HPEC 2004 Panel Session: Amending Moore’s Law for Embedded Applications

Roadmapping the Semiconductor Industry: Are we reaching the end of the road?

Bob Schaller
College of Southern Maryland

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**Report Documentation Page**

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Standard Form 298 (Rev. 8-98)  
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The Road to Technology Roadmaps

TECHNOLOGY ROADMAPS: Implications for Innovation, Strategy, and Policy

• Personal experience in computer service since mid 1970s: from mainframe to minicomputer to personal computer
  – observed miniaturization but had no “label” for trend
  – first introduced to “Moore's Law” in PhD Special Topics course
  – wrote term paper on Moore's Law, later published in *IEEE Spectrum* (June 1997) - met Gordon Moore as part of research

• Proposed Intel case study as dissertation topic (i.e., coordinating effect of Moore’s Law) but did not work

• Request to Sematech to study SIA Roadmap (Moore's Law "Insurance")
  – formal research arrangement with ITRS Managing Editor
  – met Ron Kostoff at ONR and co-authored S&T Roadmap paper (*IEEE TEM*, May 2001); got connected w/ other “roadmappers”
Rycroft/Kash Innovation Patterns

Normal Pattern
(silicon, CMOS, microprocessor, stepper litho, copper, SoC, etc.)

Transition Pattern
(IC and planar process)

Transformation Pattern (transistor)

Innovation legend:
- Incremental
- Major
- Fundamental
Chapter 8: Moore's Law: Basis for Industrial Cadence

• Simple observation (plot) becomes an imperative (law)
• Fundamentally defines industry, part of its culture
• Made possible by upstream SM&E capabilities and permeates downstream user capabilities
• Basis for Roadmap
• Appendix includes 8yr retrospective and new formulations (e.g., as learning curve)
What is Moore’s Law?

"The Roadmap is just Moore's Law, heavily decorated."

- Sonny Maynard, SRC VP

"We don't adhere to Moore's Law for the hell of it. It's a fundamental expectation that everybody at Intel buys into... We simply don't accept the growing complexity of the challenge as an excuse not to keep it going."

- Craig Barrett, Intel CEO

"Moore's Law is not a law; it is an act of will."

- Chris Mack, KLA-Tencor VP
# A Retroactive Look at Moore’s Law

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<tr>
<th>Year</th>
<th>Feature Size</th>
<th>Technology</th>
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<tr>
<td>1900</td>
<td>1 inch</td>
<td>Telegraph wires</td>
</tr>
<tr>
<td>1912</td>
<td>1/4 inch</td>
<td>Electromechanical relays</td>
</tr>
<tr>
<td>1924</td>
<td>1/16 inch</td>
<td>de Forest Audion</td>
</tr>
<tr>
<td>1936</td>
<td>16 mils</td>
<td>Triode vacuum tubes</td>
</tr>
<tr>
<td>1948</td>
<td>4 mils</td>
<td>Miniature vacuum tubes</td>
</tr>
<tr>
<td>1960</td>
<td>1 mil (25 µm)</td>
<td>Planar transistor</td>
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Gordon Moore: *No Exponential is Forever … but We Can Delay “Forever,”* ISSC03

Projected 2000 Wafer, circa 1975

Moore was not always accurate

Source: [www.intel.com/research/silicon/mooreslaw.htm](http://www.intel.com/research/silicon/mooreslaw.htm), Slide #12
“The lesson to be learned here is simple: Moore’s Law is not forever… Given the above scenario for the year 2025, I would say that forcing ourselves to adhere to our current path without economic justification is even more dangerous.”
Moore's Law: Literature S-Curve

"Moore's Law" Articles Found in ProQuest

Source: http://proquest.umi.com/
ITRS: Moore’s Law “Insurance”

International Technology Roadmap for Semiconductors

Jointly Sponsored by
European Semiconductor Industry Association
Japan Electronics and Information Technology Industries Association
Korea Semiconductor Industry Association
Taiwan Semiconductor Industry Association
Semiconductor Industry Association
Generic Roadmap

MARKET
  M1 → M2

PRODUCT
  P1 → P2 → P3 → P4

TECHNOLOGY
  T1 → T2 → T3 → T4

R&D PROJECT (SCIENCE)
  RD1 → RD2 → RD4 → RD6
  RD3 → RD5

Time (years): 0 → 1 → 2 → 3 → 4 → 5 → 6
The ITRS and Organized Innovation

International Participant Networks

U.S. Semiconductor Innovation Network (expanded view)

SIA  SEMI
SRC  Sematech  SISA
U.S. SM&E Industry  Universities
NIST, other Government Agencies
MARCO Focus Centers
DoE Labs

Technology Working Groups

Modeling & Simulation  Test  Factory Integration  Design
Environment, Safety & Health  Assembly & Packaging  Process Integration, Devices & Structures
Lithography  Front End Processes  Metrology  Interconnect

Future
2003 ITRS TWG Demographics
936 Global Participants

TWG Members by Region

USA 395 (42%)
Europe 108 (12%)
Japan 205 (22%)
Korea 32 (3%)
Taiwan 196 (21%)

TWG Members by Affiliation

Chipmakers 549 (59%)
Consortia, Research Institutes, Universities 183 (20%)
Equipment/Materials Suppliers 181 (19%)
Others 23 (2%)
Changing Roadmap Participation Mix

Roadmap Participation Mix
Industry, Consortia & University, Government
ITRS Future Challenges

– Overcoming “red brick wall”
– Path dependency: how to balance on- and off-roadmap innovation
– Caution of becoming too unwieldy and prescriptive
– “Roadmap” may not be the best metaphor (implies certainty)
– Maintaining voluntary participation
– Increasing cost of roadmapping