

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

WHOOOP, INC.
Petitioner

v.

OMNI MEDSCI, INC.,
Patent Owner.

Case No. IPR2025-01584

U.S. Patent No. 10,874,304

**DECLARATION OF DR. PATRICK MERCIER IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. 10,874,304**

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Document	Description
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TABLE OF EXHIBITS

Exhibit	Description
1001	U.S. Patent No. 10,874,304
1002	File History, U.S. Patent No. 10,874,304
1004	U.S. Patent No. 9,651,533
1005	U.S. Patent No. 10,517,484
1006	Docket Sheet, <i>Omni MedSci, Inc. v. WHOOP, Inc.</i> , No. 1:25-cv-00140 (D. Del.)
1007	Docket Sheet, <i>Omni MedSci, Inc. v. Samsung Elecs., et al.</i> , No. 2:24-cv-01070 (E.D. Tex.)
1008	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2019-00916, Paper No. 39 (P.T.A.B. Oct. 14, 2020) (Final Written Decision, '533 IPR)
1009	<i>Omni MedSci, Inc. v. Apple Inc.</i> , No. 21-1229, 2022 WL 2062168 (Fed. Cir. Jun. 8, 2022) (summary affirmance, '533 IPR)
1010	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2021-00453, Patent Owner's Notice of Appeal (P.T.A.B. Apr. 11, 2025)
1011	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2021-00453, Paper No. 22 (P.T.A.B. Aug. 3, 2022) (First Final Written Decision, '484 IPR)
1012	<i>Apple Inc. v. Omni MedSci, Inc.</i> , No. 23-1034, 2024 WL 3084509 (Fed. Cir. Jun. 21, 2024) (First Federal Circuit Decision, '484 IPR)
1013	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2021-00453, Paper No. 26 (P.T.A.B. Feb. 14, 2025) (Second Final Written Decision, '484 IPR)
1014	Docket Sheet, <i>Omni MedSci, Inc. v. Apple Inc.</i> , No. 25-1646 (Fed. Cir.) (Docket Sheet, Second Federal Circuit Appeal, '484 IPR)

Exhibit	Description
1015	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2019-00916, Paper No. 1 (P.T.A.B. Apr. 10, 2019) (Petition, '533 IPR)
1016	RESERVED
1017	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2019-00916, Paper No. 16, (P.T.A.B. Oct. 18, 2019) (Institution Decision, '533 IPR)
1018	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2019-00916, Paper No. 23 (P.T.A.B. Jan. 31, 2020) (Patent Owner Response)
1019	RESERVED
1020	RESERVED
1021	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2021-00453, Paper No. 1, (P.T.A.B. Jan. 22, 2021) (Petition, '484 IPR)
1022	RESERVED
1023	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2021-00453, Paper No. 7 (P.T.A.B. Aug. 6, 2021) (Institution Decision, '484 IPR)
1024	<i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2021-00453, Paper No. 10 (P.T.A.B. Nov. 12, 2021) (Patent Owner Response, '484 IPR)
1025	RESERVED
1026	RESERVED
1027	U.S. Patent No. 9,241,676 (Lisogurski)
1028	U.S. Patent App. Pub. No. 2005/0049468 ("Carlson")
1029	U.S. Patent No. 8,175,667 ("Debreczeny")
1030	U.S. Patent No. 6,304,767 ("Soller")
1031	U.S. Patent No. 8,108,036 ("Tran")
1032	U.S. Patent Appl. Pub. No. 2012/0197093 ("Valencell-093")
1033	"The Biomedical Engineering Handbook," by Joseph D. Bronzino (1995)
1034	Patel, et al., A review of wearable sensors and systems with application rehabilitation, <i>Journal of Neuroengineering & Rehabilitation</i> (2012)
1035	A. Omre, Bluetooth Low Energy: Wireless Connectivity for Medical Monitoring, <i>Journal of Diabetes Science & Technology</i> (Mar. 2010)
1036	P. Baum, et al., Strategic Intelligence Monitor on Personal Health Systems, Phase 2: Market Developments - Remote Patient Monitoring and Treatment, Telecare, Fitness/Wellness and mHealth, JRC <i>Scientific and Policy Reports of European Commission</i> (2013)

Exhibit	Description
1037	M. Kranz, et al., The mobile fitness coach: Towards individualized skill assessment using personalized mobile devices, <i>Pervasive and Mobile Computing</i> (June 2012)
1038	M. Swan, Senior Mania! The Internet of Things, Wearable Computing, Objective Metrics, and the Quantified Self 2.0, <i>Journal of Sensor and Actuator Networks</i> (2012)
1039	RESERVED
1040	“The Usage of Tablets in the HealthCare Industry,” by Rauf Adil (Aug. 2, 2012), available through the Internet Archive at https://web.archive.org/web/20121014002306/https://www.healthcareitnews.com/blog/usage-tablets-healthcare-industry (last accessed Sept. 4, 2025)
1041	Remote Deposition of Duncan Leo MacFarlane, Ph.D., P.E., <i>Apple Inc. v. Omni MedSci, Inc.</i> , IPR2019-00916 (PTAB April 16, 2020)
1042	Curriculum Vitae of Patrick Mercier, PhD
1043	Docket Sheet, <i>Omni MedSci, Inc. v. Apple Inc.</i> , No. 4:19-cv-05924 (N.D. Cal.)
1044	RESERVED
1045	Webster, J. G. (1997) <i>Design of Pulse Oximeters</i> , IOP Publishing.
1046	RESERVED
1047	RESERVED
1048	RESERVED
1049	RESERVED
1050	<i>Samsung Elecs. Co. et al. v. Omni MedSci, Inc.</i> , IPR2025-01250, Paper No. 1 (P.T.A.B. Aug. 5, 2025) (533 IPR Petition)
1051	<i>Samsung Elecs. Co. et al. v. Omni MedSci, Inc.</i> , IPR2025-01251, Paper No. 1 (P.T.A.B. Aug. 5, 2025) (304 IPR Petition)
1052	<i>Samsung Elecs. Co. et al. v. Omni MedSci, Inc.</i> , IPR2025-01252, Paper No. 1 (P.T.A.B. Aug. 5, 2025) (455 IPR Petition)
1053	<i>Samsung Elecs. Co. et al. v. Omni MedSci, Inc.</i> , IPR2025-01253, Paper No. 1 (P.T.A.B. Aug. 5, 2025) (790 IPR Petition)
1054	<i>Samsung Elecs. Co. et al. v. Omni MedSci, Inc.</i> , PGR2025-00064, Paper No. 1 (P.T.A.B. Aug. 5, 2025) (790 PGR Petition)
1055	<i>Samsung Elecs. Co. et al. v. Omni MedSci, Inc.</i> , IPR2025-01254, Paper No. 1 (P.T.A.B. Aug. 5, 2025) (475 IPR Petition)

Exhibit	Description
1056	<i>Samsung Elecs. Co. et al. v. Omni MedSci, Inc.</i> , IPR2025-00063, Paper No. 1 (P.T.A.B. Aug. 5, 2025) (475 PGR Petition)
1057	RESERVED
1058	U.S. Patent No. 11,160,455
1059	U.S. Patent No. 12,193,790
1060	U.S. Patent No. 12,268,475
1061	<i>Omni MedSci, Inc. v. Apple Inc.</i> , No. 25-1646, Dkt. 17 (Fed. Cir. Sept. 11, 2025) (Omni's Corrected Opening Brief)

I, Dr. Patrick Mercier, hereby declare as follows:

I. INTRODUCTION

1. I have been retained on behalf WHOOP, Inc (“WHOOP” or “Petitioner”) as an independent expert in this Petition for *inter partes* review by the U.S. Patent and Trademark Office to offer my technical opinion as to the following topics: (1) the disclosure of the U.S. Patent No. 10,874,304 (“the ’304 Patent”) (EX1001); and (b) the invalidity of claims 1–27.

2. In summary, it is my opinion that claims 1–27 of the ’304 patent (“the Challenged Claims”) are invalid in view of the prior art I discuss in this Declaration. In particular, it is my opinion that the prior art discussed herein discloses, teaches, or suggests the invention claimed in the Challenged Claims, rendering the Challenged Claims invalid as obvious over the prior art. The particular references and/or combinations that invalidate the Challenged Claims, as well as the reasons for my opinions and bases thereof, are set forth in detail below.

3. I am being compensated for my work on this case at my standard consulting rate of \$650. I am also being reimbursed for my expenses that I may incur. My compensation is in no way contingent upon the results of my study, the substance of my testimony, or the outcome of this case.

4. Based upon the facts and information available to me to date, I detail my opinions relevant to this petition for *inter partes* review. I am prepared to provide

expert testimony on the opinions formed herein if asked about those issues by the Board or others.

5. Additionally, I may discuss my own work, teachings, and knowledge of the state of the art in the relevant time period. I may rely on handbooks, textbooks, technical literature, and the like to demonstrate the state of the art in the relevant period and evolution of the technology.

6. Throughout this declaration, I refer to specific line numbers or page numbers of the relevant prior art or other technical documents. The citations are intended to be exemplary as opposed to being exhaustive and are not intended to convey that the citations are the only source of evidence to support the propositions for which they are cited.

II. QUALIFICATIONS AND EXPERIENCE

A. Overview of Qualifications and Experience

7. My educational background, professional experience, and a list of my publications are set forth in my *curriculum vitae*, attached to this Declaration as **Appendix B (EX1042)**.

8. As discussed in more detail below, I have particular expertise in the subject matter discussed in the '304 patent as I am the co-founder and co-director of the Center for Wearable Sensors at the University of California San Diego ("UCSD").

9. I received my B.Sc. degree in Electrical and Computer Engineering in 2006 from the University of Alberta. I received my S.M. in 2008, and my Ph.D. in Electrical Engineering in 2012, both from the Massachusetts Institute of Technology.

10. In 2012, after receiving my Ph.D., I joined UCSD as an Assistant Professor, and I became a Full Professor in 2023 and Vice Chair of the Electrical and Computer Engineering department in 2024. My professional experience includes three main components: research, teaching, and service to the scientific community.

B. Research and Development

11. My research relates to the design of energy-efficient microsystems, including the design of RF circuits, power converters, and sensor interfaces for miniaturized systems. My research has involved the development of wearable sensors, low-power wireless sensing systems, and power management integrated circuits. My research has been and/or is being incorporated for use in retinal prosthetics, diagnostic saliva sensing, and wearable microneedle platforms.

12. I currently lead an approximately 20-person group undertaking high-impact research spanning multiple domains, from near-zero-power integrated circuits, power management, energy harvesting, neural interfaces, wearable physiochemical sensors, RFICs and RF systems, and beyond.

13. As noted above, I am the co-founder and co-director of the Center for Wearable Sensors at UCSD, which includes over 20 faculty across four engineering departments within UCSD, the School of Medicine, and the Arts and Humanities Department (Department of Visual Arts). The purpose of the Center is to bring together top UCSD faculty, students, and researchers with complementary expertise in areas such as sensors, low-power circuits, materials, electrochemistry, bioengineering, wireless network technologies, preventive medicine, and life sciences to create an environment that fosters the acceleration of research and system development.

14. I am also the Site Director for the Power Management Integration Center (“PMIC”), a National Science Foundation Industry University Collaborative Research Center that is a partnership between UCSD and Dartmouth College. The mission of the PMIC is to target innovations that support higher efficiency, smaller size, and reduced cost by considering system reliability, robustness, and performance in a diverse range of industry sectors and applications spanning consumer, industrial, and automotive electronics. My work with both the Center for Wearable Sensors and the PMIC includes hardware design for wearable, wireless, and power management systems.

15. My research has resulted in over 200 peer-reviewed publications, including 30 ISSCC papers, 33 JSSC papers, and several papers in high-impact

journals such as Science, Nature Biotechnology, Nature Biomedical Engineering, Nature Electronics, Nature Communications, Advanced Science, and Energy and Environmental Science. Some of the articles I have published on the topic of wearables and power management include, for example:

- E. De La Paz, N.H. Maganti, A. Trifonov, I. Jeerapan, K. Mahato, L. Yin, T. Sonsa-ard, N. Ma, W. Jung, R. Burns, A. Zarrinpar, J. Wang, P.P. Mercier, “A Self-Powered Ingestible Wireless Biosensing System for Real-Time in Situ Monitoring of Gastrointestinal Tract Metabolites,” *Nature Communications*, Vol. 13, 7405, Dec. 2022.
- F. Tehrani, H. Teymourian, B. Wuerstle, J. Kavner, R. Patel, A. Furnidge, R. Aghavali, H. Hosseini-Toudeshki, C. Brown, F. Zhang, K. Mahato, Z. Li, A. Barfidokht, L. Yin, P. Warren, N. Huang, Z. Patel, P.P. Mercier & J. Wang, “An Integrated Wearable Microneedle Array for the Continuous Monitoring of Multiple Biomarkers in Interstitial Fluid,” *Nature Biomedical Engineering*, May 2022.
- J. Tian, P. Mercier, C. Paolini, “Ultra Low-Power, Wearable, Accelerated Shallow-Learning Fall Detection for Elderly At-Risk Persons,” *Smart Health*, Vol. 33, Sept. 2024.
- A. Akinin, J.M. Ford, J. Wu, C. Kim, H.D. Thacker, P.P. Mercier, G. Cauwenberghs, “An Optically Addressed Nanowire-Based Retinal Prosthesis with Wireless Stimulation Waveform Control and Charge Telemetry,” *IEEE Journal of Solid-State Circuits*, Vol. 56, No. 11, pp. 3263-73, Nov. 2021.
- P.P. Mercier, J. Wang, “Why Sweat Will Power Your Next Wearable,” *IEEE Spectrum*, Jun. 2020 (Cover article).
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16. I have also published chapters and edited books in the area of wearable and implantable medical monitors and power management. For example, I was co-editor of books entitled “Power Management Integrated Circuits,” “Ultra-Low-Power Short-Range Radios,” and “High-Density Integrated Electrocortical Neural Interfaces,” and also authored a chapter titled “Low-Power Integrated Circuits for Wearable Electrophysiology” in the book titled “Wearable Sensors – Fundamentals, Implementation and Applications 2nd Edition.”

17. Beyond my scientific articles and publications, I am also a named inventor on 24 U.S. patents, including several directed to power circuits and systems.

C. Teaching Experience

18. At UCSD, I have taught the following courses:

- Digital Integrated Circuits, ECE 165 (2013-2015, 2017-2025): a course that discusses fundamentals of transistor-based implementations of Boolean logic functions, then expands towards design of various combinational and sequential logic circuits. The final project involves the design of a high-speed, yet low-power digital arithmetic circuit for use in microprocessors.
- Biomedical Integrated Circuits and Systems, ECE 203 (2013-2024): a course of my own design that covers the basics of low-power integrated circuit design, including topics on pulse oximetry, instrumentation amplifiers, wearable medical devices, and more.
- VLSI Digital System Algorithms and Architectures (2014-2016): this is the graduate version of ECE 165 that includes advanced topics on microprocessor design.

19. These and the other courses I teach include a number of subjects that bear on the technology in this case. For example, in ECE 203 we discuss how pulse oximeters work, and discuss methods to develop low-power and low-noise optical readout technologies. Beyond this specific example, much of ECE 203 is focused on how to minimize power in both analog and digital circuits, while meeting performance (e.g., noise for analog, clock frequency/throughput for digital) targets. We discuss concepts like duty-cycling, power gating, power-saving modes, dynamic voltage and frequency scaling (and thus dynamic power scaling), and so on.

20. I have received a number of awards recognizing my teaching. For example, in 2016 I received the UCSD Academic Senate Distinguished Teaching Award, which is awarded yearly to five distinguished teachers across all departments

at UCSD. In 2023, I received the Teacher of the Year Award from the Jacobs School of Engineering at UCSD, which is selected by ballot of UCSD students.

21. Beyond my teaching at UCSD, I have taught tutorials as part of engineering organization conferences. For example, I taught a tutorial entitled “Interface Circuits for Wearable and Implantable Sensing Systems” at the IEEE International Solid-State Circuits Society. I also presented a tutorial entitled “Power Management for the Internet-of-Things” at the IEEE Custom Integrated Circuits Conference (CICC), and gave a keynote presentation entitled “Energy-Efficient Power Management Circuits for IoT and Wearable Devices” at the IEEE Sensor Interfaces Meeting. As part of these presentations, I dive into circuit design techniques that can deliver low-power operation.

D. Service to the Scientific Community

22. My most time-consuming role related to UCSD service is the directorship of the Center for Wearable Sensors and the Power Management Integration Center, covered earlier.

23. Beyond UCSD, I have been an Associate Editor with IEEE Solid-State Circuits Letters (2017-2023), IEEE Transactions on Biomedical Circuits & Systems (2013-2023), and IEEE Transactions on VLSI (2015-2017). I have been a Guest Editor with IEEE Open Journal of the Solid-State Circuits Society (OJ-SSCS) Special Issue on Low-Power RF Circuits and Systems (2023), and IEEE Journal of

Solid-State Circuits Special Issue on the 2018 International Solid-State Circuits Conference (ISSCC) (2018). I have chaired numerous committees for international conferences including, for example, as the Executive Committee member – Demo Chair – IEEE International Solid-State Circuits Conference (ISSCC) (2022-present), Technical Program Co-Chair – IEEE Sensor Interfaces Meeting (2022-2024), Subcommittee Chair – Power Management – IEEE Custom Integrated Circuits Conference (CICC) (2021-2023), Technical Program Committee member – IEEE VLSI Circuits Symposium (2018-2022), International Technical Program Committee member – IEEE International Solid-State Circuits Conference (ISSCC) Technology Directions subcommittee (2017-2022), and Technical Program Committee member – IEEE Custom Integrated Circuits Conference (CICC) (2017-2023). I am also a peer reviewer for numerous journals including, for example, *IEEE Journal of Solid-State Circuits* (JSSC), *IEEE Transactions on Circuits and Systems I* (T-CAS I), *IEEE Transactions on Circuits and Systems II* (T-CAS II), *IEEE Transactions on Microwave Theory and Techniques* (T-MTT), *IEEE Sensors Journal*, *IEEE Transaction on Power Electronics*, *Journal of Low Power Electronics and Applications* (JLPEA), *IET Circuits, Devices & Systems*, *IEEE International Conference on Ultra-Wideband* (ICUWB), *IEEE Transactions on Biomedical Circuits & Systems* (TBioCAS), *IEEE Transactions on Biomedical Engineering* (TBME), *IEEE International Conference on Circuits and Systems* (ISCAS), *IEEE*

Biomedical Circuits and Systems Conference (BioCAS), IEEE Journal of Emerging and Selected Topics in Power Electronics, and IEEE Transactions on Industrial Electronics.

III. PERSON OF ORDINARY SKILL IN THE ART

24. In evaluating the prior art references and other material, I have used the perspective of a person of ordinary skill in the art (“POSITA”) to which the patent is related as of the time of the patent’s priority date. I am informed by Counsel that a POSITA is presumed to be aware of pertinent prior art and the conventional wisdom in the art and is a person of ordinary creativity. I have applied this standard in my analysis throughout my declaration.

25. The ’304 patent is entitled “Semiconductor Source Based Near Infrared Measurement Device with Improved Signal-to-Noise Ratio” and purports to describe optical measurement systems that use “lasers and light sources” and can be used to monitor physiological parameters “for healthcare, medical, dental, or biotechnology applications.” EX1001, 3:6–10; *id.*, Abstract. A POSITA in the December 2012 timeframe, which I am informed by Counsel is the earliest claimed effective filing date of the ’304 patent, would have had good working knowledge of optical sensing techniques and their applications, including the design of such systems and signal processing techniques used in such systems. Specifically, a POSITA would have had an undergraduate degree in engineering (electrical,

mechanical, biomedical, or optical) or a related field of study, along with either (a) relevant industrial experience studying or developing physiological monitoring devices (*e.g.*, non-invasive optical biosensors) in industry or (b) additional education or experience in academia (*e.g.*, a Ph.D) studying or developing physiological monitoring devices. In other words, additional education in the field could compensate for less professional experience, and vice versa.

26. I understand that the Board adopted this definition of a POSITA in *inter partes* reviews of certain parent patents to the '304 patent. EX1023, 7–8; EX1008, 8–9, *aff'd*, EX1009.

27. I meet the criteria described above and I am a person with at least ordinary skill in the art pertaining to the '304 patent. I would have qualified as such a person by at least December 31, 2012, which I understand is the earliest claimed priority date of the '304 patent.

IV. APPLIED LEGAL PRINCIPLES

28. I am informed by Counsel for the Petitioner about the following legal standards, which I have applied throughout my analysis.¹

¹ I am informed by Counsel that the patent laws were amended by the America Invents Act (AIA), but that the earlier statutory requirements still apply to pre-AIA patents. I have been informed by Counsel that the '304 patent was

A. Prior Art

29. I am informed by Counsel that a patent, published patent application, or other publication, must first qualify as prior art before it can be used to invalidate a patent claim.

30. I am further informed by Counsel that a U.S. or foreign patent qualifies as prior art to a patent claim if the date of application, issuance, and/or publication of the prior art patent is prior to the purported date of invention of the patent claim.

31. I am additionally informed by Counsel that a printed publication, such as a technical publication, a magazine article, or newsgroup post, qualifies as prior art to a patent claim so long as the date of publication is prior to the purported date of invention of the patent claim.

32. I am moreover informed by Counsel that a U.S. patent qualifies as prior art to a patent claim if the application for the prior art patent was filed in the United States before the purported date of invention of the patent claim.

prosecuted as an AIA patent, but that it is part of a chain of continuations that claim priority to a 2012 (pre-AIA) provisional application. Unless otherwise stated, my understanding of the law about patent invalidity as set forth in this Declaration relates to the pre-AIA requirements, but from what I understand from Counsel for WHOOP, my opinion would not change under the AIA requirements.

33. I am further informed by Counsel that, if a U.S. Patent incorporates another patent or document by reference, it is considered to be part of that same reference.

B. Anticipation

34. I am informed by Counsel that, once the claims of a patent have been construed, the second step in determining anticipation of a patent claim requires a comparison of the construed claim language to the prior art on a limitation-by-limitation basis.

35. I am further informed by Counsel that a prior art reference anticipates a claim, and thus renders the claim invalid, if all elements of the claimed process, system, or device are disclosed in the prior art reference, either explicitly or inherently.

36. I am also informed by Counsel that, under Section 102 of the Patent Act, claims of a patent are invalid for lack of novelty if they are anticipated by a single prior art reference. I am further informed by Counsel that a claimed invention is invalid as anticipated and hence lacks novelty if all of the limitations of the claim as construed by the Court are present in a prior art reference, or any document that the reference incorporates by reference. However, I am informed by Counsel that a limitation of the claim need not be shown directly in a reference so long as a POSITA

would have understood the limitation to be inherent, or necessarily present in the reference.

C. Obviousness

37. I am informed by Counsel that an invention may also be obvious, even though the invention is not identically disclosed or described in a single prior art reference, which is required for anticipation. This is true if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the relevant art.

38. I am further informed by Counsel the Supreme Court has urged caution in granting a patent based on the combination of elements found in the prior art. This is because a patent for a combination that only unites old elements with no change in their respective functions withdraws what already is known from the public, giving it exclusively to the patentee. The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results.

39. I am also informed by Counsel that when a work is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or a different one. If a person of ordinary skill can implement a predictable variation, the invention is likely obvious. For the same

reason, if a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill. Put another way, I am informed by Counsel that a court must ask whether the improvement is more than the predictable use of prior art elements according to their established functions. I am further informed by Counsel that this is a flexible standard and it is not confined to any particular formalistic conception.

40. I am also additionally informed by Counsel that, when conducting an obviousness inquiry, the analysis should consider the scope and content of the prior art, differences between the prior art and the claims of the challenged patent claims, and the level of ordinary skill in the art. Secondary considerations of nonobviousness can also be considered, which include commercial success enjoyed by devices practicing the patented invention, industry praise for the patented invention, copying by others, and the existence of a long-felt but unsatisfied need for the invention. I am also informed by Counsel that there must be a nexus between these factors and the claims themselves for these secondary considerations to impact the analysis of obviousness.

41. I am informed by Counsel that there generally must be a motivation to combine the references in order to find obviousness. This motivation or reason to

combine can arise from the references themselves, changing market dynamics, or from simple common sense.

42. I am further informed by Counsel that a single reference can render a patent claim obvious, even if that reference does not fully anticipate the claim. To determine whether there was an apparent reason to combine the known elements in the way a patent claims, it will often be necessary to look to interrelated teachings of multiple patents; to the effects of demands known to the design community or present in the marketplace; and to the background knowledge possessed by a person having ordinary skill in the art.

D. Claim Construction Standard

43. I am informed by Counsel that, during an *inter partes* review, the same standard is used as during claim construction in district court civil actions. I am further informed by Counsel that, in the district court context and in this IPR, the words of a claim are generally given their ordinary and customary meaning. This is the meaning the term would have to a person of ordinary skill in the art in question at the time of the invention, which generally means the time the application was filed.

44. I am further informed by Counsel that the specification informs the proper interpretation of a claim. This is because a person of ordinary skill in the art is deemed to have read the claim term not only in the context of the particular claim

in which the dispute term appears, but in the context of the entire patent, including the specification. I am also informed by Counsel that the prosecution history and extrinsic evidence concerning relevant scientific principles, the meaning of technical terms, and the state of the art are also considered in ascertaining the meaning of claim terms.

V. TECHNOLOGY BACKGROUND

45. To put in context my opinions on the validity of the claims of the '304 patent, in this section I provide some background on wearable optical sensors, including those used for physiological monitoring. All of the concepts discussed in this section were well-known and widely used well before the alleged December 31, 2012, priority date for the '304 patent.

A. Overview of Optical Sensing Techniques

46. Optical sensors have been used in medical monitoring systems for decades. EX1033, 764. Although these optical systems may vary in the details, they typically consist of “basic building blocks” that include (1) one or more light sources (*e.g.*, lasers, lamps, or light-emitting diodes (LEDs)) producing light of a particular wavelength and a finite bandwidth; (2) certain “optical elements” (*e.g.*, filters and lenses) that can be used to manipulate the light from the light source and direct it to the target (*e.g.*, human tissue); (3) one or more photodetectors that capture the light reflected back from or transmitted through the target; and (4) signal processing

technology (*e.g.*, analog-to-digital conversion circuitry, digital signal processors, microprocessors, etc.) that processes the signal obtained from the photodetector and can thereby extract data relating to one or more physiological parameters. EX1033, 764–66. An illustration of a typical optical sensor system is shown below. EX1033, 765.

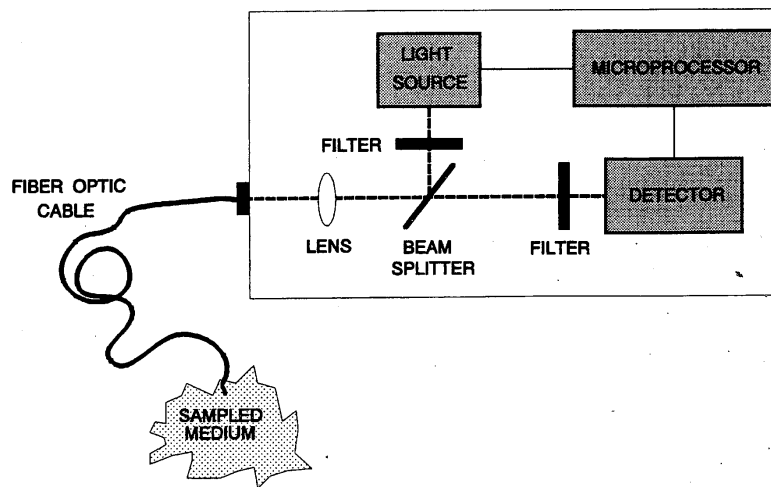


FIGURE 52.1 General diagram representing the basic building blocks of an optical instrument for optical sensor applications.

EX1033, 765.

47. Photoplethysmography (PPG) is a particular optical sensing technique that has also been used in medical monitoring systems for decades, since at least the 1930s. PPG works by shining a light through the subject's tissue and measuring the light that is either reflected back from the tissue or transmitted through the tissue. The various components of blood and tissue (*e.g.*, hemoglobin) reflect and absorb different wavelengths of light, such that a PPG device can calculate the composition

of the blood flow or tissue by measuring how much light is absorbed and reflected over time at one or more wavelengths. For example, hemoglobin (the substance in blood that carries oxygen to the cells) reflects more red light when it has a higher oxygen content (*i.e.*, is oxygenated, HbO₂) and absorbs more red light when it has a lower oxygen content (*i.e.*, is deoxygenated, Hb), but reflects the same amount of infrared (IR) light regardless of whether it is oxygenated or deoxygenated. EX1033, 769. Thus, by measuring the absorption of red and IR light multiple times per second, a PPG device can calculate a subject's (i) oxygen saturation (*i.e.*, ratio of oxygenated hemoglobin to deoxygenated hemoglobin) and (ii) pulse (based on the change in blood volume in the tissue over time). EX1033, 769–771. The measurement of the degree of oxygen saturation is referred to as “oximetry,” and the addition of the continuous monitoring of blood volume to evaluate pulse rate is referred to as “pulse oximetry.” *Id.*

48. Optical sensors, including those employing PPG and non-invasive pulse oximetry, can also be integrated into portable devices, which increases their usefulness for medical monitoring, since they can then travel with (or be worn by) the subjects anywhere. EX1033, 771. For portable optical sensors, LEDs are typically selected as the light source, due to the fact they are small, inexpensive, consume low amounts of power, produce selective wavelengths of particular interest

for medical monitoring, and are easy to manipulate and work with. EX1033, 765, 771.

49. In order to return the most accurate data possible, optical sensors are designed to maximize the strength of the target signal received by the detector (corresponding to a particular physiological measurement from the tissue) relative to other light received by the detector (*e.g.*, ambient light reflected from the patient's surroundings), known as "interference," "background," or "noise." The better the system is able to isolate the target signal captured from the tissue from the surrounding noise, the higher the "signal-to-noise ratio" (SNR) of the sensor will be, and, thus, the more accurate the resulting health data will be. EX1045, § 8.4.1 (p. 119) § 9 (p. 138); § 11.4 (pp. 197–98).

50. Optical sensing systems, including those employing PPG, use various techniques to improve SNR. For example, most optical sensors use two or more photodetectors, with one functioning as a "reference detector" that tracks fluctuations in the intensity of the received light and temperature, so that a baseline measurement is collected that can then be compared to the reading from the sample in order to isolate the signal associated with the desired measurement from the sample. Other common techniques include modulating the light source by, *e.g.*, using "synchronized lock-in amplifier detection" techniques. EX1033, 764–766.

Lock-in detection works by operating at a very narrow frequency range, such that noise at other frequencies can be largely eliminated

51. Optical sensing systems used for medical monitoring have traditionally been integrated with electronic devices to allow the physiological data they collect to be processed, transmitted, stored, and displayed. One example of such a system is depicted below and was published in the 1995 *Bioengineering Handbook*. EX1033, 1363. In this system, health data is collected by a wired, wearable sensor and transmitted to a remote computer located in a physician's or primary care provider's office via a home monitor and landline phones. EX1033, 1363. The physician could then use the collected data to generate reports that would later be shared with patients. *Id.* As I discuss below, as electronics increasingly became wireless, the market moved from the 1995 wired system depicted in the *Bioengineering Handbook* to an analogous system that was able to collect, transmit, process, store, and display physiological data wirelessly using, *e.g.*, cell phones and cloud-based systems.

process the data collected by wearable sensors to remote systems for continuous medical monitoring.

53. Wearable optical sensors, including those integrated with personal devices and cloud-based architecture, were thus well-known and widely available by December 2012, the earliest claimed priority date of the '304 patent. Indeed, I am very familiar with the market for wearable sensors in 2012 because, during that timeframe, I was in the process of establishing the Center of Wearable Sensors at UCSD. Below, I discuss some of these market trends.

54. As an initial matter, during the late 1990s and continuing to 2012, the market for miniaturizing electronics increased rapidly. EX1034, 3; EX1037, 2. This trend became particularly pronounced with the proliferation of personal devices, like cell phones and tablets, which became ubiquitous. As a result, the market moved to develop systems and products that could be integrated into or work with personal devices and used in a variety of fields, including health and personal fitness applications. EX1034, 3; EX1037, 1.

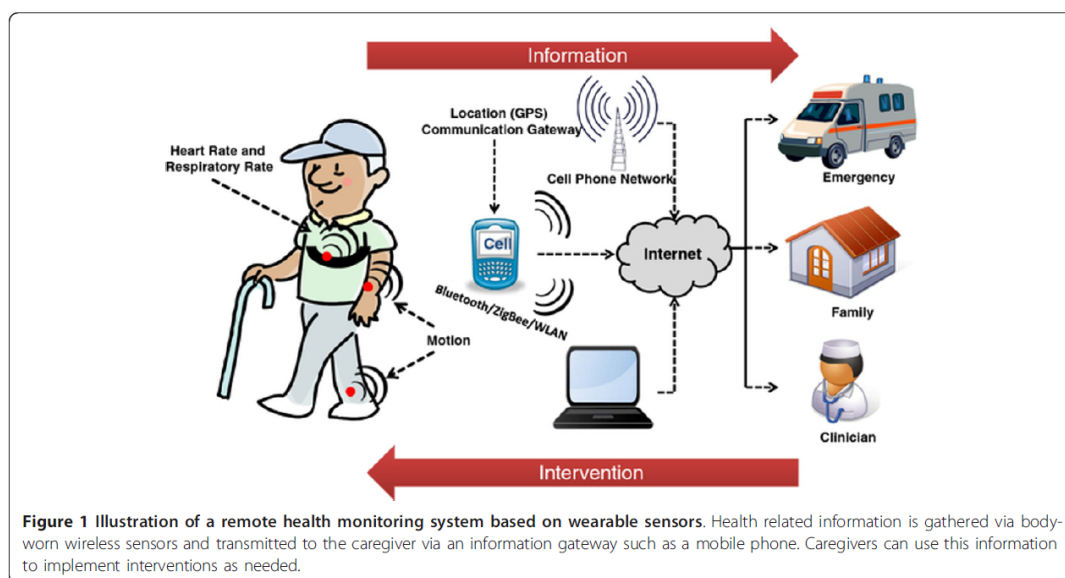
55. Similarly, beginning in the late 1990s, the medical device industry began responding to the challenge of monitoring the health of patients who were located in remote areas or who lacked easy, continuous access to a physician's office. EX1034, 2; EX1035, 462; EX1036, 15–31. One such response included the development of wireless, wearable devices the subjects could wear outside of the

physician's office, for example, as a wristwatch or a waistband, to continuously monitor particular health parameters. EX1034, 2; EX1035, 462; EX1036, 15–31. Medical professionals recognized that the continuous monitoring of a patient's physiological data (like heart rate, oxygen saturation, and blood pressure) enabled by these wearable devices could improve both diagnosis and ongoing treatment of neurological, cardiovascular, and pulmonary diseases. EX1034, 2.

56. Along with the development of the wearable optical sensing devices themselves, the medical field began implementing systems for medical monitoring that could be used with personal devices (*e.g.*, cell phones), including via “apps” for such devices. EX1036, 9–10, 40–49; EX1034, 4; EX1040, 1–2 (“Doctors and nurses were the early adopters of tablets”), *id.* at 5 (describing “[p]atient monitoring and data collection” using “Bluetooth enabled sensor devices and Wi-Fi+ Bluetooth enabled interfaces to patient monitoring devices”). These integrated medical monitoring systems (wearable sensor + personal device or application) enabled patients to transmit health data collected by the wearable sensor to their healthcare providers, including via a “cloud-based” system. EX1034, 4; EX1036, 9–10, 40–49; EX1040, 1–2, 5.

57. One example of a system integrating a wearable optical sensor and remote medical monitoring capabilities is illustrated below and was described in a 2012 article in the *Journal of NeuroEngineering and Rehabilitation*. EX1034. As

depicted, the patient wears a band with an integrated optical sensor (“body-worn wireless sensors”), which “gather[s]” the patient’s heart rate and respiratory data. EX1034, 2. The wearable device then transmits the data it gathers to a healthcare provider or emergency responder “via an information gateway,” like a cell phone. *Id.* The cell phone can also transmit the health data it collects to a “cloud” based system for storage and retrieval at a later time. EX1034, 2, 5.



EX1034, 2.

58. In parallel with the expansion of wearable optical sensors used for medical monitoring and the corresponding applications and personal devices configured to work with such systems, a market began to emerge for commercial health devices that could be used for monitoring personal health and fitness. EX1037, 3; EX1028, [0004]; EX1032, [0003]; EX1038, 221. Indeed, by June of 2012, pulse oximeters and heart rate monitors—which had previously been

“reserved for professional use”—were available to consumers as wearable devices (e.g., as a smartwatch) and could be connected to their smartphones. EX1037, 3; EX1028, [0004]; EX1032, [0003]; EX1038, 221. By the priority date of the ’304 patent, these integrated wearable device systems were generating “growing market demand” from consumers, including for “gauging overall health, fitness, metabolism, and vital status during exercise [or] athletic training.” EX1032, [0003]. The rising demand for such products impacted my own decision to start the Center for Wearable Sensors at UCSD.

59. One example of an integrated wearable device system that could be applied to both medical monitoring and personal fitness was described in the *Journal of Diabetes Science & Technology* in 2010 by Alf Helge Omre. EX1035, 459–61. Omre illustrates a system with three interconnected components: (1) a “sensor” that is integrated into a device worn or carried by a user (like a watch or a belt) and that gathers a particular type of data from the subject (e.g., heart rate or blood pressure); (2) a “[h]ost device” (like a smartphone or laptop) that receives the data collected by the sensor; and (3) a remote “[w]eb service” that receives the health data from the host device and uses that data to assist with a service, including “[w]eight loss” or “fitness coaching.” *Id.*

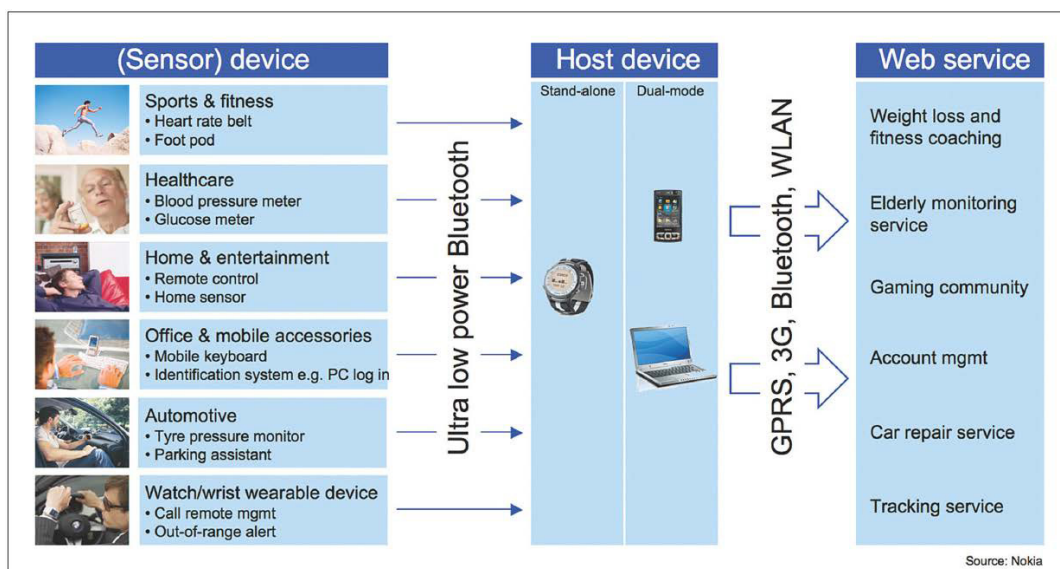


Figure 2. Bluetooth low energy will extend interoperable wireless connectivity to coin-cell-powered wireless sensors in health care, fitness, and related sectors. WLAN, wireless local area network; GPRS, general packet radio service.

EX1035, 459.

60. Other publications from the same timeframe illustrated interconnected networks that combined “cloud” based services or architecture with a wearable optical sensor and a personal device to improve health and fitness. For example, an article published in 2012 described a system for a “mobile fitness coach” “using personalized mobile devices.” EX1037, 1, 6–7, 12. That system, illustrated below, includes a smartphone that “records sensor data” from, for example, a heart rate monitor or other optical sensor, while the user is exercising. EX1037, 6–7, 12. The smartphone then sends the collected fitness data to a server for further processing by a fitness application, and the application then returns the processed data to the smartphone so it can be displayed to the user. EX1037, 6–7, 12.

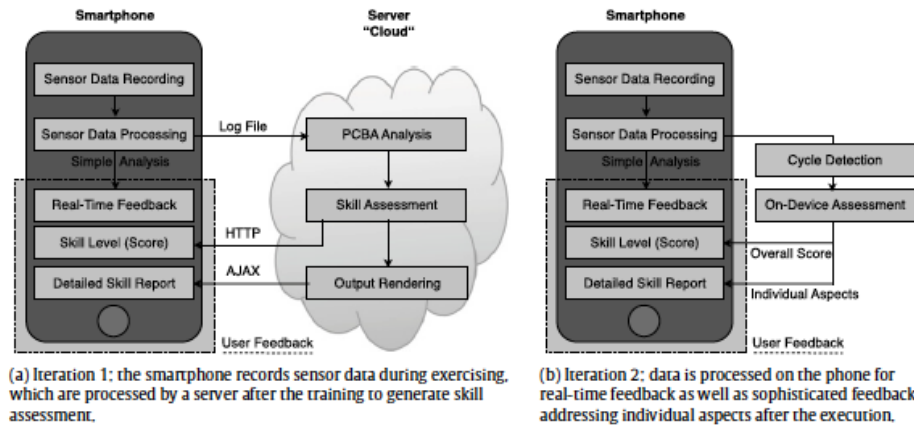
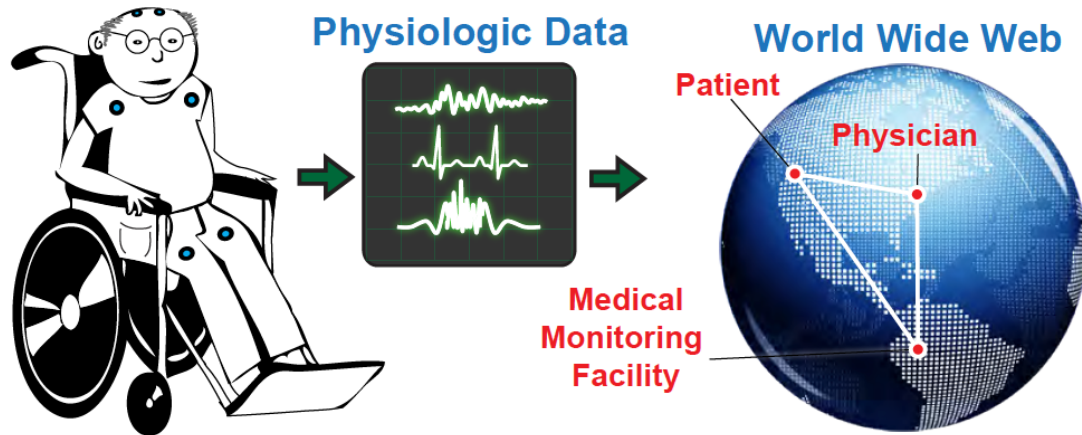


Fig. 3. Iterations of the GymSkill application.

61. In fact, I had personally written about using wearable sensors for medical monitoring applications in my PhD thesis, published in June 2012. For example, I created a figure, shown below, describing the idea of using wearable devices to capture physiological data from a user, and transmit this data from a patient to a physician or a medical monitoring facility.



62. The trends described above led to the proliferation of integrated systems (including, *e.g.*, a wearable optical sensor, a personal device, and a cloud-

based architecture) that could be used for medical monitoring, personal health, and sport performance. As a result, rising demand for these products would have provided a strong motivation for a POSITA to explore ways of integrating optical sensing techniques into small, portable, and wearable devices that could be used to monitor health and fitness parameters and could remotely communicate with a user's personal device (like a smartphone), including ways of improving the quality of the health and fitness data by improving the SNR of the wearable sensor.

VI. BACKGROUND OF THE '304 PATENT

A. Summary of the '304 Patent

63. The '304 Patent “relates to lasers and light sources for healthcare, medical, dental, or bio-technology applications, including systems and methods for using near-infrared or short-wave infrared light sources.” EX1001, 3:6–10.² One such system is a “measurement device [] adapted to be placed on a wrist or an ear of

² Although the '304 patent describes a variety of applications of optical systems that have no relation to the biomedical industry (*e.g.*, the detection of counterfeit pharmaceuticals, EX1001, 33:7–22), it discloses certain biomedical applications, including the use of optical measurement systems to detect “dental caries, often called cavities,” using, for example, a “mouth-guard type apparatus.” EX1001, 3:6–10, 4:46–48.

a user.” EX1001, 5:13–18. The system inspects a sample “by comparing different features, such as wavelength (or frequency), spatial location, transmission, absorption, reflectivity, scattering, refractive index, or opacity” of the sample. EX1001, 12:19–24.

64. The measurement system may include:

a wearable measurement device for measuring one or more physiological parameters, including a light source comprising a plurality of semiconductor sources that are configured to generate an output optical beam with one or more optical wavelengths. The light source is configured to increase signal-to-noise ratio by increasing a light intensity from at least one of the plurality of semiconductor sources. The wearable measurement device is configured to receive a portion of the output optical beam and to deliver an analysis output beam to a sample. The wearable measurement device further comprises a receiver configured to receive and process at least a portion of the analysis output beam reflected or transmitted from the sample and to generate an output signal, wherein the wearable measurement device receiver is configured to be synchronized to pulses of the light source. The measurement system is also provided with a smart phone or tablet and a remote device. The smart phone or tablet comprises a wireless receiver, a wireless transmitter, a display, a microphone, a speaker, one or more buttons or knobs, a

microprocessor and a touch screen. The smart phone or tablet is configured to receive and process at least a portion of the output signal, to store and display the processed output signal, and to transmit a portion of the processed output signal over a wireless transmission link. The remote device is configured to receive over the wireless transmission link an output status comprising the at least a portion of the processed output signal, to process the received output status to generate processed data and to store the processed data. The remote device is capable of storing a history of at least a portion of the received output status over a specified period of time.

EX1001, 8:51–9:15.

65. Figure 13 of the '304 Patent shows “the medical measurement device can be part of a personal or body area network.” EX1001, Fig. 13; *id.*, at 10:46–51. In this depiction, the measurement device “communicates with another device (e.g., smartphone or tablet) that communicates with the cloud. The cloud may in turn communicate information with the user, dental or healthcare providers, or other designated recipients.” EX1001, 10:46–51.

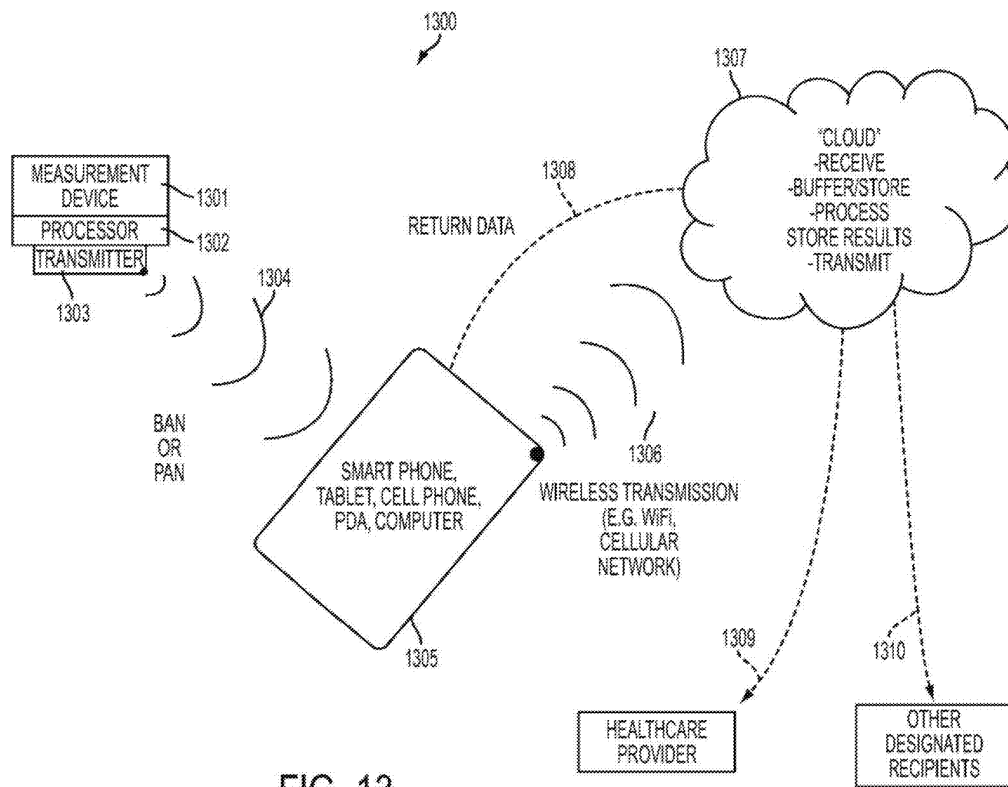


FIG. 13

EX1001, Fig. 13.

66. The '304 patent also describes certain techniques to improve signal processing for the desired physiological signal. *See* EX1001, 20:5–25. For example, the system can improve SNR by using a “higher light level or intensity.” *Id.* Furthermore, the '304 patent teaches:

Using a lock-in type technique (e.g., detecting at the same frequency as the pulsed light source and also possibly phase locked to the same signal), the detection system may be able to reject background or spurious signals and increase the signal-to-noise ratio of the measurement.

EX1001, 18:24–29.

