Filed on behalf of Invensys Systems, Inc.
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UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

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MICRO MOTION, INC.

Petitioner

v.

INVENSYS SYSTEMS, INC.

Patent Owner

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Case IPR 2014-00170

U.S. Patent No. 6,311,136

Issue Date: October 30, 2001

Title: DIGITAL FLOWMETER

DECLARATION OF DR. JEFFREY S. VIPPERMAN IN SUPPORT OF PATENT OWNER'S RESPONSE UNDER 35 USC §§ 316(a)(8) AND MOTION FOR CONDITIONAL AMENDMENT UNDER 37 CFR § 42.121

I, Jeffrey S. Vipperman, do hereby declare and state, that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: August 18, 2014

Jeffrey S. Vipperman

I. BACKGROUND AND QUALIFICATIONS

A. Scope of Work

1. I have been asked by Patent Owner's counsel to analyze claims 21 and 36 of U.S. Patent No. 6,311,136 ("the '136 patent"; Ex. 1001), and submit this Declaration in Support of Patent Owner's Response and Motion for Amendment in the instant proceeding, in rebuttal to the Declaration of Dr. Michael D. Sidman (Ex. 1002).

2. The opinions provided are my own and are based on my analysis and work in this case and the education, experience, and skills I have acquired and developed throughout my career.

3. In reaching my conclusions and opinions, I have relied upon my experience and training, and my review of the evidence produced in this proceeding, and I have considered the documents and materials described in Petitioner's Petition, Patent Owner's Preliminary Response, and the documents and information referenced in this declaration in the process of forming my opinions.

4. For the time I expend on this case, I am currently being compensated at a rate of $300/hour. My compensation is not in any way dependent on the outcome of the dispute.

B. Expertise

5. Details of my professional qualifications and background are set out

in my curriculum vitae, a copy of which is attached as Appendix A.

6. I am an independent consultant. All of my opinions stated in this declaration are based on my own personal knowledge and professional judgment. In forming my opinions, I have relied on my knowledge and experience in smart materials and systems (transducers, measurements, acoustics, vibrations, electronics, signal processing, and embedded systems); software development practices; digital signal processing and programming, including C/C++ and assembler code programming; and on the documents and information referenced in this report. I am over 18 years of age and am competent to testify as to the matters set forth herein. I have attached as Appendix B a copy of my current curriculum vitae (CV), which details my education and experience. The following thus provides only a brief overview of some of my experience that is relevant to the matters set forth in this report.

7. Since 1990, I have designed, developed, and deployed control systems for vibrating or acoustic systems containing electromagnetic and solid state (e.g. piezoceramic) transducers. As such, I have acquired expertise and am an expert in the areas of applied controls, piezoelectric transducers, vibrations, acoustics, electronics, signal processing, and signal analysis. I have also performed embedded systems development and programming on Texas Instruments digital signal processors, PC/104s, Aerotech Soloist™, and Arduino platforms, using

various programming languages for the development, design, and deployment of those systems and products. I have been employed by or retained as a consultant, including acting as a litigation consultant, for numerous companies and firms such as Covidien, DLA Piper, Apple Computer, Wilmer Hale, Mosebach Manufacturing, Inc., MIRATECH Corporation, Siemens Government Services, Thompson, Coburn and Fagel Haber LLC, Westinghouse Electric Company, National Institute of Occupational Safety and Health, Brashear LP, NASA Langley Research Center, Duke University, and Sandia National Laboratory.

8. As my curriculum vitae shows, I have spent the past 24 years as an applied researcher. The early part of my career (1990-1997) was spent as Graduate Project Assistant, Research Associate, or an Assistant Research Professor. During this time, I have had numerous occasions to develop or review bodies of source code for digital devices. I have developed or analyzed source code written in C/C++, Assembler languages, and MATLAB. Various algorithms related to noise and vibration control were implemented. The goals of active control are similar to those of Coriolis flow meters. The phase and amplitude of harmonic signals are adapted to create a signal that is out of phase to achieve vibration control through superposition (feedforward) or feedback control. As such, the goal was to minimize vibration, rather than increasing or causing vibration, as with Coriolis flow meters. These goals have similarities. For example, feedforward vibration

control is achieved when the control input creates a response that has a particular phase relationship to that of the disturbing input (180 degrees out of phase).

9. I continue to develop code. For example, I developed a sun avoidance routine that controls large aperture research telescopes and most recently, I have been involved in the development of a noise classifier that was implemented on an embedded Linux platform that has a become a commercial product.

10. During my career as a professor (1997-present), I have several relevant professional experiences that demonstrate my expertise in the field of applied control. For example, I have publicly lectured regarding the development of piezoceramic transducer systems for exciting structural vibration while performing health monitoring as well as various feedback and adaptive feedforward control algorithms used to adapt phase and amplitude to achieve structural control. I have also been involved in the development of generators to drive a thermoacoustic refrigerator (TAR) on resonance in various ways, including using phase locked loops (PLL), which include PID control loops. Similar approaches have been used for Coriolis flow meters. The goal of the PLL control was to drive the phase relationship between the acoustic pressure and speaker velocity to a certain phase relationship, much like the positive feedback or PLL control approaches in Coriolis mass flow meters.

11. In the early to mid 2000s I also developed and demonstrated active

transducers for energy systems through funding from the US Dept. of Energy, including a piezoelectrically MEMS (microelectromechanical system) microvalve used to meter the hydrogen fuel inside of fuel cells. I also completely developed and fabricated a high-pressure, high-temperature electromagnetically activated valve for gas turbine engines that can restore equivalence ratios when the fuel orifices wear. They were also fast enough to provide active combustion control.

12. I have also implemented various feedback approaches, including PID, robust, and optimal control designs. I have also taught for many years in the areas of computer programming, mechanical measurements, vibrations, acoustics, signal analysis, dynamic systems, and controls. These courses include significant amounts of material on electronics and transducers. In addition, I have taught short courses on active control and measurement and analysis of vibration and acoustic signals.

13. I have performed system programming assignments with the following operating systems or platforms: MS-DOS, Windows, embedded Linux, and a real time kernel written by a colleague for Texas Instruments TMS320 series of digital signal processors.

14. I have authored over 100 technical publications from which at least nine (9) are representative publications relevant to the technology at issue. For example:

a) Bucci, B., Cole, D., Ludwick, S., Vipperman, J.S., “A Nonlinear Control Algorithm for Reducing Settling Time in High-Precision Point to Point Motion,” IEEE Transactions on Control System Technology, Issue 99, 10.1109/TCST.2012.2206812, Sep. 11, 2012. In this work, a high performance, nonlinear PID servo control algorithm was developed and implemented on a proprietary embedded system using C language. Note that PLLs can be viewed as a servo control system for signal phase.

b) Ryan, T. S., L.A. Schaefer, and J.S. Vipperman, “Control of a Standing Wave Thermoacoustic Refrigerator,” IMECE2010-38966, Proceedings of ASME IMECE-10, November 12-18, 2010, Vancouver, BC, Canada. We developed various generators based upon phase locked loops as well as other techniques to drive a standing wave thermoacoustic system at its primary acoustic resonance (in the same manner as a Coriolis flow meter device). The PLL was realized in software.

c) Kuxhaus L, Schimoler PJ, Vipperman JS, Miller MC. “Validation of a Feedback-Controlled Elbow Simulator Design: Elbow Muscle Moment Arm Measurement”. ASME Journal of Medical Devices, 3(3), 7pp., Sep. 2009.

d) Bisnette, Jesse, Adam K. Smith, J. S. Vipperman, and D. B. Budny, "Active Noise Control Using Phase-Compensated, Damped Resonant Filters," ASME Journal of Vibration and Acoustics 128(2), pp. 148-55, April, 2006. This was a demonstration of positive position control (PPC) on acoustic systems where the speaker phase dynamics were compensated.

e) Haljasmaa, Igor V., J. S. Vipperman, Ronald J. Lynn, Robert P. Warzinski, "Control of a Fluid Particle Under Simulated Deep-Ocean Conditions in a High-Pressure Water Tunnel," AIP Review of Scientific Instruments, 76(2), Feb. 2005, pp. 1-11.

f) Cabell, R. H., D. L. Palumbo, and J. S. Vipperman, "A Principal Component Feedforward Algorithm for Active Noise Control: Flight Test Results," IEEE Transactions on Control Systems Technology, 9(1), January, 2001, pp. 76-83. In this project, algorithms were developed for Texas Instruments TMS320 series of digital signal processors (DSPs) in C and assembly languages to lock onto the phase of harmonic signals and control them by adapting the phase and magnitude.

g) Vipperman, J. S., R. L. Clark, "Multivariable Feedback Active Structural Acoustic Control Using Adaptive Piezoelectric

Sensoriactuators," Journal of the Acoustical Society of America, 105(1), Jan. 1999, pp. 219-225. Here is another example of developing an embedded control system on Texas Instruments chips that involved exciting and controlling structural vibration.

h) Vipperman, J. S., and R. L. Clark, "Hybrid Model-Insensitive Control Using a Piezoelectric Sensoriactuator," Journal of Intelligent Material Systems and Structures, 7(6), November 1996, pp. 689-695. This article presented a novel control algorithm to create harmonic signals of the proper phase and amplitude to control structural vibration using piezoceramic self-sensing transducers.

i) Vipperman, J. S., R. A. Burdisso, and C. R. Fuller, 1993, "Active Control of Broadband Structural Vibration Using the LMS Adaptive Algorithm," Journal of Sound and Vibration. 166(2), Sep. 1993, pp. 283-299. The first embedded control system developed on Texas Instruments TMS320 series of digital signal processors to perform vibration control on a distributed structure using piezoceramic actuators.

15. My three patents for active transducers are also related to this work:

1. Hensel, J.P., N. Black, J.D. Thornton, J.S. Vipperman, D.N. Lambeth, W.W. Clark, "Active Combustion Flow Modulation Valve," United

States Patent Number 8,540,209, Sep. 24, 2013.

2. Gemmen, Randall, Jimmy Thornton, Jeffrey S. Vipperman, William W. Clark, "Piezoelectric Axial Flow Microvalve," United States Patent Number 7,159,841, Jan. 9, 2007.
3. Clark, R. L., J. S. Vipperman, and Daniel G. Cole, "Adaptive Piezoelectric Sensoriactuator," United States Patent Number 5,578,761, Nov. 26, 1996.

C. Patent Cases in Which I Have Offered Expert Testimony or Consulting

16. The patent cases in which I have offered expert testimony or consulting services are set out in my curriculum vitae.

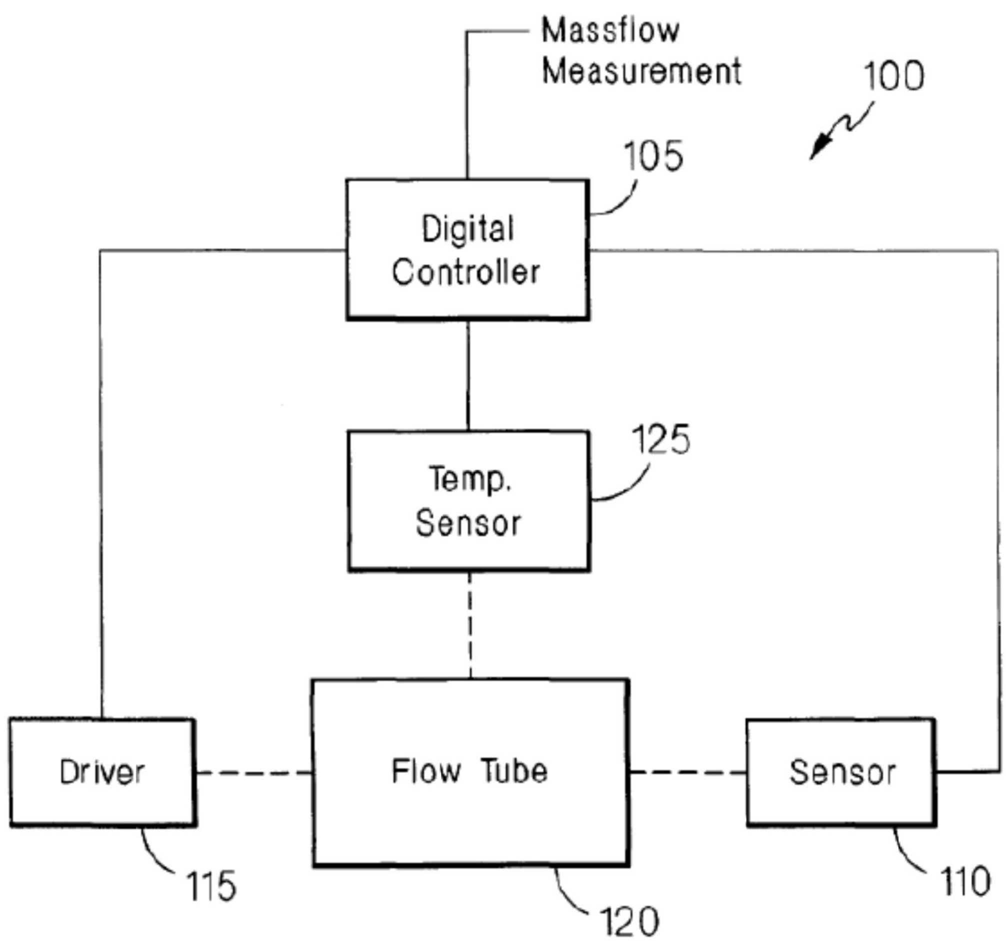
II. TECHNICAL OVERVIEW OF THE PATENTED TECHNOLOGY

17. The '136 patent teaches a control and measurement system for a digital flowmeter. A digital flowmeter is one that not only makes measurements digitally—that is generally a given—but also digitally generates a drive signal to control conduit oscillation. (Ex. 1001, 1:50-59, 3:1-11.)

18. The '136 patent discloses multiple embodiments of the mechanical components of a Coriolis flowmeter and digital control and measurement system. (*Id.* 3:12-6:24.) These embodiments each include (1) a vibratable conduit, (2) a digital controller to measure conduit vibration and to generate a drive signal to

control conduit vibration, (3) a sensor between the conduit and digital circuitry to sense conduit vibration, and (4) a driver between the digital circuitry and the conduit to drive conduit vibration based on the drive signal from the digital controller. (*Id.* 3:1-11.)

19. An exemplary embodiment of the primary components of a digital flowmeter system of the '136 patent is reproduced below:



20. The digital controller above may be comprised of "a processor, a

field-programmable gate array, an ASIC, other programmable logic or gate arrays, or programmable logic with a processor core." (*Id.* 8:38-42.)

21. The '136 patent discloses multiple features and capabilities created by the digital circuitry that allow for precise measurement and control. For example, the patent discloses the ability to digitally generate drive signals using multiple different drive modes. (Ex. 1001, 4:37-57.)

22. The '136 patent also discloses the ability to use a proportional-plus-integral (PI) control algorithm to control the motion of the conduit. (*Id*. 5:8-15.)

23. The '136 patent also discloses a control system capable of "apply[ing] a negative gain to the sensor signal to reduce motion of the conduit." (*Id*. 5:45-47.)

24. The digital circuitry of '136 patent also discloses the ability to compensate for time delays "associated with the sensor and components connected between the sensor and the driver" In the digital flowmeter. (*Id*. 7:19-22.)

25. Prior flowmeter control mechanisms lacked sufficient control capability, precision and adaptability to adjust the conduit drive signal to overcome problems induced by variations in material flow within the conduit associated with twophase flow. (Ex. 1001, 1:60-65, 46:26-40.)

26. Processing separate batches of fluid through the flowtube is another instance in which the digital flowmeter is vastly superior to prior analog flowmeters. (Ex. 1001, 49:58-50:21.)

27. Thus, the digital flowmeters disclosed in the ’136 patent are substantially superior to previous analog drive flowmeters for multiple applications.

III. OPINIONS RELATING TO PATENT OWNER’S RESPONSE

A. Claim Construction

1. Applicable Legal Standards

28. It is my understanding that, in an *inter partes* review, claim terms in an unexpired patent are interpreted according to their broadest reasonable construction in light of the specification of the patent in which they appear. It is also my understanding that under a broadest reasonable interpretation, words of the claim must be given their plain meaning, unless such meaning is inconsistent with the specification, such as where the inventor acted as his or her own lexicographer, used terms without an established plain and ordinary meaning in the art, or redefined a well-known term of art. It is the use of the words in the context of the written description and customarily by those skilled in the relevant art that accurately reflects both the ‘ordinary’ and the ‘customary’ meaning of the terms in the claims. I understand that the plain meaning to one of skill in the art is considered at the time of the invention (i.e., the date the earliest supporting priority application was filed, namely November 26, 1997).

29. I further understand that, if there is no plain and ordinary meaning of a

claim term, then the construction of the claim term should be derived from the specification. I also understand that the specification plays a crucial role in claim construction, and that the claims must be read in view of the specification of which they are a part. I also understand that the specification may reveal a special definition given to a claim term by the patentee that differs from the meaning it would otherwise possess, and that in such cases the lexicography governs. I further understand that the prosecution history of the patent should also be considered, and that it provides evidence of how the U.S. Patent and Trademark Office and the inventor understood the patent.

30. I further understand that the claim language is to be viewed from the perspective of a person of ordinary skill in the art at the time of invention. When analyzing the '136 patent, the disputed claims, and the prior art, I apply this standard set forth above to reach my conclusions, and any reference to a "person of ordinary skill in the art" below refers to a person of ordinary skill in the relevant art of the '136 patent at the time of the invention.

2. Definition of a Person of Ordinary Skill in the Art

31. I understand that neither the Petitioner nor its expert expressed an opinion as to the level of ordinary skill in the art.

32. It is my opinion that a person having an ordinary level of skill would have at least the following qualifications: (1) a bachelor's degree in electrical

engineering or the equivalent education through work experience; and (2) three or four years of experience or post-graduate education. This experience would include digital signal processing and control theory. I consider myself to be at least of ordinary skill in the art under this definition, and I have done the analysis supportive of my opinions here in the context of a person having an ordinary level of skill in the art.

