

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

WESTERN DIGITAL TECHNOLOGIES, INC.,
Petitioner

v.

LONGITUDE LICENSING LTD.,
Patent Owner

U.S. Patent No. 9,207,701

**IN SUPPORT OF PETITION FOR INTER PARTES REVIEW
DECLARATION OF SYLVIA D. HALL-ELLIS, PH.D.**

UNDER 37 C.F.R. § 1.68

I. INTRODUCTION

1. My name is Sylvia D. Hall-Ellis. I have been retained as an expert by counsel for Western Digital Technologies, Inc. (“WDT” or “Petitioner”).

2. I have written this declaration at the request of Petitioner to provide my expert opinion regarding the authenticity and public availability of a publication. My declaration sets forth my opinions in detail and provides the basis for my opinions regarding the public availability of these publications.

3. I reserve the right to supplement or amend my opinions, and bases for them, in response any additional evidence, testimony, discovery, argument, and/or other additional information that may be provided to me after the date of this declaration.

4. I am being compensated for my time spent working on this matter at my normal consulting rate of \$300 per hour, plus reimbursement for any additional reasonable expenses. My compensation is not in any way tied to the content of this declaration, the substance of my opinions, or the outcome of this litigation. I have no other interests in this proceeding or with any of the parties.

5. All of the materials that I considered are discussed explicitly in this Declaration.

II. QUALIFICATIONS

6. I am currently an Adjunct Professor in the School of Information at San José State University. I obtained a Master of Library Science from the University of North Texas in 1972 and a Ph.D. in Library and Information Science from the University of Pittsburgh in 1985. Over the last fifty years, I have held various positions in the field of library and information resources. I was first employed as a librarian in 1966 and have been involved in the field of library sciences since, holding numerous positions.

7. I am a member of the American Library Association (ALA) and its Association for Library Collections & Technical Services (ALCTS) Division, and I served on the Committee on Cataloging: Resource and Description (which wrote the new cataloging rules) and as the chair of the Committee for Education and Training of Catalogers and the Competencies and Education for a Career in Cataloging Interest Group. I also served as the Chair of the ALCTS Division's Task Force on Competencies and Education for a Career in Cataloging. Additionally, I have served as the Chair for the ALA Office of Diversity's Committee on Diversity, as a member of the national Board of Directors for REFORMA, as a member of the Editorial Board for the ALCTS premier cataloging journal, *Library Resources and Technical Service*, as a Co-Chair for the Library Research Round Table (LRRT) of the

American Library Association, and as a member of the LRRT Nominating Committee.

8. I have also given over one hundred presentations in the field, including several on library cataloging systems and Machine-Readable Cataloging (“MARC”) standards. My current research interests include library cataloging systems, metadata, and organization of electronic resources.

9. My full curriculum vitae is attached hereto as an Appendix to this declaration.

III. LIBRARY CATALOGING PRACTICES

A. MARC RECORDS AND THE ONLINE LIBRARY CATALOG

10. I am fully familiar with the library cataloging standard known as the MARC standard, which is an industry-wide standard method of storing and organizing library catalog information.¹ MARC was first developed in the 1960s by the Library of Congress. A MARC-compatible library is one that has a catalog consisting of individual MARC records for each of its items. Today, MARC is the primary communications protocol for the transfer and storage of bibliographic

¹ The full text of the standard is available from the Library of Congress at <http://www.loc.gov/marc/bibliographic/> (last visited July 5, 2023).

metadata in libraries.²

11. MARC is a framework into which descriptive bibliographic data are transcribed to interact with the software in online library catalogs to provide access to books, journals, and other resources in the collection. The bibliographic data provide points of access and can be searched by a POSITA to identify and obtain resources in the library collection. An information seeker (or POSITA) can search a local online library catalog or the holdings of a group of libraries in a state or region or in the global catalog WorldCat.

12. MARC records are not designed for public viewing. Although a significant number of libraries provide access to the MARC version of a bibliographic record, the public display is designed to show information in a succinct manner that is quickly understood and useful to the information seeker. Libraries

² Almost every major library in the world is MARC-compatible. *See, e.g., MARC Frequently Asked Questions (FAQ)*, Library of Congress, <https://www.loc.gov/marc/faq.html> (last visited July 5, 2023) (“MARC is the acronym for Machine-Readable Cataloging. It defines a data format that emerged from a Library of Congress-led initiative that began nearly fifty years ago. It provides the mechanism by which computers exchange, use, and interpret bibliographic information, and its data elements make up the foundation of most library catalogs used today.”). MARC is the ANSI/NISO Z39.2-1994 (reaffirmed 2016) standard for Information Interchange Format.

determine the default search for the online catalog to make the entry of search terms efficient and result in a successful search. Information seekers can enter a keyword, title, author, or standard number for the item. Libraries may also provide a search capability called “Summon” that allows the information seeker to enter known information about the item to conduct a search.

13. Since at least the early 1970s and continuing to the present day, MARC has been the primary communications protocol for the transfer and storage of bibliographic metadata in libraries.³ As explained by the Library of Congress:

You could devise your own method of organizing the bibliographic information, but you would be isolating your library, limiting its options, and creating much more work for yourself. Using the MARC standard prevents duplication of work and allows libraries to better share bibliographic resources. Choosing to use MARC enables libraries to acquire cataloging data that is predictable and reliable. If a library were to develop a “home-grown” system that did not use MARC

³ A complete history of the development of MARC can be found in *MARC: Its History and Implications* by Henrietta D. Avram (Washington, DC: Library of Congress, 1975) and available online from the Hathi Trust (<https://babel.hathitrust.org/cgi/pt?id=mdp.39015034388556;view=1up;seq=1>; last visited July 5, 2023).

records, it would not be taking advantage of an industry-wide standard whose primary purpose is to foster communication of information.

Using the MARC standard also enables libraries to make use of commercially available library automation systems to manage library operations. Many systems are available for libraries of all sizes and are designed to work with the MARC format. Systems are maintained and improved by the vendor so that libraries can benefit from the latest advances in computer technology. The MARC standard also allows libraries to replace one system with another with the assurance that their data will still be compatible.

Why Is a MARC Record Necessary? LIBRARY OF CONGRESS.⁴

14. Thus, almost every major library in the world is MARC-compatible. See, e.g., *MARC Frequently Asked Questions (FAQ)*, LIBRARY OF CONGRESS.⁵ (“MARC is the acronym for MACHine-Readable Cataloging. It defines a data format that emerged from a Library of Congress-led initiative that began fifty years ago. It provides the mechanism by which computers exchange, use, and interpret bibliographic information, and its data elements make up the foundation of most

⁴ <http://www.loc.gov/marc/umb/um01to06.html#part2>

⁵ <https://www.loc.gov/marc/faq.html>

library catalogs used today.”). MARC is the ANSI/NISO Z39.2-1994 standard (reaffirmed in 2016) for Information Interchange Format. The full text of the standard is available from the Library of Congress.⁶

15. Examining the MARC records for a specific item reveals the comprehensive data transcribed about a particular item at the time that cataloging and classification occurred. In addition to the creator, title, subjects, and standard numbers, additional information may provide additional and relevant data depending on the type of resource. Understanding the full extent of bibliographic data for an item and the points of access associated with it provides essential information that can be used to determine the indexing and public availability for documents described in this declaration.