B. File History of the '304 Patent

67. As I state below, in forming my opinions, I have also reviewed the file history of the '304 patent.

68. The '304 patent was filed October 31, 2019, as part of a family of patents that I understand claims priority to December 31, 2012, provisional patent applications. The applicant filed a terminal disclaimer to some of the patents in this chain. EX1001, at (*); *id.* at 89–90, 266–86. As mentioned above, I understand that the '304 patent was prosecuted as an AIA patent application and that the applicant acknowledged that at least one claim in the '304 patent “contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013,” such that the application was “examined under the first to file provisions of the AIA.” EX1002, 89-90, 270, 272. The claims submitted with the application that became the '304 patent did not incur any rejections during prosecution and were allowed without any substantive comments from the Examiner. EX1002, 266–86. The Examiner simply proposed an amendment to prosecution claims 1 and 8 (both independent claims) to specify that: (a) the light intensity is increased “relative to an initial light intensity” and (b) that the generated output signal “represent[s] at least in part a non-invasive measurement on blood

contained within the sample.” EX1002, 272–83, 287. The applicant agreed to the amendments, and the claims were allowed. *Id.*, 287.

69. I understand that some of the prior art references I discuss below (Lisogurski, Carlson, and Valencell-093) were included by the applicant in Information Disclosure Statements (IDS) submitted during the prosecution of the ’304 patent. EX1002, 168 (Carlson), 374 (Valencell-093/LeBoeuf), 400 (Lisogurski). The Examiner did not, however, indicate that these references received more than cursory consideration; as mentioned, the claims were allowed without rejection, and the Examiner did not cite these references in the Notice of Allowance. EX1002, 266–86 (Notice Of Allowance).

70. Furthermore, I understand that two of the parent patents to the ’304 patent—U.S. Patent Nos. 9,651,533 (the “’533 patent”) (EX1004) and 10,517,484 (the “’484 patent”) (EX1005)—have been the subject of IPRs that found all challenged claims of those patents unpatentable based on, among others, the references included in the IDS for the ’304 patent (Lisogurski, Carlson, and Valencell-093). For example, I understand that the Board held all challenged claims of the ’533 patent (claims 5, 7–10, 13, and 15–17) to be unpatentable in a separate IPR proceeding based on the Lisogurski and Carlson references, and that the Federal Circuit affirmed that decision. *See Apple Inc. v. Omni MedSci, Inc.*, IPR2019-00916,

Paper No. 39 (P.T.A.B. Oct. 14, 2020) (EX1008); *aff'd*, *Omni MedSci, Inc. v. Apple Inc.*, No. 21-1229, 2022 WL 2062168 (Fed. Cir. Jun. 8, 2022) (EX1009).

71. I further understand that the '484 patent is the subject of an ongoing IPR before the Board, where all claims (1–27) have been challenged as unpatentable as obvious based on, among others, the Lisogurski, Carlson, Tran, and Valencell-093 references discussed below. *See* Patent Owner's Notice of Appeal, *Apple Inc. v. Omni MedSci, Inc.*, IPR2021-00453 (P.T.A.B.) (EX1010). I understand the Board initially determined that claims 1, 2, 7 and 15–23 of the '484 patent were unpatentable, but that the Petitioner (Apple) had not shown claims 3–6 and 8–14 to be unpatentable based on a limitation that required the claimed system to “identify an object.” *Id.*, Paper No. 22, at 2 (P.T.A.B. Aug. 3, 2022) (EX1011). I understand the Petitioner appealed that determination to the Federal Circuit, and that the Federal Circuit reversed and remanded for the Board to consider whether those claims are unpatentable as obvious under an alternative argument. *Apple Inc. v. Omni MedSci, Inc.*, No. 23-1034, 2024 WL 3084509 (Fed. Cir. Jun. 21, 2024) (EX1012). I understand that Omni did not cross-appeal as to the findings for the claims initially held unpatentable. *Id.*, n.2. I understand that the Board held the remaining claims to be unpatentable as obvious on remand, *Apple Inc. v. Omni MedSci, Inc.*, IPR2021-00453, Paper No. 26 (P.T.A.B. Feb. 14, 2025) (EX1013), and that Omni has appealed

that decision as to claims 3-6 and 8-14. *Omni MedSci, Inc. v. Apple Inc.*, No. 25-1646 (Fed. Cir.) (EX1014).

72. As discussed below, I have reviewed the challenged claims of the related '533 and '484 patents that were the subject of the IPR proceedings and certain materials from those proceedings. It is my opinion that a POSITA would have understood the invention described in the Challenged Claims of the '304 Patent significantly overlaps with and is not meaningfully distinct from the challenged claims of those two patents.

VII. MATERIALS AND PRIOR ART CONSIDERED

73. I have considered information from various sources in forming my opinions. I have drawn on my decades of experience in this field. I have employed methods and analyses of a type reasonably relied upon by experts in my field in forming opinions or inferences on the subject. Additionally, in preparing this Declaration, I have relied upon '304 patent and its file history, the exhibits cited to below, and the additional exhibits listed at the beginning of this Declaration. I have also reviewed the related '533 and '484 patents, and materials from the IPR proceedings related to those patents. Furthermore, I have reviewed U.S. Patent Nos. 11,160,455 (the "'455 patent") (EX1058), 12,193,790 (the "'790 patent") (EX1059), 12,268,475 (EX1060) (the "'475 patent"), which are "child" patents in the same chain of continuations as the '304 patent.

74. In this Declaration, I provide six prior art references with exemplary citations identifying the relevant features related to the claim language of the Challenged Claims.³ I have also described combinations of these prior art references that, when combined, render the Challenged Claims of the '304 patent obvious. It is my opinion that the Challenged Claims of the '304 patent are rendered obvious in light of the prior art specifically discussed in this Declaration.

75. The citations presented in the body of this declaration correspond to the teachings disclosed in exemplary items of prior art that identify: (1) the problem(s) confronted by one of ordinary skill in the art; (2) an express suggestion to make one or more of the combinations; (3) an implicit suggestion to make one or more of the combinations; or (4) the knowledge of those skilled in the art as to the applicable field of technology at the relevant timeframe.

76. It is my opinion that a person of ordinary skill would consider at least the prior art references below:

Prior Art Reference	Date of Publication	Exhibit No.
U.S. Patent No. 9,241,676 ("Lisogurski")	May 31, 2012 (filing date)	1027
U.S. Patent App. Pub. No. 2005/0049468 ("Carlson")	March 3, 2005	1028
U.S. Patent No. 8,175,667 ("Debreczeny")	May 8, 2012	1029

³ The complete text of the Challenged Claims is set forth in **Appendix A** hereto.

U.S. Patent No. 6,304,767 (“Soller”)	October 16, 2001	1030
U.S. Patent No. 8,108,036 (“Tran”)	January 31, 2012	1031
U.S. Patent Appl. Pub. No. 2012/0197093 (“Valencell-093”)	January 25, 2012	1032

77. I understand that four of these six references (all but Debreczeny and Soller) have been considered by the Board in the IPRs of the related ’533 and ’484 patents, where the Board found all challenged claims of those two patents unpatentable.

78. Specifically, it is my opinion that the claims of the ’304 patent would have been obvious as follows:

’304 Patent Claims	Basis of Invalidity
1, 11, 19–20, 25	Obvious over Lisogurski in view of Carlson
3	Obvious over Lisogurski in view of Carlson and Debreczeny
2, 14, 27	Obvious over Lisogurski in view of Carlson and Valencell-093
4–8, 10, 15–18, 21–24	Obvious over Lisogurski in view of Carlson and Soller
12–13, 26	Obvious over Lisogurski in view of Carlson and Tran
9	Obvious over Lisogurski in view of Carlson, Soller, and Tran

79. I am also not aware of any secondary considerations of non-obviousness that affect my conclusions regarding the obviousness of these claims.

80. Other references and knowledge described earlier in this declaration are relevant to show the state of the art (*i.e.*, what a person of ordinary skill would have known when using the references identified above) or to use in combination with the references above to render the Challenged Claims invalid.

VIII. INVALIDITY ANALYSIS OF THE CHALLENGED CLAIMS

81. Below is a detailed analysis of the bases of invalidity identified above. For my analysis, I have grouped claim limitations where they are substantively similar or where it made sense to discuss them together.

A. Overview of Prior Art References

1. Lisogurski

82. Lisogurski is directed to a portable “physiological monitoring system,” for example, a “pulse oximeter, which may non-invasively measure the oxygen saturation of a patient’s blood.” EX1027, 3:44–46, 3:60–4:5. The system includes an **optical sensor**, which includes “a light source and a photosensitive detector,” to measure the “physiological parameters of a patient,” such as the patient’s pulse, blood pressure, and oxygen saturation. EX1027, 3:44–4:8. The sensor can be worn by a patient in various locations, including “the neck to monitor carotid artery pulsatile flow, the wrist to monitor radial artery pulsatile flow, the inside of a patient’s thigh to monitor femoral artery pulsatile flow, the ankle to monitor tibial artery pulsatile flow, and around or in front of the ear.” EX1027, 4:15–20; *id.*, at 4:6–4:8 (“An oximeter may include a light sensor that is placed at a site on a patient,

typically a fingertip, toe, forehead, or earlobe.”). The sensor may be battery-powered and configured to “wirelessly connect[]” to a **monitor**. EX1027, 17:55–58.

83. Figure 1 illustrates an embodiment of the physiological measurement system with a sensor, monitor, and remote devices (*e.g.*, servers), where “**monitor 104** includes control circuitry 110, light drive circuitry 120, front end processing circuitry 150, back end processing circuitry 170, user interface 180, and communication interface 190. **Monitor 104** may be communicatively coupled to **sensor 102**.” EX1027, 11:28–32. The “[c]ommunication interface 190 may enable monitor 104 to exchange information with external devices” and also may include “any suitable hardware, software, or both, which may allow **monitor 104** to communicate with electronic circuitry, a device, a network, a server, or other workstations, a display, or any combination thereof.” EX1027, 15:43–48.

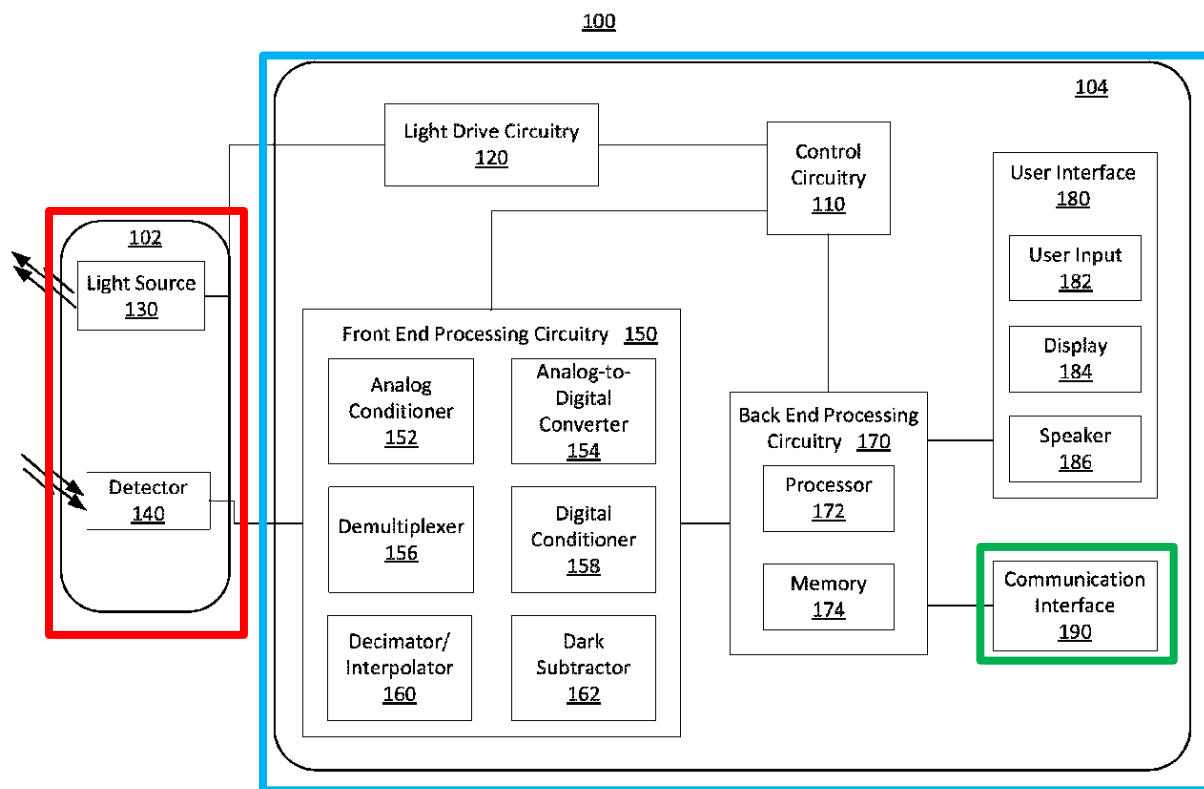


FIG. 1

EX1027, Fig. 1 (annotated).

84. The light source in the sensor may include one or more light-emitting diodes (LEDs) of “one or more wavelengths.” EX1027, 10:48–64; *see also* EX1027, 4:42–48, 11:9–13, 17:37–45. For example, “[r]ed and infrared (IR) wavelengths may be used because it has been observed that highly oxygenated blood will absorb relatively less red light and more IR light than blood with a lower oxygen saturation.” EX1027, 4:42–48; *id.* at 10:48–64, 11:9–13, 17:37–45. The LEDs emit the light in beams; the beams pass through or are reflected back by the tissue, and the reflected and/or transmitted light is detected by the photodetector in the sensor. EX1027, 4:7–11 (“The oximeter may use a light source to pass light through blood perfused tissue

and photoelectrically sense the absorption of the light in the tissue”), 10:48–56 (the light sources “emit” light of a particular wavelength, *i.e.*, a beam), 11:13–20 (the “light may enter detector 140 after passing through the subject’s tissue”). The photodetector then “convert[s] the intensity of the received light into an electrical signal.” EX1027, 11:14–16.

85. The **sensor** can then either (i) send the converted electrical signal directly to the **monitor** for processing, or (ii) it can pre-process the signal before sending it to the monitor. EX1027, 11:20–27 (“After converting the received light to an electrical signal, detector 140 may send the detection signal to monitor 104, where the detection signal may be processed and physiological parameters may be determined (e.g., based on the absorption of the Red and IR wavelengths in the subject’s tissue). In some embodiments, the detection signal may be preprocessed by the sensor 102 before being transmitted to monitor 104”). In either scenario, the system processes the signal using standard signal processing techniques to isolate the desired signal from the reflected and/or transmitted light. EX1027, 7:16–21, 12:48–49 (“Front end processing circuitry 150 may perform various analog and digital processing of the detector signal.”), 13:7–14:55 (“Analog conditioner 152 may perform any suitable analog conditioning of the detector signal. The conditioning performed may include any type of filtering (e.g., low pass, high pass, band pass, notch, or any other suitable filtering), amplifying, performing an

operation on the received signal (e.g., taking a derivative, averaging), performing any other suitable signal conditioning (e.g., converting a current signal to a voltage signal), or any combination thereof”).

86. Lisogurski’s system also regulates the “light drive signal” of the sensor, which refers to the electric current applied to the LEDs. EX1027, 1:60–61, 7:12–36, 8:4–8, 11:38–41, 11:50–54, 12:3–9. Thus, as the current applied to a particular LED increases, the light intensity emitted from that LED also increases. EX1027, 7:13–16, 7:24–31, 12:3–9, 12:16–22. The system can also modulate the LEDs and “vary light drive signal parameters” of the LEDs in response to a “trigger” caused by various conditions, *e.g.*, interference or noise. EX1027, 1:10–25, 1:67–2:3; *see also id.*, 1:60–61, 8:4–8, 8:27–35, 16:24–32. For example, the measurement system can control the “light intensity, duty cycle, light source firing rate, any other suitable parameter, or any combination thereof” of the LEDs. EX1027, 1:60–61, 1:67–2:3, 1:10–25, 5:48–54, 25:46–65 (“The system may vary parameters related to the light drive signal including drive current or light brightness, duty cycle, firing rate, modulation parameters, other suitable parameters, or any combination thereof”). Lisogurski explains that varying these drive cycle parameters can increase the signal-to-noise ratio (SNR) of the measurement device, for example:

In some embodiments, **the system may alter the cardiac cycle modulation technique based on the level of noise, ambient light, other suitable**

reasons, or any combination thereof. The system may receive, for example, an increased level of background noise in the signal due to patient motion. **The system may increase the brightness of the light sources in response to the noise to improve the signal-to-noise ratio.** In some embodiments, the system may increase brightness throughout the cardiac cycle because the system may require increased signal amplitudes to differentiate between fiducial and other points of interest related to physiological parameters and those related to noise or motion. In some embodiments, the system may change from a modulated light output to a constant light output in response to noise, patient motion, or ambient light.

EX1027, 9:46–60.

2. Carlson

87. Carlson is directed to a system for “the acquisition and/or monitoring of medical data, in particular the state of the cardiovascular and pulmonary system, blood values or blood composition.” EX1028, Abstract. The system includes “at least one measuring sensor for the acquisition of the medical data,” which further includes “at least one light source which can emit light at least at two wavelengths, as well as at least one light receiver for determining the light transmitted and/or reflected through a tissue” and “means in order to increase the optical Signal-to-Noise and/or Signal-to-Background ratio.” EX1028, Abstract. Carlson further

teaches that the pulse oximetry system is portable, such that “[t]he measured values can be transmitted via a wire connection or wireless” (e.g., via “‘Bluetooth’ technology”) “to a medical doctor, to a hospital, etc.” EX1028, [0077]–[0078]; *see also* EX1028, [0072].

88. One embodiment of Carlson is directed to a wearable pulse oximeter that can be worn on the ear, finger, or “other parts of the human body.” EX1028, [0003], [0052], [0078]. The oximeter includes a conventional sensor with “two light emitting sources” (“which means **two LEDs**”) that emit optical wavelengths “at two wavelengths, at 660 nm, and a second wavelength within the range of 800 to 1000 nm.” EX1028, [0050], [0003]. A POSITA would have understood that optical wavelengths of 660 nm correspond to red light, whereas wavelengths of 800–1000 nm correspond to infrared (IR) light. Carlson further explains that the sensor can include “at least two light receivers,” as well as “**beam shaping optics**” that can be used to “direct the emitted optical radiation 8 from the **two LEDs**” to, e.g., “the middle of the earlobe.” EX1028, [0052]–[0054]. These beam-shaping optics are illustrated in Figure 4:

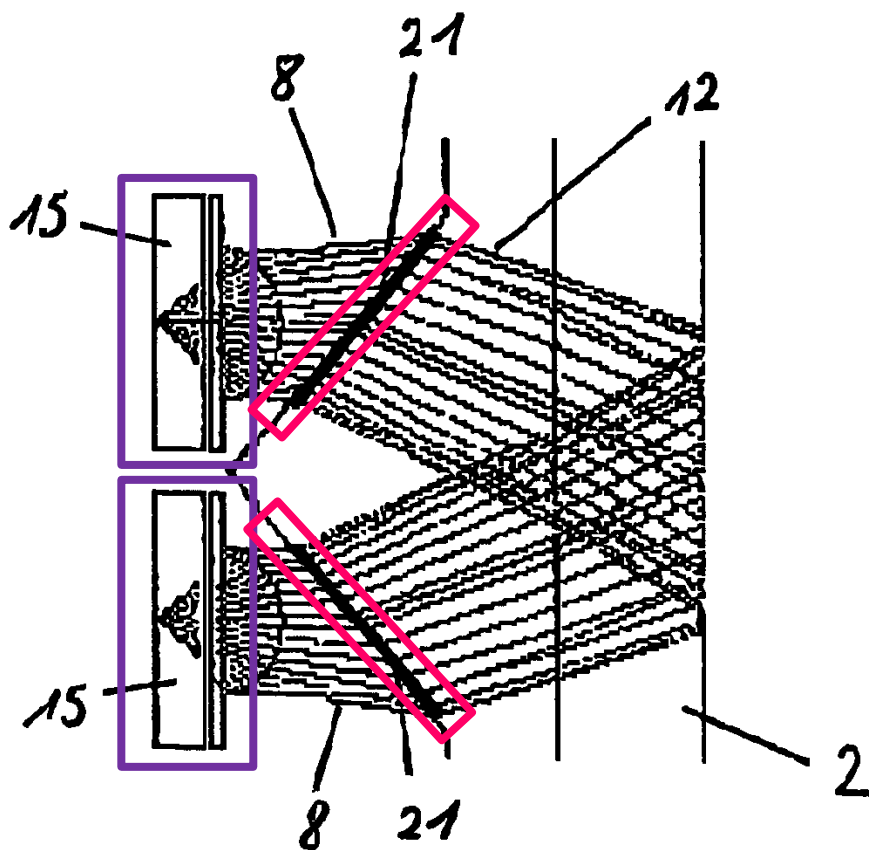


Figure 4

EX1028, Figure 4 (annotated).

89. Carlson is further directed to the objective of “increasing the technical performance of pulsoximetry in terms of quality and robustness of the measurement signal versus environmental disturbances and energy consumption.” EX1028, [0002]. For example, Carlson explains that “[w]hen using pulsoximetry in telemedicine” (*i.e.*, outside of a doctor’s office setting, such as in athletics or in “self-testing”), “standard pulsoximeter sensors suffer from signal instability and

insufficient robustness versus environmental disturbances.” EX1028, [0004].

Carlson states that:

It is therefore an object of the present invention to define optical and/or electronic means for increasing the Signal-to-Noise ratio (S/N) and Signal-to-Background ratio (S/B) of a pulsoximeter sensor for robust application of pulsoximetry in telemedicine- and near patient testing applications in rough (optical) environmental conditions, e.g. at changing light influences, such as sunlight, shadow, artificial light, etc.

EX1028, [0010]. Carlson provides multiple ways of accomplishing this objective, including “us[ing] a **beam-shaping element**, such as e.g., diffractive or refractive lenses, to direct the emitted optical radiation of, e.g., the **LED** light source into the human or animal tissue and the photon detecting element in order to increase the optical signal power detected by the pulsoximeter sensor.” EX1028, [0014]. The beam-shaping element is illustrated by Figure 4, above.

3. Debreczeny

90. Debreczeny is similarly directed to a “pulse oximeter system[.]” EX1029, 2:51–63. The pulse oximeter “includes a sensor 11 having a detector 12 which receives electromagnetic radiation from the blood perfused tissue of a patient 14,” where the “electromagnetic radiation originates from emitters 16.” EX1029, 4:1–12. The “emitters 16 may be one or more LEDs configured to emit in the red

or near infrared regions of the electromagnetic spectrum” and arranged in such a way “to provide spatial symmetry about an axis.” EX1029, 4:13–19. The pulse oximeter also “includes a microprocessor 24 that processes data received from the sensor 11 to compute various physiological parameters.” EX1029, 4:39–43. “A time processing unit (TPU) may be provided to control the timing of pulse oximeter 20” and “may be coupled to light drive circuitry and a switch 34.” EX1029, 4:44–47. “The light drive circuitry 32 controls light emissions of the emitters 16, and the switch 34 receives and controls the gating-in of the amplified signals from the detector 12.” EX1029, 4:47–50. “The received signals are passed from the switch 34 through a second amplifier 36, a filter 38, and an analog-to-digital converter (A/D) 40, before arriving at the microprocessor 24.” EX1029, 4:50–53. Once the microprocessor receives the signals, it “calculates the oxygen saturation and other physiological parameters.” EX1029, 4:54–63.

91. Debreczeny teaches that traditional pulse oximetry systems use LEDs “held in close proximity” to one another to emit light to the tissue, but that “motion and/or the application of excessive pressure can have the effect of changing the optical coupling efficiency of the light sources and the detector,” and thereby cause a “decrease in the accuracy of the sensor.” EX1029, 1:66–2:18. “In the context of pulse oximetry, optical coupling refers to a relationship between the sensor and the patient, permitting the sensor to transmit light into the patient’s blood profused tissue

and permitting a portion of the light to return to the sensor after passing through or reflecting from within the tissue.” *Id.*, 2:1–8. Debreczeny explains that the “quality of optical coupling” is “related to the amount of light that actually enters the patient’s tissue,” and, correspondingly, the portion of light received by the sensor. *Id.*, 2:7–10. Pulse oximetry systems are “sensitive to movement” by the patient, and “motion induced changes” can distort the “accuracy of the sensor” by decreasing the amount of optical coupling (*i.e.*, light received by and reflected from the tissue). *Id.*, 1:63–2:18, 4:53–62.

92. Debreczeny thus describes a system for counteracting the effect of motion on optical coupling (and therefore increasing the strength of the signal received from the tissue) and “providing better readings.” EX1029, 5:6–67. Specifically, Debreczeny teaches the use of two red LEDs in the pulse oximetry system, rather than one, and the use of “[s]patial symmetry” to separate the two red LEDs from one another by positioning them on either side of a center LED emitting infrared or near infrared light. *Id.*, 5:6–24. Such positioning of the red LEDs “help[s] ensure that any coupling issues that may occur due to movement of the tissue relative to one LED may be compensated for by the other LED.” *Id.* “[B]ecause the light sources are spectrally symmetrical,” the intensities emitted by the two red LEDs “may add” to one another, such that there is greater intensity of signal being delivered to the tissue than using one LED alone. EX1029, 6:11–33.

In other words,” “[b]ecause the signal from the two LEDs 64 and 66 [(the red LEDs)] is additive, the signal-to-noise ratio may be increased.” *Id.*, 5:25-35. Debreczeny illustrates the spatial symmetry configuration in Figure 2:

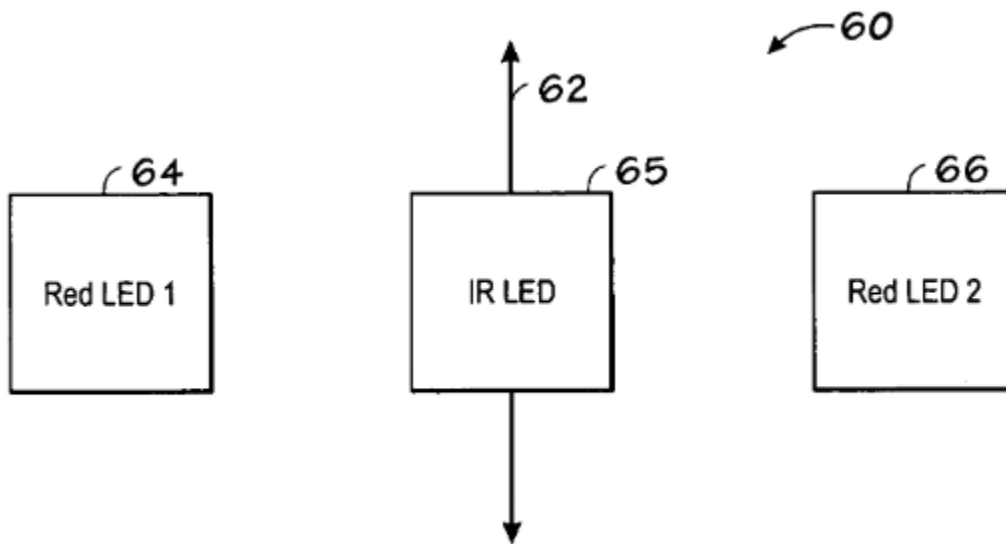


FIG. 2

EX1029, Fig. 2.

4. Valencell-093

93. Valencell-093 is directed to an optical sensor (“wearable monitoring apparatus”) that “includes a housing (e.g., an earpiece, earbud, etc.) and a sensor module disposed within or attached to the housing” and can be used to measure the user’s heart rate and blood constituents. EX1032, [0006], [0050] (describing a sensor integrated into “wristbands, armbands, legbands, neckbands, waistbands, anklebands, footbands, handbands, ringbands, headbands, etc.”), [0109] (the sensor may be a pulse oximeter that measures “blood oxygen levels” of the subject), [0150]

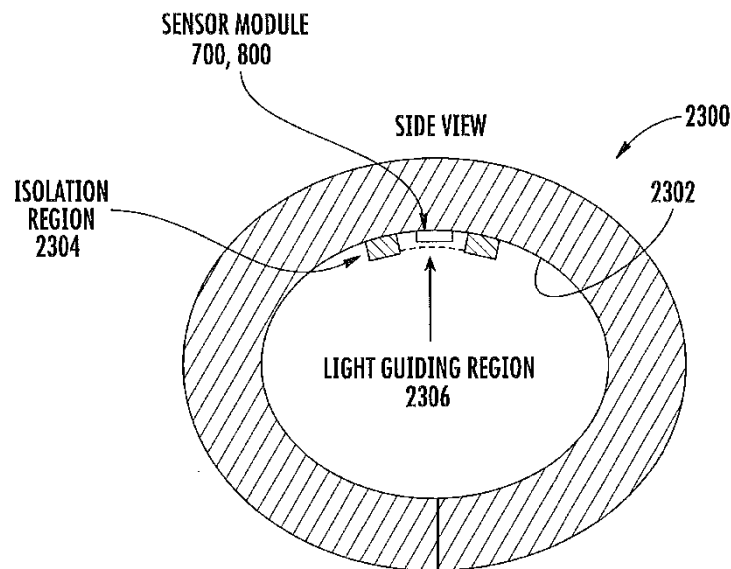
(the apparatus can be worn “around various parts of the body, such as an arm, leg, neck, etc.”); Fig. 23 (showing wristwatch configuration). For example:

The housing is configured to be attached to a body of a subject, for example the ear. The sensor module includes an energy emitter, a detector, a filter, and at least one processor. The energy emitter directs energy (e.g., optical energy, acoustic energy, ultrasonic energy, electromagnetic radiation, electrical energy, mechanical energy, magnetic energy, nuclear energy, etc.) at a target region of the subject and the detector detects an energy response signal from the subject. The energy response signal is associated with a physiological condition of the subject (e.g., heart rate, pulse pressure, respiration rate, lactic threshold, blood pressure, volume of blood flow through a blood vessel, blood metabolite level, blood oxygen level, size of at least one blood vessel, etc.). The filter removes or attenuates time-varying environmental interference from the energy response signal, wherein the time-varying environmental interference is caused by one or more of the following: sunlight, ambient light, airflow, temperature, etc.

EX1032, [0006].

94. Valencell-093’s objective is “to teach how to make a wearable monitor...that may provide accurate information on physiological conditions in the midst of environmental noise, such as noise from ambient light and/or sunlight.”

EX1032, [0112]. Specifically, Valencell-093 teaches that the sensor in the wearable apparatus can be surrounded by a “light guiding region” that “helps direct light to and/or from the sensor module [] and a blood flow region within the body part.” EX1032, [0152]. The light-guiding region can include a “reflector, such as a metal, metallic alloy, mylar, mica, reflective plastic, reflective textile, or the like.” EX1032, [0152]. One such embodiment showing the light guiding region is shown in Figure 24:



EX1032, Fig. 24.

5. Soller

95. Soller is directed to a “non-invasive optical and mathematical method to measure hematocrit with an accuracy of approximately 99%.” EX1030, 1:45–51.

“Hematocrit is the volume percent of red blood cells in a blood sample” that can be “measured using only the concentrations of oxygenated and deoxygenated hemoglobin,” but also includes the concentrations of other components like “methemoglobin, carboxyhemoglobin, and sulphemoglobin.” EX1030, 1:19–44, 5:33–37. Soller teaches a method of “measur[ing] hematocrit with an accuracy of approximately 99%” by “quantifying all of the components of red blood cells,” in addition to oxygenated and deoxygenated hemoglobin. EX1030, 1:46–52, 5:33–54.

96. Soller further discloses a measuring device with an “illumination component” (like LEDs) that emits beams of light of one or more wavelengths in the “visible and near-infrared spectral region[s]” to measure the optical properties of a sample for the concentrations of various blood constituents. EX1030, 11:44–12:2; *see also id.*, 1:53–62, 13:13–28, 18:18–23. Soller teaches that the device may have “between 5 and 20 LEDs,” each emitting a different wavelength in the range of, *e.g.*, 500–110 nm. EX1030, 13:13–28, 13:39–40. The LEDs are “evenly spaced and arranged in a circular pattern” and “preferably tilted inward,” which Soller teaches “increase[es] the accuracy of the measurement” for each blood constituent in hematocrit. EX1030, 13:35–49; 16:39–48 (a “ring-like pattern” for the LEDs “maximize[s] the amount of radiation” directed to the sample). The light is delivered to the skin with a probe “in close proximity to the skin,” such as via a “hand-held unit.” EX1030, 12:30–38. The device also includes interior and exterior detectors

for capturing the light reflected back from or transmitted through the tissue. EX1030, 13:50–63. Soller teaches that “[b]ecause of its small size,” the device is “portable, handheld, and easily manipulated,” which allows the measurement of hematocrit in “remote locations, such as in an ambulance or outdoors.” EX1030, 15:50–56, 15:31–40 (Soller’s device is “particularly desirable for applications necessitating a portable or hand-held device”).

97. Figure 11A of Soller illustrates “an integrated, self-contained hematocrit measuring device 600 for measuring a reflection spectrum from a sample 505. The hematocrit measuring device 600 features a circular array, e.g., typically at least seven, of **light-emitting diode (LED) radiation sources 604**, for providing optical radiation.” EX1030, 17:36–50; Fig. 11A. The device also includes a “reflectance detector 605 and **a series of reference detectors 610**,” which are “mounted on the side of each **LED** to measure and correct for variations in the **LED** intensity due to temperature, aging, or electrical power source drifts.” EX1030, 17:36–50, Fig. 11A.

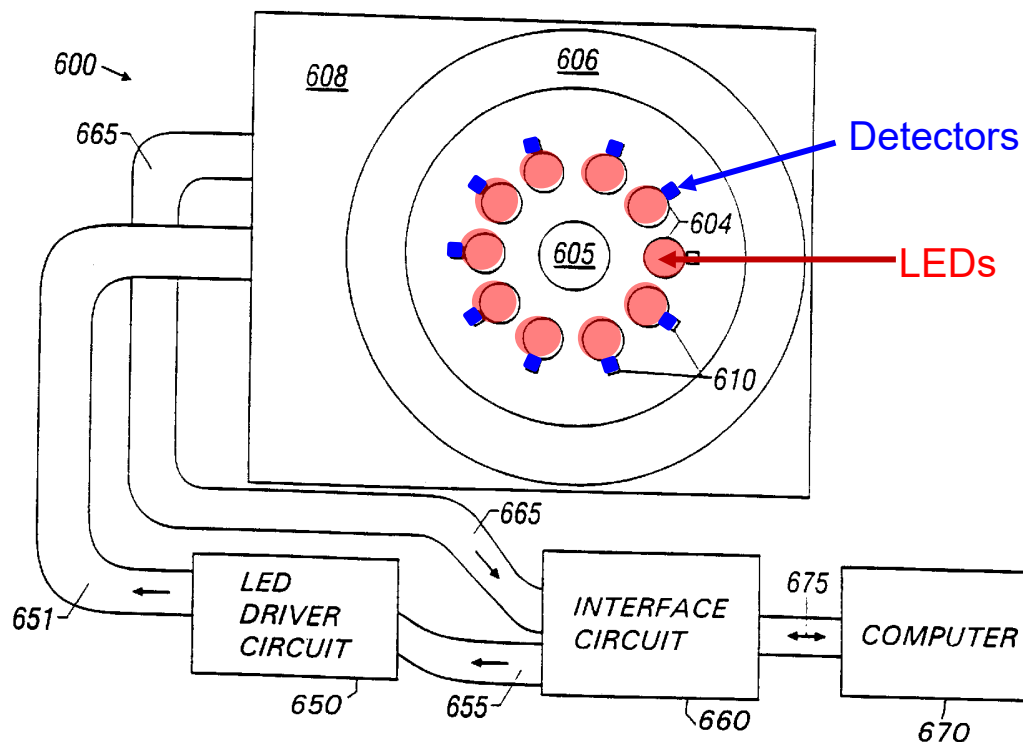


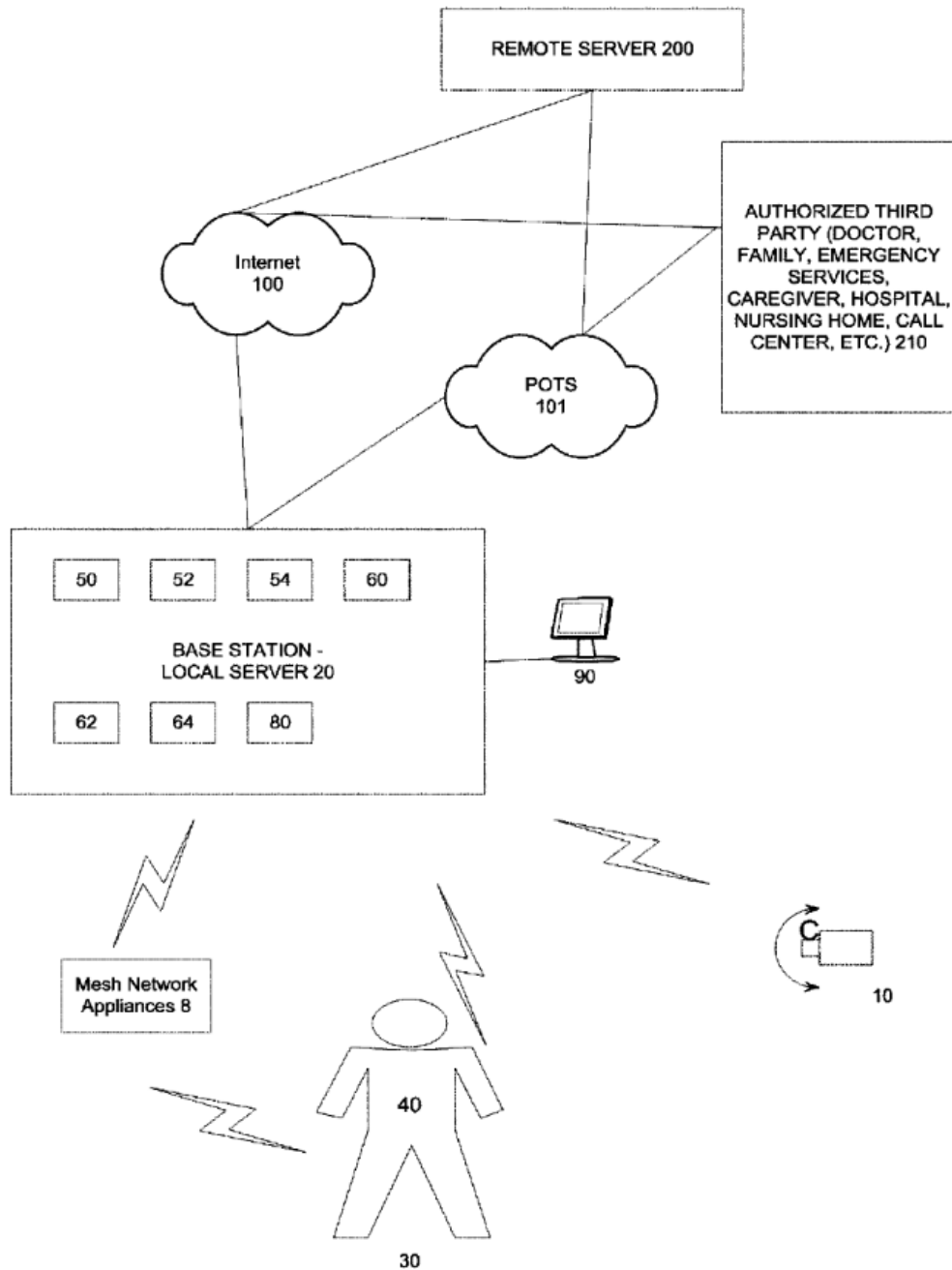
Figure 11A

EX1030, Fig. 11A (annotated).

6. Tran

98. Tran is directed to a “heart monitoring system” with a “statistical analyzer” to monitor patient health conditions, *e.g.*, “determine heart attack or stroke attack.” EX1031, Abstract. The monitoring device is “worn by the patient” (as, *e.g.*, a “wrist-watch[,]” “clip on device[,]” or “electronic jewelry,” EX1031, 9:23–31) and collects physiological measurements that may include pulse oximetry measurements. EX1031, 25:20–29; *see also* 25:36–43, 26:17–29, 36:62–37:13, 46:25–42, 60:58–61:37, 74:29–44. The health information collected by the device

is communicated to, *e.g.*, a server, which passes the data to a statistical analyzer to, for example, “track the patient’s risk of stroke or heart attack[]” and provide alerts to an “authorized third party” “should the appliance 8 detect[] that the user needs assistance or that an emergency ha[s] occurred.” EX1031, 54:35–36, 9:1–14; *id.* at 8:28–53, 9:23–54, 11:1–31, 54:14–57:13. The monitoring device can be used with a smartphone, so that the patient’s data can be collected and transmitted continuously, including when the patient is away from home. EX1031, 33:50–34:40. An example of this system is illustrated in Figure 1:



EX1031, Fig. 1.

99. Tran teaches that its statistical analyzers use “artificial neural networks,” a form of artificial intelligence, to help classify potential risks to warn patients or health-care providers. EX1031, 22:24–28, 74:45–46 (“In one

embodiment, feed forward artificial neural networks (NN) are used to classify valve-related heart disorders.”), 75:18–20 (“In another embodiment, ... [a]n artificial neural network classification method classifies the heart sound signals into physiological and pathological murmurs”), 94:57–65 (“Various mathematical techniques and Artificial Intelligence (AI) analyzer can be applied.”). “Prior to operation, data driven analyzers or models of the patient’s habits or ambulation patterns are built using one or more training sessions,” and the analyzer is trained and evaluated against a “test set” “until the performance of the analyzer in classifying the test set reaches an optimal point.” EX1031, 22:24–60. “At this point, the training process is completed.” *Id.*

B. Motivations to Combine

1. Lisogurski and Carlson

100. A POSITA would have been motivated to combine Lisogurski and Carlson because both references concern miniaturized, wireless pulse oximetry devices directed to the same applications (in particular, remote monitoring of a person’s pulse, oxygen saturation, and other characteristics). Furthermore, both references teach techniques for improving the signal-to-noise ratio (SNR) of pulse oximeter systems. Accordingly, as discussed in more detail below, Lisogurski and Carlson are directed to analogous systems that aim to solve the same problems; they thus would have been considered together by a POSITA.

101. Lisogurski teaches a PPG system that is designed to allow “for increased battery life” and “portability” by optimizing power consumption by the miniaturized, wearable monitoring system. EX1027, 1:4–6, 1:16–18, 3:50–53. For example, Lisogurski teaches a variety of techniques to reduce the power requirements necessary for a portable oximetry system, thereby allowing for a smaller device (*e.g.*, a wearable sensor worn on a wrist) or longer battery life. EX1027, 4:63–67, 4:15–20, 17:51–58. Lisogurski similarly teaches “improv[ing] the signal-to-noise ratio” of the measured signals from the user using various techniques, *e.g.*, by “alter[ing] the cardiac cycle modulation technique based on the level of noise, ambient light, other suitable reasons, or any combination thereof.” EX1027, 9:46–60. These teachings in Lisogurski would have motivated a POSITA to look for other techniques accomplishing the same objectives (minimizing power consumption and increasing SNR), particularly as applied to the same type of wearable sensor device. Indeed, evaluating Lisogurski’s system in view of complementary designs and techniques for accomplishing the same objectives in analogous wearable devices would have been part of a POSITA’s ordinary design process when seeking to improve the operation of a PPG device.

102. Thus, a POSITA would have looked to Carlson and considered it together with Lisogurski when designing an improved PPG system integrated with a wearable sensor. Carlson describes improvements to pulse oximetry devices,

including improvements to energy consumption and signal measurement. EX1028, [0002]. For example, Carlson teaches increasing the signal-to-noise ratio of an optical sensor using various techniques (such as including a “beam-shaping element” “to direct the emitted optical radiation of, e.g., the LED light source into the human or animal tissue”). EX1028, [0010], [0014]. Carlson further teaches that its techniques permit for a small, battery-operated device that could be worn by a user (on, for example, the user’s earlobe, finger, or toe), which a POSITA would have understood to refer to an energy-efficient oximetry device. EX1028, [0048], [0052]. Finally, Carlson teaches that its system and techniques for improving the signal-to-noise ratio can be applied to a number of different health and fitness uses, including mobile monitoring, telemedicine, and sports. EX1028, [0004].

103. Thus, because Lisogurski and Carlson both describe analogous systems with overlapping applications and objectives (namely, techniques for improving performance, utility, and power consumption of portable, wearable, optical sensors), a POSITA would have considered the two references together when implementing an optical measurement system based on Lisogurski’s teachings, consistent with the market trends described above. A POSITA further would have had a reasonable expectation of success in combining features from Carlson with Lisogurski’s system because such modifications would have been a routine part of a POSITA’s ordinary design process and within the POSITA’s skill.

104. I understand that the Board has already considered whether a POSITA would have been motivated to combine the Lisogurski system with Carlson in the IPRs for the related '533 and '484 patents, and found that such a motivation existed. EX1008, 22–25; EX1011, 22, 28, 36–43. I understand that the Board's Final Written Decision for the '533 IPR, finding a motivation to combine Lisogurski and Carlson, was affirmed by the Federal Circuit. EX1009. I understand that Omni did not cross-appeal the finding in the Board's First Final Written Decision for the '484 IPR that there would have been a motivation to combine Lisogurski and Carlson, and that that decision has therefore been affirmed by the Federal Circuit. EX1012, n.2.

2. Lisogurski, Carlson, and Debreczeny

105. A POSITA would have further considered Debreczeny in combination with Lisogurski and Carlson. All three references are directed to analogous portable, optical systems with the shared objective of describing techniques for improving miniaturized optical sensors by improving the accuracy of the measurements taken by such systems, *e.g.*, by improving the signal-to-noise ratio of such systems. Furthermore, all three references teach that their systems can be applied to similar biomedical applications, like pulse oximetry.

106. As discussed above (*supra* § VIII.B.1), Lisogurski teaches various techniques for improving SNR of measured signals while minimizing power consumption of a wearable optical sensor. A POSITA would therefore have been

motivated to look to other optical measurement systems with the same objectives, like Carlson, as part of the natural design process for designing such a system. *Supra* § VIII.B.1 Debreczeny, too, is directed to a “pulse oximeter system[]” integrated into a “monitoring device[]” used for monitoring “physiological characteristics of [] patients” that can be worn by the patient, for example, “about a patient’s finger.” EX1029, 1:19–26, 2:51–63, cl. 1. Furthermore, Debreczeny teaches various techniques for improving the measurement accuracy of the pulse oximetry device (and correspondingly, the signal-to-noise-ratio), including “physically dispos[ing] in a symmetrical relationship” two red LEDs that “when summed together [] achieve a maximum intensity” that is “greater” than the intensity of either LED acting alone. EX1029, 5:36–67, 5:32–35 (“Because the signal from the two LEDs 64 and 66 is additive, the signal-to-noise ratio of the sensor may be increased, thus, providing better readings.”). Thus, a POSITA would have looked to Debreczeny, in addition to Carlson, when designing a wearable measurement system for monitoring physiological characteristics with the objective of improving signal-to-noise ratio. Doing so would have been part of the POSITA’s natural design process, within the POSITA’s knowledge and skill, and a POSITA would have had a reasonable expectation of success in combining the techniques from Carlson and Debreczeny with the system described in Lisogurski.

3. Lisogurski, Carlson, and Valencell-093

107. A POSITA would have considered the systems taught by Lisogurski and Carlson together with Valencell-093. All three are analogous systems with common applications and utility. Specifically, all three references concern miniaturized, wireless pulse oximetry devices that can be used for remotely monitoring the physiological characteristics (*e.g.*, pulse and oxygen saturation) of a user. *Supra* § VIII.B.1; EX1032, [0003], [0006], [0012].

108. Furthermore, as explained above, Lisogurski teaches techniques for optimizing power consumption by increasing the battery life of wearable (*e.g.*, wristband) sensors, as well as techniques for increasing the signal-to-noise ratio of measured signals. *Supra* §§ VIII.A.1, VIII.B.1. These teachings would have motivated a POSITA to look to other references concerned with the same objectives, particularly references directed to analogous systems (like Carlson), as part of the natural design process. *Supra* § VIII.B.1.

109. Thus, a POSITA would have looked to Valencell-093 with Lisogurski and Carlson, given that Valencell-093 teaches a similar system directed to the same objectives. Specifically, Valencell-093 describes a wearable optical sensor and teaches certain techniques to maximize optical coupling and minimize the motion between a wearable device and the user's skin. EX1032, [0151]–[0152]. These techniques include using light-guiding elements (such as reflectors made of metal or

plastic) that direct the emitted beams of light to the tissue and allow the sensors to be positioned in a manner that increases the accuracy of the signal from a user's blood flow and reduces the detection of environmental noise. EX1032, [0151]–[0153]; *see also* EX1032, [0126] (positioning an emitter at a higher angle relative to a detector results in a “higher” “ratio of desired optical signal to undesired optical signal”). Implementing the techniques from Valencell-093 into Lisogurski's system in view of Carlson would have been within a POSITA's knowledge and a POSITA would have had a reasonable expectation of success in such a combination.

110. I understand that in the related '484 IPR, the Board found that there would have been a motivation to combine Valencell-093 with Lisogurski and Carlson, and that Omni did not cross-appeal that finding, such that it was affirmed by the Federal Circuit. EX1011, 58–59; EX1012, n.2.

4. Lisogurski, Carlson, and Soller

111. A POSITA would have considered the optical measurement systems taught by Lisogurski and Carlson together with Soller because (and described above for Lisogurski and Carlson, *supra* § VIII.B.1) all three references are directed to analogous systems with common applications and utility. Specifically, a POSITA would have been motivated to combine Lisogurski, Carlson, and Soller because they all concern techniques for improving the performance of non-invasive, miniaturized,

optical devices directed to the same applications (in particular, remote monitoring of a person's pulse, oxygen saturation, and other characteristics).

112. Like Lisogurski and Carlson, *supra* § VIII.B.1, Soller also describes a battery-operated, energy efficient optical sensor that can operate remotely and can be used to monitor physiological parameters, including oxygenated and deoxyhemoglobin. EX1030, 15:50–56 (“Because of its small size, the integrated device is portable, hand-held, and easily manipulated. Hematocrit can also be measured in remote locations, such as in an ambulance or outdoors.”); 15:6–22 (the “power supply” includes “[s]tandard electrical batteries and circuits known in the art”); *id.* at 15:31–40 (describing applications for monitoring hematocrit in a “portable or hand-held device”). Furthermore, Soller teaches configuring an optical sensor in a manner that maximizes the accuracy of the measured physiological signal by positioning the LEDs in, *e.g.*, a “symmetric, ring-like pattern” or in a “circular array.” EX1030, 16:31–53. “In this way, each LED can irradiate approximately the same part of the tissue, hereby increasing the accuracy of the measurement.” *Id.* at 13:41–49.