3. Proposed Claim Constructions

33. "applies a negative gain to the sensor signal" should be construed to mean "multiplies the sensor signal by a negative value." This is the plain and ordinary meaning of this phrase. This construction is also consistent with the description in the '136 patent of multiplying the combination of the right and left sensor signals by the value of the gain using a multiplying digital-to-analog converter at 25:1-26:6.

34. I also note that this construction is consistent with the cross examination testimony of Petitioner's expert, Dr. Sidman. Ex. 2014 at 143:20-23; 143:24-144:14. Dr. Sidman also testified that gain can be expressed as a ratio of the amplitudes of the output and input signals. Ex. 2014 at 148:15-149:3. If gain is the output amplitude divided by the input amplitude, i.e., if Gain = V_{out}/V_{in}, it necessarily follows that the output amplitude is equal to the input multiplied by the gain, i.e., $V_{out} = V_{in}$*Gain. This testimony further confirms that applying a negative

gain to a sensor signal should be understood to mean multiplying a sensor signal by a negative value. (If the sensor signal is harmonic, this will result in a phase inversion).

B. Opinions Regarding Validity of the '136 Patent

35. I understand that the claims under review in this IPR are claims 17, 21 and 36. I have been informed that Patent Owner has decided to cancel claim 17, and thus I have been asked to form an opinion only with respect to the validity of claims 21 and 36 of the '136 patent.

1. Applicable Legal Standards

36. My understanding with respect to construction of the claims of the '136 patent are to be construed, and my opinion concerning the level of ordinary skill in the art, are set forth above in section III.A.

37. I have been informed that, in the context of the *inter partes* review, the party asserting invalidity of a patent must prove invalidity by a preponderance of the evidence. I have been informed that a "preponderance of the evidence" is evidence sufficient to show that a fact is more likely than not.

a. Anticipation

38. Patent Owner's counsel has informed me that a patent claim is invalid for lack of novelty, or as "anticipated," under 35 U.S.C. § 102, if, among other things, (a) the alleged invention was known or used by others in this country, or

patented or described in a printed publication in the United States or a foreign country, before the alleged invention thereof by the patent's applicant(s), or (b) the alleged invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of the application for patent in the United States, or (e) the alleged invention was described in an application for patent by another person in the United States before the alleged invention by the applicant thereof. I have also been informed that an *inter partes* review is only concerned with the validity of patent claims with respect to patents and printed publications.

39. Patent Owner's counsel has also informed me that references or items that fall into one or more of these categories are called "prior art," and that in order to anticipate a patent claim pursuant to 35 U.S.C. § 102, a reference must contain all of the elements and limitations described in the claim either expressly or inherently. As such, counsel for Patent Owner has informed me that in deciding whether or not a single item of prior art anticipates a patent claim, one should consider what is expressly stated or present in the item of prior art, and what is inherently present.

40. I understand that, to establish inherency, the missing characteristic must be necessarily present in the single reference, and that it would be so recognized by persons of ordinary skill in the art. I also understand that the missing

descriptive material cannot merely be probably or possibly present. It is my understanding that one of ordinary skill in the art may not have recognized the inherent characteristics or functioning of the prior art at the time. I further understand that obviousness is not inherent anticipation, and that it is insufficient that a missing limitation is so similar to a limitation actually disclosed in the reference that one of ordinary skill in the art would see the substitution as obvious. I also understand that, if it is necessary to reach beyond the boundaries of a single reference to provide missing disclosure of the claimed invention, the proper ground is not anticipation, but obviousness.

41. I understand that invalidity based on anticipation requires that the reference enable the subject matter of the reference and therefore the patented invention without undue experimentation. I also understand that the proper test of a publication as prior art is whether one skilled in the art to which the invention pertains could take the description in the printed publication and combine it with his own knowledge of the particular art and from this combination be put in possession of the invention on which a patent is sought.

b. Obviousness

42. I understand that a patent claim is invalid because it lacks novelty or is "obvious" under 35 U.S.C. § 103 if the claimed subject matter would have been obvious to a person of ordinary skill in the art at the time the application for patent

was filed, based upon one or more prior art references. I understand that an obviousness analysis should take into account (1) the scope and content of the prior art; (2) the differences between the claims and the prior art; (3) the level of ordinary skill in the pertinent art; and (4) secondary considerations, if any, of obviousness (such as unexpected results, commercial success, long-felt but unsolved needs, failure of others, copy by others, licensing, and skepticism of experts).

43. I understand that a conclusion of obviousness may be based upon a combination of prior art references. However, I also understand that a patent composed of several elements may not be proved obvious merely by demonstrating that each of its elements was independently known in the art. I further understand that there must be an appropriate articulation of a reason to combine the elements from the prior art in the manner claimed, and obviousness cannot be based on a hindsight combination of components selected from the prior art using the patent claims as a roadmap.

44. I understand that the following exemplary rationales may lead to a conclusion of obviousness: the combination of prior art elements according to known methods to yield predictable results; the substitution of one known element for another to obtain predictable results; the use of known techniques to improve similar devices in the same way; and some teaching, suggestion, or motivation in

the prior art that would have led one of ordinary skill to modify the prior art reference teachings to arrive at the claimed invention. However, a claim is not obvious if the improvement is more than the predictable use of prior art elements according to their established functions. Similarly, a claim is not obvious if the application of a known technique is beyond the level of ordinary skill in the art. Furthermore, when the prior art teaches away from combining certain known elements, discovery of a successful means of combining them is not obvious.

45. I further understand that, to determine obviousness, the courts look to the interrelated teachings of multiple patents, the effects of demands known to the design community or present in the marketplace, and the background knowledge possessed by a person having ordinary skill in the art.

46. I understand that a prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention. I also understand that if the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render a claim prima facie obvious. I further understand that, when considering a disclosure or reference, it is proper to take into account not only specific teachings of the reference but also the inferences which one skilled in the art would reasonable be expected to draw therefrom.

47. I understand that, to establish *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art.

2. Opinion Regarding Claim 36 and Romano (Ground 5)

a. Summary of Opinion

48. It is my opinion that claim 36 is not anticipated by Romano (Exhibit 1006).

49. Claim 36 includes a requirement to "adjust a phase of the drive signal to compensate for a time delay associated with the sensor and components connected between the sensor and the driver." Ex. 1001 at 62:21-24. This limitation of claim 36 is not disclosed by Romano.

50. I have reviewed Dr. Sidman's opinion concerning claim 36 as set out in ¶¶ 175-182 of his expert declaration, Ex. 1002. I note that, in an attempt to show that Romano adjusts a phase of the drive signal as required by the aforementioned limitation of claim 36, Dr. Sidman identified a 2π/128 radian phase shift applied to the digitized right channel *sensor* signal by the microprocessor 330 of Romano's Fig. 3, and opined that the "right and left channel signals are both used by the microprocessor 330 to generate the drive signal" and "thus the correction of the phase shift in the right channel propagates through as a phase shift of the drive signal." Ex. 1002 ¶ 1008. This is the sole basis identified in Dr.

Sidman's declaration for asserting that Romano discloses the limitation of claim 36 discussed above.

51. I disagree with Dr. Sidman's opinion for at least two reasons. First, Romano discloses that the microprocessor 330 uses only the magnitude of one sensor channel, for example, the left sensor channel, to generate drive signal. Second, even if the right sensor channel were to be used in place of the left sensor channel, the phase shift applied to the right sensor channel would have no effect on the drive signal generated by the microprocessor 330 using the method disclosed by Romano, since the DFT magnitude computed with equation (4) (*Id*., 12:7-12) is not effected by signal phase, as will be shown below in equations (g)-(i).. Thus, contrary to Dr. Sidman's opinion, the 2π/128 radian phase shift applied to the digitized right channel *sensor* signal by the microprocessor 330 does ***not*** propagate through to the drive signal.

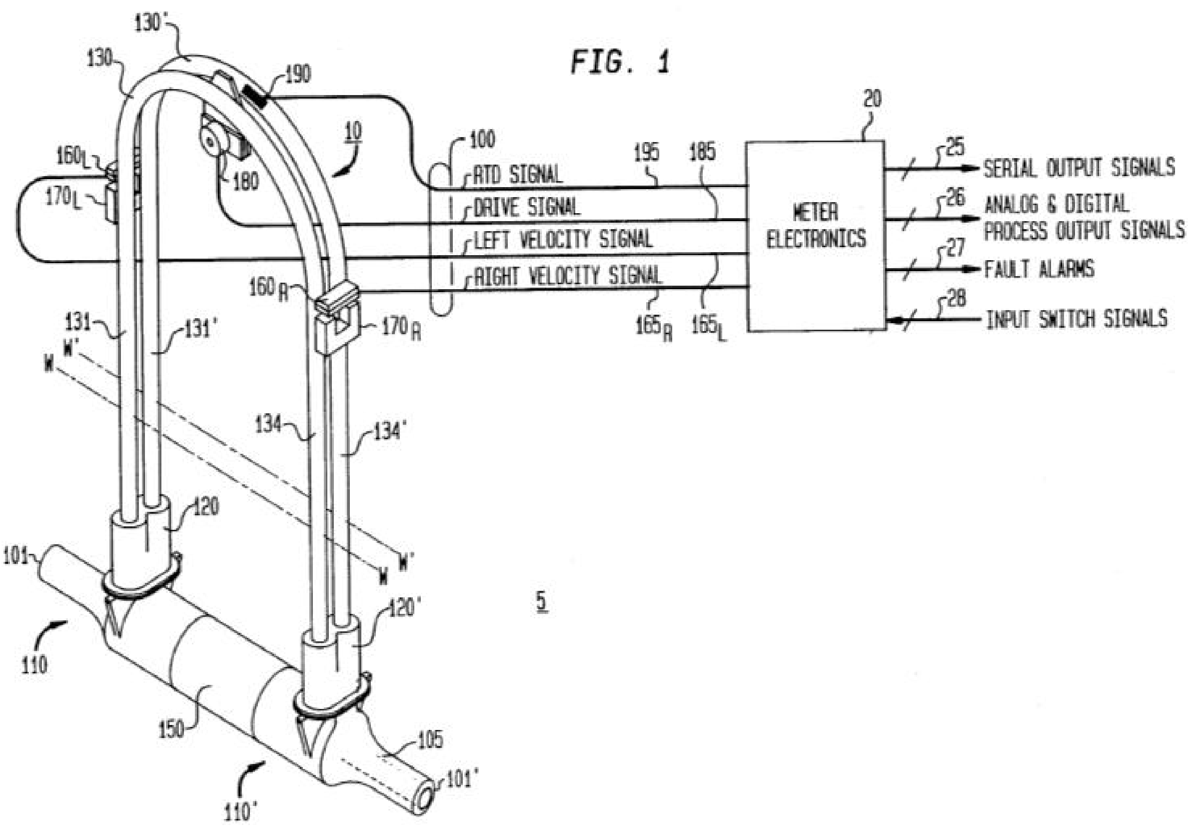
52. In addition, the 2π/128 radian phase shift applied to the digitized right channel *sensor* signal by the microprocessor 330, to the extent it compensates for any delay, compensates for the delay associated with a single component, the multiplexer 302 of Fig. 3 of Romano. Therefore, even assuming that this phase shift did propagate through to the drive signal (which it does not), the drive signal would be phase shifted to compensate for the delay associated with only a single

component rather than the delay associated with the multiple "component*s* located between the sensor and the driver" (emphasis added) as required by claim 36.

53. The detailed basis for these opinions is set forth below.

b. Romano's Microprocessor Uses Only a Single Sensor Channel to Generate the Drive Signal

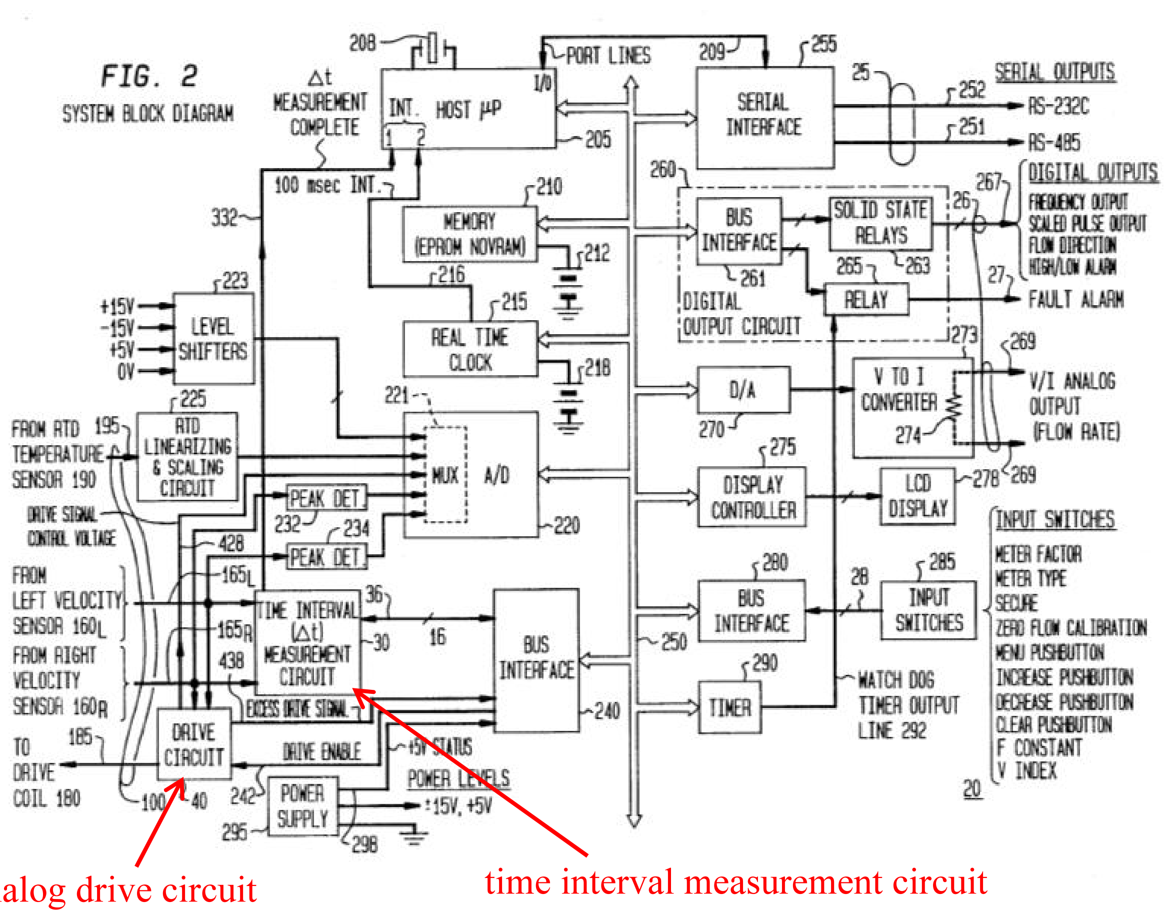
54. Romano discloses a Coriolis flowmeter as shown in Fig. 1, reproduced below:



55. In relevant part, Romano's flowmeter 5 includes two vibratable conduits 130, 130'. Attached these conduits 130, 130' are a drive mechanism 180 and a pair of velocity sensing coils 160_L and 160_R. Ex. 1006 at 14:6-11. Meter

electronics 20 uses analog signals from the velocity sensing coils 160_L and 160_R to, among other things, provide a measure of the mass flow rate and, as will be explained in further detail below, to generate the drive signal applied to the drive mechanism 180.

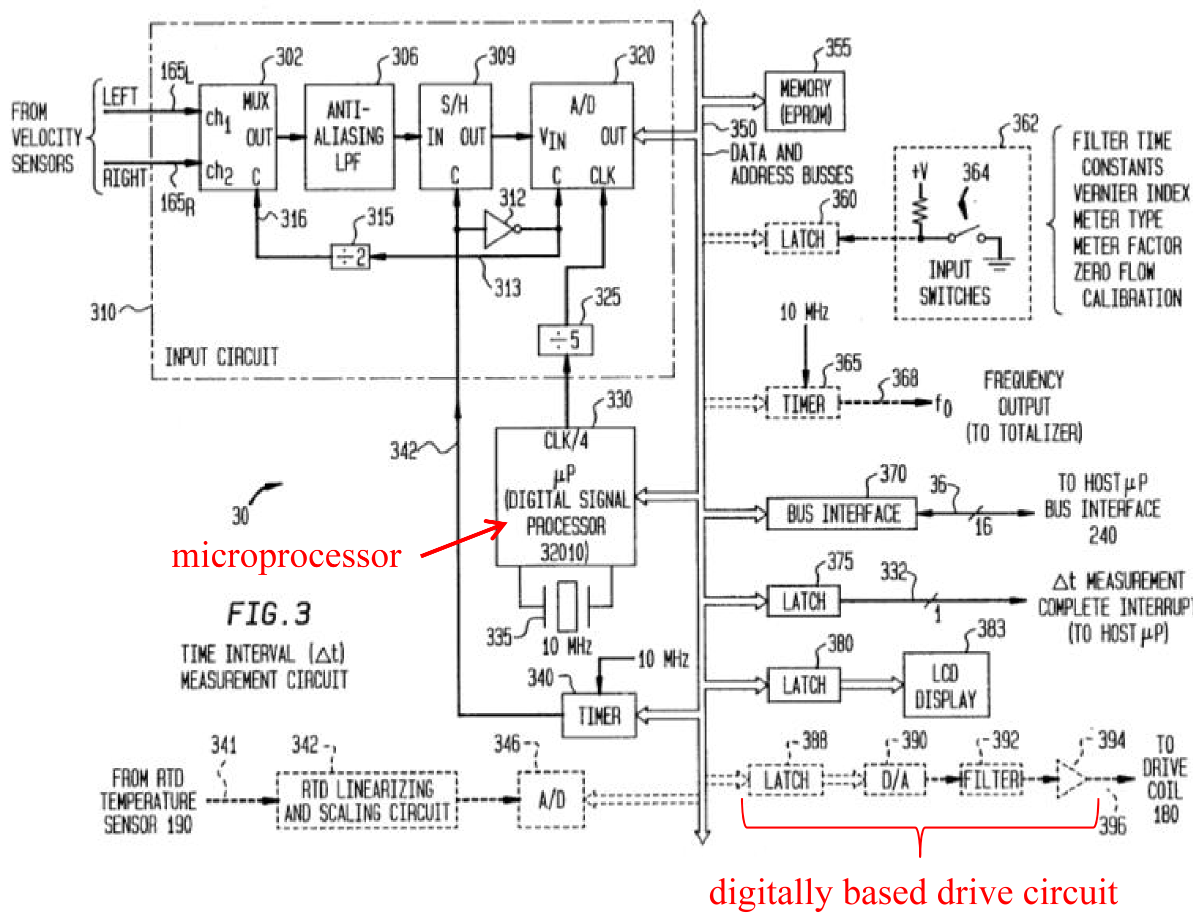
56. The meter electronics 20 of Fig. 1 is shown in further detail in Romano's Fig. 2 reproduced below (annotations in red added):



57. The meter electronics 20 includes two portions relevant to this analysis: the analog drive circuit 40 and the time interval measurement circuit 30.

