UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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

v.

AMERICAN GNC CORPORATION,
Patent Owner.

Case IPR 2024-00667
U.S. Patent No. 6,508,122 B1

DECLARATION OF INGRID HSIEH-YEE, PH.D.

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I, Ingrid Hsieh-Yee, declare as follows:

I. Introduction and Qualifications

1. I am over the age of eighteen and otherwise competent to make this declaration.

2. I have been retained by counsel for Petitioner to provide my expert opinion in connection with the above-captioned proceeding ("IPR") regarding the public availability of certain prior art references in relation to U.S. Patent No. 6,508,122 B1 ("Challenged Patent").

3. I am being compensated for my time in connection with this IPR at my current consulting rate. I am also being reimbursed for any reasonable expenses associated with my work and testimony in this investigation. My compensation is not contingent on the results of my study, the substance of my opinions, or the outcome of this matter.

A. Qualifications and Professional Experience

4. My complete qualifications and professional experience are described in my academic curriculum vitae (**Appendix A**). The following is a brief summary of my relevant qualifications and professional experience.

5. I was a professor in the Department of Library and Information Science at the Catholic University of America for 32 years and was conferred the title of Professor Emerita in December 2022. I have experience working in an academic

library, a medical library, and a legislative library. I hold a Ph.D. and a Masters in Library and Information Studies from the University of Wisconsin-Madison.

6. I am an expert on library cataloging and classification and have published two editions on this subject, *Organizing Audiovisual and Electronic Resources for Access: A Cataloging Guide* (2000 and 2006). I taught a variety of courses, including Cataloging and Classification, Advanced Cataloging and Classification, Organization of Internet Resources, Organization of Information, Metadata, Digital Content Creation and Management, Internet Searches and Web Design, Information Literacy Instruction, Advanced Information Retrieval and Analysis Strategies, and The Information Professions in Society. I am familiar with metadata schema design and implementation. In my teaching, I covered the design and implementation of metadata in databases, search engines, digital repositories, digital libraries, and digital archives. I also covered how information organization affects the discovery and access to digital resources on the Internet. My research interests cover cataloging and classification, information organization, metadata, information retrieval, information architecture, digital collections, scholarly communication, social media, user interaction with information systems, and others.

II. Background of Library Cataloging

A. Machine-Readable Cataloging ("MARC")

7. I am very familiar with a library cataloging encoding standard known

as the "Machine-Readable Cataloging" standard, also known as "MARC," which became the national standard for sharing bibliographic data in the United States by 1971 and the international standard by 1973. MARC is the primary communications protocol for the transfer and storage of bibliographic metadata in libraries. Experts in my field reasonably rely upon MARC records when forming their opinions.

8. A MARC record consists of several fields, each of which contains specific data about the work. Each field is identified by a standardized, unique, three-digit code corresponding to the type of data that follows. **Appendix B** is a true and correct copy of Parts VII to X of "Understanding MARC Bibliographic: Machine-Readable Cataloging" (https://www.loc.gov/marc/umb/um07to10.html), a brief description and tutorial published by the Library of Congress in 2009 that explains commonly used MARC fields. For example, the personal author of a work is recorded in Field 100, the title is recorded in Field 245, publisher information is recorded in Field 260, the physical volume and characteristics of a publication are recorded in Field 300, and topical subjects are recorded in Field 650. More details of MARC21 format for Bibliographic Data are available on the Library of Congress website at https://www.loc.gov/marc/bibliographic/.

9. I am very familiar with library cataloging and processing practices and the relationships between OCLC (Online Computer Library Center) and library catalogs, and how libraries create and share their records to help the public discover

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and access information.

10. OCLC is the largest bibliographic network of the world, and its WorldCat database contains more than 559 million records from thousands of member institutions (many of which are libraries of some type) in more than 100 countries. OCLC was founded in 1967 to promote and support library cooperation. According to the third article of the "Amended Articles of Incorporation of OCLC [Online Computer Library Center], Inc.," OCLC was created "to establish, maintain, and operate a computerized library network and to promote the evolution of library use, of libraries themselves, and of librarianship, and to provide processes and products for the benefit of library users and libraries, including such objectives as increasing availability of library resources to individual library patrons and reducing the rate of rise of library per-unit costs, all for the fundamental public purpose of furthering ease of access to and use of the ever-expanding body of worldwide scientific, literary, and educational knowledge and information" (source: https://www.oclc.org/content/dam/oclc/membership/articles-of-incorporation.pdf).

11. OCLC members can contribute original cataloging records in MARC to the system or derive cataloging records from existing records, an activity referred to as "copy cataloging." When an OCLC participating institution acquires a work, it can create an original MARC record for the work in OCLC's WorldShare system (a system for catalogers to create and share MARC records), and the system will

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automatically generate a code for the date of record creation in the yymmdd format in the 008 field, and the creating library's OCLC symbol is recorded in subfield "a" of the 040 field. Once the MARC record is created in WorldShare, the record is stored in the OCLC WorldCat database and becomes available to other OCLC members for adoption to their local online catalogs (*i.e.*, copy cataloging). "WorldCat is the world's most comprehensive database of information about library collections" (source: WorldCat, https://www.oclc.org/en/worldcat.html).

12. After a MARC record is added to OCLC's WorldCat database, it also becomes searchable and viewable on WorldCat.org, a free web portal for the public to explore more than 10,000 libraries worldwide. Records in WorldCat.org, however, are not presented in MARC fields. Instead, the data elements are labeled to help users interpret the records. Thus, the information stored in MARC records in the WorldCat database is available to the interested public through the user-friendly WorldCat web portal. In addition, WorldCat database records can be searched on OCLC FirstSearch, a subscription-based search system that provides access to many proprietary databases, including the WorldCat database.

B. Library Online Catalogs

13. Library online catalogs gained acceptance in the early 1980s and many libraries migrated their systems to the World Wide Web in the mid-1990s. Library online catalogs are based on MARC records that represent their collections in order

to help the public understand what materials are publicly accessible in those libraries. Most libraries with online catalogs have made their catalogs freely available on the Web. These online catalogs offer user-friendly search interfaces. Strong user interest in keyword searches and the popularity of Google have led to the "googlization" of library search systems. As a result, many library catalogs nowadays provide a single search box for users to conduct keyword searches, with additional support for searches by author, title, subject terms, and other data elements such as ISBN (International Standard Book Number). Library catalogs these days also offer features for users to narrow their search results by language, year, format, and other elements. Many libraries display MARC records on their online catalogs with labels for the data elements to help the public interpret MARC records. Many libraries also offer the option to display MARC records in MARC fields.

14. Libraries create MARC records for works they acquire, including books, serials, motion pictures, and publications in other formats. Monograph cataloging is fairly common in libraries, and most libraries make a newly cataloged monograph available to the public soon after the cataloging work is completed, usually within a week.

15. Libraries can create original cataloging records or use an existing record in the OCLC WorldCat database to create a copy cataloging record. As soon as the cataloging record is completed, it is added to the library's online catalog for

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users. If the record is an original record, it is also entered into the OCLC WorldCat database. If it is a copy cataloging record, the library's holding symbol is attached to the existing original record in the OCLC WorldCat database to facilitate searching and interlibrary loan.

16. The cataloging of serials and the serial check-in process are discussed here to show how libraries usually provide access to newly received serial issues. According to the glossary of the *RDA: Resource Description and Access* cataloging standard, a serial is "a mode of issuance of a manifestation issued in successive parts, usually bearing numbering, that has no predetermined conclusion. A serial includes a periodical, monographic series, newspaper, etc." (RDA Glossary at https://original.rdatoolkit.org/rdagloss_rdaregistry.info-termList-ModeIssue-1003_1.html (subscription required for access); cited in https://www.ccslib.org/Catalogers/index.php/Category:Serials). Because the publisher of a serial makes new issues of the serial available successively, a customary cataloging practice is to create one bibliographic record for the entire serial, and the serial record (encoded in MARC) typically provides information on the beginning date and frequency of the serial, not the dates of individual issues. In other words, libraries typically do not create MARC records for individual issues of a serial. Instead, they rely on a serial check-in system to track the receipt of new issues. A common check-in practice is to date stamp a new issue when it arrives. This

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practice has become automated since the late 1990s, and libraries now vary in how they share the receipt date of a new serial issue with the public. Some libraries use a date stamp, some affix a label to indicate the receipt date, some pencil in the receipt date, and some do not provide the information to the public.

17. The serial check-in process usually takes less than an hour, and one of the steps involves placing a date stamp on the new issue to document the date the issue is checked in. After that, the holdings information of the serial is updated in the library's catalog so that users know which issues are available for request or access. After serial check-in is completed, the new issue is placed on the shelf with the previous issues of the serial. Libraries with a public periodical room typically place new issues in the periodical room for easy user access. Because information presented in serials often reflects latest discovery, a general practice of libraries is to make new issues of serials available for user access soon after they are checked in, usually within a week.

18. I am personally familiar with many online catalogs, databases, and search engines. In preparing for this declaration, I used the following authoritative information systems to search for records:

- Google Scholar (https://scholar.google.com/)
- Internet Archive (https://archive.org/)
- Libraries.org, a directory of libraries throughout the world

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(https://librarytechnology.org/libraries/)

- OCLC FirstSearch (https://firstsearch.oclc.org/; subscription required for access)
- Online catalog of the Library of Congress (https://catalog.loc.gov/)
- Online catalog of the University of California, Berkeley Library (https://search.library.berkeley.edu/discovery/search?vid=01UCS_BER:UCB)
- Online catalog of the University of Wisconsin-Madison Library System (https://search.library.wisc.edu/search/system)
- Patentscope (https://patentscope.wipo.int/search/en/search.jsf)
- Public catalog of the US Copyright Office (https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?DB=local&PAGE=First)
- WorldCat.org, a free web portal (https://search.worldcat.org/)

C. Scope of this Declaration

19. I have been asked to offer an opinion on the public availability date of each of the following documents in this proceeding:

EXHIBIT	DOCUMENT
1037	Juneau, T. N. (1997). *Micromachined dual input axis rate gyroscope*. Dissertation of University of California, Berkeley ("*Juneau*").

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1040	First page of Micromachined Vibratory rate gyroscope, WO 97/45699. ("*WO 97/45699*")
1044	G. C. Temes, L. E. Larson and K. W. Martin, State-of-the-art and future prospects for analogue signal processing - A tutorial, *1988 IEEE International Symposium on Circuits and Systems*, Espoo, Finland, 1988, pp. 1655-1660 vol.2. ("*Temes*")
1053	Crossbow. (1998, April). DMU-6X and DMU-VGX Silicon IMU and Vertical Gyro. ("*DMU*")
1057	Micromachined Vibratory rate gyroscope, WO 97/45699. ("*WO 97/45699*")
1058	Mark Alan Lemkin, *Micro Accelerometer Design with Digital Feedback Control* ("*Lemkin*")
1059	C. Lu, Lemkin, M., and B. E. Boser, "A monolithic surface micromachined accelerometer with digital output," *IEEE Journal of Solid-State Circuits*, 30(12), 1367-1373 ("*Lu*")
1060	W. Yun, R.T. Howe, and P.R. Gray, "Surface micromachined, digitally force-balanced accelerometer with integrated CMOS detection circuitry," *IEEE Solid-State Sensor and Actuator Workshop Technical* Digest, pp. 126-131 ("*Yun*")
1063	Measurement Specialties. (1998, August). Accelerometer ACH-04-08-05. Application Specification. 114-27002. 27 Aug 98 Rev A. ("*ACH-04-08-05*")
1064	Analog Devices. ADXL05. ±1g to ±5g Single Chip Accelerometer with Signal Conditioning. ("*ADXL05*")
1065	Analog Devices. (1996). ADXL50* Monolithic Accelerometer With Signal Conditioning datasheet. ("*ADXL50*")

20. I am informed by counsel and understand that a given reference is "published" upon a satisfactory showing that such a document has been disseminated or otherwise made publicly available to the extent that persons interested and

ordinarily skilled in the subject matter or art could locate it exercising reasonable diligence and obtain the document. I have also been informed by counsel and understand that materials available in a library constitute "printed publications" if they are catalogued and indexed according to general library practices and protocols that make the references available and accessible to members of the interested public.

21. I have been informed by counsel that Patent Owner is asserting that the Challenged Patent is entitled to a priority date of May 1999. I have assessed public accessibility of the documents referenced below as of this claimed priority date.

22. I have been informed by counsel that the subject matter of this proceeding generally relates to sensors for measuring movement, such as acceleration and rotational position.

23. I have been informed by counsel that a "person of ordinary skill in the art at the time of the invention" (POSA) is a hypothetical person who is presumed to be familiar with the relevant field and its literature at the time of the inventions. I have been informed by counsel that this hypothetical person is also a person of ordinary creativity, capable of understanding the scientific principles and literature applicable to the pertinent field.

24. I have been informed by counsel that a person of ordinary skill in the art as of May 1999, would have possessed a bachelor's degree in electrical engineering or similar degree, with two to three years of practical experience

designing and/or implementing systems that include sensors for measuring movement, such as acceleration and rotational position. A person could also have qualified as a person of ordinary skill in the art with a combination of (1) more formal education (such as a Master of Science degree) and less technical experience, or (2) less formal education and more technical or professional experience.

25. It is my opinion that such a person would have been actively engaged in learning about the field, possibly through formal instruction and through bibliographic resources. By at least May 1999, such a person would have had access to a vast array of print and electronic resources, including at least the documents referenced below.

D. Evidence Considered in Forming My Opinion

26. In the preparation of this declaration, I have reviewed the exhibits referenced in paragraph 19 above, and any other documents I reference herein. Each of these is a type of material that experts in my field would reasonably rely upon when forming their opinions. I provided a further description of materials I considered in **Appendix C**.

III. Authenticity and Public Availability of *Juneau* (EX1037)

A. Authentication

27. **EX1037** is a true and correct copy of *Micromachined Dual Input Axis Rate Gyroscope,* ("*Juneau*"), by Thor Nelson Juneau, a doctoral dissertation

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completed in 1997 at the University of California, Berkeley, that I received from counsel. This copy is identified as "Nintendo Exhibit 1037" and the pages are numbered as "IPR2024-00667 – Page #".

28. Page 1 of **EX1037** is the "Information to Users" page from UMI that states "[t]his manuscript has been reproduced from the microfilm master." Page 3 is the title page that shows the title, author, committee members, and the degree-granting institution. Page 4 shows the UMI number for this thesis is 9826975. Page 5 is the copyright page of *Juneau* that shows the thesis has a "1997" copyright date and Thor N. Juneau holds the copyright. Page 6 shows the dissertation committee's approval of this thesis and the signatures of committee members signed in December 1997. Pages 8 to 10 (internal pages iv to vi) are the table of contents that shows *Juneau* has eight chapters, including a bibliography as Chapter 8 that begins on internal page 123 and includes 81 references. **EX1037** shows *Juneau* includes seven pages of front matter, and the main text has a total of 127 leaves, including equations, figures, and tables.

29. **EX1037** is in a condition that raises no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, this copy includes the approval sheet and signatures of the doctoral committee members from the degree-granting university. Based on my review and analysis, it is my opinion that **EX1037** is authentic.

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B. Records of the University of California, Berkeley Library

30. To show *Juneau* is publicly accessible, I have personally located, identified, and obtained records from the online catalog of the University of California, Berkeley Library ("UCB Library"). **EX1037A** is a true and correct copy of the bibliographic and MARC records for *Juneau*. They are the type of records experts in my field would reasonably rely upon when forming their opinions.

31. Pages 1 to 3 are the bibliographic record. Page 1 shows the dissertation title, author, and completion year ("1997"), and shows this work is available at the Northern Regional Library Facility Main (Gardner) Stacks (NRLF) and the local call number is "308t 1997 795." Record details include title, creator, creation date, format, notes, degree, degree-granting institution, and date of degree ("Dec. 1997"). Subjects, genre, related titles, and record source are also included. The title, creator, creation date, format, notes, degree, degree-granting institution, and date of degree match the information presented in **EX1037**, confirming this record represents *Juneau*.

32. Page 4 is the MARC record I copied from the online catalog of the UCB Library. The first six digits of Field 008 shows the MARC record was created on "980629" (*i.e.*, June 29, 1998), and the code of "s1997" following the record creation date indicates this dissertation has single publication date of 1997. Subfields "a" and "c" of Field 040 show CUY created the record and entered it into the OCLC WorldCat database. According to the Directory of OCLC Members

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(https://www.oclc.org/en/contacts/libraries.html), "CUY" is the OCLC library symbol for the University of California, Berkeley Library. Fields 008 and 040 inform my opinion that the UCB Library created an original cataloging record for *Juneau* on June 29, 1998, making this work discoverable in their online catalog. In addition, subfield "c" of Field 040 shows the record was entered into the OCLC WorldCat database, making it discoverable by users outside of the University of California, Berkeley. A customary library practice is to process a newly cataloged work promptly for access, usually within a week after the cataloging work is completed. It is therefore my opinion that, after processing, *Juneau* would become publicly accessible at the UCB Library by July 6, 1998.

33. Fields 035 show this record has an OCLC number of 230741619. Field 100 shows the author, Field 245 shows the title, Field 264 shows the dissertation has a "1997" copyright date, and Field 300 shows the dissertation includes seven pages of front matter and the main text has 127 leaves including illustrations. Field 502 shows the degree and degree-granting institution, and Field 504 shows a bibliography note. Field 968 is a local note, and the "Addate" element shows that *Juneau* was added to the library collections on "980629" (*i.e.*, June 29, 1998).

34. The subjects of *Juneau* are represented in Field 090 by a local call number and in Field 690 by a local subject heading: Dissertations, Academic $x UCB $x Engineering $y 1991-2000. These subject representations provide broad

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categories for interested users to discover *Juneau*.

35. This MARC record (**EX1037A**) has made *Juneau* discoverable since June 29, 1998, when the UCB Library created the original record for this dissertation. As of that date, interested users could discover this work by the author, title, and local subject heading and classification number. The physical copy, after processing, would become publicly accessible by July 6, 1998.

36. As evidence that the UCB Library had an online catalog in operation when *Juneau* was added to the library collections, I obtained a profile (**EX1037B**) of the library from libraries.org, a directory of libraries throughout the world. This library profile is available at https://librarytechnology.org/library/11. I personally located, identified, and obtained this record. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

37. The Technology Profile on page 2 of **EX1037B** on the library profile for the UCB Library shows that it used a locally developed system from 1972 and migrated into Millennium in 2008. These dates mean that in June 1998 interested users would be able to use the local online system to discover *Juneau*.

38. As further evidence of the availability of an online catalog in 1998, I obtained webpages of the UCB Library catalogs. This archived copy is presented as page 3 and 4 of **EX1037B**. Page 3 is a screen capture of a Wayback Machine calendar that shows the archiving history of the webpage and indicates this particular copy

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was archived on "DEC 12 1998" and available at https://web.archive.org/web/19981212030542/http://www.lib.berkeley.edu/. Page 4 is the PDF of this archived copy that shows the UCB Library offered several catalogs to users in 1998, including "UC Berkeley – Pathfinder or GLADIS." Page 5 is a screen capture of a webpage archived on January 17, 1999, and available at https://web.archive.org/web/19990117024322/http://sunsite2.berkeley.edu:8000/. Page 6 is the PDF of this archived copy that explains Pathfinder "is the Web-browsable online public access catalog of the University of California at Berkeley Library."

39. Records in **EX1037B** confirm that the UCB Library had an online catalog in place by late 1998 and early 1999, and interested users would be able to use Pathfinder to discover *Juneau* and access the full text at the UCB Library.

C. WorldCat Record from OCLC FirstSearch

40. Subfield "c" of field 040 of the MARC record for *Juneau* (**EX1037A**) shows the record was entered into the OCLC WorldCat database. As evidence, I have obtained the WorldCat database record for *Juneau* from the OCLC FirstSearch system. As discussed earlier, OCLC's WorldCat database is the world's most comprehensive database of information about library collections. Records in this database are shared among OCLC members, available for discovery by subscribers to the OCLC FirstSearch system that supports users to access proprietary databases,

and also available for discovery by the general public through the WorldCat.org free web portal. **EX1037C** is a true and correct copy of the record created by the UCB Library in the OCLC FirstSearch system. I personally located, identified, and obtained this record. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

41. The top of **EX1037C** shows the title, author, and the Accession Number of this record, and also shows the University of California Berkeley Library holds this dissertation. The essential bibliographic details are the same as the details in **EX1037A**. The Database field and the "Date of Entry" field show the record was entered into the OCLC WorldCat database on "19980629" (*i.e.*, June 29, 1998). **EX1037C** confirms that the record for *Juneau* created by the UCB Library was entered into the WorldCat database on June 29, 1998, making this record available to OCLC members for cataloging, collection management, and interlibrary loan purposes. In addition, the record also became discoverable by subscribers to the OCLC FirstSearch system, and by the public in WorldCat.org, the free web portal.

42. As evidence that the OCLC FirstSearch system was in operation when the record for *Juneau* became available to subscribers to this system, I located an article about OCLC FirstSearch. **EX1037D** is a true and correct copy of "FirstSearch launched" in the November 1991 issue of *Library Systems Newsletter*. The article reports that a "new online reference tool for end-users is now available from OCLC.

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The FirstSearch Catalog is a relatively low-cost, easy-to-use reference system that library patrons can use to search the OCLC Online Union Catalog, as well as a variety of reference data bases." The "OCLC Online Union Catalog" in this statement was later called OCLC WorldCat database.

D. ProQuest Record

43. ProQuest has offered the ProQuest Digital Dissertations database for interested users to discover and access dissertations of interest. **EX1037E** is a true and correct copy of the database record for *Juneau*. Page 1 shows the abstract, subjects, classification number, keywords, title, author, pagination, degree date, and dissertation number ("9826975"). **EX1037E** also indicates this dissertation has been indexed in "DAI-B 59/03, Dissertation Abstracts International." The print issue of vol. 59, no. 3 (**EX1037F**) discussed below shows this print index issue became publicly available at the University of Wisconsin-Madison Library System on September 15, 1998. Since the ProQuest database records usually become available for searching earlier than the print index records, it is my opinion that by September 1998 interested users would have been able to discover *Juneau* in the ProQuest Dissertation Database. They could search for this dissertation by the title, author, subjects, and keywords.

E. Dissertation Abstracts International Index Record

44. To determine when the print index of vol. 59, no. 3 of the B series of

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Dissertation Abstracts International became publicly available, I obtained a copy of the index record for *Juneau* from the University of Wisconsin-Madison Library system. This copy is presented as **EX1037F** in this declaration.

45. Page 1 is the cover that identifies this issue as vol. 59, no. 3 of *Dissertation Abstracts International B* that has an issue date of "September 1998." The cover shows the title, ISSN, and call number of this issue and two library stamps on the cover show this issue was initially in the "Reference Collection, Memorial Library, Non-Circulating" and later transferred to the stacks. In addition, the cover shows a date stamp of "Received SEP 15 1998 University Library" that documents the receipt date of this issue in the library system. Page 3 is the title page, pages 5 to 6 are the table of contents, page 7 explains the data elements in the index record, and the keyword Index and author index in each issue of *Dissertation Abstracts International*. Pages 8 and 9 explain the purpose of the UMI dissertation database and how users can search for items of interest online, on CD-ROM, and in the print index. Page 10 presents ordering information. Page 14 shows the University of California, Berkeley participates in UMI's dissertation publishing program. Page 20 is an author index page that shows *Juneau* is indexed in page 1330B. Pages 21 to 23 are keyword index pages that show *Juneau* is indexed under "Micromachined," "dual input axis," and "Gyroscope." Page 24 (internal page 1330-B) shows the index record for *Juneau* that includes the title, author, degree, degree-granting institution, date of

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degree completion, pagination, committee chair, the order number of this dissertation ("DA9826975"), and an abstract.

46. **EX1037F** shows that from September 15, 1998 on, interested users would have been able to use the author index and the keyword index to discover *Juneau* in the print issue of *Dissertation Abstracts International* and use the record to order printed copies of the dissertation.

F. Summary of My Opinion on *Juneau*

47. **EX1037** contains no signs to raise suspicion about its authenticity. The copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, this copy includes the approval sheet and signatures of the doctoral committee members from the degree granting university. Based on my review and analysis, it is my opinion that **EX1037** is authentic.

48. The UCB Library's MARC record for *Juneau* (**EX1037A**) shows that *Juneau* became discoverable at this library on June 29, 1998, when the original MARC record was created. The OCLC FirstSearch system record for *Juneau* (**EX1037C**) shows that on June 29, 1998, *Juneau* became discoverable by OCLC members, OCLC FirstSearch subscribers, and the general public on the Internet. The physical copy, after processing, would become publicly accessible at the UCB Library by July 6, 1998.

49. The ProQuest database record for *Juneau* (**EX1037E**) became available

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by September 15, 1998, making this dissertation discoverable to database users. The print version of vol. 59, no. 3 of *Dissertation Abstracts International* that contains the index record for *Juneau* (**EX1037F**) was received on September 15, 1998, by the University of Wisconsin Library system, meaning interested users could discover *Juneau* from the print index by September of 1998.

50. Based on the documents and records I have reviewed and analyzed, it is my opinion that *Juneau* became publicly discoverable on June 29, 1998, at the online catalog of the UCB Library. This dissertation also became publicly discoverable on June 29, 1998, by OCLC members, OCLC FirstSearch subscribers, and the general public. In addition, interested users could search the ProQuest Dissertation Database by September 1998 to discover *Juneau*. From September 15, 1998 on, interested users could also search the print version of *Dissertation Abstracts International* to discover *Juneau*.

IV. Authentication and Public Availability of *Temes* (EX1044)

A. Authentication

51. **EX1044** is a true and correct copy of "State-of-the-art and future prospects for analogue signal processing - A tutorial," ("*Temes*"), by Temes, G. C., Larson, L. E., Martin, K. W., in *1988 IEEE International Symposium on Circuits and Systems, Espoo, Finland, 1988*, vol. 2, pp. 1655-1660, that I received from counsel. This document is identified as Nintendo **EX1044**, and the pages are marked as

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"IPR2024-00667 – Page #." This copy is presented as **EX1044** in this declaration.

52. Page 1 (internal page 1655) shows the title, authors, and abstract. The bottom of this page shows the paper is part of "ISCAS '88" and is published in "CH2458-8," and has a 1988 copyright date with IEEE as the copyright holder. **EX1044** has a total of six pages, including two tables, nine figures, and 22 references.

53. To authenticate **EX1044**, I searched WorldCat.org to identify libraries holding the conference proceedings containing *Temes*, and learned that the University of Wisconsin-Madison Library system ("UW") is one of the holding libraries. After verifying the holdings information in their online catalog, I obtained a copy of *Temes* from UW through a document vendor. This library copy is presented as **EX1044A** in this declaration.

54. Page 1 shows a bound volume identified as "1988 IEEE International Symposium on Circuits and Systems Vol. 2." Page 2 shows a library date stamp of "Kurt F. Wendt Library, College of Engineering OCT 27 1988 UW-Madison, WI 53703." Page 3 is the same page in a different resolution to make the date stamp more legible. Page 4 is the title page that shows "1988 IEEE International Symposium on Circuits and Systems, Proceedings" as the title, indicates this volume is "Volume 2 of 3", and also shows the conference location and dates, and a number of "88CH2458-8." Page 5 is the copyright page that shows this publication has a "1988" copyright date and the Institute of Electrical and Electronics Engineers, Inc. holds the copyright.

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This page also shows the ISBN, IEEE catalog number, and Library of Congress catalog number for this publication. Pages 6 and 7 are pages from the table of contents selected to show the first group of papers included in Vol. 2 and the page showing *Temes* is included in the "Design Strategies for Analogue Interface Systems" and begins on internal page 1655. Pages 8 to 13 (internal pages 1655 to 1660) are the full text of *Temes*. I have closely compared **EX1044** with this library copy and found them to have the same content for *Temes*.

55. **EX1044** is in a condition that raises no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, **EX1044** has the same content as the UW copy (**EX1044A**). Based on my review and analysis, it is my opinion that **EX1044** is authentic.

B. Records of the University of Wisconsin-Madison Library System

56. To determine the public availability date of the *1988 IEEE International Symposium on Circuits and Systems* ("IEEE ISCAS") that contains *Temes* at libraries, I obtained records for the publication from the online catalog of UW. **EX1044B** is a true and correct copy of the bibliographic and MARC records for IEEE ISCAS. I personally located, identified, and obtained these records. They are the type of records experts in my field would reasonably rely upon when forming their opinions.

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57. Pages 2 to 5 of **EX1044B** are the bibliographic record. Page 2 shows IEEE ISCAS is available online and in print, and is cataloged as a serial by UW. The bibliographic record includes the conference name, title of the proceedings of IEEE ISCAS, language, corporate contributor, publisher, and ISSNs. These details match the information presented in **EX1044A**, confirming this record represents the IEEE ISCAS proceedings.

58. Pages 5 to 7 are the MARC record. The first six digits of Field 008 show the MARC record was first created on "800808" (*i.e.*, August 8, 1980), and the code of "c19779999" following the record creation date shows this publication is a continuing resource that began in 1977 and has no predetermined conclusion date. Subfield "a" of Field 040 shows DLC (*i.e.*, Library of Congress) created the original MARC serial record. Fields 008 and 040 inform my opinion that the Library of Congress created a serial record for *IEEE International Symposium on Circuits and Systems*, and UW used the original record to create their copy cataloging record.

59. Field 022 shows the ISSN, Field 111 shows the symposium name is used as a corporate author for this serial, Field 245 shows the title of the serial, and Fields 246 show four variant titles are included in the MARC record to help users discover this serial. Field 260 shows the publisher. Field 300 shows physical details, leaving the volume number field open because this is an ongoing serial. Field 362 shows the serial began in 1977, and Field 310 shows the publication frequency is

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"Annual." Fields 510 show this serial has been completely indexed by *Index to IEEE publications*, and selectively indexed by *Engineering Index Annual* and *Engineering Index Monthly*, meaning interested users can use those indexes to search for papers of interest. Field 550 shows sponsor information, and Field 710 shows the IEEE Circuits and Systems Society is included to help users discover this serial.

60. The subjects of this serial are represented in Field 050 by a Library of Congress Classification (LCC) number of "TK454.2" that represents "Electric networks" (source: Library of Congress Classification Schedule T at https://www.loc.gov/aba/publications/FreeLCC/LCC_T2019TEXT.pdf); and in Field 082 by a Dewey Decimal Classification (DDC) number of "621.319" that represents "Transmission" (source: Dewey Decimal Classification 600 Technology (Applied Sciences) at https://www.oclc.org/content/dam/oclc/webdewey/help/600.pdf). Subjects are also represented in Fields 650 by four Library of Congress subject headings, with "Electric networks," "Electric circuits," "Electronic circuits," and "Electronic apparatus and appliances" as the main topics, each followed by "Congresses" as a form subheading encoded in subfield "v" to indicate the main topics are treated at a conference. These subject representations enable users to conduct subject searches to discover the serial that contains *Temes*.

61. The MARC serial record (**EX1044B**) shows that UW used an original

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record created by the Library of Congress in 1980 for copy cataloging. The date stamp in **EX1044A** shows the issue containing *Temes* was received by UW on October 27, 1988. It is therefore my opinion that this serial became discoverable in the library online catalog by at least that date, if not earlier. As of that date, interested users would be able to discover this serial by the ISSN, conference name, serial title, and sponsor. They could also conduct subject searches to discover this serial.

62. As evidence that UW had an online catalog in operation in 1988 when the library's MARC record for the serial containing *Temes* was completed, I obtained a profile of this library system from libraries.org, a directory of libraries throughout the world. I personally located, identified, and obtained this record from https://librarytechnology.org/library/2090. This is the type of record experts in my field would reasonably rely upon when forming their opinions. This library profile is presented as **EX1044C** in this declaration.

63. The Technology Profile on page 2 shows UW began using LS/2000 as their online catalog in 1988 and migrated to NOTIS in 1993. These dates mean that in 1988 interested users could use LS/2000 to search for the serial containing *Temes*.

C. Copyright Registration Record

64. **EX1044D** is a true and correct copy of the copyright registration record for *IEEE International Symposium on Circuits and Systems.* I personally located, identified, and obtained this record from the public catalog of the US Copyright

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Office. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

65. The "Issues Registered" field of **EX1044D** shows the 1988 IEEE International Symposium on Circuits and Systems was created in 1988 and published on "1988-06-07" (*i.e.*, June 7, 1988) and registered with the US Copyright Office on "1988-09-09" (*i.e.*, September 9, 1988). These dates align well with the date stamp in **EX1044A** that shows UW received the issue containing *Temes* on October 27, 1988.

D. Records of the University of Texas at Austin Libraries

66. As discussed earlier, libraries could choose to catalog conference proceedings as serial, as UW has done with this serial, to expedite the cataloging of a serial and make issues available to users promptly. Another option for libraries is to catalog conference proceedings as books to make them easier for discovery purposes. *Proceedings of the 1988 IEEE International Symposium on Circuits and Systems* ("ISCAS") has in fact been cataloged as books by a few libraries. **EX1044E** is a true and correct copy of the bibliographic and MARC record for ISCAS that contains *Temes*. I personally located, identified, and obtained these records from the online catalog of the University of Texas at Austin Libraries ("UT"). They are the type of record experts in my field would reasonably rely upon when forming their opinions.

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67. Pages 1 to 3 are the bibliographic record that shows ISCAS is available at "Library Storage Facility, Closed Stacks" with a call number of "TK454.2 I22 1988." Record details include title, other title, conference name, publisher, format (three volumes), IEEE catalog number ("88CH2458-8") and creation date ("c1988"). These details match the information presented in the UW copy (**EX1044A**), confirming this record represents this ISCAS conference proceedings. The bibliographic details include subject headings and other information.

68. Pages 5 and 6 of **EX1044E** are the MARC record that I copied from the library's online catalog. Field 008 shows the record was created on "870330" (i.e., March 30, 1987) and the code of "s1988" following the record creation date indicates this work has a single publication date of 1988. Subfield "a" of Field 040 shows DLC (i.e., Library of Congress) created the original MARC record, and subfield "d" shows IXA (i.e., the University of Texas at Austin Libraries) used that record for copy cataloging later. Field 005 is a machine-generated field that automatically records the last time when the MARC record was modified by UT, and it shows a modification date of "19881209173455" (i.e., December 9, 1988, 5 p.m., 34 minutes and 55 seconds). Record modification can take place for various reasons, such as correcting typos or updating the record to conform to the latest cataloging encoding practice. Fields 008, 040, and 005 inform my opinion that the Library of Congress created a MARC record for ISCAS in 1997 before the work was published, and UT used that

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record for copy cataloging later; and the last time UT modified their MARC record for ISCAS was December 9, 1988. These dates mean that ISCAS became discoverable in the online catalog of UT by December 9, 1988. A customary library practice is to process a newly cataloged work promptly for public access, usually within a week after the cataloging work is completed. This means that, after processing, the physical copy of ISCAS that contains *Temes* would become publicly available by December 16, 1988.

E. Summary of My Opinion on *Temes*

69. The copyright registration record for IEEE ISCAS that contains *Temes* (**EX1044D**) shows this work was published on June 7, 1988. The MARC record (**EX1044B**) shows UW cataloged this work as a serial issue and the UW copy of *Temes* carries a date stamp indicating the library received this issue on October 27, 1988 (**EX1044A**), making it discoverable in the library's online catalog from that date on, and the physical copy, after processing, would become publicly available by November 3, 1988. The University of Texas Austin Libraries cataloged ISCAS as a book and last modified their MARC record on December 9, 1988 (**EX1044E**), making this work discoverable in their online catalog by at least that date. The physical copy, after processing, would become publicly available by December 16, 1988.

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V. Authenticity and Public Availability of *DMU* (EX1053)

A. Authentication

70. **EX1053** is a true and correct copy of *DMU-6X and DMU-VGX Silicon IMU and Vertical Gyro,* ("*DMU*"), from Crossbow Technology, Inc., that I received from counsel. This copy is identified as "Nintendo Exhibit 1053" and the pages are numbered as "IPR2024-00667 – Page #". This copy is presented as **EX1053** in this declaration.