113. Given their overlapping applications and the fact that the references are directed to the same problem of optimizing power consumption while obtaining accurate measurements, a POSITA would have been motivated to combine the techniques from Soller into Lisogurski's system as part of the natural design process

and would have had a reasonable expectation of success in doing so. Indeed, a POSITA would have found the application of Carlson and Soller's teachings to Lisogurski's optical system to be a routine modification to Lisogurski for which a POSITA would have had a reasonable expectation of success. This is because combining features from Carlson and Soller with Lisogurski's system would have required routine knowledge and skill and would have been a part of the ordinary design process for a POSITA.

5. Lisogurski, Carlson, and Tran

114. As described above, Lisogurski and Carlson are analogous references directed to similar applications and seeking to solve the same problems, describing techniques applicable to measurements taken by wearable optical sensing devices. *Supra* § VIII.B.1.

115. Similarly, Tran describes an "artificial neural network" that analyzes, among other things, pulse oximetry data, using a remote measurement system integrated with a wearable device, and may provide warnings to a care provider regarding a patient's condition. EX1031, 22:23–28, 25:36–43, 26:17–29, 36:62–37:13, 46:25–42, 60:58–61:37, 74:29–67. Tran teaches that its data analysis technique "provides an in-depth, cost-effective mechanism to evaluate a patient's cardiac condition" and further allows for "[c]ertain cardiac conditions [to] be controlled, and in some cases, predicted, before they actually occur." EX1031, 5:5–

7. Further, Tran teaches methods for improving the signal-to-noise ratio of its system. EX1031, 37:28–29 (“The electrode output signals are processed to obtain a differential measurement enhancing the signal to noise ratio”), 66:17–29 (teaching “beamforming” techniques for improving SNR), 91:26–28 (“The signal to noise ratio is increased by filtering between 20-500 Hz with a roll-off of 12 dB/octave.”).

116. A POSITA would have been motivated to incorporate Tran’s data analysis technique, including Tran’s neural networks, into Lisogurski to achieve the same benefits, as part of the natural design process for designing an improved wearable optical sensor, and would have had a reasonable expectation of success in doing so because data analysis techniques were known in the art, such that implementing Tran into a system based on Lisogurski would have been a routine modification yielding predictable results. For example, Lisogurski describes processing collected data to track a patient’s health status. And as described above, *supra* § V.B, market trends would have motivated a POSITA to find additional ways to use Lisogurski’s tracked data in a mobile or remote scenario.

117. I understand that in the related ’484 IPR, the Board found that there would have been a motivation to combine Tran with Lisogurski and Carlson, and that Omni did not cross-appeal that finding, such that it was affirmed by the Federal Circuit. EX1011, 46–47; EX1012, n.2.

6. Lisogurski, Carlson, Soller, and Tran

118. A POSITA would have been motivated to combine Lisogurski's system with the various techniques for improving optical sensors taught by Carlson, Soller, and Tran. *Supra* §§VIII.B.4–5. All four references pertain to wearable sensors that can be used for remote medical monitoring physiological characteristics, including monitoring the hemoglobin content and oxygen saturation of a patient. *Supra* §§VIII.B.4–5. Further, all four references discuss using a battery-powered or energy-efficient mobile device and techniques for improving the measured physiological signals of such a device (*i.e.*, increasing the SNR). A POSITA seeking to design an improved optical sensor for remote medical monitoring would have been motivated to implement the teachings from Carlson, Soller, and Tran into Lisogurski's system to obtain the benefits taught by these references, and would have done so as part of the ordinary design process, particularly given the market trends discussed above. Modifications to Lisogurski's system based on Carlson, Soller, and Tran would have been within the knowledge and skill of a POSITA and would have had a reasonable expectation of success. As detailed above, the implementation of Carlson's "beam shaping element" and light modulation techniques, with Soller's arrangement and number of LEDs and detectors, and Tran's analysis techniques, would have been routine modifications to Lisogurski for which a POSITA would have had a reasonable expectation of success.

C. Specific Grounds of Invalidity

1. Ground 1: Claims 1, 11, 19–20, and 25 would have been obvious over Lisogurski in view of Carlson

119. I have analyzed claims 1, 11, 19–20, and 25 in my opinion they would have been obvious over Lisogurski in view of Carlson. I provide a detailed analysis of each claim limitation below.

a. Claim 1[pre]: A measurement system comprising:

120. In my opinion, Lisogurski discloses 1[pre]. Specifically, Lisogurski teaches a “physiological monitoring system,” such as a “pulse oximeter, which may non-invasively **measure** the oxygen saturation of a patient’s blood.” EX1027, 3:43–66. Lisogurski further teaches that “[p]ulse oximeters may be included in patient monitoring **systems** that measure and display various blood flow characteristics, including, but not limited, to the oxygen saturation of hemoglobin,” as well as a patient’s “pulse rate and blood pressure.” EX1027, 3:61–4:5. Finally, Figure 1 of Lisogurski illustrates this “physiological monitoring system,” which consists of, *e.g.*, a sensor, a monitor, and a communication interface. EX1027, 2:11–13, Fig. 1.

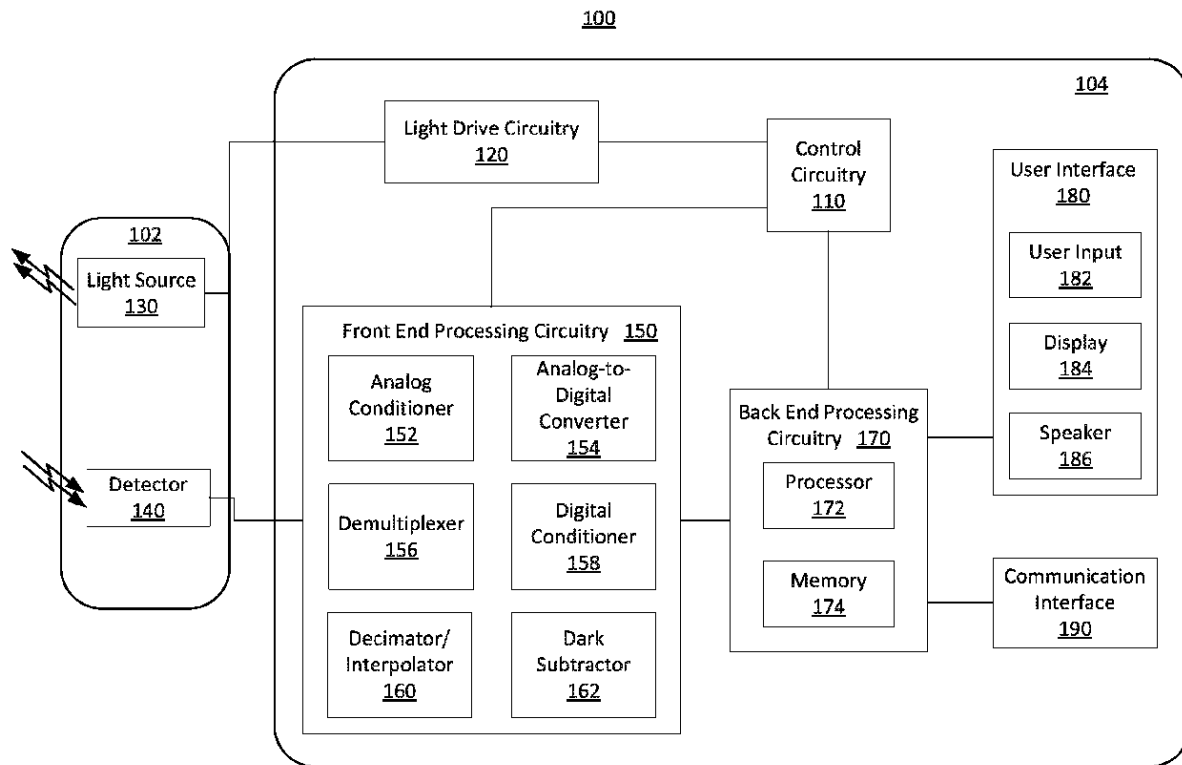


FIG. 1

EX1027, Fig. 1.

121. Accordingly, Lisogurski teaches or renders obvious 1[pre].

- b. **Claim 1[a]: a light source comprising a plurality of semiconductor sources that are configured to generate an output optical beam with one or more optical wavelengths, the light source configured to increase signal-to-noise ratio by increasing a light intensity relative to an initial light intensity from at least one of the plurality of semiconductor sources;**

122. In my opinion, Lisogurski discloses 1[a].

(i) “a light source”

123. Lisogurski teaches that the sensor, illustrated in Figure 1, in its measurement system “may include multiple **light sources** and detectors.” EX1027,

17:42–45; Fig. 1 (130); Fig. 3 (316). Moreover, Lisogurski teaches that “**light source 130** may include any number of **light sources with any suitable characteristics.**” EX1027, 10:48–64.

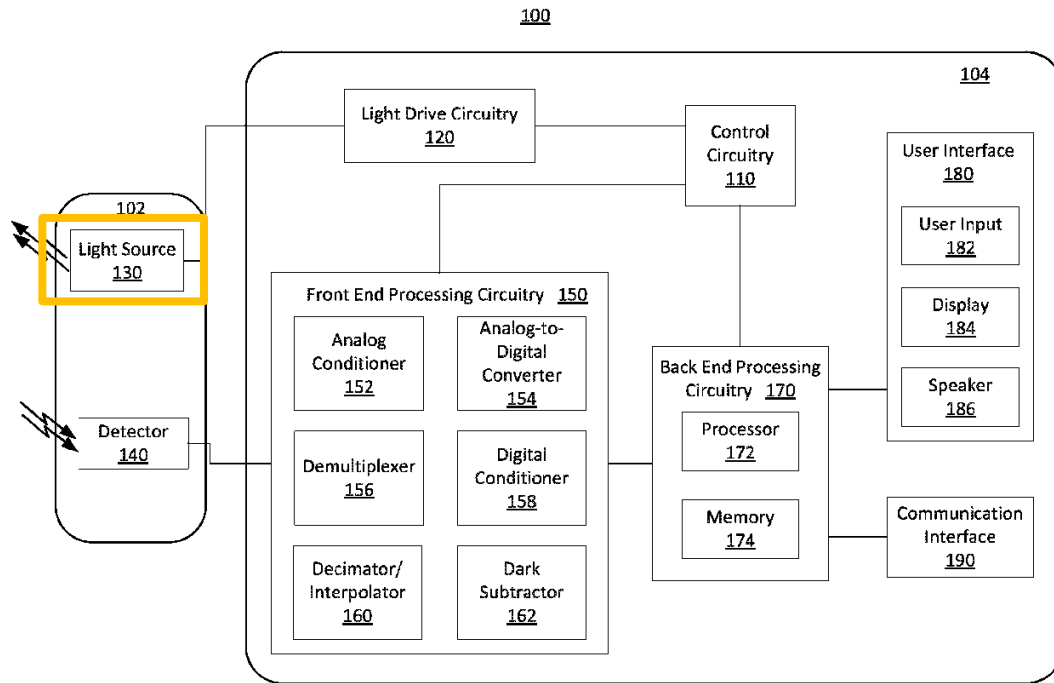


FIG. 1

EX1027, Fig. 1 (annotated).

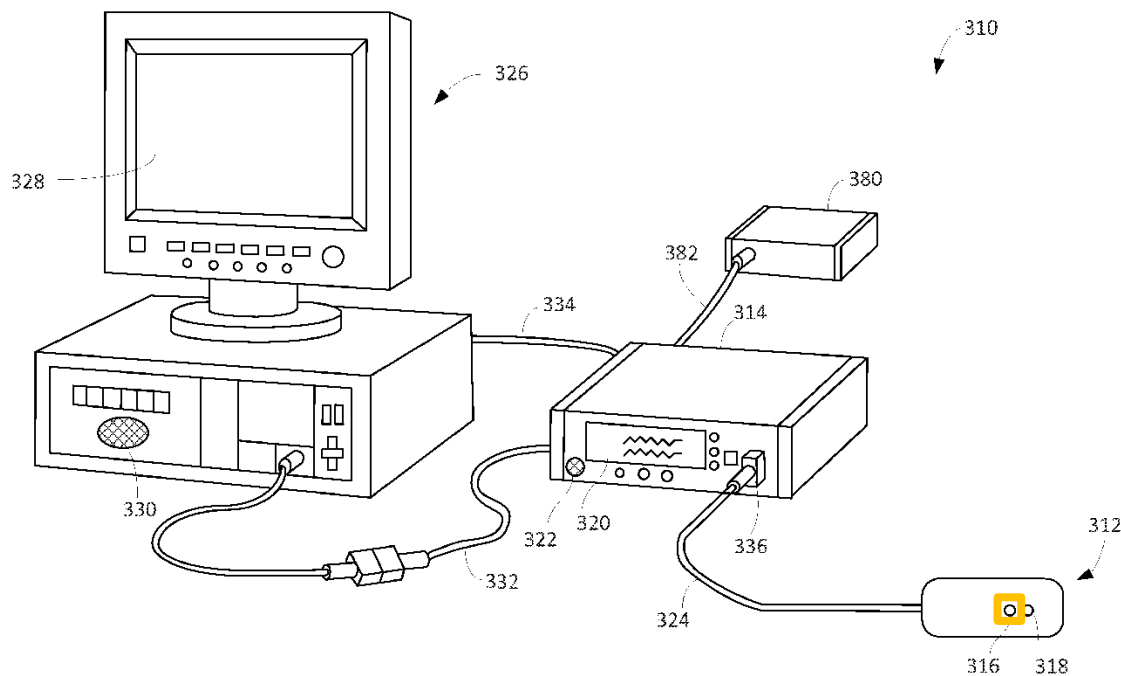


FIG. 3

EX1027, Fig. 3 (annotated).

- (ii) **“comprising a plurality of semiconductor sources that are configured to generate an output optical beam with one or more optical wavelengths”**

124. Lisogurski further discloses that the “any number of light sources with suitable characteristics” comprising the light source may be light-emitting diodes (LEDs). EX1027, 7:38–67 (“For example, **the first light source may be a high efficiency infrared (IR) LED** while **the one or more additional light sources may be lower efficiency red LEDs**”), 19:20–39 (“ For example, the light source may include light source 130 of FIG. 1 or light source 316 of FIG. 3. In some embodiments, **the light source may include LEDs of multiple wavelengths**, for example, a red LED and an IR [LED]. In some embodiments, **the light source may**

include multiple LEDs of the same wavelength, multiple LEDs of different wavelengths, any other suitable arrangement, or any combination thereof.”).

LEDs are semiconductors, so it is my opinion that a POSITA would have understood the LEDs in the light source of Lisogurski to be a plurality of “semiconductor sources.”

125. Lisogurski further teaches that the LEDs emit light of “one or more wavelengths” and that the light is transmitted to a particular location in space (specifically, the “subject’s tissue”). EX1027, 10:49–52 (“Light source 130 may be **configured to emit photonic signals having one or more wavelengths of light (e.g., Red and IR) into a subject’s tissue.**”); 17:37–45 (“Sensor unit 312 may include one or more light source 316 for **emitting light at one or more wavelengths into a subject’s tissue**”); *see also* EX1027, 7:38–67 (“For example, the first light source may be a high efficiency **infrared (IR) LED** while the one or more additional light sources may be lower efficiency **red LEDs**”); *id.*, 10:49–64 (“For example, light source 130 may include a **Red light emitting source** and an **IR light emitting source, e.g., Red and IR light emitting diodes (LEDs) for emitting light into the tissue of a subject to generate physiological signals.** In one embodiment, the **Red wavelength** may be **between about 600 nm and about 700 nm**, and the **IR wavelength** may be **between about 800 nm and about 1000 nm.** It will be understood that light source 130 may include any number of light sources with any

suitable characteristics.”); *id.*, 19:20–39 (“For example, the light source may include light source 130 of FIG. 1 or light source 316 of FIG. 3. In some embodiments, the **light source may include LEDs of multiple wavelengths**, for example, a red LED and an IR [LED]. In some embodiments, the light source may include multiple LEDs of the same wavelength, **multiple LEDs of different wavelengths**, any other suitable arrangement, or any combination thereof.”). It is my opinion that a POSITA would have understood these and other disclosures in Lisogurski to mean the LEDs emit an “optical output light” “of one or more wavelengths” in a “beam” toward a particular location, *e.g.*, tissue; thus, the LEDs are “configured to generate an output optical beam of one or more wavelengths.”

(iii) **“the light source configured to increase signal-to-noise ratio by increasing a light intensity relative to an initial light intensity from at least one of the plurality of semiconductor sources”**

126. Lisogurski further teaches that the certain parameters of the LEDs (semiconductor sources) may be varied by the measurement system using a “cardiac cycle modulation technique” in response to a number of factors, including “the level of noise, ambient light, other suitable reasons.” EX1027, 9:46–52. Specifically, Lisogurski teaches that the “[p]arameters [of the semiconductor sources] that may be varied include **light intensity**, firing rate, duty cycle, other suitable parameters, or any combination thereof.” EX1027, 1:19–21. A POSITA would have understood that “**light intensity**” corresponds to the brightness of the emitted light, “firing rate”

corresponds to the frequency of the emitted light, and “duty cycle” corresponds to the pulse width of the emitted light (*i.e.*, the duration of each pulse of light from the LED). Thus, a POSITA would have understood that Lisogurski teaches varying the intensity (or brightness) of the semiconductor sources, which would include increasing light intensity from an initial light intensity. *E.g.*, EX1027, 9:50–52 (“The system may **increase the brightness of the light sources** in response to the noise to improve the signal-to-noise ratio.”), 1:44–47, 11:38–41, 11:50–54.

127. Lisogurski further teaches that altering the parameters of the semiconductor sources improves the signal-to-noise ratio, for example:

- “In some embodiments, conventional servo algorithms may be used in addition to any combination of cardiac cycle modulation and drive cycle modulation. Conventional servo algorithms may adjust the light drive signals due to, for example, ambient light changes, emitter and detector spacing changes, sensor positioning, other suitable parameters, or any combination thereof. Generally, conventional servo algorithms vary parameters at a slower rate than cardiac cycle modulation. **For example, a conventional servo algorithm may adjust drive signal brightness due to ambient light every several seconds.** The system may use conventional servo algorithms in part to keep received signal levels within the range of an analog to digital converter’s dynamic range. For example,

a signal with amplitudes that are large may saturate an analog to digital convertor. In response to a signal with high amplitudes, the system may reduce emitter brightness. In a further example, **the quality of a low amplitude signal may be degraded by quantization noise by an analog to digital converter. In response, the system may increase the emitter brightness.**” EX1027, 5:55–6:6.

- “In some embodiments, the system may alter the cardiac cycle modulation technique based on the level of noise, ambient light, other suitable reasons, or any combination thereof. The system may receive, for example, an increased level of background noise in the signal due to patient motion. **The system may increase the brightness [*i.e.*, intensity] of the light sources [from an initial intensity] in response to the noise to improve the signal-to-noise ratio.** In some embodiments, the system may increase brightness throughout the cardiac cycle because the system may require increased signal amplitudes to differentiate between fiducial and other points of interest related to physiological parameters and those related to noise or motion. In some embodiments, the system may change from a modulated light output to a constant light output in response to noise, patient motion, or ambient light.” EX1027, 9:46–60.

- “However, if the contribution of ambient light is large relative to the contribution of light from a light source, the total analog gain applied to the detection current may need to be reduced to avoid saturating analog-to-digital converter 154. When the analog gain is reduced, the portion of the signal corresponding to the light source may map to a smaller number of analog-to-digital conversion bits. **Thus, more ambient light noise in the input of analog-to-digital converter 154 may result[] in fewer bits of resolution for the portion of the signal from the light source. This may have a detrimental effect on the signal-to-noise ratio of the detection signal. Accordingly, passive or active filtering or signal modification techniques may be employed to reduce the effect of ambient light on the detection signal that is applied to analog-to-digital converter 154, and thereby reduce the contribution of the noise component to the converted digital signal.**” EX1027, 14:40–55.
- “It will be understood that the output rate may not be a constant rate. It will also be understood **that sampling rate is one of the components that may be modulated in cardiac cycle modulation as described above.** It will also be understood that the earlier described embodiments relating to varying light output may also apply to sampling rate.” EX1027, 35:4–9.

128. In particular, as noted above, Lisogurski teaches “The system may receive, for example, an increased level of background noise in the signal due to patient motion. **The system may increase the brightness of the light sources in response to the noise to improve the signal-to-noise ratio.**” EX1027, 9:46–60. Varying the brightness (intensity) of the light sources may be accomplished using “[l]ight drive circuitry 120,” which is “configured to generate a light drive signal that is provided to light source 130” in order to “**control the intensity of light source 130** and the timing of when light source 130 is turned on and off.” EX1027, 11:50–60; *see also id.*, 1:44–48 (“The system may generate a light drive signal for activating a light source to emit a photonic signal, wherein at least one parameter of the light drive signal is configured to vary substantially synchronously with physiological pulses of the subject.”); *id.*, 11:38–41 (“For example, **light drive circuitry 120** may generate a light drive signal, which may be used to turn on and off the **light source 130**, based on the timing control signals. The front end processing circuitry 150 may use the timing control signals to operate synchronously with light drive circuitry 120”). Furthermore, to the extent required by the claims for the light drive circuitry to be in the same unit as the light source, a POSITA would have understood that the **light drive circuitry 120** and **control circuitry 110** (which together with the front end processing circuitry 150 control the parameters of the **light source 130**) could be integrated from the monitor 104 directly into the sensor

unit 102 in the manner depicted below. Modifying Lisogurski in this manner would have been a routine design modification that would not have affected Lisogurski's operation, because the circuitry is small and power-efficient, so a POSITA would have had a reasonable expectation of success. Furthermore, this modification is consistent with industry trends to miniaturize electronics (and mimics the design of existing sensors in 2012) and consistent with the express recognition in Lisogurski that "the functionality of some of the components may be combined in a single component... [or] the functionality of some of the components of monitor 104... may be divided over multiple components," so a POSITA would have been modified to make this modification. EX1027, 16:2–9. I understand the Board previously held that Lisogurski could be modified in the manner I describe and that the Federal Circuit affirmed. EX1008, 22–23; EX1009; EX1011, 24–25; EX1012 n.2. Thus, Lisogurski expressly teaches the light source is configured to increase the signal-to-noise ratio by increasing a light intensity (brightness) of at least one of the LEDs (the semiconductor sources).

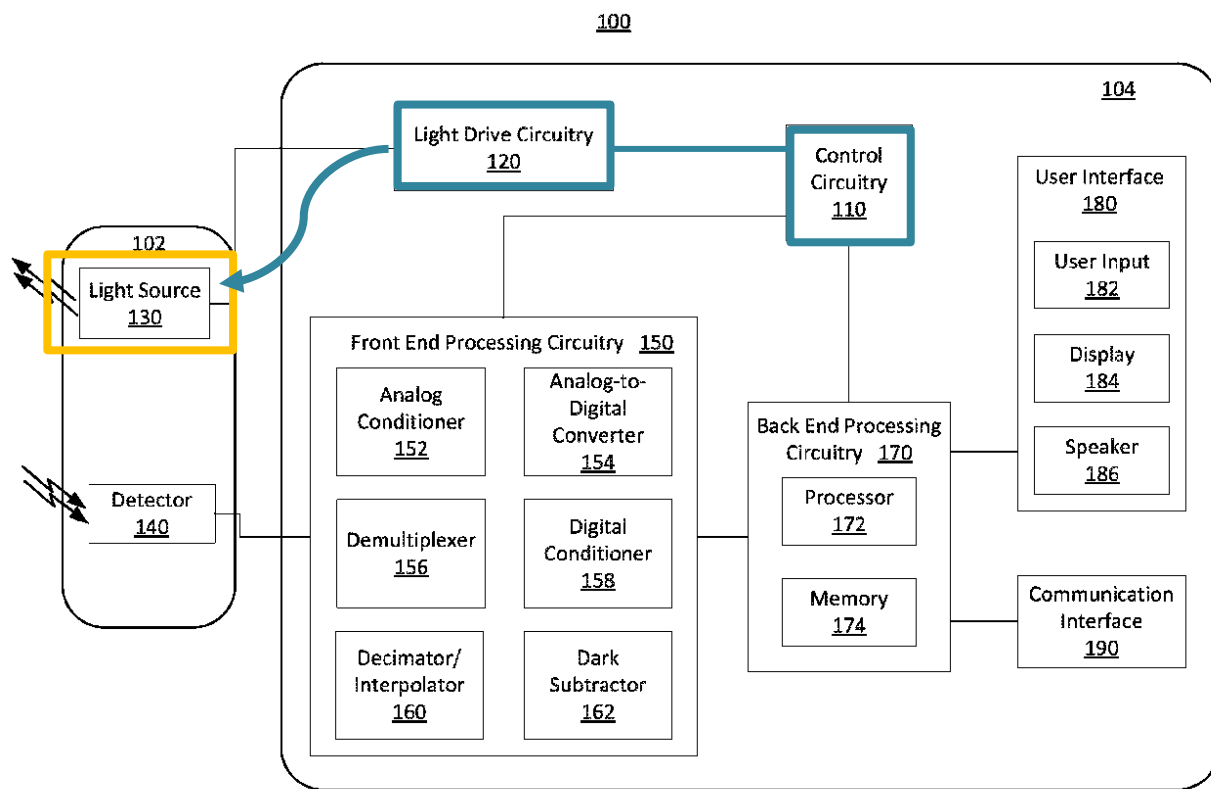


FIG. 1

* * *

129. I note that the Board found in the '533 IPR that Lisogurski discloses a “light source including a plurality of LEDs” and “[t]he light source configured to increase the signal-to-noise ratio by increasing a light intensity.” EX1008, 25–26. I understand this decision has been affirmed by the Federal Circuit. EX1009. I further note that the Board found in the '484 IPR that Lisogurski teaches “a light source comprising a plurality of semiconductor sources that are light emitting diodes, each of the light emitting diodes configured to generate an output optical light having one or more optical wavelengths” and “the wearable device configured to increase the signal-to-noise ratio ... by increasing light intensity of at least one of the plurality of

semiconductor sources from an initial light intensity,” and that Omni did not cross-appeal as to those findings, such that they were affirmed by the Federal Circuit. EX1011, 5, 23, 26–27; EX1012, n.2.

130. Accordingly, Lisogurski teaches or renders obvious 1[a].

c. Claim 1[b]: a measurement device configured to;

131. In my opinion, Lisogurski discloses claim 1[b]. As discussed above, Lisogurski teaches a measurement system (100/310, below) (*supra* §§ VIII.C.1.a (1[pre]))), which includes a sensor (102/312, depicted below). EX1027, Abstract; *id.*, Figs. 1, 3. Furthermore, Lisogurski states that the system “is directed towards power optimization in a medical **device**,” specifically an “oximeter” (or a “pulse oximeter”) that may “non-invasively **measure** the oxygen saturation of a patient’s blood.” EX1027, 3:43–4:3 (“An oximeter is a medical device that may determine the oxygen saturation of an analyzed tissue.”); *see also id.* at 4:6–20 (“An oximeter may include a light sensor that is placed at a site on a patient, typically a fingertip, toe, forehead, or earlobe, or in the case of a neonate, across a foot.”), 4:52–62 (describing a system that “may process data to determine physiological parameters”). The pulse oximeter can be battery powered and wirelessly connected to a monitor. EX1027, 17:54–59 (“In some embodiments, sensor unit 312 may be connected to monitor 314 as shown. Sensor unit 312 may be powered by an internal power source, e.g., a battery (not shown). Sensor unit 312 may draw power from

monitor 314. In another embodiment, the sensor may be wirelessly connected to monitor 314 (not shown).”).

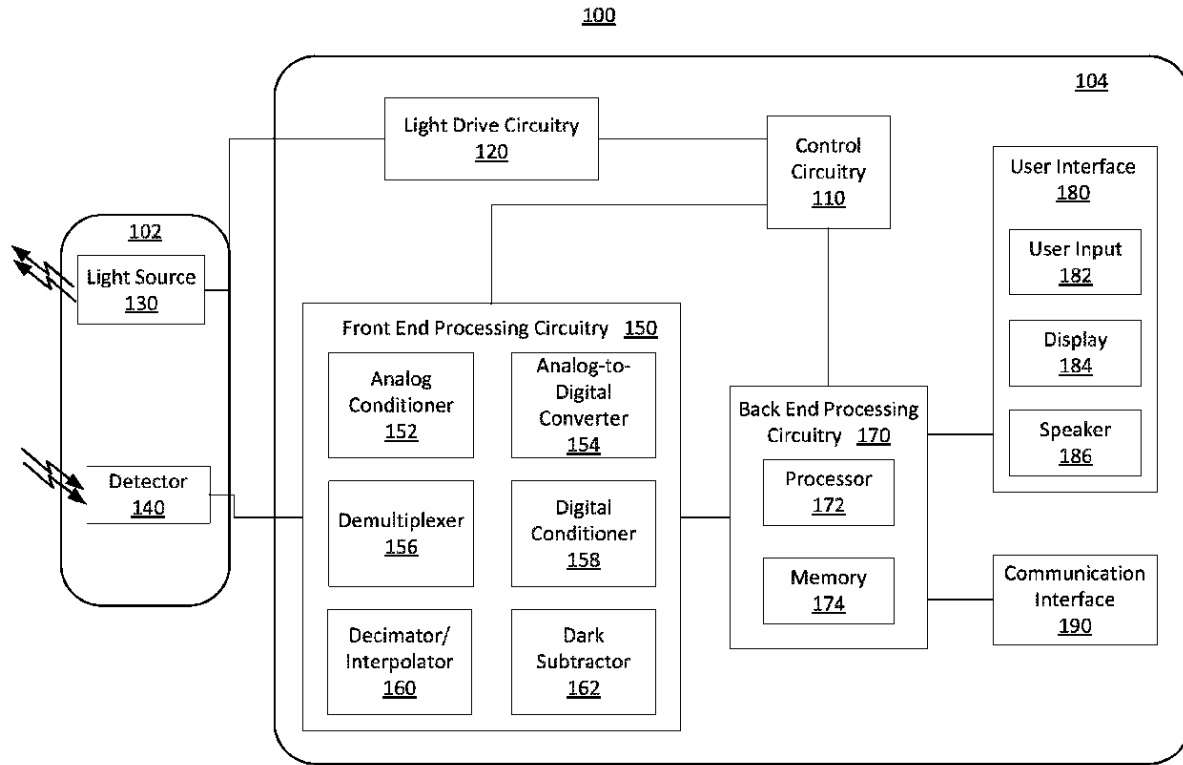


FIG. 1

EX1027, Fig. 1.

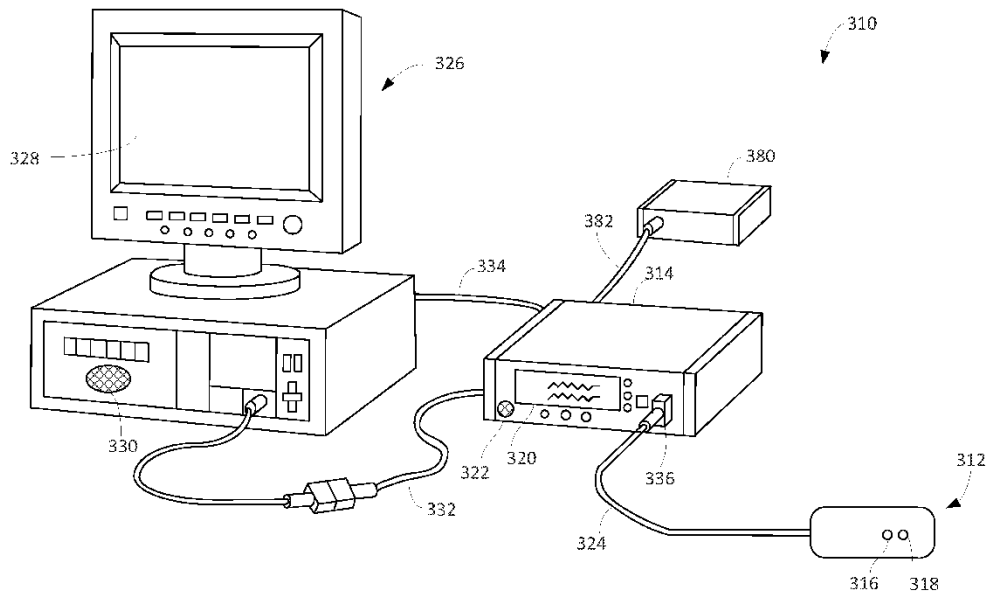


FIG. 3

EX1027, Fig. 3.

132. Accordingly, Lisogurski teaches or renders obvious 1[b]. I note that the Board found in the '533 IPR that Lisogurski discloses a limitation materially identical to 1[b]. EX1008, 25. I understand this decision has been affirmed by the Federal Circuit. EX1009. I further note that the Board found in the '484 IPR that Lisogurski teaches “a wearable device” “for measuring one or more physiological parameters,” and that Omni did not cross-appeal as to those findings, such that they were affirmed by the Federal Circuit. EX1011, 5, 23; EX1012, n.2.

d. Claim 1[c]: receive a portion of the output optical beam, and;

133. In my opinion, Lisogurski discloses claim 1[c]. As discussed, Lisogurski teaches a light source that includes conventional red and infrared LEDs

configured to emit a beam of light (the “output optical beam”) in a particular direction (*e.g.*, toward the subject’s tissue). *Supra* §§ VIII.C.1.b (1[a]). It is my opinion that a POSITA would have understood that a conventional LED semiconductor is conventionally encapsulated in a medium, typically glass, to protect the LED. The encapsulant may or may not be shaped in such a way to focus the light emitted by the LED, or, more specifically, to function as a lens in directing light toward the tissue. A POSITA would have understood that—regardless of whether the LEDs disclosed by Lisogurski include an encapsulant functioning as a lens—the beam emitted by the LED semiconductor would be captured, at least in part, by the encapsulant covering the LED as the beam is emitted and directed toward tissue. A POSITA would not have understood the LEDs in Lisogurski to teach an LED without an encapsulant, as such an approach would not likely operate reliably under real-world use. It is therefore my opinion that Lisogurski teaches a measurement device configured to receive at least a portion of the output optical beam.

134. Accordingly, Lisogurski teaches or renders obvious 1[c]. I note that the Board found in the ’533 IPR that Lisogurski, in view of Carlson, discloses “the wearable device comprising a plurality of lenses configured to receive a portion of the output optical beam,” a limitation nearly identical to 1[c]. EX1008, 7, 35–37. I understand this decision has been affirmed by the Federal Circuit. EX1009. I further

note that the Board found in the '484 IPR that Lisogurski (or Lisogurski in view of Carlson) teaches receiving a “lens output beam,” and that Omni did not cross-appeal as to that finding, such that it was affirmed by the Federal Circuit. EX1011, 23, 26–27; EX1012, n.2.

e. Claim 1[d]: deliver an analysis output beam to a sample;

135. In my opinion, Lisogurski alone, or Lisogurski in combination with Carlson, discloses claim 1[d]. As I discussed above, Lisogurski is directed to a measurement device that includes semiconductor sources (LEDs) that emit beams of light and direct that light toward the tissue. *Supra* VIII.C.1.a–d (1[pre]–[d]). It is my opinion that a POSITA would have understood LEDs, including those taught by Lisogurski, conventionally are surrounded by an encapsulant or cover. *Supra* VIII.C.1.d (1[c]). A POSITA would thus have understood that the encapsulant covering an LED receives at least a portion of the emitted optical output beam from the LED and delivers it to the subject’s tissue as a second (“analysis output”) beam. Thus, it is my opinion that a POSITA would have understood that Lisogurski alone teaches or renders obvious 1[d].

136. It is further my opinion that, to the extent not disclosed or rendered obvious by Lisogurski alone, Lisogurski in view of Carlson would render 1[d] obvious. Carlson teaches using “at least one beam shaping optical element to direct the emitted light” from a semiconductor and deliver it to a sample, for example:

- “The posed problem is solved by means of a configuration/method according to the invention. Proposed is a configuration for monitoring which comprises at least one of the following components:

at least one measuring sensor for the acquisition of the medical data, such as the state of the cardiovascular and pulmonary system, as e.g. pulsation frequency, oxygen saturation of blood, breathing frequency, etc. of a human being or an animal, comprising at least one light source which can emit light at least at two wavelengths, as well as at least one light receiver for determining the light transmitted through a tissue portion of the person or the animal;

at least one beam shaping optical element to direct the emitted light to a human or animal tissue and the light receiver in order to increase the optical signal power.

EX1028, [0011]–[0013].

- “**The basic idea therefore is to use a beam-shaping element, such as e.g. diffractive or refractive lenses, to direct the emitted optical radiation of, e.g., the LED light source into the human or animal tissue** and the photon detecting element in order to increase the optical signal power, detected by the pulsoximeter sensor, and thus increasing the

Signal/Noise—and signal/Background ratio. The increase of the S/B ratio is estimated e.g. to a factor 5.”

EX1028, [0014].

- “Furthermore, the above mentioned problem is solved according to the invention by means of methods according to the invention. Proposed is a method for monitoring e.g. pulsation frequency, oxygen saturation in blood or breathing frequency, which comprises at least one of the following steps:

measuring or monitoring medically relevant data of a person or an animal, such as in particular data, which describe the cardiovascular and pulmonary function and/or contain data regarding blood values or blood composition with the use of at least one measuring sensor, which sensor comprises at **least one light source which can emit light at least at two wavelengths:**

direct the emitted light or optical radiation, respectively, by using a beam shaping element, such as e.g. a diffractive or refractive lens to the human or animal tissue;

receiving and detecting the emitted and shaped light with at least one light receiving element for determining the light transmitted through the tissue portion of the person or the animal.”

EX1028, [0022]–[0025].

137. Figure 4 of Carlson illustrates the role of the **“beam shaping element” (21)** in receiving the emitted light beams from **the LEDs (15)** (the “at least a portion of the **optical output beam**”) and delivering those **light beams (12)** to **sample (2)**.

EX1028, [0062], Fig. 4. Specifically, Carlson teaches:

- “Therefore, it is proposed, as shown in FIG. 4, to use **beam shaping optics 20** to direct the emitted optical radiation 8 emitted from the **two LEDs 15** to the middle of the earlobe. As it is shown clearly in FIG. 4, using the **beam shaping optics 21**, the **two initial light beams 8** are guided **in form of bundled beams 12** to a **relatively small area within the middle ear 2**. By using the **beam shaping optics 21**, of course the influence of environmental light or noise, respectively, can be reduced substantially by increasing the S/B ratio. First o[f] all, the light beam is bundled and, in addition, the optical signal power can be increased.”

EX1028, [0054].

- “According to the preferred embodiment of the invention, the various described optical and geometric means, such as **the beam shaping element as shown in FIG. 4**, the wavelength filters, the sensor architecture, and the mentioned baffles, can be combined as shown in principle and perspective view in FIG. 6c. Again, **light is emitted from**

the two LEDs 15 and is shaped by the two beam shaping elements or lenses 21 to be guided as beams 12 through the earlobe 2. After the earlobe, the double pass filter 33 is arranged to guarantee that only light in the range of approximately 660 nm and in the range of approximately 890 nm is transmitted through the filter. After the filter, any stray light, entered the sensor e.g. through the earlobe from the side, will be trapped within the baffles 37 which are arranged in circumferential direction. Finally, a photo detecting element 35 is arranged with specific spectrum sensitivity.”

EX1028, [0062].

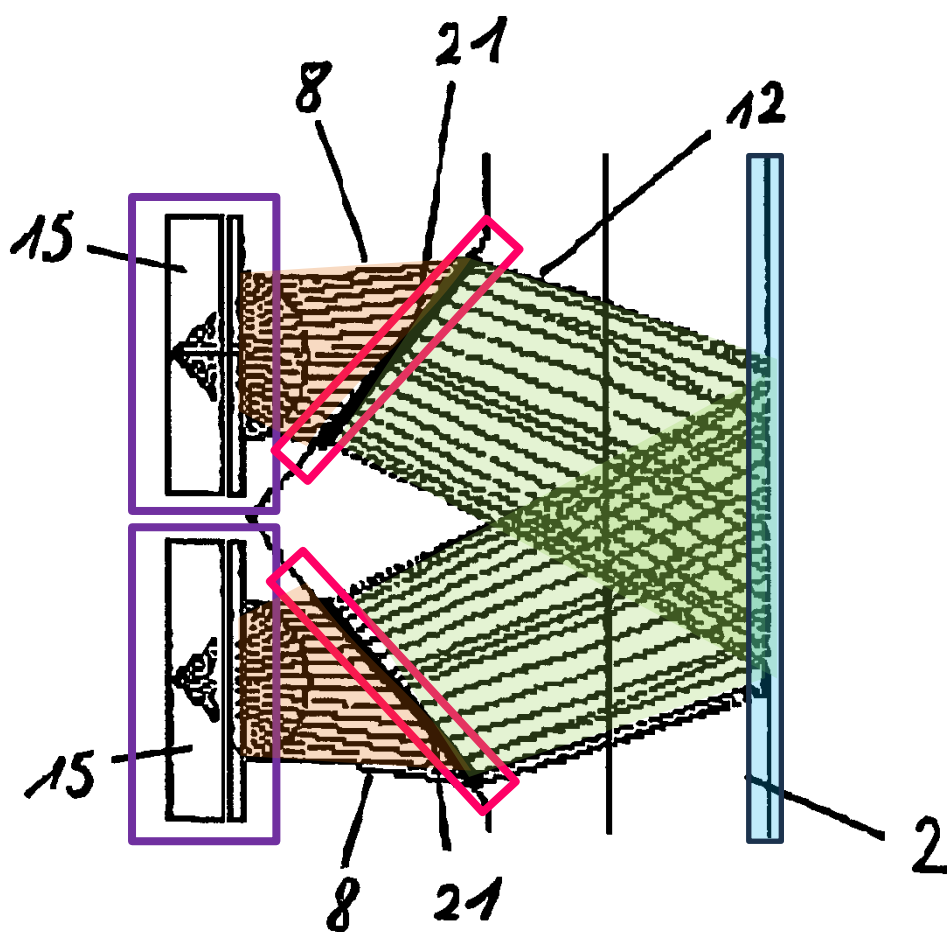


Figure 4

EX1028, Fig. 4. A POSITA would have understood from these disclosures that Carlson teaches a beam shaping element that receives a portion of an output optical beam (illustrated in **orange** above) from the semiconductor sources (LEDs), and focuses the output optical beam toward the tissue, where it is delivered as an analysis output beam (illustrated in **green** above).

138. It is my opinion that a POSITA would have found it obvious to include a “beam shaping element” disclosed by Carlson to modify the output optical beam

from the conventional semiconductor LEDs taught by Lisogurski, such that the emitted beam from those LEDs would be delivered to the sample as an analysis output beam. For example, Carlson explains that including a beam shaping element improves SNR, which is a stated goal of Lisogurski. *Supra* §§VIII.B.1; EX1027, 9:49–60, 13:60–14:10, 14:40–55, 37:6–20. A POSITA would have been motivated to include the beam shaping element from Carlson in Lisogurski’s system based on their shared objective of improving the SNR in a portable pulse oximetry system, and would have found such a modification to be routine. Indeed, as mentioned above, beam-shaping elements (like lenses) are “basic building blocks” of conventional optical measurement systems. *Supra* §§V. Therefore, a POSITA would have had a reasonable expectation of success implementing the beam shaping element disclosed by Carlson into Lisogurski.

139. Accordingly, Lisogurski, or Lisogurski in view of Carlson, teaches or renders obvious 1[d]. I note that the Board found in the ’533 IPR that Lisogurski, alone or in view of Carlson, discloses “a wearable measurement device ... configured ... to deliver an analysis output beam to a sample.” EX1008, 7, 35–37. I understand this decision has been affirmed by the Federal Circuit. EX1009. I further note that the Board found in the ’484 IPR that Lisogurski (or Lisogurski in view of Carlson) teaches “direct[ing] a lens output beam to tissue,” and that Omni

did not cross-appeal as to that finding, such that it was affirmed by the Federal Circuit. EX1011, 5, 23, 26–27; EX1012, n.2.

f. Claim 1[e]: a receiver configured to;

140. In my opinion, Lisogurski discloses claim 1[e]. Lisogurski teaches:

- “In some embodiments, **detector 140** may be configured to **detect the intensity of light at the Red and IR wavelengths.**” Lisogurski, 11:9–10.

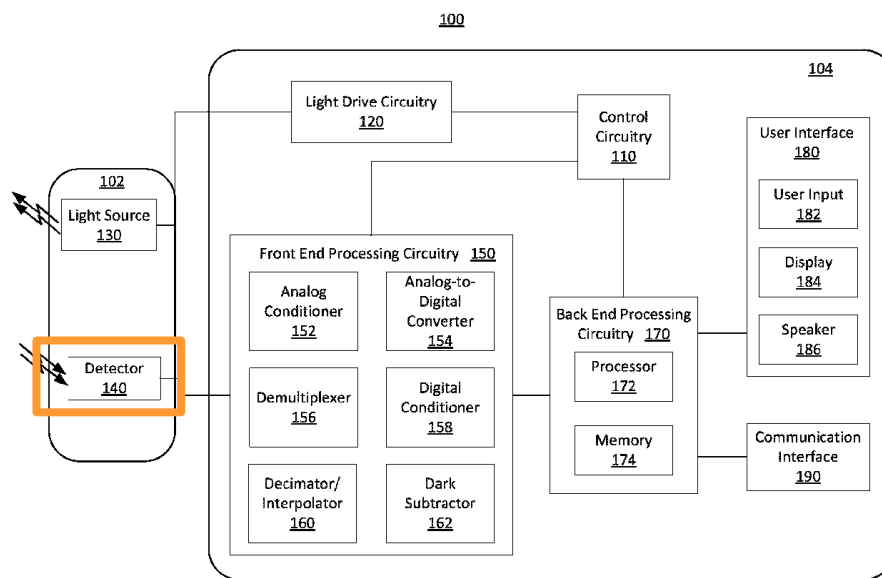


FIG. 1

EX1027, Fig. 1 (annotated).

- “One or more **detector 318** may also be provided in sensor unit 312 for detecting the light that is reflected by or has traveled through the subject’s tissue.” EX1027, 17:39–42.

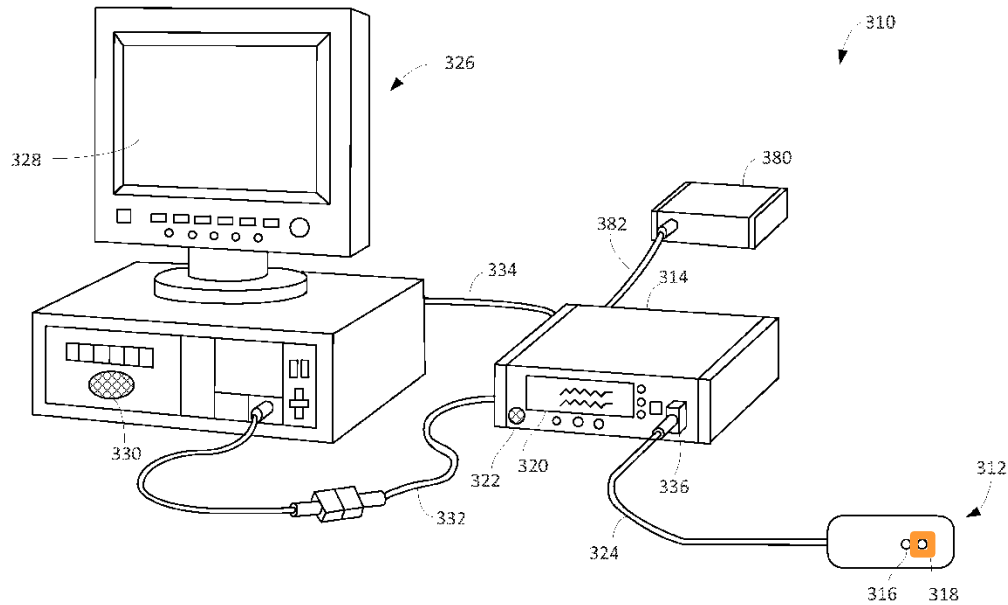


FIG. 3

EX1027, Fig. 3 (annotated).

- “Detector 140 may be chosen to be specifically sensitive to the chosen targeted energy spectrum of light source 130. In some embodiments, detector 140 may be configured to detect the intensity of light at the Red and IR wavelengths. In some embodiments, an array of sensors may be used and each sensor in the array may be configured to detect an intensity of a single wavelength. **In operation, light may enter detector 140 after passing through the subject's tissue. Detector 140 may convert the intensity of the received light into an electrical signal. The light intensity may be directly related to the absorbance and/or reflectance of light in the tissue. That is, when more light at a certain wavelength is absorbed or reflected, less light of that wavelength is received from**

- the tissue by **detector 140**. After converting the received light to an electrical signal, **detector 140** may send the detection signal to monitor 104, where **the detection signal may be processed and physiological parameters may be determined (e.g., based on the absorption of the Red and IR wavelengths in the subject's tissue)**. In some embodiments, the detection signal may be preprocessed by sensor 102 before being transmitted to monitor 104.” EX1027, 11:6–27.
- “Referring back to FIG. 1, **front end processing circuitry 150** may receive a detection signal from **detector 140** and provide one or more processed signals to back end processing circuitry 170. The term “detection signal,” as used herein, may refer to any of the signals generated within **front end processing circuitry 150** as it processes the output signal of **detector 140**. **Front end processing circuitry 150** may perform various analog and digital processing of the detector signal. One suitable detector signal that may be received by **front end processing circuitry 150** is shown in FIG. 2B.” EX1027, 12:42–50.
 - “In step 410, the system may determine a physiological parameter using information from the attenuated photonic signals. The physiological parameter may be determined using any suitable hardware technique, software technique, or combination thereof. **In some**

embodiments, processing equipment remote to the system may be used to determine physiological parameters. The system may display the determined physiological parameter using a local display (e.g., display 320 of FIG. 3 or display 328 of FIG. 3), display them on a remote display, publish the data to a server or website, make the parameters available to a user by any other suitable technique, or any combination thereof.” EX1027, 20:49–60.