As shown in this figure, the analog drive circuit 40 outputs a signal to the drive mechanism/coil 180 and the time interval measurement circuit 30 inputs sensor signals from the left and right velocity sensors 160_L and 160_R.

58. The time interval measurement circuit 30, shown in detail below, includes a microprocessor 330 and a digitally based drive circuit, including a latch 388, a digitial-to-analog (D/A) converter 390, a filter 392, and an amplifier 394, that can be used in lieu of the analog drive circuit 40. Ex. 1006 at 24:32-36.



59. As discussed above, Romano discloses that a phase shift is applied to the digitized samples from the right channel velocity sensors 160_L and 160_R:

> **Input circuit 310** samples both the left and right velocity sensor signals appearing over leads **165_L** and **165_R**, respectively, on an interleaved basis to produce "128" samples per tube cycle: "64" samples for right velocity sensor **160R** interleaved between "64" samples for the left velocity sensor **160L**, respectively (see FIG. 1). Specifically, both velocity signals can not be sampled at the same time. Consequently, the two velocity sensor signals are continuously sampled on an alternating basis. As a result, the samples for one sensor, illustratively the left sensor, will always lead the corresponding samples for the right sensor by a phase shift of 2P/128 radians. In calculating the fourier components, microprocessor **330**, as shown in FIG. **2** and discussed in detail below, utilizes a "128" point look-up table of sine values. Now, to compensate for this phase shift between the sampled velocity signals, each of the "64" samples for every tube cycle produced by the left velocity sensor is multiplied by a corresponding sine term, while, as discussed below, each of the "64" samples produced by the right channel is multiplied by a corresponding sine term that includes a phase shift of 2P/128 radians.

Ex. 1006 at 22:10-32. In this passage, the "P" in the expression "2P/128 radians" refers to π, and thus I will use π rather than P when referring to this expression throughout the remainder of this declaration.

60. The 2π/128 radian phase shift discussed in this passage is applied after the right channel sensor signals have been digitized by the analog-to-digital converter 320 shown in Fig. 3. Ex. 1008 at 22:33-23:3. This 2π/128 radian phase

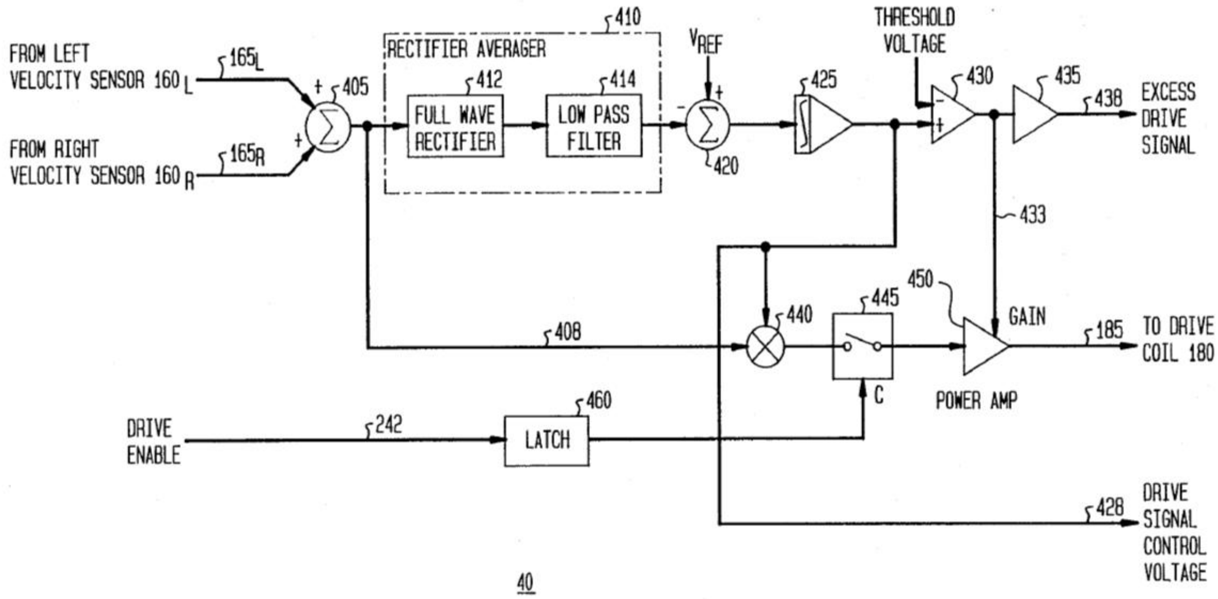
shift applied to the digitized samples from the right sensor channel is the phase shift relied on in ¶ 180 of Dr. Sidman's declaration, Ex. 1002. However, while this phase shift applied to the right sensor channel is utilized by the microprocessor 330 to measure the mass flow rate, this phase shift has no impact on, and does not propagate through to the drive signal generated by the microprocessor 330 and applied to the drive coil 180 as will be explained in detail below.

61. In order to understand why this is so, it should be noted that Romano discloses two circuits for generating the drive signal applied to coil 180: the analog drive circuit 40 discussed above in connection with Fig. 2, and the digitally based drive circuit discussed above in connection with Fig. 3.

62. This analog drive circuit 40 is shown in detail in Fig. 4 of Romano, reproduced below.

FIG. 4

DRIVE CIRCUIT 40



63. As shown in Fig. 4, the analog drive circuit 40 inputs the *analog* signals from the right and left velocity sensors 160_L and 160_R. Neither of these signals is phase shifted. In particular, the 2π /128 radian phase shift applied to the digitized samples from the right sensor channel is not present in the analog right channel sensor signal input to analog drive circuit 40 because, as explained above, this phase shift is only applied after the right channel signal has been digitized by the A/D converter 320 of Fig. 3. Perhaps in recognition of this fact, neither Dr. Sidman nor the Petition contend that the phase of the drive signal output by the analog drive circuit 40 has been adjusted by the 2π /128 radian phase shift identified in paragraph 180 of Dr. Sidman's declaration.

64. However, Dr. Sidman and the Petition do contend that the phase of the drive signal output by the digitally based drive circuit of Fig. 3 is adjusted by the 2π /128 radian phase shift; i.e., that the 2π /128 radian phase shift applied to the digitized right channel sensor signal "propagates through as a phase shift of the drive signal." Ex. 1002¶ 180; Petition at 37. This assertion is incorrect because Romano discloses that the drive signal generated by the microprocessor 330 and output via the digitally based drive circuit of Fig. 3 is generated using only digitized samples from only one sensor channel, the left sensor channel.

65. As discussed above, Romano discloses that "a digitally based drive circuit, shown in dotted lines and formed of latch 388, digital-analog (D/A) converter 390, filter 392 and amplifier 394 could be used in lieu of analog drive circuit 40 shown in Fig. 4." Ex. 1006 at 24:32-36. These components are shown above in Fig. 3.

66. The functions performed by the microprocessor to generate the drive signal are summarized in Romano at 1006 at 24:36-60:

> As discussed in detail below, microprocessor 330, as shown in Fig. 3, calculates the magnitude of a succession of frequency components, using the DFT – specifically using equation 4 above, to locate the frequency at which the flow tubes resonantly vibrate, i.e., that frequency component at which the magnitude of the DFT reaches a peak value. Therefore, once this frequency component is known,

> microprocessor 330 can readily generate a quantized sinusoidal waveform at exactly this frequency. Specifically, once the frequency component is found, microprocessor 330 could easily set the period at which a sine look up table (not shown and which can either be situated internal to or more likely external to the microprocessor) is successively and consecutively indexed, through well known circuitry not shown, to produce a continuous series of multi-bit digital values that represent this waveform. Each of these values would be applied to latch 388 which, in turn, would apply the value to D/A converter 390. This converter would produce an equivalent analog voltage. This analog voltage would then be applied to low pass filter 392 to remove unwanted high frequency noise. The resulting filtered value would then be amplified by amplifier 394 to an appropriate drive level and thereafter routed, via lead 396, to drive coil 180.

I note that this is the same passage of Romano relied on by Dr. Sidman in paragraph 180 of his declaration as support for his assertion that both the left and the right sensor signals are used to generate the drive signal.

67. Nothing in the foregoing description of the digitally based drive circuit discloses the use of both sensor channels to generate the drive signal. In fact, Romano makes clear that only a single sensor signal – the left channel sensor signal – is used to generate the drive signal.

68. The reference to Equation 4 in this passage indicates that only a single sensor signal is used to calculate the DFT. Equation 4, which appears in Ex. 1006 at 12:7-13 gives the magnitude of a digitized signal at a particular frequency. This equation references only a single digitized signal, s(KT), from one of the velocity sensors. Indeed, even when microprocessor uses both the left and right velocity sensor signals for measurement purposes (rather than for generating the drive signal), Romano discloses that the right and left channel signals are input to the DFT routine *separately*:

> After these operations [referring to the resonance frequency determination discussed below] have occurred, mass flow rate measurements begin. ***To determine the mass flow rate***, both sensor signals are ***separately*** transformed form the time domain to the frequency domain again illustratively using the DFT . . . .

Ex. 1006 at 6:29-33 (emphasis added).

69. This understanding that only a single channel is used to calculate the DFT is confirmed by the detailed disclosure of how the microprocessor 330 "calculates the magnitude of a succession of frequency components, using the DFT – specifically using equation 4 above, locate the frequency at which the flow tubes resonantly vibrate, i.e., that frequency component at which the magnitude of the DFT reaches a peak value" starting at col. 26, line 60.

70. This passage discloses that the microprocessor 330 first executes an initialization that involves, among other things, determining the natural frequency at which the flow tubes are vibrating. Ex. 1006 at 26:67-27:3. This natural frequency is the resonance frequency discussed in the passage of Romano at 24:36-60 reproduced above.

71. The initialization routine 600 is discussed in detail at 28:26-30:45. After performing a number of diagnostics, the initialization routine first determines the "fundamental frequency" at which both flow tubes vibrate. Ex. 1006 at 29:13-17. This "fundamental frequency" is yet another name for the resonance frequency discussed in the passage of Romano at 24:36-60 reproduced above.

72. In particular, Romano discloses that ***only the left sensor channel*** is used to determine this resonance frequency:

> To save processing time, a power spectrum is computed at a fairly "coarse" resolution, using the discrete fourier transform, for *one of the velocity waveforms, illustratively that produced by the left velocity sensor*. This operation occurs within block 625 which invokes DFT Routine 700 which, when executed and as discussed in detail shortly in conjunction with FIGS. 7A-7B, *samples one of the velocity waveform*s at a fixed sampling rate and calculates the magnitude (squared--for reasons that will become clearer later) of all the frequency components, from n=1, . . . , N-1 (here N-1 equals the value "63") that comprise the discrete fourier transform of the *waveform*

> *produced by the left velocity sensor*. The coarse search is preferably undertaken with a sampling frequency of 640 Hz which, with "64" samples per measurement interval, provides 32 different frequencies at a resolution (1/NT) of approximately 5 Hz. Once the coarse power spectrum has been computed, execution proceeds, as shown in FIGS. 6A-6B, to block 630 which determines the maximum value within that spectrum and selects the frequency corresponding to that maximum (n.sub.max) as being the initial fundamental frequency at which both flow tubes resonantly vibrate.

Ex. 1006 at 29:17-40 (emphasis added). This description corresponds to Romano's disclosure at col. 24, lines 36-42, that "[a]s discussed in detail below, microprocessor 330 . . . calculates the magnitude of a succession of frequency components, using the DFT . . . to locate the frequency at which the flow tubes resonantly vibrate, i.e., that frequency component at which the magnitude of the DFT reaches a peak value."

73. To aid the Board's understanding of Romano, I will explain how the DFT is used to locate the resonance frequency. Figure 5 below shows one period of a sine wave, sin(x), which begins and ends at zero. The period of the signal is τ in seconds, which is related to its frequency as $f=1/\tau$ in Hz or $\omega=2\pi/\tau$ in rad/s. If the sine wave had any phase, ϕ, added to argument x that was not equal to 0 (or a multiple of π radians), it would start at a value other than zero.

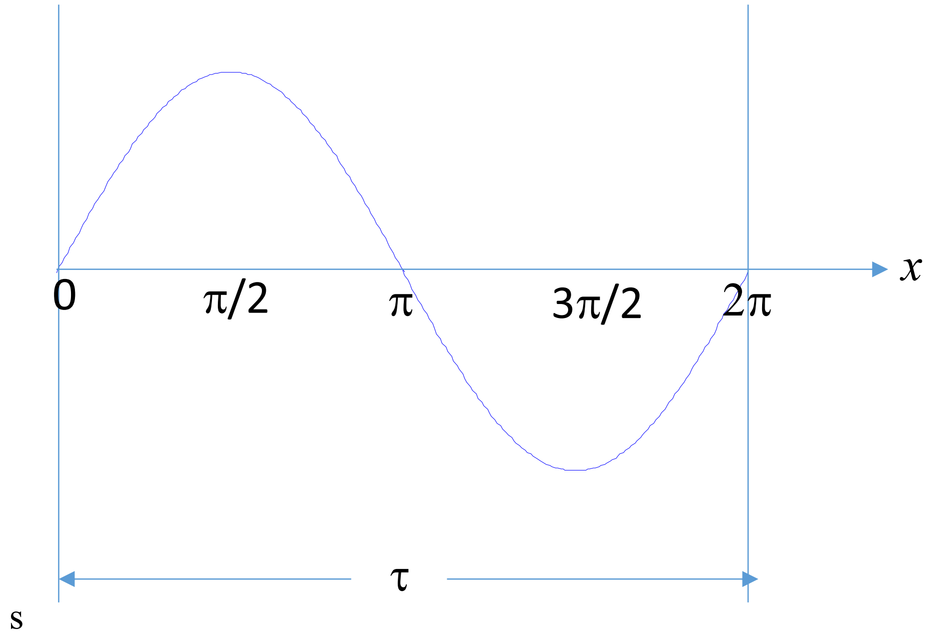


Figure 5. Single cycle or period of a sine wave.

74. The signals produced by Coriolis flow meter sensors are dominated by a single mode. That mode is driven harmonically, producing a sine wave, $s(t)$, plus noise $n(t)$.

$$s(t) = A\sin(\omega + \phi) + n(t) \qquad \text{(a)}$$

75. The noise, $n(t)$, can be from nonlinearities, other system modes, flow noise, electrical noise, etc.

76. Figure 6 shows an example of a sampled sine wave (top) and the magnitude of its discrete Fourier transform, or DFT (bottom). The sine wave has (A=1V, ω=2π×20 rad/s, ϕ=π/4 rad, $n(t)$=0 – see Equation (a)) and is sampled exactly 10× per period. Since ϕ=π/4, the sine wave doesn't start at zero, but rather sin(π/4). It is the same quantity referred to as the "phase with respect to the

signal's own zero crossing" mentioned in the '136 patent (Ex 1001: 18:8-11) patent and in Romano (Ex 1006: at 8:4-8). The magnitude of the DFT of the 200 point time signal (top) can provide frequency information for 100 discrete frequencies (bottom). This is called a "frequency spectrum" or simply a "spectrum." Note that there is a single line at 20 Hz with a magnitude of 1 V, which is the frequency domain representation of the signal. The magnitudes at the other frequencies are approximately zero. When a DFT is computed in the '136 patent or in Romano, the goal is to identify a single line in the spectrum, a single frequency - the resonance frequency.

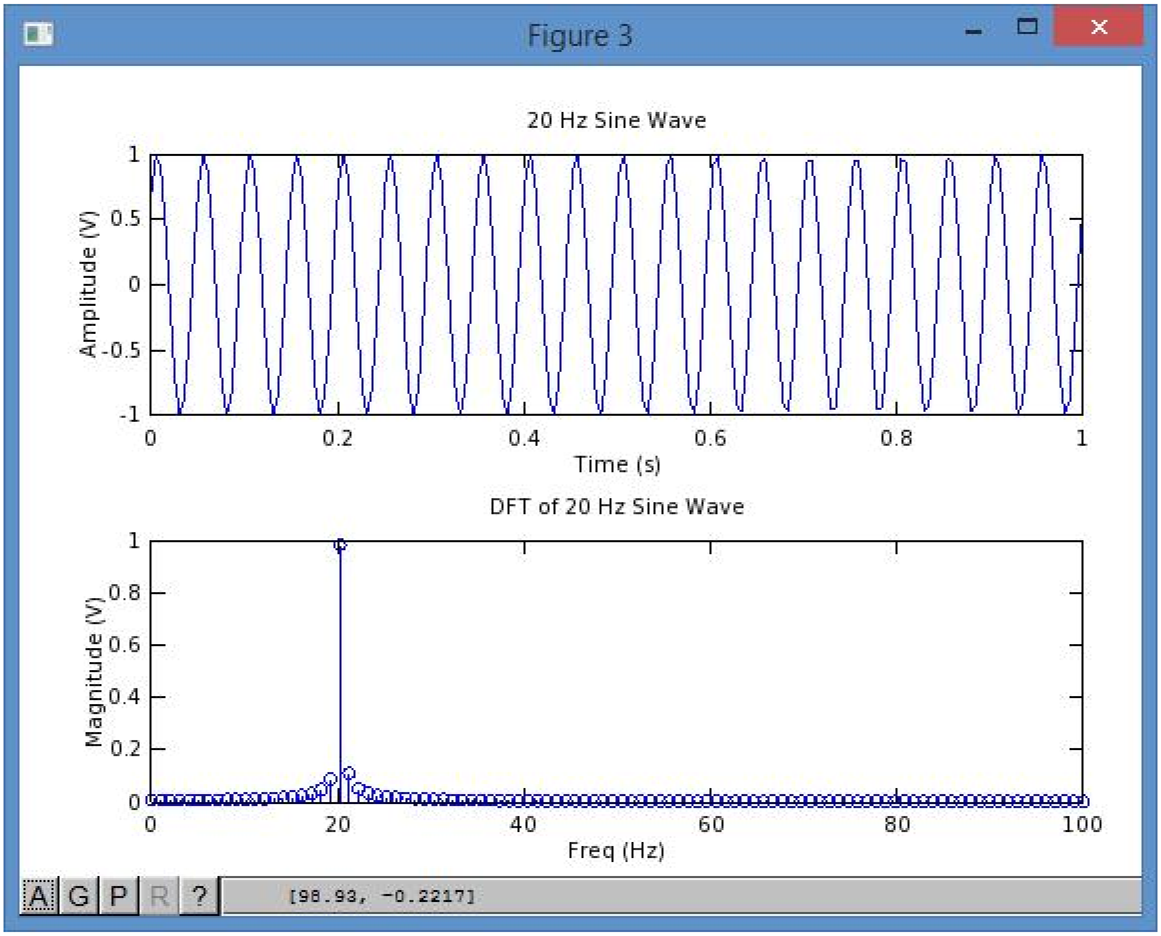


Figure 6. Plot of a sine wave (top) with an amplitude of A=1, and phase of $\phi=\pi/4$, and a frequency of $f=\omega/(2\pi)$=20 Hz, along with the magnitude of its spectrum (bottom) showing energy at only 20 Hz.

