EE 330
Fall 2013

Integrated Electronics

Lecture Instructor: Randy Geiger
2133 Coover
rlgeiger@iastate.edu 294-7745

Course Web Site: http://class.ece.iastate.edu/ee330/

Lecture: MWF 12:10 1312 Hoover

Lab:

Sec A	Tues	8:00 - 10:50
Sec B	Tues	11:00 - 1:50
Sec C	Wed	5:10 - 8:00
Sec D	Fri	8:00 - 10:50
Sec E	Thur	8:00 - 10:50
Sec G	Fri	1:10 - 4:00

Labs all meet in Rm 2046 Coover

Labs start this week !

HW Assignment 1 has been posted and is due this Friday

Laboratory Instructors and TAs:

Rui Bai	bairui@iastate.edu
Rebekah Dejmal	redejmal@iastate.edu
Yunxi Guo	yunxig@iastate.edu
Craig Gustafson	craigg@iastate.edu
Shiya Liu	lsy105@iastate.edu

Instructor Access:

- Office Hours
  - Open-door policy
  - MWF 1:00-2:00

    reserved for EE 330 students
  - By appointment
- Email
  - rlgeiger@iastate.edu
  - Include **EE 330** in subject

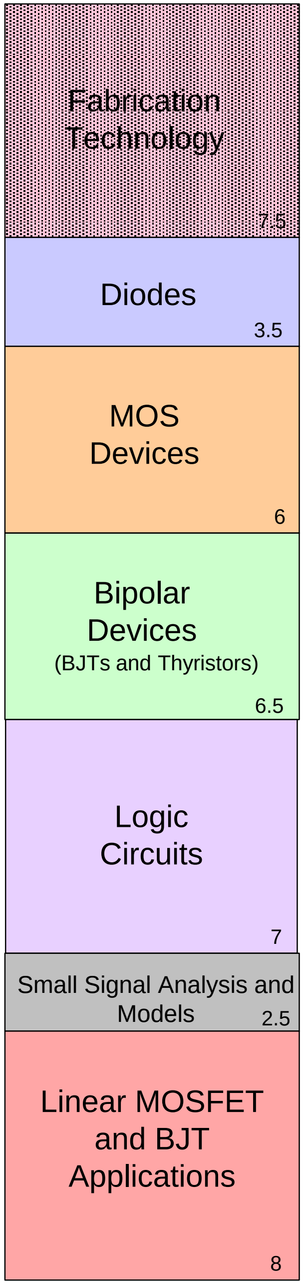
Catalog Description

E E 330. Integrated Electronics. (Same as Cpr E 330.) (3-3) Cr. 4. F.S. *Prereq:* 201, credit or enrollment in 230, Cpr E 210. Semiconductor technology for integrated circuits. Modeling of integrated devices including diodes, BJTs, and MOSFETs. Physical layout. Circuit simulation. Digital building blocks and digital circuit synthesis. Analysis and design of analog building blocks. Laboratory exercises and design projects with CAD tools and standard cells.

Topical Coverage

- Semiconductor Processes
- Device Models (Diode,MOSFET,BJT, Thyristor)
- Layout
- Simulation and Verification
- Basic Digital Building Blocks
- Behavioral Design and Synthesis
  - Standard cells
- Basic Analog Building Blocks

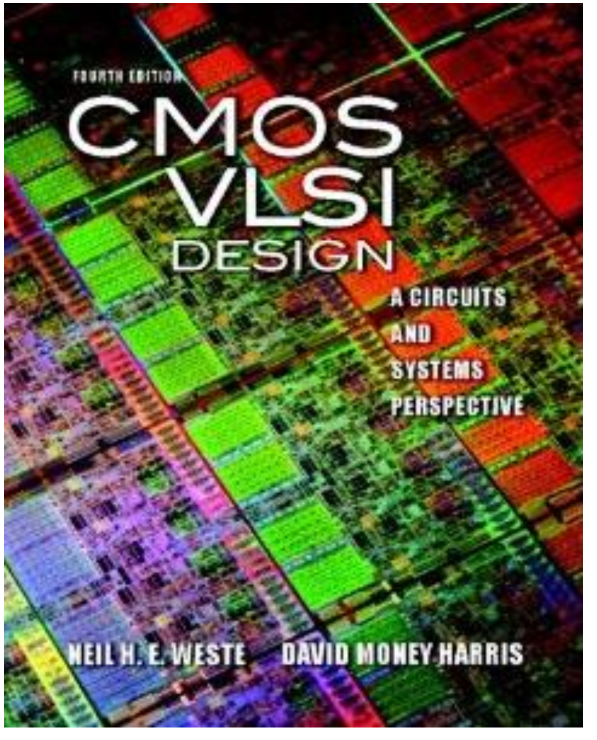
Topical Coverage Weighting



Textbook:

CMOS VLSI Design – A Circuits and Systems Perspective
by Weste and Harris Addison Wesley/Pearson, 2011

- Fourth edition



Extensive course notes will be posted but lecture material will not follow textbook on a section-by-section basis

Grading Policy

3 Exams	100 pts each
1 Final	100 pts.
Homework	100 pts.total
Quizzes/Attendance	100 pts
Lab and Lab Reports	100 pts.total
Design Project	100 pts.

- A letter grade will be assigned based upon the total points accumulated
- Grade breaks will be determined based upon overall performance of the class

Attendance and Equal Access Policy

Participation in all class functions and provisions for special circumstances will be in accord with ISU policy

Attendance of any classes or laboratories, turning in of homework, or taking any exams or quizzes is optional however grades will be assigned in accord with described grading policy. No credit will be given for any components of the course without valid excuse if students choose to not be present or not to contribute. Successful demonstration of ALL laboratory milestones and submission of complete laboratory reports for ALL laboratory experiments to TA by deadline established by laboratory instructor is, however, required to pass this course.

Due Dates and Late Reports

Homework assignments are due at the beginning of the class period on the designated due date. Late homework will be accepted without penalty up until 5:00 p.m. on the designated due date. Homework submitted after 5:00 p.m. will not be graded without a valid written excuse.

Laboratory reports are due at the beginning of the period when the next laboratory experiment is scheduled. Both a hard copy and a pdf file should be submitted. The file name on the pdf file should be of the following format:

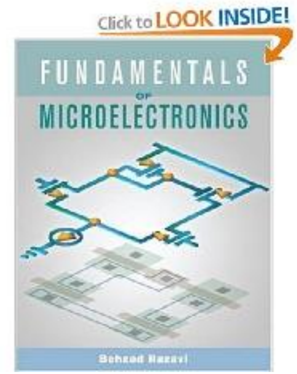
EE330Lab1JonesP.pdf

where the lab number, your last name, and your first initial should be replaced as appropriate. The electronic version should be submitted to your TA and copied to the course instructor rlgeiger@iastate.edu

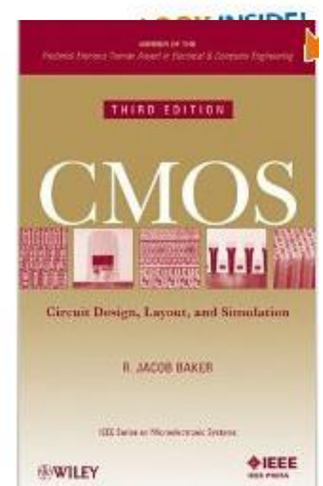
All milestones must be demonstrated to and recorded by the TA prior to turning in the laboratory report. Late laboratory reports will be accepted with a 30% penalty within one week of the original due date unless a valid written excuse is provided to justify a late report submission. Any laboratory reports turned in after the one-week late period will not be graded. The last laboratory report will be due one week after the scheduled completion of the experiment.