141. Lisogurski therefore teaches that its **detectors** receive “light that is reflected by or has traveled through the subject’s tissue.” EX1027, 17:39–42. Lisogurski further teaches that the detector(s) “convert[s] the intensity of the received light into an electrical signal.” EX1027, 11:14–16. Lisogurski’s detectors are connected via “**front-end processing circuitry**,” which may “**receive** a detection signal from **detector 140** and provide one or more processed signals to back end processing signal 170.” EX1027, 12:42–45.

142. A POSITA would have understood the **detector** and the **front end processing circuitry** in Lisogurski to comprise the “receiver” that is configured to perform the functions described below. *Infra* §§ VIII.C.1.g–k (cl. 1[f]–[j]). Nevertheless, because the **front end processing circuitry** in Lisogurski is depicted in monitor 104 (which, as shown below, is depicted as a separate device from the **detector** in the wearable sensor), it is further my opinion that if Lisogurski alone

does not teach a “receiver” comprising detector(s) and processing circuitry, this limitation would have been an obvious modification to Lisogurski. Specifically, a POSITA would have considered it obvious to integrate **the front-end processing circuitry** (150) and **detector (140)** in the same device in the manner shown below. This is particularly evident in light of Lisogurski’s teachings that the detector may “preprocess[]” the electrical signal before sending it to the monitor and that the sensor may be a separate device wirelessly connected to the monitor. EX1027, 11:20–25, 17:55-59 (“Sensor unit 312 may be powered by an internal power source, e.g., a battery (not shown). . . . [T]he sensor may be wirelessly connected to monitor 314 (not shown).”), 18:23–25 (“In some embodiments, a wireless transmission device (not shown) or the like may be used instead of or in addition to cable 324); *see also id.*, 17:32–35. Further, a POSITA would have considered this modification obvious in view of existing wearable sensors (e.g., Nonin Onyx 9500 finger clip sensors) that had this functionality and existed prior to the purported priority date of the ’304 patent.

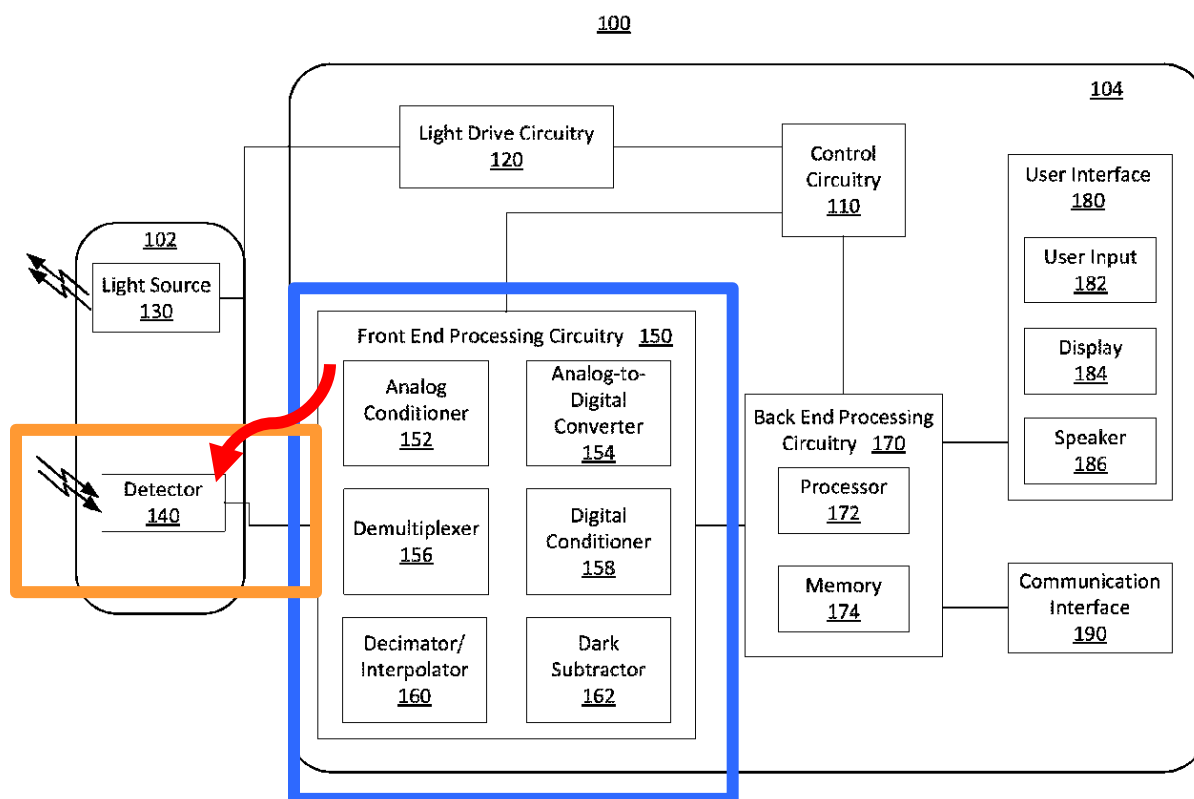


FIG. 1

EX1027, Fig. 1 (annotated).

143. A POSITA would have considered it obvious and routine to integrate **front-end processing circuitry 150** into the **detector** and would have been motivated to make such a modification. It is my opinion that a POSITA would have understood the functional relationship between the detector and the monitor; specifically, the signal received by the detector would preferably need to be converted from analog to digital form in order to be wirelessly transmitted to the monitor. A POSITA would have understood, and indeed, Lisogurski teaches, that the front end processing circuitry in Lisogurski can perform analog-to-digital conversion and other initial signal processing. See EX1027, 12:42–50 (**Front end**

processing circuitry 150 may perform various analog and digital processing of the detector signal.”).

144. Thus, in order to satisfy Lisogurski’s disclosed embodiment of wirelessly connecting the monitor to the detector, a POSITA would have understood that the analog-to-digital conversion processing circuitry would need to be integrated into the sensor where the signal is initially captured/received by the detector/receiver. A POSITA would have understood that adding this additional necessary circuitry in the sensor would not affect the device’s operation, because such circuitry is small and power efficient, and would have been straightforward to integrate into the wearable sensor. Furthermore, a POSITA would have understood this variation to be consistent with Lisogurski’s disclosure that “[i]n some embodiments the functionality of some of the components may be combined in a single component... [or] the functionality of some of the components of monitor 104... may be divided over multiple components.” EX1027, 16:2–9. A POSITA would have been motivated to make this routine adjustment to Lisogurski’s optical sensor based on the market trends toward miniaturized, power-efficient electronics used for health and fitness applications that I discussed above (*supra* § V.B), rather than implementing Lisogurski with a wired connection between sensor and monitor.

145. Thus, in my opinion, a POSITA would have understood the “detector” and the “front end processing circuitry” taught by Lisogurski to be a “receiver”

configured to receive light reflected by or transmitted through a sample, and further configured to perform particular functions, described further below. *Infra* §§ VIII.C.1.g–k (1[f]–[j]).

146. Accordingly, Lisogurski teaches or renders obvious 1[e]. I also note that the Board found in the '533 IPR that Lisogurski (modified in the way I depicted above to combine the front end processing circuitry with the sensor) teaches a limitation identical to 1[e]. EX1008, 7, 37–39. I understand this decision has been affirmed by the Federal Circuit. EX1009.

g. Claim 1[f]: receive and process at least a portion of the analysis output beam reflected or transmitted from the sample;

147. In my opinion, Lisogurski teaches 1[f]. As I discussed above, Lisogurski includes a sensor unit with a detector that detects “light that is reflected by or has traveled through the subject’s tissue,” which a POSITA would have understood to correspond to “receiv[ing]” an analysis output beam reflected or transmitted from the sample, as well as front end processing circuitry for processing the electrical signal from the received light. *Supra* §§ VIII.C.1.f ([1[e]); EX1027, 17:39–42.

148. Lisogurski further teaches:

- “Detector 140 may **convert the intensity of the received light into an electrical signal**. The light intensity may be **directly related to the**

absorbance and/or reflectance of light in the tissue.” EX1027, 11:14–17.

- “After converting the received light into an electrical signal, detector 140 may send the detection signal to monitor 104, where the detection signal may be processed and physiological parameters may be determined (e.g., based on the absorption of Red and IR wavelengths in the subject’s tissue). In some embodiments, the **detection signal may be preprocessed by sensor 102** before being transmitted to monitor 104.” EX1027, 11:20–25.

149. It is therefore my opinion that Lisogurski teaches a receiver that receives at least a portion of the analysis output beam from tissue and processes that portion of the analysis beam, by *e.g.*, “convert[ing] the intensity of the received light into an electrical signal” and, in some instances, “preprocess[ing]” the electrical signal to determine physiological parameters before transmitting the detected signal to the monitor. EX1027, 11:14–25.

150. Accordingly, Lisogurski teaches or renders obvious 1[f]. I also note that the Board found in the ’533 IPR that Lisogurski teaches a limitation identical to 1[f]. EX1008, 7, 37–39. I understand this decision has been affirmed by the Federal Circuit. EX1009.

- h. Claim 1[g]: generate an output signal representing at least in part a non-invasive measurement on blood contained within the sample;**

151. In my opinion, Lisogurski teaches 1[g]. As I discussed previously, Lisogurski teaches a receiver with one or more detectors. *Supra* §§ VIII.C.1.f–g (1[e]–[f]). Lisogurski teaches:

- “Detector 140 may be chosen to be specifically sensitive to the chosen targeted energy spectrum of light source 130. In some embodiments, detector 140 may be configured to detect the intensity of light at the Red and IR wavelengths. In some embodiments, an array of sensors may be used and each sensor in the array may be configured to detect an intensity of a single wavelength. **In operation, light may enter detector 140 after passing through the subject's tissue. Detector 140 may convert the intensity of the received light into an electrical signal. The light intensity may be directly related to the absorbance and/or reflectance of light in the tissue. That is, when more light at a certain wavelength is absorbed or reflected, less light of that wavelength is received from the tissue by detector 140.** After converting the received light to an electrical signal, detector 140 may send the detection signal to monitor 104, where **the detection signal may be processed and physiological parameters may be determined (e.g., based on the absorption of the Red and IR wavelengths in the subject's tissue).** In some embodiments,

the detection signal may be preprocessed by sensor 102 before being transmitted to monitor 104.” EX1027, 11:6–27.

- “Referring back to FIG. 1, **front end processing circuitry 150** may **receive a detection signal from detector 140** and provide one or more processed signals to back end processing circuitry 170. **The term “detection signal,” as used herein, may refer to any of the signals generated within front end processing circuitry 150 as it processes the output signal of detector 140.** Front end processing circuitry 150 may perform various analog and digital processing of the detector signal. One suitable detector signal that may be received by front end processing circuitry 150 is shown in FIG. 2B.” EX1027, 12:42–51.
- “One or more detector 318 may be provided in sensor unit 312 for **detecting the light that is reflected by or has traveled through the subject’s tissue.**” EX1027, 17:39–42.
- “**In step 410, the system may determine a physiological parameter using information from the attenuated photonic signals.** The physiological parameter may be determined using any suitable hardware technique, software technique, or combination thereof. **In some embodiments, processing equipment remote to the system may be used to determine physiological parameters.** The system may display the

determined **physiological parameter** using a local display (e.g., display 320 of FIG. 3 or display 328 of FIG. 3), display them on a remote display, publish the data to a server or website, make the parameters available to a user by any other suitable technique, or any combination thereof.” EX1027, 20:49–60.

152. Lisogurski therefore teaches that its detectors receive “light that is reflected by or has traveled through the subject’s tissue,” (EX1027, 17:39–42), which, as I discussed earlier, represents a non-invasive measurement of blood within a sample including, *e.g.*, blood oxygen saturation. *Supra* VIII.C.1.a–d (1[pre]–[d]). Lisogurski further teaches that the detector “convert[s] the intensity of the received light into an electrical signal,” which a POSITA would have understood to mean “generat[ing] an output signal.” EX1027, 11:6–27. As discussed, Lisogurski’s detectors are connected via “front-end processing circuitry,” which may “receive a detection signal from detector 140 and provide one or more processed signals to back end processing signal 170.” EX1027, 12:42–45. “After converting the received light to an electrical signal,” Lisogurski’s detectors may send the “detection signal to monitor 104,” and monitor 140 can “determine[.]” “physiological parameters” based on the received signal (“output signal”) from the detector(s). EX1027, 11:20–27.

153. Accordingly, Lisogurski teaches or renders obvious 1[g]. I note that the Board found in the '533 IPR that Lisogurski discloses a receiver configured to “generate[] an output signal” and that Lisogurski further teaches a monitor that receives the output signal and “determines one or more physiological parameters based on the received signals.” EX1008, 7, 37–39, 41 (alterations omitted). I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand similar determinations were made by the Board in the '484 IPR and that Omni did not cross-appeal those decisions, which were therefore affirmed by the Federal Circuit. EX1011, 26–27; EX1012, n.2.

i. Claim 1[h]: synchronize to the light source,;

154. In my opinion, Lisogurski discloses or renders obvious claim 1[h]. As I discussed above, Lisogurski discloses a detector that generates an “output signal” by “converting the intensity of the received light [from a subject’s tissue into an electrical signal.” EX1027, 17:39–42; *supra* §§ VIII.C.1.f–h (1[e]–[g]). Lisogurski also teaches that the electrical signal may be pre-processed by the sensor before being transmitted to the monitor, or it may be transmitted directly to the monitor for processing. *Id.* As I discussed (*supra* § VIII.C.1.f), the detector is connected to “front end processing circuitry” in the monitor that receives the “detection signal from detector 140 and provide[s] one or more processed signals to back end processing circuitry 170.” EX1027, 12:42–45. As I discussed above, a POSITA

would have found it obvious to integrate the front end processing circuitry into the detector such that they comprise one single component/receiver. *Supra* § VIII.C.1.f (1[e]). A POSITA would also have found it obvious to integrate the light drive circuitry and the control circuitry into the sensor unit, for the reasons I discussed above. *Supra* § VII.C.1.b.iii (1[a]).

155. Lisogurski further teaches that the front end processing circuitry is synchronized with the light drive circuitry that I discussed above (specifically, the light drive circuitry that controls the modulation of certain parameters of the LEDs). *Supra* § VIII.C.1.b (1[a]); EX1027, 11:33–49 (“**front end processing circuitry 150** may... **operate synchronously with light drive circuitry 120**. For example, front end processing circuitry 150 may **synchronize** the operation of an analog-to-digital converter and a demultiplexer with the light drive signal based on the timing control signals.”). Thus, a POSITA would have understood that the receiver in Lisogurski is “synchronized” to the light source in Lisogurski, because the received signal is converted into an electrical signal that affects the processing of the light drive circuitry.

156. Accordingly, Lisogurski teaches or renders obvious 1[h]. I note that the Board found in the ’533 IPR that Lisogurski, or Lisogurski in view of Carlson, teaches a limitation identical to 1[h]. EX1008, 7, 37–39, 41. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand similar

determinations were made by the Board in the '484 IPR and that Omni did not cross-appeal those decisions, which were therefore affirmed by the Federal Circuit. EX1011, 24–27; EX1012, n.2.

j. Claim 1[i]: capture light while the semiconductor sources are off and convert the captured light into a first signal,;

157. In my opinion, Lisogurski discloses claim 1[i]. Lisogurski teaches a dark subtraction technique to “remove ambient and background signals.” EX1027, 6:7–19. Specifically, Lisogurski teaches:

- “In some embodiments, a technique to remove ambient and background signals may be used in addition to or in place of a power saving light modulation scheme. In a drive cycle modulation technique, the system may cycle light output at a rate significantly greater than the cardiac cycle. For example, a drive cycle modulation cycle may include the system turning on a first light source, followed by a “dark” period, followed by a second light source, followed by a “dark” period. **The system may measure the ambient light detected by the detector during the “dark” period and then subtract this ambient contribution from the signals received during the first and second “on” periods.**” EX1027, 6:7–19.
- “Detector 140 may convert the intensity of the received light into an electrical signal.” EX1027, 11:14–16.

- “FIG. 2B shows an illustrative plot of detector signal 214 that may be generated by a sensor in accordance with some embodiments of the present disclosure. The peaks of detector current waveform 214 may represent current signals provided by a detector, such as detector 140 of FIG. 1, when light is being emitted from a light source. The amplitude of detector current waveform 214 may be proportional to the light incident upon the detector. The peaks of detector current waveform 214 may be synchronous with light “on” periods driving one or more emitters of a light source, such as light source 130 of FIG. 1. For example, detector current waveform 214 may be generated in response to a light source being driven by the light drive signal of FIG. 2A. **The valleys of detector current waveform 214 may be synchronous with periods of time during which no light is being emitted by the light source. While no light is being emitted by a light source during the valleys, detector current waveform 214 may not fall all of the way to zero. Rather, dark current 222 may be present in the detector waveform. Since dark current 222 may interfere with accurate determinations of physiological characteristics, dark current 222 may be removed as discussed in more detail below.**” EX1027, 12:52–13:6.

- “Dark subtractor 162 may operate on the digital signal. In some embodiments, dark subtractor 162 may subtract dark values from the Red and IR components to generate adjusted Red and IR signals. **For example, dark subtractor 162 may determine a subtraction amount from the dark signal portion of the detection signal and subtract it from the peak portion of the detection signal in order to reduce the effect of the dark signal on the peak. For example, in reference to FIG. 2A, a detection signal peak corresponding to red “on” period 202 may be adjusted by determining the amount of dark signal during the “off” period 220 preceding red “on” period 202. The dark signal amount determined in this manner may be subtracted from the detector peak corresponding to red “on” period 202. Alternatively, the “off” period 220 after red “on” period 202 may be used to correct red “on” period 202 rather than the “off” period 220 preceding it. Additionally, an average of the “off” periods 220 before and after red “on” period 202 may be used.”** EX1027, 13:60–14:10.
- “Demultiplexer 156 may operate on detector current waveform 214 of Fig. 2B to generate a Red signal, an IR signal, **a first dark signal (e.g., corresponding to the dark component that occurs immediately after the Red component), and a second dark signal (e.g., corresponding to**

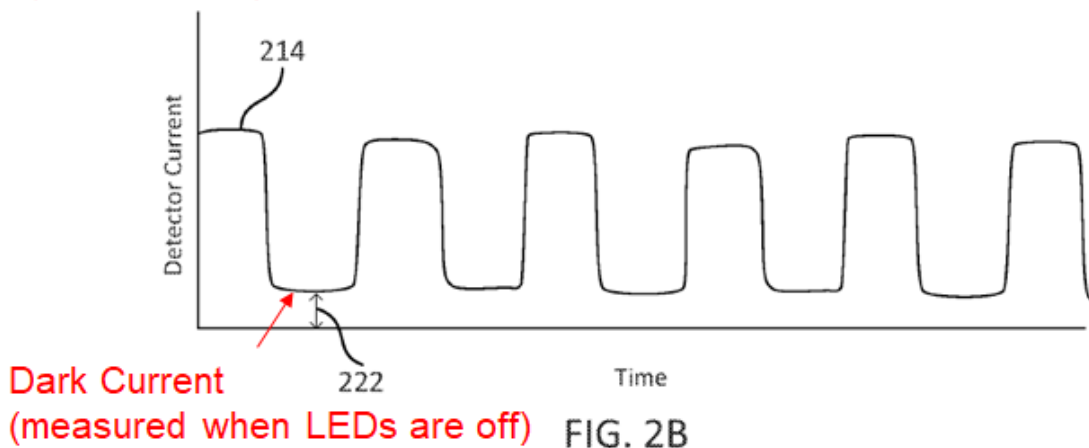
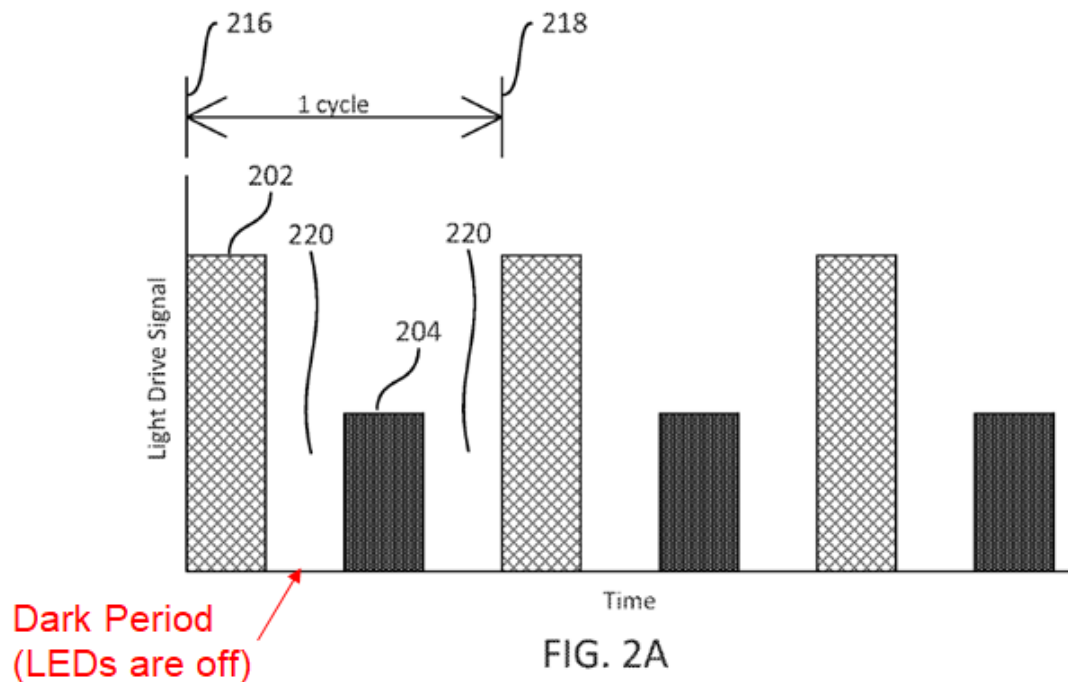
the dark component that occurs immediately after the IR component).” EX1027, 13:35–41.

- “Region 256 of plot 250 indicates an interval of the timing diagram where both red light modulation 252 and IR light modulation 254 are in an “on” portion of the cardiac cycle modulation. Plot 270 shows an illustrative portion of region 256, where the system is employing a cardiac cycle modulation in addition to the drive cycle modulation. Plot 250 may include a drive cycle modulation technique with a period of time interval 272. The time scale of plot 270 may be significantly shorter than the time scale of plot 250, such that time interval 272 is significantly shorter than time interval 260. For example, time interval 260 (i.e., the period of the cardiac cycle modulation) may be on the order of 1 second, while time interval 272 (i.e., the period of the drive cycle modulation) may be on the order of 1 ms. Time interval 272 may include a sequence of red “on” portion 274, a first “off” portion 276, IR “on” portion 278, and a second “off” portion 280. **The first “off” portion 276 and second “off” portion 280 may be used to determine the level of ambient light, noise, dark current, other suitable signals, or any combination thereof. The system may subtract the background or dark level from the levels**

received during red “on” portion 274 and IR “on” period 278.”

EX1027, 16:33–54.

158. A POSITA would have understood from the above disclosures in Lisogurski that Lisogurski teaches that its “system may measure the ambient light detected by the detector” by generating a signal corresponding to the captured light during a “dark period” (a “dark signal”). EX1027, 6:12–19, 13:67–14:6, 13:35–41. Specifically, Lisogurski measures the current that is captured by the detector during a period when the semiconductor sources are turned “off.” EX1027, 6:12–19, 13:67–14:6, 13:35–41. After measuring this current (which corresponds to the amount of ambient light), the demultiplexer in Lisogurski’s front end processing circuitry “converts the intensity of the received light into an electrical signal” EX1027, 11:14–16, 12:59–13:6, 13:35–41. This process of generating a dark signal 222 (also called dark current 222) by capturing the ambient light when the semiconductor sources are turned “off” is illustrated in Figures 2A and 2B of Lisogurski, annotated using figures from the ’484 IPR:



EX1027, Figs. 2A, 2B (annotated in view of EX1021, pp 54–56); *see also*, EX1027, 12:64–13:6, 13:67–14:6.

159. Accordingly, Lisogurski teaches or renders obvious 1[i]. I note that the Board found in the '484 IPR that Lisogurski “generates a first signal responsive to light while the LEDs are off” and that Omni did not cross-appeal that decision, which was therefore affirmed by the Federal Circuit. EX1011, 7, 43–44; EX1009, n.2.

- k. **Claim 1[j]: capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a part of the at least a portion of the analysis output beam reflected or transmitted from the sample, and**

160. In my opinion, Lisogurski discloses claim 1[j]. As I discussed above, Lisogurski teaches a dark subtraction technique to “remove ambient and background signals.” EX1027, 6:7–19; *supra* § VIII.C.1.j (1[i]). Specifically, Lisogurski teaches:

- “In some embodiments, a technique to remove ambient and background signals may be used in addition to or in place of a power saving light modulation scheme. In a drive cycle modulation technique, the system may cycle light output at a rate significantly greater than the cardiac cycle. For example, a drive cycle modulation cycle may include **the system turning on a first light source, followed by a “dark” period, followed by a second light source, followed by a “dark” period. The system may measure the ambient light detected by the detector during the “dark” period and then subtract this ambient contribution from the signals received during the first and second “on” periods.**” EX1027, 6:7–19.
- “Detector 140 **may convert the intensity of the received light into an electrical signal.**” EX1027, 11:14–16.

- “FIG. 2B shows an illustrative plot of detector signal 214 that may be generated by a sensor in accordance with some embodiments of the present disclosure. **The peaks of detector current waveform 214 may represent current signals provided by a detector, such as detector 140 of FIG. 1, when light is being emitted from a light source. The amplitude of detector current waveform 214 may be proportional to the light incident upon the detector. The peaks of detector current waveform 214 may be synchronous with light “on” periods driving one or more emitters of a light source, such as light source 130 of FIG. 1. For example, detector current waveform 214 may be generated in response to a light source being driven by the light drive signal of FIG. 2A. The valleys of detector current waveform 214 may be synchronous with periods of time during which no light is being emitted by the light source. While no light is being emitted by a light source during the valleys, detector current waveform 214 may not fall all of the way to zero. Rather, dark current 222 may be present in the detector waveform. Since dark current 222 may interfere with accurate determinations of physiological characteristics, dark current 222 may be removed as discussed in more detail below.**” EX1027, 12:52–13:6.

- “Dark subtractor 162 may operate on the digital signal. In some embodiments, dark subtractor 162 may subtract dark values from the Red and IR components to generate adjusted Red and IR signals. **For example, dark subtractor 162 may determine a subtraction amount from the dark signal portion of the detection signal and subtract it from the peak portion of the detection signal in order to reduce the effect of the dark signal on the peak. For example, in reference to FIG. 2A, a detection signal peak corresponding to red “on” period 202 may be adjusted by determining the amount of dark signal during the “off” period 220 preceding red “on” period 202. The dark signal amount determined in this manner may be subtracted from the detector peak corresponding to red “on” period 202. Alternatively, the “off” period 220 after red “on” period 202 may be used to correct red “on” period 202 rather than the “off” period 220 preceding it. Additionally, an average of the “off” periods 220 before and after red “on” period 202 may be used.**”
EX1027, 13:60–14:10.

- **“Demultiplexer 156 may operate on detector current waveform 214 of Fig. 2B to generate a Red signal, an IR signal, a first dark signal (e.g., corresponding to the dark component that occurs immediately after the Red component), and a second dark signal (e.g., corresponding to the dark**

component that occurs immediately after the IR component).” EX1027, 13:35–41.

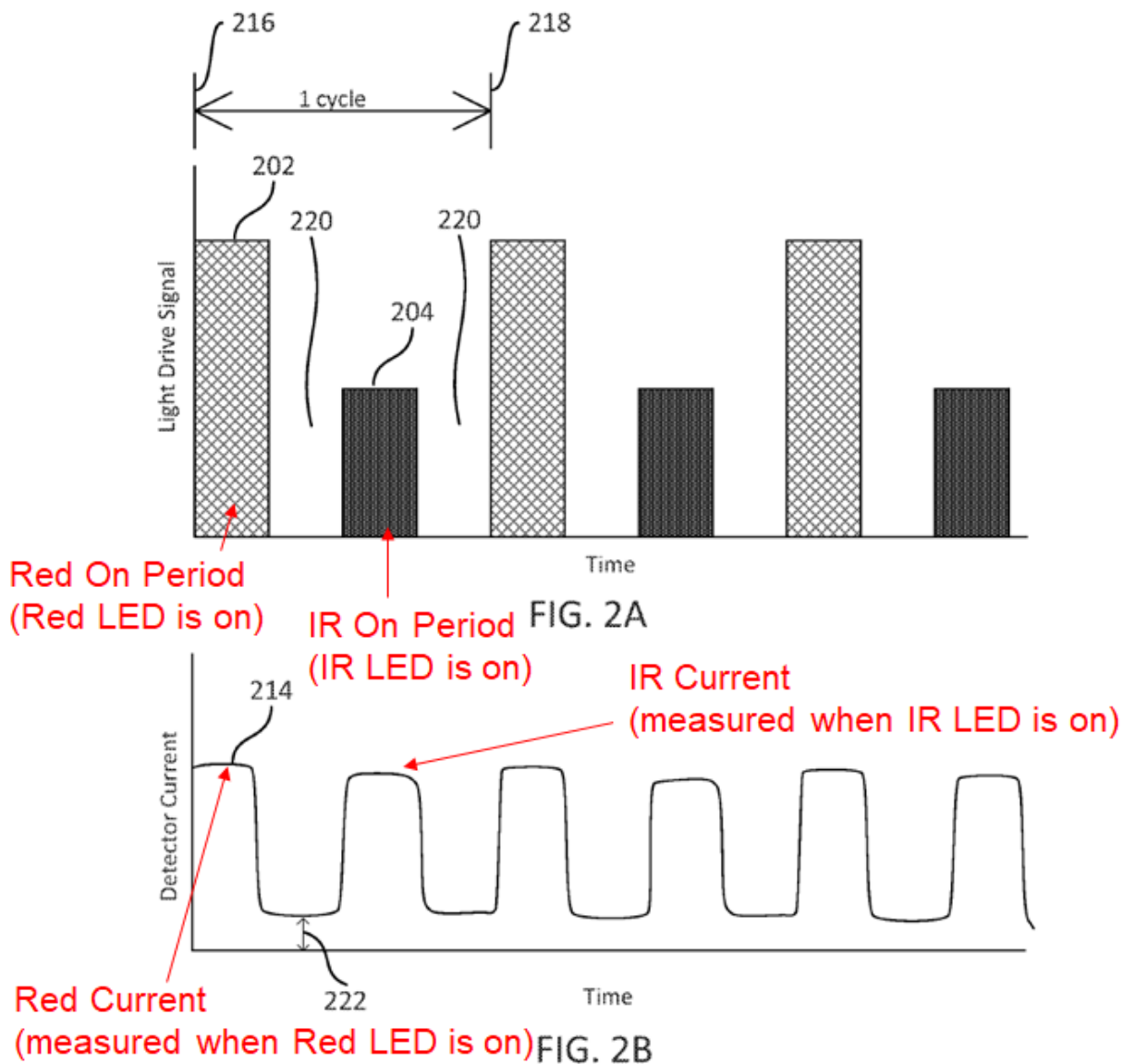
- **“Region 256 of plot 250 indicates an interval of the timing diagram where both red light modulation 252 and IR light modulation 254 are in an “on” portion of the cardiac cycle modulation.** Plot 270 shows an illustrative portion of region 256, where the system is employing a cardiac cycle modulation in addition to the drive cycle modulation. Plot 250 may include a drive cycle modulation technique with a period of time interval 272. The time scale of plot 270 may be significantly shorter than the time scale of plot 250, such that time interval 272 is significantly shorter than time interval 260. For example, time interval 260 (i.e., the period of the cardiac cycle modulation) may be on the order of 1 second, while time interval 272 (i.e., the period of the drive cycle modulation) may be on the order of 1 ms. **Time interval 272 may include a sequence of red “on” portion 274, a first “off” portion 276, IR “on” portion 278, and a second “off” portion 280.** The first “off” portion 276 and second “off” portion 280 may be used to determine the level of ambient light, noise, dark current, other suitable signals, or any combination thereof. **The system may subtract the background or dark level from the levels**

received during red “on” portion 274 and IR “on” period 278.”

EX1027, 16:33–54.

161. A POSITA would have understood from the above disclosures that Lisogurski teaches a system where one or more detectors receive “light that is reflected by or has traveled through the subject’s tissue” when one or more semiconductor sources (LEDs) are turned “on.” EX1027, 17:40–42 (light received by the detectors includes “light that is reflected by or has traveled through the subject’s tissue”); *id.*, 11:12–20; 6:12–19 (the system “may measure...the signals received during the first and second ‘on’ periods”). A POSITA would further have understood that during “light ‘on’ periods,” light is “being emitted from a light source,” and the detector therefore receives and generates “current signals” that are “proportional to the light incident upon the detector” from those light sources after they pass through or are reflected by the tissue. EX1027, 12:52–13:6. Thus, a POSITA would have understood that Lisogurski teaches capturing light while at least one of the semiconductor sources is on and converting the captured light into a second signal, the captured light including at least a part of the at least a portion of the analysis output beam reflected or transmitted from the sample.

162. This process of capturing light when the semiconductors are “on” is illustrated by Figures 2A and 2B of Lisogurski (annotated in accordance with the 484 IPR):



EX1027, Figs. 2A, 2B (annotated in view of EX1021, p. 55); *see also*, EX1027, 12:52–13:6.

163. Accordingly, Lisogurski teaches or renders obvious 1[j]. I note that the Board found in the '484 IPR that Lisogurski “generates a second signal responsive to light when at least one of the LEDs is on” and that Omni did not cross-appeal that

decision, which was therefore affirmed by the Federal Circuit. EX1011, 5, 43–44; EX1012, n.2.

l. Claim 1[k]: the measurement system further configured to improve the signal-to-noise ratio by differencing the first signal and the second signal;

164. In my opinion, Lisogurski discloses claim 1[k]. As I discussed above, Lisogurski teaches a “dark subtraction” technique to “remove ambient and background signals” from the measurement of a desired analog signal corresponding to a particular physiological parameter. EX1027, 6:7–19; *supra* § VIII.C.1.j–k (1[i]–[j]). Specifically, Lisogurski teaches:

- **“In some embodiments, a technique to remove ambient and background signals may be used in addition to or in place of a power saving light modulation scheme. In a drive cycle modulation technique, the system may cycle light output at a rate significantly greater than the cardiac cycle. For example, a drive cycle modulation cycle may include the system turning on a first light source, followed by a “dark” period, followed by a second light source, followed by a “dark” period. The system may measure the ambient light detected by the detector during the “dark” period and then subtract this ambient contribution from the signals received during the first and second “on” periods.”**

EX1027, 6:7–19.

- “FIG. 2B shows an illustrative plot of detector signal 214 that may be generated by a sensor in accordance with some embodiments of the present disclosure. The peaks of detector current waveform 214 may represent current signals provided by a detector, such as detector 140 of FIG. 1, when light is being emitted from a light source. The amplitude of detector current waveform 214 may be proportional to the light incident upon the detector. The peaks of detector current waveform 214 may be synchronous with light “on” periods driving one or more emitters of a light source, such as light source 130 of FIG. 1. For example, detector current waveform 214 may be generated in response to a light source being driven by the light drive signal of FIG. 2A. The valleys of detector current waveform 214 may be synchronous with periods of time during which no light is being emitted by the light source. While no light is being emitted by a light source during the valleys, detector current waveform 214 may not fall all of the way to zero. Rather, dark current 222 may be present in the detector waveform. **Since dark current 222 may interfere with accurate determinations of physiological characteristics, dark current 222 may be removed as discussed in more detail below.**” EX1027, 12:52–13:6.
- **“Dark subtractor 162 may operate on the digital signal. In some embodiments, dark subtractor 162 may subtract dark values from the**

Red and IR components to generate adjusted Red and IR signals. For example, dark subtractor 162 may determine a subtraction amount from the dark signal portion of the detection signal and subtract it from the peak portion of the detection signal in order to reduce the effect of the dark signal on the peak. For example, in reference to FIG. 2A, a detection signal peak corresponding to red “on” period 202 may be adjusted by determining the amount of dark signal during the “off” period 220 preceding red “on” period 202. The dark signal amount determined in this manner may be subtracted from the detector peak corresponding to red “on” period 202. Alternatively, the “off” period 220 after red “on” period 202 may be used to correct red “on” period 202 rather than the “off” period 220 preceding it. Additionally, an average of the “off” periods 220 before and after red “on” period 202 may be used.” EX1027, 13:60–14:10.

- “However, if the contribution of ambient light is large relative to the contribution of light from a light source, the total analog gain applied to the detection current may need to be reduced to avoid saturating analog-to-digital converter 154. When the analog gain is reduced, the portion of the signal corresponding to the light source may map to a smaller number of analog-to-digital conversion bits. **Thus, more ambient light noise in**

the input of analog-to-digital converter 154 may results in fewer bits of resolution for the portion of the signal from the light source. This may have a detrimental effect on the signal-to-noise ratio of the detection signal. Accordingly, passive or active filtering or signal modification techniques may be employed to reduce the effect of ambient light on the detection signal that is applied to analog-to-digital converter 154, and thereby reduce the contribution of the noise component to the converted digital signal.” EX1027, 14:40–55.

- “Region 256 of plot 250 indicates an interval of the timing diagram where both red light modulation 252 and IR light modulation 254 are in an “on” portion of the cardiac cycle modulation. Plot 270 shows an illustrative portion of region 256, where the system is employing a cardiac cycle modulation in addition to the drive cycle modulation. Plot 250 may include a drive cycle modulation technique with a period of time interval 272. The time scale of plot 270 may be significantly shorter than the time scale of plot 250, such that time interval 272 is significantly shorter than time interval 260. For example, time interval 260 (i.e., the period of the cardiac cycle modulation) may be on the order of 1 second, while time interval 272 (i.e., the period of the drive cycle modulation) may be on the order of 1 ms. **Time interval 272 may include a sequence of red “on”**

portion 274, a first “off” portion 276, IR “on” portion 278, and a second “off” portion 280. The first “off” portion 276 and second “off” portion 280 may be used to determine the level of ambient light, noise, dark current, other suitable signals, or any combination thereof. The system may subtract the background or dark level from the levels received during red “on” portion 274 and IR “on” period 278.”
EX1027, 16:33–54.

165. A POSITA would have understood from these teachings in Lisogurski that the dark subtraction process removes “noise” (which Lisogurski often refers to as “ambient light”) from an analog signal received by Lisogurski’s detector. EX1027, 14:46–55. Specifically, the dark subtractor subtracts the dark signal (captured while the semiconductor sources are off) from each of the red and IR signals (captured while the semiconductor sources are on) to generate “adjusted Red and IR signals.” EX1027, 13:60–14:10, 16:51–54 (“The system may subtract the background or dark level from the levels received during red [or IR] ‘on’ period[s]”). Thus, a POSITA would have understood that Lisogurski teaches subtracting (“*differencing*”) the dark level (*first signal*) from the IR or red level (*second signal*), which a POSITA would have understood increases the SNR (“*improves the signal-to-noise ratio*”). This is because the SNR is calculated by dividing signal power by noise power, and decreasing noise necessarily increases SNR.

166. Accordingly, Lisogurski teaches or renders obvious 1[k]. I note that the Board found in the '484 IPR that Lisogurski a limitation identical to 1[k], and that Omni did not cross-appeal that decision, which was therefore affirmed by the Federal Circuit. EX1011, 5–6, 43–44; EX1012, n.2.

m. **Claim 1[l]: a smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a microphone, a speaker, one or more buttons or knobs, a microprocessor and a touch screen, the smart phone or tablet configured to:**

167. In my opinion, Lisogurski discloses claim 1[l]. Specifically, Lisogurski teaches a sensor designed to be used with a **monitor, where the monitor can be a portable, battery-powered computer system** with a **touchscreen**, a **speaker**, a **microprocessor**, a **display**, **wireless receiver**, **wireless transmitter**, **microphone**, and **one or more buttons or knobs**:

- “In some embodiments, reducing power consumption may allow for increased **battery life in portable systems** or increased portability.” EX1027, 1:15–18.
- “Back end processing circuitry 170 may include **processor 172** and memory 174. **Processor 172 may be adapted to execute software**, which may include an operating system and one or more applications, as part of performing the functions described herein. **Processor 172** may receive and process physiological signals received from front end processing circuitry 150. For example, **processor 172** may determine one or more

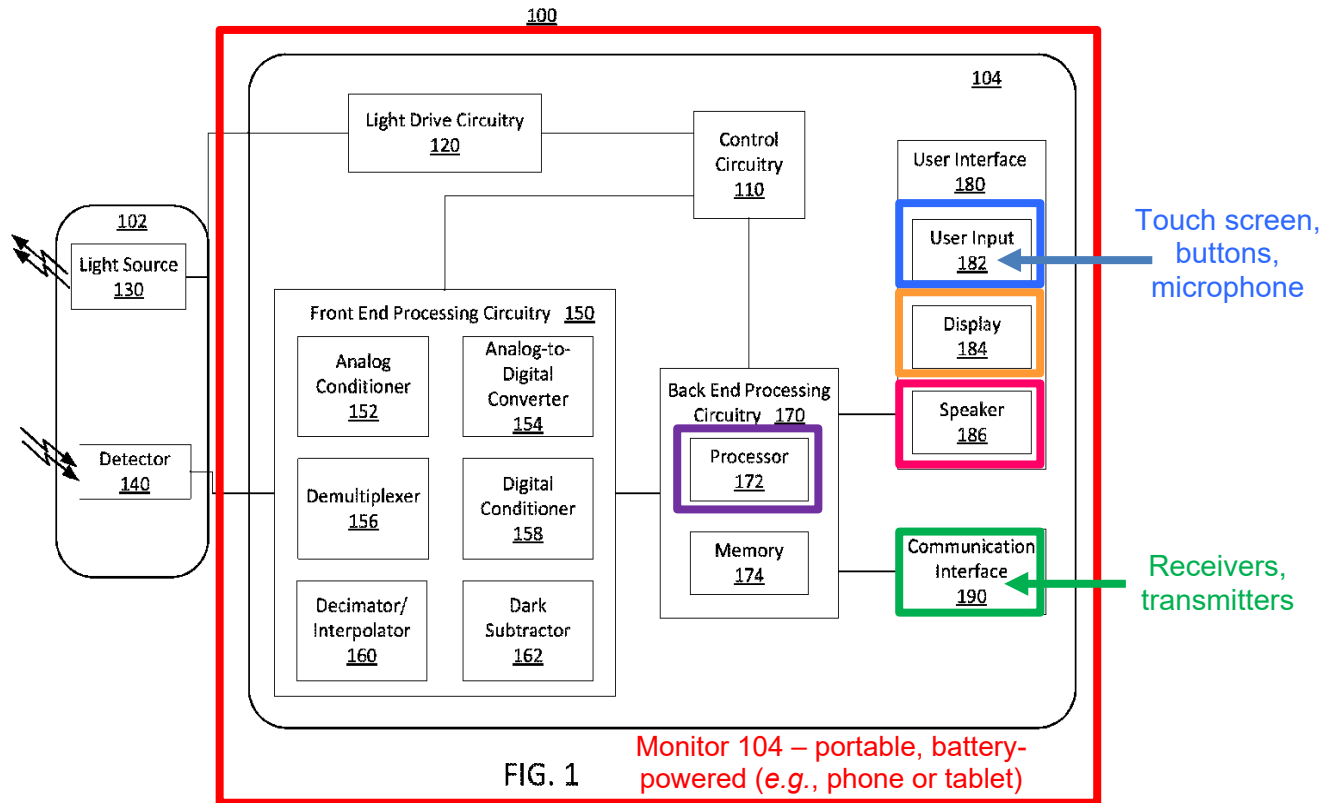
physiological parameters based on the received physiological signals. Memory 174 may include any suitable computer-readable media capable of storing information that can be interpreted by **processor 172**. This information may be data or may take the form of computer-executable instructions, such as software applications, that cause the **microprocessor to perform certain functions and/or computer-implemented methods**. Depending on the embodiment, such computer-readable media may include computer storage media and communication media. Computer storage media may include volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data. Computer storage media may include, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid state memory technology, CD-ROM, DVD, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by components of the system. **Back end processing circuitry 170 may be communicatively coupled with use[r] interface 180 and communication interface 190.”**

EX1027, 14:56–15:18.

- “User interface 180 may include user input 182, **display 184**, and **speaker 186**. User input 182 may include any type of user input device such as a keyboard, a mouse, **a touch screen**, **buttons**, switches, **a microphone**, a joy stick, **a touch pad**, or any other suitable input device. The inputs received by user input 182 can include information about the subject, such as age, weight, height, diagnosis, medications, treatments, and so forth. In an embodiment, the subject may be a medical patient and **display 184** may exhibit a list of values which may generally apply to the patient, such as, for example, age ranges or medication families, which the user may select using user input 182. Additionally, **display 184** may display, for example, an estimate of a subject's blood oxygen saturation generated by monitor 104 (referred to as an “SpO₂” measurement), pulse rate information, respiration rate information, blood pressure, any other parameters, and any combination thereof. **Display 184** may include any type of display such as a cathode ray tube display, a flat panel display such [as] a liquid crystal display or plasma display, or any other suitable display device. **Speaker 186** within user interface 180 may provide an audible sound that may be used in various embodiments, such as for example, sounding an audible alarm in the event that a patient's physiological parameters are not within a predefined normal range.” EX1027, 15:19–42.

- “Communication interface 190 may enable **monitor 104** to exchange information with external devices. Communications interface 190 may include any suitable hardware, software, or both, which may allow **monitor 104** to communicate with electronic circuitry, a device, a network, a server or other workstations, **a display**, or any combination thereof. **Communications interface 190 may include one or more receivers, transmitters**, transceivers, antennas, plug-in connectors, ports, communications buses, communications protocols, device identification protocols, any other suitable hardware or software, or any combination thereof. **Communications interface 190 may be configured to allow wired communication (e.g., using USB, RS-232 or other standards), wireless communication (e.g., using WiFi, IR, WiMax, BLUETOOTH, UWB, or other standards), or both.** For example, communications interface 190 may be configured using a universal serial bus (USB) protocol (e.g., USB 2.0, USB 3.0), and may be configured to couple to other devices (e.g., remote memory devices storing templates) using a four-pin USB standard Type-A connector (e.g., plug and/or socket) and cable. In some embodiments, communications interface 190 may include an internal bus such as, for example, one or more slots for insertion of expansion cards.” EX1027, 15:43–65.

- “**Monitor 314 may be powered by a battery** (not shown) or a conventional power source such as a wall outlet.” EX1027, 18:65–66.



EX1027, Fig. 1 (annotated).

168. A POSITA would have understood from these disclosures that Lisogurski’s system may include a **battery-powered, portable computer system with a monitor** and **touch screen that may communicate (receive/transmit) wirelessly** and may have a **microphone, speaker, microprocessor**, and **one or more buttons or knobs**. A POSITA would have understood that this type of computing device would commonly refer to a **flat, portable electronic device, like a smartphone or tablet**. As I discussed above, as of the priority date of the ’304

patent, tablets and smartphones were well-known in the field of optical sensing systems, particularly those used for health and fitness applications. *Supra* § V.B. Therefore, it is my opinion that a POSITA reading Lisogurski would have found it obvious to use a smartphone or a tablet as the “monitor” in Lisogurski’s measurement system.

169. Accordingly, Lisogurski teaches or renders obvious 1[l]. I note that the Board found in the ’533 IPR that Lisogurski teaches a limitation nearly identical to 1[l]. EX1008, 39–42. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand similar determinations were made by the Board in the ’484 IPR and that Omni did not cross-appeal those decisions, which were therefore affirmed by the Federal Circuit. EX1011, 5–6, 25–27; EX1012, n.2.

n. Claim 1[m]: receive and process at least a portion of the output signal,;

170. In my opinion, Lisogurski discloses claim 1[m]. As I discussed above, Lisogurski teaches a monitor (like a smartphone or tablet) that includes back end processing circuitry. *Supra* § VIII.C.1.m (1[l]). Lisogurski teaches that this back end processing circuitry includes “processor 172,” which “**receive[s] and process[es] physiological signals received from front end processing circuitry**” 150. For example, processor 172 may determine one or more physiological parameters based on the **received physiological signals.**” EX1027, 14:56–64.

171. Accordingly, Lisogurski teaches or renders obvious 1[m]. I note that the Board found in the '533 IPR that Lisogurski teaches a limitation identical to 1[m]. EX1008, 7, 41–42. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand the Board made a similar determination in the '484 IPR and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit. EX1011, 5–6, 25–26; EX1012, n.2.

o. Claim 1[n]: store and display the processed output signal, and

172. In my opinion, Lisogurski teaches 1[n]. As I discussed above, Lisogurski teaches a monitor (*e.g.*, a personal device like a smartphone or tablet) with processing circuitry configured to receive and process at least a portion of an output signal corresponding to a particular physiological parameter measured by a wearable sensor. *Supra* §§ VIII.C.1.m–n (1[l]–[m]). Lisogurski further teaches that the “received physiological signals” (output signals) may be “store[d]” and “display[ed]” by the personal device after they are processed. Specifically, Lisogurski discloses:

- **Memory 174** may include any suitable computer-readable media capable of **storing information** that can be interpreted by processor 172. This information may be data or may take the form of computer-executable instructions, such as software applications, that cause the microprocessor to perform certain functions and/or computer-implemented methods.