77. If we add some random noise to the sine wave, the time signal shows degradation, but the spectrum is relatively unchanged (see Figure 7). It is still dominated by the peak at 20 Hz, which can be identified by the microprocessor 330 as the resonance frequency. This illustrates some of the immunity to noise afforded by performing calculations in the frequency domain.

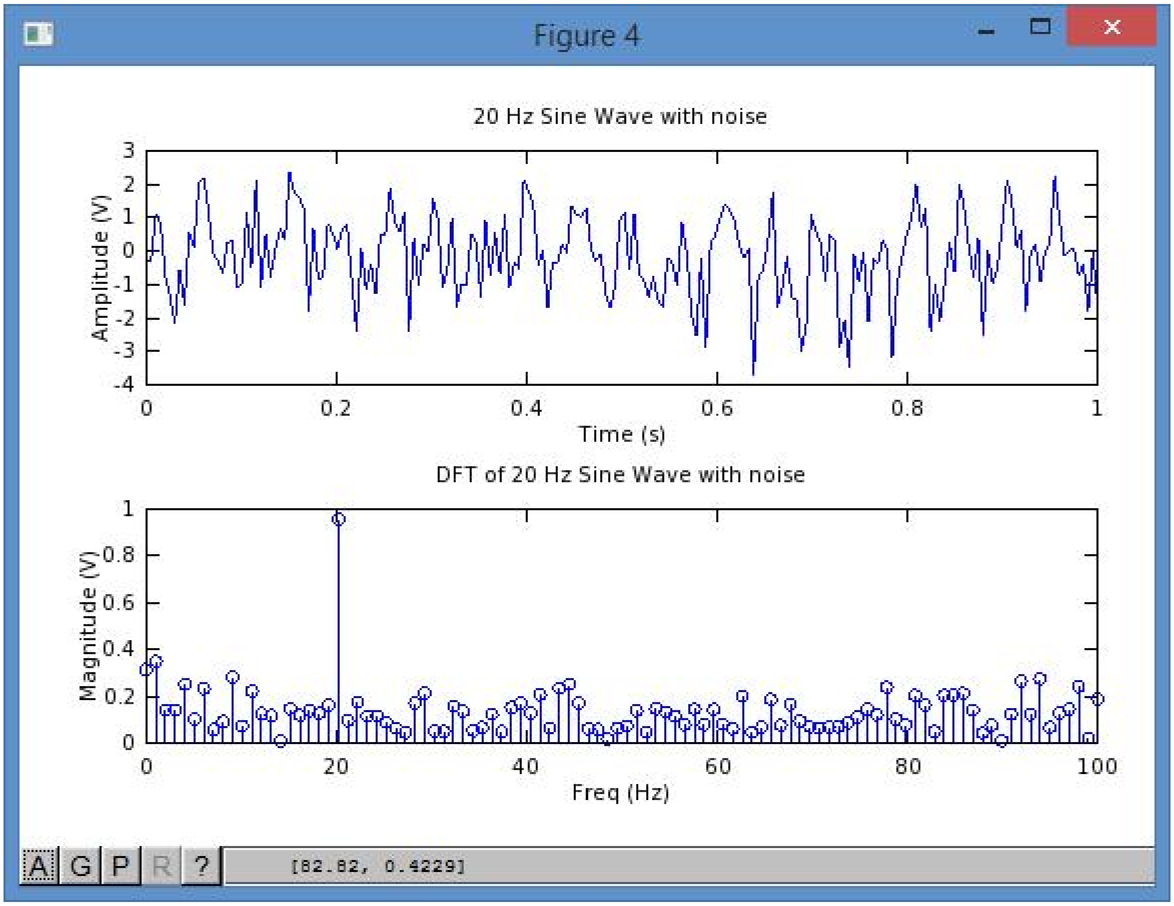


Figure 7. Plot of a sine wave (top) with an amplitude of A=1, phase of $\phi=\pi/4$, a frequency of $f=\omega/(2\pi)$=20 Hz, and random noise, $n(t)$, with a standard deviation of σ = 1V, along with its spectrum (bottom) showing that the energy is still mostly concentrated at 20 Hz, despite the noise obscuring the sine wave in the time domain (top).

78. A linear system responds differently at various frequencies. Figure 8 shows the magnitude of the frequency response function (FRF) for a single mode plant having a resonant frequency at 20 Hz and a viscous damping ratio (system loss) of 1%. This FRF magnitude curve represents the level of the system response in the frequency domain as a 1 V sine wave is varied in frequency from 0-100 Hz. It is defined as the magnitude of the ratio of the Fourier transform of the output

signal divided by the Fourier transform of the input signal. Note that the system has the highest response (approximately 0.3 units) at the resonance frequency, 20 Hz. Since the vertical axis is plotted on logarithmic axes, the ratio between the highest point at 20 Hz and the lowest point at 1 Hz is about 750:1. Although Coriolis flow meters are multimodal systems, Figure 8 approximates the flow meter mode for which it is driven. It is desirable to drive the system on resonance, since a relatively larger response can be obtained for a relatively small amount of input energy. Driving on resonance also permits calculating the density of the flowing fluid. Resonance can be tracked through a self-sustaining positive feedback system or by computing the DFT of the system response to find the resonance, then driving at that frequency, as described for the digital based drive circuit in Romano.

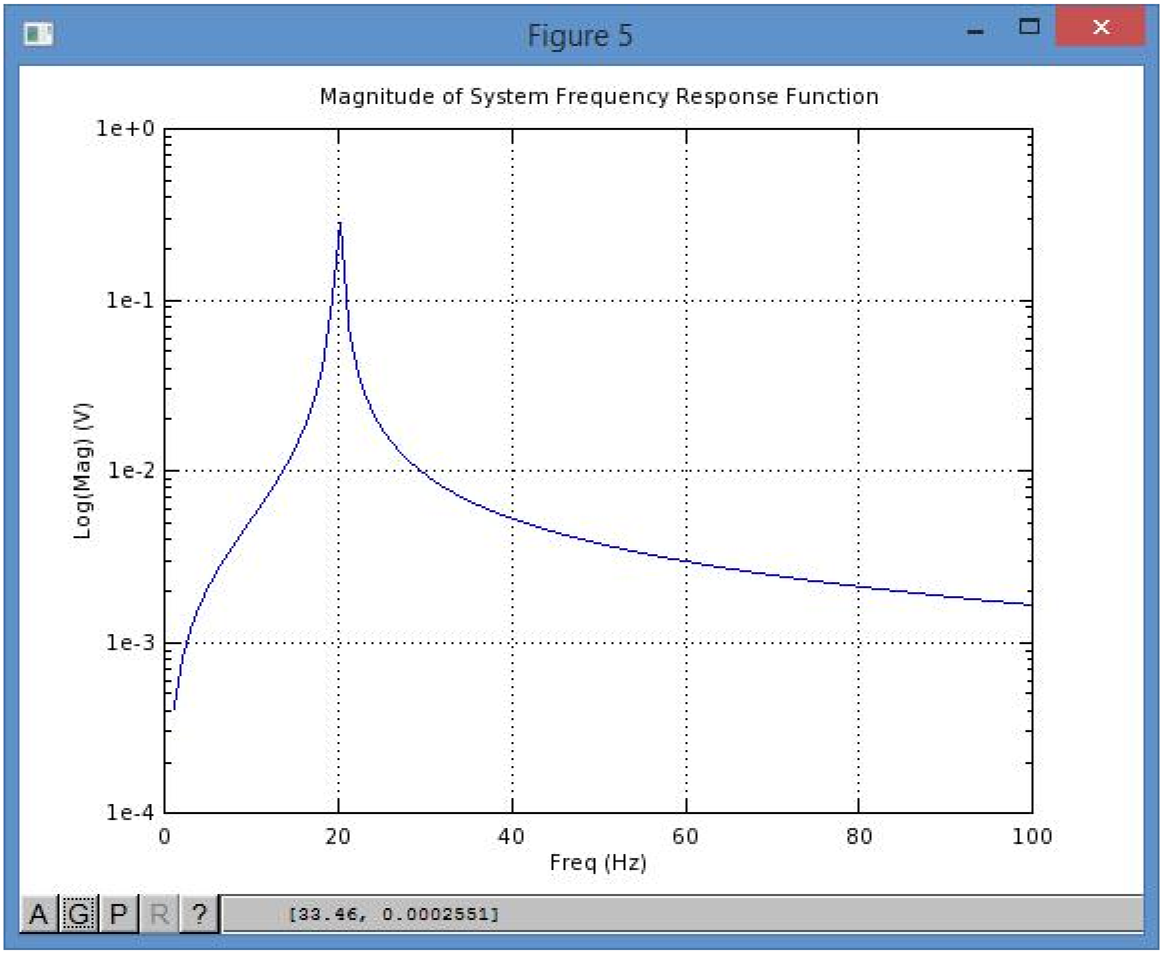


Figure 8. Magnitude of the Frequency Response Function for a single mode plant with a resonant frequency of 20 Hz and 1% viscous damping.

79. This disclosure that only the left sensor channel is used to determine the resonance frequency is confirmed in the detailed discussion of the DFT Routine 700 discussed in Ex. 1006 at 30:46-32:13. This passage discloses that "this routine samples *one of the velocity waveforms* at a fixed sample rate and calculates the magnitude of all frequency components . . . that comprise the discrete Fourier transform of the *waveform produced by the left velocity sensor*. Ex. 1006 at 30:49-54 (emphasis added).

80. Thus, the passage of Romano at 24:32-60 relied on by the Petition and Dr. Sidman as support for the assertion that both sensor channels are used to generate the drive signal is clearly incorrect. The calculation of the DFT to determine the resonance frequency is performed using only a single sensor channel, the left sensor channel, as discussed above. Nothing else in this cited passage disclosing using both sensor channels for generating the drive signal.[1]

[1] I am told that the rules governing this *inter partes* review proceeding preclude both the Petitioner and Dr. Sidman from taking new positions in the Petitioner's Reply. Nonetheless, I have been asked to opine as to whether any need (which neither Dr. Sidman's Declaration nor the Petition identified), to align the phase of the drive signal to the sensor signal would result in the $2\pi/128$ radian phase shift applied to the right channel sensor signals propagating through to the drive signal. In my opinion, it would not. The phase of the drive signal is kept aligned to the sensor signal in Romano's system through the Vernier Search Routine 800 (discussed in Ex. 1006 starting at 32:15) and the Frequency Tracking Routine 1300 (discussed in Ex. 1006 starting at 40:10). Both of these routines use only the left channel sensor signals to generate the drive signal and, in the event that the right channel were to be used in place of the left channel signals, the aforementioned phase shift would not affect the output of either of these routines.

Thus, this section of Romano cited by Petitioner and Dr. Sidman does not support the assertion that Romano discloses using both sensor channels to generate the drive signal. In fact, it proves the opposite – only a single sensor channel is used to generate the drive signal.

81. A second portion of Romano cited by the Petition and Dr. Sidman as support for the proposition that the "right and left channel signals are both used by the microprocessor 330 to generate the drive signal" is the passage at 25:26-30. Petition at 37, citing Ex. 1002 (Sidman Decl.) ¶ 180. This passage of Romano appears in the description of an analog drive circuit 40 shown in Fig. 4 of Romano. Ex. 1006 at 25:21-23. As discussed above, this analog drive circuit 40 is what is replaced by the digitally based drive circuit. Ex. 1006 at 24:32-36. The analog drive circuit 40 uses both the left and the right channel sensors to generate the drive signal. *See* ex. 1006 at Fig. 4 (showing left and right channels signals being input to summer 405). However, as discussed above, the $2\pi/128$ radian phase shift applied to the digitized right channel sensor signals in Fig. 3 is not applied to the analog right channel sensor signals in Fig. 4. I understand that Dr. Sidman admitted this during cross examination. Ex. 2015 (8/7/14 Sidman Tr.) at 81:21-82:4. Thus, Fig. 4 does not disclose that the $2\pi/128$ radian phase shift identified by the Petition and Dr. Sidman propagates through to the drive signal.

82. Although not explained in either the Petition or Dr. Sidman's declaration, I understand that Dr. Sidman testified during cross examination that he believed that the statement in Romano that the digitally based drive circuit discussed could be used in lieu of the analog drive circuit 40, together with his belief that Romano "teaches no alternative" to using both sensor signals to generate the drive signal, was a disclosure that the both sensor signals are used to generate the drive signal. Ex. 2015 (8/7/14 Sidman Tr.) at 82:10-84:4.

83. I disagree with this testimony. Dr. Sidman's assertion that Romano discloses no alternative to using both sensor signals is not sufficient to demonstrate anticipation of claim 36 for at least two reasons. First, prior art systems (both analog and digital) that used only one sensor signal to generate a drive signal were known in the art. For example, the Kalotay patent (Ex. 1008) discloses both an analog circuit (Fig. 3) and a digital circuit (Fig. 4) that generate a drive signal using only the left sensor signal. Ex. 1008 at Fig. 3 and 4; *see also* Ex. 2014 (8/6/14 Sidman Tr.) at 136:5-17 , Ex. 2015 (8/7/14 Sidman Tr.) at 44:11-20. Second, as discussed above, Dr. Sidman's assertion is simply wrong because Romano discloses that the DFT Routine 700 uses only a single sensor channel to generate the drive signal. Accordingly, this second passage of Romano cited by the Petition and Dr. Sidman also does not support the assertion that Romano discloses that both sensor signals are used to generate the drive signal.

84. The third and final passage cited in the Petition and Dr. Sidman's declaration to support the assertion that Romano discloses that both sensor signals are used to generate the drive signal is Romano's Fig. 3. However, during cross examination, Dr. Sidman admitted that Romano did not "restrict his digital implementation [as shown in Fig. 3] in that way." Ex. 2015 (8/7/14 Sidman Tr.) at 89:5-21. I agree with Dr. Sidman to the extent that Romano's Fig. 3 is not restricted to using both sensor signals to generate the drive signal. In fact, nothing in Fig. 3 itself indicates whether or not one or both sensor signals are used to generate the drive signal and, as discussed above, the explanation of Fig. 3 indicates that only the left sensor signal is used to do so. Accordingly, the third passage of Romano cited by the Petition and Dr. Sidman also fails to support the assertion that Romano discloses that both sensor signals are used to generate the drive signal.

85. Even if the right channel signals were to be used in place of the left channel signals to generate the drive signal, the $2\pi/128$ radian phase shift applied to the right sensor channel would not propagate through to the drive signal. The reason for this is explained below.

86. The continuous time Fourier transform, $G(\omega)$, applied to a signal, $s(t)$, can be represented as:

$$. G(\omega) = \frac{1}{\pi}\int_{-\infty}^{\infty} s(t)\exp(-j\omega t)dt = \frac{1}{\pi}\int_{-\infty}^{\infty} s(t)\left[\cos(\omega t) - j\sin(\omega t)\right]dt \qquad \text{(b)}$$

The rightmost portion takes advantage of Euler's identity: ($\exp(j\omega t)$=cost(ωt) +$j$sin(ωt)). Note that the real part comes from the cosine term and the imaginary part from the sine term. The magnitude, M, and phase, ϕ, of the signal can then be computed from the real (Re[]) and imaginary (Im[]) parts of $G(\omega)$ as

$$M = \sqrt{\left(\mathrm{Im}\left[G(\omega)\right]\right)^2 + \left(\mathrm{Re}\left[G(\omega)\right]\right)^2} \qquad \text{(c)}$$

$$\phi = -\arctan\left[\mathrm{Im}\left[G(\omega)\right] / \mathrm{Re}\left[G(\omega)\right]\right] \qquad \text{(d)}$$

87. The algorithm in Figure 13 of Romano provides coherent sampling of the sensor signal (an integer number of samples per period) (Ex. 1006 at 7:8-10). For each channel, exactly 64 points are sampled over one period, $\tau = 2\pi/\omega$, of the signal (*Id*. at 21:68-22:3). The discrete Fourier transform or DFT given by equations (1) and (2) of Romano (repeated below) is computed over a single, N=64 point period.

$$G\left[\frac{n}{NT}\right] = \sum_{K=0}^{K=N-1} s(KT)\; e^{-j2(n\;K)/N} \qquad (1)$$

where:

n is an index value equivalent to the frequency component of interest, i.e. 0, 1, . . . , N−1;

N is the total number of samples that have been taken; and

T is the sampling interval.

