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# **The U.S. Microelectronics Industry**

**Technical Change, Industry Growth  
and Social Impact**



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**Nico Hazewindus  
with John Tooker**

The Technology Policy and Economic Growth Series,  
Herbert I. Fusfeld and Richard R. Nelson, Editors

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# Preface

This book is intended to serve as a guide to the interactions of technical change, industry growth, and public policy in the field of microelectronics. The approach is a broad technical perspective on the next five to ten years. It provides an introduction to the technology of microelectronics, the structure of the industry, the base of research and manpower supporting this capability, and selected government policies which can affect the vitality of this exceptional field.

This study thus presents an integrated view of the diverse facets that characterize microelectronics. It can serve as a reference for considering, in greater depth, areas of special concern to policymakers in both the public and private sectors who require a sense of the whole system to understand better their own particular interests.

This book was conceived and written during the author's half-year stay in 1981 as a Visiting Research Fellow at the Center for Science and Technology Policy, Graduate School of Business Administration, New York University. This stay marked a leave of absence from the Product Development Coordination Bureau of N.V. Philips' Gloeilampenfabrieken in The Netherlands. The material contained here is based on discussions during that time with experts in government, industry, and universities whose knowledge and experience brought special insight to the research. A diverse range of references is included in this book and may serve as a substantive base of background information. To this the author added his own opinions and conclusions and the final text therefore remains his sole responsibility.

Eindhoven/New York, March 1982  
Nico Hazewindus with the  
collaboration of John Tooker

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I gratefully acknowledge the cooperation of my colleagues at the Center. Dr. Lois S. Peters introduced me to the topic of university-industry relations. Mrs. Carmela S. Haklisch critically read several versions of the manuscript and suggested many changes. Her efforts have contributed substantially to the completion of the book.

The material contained here has been strongly influenced by discussions with members of an ad hoc advisory group. The participants of this group included Dr. Erich Bloch, Vice President, Technical Personnel Development, IBM; Dr. W.F. Brinkman, Director, Chemical Physics Research Laboratory, Bell Laboratories; Dr. W. Chu, Manager, Technology Development Operation, G.E.; Dr. David Golibersuch, Manager, Signal Electronics Lab, G.E.; Dr. Donald King, President, Philips Laboratories, North American Philips Corporation; Dr. Henry Kressel, Staff Vice President, Solid State Research, RCA; Mr. Joseph Reed, Technical Director of Military Communications, ITT Corporation; Dr. Frank A. Sewell, Jr., Director, Semiconductor Laboratory, Sperry; and Dr. Lee L. Davenport, Vice President and Chief Scientist (retired), GTE. Dr. Davenport's continuing interest assisted me throughout the study in various discussions, and I thank him for his very helpful review of the first draft of this manuscript.

I am grateful to many people in the U.S. and Europe who helped me, either by sharing their ideas in interviews or by sending me materials and information.

At the Center for Science and Technology Policy my collaborator John Tooker was the research assistant for the project. Among his many contributions I mention especially his work on the sections on employment effects, the IC industry, various national policies, and manpower needs.

Maria Ortiz and Shawn Roberts patiently typed the manuscript and Carlos Santiago drafted all the illustrations.

Finally, I would like to thank everyone at the Center for their gracious hospitality which made my stay such a memorable occasion.

Nico Hazewindus  
Eindhoven, March 1982



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# Glossary

Actuator	- Electronically driven device that affects some mechanical movement.
Active component	- Electronic component like a diode or transistor used to switch or amplify electric signals.
ADA	- High-level computer language developed for the U.S. Department of Defense.
A/D converter	- Electronic circuit that converts analog signals into a digital representation.
Algorithm	- Rule or procedure for solving a mathematical problem.
Analog	- Electric signal with continuously varying amplitude (usually used as opposed to digital).
Application software	- Software that is needed to apply a general computer to a specific task.
Arpanet	- U.S. data network linking computers nationwide.
BASIC	- Relatively simple high-level computer language.
Bipolar device	- Transistor device consisting of two types (n and p) semiconductor.