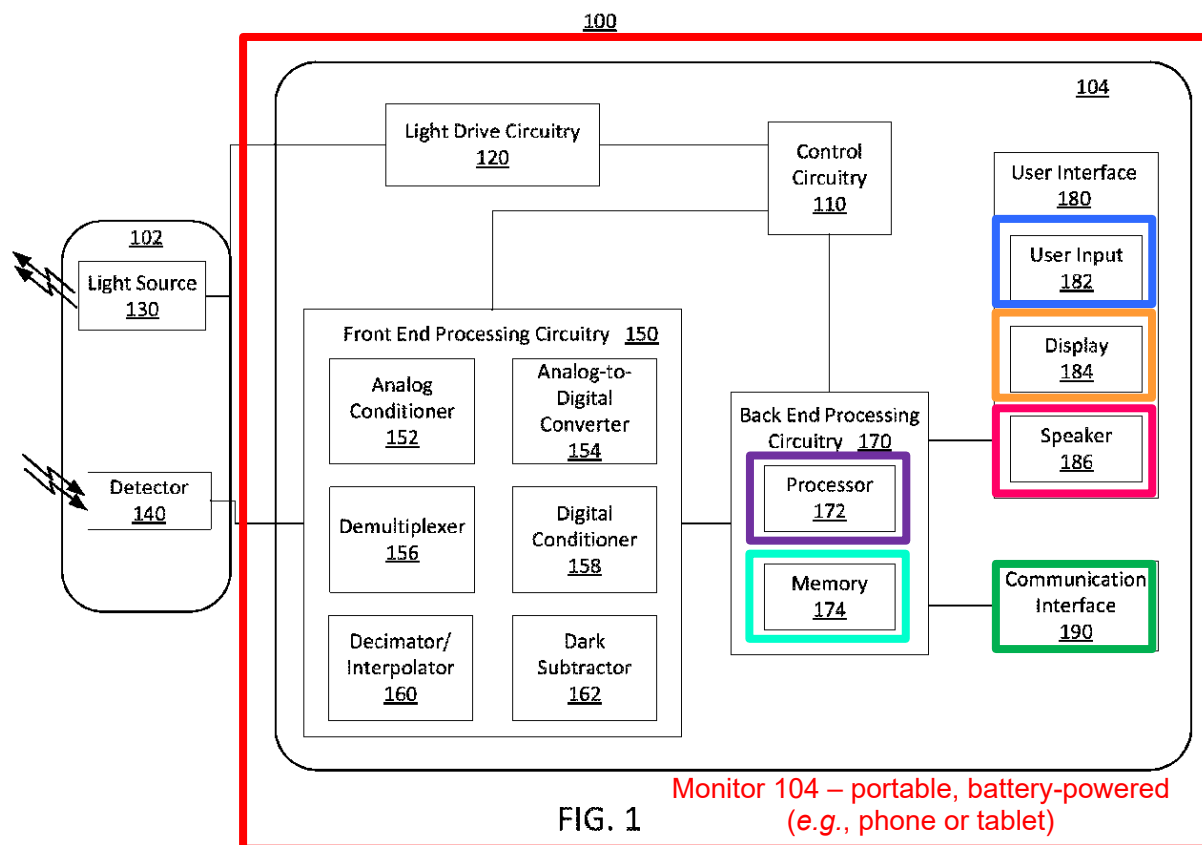
Depending on the embodiment, such computer-readable media may include **computer storage media** and communication media. **Computer storage media** may include volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data. **Computer storage media may include, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid state memory technology, CD-ROM, DVD, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by components of the system.** Back end processing circuitry 170 may be communicatively coupled with use[r] interface 180 and communication interface 190.” EX1027, 14:64–15:18.

- “User interface 180 may include user input 182, **display 184**, and speaker 186. User input 182 may include any type of user input device such as a keyboard, a mouse, a touch screen, buttons, switches, a microphone, a joy stick, a touch pad, or any other suitable input device. The inputs received by user input 182 can include information about the subject, such as age, weight, height, diagnosis, medications, treatments, and so forth. In an

embodiment, the subject may be a medical patient and display 184 may exhibit a list of values which may generally apply to the patient, such as, for example, age ranges or medication families, which the user may select using user input 182. **Additionally, display 184 may display, for example, an estimate of a subject's blood oxygen saturation generated by monitor 104 (referred to as an "SpO₂" measurement), pulse rate information, respiration rate information, blood pressure, any other parameters, and any combination thereof.** Display 184 may include any type of display such as a cathode ray tube display, a flat panel display such [as] a liquid crystal display or plasma display, or any other suitable display device. Speaker 186 within user interface 180 may provide an audible sound that may be used in various embodiments, such as for example, sounding an audible alarm in the event that a patient's physiological parameters are not within a predefined normal range." EX1027, 15:19–42.

- **"The system may determine the timing of the diastole periods using historical information from previous cardiac cycles, from an external sensor, from user input, from measurements made with a different cardiac cycle modulation, by any other suitable technique, or any combination thereof."** EX1027, 27:31–36.

- “In some embodiments, **the duration of the “on” state following a signal pulse (e.g., signal pulse 1320) may be** a predetermined length of time, a length of time determined by previous measurements, a length of time determined by data collected during previous periods, a length of time set by user input, a length of time determined by any other suitable technique, or any combination thereof.” EX1027, 30:42–48.
- “**The system may determine the timing of the cardiac cycles using historical information from previous cardiac cycles,** from an external sensor, from user input, from measurements made with a different cardiac cycle modulation, by any other suitable technique, or any combination thereof.” EX1027, 33:23–27.



EX1027, Fig. 1 (annotated).

173. A POSITA would have understood from the above that Lisogurski teaches a system that can store and display information a processed output signal corresponding to a physiological parameter (e.g., “SpO₂ measurement[s]” and “pulse rate information”) collected by the sensor unit. EX1027, 14:62–64, 15:30–35. A POSITA would further have understood that Lisogurski’s back-end processing circuitry includes a conventional memory (e.g., RAM, ROM, flash, or hard drive (magnetic disk)) that can be used to store “historical information” related to the determined physiological parameters. EX1027, 14:64–15:16; 27:31–36, 30:42–48, 33:23–27, Fig. 1 (174). Thus, in my opinion, Lisogurski teaches a system where the

processed output signal is both “store[d]” and “display[ed]” by the smartphone or tablet, as required by claim 1[n].

174. Accordingly, Lisogurski teaches or renders obvious 1[n]. I note that the Board found in the ’533 IPR that Lisogurski teaches a limitation identical to 1[n]. EX1008, 7, 40–42. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand similar determinations were made in the ’484 IPR and that Omni did not cross-appeal those determinations, which were affirmed by the Federal Circuit. EX1011, 5–6, 25–27; EX1012, n.2.

p. Claim 1[o]: transmit at least a portion of the processed output signal over a wireless transmission link; and

175. In my opinion, Lisogurski discloses claim 1[o]. As I explained above, Lisogurski teaches receiving, processing, storing, and displaying an output signal corresponding to one or more physiological parameters. *Supra* §§ VIII.C.1.n–o (1[m]–[n]). Lisogurski further discloses:

- **“Communication interface 190 may enable monitor 104 to exchange information with external devices. Communications interface 190 may include any suitable hardware, software, or both, which may allow monitor 104 to communicate with electronic circuitry, a device, a network, a server or other workstations, a display, or any combination thereof. Communications interface 190 may include one or more receivers, transmitters, transceivers, antennas, plug-in connectors,**

ports, communications buses, communications protocols, device identification protocols, any other suitable hardware or software, or any combination thereof. **Communications interface 190 may be configured to allow** wired communication (e.g., using USB, RS-232 or other standards), **wireless communication (e.g., using WiFi, IR, WiMax, BLUETOOTH, UWB, or other standards)**, or both. For example, **communications interface 190 may be configured using a universal serial bus (USB) protocol (e.g., USB 2.0, USB 3.0), and may be configured to couple to other devices (e.g., remote memory devices storing templates)** using a four-pin USB standard Type-A connector (e.g., plug and/or socket) and cable. In some embodiments, communications interface 190 may include an internal bus such as, for example, one or more slots for insertion of expansion cards. EX1027, 15:43–65.

- “In some embodiments, the system 310 includes **a stand-alone monitor in communication with the monitor 314 via a cable or a wireless network link**. In some embodiments, monitor 314 may be implemented as monitor 104 of Fig. 1.” EX1027, 18:10–15.
- “In the illustrated embodiment, system 310 includes a multi-parameter physiological monitor 326. The monitor 326 may include a cathode ray tube display, a flat panel display (as shown) such as a liquid crystal display

(LCD) or a plasma display, or may include any other type of monitor now known or later developed. Multi-parameter physiological monitor 326 may be configured to calculate physiological parameters and to provide a display 328 for information from monitor 314 and from other medical monitoring devices or systems (not shown). For example, multi-parameter physiological monitor 326 may be configured to display an estimate of a subject's blood oxygen saturation and hemoglobin concentration generated by monitor 314. Multi-parameter physiological monitor 326 may include a speaker 330.” EX1027, 18:44–57.

- **“Monitor 314 may be communicatively coupled to multi-parameter physiological monitor 326** via a cable 332 or 334 that is coupled to a sensor input port or a digital communications port, respectively **and/or may communicate wirelessly (not shown).** In addition, **monitor 314 and/or multi-parameter physiological monitor 326 may be coupled to a network to enable the sharing of information with servers or other workstations (not shown).** Monitor 314 may be powered by a battery (not shown) or by a conventional power source such as a wall outlet. EX1027, 18:58–67.
- “The system may display the **determined physiological parameter** using a local display (e.g., display 320 of FIG. 3 or display 328 of FIG. 3),

display them on a remote display, publish the data to a server or website, make the parameters available to a user by any other suitable technique, or any combination thereof.” EX1027, 20:55–60; *see also* EX1027, 26:55–60 (same).

176. A POSITA would have understood from the above that Lisogurski discloses that the processed output signal corresponding to a physiological parameter can be “transmit[ted]” wirelessly (via, e.g., “WiFi, IR, WiMax, BLUETOOTH, UWB, or other standards” or by “publish[ing]” such data to a “server or website”) from the smartphone or tablet to other remote devices, and that such devices may include a multi-parameter physiological monitor. EX1027, 15:43–48, 15:53–57, 18:11–15, 18:49–53, 18:58–65, 20:55–60, 26:55–60. Thus, in my opinion, Lisogurski teaches a system where at least a portion of the processed output signal is “transmitt[ed]” “over a wireless transmission link,” as required by claim 1[o].

177. Accordingly, Lisogurski teaches or renders obvious 1[o]. I note that the Board found in the ’533 IPR that Lisogurski teaches a limitation identical to 1[o]. EX1008, 7–8, 39–42. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand the Board made a similar determination in the ’484 IPR and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit. EX1011, 5–6, 25–27; EX1012, n.2.

q. Claim 1[p]: a cloud configured to:

178. In my opinion, Lisogurski (or Lisogurski in view of Carlson) discloses or renders obvious claim 1[p]. As I explained above, Lisogurski teaches that determined physiological parameters can be wirelessly transmitted to another monitor, such as multi-parameter physiological monitor (MPPM) or a “server or website.” *Supra* § VIII.C.1.p (1[o]). Specifically, Lisogurski discloses:

- “Communication interface 190 may enable **monitor 104** to **exchange information with external devices**. Communications interface 190 may include any suitable hardware, software, or both, which **may allow monitor 104 to communicate with electronic circuitry, a device, a network, a server or other workstations, a display, or any combination thereof**. Communications interface 190 may include one or more receivers, transmitters, transceivers, antennas, plug-in connectors, ports, communications buses, communications protocols, device identification protocols, any other suitable hardware or software, or any combination thereof. Communications interface 190 may be configured to allow wired communication (e.g., using USB, RS-232 or other standards), **wireless communication (e.g., using WiFi, IR, WiMax, BLUETOOTH, UWB, or other standards)**, or both. For example, communications interface 190 may be configured using a universal serial bus (USB) protocol (e.g., USB

2.0, USB 3.0), and **may be configured to couple to other devices (e.g., remote memory devices storing templates)** using a four-pin USB standard Type-A connector (e.g., plug and/or socket) and cable. In some embodiments, communications interface 190 may include an internal bus such as, for example, one or more slots for insertion of expansion cards. EX1027, 15:43–65.

- “In some embodiments, the system 310 includes a **stand-alone monitor in communication with the monitor 314 via a cable or a wireless network link**. In some embodiments, monitor 314 may be implemented as monitor 104 of Fig. 1.” EX1027, 18:11–15.
- “In the illustrated embodiment, system 310 **includes a multi-parameter physiological monitor 326**. The monitor 326 may include a cathode ray tube display, a flat panel display (as shown) such as a liquid crystal display (LCD) or a plasma display, or may include any other type of monitor now known or later developed. **Multi-parameter physiological monitor 326 may be configured to calculate physiological parameters and to provide a display 328 for information from monitor 314 and from other medical monitoring devices or systems (not shown). For example, multi-parameter physiological monitor 326 may be configured to display an estimate of a subject's blood oxygen saturation and hemoglobin**

concentration generated by **monitor 314**. Multi-parameter physiological monitor 326 may include a speaker 330.” EX1027, 18:44–57.

- “**Monitor 314** may be communicatively coupled to **multi-parameter physiological monitor 326** via a cable 332 or 334 that is coupled to a sensor input port or a digital communications port, respectively **and/or** may communicate wirelessly (not shown). In addition, **monitor 314** and/or **multi-parameter physiological monitor 326** may be coupled to a network to enable the sharing of information with servers or other workstations (not shown). **Monitor 314** may be powered by a battery (not shown) or by a conventional power source such as a wall outlet.” EX1027, 18:58–67.
- “The system may display the determined physiological parameter using a local display (e.g., display 320 of FIG. 3 or display 328 of FIG. 3), **display them on a remote display, publish the data to a server or website**, make the parameters available to a user by any other suitable technique, or any combination thereof.” EX1027, 20:55–60; *see also* EX1027, 26:55–60 (same).

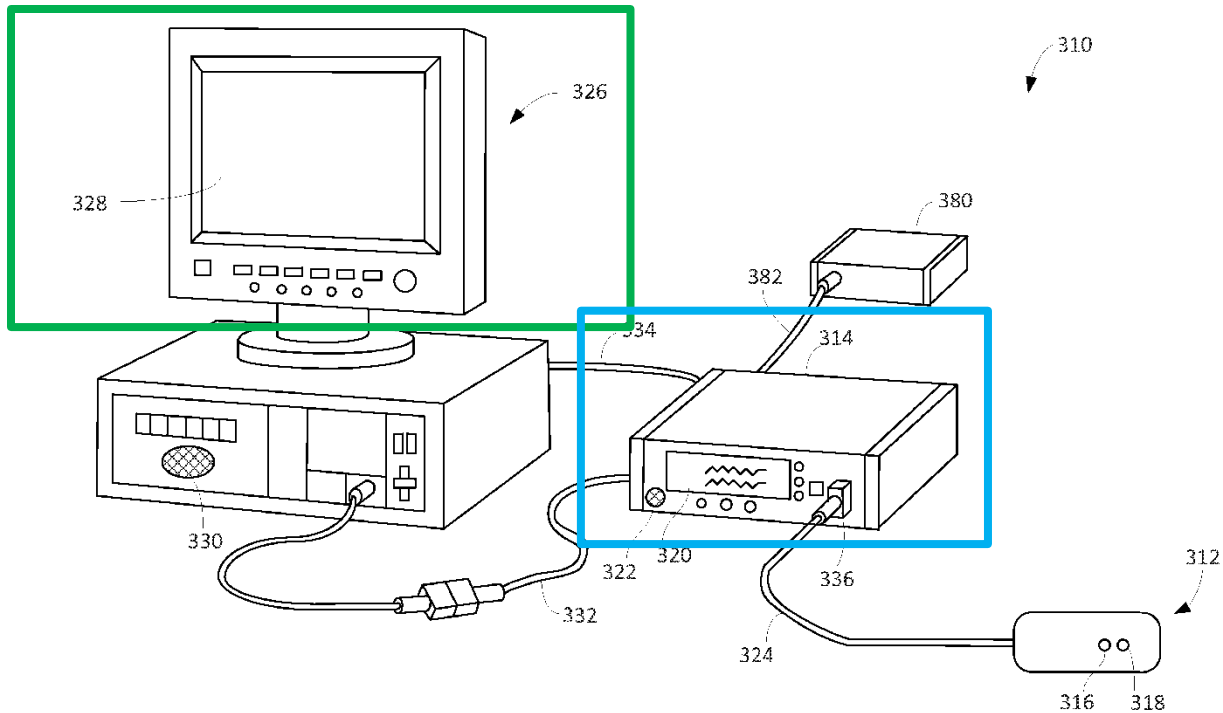


FIG. 3

EX1027, Fig. 3.

179. A POSITA would have understood from the above that Lisogurski teaches that determined physiological parameters and other data can be wirelessly transmitted from the monitor/personal device in Lisogurski's system to a "server or website" or another monitor (such as MPPM 326). EX1027, 26:55–60 (sending data to a server/website), 18:11–15, 18:58–62 (second monitor/MPPM); *see also id.*, 15:43–48 (describing Lisogurski's system wirelessly sending data to "electronic circuitry, a device, a network, a server or other workstations"), 15:55–57 (describing wireless transmission). A POSITA would have understood these second monitors (MPPM) and servers/websites to be "cloud" based devices. Indeed, Lisogurski

teaches that MPPM 326 is a remote device that can wirelessly communicate with the monitor (*e.g.*, the smartphone/tablet) and that can be “coupled to a network to enable the sharing of information with servers or other workstations,” which a POSITA would have understood to mean that MPPM can be part of a cloud-based server. EX1027, 18:49–67, Fig. 3. To the extent these disclosures do not expressly teach a “cloud,” it would have been obvious to a POSITA to transmit a determined physiological parameter to the cloud based on the remote transmission techniques discussed in Lisogurski.

180. Furthermore, it is also my opinion that Carlson teaches or renders obvious a cloud in a wearable optical system like the one described by Lisogurski. Specifically, Carlson teaches:

- “Taking prior art into consideration, **the measured values can be monitored at a special unit worn by the person or patient**, respectively, where *e.g.* a signal is generated, if the measured value is not within a predetermined range. In other words, health problems could be detected and **an alarm signal could be generated which can be transmitted to a respective person, to a medical doctor, to a hospital, etc. so that help can be organised**. Furthermore, it is possible to include *e.g.* a so-called GPS device which at any time gives the location of the person using the pulsoximetric sensor monitoring configuration.”

EX1028, [0078].

181. Carlson therefore teaches that its wearable device (“special unit”) can measure physiological values that may be wirelessly transmitted to remote locations, like a doctor or a hospital, along with the location of the person wearing the device. EX1028, [0078]. A POSITA would have understood this to refer to the wireless transmission of the processed output signal to a remote device like a “cloud.” It would have been obvious to implement Carlson’s wireless transmission/alert system into Lisogurski given their overlapping applications and the market trends discussed above. *Supra* §§ V.B, VIII.B.1. A POSITA would have found this to be a routine modification that would have been part of the ordinary design process when designing an improved wearable optical sensor and therefore would have had a reasonable expectation of success.

182. Accordingly, Lisogurski, or Lisogurski in view of Carlson, teaches or renders obvious 1[p]. I note that the Board found in the ’533 IPR that Lisogurski, or Lisogurski in view of Carlson, teaches a “remote device.” EX1008, 7–8, 42–43. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand the Board made a similar determination in the ’484 IPR (that Lisogurski’s MPPM taught a “cloud”) and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit. EX1011, 26–27; EX1012, n.2.

- r. Claim 1[q]: receive, over the wireless transmission link, an output status comprising the at least a portion of the processed output signal,**

183. In my opinion, Lisogurski (alone or combined with Carlson) discloses or renders obvious 1[q]. As I discussed above, Lisogurski teaches the wireless transmission of a processed output signal to a remote location (*e.g.*, a cloud). *Supra* VIII.C.1.q § (1[p]). Carlson similarly teaches the wireless transmission of determined physiological parameters to remote locations. *Id.* A POSITA would have understood that the transmission would be “receive[d]” by the cloud/remote device in either system, and that this “receive[d]” data corresponds to the claimed “output signal.”

184. Accordingly, Lisogurski, alone or in view of Carlson, teaches or renders obvious 1[q]. I note that the Board found in the ’533 IPR that Lisogurski, or Lisogurski in view of Carlson, teaches a limitation materially identical to 1[q]. EX1008, 7–8, 42–43. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand the Board made a similar determination in the ’484 IPR and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit. EX1011, 5–6, 26–27; EX1012, n.2.

- s. Claim 1[r]: process the received output status to generate processed data, and**

185. In my opinion, Lisogurski (alone or in combination with Carlson) discloses 1[r]. As I discussed above, Lisogurski teaches a multi-parameter

physiological monitor that corresponds to a remote device (“cloud”) that receives an output status from a wireless link. *Supra* VIII.C.1.q–r §§ (1[p]–[q]). Lisogurski further teaches:

- “In the illustrated embodiment, system 310 includes a **multi-parameter physiological monitor 326**. The monitor 326 may include a cathode ray tube display, a flat panel display (as shown) such as a liquid crystal display (LCD) or a plasma display, or may include any other type of monitor now known or later developed. **Multi-parameter physiological monitor 326 may be configured to calculate physiological parameters** and to provide a display 328 for information from monitor 314 and from other medical monitoring devices or systems (not shown). **For example, multi-parameter physiological monitor 326 may be configured to display an estimate of a subject's blood oxygen saturation and hemoglobin concentration generated by monitor 314.** Multi-parameter physiological monitor 326 may include a speaker 330.” EX1027, 18:44–57.
- “In step 906, the system may determine a physiological parameter using information from the attenuated photonic signals. The physiological parameter may be determined using any suitable hardware technique, software technique, or combination thereof. **In some embodiments,**

processing equipment remote to the system may be used to determine physiological parameters. The system may display the determined physiological parameter using a local display (e.g., display 320 of FIG. 3 or display 328 of FIG. 3), display them on a remote display, publish the data to a server or website, make the parameters available to a user by any other suitable technique, or any combination thereof.” EX1027, 26:49–60.

186. A POSITA would have understood from the above that the physiological data corresponding to the “output” signal received by the remote device (cloud) can be processed *by* the remote device or cloud. For example, a POSITA would have understood that the “processing equipment remote to the system” “used to determine physiological parameters” described in Lisogurski would refer to processing the received output signal on the remote device/cloud. EX1027, 26:49–60. A POSITA would further have understood that for data to be “publish[ed]” on a “server or website,” the server or website would necessarily need to process the data and then store it. EX1027, 26:55–60. Finally, a POSITA would have understood that MPPM 326 can remotely process the received output signal, given Lisogurski’s teaching that MPPM 326 is “configured to calculate physiological parameters.” EX1027, 18:49–53.

187. Accordingly, Lisogurski, alone or in view of Carlson, teaches or renders obvious 1[r]. I note that the Board found in the '533 IPR that Lisogurski, or Lisogurski (in view of Carlson) teaches limitations materially identical to 1[r]. EX1008, 7–8, 42–44, 46–47. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand the Board made a similar determination in the '484 IPR and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit. EX1011, 5–6, 26–27; EX1012, n.2.

t. Claim 1[s]: store the processed data.

188. In my opinion, Lisogurski (alone or in combination with Carlson) discloses 1[s]. For example, Lisogurski discloses:

- “Communication interface 190 may enable **monitor 104** to **exchange information with external devices**. Communications interface 190 may include any suitable hardware, software, or both, which **may allow monitor 104 to communicate with electronic circuitry, a device, a network, a server or other workstations, a display, or any combination thereof**. Communications interface 190 may include one or more receivers, transmitters, transceivers, antennas, plug-in connectors, ports, communications buses, communications protocols, device identification protocols, any other suitable hardware or software, or any combination thereof. Communications interface 190 may be configured to allow wired

communication (e.g., using USB, RS-232 or other standards), wireless communication (e.g., using WiFi, IR, WiMax, BLUETOOTH, UWB, or other standards), or both. For example, communications interface 190 may be configured using a universal serial bus (USB) protocol (e.g., USB 2.0, USB 3.0), and may be configured to couple to other devices (e.g., remote memory devices storing templates) using a four-pin USB standard Type-A connector (e.g., plug and/or socket) and cable. In some embodiments, communications interface 190 may include an internal bus such as, for example, one or more slots for insertion of expansion cards. EX1027, 15:43–65.

- “In the illustrated embodiment, system 310 includes **a multi-parameter physiological monitor 326**. The monitor 326 may include a cathode ray tube display, a flat panel display (as shown) such as a liquid crystal display (LCD) or a plasma display, or may include any other type of monitor now known or later developed. **Multi-parameter physiological monitor 326 may be configured to calculate physiological parameters** and to provide a display 328 for information from monitor 314 and from other medical monitoring devices or systems (not shown). **For example, multi-parameter physiological monitor 326 may be configured to display an estimate of a subject's blood oxygen saturation and hemoglobin**

concentration generated by monitor 314. Multi-parameter physiological monitor 326 may include a speaker 330.” EX1027, 18:44–57.

- “Monitor 314 may be communicatively coupled to multi-parameter physiological monitor 326 via a cable 332 or 334 that is coupled to a sensor input port or a digital communications port, respectively and/or may communicate wirelessly (not shown). In addition, monitor 314 and/or **multi-parameter physiological monitor 326 may be coupled to a network to enable the sharing of information with servers or other workstations (not shown).** Monitor 314 may be powered by a battery (not shown) or by a conventional power source such as a wall outlet. EX1027, 18:58–67.
- “In some embodiments, the system may use information determined from analyzing the first light source in addition to other information. Other information may include, for example, **historical analysis of prior cardiac cycles** and information from external sensors. For example, the system may **determine an average pulse period from a number of prior pulse cycles.** Statistical information such as the standard deviation may also be calculated to in part determine a confidence parameter **for the historical information.**” EX1027, 20:5–13.

- “In step 906, the system may determine a physiological parameter using information from the attenuated photonic signals. The physiological parameter may be determined using any suitable hardware technique, software technique, or combination thereof. **In some embodiments, processing equipment remote to the system may be used to determine physiological parameters. The system may display the determined physiological parameter using a local display (e.g., display 320 of FIG. 3 or display 328 of FIG. 3), display them on a remote display, publish the data to a server or website, make the parameters available to a user by any other suitable technique, or any combination thereof.**” EX1027, 26:49–60.

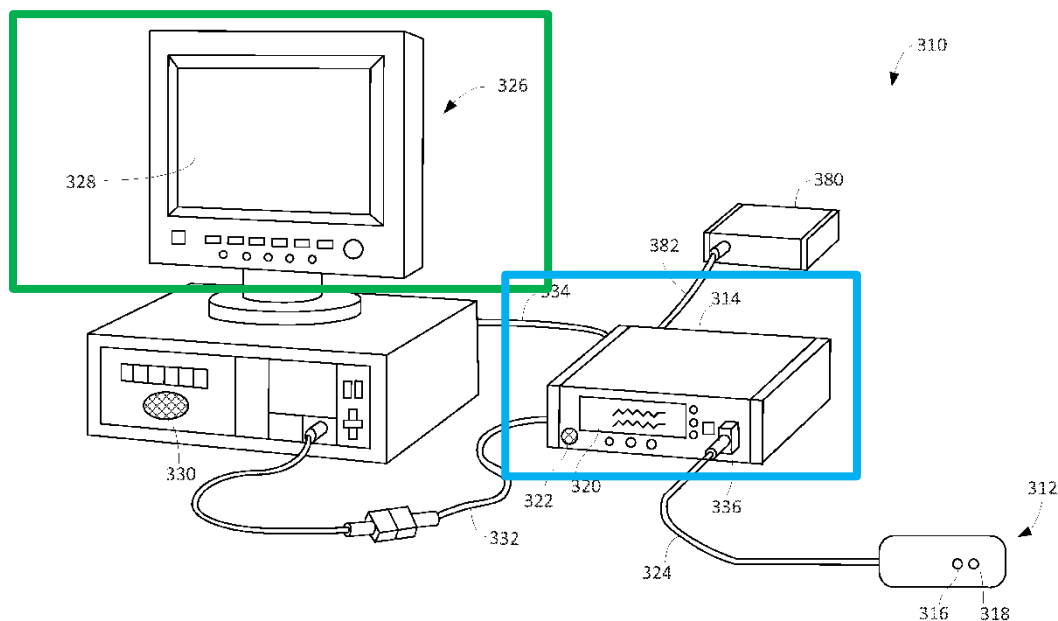


FIG. 3

EX1027, Fig 3.

189. A POSITA would have understood from the above that the remote device (“cloud”) in Lisogurski’s system can “store” the processed data corresponding to the collected physiological parameters. For example, Lisogurski teaches that the data processed remotely can be “publish[ed]” on a server or website, which a POSITA would have understood requires that the processed data be stored. EX1027, 26:51–60. Lisogurski further teaches that MPPM 326 can store historical information corresponding to physiological parameters and processed signal data, evidenced by the fact it can perform statistical analysis on a history of physiological parameter measurements to determine, *e.g.*, the average value or standard deviation of those measurements. EX1027, 20:8–13. A POSITA would therefore have understood that MPPM 26 can store the processed data not just temporarily, but over a “specified period of time,” as required by claims 11[l] and 25[d], *infra* §§ VIII.C.1.gg, ccc (11[l], 25[d]).

190. Accordingly, Lisogurski, alone or in view of Carlson, teaches or renders obvious 1[s]. I note that the Board found in the ’533 IPR that Lisogurski, or Lisogurski in view of Carlson, teaches a limitation materially identical to 1[s], 11[l], and 25[d]. EX1008, 7–8, 42–43, 46–47. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand the Board made a similar determination in the ’484 IPR and that Omni did not cross-appeal that determination,

which was therefore affirmed by the Federal Circuit. EX1011, 5–6, 26–27; EX1012, n.2.

u. Claim 11[pre]: A measurement system comprising:

191. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[pre]. *See supra* § VIII.C.1.a (cl. 1[pre]).

v. Claim 11[a]: a wearable measurement device for measuring one or more physiological parameters, including a light source comprising a plurality of semiconductor sources that are configured to generate an output optical beam with one or more optical wavelengths;

192. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[a]. *See supra* §§ VIII.C.1.b–c (cl. 1[a]–[b]).

w. Claim 11[b]: the light source configured to increase signal-to-noise ratio by increasing a light intensity relative to an initial light intensity from at least one of the plurality of semiconductor sources;

193. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[b]. *See supra* § VIII.C.1.b (cl. 1[a]).

x. Claim 11[c]: the wearable measurement device configured to receive a portion of the output optical beam and to deliver an analysis output beam to a sample;

194. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[c]. *See supra* §§ VIII.C.1.[d]–[e] (cl. 1[c]–[d]).

- y. **Claim 11[d]: the wearable measurement device further comprising a receiver configured to:**

195. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[d]. *See supra* § VIII.C.1.f (cl. 1[e]).

- z. **Claim 11[e]: receive and process at least a portion of the analysis output beam reflected or transmitted from the sample,**

196. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[e]. *See supra* § VIII.C.1.g (cl. 1[f]).

- aa. **Claim 11[f]: generate an output signal representing at least in part a non-invasive measurement on blood contained within the sample,**

197. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[f]. *See supra* § VIII.C.1.h (cl. 1[g]).

- bb. **Claim 11[g]: synchronize to the light source,**

198. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[g]. *See supra* § VIII.C.1.i (cl. 1[h]).

- cc. **Claim 11[h]: capture light while the semiconductor sources are off and convert the captured light into a first signal,**

199. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[h]. *See supra* § VIII.C.1.j (cl. 1[i]).

- dd. **Claim 11[i]: capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a**

part of the at least a portion of the analysis output beam reflected or transmitted from the sample, and

200. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[i]. *See supra* § VIII.C.1.k (cl. 1[j]).

ee. Claim 11[j]: wherein the measurement system is further configured to improve the signal-to-noise ratio by differencing the first and second signal;

201. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[j]. *See supra* § VIII.C.1.l (cl. 1[k]).

ff. Claim 11[k]: a smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a microphone, a speaker, one or more buttons or knobs, a microprocessor and a touch screen, the smart phone or tablet configured to receive and process at least a portion of the output signal, to store and display the processed output signal, and to transmit a portion of the processed output signal over a wireless transmission link; and

202. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[k]. *See supra* §§ VIII.C.1.m–p (cl. 1[l]–[o]).

gg. Claim 11[l]: a cloud configured to receive over the wireless transmission link an output status comprising the at least a portion of the processed output signal, to process the received output status to generate processed data and to store the processed data, and wherein the cloud is capable of storing a history of at least a portion of the received output status over a specified period of time.

203. In my opinion, Lisogurski, in combination with Carlson, discloses claim 11[l]. *See supra* §§ VIII.C.1.q–t (cl. 1[p]–[s]).

hh. Claim 19[pre]: A wearable device for use with a smart phone or tablet, the wearable device comprising:

204. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[pre].

205. Lisogurski teaches or renders obvious a wearable device for use with a smart phone or tablet for the reasons I discussed for claims 1[pre], and 1[l]. *Supra* §§ VIII.C.1.a, m; *see also* EX1027, 4:6–8 (sensor can be placed on “a fingertip, toe, forehead, or earlobe”), 4:15–20 (identifying “wrist” and “neck” as additional “suitable sensor locations”), 15:19–27 (describing the “user interface” for use with a sensor includes a battery-operated, portable device with a touchscreen); 15:43–56 (describing wireless communication of the monitor), 17:54–58 (senor unit may be “wirelessly connected to the monitor”).

ii. Claim 19[a]: a measurement device including a light source comprising a plurality of semiconductor sources for measuring one or more physiological parameters, the measurement device configured to:

206. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[a]. *See supra* § VIII.C.1.c (cl. 1[b]).

jj. Claim 19[b]: generate, by modulating at least one of the semiconductor sources having an initial light intensity, an input optical beam having one or more optical wavelengths, and

207. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[b]. *See supra* § VIII.C.1.b (cl. 1[a]).

208. Lisogurski teaches generating an input optical beam, which a POSITA would have understood to be analogous with the output optical beam in claims 1 and 11. Specifically, a POSITA would have understood that the same beam is “output” by the device and “input” into the tissue, and that therefore the “output” optical beam can refer to the same beam as the “input” optical beam depending on the reference point. A POSITA would have understood that the input optical beam may have one or more optical wavelengths for the reasons described above for claim 1[a]. *Supra* §§ VIII.C.1.b (cl. 1[a]). Lisogurski teaches that the semiconductor sources have an initial light intensity for the reasons described above for claim 1[a]. *Id.*

209. Lisogurski further teaches “generating” the in/output optical beam by “modulating the semiconductor sources.” For example, Lisogurski teaches that the LEDs may operate in “continuous modulation” during “on” and “off” periods. EX1027, 11:61–12:9. Lisogurski further teaches that the “light sources are driven in this manner...[to] emit pulses of light at their respective wavelengths into the tissue of a subject,” *i.e.*, in a “beam”). EX1027, 12:11–22. Thus, a POSITA would have understood that Lisogurski generates an in/output optical beam from the semiconductor sources (LEDs) by modulating those LEDs.

210. Accordingly, Lisogurski teaches or renders obvious 19[b].

kk. Claim 19[c]: receive and to deliver a portion of the input optical beam to tissue, wherein the tissue reflects a least a portion of the input optical beam delivered to the tissue;

211. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[c]. *See supra* §§ VIII.C.1.d–e, g (cl. 1[c], 1[d], 1[f]).

ll. Claim 19[d]: the measurement device further comprising a receiver configured to:

212. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[d]. *See supra* § VIII.C.1.f (cl. 1[e]).

mm. Claim 19[e]: capture light while the semiconductor sources are off and convert the captured light into a first signal, and

213. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[e]. *See supra* § VIII.C.1.j (cl. 1[i]).

nn. Claim 19[f]: capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a portion of the input optical beam reflected from the tissue;

214. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[f]. *See supra* § VIII.C.1.k (cl. 1[j]).

oo. Claim 19[g]: synchronize to the modulation of the at least one of the semiconductor sources;

215. In my opinion, Lisogurski discloses claim 19[g]. As I discussed above, Lisogurski teaches a measurement system where the receiver may “synchronize to the light source.” *Supra* § VIII.C.1.i (cl. 1[h]). I further opined above that the “light source” in Lisogurski comprises multiple semiconductor sources, specifically,

LEDs. *Supra* § VIII.C.1.b (cl. 1[a]). Lisogurski further discloses that the receiver (detector) in its measurement system may be synchronized to the “modulation of the at least one of the semiconductor sources.” For example, Lisogurski teaches:

- “In some embodiments, the system may use various cardiac cycle **modulation** schemes to adjust the brightness of a light source controlled by the light drive signal used in determining physiological parameters. **The system may modulate the brightness of the light source using a periodic waveform, for example, a sinusoidal or triangle wave.** The period of the waveform may be substantially related to the cardiac pulse rate, for example, in a one-to-one relationship, a two-to-one relationship, any other suitable relationship, or any suitable combination thereof. **The system may align the peak of the modulated light drive signal with a particular point in the cardiac cycle to improve the quality of the determined physiological parameter,** for example, it may be aligned with the diastolic period, the systolic period, the dicrotic notch, any other suitable point, or any combination thereof. **In some embodiments, the system may modulate the light drive signal with a square wave function,** such that it is at a low brightness level during a first part of the cardiac cycle and a high brightness level during a second part of the cardiac

cycle. In some embodiments, the low brightness level may include turning one or more light sources off.” EX1027, 6:31–52.

216. A POSITA would have understood that these disclosures in Lisogurski teach 19[g]. Specifically, a POSITA would know that “align[ing] the peak of the modulated light drive signal with a particular point in the cardiac signal to improve the quality of the determined physiological parameter,” refers to synchronizing the modulation of the LEDs (semiconductor sources) with the receiver (which receives and determines signals corresponding to physiological parameters). EX1027, 6:41–52.

217. Accordingly, Lisogurski teaches or renders obvious 19[g]. Indeed, I note that the Board determined in the ’533 IPR that Lisogurski teaches a measurement device where the receiver is “synchronized to the light source’s pulses of light,” and that the Federal Circuit affirmed that decision. EX1008, 7–8, 37–39; EX1009.

pp. Claim 19[h]: the measurement device further configured to improve a signal-to-noise ratio of the input optical beam reflected from the tissue by:

218. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[h]. *See supra* § VIII.C.1.1 (cl. 1[k]).

qq. Claim 19[i]: differencing the first signal and the second signal, and

219. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[i]. *See supra* § VIII.C.1.1 (cl. 1[k]).

rr. Claim 19[j]: increasing the light intensity relative to the initial light intensity from at least one of the semiconductor sources;

220. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[j]. *See supra* §§ VIII.C.1.b (cl. 1[a]).

ss. Claim 19[k]: the measurement device further configured to generate an output signal representing at least in part a non-invasive measurement on blood contained within the tissue;

221. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[k]. *See supra* §§ VIII.C.1.h (cl. 1[g]).

tt. Claim 19[l]: the wearable device configured to communicate with the smart phone or tablet, the smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a voice input module, a speaker, and touch screen; and

222. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[l]. *See supra* § VIII.C.1.m (cl. 1[l]).

uu. Claim 19[m]: the smart phone or tablet configured to:

223. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[m]. *See supra* § VIII.C.1.m (cl. 1[l]).

vv. Claim 19[n]: receive and to process at least a portion of the output signal,

224. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[n]. *See supra* § VIII.C.1.n (cl. 1[m]).

ww. Claim 19[o]: store and display the processed output signal, and

225. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[o]. *See supra* § VIII.C.1.o (cl. 1[n]).

xx. Claim 19[p]: transmit at least a portion of the processed output signal over a wireless transmission link.

226. In my opinion, Lisogurski, in combination with Carlson, discloses claim 19[p]. *See supra* § VIII.C.1.p (cl. 1[o]).

yy. Claim 20: The wearable device of claim 19, wherein the light source is configured to further improve the signal-to-noise ratio of the input optical beam reflected from the tissue by increasing a pulse rate of at least one of the plurality of semiconductor sources from an initial non-zero pulse rate.

227. In my opinion, Lisogurski (or Lisogurski in view of Carlson) discloses or renders obvious claim 20. For example, Lisogurski discloses:

- “The system may, in response to the external trigger, vary the light intensity, duty cycle, **light source firing rate**, any other suitable parameter, or any combination thereof.” EX1027, 1:67–2:2.
- “As used herein, the terms ‘on’ and ‘off’ are merely exemplary and may not necessarily refer to a fully on or off state. **For example, ‘on’ and ‘off’**

may refer to switching power or other components, high and low brightness output states, high and low values within a continuous modulation, high and low values of electrical current provided to an emitter, high and low values of a duty cycle, high and low values of a decimation ratio (i.e., how often an emitter is switched on), any other suitable relatively distinct states, or any combination thereof. In some embodiments, ‘on’ and ‘off’ states may relate to high and low values of a variable that varies with multiple discrete steps. For example, an emitter brightness may be provided by the system as off, low, medium, and high. In this example, an ‘off’ state may refer to off or low emission and ‘on’ may refer to medium or high. In another example, ‘off’ may refer to an off state and ‘on’ may refer to a low, medium, or high output depending on a second input or system variable.” EX1027, 8:27–44.

- “In some embodiments, the system may alter the cardiac cycle modulation technique based on the level of noise, ambient light, other suitable reasons, or any combination thereof. The system may receive, for example, an increased level of background noise in the signal due to patient motion. The system may increase the brightness of the light sources in response to the noise to improve the signal-to-noise ratio. In some embodiments, the system may increase brightness throughout the

cardiac cycle because the system may require increased signal amplitudes to differentiate between fiducial and other points of interest related to physiological parameters and those related to noise or motion. In some embodiments, the system may change from a modulated light output to a constant light output in response to noise, patient motion, or ambient light. EX1027, 9:46–60.

- “Control circuitry 110 may be coupled to light drive circuitry 120, front end processing circuitry 150, and back end processing circuitry 170, and may be configured to control the operation of these components. **In some embodiments, control circuitry 110 may be configured to provide timing control signals to coordinate their operation. For example, light drive circuitry 120 may generate a light drive signal, which may be used to turn on and off the light source 130, based on the timing control signals. The front end processing circuitry 150 may use the timing control signals to operate synchronously with light drive circuitry 120. For example, front end processing circuitry 150 may synchronize the operation of an analog-to-digital converter and a demultiplexer with the light drive signal based on the timing control signals.** In addition, the back end processing circuitry 170 may use the

timing control signals to coordinate its operation with front end processing circuitry 150.” EX1027, 11:33–49.

- “Light drive circuitry 120, as discussed above, may be configured to generate a light drive signal that is provided to light source 130 of sensor 102. **The light drive signal may, for example, control the intensity of light source 130 and the timing of when light source 130 is turned on and off. When light source 130 is configured to emit two or more wavelengths of light, the light drive signal may be configured to control the operation of each wavelength of light.** The light drive signal may comprise a single signal or may comprise multiple signals (e.g., one signal for each wavelength of light). An illustrative light drive signal is shown in FIG. 2A.” EX1027, 11:50–60.
- “**The system may generate the light drive signal such that a parameter of the emitted one or more photonic signals varies substantially synchronously with physiological pulses of the subject. For example, the system may generate a light drive signal that varies with a period the same as or closely related to the period of the cardiac cycle, thus generating a cardiac cycle modulation. The system may vary parameters related to the light drive signal including drive current or light brightness, duty cycle, firing rate, modulation parameters, other**

suitable parameters, or any combination thereof. In some embodiments, the system may use a cardiac cycle modulation that spans several cardiac cycles (e.g., emitting light from a light source during the first one of every five cycles). In some embodiments, the system may generate a light drive signal that modulates parameters of more than one light source using more than one modulation technique. It will be understood that the system may apply this cardiac cycle modulation to the light drive signal in addition to a drive cycle modulation, as illustrated in FIG. 2C, and conventional servo algorithms.” EX1027, 25:46–25:65.

- “In some embodiments, physiological pulses may be cardiac pulses, respiratory pulses, muscular pulses, any other suitable pulses, or any combination thereof. Where physiological pulses are respiratory pulses, they may relate to respiration rate, inspiration, expiration, ventilator parameters, changes in a respiratory pressure signals, any other suitable parameter, or any combination thereof. **In some embodiments, particular segments of a respiratory cycle may provide an increased signal to noise ratio, increased signal strength, increased physiological parameter accuracy, increased physiological parameter precision, any other suitable parameters, or any combination thereof.** In some

embodiments, respiration may cause variations in photoplethysmography data, and thus it may be desired to correlate a modulation technique with respiration variations or both respiration variations and cardiac pulses.”
EX1027, 25:66–26:14.

- **“It will also be understood that modulation of the light drive signal (i.e., the “on” and “off” states illustrated by light drive signal 1010) is merely exemplary and may include modulation of parameters including drive current or light brightness, duty cycle, firing rate, modulation parameters, other suitable parameters, or any combination thereof. It will also be understood that the “on” and “off” states are merely exemplary and that the system may use any suitable variations of discrete and/or continuous modulations. For example, discrete modulations may include drive signals with one or more step functions. Continuous modulations may include sinusoidal waveforms.”**
EX1027, 27:44–55.

- **“In some embodiments, the system may vary the sampling rate to reduce or optimize power consumption. In some embodiments, sampling rate modulation may be correlated with light drive signal modulation. Varying the sampling rate may reduce power consumption by reducing emitter drive time and lowering utilization of an analog-to-**

digital converter. In some embodiments, varying the sampling rate may increase the time resolution of identified features. **For example, in a continuous non-invasive blood pressure measurement where the pulse transit time is used in calculations, increasing the sampling rate for a portion of the cardiac cycle may result in more accurate and reliable physiological information.** In another example, varying the sampling rate around a cardiac pulse cycle feature, such as a peak or notch, may increase the accuracy of determining the location of that feature in time. **In some embodiments, lower frequency or less critical parts of the cardiac pulse cycle may be sampled at a lower rate while maintaining highly accuracy and reliable physiological parameter determination.”** EX1027, 33:46–64.

- “It will also be understood that the earlier described embodiments relating to varying light output may also apply to sampling rate.” EX1027, 35:7–9.
- “In some embodiments, **the sampling rate may represent the amount of time between “on” periods.** For example, the time between “on” periods may be the length of time of “off” period 220 of FIG. 2A. **Increasing the duration of the “off” periods (i.e., decreasing the emitter firing rate) relates to a decreased sampling rate. Similarly, decreasing the**

duration of the “off” periods (i.e., increasing the emitter firing rate) relates to an increased sampling rate.” EX1027, 35:24–31.

- **“In some embodiments, the system may use a high sampling rate during the high light output periods and a low sampling rate during low light output periods to reduce power consumption while still obtaining high quality determinations of physiological parameters.** It will be understood that the particular sampling rates shown in plot 1800 are merely exemplary and that **the system may employ any suitable sampling rate and any suitable sampling rate modulation.** In some embodiments, the system may process raw sampling rate signal 1814 to produce decimated sampling rate signal 1816 by decimation, interpolation, any other suitable sampling rate modification, or any combination thereof. As used herein, “raw” refers to the sampling rate at the analog-to-digital converter prior to interpolation or decimation. It will be understood that the system may decimate and interpolate samples using any suitable hardware technique, software technique, or any combination thereof.” EX1027, 36:3–19.

- “Pulse amplitude and variations thereof are common calculations in physiological monitors. The simulated waveforms of plot 2600 of FIG. 26 may be used to calculate pulse amplitudes (i.e., the differences between

maxima and minima). The calculations may be computed on the maxima and minima of correctly identified pulses. Based on this analysis, it may be determined that noise contributes coefficients of variation of 2.6%, 1.9%, and 3.8% to the computed pulse amplitudes of PPG signal 2602, systole period modulated PPG signal 2604, and diastole period modulated PPG signal 2606, respectively. **Accordingly, for pulse amplitude calculation techniques in the presence of moderate noise, the systole period cardiac cycle modulation technique may provide improved performance.”** EX1027, 42:45–58.

228. A POSITA would have understood from the above disclosures that Lisogurski teaches adjusting the parameters of the LEDs to improve SNR. EX1027, 9:46–52. As I discussed above, these parameters may include the “drive current or light brightness, duty cycle, [and] firing rate” of the semiconductor sources/LEDs. EX1027, 27:44–52; *id.*, 2:1–3, 8:29–35, 25:46–55. A POSITA would have understood that the “firing rate” of the LEDs described by Lisogurski corresponds to the “pulse rate” of at least one of the plurality the semiconductor sources in claim 20.

229. Lisogurski further teaches that its system may switch between a first and second modulation mode (with each modulation mode corresponding to different light drive parameters) in response to a “change in background noise

[or]...ambient light.” EX1027, 37:6–20. A POSITA would have understood from these disclosures that Lisogurski teaches an *initial* firing rate (initial pulse rate) in the first modulation mode that the system can later vary depending on a change in light or ambient noise. A POSITA would have understood that the initial firing rate may not necessarily be equal to zero (and, indeed, Lisogurski is not so limited). *E.g.*, EX1027, 1:67-2:3 (explaining that the system may, “in response to [an] external trigger, vary . . . firing rate”); 27:44-55 (explaining that modulation of firing rate may use “any suitable variations of discrete and/or continuous modulations”), 27:39-43 (“the system may use any suitable number of discrete or continuous modulation variations”), 29:25-37 (similar), 37:19-20 (the system “may lengthen the ‘on’ periods), 24:49-55 (explaining that the “light drive signal” may vary “with a period the same as or closely related to the period of the cardiac cycle”), 35:10-49 (disclosing that “increasing the emitter firing rate” relates to “an increased sampling rate”).

230. A POSITA would have understood that Lisogurski teaches that increasing the pulse rate of one of the LEDs improves the signal-to-noise ratio. For example, Lisogurski teaches “decreasing the duration of the ‘off’ periods (i.e., increasing the emitter firing rate) relates to an increased sampling rate.” EX1027, 35:27–31. A POSITA would have understood that an increased sampling rate from the semiconductor sources results in more samples, which improves SNR because

the noise is averaged across more samples. Indeed, Lisogurski explains that increasing the sampling rate “may result in more accurate and reliable physiological information,” without limiting this principle to situations where the sampling rate starts at zero. EX1027, 33:53–58, 9:46–52 (varying parameters can increase SNR), 35:7–9. Lisogurski therefore teaches that as both the firing and sampling rate from the LEDs increases, the “signal to noise ratio” also increases, and therefore, improves.