B. MARC RECORDS

16. A MARC record comprises 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 follow. For example, a work’s title is recorded in Field 245; the primary author of the work is transcribed in Field 100; an item’s International Standard Book Number (“ISBN”) consisting of ten or thirteen digits is transcribed in Field 020; an item’s International Standard Serial

⁶ <http://www.loc.gov/marc/bibliographic/>

Number (“ISSN”) is transcribed in Field 022; the Library of Congress classification notation is recorded in Field 050; and the publication date is recorded in Field 260 under the subfield “c.” If a work is a periodical, then its publication frequency is recorded in Field 310, and the publication dates (e.g., the first and last publication) are recorded in Field 362, which is also referred to as the enumeration/chronology field.⁷

17. The library that created the record is recorded in Field 040 in subfield “a” with a unique library code. When viewing the MARC record online via Online Computer Library Center’s (“OCLC”) bibliographic database, hovering over this code with the mouse reveals the full name of the library. I used this method of “mousing over” the library codes in the OCLC database to identify the originating library for the MARC records discussed in this Declaration. Where this “mouse over” option was not available, I consulted the Directory of OCLC Libraries to identify the institution that created the MARC record.⁸

18. MARC records also include several fields that include subject matter classification information. An overview of MARC record fields is available through

⁷ <http://www.loc.gov/marc/bibliographic/bd3xx.html>

⁸ <https://www.oclc.org/en/contacts/libraries.html>

the Library of Congress.⁹ For example, 6XX fields are termed “Subject Access Fields.”¹⁰ Among these, for example, is the 650 field; this is the “Subject Added Entry – Topical Term” field.¹¹ The 650 field is a “[s]ubject added entry in which the entry element is a topical term.” These entries “are assigned to a bibliographic record to provide access according to generally accepted thesaurus-building rules (e.g., *Library of Congress Subject Headings* (LCSH), *Medical Subject Headings* (MeSH)).” *Id.* Further, MARC records include call numbers, which themselves include a classification number. For example, the 050 field is the “Library of Congress Call Number.”¹² A defined portion of the Library of Congress Call (LCC) Number is the classification number, and “source of the classification number is *Library of Congress Classification* and the *LC Classification-Additions and Changes*.” Thus, included in the 050 field is a subject matter classification. Further, the 082 field is the “Dewey Decimal Call Number.”¹³ A defined portion of the Dewey Decimal Call (DDC) Number is the classification number, and “source of the classification number is the *Dewey Decimal Classification and Relative Index*.”

⁹ <http://www.loc.gov/marc/bibliographic/>

¹⁰ <http://www.loc.gov/marc/bibliographic/bd6xx.html>

¹¹ <http://www.loc.gov/marc/bibliographic/bd650.html>

¹² <http://www.loc.gov/marc/bibliographic/bd050.html>

¹³ <http://www.loc.gov/marc/bibliographic/bd082.html>

Thus, included in the 082 field is a subject matter classification. Each item in a library has a single classification number. A library selects a classification scheme (*e.g.*, the Library of Congress classification scheme just described or a similar scheme such as the Dewey Decimal classification scheme) and uses it consistently. When the Library of Congress assigns the LCC classification number, it appears as part of the 050 field. When the Library of Congress assigns the DDC classification number, it appears as part of the 082 field. If a local library assigns the classification number, it appears in a 090 field. In either scenario, the MARC record includes a classification number that represents a subject matter classification.

C. OCLC

19. The 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.”¹⁴ Among other services, OCLC and its members are responsible for maintaining the WorldCat database (<http://www.worldcat.org/>), used by independent and institutional libraries throughout the world.

20. OCLC also provides its members online access to MARC records through its OCLC bibliographic database. When an OCLC member institution acquires a work, it creates a MARC record for this work in its computer catalog system in the ordinary course of its business. MARC records created at the Library of Congress are tape-loaded into the OCLC database through a subscription to MARC Distribution Services daily or weekly. Once the MARC record is created by a cataloger at an OCLC member institution or is tape-loaded from the Library of Congress, the MARC record is then made available to any other OCLC members online, and therefore made available to the public. Accordingly, once the MARC record is created by a cataloger at an OCLC member institution or is tape-loaded from the Library of Congress or another library anywhere in the world, any publication corresponding to the MARC record has been cataloged and indexed

¹⁴ Third Article, Amended Articles of Incorporation of OCLC Online Computer Library Center, Incorporated (available at <https://www.oclc.org/content/dam/oclc/membership/articles-of-incorporation.pdf>).

according to its subject matter such that a person interested in that subject matter could, with reasonable diligence, locate and access the publication through any library with access to the OCLC bibliographic database or through the Library of Congress.

21. When an OCLC member institution creates a new MARC record, OCLC automatically supplies the date of creation for that record. The date of creation for the MARC record appears in the fixed Field (008), characters 00 through 05. The MARC record creation date reflects the date on which, or shortly after which, the item was first acquired or cataloged. Initially, Field 005 of the MARC record is automatically populated with the date the MARC record was created in year, month, day format (YYYYMMDD) (some of the newer library catalog systems also include hour, minute, second (HHMMSS)). Thereafter, the library's computer system may automatically update the date in Field 005 every time the library updates the MARC record (*e.g.*, to reflect that an item has been moved to a different shelving location within the library). Field 005 is visible when viewing a MARC record via an appropriate computerized interface, but when a MARC record is printed to hardcopy, no "005" label appears. The initial Field 005 date (*i.e.*, the date the MARC

record was created) does appear, however, next to the label “Entered.”¹⁵ The date upon which the most recent update to Field 005 occurred also appears, next to the label “Replaced.” Thus, when an item’s MARC record has been printed to hardcopy—as is the case with the exhibit to this Declaration—the date reflected next to the label “Entered” is necessarily on or after the date the library first cataloged and indexed the underlying item.

22. Once one library has cataloged and indexed a publication by creating a MARC record for that publication, other libraries that receive the publication do not create additional MARC records—the other libraries instead rely on the original MARC record. They may update or revise the MARC record to ensure accuracy, but they do not replace or duplicate it. This practice does more than save libraries from duplicating labor. It also enhances the accuracy of MARC records. Further, it allows librarians around the world to know that a particular MARC record is authoritative (in contrast, a hypothetical system wherein duplicative records were created would result in confusion as to which record is authoritative).

¹⁵ Field 005 is visible when viewing a MARC record via an appropriate computerized interface. But when a MARC record is printed directly to hardcopy from the OCLC database, the “005” label is not shown. The date in the 005 field instead appears next to the label “Replaced.”