Reference Texts:

Fundamentals of Microelectronics
by B. Razavi, Wiley, 2008



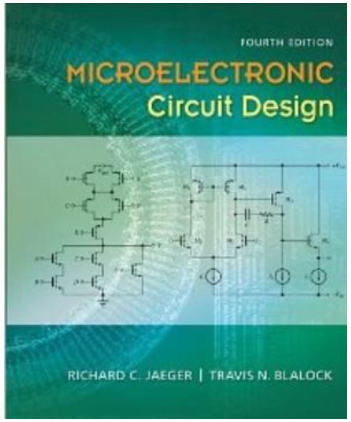
CMOS Circuit Design, Layout, and Simulation (3rd Edition)
by Jacob Baker, Wiley-IEEE Press, 2010.



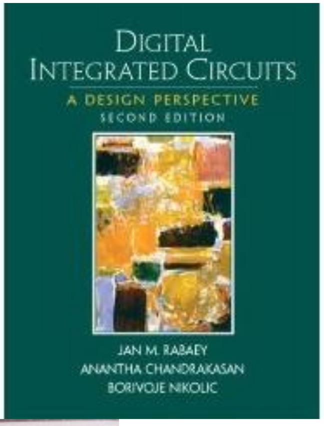
The Art of Analog Layout
by Alan Hastings, Prentice Hall, 2005

Reference Texts:

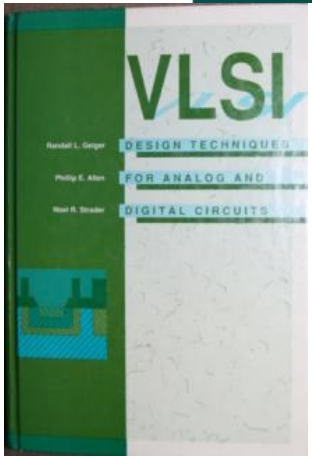
Microelectronic Circuit Design (4th edition)
By Richard Jaeger and Travis Blalock,
McGraw Hill, 2010



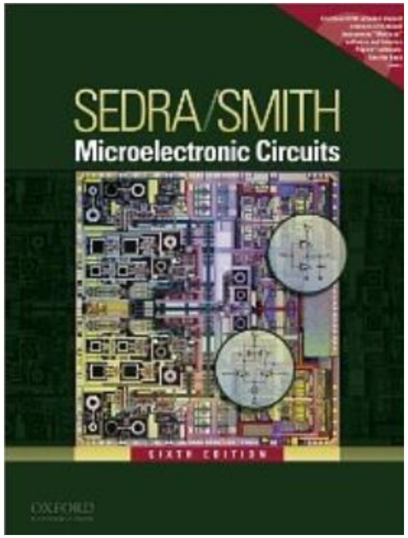
Digital Integrated Circuits (2nd Edition)
by Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, Pre
2002



VLSI Design Techniques for Analog and Digital Circuits
by Geiger, Allen and Strader, McGraw Hill, 1990



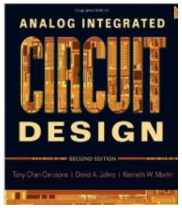
Reference Texts:



Microelectronic Circuits (6th Edition)
by Sedra and Smith, Oxford, 2009

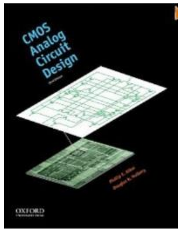
Other useful reference texts in the VLSI field:

Analog Integrated Circuit Design (2nd edition)
by T. Carusone, D. Johns and K. Martin, Wiley, 2011



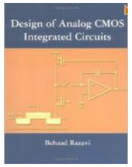
Principles of CMOS VLSI Design
by N. Weste and K. Eshraghian, Addison Wesley, 1992

CMOS Analog Circuit Design (3rd edition)
by Allen and Holberg, Oxford, 2011.

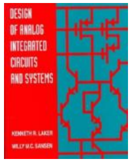


Other useful reference texts in the VLSI field:

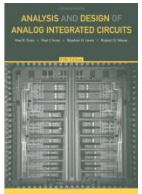
Design of Analog CMOS Integrated Circuits
by B. Razavi, McGraw Hill, 1999



Design of Analog Integrated Circuits
by Laker and Sansen, McGraw Hill, 1994

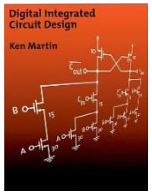


Analysis and Design of Analog Integrated Circuits-Fifth Edition
Gray,Hurst, Lewis and Meyer, Wiley, 2009

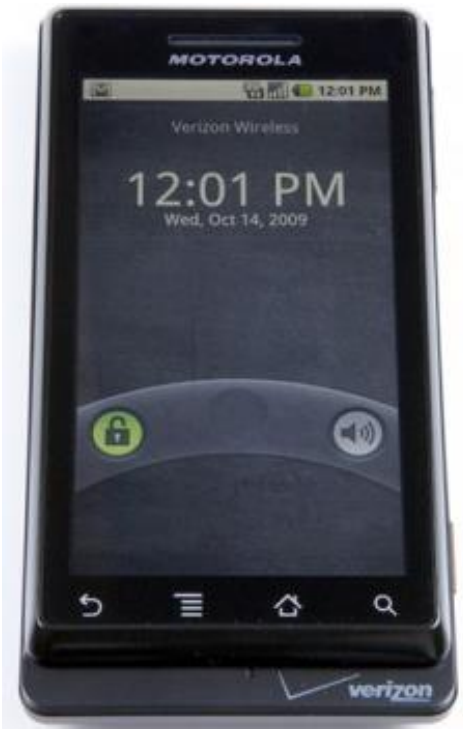


Analog MOS Integrated Circuits for Signal Processing
Gregorian and Temes, Wiley, 1986

Digital Integrated Circuit Design
by Ken Martin, Oxford, 1999.



Untethered Communication Policy



Use them !

Hearing them ring represents business opportunity !

Please step outside of the room to carry on your conversations

The Semiconductor Industry

(just the “chip” part of the business)

How big is it ?

How does it compare to other industries?

How big is the semiconductor industry?