231. Lisogurski also teaches “cardiac cycle modulation,” a technique that improves SNR in the same way as the coordination of the sampling and firing rate. EX1027, 25:46–65. Specifically, cardiac cycle modulation in Lisogurski configures the LEDs such that their firing rate (pulse rate) increases when a subject’s heart rate increases. EX1027, 42:50–54, 25:46–26:14. A POSITA would have understood that by taking more samples when heart rate increases, the system in Lisogurski decreases the amount of noise detected in the measured signal and thereby improves SNR. Thus, in my opinion, Lisogurski teaches claim 20.

232. It is further my opinion that Carlson also teaches increasing the pulse rate of the semiconductor sources from an initial non-zero pulse rate (and thereby increasing SNR). For example, Carlson teaches:

- “The frequency spectrum of ambient light is schematically shown in diagram 7b. **Sunlight is at 0 Hz, while artificial light, such as e.g.**

electrical in-house light, is going up to approximately 120 Hz (USA). In other words, within the range of frequencies of physiological signals, we have high influence of frequencies of sunlight and ambient light. A corresponding combined frequency spectrum is shown in Fig. c, which would be detected by a photo diode without the use of any means as described above in relation to FIGS. 1 to 6. FIG. 7c shows a basic signal contribution due to physiological signal and **additional signal contribution due to ambient light.** In other words, the influence of ambient light is quite substantial, and therefore the deviations of the measured values compared to the real values can be dramatic.” EX1028, [0067].

- “Besides the high influence of ambient light, also sunlight can have a dramatic influence, e.g. if a person is walking through streets with relatively quick changing conditions between sunlight and shadow. Another serious possibility is caused by a tree avenue when driving along the trees. **Sunlight then is received e.g. by the pulsoximetric sensor at a certain frequency, which means that every time when passing a tree, sunlight is attenuated and between the trees sunlight is influencing the measurement of the pulsoximetric sensor.**” EX1028, [0068].

- **“As a consequence, it is therefore proposed to emit light by the LEDs not as current or continuous light but as pulsed light. The frequency is chosen in such a way that it is outside the frequency spectrum of sunlight and of ambient light which, according to FIG. 7b, is in the range of above approximately 1000 Hz. Thus, the pulsoximeter signals are readily discriminated from electronic and parasitic contributions of environmental optical radiation outside the frequency $f_c \pm 5$ Hz increasing significantly the Signal-to-Noise and Signal-to-Background ratio. FIG. 8 shows the shift spectrum of signal to a region where there is little influence, e.g. of ambient light. F_0 is the chosen frequency of the emitted light to operate the pulsoximeter sensor and the range between $f_0 - 5$ Hz and $f_0 + 5$ Hz is the consequence of the influence of the frequency due to physiological signal. Therefore, as shown in FIG. 8, the frequency spectrum of signal at the photo diode does have a basic signal contribution due to physiological signal. The signal contribution which is shown at the top of the signal contribution due to physiological signal and which is due to ambient light, is very small and as a consequence is approximately neglectable. Any noise or sunlight within the range of 0 to 120 Hz, while the light beam for the pulsoximetric measurement is within the range of approximately $f_0 - 5$ Hz to $f_0 + 5$ Hz, will not**

influence the measurement of the pulsoximetric sensor. F_0 could be e.g., as mentioned, 1000 Hz which of course is a frequency far outside of any indoor light source, as e.g. halogen light, conventional light, etc. f_0 of course can be chosen at any other frequency, as e.g. 2000 Hz or even higher. By using light source modulation, it is even possible to use an additional filter removing a certain frequency spectrum. Looking e.g. at FIG. 9, it is possible to arrange a filter band pass 51 which is e.g. removing any frequencies in the range of 0 to 120 Hz. The respective filter is shown in form of the dashed line 51. As a result, we end up by a diagram according to FIG. 9 b only showing any measurements in the range of f_0-5 Hz to f_0+5 Hz.” EX1028, [0069].

233. A POSITA would have understood that Carlson therefore teaches that increasing the “pulse frequency” (pulse rate) of the LEDs counteracts the effects of ambient light, like sunlight, which may have a frequency of 0–120 Hz. EX1028, [0067]–[0069]. Specifically, Carlson explains that selecting a higher pulse frequency “in such a way that it is outside the frequency spectrum of sunlight and ambient light” (e.g., 1000 Hz, 2000 Hz, or “even higher”) improves “significantly the Signal-to-Noise and Signal-to-Background ratio.” EX1028, [0069]. Carlson further teaches “shift[ing] the frequency of the emitted light” during the operation of Carlson’s device in response to changes in environmental signals (like sunlight,

which is temporary), which a POSITA would have understood to mean shifting from a first non-zero pulse rate to an increased pulse rate to improve SNR. EX1028, claims 10–11, [0067]–[0069].

234. Thus, as I discussed above, both Lisogurski and Carlson identify the same problem of needing to offset noise created by ambient light to improve SNR, and both systems describe increasing the pulse rate of the semiconductor sources (LEDs) in order to do so. *Supra* § VIII.B.1. A POSITA would have been motivated to consider the two systems together. *Id.* Thus, to the extent Lisogurski does not explicitly teaching increasing the pulse rate from a “non-zero” pulse rate, it would have been obvious to a POSITA to modify Lisogurski’s system to meet this limitation, and it would have required routine effort to do so. Because a POSITA would have viewed Lisogurski and Carlson’s techniques as interchangeable, *i.e.*, one could be a substitute for the other, a POSITA would have had reasonable expectation of success implementing Carlson’s modulation technique in Lisogurski’s system.

235. Accordingly Lisogurski, or Lisogurski in view of Carlson, teaches or renders obvious Claim 20. I note that the Board found in the ’533 IPR that Lisogurski, or Lisogurski in view of Carlson, teaches a limitation nearly identical to Claim 20 (specifically, “increas[ing] signal-to-noise ratio ... by increasing a pulse rate of at least one of the plurality of semiconductor sources”). EX1008, 7, 26–35. I understand this decision has been affirmed by the Federal Circuit. EX1009. I

understand the Board made a similar determination in the '484 IPR and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit. EX1011, 6, 28–43; EX1012, n.2. In my opinion, the addition of “non-zero” to claim 20 does not change my opinion that Lisogurski (or Lisogurski combined with Carlson) teaches or renders obvious claim 20.

zz. Claim 25[a]: The wearable device of claim 19, further comprising a cloud configured to: receive, over the wireless transmission link, an output status comprising the at least a portion of the processed output signal,

236. In my opinion, Lisogurski, in combination with Carlson, discloses claim 25[a]. *See supra* § VIII.C.1.r (cl. 1[q]).

aaa. Claim 25[b]: process the output status to generate processed data, and

237. In my opinion, Lisogurski, in combination with Carlson, discloses claim 25[b]. *See supra* § VIII.C.1.s (cl. 1[r]).

bbb. Claim 25[c]: store the processed data, and

238. In my opinion, Lisogurski, in combination with Carlson, discloses claim 25[c]. *See supra* § VIII.C.1.t (cl. 1[s]).

ccc. Claim 25[d]: wherein the cloud is capable of storing a history of at least a portion of the output status over a specified period of time.

239. In my opinion, Lisogurski, in combination with Carlson, discloses claim 25[d]. *See supra* § VIII.C.1.t (cl. 1[s]).

2. Ground 2: Claim 3 would have been obvious over Lisogurski in view of Carlson in further view of Debreczeny.

240. I have analyzed claim 3 and conclude that it would have been obvious over Lisogurski in combination with Carlson and Debreczeny. I provide a detailed analysis of each claim limitation below.

a. Claim 3: The measurement system of claim 1, wherein the light source is further configured to increase the light intensity from the plurality of semiconductor sources by spatially coupling the optical output beam from at least two of the plurality of semiconductor sources.

241. In my opinion, Lisogurski, in combination with Carlson and Debreczeny, discloses claim 3. Debreczeny teaches a pulse oximetry system with at least three semiconductor sources—“having emitter LEDs 64, 65, and 66.” EX1029, 5:6–67. Debreczeny further teaches that two of the LEDs emit red light, and that those two LEDs are positioned using “[s]patial symmetry” about a center LED emitting infrared light. EX1029, 5:6–25. This arrangement is illustrated by Figure 2:

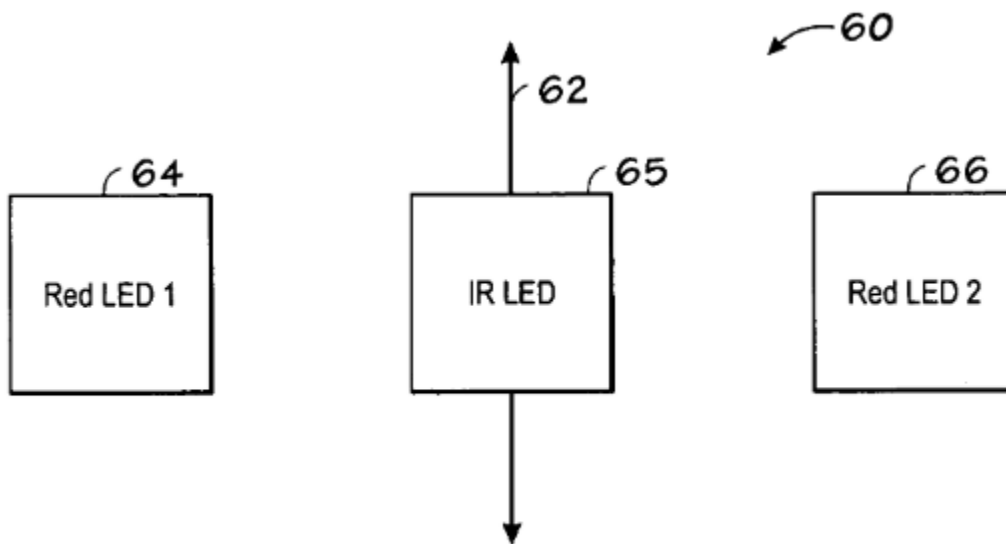


FIG. 2

EX1029, Fig. 2.

242. Debreczeny further teaches that using such an arrangement as illustrated by Figure 2 “help[s] ensure that any **coupling** issues that may occur due to the movement of tissue relative to one LED may be compensated for by the other LED.” EX1029, 5:16–25. Specifically, the two red LEDs in Debreczeny’s system are selected to have “maxima at wavelengths that overlap at their half power level or greater,” such that “when **summed together they achieve a maximum intensity**” that is “**greater than that of either LED 64 or 66 alone.**” *Id.*, 5:36–67; *see also* 6:1–29. “Because the signal from the two [red] LEDs 64 and 66 is additive, the signal-to-noise ratio of the sensor may be increased, thus providing better readings.” EX1029, 5:26–35. It is my opinion that a POSITA would have understood from these disclosures and others in Debreczeny that the output optical beam from two or

more semiconductor sources (specifically, the two LEDs) are “spatially coupled” in order to increase the light intensity from the plurality of semiconductor sources.

243. Furthermore, a POSITA would have been motivated to incorporate the spatial coupling disclosed in Debreczeny into the system described by Lisogurski as part of the routine design process and would have had a reasonable expectation of success in doing so. *Supra* § VIII.B.2. Specifically, as noted, Debreczeny’s arrangement of the red LEDs offers a technique for increasing the signal-to-noise ratio, so a POSITA looking to improve SNR (as suggested by Lisogurski) would have found it obvious to implement the spatial arrangement of the semiconductor sources (LEDs) from Debreczeny into Lisogurski’s sensor. This is especially true because Lisogurski contemplates “any suitable configuration” for the LEDs in the sensor, including a sensor with “multiple light sources” that “**may be spaced apart.**” EX1027, 17:42–45 (“Any suitable configuration of light source 316 and detector 318 may be used. In an embodiment, sensor unit 312 may include multiple light sources and detectors, which may be spaced apart.”). Implementing the configuration from Debreczeny into the light source from Lisogurski would have been a straightforward modification with predictable results (increasing SNR), and part of a POSITA’s ordinary design process.

244. Accordingly, Lisogurski in view of Carlson and Debreczeny teaches or renders obvious claim 3.

3. Ground 3: Claims 2, 14, and 27 would have been obvious over Lisogurski in view of Carlson in further view of Valencell-093.

245. I have analyzed claims 2, 14, and 27, and conclude that they would have been obvious over Lisogurski in combination with Carlson and Valencell-093. I provide a detailed analysis of each claim limitation below.

- a. Claim 2: The measurement system of claim 1, wherein the plurality of semiconductor sources comprises at least one of: light emitting diodes (LEDs), laser diodes (LD's), tunable LD's, and super-luminescent laser diodes (SLDs), and wherein the measurement system further comprises a reflective surface to receive and redirect at least some of the at least a portion of the analysis output beam reflected or transmitted from the sample.**

246. In my opinion, Lisogurski, in combination with Carlson and Valencell-093, discloses claim 2.

247. As I discussed above, Lisogurski teaches the plurality of semiconductor sources comprises light emitting diodes. *Supra* § VIII.C.1.b (cl. 1[a]); EX1027, 7:38–67 (“For example, **the first light source may be a high efficiency infrared (IR) LED while the one or more additional light sources may be lower efficiency red LEDs**”), 19:20–39 (“For example, the light source may include light source 130 of FIG. 1 or light source 316 of FIG. 3. In some embodiments, **the light source may include LEDs of multiple wavelengths**, for example, a red LED and an IR led. In some embodiments, **the light source may include multiple LEDs of the same**

wavelength, multiple LEDs of different wavelengths, any other suitable arrangement, or any combination thereof.”).

248. Valencell-093 adds that the measurement system further comprises a reflective surface that receives and redirects at least a portion of the analysis output beam reflected or transmitted from the sample. Specifically, Valencell-093 teaches:

- “In some embodiments of the present invention, a **light guiding region 2306 may surround or partially surround the sensor module 700, 800 and/or isolation region 2304, as illustrated in FIGS. 24-27.** In FIGS. 24-26, the light guiding region 2306 surrounds the sensor module 700, 800. In FIG. 27, the light guiding region 2306 partially surrounds the sensor module 700, 800. **The light guiding region 2306 helps direct light to and/or from the sensor module 700, 800 and a blood flow region within the body part.** In some embodiments, the light guiding region 2306 may be a reflector, such as a metal, metallic alloy, mylar, mica, reflective plastic, reflective textile, or the like. In other embodiments, the light guiding region 2306 may be a transparent light guide, such as transparent silicone, polymers, rubbers, textiles, glass, epoxies, glues, or the like. **In the case of a reflective layer, the sensor module 700, 800 is at least partially exposed.** In the case of a transparent light-guiding layer, the sensor module 700, 800 may be completely covered.” EX1032, [0152].

- “Referring to FIGS. 28 and 29, the sensor module 700, 800 may be tilted with respect to a body part region (e.g., the wrist area) of a subject. In the illustrated embodiments of FIGS. 28 and 29, the sensor module 700, 800 is tilted towards the wrist (away from the upper arm). The embodiment illustrated in FIG. 28 has a light guiding region 2306 with a different configuration from the light guiding region 2306 illustrated in the embodiment of FIG. 29. The tilting of the sensor module 700, 800 serves at least the following functions: 1) protection from sunlight and 2) improvement of coupling between light from the sensor module 700, 800 and blood flow in the body part (i.e., wrist area). Sunlight immunity may be improved in this fashion because a human's wrist is typically pointed away from sunlight, and so pointing the sensor module down along the arm may help prevent environmental (i.e., sunlight) interference. Also, pointing the sensor module 700, 800 towards the wrist may increase the surface area of blood flow exposed to the sensor module 700, 800, thus increasing the blood flow signal intensity for PPG and the like.” EX1032, [0153].

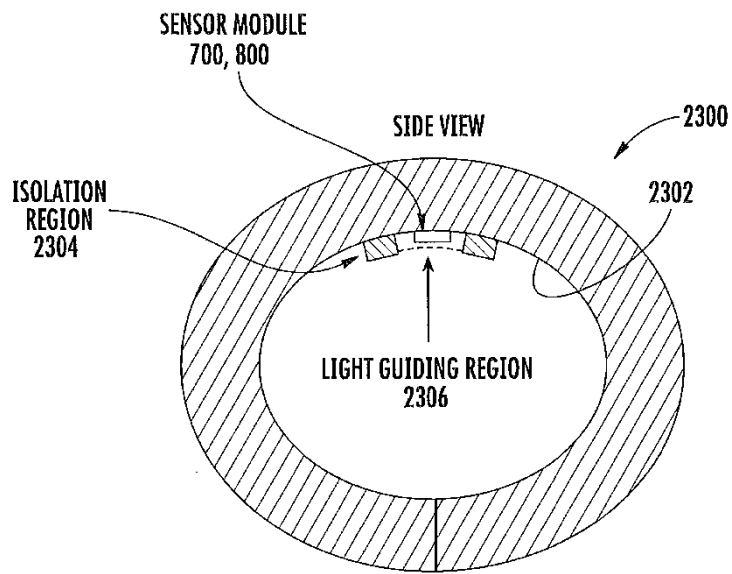


FIG. 24

EX1032, Fig. 24.

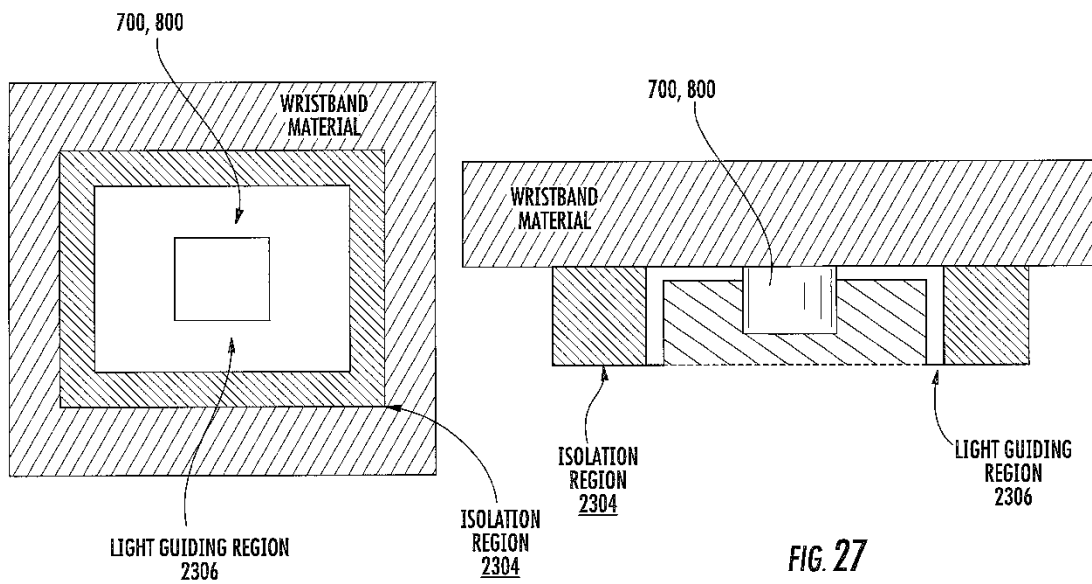


FIG. 26

FIG. 27

EX1032, Fig. 26–27.

249. As described above, Valencell-093 teaches a sensor that can be surrounded by a “light guiding region,” which “helps direct light to and/or from the sensor module,” *e.g.*, toward a “blood flow region within the body part.” EX1032, [0152]. The light-guiding region can include a “reflector,” like a “metal,” “metallic alloy,” or “reflective plastic.” EX1032, [0152]. A POSITA would have understood that the light-guiding region comprised of a “reflector” or “reflective plastic” in Valencell-093 receives and redirects at least a portion of an analysis output beam reflected or transmitted from a sample.

250. A POSITA would further have been motivated as part of the ordinary design process to incorporate the light-guiding region in Valencell-093 into Lisogurski’s measurement system and would have found it an obvious variation of Lisogurski with a reasonable expectation of success. *Supra* § VIII.B.3. For example, Valencell-093 teaches that the light-guiding region assists the wearable measurement device in coupling the optical sensor to the tissue and in reducing interference from environmental noise, which a POSITA would have understood corresponds to improving SNR. EX1032, [0153]. In my opinion, this recognition alone would have motivated a POSITA to incorporate Valencell-093’s light-guiding region into the wearable device taught by Lisogurski, since (as I discussed above) both references are concerned with techniques for improving SNR of wearable sensors. *Supra* § VIII.B.3. Additionally, a POSITA would have recognized that

adding Valencell-093's reflective surface to Lisogurski would improve the received signal measurement from the sample and thereby complement the operation of Lisogurski's system, which seeks to improve efficiency and optimize power consumption. *Supra id.*; EX1027, 1:10–11.

251. Incorporating the light-guiding region / reflective surface from Valencell-093 into Lisogurski's system would have been a straightforward and routine modification with a reasonable expectation of success. Specifically, a POSITA would have been familiar with the materials and coatings described by Valencell-093, as the use of reflective materials to focus light output was well known, and would have been able to integrate these materials into Lisogurski's wearable sensor unit with routine effort and expected results. Therefore, a POSITA would have had a reasonable expectation of success incorporating Valencell-093's teachings into a system based on Lisogurski, whether alone or as modified by Carlson.

252. Accordingly, Lisogurski in view of Carlson and Valencell-093 teaches or renders obvious Claim 2. I note that the Board found in the '484 IPR that Valencell-093 teaches a similar limitation, specifically "a reflective surface positioned to reflect at least a portion of ... light reflected from the tissue," and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit. EX1011, 59–60; EX1012, n.2.

- b. **Claim 14: The measurement system of claim 11, wherein the plurality of semiconductor sources comprises at least one of: light emitting diodes (LEDs), laser diodes (LD's), tunable LD's, and super-luminescent laser diodes (SLDs), and the measurement system further comprising a reflective surface to receive and redirect at least some of the at least a portion of the analysis output beam reflected or transmitted from the sample.**

253. In my opinion, Lisogurski, in combination with Carlson and Valencell-093, discloses claim 14. *See supra* § VIII.C.3.a (cl. 2).

- c. **Claim 27: The wearable device of claim 19, wherein the measurement device further comprises a reflective surface configured to receive and redirect at least a portion of light reflected from the tissue.**

254. In my opinion, Lisogurski, in combination with Carlson and Valencell-093, discloses claim 27. *See supra* § VIII.C.3.a (cl. 2).

4. Ground 4: Claims 4–8, 10, 15–18, and 21–24 would have been obvious over Lisogurski in view of Carlson in further view of Soller.

255. I have analyzed claims 4–8, 10, 15–18, and 21–24, and conclude that they would have been obvious over Lisogurski in combination with Carlson and Soller. I provide a detailed analysis of each claim limitation below.

- a. **Claim 4: The measurement system of claim 1, wherein the receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor sources are arranged along a second arc.**

256. In my opinion, Lisogurski in combination with Carlson and Soller discloses or renders obvious claim 4. Lisogurski discloses one or more detectors

and one or more semiconductor sources, as I discussed above. *Supra* §§ VIII.C.1.b, f (cl. 1[a], cl. 1[e]). Soller further discloses:

- “The cover 106 is attached to a mounting plate 108. The mounting plate 108 includes a series of portholes 109, 109' positioned above each LED so that radiation 122, 122' can pass through the mounting plate 108 and onto the sample. For example, **the hematocrit measuring device includes between 5 and 20 LEDs**. A single porthole is preferably included for each LED. The LEDs are preferably tilted inward so that radiation leaves the device at an angle relative to the mounting plate. In this way, each LED can irradiate approximately the same part of the tissue, **hereby increasing the accuracy of the measurement**. Alternatively, the LEDs can be leveled so that radiation is emitted upwards in a vertical direction. **In both cases, the LEDs and portholes are evenly spaced and arranged in a circular pattern on the cover 106 and mounting plate 108, respectively.**” EX1030, 13:35–49.
- “The device 100 includes **interior detectors 105 and exterior detectors 110 for detecting radiation**. Typically, both the interior and exterior detectors include photodiodes and detection electronics, such as preamplifiers and electrical circuits for gated or phase-sensitive detection, **for generating analog electrical signals in response to visible and near-**

infrared optical radiation. The exterior reflection detector 110 is attached to the outer surface of the mounting plate. **During operation, optical radiation 122, 122' from each LED is emitted in all directions.**

A majority of the radiation 122, 122' passes through the portholes 109, 109' and through skin onto the sample 102. This radiation is partially reflected by the sample towards the exterior reflection detector 110 for detection.” EX1030, 13:50–63.

- “In another embodiment, a separate microprocessor 111' is included directly in the hematocrit measuring device. Microprocessor 111' receives the radiation-induced signals from the signal processor to calculate the reflection spectrum. The reflection spectrum can then be further analyzed to calculate the hematocrit of the sample using the method described above. This embodiment can be used to determine the hematocrit of the sample without using an external computer, **and is thus particularly desirable for applications necessitating a portable or hand-held device.**” EX1030, 15:31–40.
- “**Because of its small size, the integrated device is portable, hand-held, and easily manipulated.** This allows the operator to measure hematocrit in hard-to-reach places on a particular patient. Hematocrit can also be measured in remote locations, such as in an ambulance or outdoors. **The**

integrated device also can be used as a body-worn sensor for continuous monitoring of hematocrit.” EX1030, 15:50–56.

- “The fiber optic cable 152 is bifurcated at a first point 158a to deliver a portion of the incident radiation through a first fiber optic cable section 160 to a reference detector 155. This radiation is then processed to determine the reference spectrum. Accordingly, as shown in FIG. 8A, a cross-sectional slice of the fiber optic cable 152 immediately after the fiber housing 156 features a delivery fiber 166 **surrounded by radially and symmetrically disposed reference fibers 168**. During operation, radiation from the LEDs is focussed [sic] by the lens into both the delivery 166 and reference fibers 168. Radiation from the delivery fiber passes through the cable and onto a sample, while radiation coupled into the reference fibers propagates through the first fiber optic cable section 160 and onto the reference detector 155.” EX1030, 16:6–21.
- “The radiation delivered by the fiber optic cable passes through a probe 162 prior to irradiating the sample. FIG. 8B shows a cross-sectional slice of the fiber optic cable 152 immediately before the probe 162. Here, a series of **signal fibers 170 are radially and symmetrically disposed around the delivery fiber 166**. In addition, the cable is bifurcated at a second point 158b. During operation, radiation reflected by the sample is

collected by the signal fibers 170 and delivered through a second cable section 164 to a signal detector 157. This radiation is then processed as described above to determine the reflection spectrum.” EX1030, 16:22–32.

- “Both the reference 168 and signal 170 fibers are preferably disposed around the delivery fiber 166 in a radial, symmetric pattern to maximize the coupling efficiency of, respectively, the incident and reflected radiation. Use of multiple fibers also facilitates optimal collection of radiation.” EX1030, 16:33–39.
- “FIG. 9 shows a preferred orientation of the lens 150 of FIG. 7 relative to the incident radiation 122, 122' generated by the LEDs. Preferably, the LEDs are arranged in the integrated optical device so that the incident radiation irradiates the lens in a symmetric, ring-like pattern disposed radially around the center of the lens 150. The component of the light from each LED that is collimated will be focused by the lens into a small spot at the entrance end of cable 52, thereby maximizing the amount of radiation coupled into the fiber optic cable.” EX1030, 16:39–48.
- “FIGS. 11A and 11B [annotated below] show an integrated, self-contained hematocrit measuring device 600 for measuring a reflection spectrum from a sample 505. The hematocrit measuring device 600 features a circular

array, e.g., typically at least seven, of light-emitting diode (LED) radiation sources 604, for providing optical radiation, as described above. Device 600 includes a reflectance detector 605 and a series of reference detectors 610. LEDS 604 and detectors 605, 610 are mounted by connections 609 onto a printed circuit board 608. Reference detectors 610 are mounted on the side of each LED to measure and correct for variations in the LED intensity due to temperature, aging, or electrical power source drifts. FIG. 11C shows an alternate mounting position for reference detectors 610 which allows more light to reach reference detectors 610.” EX1030, 17:36–60.

- “FIGS. 12A and 12B show a hematocrit measuring device 700 for measuring a reflection spectrum from a sample 705. The hematocrit measuring device 700 features an array of, e.g., at least seven, light-emitting diode (LED) radiation sources 604, for providing optical radiation, as described above. Device 700 includes a reflectance detector 710 and a reference detector 720. LEDs 704 and detectors 710, 720 are integrated onto a printed circuit board 708. Each LED 704 is coupled to one of a series of single optical fiber elements 730 and then to a fiber splitter 735 which sends an amount, e.g., 60%, of the fiber coupled LED light through a probe fiber 740 to a probe tip 790 and the remaining, e.g.,

40%, of the light through reference fibers 745 to reference detector 720. **Reference detector 720 is coupled to one optical fiber from each LED.** The fiber-optic coupling is shown for only **three of the ten LEDs** to simplify the diagram. All of LEDs 704 have similar fiber coupling. Probe fibers 740 from fiber splitter 735 are combined into a single fiber bundle 750 terminating at a probe tip 790. **Light from fiber bundle 750 illuminates sample 705. The return reflected light is received by an array of, e.g., twenty-five, single fibers 780 configured in a ring 781 concentric about fiber bundle 750.** For simplicity, only three of the twenty-five fibers connected to the **circular reflectance array** are shown in FIG. 12b. The spacing between the center illuminating fiber bundle 750 and the outer fiber ring 781 is preferably 2-4 mm when the probe tip 790 has a diameter of 5 mm.” EX1030, 18:18–46.

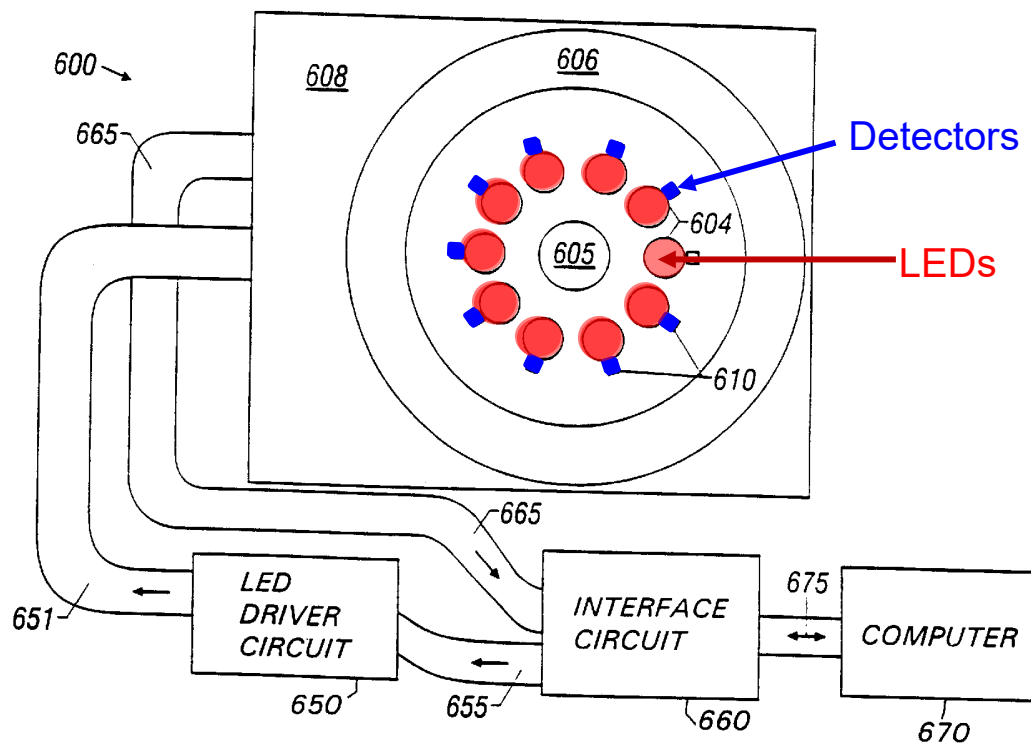


Figure 11A

EX1030, Fig. 11A (annotated).

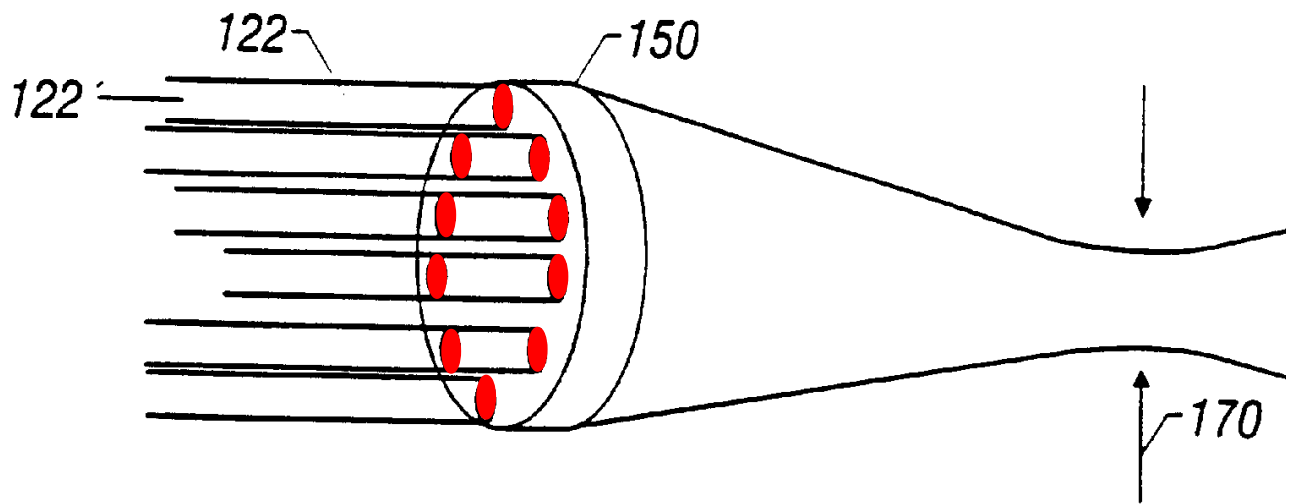


Figure 9

EX1030, Fig. 9 (annotated).

257. Soller thus teaches a **plurality of detectors** (e.g., “**interior detectors 105 and exterior detectors 110**”), which are coupled to a single fiber “configured in a **ring**” and can number as many as 25. EX1030, 13:50–63, 18:36–46 (detectors receive “return reflected light” via “an array of, e.g., twenty-five single fibers” “configured in a ring”); 16:6–39 (radiation reflected by the tissue is collected by “signal fibers” attached to the detectors “disposed around the delivery fiber [i.e., semiconductor source fiber] in a radial, symmetrical pattern to maximize the coupling efficiency of, respectively, the incident and reflective radiation”). A POSITA would have understood from these disclosures that Soller teaches or renders obvious a plurality of detectors arranged in a first arc. Even if Soller does not

expressly disclose the arrangement of detectors in an arc, this would have been a straightforward design modification that would have been obvious and a routine design change.

258. Soller further teaches a wearable optical sensor with a plurality of LEDs (semiconductor sources) that are “evenly spaced and arranged in a circular pattern,” *i.e.*, arranged in an arc. EX1030, 13:47–49, *id.*, at 16:39–48 (describing LEDs in a “symmetric, ring-like pattern around the center of the lens”), 17:36–41 (describing a “circular array” of LEDs). A POSITA would have understood based on the above disclosures that Soller teaches the LEDs are arranged along a second arc. Even if Soller does not expressly disclose the arrangement of LEDs in an arc, this would have been a straightforward design modification that would have been obvious and a routine design change.

259. Soller further illustrates a sample embodiment in Figure 11A (which I have annotated above) with a “series of **reference detectors**” “mounted on the side of **each LED** to measure and correct for variations in the LED intensity.” EX1030, 17:36–50, Fig. 11A. Soller teaches that the “**reference detectors**” are “mounted on the side of each LED to measure and correct for variations in the LED intensity due to temperature, aging, or electrical power source drifts,” and that the “reflectance detector” for receiving light transmitted/reflected from the sample is denoted by 605. EX1030, 17:42–60. A POSITA would have understood all of these “**detectors**”

(reference and reflectance) detectors to be conventional photodiodes. Soller itself teaches that the “**interior and exterior detectors** include photodiodes.” EX1030, 13:50–62 (“Typically, both the interior and exterior detectors include photodiodes”).

260. It therefore would have been obvious to a POSITA to modify Figure 11A of Soller such that the “**reference detectors**” (surrounding the LEDs) could serve as “**reflectance detector(s)**” for detecting light from the sample. In fact, Soller itself directly teaches modifying the arrangement of detectors. EX1030, 17:42–49 (“Fig. 11C shows an alternate mounting position for **reference detectors 610**, which allows more light to reach **reference detectors 610**”); *see also id.*, 18:47–58 (“Hematocrit measuring device 700 can be modified”). For example, Soller teaches that the reference detectors can be moved to the interior of the LEDs to allow “more light” to reach them. EX1030, 17:42–49; Fig 11C.

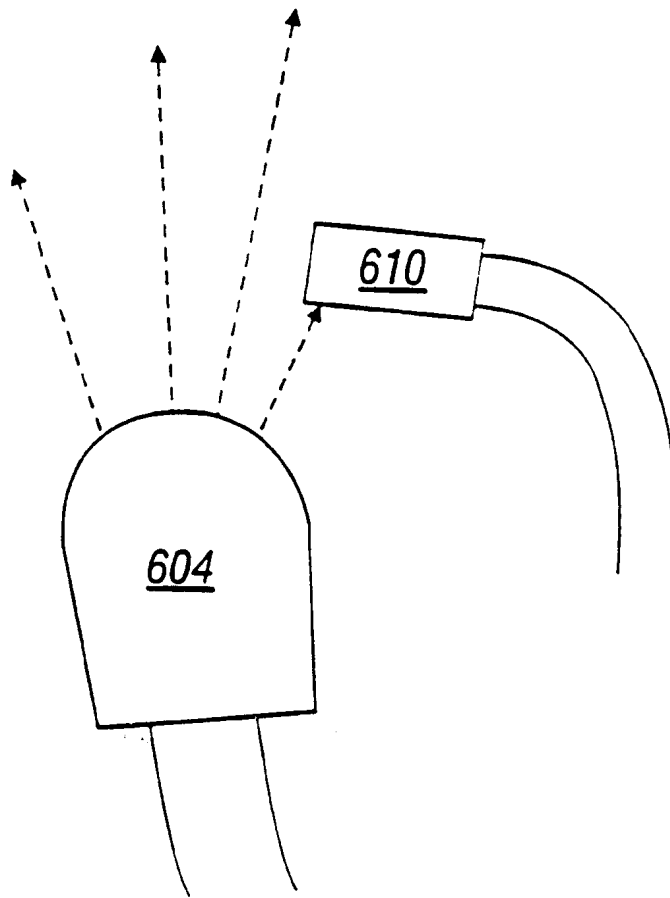


Figure 11C

EX1030, Fig. 11C.

261. It would have been readily apparent to a POSITA reading Soller that the reflectance detector(s) could also be arranged in a different position, including to be further away from the LEDs. Arranging the reflectance detector(s) to take the place of the reference detectors would have been a straightforward substitution, given that

both types of detectors are conventional photodiodes and the substitution would have required routine effort.

262. A POSITA would further have understood from Figure 11A in Soller that the detectors can be arranged in a circular pattern surrounding the LEDs, representing a “first arc.” Even if Soller does not expressly disclose the arrangement of detectors in an arc, this would have been a straightforward design modification that would have been obvious.

263. A POSITA would have been motivated to combine the arrangement of detectors and LEDs in a first and second “arc” disclosed in Soller into the wearable sensor described by Lisogurski. *Supra* § VIII.B.4. Soller teaches a wearable sensor comprised of LEDs and photodiodes (detectors), and designed to be easily portable and worn by a user. EX1030, 15:50–56 (“Because of its small size, the integrated device is portable, hand-held, and easily manipulated. ... Hematocrit can also be measured in remote locations, such as in an ambulance or outdoors. The integrated device can also be used as a **body-worn sensor** for continuous monitoring of hematocrit”). Lisogurski, too, teaches a wearable optical sensor designed to increased portability. *Supra* § VIII.A.1.

264. Similarly, as I discussed above, Lisogurski also teaches a portable, wearable sensor that uses multiple LEDs of varying wavelengths (*e.g.*, EX1027, 10:48–64, 19:20–39, 25:31–45) and further teaches “[o]ne or more detector[s] ... for

detecting the light that is reflected by or has traveled through the subject's tissue" (EX1027, 17:30–53). Lisogurski does not teach arranging the LEDs and detectors in arcs, but instead teaches "[a]ny suitable configuration of light source 316 and detector 318" is appropriate for the sensor unit, including "multiple light sources and detectors, which may be spaced apart." EX1027, 17:39–45. A POSITA would therefore have understood that modifications to the arrangement and number of LEDs and detectors in Lisogurski's sensor unit would have been straightforward design modifications within the skill of a POSITA that yielded predictable results. A POSITA would further have known that arranging the LEDs and detectors in a first and second arc would not require significant time or cost-intensive changes to Lisogurski's system. Therefore, a POSITA would have a reasonable expectation of success implementing Soller's teaching into Lisogurski's system. A POSITA thus would have been motivated to select an arrangement that meets Lisogurski's goal of improving SNR and optimizing power consumption (which I discuss above). *Supra* § VIII.B.4. Soller teaches such an arrangement; specifically, Soller discloses that a "radial, symmetric pattern" (*i.e.*, arc) increases the "coupling efficiency" of the optical measurement system and thereby improves the accuracy of the measurement. EX1030, 13:40–49, 16:33–39. Soller further teaches that the configuration of its optical sensor implements numerous techniques to improve SNR and increase

efficiency. *E.g.*, EX1030, 15:31–40 (describing the increased efficiency of Soller’s portable, wearable sensor which does not require an “external computer”).

265. Accordingly, Lisogurski in view of Carlson and Soller teaches or renders obvious claim 4.

b. Claim 5: The measurement system of claim 4, wherein the first arc is offset from the second arc.

266. In my opinion, Lisogurski in combination with Carlson and Soller discloses or renders obvious claim 5. As discussed above, Soller teaches a first arc (with an arrangement of detectors) and a second arc (with an arrangement of LEDs). *Supra* § VIII.C.4.a. Soller further discloses that there can be a “spacing between the center illuminating fiber bundle” (*i.e.*, the fibers corresponding to the second arc of LEDs) and “the outer fiber ring” (*i.e.*, the fibers corresponding to the first arc of semiconductors), and that the spacing may be “preferably 2-4 mm.” EX1030, 18:43–46; *id.*, 18:18–46. As discussed above, Soller further depicts an arrangement where the first arc of detectors is separate from the second arc of LEDs:

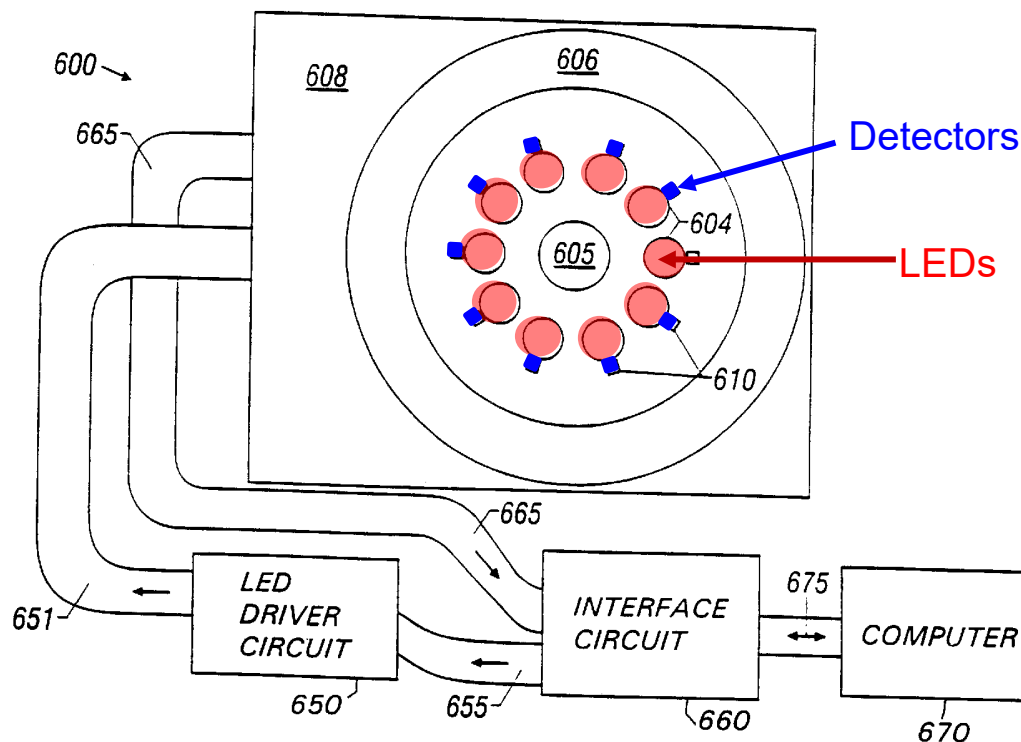


Figure 11A

EX1030, Fig. 11A.

267. A POSITA would have understood these disclosures to refer to an arrangement where the first arc of detectors is “offset” from (meaning not congruent/overlapping with) the second arc of semiconductor sources. Furthermore, to the extent the two arcs depicted above in Figure 11A are not expressly taught as “offset” from one another, this would have been an obvious variation to Soller and a routine design choice for a POSITA when implementing Soller’s two arcs into Lisogurski’s sensor. Indeed, Lisogurski expressly teaches that the sensor may

include “multiple light sources and detectors, which **may be spaced apart.**”
EX1027, 17:39–45.

268. A POSITA would have been motivated to modify Lisogurski’s sensor to arrange the LEDs and detectors in offsetting arcs in the manner taught by Soller and would have found this modification to Lisogurski to be a straightforward design choice involving the combination of known elements given the overlapping applications and objectives of the two systems. *Supra* § VIII.B.4 As I discussed above, Soller teaches that radial patterns achieve maximal coupling efficiency and thereby improve the accuracy of measured physiological signals, which is consistent with Lisogurski’s stated goal of increasing SNR. *Supra* §§ VIII.B.4, VIII.C.4.a. Thus, in my opinion, claim 5 would have been obvious.

269. Accordingly, Lisogurski in view of Carlson and Soller teaches or renders obvious claim 5.

c. Claim 6: The measurement system of claim 4, wherein the first arc and the second arc are concentric.

270. In my opinion, Lisogurski in combination with Carlson and Soller discloses or renders obvious claim 6. As discussed above and illustrated in Figure 11A below, Soller teaches a first arc of detectors that surrounds a second arc of LEDs. *Supra* § VIII.C.4.a. A POSITA would have understood that these two arcs are concentric circles.

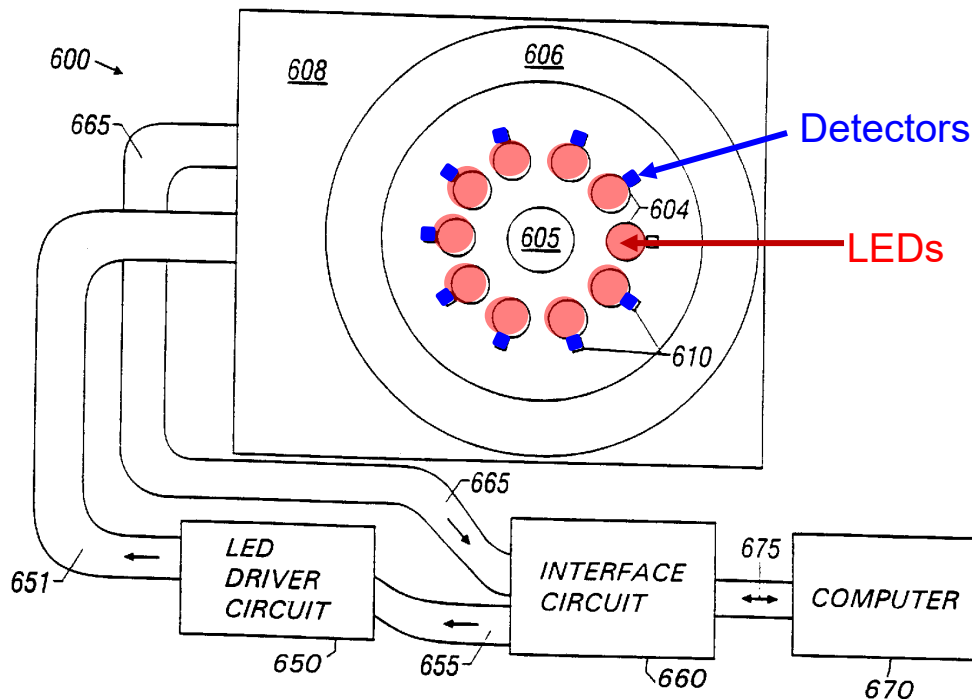


Figure 11A

EX1027, Fig. 11A; *see also* EX1030, 18:36–46 (describing the light from the semiconductor sources is emitted by the “fiber bundle” and the “return reflected light” from the tissue is “received by an array of, e.g., twenty-five single fibers,” which are “**configured in a ring 781 concentric** about fiber bundle 750”); 16:6–39 (radiation reflected by the tissue is collected by “signal fibers” attached to the detectors “disposed around the delivery fiber [*i.e.*, semiconductor source fiber] in a radial, symmetrical pattern to maximize the coupling efficiency of, respectively, the incident and reflective radiation”).

271. In my opinion, a POSITA would have been motivated to modify Lisogurski's sensor to arrange the LEDs and detectors in the concentric arcs (such as in the manner taught by Soller and depicted in Fig. 11A of Soller) because doing so would have been a straightforward design choice involving the combination of known elements, and achieved with routine effort. *Supra* §§ VIII.B.4; VIII.C.4.a. Furthermore, as I discussed above, Lisogurski contemplates any "suitable configuration" of LEDs and detectors for the sensor unit, and Soller's configuration would achieve the benefits taught by Lisogurski. *Supra* §§ VIII.B.4; VIII.C.4.a

272. Accordingly, Lisogurski in view of Carlson and Soller teaches or renders obvious claim 6.

d. Claim 7: The measurement system of claim 6, wherein the plurality of semiconductor sources comprises six light emitting diodes, and wherein the receiver comprises six detectors.