23. Catalogers can create MARC records for all types of print, online, and digital resources. The date of creation of the MARC record by a cataloger at an OCLC member institution reflects when the underlying item is accessible to the public. Upwards of two-thirds to three-quarters of book sales and magazine subscriptions to libraries come from a jobber or wholesaler for online and print resources. These resellers make it their business to provide items to their customers as fast as possible, often providing turnaround times of only a single day after publication. Libraries purchase a significant portion of the balance of their books and journals directly from publishers themselves, which provide delivery on a similarly expedited schedule. In general, libraries make these purchases throughout the year and shelve the newly received items as soon thereafter as possible to make them available to their patrons.

24. *Journals.* The handling of printed journal subscriptions is shown on the covers of individual issues. As was the best practice among libraries, issues arrived at a central facility and were immediately received, verified as part of a subscription, checked in, and stamped with the institution's name and date. Determining that the issue was part of the library subscription ensured that the entire set of publications for the year had been received so that they could be professionally bound and retained. This process also verified that each of the published issues arrived so that the library staff did not have to request or claim an issue that did not arrive as

expected. In large public libraries with branches and multi-campus libraries within academic institutions, the journals were sorted and delivered to the subscribing unit. The issues were frequently stamped again to acknowledge receipt. The new issue was placed in the public area; the older issue was stored so that it remained available.

25. The foregoing process has been standard library practice longer than I have been working in the profession. I first learned the steps in the process in the late 1970s and later supervised it. Although the checking in process has become automated and now links electronically to holdings records for the MARC record for each serial title, the manual stamping and placing the issue in a public area has not changed for 50 years. Unless I note otherwise below in reference to a specific serial publication, it is my expert opinion that this standard protocol was followed for each of the serial publications discussed below.

26. In preparing this declaration, I used authoritative databases, such as the OCLC bibliographic database and the Library of Congress Online Catalog, to confirm citation details of the various publications discussed.

27. *Indexing.* A researcher may discover material relevant to his or her topic in a variety of ways. One common means of discovery is to search for relevant information in an index of periodical and other publications. Having found relevant material, the researcher will then normally obtain it online, look for it in libraries, or purchase it from the publisher, a bookstore, a document delivery service, or other

provider. Sometimes, the date of a document's public accessibility will involve both indexing and library date information. However, date information for indexing entries is often unavailable. This is especially true for online indices.

28. Indexing services use a wide variety of controlled vocabularies to provide subject access and other means of discovering the content of documents. The formats in which these access terms are presented vary from service to service.

29. Online indexing services commonly provide bibliographic information, abstracts, and full-text copies of the indexed publications, along with a list of the documents cited in the indexed publication. These services also often provide lists of publications that cite a given document. A citation of a document is evidence that the document was publicly available and in use by researchers no later than the publication date of the citing document.

30. Before the widespread development of online databases to index articles in journals, magazines, conference papers, and technical declarations, libraries purchased printed volumes of indices. Graduate library school education mandated that students learn about the bibliographic control of disciplines, the prominent indexing volumes, and searching strategies required to use them effectively and efficiently. Half of the courses that I studied in library school were focused on the bibliography and resources in academic disciplines.

31. Librarians consulted with information seekers to verify citations, check

availability in union catalogs, printed books catalogs, the OCLC database, and make formal requests for materials (e.g., books, conference proceedings, journal articles). Requests were transmitted using Telex machines, rudimentary email systems, and the United States Postal Service. During my career, I have performed and supervised staff who handled these resource sharing tasks.

32. A major firm known for the breadth of subjects and comprehensive treatment in the preparation of index volumes, the H. W. Wilson Company offered these reference resources since the firm was founded in 1898. The *Reader's Guide to Periodical Literature* is one of the best-known titles available from H. W. Wilson. Each volume includes a comprehensive index for 300 of the most popular and important periodicals published in the United States and Canada. Information seekers have subject access expressed in plain language terminology, author access, and cross references to find the desired results from their searches. The family of index titles included *Science & Technology Index*, *Business Periodicals*, *Applied Science & Technology Index*, *Humanities Index*, *Biological & Agricultural Index*, and *Industrial Arts Index*. These printed indices have been superseded by digital database offerings available to information seekers through Ebsco.

33. Online indexing services such as *Google Scholar*¹⁶ or *ScienceDirect*¹⁷ commonly provide bibliographic information, abstracts, and full-text copies of the indexed publications, along with a list of the documents cited in the indexed publication. These services also often provide lists of publications that cite a given document.

34. A citation of a document by another is evidence that the document was publicly available and in use no later than the publication date of the citing document.

IV. PRELIMINARIES

35. *Scope of this Declaration.* I am not an attorney and will not offer opinions on the law. I am, however, rendering my expert opinion on the authenticity of the documents referenced herein and when and how each of these documents was disseminated or otherwise made available to the extent that persons interested and ordinarily skilled in the subject matter or art, exercising reasonable diligence, could have located the documents before March 27, 2007.

36. I am informed by counsel that a printed publication qualifies as publicly accessible as of the date it was disseminated or otherwise made available such that

¹⁶ <https://scholar.google.com/>

¹⁷ <https://www.sciencedirect.com/>

a person interested in and ordinarily skilled in the relevant subject matter could locate it through the exercise of ordinary diligence.

37. While I understand that the determination of public accessibility under the foregoing standard rests on a case-by-case analysis of the facts particular to an individual publication, I also understand that a printed publication is rendered “publicly accessible” if it is cataloged and indexed by a library such that a person interested in the relevant subject matter could locate it exercising reasonable diligence (*i.e.*, I understand that cataloging and indexing by a library in a manner that permits a person of ordinary skill in the relevant subject matter to locate the publication is sufficient, though there are other ways that a printed publication may qualify as publicly accessible). One manner of sufficient indexing is indexing according to subject matter category. I understand that the cataloging and indexing by a single library of a single instance of a particular printed publication is sufficient, even if the single library is in a foreign country. I understand that, even if access to a library is restricted, a printed publication that has been cataloged and indexed therein is publicly accessible so long as a presumption is raised that the portion of the public concerned with the relevant subject matter would know of the printed publication. I also understand that the cataloging and indexing of information that would guide a person interested in the relevant subject matter to the printed publication, such as the cataloging and indexing of an abstract for the printed

publication, is sufficient to render the printed publication publicly accessible.

38. I understand that routine business practices, such as general library cataloging and indexing practices, can be used to establish an approximate date on which a printed publication became publicly accessible.

39. *Persons of ordinary skill in the art.* I am told by counsel that the subject matter of this proceeding relates generally to the design of integrated circuits.

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

41. I am told by counsel that persons of ordinary skill in this subject matter or art would have (1) at least an undergraduate degree in electrical or computer engineering or a closely related scientific field, or similar advanced post-graduate education in this area; and (2) two or more years of experience with circuit design. A person with less or different education but more relevant practical experience, or vice versa, may also meet this standard.

42. Based on my experience working in research libraries with researchers having the qualifications described above, or even lesser qualifications, it is my opinion that such researchers would have been able to locate the material discussed

herein on their own or with the assistance of a research librarian with relative ease using the tools and resources described herein.