1984	$25B
1990	$50B
1994	$100B
2004	$200B
2010	$304B
2012	$300B
2013	$310B (projected)

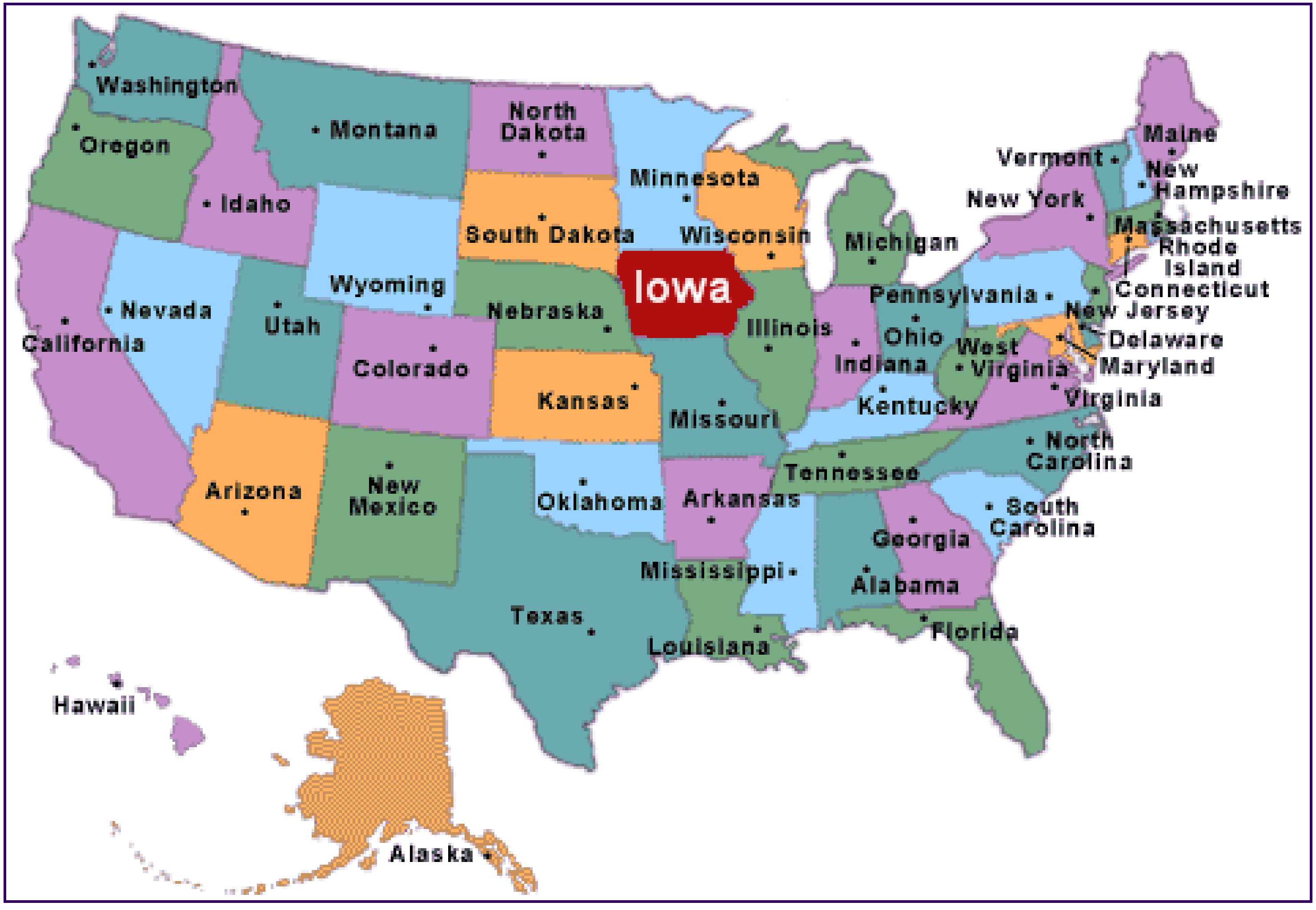
Semiconductor sales do not include the sales of the electronic systems in which they are installed and this marked is much bigger !!

The Semiconductor Industry

How big is it ?

How does it compare to Iowa-Centric Commodoties?

Iowa-Centric Commodities



Iowa-Centric Commodities

In the United States, Iowa ranks:

First in Corn production
First in Soybean production
First in Egg production
First in Hog production
Second in Red Meat production

http://www.iowalifechanging.com/travel/iowafacts/statistics.html

Iowa-Centric Commodities

Corn

Beans

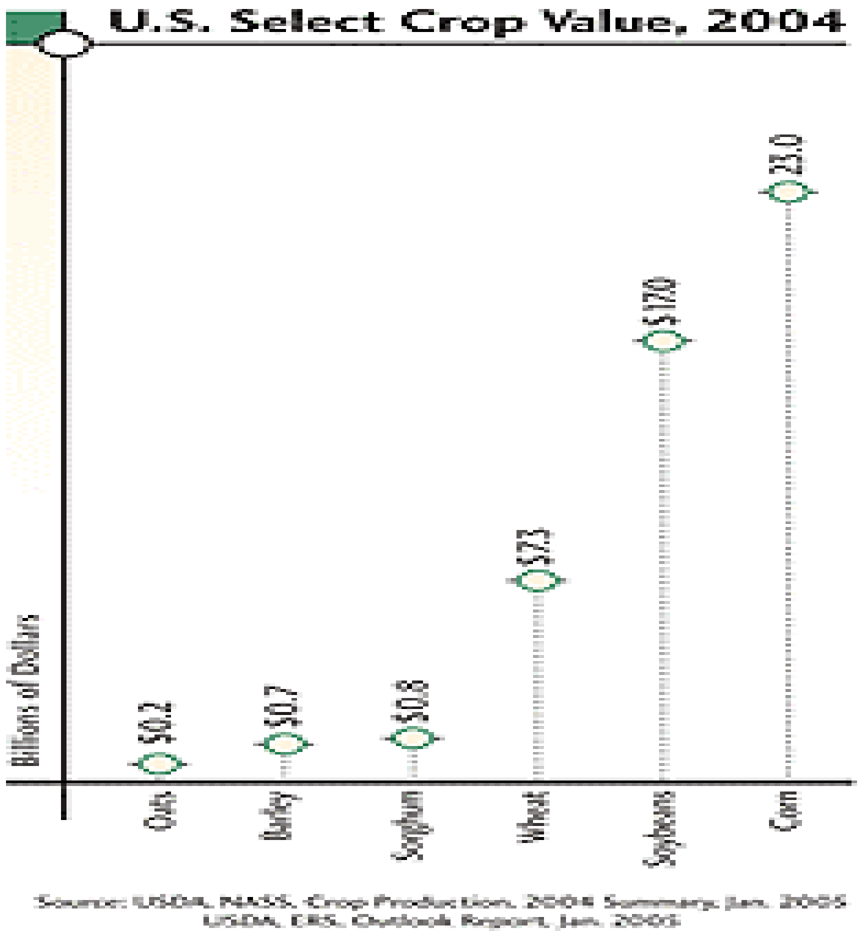
Iowa-Centric Commodities

Corn

Beans

Agricultural Commodities are a Major Part of the Iowa Economy

Value of Agricultural Commodoties



Corn and Beans Dominate the US Agricultural Comodoties

Value of Agricultural Commodities

Corn Production

	Bushels (Billions)
Iowa	**2.2**
United States	**12**
World	**23**

Soybean Production

	Bushels (Billions)
Iowa	**0.34**
United States	**3.1**
World	**8.0**

Based upon Aug 26, 2013 mid-morning market in Boone Iowa

Corn		Soybeans	
O/N13 2013	4.57	O/N13 2013	13.32

Value of Agricultural Commodities

(Based upon commodity prices in Boone Iowa on Aug 26 October futures simplifying assumption: value constant around world)

