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John C. Eidson

Measurement, Control, and Communication Using IEEE 1588

With 38 Figures
(including 4 in Color)

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To my loving family, and to my many friends and colleagues worldwide who have contributed much to IEEE 1588

Series Editors' Foreword

The series *Advances in Industrial Control* aims to report and encourage technology transfer in control engineering. The rapid development of control technology has an impact on all areas of the control discipline. New theory, new controllers, actuators, sensors, new industrial processes, computer methods, new applications, new philosophies…, new challenges. Much of this development work resides in industrial reports, feasibility study papers and the reports of advanced collaborative projects. The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination.

In an increasingly complex technological world, standards of all different types play an important role in ensuring the uniform comprehension of technology and aiding compatibility in different technological domains. The ISO series of international standards covers a wide range of technology including, for example, assistive technological devices for accessibility. In the construction industry, the International Building Code gives standards on all aspects of buildings and their internal layout. For the electrical and electronic industries the IEEE issues a series of technological standards and the particular standard IEEE 1588 for real-time applications in measurement, control and communications systems is the subject of this new *Advances in Industrial Control* monograph by John Eidson (Agilent Technologies, Inc., USA).

Engineers involved with the application of standards are well acquainted with their value, but one suspects that many in the engineering community are not very familiar with either the standards system or its value as a pedagogical resource. Standards are usually the distillation of the expertise and knowledge of a group of world-leading experts in a technological field. Thus, standards almost always contain invaluable information about categories, classification, definitions and technological description. Whilst this information may be given in condensed form it is a valuable resource for study. If you are a lecturer, using a standard may give you the framework that you need to explain a technology clearly and precisely to an engineering audience.

John Eidson's approach to his presentation of the IEEE 1588 standard follows three themes: the background and context to the standard, the detail of the standard

and, finally, the application of the standard. In this way a very rich picture emerges from what might have been thought to be an arcane subject. The book opens with an exploration of the background to the tasks of time-keeping and synchronization and an authentic historical context is presented to the problems involved in these tasks.

The middle section of the book is devoted to the IEEE 1588 standard *per se* where an analysis of the standard is presented along with a discussion of practical implementation issues. One item of special note for the control specialist is the control design for a clock servo system that turns out to be a discrete PI control loop design problem (page 146 onward). The later chapters of the book report actual or proposed applications in a series of case studies from large turbine operations power systems, instrumentation systems, robotics, motion control and communication systems.

Overall this text is a very welcome addition to the *Advances in Industrial Control* monograph series. John Eidson has ensured that this monograph offers material for both the general and the specialist reader alike. Whilst the specialist reader will find the explanation of the IEEE 1588 standard invaluable and instructive, the general reader will undoubtedly enjoy the historical background to timekeeping problems and gain real insight through a perusal of the applications and case study chapters.

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Preface

This book is about the use of IEEE 1588, and the explicit representation of time in the design and operation of measurement, control, and communication systems. In a larger sense, it is about the combination of the explicit representation of time, and the use of networking and distributed system technology in solving hard real-time application problems.

IEEE 1588 is a new standard that was published in November 2002. It has attracted the attention of technologists worldwide in the fields of industrial automation, test and measurement, and telecommunications. Products and installed systems based on the standard are beginning to appear, and both the protocol and its implications are attracting the attention of university researchers.

As with all new technologies, there is a learning curve that must be overcome by potential users. Reading a standard has never proved to be a particularly pleasant task, and is certainly not the ideal vehicle for an introduction to a technology. This book is intended to make climbing this learning curve both easier and, hopefully, more interesting.

The book is organized in three major parts. The first part provides an introduction to the field, some background on timekeeping and synchronization, and a high-level overview of the IEEE 1588 standard. The second part consists of a detailed analysis of IEEE 1588 and a discussion of the more important practical issues in implementing the standard. The third part begins with a general discussion of system architectures based on IEEE 1588 technology, and then provides examples of actual or proposed applications in the fields of industrial automation and power, test and measurement, and communications. The last part consists of appendices giving more detailed information concerning IEEE 1588 messages and data sets. Readers whose primary interest is in the application of IEEE 1588 will find that Part II can be skipped on first reading.

IEEE 1588, like all technologies, is the result of the efforts of many people. The cited references represent a partial list of the researchers on whose work this book is based, and to whom I am indebted. Credit must also be given to

the past and current members of the IEEE P1588 committee that produced the original version of the IEEE 1588 standard, and who are currently hard at work on the first revision.

Everyone using IEEE 1588, including myself, owes special thanks to Kang Lee of NIST not only for his work as the IEEE sponsor of the standard, but also for his tireless efforts in its promotion. Thanks are also due to NIST for its support of the standard, and for hosting the first two conferences on IEEE 1588. These conferences brought together many researchers, developers, and users of the technology, and did much to foster the cooperative spirit that has enabled its rapid development.

On a more personal note, I would like to thank Hermann Kopetz of the Technical University of Vienna, and Edward Lee of the University of California at Berkeley for many inspirational discussions on topics related to IEEE 1588 technology.

I would also like to thank the management of Agilent Technologies, and earlier of Hewlett-Packard, for their continued support of the technology, the standards activities, and my work on this book. Those in large organizations appreciate that *the management* always points to a few individuals willing to champion a technology in the face of very good arguments for its termination. Simply put, this technology would never have seen the light of day but for the extraordinary support of Randy Coverstone, Jon Kim, Bill Shreve, and—most especially—Jay Warrior, who shared the dream and promoted it both inside and outside the corporation.

It has been my privilege over the years to work with a particularly stimulating group of colleagues at Agilent Technologies and Hewlett-Packard. Many continue to contribute to the development of this technology. I would like to especially acknowledge Jeff Burch, Bruce Hamilton, and Stan Woods, who have been my closest collaborators.

The technical presentation in this book has benefited greatly from discussions with Danny Abramovitch of Agilent Technologies, Glenn Algie of Nortel, Galina Antonova of General Electric, Doug Arnold of Symmetricom, Len Cutler of Agilent Technologies, Pat Diamond of Semtech, Michael Gerstenberger of KUKA Robotics, Dirk Mohl of Hirschmann Automation and Control, Anatoly Moldovansky of Rockwell Automation, David Petticord of Complete Networks, Dan Pleasant of Agilent Technologies, Silvana Rodrigues of Zarlink Semiconductor, Mark Shepard of General Electric, Dave Tonks of Semtech, Veselin Skendzic of Schweitzer Engineering, and Miao Zhu of Agilent Technologies.

Thanks are due to Anthony Doyle, Oliver Jackson, and the staff at Springer for their encouragement and support in preparing and publishing this book.

Palo Alto, California *John C. Eidson*

January 2006

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