Run-to-Run Control in SEMICONDUCTOR MANUFACTURING

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Preface

The goal of this book is to provide a practical guide to the understanding, implementation, and use of run-to-run (R2R) control in semiconductor manufacturing as well as manufacturing in general. The target audience is intentionally wide and includes technology directors and strategists, technical managers, control engineers, process engineers, systems designers, integrators, and users. The aim of the authors is to provide insight into the development, integration, application, enhancement, and operation of R2R control. In addition, the book points to new directions in R2R process control, some of which have only recently been discussed in the literature. These directions point to avenues of opportunity for developing even more effective R2R control strategies for the fabricator of the future.

WHO SHOULD USE THIS BOOK

The benefits of R2R control implementation are wide-ranging and affect the many levels of the manufacturing hierarchy. As such, this book is structured to provide benefit to readers at each of these levels. For example, the following is a sample of who might utilize this book as a guide and aid in implementing an effective R2R control initiative either on a single tool, or facility-wide in a fabrication facility:

- A *corporate-level technical strategist* would utilize the book as a resource to:
  1. Collect convincing evidence indicating that R2R control will provide significant competitive advantage.
  2. See that proven R2R control solutions are available.
  3. Read that benefits, such as C_{pk} and yield, have been proven and quantified.
  4. Plan a strategy for integration.
- A *facility director* would utilize the book for directing facility-wide R2R control development and deployment. Specifically, the facility director would utilize the book to define plans for:
  1. Identifying target applications for R2R control.
  2. Performing the necessary requirements analysis and identifying equipment, metrology, control, and integration deficiencies.
  3. Identifying the "control problem" for each candidate process, including process quality metrics.
  4. Determining the controllability of each candidate process.
  5. Developing stand-alone control solutions for each candidate process.
  6. Integrating these control solutions for a fab-wide R2R control solution.

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- The *process engineer* for each process would utilize the book to develop an effective control solution for his/her process. The book would aid the process engineer in:
  1. Process input and output parameter selection and refinement.
  2. Process identification for control.
  3. Development of an industrial-quality solution that addresses requirements of parameter bounds, discretization, parameter weighting, process and metrology noise rejection, etc.
  4. Development, integration, and testing of the control software solution.

HOW TO READ THIS BOOK

We have put this book together with the intent that it be of use to the beginning reader in R2R control as well as the specialist seeking detailed information on R2R control methods and/or recent directions and developments. In order to achieve this we have divided the text into six parts plus a conclusion. *The Introduction and first chapter of each part* should be read first* by the reader new to the subject. These first chapters have been chosen because they are, on the whole, more introductory and less burdened with technicalities than later chapters in the same part. Specialist readers may, of course, pick and choose as they wish.

* Excerpt for Part 6: Advanced Topics.

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Editors

James Moyne, Ph.D., is an Associate Research Scientist in the Electrical Engineering and Computer Science Department at the University of Michigan, and is President and co-founder of MiTeX Solutions, Inc., Canton, Michigan. (MiTeX Solutions was acquired by Brooks Automation, Inc. in June 2000.) James received his B.S.E.E. and B.S.E. in math, and his M.S.E.E. and Ph.D. in electrical engineering from the University of Michigan. He has over 30 refereed publications in the areas of discrete control, advanced process control, databases, sensor bus technology, and communications, and is the author of the patent on the Generic Cell Controller run-to-run control enabling technology. He is also the author of a number of SEMI (semiconductor manufacturing) international standards in the areas of sensor bus systems and communications, and has received four SEMI outstanding achievement awards and a technology transfer award.

James lives in Canton, Michigan, where his hobbies include writing music and playing the keyboard and sax. He is a published poet, has released a solo album of New Age music, and is a member of Cornerstone, which is currently working on its second Rock/Pop album.

Enrique del Castillo, Ph.D., is an Associate Professor in the Harold and Inge Marcus Department of Industrial and Manufacturing Engineering at the Pennsylvania State University. He holds a Ph.D. in industrial engineering from Arizona State University, and a Master of Engineering in operations research and industrial engineering from Cornell University. Dr. Castillo's research interests include quality engineering and applied statistics, with particular emphasis on response surface methodology and time series control. He has over 35 papers in journals such as *IIE Transactions*, *Journal of Quality Technology*, *Metrika*, *Communications in Statistics*, *International Journal of Production Research*, *European Journal of Operational Research*, and *Journal of the Operational Research Society.* He has been awarded an NSF CAREER grant for research in semiconductor manufacturing process control. Dr. Castillo is an Associate Editor of the *IIE Transactions on Quality and Reliability Engineering* journal and a member of the editorial board of the *Journal of Quality Technology.*

Arnon Max Hurwitz, Ph.D., is Managing Director of Qualtech Productivity Solutions, South Africa, and Vice President of MiTeX Solutions, Inc., Canton, Michigan. He gained his M.S. in applied statistics from Oxford University, England, and his Ph.D. in mathematical statistics from the University of Cape Town, South Africa. Dr. Hurwitz lectured at the Graduate School of Business, Cape Town, and at Guilford College, North Carolina, and was Head of the Mathematics Department at Oak Ridge Military Academy, North Carolina. He was Quality Engineer at Corning

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