71. The lower right corner of each page in **EX1053** shows a note of "4/23/98. Revision 2.1" and a "1998" copyright date with Crossbow Technology Inc. as the copyright holder. Page 1 shows the company name and the document title "DMU-6X and DMU-VGX Silicon IMU and Vertical Gyro." The document covers Description of the DMU products, including Features, Applications, Specifications, Principle of Operation, DMU-6X output options, DMU-VGX function, X-View Development Software, and Timing Diagrams. **EX1053** has a total of five pages, including tables and figures.

72. To authenticate **EX1053**, I searched Internet Archive for records. Internet Archive is a digital library that archives scholarly materials, cultural artifacts, and other web resources on the Internet and provides the public with free access to its collections. I have used the Internet Archive in the past and am familiar with their practice of assigning an extended URL to an archived resource in the format of

http://www.archive.org/web/[Year in yyyy][Month in mm][Day in dd][Time code in hh:mm:ss]/[Archived URL] to show the point of time the archived file was captured.

73. Since Internet Archive usually does not archive web resources the moment they appear on the Internet, and a web resource must be available first before it can be archived, the archive date of a file captured by the Internet Archive is typically later than the date when the file first became publicly accessible. In other words, the archive date means that the archived file was typically available before, and definitely no later than, the archive date.

74. **EX1053A** is a true and correct copy of *Crossbow* that I personally located, identified, and obtained from Internet Archive. Page 1 is a screen capture of a Wayback Machine calendar that shows this document was archived twice between "29 Jun 1998" and "2 May 1999" and this particular copy was archived on "JUN 29 1998" and available at https://web.archive.org/web/19980629124810/http://www.xbow.com/pdf/DMU-6X.pdf. Pages 2 to 6 are the PDF of this archived copy of *DMU*. I have closely compared this copy with **EX1053** and found them to be the same.

75. **EX1053** is in a condition that raises no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. In addition, this copy includes the date of production, the revision number, the copyright date, and the copyright holder. Furthermore, **EX1053**

is the same as a copy archived by Internet Archive (**EX1053A**). Based on my review and analysis, it is my opinion that **EX1053** is authentic.

B. Public Availability Date

76. As discussed earlier, the archive date of a web resource archived by Internet Archive is typically later than the first public availability date, because Internet Archive usually does not archive web resources the moment they appear on the Internet. The archive date of "19980629124810" (*i.e.*, June 29, 1998, at 12 p.m., 48 minutes and 10 seconds) for **EX1053A** means that *DMU* became publicly discoverable and accessible on the Internet no later than June 29, 1998.

C. Summary of My Opinion on *DMU*

77. **EX1053** is authentic because this data sheet contains no signs to raise suspicions about its authenticity. The copy is not missing any intermediate pages. There are no visible alterations to the copy. Furthermore, this copy is the same as a copy archived by Internet Archive. It is therefore my opinion that **EX1053** is authentic.

78. The archived copy from Internet Archive (**EX1053A**) shows this data sheet was first archived by Internet Archive on June 29, 1998. It is therefore my opinion that **EX1053** became publicly discoverable and accessible on the Internet by June 29, 1998.

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VI. Authenticity and Public Availability of *WO 97/45699* (EX1040 and EX1057)

A. Authentication

79. **EX1057** is a true and correct copy of "Micromachined Vibratory rate gyroscope, WO 97/45699," ("*WO 97/45699*"), that I received from counsel. This copy is identified as "Nintendo Exhibit 1057" and the pages are numbered as "IPR2024-00667 – Page #". This copy is presented as **EX1057** in this declaration.

80. **EX1040** is a true and correct copy of the first page of "Micromachined Vibratory rate gyroscope, WO 97/45699," ("*WO 97/45699*"), that I received from counsel. This copy is identified as "Nintendo Exhibit 1040" and the single page is numbered as "IPR2024-00667 – Page #". This copy is presented as **EX1040** in this declaration. I have closely compared **EX1040** with the first page of **EX1057** and found them to be the same.

81. Page 1 of **EX1057** shows *WO 97/45699* is a patent application published under the Patent Cooperation Treaty (PCT). This page shows "WO 97/45699" as the International Publication Number of the World Intellectual Property Organization; "4 December 1997 (04.12.97)" as the International Publication Date; "PCT/US97/09150" as the International Application Number, and "30 May 1997 (30.05.97)" as the International Filing Date. "The Regents of the University of California" is shown as the applicant, and Clark, Juneau, and Howe are the inventors. The title of the application is "Micromachined Vibratory Rate Gyroscope." Page 1

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includes an abstract of the application. The application text from page 1 to the end of the document shows a header of "WO 97/45699 PCT/US97/09150" on each page. **EX1057** shows *WO 97/45699* has a total of 102 pages, including equations and figures.

82. To authenticate **EX1057**, I searched Patentscope, a worldwide patent documents database, that provides "access to the international Patent Cooperation Treaty (PCT) applications in the full-text format published in more than 30 countries from national and regional patent offices" (source: Patentscope: Worldwide Patent Database at https://www.ovtt.org/en/resources/patentscope-patent-database/). **EX1057A** is a true and correct copy of *WO 97/45699* that I obtained from Patentscope. After I located the database record for *WO 97/45699* on Patentscope, I selected the Documents tab to download the PDF of the initial application, available at https://patentscope.wipo.int/search/en/detail.jsf?docId=WO1997045699&_cid=P11-MAD3ZF-29133-1. I have closely compared **EX1057** with **EX1057A** and found them to be the same.

83. To further authenticate **EX1057**, I searched Google Patents (https://patents.google.com/) by "WO 97/45699" to locate and obtain a copy of the application from https://patentimages.storage.googleapis.com/c8/95/eb/b0cbad41e86272/WO199704

5699A2.pdf. This copy from Google Patents is presented as **EX1057B** in this declaration. I have closely compared **EX1057** with **EX1057B** and found them to be the same.

84. To provide index information on *WO 97/45699*, I personally located, identified, and obtained the database record for this document from Patentscope at https://patentscope.wipo.int/search/en/detail.jsf?docId=WO1997045699. It is presented as **EX1057C** in this declaration. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

85. Page 1 of **EX1057C** presents the publication number, publication date, international application number, international filing date, applicant, inventors, and priority date. These details match the information presented in **EX1057**, confirming this database record represents *WO 97/45699*. Page 2 shows a screen capture of the information under the Documents tab. This webpage includes PDFs and ZIP for the application file on April 12, 1997. Since Patentscope is a worldwide patent database and the search engine of WIPO, the database is a reliable source of information. It is therefore my opinion that *WO 97/45699* was published on April 12, 1997.

86. **EX1057D** is a true and correct copy of the July 1998 issue of *PCT Gazette, Section II* that I personally located, identified, and obtained from the Internet at https://www.wipo.int/edocs/pctdocs/en/1998/pct_1998_26-section2.pdf. Page 1 indicates Section II provides "Notices and Information Relating to Published

International Applications and/or Entries in Section I" and page 28 (internal page 10962) shows *WO 97/45699* (international application number: PCT/US97/09150) is a published document.

B. Summary of My Opinion on *WO 97/45699*

87. **EX1057** is authentic because it has the same content as the copy obtained from the Patentscope database (**EX1057A**) and the copy obtained from Google Patents (**EX1057B**).

88. The database record from Patentscope shows *WO 97/45699* was published on April 12, 1997 (**EX1057C**). In addition, the July 1998 issue of *PCT Gazette Section II* shows *WO 97/45699* as a published document (**EX1057D**). It is therefore my opinion that *WO 97/45699* was publicly available on April 12, 1997, and interested users would be able to find it soon after April 12, 1997, and definitely no later than July 1998.

VII. Authenticity and Public Availability of *Lemkin* (EX1058)

A. Authentication

89. **EX1058** is a true and correct copy of *Micro Accelerometer Design with Digital Feedback Control,* ("*Lemkin*"), by Mark Alan Lemkin, a doctoral dissertation completed in 1997 at the University of California, Berkeley, that I received from counsel. This copy is identified as "Nintendo Exhibit 1058" and the pages are numbered as "IPR2024-00667 – Page #".

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90. Page 1 of **EX1058** is the "Information to Users" page from UMI that states "[t]his manuscript has been reproduced from the microfilm master." Page 3 is the title page that shows the title, author, committee members, and the degree-granting institution. Page 4 shows the UMI number for this thesis is 9827011. Page 5 is the copyright page of *Lemkin* that shows the thesis has a "1997" copyright date and Mark Alan Lemkin holds the copyright. Page 6 shows the dissertation committee's approval of this thesis and the signatures of committee members signed in August 1997. Pages 8 to 10 (internal pages iv to vi) are the table of contents that shows *Lemkin* has seven chapters, including a bibliography in Chapter 7 that begins on internal page 109 and includes 74 references. **EX1058** shows *Lemkin* includes seven pages of front matter, and the main text has a total of 114 leaves, including equations, figures, and tables.

91. **EX1058** is in a condition that raises no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, this copy includes the approval sheet and signatures of the doctoral committee members from the degree-granting university. Based on my review and analysis, it is my opinion that **EX1058** is authentic.

B. Records of the University of California, Berkeley Library

92. To show *Lemkin* is publicly accessible, I have personally located, identified, and obtained records from the online catalog of the University of

California, Berkeley Library ("UCB Library"). **EX1058A** is a true and correct copy of the bibliographic and MARC records for *Lemkin*. They are the type of records experts in my field would reasonably rely upon when forming their opinions.

93. Pages 1 to 3 are the bibliographic record. Page 1 shows the dissertation title, author, and completion year ("1997"), and shows this work is available at the Northern Regional Library Facility Main (Gardner) Stacks (NRLF) and the local call number is "308t 1997 827." Record details include title, creator, creation date, format, notes, degree, degree-granting institution, and date of degree ("Dec. 1997"). Subjects, genre, related titles, and record source are also included. The title, creator, creation date, format, notes, degree, degree-granting institution, and date of degree match the information presented in **EX1058**, confirming this record represents *Lemkin*.

94. Page 4 is the MARC record I copied from the online catalog of the UCB Library. The first six digits of Field 008 shows the MARC record was created on "980706" (*i.e.*, July 6, 1998), and the code of "s1997" following the record creation date indicates this dissertation has single publication date of 1997. Subfields "a" and "c" of Field 040 show CUY created the record and entered it into the OCLC WorldCat database. According to the Directory of OCLC Members (https://www.oclc.org/en/contacts/libraries.html), "CUY" is the OCLC library symbol for the University of California, Berkeley Library. Fields 008 and 040 inform my opinion that the UCB Library created an original cataloging record for *Lemkin* on

July 6, 1998, making this work discoverable in their online catalog. In addition, subfield "c" of Field 040 shows the record was entered into the OCLC WorldCat database, making it discoverable by users outside of the University of California, Berkeley. A customary library practice is to process a newly cataloged work promptly for access, usually within a week after the cataloging work is completed. It is therefore my opinion that, after processing, *Lemkin* would become publicly accessible at the UCB Library by July 13, 1998.

95. Fields 035 show this record has an OCLC number of 39475574. Field 100 shows the author, Field 245 shows the title, Field 264 shows the dissertation has a "1997" copyright date, and Field 300 shows the dissertation includes seven pages of front matter and the main text has 114 leaves including illustrations. Field 502 shows the degree and degree-granting institution, and Field 504 shows a bibliography note. Field 968 is a local note, and the "Addate" element shows that *Lemkin* was added to the library collections on "980706" (*i.e.*, July 6, 1998).

96. The subjects of *Lemkin* are represented in Field 090 by a local call number and in Field 690 by a local subject heading: Dissertations, Academic $x UCB $x Engineering $y 1991-2000. These subject representations provide broad categories for interested users to discover *Lemkin*.

97. This MARC record (**EX1058A**) has made *Lemkin* discoverable since July 6, 1998, when the UCB Library created the original record for this dissertation.

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As of that date, interested users could discover this work by the author, title, and local subject heading and classification number. The physical copy, after processing, would become publicly accessible by July 13, 1998.

98. As evidence that the UCB Library had an online catalog in operation when *Lemkin* was added to the library collections, I obtained a profile of the library from libraries.org, a directory of libraries throughout the world. This library profile is available at https://librarytechnology.org/library/11. (**EX1058B**.) I personally located, identified, and obtained this record. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

99. The Technology Profile on page 6 of **EX1058B** shows the UCB Library used a locally developed system from 1972 and migrated into Millennium in 2008. These dates mean that in July 1998 interested users would be able to use the local online system to discover *Lemkin*.

100. As further evidence of the availability of an online catalog in 1998, I obtained webpages of the UCB Library catalogs. This archived copy is presented as **EX1058B**. Page 1 is a screen capture of a Wayback Machine calendar that shows the archiving history of the webpage and indicates this particular copy was archived on "DEC 12 1998" and available at https://web.archive.org/web/19981212030542/http://www.lib.berkeley.edu/. Page 2 is the PDF of this archived copy that shows the UCB Library offered several catalogs

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to users in 1998, including "UC Berkeley – Pathfinder or GLADIS." Page 3 is a screen capture of a webpage archived on January 17, 1999, and available at https://web.archive.org/web/19990117024322/http://sunsite2.berkeley.edu:8000/. Page 4 is the PDF of this archived copy that explains Pathfinder "is the Web-browsable online public access catalog of the University of California at Berkeley Library."

101. Records in **EX1058B** confirm that the UCB Library had an online catalog in place by late 1998 and early 1999, and interested users would be able to use Pathfinder to discover *Lemkin* and access the full text at the UCB Library.

C. WorldCat Record from OCLC FirstSearch

102. Subfield "c" of Field 040 of the MARC record for *Lemkin* (**EX1058A**) shows the record was entered into the OCLC WorldCat database. As evidence, I have obtained the WorldCat database record for *Lemkin* from the OCLC FirstSearch system. As discussed earlier, OCLC's WorldCat database is the world's most comprehensive database of information about library collections. Records in this database are shared among OCLC members, available for discovery by subscribers to the OCLC FirstSearch system that supports users to access proprietary databases, and also available for discovery by the general public through the WorldCat.org free web portal. **EX1058C** is a true and correct copy of the record created by the UCB Library in the OCLC FirstSearch system. I personally located, identified, and

obtained this record. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

103. The top of **EX1058C** shows the title, author, and the Accession Number of this record, and also shows the University of California Berkeley Library and two other libraries hold this dissertation. The essential bibliographic details are the same as the details in **EX1058A**. The Database field and the "Date of Entry" field show the record was entered into the OCLC WorldCat database on "19980706" (*i.e.*, July 6, 1998). The OCLC number in the Accession number field is the same as the OCLC number in the UCB Library MARC record. **EX1058C** confirms that the record for *Lemkin* created by the UCB Library was entered into the WorldCat database on July 6, 1998, making this record available to OCLC members for cataloging, collection management, and interlibrary loan purposes. The two other holding libraries in this record show that other libraries did use the UCB Library MARC record for copy cataloging. In addition, the record also became discoverable by subscribers to the OCLC FirstSearch system, and by the public in WorldCat.org, the free web portal.

104. As evidence that the OCLC FirstSearch system was in operation when the record for *Lemkin* became available to subscribers to this system, I located an article about OCLC FirstSearch. **EX1058D** is a true and correct copy of "FirstSearch launched" in the November 1991 issue of *Library Systems Newsletter*. The article reports that a "new online reference tool for end-users is now available from OCLC.

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The FirstSearch Catalog is a relatively low-cost, easy-to-use reference system that library patrons can use to search the OCLC Online Union Catalog, as well as a variety of reference data bases." The "OCLC Online Union Catalog" in this statement was later called OCLC WorldCat database.

D. ProQuest Record

105. ProQuest has offered the ProQuest Digital Dissertations database for interested users to discover and access dissertations of interest. **EX1058E** is a true and correct copy of the database record for *Lemkin*. The record shows the abstract, subjects, classification number, keywords, title, author, pagination, degree date, and dissertation number ("9827011") and also indicates this dissertation has been indexed in "DAI-B 59/03, Dissertation Abstracts International." The print issue of vol. 59, no. 3 (**EX1058F**) discussed below shows this print index issue became publicly available at the University of Wisconsin-Madison Library System on September 15, 1998. Since ProQuest database records usually become available earlier than the print index records, it is my opinion that by September 1998 interested users would have been able to discover *Lemkin* in the ProQuest Dissertation Database. They could search for this dissertation by the title, author, subjects, and keywords.

E. Dissertation Abstracts International Index Record

106. To determine when the print index of vol. 59, no. 3 of the B series of *Dissertation Abstracts International* became publicly available, I obtained a copy of

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the index record for *Lemkin* from the University of Wisconsin-Madison Library system. This copy is presented as **EX1058F** in this declaration.

107. Page 1 is the cover that identifies this issue as vol. 59, no. 3 of *Dissertation Abstracts International B* that has an issue date of "September 1998." The cover shows the title, ISSN, and call number of this issue and two library stamps on the cover show this issue was initially in the "Reference Collection, Memorial Library, Non-Circulating" and later transferred to the stacks. In addition, the cover shows a date stamp of "Received SEP 15 1998 University Library" that documents the receipt date of this issue in the library system. Page 3 is the title page, pages 5 to 6 are the table of contents, page 7 explains the data elements in the index record, and the keyword Index and author index in each issue of *Dissertation Abstracts International*. Pages 8 and 9 explain the purpose of the UMI dissertation database and how users can search for items of interest online, on CD-ROM, and in the print index. Page 10 presents ordering information. Page 14 shows the University of California, Berkeley participates in UMI's dissertation publishing program. Page 20 is an author index page that shows *Lemkin* is indexed in page 1276B. Pages 21 to 22 are keyword index pages that show *Lemkin* is indexed under "micro accelerometer" and "digital feedback control." Pages 23 and 24 (internal page 1276-B and 1277B) show the index record for *Lemkin* that includes the title, author, degree, degree-granting institution, date of degree completion, pagination, committee chair, the order

number of this dissertation ("DA9827011"), and an abstract.

108. **EX1058F** shows that from September 15, 1998 on, interested users would have been able to use the author index and the keyword index to discover *Lemkin* in the print issue of *Dissertation Abstracts International* and use the record to order printed copies of the dissertation.

F. Summary of My Opinion on *Lemkin*

109. **EX1058** contains no signs to raise suspicion about its authenticity. The copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, this copy includes the approval sheet and signatures of the doctoral committee members from the degree-granting university. Based on my review and analysis, it is my opinion that **EX1058** is authentic.

110. The UCB Library's MARC record for *Lemkin* (**EX1058A**) shows that *Lemkin* became discoverable at this library on July 6, 1998, when the original MARC record was created. The OCLC FirstSearch system record for *Lemkin* (**EX1058C**) shows that on July 6, 1998, *Lemkin* became discoverable by OCLC members, OCLC FirstSearch subscribers, and the general public on the Internet. The physical copy, after processing, would become publicly accessible at the UCB Library by July 13, 1998.

111. The ProQuest database record for *Lemkin* (**EX1058E**) became available for searching by September 15, 1998, making this dissertation discoverable to

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database users by that date. The print version of vol. 59, no. 3 of *Dissertation Abstracts International* that contains the index record for *Lemkin* (**EX1058F**) was received on September 15, 1998, by the University of Wisconsin Library system, meaning interested users could discover *Lemkin* from the print index from September 15 of 1998.

112. Based on the documents and records I have reviewed and analyzed, it is my opinion that *Lemkin* became publicly discoverable on July 6, 1998, at the online catalog of the UCB Library. This dissertation also became publicly discoverable on July 6, 1998, by OCLC members, OCLC FirstSearch subscribers, and the general public. In addition, interested users could search the ProQuest Dissertation Database by September 1998 to discover *Lemkin*. From September 15, 1998 on, interested users could also search the print version of *Dissertation Abstracts International* to discover *Lemkin*.

VIII. Authenticity and Public Availability of *Lu* (EX1059)

A. Authentication

113. **EX1059** is a true and correct copy of "A monolithic surface micromachined accelerometer with digital output," ("*Lu*"), by C. Lu, Lemkin, M., and B. E. Boser, *IEEE Journal of Solid-State Circuits*, 30(12), 1367-1373, that I received from counsel. This journal issue has an issue date of "December 1995." This copy is identified as Exhibit 1059, and the pages are marked as "IPR2024-00667 –

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Page #." This counsel copy is presented as **EX1059** in this declaration.

114. Page 1 (internal page 1367) shows the title, authors, abstract, and the International Standard Serial number of *IEEE Journal of Solid-State Circuits* ("0018-9200"). A publication history note shows the manuscript was received on May 20, 1995 and revised on September 1, 1995. This page shows *Lu* has a 1995 copyright date and IEEE holds the copyright. **EX1059** shows *Lu* has a total of seven pages, including 11 figures and 26 references.

115. To authenticate **EX1059**, I searched WorldCat.org (a free web portal) for libraries holding *Lu*, and a record for this paper at https://search.worldcat.org/title/5871955387 shows that the Library of Congress (LC) is one of the holding libraries of the journal that contains *Lu*. After verifying the holdings information in the online catalog of LC, I requested a copy of *Lu* from LC through a document vendor. This LC copy is presented as **EX1059A** in this declaration.

116. **EX1059A** is a true and correct copy of *Lu*. Page 1 shows a bound volume identified as "IEEE Journal of Solid-State Circuits, 30, 1995" that has "TK7871.85 .I23" as its call number. Page 2 is the issue cover that shows this journal is a publication of the IEEE Solid-State Circuits Council, and this issue is volume 30, number 12 that has an issue date of "December 1995" and the ISSN is 0018-9200. The cover includes the table of contents and shows this issue is a special issue on

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"The 1995 ISSCC: Analog, Signal Processing, and Communications Circuits," and *Lu* begins on internal page 1367.

117. Page 3 is the copyright page that shows this issue has a 1995 copyright date and IEEE holds the copyright. It also shows this journal is published monthly by IEEE. Pages 4 and 5 are the table of contents pages. Page 4 carries a library stamp of "Copyright Office MAR 1 1996 Library of Congress." Pages 6 to 12 (internal pages 1367 to 1373) is the full text of *Lu*. I have closely compared **EX1059** with the copy from the Library of Congress (**EX1059A**), and found them to contain the same content for *Lu*.

118. **EX1059** is in a condition that creates no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, **EX1059** has the same content as **EX1059A**, which is scanned from a copy held by the Library of Congress. Based on my review and analysis, it is my opinion that **EX1059** is authentic.

B. Records of Library of Congress

119. To determine the public availability date of *Lu*, I obtained records for the journal containing *Lu* from the online catalog of the Library of Congress. **EX1059B** is a true and correct copy of the bibliographic and MARC serial records for *IEEE Journal of Solid-State Circuits*. I personally located, identified, and obtained these records. They are the type of records experts in my field would reasonably rely

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upon when forming their opinions.

120. Pages 1 to 4 of **EX1059B** are the bibliographic record that shows the journal title, publisher, current publication frequency, and ISSN. These details match the information presented in **EX1059A**, confirming this serial record represents the journal containing *Lu*. The bibliographic record also includes variant titles, subject headings, classification numbers, and Library of Congress catalog number.

121. The Item Availability area on pages 3 and 4 shows Library of Congress has two copies of this journal, the journal call number is "TK7871.85 .I23," users can request access at the Jefferson or Adams Building Reading Rooms, and the status of the issues is "Not Charged" (meaning available for user request).

122. Pages 5 to 8 are the MARC record. The first six digits of Field 008 show the MARC record was created on "750901" (*i.e.*, September 1, 1975), and the code of "c19669999" following the record creation date indicates the journal is a continuing resource that began publication in 1966 and has no predetermined conclusion date. Subfields "a" and "c" of Field 040 show MUL (the Minnesota Union List) created the original serial record, and subfield "d" shows "DLC" (Library of Congress) modified the original record later.

123. Field 022 shows the ISSN of this journal. Field 245 shows the title, and Fields 246 show two variant titles are included to help users discover this journal. Field 260 shows IEEE of New York, NY has published this journal since 1966. Field

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362 shows the journal began in September 1966, and Field 310 shows the publication frequency since 1991 is "Monthly." Field 530 shows this journal is also available on CD-ROM. Field 550 shows the issue bodies of this journal. Fields 710 show the two issuing bodies are included in the MARC record to help users discover this journal.

124. The subjects of this journal are represented in Field 050 by a Library of Congress Classification (LCC) number of "TK7871.85" that represents general works on "Semiconductors" (source: Library of Congress Classification, Schedule T, at https://www.loc.gov/aba/publications/FreeLCC/LCC_T2019TEXT.pdf). Subjects are also represented in Fields 650 by three Library of Congress subject headings with "Semiconductors," "Integrated circuits," and "Solid state electronics" as the main topics, each followed by "Periodicals" as a form subheading encoded in subfield "v" ("|v") to indicate the main topics are treated in a journal. These subject representations enable users to conduct subject searches to discover the journal that contains *Lu*.

125. This MARC record (**EX1059B**) shows that *IEEE Journal of Solid-State Circuits* is a long-running journal and the MARC record makes this journal discoverable. The date stamp of "MAR 1 1996" on **EX1059A** informs my opinion that this MARC record was discoverable in the online catalog of the Library of Congress at least by that date. As of March 1, 1996, interested users would be able to discover this journal by its ISSN, title, variant titles, and issuing bodies of the journal.

They would also be able to conduct subject searches to discover this journal.

126. The "Mar 1 1996" date stamp on **EX1059A** shows the Library of Congress received the issue containing *Lu* on March 1, 1996. As discussed above, a customary library practice is to place a newly received journal issue through the serial check-in process to document its receipt, and the new issue is usually processed promptly to make it publicly accessible, usually within a week after serial check-in is completed. It is therefore my opinion that the issue containing *Lu* became publicly accessible at the Library of Congress by March 8, 1996.

127. As evidence that the Library of Congress had an online catalog in operation in 1996 when the journal issue containing *Lu* was received, I obtained a copy of "LOCIS: Library of Congress Information System" archived by Internet Archive. I personally located, identified, and obtained this profile. This is the type of record experts in my field would reasonably rely upon when forming their opinions. This archived copy is presented as **EX1059C** in this declaration. This Internet Archive record shows that by May 1997 interested users could use Telnet to log into the online catalog of the Library of Congress remotely. Since Internet Archive was launched in May 1996, web resources before that date could not be captured, hence the 1997 date. My personal experience is that one could use the Library of Congress online catalog on site and remotely since the early 1990s.

128. Page 1 is a screen capture of a Wayback Machine calendar that shows

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this webpage was archived 75 times between 1997 and 2021, and this particular copy was archived on "May 24 1997" and available at https://web.archive.org/web/19970524160715/http://library.usask.ca/hytelnet/us3/us373.html. Page 2 is a PDF of the archived webpage that shows that by May 1997 interested users would be able to telnet into the Library of Congress Information System that includes their catalog. Telnet is a network protocol that supports users to access remote systems on the Internet or other local area networks (source: Telnet at https://en.wikipedia.org/wiki/Telnet). **EX1059C** confirms that by May 1997 interested users were able to log into the Library of Congress online catalog on the Internet.

C. Copyright Record

129. **EX1059D** is a true and correct copy of the copyright registration record for *IEEE Journal of Solid-State Circuits* that contains *Lu*. I personally located, identified, and obtained this record from the public catalog of the US Copyright Office. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

130. The title, imprint, ISSN, and copyright claimant match the information presented in **EX1059B**, confirming this record represents the journal that contains *Lu.* The "Issues Registered" field shows vol. 30, no. 12 has a publication date of "1996-02-12" (*i.e.*, February 12, 1996). This date aligns well with the date stamp date

in **EX1059A** that shows the Library of Congress received the journal issue containing *Lu* on March 1, 1996.

D. Summary of My Opinion on *Lu*

131. **EX1059** is authentic because it contains no signs to raise suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. In addition, this copy has the same content as the copy held by the Library of Congress copy (**EX1059A**).

132. The copyright registration record for the journal containing *Lu* shows vol. 30, no. 12 was published on February 12, 1996 (**EX1059D**). The MARC serial record of the Library of Congress (**EX1059B**) shows *IEEE Journal of Solid-State Circuits* is a long-running journal, and the MARC record has made this journal discoverable in the library's catalog. The date stamp on the Library of Congress copy of *Lu* (**EX1059A**) shows the library received the journal issue containing *Lu* on March 1, 1996. It is therefore my opinion that the journal containing *Lu* became discoverable at the Library of Congress by at least that date, and the physical copy of the issue containing *Lu*, after processing, would become publicly accessible at the Library of Congress by March 8, 1996.

IX. Authentication and Public Availability of *Yun* (EX1060)

A. Authentication

133. **EX1060** is a true and correct copy of "Surface micromachined, digitally

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force-balanced accelerometer with integrated CMOS detection circuitry," ("*Yun*"), by W. Yun, R.T. Howe, and P.R. Gray, in *IEEE Solid-State Sensor and Actuator Workshop Technical Digest*, pp. 126-131, that I received from counsel. This document is identified as Nintendo Exhibit 1060, and the pages are marked as "IPR2024-00667 – Page #." This copy is presented as **EX1060** in this declaration.

134. Page 1 (internal page 126) shows the title, authors, abstract, and "0-7803-0456-X" as the ISBN of the publication that contains *Yun*. **EX1060** has a total of six pages, including nine figures, and 21 references.

135. To authenticate **EX1060**, I searched WorldCat.org to identify libraries holding the conference proceedings containing *Yun*, and learned that the Library of Congress is one of the holding libraries. After verifying the holdings information in their online catalog, I obtained a copy of *Yun* from the Library of Congress through a document vendor. This library copy is presented as **EX1060A** in this declaration.

136. Page 1 shows a bound volume identified as IEEE Solid-State Sensor and Actuator that has a call number of "TK 7871.85 .I28 1992." Page 2 is the front cover that shows "IEEE Solid-State Sensor and Actuator Workshop: Technical Digest" as the title and indicates the workshop dates and location. The cover carries a library date stamp of "Library of Congress SEP 23 1992 Copyright Office." It also shows the IEEE catalog number and Library of Congress number for this publication. Page 3 is the title page that shows the same title and workshop information as the

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cover and the IEEE Electron Devices Society as the workshop sponsor. Page 4 is the copyright page that shows this publication has a "1992" copyright date and the Institute of Electrical and Electronics Engineers, Inc. holds the copyright. This page also shows the ISBNs, IEEE catalog number, and Library of Congress catalog number for this publication. The top of this page shows a hand-written call number of "TK7871.85 .I28 1992." Pages 5 to 9 are the table of contents, and pages 7 shows *Yun* is included in Session 5 Accelerometers and begins on internal page 126. Pages 10 to 15 (internal pages 126 to 131) are the full text of *Yun*. I have closely compared **EX1060** with this library copy and found them to have the same content for *Yun*.

137. **EX1060** is in a condition that raises no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, **EX1060** has the same content as the Library of Congress copy (**EX1060A**). Based on my review and analysis, it is my opinion that **EX1060** is authentic.

B. Records of Library of Congress

138. To determine the public availability date of the *IEEE Solid-State Sensor and Actuator Workshop Technical Digest* ("IEEE SSAW") that contains *Yun* at libraries, I obtained records for the publication from the online catalog of the Library of Congress. **EX1060B** is a true and correct copy of the bibliographic and MARC records for this work. I personally located, identified, and obtained these records.

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They are the type of records experts in my field would reasonably rely upon when forming their opinions.

139. Pages 1 and 2 of **EX1060B** are the bibliographic record. Page 1 shows IEEE SSAW is cataloged as a book by the Library of Congress. The bibliographic record includes the workshop name, title of IEEE SSAW, publisher, copyright date, ISBNs, Call number, and Library of Congress cataloging number. These details match the information presented in **EX1060A**, confirming this record represents IEEE SSAW that contains *Yun*.

140. Pages 3 and 4 are the MARC record. The first six digits of Field 008 show the MARC record was first created on "910907" (*i.e.*, September 7, 1991), and the code of "s1992" following the record creation date shows this work has a single publication date of 1992. Field 955 records local cataloging activities and shows the Library of Congress completed their cataloging work for this publication on "04-07-93" (*i.e.*, April 7, 1993). Subfield "a" of Field 040 shows DLC (*i.e.*, Library of Congress) created the original MARC record. Data from Fields 008, 955, and 040 inform my opinion that the Library of Congress created an original record created on September 7, 1991 before this work was published and completed their cataloging work on April 7, 1993. As discussed above, a customary library practice is to process a newly cataloged monograph promptly for user access, usually within a week after the cataloging work is completed. My personal experience with the Library of

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Congress collections is that it can take one to three months for a newly cataloged monograph to become publicly available. It is therefore my opinion that IEEE SSAW that contains *Yun* became discoverable at the Library of Congress from April 7, 1993 on, and the physical copy, after processing would become publicly accessible by July 7, 1993.

141. Field 010 shows the Library of Congress catalog number, Fields 020 show the ISBNs, Field 111 shows the workshop name is presented as the corporate author, Field 245 shows the title, subtitles, and statement of responsibility, and Field 260 shows the publisher and copyright date. Field 300 shows physical details. Field 500 shows the IEEE catalog number. Field 504 shows a note on bibliographical references and index. Field 710 shows the workshop sponsor IEEE Electron Devices Society is included to help users discover IEEE SSAW.

142. The subjects of this publication are represented in Field 050 by a Library of Congress Classification (LCC) number of "TK7871.85" that represents general works on "Semiconductors" (source: Library of Congress Classification Schedule T at https://www.loc.gov/aba/publications/FreeLCC/LCC_T2019TEXT.pdf); and in Field 082 by a Dewey Decimal Classification (DDC) number of "621.381" that represents "Electronics" (source: Dewey Decimal Classification 600 Technology (Applied Sciences) at

https://www.oclc.org/content/dam/oclc/webdewey/help/600.pdf). Subjects are also represented in Fields 650 by three Library of Congress subject headings, with "Solid state electronics," "Detectors," and "Actuators" as the main topics, each followed by "Congresses" as a form subheading encoded in subfield "x" to indicate the main topics are treated at a conference. These subject representations enable users to conduct subject searches to discover IEEE SSAW that contains *Yun*.

143. The MARC record (**EX1060B**) was completed at the Library of Congress on April 7, 1993, making IEEE SSAW that contains *Yun* discoverable in the library's online catalog from that date on. As of that date, interested users would be able to discover this publication by the Library of Congress catalog number, ISBNs, workshop name, publication title, and the workshop sponsor. Interested users could also conduct subject searches to discover this work.

144. As evidence that the Library of Congress had an online catalog in operation in 1993 when the library's MARC record for IEEE SSAW was completed, I obtained a copy of "LOCIS: Library of Congress Information System" archived by Internet Archive. I personally located, identified, and obtained this profile. This is the type of record experts in my field would reasonably rely upon when forming their opinions. This archived copy is presented as **EX1060C** in this declaration. This Internet Archive record shows that by May 1997 interested users could use Telnet to log into the online catalog of the Library of Congress remotely. Since Internet

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Archive was launched in May 1996, web resources before that date could not be captured, hence the 1997 date. My personal experience is that one could use the Library of Congress online catalog on site and remotely since the early 1990s.

145. Page 1 is a screen capture of a Wayback Machine calendar that shows this webpage was archived 75 times between 1997 and 2021, and this particular copy was archived on "May 24 1997" and available at https://web.archive.org/web/19970524160715/http://library.usask.ca/hytelnet/us3/us373.html. Page 2 is a PDF of the archived webpage that shows that by May 1997 interested users would be able to telnet into the Library of Congress Information System that includes their catalog. Telnet is a network protocol that supports users to access remote systems on the Internet or other local area networks (source: Telnet at https://en.wikipedia.org/wiki/Telnet). **EX1060C** confirms that by May 1997 interested users were able to log into the Library of Congress online catalog on the Internet.

C. Copyright Registration Record

146. **EX1060D** is a true and correct copy of the copyright registration record for *IEEE Solid-State Sensor and Actuator Workshop: 1992 ... technical digest* that contains *Yun*. I personally located, identified, and obtained this record from the public catalog of the US Copyright Office. This is the type of record experts in my field would reasonably rely upon when forming their opinions.

147. The title, performer, and copyright claimant match the information presented in the Library of Congress copy of *Yun* (**EX1060A**), confirming this record represents the workshop digest that contains *Yun*. The "Date of Publication" field shows this work was published on "1992-06-22" (*i.e.*, June 22, 1992). This date aligns well with the date of April 7, 1993 when the Library of Congress completed their cataloging record for this publication.