V. PUBLICATION

A. Exhibit 1020 (“Kang”)

43. Exhibit 1020 is a copy of the a journal article titled “Charge Pump Circuits with Low Area and High Power Efficiency for Memory Applications” by Kyeong-Pil Kang and Kyeong-Sik Min (hereafter “Kang”). The Kang article was published in Volume 6, Number 4 of the open access *Journal of Semiconductor Technology and Science*. The Kang article appears beginning on page 257 of this issue dated December 2006. Exhibit 1020 is a true and correct copy of the Kang article (pages 257-263) that I obtained from the University of Wisconsin – Madison Libraries. Specifically, the text of the article is complete; no pages are missing, and the text on each page appears to flow seamlessly from one page to the next; further, there are no visible alterations to the document. Exhibit 1020 was found within the custody of a library – a place where an authentic copy of this journal would likely be. Exhibit 1020 is a true and correct copy in a condition that creates no suspicion about its authenticity.

44. The Kang article is also available from the publisher Korea Science.¹⁸

¹⁸ <https://koreascience.kr/article/JAKO200627543143600.page>

The publisher's website indicates a December 31, 2006, publication date.

45. Attached hereto as Attachment 1A is a true and correct copy of the MARC record for the online access *Journal of Semiconductor Technology and Science* from the University of Wisconsin – Madison Libraries online catalog. Library ownership is indicated by the presence of the library's name at the top of the screen. The library continues to update and enhance the MARC record to meet current cataloging rules. The most recent enhancement to Attachment 1A occurred on March 30, 2023, as shown in field 005 ("20230330"). I personally identified and retrieved the MARC record that is Attachment 1A.

46. Based on finding a copy of Exhibit 1020 in the University of Wisconsin – Madison Libraries and MARC record in its online library catalog attached as Attachment 1A, it is my opinion that the Kang article published in the open access *Journal of Semiconductor Technology and Science* was publicly available on December 31, 2006, as indicated on the publisher's website. Attachment 1A also shows that Exhibit 1020 was catalogued with a descriptor term reading "Semiconductors \$v Periodicals" (see Attachment 1B, Library of Congress subject heading sh2010112607) in the 650 field.

47. As noted in the holdings information (362 field), the University of Wisconsin – Madison Libraries has received the open access *Journal of Semiconductor Technology and Science* since the publication began in March 2001

and continues to receive the publication. In view of the MARC record for Exhibit 1020, the Kang article was publicly available on December 31, 2006, because the serial title had been received, cataloged, and indexed in the University of Wisconsin – Madison Libraries and made part of its online catalog database.

48. Attached hereto as Attachment 1C is a true and correct copy of the MARC record for the open access *Journal of Semiconductor Technology and Science* obtained from the OCLC bibliographic database. As previously noted, the library that created the record is recorded in field 040 with a unique library code. For Attachment 1C, that library code is “CAI,” which means that the MARC record for this serial was cataloged at the National Science Library/Bibliothèque Scientifique Nationale (Ottawa, Ontario, Canada). As can be seen in the “Entered” field in the MARC record for this exhibit, a cataloger in the National Science Library/Bibliothèque Scientifique Nationale created OCLC record number 50330461 on August 29, 2001, as shown in the “Entered” field (“20010829”). The library continues to update this MARC record and enhanced the MARC record to meet current cataloging rules. The most recent enhancement to Attachment 1C occurred on August 25, 2021, as shown in the “Replaced” field (“20210805”). I personally identified and retrieved the MARC record that is Attachment 1C. The “BLvl” entry in Attachment 1C is “s,” which indicates that the open access *Journal of Semiconductor Technology and Science* is a serial publication. Field 310 of

Attachment 1C reads “Bimonthly, \$b <2013-.” Accordingly, the MARC record for Exhibit 1020 corresponds to the open access *Journal of Semiconductor Technology and Science* from the time the serial began and includes the date of the Kang article.

49. Attachment 1C includes an entry in field 050 (“TK7871.85 \$b .J68”)—as described above, a subject matter classification number consistent with the Library of Congress classification system (analogous to the Dewey Decimal classification system). Attachment 1C further includes a descriptor term reading “Semiconductors \$v Periodicals” (see Attachment 1B, Library of Congress subject heading sh2010112607) in the 650 field. Thus, as of its cataloging, the publication corresponding to the MARC record attached hereto as Attachment 1C was indexed according to its subject matter by virtue of at least two independently sufficient classifications: the field 050 entry and the field 650 entry. As of August 29, 2001, the MARC record attached hereto as Attachment 1C was accessible through any library with access to the OCLC bibliographic database or the online catalog at a library that subscribed to the serial, which means that the corresponding publication was publicly available on or before that same date through any library with access to the OCLC bibliographic database or through an individual library.

50. Attachment 1C indicates that the open access *Journal of Semiconductor Technology and Science* as cataloged at the National Science Library/Bibliothèque Scientifique Nationale is currently available from 22 libraries. In view of the above,

this issue of the open access *Journal of Semiconductor Technology and Science* was publicly available on December 31, 2006, because by that date it had been cataloged and indexed at the National Science Library/Bibliothèque Scientifique Nationale, made part of the OCLC bibliographic database, and received in the University of Wisconsin – Madison Libraries. For these reasons, it is my opinion that Exhibit 1020 was published and accessible to the public on December 31, 2006.

VI. SUMMARY OF OPINIONS

51. In view of the foregoing, it is my opinion that the publications described above were publicly available no later than the corresponding date listed in the table below:

Exhibit	Publication	Publicly Available
1020	Kang, Kyeong-Pil, and Kyeong-Sik Min. "Charge Pump Circuits with Low Area and High Power Efficiency for Memory Applications." <i>Journal of Semiconductor Technology and Science</i> , vol. 6, no. 4 (December 2006): 257-263.	December 31, 2006

52. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a 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 the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

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

July 10, 2023


Sylvia D. Hall-Ellis, Ph.D.

Declaration of Dr. Sylvia Hall-Ellis

ATTACHMENT 1A

MARC Bibliographic Record

LEADER 01927nas--2200469-i-4500

001 991021974111702122

005 20230330000404.0

008 010829c20019999ko-br-p-o-----0----0eng-c

016 7_ \$a2757948-7\$b2DE-600

022 \$a2233-4866

035 \$a(CKB)1000000000108197

035 \$a(CONSER)--2015223110

035 \$a(DE-599)ZDB2757948-7

035 \$a(EXLCZ)991000000000108197

042 \$apcc

050 14 \$aTK7871.85\$b.J68

210 \$aJSTS:JOURNAL OF SEMICONDUCTOR TECHNOLOGY AND SCIENCE

210 \$aJOURNAL OF SEMICONDUCTOR TECHNOLOGY & SCIENCE

210 \$aJSTS

210 \$aJ SEMICOND TECH SCI

210 \$aJ. SEMICOND. TECHNOL. SCI

210 0_ \$aJ. Semicond. Technol. Sci.