273. In my opinion, Lisogurski in combination with Carlson and Soller discloses or renders obvious claim 7. As discussed above and illustrated in Figure 11A below, Soller teaches a first arc of detectors that surrounds a second arc of LEDs in concentric circles. *Supra* §§ VIII.C.4.a–c. Soller further teaches "between 5 and 20 LEDs." EX1030, 13:39–40; *see also id.*, 13:13–18 ("an array of, **e.g., eight** light-emitting diode (LED) radiation sources"); 17:36–41 ("a circular array, **e.g., typically at least seven**, of light-emitting diode (LED) radiation sources"); Fig. 11A (below) (depicting 10 LEDs), Soller, 17:36–60 (describing Fig. 11A). A POSITA would have

understood that “between 5 and 20 LEDs” necessarily includes an arrangement with six LEDs.

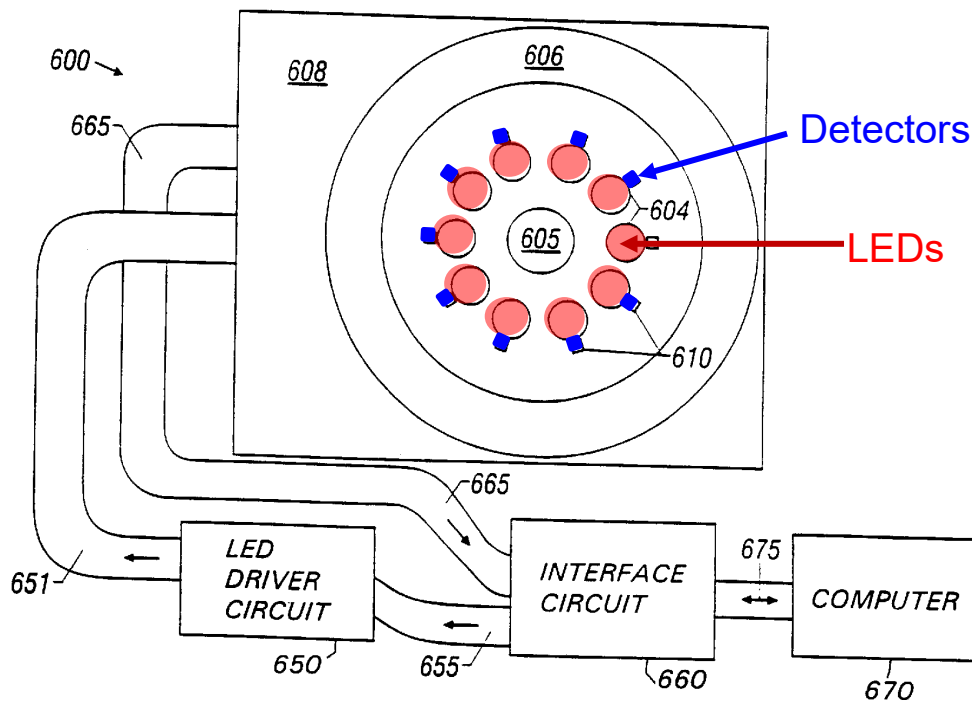


Figure 11A

274. Furthermore, Soller describes a system with “interior detectors 105 and exterior detectors 110 for detecting radiation,” which a POSITA would have understood refers to a receiver comprised of multiple detectors (*e.g.*, photodiodes). EX1030, 13:50–63. Soller further teaches that light reflected back from a sample is received by “an array of, **e.g., twenty-five** single fibers 780 configured in a ring 781,” with each of the “reference detector[s] coupled to one optical fiber.” EX1030, 18:32–46. Finally, Figure 11A of Soller (above) illustrates a configuration with 10

reference detectors, each corresponding to a single LED (of which Soller teaches there may be between 5 and 25). Thus, a POSITA would have understood Soller to disclose, or, at a minimum, render obvious a configuration of a wearable optical sensor with six detectors comprising the receiver.

275. Thus, Soller teaches or renders obvious a measurement system with six detectors on the receiver and six LED semiconductor sources. It would have been obvious to implement this configuration into Lisogurski's system and a POSITA would have been motivated to make such a straightforward design choice; indeed Lisogurski expressly contemplates "[a]ny suitable configuration of light source 316 and detector 318," including "**multiple light sources and detectors.**" EX1027, 17:37–45. Given that six LEDs and six detectors fall within the ranges contemplated by Soller, this would have been an obvious design choice involving the combination of known elements through routine effort that would achieve Soller's goal of delivering the maximum amount of radiation to the sample for improved measurements. *Supra* VIII.B.4, VIII.C.4.a–c.

276. Accordingly, Lisogurski in view of Carlson and Soller teaches or renders obvious claim 7.

- e. **Claim 8: The measurement system of claim 7, wherein the six detectors are located on the first arc surrounding the six light emitting diodes.**

277. In my opinion, Lisogurski in combination with Carlson and Soller discloses or renders obvious claim 8. As I discussed above, it would have been obvious to implement a configuration of Soller into Lisogurski's system comprising six detectors and six LEDs in concentric circles (a first and second arc, respectively). *Supra* §§ VIII.C.4.a–d. Further, it would have been obvious to locate the detectors on the first arc surrounding the LEDs, and in fact, such a configuration is depicted in Soller:

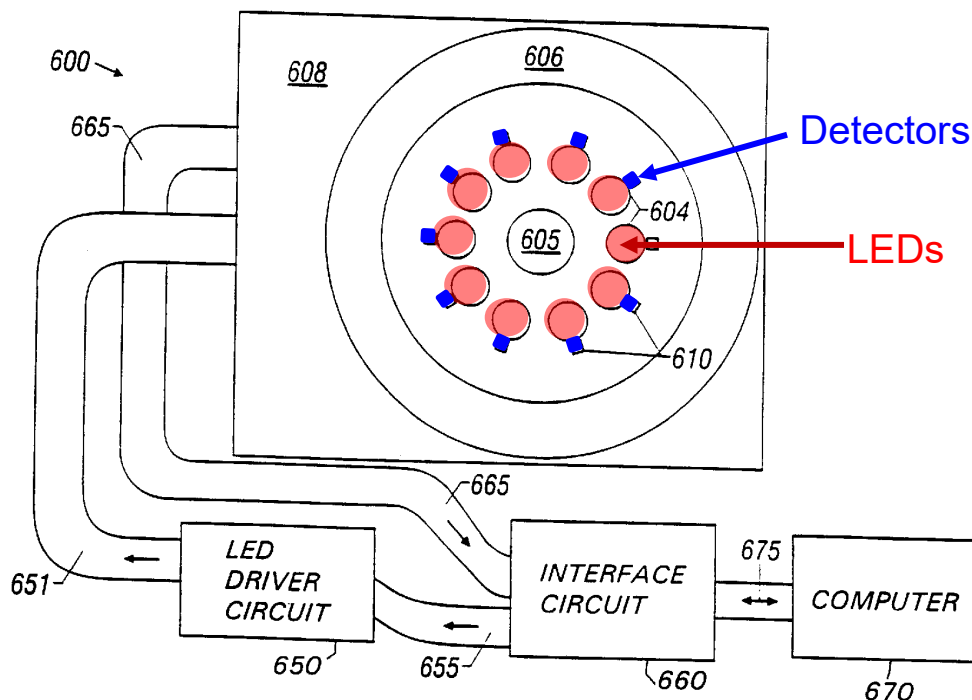


Figure 11A

EX1030, Fig. 11A. Implementing six LEDs and six detectors into the system depicted above would have been a straightforward variation that a POSITA would have been motivated to make. *Supra* §§ VIII.C.4.a–d.

278. Accordingly, Lisogurski in view of Carlson and Soller teaches or renders obvious claim 8.

- f. Claim 10: The measurement system of claim 8, wherein the light source is configured to further increase signal-to-noise ratio by increasing a pulse rate of at least one of the plurality of semiconductor sources from an initial non-zero pulse rate.**

279. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 10. *See supra* § VIII.C.1.yy (cl. 20).

- g. Claim 15: The measurement system of claim 11, wherein the receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor sources are arranged along a second arc that is offset from the first arc.**

280. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 15. *See supra* § VIII.C.4.a–b (cl. 4–5).

- h. Claim 16: The measurement system of claim 15, wherein the first arc and the second arc are concentric.**

281. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 16. *See supra* § VIII.C.4.c (cl. 6).

- i. Claim 17: The measurement system of claim 16, wherein the plurality of semiconductor sources comprises six light**

emitting diodes, and wherein the receiver comprises six detectors.

282. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 17. *See supra* § VIII.C.4.d (cl. 7).

j. Claim 18: The measurement system of claim 17, wherein the six detectors are located on the first arc surrounding the six light emitting diodes.

283. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 18. *See supra* § VIII.C.4.e (cl. 8).

k. Claim 21: The wearable device of claim 20, wherein the receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor sources are arranged along a second arc that is offset from the first arc.

284. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 21. *See supra* §§ VIII.C.4.a–b (cl. 4–5).

l. Claim 22: The wearable device of claim 21, wherein the first arc and the second arc are concentric.

285. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 22. *See supra* § VIII.C.4.c (cl. 6).

m. Claim 23: The wearable device of claim 22, wherein the plurality of semiconductor sources comprises six light emitting diodes, and wherein the receiver comprises six detectors.

286. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 23. *See supra* § VIII.C.4.d (cl. 7).

- n. **Claim 24: The wearable device of claim 23, wherein the six detectors are located on the first arc surrounding the six light emitting diodes.**

287. In my opinion, Lisogurski, in combination with Carlson and Soller, discloses claim 24. *See supra* § VIII.C.4.e (cl. 8).

5. Ground 5: Claims 12–13 and 26 would have been obvious over Lisogurski in view of Carlson in further view of Tran.

288. I have analyzed claims 12–13 and 26 and conclude that they would have been obvious over Lisogurski in combination with Carlson and Tran. I provide a detailed analysis of each claim limitation below.

- a. **Claim 12[a]: The measurement system of claim 11, wherein the measurement system is configured to use artificial intelligence in making decisions;**

289. In my opinion, Lisogurski, in combination with Carlson and Tran, discloses claim 12[a]. Specifically, Tran discloses a wearable optical sensor that uses artificial intelligence to make decisions. For example, Tran teaches:

- “In another aspect, **heart monitoring system for a patient** includes one or more wireless nodes forming a wireless mesh network; **a wearable appliance** having a wireless transceiver adapted to communicate with the one or more wireless nodes; **and a statistical analyzer to determine heart attack or stroke attack**, the statistical analyzer coupled to the wireless transceiver to communicate patient data over the wireless mesh network.”

EX1031, 3:6–13.

- **“The patient 30 may wear one or more wearable patient monitoring appliances such as wrist-watches or clip on devices or electronic jewelry to monitor the patient. One wearable appliance such as a wrist-watch includes sensors 40, for example devices for sensing ECG, EKG, blood pressure, sugar level, among others. In one embodiment, the sensors 40 are mounted on the patient’s wrist (such as a wristwatch sensor) and other convenient anatomical locations. Exemplary sensors 40 include standard medical diagnostics for detecting the body’s electrical signals emanating from muscles (EMG and EOG) and brain (EEG) and cardiovascular system (ECG). Leg sensors can include piezoelectric accelerometers designed to give qualitative assessment of limb movement. Additionally, thoracic and abdominal bands used to measure expansion and contraction of the thorax and abdomen respectively. A small sensor can be mounted on the subject’s finger in order to detect blood-oxygen levels and pulse rate. Additionally, a microphone can be attached to throat and used in sleep diagnostic recordings for detecting breathing and other noise. One or more position sensors can be used for detecting orientation of body (lying on left side, right side or back) during sleep diagnostic recordings. Each of sensors 40 can individually transmit data to the server 20 using wired or wireless transmission. Alternatively, all**

sensors 40 can be fed through a common bus into a single transceiver for wired or wireless transmission. The transmission can be done using a magnetic medium such as a floppy disk or a flash memory card, or can be done using infrared or radio network link, among others. The sensor 40 can also include an indoor positioning system or alternatively a global position system (GPS) receiver that **relays the position and ambulatory patterns of the patient to the server 20 for mobility tracking.**” EX1031, 9:23–53.

- “In one embodiment, **the server 20 feeds the data to a statistical analyzer such as a neural network which has been trained to flag potentially dangerous conditions.** The neural network can be a back-propagation neural network, for example. In this embodiment, the statistical analyzer is trained with training data where certain signals are determined to be undesirable for the patient, given his age, weight, and physical limitations, among others. For example, the patient's glucose level should be within a well established range, and any value outside of this range is flagged by the statistical analyzer as a dangerous condition. **As used herein, the dangerous condition can be specified as an event or a pattern that can cause physiological or psychological damage to the patient.** Moreover, interactions between different vital signals can be

accounted for so that the statistical analyzer can take into consideration instances where individually the vital signs are acceptable, but in certain combinations, the vital signs can indicate potentially dangerous conditions. **Once trained, the data received by the server 20 can be appropriately scaled and processed by the statistical analyzer. In addition to statistical analyzers, the server 20 can process vital signs using rule-based inference engines, fuzzy logic, as well as conventional if-then logic.** Additionally, the server can process vital signs using Hidden Markov Models (HMMs), dynamic time warping, or template matching, among others.” EX1031, 11:6–30.

- “In one embodiment, **data driven analyzers may be used to track the patient’s habits. These data driven analyzers may incorporate a number of models such as parametric statistical models, non-parametric statistical models, clustering models, nearest neighbor models, regression methods, and engineered (artificial) neural networks.** Prior to operation, data driven analyzers or models of the patient’s habits or ambulation patterns are built using one or more training sessions. The data used to build the analyzer or model in these sessions are typically referred to as training data. As data driven analyzers are developed by examining only training examples, the selection of the

training data can significantly affect the accuracy and the learning speed of the data driven analyzer. One approach used heretofore generates a separate data set referred to as a test set for training purposes. The test set is used to avoid overfitting the model or analyzer to the training data. Overfitting refers to the situation where the analyzer has memorized the training data so well that it fails to fit or categorize unseen data. Typically, during the construction of the analyzer or model, the analyzer's performance is tested against the test set. The selection of the analyzer or model parameters is performed iteratively until the performance of the analyzer in classifying the test set reaches an optimal point. At this point, the training process is completed. An alternative to using an independent training and test set is to use a methodology called cross-validation. Cross-validation can be used to determine parameter values for a parametric analyzer or model for a non-parametric analyzer. In cross-validation, a single training data set is selected. Next, a number of different analyzers or models are built by presenting different parts of the training data as test sets to the analyzers in an iterative process. The parameter or model structure is then determined on the basis of the combined performance of all models or analyzers. Under the cross-validation approach, the analyzer

or model is typically retrained with data using the determined optimal model structure.” EX1031, 22:24–30.

- “An EKG analyzer is provided to interpret EKG/ECG data and **generate warnings** if needed.” EX1031, 85:60–61.
- “The speech recognizer also detects if the user exhibits signs of confusion, trouble speaking or understanding (3014). The system also asks the patient if they feel numbness in the body—arms, legs, face (3016). Next the system asks the patient to squeeze gauge/force sensor to determine force applied during squeeze (3018). **If any of the above tests indicate a possible stroke, the system displays a warning to the patient and also connects the patient to the appropriate emergency response authority, family member, or physician.**” EX1031, 87:28–37.
- “If the variance between historical and current strength exceeds threshold, the process **generates warnings** (3208).” EX1031, 88:48–50
- “In yet another embodiment, the EMG data is used to **detect muscle fatigue and to generate a warning to the patient to get to a resting place or a notification to a nurse or caregiver to render timely assistance.**” EX1031, 90:58–61.

290. A POSITA would have understood from the above that Tran teaches a wearable optical measurement system (“wearable patient monitoring appliance[.]”)

that collects physiological data and “feed[s] the data to a statistical analyzer such as a neural network.” EX1031, 9:23–53, 11:6–30; *see also id.*, 3:6–13. Tran teaches that the statistical analyzer may include “engineered (artificial) neural networks,” which a POSITA would have understood are a form of “artificial intelligence.” EX1031, 22:24–30. Tran further teaches that its neural networks can be used to analyze patient data and “flag potentially dangerous conditions,” which include can be “specified as an event or pattern that can cause physiological or psychological damage to the patient.” EX1031, 11:6–19. Tran teaches that when its analyzer recognizes a dangerous condition, the system is configured to react in a certain way, for example, to “display[] a warning to a patient” or “connect[] the patient to the appropriate emergency response authority.” EX1031, 87:33–37, 85:60–61 (“An EKG analyzer is provided to interpret EKG and ECG data and generate warnings if needed”), 88:48–50 (“If the variance between historical and current strength exceeds threshold, the process generates warnings (3208)”), 90:58–61 (“[T]he EMG data is used to detect muscle fatigue and to generate a warning to the patient to get to a resting place or a notification to a nurse or caregiver to render timely assistance”). A POSITA would have understood this to mean that Tran teaches a data analyzer that uses artificial intelligence to “mak[e] decisions” based on measured physiological parameters.

291. A POSITA would further have been motivated to implement the neural network taught by Tran into Lisogurski's measurement system. As I discussed above, both Tran and Lisogurski are concerned with medical monitoring using a wearable optical appliance. *Supra* § VIII.B.5. Both references teach techniques for improving SNR and integrating optical medical monitoring systems into portable devices. *Id.* A POSITA would therefore have been motivated to implement Tran's data analyzer (and neural networks) into Lisogurski's system (specifically, its processing circuitry, whether in the "cloud" or smartphone/tablet). Neural networks were well known in the art in 2012, and a POSITA would have found it a straightforward and obvious design modification to use such methods of analysis to improve the measurement system in Lisogurski for which a POSITA would have had a reasonable expectation of success, particularly in light of the market trends I discuss above. *Supra* § V.B.

292. Accordingly, Lisogurski in view of Carlson and Tran teaches or renders obvious claim 12[a]. I note that the Board found in the '484 IPR that the combination of Lisogurski, Carlson, and Tran would have rendered obvious a materially identical limitation, and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit and restated by the Board in its Final Decision on Remand. EX1011, 48–49; EX1012, n.2; EX1013, 11.

b. Claim 12[b]: wherein the measurement system is configured to perform pattern identification or classification, and

wherein the measurement system is configured to apply a threshold function to a comparison with a stored data set; and

293. In my opinion, Lisogurski, in combination with Carlson and Tran, discloses or renders obvious claim 12[b]. Tran teaches that the neural networks used by its data analyzer are “used to recognize” and are in fact “quite robust at recognizing user habits or **patterns**.” EX1031, 23:39–50 (“[C]lustering operations are used to **detect patterns** in the data. In one embodiment, a neural network is used to **recognize each pattern** as the neural network is quite robust at recognizing user habits or patterns.”). Tran further teaches that its data analyzer monitors a “patient’s vital signs” and—when the vital signs depart from a baseline pattern and represent a possible dangerous condition—the data analyzer flags these conditions. EX1031, 11:1–8, 11:16–23, 23:39–50, 22:23–59, 23:4–16. One technique the data analyzer uses to recognize patterns (and departures from those patterns) is a “Hidden Markov Model” that “derive[s] a set of **reference pattern templates**,” where “each template is representative of **an identified pattern** in a vocabulary set of reference treatment patterns.” EX1031, 24:45–25:18, 80:24–81:3. A Hidden Markov Model can be used with neural networks, as Tran recognizes. EX1031, 24:58–60 (“The addition of a neural network at the front end of the HMM in an embodiment provides the capability of representing states with dynamic values”). Taken together, a POSITA

would have understood that Tran teaches a system that uses statistical methods to “perform pattern identification or classification” as required by claim 12[b].

294. A POSITA would further have understood that both Lisogurski and Tran teach a measurement system configured to apply a threshold function to a comparison with a stored data set, a further requirement of claim 12[b]. For example, Lisogurski teaches that the measured “blood oxygen saturation **may be compared to a threshold or target value, such as threshold 830,**” EX1027, 24:41–43, and the outcome of that comparison may be used to change the device’s mode of operation, EX1027, 24:43–57. Lisogurski further teaches comparing the received output signal to a threshold to identify portions of the signal that are of interest for further processing or for changing the modulation of the light source. EX1027, 40:42–41:39, claims 15–18 (“wherein the pulse oximeter is configured to cease the light drive signal modulation when at least one of the physiological parameters passes a threshold values”). Lisogurski explains that the measurement system “**may use historical information from previous pulse cycles in determining thresholds**” (*i.e.*, a “*stored data set*”) and may employ “conventional servo algorithms, other suitable criteria, or any combination thereof” (*i.e.*, a “*threshold function*”) in making such a comparison to these thresholds. EX1027, 40:42–41:14; *see also* EX1027, 9:46–52, 37:8–14 (system can detect increases in ambient light and noise and change modulation techniques in response).

295. Similarly, Tran teaches that its data analyzer allows the user to choose “a condition that they would like to be alerted to and [] provid[e] the parameters (e.g., **threshold value** for the reading) for alert generation.” EX1031, 27:26–28. If such a condition is met, the user receives an alert according to their set preference. *Id.*; *see also* EX1031, 28:53–56 (“For example, an instant message or email can be sent out as an alert in response to blood pressure indicating a medical condition that requires immediate attention.”). A POSITA would have understood that Tran therefore compares measured data against a pre-set threshold value (*i.e.*, “appl[ies] a threshold function to a comparison with a stored data set”) and would have been motivated to implement this technique to improve Lisogurski’s own threshold value comparison in its measurement system, for the reasons I explain above regarding the similarity between the applications and objectives of the two systems. *Supra* §§ VIII.B.5, VIII.C.5.a. Implementing Tran’s measurement system into Lisogurski’s own threshold value comparison would have been within the skill of a POSITA and require only routine modification.

296. Accordingly, Lisogurski in view of Carlson and Tran teaches or renders obvious claim 12[b]. I note that the Board found in the ’484 IPR that Tran teaches “perform[ing] pattern identification and classification,” and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit and restated by the Board in its Final Decision on Remand. EX1011, 52–53; EX1012,

n.2; EX1013, 11–12. The Board further found in its Second Final Decision on Remand that Tran teaches a wearable device configured “to identify an object, and to compare a property of at least some of the output signal to a threshold.” EX1013, 3–7.

- c. **Claim 12[c]: wherein the measurement system is at least in part configured for selection or identification of an object, and wherein the measurement system is configured to improve a signal-to-noise ratio of the selection or identification by applying regression signal processing methodologies or multivariate techniques.**

297. In my opinion, Lisogurski, in combination with Carlson and Tran, discloses or renders obvious claim 12[c].

- (i) **“wherein the measurement system is at least in part configured for selection or identification of an object”**

298. I first note that in the ’484 IPR, the Board construed a similar limitation (“identify[ing] an object”) to mean “to recognize or establish an object as being a particular thing,” and that the Federal Circuit affirmed this construction. EX1011, 10, *aff’d* EX1012, *5. I apply this construction below for the limitation requiring “identification of an object.”

299. A POSITA would have understood that both Lisogurski and Tran teach techniques “for selection or identification of an object” by the measurement system. Tran, for example, teaches techniques for calculating a user’s blood oxygen saturation and other blood constituents. EX1031, 25:36–43 (Tran’s system

“analyze[s] the blood pressure, and heart rate, and pulse oximetry values to characterize the patient’s cardiac condition”), 26:17–29 (“the wearable device” can display “heart rate, pulse oximetry, and temperature”), 36:62–37:13 (“As the heart pumps blood through the patient’s finger, blood cells absorb and transmit varying amounts of the red and infrared radiation depending on how much oxygen binds to the cells’ hemoglobin”), 46:25–42, 60:58–61:37 (describing measurement and calculation of “blood pressure”), 74:29–67 (“[T]he system can analyze blood pressure, heart rate, and pulse oximetry values to characterize the user’s cardiac condition”). Tran also teaches selecting a blood constituent (e.g., hemoglobin). EX1031, 36:62–37:13 (“As the heart pumps blood through the patient’s finger, blood cells absorb and transmit varying amounts of the red and infrared radiation depending on how much oxygen binds to the cells’ hemoglobin”). Lisogurski similarly teaches calculating the amount of oxyhemoglobin in the blood, which a POSITA would have understood refers to calculating blood oxygen saturation. EX1027, 4:36–62 (“The light intensity or the amount of light absorbed may then be used to calculate any of a number of physiological parameters, including an amount of a blood constituent (e.g., oxyhemoglobin) being measured as well as pulse rate and when each individual pulse occurs”), 9:38–42 (describing “blood oxygen saturation algorithm”), 24:41–57 (“the blood oxygen saturation may be compared to a threshold or target value”), 37:2–12. Lisogurski teaches the selection of a blood

constituent. EX1027, 4:36-51 (“The light intensity . . . may then be used to calculate any of a number of physiological parameters, including an amount of a blood constituent (e.g., oxyhemoglobin) being measured [T]he photonic signal . . . is selected to be . . . representative of the blood constituent concentration”). A POSITA would have known that measuring blood oxygen saturation requires **selecting**, **identifying**, and quantifying both oxygenated and deoxygenated hemoglobin in the blood, among other constituents, which Lisogurski and Tran do by measuring reflected/transmitted light at particular wavelengths known to be associated with each substance. EX1027, 4:42–51; EX1031, 37:2–12, 50:10–15. The ’304 patent discloses the same technique for selecting and measuring components of a substance. *E.g.*, EX1001, 20:5-15; 35:27–44. A POSITA would have understood that the “selection or identification of an object,” as described in limitation 12[c], is met by either or both of the selection of oxygenated and deoxygenated hemoglobin from among other blood constituents to measure and the identification of such components in the measurement and quantification of blood oxygen saturation, as described in Lisogurski and Tran.

300. Thus, in my opinion, both Lisogurski and Tran teach **selecting**, detecting, and **identifying** objects—specifically, oxygenated and deoxygenated hemoglobin. To the extent not fully disclosed by Lisogurski, it would have been obvious to implement Tran’s techniques for calculating oxygen saturation into

Lisogurski's measurement system for the reasons explained above relating to the overlapping applications and objectives of the two references and the routine skill it would have required to make such a modification. *Supra* §§ VIII.B.5, VIII.C.5.a.

301. I note that the Board found in its Second Final Decision on Remand that Lisogurski and Tran teach “identify[ing] an object.” EX1013, 3–7.

(ii) **“wherein the measurement system is configured to improve a signal-to-noise ratio of the selection or identification by applying regression signal processing methodologies or multivariate techniques”**

302. It is also my opinion that Lisogurski teaches improving SNR of the selection or identification of an object by applying regression signal processing methodologies or multivariate techniques. For example, Lisogurski further teaches that its measurement system “may vary the algorithm used to **determine a physiological parameter based, in part, on the cardiac cycle modulation technique,**” and that “[i]f the cardiac cycle modulation technique detects the entire pulse, a **different blood oxygen saturation detection algorithm may be used (e.g., a regression based algorithm).**” EX1027, 9:36–45. Lisogurski further teaches that a cardiac cycle modulation technique can be used to improve the SNR of particular signals. EX1027, 25:49–55; 31:11–24, 31:39–55. For example, Lisogurski states that “particular segments of a respiratory cycle may provide an increased signal to noise ratio” and that “it may be desired to correlate a modulation technique with respiration variations or both respiration variations and cardiac pulses.” EX1027,

25:66–26:14. Lisogurski teaches “[t]he signals provide examples that illustrate when cardiac cycle modulation is properly selected, the accuracy of monitoring functions can be enhanced.” EX1027, 41:40–58. A POSITA would have understood based on these teachings that Lisogurski teaches or renders obvious improving the SNR of a selected or identified object (*e.g.*, oxygenated hemoglobin) by applying multivariate or regression signal processing techniques.

303. I note that the Board found in the ’533 IPR that Lisogurski’s “cardiac cycle modulation” technique is a data analysis technique for “improving SNR.” EX1008, 24–25, 28–30. I understand this decision has been affirmed by the Federal Circuit. EX1009. I understand the Board made a similar determination in the ’484 IPR and that Omni did not cross-appeal that determination, which was therefore affirmed by the Federal Circuit. EX1011, 28–43; EX1012 n.2.

304. Accordingly, Lisogurski in view of Carlson and Tran teaches or renders obvious claim 12[c].

- d. Claim 13: The measurement system of claim 12, wherein the light source is configured to further increase the signal-to-noise ratio by increasing a pulse rate of at least one of the plurality of semiconductor sources from an initial non-zero pulse rate.**

305. In my opinion, Lisogurski, in combination with Carlson and Tran, discloses claim 13. *See supra* § VIII.C.1.yy (cl. 20).

- e. **Claim 26[a]: The wearable device of claim 19, wherein the wearable device is configured to use artificial intelligence in making decisions;**

306. In my opinion, Lisogurski, in combination with Carlson and Tran, discloses claim 26[a]. *See supra* § VIII.C.5.a (cl. 12[a]).

- f. **Claim 26[b]: wherein the wearable device is configured to perform pattern identification or classification, and wherein the wearable device is configured to apply a threshold function to a comparison with a stored data set; and**

307. In my opinion, Lisogurski, in combination with Carlson and Tran, discloses claim 26[b]. *See supra* § VIII.C.5.b (cl. 12[b]).

- g. **Claim 26[c]: wherein the wearable device is at least in part configured for selection or identification of an object, and wherein the wearable device is configured to improve a signal-to-noise ratio of the selection or identification by applying regression signal processing methodologies or multivariate techniques.**

308. In my opinion, Lisogurski, in combination with Carlson and Tran, discloses claim 26[c]. *See supra* § VIII.C.5.c (cl. 12[c]).

- 6. **Ground 6: Claim 9 would have been obvious over Lisogurski in view of Carlson, Soller, and Tran.**

309. I have analyzed claim 9 and conclude that it would have been obvious over Lisogurski in combination with Carlson, Soller, and Tran. I provide a detailed analysis of each claim limitation below.

- a. **Claim 9[a]: The measurement system of claim 8, wherein the measurement system is configured to use artificial intelligence in making decisions.**

310. In my opinion, Lisogurski, in combination with Carlson, Soller, and Tran, discloses claim 9[a]. *See supra* §§ VIII.C.4.e (cl. 8), VIII.C.5.a (cl. 12[a]).

- b. **Claim 9[b]: wherein the measurement system is configured to perform pattern identification or classification, and wherein the measurement system is configured to apply a threshold function to a comparison with a stored data set; and**

311. In my opinion, Lisogurski, in combination with Carlson, Soller, and Tran, discloses claim 9[b]. *See supra* §§ VIII.C.4.e (cl. 8), VIII.C.5.b (cl. 12[b]).

- c. **Claim 9[c]: wherein the measurement system is at least in part configured for selection or identification of an object, and wherein the measurement system is configured to improve a signal-to-noise ratio of the selection or identification by applying regression signal processing methodologies or multivariate techniques.**

312. In my opinion, Lisogurski, in combination with Carlson, Soller, and Tran, discloses claim 9[c]. *See supra* §§ VIII.C.4.e (cl. 8), VIII.C.5.c (cl. 12[c]).

IX. ADDITIONAL REMARKS

313. I currently hold the opinions expressed in this Declaration. I reserve the right to further explain and supplement my opinions as I may acquire additional information and/or attain supplemental insights that may result in added observations.

314. I hereby declare that to the best of my knowledge all statements made are true and that all statements made on information and belief are believed to be true. I further declare 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 and that such willful false statements may jeopardize the validity of this proceeding.

Executed this 19th day of September, 2025.

/Patrick Mercier/

Dr. Patrick Mercier

APPENDIX A: TEXT OF CHALLENGED CLAIMS

No.	Limitation
1[pre]	A measurement system comprising
1[a]	a light source comprising a plurality of semiconductor sources that are configured to generate an output optical beam with one or more optical wavelengths, the light source configured to increase signal-to-noise ratio by increasing a light intensity relative to an initial light intensity from at least one of the plurality of semiconductor sources;
1[b]	a measurement device configured to;
1[c]	receive a portion of the output optical beam, and;
1[d]	deliver an analysis output beam to a sample;
1[e]	a receiver configured to;
1[f]	receive and process at least a portion of the analysis output beam reflected or transmitted from the sample;
1[g]	generate an output signal representing at least in part a non-invasive measurement on blood contained within the sample;
1[h]	synchronize to the light source,
1[i]	capture light while the semiconductor sources are off and convert the captured light into a first signal,
1[j]	capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a part of the at least a portion of the analysis output beam reflected or transmitted from the sample, and
1[k]	the measurement system further configured to improve the signal-to-noise ratio by differencing the first signal and the second signal;
1[l]	a smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a microphone, a speaker, one or more buttons or knobs, a microprocessor and a touch screen, the smart phone or tablet configured to:
1[m]	receive and process at least a portion of the output signal,
1[n]	store and display the processed output signal, and
1[o]	transmit at least a portion of the processed output signal over a wireless transmission link; and
1[p]	a cloud configured to:
1[q]	receive, over the wireless transmission link, an output status comprising the at least a portion of the processed output signal,
1[r]	process the received output status to generate processed data, and

No.	Limitation
1[s]	store the processed data.
2	The measurement system of claim 1, wherein the plurality of semiconductor sources comprises at least one of: light emitting diodes (LEDs), laser diodes (LD's), tunable LD's, and super-luminescent laser diodes (SLDs), and wherein the measurement system further comprises a reflective surface to receive and redirect at least some of the at least a portion of the analysis output beam reflected or transmitted from the sample.
3	The measurement system of claim 1, wherein the light source is further configured to increase the light intensity from the plurality of semiconductor sources by spatially coupling the optical output beam from at least two of the plurality of semiconductor sources.
4	The measurement system of claim 1, wherein the receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor sources are arranged along a second arc.
5	The measurement system of claim 4, wherein the first arc is offset from the second arc.
6	The measurement system of claim 4, wherein the first arc and the second arc are concentric.
7	The measurement system of claim 6, wherein the plurality of semiconductor sources comprises six light emitting diodes, and wherein the receiver comprises six detectors.
8	The measurement system of claim 7, wherein the six detectors are located on the first arc surrounding the six light emitting diodes.
9[a]	The measurement system of claim 8, wherein the measurement system is configured to use artificial intelligence in making decisions;
9[b]	wherein the measurement system is configured to perform pattern identification or classification, and wherein the measurement system is configured to apply a threshold function to a comparison with a stored data set; and
9[c]	wherein the measurement system is at least in part configured for selection or identification of an object, and wherein the measurement system is configured to improve a signal-to-noise ratio of the selection or identification by applying regression signal processing methodologies or multivariate techniques.
10	The measurement system of claim 8, wherein the light source is configured to further increase signal-to-noise ratio by increasing a pulse rate of at least one of the plurality of semiconductor sources from an initial non-zero pulse rate.
11[pre]	A measurement system comprising;

No.	Limitation
11[a]	a wearable measurement device for measuring one or more physiological parameters, including a light source comprising a plurality of semiconductor sources that are configured to generate an output optical beam with one or more optical wavelengths;
11[b]	the light source configured to increase signal-to-noise ratio by increasing a light intensity relative to an initial light intensity from at least one of the plurality of semiconductor sources;
11[c]	the wearable measurement device configured to receive a portion of the output optical beam and to deliver an analysis output beam to a sample;
11[d]	the wearable measurement device further comprising a receiver configured to:
11[e]	receive and process at least a portion of the analysis output beam reflected or transmitted from the sample
11[f]	generate an output signal representing at least in part a non-invasive measurement on blood contained within the sample,
11[g]	synchronize to the light source,
11[h]	capture light while the semiconductor sources are off and convert the captured light into a first signal,
11[i]	capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a part of the at least a portion of the analysis output beam reflected or transmitted from the sample,
11[j]	wherein the measurement system is further configured to improve the signal-to-noise ratio by differencing the first signal and the second signal
11[k]	a smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a microphone, a speaker, one or more buttons or knobs, a microprocessor and a touch screen, the smart phone or tablet configured to receive and process at least a portion of the output signal, to store and display the processed output signal, and to transmit a portion of the processed output signal over a wireless transmission link; and
11[l]	a cloud configured to receive over the wireless transmission link an output status comprising the at least a portion of the processed output signal, to process the received output status to generate processed data and to store the processed data, and wherein the cloud is capable of storing a history of at least a portion of the received output status over a specified period of time.
12[a]	The measurement system of claim 11, wherein the measurement system is configured to use artificial intelligence in making decisions;

No.	Limitation
12[b]	wherein the measurement system is configured to perform pattern identification or classification, and wherein the measurement system is configured to apply a threshold function to a comparison with a stored data set; and
12[c]	wherein the measurement system is at least in part configured for selection or identification of an object, and wherein the measurement system is configured to improve a signal-to-noise ratio of the selection or identification by applying regression signal processing methodologies or multivariate techniques.
13	The measurement system of claim 12, wherein the light source is configured to further increase the signal-to-noise ratio by increasing a pulse rate of at least one of the plurality of semiconductor sources from an initial non-zero pulse rate.
14	The measurement system of claim 11, wherein the plurality of semiconductor sources comprises at least one of: light emitting diodes (LEDs), laser diodes (LD's), tunable LD's, and super-luminescent laser diodes (SLDs), and the measurement system further comprising a reflective surface to receive and redirect at least some of the at least a portion of the analysis output beam reflected or transmitted from the sample.
15	The measurement system of claim 11, wherein the receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor sources are arranged along a second arc that is offset from the first arc.
16	The measurement system of claim 15, wherein the first arc and the second arc are concentric.
17	The measurement system of claim 16, wherein the plurality of semiconductor sources comprises six light emitting diodes, and wherein the receiver comprises six detectors.
18	The measurement system of claim 17, wherein the six detectors are located on the first arc surrounding the six light emitting diodes.
19[pre]	A wearable device for use with a smart phone or tablet, the wearable device comprising:
19[a]	a measurement device including a light source comprising a plurality of semiconductor sources for measuring one or more physiological parameters, the measurement device configured to:
19[b]	generate, by modulating at least one of the semiconductor sources having an initial light intensity, an input optical beam having one or more optical wavelengths, and
19[c]	receive and to deliver a portion of the input optical beam to tissue, wherein the tissue reflects a least a portion of the input optical beam delivered to the tissue;
19[d]	the measurement device further comprising a receiver configured to:
19[e]	capture light while the semiconductor sources are off and convert the captured light into a first signal, and

No.	Limitation
19[f]	capture light while at least one of the semiconductor sources is on and convert the captured light into a second signal, the captured light including at least a portion of the input optical beam reflected from the tissue;
19[g]	synchronize to the modulation of the at least one of the semiconductor sources;
19[h]	the measurement device further configured to improve a signal-to-noise ratio of the input optical beam reflected from the tissue by:
19[i]	differencing the first signal and the second signal, and
19[j]	increasing the light intensity relative to the initial light intensity from at least one of the semiconductor sources;
19[k]	the measurement device further configured to generate an output signal representing at least in part a non-invasive measurement on blood contained within the tissue;
19[l]	the wearable device configured to communicate with the smart phone or tablet, the smart phone or tablet comprising a wireless receiver, a wireless transmitter, a display, a voice input module, a speaker, and touch screen; and
19[m]	the smart phone or tablet configured to:
19[n]	receive and to process at least a portion of the output signal,
19[o]	store and display the processed output signal, and
19[p]	transmit at least a portion of the processed output signal over a wireless transmission link.
20	The wearable device of claim 19, wherein the light source is configured to further improve the signal-to-noise ratio of the input optical beam reflected from the tissue by increasing a pulse rate of at least one of the plurality of semiconductor sources from an initial non-zero pulse rate.
21	The wearable device of claim 20, wherein the receiver comprises a plurality of detectors arranged along a first arc, and wherein the plurality of semiconductor sources are arranged along a second arc that is offset from the first arc.
22	The wearable device of claim 21, wherein the first arc and the second arc are concentric.
23	The wearable device of claim 22, wherein the plurality of semiconductor sources comprises six light emitting diodes, and wherein the receiver comprises six detectors.
24	The wearable device of claim 23, wherein the six detectors are located on the first arc surrounding the six light emitting diodes.
25[a]	The wearable device of claim 19, further comprising a cloud configured to: receive, over the wireless transmission link, an output status comprising the at least a portion of the processed output signal,

No.	Limitation
25[b]	process the output status to generate processed data, and
25[c]	store the processed data, and
25[d]	wherein the cloud is capable of storing a history of at least a portion of the output status over a specified period of time.
26[a]	The wearable device of claim 19, wherein the wearable device is configured to use artificial intelligence in making decisions;
26[b]	wherein the wearable device is configured to perform pattern identification or classification, and wherein the wearable device is configured to apply a threshold function to a comparison with a stored data set; and
26[c]	wherein the wearable device is at least in part configured for selection or identification of an object, and wherein the wearable device is configured to improve a signal-to-noise ratio of the selection or identification by applying regression signal processing methodologies or multivariate techniques.
27	The wearable device of claim 19, wherein the measurement device further comprises a reflective surface configured to receive and redirect at least a portion of light reflected from the tissue.

APPENDIX B: CURRICULUM VITAE

Patrick P. Mercier

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Professional Highlights

- Currently leading a ~20-person group undertaking high-impact research spanning multiple domains, from near-zero-power integrated circuits, power management, energy harvesting, neural interfaces, wearable physiochemical sensors, RFICs and RF systems, and beyond
- Over 220 peer-reviewed publications, including 30 *ISSCC* papers, 37 *JSSC* papers, and several papers in high-impact journals such as *Science*, *Nature Biotechnology*, *Nature Biomedical Engineering*, *Nature Electronics*, *Nature Communications*, *Advanced Science*, *Energy and Environmental Science*, and more
- Recognized as one of the top contributors of all time at the 2023 *IEEE International Solid-State Circuits Conference (ISSCC)*
- Co-founder and co-director of the successfully industry-supported UCSD Center for Wearable Sensors
- Site Director of the successfully industry/NSF-supported IUCRC Power Management Integration Center, partnered with Dartmouth College
- Multiple young investigator awards: DARPA YFA, NSF CAREER, Beckman YIA
- ISSCC Jack Kilby Award for Outstanding Student Paper
- Over \$40MM in research fundraising to date
- UCSD-wide Academic Senate Teaching Award, and two ECE department teaching awards
- IEEE Fellow, Class of 2025
- ISSCC Executive Committee member; former ISSCC, VLSI, and CICC TPC member
- Startup co-founder (Traq), board member (QuantalRF), and scientific advisory board member (Nanovision and NeuroVigil)
- 24 issued US patents

Education

Ph.D. **Massachusetts Institute of Technology**, Electrical Engineering, June 2012

Thesis title: *Communication and Power Delivery Architectures for Personal Medical Devices* (GPA: 5.0/5.0)

Advisor: Anantha P. Chandrakasan

- S.M. **Massachusetts Institute of Technology**, Electrical Engineering, June 2008
Thesis title: *An All-Digital Transmitter for Pulsed Ultra-Wideband Communication* (GPA: 5.0/5.0)
Advisor: Anantha P. Chandrakasan
- B.Sc. **University of Alberta**, Electrical and Computer Engineering, May 2006
GPA: 4.0/4.0

Related Experience

University of California, San Diego

Vice Chair, Electrical and Computer Engineering (2024-present)
Professor, Electrical and Computer Engineering (2023-present)
Site Director, Power Management Integration Center (2021-present)
Associate Professor, Electrical and Computer Engineering (2018-2023)
Co-Founder/Co-Director, Center for Wearable Sensors (2014-present)
Assistant Professor, Electrical and Computer Engineering (2012-2018)

Expert Witness

Providing expert technical advice, reports, and depositions on a variety of patent litigation cases (2020-present)

NeuroVigil

Scientific Advisory Board Member (2020-present)

Nanovision

Scientific Advisory Board Member (2019-present)

Quantal RF

Board Member (2018-2024)

Traq / Mouthsense Inc.

Co-Founder/Scientific Advisor (2016-present)

Mercier Engineering

Owner, providing engineering and technical expertise to technology companies. (2013-present)

Massachusetts Institute of Technology, Microsystems Technology Laboratory, *Research Assistant* (2006-2012)

Intel Corporation, Circuits Research Lab, *Graduate Technical Intern* (2008)

Selected Honors and Awards

- **IEEE Fellow** – awarded to less than 0.1% of voting members in the IEEE Solid-State Circuits Society – Class of 2025
- **Teacher of the Year Award** – Jacobs School of Engineering at UC San Diego Annual Best Teacher Award Selected by Ballot of the Students – 2023

- **IEEE International Solid-State Circuits Conference (ISSCC) Author-Recognition Award** – Awarded to authors who have contributed more than 20 papers to ISSCC – 2023
- **San Diego County Engineering Council Outstanding Engineer Award** – Awarded annually to a single local engineer who has made significant technical contributions to their society – 2020
- **National Academy of Engineering Frontiers of Engineering Speaker** – A competitive invitation-only event for those who have demonstrated accomplishment in engineering research and technical work with recognizable contributions to advancing the frontiers of engineering – 2019
- **IEEE Solid-State Circuits Society Distinguished Lecturer** – Nominated to deliver invited lectures at local chapters and regional meetings across the world for a two-year term – 2019
- **NSF CAREER Award** – The National Science Foundation’s most prestigious awards in support of early-career faculty – 2018
- **Biocom Catalyst Award** – Awarded to ten academics, entrepreneurs, investors, corporate leaders, and business advisers under 40 years old who are igniting innovation and growth in the San Diego and Los Angeles life sciences industry – 2017
- **IEEE Senior Member** – Elected for showing significant performance over a 10+ year career – 2017
- **Moore Inventor Fellow Finalist** – Selected as a top-10 fellow amongst >200 other applicants at top US universities; received \$25k award – 2017
- **UCSD Academic Senate Distinguished Teaching Award** – Awarded yearly to five distinguished teachers across all departments at UCSD (totaling ~2200 senate members – i.e., the top 0.2% of teachers). First winner in the ECE department since Jack Wolf in 1999. Received 2016
- **DARPA Young Faculty Award** – Awarded to young faculty members who propose high-impact, high-risk research programs – 2015
- **Beckman Young Investigator Award** – Awarded to eight junior faculty members across the US for innovating research within the chemical and biological sciences – 2015
- **Hellman Fellowship Award** – Awarded to junior faculty members who show capacity for great distinction in their research and creative activities – 2014
- **Graduate Teaching Award** – Awarded annually to one (of ~50) faculty in the UCSD ECE department for outstanding teaching and service – 2013
- **Jack Kilby Award** – One awarded per year for outstanding student paper at the *International Solid-State Circuits Conference (ISSCC)* – received 2010
- **Intel Foundation Ph.D. Fellowship** – awarded to 26 applicants across the US – 2009
- **Post Graduate Scholarship** – Natural Sciences and Engineering Council of Canada (NSERC) – 2007, 2009
- **Best Presentation Award**, Microsystems Technology Lab Annual Research Conference – 2008, 2010
- **Julie Payette Postgraduate Research Fellowship** – Awarded to the top 24 Master’s NSERC applicants in Canada – 2006
- **APEGGA Medal** – Highest undergraduate GPA in Electrical Engineering – 2006
- **Atco Electric Centennial Award** – March 2005
- **Schlumberger Scholarship** in Electrical Engineering – 2004, 2005

Other Awards and Recognitions

- **IEEE Custom Integrated Circuits Conference (CICC) 2025** – Best Paper Award Finalist
- **IEEE International Solid-State Circuits Conference (ISSCC) Student Research Preview Poster Award** – 2024
- **IEEE Solid-State Circuits Society (SSCS) Outstanding Reviewer Reward** – 2024.
- **IEEE ISCAS Women in Circuits and Systems (WiCAS)** – Runner Up Paper Award – 2023.
- **IEEE International Symposium on Circuits and Systems (ISCAS)** – Best Runner Up Paper – 2023.
- **Qualcomm Innovation Fellowship (QIF) 2023** – Winner
- **IEEE Applied Power Electronics Conference (APEC)** – Outstanding Presentation Award 2023 – “A Series/Parallel Magnetic-Less Step-Down Converter Based on Piezoelectric Resonators”
- **IEEE Brain Technical Community and IEEE Solid-State Circuits Society** – Brain-Related Best Paper Award 2021 – “An Optically-Addressed Nanowire-Based Retinal Prosthesis with 73% RF-to-Stimulation Power Efficiency and 20nC-to-3°C Wireless Charge Telemetry” presented at ISSCC 2021.
- **IEEE Symposium on Very Large Scale Integration (VLSI Symposium) 2020** – Best Student Paper Award Nominee – “A -105dB THD 87dB-SNDR VCO-based Sensor Front-end Enabled by Background-Calibrated Differential Pulse Code Modulation”
- **IEEE Symposium on Very Large Scale Integration (VLSI Symposium) 2020** – Best Student Paper Award Nominee – “A 4.4μW -92/-90.3dBm Sensitivity Dual-mode BLE/Wi-Fi Wake-up Receiver”
- **Qualcomm Innovation Fellowship (QIF) 2020** – Winner
- **IEEE EMBS Workshop on Brain, Mind and Body – Cognitive Neuroengineering for Health and Wellness 2019** – Third place poster award
- **IEEE Custom Integrated Circuits Conference (CICC) 2019** – Outstanding Student Paper Award Nominee
- **IEEE Custom Integrated Circuits Conference (CICC) 2018** – Outstanding Student Paper Award Nominee
- **IEEE Custom Integrated Circuits Conference (CICC) 2015** – Outstanding Student Paper Award Nominee
- **Qualcomm Innovation Fellowship (QIF) 2014** – Finalist

List of Publications

BOOKS

- [1] S. Ha, C. Kim, P.P. Mercier, G.C. Cauwenberghs, **High-Density Integrated Electrocortical Neural Interfaces**, Elsevier Academic Press, 2019, 187 pages.
- [2] M.M. Hella and P.P. Mercier (eds), **Power Management Integrated Circuits**, CRC Press, 2016, 329 pages.
- [3] P.P. Mercier and A.P. Chandrakasan (eds), **Ultra-low-power Short-Range Radios**, Springer, 2015, 394 pages.