D. Summary of My Opinion on *Yun*

148. **EX1060** is in a condition that creates no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. Furthermore, **EX1060** has the same content as **EX1060A**, which is scanned from a copy held by the Library of Congress. Based on my review and analysis, it is my opinion that **EX1060** is authentic.

149. The copyright registration record for IEEE SSAW that contains *Yun* (**EX1060D**) shows this work was published on June 22, 1992. The MARC record (**EX1060B**) shows the Library of Congress completed their cataloging work on April 7, 1993, making this work publicly discoverable in their online catalog from that date on. The physical copy, after processing, would become publicly accessible by July 7, 1993.

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X. Authenticity and Public Availability of *ACH-04-08-05* (EX1063)

A. Authentication

150. **EX1063** is a true and correct copy of "Accelerometer ACH-04-08-05," ("*ACH-04-08-05*"), published by Measurement Specialties, that I received from counsel. This copy is identified as "Nintendo Exhibit 1063" and the pages are numbered as "IPR2024-00667 – Page #". This copy is presented as **EX1063** in this declaration.

151. Page 1 of **EX1063** shows *ACH-04-08-05* is an application specification produced by Measurement Specialties that covers "the application requirements of Measurement Specialties Accelerometer ACH-04-08-05." Page 1 shows this document is "Application Specification 114-27002, 27 AUG 98 Rev A." The bottom of the page shows this document has a "1996" copyright date and MSI holds the copyright. **EX1063** has a total of 10 pages, including three major sections (1. Introduction, 2.0 Reference Materials, and 3.0 Requirements) and figures.

152. To authenticate **EX1063**, I searched Internet Archive for records. Internet Archive is a digital library that archives scholarly materials, cultural artifacts, and other web resources on the Internet and provides the public with free access to its collections. I have used the Internet Archive in the past and am familiar with their practice of assigning an extended URL to an archived resource in the format of http://www.archive.org/web/[Year in yyyy][Month in mm][Day in dd][Time code in

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hh:mm:ss]/[Archived URL] to show the point of time the archived file was captured.

153. Since Internet Archive usually does not archive web resources the moment they appear on the Internet, and a web resource must be available first before it can be archived, the archive date of a file captured by the Internet Archive is typically later than the date when the file first became publicly accessible. In other words, the archive date means that the archived file was typically available before, and definitely no later than, the archive date.

154. **EX1063A** includes a true and correct copy of the website for Piezo Film Technical Manual and a copy of *ACH-04-08-05*. I personally located, identified, and obtained from Internet Archive. They are the type of material experts in my field would reasonably rely upon when forming their opinions.

155. Page 1 is a screen capture of a Wayback Machine calendar that shows the technical manual website was archived 18 times between 1999 and 2021, and this particular copy was archived on "FEB 21 1999" and available at https://web.archive.org/web/19990221083428/http://www.msiusa.com/piezo_film_manual.htm. The link to "Accelerometer ACH Specifications 805SPEC3.pdf" from this website leads to a copy of "Accelerometer ACH-04-08-05" archived by Internet Archive on September 25, 2000 (available at https://web.archive.org/web/20000925200945/http://www.msiusa.com/805spec3.pdf). This archived copy of *ACH-04-08-05* is included as pages 4 to 13 of **EX1063A**. I

have closely compared this archived copy with **EX1063** and found them to be the same.

156. **EX1063** is in a condition that raises no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. In addition, this copy includes the company that produces this product, and shows the copyright date, and the copyright holder. Furthermore, **EX1063** is the same as a copy archived by Internet Archive in 2000 (**EX1063A**). Based on my review and analysis, it is my opinion that **EX1063** is authentic.

B. Usage Records

157. The copy of *ACH-04-08-05* archived by Internet Archive in 2000 does not mean the first public availability date of this document was 2000. I have discovered three documents that discuss *ACH-04-08-05*. My discussion below shows that these citing documents were available in 1998 and early 1999. They inform my opinion that *ACH-04-08-05* was publicly discoverable and accessible soon after it was published in August 1998, and definitely no later than February 21, 1999.

158. **EX1063B** is a true and correct copy of "Application report: 3-V accelerometer featuring TLV2772" by Jim Karki of Advanced Analog Products, Advanced Analog Applications Group, that I located on the Internet at https://www.ti.com/lit/an/slva040/slva040.pdf?ts=1746405483657&ref_url=https%253A%252F%252Fwww.google.com%252F. This 1998 application report is an

early citation to *ACH-04-08-05*. The references appear on pages 4, 6, 13, 15, 18, 20, and 22.

159. **EX1063C** is a true and correct copy of "Piezo Film Sensors Technical Manual, REV B" from Measurement Specialties, Inc. that I personally located, identified, and obtained from the Internet at https://cdn.sparkfun.com/assets/d/a/a/b/b/Piezo_Film_Sensors_Technical_Manual.pdf. Page 1 shows this manual is "P/N 1005663-1 REV B 02 APR 99" indicating it was produced on April 2, 1999. This manual discusses ACH-04-08-05 on pages 52, 53 and 54.

160. **EX1063D** is a true and correct copy of the website for the Piezo Film Technical Manual. Page 1 shows a screen capture of a Wayback Machine that shows this website was archived 18 times between 1999 and 2021, and this particular copy was archived on "FEB 21 1999" and available at https://web.archive.org/web/19990221083428/http://www.msiusa.com/piezo_film_manual.htm. The archived website includes links to 18 parts of the online version of "Piezo Film Sensors Technical Manual" and the link for Part 11 leads to a copy archived on September 25, 2000 (available at https://web.archive.org/web/20000925200634/http://www.msiusa.com/PART11-INT.pdf). Page 5 of **EX1063D** shows the Internet version of "Piezo Film Sensors Technical Manual" has an "August 1998" publication date, and Part 11 includes three

pages that discuss ACH-04-08-05.

161. **EX1063B**, **EX1063C**, and **EX1063D** show *ACH-04-08-05* was discussed in 1998, August 1998, and April 1999; and the online document that covers *ACH-04-08-05* is included in a website archived by Internet Archive on February 21, 1999.

C. Summary of My Opinion on *ACH-04-08-05*

162. **EX1063** is authentic because it contains no signs to raise suspicions about its authenticity. The copy is not missing any intermediate pages, and there are no visible alterations to the copy. Furthermore, **EX1063** is the same as a copy of *ACH-04-08-05* archived by Internet Archive in 2000. It is therefore my opinion that **EX1063** is authentic.

163. The 2000 archive date of *ACH-04-08-05* does not represent the first public availability date of this document, because Internet Archive usually does not archive web files as soon as they appear on the Internet, and EX1063 carries a publication date of August 27, 1998. Documents from 1998 (**EX1063B**), 1999 (**EX1063C**), and August 1998 (**EX1063D**) show that *ACH-04-08-05* was discussed in these documents. These documents show usage of *ACH-04-08-05* and inform my opinion that *ACH-04-08-05* was publicly available soon after it was published on August 27, 1998, and definitely no later than February 21, 1999, when the website that links to the online technical manual discussing *ACH-04-08-05* was archived by

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Internet Archive.

XI. Authenticity and Public Availability of *ADXL05* (EX1064)

A. Authentication

164. **EX1064** is a true and correct copy of "ADXL05* ±1g to ±5g Single Chip Accelerometer with Signal Conditioning," ("*ADXL05*"), from Analog Devices, that I received from counsel. This copy is identified as "Nintendo Exhibit 1064" and the pages are numbered as "IPR2024-00667 – Page #". This copy is presented as **EX1064** in this declaration.

165. Page 1 of **EX1064** shows *ADXL05* is a product of Analog Devices, and the company issues this data sheet with a title of "ADXL05* ±1g to ±5g Single Chip Accelerometer with Signal Conditioning." The bottom of page 1 shows **EX1064** has a "1996" copyright date and Analog Devices, Inc. holds the copyright. **EX1064** has a total of 20 pages, including equations, tables, and 33 figures. The bottom of each page is marked by "REV. B" indicating this document is Revision B. Page 20 carries a notation of "C2028b-5-3/96" and indicates the document was printed in the U.S.A.

166. To authenticate **EX1064**, I searched Internet Archive for records. Internet Archive is a digital library that archives scholarly materials, cultural artifacts, and other web resources on the Internet and provides the public with free access to its collections. I have used the Internet Archive in the past and am familiar with their practice of assigning an extended URL to an archived resource in the format of

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http://www.archive.org/web/[Year in yyyy][Month in mm][Day in dd][Time code in hh:mm:ss]/[Archived URL] to show the point of time the archived file was captured.

167. Since Internet Archive usually does not archive web resources the moment they appear on the Internet, and a web resource must be available first before it can be archived, the archive date of a file captured by the Internet Archive is typically later than the date when the file first became publicly accessible. In other words, the archive date means that the archived file was typically available before, and definitely no later than, the archive date.

168. **EX1064A** is a true and correct copy of *ADXL05* that I personally located, identified, and obtained from Internet Archive. Page 1 is a screen capture of a Wayback Machine calendar that shows this document was archived four times between 2015 and 2024, and this particular copy was archived on "NOV 06 2015" and available at https://web.archive.org/web/20151106170116/https://www.analog.com/media/en/technical-documentation/obsolete-data-sheets/66309706ADXL05.pdf. Pages 2 to 21 are the PDF of this archived copy of *ADXL05*. I have closely compared this 2015 archived copy with **EX1064** and found them to be the same. The only difference is **EX1064** carries a watermark of "OBSOLETE." Since the notation of "c1808b-5-3/96" in **EX1064** and **EX1064A** indicates the document was produced in 1996, and ADXL05 may have evolved in subsequent years, it is understandable why a copy of

the ADXL05 datasheet archived in 2015 (**EX1064A**) would carry an "OBSOLETE" watermark. In short, it is my opinion that the "OBSOLTE" watermark was added to this datasheet sometime after the document was produced in 1996, and the watermark was captured by Internet Archive when it archived this document in 2015.

169. **EX1064** is in a condition that raises no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. In addition, this copy includes the date of production, the revision number, the copyright date, and the copyright holder. Furthermore, **EX1064** is the same as a copy archived by Internet Archive in 2015 (**EX1064A**), except for the "OBSOLETE" watermark. Based on my review and analysis, it is my opinion that **EX1064** is authentic.

B. Records on Public Availability Date

170. The copy of *ADXL05* archived by Internet Archive in 2015 does not mean the first public availability date of this document was 2015. Three Internet Archive records about ADXL05 that I obtained and discussed below show that *ADXL05* was in fact publicly discoverable and accessible by June 6, 1997.

171. **EX1064B** is a true and correct copy of a press release of Analog Devices that is entitled "Multi-Purpose Accelerometer Measures Low g Forces with 0.005g Resolution [ADXL05]" and has an original release date of "May 1, 1995." Page 1 is a screen capture of a Wayback Machine calendar that shows this document

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was archived eight times by Internet Archive between 1997 and 2001, and this particular copy was archived on "JUN 06 1997" and available at https://web.archive.org/web/19970606212637/http://www.analog.com/publications/press/products/ADXL05_050195.html. Pages 2 and 3 are the PDF of this archived press release webpage that explains that "Analog Devices' ADXL05 is the industry's first single-chip integrated low-g accelerometer which resolves minute changes in acceleration (from 0 g to ±5 g full scale) with 0.005 g resolution-ten times more precise than the ADXL50 ±50 g airbag version." It further explains that the ADXL05 "is designed to simplify system complexity, improve performance, and reduce engineering costs in automotive, industrial, and commercial applications where tilt, inertial, shock, vibration, velocity and acceleration characteristics must be measured." This archived press release webpage shows a revision date of "March 4, 1997." It is therefore my opinion that the "March 4, 1997" version of the press release on ADXL05 became publicly discoverable and accessible by at least June 6, 1997, the archive date of this copy. Interested users would have been able to discover this archived copy to learn about ADXL05, then explore the company website to learn more about ADXL05.

172. **EX1064C** is a true and correct website for ADXL05 that I located on the website of Analog Devices. Page 1 is a screen capture of a Wayback Machine calendar that shows this website was archived 23 times between 1997 and 2021, and

this particular copy was archived on "JUN 06 1997" and available at https://web.archive.org/web/19970606201119/http://www.analog.com/products/sheets/ADXL05.html. Since the website was designed with frames, I used screen captures (as pages 1 and 2 of **EX1064C**) to show that this archived website contains a general description of ADXL05, a datasheet for this product (access through a link to "±1g to ±5g Single Chip Accelerometer with Signal Conditioning"), and three press releases on ADXL05. Internet Archive has not archived the link to this datasheet, and that is understandable because Internet Archive does not archive everything on the Internet. Nevertheless, this website for ADXL05 archived on June 6, 1997, does show the "±1g to ±5g Single Chip Accelerometer with Signal Conditioning" datasheet was available at this website by at least that date.

173. As evidence that the "±1g to ±5g Single Chip Accelerometer with Signal Conditioning" datasheet was archived by Internet Archive, I obtained the Wayback Machine index pages for the product sheets section of the Analog Devices website (http://www.analog.com/products/sheets/). **EX1064D** is a true and correct copy of the Wayback Machine index pages I personally located, identified, and obtained. Page 1 shows 3,081 URLs from the product sheets section have been archived by Internet Archive, and page 3 shows "http://www.analog.com:80/products/sheets/ADXL05.html" was archived 15 times between "Jun 6, 1997" and "Feb 11, 2021." **EX1064D** supports my finding from

EX1064C that the ADXL05 website (and the *ADXL05* datasheet contained therein) became publicly accessible by at least June 6, 1997.

C. Summary of My Opinion on *ADXL05*

174. **EX1064** is authentic because this datasheet contains no signs to raise suspicions about its authenticity. The copy is not missing any intermediate pages. There are no visible alterations to the copy. Furthermore, this copy is the same, except for the watermark, as a copy archived by Internet Archive in 2015. It is therefore my opinion that **EX1064** is authentic.

175. An archived copy of a press release from Analog Devices announced the purpose and strengths of ADXL05 (**EX1064B**). The press release webpage in this archived copy was last updated by the company on March 4, 1997, and archived by Internet Archive on June 6, 1997. This means that by at least June 6, 1997, interested users would have been able to discover this archived press release to learn about ADXL05 and explore the Analog Devices website to learn more about the features, specification, and applications of this product. The website for ADXL05 was first archived by Internet Archive on June 6, 1997 (**EX1064C**) and it includes a link to the "±1g to ±5g Single Chip Accelerometer with Signal Conditioning" datasheet. Index pages from the Wayback Machine show the website for ADXL05 was indeed archived by Internet Archive starting on June 6, 1997.

176. Based on the documents and records I have reviewed, it is my opinion

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that the datasheet of "ADXL05 ±1g to ±5g Single Chip Accelerometer with Signal Conditioning" (*ADXL05*) was publicly discoverable and accessible on the Internet by at least June 6, 1997.

XII. Authenticity and Public Availability of *ADXL50* (EX1065)

A. Authentication

177. **EX1065** is a true and correct copy of "ADXL50* Monolithic Accelerometer With Signal Conditioning," ("*ADXL50*"), from Analog Devices, that I received from counsel. This copy carries a watermark of "OBSOLETE" and is identified as "Nintendo Exhibit 1065" and the pages are numbered as "IPR2024-00667 – Page #". This copy is presented as **EX1065** in this declaration.

178. Page 1 of **EX1065** shows *ADXL50* is a product of Analog Devices, and the company issues this data sheet with a title of "ADXL50* Monolithic Accelerometer with Signal Conditioning." The bottom of page 1 shows **EX1065** has a "1996" copyright date and Analog Devices, Inc. holds the copyright. **EX1065** has a total of 16 pages, including equations, tables, and 30 figures. The bottom of each page is marked by "REV. B" to indicate this document is Revision B. Page 16 carries a notation of "C1808b-5-3/96" and indicates the document was printed in the U.S.A.

179. To authenticate **EX1065**, I searched Internet Archive for records. Internet Archive is a digital library that archives scholarly materials, cultural artifacts, and other web resources on the Internet and provides the public with free access to

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its collections. I have used the Internet Archive in the past and am familiar with their practice of assigning an extended URL to an archived resource in the format of http://www.archive.org/web/[Year in yyyy][Month in mm][Day in dd][Time code in hh:mm:ss]/[Archived URL] to show the point of time the archived file was captured.

180. Since Internet Archive usually does not archive web resources the moment they appear on the Internet, and a web resource must be available first before it can be archived, the archive date of a file captured by the Internet Archive is typically later than the date when the file first became publicly accessible. In other words, the archive date means that the archived file was typically available before, and definitely no later than, the archive date.

181. **EX1065A** is a true and correct copy of *ADXL50* that I personally located, identified, and obtained from Internet Archive. Page 1 is a screen capture of a Wayback Machine calendar that shows this document was archived six times between "7 Jul 1997" and "15 Jan 2006" and this particular copy was archived on "JUL 07 1997" and available at https://web.archive.org/web/19970707142701/http://www.analog.com/pdf/adxl50.pdf. Pages 2 to 17 are the PDF of this archived copy of *ADXL50*. I have closely compared this copy with **EX1065** and found them to be the same. Since the notation of "c1808b-5-3/96" on PDF page 17 indicates the document was produced in 1996, it is understandable why the 1997 archived copy (**EX1065A**) does not carry a mark

of "OBSOLETE." It is my opinion that the "OBSOLTE" watermark was added to this data sheet after the document was archived by Internet Archive on July 7, 1997.

182. **EX1065** is in a condition that raises no suspicion about its authenticity. Specifically, this copy is not missing any intermediate pages, and there are no visible alterations to the document. In addition, this copy includes the date of production, the revision number, the copyright date, and the copyright holder. Furthermore, **EX1065** is the same as a copy archived by Internet Archive in July 1997 (**EX1065A**). Based on my review and analysis, it is my opinion that **EX1065** is authentic.

B. Public Availability Date

183. As discussed earlier, the archive date of a web resource archived by Internet Archive is typically later than the first public availability date, because Internet Archive usually does not archive web resources the moment they appear on the Internet. The archive date of "19970707142701" (*i.e.*, July 7, 1997, at 2 p.m., 27 minutes and 1 second) for **EX1065A** means that *ADXL50* became publicly discoverable and accessible on the Internet no later than July 7, 1997.

C. Summary of My Opinion on *ADXL50*

184. **EX1065** is authentic because this data sheet contains no signs to raise suspicions about its authenticity. The copy is not missing any intermediate pages. There are no visible alterations to the copy. Furthermore, this copy is the same as a copy archived by Internet Archive. It is therefore my opinion that **EX1065** is

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authentic.

185. The archived copy from Internet Archive (**EX1065A**) shows this data sheet was first archived by Internet Archive on July 7, 1997. It is therefore my opinion that **EX1065** became publicly discoverable and accessible on the Internet by July 7, 1997.

XIII. Conclusion

186. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in this proceeding. If required, I will appear for cross-examination at the appropriate time.

187. I hereby declare that all statements made herein of my own knowledge are true and that all statements are made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. §1001.

Dated: 5-6-2025

Respectfully submitted,

Ingrid Hsieh-Yee

Ingrid Hsieh-Yee, Ph.D.
Annapolis, Maryland

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APPENDIX A

Ingrid Hsieh-Yee

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Education

Ph.D. 1990. Library and Information Studies, University of Wisconsin-Madison
Minors: Sociology and Psychology

M.A. 1984. Library and Information Studies, University of Wisconsin-Madison.

M.A. 1983. Comparative Literature, University of Wisconsin-Madison.

B.A. 1980. Foreign Languages and Literature, National Taiwan University.

Work Experience

Professor, School/Dept. of Library and Information Science, Catholic University of America, 1990-2022 (Assistant Professor, 1990-1996; Associate Professor, 1997-2004; Professor 2004-2022; Professor Emerita 2022)

Co-Chair, Dept. of Library and Information Science, Catholic University of America, June 2015-August 2016.

Acting Dean, School of Library and Information Science, Catholic University of America, January 2010-June 2012.

Cataloger, Dept. of Legislative Reference Library, Annapolis, Maryland, 1989-1990.

Lecturer, School of Library and Information Studies, University of Wisconsin-Madison, 1988.

Teaching Assistant, School of Library and Information Studies, University of Wisconsin-Madison, 1986-1988.

Cataloger, Health Sciences Library, University of Wisconsin-Madison, 1984-1986.

Areas of Teaching and Research Interests

Information Organization and Access; Metadata; Cataloging & Classification; Information Architecture; Information Retrieval; Digital Collections; Social Media; Scholarly

Communication; Information Behavior; Health Informatics; Human Computer Interaction; Usability Studies

Grants & Honors

Cultural Heritage Information Management Project. IMLS grant. Amount: $498,741. Period: Aug. 2012 to July 2015. Co-PI with Dr. Youngok Choi.

D.C. Health Information Technology (HIT4): Building Capacity & Providing Access in Our Nation's Capital. Dept. of Labor H2B Training Grant. Grant amount: $4,175,500. Grant period: Nov. 2011 to Dec. 2015. Partner with the Metropolitan School of Professional Studies of the Catholic University of America, Children's National Medical Center, D.C. Department of Employment Services, Holy Cross Hospital, Howard University, Center for Urban Progress, Providence Hospital, and Sibley Memorial Hospital.

Capital Health Careers Project. Department of Labor Healthcare Sector and Other High Growth and Emerging Industries Grant. Grant amount: $4,953,999. Grant period: March 2010 – February 2013. Awarded to a group of healthcare organizations and educational institutions in Washington, D.C. Providence Health Foundation of Providence Hospital (Lead institution). Part of the grant supported the development of a Master's degree program in Information Technology with a concentration in Health Information Technology offered by the School of Library and Information Science.

The Washington D.C. School Librarians Project. IMLS grant. Grant amount: $412,660. Grant period: Aug. 2007 – June 2011. The School partnered with the District of Columbia Public Schools (DCPS) and the District of Columbia Library Association to educate and mentor school media specialists for the DCPS system. PI, Jan. 2010 to June 2011.

SIG Member of the Year, American Society for Information Science and Technology (2009).

Most Outstanding Paper of *OCLC Systems & Services* (2001).

ALISE Research Grant (2001).

Most Outstanding Paper of *OCLC Systems & Services* (2000).

Research Grant from ERIC (1999-2000).

Best Research Paper Award; Association for Library and Information Science Education (1998).

Research Grants, Catholic University of America. 1991, 1992, 1993, 1996, 1998, 1999, 2004, 2005, 2006, 2007, 2013-14.

Cooperative Faculty Research Grant, Consortium of Universities in the Washington Metropolitan Area (1993-1994).

Cooperative Research Grant, Council on Library Resources (1993-1994).

Journal of the American Society for Information Science Best Paper Award (1993).

ASIS/ISI Information Science Doctoral Dissertation Scholarship (1989).

HEA Title IIB Fellowship (Dept. of Education) (1989)

Chinese-American Librarians Association Scholarship (1987).

Beta Phi Mu (1985).

Vilas Fellowship, University of Wisconsin-Madison. 1984

Publications

Hsieh-Yee, I. (2021). Can We Trust Social Media? *Internet Reference Services Quarterly*, 1-15. Published online: 28 July, 2021. 10.1080/10875301.2021.1947433.

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Choi, Y., Hsieh-Yee, I., and Kules, B. (2007). Retrieval Effectiveness of TOC and LCSH. *Proceedings of the Joint Conference on Digital Libraries*, pp. 233-234.

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a Digital Teaching Commons to Enhance Metadata Teaching, Learning and Research. *Proceedings of the National Conference of the Association of College and Research Libraries, Baltimore, MD*, pp. 26-31.

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Hsieh-Yee, I., Tang, R., and Zhang, S. (2006). User Perceptions of a Federated Search System. *Proceedings of the Joint Conference on Digital Libraries*, *June 11-15, 2006, Chapel Hill*, p. 338.

Hsieh-Yee, I. (2006). *Organizing Audiovisual and Electronic Resources for Access: A Cataloging Guide*. 2nd ed. Westport, Conn.: Libraries Unlimited.

NISO A Framework of Guidance for Building Good Digital Collections. 2nd ed. Bethesda, MD: National Information Standards Organization, 2004. Framework Advisory Group: Grace Agnew, Liz Bishoff, Priscilla Caplan (Chair), Rebecca Gunther and Ingrid Hsieh-Yee.

Hsieh-Yee, I. (2004). Cataloging and Metadata Education in North American LIS Programs. *Library Resources & Technical Services,* 48(1): 59-68.

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Yee, P. L., Hsieh-Yee, I., Pierce, G.R., Grome, R., and Schantz, L. (2004). Self-Evaluative Intrusive Thoughts Impede Successful Searching on the Internet. *Computers in Human Behavior,* 20(1): 85-101.

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Logan, E., and Hsieh-Yee, I. (2001). Library and Information Science Education in the Nineties. *Annual Review of Information Science and Technology,* 35: 425-477.

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Hsieh-Yee, I. (1995). Ten entries in James S. C. Hu (Ed.), *Encyclopedia of Library & Information Science*, 913, 1028-29, 1036, 1037, 1145-46, 1514, 1575, 1763-64, 2216-27, 2378-79. Taipei, Taiwan: Sino-American Publishing. (Topics include "Advanced Technology/Libraries," "Information Ethics," "Instruction on Cataloging and Classification," "Instruction on Reference Services.")

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Works in Progress

Hsieh-Yee, I. Actionable lessons for debunking false information: A comparative analysis of literacy lessons in communication and library and information science

Hsieh-Yee, I. Representing diverse voices and communities in cataloging and indexing: The evolution of controlled vocabularies

Hsieh-Yee, I. Information Organization and Retrieval in Practice (a monograph scheduled for completion and publication in 2023)

Presentations

Bailey, T. & Hsieh-Yee, I. (February 2020). The Phenomena of Sharing Misinformation and the Need for Information Literacy. Presented at the 2020 Bridging the Spectrum Symposium, Washington, D.C., February 14, 2020.

Hsieh-Yee, I. and Fragan-Fly, J. (May 2018) Trends, Design & Strategies for Digital Scholarship Services. Presented at the 2018 Maryland/Delaware Library Association Conference, Cambridge, MD.

Hsieh-Yee, I. (February, 2018) Research Data Management: What It Takes to Succeed. Presented at the 10th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I. (February, 2017) *Research Data Management: New Competencies and Opportunities for Information Professionals*. Presented at the 9th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I. and Lawton, P. (February, 2017) *Enhancing Catholic Portal Searches with User Terms and LCSH*. Presented at the 9th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I. (2016, October) *Visualizing Data for Information*. Presented at the 2016 Virginia Library Association Conference, Hot Springs, VA.

Hsieh-Yee, I. (2016, August) *Religious Materials Toolbox for Archivists: Solutions to Problems Facing the Profession*. Presented at Archives * Records 2016, Atlanta, GA.

Hsieh-Yee, I. and Lawton, P. (2016, March) *Enhancing Retrieval of Catholic Materials with LCSH Knowledge Structure*. Presented at the 2016 Catholic Library Association Conference, San Diego, CA.

Fagan-Fry, J. and Hsieh-Yee, I. (2016, February) *Approaches to Digital Scholarship at Top Universities around the World: Scholarly Publishing in the Digital Age.* Presented at the 8th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee and Fagan-Fry, J. (2016, January) *Innovative Services for Digital Scholarship at Top 100 Research Libraries of the World*. Poster presented at the 2016 Annual Conference of the Association for Library and Information Science Education, Boston, Mass.

Hsieh-Yee, I. and Lawton, P. (2015, June). *Crowdsourcing terms for CRRA portal themes.* Poster presented at the third CRRA symposium and annual meeting, Bringing the created toward the Creator: Liturgical art and design since Vatican II. Catholic Theological Union, Chicago, Illinois.

Hsieh-Yee, I. and Lawton, P. (2015, February). *Crowdsourcing terms for thematic exploration in the Catholic Portal.* Poster presented at the 7th Annual Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I., James, R., and Fagan-Fry, J. (2015, February). *Support for digital scholarship at top university libraries of the world*. Poster presented at the 7th Annual Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I., Zhang, S., Lin, K., and Cherry, S. (2015, February). *Thus said the end users: Summon experience and support for research workflows*. Poster presented at the 7th Annual Bridging the Spectrum Symposium, Washington, D.C.

Yontz, E., Hsieh-Yee, I., & Houston, S. (2015, February). *Healthy Heroes Summer Reading Club: Developing healthy youth at public libraries.* 11th Annual Jean Mills Health Symposium, Greenville, North Carolina.

Yontz, E., Hsieh-Yee, I., and Houston, S. (2015, January). *Healthy youth and libraries: A pilot study.* Association for Library & Information Science Education (ALISE) Annual Conference, Chicago, Illinois.

Hsieh-Yee, I. (2014, May). *Linking CRRA resources to portal themes via authority files*. Presented at the Catholic Research Resources Alliance 2014 Membership Meeting, Marquette, WI.

Hsieh-Yee, I. (2014, April). *Enhancing subject access to CRRA resources*. Presented at the 2014 Catholic Library Association Conference, Pittsburgh, PA.

Hsieh-Yee, I. (2014, January). *Health Information Technology Program: Educational entrepreneurship in action*. Presented at the 2014 annual Conference of the Association for Library and Information Science Education, Philadelphia, PA

Hsieh-Yee, I., Zhang, S., Lin, K., and Cherry, S. (2014, January). *Discovering information through Summon: An analysis of user search strategies and search success*. Paper presented at the 6th Bridging the Spectrum Symposium, Washington, D.C.

Hsieh-Yee, I. (2012, December). *National Digital Stewardship Alliance and SLIS at CUA: An Educational Partnership*. Paper presented at Best Practices Exchange: Acquiring, Preserving, and Providing Access to Government Information in the Digital Era, Annapolis, MD

Choi, Y. and Hsieh-Yee, I. (2010, January). *Finding Images in an OPAC: Analysis of User Queries, Subject Headings, and Description Notes*. Paper presented at 2nd Annual Bridging the Spectrum Symposium, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. and Coogan, J. (2010, January). *Google Scholar vs. Academic Search Premier: What Libraries and Searchers Need to Know*. Paper presented at 2nd Annual Bridging the Spectrum Symposium, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. (2009, November). *Information Science Education: An LIS School's Perspective*. Paper presented at Annual Meeting of the American Society for Information Science and Technology, Vancouver, British Columbia, Canada.

Hsieh-Yee, I., Menard, E., Ya-Ning Chen, A., Shu-Jiun Chen, S., Kalfatovic, M. R., Wisser. K. M. (2009, November). *Information Organization in Libraries, Archives and Museums: Converging Practices and Collaboration Opportunities*. Presented at Annual Meeting of the American Society for Information Science and Technology, Vancouver, British Columbia, Canada. (Organizer and moderator of this panel.)

Hsieh-Yee, I. and Coogan, J. (2009, July). *Catching up to Google Scholar: The Retrieval Power of Academic Search Premier and Google Scholar*. Poster presented at American Library Association Conference, Chicago, Illinois.

Hsieh-Yee, I., with the CUA Scholarly Communications Project Team. (2009, January). *Digital Scholarship@CUA: Developing an Institutional Repository for CUA*. Poster presented at 1st Annual Bridging the Spectrum Symposium, Catholic University of America, Washington, D.C.

Wise, M., Cylke, K., and Hsieh-Yee, I. **(**2009, January). *Digital Talking Books: Meeting the Needs of the Blind and the Handicapped*. Paper presented at the Bridging the Spectrum Symposium, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. (2009, January). *User Expectations of MERIC*. Presented at the Information Organization Competencies for the 21st Century Discussion Session of the 2009 Conference of the Association for Library and Information Science Education, Denver, Colorado.

Choi, Y., and Hsieh-Yee, I. (2008,November). *Subject Access for Images in an OPAC.* Annual Meeting of the American Society for Information Science and Technology, Columbus, Ohio. (Also co-organized a panel on Retrieving and Using Visual Resources: Challenges and Opportunities for Research and Education.)

Hsieh-Yee, I. (2008, June). *Educating Cataloging Professionals in a Changing Information Environment*. National Taiwan University, Taipei, Taiwan.

Vellucci, S. L., Moen, W.E., Hsieh-Yee, I., Marson, B., and Wisser, K. (2008, January) *Building a Metadata Education and Research Community through MERIC (Metadata Education and Research Information Commons): Demo and Stakeholder Input*. A panel presented at the 2008 Conference of the Association for Library and Information Science Education, Philadelphia, Pennsylvania.

Hsieh-Yee, I., Choi,Y. and Kules, B. (2007, October). *Searching for Books and Images in OPAC: Effects of LCSH, TOC and Subject Domains.* A poster presented at the American Society for Information Science and Technology Annual Meeting, Milwaukee, Wisconsin.

Hsieh-Yee, I. and Coogan, J. (2007, August) *Google Scholar vs. Academic Search Premier: A Comparative Analysis.* Presented to the Faculty and Staff of the University of the District

of Columbia.

Hsieh-Yee, I. and Coogan, J. (2007, June). *Google Scholar vs. Academic Search Premier: A Comparative Analysis*. Presented to the Washington Research Library Consortium Community, Catholic University of America, Washington, D.C.

Hsieh-Yee, I., Choi, Y., and Kules, B.. (2007, June). *What Users Need for Subject Access: Table of Contents or Subject Headings?* A poster presented at the 2007 American Library Association Annual Conference, Washington, D.C., June 2007.

Choi, Y., Hsieh-Yee, I., and Kules, B. (2007, June). *Retrieval Effectiveness of TOC and LCSH.* A paper presented at the Joint Conference on Digital Libraries 2007, Vancouver, Canada.

Vellucci, S. L., Hsieh-Yee, I., and Moen, W.E. (2007, May). *If We Build It, Will They Come? Building a Community of Practice for Metadata Stakeholders.* A poster presented at the Rutgers University Research Day, Bridgeton, New Jersey.

Hsieh-Yee, I. (2007, May). *Federated Searching: User Experience & Perceptions.* International Conference on Information Organization & Retrieval, National Taiwan University, Taipei, Taiwan.

Hsieh-Yee, I. (2007, May). *Search Performance of Google Scholar and Academic Search Premier.* International Conference on Information Organization & Retrieval, National Taiwan University, Taipei, Taiwan.

Hsieh-Yee, I. (2007, May) *MERIC: Building a Digital Commons for Metadata Education & Research.* International Conference on Information Organization & Retrieval, National Taiwan University, Taipei, Taiwan.

Hsieh-Yee, I., and Coogan, J. (2007, March/April). *A Comparative Analysis of Google Scholar and Academic Search Premier.* Poster presented at the Association of College & Research Libraries 13th National Conference, Baltimore, Maryland.

Vellucci, S. L. and Hsieh-Yee, I. (2007, March/April) *They Didn't Teach Me That in Library School! Building a Digital Teaching Commons to Enhance Metadata Teaching, Learning and Research*. On-site presentation and Webcast by Elluminate. A contributed paper presented at the Association of College & Research Libraries 13th National Conference, Baltimore, Maryland. The acceptance rate for contributed paper was 20%. This paper was one of 10 conference papers chosen for live webcast during the conference.

Moen, W., Hsieh-Yee, I. and Vellucci, S.L. (2007, January) *A DSpace Foundation for a Teaching & Research Commons: The Metadata Education and Research Information Commons.* A poster session presented at the Open Repositories Conference 2007, San Antonio, Texas.

Tang, R., Hsieh-Yee, I., and Zhang, S. (2006, November) *User Perception of MetaLib Combined Search*. Paper presented at the Annual Meeting of the American Society for Information Science and Technology, Austin, Texas, Nov. 2006.

Hsieh-Yee, I. (2006, November). *Federated Searching: User Perceptions, System Design, and Library Instructions.* Paper presented at the Annual Meeting of the American Society for Information Science and Technology, Austin, Texas. (Panel organizer, moderator, presenter).

Hsieh-Yee, I. (2006, November). *Building a Digital Teaching Commons to Enhance Teaching and Learning: The MERIC Experience and Challenges.* Paper presented at the Annual Meeting of the American Society for Information Science and Technology, Austin, Texas. (Panel organizer, moderator, presenter)

Hsieh-Yee, I. (2006, September). *Search Performance of Google Scholar and Academic Search Premier.* Paper presented at the ERIC Publishers Meeting, Washington, D.C.