Corn Production

	Bushels (Billions)	Value (Billion Dollars)
Iowa	**2.2**	**$10.1**
United States	**12**	**$54.8**
World	**23**	**$108**

Soybean Production

	Bushels (Millions)	Value (Billion Dollars)
Iowa	**340**	**$4.5**
United States	**3,100**	**$41.3**
World	**8,000**	**$106**

World 2013 semiconductor sales of $310B about 45% larger than value of total corn and soybean production today!

Semiconductor sales has averaged about 300% larger than value of total corn and soybean production for much of past two decades!

The Semiconductor Industry

How big is it ?

About $310B/Year and growing

How does it compare to Iowa-Centric Commodities?

Larger than major agricultural commodities (1.5X to 3X)

The semiconductor industry is one of the largest sectors in the world economy and continues to grow

How is the semiconductor industry distributed around the world?

Rank 2011	Rank 2012	Vendor	2011 Revenue	2012 Revenue	2011-2012 Growth (%)	2012 Market Share (%)
1	1	Intel	50,669	49,089	-3.1	16.4
2	2	Samsung Electronics	27,764	28,622	3.1	9.5
6	3	Qualcomm	9,998	13,177	31.8	4.4
4	4	Texas Instruments	11,754	11,111	-5.5	3.7
3	5	Toshiba	11,769	10,610	-9.8	3.5
5	6	Renesas Electronics	10,650	9,152	-14.1	3.1
8	7	SK Hynix	9,388	8,965	-4.5	3.0
7	8	STMicroelectronics	9,635	8,415	-12.7	2.8
10	9	Broadcom	7,160	7,846	9.6	2.6
9	10	Micron Technology	7,643	6,917	-9.5	2.3
		Others	151,343	146,008	-3.5	48.7
		Total Market	**307,773**	**299,912**	**-2.6**	**100.0**

From: http://www.gartner.com/newsroom/id/240521

Applications of Electronic Devices

- Communication systems
- Computation systems
- Instrumentation and control
- Signal processing
- Biomedical devices
- Automotive
- Entertainment
- Military
- Many-many more

Applications often incorporate several classical application areas

Large number (billions) of devices (transistors) in many applications

Electronic circuit designers must understand system operation to provide useful electronic solutions

e2af.com/trend/071210.shtml

Automotive industry seeking electronic solutions to four main issues

Part.1

Electronics to account for 40% of automotive production costs by 2015

The proportion of electronic components used in motor vehicles has been increasing steeply in recent years. In fact, many industry observers expect electronic components to account for 40% of total car production costs in the near future. Automakers are already relying more heavily on electronics technology, with electronic components making up 10-15% of the total production cost of a 2007-model compact car such as the Toyota Corolla, for 20-30% of the cost of luxury models like Lexus-brand cars, and for around 50% in the case of hybrid electric vehicles (HEVs) such as the Toyota Prius.

Electronic components currently comprise some 20-30% of total costs for all car categories, and this figure is expected to reach 40% or so by 2015. Roughly speaking, materials and components represent 70% of total car production costs, while labor costs account for 15% and miscellaneous expenses for the remaining 15%. If present trends continue, by 2015 electronic component costs will comprise the majority of materials/components costs.

An example of electronic opportunities

Consider High Definition Television (HDTV)

Video:

Frame size: 1920 x 1080 pixels (one HDTV frame size)

Frame rate: 24 frames/second (one HDTV frame rate)

Pixel Resolution: 8 bits each RGB plus 8 bits alpha (32 bits/pixel) (no HDTV standard)

RAW (uncompressed) video data requirements: (1920*1080)*24*(32) = 1.59 G bits/sec

Audio:

Sample rate: 192 K SPS (44.1 more common)

Resolution: 24 bits (16 bits or less usually adequate)

Number of Channels: 2 (Stereo)

RAW (uncompressed) audio data requirements: 192K*24*2 = 9.2 Mbits/sec

- RAW video data rate approximately 170X the RAW audio data rate
- Are RAW video data rates too large to be practical ??

How much would it cost to download a 2-hour HDTV "movie" using RAW audio and video on a Verizon Smart Phone today?

Verizon Data Plan (after 1.5GB included in monthly fee) $15/GB

RAW (uncompressed) video data requirements: (1920*1080)*24*(32) = 1.59 G bits/sec

RAW (uncompressed) audio data requirements: 192K*24*2 = 9.2 Mbits/sec

Total bits: 1.5992x60x120 Gb = 11,514Gb

Total bytes: 1.5992x60x120/8 GB = 1,439GB

Total cost: $21,589

- Moving audio and video data is still expensive and still challenging !
- Be careful about what you ask for !

What can be done to reduce these costs?

An example of electronic opportunities

Consider High Definition Television (HDTV)

Video:

RAW (uncompressed) video data requirements: (1920*1080)*24*(32) = 1.59 G bits/sec

Audio:

RAW (uncompressed) audio data requirements: 192K*24*2 = 9.2 Mbits/sec

Compressive video coding widely used to reduce data speed and storage requirements

- HDTV video streams used by the broadcast industry are typically between 14MB/sec and 19MB/sec (a compressive coding of about 14:1)
- But even with compression, the amount of data that must be processed and stored is very large
- Large electronic circuits required to gather, process, record, transmit, and receive data for HDTV

How much would it cost to download a 2-hour HDTV “movie” using compressed audio and video on a Verizon Smart Phone today? Assume total signal compressed to 14MB/sec

Verizon Data Plan (after 1.5GB included in monthly fee) $15/GB

Total bytes: 14MBx60x120 GB = 101GB

Total cost: $1,515

Moving audio and video data is still expensive and still challenging !