BOOK CHAPTERS

- [1] F. Laiwalla, V.W. Leung, J. Lee, P. Mercier, P. Asbeck, R. Rao, L. Larson, A. Nurmikko, “Next Generation Microscale Wireless Implant System for High-Density, Multi-areal, Closed-Loop Brain Computer Interfaces,” in **Brain-Computer Interface Research**, C. Guger et al. (eds.), Springer Nature Switzerland, 2021.
- [2] S. Ha, C. Kim, H. Wang, Y.M. Chi, P.P. Mercier, G. Cauwenberghs, “Low-power integrated circuits for wearable electrophysiology,” in **Wearable Sensors – Fundamentals, Implementation and Applications 2nd Edition**, E. Sazonov, Ed., Academic Press, 2021.
- [3] L.G. Salem and P.P. Mercier, “Recursive Switched-Capacitor DC-DC Converters,” in **Power Management Integrated Circuits**, M.M. Hella and P.P. Mercier, Eds., CRC Press, 2016.
- [4] D. Lee and P.P. Mercier, “Introduction to Ultra Low Power Transceiver Design,” in **Ultra-low-power Short-Range Radios**, P.P. Mercier and A.P. Chandrakasan, Eds., Cham, Switzerland: Springer, 2015.
- [5] P.M. Nadeau, A. Paidimarri, P.P. Mercier, and A.P. Chandrakasan, “Architectures for Ultra-Low-Power Multi-Channel Resonator-Based Wireless Transceivers,” in **Ultra-low-power Short-Range Radios**, P.P. Mercier and A.P. Chandrakasan, Eds., Cham, Switzerland: Springer, 2015.
- [6] P.P. Mercier, D.C. Daly, F.S. Lee, D.D. Wentzloff, and A.P. Chandrakasan, “Pulsed Ultra-Wideband Transceivers,” in **Ultra-low-power Short-Range Radios**, P.P. Mercier and A.P. Chandrakasan, Eds., Cham, Switzerland: Springer, 2015.
- [7] P.P. Mercier and A.P. Chandrakasan, “Near-Field Wireless Power Transfer,” in **Ultra-low-power Short-Range Radios**, P.P. Mercier and A.P. Chandrakasan, Eds., Cham, Switzerland: Springer, 2015.

JOURNAL PAPERS

- [1] N.S.K. Fathy, R. Vatsyayan, A.M. Bourhis, S.A. Dayeh, P.P. Mercier, “A TDMA Neural Recording SoC With IIR-RLS Adaptive Filters for 83.4 dB Artifact Suppression Across 256 Channels,” *IEEE Journal of Solid-State Circuits*, 2025.
- [2] D. Valencia, P.P. Mercier, A. Alimohammad, “An Efficient Brain-Switch for Asynchronous Brain-Computer Interfaces,” *IEEE Transactions on Biomedical Circuits and Systems*, vol. 19, no. 1, pp. 130-141, Feb. 2025.
- [3] W.-C.B. Liu, G. Pillonnet, P.P. Mercier, “An Integrated Dual-Side Series/Parallel Piezoelectric Resonator-Based DC–DC Converter,” *IEEE Journal of Solid-State Circuits*, vol. 59, no. 12, pp. 4162-4174, Dec. 2024.
- [4] H. Lu, P.P. Mercier, “Linear Periodically Time-Variant Digital PLL Phase Noise Modeling Using Conversion Matrices and Uncorrelated Upsampling,” *IEEE Transactions on Circuits and Systems I*, vol. 71, no. 12, pp. 6021-6033, Dec. 2024.
- [5] Y. Xu, A. Uppal, M.S. Lee, K. Mahato, B.L. Wuerstle, M. Lin, O. Djassemi, T. Chen, R. Lin, A. Paul, S. Jain, F. Chapotot, E. Tasali, P. Mercier, S. Xu, J. Wang, G. Cauwenberghs, “Earable Multimodal Sensing and Stimulation: A Prospective Towards Unobtrusive Closed-Loop Biofeedback,” *IEEE Reviews in Biomedical Engineering*, vol. 18, pp. 5-25, Nov. 2024.
- [6] W.-C.B. Liu, P.P. Mercier, “Design and Analysis of a Frontside Series/Parallel Piezoelectric Resonator-Based DC-DC Converter,” *IEEE Transactions on Power Electronics*, vol. 40, no. 1, pp. 1389-1403, Sep. 2024.

- [7] J. Tian, P. Mercier, C. Paolini, "Ultra low-power, wearable, accelerated shallow-learning fall detection for elderly at-risk persons," *Smart Health*, vol. 33, Sep. 2024.
- [8] N.S.K. Fathy, R. Vatsyayan, A.M. Bourhis, S.A. Dayeh, P.P. Mercier, "A 0.00179 mm²/Ch Chopper-Stabilized TDMA Neural Recording System with Dynamic EOVCancellation and Predictive Mixed-Signal Impedance Boosting," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 18, no. 4, pp. 908-922, Aug. 2024.
- [9] H. Lu, A.G. Gadelkarim, J. Huang, P.P. Mercier, "A 0.69-mW Sub-Sampling NB-IoT Receiver Employing a Linearized Q-Boosted LNA," *IEEE Open Journal of the Solid-State Circuits Society*, vol. 4, pp. 57-68, Jun. 2024.
- [10] D. Valencia, P.P. Mercier, A. Alimohammad, "Efficient In Vivo Neural Signal Compression Using an Autoencoder-based Neural Network," *IEEE Transactions on Biomedical Circuits and Systems*, vol 18., no 3, pp. 691-701, Jun. 2024.
- [11] G. Pillonnet, P. Mercier, "Analytical Benchmarking of Direct Hybrid Switched-Capacitor DC-DC Converters," *IEEE Open Journal of Power Electronics*, vol. 5, pp. 664-682, May 2024.
- [12] J. Wu, A. Akinin, J. Somayajulu, M.S. Lee, A. Paul, H. Lu, Y. Park, S.-J. Kim, P.P. Mercier, G. Cauwenberghs, "A Low-Noise Low-Power 0.001Hz-1kHz Neural Recording System-on-Chip with Sample-Level Duty-Cycling," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 18, no. 2, pp. 263-273, Apr. 2024.
- [13] E.H. Shinn, A.S. Garden, S.K. Peterson, D.J. Leupi, M. Chen, R. Blau, L. Becerra, T. Rafeedi, J. Ramirez, D. Rodriguez, F. VanFossen, S. Zehner, P.P. Mercier, J. Wang, K. Hutcheson, E. Hanna, D.J. Lipomi, "Iterative Patient Testing of a Stimuli-Responsive Swallowing Activity Sensor to Promote Extended User Engagement During the First Year After Radiation: Multiphase Remote and In-Person Observational Cohort Study", *JMIR Cancer*, 2024.
- [14] H. Lu, H.R. Kooshkaki, P.P. Mercier, "A Mixer-First Receiver with On-Demand Passive Harmonic Rejection," *IEEE Solid-State Circuits Letters*, vol. 7, pp. 46-49, Jan. 2024.
- [15] S.-H. Kuo, M. Dunna, D. Bharadia, P.P. Mercier, "A WiFi and Bluetooth Low Energy Backscatter Combo Chip with Beam Steering Capabilities," *IEEE Open Journal of the Solid-State Circuits Society*, vol. 3, pp. 239-248, Sep. 2023.
- [16] Y. Xu, E. De la Paz, A. Paul, K. Mahato, J.R. Sempionatto, N. Tostado, M. Lee, G. Hota, M. Lin, A. Uppal, W. Chen, S. Dua, L. Yin, B.L. Wuerstle, S. Deiss, P. Mercier, S. Xu, J. Wang, G. Cauwenberghs, "In-ear integrated sensor array for the continuous monitoring of brain activity and of lactate in sweat," *Nature Biomedical Engineering*, Sep. 2023.
- [17] M. Meng, M. Dunna, S.-K. Kuo, P.-H.P. Wang, D. Bharadia, P.P. Mercier, "A Fully-Reflective WiFi-Compatible Backscatter Communication System with Retro-Reflective MIMO Gain for Improved Range," *IEEE Journal of Solid-State Circuits*, vol. 58, no. 9, pp. 2501-2512, Sep. 2023.
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- [19] W.-C. Liu, C.-H. Cheng, P.P. Mercier, C.C. Mi, "Small Signal Analysis and Design of Constant On-Time Controlled Buck Converters with Duty-Cycle-Independent Quality Factors," *IEEE Transactions on Power Electronics*, vol. 38, no. 7, pp. 8379-8393, Jul. 2023.
- [20] E. Wen, D.F. Sievenpiper, P.P. Mercier, "Analysis of Coil Coupling in the Near-Field Far-Field Hybrid Region," *IEEE Antennas and Wireless Propagation*, vol. 22, no. 7, pp. 1771-1775, Jul. 2023.

- [21] H.A. Zadeh, H.R. Kooshkaki, K.-Y. Lee, P.P. Mercier, "An Adaptive Constant-On-Time-Controlled Hybrid Multilevel DC-DC Converter Operating from Li-ion Battery Voltages with Low Spurious Output," *IEEE Transactions on Power Electronics*, vol. 38, no. 5, pp. 5763-5776, May 2023.
- [22] C.B. Gungor, P.P. Mercier, H. Toreyin, "A 2.2 nW Analog Electrocardiogram Processor based on Stochastic Resonance Achieving a 99.94% QRS Complex Detection Sensitivity," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 17, no. 1, Feb. 2023.
- [23] A. Nikoofard, H. Givehchian, N. Bhaskar, A. Schulman, D. Bharadia, P.P. Mercier, "Protecting Bluetooth User Privacy through Obfuscation of Carrier Frequency Offset," *IEEE Transactions on Circuits and Systems II*, vol. 70, no. 2, pp. 541-545, Feb. 2023.
- [24] D. Valencia, G. Leone, N. Keller, P.P. Mercier, A. Alimohammad, "Power-Efficient In Vivo Brain-Machine Interfaces via Brain-State Estimation," *Journal of Neural Engineering*, 20, 016032, Jan. 2023.
- [25] B. Polat, T. Rafeedi, L. Becerra, A.X. Chen, K. Chiang, V. Kaipu, R. Blau, P.P. Mercier, C.-K. Cheng, D.J. Lipomi, "External Measurement of Swallowed Volume During Exercise Enabled by Stretchable Derivatives of PEDOT:PSS, Graphene, Metallic Nanoparticles, and Machine Learning," *Advanced Sensor Research*, 2200060, Jan. 2023.
- [26] B.H. Lam, H. Lu, A.G. Gadelkarim, N. Fathy, P. Gudem, P.P. Mercier, "A 0.11mW 2.4GHz Receiver Employing a Q-Boosted Impedance Transformer and Regenerative Amplifier Achieving a -101dBm Sensitivity and -28dB SIR," *IEEE Solid-State Circuits Letters*, vol. 6, Jan. 2023.
- [27] H.R. Kooshkaki, P.P. Mercier, "A 36 uW 2.8–3.4 dB Noise Figure Impedance Boosted and Noise Attenuated LNA for NB-IoT," *IEEE Transactions on Circuits and Systems I*, vol. 70, no. 1, pp. 101-113, Jan. 2023.
- [28] E. De La Paz, N.H. Maganti, A. Trifonov, I. Jeerapan, K. Mahato, L. Yin, T. Sonsa-ard, N. Ma, W. Jung, R. Burns, A. Zarrinpar, J. Wang, P.P. Mercier, "A self-powered ingestible wireless biosensing system for real-time in situ monitoring of gastrointestinal tract metabolites," *Nature Communications*, vol. 13, 7405, Dec. 2022.
- [29] P.P. Mercier, B.H. Calhoun, P.-H.P. Wang, A. Dissanayake, L. Zhang, D.A. Hall, S.M. Bowers, "Low-Power RF Wake-Up Receivers: Analysis, Trade-Offs, and Design," *IEEE Open Journal of the Solid-State Circuits Society*, vol. 2, pp. 144-164, 2022.
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- [31] B.H. Lam, P. Gudem, P.P. Mercier, "Analysis and Measurement of Noise Suppression in Nonlinear Regenerative Amplifier," *IEEE Transactions on Circuits and Systems I*, vol. 69, no. 10, pp. 4117-4127, Oct. 2022.
- [32] S. Chamanian, P.P. Mercier, "MIPSIMO: A Multi-Input Piezo-Adaptive Single-Inductor Multi-Output Energy Harvester Achieving using a Shared Inductor with an Integrated Analog Computer Achieving 95% MPPT Efficiency," *IEEE Solid-State Circuits Letters*, vol. 5, pp. 222-225, Sep. 2022.
- [33] A. Nikoofard, P.P. Mercier, "A 900MHz GFSK and 16-FSK TX Achieving up to 63.9% TX Efficiency and 76.2% PA Efficiency via a DC-DC-Powered Class-D VCO and a Class-EE PA," *IEEE Transactions on Circuits and Systems II*, vol. 69, no. 9, pp. 3739-3743, Sep. 2022.
- [34] C.B. Gungor, P.P. Mercier, H. Toreyin, "A Stochastic Resonance Electrocardiogram Enhancement Algorithm for Robust QRS Detection," *IEEE Journal of Biomedical and Health Informatics*, vol. 26, no. 8, pp. 3743-3754, Aug. 2022.

- [35] H. Cui, D. Yao, H. Lu, A. Calderon, Z. Xu, S. Davaria, Z. Wang, P. Mercier, P. Tarazaga, X. Zheng, "Design and printing of proprioceptive three-dimensional architecture robotic metamaterials," *Science*, 376, 6599, pp. 1272-1272, Jun. 2022.
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- [37] M. Meng, H.R. Kooshkaki, X. Wang, S.-H. Kuo, E. Wen, P.P. Mercier, "A GMSK/PAM4 Multi-Channel Magnetic Human Body Communication Transceiver," *IEEE Solid-State Circuits Letters*, vol. 5, pp. 66-69, Mar. 2022.
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- [39] E. Wen, D. Sievenpiper, P.P. Mercier, "Channel Characterization of Magnetic Human Body Communication," *IEEE Transactions on Biomedical Engineering*, vol. 69, no 2, pp. 569-579, Feb. 2022.
- [40] C. Pochet, J. Huang, P. Mercier, D. Hall, "A 174.7-dB FoM, 2nd-order VCO-based ExG-to-Digital Front-End Using a Multi-phase Gated-Inverted Ring Oscillator Quantizer," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 15, no. 6, pp. 1283-1294, Dec. 2021.
- [41] A. Akinin, J.M. Ford, J. Wu, C. Kim, H.D. Thacker, P.P. Mercier, G. Cauwenberghs, "An Optically Addressed Nanowire-Based Retinal Prosthesis With Wireless Stimulation Waveform Control and Charge Telemetry," *IEEE Journal of Solid-State Circuits*, vol. 56, no. 11, pp. 3263-3273, Nov. 2021. **(ISSCC Special Issue)**
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- [45] J. Lee, V. Leung, A. Lee, J. Huang, P. Asbeck, P.P. Mercier, S. Shellhammer, L. Larson, F. Laiwalla, A. Nurmikko, "Neural recording and stimulation using wireless networks of microimplants," *Nature Electronics*, no 4, pp. 604-614, Aug. 2021.
- [46] J. Huang, P.P. Mercier, "A 94.2-dB SNDR 142.6- μ W VCO-based Audio ADC with a Split-ADC Differential Pulse Code Modulation Architecture," *IEEE Solid-State Circuits Letters*, vol. 4, pp. 121-124, Jun. 2021.
- [47] C. Gungor, P. Mercier, H. Toreyin, "A 1.2nW Analog Electrocardiogram Processor Achieving a 99.63% QRS Complex Detection Sensitivity," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 15, no. 3, pp. 617-628, Jun. 2021.
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- [59] X. Wang, P.P. Mercier, "A Dynamically-High-Impedance Charge-Pump-Based LDO with Digital-LDO-Like Properties Achieving a sub-4fs FoM," *IEEE Journal of Solid-State Circuits*, vol. 55, no. 3, pp. 719-730, Mar. 2020 **(CICC Special Issue)**
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TUTORIALS

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- [2] P.P. Mercier, "Interface Circuits for Wearable and Implantable Sensing Systems," *Tutorial presented at the IEEE International Solid-State Circuits Conference (ISSCC)*, San Francisco, CA, Feb. 2020.
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- [7] P.P. Mercier, "Design of Low-Power Wake-up Radios for IoT Applications," *Tutorial presented at the IEEE Custom Integrated Circuits Conference (CICC)*, San Diego, CA, April 2018.

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INVITED ABSTRACTS, PRESENTATIONS, AND POSTERS

- [1] P.P. Mercier, “Wearable, Ingestible, and Implantable Wireless Sensing Systems for Healthcare Applications,” *Presented at the Department of Neurosciences-Digital Tools and Wearable Devices Seminar*, La Jolla, CA, May. 2025.
- [2] P.P. Mercier, “Wearable, Ingestible, and Implantable Wireless Sensing Systems for Healthcare Applications,” *Presented at the LINKJ Special Symposium*, Tokyo, Japan, Apr. 2025.
- [3] P.P. Mercier, “Ambient IoT: Power and Connecting the Next Information Frontier,” *Presented at the University of California, Berkeley*, Berkeley, CA, Feb. 2025.
- [4] P.P. Mercier, “Directions in Wearable Sensing,” *Presented at the EverythingALS and ALSOne Neurotech Day*, Nov. 2024.
- [5] P.P. Mercier, “Unawareables: Enabling Unobtrusive Wearable Devices via Smart Sensors and Low-Power Wireless Circuits,” *Presented at the UC Davis ECE Department Distinguished Seminar Series*, Nov. 2024.
- [6] P.P. Mercier, “Low-Power Wearable and Ingestible Physiochemical Monitoring Devices,” *Presented at the Medical Wearables Conference*, Oct. 2024.
- [7] P.P. Mercier, “Low-Power Standards-Compatible Wireless Communication Circuits for Next-Generation IoT and Wearable Applications,” *Presented at the Tokyo Institute of Technology*, Tokyo, Japan, Jul. 2024.
- [8] P.P. Mercier, “Low-Power Sensing and Wireless Communication Circuits,” *Presented at the IEEE Internet of Things Vertical and Topical Summit*, Jan. 2024.
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- [12] P.P. Mercier, “Unawareables: Building Invisible yet Useful Wearable Devices,” *Chancellor’s Associates Colloquium*, La Jolla, CA, Mar. 2023.
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- [16] P.P. Mercier, “Energy Harvesting and Self-Powered Sensing for Miniaturized IoT and Unawareable Devices,” *Presented at the ACM International Workshop on Energy Harvesting & Energy-Neutral Sensing*, Boston, CA, Nov. 2022.
- [17] P.P. Mercier, “Unaware-ables: Low-Power, Robust, and Useful Wearable Devices”, *Presented at the IEEE International Microwave Symposium*, Denver, CO, Jun. 2022.
- [18] P.P. Mercier, “Energy-Efficient Power Management Circuits for IoT and Wearable Devices,” *Keynote presentation at the IEEE Sensors Interface Meeting*, Veldhoven, The Netherlands, May 2022.
- [19] P.P. Mercier, “Energy Harvesting and Self-Powered Sensing for Miniaturized IoT and “Unawareable” Devices,” *Presented at the PSMA International Energy Harvesting Workshop (EnerHarv)*, Raleigh, NC, Apr. 2022.
- [20] P.P. Mercier, “Enabling Low-Power yet Standards Compatible Wireless Communication via Wake-up Receivers and Backscatter Circuits for the IoT,” *Presented as an IEEE SSCS Society-wide Webinar*, Jan. 2022.
- [21] P.P. Mercier, “Energy Harvesting and Self-Powered Sensing for Next-Generation “Unawareables” and IoT,” *Presented at the Sensors Converge Conference*, (virtual due to COVID-19), Sep. 2021.
- [22] P.P. Mercier, “Ultra-low-power integrated circuits and physiochemical sensors for next-generation unawearables,” *IEEE Solid-State Circuits Society Distinguished Lecture at Oregon IEEE Solid-State Circuits Society local chapter*, Hillsboro, OR (virtual due to COVID-19), Jun 2021.
- [23] P.P. Mercier, “Ultra-Low-Power Integrated Circuits and Physiochemical Sensors for Next-Generation Unawearables”, *Presented at the International Symposium on Advanced Sensor Technology*, Seoul, Korea (virtual due to COVID-19), Mar. 2021.
- [24] P.P. Mercier, “Energy-Efficient Communication Technologies for Emerging Internet-of-Things Applications,” *IEEE Solid-State Circuits Society Distinguished Lecture at the SSCS Northern Virginia Section*, (virtual due to COVID-19), Oct. 2020.
- [25] P.P. Mercier, “Hybrid Converters for Mobile and IoT Applications,” *Presented at the Integrated Power Conversion and Power Management Conference (PwrSoC)* (virtual due to COVID-19), Nov. 2020.
- [26] P.P. Mercier, “Low-Power Communication Circuits and Technologies for Emerging Internet-of-Things Applications,” *IEEE Solid-State Circuits Society Distinguished Lecture at the SSCS Princeton Central Jersey Section*, (virtual due to COVID-19), Nov. 2020.
- [27] P.P. Mercier, “Energy-Efficient Communication Technologies for Emerging Internet-of-Things Applications,” *Presented at the 2020 RFID Conference*, (virtual due to COVID-19), Oct. 2020.
- [28] P.P. Mercier, “Energy-Efficient Communication Technologies for Emerging Internet-of-Things Applications,” *IEEE Solid-State Circuits Society Distinguished Lecture at the SSCS Utah Section*, (virtual due to COVID-19), Oct. 2020.
- [29] P.P. Mercier, “Energy-Efficient Communication Technologies for Emerging Internet-of-Things Applications,” *IEEE Solid-State Circuits Society Distinguished Lecture at the Advanced Circuits Research Center in Israel*, (virtual due to COVID-19), July 2020.
- [30] P.P. Mercier, “Ultra-low-power integrated circuits and physiochemical sensors for next-generation unawearables,” *IEEE Solid-State Circuits Society Distinguished Lecture at the Beijing IEEE Solid-State Circuits Society local chapter*, (virtual due to COVID-19), May 2020.
- [31] P.P. Mercier, “Low-Power Wireless Systems: Opportunities and Challenges,” *Presented at the DARPA MTO Offsite Planning Meeting on the U.S.S. Midway*, San Diego, CA, Dec. 2019.

- [32] P.P. Mercier, "Ultra-low-power integrated circuits and physiochemical sensors for next-generation unawearables," *IEEE Solid-State Circuits Society Distinguished Lecture at the Scotland and UK IEEE Solid-State Circuits Society local chapter*, Edinburgh, UK, Sep. 2019.
- [33] P.P. Mercier, "Ultra-low-power integrated circuits and physiochemical sensors for next-generation unawearables," *IEEE Solid-State Circuits Society Distinguished Lecture at the Maryland/Virginia/DC IEEE Solid-State Circuits Society and Circuits and Systems local chapter*, College Park, MD, Sep. 2019.
- [34] P.P. Mercier, "Ultra-low-power integrated circuits enabling next-generation IoT applications," *Presented at the National Academy of Engineering Frontiers of Engineering event*, San Diego, CA, Jun. 2019.
- [35] P.P. Mercier, "Ultra-low-power integrated circuits and physiochemical sensors for next-generation unawearables," *IEEE Solid-State Circuits Society Distinguished Lecture at the San Diego IEEE Solid-State Circuits Society local chapter*, San Diego, CA, May. 2019.
- [36] P.P. Mercier, "Unwearables: Addressing Sensor, Circuit, and Energy Harvesting Challenges in Next-Generation Wearable Devices," *Presented at the IEEE Custom Integrated Circuits Conference (CICC)*, Austin, TX, Apr. 2019.
- [37] P.P. Mercier, "Ultra-Low-Power Integrated Circuits and Physiochemical Sensors for Next-Generation Unawearables," *Presented at the DARPA Actuation, Sensing, and Control for Rapid Injury Response Workshop*, Arlington, VA, Apr. 2019.
- [38] P.P. Mercier, "Ultra-Low-Power Integrated Circuits and Physiochemical Sensors for Next-Generation Unawearables," *Presented at the University of Southern California*, Los Angeles, CA, Nov. 2018.
- [39] P.P. Mercier, "Unwearables: new wearable sensors, circuits, and analytics for unobtrusive monitoring," *Presented at the SEMI MEMS & Sensors Executive Congress*, Napa, CA, Nov. 2018.
- [40] P.P. Mercier, "Ultra-small near-zero-power radios, implants, and sensing systems," *Presented at the DARPA Microsystems Exploratory Council Millimeter-Scale Wirelessly Powered Sensors Workshop*, Los Angeles, CA, Jul. 2018.
- [41] P. P. Mercier, "Wearable Sensors", *Presented at the US Marine Corps Innovation Event*, La Jolla, CA, Feb. 2018.
- [42] P.P. Mercier, "The Next Industrial Revolution: IoT, Wearables, and AI," *Presented at the Next Business Forum*, Seoul, South Korea, Nov. 2017.
- [43] P.P. Mercier, "Global Hubs for Innovative Ecosystems in Biotechnology," *Presented at the Stevanato Innovation Day*, San Diego, CA, Jun. 2017.
- [44] P.P. Mercier, "Non-Invasive Blood Alcohol Monitoring," *Presented at the Biomedical Technology Exhibition, sponsored by the American Institute for Medical and Biological Engineering (AIMBE) in partnership with the Congressional Research and Development Caucus and the Congressional Robotics Caucus*, Capitol Hill, Washington, DC, May 2017.
- [45] P.T. Theilman, J. Warchall, P. Mercier, H. Garudari, "Work Towards a Fieldable Multi-Channel EEG System for Continuous Monitoring," in *Proc. IEEE International Symposium on Circuits and Systems (ISCAS)*, Baltimore, MD, May 2017.
- [46] P.P. Mercier, "Beyond Activity Tracking: next-generation wearable and implantable sensor technologies" *Presented at the SPIE Defense and Commercial Sensing Conference*, Anaheim, CA, Apr. 2017.
- [47] D.A. Hall, H. Jiang, P.-H. Wang, L. Gao, P. Sen, Y.-H. Kim, G. Rebeiz, P.P. Mercier, "A 10nW Wake-up Radio with -60dBm Sensitivity," in *Government Microcircuit Applications & Critical Technology Conference (GOMACTech)*, Reno, NV, Mar. 2017.

- [48] P.P. Mercier, "Physiochemical Sensor Technologies and Ultra-Low-Power Integrated Circuits for Next-Generation "Unawearables" Systems," *Invited Seminar at the Microsystems Technology Lab at MIT*, Cambridge, MA, Dec. 2016.
- [49] P.P. Mercier, "Transcutaneous Power of Single-Chip Implants," *Presented at the Sensors Global Summit*, La Jolla, CA, Dec. 2016.
- [50] D. Ahn, P.P. Mercier, "A 200-kHz/6.78-MHz Wireless Power Transmitter Featuring Concurrent Dual-Band Operation," in *Proc. IEEE International SoC Design Conference (ISOC)*, Jeju, South Korea, Oct. 2016. DOI: 10.1109/ISOC.2016.7799763
- [51] P.P. Mercier, J. Rogers, A. Arias, N. Verma, J. Rabaey, "Drawing the line(s): processing sensor information in the right place(s) in energy-constrained systems," *Panel organization and presentation at the SRC SONIC Center Annual Review*, Champaign, IL, Oct. 2016.
- [52] P.P. Mercier, "Wearables: an opportunity for healthcare?," *Presented at the 5G Connected Healthcare Workshop*, La Jolla, CA, May 2016.
- [53] P.P. Mercier, "New Circuit Topologies & Techniques for High-Efficiency Power Conversion in Compact Form Factors," *Invited seminar presented at UCLA and Intel Corporation*, Apr. 2016.
- [54] P.P. Mercier, "Energy-Efficient Wearable Sensors," *Presented at the UCSD Orthopaedic Surgery Research Conference*, April 2016.
- [55] P.P. Mercier and L.G. Salem, "Multi-Ratio Switched-Capacitor DC-DC Converters for Power Management Applications," *Presented at the International Symposium on Quality Electronic Design*, Santa Clara, CA, Mar. 2016.
- [56] P.P. Mercier, "Energy-Harvesting for Autonomous Operation of Low-Power Wireless Sensors," *Presented at the Sensors Global Summit*, La Jolla, CA, Nov. 2015.
- [57] P.P. Mercier, "Enabling energy-autonomous wearable and implantable sensors through energy harvesting and near-zero-power electronics," *Presented at the KAIST-UCSD Joint Symposium on Wearable Devices*, Daejeon, Korea, Oct. 2015.
- [58] P.P. Mercier, "Enabling wide output voltage range switched-capacitor DC-DC converters," *Presented at a SRC/SONIC eWorkshop*, Jun. 2015.
- [59] P.P. Mercier, "Next generation switched-capacitor DC-DC converter topologies," *Presented at the CMOS Emerging Technologies Research Symposium*, Vancouver, BC, May 2015.
- [60] P.P. Mercier, "Harvesting small amounts of power to enable miniaturized sensors," *Presented at the Trillion Sensors Summit*, La Jolla, CA, Nov. 2014
- [61] P.P. Mercier, "Efficient on-chip power conversion for energy harvesting and low-power mobile applications," *Presented at the International Power Supply On Chip Workshop*, Boston, MA, Oct. 2014.
- [62] P.P. Mercier, "A Tutorial on Wireless Power Transfer and Miniaturized DC/DC Power Converters," *Presented at SPAWAR Systems Center Pacific*, San Diego, CA, June 2014.
- [63] P.P. Mercier, "New Advances in Wearable Devices, Biosensors, and Analytics", Panelist at the *Digital Health Forum of San Diego: The Future of Wearable Technologies in Healthcare*, La Jolla, CA, June 2014.
- [64] P.P. Mercier, "Breaking down power barriers: efficient and miniaturized energy management and energy harvesting," *Presented at the Huawei Power Summit*, San Diego, CA, May 2014.
- [65] P.P. Mercier S. Bandyopadhyay, A.C. Lysaght, K.M. Stankovic, A.P. Chandrakasan, "Powering Wireless Devices from the Biologic Battery in the Inner-Ear," *IEEE International SoC Conference*, Irvine, CA, Oct. 2013.
- [66] P.P. Mercier and V. Sridharan, "Low-Power Transmitters for Body-Area Networks," *IEEE Symposium on Power Amplifiers for Wireless Communication*, La Jolla, CA, Sep. 2013.

- [67] P.P. Mercier, "Powering a 2.4 GHz Radio from the Biologic Battery in the Inner-Ear," *Presented at the CMOS Emerging Technologies Symposium*, Whistler, BC, Canada, Jul. 2013.
- [68] P.P. Mercier, "Electrochemical energy harvesting from the inner-ear," *Presented at the INC-IEM Neuroengineering Seminar Series*, La Jolla, CA, Mar. 2013.
- [69] A.C. Lysaght, P.P. Mercier, S. Bandyopadhyay, A.P. Chandrakasan, and K.M. Stankovic, "Endocochlear Potential Powered Electronics" *Associated for Research in Otolaryngology Annual MidWinter Meeting*, vol. 36, Baltimore, MD, Feb., 2013.
- [70] P.P. Mercier, "Enabling study and control of insects through extreme miniaturization of wireless electronics," *Presented at Burapha Univeristy*, Chonburi Province, Thailand, Dec., 2012.
- [71] P.P. Mercier, "nW Energy Harvesting: What can it do for you?," *Presented at the Office of Naval Research Power and Energy Systems 6.1 Program Review*, San Diego, CA, Nov. 2012.
- [72] P.P. Mercier, "Ultra-Low-Power Radios for Miniaturized Sensing Systems," *Presented at the Center for Wireless Communications Semiannual Research Review*, La Jolla, CA, Nov. 2012.
- [73] P.P. Mercier, "Zero-Leakage Electronics and Opportunities in Miniaturized Wireless Systems," *Presented at the Center for Magnetic Recording Research Review*, La Jolla, CA, Oct. 2012.
- [74] P.P. Mercier, "Cyborg Insects and Autonomous Sensors: How Efficient Radios can Enable the Next Generation of Connectivity," *Presented at the Qualcomm Research Center*, San Diego, CA, Oct. 2012.
- [75] A. Paidimarri, P. Nadeau, P.P. Mercier, and A. Chandrakasan, "Ultra-low Power FBAR-based Multi-Channel Transceivers," *Presented at the ISSCC Student Research Preview*, San Francisco, CA, Feb. 2012.
- [76] P.P. Mercier, "Self-Powered Personal Microsystems for Medical Monitoring Applications," *Presented at TechConnect World*, Boston, MA, Jun. 2011.
- [77] P.P. Mercier, "Attaining Extreme Energy Efficiency in Body-Area Networks Using Electronic Textiles," *Presented at the MEDRC Next Generation Medical Electronic Systems Workshop*, Cambridge, MA, May, 2011.
- [78] P.P. Mercier, "Connected Health for Remote Patient Monitoring," *Presented at the MTL Annual Research Conference (MARC)*, Cambridge, MA, Jan. 2010.
- [79] P.P. Mercier, "Personal Medical Connectivity: Research Overview," *Presented at the Intel Digital Health Group*, Hillsboro, OR, Oct. 2009.
- [80] P.P. Mercier, "Energy Efficient Pulsed-UWB for Miniaturized Flying Vehicles," *Presented at the CMOS Emerging Technologies Workshop*, Banff, AB, Canada, Feb. 2009.
- [81] P.P. Mercier, "An Energy-Efficient UWB Transmitter with Dual Capacitively-Coupled Digital Power Amplifiers," *Presented at the Center for Integrated Circuits and Systems*, Cambridge, MA, Apr. 2008.
- [82] P.P. Mercier, "A 22pJ/pulse All-Digital UWB Transmitter in 90nm CMOS," *Presented at the International Solid-State Circuits Conference (ISSCC) Student Forum*, San Francisco, CA, Feb. 2008.
- [83] P.P. Mercier, "Fully Integrated Pulsed-UWB Transceivers for Small Lightweight Flying Vehicles," *Presented at the MTL Annual Research Conference (MARC)*, Waterville Valley, MA, Jan. 2008.
- [84] P.P. Mercier, "Cost Modeling for Vertically Integrated Chip Sets," *Presented at the CMOS Emerging Technologies Workshop*, Banff, AB, Canada, Jul. 2006.

ISSUED PATENTS

- [1] P.-H. Wang, P. Mercier, D. Bharadia, “Low Power Wi-Fi backscatter communication,” U.S. Patent 12,349,069, Jul. 1, 2025.
- [2] M. Dunna, M. Meng, P.P. Mercier, D. Bharadia, “Termination circuit for low power backscatter communication,” U.S. Patent 12,267,127 B2, Apr. 1, 2025.
- [3] P. Mercier, J. Park, “Low Power Magnetic Field Body Area Network With Quenching and Quick Start,” U.S. Patent 12,121,318, Oct. 22, 2024.
- [4] J. Wang, A.J. Bandodkar, P.P. Mercier, “Non-invasive and wearable chemical sensors and biosensors,” U.S. Patent 12,023,154, Jul. 2, 2024.
- [5] J. Wang, P. Mercier, “Salivary Biosensors and Biofuel Cells,” U.S. Patent 11,980,462, May 14, 2024.
- [6] J. Wang, P. Mercier, A.F. Yeknami, S. Imani, “Self-Powered Biosensors,” U.S. Patent 11,633,134, Apr. 25, 2023.
- [7] P.-H. Wang, P. Mercier, “BLE and/or WiFi Compliant and Blocker-Resilient Wake-up Receiver and Method,” U.S. Patent 11,570,709, Jan 31, 2023.
- [8] H. Wang, P. Mercier, “Near Zero Power Fully Integrated Digital Conversion, Sensors, and Sensing Methods,” U.S. Patent 11,444,633, Sep. 13, 2022.
- [9] S. Amin, P. Mercier, “Li-ion-compatible fully-integrated hybrid converter,” U.S. Patent 11,356,017, Jun. 7, 2022.
- [10] P. Mercier, H. Wang, “Stabilized voltage and current reference generator and circuits,” U.S. Patent 11,334,105, May 17, 2022.
- [11] J. Wang, P. Mercier, “Flexible epidermal multimodal health monitor,” U.S. Patent 11,122,982, Sep. 21, 2021.
- [12] X. Wang, P. Mercier, “Low Power Transmitter Oscillator Circuits and Methods,” U.S. Patent 10,897,240, Jan. 19, 2021.
- [13] P. Mercier, H. Wang, “Near Zero Power Charging to Digital Converter, Sensors, and Sensing Methods,” U.S. Patent 10,877,439, Dec. 29, 2020.
- [14] C. Kim, G. Cauwenberghs, P.P. Mercier, S. Ha, J. Park, A. Akinin, “Resonant Regulating Rectifier with an Integrated Antenna,” U.S. Patent 10,873,215, Dec. 22, 2020.
- [15] P. Mercier, D. Ahn, “Wireless Power Transfer Device and Method with Dual-Frequency Operation,” U.S. Patent 10,855,115, Dec. 1, 2020.
- [16] P.-H. Wang, H. Jiang, D. Hall, P. Mercier, “Low Power Wake-up Receiver,” U.S. Patent 10,804,946, Oct. 13, 2020.
- [17] C.-K. Cheng, P. Mercier, S.-H. Weng, “Electrical Wearable Capacitive Biosensor and Noise Artifact Suppression Method,” U.S. Patent 10,729,379, Aug. 4, 2020.
- [18] J. Wang, A.J. Bandodkar, P. Mercier, “Non-invasive and Wearable Chemical Sensors and Biosensors,” U.S. Patent 10,722,160, Jul. 28, 2020.
- [19] S. Ha, G. Cauwenberghs, C. Kim, J. Park, P.P. Mercier, A. Akinin, H. Wang, C.H. Maier, “Radio Frequency Powered Adiabatic Stimulation with Energy Replenishment,” U.S. Patent 10,716,948, Jul 21, 2020.
- [20] T. Nguyen, H. Garudadri, P. Mercier, A. Boothroyd, C. Mackersie, “External Device Leveraged Hearing Assistance and Noise Suppression Device, Method and Systems,” U.S. Patent 10,701,495, Jun. 30, 2020.
- [21] J. Park, P. Mercier, “Low power magnetic field body area network,” U.S. Patent 10,623,112, Apr. 14, 2020.
- [22] J. Wang, P. Mercier, “Salivary biosensors and biofuel cells,” U.S. Patent 10,595,759, Mar. 24, 2020.

- [23] L.G. Salem, P.P. Mercier, "Switched capacitor DC-to-DC converter and power conversion control methods," U.S. Patent 10,374,511, Aug. 6, 2019.
- [24] L.G. Salem, P.P. Mercier, "Multi-level adiabatic charging methods, devices and systems," U.S. Patent 10,348,300, Jul. 9, 2019.
- [25] L.G. Salem, J.F. Buckwalter, P.P. Mercier, "Switched Capacitor House of Cards Power Amplifier," U.S. Patent 10,333,477, Jun. 25, 2019.
- [26] L.G. Salem, P.P. Mercier, "Successive approximation digital voltage regulation methods, devices and systems," U.S. Patent 10,224,944, Mar. 5, 2019.
- [27] K. Stankovich, A. Chandrakasan, P. Mercier, S. Bandyopadhyay, A. Lysaght, "Energy Extraction," U.S. Patent 9,369,005, Jun. 14, 2016.
- [28] P.P. Mercier and A.P. Chandrakasan, "Multi-Taped Inductively-Coupled Charging System," U.S. Patent 9,293,942, Mar. 22, 2016.

Teaching Experience

University of California, San Diego

La Jolla, CA

Instructor

Fall 2024: ECE 203 – Biomedical Integrated Circuits and Systems

Spring 2024: ECE 165 – Digital Integrated Circuits

Fall 2023: ECE 203 – Biomedical Integrated Circuits and Systems (87% instructor rating)

Spring 2023: ECE 165 – Digital Integrated Circuits (98% instructor rating)

Fall 2022: ECE 203 – Biomedical Integrated Circuits and Systems (92% instructor rating)

Spring 2022: ECE 165 – Digital Integrated Circuits (93% instructor rating)

Fall 2021: ECE 203 – Biomedical Integrated Circuits and Systems (83% instructor rating)

Spring 2021: ECE 165 – Digital Integrated Circuits (85% instructor rating)

Fall 2020: ECE 203 – Biomedical Integrated Circuits and Systems (94% instructor rating)

Spring 2020: ECE 165 – Digital Integrated Circuits (92% instructor rating – **even during fully virtual instruction due to COVID-19**)

Fall 2019: ECE 203 – Biomedical Integrated Circuits and Systems (94% instructor rating – **TA won the best ECE TA Award**)

Spring 2019: ECE 165 – Digital Integrated Circuits (96% course rating)

Fall 2018: ECE 203 – Biomedical Integrated Circuits and Systems (95% instructor rating)

Winter 2018: ECE 165 – Digital Integrated Circuits (100% instructor rating)

Winter 2018: ECE 203 – Biomedical Integrated Circuits and Systems (91% instructor rating)

Spring 2017: ECE 165 – Digital Integrated Circuits (100% instructor rating)

Spring 2017: ECE 203 – Biomedical Integrated Circuits and Systems (93% instructor rating)

Fall 2016: ECE260A - VLSI Digital System Algorithms and Architectures (93% instructor rating)

Spring 2015: ECE 165 – Digital Integrated Circuits (**100% instructor & course rating from an 82 student class – ECE dept. record**)

Winter 2015: ECE 203 – Biomedical Integrated Circuits and Systems (93% instructor rating)

Fall 2014: ECE260A - VLSI Digital System Algorithms and Architectures (87% instructor rating)

Spring 2014: ECE 165 – Digital Integrated Circuits (**100% instructor & course rating from a 77 student class – ECE dept. record**)

Winter 2014: ECE 203 – Biomedical Integrated Circuits and Systems (98% instructor rating)

Spring 2013: ECE 283 – Biomedical Integrated Circuits and Systems (99% instructor rating)

Winter 2013: ECE 165 – Digital Integrated Circuits (94% instructor rating)

Massachusetts Institute of Technology

Cambridge, MA

Teaching Assistant

Spring 2010: MIT EECS Course 6.776 – High Speed Communication Circuits.

Funding

Energy-Efficient Microsystems Lab

As PI of the Energy-Efficient Microsystems Lab, I have raised over \$40MM for research at UCSD from the following sources:

- DARPA
- NIH
- NSF
- The Arnold and Mabel Beckman Foundation
- Semiconductor Research Corporation
- ONR
- iARPA
- Army Research Lab
- KETI
- NextFlex
- The Fetzer Franklin Fund
- The Hellman Foundation
- Samsung
- Qualcomm
- Dockon Inc.
- Mouthsense Inc.
- Peregrine Semiconductor
- IMA Life North America
- Moore Foundation
- University of California Multi-Campus Research Programs and Initiatives
- California Energy Commission
- The UCSD Center for Brain Activity Mapping
- The UCSD Center for Wireless Communications (corporate sponsored)
- The UCSD Center for Wearable Sensors (corporate sponsored)
- The Power Management Integration Center (corporate sponsored)

UC San Diego Center for Wearable Sensors

As co-director of the Center for Wearable Sensors, I have been instrumental in fundraising over \$7MM from corporate partners, with the bulk of this funding used to support collaborative

efforts across six engineering departments, the School of Medicine, and the Department of Visual Arts.

Power Management Integration Center

As Site Director of the Power Management Integration Center, I have help recruit corporate members to support research at both UCSD and at Dartmouth College.

Service

Journal service

- Guest Editor – *IEEE Open Journal of the Solid-State Circuits Society (OJ-SSCS) Special Issue on Low-Power RF Circuits and Systems (2023)*
- Guest Editor – *IEEE Journal of Solid-State Circuits* Special Issue on the 2018 *International Solid-State Circuits Conference (ISSCC) (2018)*
- Associate Editor – *IEEE Solid-State Circuits Letters* (2017-2023)
- Associate Editor – *IEEE Transactions on Biomedical Circuits & Systems* (2013-2023)
- Associated Editor – *IEEE Transactions on VLSI* (2015-2017)
- Guest Editor – *IEEE TBioCAS Special Issue on the 2014 International Solid-State Circuits Conference (ISSCC) (December, 2014)*
- Guest Editor – *IEEE TBioCAS Special Issue on the 2013 International Solid-State Circuits Conference (ISSCC) (December, 2013)*

Conference service

- Executive Committee member – Demo Chair – *IEEE International Solid-State Circuits Conference (ISSCC)* (2022-present)
- Technical Program co-Chair – *IEEE Sensor Interfaces Meeting* (2022-2024)
- Subcommittee Chair – Power Management – *IEEE Custom Integrated Circuits Conference (CICC)* (2021-2023)
- Technical Program Committee member – *IEEE VLSI Circuits Symposium* (2018-2022)
- International Technical Program Committee member – *IEEE International Solid-State Circuits Conference (ISSCC)* Technology Directions subcommittee (2017-2022)
- Technical Program Committee member – *IEEE Custom Integrated Circuits Conference (CICC)* (2017-2023)
- Technical program committee – *IEEE Biomedical Circuits and Systems Conference (BioCAS)* (2014-2015)
- Session chair – *International Symposium on Low-Power Electronics and Design (ISLPED)* (2014)
- Technical program committee - *CMOS Emerging Technologies Research Symposium* (2013-2016)

Peer reviewer (2009-present)

- *IEEE Journal of Solid-State Circuits (JSSC)*
- *IEEE Transactions on Circuits and Systems I (T-CAS I)*
- *IEEE Transactions on Circuits and Systems II (T-CAS II)*
- *IEEE Transactions on Microwave Theory and Techniques (T-MTT)*
- *IEEE Sensors Journal*
- *IEEE Transaction on Power Electronics*

- *Journal of Low Power Electronics and Applications (JLPEA)*
- *IET Circuits, Devices & Systems*
- *IEEE International Conference on Ultra-Wideband (ICUWB)*
- *IEEE Transactions on Biomedical Circuits & Systems (TBioCAS)*
- *IEEE Transactions on Biomedical Engineering (TBME)*
- *IEEE International Conference on Circuits and Systems (ISCAS)*
- *IEEE Biomedical Circuits and Systems Conference (BioCAS)*
- *IEEE Journal of Emerging and Selected Topics in Power Electronics*
- *IEEE Transactions on Industrial Electronics*
- *Nature Nanotechnology*
- *Advanced Materials*
- *Nature Biomedical Engineering*
- *Science Advances*

Grant review service

- NSF SenSE panel reviewer (July 2020)
- NSF ECCS panel reviewer (February 2019)
- NSF ECCS panel reviewer (January 2018)
- NSF ECCS panel reviewer (March 2015)
- ARL ARL Director's Research Initiative (DRI) reviewer (June 2015)

UCSD Campus-wide Service

- Chair, Academic Senate Faculty Affairs Committee (2024-present)
- Co-Director – *Center for Wearable Sensors* – including 23 faculty across four engineering departments, the School of Medicine, and Arts and Humanities (Department of Visual Arts). Funding comes from the membership of 6-10 corporate partners. (2014-present)
- Site Director – *Power Management Integration Center* – includes 5 faculty across multiple engineering departments. Funding comes from the membership of 8-12 corporate partners. (2021-present)
- Vice Chair Academic Senate Faculty Affairs Committee (2023-2024)
- Chair, UCSD Academic Senate Awards Committee (2020-2022)
- Member, UCSD Academic Senate Awards Committee (2018-2020)
- Member, Office of Research Affairs Center Launch Review Panel. (2017-2018)
- Member, UCSD School of Public Health Advisory Committee (2017-2019)
- UCSD representative on Capitol Hill – presented to congressional staffers via an event hosted by the American Institute for Medical and Biological Engineering, then met, alongside UCSD's Executive Director of Government Research Relations, with the offices of three San Diego Congressmen and one California Senator to discuss research at UCSD. (2017)
- Faculty representative, Campus-wide commencement ceremony (2017)
- Organizer & presenter, KAIST-UCSD Symposium on Micro/Nanotechnologies and Electronics for Next-Generation Mobile, Wearable, and IoT Systems, Deajeon, Korea (2015)
- Faculty representative, Welcome Week Convocation Ceremony (2013)

UCSD ECE Departmental Service

- Vice Chair, ECE Department (2024-present)
- Member, Faculty search committee, Systems Focus (2024)
- Adhoc committee member, faculty review files (2x in 2024)
- Chair, ECE Faculty Awards Committee (2023-present)

- Chair, ECE Admissions Steering Committee (2020-2022)
- Member, ECE Admissions Committee (2019-present)
- Medical Devices and Systems curriculum advisor (2018-2020)
- ECE 50th Anniversary planning committee (2015-2016)
- MS Exam committee (2014-present)
- Alumni Initiative (2014-2020)
- Undergraduate/Graduate Affairs and Student Award Nomination committee (2012-2014)
- Medical Devices and Systems curriculum director (2013-2014)
- Medical Devices and Systems Ad-hoc committee - responsible for creating a new program in this area (2012-2013)

Co-Chair, Microsystem Technology Lab Annual Research Conference (2011)

Annual research conference with over 200 academic and industrial attendees. Responsible for steering committee leadership and conference organization including: solicitation of papers, managing paper edits, keynote speaker invitation, opening and closing remarks, and general planning. Created interactive attendee activities to solicit social and technical engagement amongst industry members and students. Cited by a high-ranking industry member as “the best student run conference in the country”.

Broader Impacts & Outreach

- Presented a webinar at BioXTech, a country-wide club founded and run by high school women interested in the intersection of biology and technology, and answered questions about technology and gave career advice (2023)
- Featured in the publication entitled “Building Blocks for Better Science: Case Studies in Low-Cost and Open Tools for Science”, which describes my work in low-cost COVID-19 symptoms monitoring devices (2020)
- Guest instructor at Hands-on-Technology summer camp at Wangenheim Middle School focused on accelerating the understanding of computer science in elementary and school-aged children (2014-present)
- Directly mentored ten B.S., M.S., and Ph.D. students from historically underrepresented backgrounds, including two high school students (2012-present)
- Directly mentored two high school students from historically underrepresented backgrounds (2013, and 2016-2017)
- Keynote speaker at ENSPIRE: one of the largest outreach at UCSD, where over 300 middle-school children visit UCSD to learn about higher education and engineering (Feb. 2015)

Press Articles

Prof. Mercier’s work across several different projects and his expert opinion have been featured in hundreds of press articles and in other forms of media (e.g., TV and radio). A few select articles/videos are shown below.

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