Hsieh-Yee, I., Zhang, S., and Rong Tang, R. (2006, June). *User Perceptions of a Federated Search System*. Poster presented at Joint Conference on Digital Libraries, Chapel Hill, North Carolina.

Hsieh-Yee, I. and Zhang, S. (2006, June). *Preparing Users for Federated Search: Implications of a MetaLib User Perceptions Study.* Paper presented at the 2006 Ex Libris User Groups of North America Conference, Knoxville, Tennessee.

Hsieh-Yee, I. (2006, January). *MERIC Organizations and Navigation*. Paper presented at the 2006 ALISE Annual Conference, San Antonio, Texas.

Hsieh-Yee, I. (2006, January). *Metadata and Cataloging Education: Recommended Competencies.* Paper presented at the 2006 ALISE Annual Conference, San Antonio, Texas.

Hsieh-Yee, I. (2005, November). *Digital Library Evaluation: Progress & Next Steps.* Presentation at the Annual Meeting of the American Society for Information Science & Technology, Charlotte, North Carolina.

Hsieh-Yee, I. (2005, August). *Providing Access to Digital Content: Issues for DL Managers.* Presentation at MDK12 Digital Library Steering Committee Meeting, Columbia, Maryland.

Hsieh-Yee, I. (2005, April). *Enhancing Teaching and Learning: The Role of School Library Media Specialists.* Presentation at Meeting of the Baltimore County Public School System School Media Specialists, Baltimore, Maryland.

Hsieh-Yee, I. (2005, January). *Subject Access and Users: Insights & Inspirations from Marcia J. Bates.* Paper presented at the Historical Perspectives SIG, 2005 Conference of the Association for Library and Information Science Education, Boston, Massachusetts.

Hsieh-Yee, I. (2005, January). *Electronic Resource Management: Practice, Employer Expectations, & CE Interests.* Paper presented at Technical Services Education SIG, 2005 Conference of the Association for Library and Information Science Education, Boston, Massachusetts.

Hsieh-Yee, I. (2004, October). *Library Professionals for the Digital Age: Competencies & Preparation.* Paper presented at Bibliographic Access Management Team meeting, Library of Congress, Washington, D.C.

Hsieh-Yee, I. (2004, January). *Cataloging and metadata expertise for the digital era.* Presented at Preparing 21st Century Cataloging and Metadata Professionals: A Workshop for Educators and Trainers, San Diego and sponsored by ALCTS, ALISE, LC, and OCLC.

Hsieh-Yee, I. (2004, January). *Educating catalogers for the digital era.* Paper presented at the Technical Services SIG, 2004 Conference of the Association for Library and Information Science Education, San Diego.

Hsieh-Yee, I. (2003, July). *Cataloging Education for the 21st Century.* A presentation at the Library of Congress, Washington, D.C.

Hsieh-Yee, I. (2002, January) *Metadata Education and Research Priorities: A Delphi Study of Metadata Experts.* Presentation at the 2002 Conference of the Association for Library and Information Science Education, New Orleans.

Hsieh-Yee, I. (2001, November). *A Delphi Study of Metadata: Preliminary Findings.* Poster session at the 2001 Annual Meeting of the American Society for Information Science & Technology, Washington, D.C.

Hsieh-Yee, I. (2001, June). *Resources on Asian American Children: Analysis of Retrieval by Search Engines and WorldCat.* Presentation at the National Conference on Asian Pacific American Librarians, San Francisco.

Hsieh-Yee, I. (2001, January). *Delphi Study on Metadata: Project Design.* Presentation at Research Awards Session, Association for Library & Information Science Education, Washington, D.C.

Hsieh-Yee, I. (2000, May). *Web Search Behavior Research: Progress and Implications.* Presentation at the Symposium on Evaluating Library and Information Science Research, University of Wisconsin-Madison, Madison, Wisconsin.

Hsieh-Yee, I. (2000, March). *ERIC User Services: Evaluation in a Decentralized Environment.* Presentation at the National ERIC Joint Directors/Technical Meeting, Arlington, Virginia.

Hsieh-Yee, I. (2000, January). *Enhancing Learning with Web Technology.* Presentation at Faculty Conversations, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. (2000, January). *From Surrogates to Objects: CUA's Approaches to Organizing Electronic Resources.* Paper presentation at the Annual Conference of the Association for Library and Information Science Education, San Antonio, Texas.

Yee, P., and Hsieh-Yee, I. (1997, November). *Individual Differences in Search Behavior on the WWW.* A poster session presented at the 38th Annual Meeting of the Psychonomic Society, Philadelphia, Pennsylvania.

Hsieh-Yee, I. (1997, April). *Research + Marketing + Preparation = Job!* Presented at the "Workshop on Resume and Interview Techniques," Special Libraries Association, Student Chapter, Catholic University of America, Washington, D.C.

Hsieh-Yee, I. (1997, February). *Creating CyberCatalogers: Education and Training.* Presentation at ALA's Midwinter Meeting, Washington, D.C.

Hsieh-Yee, I. (1997, February). *Search Tactics of Web Users in Searching for Texts, Graphics, Known Items and Subjects: A Search Simulation Study.* Presented at the Conference of the Association for Library and Information Science Education, Washington, D.C.

Hsieh-Yee, Ingrid. "Beginning Your Special Library/Information Center Career." Presented at SLA's "Career Day," Jan. 11, 1997, Catholic University of America.

Hsieh-Yee, I. (1996, September). *The Roles of Library and Information Scientists in Managing Electronic Information.* Presentation at Hamilton College, Clinton, New York.

Hsieh-Yee, I. (1996, May). *The Future of Cataloging as a Profession.* Presented at "The Cataloging Forum, Library of Congress, Washington, D.C.

Hsieh-Yee, I. (1994, October). *The Impact of the Internet on OPACs.* Presented at the Third Workshop on User Interfaces for OPACs, Library of Congress, Washington, D.C.

Reports

Hsieh-Yee, I., with Knowledge Management Competencies and Performance Action Group of the Federal Knowledge Management Initiative. "From Knowledge Management Competencies to Improved Organizational Performance." April 9, 2009.

Hsieh-Yee, I., with Knowledge Practices Action Group of the Federal Knowledge Management Initiative. "KM Practice in Government Agencies: Findings and Recommendations." April 9, 2009.

Hsieh-Yee, I. "Delphi Study on Metadata." 2001. Three quarterly reports submitted to the Association for Library and Information Science Education.

Hsieh-Yee, I. "College Students' Information Channels: Patterns of Use and Possible Factors in Channel Selection." 1995. Submitted to the Catholic University of America.

Hsieh-Yee, I. "The Information-Seeking Patterns of Scholars and Their Use of an Online Information System." 1994. Submitted to the Council on Library Resources.

Book Reviews

Review of *The Measurement and Evaluation of Library Services*, by Sharon L. Baker and F. Wilfrid Lancaster. *Information Processing and Management* 30 (1994): 450-52.

Review of *Subject Access to Films and Videos, by Sheila S. Intner and William E. Studwell; and Cataloging Unpublished Nonprint Materials*, by Verna Urbanski with Bao Chu Chang and Bernard L. Karon. *Information Processing and Management* 30 (1994): 449-50.

Review of *Automated Information Retrieval in Libraries: A Management Handbook*, by Vicki Anders. *Journal of Library and Information Science* 19 (1993): 98-100.

Review of *Full Text Databases*, by Carol Tenopir and Jung Soon Ro. *Information Processing and Management* 28 (1992): 667-68.

Review of *Descriptive Cataloging for the AACR2R And USMARC: A How-to-Do It Workbook*, by Larry Millsap and Terry Ellen Ferl. *Information Processing and Management* 28 (1992): 809-11.

Review of *MARC Manual: Understanding and Using MARC Records*, by Deborah J. Byrne. *Information Processing and Management* 28 (1992): 537-38.

Service

Professional Associations and Societies

- Library of Congress. RDA Training Program for the Profession. Co-authored with Tim Carlton. 2013-2014.
- 2014 Digital Preservation Outreach & Education Survey. Contributed to the design of the survey, 2014.
- National Digital Stewardship Alliance. Outreach Committee. 2011-2014.
- National Digital Stewardship Residency Program. Advisory Group, 2012-2013.
- FEDLINK Health Information Technology Advisory Council, 2011-2015.

- 2012 Joint Conference on Digital Libraries. Program Planning Committee, Pre-Conference Proposals Review Committee, 2012
- Catholic Research Resources Alliance. Five-Year Strategic Plan Task Force, 2011-2012
- Institute of Museum and Library Services. Grant reviewer. 2004, 2005, 2010.

- Association for Library and Information Science Education.
  * ALISE Bodan Wynar Research Paper Award Committee, 2015, 2016, 2017
  * ALISE Eugene Garfield Dissertation Award Competition, Jury, 2013, 2014
  * ALISE Research Grant Competition Committee. Chair, 2012
  * Pratt-Severn Faculty Innovation Award. Chair, 2009, 2010
  * ALISE Doctoral Poster Jury, 2012
  * "Information Organization Competencies for the 21st Century" Discussion session leader. 2009 Conference of the Association for Library and Information Science Education.
  * Assisted Technical Services SIG Convener in organizing a program, ""Building a Metadata Education and Research Community through MERIC (Metadata Education and Research Information Commons): Demo and Stakeholder Input" for the 2008 ALISE conference.
  * Association for Library Collections and Technical Services/Association for Library and Information Science Education (ALCTS/ALISE) Metadata Education and Research Information Center (MERIC) Advisory Board, Co-Chair (with Sherry Vellucci), 2005-2007. Chair, 2008-2009 (leading the effort to build MERIC, a repository and collaborative space for metadata educators, practitioners, and researchers)
  * Technical Services SIG, Convener, 2004-2005. Organized a program on "Electronic Resources Management: Current Practices, Employer Expectations, and Teaching Strategies" for the 2005 conference in Boston, Massachusetts.
  * Technical Services SIG, Convener, 2003-2004. Organized a program on "Organizing Information with Metadata: Desired Competencies and Teaching Innovations" for the 2004 conference.
  * Technical Services SIG, Convener, 1999-2000. Organized a program on "Teaching the Organization of Electronic Resources" for the 2000 conference.
  * Curriculum SIG, Co-convener (with Sibyl Moses), 1996-97. Organized a program on "Government Information Policy" for the 1997 conference.

- American Society for Information Science & Technology.
  * Reviewer, Conference program panel submissions and poster submissions, 2005, 2006, 2007, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2017
  * Nomination Committee, 2009-2011
  * Information Science Education Special Interest Group. American Society for Information Science and Technology. Chair-Elect, 2007-2008. Chair 2008-2009.
  * Committee on Information Science Education. 1999-2006.
  * Committee on Information Science Education. Organizing Committee for an orientation program for students at ASIS annual meetings, 1999-2001
  * Committee on Information Science Education. Sub-committee on Student Welfare (focusing on issues related to master's education), 1998-2001

* SIG ED. Organizing Committee for the "Seminar on Research and Career Development" for junior researchers. 1995-96 (chair), 1997-2001
* ISI Doctoral Dissertation Proposal Scholarship Jury, 1997; 2001, 2002
* Pratt-Severn Best Student Research Paper Award Jury. Chair. 1997
* 1998 Midyear Meeting (referee of contributed papers), 1997
* Organizer and moderator of the ASIS Doctoral Forum and the Doctoral Research Seminar 1994-1995
* SIG Human Computer Interaction. Chair-Elect, Chair, 1993-1995
* Doctoral Forum Award Jury, 1995
* Best Student Paper Award Jury, 1995

- American Library Association.
  * Committee on Accreditation, External Review Panelist, 2009- (site visiting team 2013-2014; site visiting team 2016-2017)
  * Association for Library Collections and Technical Services Task Force on Competencies and Education for a Career in Cataloging, member, 2008-2009
  * Facilitator for "What They Don't Teach in Library School: Competencies, Education and Employer Expectations for a Career in Cataloging," an Association for Library Collections and Technical Services Preconference, June 22, 2007 in Washington, D.C. Also a local liaison for bringing this program to the Catholic University of America.
  * Facilitator for a discussion on "Effect of Electronic Resources on Technical Services" at ALA's Midwinter Meeting held in Feb. 1997 in Washington, D.C.
  * International Relations Committee, Subcommittee Task Force for IFLA and China, 1994-1997

- Virginia Association of School Librarians. Scholarships and Awards Committee. 2010-2012

- Federal Knowledge Management Initiative, Knowledge Management Practices Action Group. Member. 2009 (leading the effort to build a knowledge management repository)
- Federal Knowledge Management Initiative, Knowledge Management Competencies & Learning Action Group. Member. 2009 (developing an action plan for helping government knowledge workers and government agencies to develop knowledge management competencies)
- National Center for Education Statistics. Technical Review Panel. 2008.
- External evaluator for a case of promotion to full professorship. University of Tennessee. 2008.
- National Information Standards Organization (NISO). Advisory Board, Revision of "IMLS Framework of Guidance for Building Good Digital Collections," 2004, 2007.
- Library of Congress, Bibliographic Control of Web Resources: A Library of Congress Action Plan. Principal Investigator of Action Item 5.1, focusing on cataloging and metadata education for students and new librarians, 2002-2003. (worked with the Association for Library Collections and Technical Services, Education Task Force)

- Chinese American Librarians Association
  * Chinese American Librarians Association Outstanding Library Leadership Award in Memory of Dr. Margaret Chang Fung, Award Committee, 2016-2017
  * Achievement Award Jury, 2000-2001
  * CALA Goal 2000 Task Force, 1997
  * Scholarship Committee, 1995, 1996-1997 (chair)
  * Board of Directors, 1994-1997
  * Publication Committee, 1993-1995
  * International Relations Committee, 1993-1996

- Sailor[SM] Assessment Advisory Group (An impact study of Sailor, Maryland's Public Information Network), 1995

- Editorial boards
  Journal of Library & Information Science. Editorial Board, 2012-
  Chinese American Librarians Association, *Occasional Papers Series*. Editorial Board, 2009-2016.
  Library Quarterly. Editorial Board, 2003-2008
  Bulletin of the Medical Library Association, 1994-97
  Newsletter editor for the Chinese American Librarians Association, 1989-92

- Referee for the following journals
  Information Processing and Management
  Journal of Digital Information
  Journal of Education for Library and Information Science
  Journal of Information Science
  Journal of Library & Information Science
  Journal of Library Metadata
  Journal of the American Society for Information Science & Technology
  Library and Information Science Research
  Library Quarterly

- Expert reviewer, "Digital Library" course, Evaluation module, University of North Carolina, Chapel Hill, 2007-2008.
- Expert reviewer, "Information Organization" course, University of Michigan, Ann Arbor. 2007.

Catholic University of America

- Academic Senate Committee on Appointments and Promotions, 2005-2008
- Academic Senate Committee on Committees and Rules, 2009-2012, 2019-2022
- Academic Senate representative (for School of Arts & Sciences), 2017-2020

- Academic Senate representative (for School of Library & Information Science) 2003-2012
- Academic Senate Library Committee, Interim Chair (2007), Member, 2008-2012
- Academic Senate Committee on Computing, 1995-2003

- President's Administrative Council, 2010-2012
- Deans' Council, 2010-2012
- Academic Leadership Group, 2010-2012
- Graduate Board, 2010-2012

- School of Arts & Sciences, Committee on Appointments and Promotions, 2015-2019
- School of Arts & Sciences, Academic Council, 2015-2016.
- School of Arts & Sciences, Ordinary Professor Group, 2013-
- Doctoral Dissertation Defense Committee, Chair, Dept. of Psychology, 2016, 2017, 2018, 2019, 2020, 2021, 2022
- Doctoral Dissertation Defense Committee, Chair, Dept. of Education, 2014, 2015, 2017, 2018, 2019
- Doctoral Dissertation Defense Committee, Chair, National Catholic School of Social Services, 2019, 2020, 2021
- Doctoral Dissertation Defense Committee, Chair, School of Nursing, 2006, 2008
- CUA Scholarly Communication Project Team, Member (2007), Chair, 2008-2009
- Dean Search Committee, 1992-1994, 1998-1999, 2002-2003, 2006-2007
- Fulbright Review Panel, 2006
- CUA Service Learning Advisory Board, 2001-2002
- CUA Faculty Conversations on Enhancing Teaching and Learning through Technology, Planning Group, 1999-2001
- CUA Initiative on Technology and Teaching, 1998-2001

Dept. of Library and Information Science

- Admissions Committee, 2007-2009, Chair 2010-2012, Member 2013-2015, Member 2018-2022
- Appointments and Promotions Committee, 1991-2022
- Student advisement, 1990-2022
- 4+1 Bachelor to Master program, Program Advisor, 2014-2022
- LIS Minor, Advisor, 2017-2022
- Curriculum Committee, 2020-21 (Member), 2021-2022 (Chair)
- Scholarship & Awards Committee, 2016-2018, 2020-21
- Comprehensive examination editor, 2020-21
- Symposium, Colloquium, Lecture Series Committee, May 2018-May 2020 (Chair)
- Symposium and Colloquium Committee, fall 2016-May 2018
- Bridging the Spectrum Symposium session moderator, 2018, 2019, 2020, 2021

- Organization of Information Core Course Outcomes Assessment, 2019, 2020
- The Information Professions in Society Core Course Outcomes Assessment, 2019, 2020
- Community Services Librarianship, Course of Study Review and Revision, 2020
- Organization of Information, Course of Study Review and Revision, 2019
- Organization of Information, Competency and Course Offerings Review, 2018-2019
- Accreditation presentation, Chair, June 2015-August 2016
- Interim Co-Chair, June 2015-August 2016.
- Blended/OWL Learning Committee, spring 2016-2018
- Technology Committee, fall 2016-2017
- Comprehensive examination editor, 2016-2017, reader (every year since 1990)
- LIS Advisory Board, 2015-2016 (chair); fall 2016- May 2018 (member)
- Committee on Planning and Assessment, 2015-2016 (chair)
- Senior Faculty Committee, 2014-2016.
- Accreditation Steering Committee, 2014-2016 (Chair, 2015-2016)
- Accreditation Students Standard Committee, co-chair, 2014-2016
- Accreditation Mission, Goals, and Objectives Standard Committee, co-chair, 2014-2016
- Accreditation Curriculum Standard, member 2014-2-16
- Accreditation Administration and Finance Standard, member 2014-2016
- Cultural Heritage Information Management Project (IMLS-funded), Co-PI, 2012-2015
- Cultural Heritage Information Management Forum (scheduled for June 2015), Co-Organizer, 2013-2015
- Health Information Technology Interim Review Committee, 2015 (chair)
- Health Sciences Librarianship Advisory Group, 2015- (chair)
- Comprehensive examination editors, 2013-2014, 2016-2017
- National Digital Stewardship Alliance liaison, 2011-2014
- Advisory Board, Chair 2010-2012
- Academic Honesty Committee, Chair, 2008-2012
- Blended Learning Committee, 2010-2012
- Colloquium Committee, 2010-2012
- Comprehensive Examination Administration, 2010-2012
- Cultural Heritage Information Management Advisory Committee, 2010-2012 (chair), 2013-
- Curriculum Committee, 1991-2003, 2007-2009, Chair 2010-2012, member 2013-
- Curriculum Subcommittee on Comprehensive Examination, Chair 2009-2012
- Health Information Technology Advisory Board, Chair 2010-2012. Member 2013-
- Health Sciences Advisory Committee, 2009, Chair 2010-2012. Member 2013-
- HIT Expert Forum, Chair 2012. Member 2013-2015
- Health Information Technology Student Group Advisor, 2011-2012
- State Council for Higher Education of Virginia, SLIS Representative, 2010-2012
- Symposium Planning Committee, 2010-2012
- Website Management Team, Chair, 2010-2012
- Urban School Librarianship Project (IMLS-Funded), PI, 2007-2011 (chair, 2010-11)

- Failing Grades Committee, 1995-1997 (chair), 2000-2001 (chair), 2004-2005 (chair), 2007 (chair)-2011
- Faculty Search Committee, 1994-1998, 2002-2004, 2006 (chair), Fall 2007-2009, Chair fall 2009-2012
- Recruitment Committee, Chair 2010-2012
- Strategic Planning Committee, Chair 2010-2012
- Technology Committee, 2010-2012
- Accreditation Advisory Committee, 2007-2009
- Accreditation Coordinating Committee, 2007-2009
- Accreditation Steering Committee, 2007-2009
- SLIS Advisory Group, 2007-2009
- Accreditation Curriculum Standard Committee, Co-chair, 2007-2009
- Accreditation Faculty Standard Committee, Co-chair, 2007-2009
- LSC 551 Information Organization Review Team, Co-chair, 2008-2009, 2015-2016.
- Curriculum Subcommittee on Portfolios, 2009
- LSC 555 Information Systems in Libraries and Information Centers Review Team, contributor, 2008-2009
- Redesign of LSC 730 Use and Users of Libraries and Information. 2009-
- Development of a metadata institute that was taught as LSC 715 Organization of Internet Resources in 2008. The institute is being revised and will be offered in 2010 under a new course title.
- Development of lesson plans, assignments, and evaluation rubrics for LSC 606, Cataloging and Classification, for the School's NCATE accreditation. 2008
- Howard and Mathilde Rovelstad Scholarship Committee, Chair, 2004-2007
- Assistant Dean Search Committee, Chair, Fall 2007
- Liaison to the Association for Library Collections and Technical Services to bring its preconference program, Cataloging Education and Employer Expectations, to CUA during the 2007 American Library Association Annual Meeting in Washington, D.C.
- Organizer of the colloquium presentation and reception for Tamar Sadeh of Ex Libris on PRIMO June 2007
- Practicum review and design (work with potential supervisors, such as the American Indian Museum internship description revision) 2006-
- Comprehensive examinations (edits, proctoring, and grading), 1990-
- SLIS Web site redesign: Comments and suggestions. Fall 2007
- Conducted surveys of current students and alumni in preparation for the 2005 re-accreditation, 2004-2005
- Technology Committee, 1992-1999 (chair, 1996-1998), 2002-2003 (member)
- Colloquia Committee 1997-1999, 2002-2003.
- Advisor of the CUA Student Chapter of the American Society for Information Science and Technology, 2002-2003
- Visiting Professor Search Committee, 1999, 2000, 2001
- Leader, Participation in the CORC experiment, 1999-2000
- Advisor of the Special Libraries Association Student Chapter, 1993-1999; the group was recognized for outstanding leadership by SLA in 1999.

- COA planning Committee, Task Force on Electronic Presentation of SLIS Reports (team leader) 1997-1998
- COA Planning Committee, Subcommittee on Technology 1996-1998
- NLM practicum coordinator, 1997-1998
- Computer Literacy Workshops: Assisted with the development and evaluation of the workshops, 1996-1998
- Leader, Participation in the InterCat project, 1995-1997

APPENDIX B

MARC 21 Reference Materials

Part VII: A Summary of Commonly Used MARC 21 Fields
Part VIII: A List of Other Fields Often Seen in MARC Records
Part IX: The Leader
Part X: Field 008 for Books

Part VII:

A Summary of Commonly Used MARC 21 Fields

This is a summary of the MARC 21 tags used most frequently by libraries in entering their own bibliographic records. For full listings of all MARC 21 tags, indicators, and subfield codes, see *MARC 21 Format for Bibliographic Data*.

In the explanations on these pages:

Tags -- The tags (3-digit numbers) are followed by the names of the fields they represent. In this summary, and in the *MARC 21 Format for Bibliographic Data*, if a tag can appear more than once in one bibliographic record, it is labeled repeatable (R). If it can only be used once, it is labeled non-repeatable (NR). For example, a catalog record can have several subjects, so the tags for subject added entries (6XX) are labeled repeatable (R).

Indicators -- The use of indicators is explained in fields where they are used. Indicators are one-digit numbers. Beginning with the 010 field, in every field -- following the tag -- are two character positions, one for Indicator 1 and one for Indicator 2. The indicators are not actually defined in all fields, however. And it is possible that a 2nd indicator will be used, while the 1st indicator remains undefined (or vice versa). When an indicator is undefined, the character position will be represented by the character # (for blank space).

Subfield codes -- All the data in each field (beginning with the 010 field) is divided into subfields, each of which is preceded by a delimiter-subfield code combination. The most common subfield codes used with each tag are shown. Each subfield code is preceded by the character $, signifying a delimiter. The name of the subfield follows the code.

In general, every field MUST have a subfield 'a' (**$a**). One exception that is often seen is in Field 020 (ISBN), when the ISBN information (subfield **$a**) is unavailable but the price (subfield **$c**) is known. Some subfields are repeatable. In this summary, repeatability is noted for only the more common repeatable subfields.

Examples: Examples follow the explanation for each field. For clarity, one space has been placed between the tag and the first indicator, one space has been placed between the second indicator and the first delimiter- subfield code, and one space has been inserted between the delimiter-subfield code and the subfield data.

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010 Library of Congress Control Number -- (LCCN)
(NR, or Not Repeatable
Indicators undefined.
Subfield used most often:
$a -- Library of Congress control number

```
Example:    010 ##  $a ###86000988#
```

020 International Standard Book Number -- (ISBN)
(R, or Repeatable)
Indicators undefined.
Subfields used most often:
$a -- International Standard Book Number
$c -- Terms of availability (often a price)
$z -- Cancelled/invalid ISBN (R)

```
Example:    020 ##  $a 0877547637
```

040 Cataloging source -- (NR)
Indicators undefined.
Subfields used most often:
$a -- Original cataloging agency
$c -- Transcribing agency
$d -- Modifying agency (R)

```
Example:    040 ## $a DLC
                   $c DLC
                   $d gwhs
```

100 Main entry -- Personal name -- (primary author)
(NR; there can be only one main entry)
Indicator 1: Type of personal name entry element
0 -- Forename
1 -- Surname (this is the most common form)
3 -- Family name
Indicator 2 undefined.
Indicator 2 became obsolete in 1990. Older records may display 0 or 1
Subfields used most often:
$a -- Personal name
$b -- Numeration

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$c -- Titles and other words associated with a name (R)
$q -- Fuller form of name
$d -- Dates associated with a name (generally, year of birth)

```
Example:    100 1# $a Gregory, Ruth W.
                   $q (Ruth Wilhelme),
                   $d 1910–
```

130 Main entry -- Uniform title -- (NR)

Indicator 1: Nonfiling characters

0-9 -- Number of nonfiling characters present (for initial articles, including spaces)

Indicator 2 undefined.

Indicator 2 became obsolete in 1990. (See 100 above.)

Subfields used most often:

$a -- Uniform title
$p -- Name of part/section of a work (R)
$l -- Language of a work
$s -- Version
$f -- Date of a work

```
Example:    130 0# $a Bible.
                   $p O.T.
                   $p Psalms.
```

240 Uniform title (NR)

Indicator 1: Uniform title printed or displayed

0 -- Not printed or displayed
1 -- Printed or displayed (most common)

Indicator 2: Nonfiling characters

0-9 -- Number of nonfiling characters present (for initial articles, including spaces)

Subfields used most often:

$a -- Uniform title
$l -- Language of a work
$f -- Date of a work

```
Example:    240 10 $a Ile mystérieuse.
                   $l English.
                   $f 1978
```


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245 Title Statement (NR)

Indicator 1: Title added entry

(Should the title be indexed as a title added entry?)

0 -- No title added entry

(indicates a title main entry; i.e. no author is given)

1 -- Title added entry

(the proper indicator when an author given in 1XX; the most common situation)

Indicator 2: Nonfiling characters

0-9 -- Number of nonfiling characters present, including spaces; usually set at zero, except when the title begins with an article; e.g., for *The robe*, the second indicator would be set to 4. The letters *T*, *h*, *e*, and the space following them are then ignored in alphabetizing titles. The record will be automatically filed under "*r*" -- for *Robe*.

Subfields used most often:

$a -- Title proper

$h -- Medium (often used for non-book media)

$p -- Name of part/section of a work (R)

$b -- Reminder of title (subtitles, etc.)

$c -- Remainder of title page transcription/Statement of responsibility

```
Example:    245 14 $a The DNA story :
                   $b a documentary history of gene
                      cloning /
                   $c James D. Watson, John Tooze.
```

246 Varying form of title (R)

Indicator 1: Note/title added entry controller

1 -- Note, title added entry

3 -- No note, title added entry

Indicator 2: Type of title

-- No information provided

0 -- Portion of title

1 -- Parallel title

4 -- Cover title

8 -- Spine title

Subfield used most often:

$a -- Title proper

```
Example:    246 3# $a Four corners power review
```

250 Edition statement (NR)

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Indicators undefined.
Subfield used most often:
$a -- Edition statement

```
Example:    250 ## $a 6th ed.
```

260 Publication, distribution, etc. (Imprint) (R)
Indicator 1: Sequence of publishing statements
-- No information provided
Indicator 2: Undefined
Subfields used most often:
$a -- Place of publication, distribution, etc. (R)
$b -- Name of publisher, distributor, etc. (R)
$c -- Date of publication, distribution, etc. (R)

```
Example:    260 ## $a New York :
                   $b Chelsea House,
                   $c 1986.
```

300 Physical description (R)
Indicators undefined.
Subfields used most often:
$a -- Extent (number of pages) (R)
$b -- Other physical details (usually illustration information)
$c -- Dimensions (cm.) (R)
$e -- Accompanying material (for example, "teacher's guide" or "manual")

```
Example:    300 ## $a 139 p. :
                   $b ill. ;
                   $c 24 cm.
```

440 Series statement / Added entry--Title
This field was made obsolete in 2008 to simplify the series statement. See 490 and 830.

490 Series statement (No added entry is traced from field) (R)
Indicator 1: Specifies whether series is traced (whether an 8XX tag is also present)
0 -- Series not traced
1 -- Series traced (8XX is in record)
Indicator 2 undefined.
Subfield used most often:

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$a -- Series statement (R)
$v -- Volume number (R)

```
Example:    490 1# $a Colonial American craftsmen
```

500 General note (R)
Indicators undefined.
Subfield used most often:
$a -- General note (Used when no specialized note field has been defined for the information. Examples: Notes regarding the index; the source of the title; variations in title; descriptions of the nature, form, or scope of the item.)

```
Example:    500 ##  $a Includes index.
```

504 Bibliography, etc. note (R)
Indicators undefined.
Subfield used most often:
$a -- Bibliography, etc. note

```
Example:    504 ## $a Includes bibliographical
                      references.
```

505 Formatted contents note (R)
Indicator 1: Type of contents note
0 -- Complete contents
1 -- Incomplete contents (used with multivolume set when some volumes are not yet published)
2 -- Partial contents
Indicator 2: Level of content designation
-- Basic
Subfield used most often:
$a -- Formatted contents note

```
Example:    505 0# $a Pride and prejudice -- Emma
                      -- Northanger Abbey.
```

520 Summary, etc. note (R)
Indicator 1: Display constant controller
-- Summary

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1 -- Review
2 -- Scope and content
3 -- Abstract

Indicator 2 undefined

Subfields used most often

$a -- Summary, abstract, or annotation
$b -- Expansion of summary note

```
Example:    520 ## $a This basic guide to parliamentary
                     procedure tells how to conduct
                     and participate in a meeting
                     properly.
```

600 Subject added entry -- Personal name (R)

Indicator 1: Type of personal name entry element

0 -- Forename
1 -- Surname (this is the most common form)
3 -- Family name

Indicator 2: Subject heading system/thesaurus (identifies the specific list or file which was used)

0 -- Library of Congress Subject Headings
1 -- LC subject headings for children's literature
2 -- Medical Subject Headings
3 -- National Agricultural Library subject authority file
4 -- Source not specified
5 -- Canadian Subject Headings
6 -- Répertoire de vedettes-matière
7 -- Source specified in subfield $2

(Note regarding Sears subject headings: The MARC 21 format does not provide an assigned indicator for Sears subject headings. Therefore, an indicator of 7 is used, and the MARC defined code "sears" is placed in subfield $2.)

