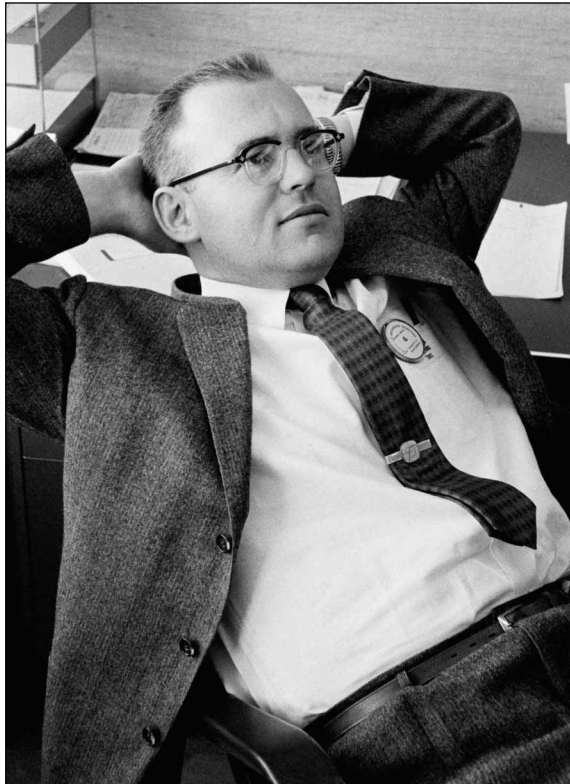
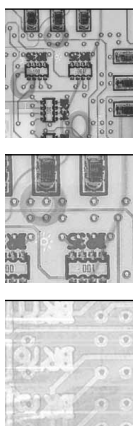


U N D E R S T A N D I N G M O O R E ' S L A W

Four Decades of Innovation



Gordon E. Moore in 1960.
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UNDERSTANDING MOORE'S LAW

Four Decades of Innovation

Edited by David C. Brock



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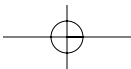
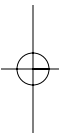
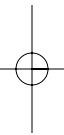
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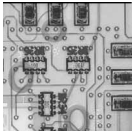
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“Chymistry is the great field of knowledge for the extension of electrical knowledge . . . yet their relation to each other has been but little considered.”

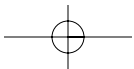
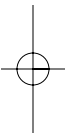
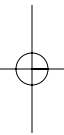
— *Joseph Priestley*, 1766

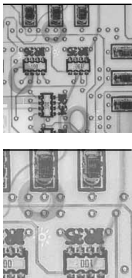




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P R E F A C E

The rise of semiconductor electronics and its underlying manufacturing technology are among the most important developments of the past half-century. Integrated circuits—silicon chips—have transformed every area of economic, technological, and social activity. Insights into the dynamics that have brought us this silicon revolution are vital to our understanding of the world today and our common future.

For the past forty years, Moore's law has served as a unique guide to the dynamics of the silicon revolution. Originating as an observation and prediction about the economic and technical trends at play in the early years of integrated circuit technology, Moore's law eventually became an industry expectation. Later, it became the organizing goal of a multibillion-dollar global industry. Even more recently, with the proliferation of silicon chips into nearly every aspect of contemporary life, Moore's law serves as an emblem for the whole of technological change.

What is Moore's law? Where did it come from? What is the underlying technology for making silicon chips? How has it changed, and who did the work? Who is Gordon Moore? Where is Moore's law leading? This book aims to answer these questions for the general reader. Part One, Historical Introduction, places Gordon Moore and semiconductor electronics within a broad sweep of scientific and technological history. Arnold Thackray's review, "Before Moore's Law: Lineages of Chemistry and Electricity," emphasizes the longstanding and productive intersections of chemistry with electronics that form an important context for the silicon revolution. David C. Brock's essay, "The Backdrop to Moore's Law: Developments in Semiconductor Electronics to 1965," introduces semiconductor technology and Gordon Moore's involvement with it up to his formulation of Moore's law.

Part Two, Articulations, presents Gordon Moore's major statements of his eponymous law. The section begins with an introductory essay by Brock, "A Clear Voice: The Origins of Gordon Moore's 1965 Paper," which describes the immediate context in which Moore developed his first statement of Moore's law. Next, reproduced here for

x PREFACE

the first time, is Moore's original manuscript for his first publication of Moore's law. Reproductions of Moore's two major published articulations of Moore's law follow: his paper of 1965, "Cramming More Components Onto Integrated Circuits," and his published speech of 1975, "Progress in Digital Integrated Electronics." Here the reader can trace the evolution of the expression of Moore's law through the original manuscript, the first publication, and the tenth anniversary update. Part Two concludes with a new, important contribution by Moore, "Moore's Law at Forty," his fortieth anniversary update and reflection.

This book has its beginnings in a symposium held in the spring of 2005, Moore's Law at 40: Chemistry and the Electronics Revolution, at which Moore delivered his "Moore's Law at Forty" update. Organized by the Chemical Heritage Foundation, this symposium gathered key contributors to and commentators on the silicon revolution. Part Three of the book, Reflections, presents a review of their reflections and observations about Moore's law and its four-decade history, as well as their predictions for the future.

ACKNOWLEDGMENTS

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Our primary debt is owed to the speakers and moderators of our conference and to those individuals and organizations who promoted and sponsored it. For speaking at our symposium, we thank Gordon Moore, Rodney Brooks, Patrick Gelsinger, Raj Gupta, Carver Mead, Elsa Reichmanis, AnnaLee Saxenian, and Harry Sello. For their able services as moderators and commentators, we thank Dennis Hess, Rob McCord, and Miles Drake. Our special thanks go to Arnold Thackray, the president of CHF, for his many roles: speaker and moderator at the event, contributor to its intellectual and logistical organization, and active contributor to our explorations of the intersection between chemistry and electronics.

Our symposium was organized in association with the Electrochemical Society. In that connection, we thank Kathryn Bullock for her advice, assistance and enthusiasm. Similarly, Rob McCord did much to promote our symposium through the Eastern Technology Council. The symposium was made possible through the financial support of the Intel Corporation (Platinum Sponsor), the Rohm and Haas Company (Gold Sponsor), and our Silver Sponsors: Cabot Microelectronics Corporation, Degussa Corporation, Mallinckrodt Baker, Solid State Equipment Corporation, 3M Company, and Wacker Chemical Corporation. Lastly, we express our deep appreciation to John Haas for his long support of both CHF and our chemical history of electronics project.