- Bit - Unit of information, consisting of a binary digit having the value 0 or 1.
- Bit-rate reduction - Technique to diminish the number of bits per second needed to represent sound or moving pictures by eliminating redundancy.
- Bubble memory - Device to store data in magnetized spots in a thin layer of magnetic material.
- Bus - Electronic circuit used to provide a (standardized) path for data exchange between devices.
- CAD - Computer-Aided Design, a method to design electronic circuits or mechanical parts with the help of a computer.
- CAM - Computer-Aided Manufacturing, the application of computers in several stages of the industrial production process.
- Captive producer - Company producing IC's for its own use, in contrast with merchant houses.
- CCD - Charge-Coupled Device, a semiconductor device in which information is stored as small electronic charges.
- Chip - Tiny piece of semiconductor crystal on which an integrated circuit has been made.
- CIF - Caltech Intermediate Format, a computer language to describe the layout of integrated circuits.
- CMOS - Complementary MOS, integrated circuit with two types (n and p) MOS transistors, which uses little power.
- COBOL - High-level computer language for business applications.
- CODEC - Coder-decoder circuit used in telephony to convert analog signals to digital ones and vice versa.

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|----------------|---|
| D/A converter  | - Electronic circuit to convert digital signals into analog ones.   |
| DARPA          | - Defense Advanced Research Projects Agency (U.S.).   |
| Database       | - Large collection of digital data, arranged in a predetermined way and stored in a computer memory.  |
| DES            | - Data Encryption Standard, method for encryption of digital data, devised by IBM and accepted by the U.S. government for certain classes of application. |
| Die            | - Tiny piece of semiconductor crystal on which an integrated circuit is made.   |
| Digital        | - Representation of a signal as a number, as opposed to analog.   |
| Diode          | - Active electronic device conducting current in one direction, but not in the other.   |
| DMOS           | - Double-diffusion MOS, devices which are suitable for high-voltage or high-power applications.   |
| Doping         | - Introduction of impurities into a semiconductor to influence its electric characteristics.  |
| Dynamic RAM    | - Semiconductor random access memory requiring a continuous refreshment of stored data.   |
| E-beam machine | - Equipment using a high-energy electron beam to make very fine patterns in the lithography for integrated circuits.                                      |
| ECL            | - Emitter Coupled Logic, class of bipolar integrated circuits.  |
| EDP            | - Electronic data processing.   |
| EE PROM        | - Electrically Erasable PROM, an E PROM that can be erased with electric pulses.  |

- E PROM - Erasable Programmable Read-Only Memory, PROM of which the contents can be erased with ultraviolet light.
- Epitaxial layer - Thin layer, deposited on a semiconductor material, with a similar crystal structure.
- FET - Field Effect Transistor, a transistor based on conduction effects, controlled by a voltage, in one kind of semiconductor material (also called unipolar transistor).
- Fibers (optical) - Thin transparent glass fibers which transmit information by means of modulated light.
- Firmware - Software "packaged" in hardware form.
- Floppy disc - Flexible magnetic disc used for storage of data in a computer.
- FORTRAN - High-level computer language, in particular suited for mathematical calculations.
- Gallium Arsenide - Semiconductor material, in particular used for high-speed transistors.
- Gate - Basic logic circuit element that determines whether certain logic conditions at its inputs are simultaneously met (e.g. "and", "or" gates).
- Gate arrays - Integrated circuits containing an array of gates, which are connected by means of a conductor pattern to perform a certain function.
- GATT - General Agreement on Tariffs and Trade.
- Hall sensor - Sensor making use of the Hall effect, converting a magnetic field into an electric signal.
- Hardware - The various physical parts of a computer system, contrasted with software.

- Hybrid circuits - Combinations of active and passive components, mounted on a substrate (usually ceramic) on which resistors and connecting conductors are applied.
- IC - Integrated Circuit, semiconductor device incorporating a number of active and passive circuit elements on a single piece of semiconducting material (chip).
- IIL, I<sup>2</sup>L - Integrated Injection Logic, bipolar integrated circuit with a particular arrangement of diodes and transistors to achieve good packing density at reasonable speed.
- Interface - Place where two equipments must be matched in order to be connected; also used as "man-machine interface"
- I/O - Input/Output, usually designating these functions in a computer system.
- Ion implantation - A method of introducing impurities in a semiconducting material by bombarding the latter with high-energy ions.
- ISL - Integrated Schottky Logic, particular type of bipolar integrated circuit with properties like IIL.
- ITAR - International Traffic in Arms Regulations (U.S.)
- Josephson junction - Superconducting semiconductor device operating at cryogenic (near absolute zero) temperatures, with extremely fast operation speed.
- Junction - Boundary between two types of semiconducting material where physical phenomena occur that are utilized in diodes or transistors.
- Learning curve - The graph showing a lowering of manufacturing costs with a certain factor every time the total series produced is doubled.
- Linear IC - Analog IC, as opposed to digital IC.