Subfields used most often:

$a -- Personal name (surname and forename)
$b -- Numeration
$c -- Titles and other words associated with a name (R)
$q -- Fuller form of name
$d -- Dates associated with a name (generally, year of birth)
$t -- Title of a work
$v -- Form subdivision (R)
$x -- General subdivision (R)
$y -- Chronological subdivision (R)
$z -- Geographic subdivision (R)
$2 -- Source of heading or term (used with 2nd indicator of 7)

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```
Example:    600 10 $a Shakespeare, William,
                   $d 1564-1616
                   $x Comedies
                   $x Stage history.
```

```
Example:    600 10 $a Shakespeare, William,
                   $d 1564-1616
                   $x Knowledge
                   $z Rome
                   $v Congresses.
```

Notice that subfields $v, $x, and $z in the 600 field are repeatable. Subfields $v, $x, $y, and $z do not have to be in alphabetical order. They will be in the order prescribed by the instructions given by the subject heading system.

610 Subject added entry -- Corporate name (R)

*Indicator 1:*Type of corporate name entry element
- 0 -- Inverted name (not used with AACR2)
- 1 -- Jurisdiction name
- 2 -- Name in direct order

Indicator 2: Subject heading system/thesaurus.
- See indicator 2 under 600

Subfields used most often:
- **$a** -- Corporate name or jurisdiction name as entry element
- **$b** -- Subordinate unit (R)
- **$v** -- Form subdivision (R)
- **$x** -- General subdivision (R)
- **$y** -- Chronological subdivision (R)
- **$z** -- Geographic subdivision (R)
- **$2** -- Source of heading or term (used with 2nd indicator of 7)

```
Example:    610 10 $a United States.
                   $b Army Air Forces
                   $v Biography.
```

650 Subject added entry -- Topical term (Most subject headings fit here.) (R)

Indicator 1: Level of subject
- # -- No information provided

Indicator 2: Subject heading system/thesaurus
(identifies the specific list or file which was used)
- 0 -- Library of Congress Subject Headings
- 1 -- LC subject headings for children's literature

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2 -- Medical Subject Headings
3 -- National Agricultural Library subject authority file
4 -- Source not specified
5 -- Canadian Subject Headings
6 -- Répertoire de vedettes-matière
7 -- Source specified in subfield $2

Note regarding Sears subject headings: The MARC 21 format does not provide an assigned indicator for Sears subject headings. Therefore, an indicator of 7 is used, and the MARC defined code "sears" is placed in subfield $2.)

Subfields used most often:
$a -- Topical term
$v -- Form subdivision (R)
$x -- General subdivision (R)
$y -- Chronological subdivision (R)
$z -- Geographic subdivision (R)
$2 -- Source of heading or term used with 2nd indicator of 7)

```
Example:    650 #0 $a Theater
                   $z United States
                   $v Biography
                   $v Dictionaries.
```

Notice that subfields $v, $x, and $z in the 650 field are repeatable. Subfields $v, $x, $y, and $z do not have to be in alphabetical order. They will be in the order prescribed by the instructions given by the subject heading system.

651 Subject added entry -- Geographic name (R)
Indicator 1: undefined.
Indicator 2: Subject heading system/thesaurus.
See indicator 2 under 600
Subfields used most often:
$a -- Geographic name
$v -- Form subdivision (R)
$x -- General subdivision (R)
$y -- Chronological subdivision (R)
$z -- Geographic subdivision (R)
$2 -- Source of heading or term (used with 2nd indicator of 7)

```
Example:    651 #0 $a United States
                   $x History
                   $v Chronology.
```


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Notice that subfields $v, $x, and $z in the 651 field are repeatable. Subfields $v, $x, $y, and $z do not have to be in alphabetical order. They will be in the order prescribed by the instructions given by the subject heading system.

700 Added entry -- Personal name (R)

Indicator 1: Type of personal name entry element

0 -- Forename
1 -- Surname (this is the most common form)
3 -- Family name

Indicator 2: Type of added entry

-- No information provided (most common; co-authors, editors, etc.)
2 -- Analytical entry (The values for Indicator 2 changed in 1994 with Format Integration, and older records may display additional values. An analytical entry involves an author/title of an item contained in a work.)

Subfields used most often:

$a -- Personal name
$b -- Numeration
$c -- Titles and other words associated with a name (R)
$q -- Fuller form of name
$d -- Dates associated with a name (generally, year of birth)
$e -- Relator term (such as ill.) (R)
$4 -- Relator code (R)

```
Example:    700 1# $a Baldridge, Letitia.
```

710 Added entry -- Corporate name (R)

Indicator 1: Type of corporate name entry element

0 -- Inverted name (not used with AACR2)
1 -- Jurisdiction name
2 -- Name in direct order

Indicator 2: Type of added entry.

See Indicator 2 under 700
-- No information provided
2 -- Analytical entry

Subfields used most often:

$a -- Corporate name or jurisdiction name as entry element
$b -- Subordinate unit (R)

```
Example:    710 2# $a Sunburst Communications (Firm)
```

740 Added entry -- Uncontrolled related/analytical title (R)

Indicator 1: Nonfiling characters

0-9 -- Number of nonfiling characters present (for initial articles, including

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spaces)

*Indicator 2:*Type of added entry. See Indicator 2 under 700

-- No information provided

2 -- Analytical entry

(This field was redefined in 1994 with Format Integration. Prior to 1994, the field was also used for variant titles, such as a different wording on a spine title. In records created since Format Integration, those variant tiles appear in a 246 field.)

Subfield used most often:

$a -- Title

```
Example:    740 02 $a Uncle Vanya.
```

800 Series added entry -- Personal name (R)

Indicator 1: Type of personal name entry element

0 -- Forename

1 -- Surname

3 -- Family name

Indicator 2 undefined.

Subfields used most often:

$a -- Personal name

$b -- Numeration

$c -- Titles and other words associated with a name (R)

$q -- Fuller form of name

$d -- Dates associated with a name (generally, year of birth)

$t -- Title of a work (the series)

$v -- Volume number

```
Example:    800 1# $a Fisher, Leonard Everett.
                   $t Colonial American craftsmen.
```

830 Series added entry -- Uniform title (R)

Indicator 1 undefined.

Indicator 2: Nonfiling characters

0-9 -- Number of nonfiling characters present (for initial articles, including spaces)

Subfield used most often:

$a -- Uniform title

$v -- Volume number

```
Example:    830 #0 $a Railroads of America (Macmillan)
```


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Part VIII:

A List of Other Fields Often Seen in MARC Records

001	Control number
003	Control number identifier
005	Date and time of latest transaction
006	Fixed-length data elements -- additional material characteristics
007	Physical description fixed field
008	Fixed length data elements (See Part X)
022	International Standard Serial Number (ISSN)
037	Source of acquisition
041	Language code
043	Geographic area code
050	Library of Congress call number
060	National Library of Medicine call number
082	Dewey Decimal classification number (the one recommended by the Library of Congress; locally-assigned call numbers may appear elsewhere)
110	Main entry -- Corporate name (less frequent under AACR2 rules)
256	Computer file characteristics
263	Projected publication date (indicates a CIP -- Cataloging in Publication -- record)
306	Playing time
508	Creation/production credits note
510	Citation/references note (review sources)
511	Participant or performer note
521	Target audience note (first indicator: 0 = reading grade level, 1 = interest age level, 2 = interest grade level, 3 = special audience characteristics, 4 = motivation interest level)
530	Additional physical form available note
538	System details note
586	Awards note
656	Index term -- Occupation
730	Added entry -- Uniform title
852	Location
856	Electronic location and access
9XX	Reserved for local use. (They are used by vendors, systems, or individual libraries to exchange additional data)

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Part IX:

The Leader

There are 24 positions in the Leader, numbered from 00 to 23. For fuller explanation, see the *MARC 21 Format for Bibliographic Data*.

00-04 Record length (calculated by the computer for each record)

05 Record status
- a = increase in encoding level
- c = corrected or revised
- d = deleted
- n = new
- p = increase in encoding from prepublication (previous CIP)

06 Type of record
- a = language material
- c = printed music
- d = manuscript music
- e = cartographic material
- f = manuscript cartographic material
- g = projected medium
- i = nonmusical sound recording
- j = musical sound recording
- k = 2-dimensional nonprojectable graphic
- m = computer file
- o = kit
- p = mixed materials
- r = 3-dimensional artifact or naturally occurring object
- t = manuscript language material

07 Bibliographic level
- a = monographic component part
- b = serial component part
- c = collection
- d = subunit
- i = integrating resource
- m = monograph/item
- s = serial

08 Type of control
- # = no specified type
- a = archival

09 Character coding scheme
- # = MARC-8
- a = UCS/Unicode

10 Indicator count (always "2")

11 Subfield code count (always "2")

12-16 Base address of data (calculated by the computer for each record)

17 Encoding level
- # = full level

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1 = full level, material not examined
2 = less-than-full level, material not examined
3 = abbreviated level
4 = core level
5 = partial (preliminary) level
7 = minimal level
8 = prepublication level (CIP)
u = unknown
z = not applicable

18 Descriptive cataloging form
= non-ISBD
a = AACR2
i = ISBD
u = unknown

19 Multipart resource record level
= Not specified or not applicable
a = Set
b = Part with independent title
c = Part with dependent title

20 Length of the length-of-field portion (always "4")
21 Length of the starting-character-position portion (always "5")
22 Length of the implementation-defined portion (always "0")
23 Undefined (always "0")

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Part X:

Field 008 for Books

Field 008 is used for Fixed Length Data Elements ("Fixed Field Codes"). There are 40 character positions in field 008, numbered from 00-39. Undefined positions must contain either a blank (#) or a fill character (|). Positions 00-17 and 35-39 are defined the same way for all media.

The information shown here for positions 18-34 applies only to books. For explanation of all the positions below and for positions 18-34 for other media, see the *MARC 21 Format for Bibliographic Data*.

Note that field 008 has no indicators or subfield codes.

00-05 Date entered on file (YYMMDD),
where Y=year, M=month, and D=day

06 Type of date/publication status:
b = no dates given; B.C. date involved
e = detailed date
s = single known date/probable date
m = multiple dates
r = reprint/reissue date (Date 1) and original date (Date 2)

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n = dates unknown
q = questionable date
t = publication date and copyright date
| = no attempt to code

07-10 Date 1/beginning date of publication

11-14 Date 2/ending date of publication

Date fields contain the year(s) of publication. The type of date(s) in these elements are specified in fixed field element 06: Type of date/publication status. (For further details, see the field 008 description in the *MARC 21 Format for Bibliographic Data*.)

15-17 Place of publication, production, or execution

For example:
pk# = Pakistan
cau = California (US)

(For a full list of codes used in these positions, see the *MARC Code List for Countries*.)

18-21 Illustrations (up to 4 codes):

= no illustrations
a = illustrations
b = maps
c = portraits
d = charts
e = plans
f = plates
g = music
h = facsimiles
i = coats of arms
j = genealogical tables
k = forms
l = samples
m = phonodisc, phonowire, etc.
o = photographs
p = illuminations
| = no attempt to code

22 Target audience:

= unknown or not specified
a = preschool
b = primary
c = pre-adolescent
d = adolescent
e = adult
f = specialized
g = general
j = juvenile
| = no attempt to code

23 Form of item:

= none of the following
a = microfilm

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b = microfiche
c = microopaque
d = large print
f = braille
r = regular print reproduction
s = electronic
| = no attempt to code

24-27 Nature of contents (up to 4):

= no specified nature of contents
a = abstracts/summaries
b = bibliographies (is one or contains one)
c = catalogs
d = dictionaries
e = encyclopedias
f = handbooks
g = legal articles
i = indexes
j = patent document
k = discographies
l = legislation
m = theses
n = surveys of literature
o = reviews
p = programmed texts
q = filmographies
r = directories
s = statistics
t = technical reports
u = standards/specifications
v = legal cases and notes
w = law reports and digests
z = treaties
| = no attempt to code

28 Government publication:

= not a government publication
i = international intergovernmental
f = federal/national
a = autonomous or semi-autonomous component
s = state, provincial, territorial, dependent, etc.
m = multistate
c = multilocal
l = local
z = other type of government publication
o = government publication -- level undetermined
u = unknown if item is government publication
| = no attempt to code

29 Conference publication:

0 = not a conference publication
1 = conference publication

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| = no attempt to code

30 Festschrift:
0 = not a festschrift
1 = festschrift
| = no attempt to code

31 Index:
0 = no index
1 = index present
| = no attempt to code

32 Undefined (since 1990) (Earlier records may contain the values 0 or 1)
= Undefined
| = no attempt to code

33 Literary form:
0 = not fiction (not further specified)
1 = fiction (not further specified)
c = comic strips
d = dramas
e = essays
f = novels
h = humor, satires, etc.
i = letters
j = short stories
m = mixed forms
p = poetry
s = speeches
u = unknown
| = no attempt to code

34 Biography:
= no biographical material
a = autobiography
b = individual biography
c = collective biography
d = contains biographical information
| = no attempt to code

35-37 Language:
A three-letter code. For example: eng fre ger spa rus ita

(For a full list of codes used in these positions, see the *MARC Code List for Languages*.)

38 Modified record:
= not modified
x = missing characters (because of characters unavailable in MARC character set)
s = shortened
d = "dashed-on" information omitted
r = completely romanized/printed cards in script
o = completely romanized/printed cards romanized
| = no attempt to code

39 Cataloging source:

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= national bibliographic agency
c = cooperative cataloging program
d = other sources
u = unknown
| = no attempt to code

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Library of Congress
Library of Congress Help Desk (10/27/2009)

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APPENDIX C

Appendix C. Materials Considered

Exhibit	Document
1037	Juneau, T. N. (1997). *Micromachined dual input axis rate gyroscope*. Dissertation of University of California, Berkeley ("*Juneau*").
1037A	Bibliographic and MARC records for *Juneau*, available at https://search.library.berkeley.edu/permalink/01UCS_BER/1thfj9n/alma991005771689706532 from the University of California Berkeley Library.
1037B	Profile of the University of California, Berkeley Library, available at https://librarytechnology.org/library/11; the website of the University of California Berkeley Libraries, archived by Internet Archive on December 12, 1998, available at https://web.archive.org/web/19981212030542/http://www.lib.berkeley.edu/; and the webpage of library's online catalog, Pathfinder, archived by Internet Archive on January 17, 1999, available at https://web.archive.org/web/19990117024322/http://sunsite2.berkeley.edu:8000/.
1037C	WorldCat database record for *Juneau*, obtained from OCLC FirstSearch (subscription required for access).
1037D	"FirstSearch launched," Library Systems Newsletter, November 1991, available at https://librarytechnology.org/document/4992/
1037E	PQDT metadata record for *Juneau*, available at https://www.proquest.com/dissertations-theses/micromachined-dual-input-axis-rate-gyroscope/docview/304349726/se-2?accountid=9940
1037F	Front matter of vol. 59, no. 3 of *Dissertation Abstract Index* B and the index records for *Juneau* in this issue, obtained from the University of Wisconsin-Madison Library System.
1040	First page of Micromachined Vibratory rate gyroscope, WO 97/45699. ("*WO 97/45699*")

1044	G. C. Temes, L. E. Larson and K. W. Martin, State-of-the-art and future prospects for analogue signal processing - A tutorial, *1988 IEEE International Symposium on Circuits and Systems*, Espoo, Finland, 1988, pp. 1655-1660 vol.2. ("*Temes*")
1044A	Copy of *Temes*, obtained from the University of Wisconsin-Madison Library System.
1044B	Bibliographic and MARC records for *IEEE International Symposium on Circuits and Systems*, Espoo, Finland, whose 1988 issue contains *Temes*, available at https://search.library.wisc.edu/catalog/999582648602121 from the online catalog of the University of Wisconsin-Madison Library System.
1044C	Profile of the University of Wisconsin-Madison Library System, available at https://librarytechnology.org/library/2090
1044D	Copyright registration record for 1988 *International Symposium on Circuits and Systems*, Espoo, Finland that contains Temes. Available at https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?v1=10&ti=1,10&Search%5FArg=IEEE%20International%20Symposium%20on%20Circuits%20and%20Systems&Search%5FCode=TALL&CNT=25&PID=Bdib-yYeznvNN_qvinjMgCNi4cmCp6&SEQ=20250505165841&SID=4 from the public catalog of the US Copyright Office.
1044E	Bibliographic and MARC records for *1998 IEEE International Symposium on Circuits and Systems* cataloged as a book, available at https://search.lib.utexas.edu/permalink/01UTAU_INST/be14ds/alma991021409729706011 from the libraries of the University of Texas at Austin.
1053	Crossbow. (1998, April). DMU-6X and DMU-VGX Silicon IMU and Vertical Gyro. ("*DMU*")
1053A	Copy of *DMU*, archived by Internet Archive on June 29, 1998, available at

	https://web.archive.org/web/19980629124810/http://www.xbow.com/pdf/DMU-6X.pdf
1057	Micromachined Vibratory rate gyroscope, WO 97/45699. ("*WO 97/45699*")
1057A	Copy of *WO 97/45699*, available from Patentscope, available at https://patentscope.wipo.int/search/en/detail.jsf?docId=WO1997045699&_cid=P11-MAD3ZF-29133-1
1057B	Copy of *WO 97/45699*, available from Google Patents at https://patentimages.storage.googleapis.com/c8/95/eb/b0cbad41e86272/WO1997045699A2.pdf
1057C	Bibliographic record for *WO 97/45699*, available at https://patentscope.wipo.int/search/en/detail.jsf?docId=WO1997045699 from Patentscope, the WIPO Search Engine.
1057D	PCT Gazette, July 1998 issue, available at https://www.wipo.int/edocs/pctdocs/en/1998/pct_1998_26-section2.pdf
1058	Lemkin, M. A. (1997). *Micro accelerometer design with digital feedback control*. Dissertation of University of California, Berkeley. ("*Lemkin*")
1058A	Bibliographic and MARC records for *Lemkin*, available at https://search.library.berkeley.edu/discovery/fulldisplay?context=L&vid=01UCS_BER:UCB&search_scope=DN_and_CI&tab=Default_UCLibrarySearch&docid=alma991005819629706532 from the University of California Berkeley Libraries.
1058B	Profile of the University of California, Berkeley Library, available at https://librarytechnology.org/library/11; the website of the University of California Berkeley Libraries, archived by Internet Archive on December 12, 1998, available at https://web.archive.org/web/19981212030542/http://www.lib.berkeley.edu/; and the webpage of library's online catalog, Pathfinder, archived by Internet Archive on January 17, 1999, available at

	https://web.archive.org/web/19990117024322/http://sunsite2.berkeley.edu:8000/.
1058C	WorldCat database record for *Lemkin*, obtained from OCLC FirstSearch (subscription required for access).
1058D	"FirstSearch launched," Library Systems Newsletter, November 1991, available at https://librarytechnology.org/document/4992/
1058E	PQDT metadata record for *Lemkin*, available at https://www.proquest.com/dissertations-theses/micro-accelerometer-design-with-digital-feedback/docview/304345036/se-2?accountid=9940
1058F	Front matter of vol. 59, no. 3 of *Dissertation Abstract Index* B and the index record for *Lemkin* in this issue, obtained from the University of Wisconsin-Madison.
1059	Lu, C., Lemkin, M., & Boser, B. E. (1995, December). A monolithic surface micromachined accelerometer with digital output, *IEEE Journal of Solid-State Circuits*, 30(12), 1367-1373 ("*Lu*")
1059A	Copy of *Lu*, obtained from the Library of Congress.
1059B	Bibliographic and MARC records for *IEEE Journal of Solid-State Circuits* that contains *Lu*, available at https://lccn.loc.gov/89657065 from the online catalog of the Library of Congress.
1059C	LOCIS: Library of Congress Information System, archived by Internet Archive on May 24, 1997, available from https://web.archive.org/web/19970524160715/http://library.usask.ca/hytelnet/us3/us373.html
1059D	Copyright registration record for 30(12) of *IEEE journal of Solid-State Circuits*, available at https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?v1=30&ti=26,30&Search%5FArg=IEEE%20Journal%20of%20Solid%2DState%20Circuits&Search%5FCode=TALL&CNT=25&PID=H2Ru8-OxHo8BNzKVHQQZWtt-

	zwhMu&SEQ=20250425114301&SID=1 from the public catalog of the US Copyright Office.
1060	Yun, W., Howe, R. T., & Gray, P. R. (1992, June). Surface micromachined, digitally force-balanced accelerometer with integrated CMOS detection circuitry, in *IEEE Solid-State Sensor and Actuator Workshop Technical Digest* (pp. 126-131). ("*Yun*")
1060A	Copy of *Yun*, obtained from Library of Congress.
1060B	Bibliographic and MARC records for *IEEE Solid-State Sensor and Actuator Workshop Technical Digest*, available at https://lccn.loc.gov/91058232 from the online catalog of the Library of Congress.
1060C	LOCIS: Library of Congress Information System, archived by Internet Archive on May 24, 1997, available from https://web.archive.org/web/19970524160715/http://library.usask.ca/hytelnet/us3/us373.html
1060D	Copyright registration record *IEEE Solid-State Sensor and Actuator Workshop Technical Digest*, available at https://cocatalog.loc.gov/cgi-bin/Pwebrecon.cgi?v1=3&ti=1,3&Search%5FArg=IEEE%20Solid%2DState%20Sensor%20and%20Actuator%20Workshop&Search%5FCode=TALL&CNT=25&PID=hcjuoHH5C8Xnndwecu1lQ5Ir7h_qJGV&SEQ=20250505170146&SID=9 from the public catalog of the US Copyright Office.
1063	Measurement Specialties. (1998, August). Accelerometer ACH-04-08-05. Application Specification. 114-27002. 27 Aug 98 Rev A. ("*ACH-04-08-05*")
1063A	Website of the Piezo Film Technical Manual of Measurement Specialties, archived by Internet Archive on February 21, 1999, available at https://web.archive.org/web/19990221083428/http://www.msiusa.com/piezo_film_manual.htm; and Accelerometer ACH-04-08-05, archived by Internet Archive on September 25, 2000, available at

	https://web.archive.org/web/20000925200945/http://www.msiusa.com/805spec3.pdf.
1063B	Karki, J. (1998). Application report: 3-V accelerometer featuring TLV2772, available at https://www.ti.com/lit/an/slva040/slva040.pdf?ts=1746405483657&ref_url=https%253A%252F%252Fwww.google.com%252F
1063C	Measurement Specialties (1999, April). Piezo Film Sensors Technical Manual. REV B. Available at https://cdn.sparkfun.com/assets/d/a/a/b/b/Piezo_Film_Sensors_Technical_Manual.pdf
1063D	Website of the Piezo Film Technical Manual of Measurement Specialties, archived by Internet Archive on February 21, 1999, available at https://web.archive.org/web/19990221083428/http://www.msiusa.com/piezo_film_manual.htm; and Part 11 of the technical manual, archived by Internet Archive on September 25, 2000, available at https://web.archive.org/web/20000925200634/http://www.msiusa.com/PART11-INT.pdf
1064	Analog Devices. ADXL05. ±1g to ±5g Single Chip Accelerometer with Signal Conditioning. ("*ADXL05*")
1064A	A copy of *ADXL05* archived by Internet Archive on November 6, 2015, available at https://web.archive.org/web/20151106170116/https://www.analog.com/media/en/technical-documentation/obsolete-data-sheets/66309706ADXL05.pdf
1064B	"Multi-Purpose Accelerometer Measures Low g Forces with 0.005g Resolution [ADXL05]," an Analog Devices press release on *ADXL05* archived by Internet Archive on June 6, 1997, available at https://web.archive.org/web/19970606212637/http://www.analog.com/publications/press/products/ADXL05_050195.html.
1064C	Website for *ADXL05* archived by Internet Archive on June 6, 1997, and available at

	https://web.archive.org/web/19970606201119/http://www.analog.com/products/sheets/ADXL05.html
1064D	Index pages of Wayback Machine that shows the website for *ADXL05* at http://www.analog.com/products/sheets/ADXL05.html was archived starting June 6, 1997.
1065	Analog Devices. (1996). ADXL50* Monolithic Accelerometer With Signal Conditioning datasheet. ("*ADXL50*")
1065A	A copy of *ADXL50*, archived by Internet Archive on July 7, 1997, available at https://web.archive.org/web/19970707142701/http://www.analog.com/pdf/adxl50.pdf.
App. A	Hsieh-Yee CV
App. B	Parts VII to X of Understanding MARC Bibliographic, available at https://www.loc.gov/marc/umb/um07to10.html from the Library of Congress.

EXHIBIT 1037A

DISSERTATION

Micromachined dual input axis rate gyroscope / by Thor Nelson Juneau.

Juneau, Thor Nelson.

1997

Available at Northern Regional Library Facility Main (Gardner) Stacks (NRLF) (308t 1997 795) >

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Title	Micromachined dual input axis rate gyroscope / by Thor Nelson Juneau.
Creator / Contributor	Juneau, Thor Nelson. ›
Publisher	1997.
Creation date	1997
Format	vii, 127 leaves : illustrations ; 28 cm
Notes	Includes bibliographical references (leaves 123-127).
Dissertation	Thesis (Ph. D. in Engineering-Mechanical Engineering)--University of California, Berkeley, Dec. 1997.
Subject	Dissertations, Academic UCB Engineering 1991-2000.
Genre	dissertations Academic theses Thèses et écrits académiques
Related titles	Available in other form: Online version: Juneau, Thor Nelson. Micromachined dual input axis rate gyroscope. 1997 ›
Source	Library Catalog

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https://search.library.berkeley.edu/permalink/01UCS_BER/1thfj9n/alma991005771689706532

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MARC record of *Micromachined dual input axis rate gyroscope* by Thor Nelson Juneau. Available at https://search.library.berkeley.edu/discovery/sourceRecord?vid=01UCS_BER:UCB&docId=alma9910057716897065 32&recordOwner=01UCS_NETWORK, copied from the online catalog of the University of California, Berkeley Libraries.

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001     9915363677406531
005     20250116213022.0
008     980629s1997    xx a     bm   000 0 eng d
035     ##$a(CUY)UCB-b151334985-01ucs_ber
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035     ##$a(OCoLC)ocn230741619
040     ##$aCUY $beng $cCUY $dOCLCQ $dOCLCO $dOCLCF $dOCLCO $dOCLCQ $dOCLCO
$dOCLCL $dOCLCQ
049     ##$aMAIN
090     ##$b308t 1997 795 $9LOCAL
100     1#$aJuneau, Thor Nelson.
245     10$aMicromachined dual input axis rate gyroscope / $cby Thor Nelson
Juneau.
264     #0$c1997.
300     ##$avii, 127 leaves : $billustrations ; $c28 cm
336     ##$atext $btxt $2rdacontent
337     ##$aunmediated $bn $2rdamedia
338     ##$avolume $bnc $2rdacarrier
502     ##$aThesis (Ph. D. in Engineering-Mechanical Engineering)--University
of California, Berkeley, Dec. 1997.
504     ##$aIncludes bibliographical references (leaves 123-127).
655     #7$adissertations. $2aat
655     #7$aAcademic theses $2fast
655     #7$aAcademic theses. $2lcgft
$0http://id.loc.gov/authorities/genreForms/gf2014026039
655     #7$aThèses et écrits académiques. $2rvmgf
690     ##$aDissertations, Academic $xUCB $xEngineering $y1991-2000. $9LOCAL
776     08$iOnline version: $aJuneau, Thor Nelson. $tMicromachined dual input
axis rate gyroscope. $d1997 $w(OCoLC)931666212
758     ##$ihas work: $aMicromachined dual input axis rate gyroscope (Text)
$1https://id.oclc.org/worldcat/entity/E39PCXFPh9dJyTVHrpRbRw8JJ8
$4https://id.oclc.org/worldcat/ontology/hasWork
908     ##$aWorldCat Daily Updates 2022-09-06 $bWorldCat record variable
field(s) change: 040, 655
908     ##$aWorldCat Daily Updates 2023-11-22 $bWorldCat record variable
field(s) change: 040, 655
908     ##$aWorldCat Daily Updates 2025-01-16 $bWorldCat record variable
field(s) change: 040, 936, LDR
936     ##$aBATCHLOAD
968     ##$aReclvl: b Addate: 980629 Addid: ELA Moddate: 080825 Modid: XRF
$9LOCAL
996     ##$eGLADN151698270 $9LOCAL
996     ##$ab151334985 $bUpdated: 02-19-21 $cCreated: 04-01-09 $dCatDate: 06-
29-98 $9LOCAL
```

EXHIBIT 1037B

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94720-6000
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Connect to: **Library Web Site**✔ **Online Catalog**

Library details: **University of California Library at Berkeley** is an **Academic** library. This library is affiliated with **University of California** (**view map**) . The collection of the library contains **16,217,948** volumes. The library circulates **707,825** items per year. The library serves a population of **43,584** FTE Enrollment.

Permalink: **https://librarytechnology.org/library/11**
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Administration: The director of the library is **Suzanne Wones** .

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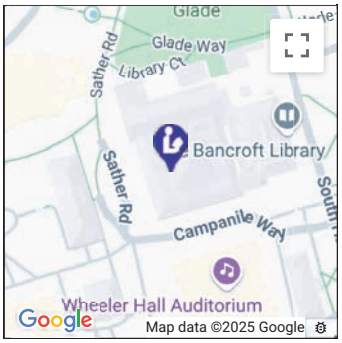
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Affiliations: The library is a member of the **Association of Research Libraries**

Statistics Academic		
Enrollment	43,584	**FTE Students**
Collection size	16,217,948	**volumes**
Annual Circulation	707,825	**transactions**



University of California Library at Berkeley

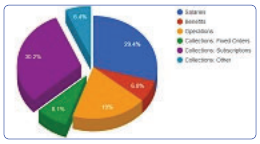


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	Product Name	Year Contracted
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Previous Automation System	Millennium	2008
Previous Automation System	Locally developed	1972
Discovery Service (w/index)	Ex Libris CDI	2019
Previous Discovery Index	EBSCO Discovery Service	2015
Discovery Interface	Primo	2019
Authentication Service	EZproxy	2017
Previous Authentication Service	Locally Developed	
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Institutional Repository	TIND IR	
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This library is responsible for the procurement of the library automation system.		

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OCLC Symbol	CUY
WorldCat Registry ID	5689
NCES LIBID	110635
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Try new features in our Experimental version of Pathfinder. You can query all the Melvyl article databases with one search. Also, several new databases from SilverPlatter are available through the Experimental Pathfinder interface.

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EXHIBIT 1037C

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Title: Micromachined dual input axis rate gyroscope **Author:** Juneau, Thor Nelson **Accession Number:** 230741619

Libraries with Item: "Micromachined dual input ..."(Record for Item | Get This Item)

Location	Library	Code
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Record for Item: "Micromachined dual input ..."(Libraries with Item)

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Title: Micromachined dual input axis rate gyroscope /

Author(s): Juneau, Thor Nelson.

Year: 1997

Description: vii, 127 leaves : illustrations ; 28 cm

Dissertation: Thesis (Ph. D. in Engineering-Mechanical Engineering)--University of California, Berkeley, Dec. 1997.

Language: English

SUBJECT(S)

Genre/Form: dissertations.
Academic theses
Academic theses.
Thèses et écrits académiques.

Note(s): Includes bibliographical references (leaves 123-127).

General Info: **Other format available:** Online version:; Juneau, Thor Nelson.; Micromachined dual input axis rate gyroscope.; 1997

Responsibility: by Thor Nelson Juneau.

Material Type: Thesis/dissertation (deg); Manuscript (mss)

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Document Type: Book; Archival Material
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EXHIBIT 1037D

ISSN 0277-0288

Library Systems Newsletter

Published by Library Technology Reports • American Library Association
50 East Huron Street, Chicago, Illinois 60611

FirstSearch launched

Library Systems Newsletter [November 1991]



A new online reference tool for end-users is now available from OCLC. The FirstSearch Catalog is a relatively low-cost, easy-to-use reference system that library patrons can use to search the OCLC Online Union Catalog, as well as a variety of reference data bases.

The FirstSearch interface was designed by OCLC staff for end-users and it provides simple directions for selecting the data base to be searched and type of search desired--subject, author, title, or other specific indexes. Online help is extensive.

Six data bases are currently mounted on FirstSearch: WorldCat, the 24-million-record OCLC Online Union Catalog with its more than 400 million location listings; ERIC (Educational Resources Information Center); GPO Monthly Catalog; Consumers Index to Product Evaluations; BIOSIS/FS, a data base created for FirstSearch that is derived from the Biological Abstracts portion of BIOSIS Previews; and Mini GeoRef, the most recent five years of GeoRef. Additional data bases will be added regularly, including 17 H.W. Wilson Company data bases. FirstSearch is priced by the search, with an institution's per-search price determined by the total number of searches purchased. The per-search price ranges from $.45 when 80,000 or more searches are purchased, to $.90 when 500 searches are purchased. Searches are sold in blocks of 500.

Libraries have the option to purchase FirstSearch cards for distribution to patrons in denominations of 10 or 25 searches per card. Libraries may offer FirstSearch as a free service or recoup costs by charging for FirstSearch cards or passwords.

Patrons with Internet access can use FirstSearch from terminals in their homes or offices with either their assigned FirstSearch authorization and password or their FirstSearch card.

Personal Computers or OCLC workstations can be used to access FirstSearch, as well as several telecommunications methods: OCLC dedicated-line, dial access, or the Internet. Institutions may also offer FirstSearch via their Online Public Access Catalog or Local Area Network, linked to OCLC with an OCLC Communications Controller.

Hours of operation for the service are: 6 a.m. to 10 p.m., Monday through Friday, and 8 a.m. to 8 p.m., Saturday, Eastern Time. Additionally, Internet access is available on Sundays from noon to 8 p.m., Eastern Time.

It is currently available to OCLC member institutions that contribute to the OCLC Online Union Catalog: full members, tapeloading members, Major Microforms and CONSER participants, Serials Union List participants, and Selective Users. It is also available to library schools. As of late October, more than 80 libraries were using FirstSearch. If OCLC is able to up several thousand libraries, it will dramatically broaden its revenue base. Thus assuring greater long-term financial stability for the bibliographic utility.

The cost of FirstSearch data bases is not only lower than that offered by Dialog and other data base services, but appears to be cost competitive with CD-ROM technology.

[Contact: OCLC, Inc., 6565 Frantz Road, Dublin, OH 430l7-3395; (614) 764-4000; Fax (614) 764-6096.]

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EXHIBIT 1037E

Full Text | Dissertation or Thesis

Micromachined dual input axis rate gyroscope

Juneau, Thor Nelson. University of California, Berkeley ProQuest Dissertations & Theses, 1997. 9826975.

Abstract

The need for inexpensive yet reliable angular rate sensors in fields ranging from automotive to consumer electronics has motivated prolific micromachined rate gyroscope research. The vast majority of research has focused on single input axis rate gyroscopes based upon either translational resonance, such as tuning forks, or structural mode resonance, such as vibrating rings. However, this work presents a novel, contrasting approach based on angular resonance of a rotating rigid rotor suspended by torsional springs. The inherent symmetry of the circular design allows angular rate measurement about two axes simultaneously, hence the name micromachined dual-axis rate gyroscope. The underlying theory of operation, mechanical structure design optimization, electrical interface circuitry, and signal processing are described in detail. Several operational versions were fabricated using two different fully integrated surface micromachining processes as proof of concept.

The heart of the dual-axis rate gyroscope is a $\sim$2 μm thick polysilicon disk or rotor suspended above the substrate by a four beam suspension. When this rotor in driven into angular oscillation about the axis perpendicular to the substrate, a rotation rate about the two axes parallel to the substrate invokes an out of plane rotor tilting motion due to Coriolis acceleration. This tilting motion is capacitively measured and on board integrated signal processing provides two output voltages proportional to angular rate input about the two axes parallel to the substrate.

The design process begins with the derivation of gyroscopic dynamics. The equations suggest that tuning sense mode frequencies to the drive

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oscillation frequency can vastly increase mechanical sensitivity. Hence the supporting four beam suspension is designed such that electrostatic tuning can match modes despite process variations. The electrostatic tuning range is limited only by rotor collapse to the substrate when tuning-voltage induced electrostatic forces over power the beam suspension. Multivariable design optimization is used to maximize performance given process constraints.

All electronics needed to sustain rotor oscillation, control oscillation amplitude, sense rotor tilting due to Coriolis acceleration, and process sense signals to produce voltage outputs are explained. A voltage controlled oscillator slaved to the structure oscillation through a phase-lock-loop is used as the master clock to produce all signals needed for signal processing and amplitude control. Thus, the micromachine serves as both a rotation sensor and a frequency reference. Final versions fabricated by Sandia National Laboratory were fully integrated and therefore required only passive components and electrical sources off-chip.

Without electrostatic tuning, dual-axis rate gyroscopes achieved 0.1$ \sp\circ$/sec/$\sqrt{Hz}$ noise level. This provided automotive grade performance of approximately 1$\sp\circ$/sec noise floor over a 100 Hz bandwidth. Electrical tuning decreased noise to below 0.02$\sp\circ$/sec/ $\sqrt{Hz}.$ However, open-loop operation with nearly matched sense and drive modes can result in higher cross-axis sensitivity, scale factor drift, and phase errors. Closed-loop feedback methods which alleviate these problems as well as reduce offset drift due to quadrature error are presented as future directions.

Less

Details

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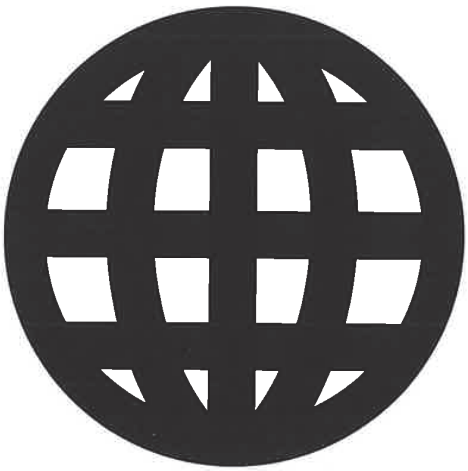
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INTRODUCTION

Dissertation Abstracts International

Dissertation Abstracts International (DAI) is published monthly by UMI Company and includes abstracts of doctoral dissertations submitted to UMI by 550 participating institutions in North America and throughout the world.

Each author-prepared abstract, up to 350 words in length, describes in detail the original research project on which the dissertation is based. Most of the approximately 45,000 dissertations published by UMI each year are abstracted in *DAI* and may be purchased in microform or as paper copies.

DAI is published in three sections:

Section A—*The Humanities and Social Sciences*

I — Communications and the Arts
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IV — Philosophy Religion and Theology
V — Social Sciences

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I — Biological Sciences
II — Earth Sciences
III — Health and Environmental Sciences
IV — Physical Sciences
V — Psychology

Section C—*Worldwide*

Section C—*Worldwide* (formerly *European Abstracts*) is published quarterly and includes abstracts of dissertations in all disciplines accepted for doctoral and post-doctoral degrees at institutions throughout the world. Most of these dissertations are not available from UMI; those which are for sale are also listed in Section A or B. Beginning with Volume 50 (Spring 1989), *DAI—C* was expanded to include institutions worldwide.

Arrangement of Entries

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Bibliographic Data

All bibliographic data relating to a dissertation appear at the head of an entry. The abstract then follows. Each entry contains the following essential information:

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- Dissertation adviser
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Each issue of *DAI* includes two indexes, both of which follow the main abstract text:

Keyword Index. A keyword is a significant word which appears in the dissertation title. Each keyword is followed in the index by citations in alphabetic sequence.

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Academic institutions join UMI's publishing program on an ongoing basis. Some schools publish all of their dissertations, while others choose to publish only current ones. Dissertations accepted by British institutions are made available through UMI in association with The British Library. A comprehensive list of participating institutions is located elsewhere in this introductory section.

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DISSERTATION SERVICES

UMI Dissertation Services is a program of publishing, bibliographic, and copy services which enables the researcher to locate doctoral dissertations, and to acquire copies of those manuscripts published by UMI. The foundation on which these services are structured is UMI's comprehensive dissertation database, one of the largest and most widely used bibliographic information files in the world.

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The landmark 37-volume *CDI 1861-1972* lists more than 417,000 dissertations under keyword headings and within a separate author index. The *CDI Ten-Year Cumulation 1973-1982* cites nearly 351,000 dissertations in a 38-volume single-source reference and the *CDI Five-Year Cumulation 1983-1987* includes over 162,000 citations in 22 volumes. Together, these powerful bibliographic tools allow access to approximately 930,000 dissertations spanning more than 125 years with just *three* separate searches. *CDI* supplements are published annually in both library-bound volumes and on microfiche.