- 222 0 \$aJournal of Semiconductor Technology and Science
- 245 00 \$aJournal of semiconductor technology and science.
- 246 1_ \$aJSTS
- 264 1 \$3March 2001-March 2012:\$aSeoul, Korea :\$bInstitute of Electronics Engineers of Korea,\$c[2001]-
- 264 31 \$3June 2012- :\$aSeoul, Korea :\$bInstitute of Electronics and Information Engineers
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EXHIBIT 1020

Charge Pump Circuits with Low Area and High Power Efficiency for Memory Applications

Kyeong-Pil Kang and Kyeong-Sik Min

Abstract—New charge pump circuits with low area and high power efficiency are proposed and verified in this paper. These pump circuits do not suffer the voltage stress higher than V_{DD} across their pumping capacitors. Thus they can use the thin-oxide MOSFETs as the pumping capacitors. Using the thin-oxide capacitors can reduce the area of charge pumps greatly while keeping their driving capability. Comparing the new pump (NCP-2) with the conventional pump circuit using the thick-oxide capacitors shows that the power efficiency of NCP-2 is the same with the conventional one but the area efficiency of NCP-2 is improved as much as 71.8% over the conventional one, when the V_{PP}/V_{DD} ratio is 3.5 and $V_{DD}=1.8V$.

Index Terms—charge pump, power efficiency, area efficiency, memory, DRAM

I. INTRODUCTION

Charge pump circuits whose output voltage (V_{PP}) is higher than supply voltage (V_{DD}) have widely been used in many SoC applications. In the charge pump circuits, a V_{PP}/V_{DD} ratio is considered important and recently this ratio goes higher while V_{DD} becomes lower as devices are scaled further. This ratio is especially high in case of DRAM circuits, where V_{PP} is used to boost the word-line voltage higher than V_{DD} . Because the long refresh time is crucial to DRAM, the threshold voltage of memory cell is high in spite of low V_{DD} . Thus V_{PP} of the word-line boosting voltage should also be high enough

to overcome the speed degradation by this high threshold voltage [1]. To make V_{PP} higher than $2V_{DD}$, the number of stages of the charge pump has to be larger than 2 in recent DRAMs.

In addition to the word-line boosting, there are many other circuits such as the bit-line switch and the sense-amplifier driver where V_{PP} is used to compensate the slow speed due to the V_{DD} lowering. As more circuits in DRAM are driven by V_{PP} instead of V_{DD} , the charge pump should deliver larger current to its load than before. To increase the output current of charge pump, the pumping capacitance should be large. Because the area of charge pump is determined mainly by the area of its pumping capacitor, the large-area capacitor increases the total area of charge pump drastically. Hence it is very favorable to design an area-efficient charge pump to decrease the total chip area.

II. NEW CHARGE PUMP CIRCUITS

Many charge pumps have been proposed since 1970's. Of these, most popular ones are based on Dickson pump [2] or cross-coupled voltage doubler [1], [3]. Fig. 1(a) shows a conceptual diagram of these conventional circuits, where C_1 , C_2 , and C_3 act as the pumping capacitors and the switches are assumed ideal. Here, though C_1 has the voltage stress as high as V_{DD} , C_2 and C_3 suffer from the stress higher than V_{DD} . At the phase-I, C_1 has a voltage of V_{DD} between its two terminals. At the following phase-II, the node 'A' is driven up to $2V_{DD}$ by the charge pumping so that a voltage as high as $2V_{DD}$ is stored across C_2 . At the following phase-I, C_2 raises the node 'B' to $3V_{DD}$. At this time, a voltage as high as $3V_{DD}$ is stored across C_3 . At the next phase-II, C_3 raises the node 'C' up to $4V_{DD}$. By doing so, the

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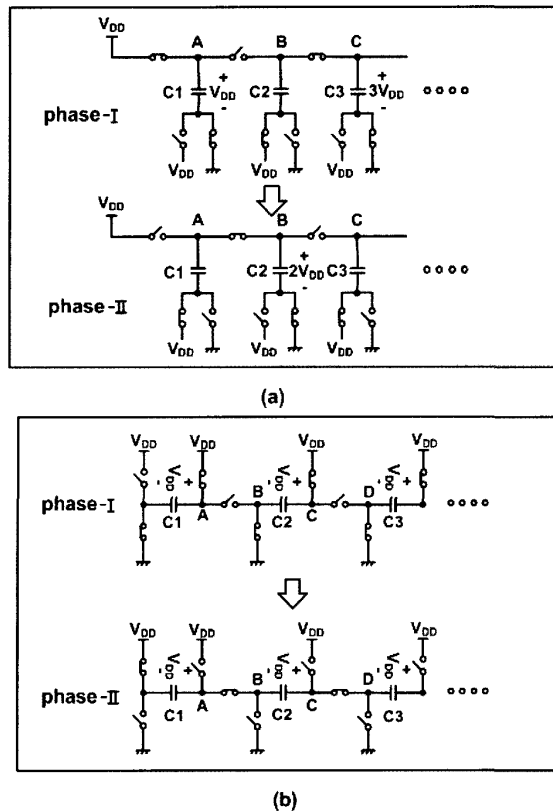


Fig. 1. (a) A conceptual diagram of the conventional charge pump (b) A conceptual diagram of new charge pump.

pump circuit can generate V_{PP} higher than V_{DD} . As mentioned earlier, one should note that C2 and C3 suffer the voltage stress as high as $2V_{DD}$ and $3V_{DD}$, respectively. The pumping capacitor with thin oxide can not tolerate the voltage stress higher than V_{DD} so that C2 and C3 in Fig. 1(a) have to be made with thick-oxide devices.

Fig. 1(b) shows a diagram of new architecture of low-area pump circuits where all the pumping capacitors suffer the stress only as high as V_{DD} . Instead of the pumping capacitors, however, the switches in Fig. 1(b) tolerate the stress higher than V_{DD} . Hence the pumping capacitors are C1, C2, and C3 as shown in Fig. 1(b) can be made with the thin-oxide transistors. By doing so, the layout area of C1, C2, and C3 becomes smaller compared with that of thick-oxide transistors. Because the area of the pumping capacitors takes the largest part of the total pump area, it is very helpful to make the area of the pumping capacitors small for reducing the total pump area. For example, when a 0.18- μm process is

used, the area of pumping capacitors takes more than 90% of the total pump area.

Now let's discuss the switches in Fig. 1(b). Here the switches should be made with the thick-oxide transistors because there is the voltage stress higher than V_{DD} unlike the pumping capacitors of C1, C2, and C3. Generally the layout area of switches is much smaller than that of pumping capacitors. Thus using the thick-oxide transistors as the switches does hardly increase the total pump area. And, using them does not give a serious impact on the performance of pump. The performance of charge pump depends on the size of pumping capacitor much more than the size of transistor as the switch.