The exponential term can be re-written as:

$$e^{-j2\pi(n^{*}K)/N} = \cos\frac{2\pi nK}{N} - j\sin\frac{2\pi nK}{N} \qquad (2)$$

88. In Romano, the magnitude of the DFT is used to find the resonance frequency (at the highest response point). It is given by equation (4) repeated below:

$$\left|G\left[\frac{n'}{NT}\right]\right| = \sqrt{\left(\left[\sum_{K=0}^{K=N-1} s(KT)\cos\frac{2\pi n'K}{N}\right]^2 + \left[\sum_{K=0}^{K=N-1} s(KT)\sin\frac{2\pi n'K}{N}\right]^2\right)} \qquad (4)$$

89. Due to the coherent sampling, the real and imaginary parts of the Fourier transform given in equation (b) at of drive frequency ω are proportional to the Fourier series coefficients, *a* and *b* as:

$$a = \frac{\omega}{\pi}\int_0^{\tau} s(t)\cos(\omega t)dt \qquad \text{(e)}$$

$$b = \frac{\omega}{\pi}\int_0^{\tau} s(t)\sin(\omega t)dt \qquad \text{(f)}$$

90. Coefficients *a* and *b* represent the real and imaginary parts of the signal. It will be next shown that the magnitude of the Fourier transform over once cycle of the signal is the same, irrespective of where in the cycle the integration begins. Using equation (a) and letting the noise, $n(t)$=0, and the phase, ϕ, represent the starting point on the cycle where the signal is sampled, then the Fourier coefficients are computed as

$$a = \frac{\omega}{\pi}\int_0^{\tau} A\sin(\omega t + \phi)\cos(\omega t)dt = A\sin(\phi) \quad \text{(g)}$$

$$b = \frac{\omega}{\pi}\int_0^{\tau} A\sin(\omega t + \phi)\cos(\omega t)dt = A\cos(\phi) \quad \text{(h)}$$

91. The magnitude, *M*, becomes

$$M = \sqrt{a^2 + b^2} = \sqrt{A^2\sin^2(\phi) + A^2\cos^2(\phi)} = A \quad \text{(i)}$$

92. Therefore, the DFT magnitude computation is independent of the signal's phase with respect to its own zero crossing. Accordingly, the 2π/128 radian phase shift mathematically applied by the microprocessor 330 to the right channel signal would have no effect on the drive signal even if the right channel signal were to be used to generate the drive signal.

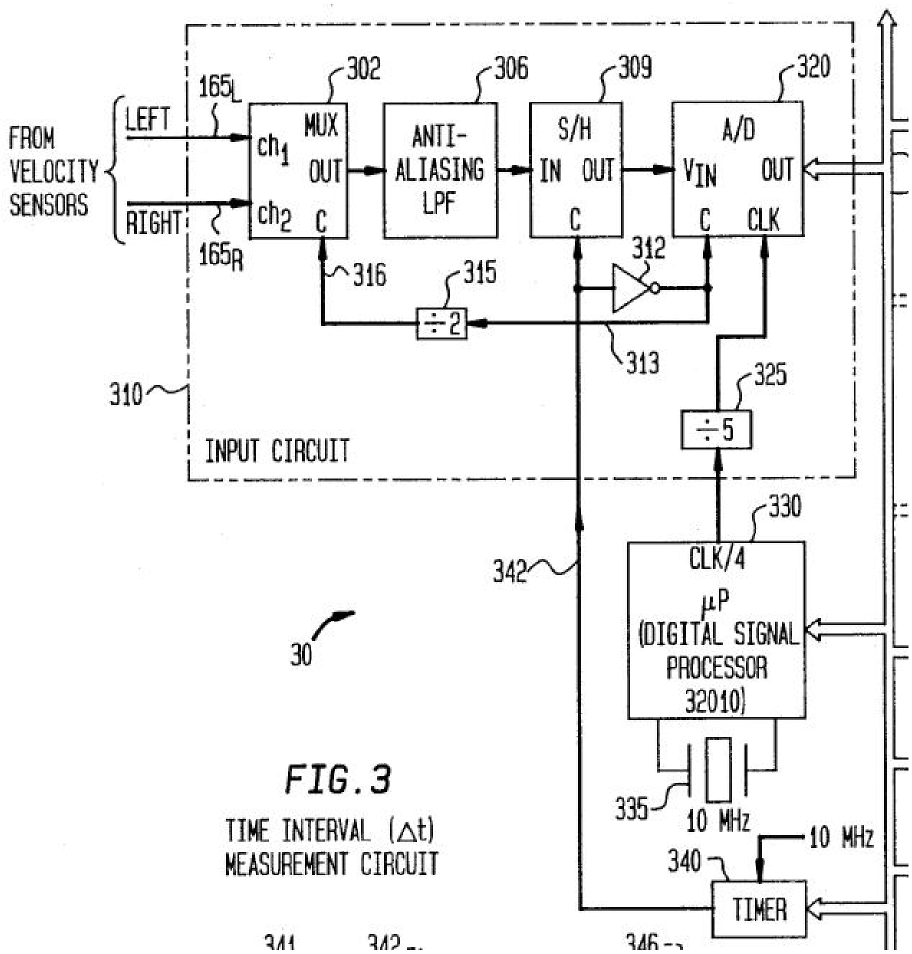
93. For all of the foregoing reasons, the assertion in the Petition and Dr. Sidman's declaration that both sensor signals are used to generate the drive signal is wrong. Because Romano discloses that only one signal is used to generate the drive signal, and because the phase shift applied to the right channel signal (the

only phase shift identified in either the Petition or Dr. Sidman's Declaration) would not propagate through to the drive signal, Romano does not anticipate claim 36.

c. Romano Does Not Compensate For Time Delays Associated With Multiple Components

94. Claim 36 requires adjusting a phase of the drive signal to "compensate for a time delay associated with the sensor and component*s* connected between the sensor and the driver." Ex. 1001 at 62:20-24 (emphasis added). Even if the 2π/128 radian phase shift applied to the right channel sensor signals were to propagate through to the drive signal (which it does not for the reasons discussed above), this phase shift compensates for the delay associated with only a *single component* rather than the multiple *components* required by claim 36. Thus, Romano does not anticipate claim 36 for this second, independent reason.

95. To satisfy this claim element, Dr. Sidman and the Petition rely solely on the disclosure in Romano 22:25-32 that the samples of the right velocity sensor signal are phase shifted by 2π/128 radians. Petition at 37; Ex. 1002 ¶ __. This phase shift occurs in a portion of Romano's system referred to as the time interval measurement circuit 30 shown in Fig. 3, the relevant portion of which is shown below:



Ex. 1006, Fig 3.

96. As shown in this portion of Fig. 3, analog signals from the left and right velocity sensors sensors 160_L and 160_R are input to a multiplexer 302. The multiplexer 302 alternates between sending either the left or the right sensor signal to the anti-aliasing filter 306, the sample and hold circuit 309 and the analog-to-digital (A/D) converter 320. Ex. 1006 at 22:33-67. 128 total samples, 64 on the left channel and 64 on the right channel, are taken for each 360 degree cycle of

flow tube oscillation. *Id.* at 22:10-16. Because the right sensor signal is sampled after the left sensor signal, the right sensor signal always lags the left sensor signal by an amount equal to the time it takes for the multiplexer to switch its output from the left channel to the right channel. This time is exactly equal to one half of a channel sample delay, as directed by timer 340 and divider 315. The time difference between the samples on the right channel and the samples on the left channel is not a signal delay like the types of delays discussed in the ’136 patent (delays due to conversion times and phase responses of signal chain components). Rather, the time difference between the left and right channel signals is exactly one half channel sample period and simply a reflection of multiplexing (302) two signals through a single filter, sample/hold, and analog-to-digital converter. Nonetheless, for the purposes of this *inter partes* review only, I will treat the time difference between these signals as a delay in the sense of the ’136 patent.

97. Since there are 128 total samples for each tube oscillation cycle, and there are 360 degrees = 2π radians in each tube oscillation cycle, this means that the multiplexer switches from the left channel to the right channel at a phase advance of exactly $2\pi/128$ radians. This is precisely the amount by which the right channel signal is phase shifted. Ex. 1006 at 22:25-32.

98. Thus, Romano’s phase shift of the right channel signals accounts for the $2\pi/128$ radian switching delay caused by the multiplexer 302, but nothing else.

There is no disclosure of a phase shift of either the right or left sensor channels for any time delay associated with the anti-aliasing filter 306, the sample and hold circuit 309, the A/D converter 320, the microprocessor 330, or any other component in Romano's device.

99. In fact, it is clear from an examination of the figure above that the left and right channel sensor signals pass through the exact same components and, other than the multiplexer 302, are processed with the exact same time delay by these components. One of ordinary skill in the art would understand that this must be the case because the accuracy of the calculation of the phase difference between the left and right channels (which is used to calculate the mass flow rate) depends on these time delays being identical.

100. The multiplexer 302 would have been understood by one of ordinary skill in the art to be a single component. Single two channel multiplexers were widely available and typically used, both in 1990 when the Romano patent issued and in 1998 at the time of the '136 patent, as stand-alone discrete integrated circuits that would be combined with other components on printed circuit boards. See Ex. 2016 (Philips MUX) and 2017 (Maxim MUX). The reference to a specific microprocessor, the TMS32010 (Ex. 2022 at 21:21-25), indicates that the circuits in Romano are implemented using discrete components, rather than in a single integrated circuit such as an ASIC (application specific integrated circuit). In any

event, one of ordinary skill in the art would still consider the multiplexer 302 to be a single component even if the circuit of Fig. 3 were implemented on a single integrated circuit.

101. Accordingly, the $2\pi/128$ radian phase shift disclosed in Romano compensates for, at most, a single component located between the sensor and the drive, namely the multiplexer 302. Romano therefore does not disclose adjusting the phase of the drive signal to "compensate for a time delay associated with the sensor and components connected between the sensor and the driver" as required by claim 36. Thus, Romano does not anticipate claim 36 for this second, independent reason.

3. Opinions Regarding Claim 21 and Kalotay

a. Summary of Opinion

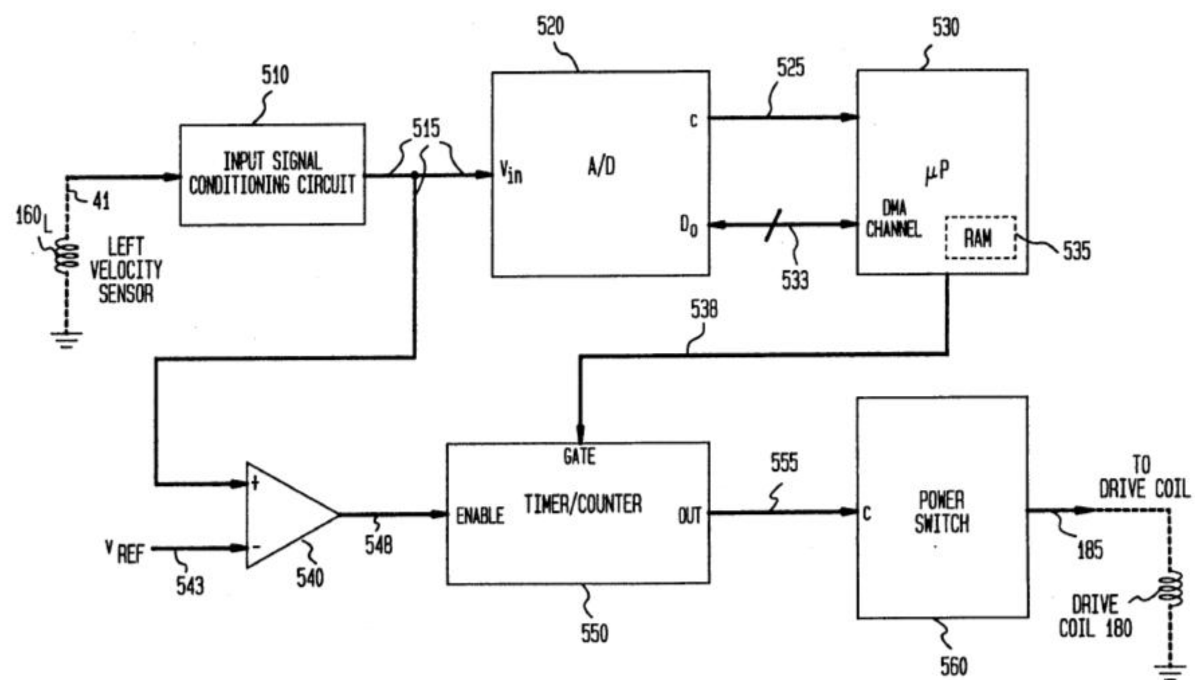
102. It is my opinion that claim 21 of the '136 patent is not obvious over Kalotay (Ex. 1008).

103. Claim 21 recites "wherein the control and measurement system selectively applies a negative gain to the sensor signal." Ex. 1001 at 58:43-45.

104. Kalotay does not disclose applying a negative gain to a *sensor* signal as recited in claim 21. Moreover, doing so would not be obvious to one of ordinary skill in the art because Kalotay teaches away from applying a negative gain from a sensor signal.

b. Kalotay Does Not Disclose Applying a Negative Gain to a Sensor Signal

105. The Petition and Dr. Sidman rely on an embodiment depicted in Fig. 4 of Kalotay, reproduced below, as disclosing this limitation (Petition at 43; Ex. 1002 ¶¶ 185-186):

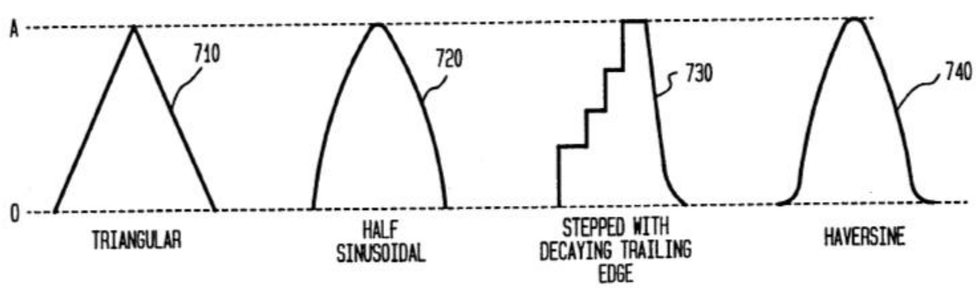


106. In the circuit of Fig. 4, above, a microprocessor 530 receives digitized samples of the signal 160_L output by the left velocity sensor from the A/D converter 520. When the microprocessor detects that the vibratory motion of the flow conduits has decayed to a sufficient value to warrant applying a burst of energy to the drive coil, the microprocessor 530 applies a signal to the gate of the timer/counter 550 via lead 538 to activate a predefined pulse width modulated

output to the drive coil 180. Ex. 1008 at 12: 39-59. This output from the microprocessor is a binary, one bit signal. Ex. 2015 (8/7/14 Sidman Tr.) at 47:8-25. The other input to the timer/counter 550 is also a binary, one bit signal input on line 548 from a comparator 540. *Id.* at 48:14-25. Together, these binary signals determine times at which the predefined, pulse width modulated drive signal will be applied to the drive coil 180.

107. Kalotay discloses an alternative embodiment in which timer/counter that supplies the predefined pulse width modulated signal is replaced by a programmable waveform generation circuit that provides a pulse having the waveforms shown in Fig. 7 reproduced below:

FIG. 7

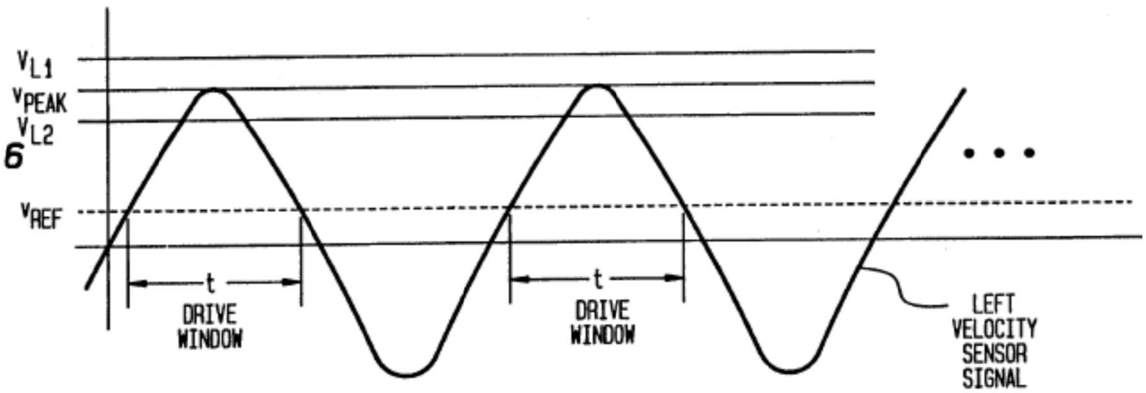


Ex. 1008 at 14:3-23.

108. In either case, the microprocessor ensures that the bursts of energy are designed to actively avoid any drive signal being present during zero crossings of the sensor signals. Specifically, Kalotay discloses, as depicted in Fig. 6

(reproduced below), pre-defined drive windows wherein the bursts of energy (drive signal) could be applied:

FIG. 6



109. Kalotay's systems apply a gain to the drive signal, not the sensor signal as required by claim 21. With respect to the circuit in Fig. 4 of Kalotay above, the inputs to the timer/counter 550 are one bit binary signals that do nothing more than determine the timing at which pulses with predetermined widths and amplitudes will be applied to the drive coil 180. These pulses, being predetermined, are not the result of multiplying the *sensor* signal by a *negative* value as required by claim 21. In this case, it is not correct to refer to a gain applied to the sensor signal, and one of ordinary skill in the art would not do so.

110. Even in embodiments in which Kalotay discloses using pulses with different amplitudes and pulse widths under control of the microprocessor (Ex. 1008 at 13:42-58), Kalotay does not apply a negative gain to the sensor signal. I understand that Dr. Sidman agreed on cross examination that gain is *not* being applied to the sensor signal. Ex. 2015 (8/7/14 Sidman Tr.) at 58:7-59:22. This is

also true when the alternative predefined waveforms of Fig. 7 are used in place of a pulse-width modulated signal.

111. For the sake of completeness, I note that Fig. 3 of Kalotay is a prior art circuit (Ex. 1008 at 5:28-20) that does not involve the use of any negative gain and therefore is not relevant to claim 21 of the '136 patent.