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- Administration
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- Art
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- Finance
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- Music
- Philosophy of
- Physical
- Reading
- Religious
- Sciences
- Secondary
- Social Sciences
- Sociology of
- Special
- Teacher Training
- Technology
- Tests and Measurements
- Vocational

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- Ancient
- Linguistics
- Modern

Literature
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- Classical
- Comparative
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- Modern
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Religion
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- Clergy
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- Philosophy of

Theology

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- Cultural
- Physical

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- Industrial and Labor Relations
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Transportation
Urban and Regional Planning
Women's Studies

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  Animal Pathology
  Fisheries and Aquaculture
  Food Science and Technology
  Forestry and Wildlife
  Plant Culture
  Plant Pathology
  Plant Physiology
  Range Management
  Soil Science
  Wood Technology
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  Animal Physiology
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The design of robust multi-rate repetitive learning controllers with applications to practical systems. James, Courtney Darwin, Ph.D. *Georgia Institute of Technology,* 1997. 129pp. Director: Nader Sadegh **Order Number DA9827258**

Presently, the convergence and asymptotic stability of a single repetitive controller can be readily assessed for a linear closed-loop system in the absence of noise and transients and subject to periodic disturbances that are strictly time dependent. This research extends the current convergence and performance criteria to include more practical cases such as: (a) systems whose periodic disturbance are a function of some state, instead of time; (b) systems in which more than one controller is used in parallel; (c) systems in which the [digital] repetitive controller must sample at a slower rate than the plant (i.e., multi-rate repetitive learning control [RLC]); and (d) systems where non-harmonic errors are also present. Tests were performed both in simulation and empirically on a custom designed test fixture to verify the predicted results.

If the system's periodic disturbances are strict functions of time, RLC is shown to drive the tracking error to zero, regardless of the disturbance amplitude. However, it is proven both theoretically and experimentally that, if the disturbances depend instead on a state of the system (e.g., angular shaft position), then an upper bound exists on the amplitude of the disturbances, above which, convergence of RLC is no longer assured. In addition, two somewhat novel repetitive controller formulations were developed: (1) a hybrid repetitive controller and (2) an adaptive external model repetitive controller (A-EMRC).

Cartesian grid embedded boundary finite difference methods for elliptic and parabolic partial differential equations on irregular domains. Johansen, Hans Svend, Ph.D. *University of California, Berkeley,* 1997. 182pp. Chair: Phillip Colella **Order Number DA9826966**

This thesis presents a natural extension of the embedded boundary method, to include elliptic and parabolic partial differential equations defined on moving domains. Our motivation is to augment the algorithms available for hyperbolic problems, and provide the tools needed to approach a broader class of problems that include both heat transfer and phase change. This thesis attempts to overcome the major drawbacks of rectangular-grid finite-volume methods-lack of adaptivity and geometric flexibility—while retaining their simplicity and regular data structures.

To demonstrate that this is possible, three model problems with Dirichlet boundary conditions are discretized on time-dependent domains: the Poisson equation, the heat equation, and classical Stefan problem. In each case, a consistent finite-volume method is derived, by integrating the differential equation over the space-time volume, defined by the intersection of a piecewise-linear moving boundary and each cell of a Cartesian grid. The resulting surface integrals are discretized with single-point quadrature rules, that take advantage of geometric properties to cancel the leading-order error terms. The integrands are then approximated to second-order, using finite-differences of the cell-centered solution, even when those cell-centers are outside the domain. Additional consideration is given to the conditioning of the resulting set of equations; gradients at the boundary are calculated using stencils that are well-separated from the partial cells. Although this yields a nonsymmetric linear system, we are able to combine point-relaxation with a multi-grid iteration strategy, to obtain residual reduction rates per iteration that are nearly independent of the grid spacing and the presence of arbitrarily small cells. This behavior persists, even when incorporated into an adaptive mesh hierarchy.

Micromachined dual input axis rate gyroscope. Juneau, Thor Nelson, Ph.D. *University of California, Berkeley,* 1997. 127pp. Chair: Albert P. Pisano **Order Number DA9826975**

The need for inexpensive yet reliable angular rate sensors in fields ranging from automotive to consumer electronics has motivated prolific micromachined rate gyroscope research. The vast majority of research has focused on single input axis rate gyroscopes based upon either translational resonance, such as tuning forks, or structural mode resonance, such as vibrating rings. However, this work presents a novel, contrasting approach based on *angular* resonance of a rotating rigid rotor suspended by torsional springs. The inherent symmetry of the circular design allows angular rate measurement about two axes simultaneously, hence the name micromachined dual-axis rate gyroscope. The underlying theory of operation, mechanical structure design optimization, electrical interface circuitry, and signal processing are described in detail. Several operational versions were fabricated using two different fully integrated surface micromachining processes as proof of concept.

The heart of the dual-axis rate gyroscope is a $\sim 2\ \mu m$ thick polysilicon disk or rotor suspended above the substrate by a four beam suspension. When this rotor in driven into angular oscillation about the axis perpendicular to the substrate, a rotation rate about the two axes parallel to the substrate invokes an out of plane rotor tilting motion due to Coriolis acceleration. This tilting motion is capacitively measured and on board integrated signal processing provides two output voltages proportional to angular rate input about the two axes parallel to the substrate.

The design process begins with the derivation of gyroscopic dynamics. The equations suggest that tuning sense mode frequencies to the drive oscillation frequency can vastly increase mechanical sensitivity. Hence the supporting four beam suspension is designed such that electrostatic tuning can match modes despite process variations. The electrostatic tuning range is limited only by rotor collapse to the substrate when tuning-voltage induced electrostatic forces over power the beam suspension. Multivariable design optimization is used to maximize performance given process constraints.

All electronics needed to sustain rotor oscillation, control oscillation amplitude, sense rotor tilting due to Coriolis acceleration, and process sense signals to produce voltage outputs are explained. A voltage controlled oscillator slaved to the structure oscillation through a phase-lock-loop is used as the master clock to produce all signals needed for signal processing and amplitude control. Thus, the micromachine serves as both a rotation sensor and a frequency reference. Final versions fabricated by Sandia National Laboratory were fully integrated and therefore required only passive components and electrical sources off-chip.

Without electrostatic tuning, dual-axis rate gyroscopes achieved $0.1°/\text{sec}/\sqrt{Hz}$ noise level. This provided automotive grade performance of approximately $1°/\text{sec}$ noise floor over a 100 Hz bandwidth. Electrical tuning decreased noise to below $0.02°/\text{sec}/\sqrt{Hz}$. However, *open-loop* operation with nearly matched sense and drive modes can result in higher cross-axis sensitivity, scale factor drift, and phase errors. Closed-loop feedback methods which alleviate these problems as well as reduce offset drift due to quadrature error are presented as future directions.

A dynamic model for heating and cooling coils. Karkamaz, Nabil, Ph.D. *University of Colorado at Boulder,* 1998. 165pp. Director: Moncef Krarti **Order Number DA9827730**

A detailed model has been developed to determine the heat and mass transfer for heating and cooling coils. This model can predict the dynamic performance of the coils. The results obtained by the developed model are useful to design and control heating and cooling coils.

The model is capable of predicting various output parameters including temperatures of the water and air, output humidity ratio, and sensible and total heat transfer rates in the coils.

The model has been validated using experimental data obtained from Larson Laboratory at the Joint Center for Energy Management. Further validation has been performed using manufacturer's data for existing heating and cooling coils.

Parametric analysis has been conducted to determine the effect of various parameters—such as tube thermal conductivity, fin thickness and number of fins per meter—on the performance of the heating and cooling coils.

Shape memory materials: Constitutive modeling and finite element analysis. Kasper, Eric Paul, Ph.D. *University of California, Berkeley,* 1997. 191pp. Co-Chairs: Robert L. Taylor; Sanjay Govindjee **Order Number DA9826978**

A constitutive model for solid-solid phase transformations has been developed for martensitic type transformations. Specifically, we investigate and model the one-dimensional behavior of shape memory alloys, with the purpose of capturing both the shape memory effect and the pseudoelasticity effect which are uniquely exhibited by this class of alloys. An appropriate numerical approximation of the constitution is

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State-of-the-Art and Future Prospects for Analogue Signal Processing -A Tutorial

Gabor C. Temes, Lawrence E. Larson and Kenneth W. Martin

University of California
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ABSTRACT

Despite the proliferation of VLSI digital integrated circuits, the development of analog interface circuits continues to advance rapidly. This paper outlines the major trends in analog integrated signal processing. A/D and D/A converters are becoming the dominant analog components in major systems, and converters that rely on digital post-processing and error correction are becoming increasingly popular. These, and other trends, will be highlighted.

INTRODUCTION

Even though predictions in the rapidly changing area of integrated circuits are risky, certain tendencies are clearly visible. Signal processing, switching and control functions increasingly use digital techniques. This is due to the accuracy, flexibility, programmability and modularity of digital systems, in addition to the high levels of integration achievable in modern digital integrated circuits. As a result, in many signal processors with analog inputs and outputs, the majority of the components are becoming digital, with only a relatively few functions remaining in analog form. These analog circuits usually include the S/H, preamplifier, input/output buffers, pre- and post-filter, equalizers, multiplexer/demultiplexer stages, and A/D and D/A converters. These circuits are necessary for conditioning an analog input signal for digital manipulation, or a digital output signal for analog transmission [1].

In addition to A/D and D/A conversion tasks, analog interface systems are increasingly used for high-speed data transmission, in disk drive systems, and linear fiber-optic ICs for inter-board communications.

A development interesting for those of us who earn their living by designing the circuits performing these functions is that, despite the increased use of digital techniques, R & D activities in the analog area are intensifying, rather than diminishing. One measure of the continuing evolution of analog integrated circuits is the relative number of sessions devoted to analog and digital circuits at the ISSCC. At the 1988 conference, five sessions were devoted to analog techniques, and eight to digital.

The accelerating evolution of analog integrated circuits occurs in part, because as digital integrated circuit technology improves the performance of the analog interface modules must also improve in terms of increased speed and accuracy, as well as reduced chip area and power dissipation. This is made more difficult by the changes (primarily the reduced supply voltage) aimed at improving the reliability, power dissipation, speed and density of the digital circuitry. With the current trend towards low-voltage (3 V) single-supply IC's, the prospect of a dual-supply arrangement is becoming attractive for mixed analog-digital chips.

Overall, especially for parallel digital systems or systems where signals can be stored and post-processed digitally in non-real time, the analog interface is often the bottleneck in mixed analog-digital signal processing. In addition, while the simulation, design and testing of digital logic circuitry has been well supplied with CAD tools, the CAD of analog circuits is still not mature. Because of the wide range and large number of design parameters (such as frequency range, dynamic range, process variables, accuracy, supplies, signal levels, etc.) the development of fully automated analog design techniques, or even of a complete library of pre-designed modules, is very unlikely. Thus, analog circuit design is likely to remain, for the foreseeable future, an art rather than an automated menial task. (It should, however, be noted that with the reduction of device dimensions to the submicron range, high-speed digital circuit design is also becoming a similarly sophisticated task - in fact it is becoming essentially analog circuit design!)

Finally, even for some "purely digital" ICs, such as dynamic and static RAMs, major improvements in speed have been obtained due to faster analog components (bus drivers, sense amplifiers, etc.)

In the next sections, recent developments in some of the most important analog signal processing circuits will be briefly discussed. The discussion will be restricted to circuits realized in MOS and GaAs technologies, since the writers' interest and experience is mostly in these fields.

DATA CONVERTERS

In terms of importance, variety, sophistication and difficulty, A/D and D/A converters represent perhaps the greatest challenge for today's circuit designer.

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Next, we list some interesting recent developments in this area. No attempt is made to make this survey complete or even fully representative of the global activities in the field.

Figure 1 (compiled by Tanju Cataltepe of UCLA) illustrates the performance of some MOS and GaAs A/D converters reported recently, in an accuracy-vs-speed coordinate system. The plot demonstrates the difficulty in overcoming technological limitations on both accuracy and speed. Major improvements in the conversion speed are currently being triggered by the use of submicron bipolar, MOS and especially GaAs technologies. As an example, Table I summarizes the performance of a recent high-speed (1 GS/s) interleaved A/D converter [2]. It requires two GaAs and four Si bipolar integrated circuits. The GaAs chips provide accurate sampling, while the Si chips act as flash ADC's. A 6-bit accuracy was achieved. This project also demonstrated an optimum use of the different high-speed technologies, since GaAs is very attractive for sample-and-hold functions, due to the availability of Schottky diodes and the low input leakage current, and Si bipolar technology is attractive for flash ADC's, due to the small offset voltage and hysteresis of the resulting comparators.

GaAs heterojunction bipolar transistor (HBT) technology promises to be the "ultimate" vehicle for ADC applications, since it combines the intrinsic high speed of GaAs with the excellent matching properties of silicon bipolar technology. A 4-bit 2.5GS/s HBT flash ADC was recently announced [3]. The comparator uniformity was comparable with 6-bit operation, and higher levels of integration are planned. Simulations indicate that a 12-14 bit resolution at sample rates approaching 100 MHz is possible with this approach.

An economical solution for high-speed and medium-accuracy data conversion is to use a pipelined - or multi-pass - configuration. Several architectures have been suggested for pipelined ADC's [5]-[7]. In a recent paper [8], a 9-bit 5 MS/s pipelined converter was realized in a 3 μm CMOS technology. Its performance is summarized in Table II. It achieved its accuracy by using an off-chip digital correction circuitry, which corrected for comparator offset voltage limitations.

At the other end of the spectrum, very high accuracy (14 - 16-bit) conversion can be achieved using oversampling and noise shaping techniques. The basic technique (often called Δ-Σ or Σ-Δ modulation) has existed for over 25 years; however, a number of theoretical and technical innovations occurred recently that renewed interest in the field. These included the discovery that the performance of a high-order Δ-Σ loop can also be achieved by using a number of coupled first-order (and hence absolutely stable) loops. A CMOS system which achieves 16 bits using three coupled stages is described in [4]. Its performance is summarized in Table III; the block diagram is shown in Figure 2.

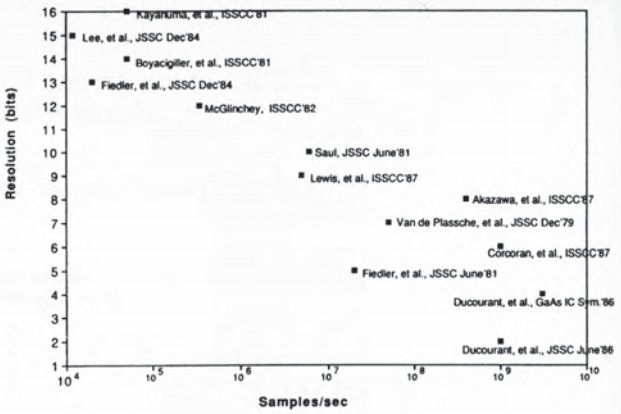


Figure 1. A/D converter performances

Table I. GaAs-BJT ADC performance [2]

Sample Rate	1 Gs/s (and lower)
Bandwidth (3 dB)	1.7 GHz
Input Range	± 0.64 V
Random Noise	< 5 mV pp < 0.25 LSB
Effective Bits	
1 Gs/s, 1 GHz input	5.2 bits
1 Gs/s, 200 kHz input	6.9 bits
Power	16 W

Table II. Pipelined CMOS ADC performance [8]

Technology	3-u CMOS
Resolution	9 bits
Conversion Rate	5 Ms/s
Area*	8500 mils^2
Power Supplies	±5 V
Power Dissipation	180 mW
Input Capacitance	3 pF
Input Offset	< 1 LSB
CM Input Range	±5 V
DC PSRR	50 dB

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Table III. Δ-Σ CMOS ADC performance [4]

Resolution	16 bit
Sampling frequency(fs)	≤ 3 MHz
Signal bandwidth	fs/128
Signal/(Noise + T H D)	91 dB
T H D	0.002 %
Supply voltage	5 V
Power Dissipation	110 mW

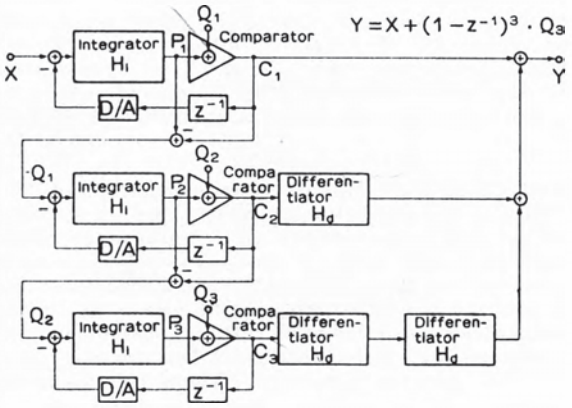


Figure 2. A recently proposed [4] Δ-Σ A/D converter architecture

A pipelined D/A converter, whose analog circuitry consists only of a small number of equal-valued grounded capacitors, switches and a buffer, is described in a companion paper [9]. The basic scheme is shown in Figure 3; the measured performance of an integrated version, fabricated in 3 μm CMOS technology, is summarized in Table IV. Another pipelined DAC, presented in another companion paper [10], is illustrated in Figure 4. It utilizes the MSB first and the LSB last, and hence can be used to provide the reference voltages needed in the pipelined ADC of ref.[7].

ANALOG FILTERS

The design of integrated analog filters is often considered to be a mature area, with many techniques available for synthesizing high-performance precision circuits. Nevertheless, a number of novel design ideas have appeared recently. In the switched-capacitor (SC) realization area, new integrator and gain stages which are insensitive to both the offset and the finite gain of the op-amps have been published [11]-[13]. These stages have been used recently to design a number of GaAs SC circuits [14] with clock rates exceeding 100 MHz and signal frequencies up to 10 MHz. Figure 5 illustrates the response of an elliptic GaAs filter with a 100 MHz clock rate.

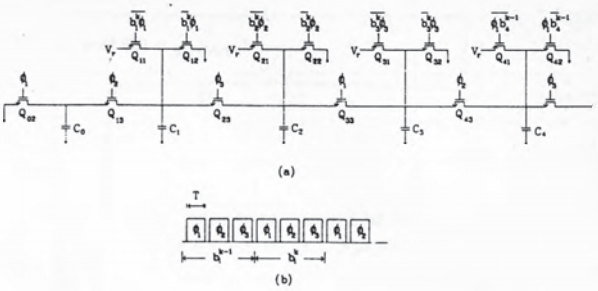


Figure 3. A pipelined D/A converter: a. configuration; b. clock signals

Table IV. Measured performance of the DAC of Figure 3

Nominal Resolution	10 bits
Accuracy Resolution	11 bits
Differential Nonlinearity	± 0.235 LSB
Integral Nonlinearity	0.2% of full scale
Analog Output Voltage	3.2V max.
Supply Voltage	10V
Data conversion Rate	333 kS/s
Chip Area	0.73 mm^2

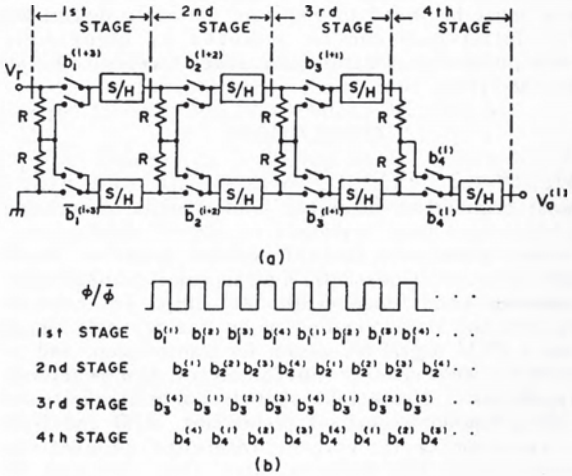


Figure 4. An alternative DAC which converts the MSB first

An alternative approach to sampled data analog filtering was presented by Vallancourt and Tsividis [15]. It is based on determining the value of each branch gain by the duty cycle of a digitally controlled analog transmission gate. The resulting circuit is

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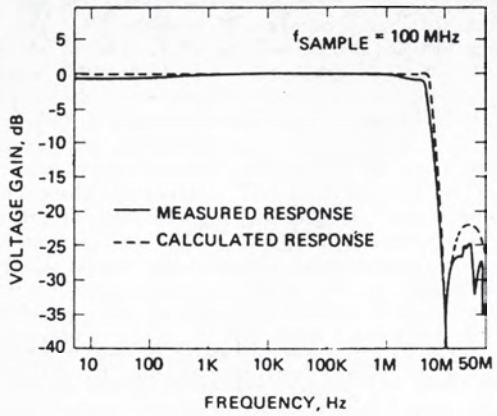


Figure 5. The measured response of a GaAs SC filter [14]

digitally programmable, and programming of the topology is also possible, so that high-pass, band-pass and low-pass configurations can be realized with the same structure.

A number of different architectures have been developed for realizing unswitched (continuous-time) integrated analog filters [16]-[18]. These circuits are not subject to the signal and wideband noise aliasing of switched-capacitor filters. On the other hand, they require fairly sophisticated control circuitry to achieve accurately controlled time constants, and also some way must be found to eliminate harmonic distortion. The latter goal can be achieved by using fully differential signal paths, and special cross-coupling circuitry [19].

APPLICATIONS

Most commercial integrated analog signal processing circuits have been developed for specific applications. In the past, the largest-volume area has been telecommunications. In digital voice transmission systems, coder/decoder (codec) chips are used to perform the transformation of an analog voice signal into a PCM digital bit stream for transmission, and to perform the reverse operation at the receiving apparatus. These tasks involve a multiplicity of analog functions, such as prefiltering, A/D and D/A conversion, S/H, voltage reference generation, amplification and buffering, etc. Over the past 10 years, more and more of these functions have been integrated on a single chip, along with the necessary digital logic functions. As an example, Figure 6 shows the block diagram of an early single-chip codec, the AMI S3506.

Another popular telecommunication chip contains the modulator-demodulator (modem). The modem converts the digital bit stream generated in data transmission systems into a signal which falls into the passband range of voice-grade telephone facilities. They may use frequency-shift keying (FSK) or phase-shift keying (PSK) modulation. Figure 7 illustrates the organization of a single-chip modem (Sierra Semiconductor's SC 11004).

In the past, both the sophistication (as measured, e.g., by the number of on-chip functions, or the total number of on-chip transistors) and the speed (bit rate) of these chips have been rapidly increasing, due to stiff competition. It is expected that this trend will continue in the foreseeable future.

There are many other high-volume communication applications for analog signal processing circuits, such as the generation and detection of dual-tone

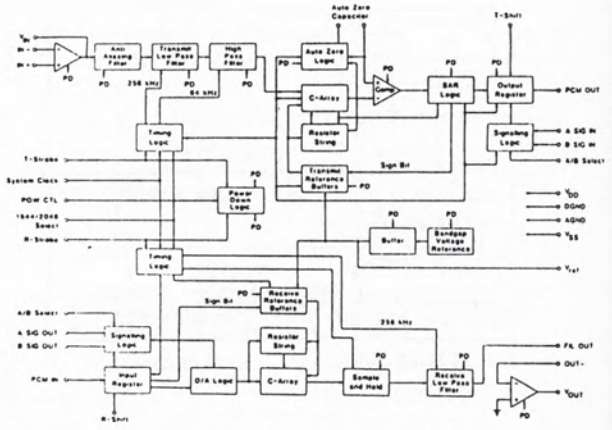


Figure 6. The block diagram of the AMI S3506 codec

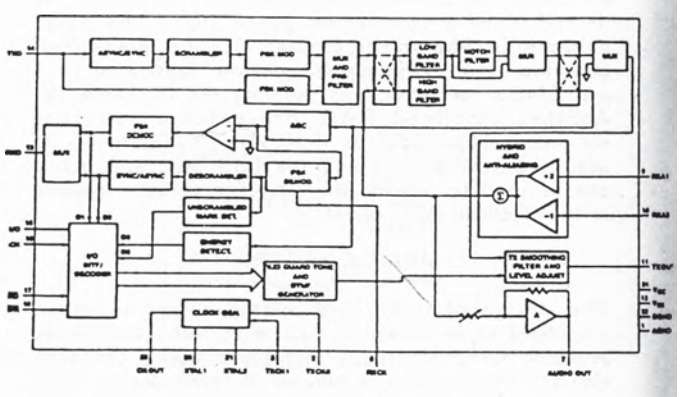


Figure 7. Block diagram of the SC 1104 modem

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multifrequency (DTMF) dial signals, in-band or out-of-band telephone signaling, etc. With the advent of the Integrated Services Digital Network (ISDN), new challenges arise and new markets open for analog circuits. As an example, Figure 8 shows the block diagram of a recently published ISDN burst transceiver [20]. Most functions are analog, and the chip uses SC circuit techniques for filtering and equalization.

A very promising future application of fully-integrated analog signal processing is the realization of FM radio receivers. If these can be produced in a cost-effective way, a very large market will open up for them in, e.g., radio controls, pagers, inexpensive radios, etc. In a recent paper [21], B.S. Song described a chip realizing a narrow-band high-selectivity FM receiver, using SC filters. The block diagram of the receiver is shown in Figure 9; the measured performance in Table V. The operation is not adequate for high-fidelity reception, but it does illustrate the feasibility of single-chip high-performance FM radios.

Another promising area is in bioelectronic applications, such as pacemakers, hearing aids and, other external or implantable stimulation or measurement devices. They are often battery powered, and hence require low-voltage, low-power and low-noise circuit. Often, the MOS devices used are operated in their subthreshold regions. A recent paper by Steyaert et al., demonstrated a micropower low-noise monolithic instrumentation amplifier for medical purposes [22].

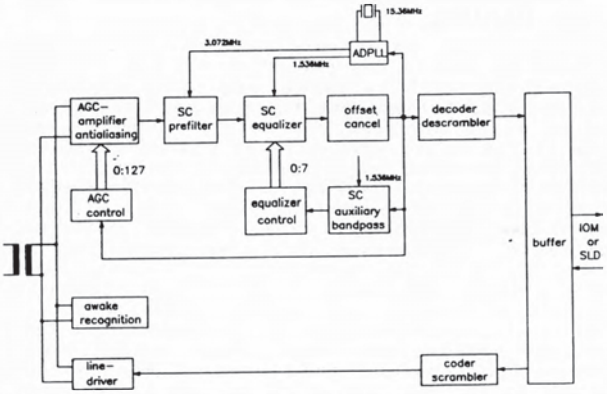


Figure 8. The block diagram of an ISDN burst transceiver [20]

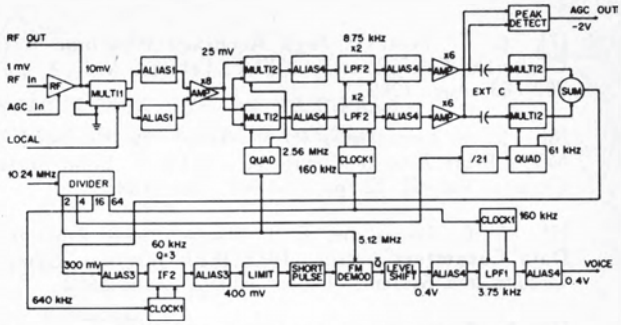


Figure 9. A schematic diagaram of a monolithic FM receiver [21]

CONCLUSIONS

Conclusions - Though the relative volume of analog integrated circuits continues to shrink compared to their digital counterparts, their importance is actually growing, as higher-speed and more complex digital integrated circuits require more advanced analog interfaces. This paper has outlined the current state-of-the-art, as well as the future direction, of analog interface circuits. Present evidence and current trends demonstrate that analog interfaces circuits will continue to evolve as long as integrated circuit technology continues to advance.

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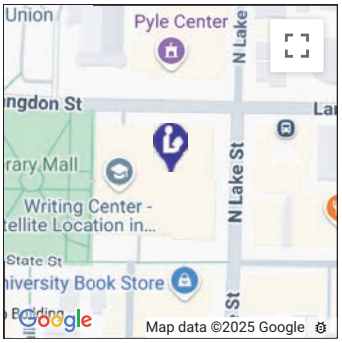
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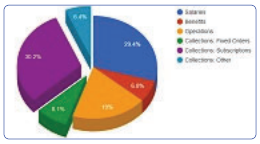
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IEEE International Symposium on Circuits and Systems.

Type of Work: Serial
Title: IEEE International Symposium on Circuits and Systems.
Serial Publication Year: 1988
Imprint: Piscataway, NJ : IEEE Service Center.
Description: print material.
Frequency: Frequency unknown.
Notes: Pub. in multiple parts.
Description based on: 1986 issue.
Copyright Claimant: the Institute of Electrical and Electronics Engineers, Inc.
Authorship on Application: the Institute of Electrical and Electronics Engineers, Inc., employer for hire.
Issues Registered: 1988. Held at Helsinki University of Technology, Espoo, Finland, June 7-9, 1988. Created 1988; Pub. 1988-06-07; Reg. 1988-09-09; TX0002395957
Names: IEEE International Symposium on Circuits and Systems, Espoo, Finland, 1988
Institute of Electrical and Electronics Engineers, Inc.
Circuits and Systems, I E E E International Symposium on

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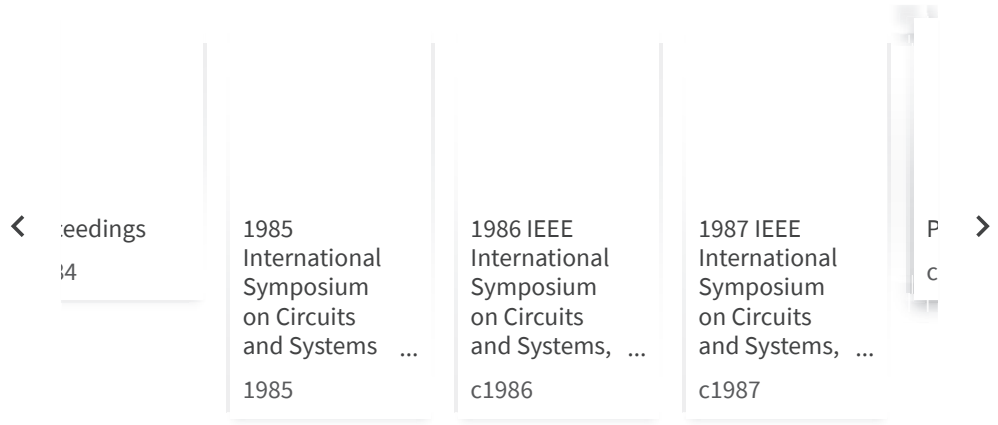
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Details

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Title	Proceedings / 1988 IEEE International Symposium on Circuits and Systems, Helsinki University of Technology, Espoo, Finland, June 7-9, 1988.
Creator	IEEE International Symposium on Circuits and Systems (1988 : Helsinki University of Technology) ›
Publisher	New York, NY : Institute of Electrical and Electronics Engineers ; Piscataway, NJ : Additional copies may be obtained from IEEE Service Center, c1988.
Format	3 v. (2915 p.) : ill. ; 28 cm.
Notes	Spine title: 1988 IEEE International Symposium on Circuits and Systems proceedings. "88CH2458-8."
Contributor	Institute of Electrical and Electronics Engineers. ›
Genre	Congresses.
Subject	Electric filters › Electronics › Signal processing ›
Other title	1988 IEEE International Symposium on Circuits and Systems proceedings
Type	Conference Proceeding
Creation Date	c1988
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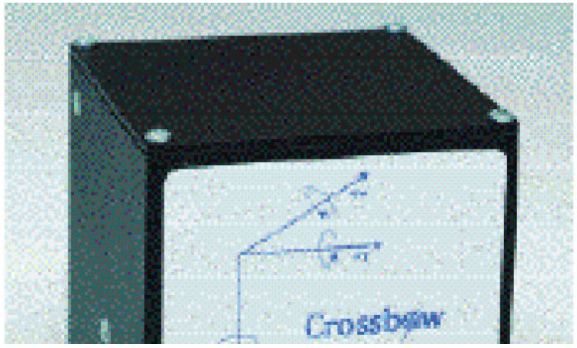
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EXHIBIT 1053A

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DMU-6X and DMU-VGX
Silicon IMU and Vertical Gyro

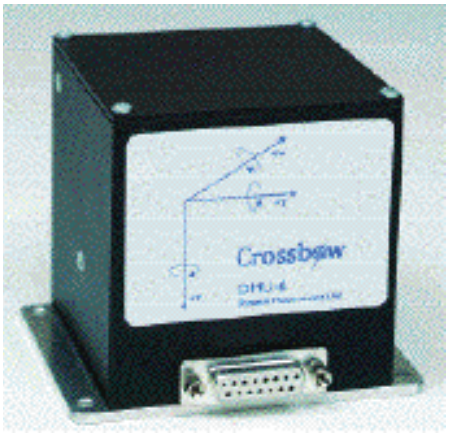


Features

X, Y, Z Acceleration
Roll, Pitch, Yaw Angular Rate
Stabilized Roll & Pitch Angle Output
Analog Signal Conditioned Output
133 Hz Digital (RS-232) Output
DSP Processing Power

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DMU-6X and DMU-VGX
Silicon IMU and Vertical Gyro



Features

X, Y, Z Acceleration
Roll, Pitch, Yaw Angular Rate
Stabilized Roll & Pitch Angle Output
Analog Signal Conditioned Output
133 Hz Digital (RS-232) Output
DSP Proccessing Power
Evaluation Software Included

Applications

Camera and Platform Stabilization
Antennae Pointing
Inertial Measurements for GPS Integration
Dynamic Positioning & Control
Automotive Testing
Flight Data Analysis

Description

The DMU is an intelligent six axis measurement system designed for accurate acceleration and angle measurement in dynamic environments. The DMU provides application-specific functionality with two product versions, the DMU-6X and DMU-VGX. The DMU-6X outputs inertial acceleration and angular rate measurements formatted for easy system integration. Example applications include GPS navigation, dynamic positioning, and automotive testing. The DMU-VGX outputs stabilized pitch and roll information in addition to the DMU-6X outputs, ideal for camera or platform stabilization. Both products allow for data to be requested via serial command or to be transferred continuously.

DMU Products	Description	Output
DMU-6X	6 degrees of freedom inertial measurement unit. Digital voltage and signal conditioned analog outputs.	XYZ Acceleration 3 Axis Angular Rate
DMU-VGX	Tilt angle (roll/pitch) is computed for measurement in dynamic environments. 133 Hz updates of RS-232 data and 400Hz updates of analog voltage output. Angular rate and acceleration outputs also included.	Roll and Pitch

Table 1. Description of DMU Products.

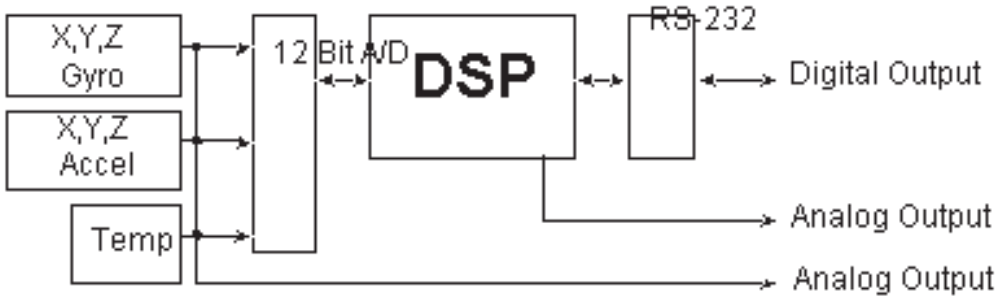


Figure 1. Block diagram of DMU

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Specifications

Power		Operating Temperature Range	
Input Supply Voltage	+8 to 30 V DC	Operating Temperature Range	-40 to 85 °C
Input Supply Current	200 mA (max)	Storage Temperature Range	-55 to 85 °C

Packaging	
Package	Aluminum housing (3" x 3.375" x 3.250")
Weight	475 grams

DMU-VGX Performance			
Roll, Pitch Angle: Dynamic Accuracy	1° RMS	Application Dependent
Resolution	0.1°	Typical
Linearity	< 1 % of FS	FS Roll =180°, FS Pitch =90°
Full Scale Span (analog outputs)	+/- 4.096 VDC	
Analog Data Update Rate	400 Hz	See page 5 for detail.
Digital Data Update Rate	133 Hz	See page 5 for detail.