Selected Semiconductor Trends

- Microprocessors
- DRAMS
- FPGA

Microprocessors

Main article: microprocessor chronology

Processor	Transistor count	Date of introduction	Manufacturer	Process	Area
Intel 4004	2,300	1971	Intel	10 µm	12 mm²
Intel 8008	3,500	1972	Intel	10 µm	14 mm²
MOS Technology 6502	3,510	1975	MOS Technology		21 mm²
Motorola 6800	4,100	1974	Motorola		16 mm²
Intel 8080	4,500	1974	Intel	6 µm	20 mm²
RCA 1802	5,000	1974	RCA	5 µm	27 mm²
Intel 8085	6,500	1976	Intel	3 µm	20 mm²
Zilog Z80	8,500	1976	Zilog	4 µm	18 mm²
Motorola 6809	9,000	1978	Motorola	5 µm	21 mm²
Intel 8086	29,000	1978	Intel	3 µm	33 mm²
Intel 8088	29,000	1979	Intel	3 µm	33 mm²
Intel 80186	55,000	1982	Intel		
Motorola 68000	68,000	1979	Motorola	4 µm	44 mm²
Intel 80286	134,000	1982	Intel	1.5 µm	
Intel 80386	275,000	1985	Intel	1.5 µm	104 mm²
Intel 80486	1,180,000	1989	Intel	1 µm	
Pentium	3,100,000	1993	Intel	0.8 µm	
AMD K5	4,300,000	1996	AMD	0.5 µm	
Pentium II	7,500,000	1997	Intel	0.35 µm	
AMD K6	8,800,000	1997	AMD	0.35 µm	
Pentium III	9,500,000	1999	Intel	0.25 µm	

W http://en.wikipedia.org/wiki/Transistor_count

Processor	Transistor count	Date of introduction	Manufacturer	Process	Area
Pentium 4	42,000,000	2000	Intel	180 nm	
Atom	47,000,000	2008	Intel	45 nm	
Barton	54,300,000	2003	AMD	130 nm	
AMD K8	105,900,000	2003	AMD	130 nm	
Itanium 2	220,000,000	2003	Intel	130 nm	
Cell	241,000,000	2006	Sony/IBM/Toshiba	90 nm	
Core 2 Duo	291,000,000	2006	Intel	65 nm	
AMD K10	463,000,000[1]	2007	AMD	65 nm	
AMD K10	758,000,000[1]	2008	AMD	45 nm	
Itanium 2 with 9MB cache	592,000,000	2004	Intel	130 nm	
Core i7 (Quad)	731,000,000	2008	Intel	45 nm	263 mm²
POWER6	789,000,000	2007	IBM	65 nm	341 mm²
Six-Core Opteron 2400	904,000,000	2009	AMD	45 nm	
Six-Core Core i7	1,170,000,000	2010	Intel	32 nm	
POWER7	1,200,000,000	2010	IBM	45 nm	567 mm²
z196[2]	1,400,000,000	2010	IBM	45 nm	512 mm²
Dual-Core Itanium 2	1,700,000,000[3]	2006	Intel	90 nm	596 mm²
Six-Core Xeon 7400	1,900,000,000	2008	Intel	45 nm	
Quad-Core Itanium Tukwila	2,000,000,000[4]	2010	Intel	65 nm	
8-Core Xeon Nehalem-EX	2,300,000,000[5]	2010	Intel	45 nm	

W http://en.wikipedia.org/wiki/Transistor_count

GPUs

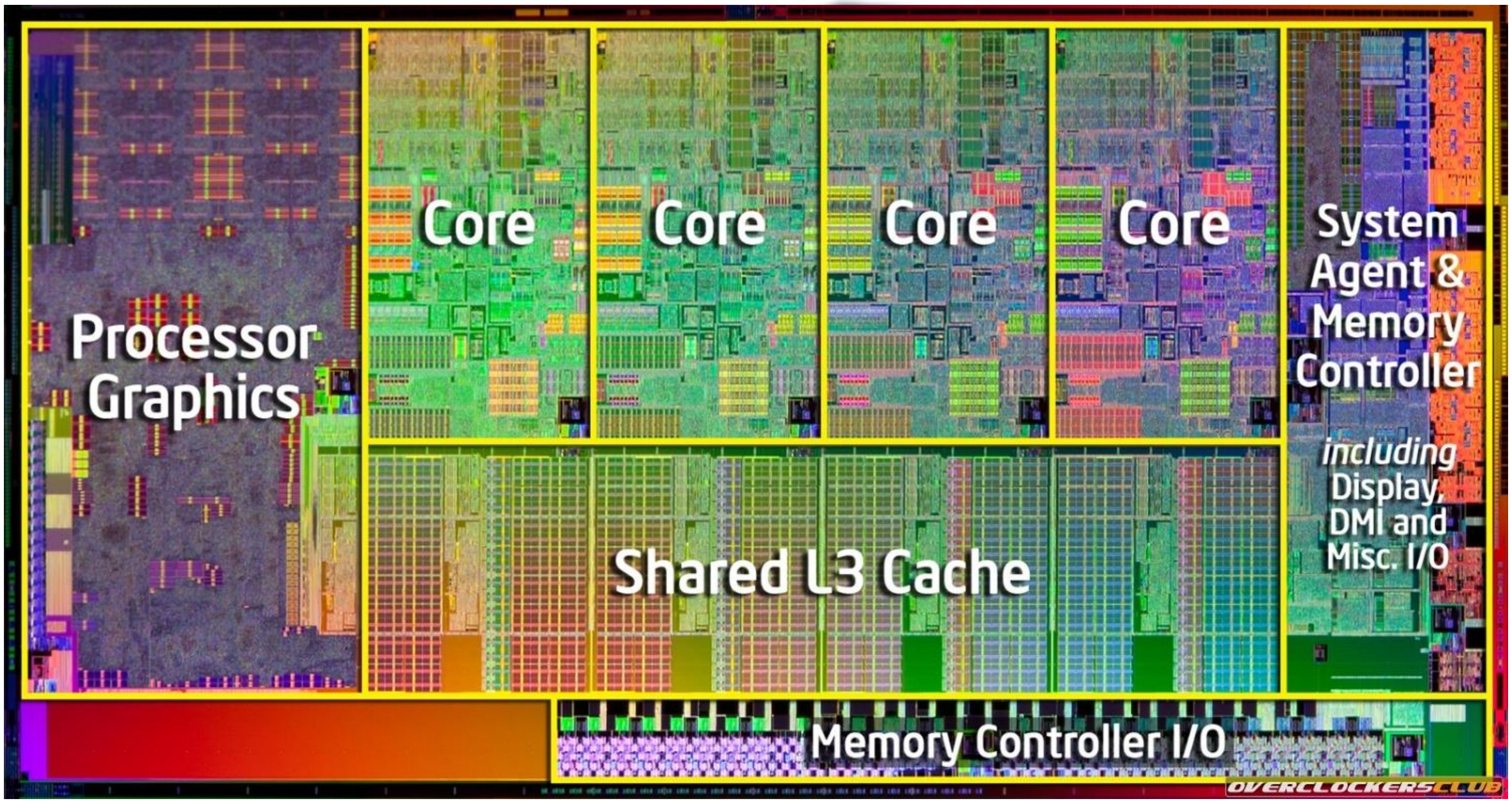
Processor	Transistor count	Date of introduction	Manufacturer	Process	Area
G80	681,000,000	2006	NVIDIA	90 nm	480 mm²
RV770	956,000,000[6]	2008	AMD	55 nm	260 mm²
RV850	1,040,000,000[7]	2009	AMD	40 nm	170 mm²
GT200	1,400,000,000[8]	2008	NVIDIA	55 nm	576 mm²
RV870	2,154,000,000[9]	2009	AMD	40 nm	334 mm²
GF100	3,000,000,000[10]	2010	NVIDIA	40 nm	529 mm²

FPGA

FPGA	Transistor count	Date of introduction	Manufacturer	Process	Area
Virtex	~70,000,000	1997	Xilinx		
Virtex-E	~200,000,000	1998	Xilinx		
Virtex-II	~350,000,000	2000	Xilinx	130 nm	
Virtex-II PRO	~430,000,000	2002	Xilinx		
Virtex-4	1,000,000,000	2004	Xilinx	90 nm	
Virtex-5	1,100,000,000[11]	2006	Xilinx	65 nm	
Stratix IV	2,500,000,000[12]	2008	Altera	40 nm	

W http://en.wikipedia.org/wiki/Transistor_count

Today !