112. Thus, for the reasons discussed above, Kalotay does not disclose applying a negative gain to the sensor signal as required by claim 21.

c. Kalotay Does Not Render Obvious Applying a Negative Gain to a Sensor Signal

113. It would not be obvious to do apply a negative gain to a sensor signal because Kalotay teaches away from such an embodiment. Kalotay criticizes prior art system did not provide the ability to apply precisely controlled energy to the drive coil at any one instant in time at 2:55-68, and explains at 4:63-5:17 that the ability to apply precisely controlled pulses of energy allows Kalotay's system to react to changes in flow density. One of ordinary skill in the art would understand that these changes include changes that would occur in the presence of the onset of two stage flow. One of ordinary skill in the art would further understand that it is necessary for the system to have the ability to quickly and accurately add a desired amount of energy to the conduits in order to maintain the desired resonance oscillation during such periods, and that the noise that would be present in the

sensor signal during periods would have an adverse effect if the drive signal were generated by applying a gain (whether positive or negative) to the sensor signal as required by claim 21. In other words, the noise that would be present in the sensor signal during such periods would severely hamper the ability of Kalotay's system to apply the desired precise amount of energy to the Coriolis meter conduits, because the amount of energy applied would be a function of both the shape of the sensor signal and the gain applied to it.

114. Thus, claim 21 would not be obvious to one of ordinary skill in the art based on Kalotay because the resulting system would be unable to accurately measure two phase flow whereas Kalotay asserts that applying a gain to drive signal pulses (rather than to the sensor signal) provides such ability.

115. In my opinion, it would therefore not be obvious to one of ordinary skill in the art to modify Kalotay to apply a negative gain to a sensor signal as required by claim 21 of the '136 patent.

IV. CONCLUSION

For the reasons discussed above, Patent Owner has not demonstrated that claim 36 of the '136 patent is anticipated by Romano, or that claim 21 of the '136 patent is obvious over Kalotay.

APPENDIX A

Curriculum Vitae

Dr. Jeffrey S. Vipperman
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July 26, 2014

Education:

1997	Ph.D., Mechanical Engineering	Duke University
1992	M.S., Mechanical Engineering	Virginia Tech
1990	B.S., Mechanical Engineering	Virginia Tech

Professional Experience:

6/14-present	Professor of Mechanical Engineering, University of Pittsburgh, Pittsburgh, PA
6/14-Present	Professor of BioEngineering, University of Pittsburgh, Pittsburgh, PA
1/08-8/11	Graduate Director (Mechanical Engineering), University of Pittsburgh, Pittsburgh, PA
4/05-6/14	Associate Professor of Mechanical Engineering, University of Pittsburgh, Pittsburgh, PA
4/05-6/14	Associate Professor of BioEngineering, University of Pittsburgh, Pittsburgh, PA
1/99-4/05	Assistant Professor of Mechanical Engineering, University of Pittsburgh, Pittsburgh, PA
6/00-6/02	Mechanical Engineer, NIOSH, Pittsburgh Research Laboratory
9/97-12/98	Assistant Professor, University of Maine, Orono, ME
2/97-8/97	Assistant Research Professor, Duke University, Durham, NC
8/93-2/97	Research Assistant, Duke University, Durham, NC
8/93-2/97	Systems Administrator, Duke University, Durham, NC
1993-1997	Vice President and Senior Research Scientist, Adaptive Technologies, Inc. Blacksburg, VA
7/92-7/93	Research Associate, Virginia Polytechnic Institute and State University, Blacksburg, VA
8/90-6/92	Graduate Project Assistant, Virginia Polytechnic Institute and State University, Blacksburg, VA
1/90-8/90	Undergraduate Researcher, Virginia Polytechnic Institute and State University and Bristol Compressors, Blacksburg, VA
5/89-8/90	Development Engineering Assistant, Ingersoll-Rand Corporation, Roanoke, VA

Consulting:

2014	Invensys / DLA Piper Global Law Firm
2013-14	Apple Computer / Wilmer Cutler Pickering Hale and Dorr (WilmerHale)
2013-14	Covidien / DLA Piper, Global Law Firm
2011-2012	Technical Analysis and Services, International

2011-2012	Mosebach Manufacturing, Inc.
2011-2012	MIRATECH Corporation
2008	Siemens Government Services
2007-2008	Thompson, Coburn and FagelHaber LLC
2007-2008,11,12	Westinghouse Electric Company
2004	National Institute of Occupational Safety and Health
2003-2008	BrashearLP
2001-2005	H. H. Reich Engineers
2000	SigmaTech
2000, 2001	Psychology Software Tools
1999	NASA Langley Research Center
1998	Nikola Engineering
1998	Duke University
1997	Sandia National Laboratory
1995	BSG Laboratories
1994	Centrair Corporation

Honors and Awards:

2014	Association for Iron and Steel Rolls Technology Best Paper Award
2011	Visiting Committee Educator Award, MEMS Department
2011	University of Pittsburgh Innovator Award
2007	Elected Fellow of ASME
2006	School of Engineering Beitle-Veltri Memorial Teaching Award
2005	Engineering Faculty Honor Roll
2003	Letter of commendation from the Chancellor of the University, for chairing ASME-Pittsburgh
2001	Who's Who in Engineering, Pittsburgh Business Times
2000	Letter of commendation from the Vice Chancellor of Student Affairs for Positively Impacting Student
1999-2001	Leighton E. and Mary N. Orr Faculty Fellowship, Univ. of Pittsburgh,
1992	Paul Torgersen Research Excellence Award, Virginia Tech: Voted best Master of Science project for the year.
1991	Student Paper Award, Acoustical Society of America: Voted second best student paper in structural acoustics for the conference.
1989	Frank O'Bell Academic Scholarship
1989	Lucille Seay Academic Scholarship

Published Journal Articles:

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11. El-Kurdi, Mohammed. S., Jeffrey S. Vipperman, and David A. Vorp, "Design and Subspace System Identification of an *Ex vivo* Vascular Perfusion System," Journal of Biomedical Engineering, **131**, 8pp., April 2009.
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3. Bernstein, Dennis, Robert Clark, Jeffrey Vipperman, and Ravinder Venugopal "Active Control of Vibration, Noise, and Structural-Acoustic Interaction", Short Course presented at the American Controls Conference, Philadelphia, PA, June 22-23, 1998.

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4. K.V. Redkin, J.S.Vipperman, C.Hrizo (WHEMCO), R.Schleiden (United Rolls), C.I.Garcia, "Microstructural Optimization and Enhanced Performance of HSS Work Rolls by Non-Conventional Heat Treatment", Materials Science and Technology 2013 Conference and Exhibition, October 2013, Montreal, Quebec, Canada.
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14. Zink, Florian, "Influence of the Thermal Properties of the Driving Components on the Performance of a Thermoacoustic Engine," IMECE2009-11325, Proceedings of ASME IMECE-09, November 13-19, 2009, Lake Buena Vista, FL.
15. Brian A. Bucci, Daniel G. Cole, Jeffrey S. Vipperman, Stephen J. Ludwick. "Friction modeling of linear rolling element bearings in high precision linear stages." Proceedings of ASPE, October 5-9, 2009 Monterey, California.
16. Zink, Florian, J.S. Vipperman, and L.A. Schaefer, "Heat Transfer Analysis in Thermoacoustic Regenerators Using CFD Simulation," ASME 2009 Heat Transfer Summer Conference, San Francisco, CA, July 19–23, 2009.
17. Zink, Florian, J.S. Vipperman, and L.A. Schaefer, "Advancing Thermoacoustics Through CFD Simulation Using Fluent," ASME IMECE 2008 Conference, IMECE2008-66510 pp. 101-110, Boston, MA, October 31–November 6, 2008.
18. Bucci, Brian A. and J.S. Vipperman, "An Investigation of the Characteristics of a Bayesian Military Impulse Noise Classifier," Proceedings of NCAD2008, Paper NCAD2008-73046, Dearborn Michigan, July 28-30, 2008.
19. Li, Deyu, J.S. Vipperman, Li Cheng, "Noise Control in a Small Enclosure Using T-Shaped Acoustic Resonators," Proceedings of NCAD2008, Paper NCAD2008-73034, Dearborn Michigan, July 28-30, 2008.
20. DeJohn, David and J.S. Vipperman, "Development and Control of "Stiff Drivers" for Thermoacoustic Refrigeration," IMECE2007-41586, ASME IMECE-07 Conference, Nov 11-15, 2007, Seattle, Washington.
21. Bucci, Brian, and J. S. Vipperman, "Bayesian Military Impulse Noise Classifier," IMECE2007-41700, ASME IMECE-07 Conference, Nov 11-15, 2007, Seattle, Washington.
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23. Bucci, Brian, and J. S. Vipperman, "Artificial Neural Network Military Impulse Noise Classifier," ASME IMECE-06, Nov 5-10, Chicago, IL.
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Structures, Structural Dynamics, and Materials Conference, St. Louis, MO, April 12-15, 1999, pp. 3115-3122.

44. Cox, David, Gary Gibbs, Robert Clark, and Jeff Vipperman, " Experimental Robust Control of Structural Acoustic Radiation," Paper #98-2089, AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Long Beach, CA, April 20-24, 1998
45. Vipperman, J. S., R. L. Clark, M. D. Conner, and E. H. Dowell, "Investigation of the Experimental Active Control of a Typical Section Airfoil With a Trailing Edge Flap," Paper AIAA-97-1078. AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference. Kissimmee, FL, April 7-10, 1997.
46. Vipperman, J. S. and R. L. Clark, "Complex Adaptive Compensation of Nonlinear Piezoelectric Sensoriactuators," Paper AIAA-96-1266. Presented at AIAA/ASME Adaptive Structures Forum. Salt Lake City, Utah, April 18-19, 1996, pp. 1-11.
47. Vipperman, J. S. and R. L. Clark, "Hybrid Analog and Digital Adaptive Compensation of Piezoelectric Sensoriactuators," Paper AIAA-95-1098-CP. Presented at AIAA/ASME Adaptive Structures Forum. New Orleans, LA, April 13-14, 1995.

Non-refereed Proceedings:

1. Shan, D, C. Wang, AR Wood, JS Vipperman, "The Biomechanical Predictino of Blast-Induced Traumatic Brain Injury Using the Finite Element Method," The 17th National Congress on Theoretical and Applied Mechanics, June 15-20, 2014, Michigan State University, East Lansing, MI.
2. Xie, X., S. Li, C. Wang, JS Vipperman, "Replicating the Friedlander Wave from a One-Dimensional Gas-Driven Shock Tube for the Study of Blast-Induced Traumatic Brain Injury," The 17th National Congress on Theoretical and Applied Mechanics, June 15-20, 2014, Michigan State University, East Lansing, MI.
3. Vipperman, J.S., "What's in a name? Putting standard terminology to use for you," Acoustics Today, July 2007.
4. Vipperman, J.S., M.M Prince, A.M. Flamm, "Analysis of Impact Noise in a manufacturing setting in the evaluation of noise-induced hearing loss: Issues of Sampling and Instrumentation," (Invited Talk) NIOSH/NHCA Impulsive Noise: A NORA Hearing Loss Team Best Practice Workshop, Cincinnati, OH, May 8-9, 2003.
5. Vipperman, J.S., D. Li, I. V. Avdeev, S. A. Lane, "Characterization and Control of Sound Radiation in a Complex Fairing Structure," InterNoise-01 Conference, (Invited Paper), The Hague, Netherlands, August 27-31, 2001, pp. 2429-2435.
6. Bauer, E.R., D.J. Podobinski, E.R. Reeves, J.S. Vipperman, "Noise Exposure in Longwall Mining and Engineering Controls Research," Longwall USA Conference, June 13-15, 2001, Pittsburgh, PA, pp. 51-69.
7. Vipperman, J.S., Eric R. Bauer, Ellsworth R. Spencer, "Noise Survey and Control in a Coal Preparation Plant," ASME IMECE 2000, (unpublished proceedings), Orlando, FL Nov. 5-10, 2000.
8. Vipperman, Jeffrey S., "Micro-acoustic source arrays," INCE Active '99, Ft. Lauderdale, FL, Dec. 2-4, 1999, pp. 1215-1224.
9. Vipperman, J. S. and R. L. Clark, "Applications of the Adaptive Piezoelectric Sensoriactuator," NOISE-CON 97, State College, PA, June 15-17, 1997.
10. Vipperman, J. S., R. L. Clark, M. D. Conner, and E. H. Dowell, "Active Control of a Typical Section Using an Articulated Flap," Eleventh VPI&SU Symposium on Structural Dynamics and Control, Blacksburg, VA, May 12-14, 1997.
11. Vipperman, J. S. and R. L. Clark, Article on Duke University Adaptive Sensoriactuator work, *Active Sound & Vibration Control News,* **3**(4), April, 1996.
12. Vipperman, J. S., and R. A. Burdisso, "Adaptive Control of Nonminimum-Phase Structural Systems," Proceedings of the *Second International Conference on Intelligent Materials*, Williamsburg, VA, 1994.
13. Hamdi, M. A., S. Dedieu, P. R. Wagstaff, C. Chassaignon, G. Leyrat, and J. S. Vipperman, "Optimization of Control Force Input Positions to Reduce Radiated Noise of Vibrating

Structures," Proceedings of the Second Conference on *Recent Advances in Active Control of Sound and Vibration*, Blacksburg, VA. , 1993.

14. Sumali, Hartono, H. H. Cudney, and J. S. Vipperman, "Vibration Control of Cylinders Using Piezoelectric Sensors and Actuators," Proceedings of ADPA/AIAA/ASME/SPIE *An International Symposium & Exhibition on Active Materials & Adaptive Structures.,* 1991.

Presentations Without Proceedings:

1. J.S. Vipperman, Snyderman, CA, Ryan, TS, (invited) "SoundSentinnel," Product pitch to Pitt/CMU KIN Lifesciences Advisory Panel, March 31, 2014, CMU Pittsburgh, PA.
2. J. S. Vipperman, "Acoustic Metamaterials and Advanced Manufacturing,", (Invited Presentation) Feb 25, 2014
3. J.S. Vipperman, WW Clark, D Lambeth, MA Clark, PJ Schimoler, "Active Combustion Throttle Valve and Actuator," (invited) Pitt/CMU Energy Materials Technology Expert Committee Technology Review, Oct. 25, 2013, University of Pittsburgh, Pittsburgh, PA.
4. K.V. Redkin, S. Rekhi (PANalytical), J.S. Vipperman, C.I. Garcia, "In-situ High Temperature XRD Studies of Carbides-Matrix Dissolution-Decomposition Behavior of As-Cast HSS Work Roll Material During Annealing", DUPAN, X-Ray Powder Diffraction Symposium and Workshop, Duquesne University, May 22-24, 2013
5. K.V. Redkin, B.V.Balakin (University of Bergen, Norway), C.Hrizo (WHEMCO), J.S.Vipperman, C.I.Garcia, 3D CFD Simulation of Horizontal Spin Casting of High Speed Steel Roll, 66th Annual Meeting of the APS Division of Fluid Dynamics (DFD13), Vol.58, No.18, David L. Lawrence Convention Center , November 2013, Pittsburgh, USA
6. Patrick J. Schimoler, Jeffrey S. Vipperman, and Mark Carl Miller, "An Itereative Learning Controller for an Elbow Simulator to Maintain Flexion Angle During Supination," American Society of Biomechanics 36th Conference, Aug. 15-18, 2012, Gainesville, FL.
7. Vipperman, J.S., "Active Control and Adaptive Filtering With Applications to Active Structural Acoustic Control," (Invited Presentation), Xi'An Jiaotong University, May 15, 2012. Xi'An, China.
8. Vipperman, J.S., "Thermoacoustic Refrigeration," (Invited Presentation), South China University of Technology, May 9, 2012. Guangzhou, China.
9. Vipperman, J.S., "Structural Acoustics and Active Structural Acoustic Control (ASAC)," (Invited Presentation), South China University of Technology, May 8, 2012. Guangzhou, China.
10. Vipperman, J.S., "Military Noise Classifier," (Invited Presentation), Automated Aircraft Noise Detection and Analysis Workshop, Feb 2-3, 2011, Boston, MA.
11. Nykaza, Ed, J.A. Allanach, J.S. Vipperman, "Improved Military Noise Monitoring System," ESTCP IPR Meeting, Feb 23, 2012.
12. Vipperman, J.S., "Active Combustion Throttle," Science2010 showcase, Pittsburgh, PA, 10/6/10.
13. Allanach, Jeffrey, Justin Borodinsky, Jeffrey Vipperman M. Rhudy, "Improved System for Detection, Localization, and Classification of Military Impulse Noise," 159th Meeting of Acoust. Soc. of Am., 19-23 April, 2010, Baltimore, Md.
14. Vipperman, J.S., M. Rhudy, B. Bucci, J. Allanach, B. Abraham, J. Brodinsky, "An Integrated Military Impulse Noise Classifier," Partners in Environmental Technology Technical Symposium and Workshop, Washington DC, Dec 1-3, 2009.
15. Rhudy, Mathew A, B. Bucci, and J.S. Vipperman "Microphone Array Techniques Using Cross-Correlations," 158th Meeting of the Acoustical Society of America, 26-30 October 2009, San Antonio, TX.
16. Vipperman, J.S., "Control of Advanced Energy Systems," (Invited Talk) Science 2009 Conference, Pittsburgh, PA, 10/15/09.
17. Schimoler, P., L. Kuxhaus, J.S. Vipperman, M.C. Miller, "Robotic Controller Design for an Elbow Simulator," BMES 2009, Oct 7-10, 2009.
18. Vipperman, J.S., B.A. Bucci, M. Rhudy, "Characterization of a Bayesian Classifier to Identify Military Impulse Noise, Partners in Environmental Technology Technical Symposium and Workshop, Washington DC, Dec 2-4, 2008.