The Schematics of Modified Dickson-based Charge Pump (MDCP) [4] and Voltage-Doubler-based Charge Pump (VDCP) [1], [3] are shown in Fig. 2(a) and (b), respectively. Both circuits have 3 stages where they can generate V_{PP} as high as $\sim 4V_{DD}$. In Fig. 2(a), MC1, MC2, MC3, and MC4 act as the pumping capacitors and MT1, MT2, MT3, MT4, and MT5 are the charge-transfer switches. MD1, MD2, and MD3 are the diode-connected transfer switches. MP1, MN1, MP2, MN2, MP3, and MN3 which drive the gates of charge-transfer switches are the control switches. The charge-transfer switches can be fully turned on through MP1 and turned off through MN1 according to the clock signal. MT5 does not deliver the output current to the load capacitor (C_L). Instead, MT5 is used to deliver an over-drive voltage to the gate of MT3. The pumping capacitors of MC2, MC3, and MC4 in Fig. 2(a) suffer the voltage stress higher than V_{DD} should be made with the thick-oxide devices if the MOSFET capacitors are used. The switches, however, can be implemented by the thin-oxide transistors.

In Fig. 2(b), MC1, MC2, MC3, MC4, MC5, and MC6 all are representing the pumping capacitors. MN1 and MP1 are responsible for precharging the pumping node and transferring the charges into the following stage, respectively. MN1 and MP1 connected to MC1 are crossly coupled with MN2 and MP2 connected to MC2. This cross-coupled architecture repeats at the following two stages in Fig. 2(b). Like Fig. 2(a), MC3, MC4, MC5, and MC6 in Fig. 2(b) suffer the voltage stress higher than V_{DD} . To operate reliably under the condition of high stress, MC3, MC4, MC5, and MC6 are made with

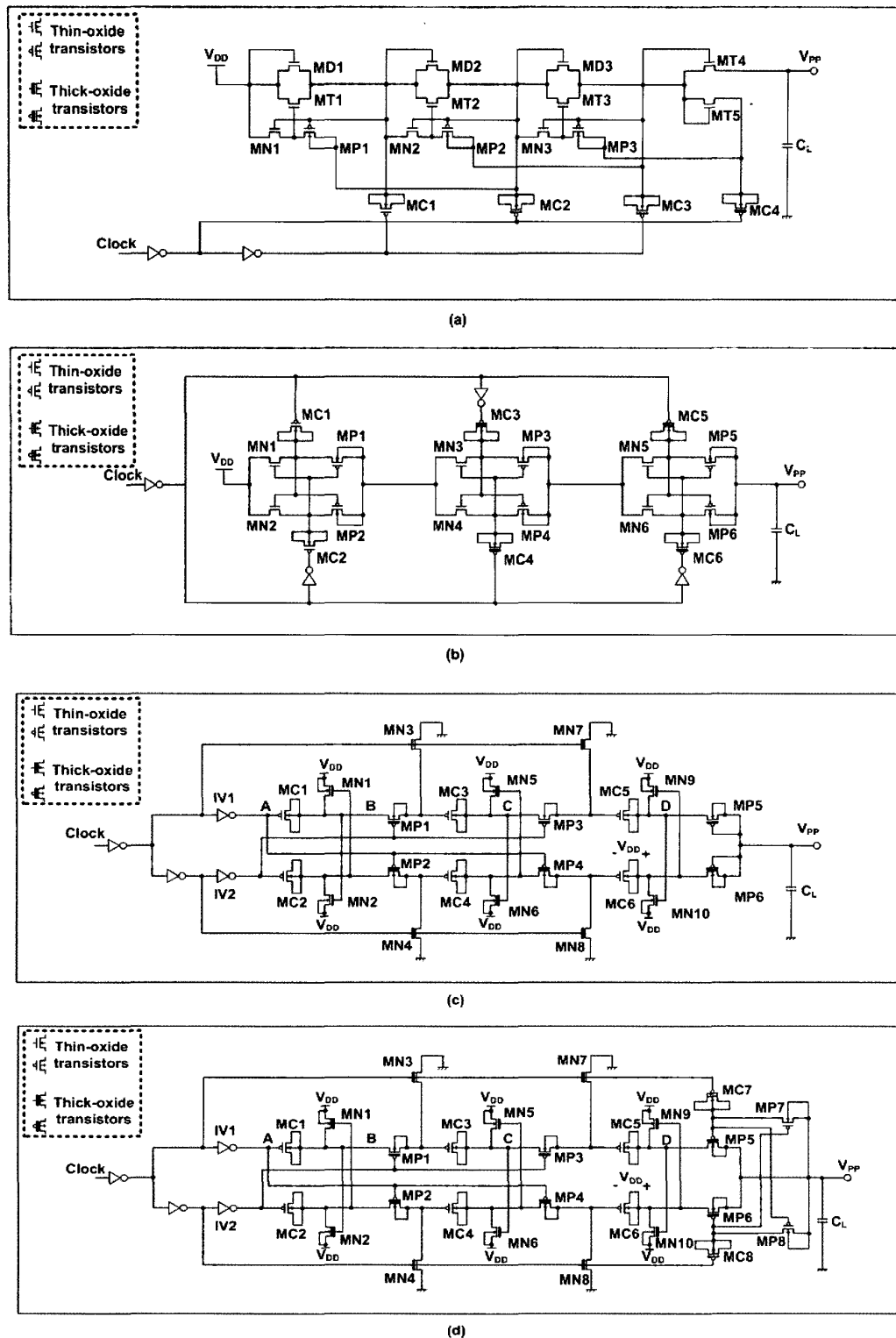


Fig. 2. Schematics of (a) Modified Dickson-based Charge Pump circuit (MDCP), (b) Voltage-Doubler-based Charge Pump circuit (VDCP), (c) New Charge Pump-1 circuit (NCP-1), and (d) New Charge Pump-2 circuit (NCP-2). They are 3-stage pumps.

the thick-oxide transistors but the switches can be made with the thin-oxide ones in Fig. 2(b).

Fig. 2(c) shows a New Charge Pump (NCP-1), where all the pumping capacitors of MC1, MC2, MC3, MC4, MC5, and MC6 have the same stress as high as V_{DD} [5]. When the clock signal is low, MN1, MN3, MN5, MN7, and MN9 are turned on so that MC1, MC3, and MC5 have the same voltage as high as V_{DD} across themselves. At this time, MP1 and MP3 are turned off. At this precharge phase, the stored voltages across MC1, MC3, and MC5 are as high as V_{DD} . And, when the clock signal becomes high, IV1 drives the node 'A' from V_{SS} to V_{DD} . The node 'A' raises the node 'B' from V_{DD} to $2V_{DD}$ and the node 'B' raises the following node 'C' from V_{DD} to $3V_{DD}$. Simultaneously, the node 'C' raises the node 'D' from V_{DD} to $4V_{DD}$. Of course, at this time, MN1, MN3, MN5, MN7, and MN9 are turned off by their cross-coupled nodes and MP1 and MP3 are turned on to transfer the charges with high voltages to the following stages. In the same manner, MC2, MC4, and MC6 work together to generate V_{PP} as high as $4V_{DD}$. As shown in Fig. 2(c), MC1, MC3, and MC5 with their control switches are crossly coupled with MC2, MC4, and MC6 with the switches. MP5 and MP6 are the diode-connected transistors, which lose their output voltage as much as their threshold voltage. Here MC1, MC2, MC3, MC4, MC5, and MC6 can be made with the thin-oxide transistors because their voltage stress is the same as V_{DD} , thus making it possible to reduce the area of pumping capacitors very much compared with Fig. 2(a) and (b).