Processor

Quad-Core Intel® Core i7 Processor Up to 3.4GHz in 32nm CMOS

Power Dissipation: 95 watts

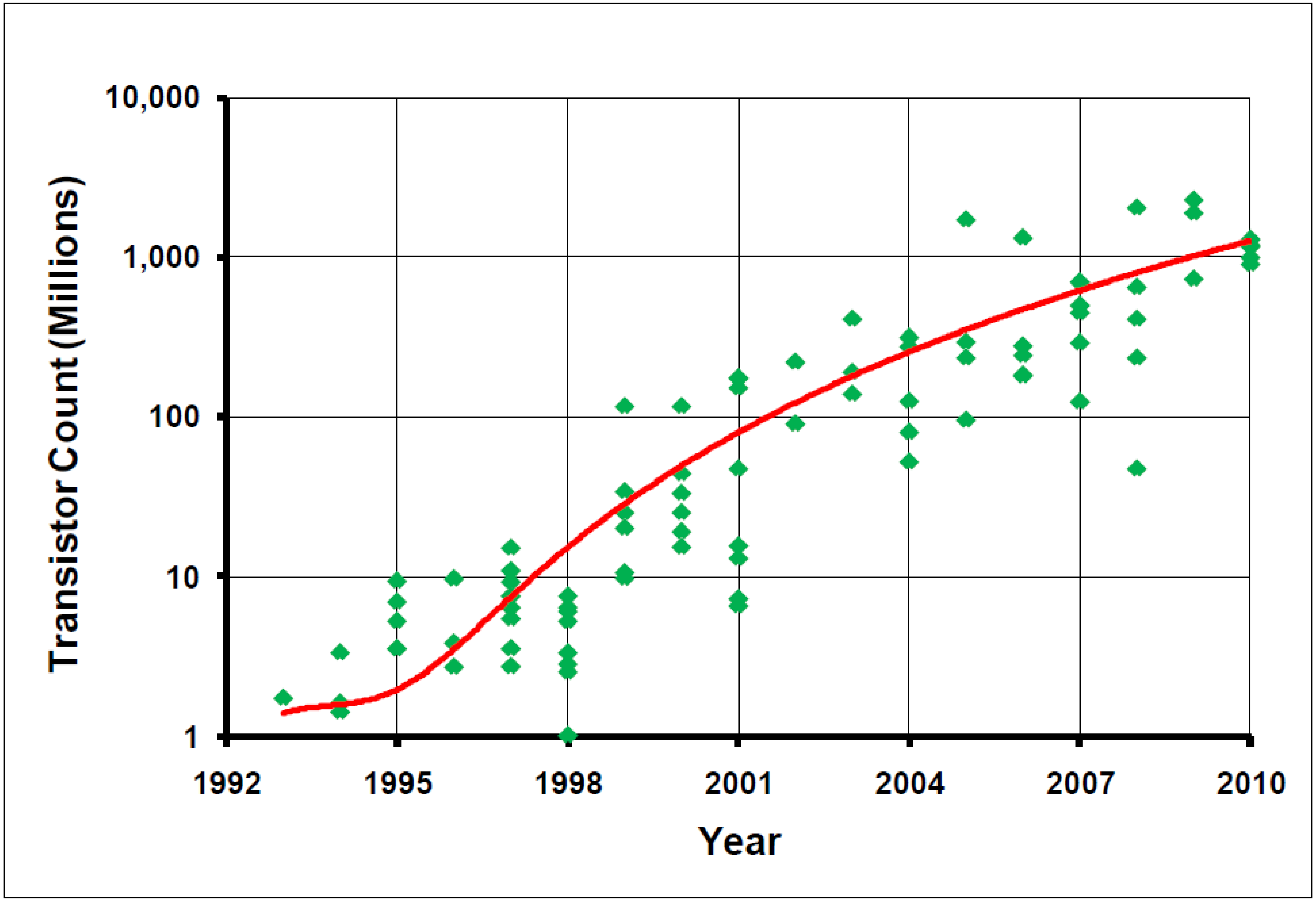


Figure 1. Microprocessor complexity (transistor count) over time

From ISSCC 2010 Summary

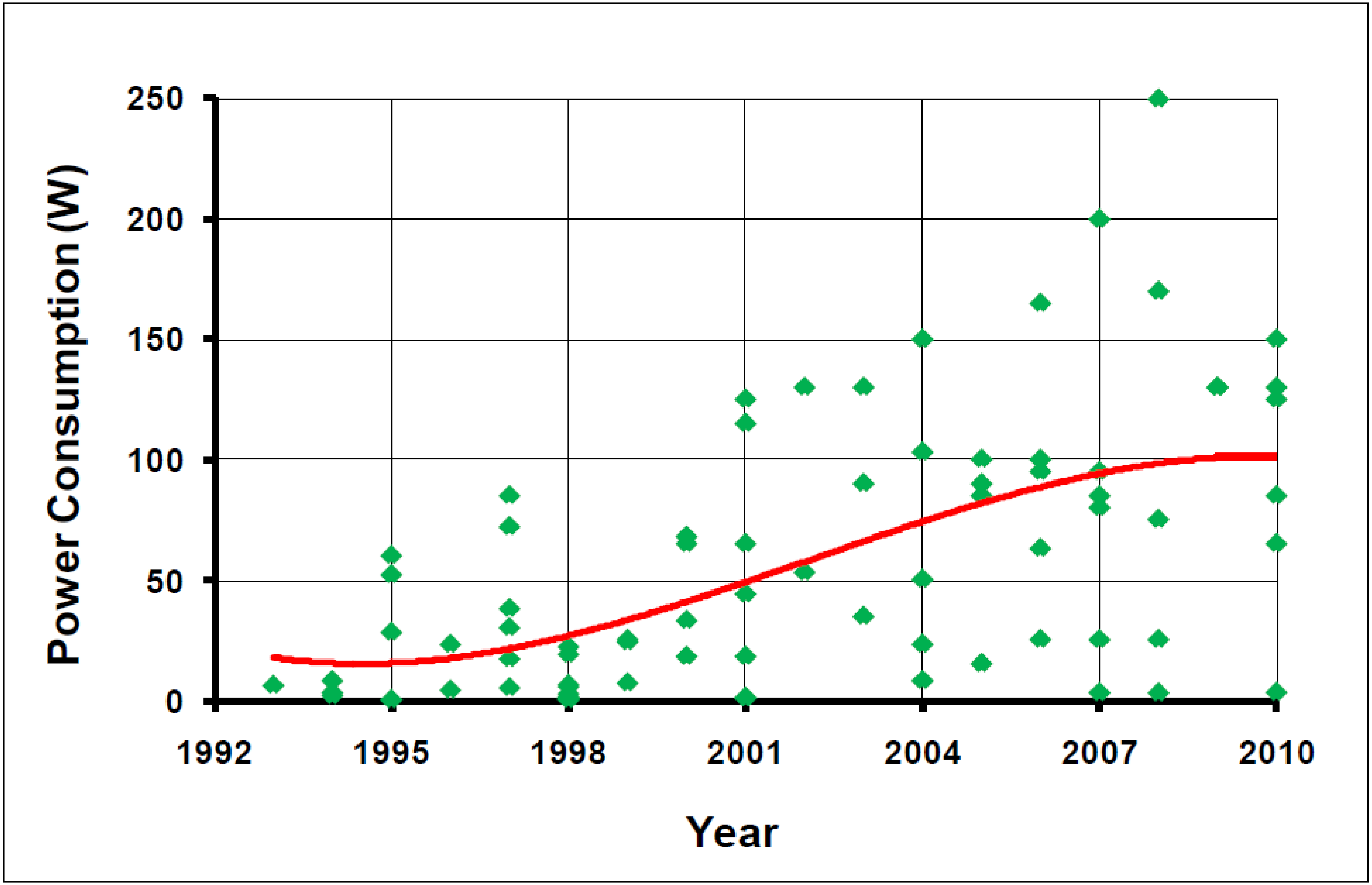


Figure 2. Microprocessor power consumption over time

From ISSCC 2010 Summary

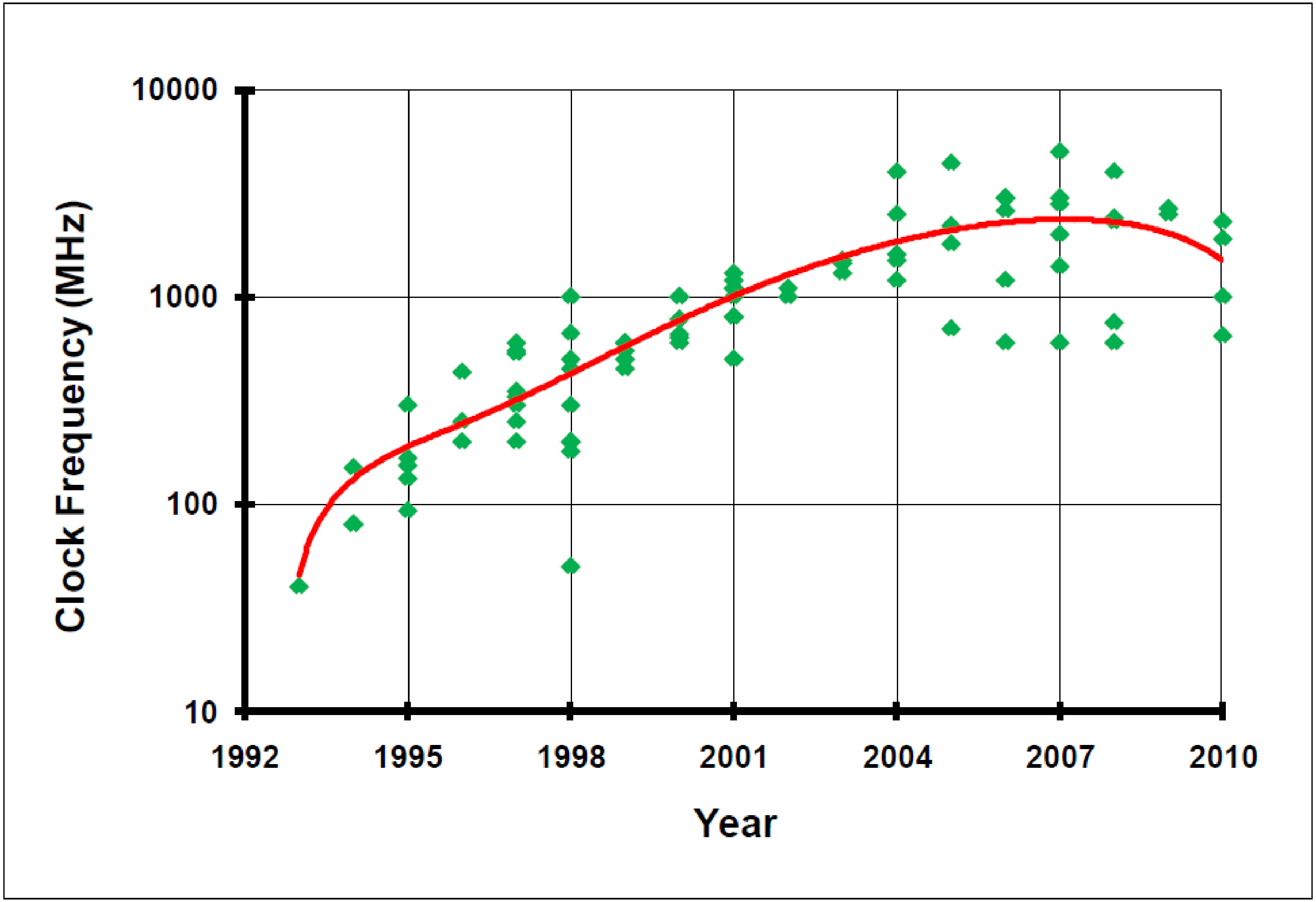


Figure 3. Microprocessor clock frequency over time

From ISSCC 2010 Summary

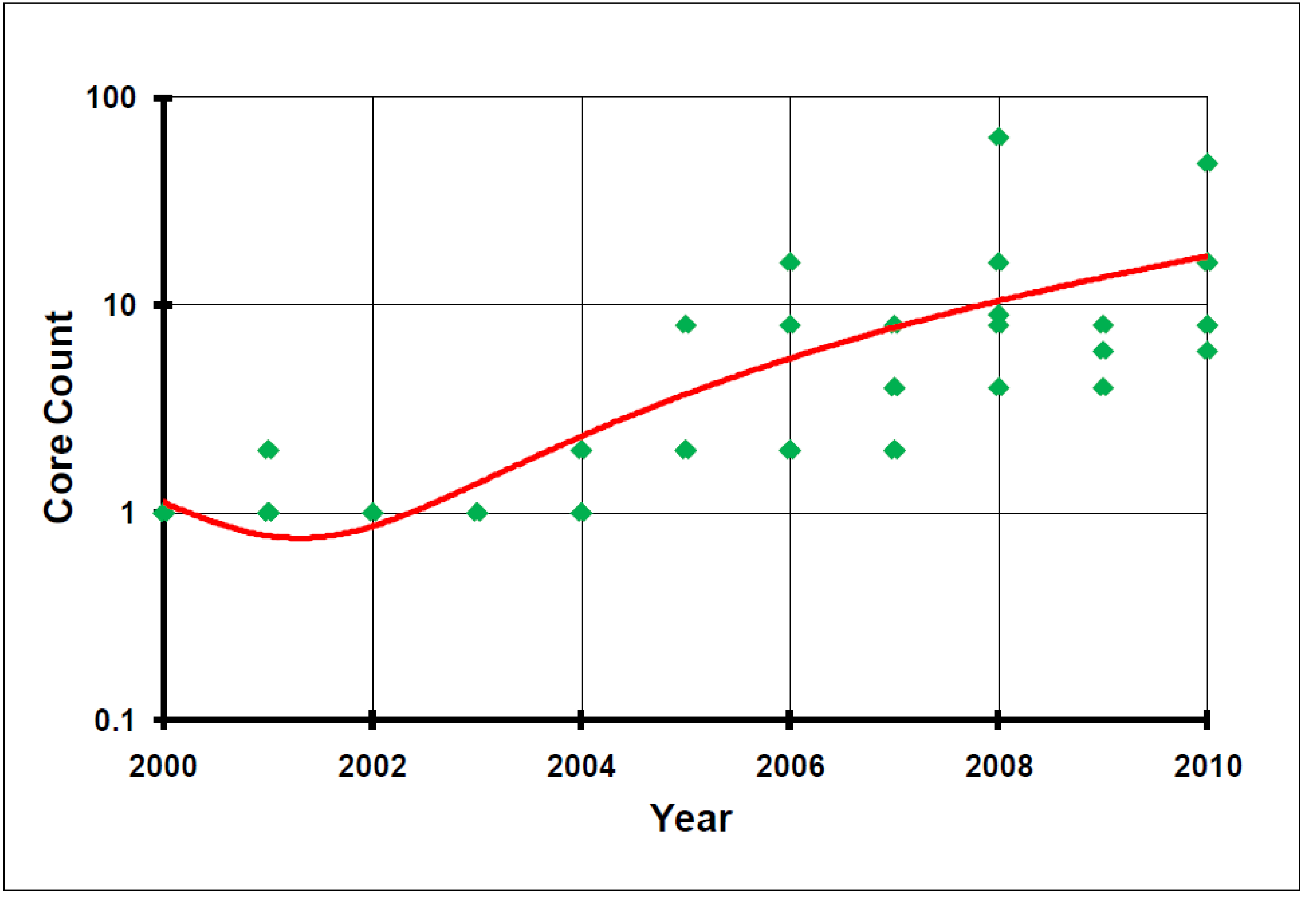