19. Vipperman, J.S. and B. A. Bucci, "An image processing based neural network method of waveform classification," 156th Meeting of the Acoustical Society of America, Miami, FL, Nov 10-14, 2008 (abstract published in JASA, **124**, p. 2597, 2008).
20. Zink, Florian, J.S. Vipperman, and L.A. Schaefer, "Potential Impact and Uses of Thermoacoustic Refrigeration," AASHE 2008 Conference, Raleigh, NC, Nov. 9-11, 2008.
21. Kuxhaus L, Thomines F, Flamm A.M., Schimoler PJ, Brogdon ML, Vipperman JS, DeMeo PJ, Miller MC. "Measurement of elbow medial ulnar collateral ligament strain: choice of reference length reduces interspecimen variability." ASB Conference, Ann Arbor, MI; August 2008.
22. Brogdon ML, Kuxhaus L, DeMeo PJ, Schimoler PJ, Flamm A.M., Vipperman JS, Miller MC. "Physiologic length of the UCL: at what flexion angle do the bands of the anterior bundle have zero strain?" ICMMB Conference, Pittsburgh, PA; July 2008.
23. Schimoler PJ, Vipperman JS, Kuxhaus L, Budny DD, Flamm AM, Miller MC. "Accuracy and precision of a control system for an elbow joint simulator." Accepted to the 2008 ASME Summer Bioengineering Conference, Marco Island, FL June 25-29, 2008.
24. Miller MC, Thomines F, Kuxhaus L, Flamm AM, Schimoler PJ, Vipperman JS, DeMeo PJ. "Tensile strain measurement of the bands of the medial ulnar collateral ligament." 2008 ORS annual meeting, San Francisco, CA, March 2-5, 2008.
25. Bucci, B. A., J.S. Vipperman, "Bayesian Classifiers to Identify Military Impulse Noise," Partners in Environmental Technology Technical Symposium and Workshop, Washington DC, Dec 4-6, 2007.
26. Bucci, B. A., J.S. Vipperman, "Artificial Neural Network Classifiers to Identify Military Impulse Noise," Partners in Environmental Technology Technical Symposium and Workshop, Washington DC, Dec 4-6, 2007.
27. Kuxhaus L, Schimoler P, Flamm AM, Vipperman JS, Baratz ME, Miller MC. "Moment arm measurement to validate a closed-loop feedback-controlled elbow joint simulator." ASB 2007 Conference, Stanford, CA, Aug 22-26, 2007.
28. Schimoler P, Vipperman JS, Kuxhaus L, Budny DD, Flamm AM, Baratz ME, Miller MC. "Switching control to actuate elbow motion." ASB 2007 Conference, Stanford, CA, Aug 22-26, 2007.
29. Kuxhaus, L., PJ. Schimoler, JS Vipperman, AM Flamm, D Budny, ME. Baratz , P J. DeMeo, MC Miller , "Measuring Moment Arms Using Closed-loop Force Control With an Elbow Simulator," Paper SBC2007-176513, Proceedings of the ASME 2007 Summer Bioengineering Conference (SBC2007), June 20-24, 2007, Keystone Resort & Conference Center, Keystone, Colorado, USA.
30. Kuxhaus L, Schimoler PJ, Vipperman JS, Baratz ME, Miller MC. "Changes in camera visibility affect measured marker motion." ASME Summer Bioengineering Conference, Keystone, CO; , June 20-24, 2007, Keystone Resort & Conference Center, Keystone, Colorado, USA.
31. Bucci, B. A. and J. S. Vipperman, "Comparison Artificial Neural Network Structures to Identify Military Impulse Noise," 153rd meeting of the Acoust. Soc. of Am., Salt Lake City, UT, June 4-8, 2007
32. Kuxhaus, L., PJ Schimoler, JS Vipperman, MC Miller, "Closed-loop Control Measurement of Moment Arms During Pronation-Supination in an Elbow Simulator," Northeast American Society of Biomechanics Conference, College Park, Md., March 30-31, 2007.
33. Vipperman, J.S. and W. J. Murphy, "Design of linear time-domain filters for hearing protector modeling," 152nd meeting of the Acoust. Soc. of Am., Nov 27-Dec 1, 2006, Honolulu, HI.
34. Jeffrey S. Vipperman, "Tutorial on Adaptive Filtering with Applications to Active Control," (invited lecture) ASME IMECE-06, Nov 5-10, Chicago, IL.
35. El-Kurdi MS, Vipperman JS, Vorp DA, 2006, "Subspace System Identification of an Ex Vivo Vascular Perfusion System" BMES: Biomedical Engineering Society Annual Conference, Chicago, IL, October 2006.
36. El-Kurdi MS, Vipperman JS, Vorp DA, 2006, "PID control of an Ex Vivo Vascular Perfusion System" BMES: Biomedical Engineering Society Annual Conference, Chicago, IL, October 2006.
37. Bucci, Brian A. and J.S. Vipperman, "Development of Artificial Neural Network Classifier to Identify Military Impulse Noise," 151st meeting of Acoustical Soc. of Am., Providence, RI, June 5-9, 2006.

38. Vipperman, J.S., (invited) "Trends in Controls Research Relevant To Modern Power Plant Systems," Plant Process Control Workshop, National Energy Technology Laboratory, Pittsburgh, PA, 03/22/06.
39. Vipperman, J.S. and Brian Bucci, "Development of a Real-Time Military Noise Monitor," SERDP/ESTCP Partners in Environmental Technology Symposium and Workshop, Washington, DC, November 28-30, 2005.
40. Kuxhaus, Laurel, J. S. Vipperman, Mark E. Barratz, Joshua P. Magnussen, and M.C. Miller, "Reproducing Physiologic Moment Arms With an Elbow Simulator," 20th meeting of the American Society of Biomechanics, Cleveland, OH, July 31-August 5, 2005.
41. Smith, Adam K and J. S. Vipperman, "Adaptive Multi-modal Active Noise Control," 149th Meeting of the Acoustical Soc. of Am., Vancouver, BC Canada, May 16-20, 2005.
42. Vipperman, J. S., "Development of Metrics to Identify Military Impulse Noise," 149th Meeting of the Acoustical Soc. of Am., Vancouver, BC Canada, May 16-20, 2005, also *JASA* **117**, p. 2448.
43. Vipperman, J. S. (Invited Panelist) on the "Open Forum on Acoustics," IMECE2003-55666, ASME IMECE 2004, IMECE2003-55666, Anaheim, CA, November 13-19, 2004.
44. Vipperman, J.S. "Noise Sampling and Analysis Issues for Impact/Impulse Noise for Predicting Noise Induced Hearing Loss," (Invited) lecture given to the Communication Sciences and Disorders Department, School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, PA, October 13, 2004.
45. Vipperman, J. S., "Active Noise Control Using Phase-Compensated, Damped Resonant Filters: Toward an Active Helmholtz Resonator," and "Additional Vibro-acoustics Research Projects in the Sound, Systems, and Structures Laboratory," NASA-Langley Research Center, August 20, 2004.
46. Li, Deyu, and J. S. Vipperman, "Theoretical Investigation of Noise Transmission Into a Finite Cylinder," 147th Meeting of ASA, New York, NY, May 27, 2004.
47. Vipperman, J. S. (Invited Panelist) on the "Future of Active Noise Control," IMECE2003-55666, ASME IMECE 2003, Washington, DC, November 15-21, 2003.
48. Vipperman, J.S., "Active Noise Control Technology," (Invited Talk) State of the Art Concepts in Noise and Hearing Loss Conference, Pacific-Northwest Section of the American Industrial Hygiene Association, Seattle, Washington, October 15, 2003.
49. Li, Deyu, and J. S. Vipperman, "Design and Resonant Frequency Calculation for Long T-Shaped Acoustic Resonators" 146th Meeting of ASA, Austin, TX, November 10-14, 2003.
50. Li, Deyu and J. S. Vipperman, "Noise Control for a ChamberCore Composite Structure Using T-Shaped Acoustic Resonators" 146th Meeting of ASA, Austin, TX, November 10-14, 2003.
51. Vipperman, J. S. M.M. Prince, A.M. Flamm, "Analysis of Impact/Impulse Noise for Predicting NIHL," *JASA* 115, pp. 2196, (Abstract only), 145th Meeting of ASA, Nashville, TN, April 28-May 2, 2003.
52. M.M. Prince, J. S. Vipperman, "Noise Sampling Issues for Impact/Impulse Noise Surveys," 145th Meeting of ASA, Nashville, TN, April 28-May 2, 2003.
53. J. B. Bisnette, J. S. Vipperman, D. B. Budny, "Active Noise Control Using Damped Resonant Filters," 145th Meeting of ASA, Nashville, TN, April 28-May 2, 2003.
54. Vipperman, J. S., "Microvalve Design for the Control of Polymer Electrolyte Fuel Cell Systems,"Given to the Swanson Center for Micro- and Nano- Systems, Pittsburgh, PA, January 30, 2003.
55. Vipperman, J. S., "Microvalve Design for the Control of Polymer Electrolyte Fuel Cell Systems," Invited presentation to the *Instrumentation, Systems, and Automation Society*, Pittsburgh, PA, January 13, 2003.
56. Li, Deyu, and J. S. Vipperman, "Helmholtz Design for Noise Transmission Attenuation on a Chamber Core Composite Cylinder," Presented at the First Pan-American/Iberian Meeting on Acoustics (144th meeting of ASA), Cancun, MX, Dec 2-6, 2002.
57. Vipperman, J.S., "Active Noise Control," Invited Panelist in the Open Forum on Issues in Noise Control and Acoustics, ASME IMECE 2002, New Orleans, LA, November 17-22, 2002.
58. Li, Deyu and J Vipperman, "Investigation of The Sound Transmission Behavior of a Chamber Core Cylinder," Presented at 143rd Meeting of ASA, Pittsburgh, PA, June 3-7, 2002.

59. Homer, J.P. and J. S. Vipperman, "Identification and Classification of Noise Sources in a Chain Conveyor," Presented at 143rd Meeting of ASA, Pittsburgh, PA, June 3-7, 2002.
60. Vipperman, J.S. and E.R. Bauer, "Dragline Noise Survey," Presented at 143rd Meeting of ASA, Pittsburgh, PA, June 3-7, 2002.
61. Bauer, E.R. and J. S. Vipperman, "Problems Associated With Noise Measurements in the Mining Industry," Presented at 143rd Meeting of ASA, Pittsburgh, PA, June 3-7, 2002.
62. Vipperman, J.S., Deyu Li, and Ilya Avdeev, "Transmission Loss of a Ribbed Composite Vessel," (abs.) *JASA* **110**(5), part 2, p. 2772, Presented at 142nd Meeting of ASA, Ft Lauderdale, FL, December 3-7, 2001.
63. Vipperman, J.S., E. R. Bauer, E. R. Spencer, and D. R. Babich, "Survey and Assessment of Noise in Coal Preparation Facilities," (abs.) *JASA* **110**(5), part 2, p. 2757, Presented at the 142nd Meeting of the ASA, Ft Lauderdale, FL, December 3-7, 2001.
64. Vipperman, J.S., "Smart Structures and Systems Research and Capabilities," Presented to Morgantown NETL group, Morgantown, WV, April 19, 2000.
65. Vipperman, J. S. "Considerations and Applications for Active Noise Control," Invited presentation at the National Institute of Occupational Safety and Health, South Park, PA, February, 2000.
66. Vipperman, J.S., W. W. Clark, W. S. Slaughter, "Embedded Sensors in .50 Caliber M2 Composite Machine Gun Barrel," DARPA Review: *Smart Structures - Advanced Development Demonstration for Army Weapon Systems*, University of Pittsburgh, Pittsburgh PA, November 4, 1999.
67. Vipperman, J. S., and R. L. Clark, "Improved Performance of Output Active Structural Acoustic Control Using Collocated Strain-Based Transducers," Presented at the 136th Meeting of the Acoustical Society of America, Norfolk, VA, October 1998.
68. Vipperman, J. S. "Adaptive Piezoelectric Sensoriactuators for Active Structural Acoustic Control," Invited Colloquium, Dept. of Physics, University of Maine, Feb 27, 1998.
69. Vipperman, J. S. and R. L. Clark, "Multivariable Active Structural Acoustic Feedback Control Using Adaptive Piezoelectric Sensoriactuators," Third joint meeting of the Acoustical Society of America and Acoustical Society of Japan, Honolulu, HI, December 2-6, 1996.
70. Clark, R. L., and J. S. Vipperman, "Experimental Results From Hybrid Control With a Sensoriactuator," Presented at the 128th Meeting of the Acoustical Society of America, Austin, TX, Nov. 1994.
71. Vipperman, J. S., and R. L. Clark, "Linear Time-invariant Approaches to Feedforward Multi-frequency Control," Presented at the 127th Meeting of the Acoustical Society of America, Cambridge, MA, June 1994.
72. Vipperman, J. S., R. A. Burdisso, and C. R. Fuller, 1993, "Active Control of Broadband Structural Vibration Using the LMS Adaptive Algorithm," Presented at the 122nd meeting of the Acoustical Society of America, Nov. 1991.
73. Vipperman, J. S., "Practical Applications of Broadband Active Control," Invited Talk to the Bradley Department of Electrical Engineering, VPI&SU, 1993.
74. Burdisso, R. A., J. S. Vipperman, "Applications of Feedforward Control," Invited Talk to the Bradley Department of Electrical Engineering, 1992.

Technical Reports:

1. E.R. Bauer, D. R. Babich, J. S. Vipperman, "Worker Exposure and Equipment Noise in the Coal Mining Industry," NIOSH Information Circular, Jan 2004.
2. E.R. Bauer, M.D.DiMartino, P.J.Hintz, E.R. Spencer, J. S. Vipperman, "INVESTIGATION OF NOISE SOURCES AT AN UNDERGROUND SILVER/LEAD/ZINC MINE," NIOSH, March 1, 2001.
3. E. R. Bauer, D. R. Babich, M. D. DiMartino, D. J. Podobinski, E.R. Reeves, E.R. Spencer, J.S. Vipperman, "INVESTIGATION OF NOISE SOURCES AT A COAL PREPARATION PLANT," NIOSH, May 22, 2001.

4. 3. E. R. Bauer, D. R. Babich, T.J. Ozanich, J.S. Vipperman, "INVESTIGATION OF NOISE SOURCES AT A COAL PREPARATION PLANT," NIOSH, July 20, 2001
5. E. R. Bauer, M. D. DiMartino, P. J. Hintz, E. R. Spencer, and J. S. Vipperman "Investigation of Noise Sources at an Underground Silver Mine," NIOSH, 3/2/01.
6. E. R. Bauer, D. R. Babich, and J. S. Vipperman "Investigation of Noise Sources at an Underground Coal Mine – Longwall and Continuous Miner Sections," NIOSH, 12/1/00.
7. E. R. Bauer, D. R. Babich, M. D. DiMartino, A. E. Prokop, J. P. Rider, E. R. Spencer, and J. S. Vipperman "Investigation of Noise Sources at an Underground Coal Mine – Longwall and Continuous Miner Sections," NIOSH, 11/20/00.
8. E. R. Bauer, D. R. Babich, M. D. DiMartino, A. E. Prokop, J. P. Rider, E. R. Spencer, and J. S. Vipperman "Investigation of Noise Sources at a Surface Coal Mine – Dragline and Air-Arcing," NIOSH, 9/13/00.

Past Graduate Students:

1. Chenzhi Wang, "Finite Element Modeling of Blast-Induced Traumatic Brain Injury," PhD Dissertation, University of Pittsburgh, September 2013.
2. Konstantin Redkin, "Development and Microstructural Refinement of Composite Spin Cast High-Speed Steel Finishing Rolls," PhD Dissertation, University of Pittsburgh, September 2013.
3. Scott Mang, "Investigation of Performance Evaluation and Design Techniques for Large Industrial Mufflers," MS Thesis, University of Pittsburgh, July, 2013.
4. Christopher Shelton, "Six Noise Type Military Noise Classifier," MS Thesis, University of Pittsburgh, July, 2013.
5. Bucci, Brian A., PhD, "A Practical Method for Friction Compensation in Rapid Point-to-Point Motion," PhD Dissertation, University of Pittsburgh, January 2011.
6. Matt Rhudy, MS, "Real Time Implementation of a Military Impulse Noise Classifier," MS Thesis, University of Pittsburgh, November 2009.
7. Nathan Black, MS, "Active Combustion Throttle," MS Thesis, University of Pittsburgh, April, 2008.
8. Schimoler, Patrick, "Design of a Control System for an Elbow Joint Motion Simulator," MS Thesis, University of Pittsburgh, March, 2008.
9. David DeJohn, MS, 2008 (Converted to Prof. MS Student)
10. Laurel Kuxhaus, PhD, "Development of a Feedback-Controlled Elbow Simulator: Design Validation and Clinical Application," PhD Dissertation, University of Pittsburgh, January 2008 (faculty member at Clarkson University).
11. Bucci, Brian A., MS, "Development of Artificial Neural Network-Based Classifiers to Identify Military Impulse Noise," MS Thesis, University of Pittsburgh, December 2007.
12. Greg Badders, MS (left for industry)
13. Adam K. Smith, MS, "Adaptive Resonant Mode Active Noise Control," October, 2005.
14. Josh Magnusen, MS, "Design and Fabrication of an Elbow Motion Simulator," August 2004.
15. Angela Flamm, MS, "Preliminary Feasibility Study of Silicon on Insulator (SOI) microphones," July, 2004.
16. Adam Hahn, M.S., "Modeling and Control of Solid Oxide Fuel Cell – Gas Turbine Power Plant Systems," April, 2004, Employed by McKesson Automation, Pittsburgh.
17. Jesse Bisnette, M.S., "Active Noise Control Using Modally Tuned Phase-Compensated Filters," November 2003, Employed by U.S. Army
18. Deyu Li, Ph.D., "Vibroacoustic Behavior and Noise Control Studies of Advanced Composite Structures," July, 2003, Research Fellow at Hong Kong Polytechnic University
19. John P. Homer, M.S., "Advanced Signal Processing Techniques for Noise Source Identification in Mining Equipment," April 2003, Employed by Mine Safety and Health Administration
20. A. Fatih Ahyan, M.S., "Design of a Piezoelectrically actuated Mircovalve for Flow Control in Fuel Cells," April 2002.

Postdoc:

Jae Bum Pahk, 2009-2012 (co-advised).