As mentioned earlier, there is a voltage drop as much as the threshold voltage through the diode-connected MP5 and MP6 of NCP-1 shown in Fig. 2(c). To avoid this voltage loss, NCP-2 in Fig. 2(d) is also proposed in this paper. As you can see in Fig. 2(d), the diode-connected PMOSFETs in Fig. 2(c) are replaced with the auxiliary pump that is composed of MP5, MP6, MP7, MP8, MC7, and MC8. Here MP5 and MP6 act as the final transfer switches that deliver the pumping current to the load without any voltage loss unlike Fig. 2(c). MP5 and MP6 in Fig. 2(d) are controlled by the MC7, MC8, MP7, and MP8. Though MC7 and MC8 should be made with the thick-oxide devices because they suffer the stress higher than V_{DD} , their sizes can be very small

because they drive only the gates of MP5 and MP6. The area of this auxiliary pump increases the total pump area very little. And, because MC7 and MC8 do not act as the pumping capacitors, their small size does not degrade the pumping capability. Here, the capability is determined mainly by the size of pumping capacitor.

III. SIMULATION AND COMPARISON

Fig. 3(a) and (b) compare the pumping speeds of MDCP, VDCP, NCP-1, and NCP-2 which are shown in Fig. 2(a), (b), (c), and (d), respectively. Fig. 3(a) is for $V_{DD}=1.8V$ and Fig. 3(b) for $V_{DD}=1.5V$. The comparison is done by SPICE simulation, where the 0.18-um SPICE model obtained from the industry is used and the temperature is kept at 25 °C. The SPICE model includes both the thin-oxide and thick-oxide transistors. The thin-oxide transistor operates with $V_{DD}=1.8V$, but the thick-oxide one can cover a wide range of voltages from

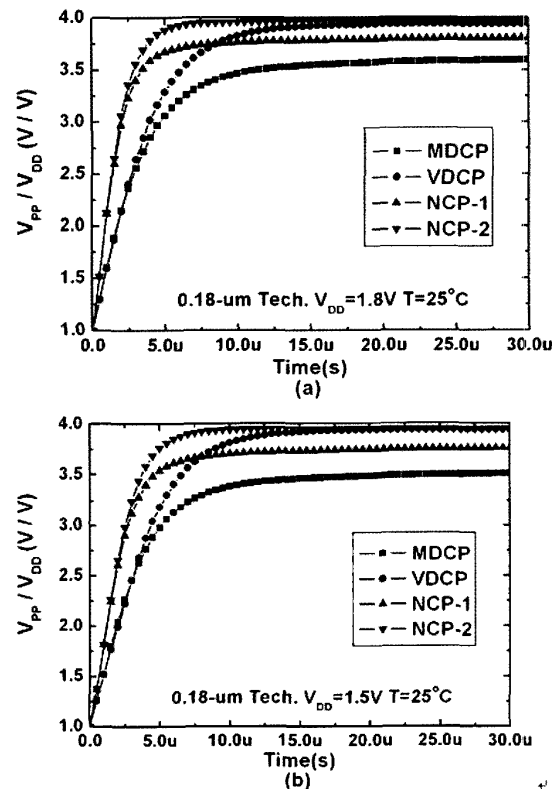


Fig. 3. (a) Comparison of the pumping speeds of MDCP, VDCP, NCP-1, and NCP-2 at $V_{DD}=1.8V$ (b) Comparison of the pumping speeds of MDCP, VDCP, NCP-1, and NCP-2 at $V_{DD}=1.5V$.

V_{SS} to $4V_{DD}$. Of MDCP, NCP-2, the pumping speeds of NCP-1 and NCP-2 seem faster than MDCP and VDCP especially when the pumping operation starts. This is because NCP-1 and NCP-2 deliver their output currents larger than those of MDCP and VDCP at the pumping start-up. Here NCP-1 and NCP-2 use the thin-oxide capacitors as their pumping capacitors, while MDCP and VDCP use the thick-oxide ones. As indicated in Fig. 3(a) and (b), V_{pp} of NCP-1 seems to saturate below $4V_{DD}$. This is because NCP-1 loses its output voltage as much as the threshold voltage when NCP-1 delivers its output voltage to the load. This voltage loss also occurs in MDCP, because the diode-connected MT4 is used as the final transfer switch. To overcome this voltage loss, as mentioned earlier, NCP-2 with the auxiliary pump to control the final transfer gates is proposed. In Fig. 3(a) and (b), NCP-2 shows a non-saturated characteristic and the V_{pp}/V_{DD} ratio of NCP-2 reaches to 4 when its number of stages is 3.

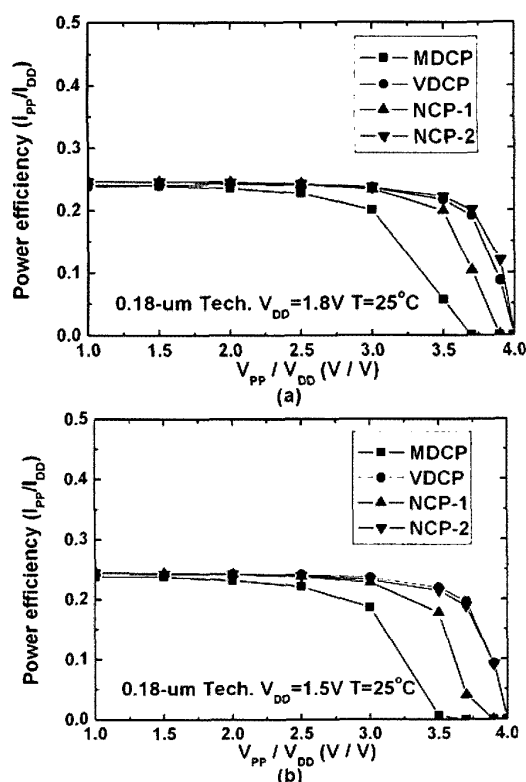


Fig. 4. (a) Comparison of the power efficiency of MDCP, VDCP, NCP-1, and NCP-2 at $V_{DD}=1.8\text{V}$ (b) Comparison of the power efficiency of MDCP, VDCP, NCP-1, and NCP-2 at $V_{DD}=1.5\text{V}$.

