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I, Gerard P. Grenier, am over twenty-one (21) years of age. I have never been convicted of a felony, and I am fully competent to make this declaration. I declare the following to be true to the best of my knowledge, information and belief:

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| | |
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| A. | H.H. Asada, et al. "Mobile monitoring with wearable photoplethysmographic biosensors" IEEE Engineering in Medicine and Biology Magazine, Vol. 22, Issue 3, May-June 2003. |

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11. H.H. Asada, et al. "Mobile monitoring with wearable photoplethysmographic biosensors" was published in IEEE Engineering in Medicine and Biology Magazine, Vol. 22, Issue 3, IEEE Engineering in Medicine and Biology Magazine, Vol. 22, Issue 3 was published in May-June 2003. Copies of this publication were made available no later than the last day of July 2003. The article is currently available for public download from the IEEE digital library, IEEE Xplore.

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

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# EXHIBIT A

# Mobile monitoring with wearable photoplethysmographic biosensors



5 Author(s)

H.H. Asada ; P. Shaltis ; A. Reisner ; Sokwoo Rhee ; R.C. Hutchinson

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**Abstract:**
We address both technical and clinical issues of wearable biosensors (WBS). First, design concepts of a WBS are presented, with emphasis on the ring sensor developed by the author's group at MIT. The ring sensor is an ambulatory, telemetric, continuous health-monitoring device. This WBS combines miniaturized data acquisition features with advanced photoplethysmographic (PPG) techniques to acquire data related to the patient's cardiovascular state using a method that is far superior to existing fingertip PPG sensors. In particular, the ring sensor is capable of reliably monitoring a patient's heart rate, oxygen saturation, and heart rate variability. Technical issues, including motion artifact, interference with blood circulation, and battery power issues, are addressed, and effective engineering solutions to alleviate these problems are presented. Second, based on the ring sensor technology the clinical potentials of WBS monitoring are addressed.

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## Contents



**Wbs System Paradigm**
For novel healthcare applications to employ WBS technology, several system criteria must be met. The WBS hardware solution must be adequate to make reliable physiologic measurements during activities of daily living or even more demanding circumstances such as fitness training or military battle. There must exist data processing and decision-making algorithms for the waveform data. These algorithms must prompt some action that improves health outcomes. Finally, the systems must be cost effective when compared with less expensive, lower technology alternatives.



**Keywords**

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**INSPEC: Controlled Indexing**
electromyography, patient monitoring, biomedical transducers, biomedical telemetry, cardiovascular system, blood pressure measurement, plethysmography, electroencephalography

**INSPEC: Non-Controlled Indexing**
battery power, mobile monitoring, wearable photoplethysmographic biosensors, cardiovascular monitoring, ring sensor, ambulatory telemetric continuous health-monitoring device, miniaturized data acquisition features, cardiovascular state, oxygen saturation, heart rate variability, technical issues, motion artifact, blood circulation

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Haruhiko Harry Asada is a Ford professor of mechanical engineering and director of the Brit and Alex d'Arbeloff Laboratory for Information Systems and Technology in the Department of Mechanical Engineering at Massachusetts Institute of Technology (MIT). He specializes in robotics, biomedical engineering, and system dynamics and control. His current research areas include wearable health monitoring, robotic aids for bedridden patients, vast DOF actuator systems, and multiphysics simulation. He received the B.S., M.S., and Ph.D. degrees in precision engineering in 1973, 1975, and 1979, respectively, all from Kyoto University, Japan. He was a visiting research scientist at the Robotics Institute of Carnegie-Mellon University from 1980 to 1981. He joined the Department of Mechanical Engineering at MIT as faculty in 1982 and became a full professor in 1989. He is a Fellow of ASME.

P. Shaltis

Phillip Shaltis received the B.A. degree in physics from Albion College, Albion, MI, in 1999 and the B.S. degree in mechanical engineering from the University of Michigan, Ann Arbor, MI in 2000. He will be finishing dual M.S. degrees in mechanical and electrical engineering at MIT in 2003 and plans to continue work towards the Ph.D. degree in mechanical engineering at MIT. His research interests include biomedical instrumentation, biomedical signal processing, analog circuit design, and system analysis and control.

A. Reisner

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