Visiting Scholars:
Jeng-Lian Yang, from Tiawan, Fall 2000
Adebayo Abayomi-Alli, Summer 2014

Current Graduate Research Students:
1. Tim Ryan, PhD student
2. Qi Li, PhD student
3. William Anderton
4. Tyler Ferris
5. Brandon Saltsman
6. Nikola Hrgic

Grants and Funding:
1. T.S. Ryan, J.S. Vipperman, Paul Johnson, Carl Snyderman, “SafeDrill: bi-modal sensing for safe and efficient neurosurgical procedures,” University of Pittsburgh Center for Medical Innovation, $25,000, 7/15/2012-7/14/2013.
2. J.S. Vipperman, “Industrial Muffler Modeling and Testing,” MIRATECH Corp, $167,700, 10/2011-9/2013.
3. J.S. Vipperman, M.C. Miller, C.A. Balaban, “Finite Element Modeling of Blast-Induced Traumatic Brain Injury,” National Science Foundation, $360,000 (+$13,320 REU Supplement), 8/2011-7/2014.
4. J.S. Vipperman, “Noise Classifier Support for Improved Military Noise Monitoring System,” US Army CERL (through Environmental Security Technology Certification Program - ESTCP), $228,391, 3/1/11-2/28/13, (1.5 months effort/year).
5. L.A. Schaefer, et al., “Greater Philadelphia Innovation Cluster for Energy Efficient Buildings,” DOE: Energy Regional Innovation Cluster, $2,000,000, 2011-2016.
6. J.S. Vipperman, “American Society of Mechanical Engineers (ASME) 2010 International Mechanical Engineering Congress & Exposition (IMECE),” Hewlett International Grant Program, International conference travel, $1,000, Nov 12-18, 2010.
7. J.S. Vipperman, “Ft Drum Noise Monitor Deployment,” Applied Physical Sciences, $5,100, 8/2010-7/2011.
8. J. S. Vipperman “ACT Active Combustion Throttling,” (continuation) US Dept. of Energy, NETL/RDS-University Consortium, $50,000, 11/15/09-11/15/10.
9. D.G. Cole (PI) and J.S. Vipperman (Co-PI), “GOALI: Nanoscale Hysteresis Modeling and Control in Precision Equipment,” National Science Foundation, $300,000, 9/1/09-8/31/11.
10. J. S. Vipperman “ACT Active Combustion Throttling,” (continuation) US Dept. of Energy, NETL/RDS-University Consortium, $132,000, 11/1/08-11/15/09.
11. J.S. Vipperman (PI) and D.G. Cole (Co-PI), “Nanoscale Hysteresis Modeling and Control in Precision Equipment,” Aerotech, Inc., $124,938.00, 10/1/08-3/31/11.
12. J. S. Vipperman “ACT Active Combustion Throttling,” (continuation) US Dept. of Energy, NETL/RDS-University Consortium, $118,500, 7/1/07-10/31/08.
13. Laura Schaefer (PI) and J.S. Vipperman (Co-PI), “Environmentally Sound: High Performance, Compact Thermoacoustic Refrigeration,” National Science Foundation, $300,000.00, 9/01/07-8/31/10.
14. J.S. Vipperman (PI) and Amro El-Jaroudi (Co-PI), “Development and Implementation of Metrics for Identifying Military Impulse Noise,” Strategic Environmental Research and Development Program - SERDP, $566,335.00, 1/1/07-5/31/09.
15. J. S. Vipperman (PI), M.A. Clarke, and W. W. Clark, “ACT Active Combustion Throttling,” US Dept of Energy, NETL/RDS-University Consortium, $186,381.00, 7/15/06-6/30/07.
16. J. S. Vipperman, “Microfabricated Thermoacoustic Refrigerators for Electronics Cooling Applications,” NSF REU Supplement, $5,000, 02/27/07.
17. J.S. Vipperman (PI), and Laura Schaefer (Co-PI), “Microfabricated Thermoacoustic Refrigerators for Electronics Cooling Applications,” National Science Foundation, $90,000.00, 9/1/05-02/28/07.

18. J.S. Vipperman (PI), "Evaluation and Characterization of Exposure to Impact Noise for Development of Acoustical Risk-Damage Parameters," NIOSH Alice Hamilton Labs, $25,000.00, 2/28/05-12/31/05.
19. J.S. Vipperman (PI), "Adaptive Multi-Modal Active Noise Control," $900.00, Hewlett International Grant Program, International conference travel, May 16-20, 2005.
20. J.S. Vipperman (PI), "Development of Metrics for Identifying Military Impulse Noise Sources," Strategic Environmental Research and Development Program (SERDP – a DoD/DOE/EPA consortium), $92,430.00, January 1, 2005, December 31, 2005.
21. J.S. Vipperman (PI) and William W. Clark (Co-PI), "Variable Orifice Area Technique (VOAT) Design: Revision," U.S. Department of Energy, $50,000, 08/1/04-10/31/04.
22. J. S. Vipperman (PI), "Development of Advanced Acoustic Sensors," John A. Swanson Center for Micro and Nano Systems, University of Pittsburgh, $8,800, 07/01/04-2/28/05.
23. J. S. Vipperman (PI), W. W. Clark (Co-PI), Qing-Ming Wang (Co-PI) "MEMS Microvalve Technology: Phase II-revision," Parsons/NETL (U.S. Dept. of Energy), $36,600, 04/01/04-8/31/05.
24. J. S. Vipperman (PI), W. W. Clark (Co-PI), Qing-Ming Wang (Co-PI) "MEMS Microvalve Technology: Phase II-revision," Parsons/NETL (U.S. Dept. of Energy), $5,670, 11/01/03-3/31/04.
25. J. S. Vipperman (PI), "Engineering Student support for Evaluation of Impact Noise and Acoustical Signal Processing," NIOSH-DSHEFS, Cincinnati, OH, $11,466.00, July 31, 2003-December 31, 2003.
26. J. S. Vipperman (PI), "Helmholtz Design for Noise Transmission Attenuation on a Chamber Core Composite Cylinder," Hewlett International Grant Program, International conference travel, $1,020.00, December, 2002.
27. J.S. Vipperman (PI) and William W. Clark (Co-PI), "Variable Orifice Area Technique (VOAT) Design," U.S. Department of Energy, $150,134.00, 11/1/02-11/30/03.
28. J.S. Vipperman (PI), "Vibro-Acoustic Studies on a Chamber Core Cylinder," Air Force Research Lab and CSA Engineering, $52,929.00, 9/1/02-8/31/03.
29. Tom Cain, *et al*., "John A. Swanson Center for Micro and Nano Systems," $1,395,000.00 8/19/02.
30. J.S. Vipperman (PI), "University of Pittsburgh Support for Worker Dose and Equipment Noise Identification," NIOSH-Pittsburgh Research Lab, $12,000, 9/1/02-8/31/03.
31. J.S. Vipperman (PI), "Enhanced Time Domain Signal Processing for the Study of Noise Generation Mechanisms," NIOSH-Pittsburgh Research Lab, $10,000, 8/15/02-9/30/03.
32. J. S. Vipperman (PI), W. W. Clark (Co-PI), Qing-Ming Wang (Co-PI) "MEMS Microvalve Technology: Phase II," Parsons/NETL (U.S. Dept. of Energy), $139,615, 5/15/02-3/31/03.
33. J.S. Vipperman (PI), "Evaluation and Signal Processing of Noise Impact Data," NIOSH-DSHEFS, Cincinnati, OH $20,293, 5/6/02-10/31/02.
34. J. S. Vipperman (PI), "Characterization and Control of Sound Radiation in a Complex Structure," Hewlett International Grant Program, International conference travel, $500.00, October 30, 2001.
35. J. S. Vipperman (PI), "University of Pittsburgh Support for Noise Source/Path Identification for the Assessment of Engineering Controls," NIOSH-Pittsburgh Research Lab, $24,500.00, 9/1/01-8/31/02.
36. J. S. Vipperman (PI), "University of Pittsburgh Support for Data Analysis in the Cross-Sectional Mining Survey," NIOSH-Pittsburgh Research Lab, $8,278.00, 6/1/01-12/31/01.
37. J. S. Vipperman (PI), "Vibro-Acoustic Studies on an Advanced Composite Chamber," CSA Engineering (Air Force Research Lab), $49,980.00, 6/1/01-5/31/02.
38. J. S. Vipperman (PI), W. W. Clark (Co-PI), "Microelectromechanical Valve Design and Control for Fuel Cell Systems," Parsons/NETL (U.S. Dept. of Energy), $98,513, 5/14/01-4/30/02.
39. Jeffrey S. Vipperman (PI), "Education Partnership Agreement Between Air Force Research Laboratory/Space Vehicles Directorate and the University of Pittsburgh," $35,000.00 (in-kind), 6/1/00-5/31/04.
40. W. W. Clark (PI), J. S. Vipperman (Co-PI), "Smart Structures -- Advanced Development Demonstration for Army Weapon Systems," Defense Advanced Research Projects Agency, $196,397.00. 5/1/99-7/30/00.
41. J. S. Vipperman (PI), "Anti-symmetric Composite Design for Enhanced ASAC," University of Pittsburgh CRDF, Small Grants Program, $15,999.60, 7/99-6/01.

42. J. S. Vipperman (PI), "Autonomous Structural Damage Detection Using Adaptive Piezoelectric Sensoriactuators," Summer Faculty Research Fund Competition, University of Maine, $5000.00, 12/17/97.
43. J. S. Vipperman (PI), "Digital Signal Processing System for the Smart Systems And Structures Laboratory," Scientific Equipment and Book Fund Competition, University of Maine, $4,497.00, 1997.
44. J. S. Vipperman (PI), "Experimental Verification of Very Large-Aperture Strain-Based Piezoelectric Sensoriactuators," Regular Faculty Research Fund Competition, University of Maine, $4,975.00, 1997.

Professional Memberships:

- Full Member, Acoustical Society of America (ASA),
- Sr. Member, American Institute of Aeronautics and Astronautics (AIAA)
- Fellow, American Society of Mechanical Engineers (ASME)
- Full Member, Institute for Noise Control Engineering (INCE)
- American Nuclear Society

Professional Service:

National Science Foundation

- Proposal Reviewer (five times)

National Academy of Sciences

- Served on the National Research Council (NRC) Committee to Review the NIOSH Mining Safety and Health Research Program (12/05-4/07)
- Proposal Reviewer

Journal Editorships:

- Associate Editor of ASME Journal of Vibration and Acoustics, (2006-2012)

National/International Technical Committees:

- Chair, Selection Committee for the American Society of Mechanical Engineers Per Bruel Gold Medal for Noise Control and Acoustics, 2013-1015
- Member, Selection Committee for the American Society of Mechanical Engineers Per Bruel Gold Medal for Noise Control and Acoustics, 2012
- Chair, Working Group 27 to revise ANSI S1.1: American National Standard Acoustical Terminology, Acoustical Society of America, 5/03-current
- Vice Chair, ASME Noise Control and Acoustics Division, 2011-2012
- Chair, ASME Noise Control and Acoustics Division, 2010-2011
- Secretary/Treasurer, ASME Noise Control and Acoustics Division, 2009-2010
- Executive Committee Member, ASME Noise Control and Acoustics Division, 2007-2012
- Chair, Active Noise Control Technical Committee, American Society of Mechanical Engineers, Noise Control and Acoustics Division, 2002-2008.
- Vice Chair, Active Noise Control Technical Committee, American Society of Mechanical Engineers, Noise Control and Acoustics Division, 2001-2002
- Member, Working group to establish ANSI S3.42: Estimation of the hazards posed by exposure to impulse noise
- "Friend," of Technical Committee on Sound and Vibration, American Society of Mechanical Engineers, 2002-present
- Member, Structural Acoustics Technical Committee, Acoustical Society of America, 1999-current
- Member, Scientific Advisory Committee, Active '99 Conference, Ft. Lauderdale, FL 1999

ASME-Pittsburgh Section:

- Section Chair, 2003-2004
- Vice Chair 2002-2003
- Secretary 2001-2002
- College Relations Chair, (2001-2006)
- Board of Directors (2001-2013)
- Executive Committee (2000-2006)
- Produced/Co-produced Professional Development Seminars on CAE/FEA for ASME-Pittsburgh, March 2001 and March 2004.

Conference Division Technical Chair:

1. ASME NCAD 2009, Technical Program Chair for Noise Control and Acoustics Division of ASME.

Conference Topical Organizer:

1. ASME IMECE '12 multiple sessions on structural acoustics.
2. Internoise 2012/NCAD 2012, three conference sessions on low-frequency noise
3. ASME NCAD 2008/NoiseCon 2008, jointly organized five conference sessions.
4. ASME IMECE '07, Track Chair
5. ASME IMECE '06, Chicago, IL sessions on *Advances in Noise Control.*
6. ASME IMECE '05, Anaheim, CA, sessions on *Active Noise Control with Distributed and Hierarchical Systems* and *Recent Advances in Active Noise Control*, Nov 2005.
7. ASME IMECE '04, Anaheim, CA, sessions on *Active Control of Combustion* and *Recent Advances in Active Noise Control*, Nov 2004.
8. ASME IMECE '03, Washington DC, session on *Analyzing and Quieting Composite Structures*, Nov 2003.
9. ASME IMECE '02, New Orleans, LA, Symposiums on *Recent Active Noise Control in Transportation Systems* and *Recent Advances in Active Noise Control*, Nov 2002.

Conference Sessions Organized or co-organized:

1. ASME IMECE '07, Seattle Washington, session on *Active and Passive Noise Control*
2. ASME IMECE '03, Washington DC, session on *Recent Advances in Active Noise Control: Transducer Development*, Nov 2003.
3. ASME IMECE '03, Washington DC, session on *Analyzing and Quieting Composite Structures*, Nov 2003.
4. 145th meeting of ASA, Nashville, TN, session on the *Structural Acoustics of Musical Instruments*, April/May, 2003.
5. ASME IMECE '02, New Orleans, LA, session on *Recent Active Noise Control in Transportation Systems*, Nov 2002.
6. Local Planning Committee (technical tours), 143rd Meeting of ASA, Pittsburgh, PA, June 3-7, 2002.
7. ASME IMECE '01, New York, NY, session on *Active/Passive Noise Control*, Nov 2001.
8. ASME IMECE '00, Orlando, FL, session on *Transportation Noise Control for NCAD*, Nov. 2000.
9. Active '99 Conference, Ft. Lauderdale, FL, session on *Transducers*, Dec. 1999.

Conference Sessions Chaired or co-chaired:

1. Internoise 2012/NCAD 2012, NYC, Aug 20-22, 2012.
2. ASME IMECE 2007, Seattle WA, Nov 5-11.
3. 147th ASA, New York, NY, May 24-28, 2004.
4. Session NCA-3, ASME IMECE '03, Washington DC, November 16-21, 2003.

5. Session NCA-4, ASME IMECE ’03, Washington DC, November 16-21, 2003.
6. 146th ASA, Austin, TX, October 10-16, 2003.
7. 145th ASA, Nashville, TN April 28-May 2, 2003.
8. 144th ASA, Cancun, MX, December 2-6, 2002.
9. ASME IMECE ’02, New Orleans, LA, November 17-22, 2002.
10. 142nd ASA, Ft. Lauderdale, FL, Dec 3-7, 2001.
11. ASME IMECE ’01, New York, NY, Nov 11-16, 2001
12. ASME IMECE ’00 (2 sessions), Orlando, FL, Nov. 5-10, 2000.
13. Active ’99 Conference, Ft. Lauderdale, FL, Dec. 2-4, 1999
14. 39th AIAA/ASME/ASC/AHS/ASC SDM Conference and AIAA/ASME/AHS Adaptive Structures Forum/Long Beach, CA April 20-24
15. *Noise-Con 97, State College, PA*, June 15-17, 1997.

<u>Reviewer for</u>

- *Shock and Vibration*
- *Journal of the Acoustical Society of America*
- ASA *Acoustics Research Letters On-line (ARLO)*
- *Journal of Fluids and Structures,*
- AIAA *Journal of Guidance, Control, and Dynamics*
- AIAA *Journal of Spacecraft and Rockets*
- *Journal of Intelligent Materials Systems and Structures*
- ASME *Journal of Vibration and Acoustics*
- *Journal of Sound and Vibration*
- *Noise Control Engineering Journal*
- *IEEE Transactions on Automatic Control*
- *ASCE Journal of Engineering Mechanics*
- *ASME IMECE Conference*
- *ASME IDECT Conference*
- *ASME Gas Turbine Institute*
- *Tenure and promotion cases*

<u>University of Pittsburgh</u>

- NETL-RUA Education Committee Member (2010-2012)
- University Academic Calendar Committee (2/2008-present)
- University Research Council (9/2007-2010)
- Conflict of Interest Committee (9/2006-2009, 2012-present)
- Entrepreneurial Oversight Committee (9/2006-2009)

<u>School of Engineering</u>

- Innovation/Entrepreneurship Curriculum Reform (1/2013-present)
- Graduate Admissions Committee (4/2012-current)
- Technology Governance Committee (3/2012-current)
- Distance Education Committee (ad-hoc, 2011)
- Dean’s marketing task force (2003-3005)
- Web editors Group (2001-2004)
- Served as a Mentor for the Minority Engineering Mentorship Program (MEMP), 2001 (she became my graduate student)
- Served as a Mentor in the Pitt REU in Physics - Focus on Minorities and Women
- Participated in Mentoring Program for Excellence in Engineering (MPE^2), 2006-2007
- Participated as a Mentor for the Pitt Excel Summer Research Internship, 2009, 2010 (he became my graduate student)

Mechanical Engineering Dept.

- Faculty Search Committee (spring 2010, spring 2011)
- Director of Graduate Studies (1/08-8/08 (supplemental/interim), and 8/08-8/11)
- Space Committee (2006-2008)
- Inter-program Graduate Committee (2007-2008)
- Strategy and Planning Committee (2004-2006)
- Graduate Curriculum Committee for ME, UPitt (2001-2004, 2006-current)
- Undergraduate Program Committee for ME, UPitt (1999-2001, 2005-2006)
- Graduate Seminar Coordinator, Spring 2002
- Chairman for Dynamics and Vibrations Area Committee for Ph.D. Preliminary Examinations (2000-2001)

References:

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(757) 864-3589 (Phone at NASA Langley Research Center)
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