DMU-6X Performance	Gyro	Acceleration
Available Full Scale Ranges	+/- 50 to 200 °/sec	+/- 1 to 50 G
Full Scale Span (analog outputs)	+/- 4.096 V DC	0 to 5V DC
Full Scale Span (digital output)	-32,768 to +32,767	-32,768 to +32,767
Scale Factor Calibration	< 1 %	< 1 %
Bandwidth	DC - 10 Hz	DC - 100Hz
Linearity	0.5 % of FS	0. 2% of FS
Bias Stability (Room)	+/- 1 °/sec	+/- 5mG
Bias Stability (-40 to 85)	+/- 9 °/sec	+/- 70 mG
Alignment (to enclosure)	< 1 °	< 1 °
Resolution	0.05 °/sec	5 mG (FS < 8G), 50mG (FS > 8G)

Temperature Sensor Output		Mechanical Shock and Vibration	
Range	-50 to 150 °C	Shock	1000 G (1 ms half sine wave)
Accuracy	+/- 2% of FS	Vibration	10 G RMS to 2 kHz
Linearity	+/- 1% of FS		

Principle of Operation

The DMU measures acceleration in three orthogonal axes as well as rotation rate about each of these axes. This is accomplished by three accelerometers and three angular rate sensors.

The DMU employs on board digital processing to provide application-specific outputs and to compensate for deterministic error sources within the unit. The DMU accomplishes these tasks with an analog to digital converter and a high performance Digital Signal Processor. (See Figure 1)

All six of the DMU sensor elements are micromachined devices. The three angular rate sensors consist of vibrating ceramic plates that utilize the Coriolis force to output angular rate independently of acceleration. The three MEMS accelerometers are surface micro-machined silicon devices that use differential capacitance to sense acceleration. The specifications of the DMU are shown above.

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DMU-6X

The DMU-6X has three output options, one analog and two digital, that allow for easy integration into measurement and control systems.

Analog Interface

The DMU features six fully signal conditioned analog outputs - three linear acceleration signals and three angular rate signals. The analog outputs can directly interface to an A/D or standard data acquisition hardware.

Digital Interface

The digital data output is standard UART at 38.4 kbaud. 8 bit data, 1 bit start, 1 bit stop, No parity. Other baud rates are avialable.

In **voltage mode**, the analog sensor signals are sampled and converted to digital data with 1mV resolution. This digital data is 12 bit, unsigned. Data can be requested via a serial command or set to continuously transfer to the host.

In **scaled sensor mode**, the analog sensor signals are sampled, converted to digital data, temperature compensated, and scaled to engineering units. An electronic data sheet for each sensor is stored in the DMU's on-board memory. The data sheet includes each sensor's bias (offset and scale factor). Data can be requested via a serial command or set to continuously transfer to the host. The digital data is 16 bit 2's compliment integers. A 16 bit timer value is also included in the packet. (See Timer section).

DMU-VGX

The DMU-VGX provides stabilized roll and pitch angles through sophisticated signal processing of the rate and acceleration sensors. Standard tilt sensors use earth's gravitational field to measure angle. Examples of these sensors include the older electrolytic fluid sensors as well as the newer accelerometer based tilt sensors such as the CXTILT02 from Crossbow. These sensors only measure tilt accurately when the object being measured is not accelerating. In dynamic environments such gravity-based tilt sensors can not distinguish between tilt and acceleration.

The DMU-VGX uses a combination of angular rate and acceleration signals to solve this problem. Tilt is calculated by integrating the angular rate sensor outputs to angle. Then the tilt response of the accelerometers corrects for error due to angular rate sensor drift. Drift corrections are applied continuously and the frequency of the updates can be set via the serial command 'T' <0-255>. In this way, corrections can be applied slowly, a T value between 70 - 255, in environments where accelerations are jerky and relatively short (e.g., marine, automotive applications) and more frequently, a T value closer to 0, in environments where accelerations are longer and smoother.

Roll and pitch angle, angular rate, and acceleration outputs are available in the DMU-VGX packet. The digital data is 16 bit 2's compliment integers. This data can be requested via a serial

Command (ASCII)	Response	Description
R	H	Reset: Resets the DMU Firmware. Default operating mode is Voltage Mode and Polled operation (Note 1).
G	Data Packet	Get Data: Requests a packet of data from the DMU. Data format depends on operating mode.
r	R	Change to Voltage Mode.
c	C	Change to Scaled Sensor Mode.
a	A	*DMU-VGX Only:* Change to DMU-VG output mode.
T <0 - 255>	None	*DMU-VGX Only: 2 byte command sequence that changes the integrator correction time constant.*
C	None	Change to continuous data transmit mode. Data packets streamed continuously. Packet rate is dependent on operating mode.
P	None	Change to polled mode. Data packets sent when a G is received by the DMU.
z <0-255>	Z	Calibrate and set zero bias for rate sensors by averaging over time. 1st byte initiates zeroing process. 2nd byte sets duration for averaging. Unit should be straight and level.

DMU serial command set [Firmware v1.2].

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command or set for continuous transfer.

X-View Development Software

Crossbow development software is shipped with the DMU for use with 486 or better PCs running MS Windows95. The software demonstrates the functionality of both the DMU-6X and the DMU-VGX. It is a convenient way to get started with system development and evaluate the performance of the DMU. The software is a run-time application based on National Instrument's LabView software. The software is shipped on 3.5" floppy disks. For software installation, simply double click the SETUP file on floppy disk #1.

Value	Conversion Factors
Roll & Pitch	180° / 32,768 digits
Range of X G's	$(X * 1.5) / 2^{15}$ from binary data to G's
Range of X °/sec	$(X * 1.5) / 2^{15}$ from binary data to °/sec
Temp	=1.375V + 22.5mV*Temp(in C) with 0 to 4V / 4095 digits
Check Sum	Step 1: Sum all packet contents but header and checksum Step 2: Divide by 256 Step 3: The remainder of this division should equal the Check Sum

Table 2. Conversion Factors.

	DMU-VG	Scaled Sensor Mode	Voltage Mode
0	Header (255)	Header (255)	Header (255)
1	Roll (MSB)	Angular Rate X (MSB)	Gyro Voltage X (MSB)
2	Roll (LSB)	Angular Rate X (LSB)	Gyro Voltage X (LSB)
3	Pitch (MSB)	Angular Rate Y (MSB)	Gyro Voltage Y (MSB)
4	Pitch (LSB)	Angular Rate Y (LSB)	Gyro Voltage Y (LSB)
5	Roll Rate (MSB)	Angular Rate Z (MSB)	Gyro Voltage Z (MSB)
6	Roll Rate (LSB)	Angular Rate Z (LSB)	Gyro Voltage Z (LSB)
7	Pitch Rate (MSB)	Acceleration X (MSB)	Accelerometer Voltage X (MSB)
8	Pitch Rate (LSB)	Acceleration X (LSB)	Accelerometer Voltage X (LSB)
9	Yaw Rate (MSB)	Acceleration Y (MSB)	Accelerometer Voltage Y (MSB)
10	Yaw Rate (LSB)	Acceleration Y (LSB)	Accelerometer Voltage Y (LSB)
11	Acceleration X (MSB)	Acceleration Z (MSB)	Accelerometer Voltage Z (MSB)
12	Acceleration X (LSB)	Acceleration Z (LSB)	Accelerometer Voltage Z (LSB)
13	Acceleration Y (MSB)	Temp Sensor Voltage (MSB)	Temp Sensor Voltage (MSB)
14	Acceleration Y (LSB)	Temp Sensor Voltage (LSB)	Temp Sensor Voltage (LSB)
15	Acceleration Z (MSB)	Time (MSB)	Time (MSB)
16	Acceleration Z (LSB)	Time (LSB)	Time (LSB)
17	Temp Sensor Voltage (MSB)	Checksum	Checksum
18	Temp Sensor Voltage (LSB)		
19	Time (MSB)		
20	Time (LSB)		
21	Checksum		

Data packet format. [v1.2]

Timing Diagrams

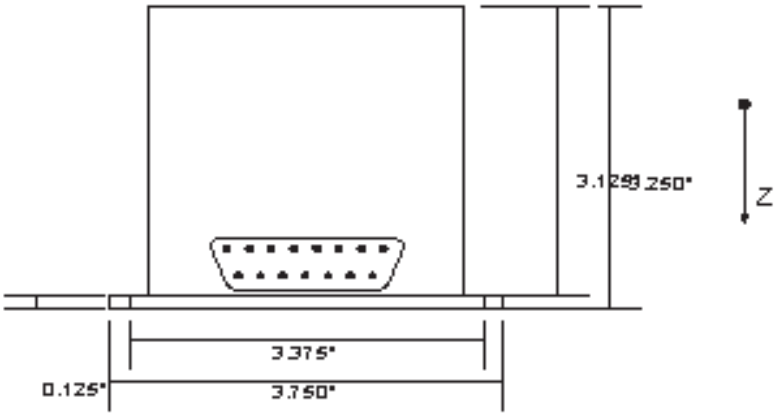
In some applications, using the DMU's digital output requires a precise understanding of the internal timing of the device. The processor internal to the DMU runs in a loop - collecting data from the sensors, processing the data, and reporting the data to the user. In continuous mode, the system processor activity is repeatable and accurate timing information can be derived based purely on the overall loop rate. The following table and graph describe these relationships.

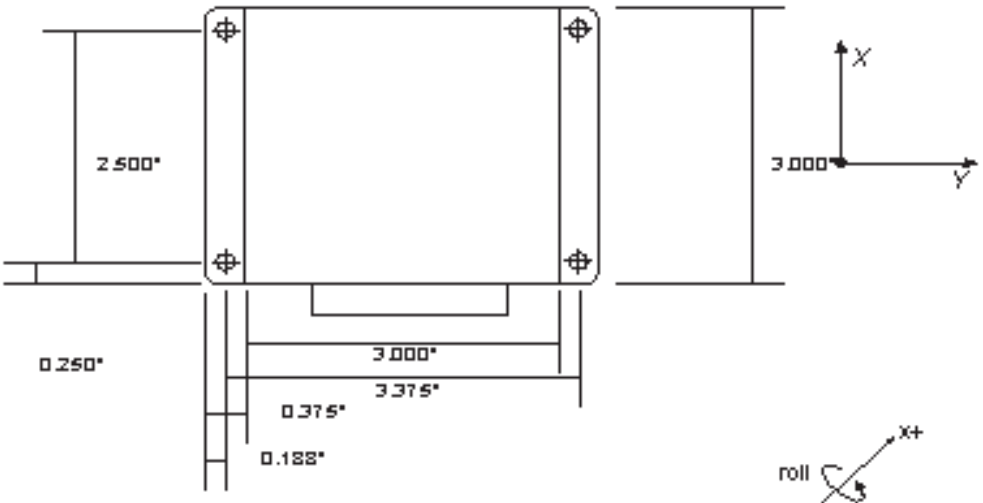
A time tag is attached to the packet in the voltage, scaled sensor, and VGX output mode. The time tag is simply the value of a free running counter at the time the A/D channels are sampled. The clock counts down from 65535 to 0, and a single tick corresponds to 0.79 micrseconds. The timer rolls over every 50 milliseconds.

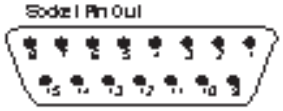
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Operating Mode	Conversion Time (T1)	Processing Time (T2)	Transfer Time (T3)	Total Time (Sum)	Data Rate Output
DMU-6X					
Voltage	0.8 ms	0.5 ms	4.7 ms		166 Hz
Scaled	0.8 ms	0.9 ms	4.7 ms	6.0 ms	156 Hz
DMU-VGX				6.4 ms	
Digital	0.8 ms	1.5 ms	5.2 ms		133 Hz
Analog	0.8 ms	1.5 ms	-	7.5 ms	400 Hz
				2.3 ms	

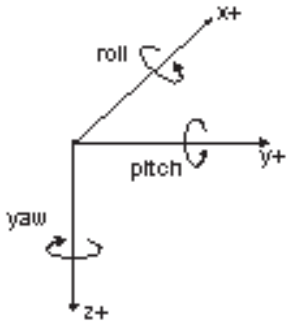
Notes:
1. Inter-channel conversion time is 0.133 milliseconds; there are a total of 6 channels which are converted on each iteration.
2. T3 assumes 38.4 Baud communications.
3. The clock signal transitions every time the 16 bit counter value rolls over. The clock signal can be used to correlate the timer stamp to an external time reference.







1 Transmit Data
2 Receive Data
3 Vcc
4 GND
5 X-axis Accelerometer Analog Voltage
6 Y-Axis Accelerometer Analog Voltage
7 Z-Axis Accelerometer Analog Voltage
8 Roll Rate Analog Voltage
9 Pitch Rate Analog Voltage
10 Yaw Rate Analog Voltage
11 Timing Pulse
12 Roll (VGX only)
13 Pitch (VGX only)
14 Unused
15 Unused



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(71) Applicant: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA [US/US]; 21st floor, 300 Lakeside Drive, Oakland, CA 94612 (US).

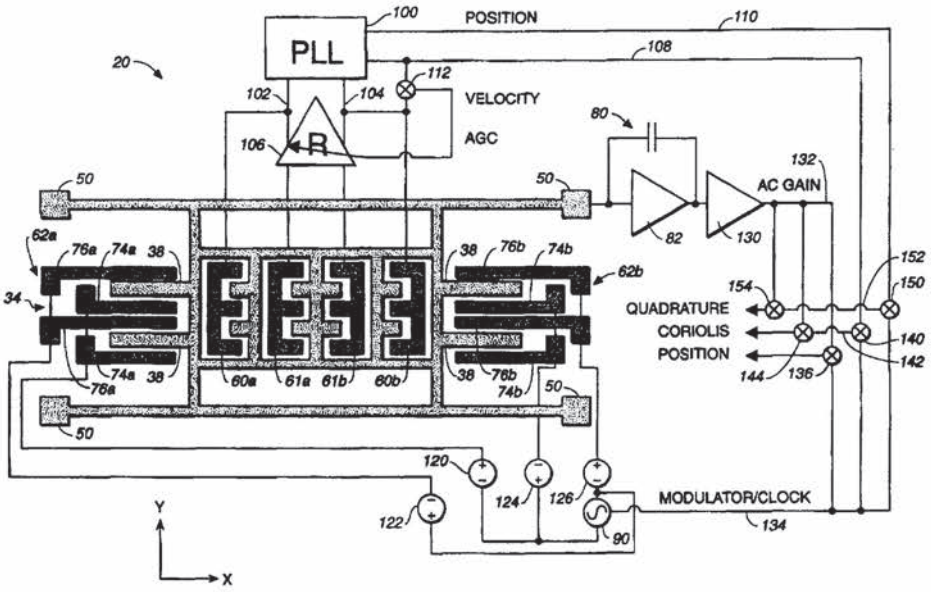
(72) Inventors: CLARK, William, A.; 35617 Pond Drive, Fremont, CA 94526 (US). JUNEAU, Thor; 1812 Delaware Street #201, Berkeley, CA 94709 (US). HOWE, Roger, T.; 3139 Sweetbriar Circle, Lafayette, CA 94549 (US).

(74) Agents: EGAN, William, J., III et al.; Fish & Richardson P.C., Suite 100, 2200 Sand Hill Road, Menlo Park, CA 94025 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

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(54) Title: MICROMACHINED VIBRATORY RATE GYROSCOPE



(57) Abstract

A microfabricated gyroscope to measure rotation about an axis parallel to the surface of the substrate. A voltage differential may be applied between pairs of electrode fingers to reduce the quadrature error. A microfabricated gyroscope includes a vibratory structure and interdigited electrodes having a high aspect ratio.

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MICROMACHINED VIBRATORY RATE GYROSCOPE

Background of the Invention

The present invention relates generally to microfabricated sensors, and more particularly to microfabricated gyroscopic sensors.

Multi-axis sensors are highly desirable for inertial sensing of motion in three dimensions. Previously, such sensors were constructed of relatively large and expensive electromagnetic devices. More recently, micromechanical sensors have been fabricated using semiconductor processing techniques. Specifically, micromechanical accelerometers and gyroscopes have been formed from silicon wafers by using photolithographic techniques. Such microfabricated sensors hold the promise of large scale production and therefore low cost.

One objective in the construction of microfabricated sensors is to increase the sensitivity and improve the signal to noise ratio of the device. Another objective is to simplify the fabrication steps so as to reduce the cost and complexity and to increase the yield in the manufacturing process.

The integration of three gyroscopic sensors to measure the rotation rates about the three separate axes coupled with three accelerometric sensors to measure the acceleration along the three axes on a single chip would provide a monolithic, six degree-of-freedom inertial measurement system capable of measuring all possible translations and orientations of the chip.

It would be useful to provide a gyroscopic sensor to measure rotation about axes parallel to the surface of

a substrate on which the gyroscopic sensor was fabricated. It would also be useful to provide a gyroscopic sensor with reduced noise.

Summary of the Invention

In one aspect, the invention is directed to a gyroscopic sensor including a substrate, a mass connected to the substrate by a suspension system, a drive system to cause the mass to vibrate along a drive axis substantially parallel to a surface of the substrate, and a position sensor to measure a deflection of the mass along a sense axis substantially parallel to the surface of the substrate. Rotation of the mass about an axis of rotation substantially perpendicular to the surface of the substrate and vibration of the mass along the drive axis generates a Coriolis force to deflect the mass along the sense axis.

Implementations of the invention include the following. A processor may be coupled to an output of the position sensor to generate a signal varying with the rate of rotation of the mass about the axis of rotation. The gyroscopic sensor may include a first sense electrode projecting from the mass, a second sense electrode connected to the substrate and positioned on a first side of the first electrode, and a third sense electrode connected to the substrate and positioned on an opposing second side of the first electrode. The position sensor may sense a change in capacitance between the first electrode and the second and third electrodes. The first, second and third electrodes may be substantially coplanar and each electrode has a longitudinal axis substantially aligned with the drive axis. The drive system may include a first drive electrode projecting

from the mass, a second drive electrode connected to the substrate and positioned on a first side of the first electrode, and a third drive electrode connected to the substrate and positioned on an opposing second side of the first electrode. An alternating voltage may be applied between the between the first electrode and the second and third electrodes. A voltage source may apply a voltage between a plurality of correction electrodes connected to the substrate to cause the mass to vibrate, absent the Coriolis force, more precisely along the drive axis. A voltage source may apply a voltage between a first tuning electrode connected to the substrate and a second tuning electrode connected to the mass to adjust a resonant frequency of vibrations of the mass along the sense axis.

In another aspect, the invention is directed to a method of sensing rotation with a gyroscopic sensor including a mass connected to a substrate by a suspension system. The mass is rotated about an axis of rotation and the mass is caused to vibrate substantially along a drive axis. Rotation of the mass about the axis of rotation and vibration of the mass along the drive axis generates a Coriolis force to deflect the mass along a sense axis. A deflection of the mass along the sense axis is measured, and a voltage is applied between electrode fingers connected to the substrate to cause the mass to vibrate, absent a Coriolis force, more precisely along the first axis.

In another aspect, the present invention is directed to a microfabricated structure. The structure comprises a substrate, a mass connected to the substrate by a suspension system to vibrate in a plane parallel to a surface of the substrate, and three pluralities of

electrode fingers. The first plurality of electrode fingers projects from the mass along a first axis in the plane. The second and third plurality of electrode fingers, electrically isolated from each other, are coplanar with the first plurality of electrode fingers, are connected to the substrate and project substantially along the first axis. The first, second and third plurality of electrode fingers are interdigitated such that each of the first plurality of electrode fingers is adjacent to one of the second plurality of electrode fingers and one of the third plurality of electrode fingers.

Implementations include the following features. A voltage source may apply a voltage between the second and third plurality of electrode fingers. The structure may further comprise a fourth plurality of electrode fingers, coplanar with the first, second and third plurality of electrode fingers, projecting from the mass along the first axis, and a fifth plurality of electrode fingers connected to the substrate but electrically isolated from the second and third plurality of electrode fingers, the fourth and fifth plurality of electrode fingers being interdigitated. Each of the first plurality of electrode fingers may be longer than each of the fourth plurality of electrode fingers.

In another aspect, the invention is directed to a microfabricated structure. The structure comprises a substrate and a suspension system to permit a mass to vibrate in a plane parallel to a surface of the substrate. The suspension system includes first and second substantially parallel beams, each of the first and second beams anchored at both ends to the substrate, and third and fourth substantially parallel beams, one

end of each of the third and fourth beams connected to the first beam and another end connected to the second beam.

Implementations include the following features. The structure may include a plurality of fingers projecting along an axis substantially parallel to the first and second beams. The structure may comprise a fifth and a sixth beam one end of each of the fifth beam and sixth beams connected to the third beam and another end connected to the fourth beam, and a seventh beam, one end of the seventh beam connected to the fifth beam and another end connected to the sixth beam. The structure may further comprise a plurality of fingers projecting from the seventh beam along an axis substantially parallel to the first and second beams. Sections of the first and second beams located between the third and fourth beams may be substantially rigid to prevent rotation of the mass.

In another aspect, the invention is directed to a sensor. The sensor comprises a substrate, a mass connected to the substrate by a suspension system to vibrate in a plane parallel to a surface of the substrate, and three pluralities of electrode fingers. The first plurality of electrode fingers projects from the mass along a first axis in the plane. The second and third plurality of electrode fingers, are connected to the substrate and project substantially along the first axis. the first, second and third plurality of electrode fingers are interdigitated such that each of the first plurality of electrode fingers is adjacent to one of the second plurality of electrode fingers and one of the third plurality of electrode fingers. A voltage source applies a first DC voltage between the second and third

plurality of electrode fingers to cause the mass to vibrate, absent a Coriolis force, more precisely along the first axis.

Implementations may include the following features. A set of electrode fingers may be positioned opposing the three pluralities of electrode fingers, and a second voltage source for may apply a second DC voltage between a fifth and sixth plurality of electrode fingers to cause the mass to vibrate, absent a Coriolis force, more precisely along the first axis. The second DC voltage may be substantially equal in magnitude but opposite in sign to the first DC voltage. The first plurality of electrode fingers may be electrically coupled to the second plurality of electrode fingers. The sensor may include a voltage source for applying a third DC voltage between the first and third pluralities of electrode fingers and the second, third, fifth and sixth pluralities of electrode fingers to adjust the resonant frequency of vibrations of the mass along a second axis in the plane perpendicular to the first axis.

In another aspect, the invention is directed to a sensor. The sensor comprises a substrate, a mass connected to the substrate by a suspension system to vibrate in a plane parallel to a surface of the substrate, and three pluralities of electrode fingers. The first plurality of electrode fingers projects from the mass along a first axis in the plane. The second and third plurality of electrode fingers, are connected to the substrate and project substantially along the first axis. the first, second and third plurality of electrode fingers are interdigitated such that each of the first plurality of electrode fingers is adjacent to one of the second plurality of electrode fingers and one of the

third plurality of electrode fingers. A voltage source applies a DC voltage between the first plurality of electrode fingers and the second and third plurality of electrode fingers to adjust the resonant frequency of vibrations of the mass along a second axis in the plane perpendicular to the first axis.

In another aspect, the invention is directed to a gyroscope for sensing rotation about a Z-axis. The gyroscope comprises a substrate, a mass connected to the substrate by a suspension system to vibrate in a plane parallel to a surface of the substrate, a drive system to cause the mass to vibrate substantially along a first axis in the plane, and three pluralities of electrode fingers. The first plurality of electrode fingers projects from the mass along a first axis in the plane. The second and third plurality of electrode fingers, are connected to the substrate and project substantially along the first axis. The first, second and third plurality of electrode fingers are interdigitated such that each of the first plurality of electrode fingers is adjacent to one of the second plurality of electrode fingers and one of the third plurality of electrode fingers. A position sensor is coupled to the first plurality of electrode fingers for measuring the deflection of the mass along a second axis in the plane perpendicular to the first axis. Rotation of the mass about a Z-axis perpendicular to the surface and vibration of the mass along the first axis generates a coriolis force to deflect the mass along the second axis. A signal processor is coupled to an output of the position sensor to generate a signal varying with the rate of rotation of the mass about the Z-axis.

Implementations include the following features. A voltage source may apply an AC voltage having a first frequency between the second and third plurality of electrode fingers. A voltage may be applied between the second and third pluralities of electrode fingers to form a capacitive bridge with the first plurality of electrodes, and the position sensor may be coupled to the first plurality of electrodes to detect changes in capacitance when the mass is deflected along the second axis. The sensor may includes an integrator to integrate a signal from the first plurality of electrode fingers. The drive system may generate a signal to cause the mass to oscillate along the first axis at a second frequency. The drive system may include a phase-locked loop to prevent phase-shifting of the signal. The sensor may include a first mixer to mix the signal from the drive system with a signal from the voltage source. The sensor may include a second mixer to mix a signal from the first mixer with an output signal from the position sensor to produce a position quadrature signal or coriolis signal. The sensor may include a mixer to mix an output signal from the position sensor with a signal from the voltage source to produce a position signal.

In another aspect, the invention is directed to a microfabricated gyroscopic sensor for measuring rotation about an input axis. The gyroscopic sensor includes a substrate, a mass, and a suspension system connecting the mass to the substrate. A drive system causes the mass to oscillate substantially about a drive axis, and a position sensor measures a rotation of the mass about a sense axis. Rotation of the mass about the input axis and oscillation of the mass about the drive axis generates a Coriolis force to oscillate the mass about

the sense axis. A voltage source to apply a voltage between a plurality of electrodes associated with the substrate to cause the mass to oscillate, in the absence of the Coriolis force, more precisely about the drive axis.

Implementations of the invention include the following. A processor may be coupled to an output of the position sensor to generate a signal varying with the rate of rotation of the mass about the axis of rotation. A second voltage source may apply a second voltage between electrodes connected to the mass and the electrodes connected to the substrate to adjust a resonant frequency of oscillations of the mass about the sense axis. The drive axis may be substantially perpendicular to the surface of the substrate and the axis of rotation and sense axis are substantially parallel to a surface of the substrate. The mass may be substantially ring-shaped. First and second pluralities of electrode fingers may project from the mass, and third and fourth pluralities of electrode fingers projecting from the substrate and be interdigitated with the first and second pluralities of electrode fingers. The fourth plurality of electrode fingers may be positioned opposing the first plurality of electrode fingers. Fifth, sixth, seventh and eighth pluralities of electrode fingers may be similarly disposed, and the pluralities of electrode fingers are substantially co-planar. The voltage source may apply a first DC voltage between the third plurality and the fourth plurality of electrode fingers and second DC voltage, which is substantially equal in magnitude and opposite in sign, between the seventh plurality and the eighth plurality of electrode fingers.

In another aspect, the invention is directed to a method of sensing rotation with a gyroscopic sensor including a mass connected to a substrate by a suspension system. The method includes rotating the mass about an input axis and causing the mass to oscillate substantially about a drive axis. The rotation of the mass about the input axis and the oscillation of the mass about the drive axis generates a Coriolis force to oscillate the mass about a sense axis. An oscillation of the mass about the sense axis is measured, a voltage is applied between electrodes associated with the substrate to cause the mass to oscillate, in the absence of a Coriolis force, more precisely about the drive axis.

In another aspect, the invention is directed to a microfabricated gyroscopic sensor. The gyroscopic sensor includes a substrate having a first plurality of electrode teeth, a vibratory structure including a second plurality of electrode teeth and a suspension system connecting the second plurality of electrode teeth to the substrate, the second plurality of electrode teeth interdigited with the first plurality of electrode teeth, a drive system to cause the vibratory structure to oscillate relative to the substrate, and a position sensor to measure a deflection of the mass caused by a Coriolis force. The first and second pluralities of electrode teeth have thicknesses substantially greater than their widths.

Implementations of the invention include the following. The suspension system may include a plurality of flexures having an aspect ratio of at least about 10:1. The first and second pluralities of electrode teeth may have an aspect ratio of at least 5:1 and may be separated by gaps having an aspect ratio of at least

10:1.

In another aspect, the invention is directed to a method of fabricating a gyroscopic sensor. An insulative layer is formed on a first substrate, a recess is formed in a first surface of a second substrate, and the first surface of the second substrate is bonded to the first substrate so that the recess defines an enclosed cavity between the first and second substrates. Circuitry for the gyroscopic sensor is formed on a second surface of the second substrate, and a plurality of trenches are etched in the second substrate from the second surface to the cavity, the plurality of trenches defining a vibratory structure connected to the first substrate.

Implementations of the invention include the following. The vibratory structure may have a thickness of at least 25 microns and the recess may have a depth of about 1 micron. The etching step may comprise a deep reactive ion etch.

Advantages of the invention include the following. The gyroscopic sensor measures rotation about an axis parallel to the surface of the substrate. The gyroscopic sensor has reduced quadrature error. The gyroscopic sensor may include a vibratory structure and interdigited electrodes with a high aspect ratio. The gyroscopic sensor has a significantly reduced noise level.

Other advantages and features of the invention will be apparent from the description which follows, including the drawings and claims.

Brief Description of the Drawings

FIG. 1 is an schematic illustration of a spring-mass system which is equivalent to an electrostatic gyroscope.

FIG. 2 is a schematic perspective view of a microfabricated gyroscopic sensor according to the present invention.

FIG. 3 is a schematic top view of the movable elements of the gyroscopic sensor of FIG. 2.

FIG. 4 is a schematic top view of the fixed elements of the gyroscopic sensor of FIG. 2.

FIG. 5 is a schematic top view of the drive system of the gyroscopic sensor of FIG. 2.

FIG. 6 is a schematic top view of the sensing system of the gyroscopic sensor of FIG. 2.

FIGS. 7A-7C are schematic illustrations of the motion of the proof mass under the influence of the Coriolis acceleration and quadrature error.

FIG. 8A is a schematic circuit diagram of an integrator used to measure the position of the proof mass in the gyroscopic sensor of FIG. 2.

FIG. 8B is a schematic circuit diagram in which the integrator of FIG. 8A is replaced by a voltage buffer.

FIG. 8C is a schematic circuit diagram in which the integrator of FIG. 8A uses a subthreshold metal oxide semiconductor field effect transistor.

FIG. 9 is a schematic illustration of the signal processing circuitry of a gyroscopic sensor according to the present invention.

FIG. 10 is a photograph of a fabricated gyroscopic sensor.

FIG. 11 is a graph illustrating the response of the gyroscopic sensor to rotation about the Z-axis.

FIG. 12 is a graph illustrating the response of the Y-axis resonant frequency to an applied bias voltage.

FIG. 13 is a graph illustrating the response of the quadrature error to an applied voltage differential.

FIG. 14 is a schematic top view of a gyroscopic sensor in which the sensing, driving and quadrature correcting functions are performed by different electrode structures.

FIG. 15 is a schematic of the circuitry of the gyroscopic sensor of FIG. 14.

FIG. 16 is a schematic illustration of a spring-mass system which is equivalent to a dual-axis electrostatic gyroscope.

FIG. 17A is a schematic top view of a dual-axis gyroscopic sensor according to the present invention.

FIG. 17B is a photograph of a fabricated dual-axis gyroscopic sensor.

FIG. 18 is a schematic illustration of the electronic circuitry of the dual-axis gyroscopic sensor of FIG. 17A.

FIG. 19 is a cross-sectional view along line 19-19 of FIG. 17A schematically illustrating the field lines generated by the quadrature correction electrodes.

FIG. 20 is a schematic top view of a dual-axis gyroscopic sensor in which the quadrature correction system includes electrode plates.

FIG. 21 is a schematic illustration of the circuitry of a gyroscopic sensor in which the sensing, driving and quadrature functions are combined in a single electrode structure.

FIG. 22 is a schematic perspective view of a gyroscopic sensor fabricated with a high-aspect-ratio vibratory structure.

FIG. 23 is a schematic circuit diagram of the signal processing circuitry of the gyroscopic sensor of FIG. 22.

FIGS. 24A-24G are schematic cross-sectional views illustrating steps in the fabrication of the gyroscopic sensor of FIG. 22.

Description of the Preferred Embodiments

Referring to FIG. 1, a Z-axis vibratory rate gyroscope functions by generating and sensing Coriolis acceleration. The functional operation of the Z-axis vibratory rate gyroscope of the present invention is illustrated by an equivalent spring-mass system. In a vibratory rate gyroscope 10, a proof mass 12 is supported by a flexible suspension 14 from a rigid frame 16. Proof mass 12 is oscillated along the X-axis (the drive mode) by a drive force F_D as the frame rotates about the Z-axis. The combination of rotation and oscillation generates a Coriolis force F_c along the Y-axis on the oscillating proof mass. The Coriolis acceleration is detected as a deflection of the proof mass along the Y-axis (the sense mode).

Referring to FIG. 2, a micromachined gyroscopic sensor 20 designed according to the present invention includes microelectromechanical sense element or proof mass 22 connected to a rigid frame or substrate 24. The gyroscopic sensor 20 measures the Z-axis vibratory rate, i.e., the rotation of the substrate about the axis normal to the micromachined surface 26 of substrate 24. The micromachined gyroscopic sensor 20 includes three major

elements: a suspension system 30, a drive system 32 used to sustain oscillation of proof mass 22 along the X-axis, and a sensing system 34 used both to detect deflections of proof mass 22 along the Y-axis and to apply electrostatic forces to cancel any quadrature error, as will be described in detail below.

Referring to FIG. 3, suspension system 30 may be formed integrally with proof mass 22. Suspension system 30 supports the proof mass so that it may vibrate in a plane parallel to surface 26. Suspension system 30 holds proof mass 22, for example, about two microns above the surface of the substrate. The total mass of proof mass 22 may be about 0.1 to 0.3 micrograms. Suspension system 30 is generally H-shaped, with two parallel beams 40 and 42 positioned generally along the X-axis. Each beam may be about 500 to 1000 microns in length, specifically about 800 microns in length. The end of each beam is connected to an anchor 44 which connects the suspension system to the substrate (see FIG. 2). The end of each beam 40, as shown in FIG. 2, may include a folded or J-shaped flexure 45 (see FIG. 3). Alternately, beams 40 and 42 may be linear.

Two beams or crossbars 46 and 48 connect beam 40 to beam 42. Crossbars 46 and 48 may be about eight-hundred microns long, and are positioned to trisect beams 40 and 42. Two cross-beams 50 and 52 connect crossbars 46 and 48. A third beam or crossbar 54 may connect the center of cross-beam 50 to the center of cross-beam 52. The flexible elements of suspension system 30 are constructed of polysilicon and, for example, have a width and a thickness on the order of two microns. The anchors may be about eight microns square.

The suspension system 30 is designed to be flexible along the X-axis and Y-axis, and as rigid as possible to other modes of vibration. In particular, the suspension system must be substantially rigid to rotation about the Z-axis, as small rotations may degrade the performance of the gyroscopic sensor. Large deflections may also result in the movable electrode fingers crashing into the stationary electrode fingers. The suspension system provides the necessary translational compliance while maintaining rotational rigidity by thickening the portions of beams 40 and 42 located between crossbars 46 and 48 to form trusses 41 and 43. Trusses 41 and 43 may have a width three to four times the width of the remainder of the beams, i.e., about six to eight microns. The portions of crossbars 46, 48 and 54 from which fingers project may have a width of approximately four microns.

The proof mass 22 also includes a plurality of finger electrodes (or simply fingers) which are used to drive and sense oscillations of proof mass along the X-axis and Y axis. A plurality of long fingers 38 project outwardly along the X-axis from crossbars 46 and 48, and a plurality of short fingers or stubs 39 project inwardly along the X-axis from crossbars 46, 48 and 54. The crossbars 46 and 48 form the spines, and long fingers 38 form the prongs of two movable sensing electrodes 56. Similarly, crossbars 46, 48 and 54 form the spines, and short fingers 39 form the prongs of two movable driving electrodes 58 and two movable feedback electrodes 59. The short fingers 39 may be about ten to twenty-five microns in length, specifically fifteen microns in length, whereas the long fingers 38 may be about one-

hundred to two-hundred microns in length, specifically one-hundred and fifty microns in length.