Fig. 4(a) and (b) compare the power efficiency of 4 pump circuits. Here, the power efficiency is defined by an I_{pp}/I_{DD} ratio, where I_{pp} and I_{DD} are the amount of current delivered to the load and the amount of current supplied from V_{DD} , respectively. Of 4 charge pumps, MDCP shows the sharpest degraded efficiency as the V_{pp}/V_{DD} ratio becomes closer to 4. The efficiency of NCP-1 is little degraded compared with that of VDCP when the V_{pp}/V_{DD} ratio is in between 1 and 3.5. When this ratio is larger than 3, however, the efficiency of NCP-1 becomes worse than that of VDCP. This is due to the loss of output voltage of NCP-1, as indicated in Fig. 3(a) and (b). NCP-2 that does not lose the output voltage has the same power efficiency with that of VDCP, even when the V_{pp}/V_{DD} ratio is over 3. One more comment here is that the power efficiency of VDCP and NCP-2 becomes worse rapidly when their V_{pp}/V_{DD} ratio becomes larger than 3.5. As the V_{pp}/V_{DD} ratio goes closer to 4, the output currents of VDCP and NCP-2 decrease rapidly, thus their efficiency being degraded,

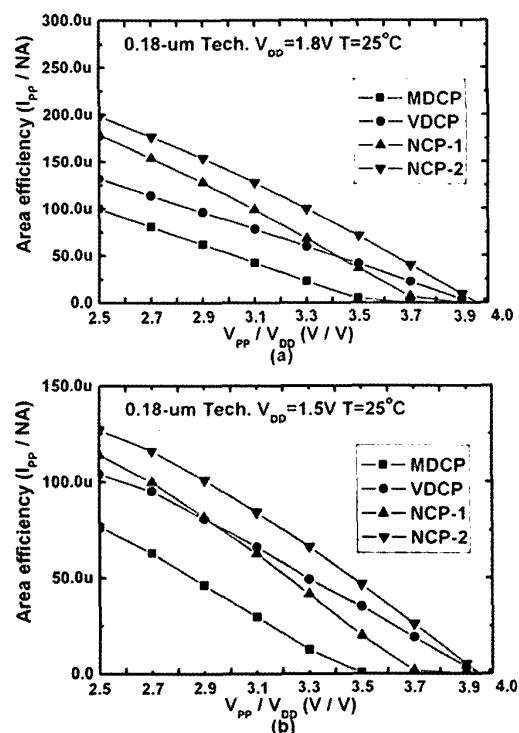


Fig. 5. (a) Comparison of the area efficiency of MDCP, VDCP, NCP-1, and NCP-2 at $V_{DD}=1.8\text{V}$ (b) Comparison of the area efficiency of MDCP, VDCP, NCP-1, and NCP-2 at $V_{DD}=1.5\text{V}$.

too. For the 3-stage pump circuits, the ratio of V_{pp}/V_{DD} is practically chosen between 3 and 3.5, since their efficiency goes very worse if the ratio becomes larger than 3.5.

Fig. 5(a) and (b) compare the area efficiency of 4 charge pumps. Here, the area efficiency is defined by an I_{pp}/NA ratio, where NA is a normalized value of charge pump area. The pump area mainly depends on the area of its pumping capacitors. Of 4 pumps, NCP-1 and NCP-2 use the thin-oxide transistors as their pumping capacitors, while MDCP and VDCP use the thick-oxide capacitors. Thus NCP-1 and NCP-2 can deliver the output currents larger than those of MDCP and VDCP, when the areas of the pumping capacitors of NCP-1 and NCP-2 are the same with those of MDCP and VDCP. Comparing NCP-1 with VDCP shows, however, the area efficiency of NCP-1 becomes worse than VDCP when the ratio of V_{pp}/V_{DD} is over 3.5 and $V_{DD}=1.8V$. This is due to the loss of output voltage of NCP-1. When $V_{DD}=1.5V$, the crossover between the efficiency of NCP-1 and VDCP occurs earlier than $V_{DD}=1.8V$. In Fig. 5(b), the V_{pp}/V_{DD} ratio corresponding to the crossover point is around 2.9. For NCP-2, the area efficiency is improved by eliminating the sacrificial voltage loss. The area efficiency of NCP-2 seems better than those of VDCP and NCP-1 in the entire range of V_{pp}/V_{DD} ratio, as shown in Fig. 5(a) and (b).

Fig. 6 compares the layout areas of pumping capacitors in Fig. 2(a), (b), and (c). Fig. 6(a) is the layout of thick-oxide capacitor for MDCP and VDCP. Fig. 6(b) is the layout of thin-oxide capacitor for NCP. Though

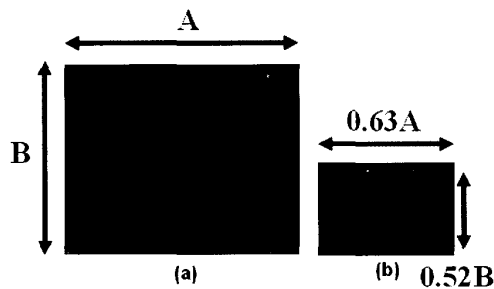


Fig. 6. (a) A layout of thick-oxide capacitor for MDCP and VDCP with their capacitance as large as 5.5pF (b) A layout of thin-oxide capacitor for NCP-1 and NCP-2 with their capacitance as large as 5.5pF.

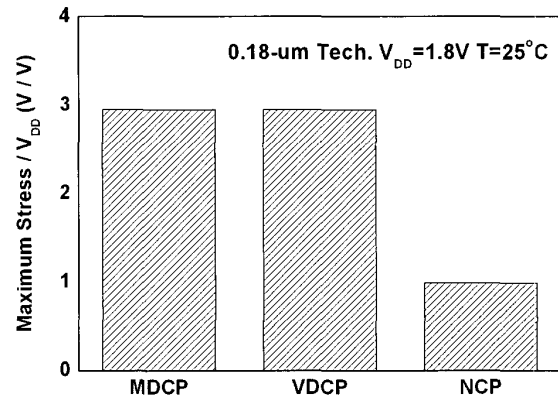


Fig. 7. (a) Comparison of the maximum voltage stress of MDCP, VDCP, NCP-1, and NCP-2 at $V_{DD}=1.8V$.

their capacitance values are the same, the area of Fig. 6(b) is only 33% of the area of Fig. 6(a). Here the capacitors are drawn by 0.18- μm design rules and their capacitance values are predetermined as 5.5pF.

Fig. 7 shows the maximum voltage stress across the pumping capacitor of NCP-1 and NCP-2 does not exceed V_{DD} . However, the stress of the MDCP and VDCP is estimated as high as almost $3V_{DD}$ when their stage number is assumed 3.

IV. CONCLUSIONS

New charge pump circuits with low area and high power efficiency are proposed and verified in this paper. These pump circuits do not suffer the voltage stress higher than V_{DD} across their pumping capacitors. Thus they can use the thin-oxide MOSFETs as their pumping capacitors. Using the thin-oxide capacitors can reduce the area of charge pump circuits greatly. Comparing NCP-2 using the thin-oxide capacitors with the conventional pumps using the thick-oxide capacitors shows that the power efficiency of NCP-2 is the same but the area efficiency is improved as much as 71.8% than VDCP, when the V_{pp}/V_{DD} ratio is 3.5. And, the area efficiency of NCP-2 shows 50% better than VDCP when the V_{pp}/V_{DD} ratio is 2.5.

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low-power circuit design.

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