, "Single Crystal 6-H Silicon Carbide Smart-Cut MEMS Fabrication Technology," *IEEE Sensors Conference*, Vienna, Austria, October, 2004. pp. 1161-1164.
19. P. Cong, D. J. Young, and W. H. Ko, "Novel Long-Term Implantable Blood Pressure Monitoring System," *IEEE Sensors Conference*, Vienna, Austria, October, 2004. pp. 1359-1362.
20. M. Suster, J. Guo, N. Chaimanonart, W. H. Ko, and D. J. Young, "High Performance Strain Sensing Microsystem," *IEEE Custom Integrated Circuits Conference*, Orlando, Florida, October 2004, pp. 693-696.
21. D. J. Young and W. H. Ko, "A High-Performance Strain Sensing Microsystem with Remote RF Power Capability (invited)," *the 7th International Conference on Solid-State and Integrated-Circuit Technology*, Beijing, China, 2004.
22. M. Suster, N. Chaimanonart, J. Guo, W. H. Ko, and D. J. Young, "Remote-Powered High-Performance Strain Sensing Microsystem," *the 18th IEEE International Conference*

On Micro Electro Mechanical Systems, Miami Beach, Florida, January 2005, pp. 255-258.

23. P. Cong, K. Olszens, D. J. Young, and W. H. Ko, "Implantable Blood Pressure Monitoring of Small Animal for Advanced Biological Research," *the 13th International Conference on Solid-State Sensors, Actuators and Microsystems*, Seoul, Korea, June 2005, pp. 2002-2005.

24. N. Chaimanonart, W. H. Ko, and D. J. Young, "Remote RF Powering and Data Telemetry System for Wireless MEMS Strain Sensors," *the 2nd International Workshop on Network Sensing System (INSS 2005)*, San Diego, June 2005, pp. 48-53.

25. D. J. Young and W. H. Ko, "Wireless Strain Sensing Microsystem," *Technical Proceeding of the 5th Emerging Information Technology Conference (EITC 2005)*, Taipei, Taiwan, R.O.C, August 2005.

26. N. Chaimanonart, K. Olszens, M. Zimmerman, W. Ko, D. J. Young, "Implantable RF Power Converter for Small Animal In Vivo Biological Monitoring," *the 27th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC-2005)*, Shanghai, China, September 2005, pp. 1559-1562.

27. J. Guo, M. Suster, D. J. Young, W. H. Ko, "High-gain Mechanically Amplified Capacitive Strain Sensor," technical proceeding of the *IEEE Sensors Conference*, Irvine, CA, October 2005, pp. 464-467.

28. C. K. Lu, H. Qu., H.K. Xie, D. J. Young, "CMOS MEMS Accelerometer for Long-Term In Vivo Real-Time Small Animal Biological Monitoring," technical proceeding of the *IEEE Sensors Conference*, Irvine, CA, October 2005, pp. 1377-1380.

29. N. Chaimanonart, M. Suster, and D. J. Young, "Two-Channel Data Telemetry with Remote RF Powering for High-Performance Wireless MEMS Strain Sensing Applications," technical proceeding of the *IEEE Sensors Conference*, Irvine, CA, October 2005, pp. 285-288.

30. W. H. Ko, D. J. Young, and C. A. Megerian, "Implantable Microphone for Cochlear Hearing System," *Asia-Pacific Conference of Transducers and Micro-Nano Technology*, Singapore, June, 2006, p. 151.

31. M. A. Zurcher, D. J. Young, T. Trang, C. A. Megerian, W. H. Ko, "Development of Middle Ear Acoustic Sensor for Fully Implantable Cochlear Prosthesis," *the 3rd International Workshop on Network Sensing System (INSS 2006)*, Chicago, May 2006, pp. 49-54.

32. M. Zimmerman, N. Chaimanonart, D. J. Young, "In Vivo RF Powering for Advanced Biological Research," *the 28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC-2006)*, New York, N.J., 2006, pp. 2506-2509.

33. P. Cong, D. J. Young, B. Hoit, W. H. Ko, "Novel Long-Term Implantable Blood Pressure Monitoring System with Reduced Baseline Drift," *the 28th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC-2006)*, New York, N.J., 2006, pp. 1854-1857.
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Invited Book Chapters

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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.

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“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,

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“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)