Lithography	- Processes to make patterns needed in integrated circuits, using light, X-rays, or electron beam to define the patterns and etching techniques to remove undesired parts.
LSI	- Large-scale integration, IC's containing 1,000 to 100,000 components.
Mainframe	- Medium or large computer without peripherals.
Masks	- Glass plates with IC layouts, used in the lithographic process.
Memory	- Store for digital or analog information, kept usually in electric or magnetic form.
Merchant house	- Company producing IC's to sell them on the open market.
Microelectronics	- The technology and manufacture of miniature electronic components and circuits.
Micron	- One thousandth of a millimeter.
Microprocessor	- Central part of a computer integrated on an IC.
Minicomputer	- Small computer, usually much less expensive than a mainframe.
MITI	- Ministry of International Trade and Industry (Japan).
Modem	- Modulator-Demodulator, circuit used to couple digital equipment to an (analog) telephone line.
MOS	- Metal-Oxide-Silicon, technology to produce transistors controlled by voltage (MOS FET).
Moore's Law	- Statement that complexity of IC's increases annually with a certain factor.

MSI	- Medium Scale Integration, IC's containing 100 to 1,000 components.
Nano second	- One thousandth of a millisecond.
NBS	- National Bureau of Standards (U.S.)
NIH	- National Institutes of Health (U.S.)
nMOS	- MOS transistor using electrons to conduct the current.
Non-volatile memory	Memory of which the content is not destroyed when electric power is switched off.
NSF	- National Science Foundation (U.S.)
n-silicon	- Silicon doped to have an excess of electrons.
OECD	- Organization for Economic Cooperation and Development.
Opto-electronics device	Semiconductor device used in optical systems, for instance to generate or detect light.
Operational amplifier	Analog amplifier for general application, the properties of which can be determined by the circuit designer.
PABX	- Private automatic branch telephone exchange, telephone switch for private (business) networks.
PASCAL	- High-level computer language.
Passivation layer	- The last, protecting layer that is applied on an integrated circuit.
Passive components-	Electronic components like resistors and capacitors which do not actively influence signals in a circuit.
Piezo-electricity	- Physical phenomenon in certain materials in which mechanical stress is transformed into electricity, and vice versa.

Printed circuit board	- Electrically isolating board with a pattern of conductors, on which electronic components are soldered.
Programmable logic array	- Circuit with a prearranged array of logic gates which can be interconnected to implement a desired logic function.
Programming language	- A coherent set of instructions resembling (English) language that can be understood by a computer.
PROM	- Programmable Read-Only Memory, a memory in which the user can write data once. Thereafter only read operations are possible.
p-silicon	- Silicon doped to have a shortage of electrons.
PTT	- Governmental organization which is, in many countries, responsible for mail and telecommunications.
RAM	- Random Access Memory, memory in which any part of the stored information can directly be accessed, read, and modified.
Resist	- Light-sensitive lacquer used in the lithographic process of IC manufacturing.
Reticle	- Glass plate with pattern to be projected on a silicon wafer in IC lithography.
ROM	- Read-only memory, a memory of which the content has been determined during manufacturing; thereafter only reading operations are possible.
SAW device	- Surface Acoustic Wave device, used in electronic filters or resonators, based on the phenomenon that different types of acoustic waves may travel on the surface of certain materials.
Second sourcing	- Practice among merchant houses to allow the manufacturing of a particular proprietary IC by a competitor, thus giv-



- ing one's customer the certainty of having two independent suppliers.
- Schottky effect - Particular effect on semiconductor material surfaces that can be used to make diodes.
- Sensor - Device that transforms a physical phenomenon into a measurable (often electric) signal.
- Semiconductor - Device employing a material (or the material itself) with electrical characteristics in between a conductor and an isolator.
- SIA - Semiconductor Industry Association, U.S. trade association.
- Silicon Valley - Region south of San Francisco (California) where many IC companies have their headquarters.
- SLIC - Subscriber Line Interface, circuit to interface a digital telephone exchange and analog subscriber lines.
- Slice - Thin wafer of silicon on which IC's are manufactured.
- Software - Programs used to instruct a computer.
- SOS - Silicon-on-sapphire, technique for making very fast transistors on a sapphire substrate.
- SSI - Small-scale integration, less than 100 components per IC.
- Static RAM - Random-access memory of which the content need not be refreshed like a dynamic RAM.
- Systems house - Electronics firm having its business in electronic systems.
- Teletext - TV-broadcast format in which pages of digital information are transmitted simultaneously with the normal video signals.