Referring to FIG. 4, one or more stationary driving electrodes, one or more stationary feedback electrodes, and one or more stationary sensing electrodes may be rigidly connected to substrate 24. For example, two stationary driving electrodes 60a, 60b may be arranged relative to each other in an opposing configuration. Similarly, two stationary feedback electrodes 61a, 61b may face each other in an opposing configuration. Each stationary driving electrode 60a, 60b and each stationary feedback electrode 61a, 61b includes a plurality of short fingers 66. Stationary driving and feedback electrodes 60a, 60b and 61a, 61b may have a few to dozens of fingers. Short fingers 66 may have a length of approximately 15 microns and a width of approximately three to six microns. The width, for example, may be four microns.

Two stationary sensing electrodes 62a, 62b may face each other in an opposing configuration. Stationary sensing electrodes 62a, 62b include a plurality of long fingers 70. Each long finger 70 protrudes from a base 72. The fingers of stationary sensing electrode 62a are arranged in pairs, each pair including a right finger 74a and a left finger 76a. Similarly, the fingers of stationary electrode 62b are arranged in pairs, each pair including a right finger 74b and a left finger 76b. Each long finger 70 may be approximately one hundred and fifty microns in length, and have a width of approximately four microns.

Referring to FIG. 5, drive system 32 includes movable and stationary driving electrodes 58 and 60a, 60b, and movable and stationary feedback electrodes 59

and 61a, 61b. One set of short fingers 39 is interdigitated with short fingers 66 of stationary driving electrodes 60a, 60b. Another set of short fingers 39 is interdigitated with short fingers 66 of stationary feedback electrodes 61a, 61b. Short fingers 39 of movable electrodes 58 and 59, and short fingers 66 of stationary electrodes 60a, 60b and 61a, 61b may be formed from the same layer of polysilicon prior to the removal of the sacrificial layer so that the fingers may be co-planar.

The driving electrodes of drive system 32 act as electrical-mechanical transducers. By the application of an alternating voltage between stationary driving electrodes 60a, 60b and movable driving electrodes 58, proof mass 22 may be forced to oscillate or reciprocate along the X-axis. The motion along the X-axis induces bending in crossbars 46 and 48 so that proof mass 22 may move toward and away from stationary driving electrodes 60a, 60b. A more detailed explanation of the manner of operating drive system 32 in order to sustain oscillations in proof mass 22 may be found in U.S. Pat. No. 5,025,346, issued June 18, 1991 to Tang et al., entitled Laterally Driven Resonant Microstructures, and assigned to the assignee of the present invention, the entire disclosure of which is incorporated herein by reference; and in U.S. Pat. No. 5,491,608, issued February 13, 1996 to Nguyen, entitled Q-Controlled Microresonators and Tunable Electronic Filters Using Such Resonators, and assigned to the assignee of the present invention, the entire disclosure of which is incorporated herein by reference.

Referring to FIG. 6, sensing system 34 includes stationary sensing electrodes 62a, 62b and movable

sensing electrodes 56. The long fingers 38 of movable sensing electrodes 56 and long fingers 70 of stationary sensing electrodes 62a, 62b are interdigitated, with each long finger 38 disposed between a right finger 74a, 74b and a left finger 76a, 76b of sensing electrodes 62a, 62b. The spacing, Y_o, between fingers 70 and fingers 38 may be approximately one micron. Fingers 38 and 70 may be formed from the same layer of polysilicon so that the fingers are co-planar. Thus all of the driving and sensing elements may be formed in the same fabrication step. In addition, the driving mode and the sensing mode operate in the X-Y plane parallel to the surface of substrate 24. As will be described in more detail below, sensing system 34 is used to sense the deflection of proof mass 22 along the Y-axis, to apply electrostatic forces to balance and eliminate the effect of quadrature error, and to tune the resonant frequency of Y-axis vibrations of the proof mass.

As discussed above, drive system 32 causes proof mass 22 to oscillate along the X-axis. The position of the proof mass along the X-axis, x(t), is given by the following equation:

$$x(t) = X_0 \sin\omega_x t \qquad (1)$$

where X_o is the amplitude of the oscillation and ω_x is the frequency of the driving voltage (and thus the oscillation frequency). The frequency of the driving voltage, ω_x, may be between 7 kHz and 100 kHz, and the driving voltage may be sufficient to cause the proof mass to undergo a maximum deflection, X_o, of about one micron. The magnitude of the Coriolis acceleration, $\ddot{y}_{Coriolis}$, is given by the following equation:

$$\ddot{y}_{Coriolis} = 2 \cdot \Omega_z(t) \times \dot{x}(t) \quad (2)$$

where $\Omega_z(t)$ is the rate of rotation of the proof mass about the Z-axis and $\dot{x}$ is the velocity of the proof mass along the X-axis. Equations 1 and 2 may be combined as follows:

$$\ddot{y}_{Coriolis} = 2 \cdot \Omega_z(t) \cdot X_0 \cdot \omega_x \cdot \cos\omega_x t \quad (3)$$

For a gyroscopic sensor with an oscillation amplitude X_0=1 μm, on oscillation frequency ω_x=20 kHz, and an input rotation rate Ω_z=1 deg/sec, the Coriolis acceleration has a magnitude of 0.45 milliG's.

The Coriolis acceleration is an amplitude-modulated signal in which the carrier frequency is the oscillation frequency and the rotation rate modulates the amplitude. The resulting Coriolis acceleration is a dual sideband signal centered on the oscillation frequency. Referring to FIG. 7A, since the Y-axis accelerations are proportional to velocity, the motion of proof mass 22 is elliptical. The maximum deflection of proof mass 22 along the Y-axis will be a few nanometers. The deflection detectable by gyroscopic sensor 20 may be on the order of a picometer.

In an ideal device, the moving electrodes are perfectly aligned with the stationary electrodes so that the only motion caused by drive system 32 is along the X-axis. However, one effect of manufacturing flaws is quadrature error. Referring to FIG. 7B, quadrature error occurs if proof mass 22 oscillates along an axis that is not exactly parallel to the X-axis. If this is the case, then there is some small fraction, ε, of the drive oscillation, X(t), which lies along the Y-axis. This

quadrature displacement along the Y-axis is given by the following equation:

$$y_{Quadrature} = -\varepsilon \cdot x(t) \qquad (4)$$

If this displacement is differentiated twice, the acceleration, $\ddot{y}_{quadrature}$, due to off-axis oscillation can be determined. This acceleration, given in Equation 5 below, is referred to as quadrature error.

$$\ddot{Y}_{Quadrature} = \varepsilon \cdot X_0 \cdot \omega_x^2 \cdot \sin\omega_x t \qquad (5)$$

Note the similarity between the quadrature error and the Coriolis acceleration: both are sinusoidal signals centered at the frequency of oscillation. However, the signals can be distinguished by their phase relative to the driven oscillation. Specifically, the Coriolis acceleration is ninety degrees out of phase relative to the drive oscillation, ω_x, whereas the quadrature error is in phase with the driven oscillation.

The quadrature error can be quite large. In fact, the quadrature error may easily exceed the Coriolis acceleration. The ratio of quadrature error and Coriolis acceleration is given by Equation 6:

$$\frac{\ddot{Y}_{Coriolis}}{\ddot{Y}_{Quadrature}} = \frac{2\Omega_z(t) \cdot X_0 \cdot \omega_x}{\varepsilon \cdot X_0 \cdot \omega_x^2} = \frac{2\Omega_z(t)}{\varepsilon \cdot \omega_x} \qquad (6)$$

Using the previous example of an input rotation rate, Ω_z, of 1 deg/sec and an oscillation frequency, ω_x, of 20 kHz, for the quadrature error to be as small as the Coriolis acceleration, the oscillation direction must be accurate to a factor of 1 part in 3.6 million. Due to manufacturing flaws and other imbalances, the quadrature error may be considerably larger than this. Accordingly,

gyroscopic sensor 20 has a mechanism to reduce, or nullify the quadrature error.

Microfabricated gyroscopic sensor 20 may apply electrostatic forces to proof mass 22 through sensing system 34. By selection of the proper electrostatic force, the quadrature error may be nullified. As shown by Equation 5, the quadrature error is directly proportional to position of the proof mass along the X-axis. To cancel this error signal without effecting the Coriolis signal, a balancing force must be applied that is also directly proportional to the position of the proof mass along the X-axis. Gyroscopic sensor 20 applies such a balancing force, using the interdigitated Y-axis position sense fingers.

Referring to FIG. 7C, proof mass 22 is shown with two fingers 38a and 38b projecting from opposite sides of the proof mass. Finger 38a is surrounded by right and left fingers 74a and 76a, whereas finger 38b is surrounded by right and left fingers 74b and 76b. A small voltage differential, $2\Delta V$, is applied between the right finger 74a and left finger 76a. The opposite voltage potential $-2\Delta V$, may be applied between right finger 74b and left finger 76b. This voltage difference creates a balancing force, F_y, which counteracts the quadrature error. The balancing force acts on proof mass 22 so that, absent the Coriolis force, fingers 39 vibrate solely along the X-axis. As mentioned above, the balancing force needs to be exactly proportional to the position of the proof mass along the X-axis. An electrostatic force between two charged surfaces is proportional to the overlapping area of the surfaces. Because the overlapping area between fingers 38 and fingers 70 is directly proportional to the position of

proof mass 22 along the X-axis, as proof mass oscillates, the position sense capacitors change proportionately. Therefore, the electrostatic balancing force F_y will also be proportional to the position of proof mass 22. Sensing system 34 applies a DC bias voltage V_{DC} to fingers 74a, 74b, 76a and 76b and a voltage differential $Z\Delta V$ between fingers 74a, 74b and 76a, 76b given by Equation 7 below:

$$F_y = \frac{C_{overlap}}{y_0} x(t) \cdot ((V_{DC}+\Delta V)^2 - (V_{DC}-\Delta V)^2) = 2\frac{C_{overlap}}{y_0} V_{DC} \Delta V \cdot x \qquad (7)$$

where $C_{overlap}$ is the maximum change in capacitance between fingers 70 and fingers 38 as the structure oscillates and y_0 is the equilibrium distance between fingers 70 and fingers 38.

By properly selecting the voltage differential ΔV, the quadrature error may be significantly reduced, e.g., by a factor ten to one-hundred. The proper voltage difference may be calculated from Equations (7) and (5) and Newton's law F = ma, as follows:

$$\Delta V = M\frac{\varepsilon y_0 \omega_x^2}{V_{DC} C_{overlap}} \qquad (8)$$

where M is the mass of proof mass 22. Because the quadrature error is a result of manufacturing defects, the proper voltage differential depends upon the specific structure and may vary from device to device. A voltage differential in the range of 1 mV to 100 mV should be appropriate. The optimum voltage differential to cancel the quadrature error may be determined experimentally (see FIG. 13 which is discussed below).

In addition to canceling the quadrature error, sensing system 34 of gyroscopic sensor 20 may be used to match the Y-axis resonant frequency ω_y of proof mass 22 to the driving oscillating frequency ω_y. Because gyroscopic sensor 20 is a high Q second order system, the response of proof mass 22 to Coriolis acceleration can be enhanced. As shown by Equation 3, the Coriolis acceleration is a signal centered around the oscillation frequency ω_x. Therefore the relative values of the oscillation frequency ω_x and the Y-axis resonant frequency ω_y have a dramatic effect on the response of the sense mode and hence the sensor sensitivity. If the Y-axis resonant frequency is matched to the oscillation frequency, the device may experience a gain of Q in the system response. However, the bandwidth of the sensor is then limited to ω_y/Q. Given that system is run in a vacuum and Q is typically greater than 10,000, the system bandwidth for $\omega_x=\omega_y$ will be only a few Hertz.

For larger bandwidth and increased sensitivity, gyroscopic sensor 20 is operated with a slight mismatch between resonant frequency ω_y and oscillation frequency ω_x. The system response of Y-axis displacement due to Coriolis acceleration is given by:

$$\frac{y}{\Omega_z} = \frac{2X_0\omega_x \sin\omega_x t}{\omega_y^2 + \frac{j\omega_x\omega_y}{Q} - \omega_x^2} = \frac{X_0\omega_x}{\omega_x\Delta\omega}\sin\omega_x t \qquad (9)$$

Provided that there is a means to tune the Y-axis resonant frequency, it is desirable to operate the gyroscopic sensor with a 5-10% frequency mismatch, $\Delta\omega/\omega_x$, yielding a gain of 5-10 in sensitivity. For example, if ω_x is about 12 kHz, then ω_y may be set to about 12.5 kHz. Alternately, the frequency mismatch may be reduced to

about 1-2%. Reducing the mismatch further might increase the sensitivity but may be difficult to maintain for any length of time because the resonant frequency changes as the temperature of the gyroscopic sensor changes.

Tuning of the Y-axis resonant to improve sensitivity is accomplished using electrostatic "negative" springs, i.e., by applying a DC bias voltage, V_{DC}, between proof mass 22 and stationary sensing electrodes 62. When the DC voltage is established between the moving proof mass and the stationary sensing electrode, the resulting attractive force reduces the total spring constant and thus adjusts the resonant frequency.

Using a first-order model for the parallel-plate capacitors, the linearized spring force due to electrostatic forces is given by:

$$F_y = \left[\frac{1}{(y_0-y)^2} - \frac{1}{(y_0+y)^2}\right]\frac{y_0 C_s V_{DC}^2}{2} \qquad (10)$$

where y is the deflection of the proof mass along the Y-axis away from its equilibrium position.

The Y-axis resonant frequency, ω_y, is given by the following equation:

$$\omega_y = \sqrt{\frac{k_y+k_e}{M}} \qquad (11)$$

where k_y is the purely mechanical spring constant, k_e is the electrostatic spring constant and M is the mass of proof mass 22. The mechanical spring constant k_y is primarily a function of the stiffness of suspension system 30.

The electromagnetic spring constant, k_e, is given by the following equation:

$$k_e = -2\frac{C_s}{y_0^2}V_{DC}^2 \qquad (12)$$

in which C_s is the sense capacitance of the gyroscopic sensor and y_o is the distance between fingers 38 and 70 (see FIG. 7A). C_s depends upon the total number of fingers and the amount of overlapping area, and should be at least 30 femtoFarads (fF). By increasing the number of fingers, C_s may be increased to about one picoFarad (pF). As mentioned above, the spacing y_o between fingers is about one micron. It may be noted that k_e has a negative value, so that as V_{DC} is increased ω_y is decreased. The system starts with ω_y larger than ω_x, and the bias voltage V_{DC} is increased, thereby reducing ω_y, until the desired mismatch $\Delta\omega/\omega_y$ is achieved. The correct valve for V_{DC} may be determined experimentally (see FIG. 12 which is discussed below), but should be in the range of one to ten volts.

In addition to canceling the quadrature error and adjusting the Y-axis resonant frequency, sensing system 34 may be used to negate the effects of centrifugal or centripetal force. As the gyroscope sensor rotates about the Z-axis, a centrifugal force will push the proof mass outwardly (assuming the axis of rotation does not pass exactly through the center of mass of the proof mass). A voltage difference, V_c, may be applied between the opposing stationary sensing electrodes 62a and 62b. Because the centripetal force varies at a low frequency, compared to the frequencies of the Coriolis force, a high pass filter may be used to remove the effect of the centripetal force from the output.

Gyroscopic sensor 20 measures the position of proof mass 22 along the Y-axis by capacitive deflection sensing. The interdigitated fingers of sensing system 34 (shown in FIG. 2) are used to sense deflection of the proof mass along the Y-axis. The fingers are arranged in a capacitor bridge so that any deflection of the proof mass results in measurable changes in the relative size of the capacitors. In a first order model, the capacitance of a parallel-plate capacitor is inversely proportional to the distance between the plates.

Referring to FIGS. 6 and 8A, the space between finger 38 of movable sensing electrode 56 and right fingers 74a, 74b of sensing electrodes 62a, 62b forms a first capacitor C_1, and the space between finger 38 and left fingers 76a, 76b forms a second capacitor C_2. As movable sensing electrode 56 is deflected along the Y-axis, C_1 and C_2 change. For example, if sensing electrode 56 is deflected leftward, the distance between finger 38 and right fingers 74a, 74b increases, thereby decreasing C_1, while the distance between finger 38 and left fingers 76a, 76b decreases, thereby increasing C_2. The change in capacitance is detected by a position sensor 80, such as an integrator or voltage buffer, which includes an amplifier 82. Finger 38 is connected to the negative input of amplifier 82. The output of amplifier 82 is connected to the negative input of the amplifier via an integrating capacitor 84 to form an integrator. The negative input of amplifier 82 is connected to ground via a parasitic capacitor 83. The positive input of amplifier 82 may be connected directly to ground.

Because capacitance cannot be measured with a DC voltage, a voltage source 90 applies an AC voltage V_S between fingers 74a, 74b and 76a, 76b. The voltage V_S is

about 0.1 to 5.0 volts, preferably about one volt, and has a frequency much higher than the driving frequency ω_x. For example, the frequency of voltage source 90 may be about one megahertz.

The integrator shown in FIG. 8A offers the flexibility of trading bandwidth for sensitivity by varying the integrating capacitor size. The integrator also provides lower distortion. Some of the parasitic capacitors involved in microelectromechanical systems are nonlinear which will vary the gain of a buffer and thereby result in distortion, and the practice of bootstrapping parasitic capacitance is a form of positive feedback which exacerbates amplifier distortion. However, because the integrator uses a fixed, linear capacitor, distortion is kept to a minimum.

Another common amplifier configurations used for capacitive position sensing is shown in FIG. 8B, in which the output of amplifier 82 is connected to its negative input and sensing electrodes 56 are connected to the positive input of the amplifier to form a voltage buffer.

Unfortunately, the integrator presents a difficult biasing problem. Ideally, biasing can be performed by placing a very large resistor in parallel with the integrating capacitor. However, any practical implementation of a large resistor results in a considerable parasitic capacitance. A diode can also be used in parallel with the integrating capacitance; however, that adds a nonlinear capacitance to the integrating capacitance resulting in distortion. Referring to FIG. 8C, this biasing problem has been solved by using a subthreshold metal oxide semiconductor field effect transistor (MOSFET) 88. The MOSFET device is connected in parallel with integrating capacitor 84 so

that the source of MOSFET 88 is connected to the output of amplifier 82, the drain is connected to the negative input of amplifier 82, and the gate is connected to ground. The negative input of amplifier 82 may be connected to ground by a diode 86, and the positive input of amplifier 82 may be connected directly to ground. In the subthreshold regime, the MOSFET device exhibits extremely low transconductance and no source-to-drain capacitance. The use of subthreshold MOSFET device has resulted in a well behaved integrator operable down to 1 kHz with a 50 F integrating capacitor without additional noise or distortion attributable to the bias circuitry.

Referring to FIG. 9, gyroscopic sensor 20 includes a phase-locked loop (PLL) 100 and several synchronous demodulators or mixers to perform signal processing. Phase-locked loop 100 produces extremely accurate digital signals having a driving frequency ω_x between about 7 kHz and 100 kHz. The drive frequency, ω_x, may be generated by dividing down the signal from voltage source 90. The phase-locked loop ensures that the position signals are exactly in phase with the position of proof mass 22. Phase-locked loop 100 may also generate a velocity signal on line 108 which is exactly ninety degrees out of phase with a position signal on line 110. Position signals on lines 102 and 104, having opposite amplitudes, are supplied by phase-locked loop 100 to the positive and negative outputs, respectively, of a transresistance amplifier 106. Opposing stationary drive electrodes 60a and 60b are also connected to the positive and negative outputs of transresistance amplifier 106. Opposing feedback electrodes 61a and 61b are connected to the positive and negative inputs of transresistance amplifier 106. One of the outputs of transresistance amplifier 106

is mixed with the velocity signal by a mixer 112. The combined output of mixer 112 is applied to trans-resistance amplifier 106 to provide an automatic gain control (AGC) circuit to control the amplitude of the oscillations of proof mass 22 along the X-axis. The phase accuracy of the phase-locked loop is critical to the operation of gyroscopic sensor 20 because any phase error will result in cross-talk between the Coriolis and quadrature signals. Assuming that a phase error $\theta_n(t)$ is generated by phase noise in the phase-locked loop, the error in the rotation rate Ω may be derived as shown in Equations 13-15 below:

$$y(t) = [\frac{X_0\omega_x}{\omega_x\Delta\omega}\Omega\cos\omega t + Y_{Quadrature}\sin\omega t] \quad (13)$$

$$\Omega_{est} = \frac{\omega_x\Delta\omega}{X_0\omega_x}y(t)\cos(\omega_x t+\theta_n(t)) \quad (14)$$

$$\Omega_{est} = \Omega + \frac{\omega_x\Delta\omega}{X_0\omega_x}Y_{Qadrature}\theta_n(t) + Higher\ terms \quad (15)$$

Because phase-locked loop 100 is extremely accurate, phase noise is minimized and variable cross-talk is extremely small. In addition, quadrature error correction reduces cross talk and phase noise.

The nulling of the quadrature error, the tuning of the Y-axis resonant frequency, and the balancing of the centrifugal forces is accomplished by the application of the proper voltages to fingers 70 of opposing stationary sensing electrodes 62a and 62b. Specifically, gyroscopic sensor 20 includes four DC bias voltage sources 120, 122,

124 and 126. Voltage source 120 applies a total voltage $V_t=V_{DC}+\Delta V+V_C$ to right fingers 74a of sensing electrode 62a. Voltage source 122 applies a total voltage of $V_{DC}-\Delta V-V_C$ to left fingers 76a. Voltage source 124 applies a total voltage of $V_{DC}-\Delta V+V_C$ to right electrode fingers 74b of sensing electrode 62b. Voltage source 126 applies a total voltage of $V_{DC}+\Delta V-V_C$ to left fingers 76b. Thus, voltage sources 120, 122, 124 and 126 provide all of the necessary bias voltages in order to nullify the quadrature error, select the desired Y-axis resonant frequency, and cancel any centrifugal or other low-frequency forces. Of course, any other combination of voltage sources providing the same effective total voltage to the fingers of the sensing electrodes could be used. Also, the voltages could be applied by different sets of fingers of the stationary sensing electrode, for example, V_{DC} could be applied by one set of fingers and ΔV could be applied by another set of fingers.

In order to extract the position, Coriolis effect, and quadrature signals from capacitive position sensor 80, the signal from amplifier 82 is boosted by an oscillation amplifier 130 to produce an output signal on line 132. This output signal may be mixed with signals from a modulator or clock and the position and velocity signals from phase locked loop 100. Voltage source 90 may produce a high frequency, e.g., one megahertz clock signal on line 134. To generate the position signal, this clock signal is mixed with the output signal on line 132 by a mixer 136. In order to produce the Coriolis signal, the clock signal on line 134 is mixed with the velocity signal on line 108 by a mixer 140 to produce a combined signal on line 142. The combined signal on line 142 is then mixed with output signal on line 132 by a

mixer 144 to produce the Coriolis signal. Finally, to produce the quadrature signal, the clock signal on line 134 is mixed with the position signal on line 110 by a mixer 150 to produce a combined signal on line 152. The combined signal on line 152 is then mixed with output signal on line 132 by a mixer 154 to produce the quadrature signal. The position, Coriolis and quadrature signals may be passed through low pass filters to filter out high frequency components.

Referring to FIG. 10, a gyroscopic sensor 20 was fabricated on a silicon substrate 24 using a combination of metal oxide semiconductor and microelectromechanical fabrication techniques. The transresistance amplifier and integrator were fabricated on the same die, and the remaining electronics was implemented off of the chip. The mechanical sensing element is about one millimeter across.

There are a number of possible noise sources in gyroscopic sensor 20. Principal among these are: Brownian noise, op-amp noise in the integrator, and phase locked loop phase noise. The Brownian noise, $\Omega_n B$, represents the fundamental limit on angular rate resolution and is given by:

$$\Omega_{nB} = \sqrt{\frac{kT\omega_y BW}{MQ\omega_x^2 X_0^2}} \qquad (16)$$

where k is Boltzman's constant, T is the temperature, M is the mass of the proof mass, BW is the bandwidth of the gyroscopic sensor, and Q is the quality factor. As an example, consider a gyroscopic sensor with mass, M=0.2μg, an oscillation amplitude X_0=1 μm, a quality factor, Q= 10,000, a bandwidth BW = 100 Hz, a drive frequency ω_x= 20

kHz and a resonant frequency ω_y= 20 kHz. For this example, we find a Brownian noise floor Ω_{nB}=0.06 deg/sec. Because the gyroscopic sensor is run in vacuum and has a high Q, Brownian noise is not the dominant noise source.

As shown by Equation 15, phase noise in the phase locked loop, represented by $\theta_n(t)$, can cause variable cross talk between quadrature and Coriolis signals. In gyroscopic sensor 20, this effect is kept to a minimum due to the low phase noise in the phase locked loop and nulled quadrature error.

The integrator op-amp noise is the dominant noise source in gyroscopic sensor 20. The input-referred noise, Ω_E, of the op-amp noise is a function of the total capacitance, C_T, attached to the summing node of the integrator, and is given by:

$$\Omega_{nE} = \frac{C_T Y_0 \nu_n}{C_S X_0 V_S} \Delta\omega \sqrt{2BW} = \frac{Y_0 \Delta\omega}{X_0 V_S} \sqrt{\frac{32kTBW}{3\pi C_S f_T}} \qquad (17)$$

where f_T is the maximum operable frequency of the transistors in gyroscopic sensor 20. The electronic noise is at best Ω_{nE}=0.08 deg/sec for a modest CMOS process with f_T=250 MHZ, a frequency mismatch $\Delta\omega$=1 kHz, a sense voltage V_s=1 volt, a sense capacitance C_s=100fF, and the oscillation amplitude and finger spacing X_0=y_o=1 μm.

An initial characterization of the gyroscopic sensor response is shown in FIG. 11. FIG. 11 is a graph of the logarithm of the output voltage of the Coriolis signal, on the Y-axis, as a function of frequency, on the X-axis. The graph was produced by measuring the output Coriolis signal in response to a 1Hz, 5 deg/sec sine wave rotation. The gyroscopic sensor was operated with an oscillation frequency, ω_x, of 12 kHz and a Y-axis resonant frequency, ω_y, of about 12.5 kHz. The noise floor for

this version of Z-axis vibratory rate gyroscopic sensor is 1 deg/sec/Hz$^{1/2}$.

Referring to FIG. 12, there is a measured mechanical resonant frequencies of proof mass 22 as a function of the DC bias voltage applied to the position sense fingers. FIG. 12 shows a graph of the resonant frequencies of proof mass 22 (on the Y-axis of the graph) as a function of the RMS voltage (on the X-axis of the graph) applied between fingers 38 and fingers 70. The RMS voltage is a combination of the DC bias voltage and the AC voltage generated by voltage source 90. The resulting electrostatic springs reduce the resonant frequency of the sense mode (ω_y), raise the resonant frequencies of the out-of-plane modes, and leaves the driven mode (ω_x) unaffected. As expected, the Y-axis resonant frequency drops as the bias voltage is increased and the oscillation frequency of proof mass 22 remains constant at 12kHz. The resonant frequencies of the vertical and tipping modes increase with DC bias due to electrostatic levitation effects.

As discussed above, gyroscopic sensor 20 includes a means to null quadrature error. FIG. 13 shows a graph of the measured voltage, V_{out} on the Y-axis, as a function of the voltage differential, ΔV, on the X-axis, which is applied between right fingers 74a, 74b and left fingers 76a, 76b. Both the quadrature and rotation rate signals were plotted for a zero rotation rate as ΔV was adjusted. Measurements of the quadrature error and rotation rate signals demonstrate that the quadrature error signal can be controlled independently of the Coriolis signal.

Another embodiment of the gyroscopic sensor, in which the sensing and quadrature correction voltages are applied by different electrode fingers, is shown by FIG.

14. Referring to FIG. 14, a micromachined gyroscopic sensor 200 includes a proof mass 202 connected to a substrate 204 by a suspension system 206. The gyroscopic sensor 200 includes three major electronic elements: a drive system 210 used to sustain oscillation of proof mass 202 along the X-axis, a sensing systems 212 used to detect deflections of proof mass 202 along the Y-axis, and a quadrature correction system 214 used to cancel any quadrature error.

The proof mass 202 includes a rectangular outer stage 220 and a rectangular inner stage 222. Each corner of outer stage 220 is connected by a folded or J-shaped first flexure 224 to an anchor 226 which secures proof mass 202 and suspension system 206 to substrate 204. Similarly, each corner of inner stage 222 is connected to outer stage 220 by a second flexure 228. The first flexure 224 is designed to permit outer stage 220 to vibrate primarily along a Y-axis with respect to substrate 204, whereas second flexure 228 is designed to permit inner stage 222 to vibrate substantially along the X-axis with respect to outer stage 220. Several beams or crossbars 230 may connect opposing sides of inner stage 222.

The physical characteristics of gyroscopic sensor 200 are similar to those of gyroscopic sensor 20. The sensor may be about 0.5 to 2.0 millimeters on a side; the proof mass may have a total mass of about 0.1 to 0.5 micrograms; the flexible elements of the suspension system may be constructed of polysilicon and may have a width and a thickness on the order of two microns. The entire assembly may be fabricated using traditional integrated circuit fabrication techniques.

Referring to FIG. 14, the drive system 210 includes two driving electrodes 232a and 232b, and two feedback electrodes 234a and 234b, all connected to substrate 204. A plurality of electrode fingers 236 project along the X-axis from each feedback electrode and each drive electrode. A plurality of electrode fingers 238 project from inner stage 222 of proof mass 202 along the X-axis, and are interdigitated with electrode fingers 236 of the sense and drive electrodes.

As shown in FIG. 15, feedback electrodes 234a and 234b are connected to the positive and negative inputs, respectively, of a transresistance amplifier 240. The driving electrodes 232a and 232b are connected to the positive and negative outputs of transresistance amplifier 240, respectively, and to a phase-locked loop 242, as previously described with respect to FIG. 9.

The sensing system 212 includes a plurality of pairs of sense electrodes fingers aligned with the X-axis. Each pair of sense electrode fingers includes a right finger 244 and a left finger 246. A plurality of electrode fingers 248 are connected to outer stage 220 and are interdigited so that each electrode finger 248 is disposed between one right finger 244 and one left finger 246. A sense voltage source 250 (see FIG. 15) applies an AC voltage between the right fingers 244 and the left fingers 246.

Quadrature correction system 214 includes several sets of correction electrodes positioned near the center-line of the sensor and connected to the substrate. Each set of correction electrodes includes an upper left electrode 260, an upper right electrode 262, a lower left electrode 264, and a lower right electrode 266. Upper right electrode 262 and lower left electrode 264 may be a

single electrode, as shown, or may be separate electrodes. A plurality of electrode fingers 268 extend from crossbars 230 and are interdigited with the connection electrodes. Specifically, each electrode finger 268 extends along the X-axis from crossbar 230 and is disposed between upper left electrode 260 and upper right electrode 262. Similarly, each electrode finger 268 extends along the X-axis from crossbar 230 and is disposed between lower left electrode 264 and lower right electrode 266. Upper left electrode 260 is electrically connected to lower right electrodes 266, and upper right electrode 262 is electrically connected to lower left electrode 264.

A voltage source 270 (FIG. 15) applies a DC bias voltage between the correction electrodes 260, 266 and 262, 264. The voltage differential between the left and right electrodes creates a balancing force to counteract the quadrature error as discussed with respect to FIG. 7C. The remainder of the circuitry, including an integrator 280 and mixers 282-286 may be assembled and function in a manner similar to the circuitry discussed above with reference to FIG. 9.

Referring to FIG. 16, quadrature correction may be used to compensate for manufacturing flaws that occur in the fabrication of other sorts of gyroscopic sensors, such as X-axis and Y-axis gyroscopic sensors. A dual-axis vibratory gyroscope functions by generating and sensing Coriolis accelerations. The functional operation of the dual-axis vibratory gyroscope is illustrated by an equivalent spring-mass system. In a dual-axis gyroscopic sensor 290, a proof mass 292 is supported by a flexible suspension 294 from a frame 296. The proof mass is generally disc-shaped, and lies in a plane generally

parallel to the surface of the substrate. The proof mass is oscillated about the Z-axis (the axis perpendicular to the surface of the substrate) by a drive torque F_d with a frequency ω_z. If the frame rotates about a first axis parallel to the surface of the substrate, e.g., the Y-axis, at a rotation rate Ω_Y, then the combination of this rotation and oscillation generates an oscillating Coriolis torque F_c about a second axis parallel to the surface of the substrate and perpendicular to the first axis, i.e., the X-axis. This Coriolis force torque will tend to oscillate the proof mass about the X-axis at a frequency ω_X. Thus, rotation of the proof mass about the Y-axis causes the proof mass to undergo a "see-saw" motion about the X-axis. Similarly, a rotation about the X-axis will induce a Coriolis oscillation about the Y-axis.

The Coriolis acceleration about the X-axis generated by rotation of the proof mass about the Y-axis is given by the following equation:

$$I_{xx}\ddot{\theta}_x + C_x\dot{\theta}_x + K_x\theta_x = -I_{zz}\Omega_y \times \theta_{z0}\omega_z \cos(\omega_z t) \qquad (18)$$

where θ_x is the sense-axis tilt angle, I_{xx} is the X-axis moment of inertia, C_x is the damping co-efficient, K_x is the spring constant, ω_z is the frequency of oscillation about the Z-axis, I_{zz} is the Z-axis movement of inertia, and Ω_y is the rotation rate of the proof mass about the Y-axis. The angular oscillation of the rotor caused by the Coriolis acceleration can be thought of as an amplitude modulated signal with a carrier frequency ω_z. The amplitude of the modulated signal is directly proportional to the Y-axis rotation rate Ω_y. The equation for Coriolis acceleration about the Y-axis is essentially

identical except that the x and y subscripts are reversed and the right-hand side of the equation is positive.

Referring to FIG. 17A, a dual-axis gyroscopic sensor 300 includes a generally ring-shaped proof mass 302 connected to a rigid frame or substrate 304 by a suspension system 306. Dual-axis gyroscopic sensor 300 measures the X-axis and Y-axis rotation rate; i.e., the rotation of the substrate about the axes parallel to the surface of substrate 304. Dual-axis gyroscopic sensor 300 includes three major electronic elements: a drive system 310 used to sustain oscillation of proof mass 302 about the Z-axis, a sensing system 312 used to detect deflections of proof mass 302 about the X-axis and Y-axis, and a quadrature correction system 314 used to cancel any quadrature error. The dual-axis gyroscopic sensor 300 may be fabricated using standard integrated circuit techniques.

The proof mass 302 includes a generally ring-shaped rotor 316. Rotor 316 may be a two micron thick polysilicon ring with an outer radius of about 250 microns and an inner radius of about 200 microns. The proof mass 302 is substantially symmetric about the X- and Y-axis.

The suspension system 306 may include four beams 320 which connect an inner edge 322 of the proof mass to an anchor 324 which secures rotor 316 to substrate 304. The beams 320 may also be constructed of polysilicon and may have a width and thickness on the order of two microns.

Alternately, the suspension system may include a serpentine suspension with folded beams. In yet another version, the proof mass may be suspended by four beams connected to an outer edge of the rotor. A serpentine

suspension system provides a lower natural frequency and can accommodate warping of the rotor.

Suspension systems 306 is designed to provide a torsional suspension for rotor 316 to allow rotation about the three perpendicular axes. However, suspension system 306 is designed to be rigid to translational accelerations along the X-axis and the Y-axis. Although rotor 316 may undergo translational acceleration along the Z-axis, the differential sensing scheme discussed below substantially cancels sensitivity to such accelerations.

For maximum mechanical sensitivity, the suspension system is designed to match the frequencies of all three rotational modes sufficiently well that electrostatic tuning may compensate for process variations during manufacture of the gyroscope sensor. In particular, the sense axis natural frequencies were designed to be about ten percent above the drive natural frequencies so that the sense frequencies may be down tuned to match the drive frequency.

A plurality of inner combs 330a-330d project inwardly from inner edge 322 of rotor 316. Each inner comb includes a spine 332 and a plurality of teeth 334 which project from both sides of the spine. The number and configuration of inner combs in FIG. 17A is merely illustrative. The dual axis gyroscope may include twelve inner combs, each having five teeth. Four outer combs 340a-340d project outwardly from an outer edge 326 of rotor 316. Each outer comb includes a spine 342 and a plurality of teeth 344 projecting from both sides of the spine. Although teeth 334 and 344 in FIG. 17A are illustrated as linear, as shown in FIG. 17B it is