Figure 4. Microprocessor core count over time

Memory Trends

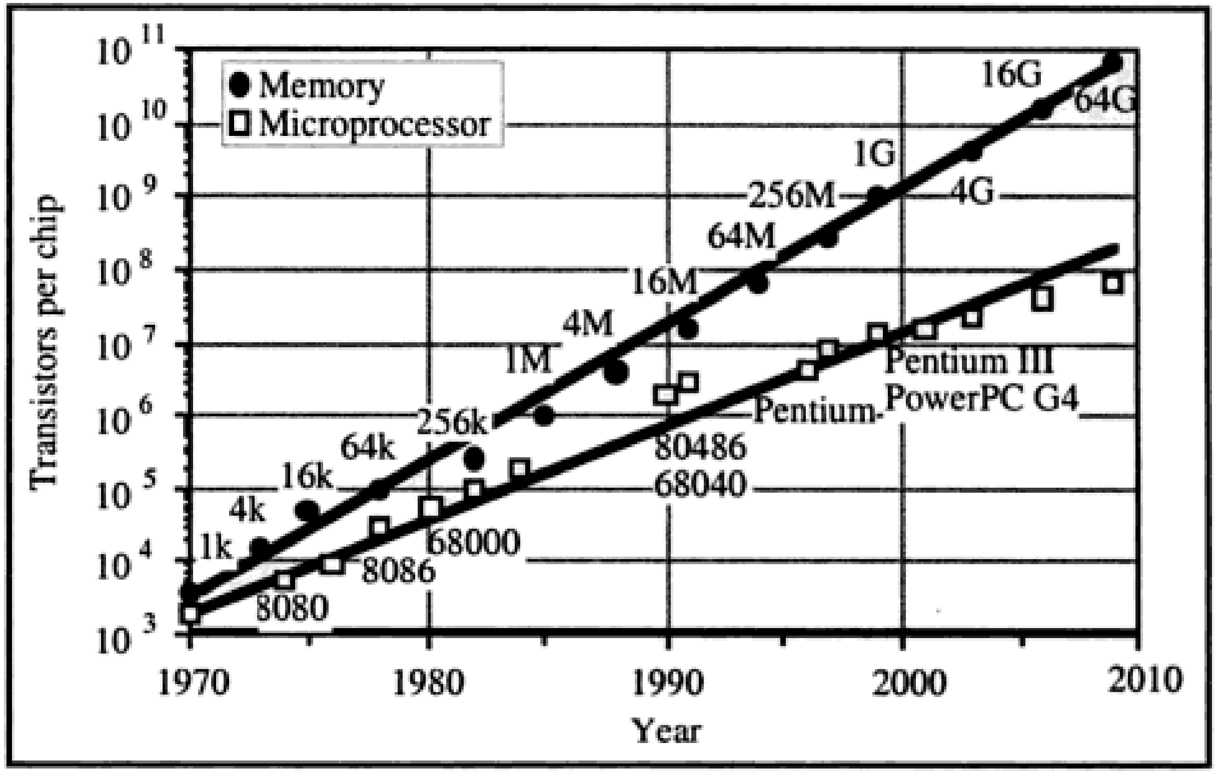


Figure 7.1: Actual and predicted evolution of circuit complexity in DRAMs and microprocessors.

Physics of semiconductor devices By Jean-Pierre Colinge, Cynthia A. Colinge

Memory Trends

Micron

Products | Innovations | How to Buy | Support | About Micron

Home ‣ Products ‣ DRAM ‣ DDR3 SDRAM ‣ DDR3 SDRAM Parts Catalog

Part Catalog

DDR3 SDRAM Part Catalog

Part Catalog Tips

- **Filter by Attribute Values:** Select appropriate attribute values from the column drop down ( ) ar
- **Add or Remove Values:** Select or deselect values from the column drop down ( ) and click "Up
- **Compare Parts:** Select the checkboxes and click "Compare"
- **Reset Values:** Click "Reset" to reset filtered values
- **Export to Spreadsheet:** To download part table to a spreadsheet, select "Export to Spreadsheet"

Update | Reset | Export to Spreadsheet

Part Number	Density	Part Status	RoHS	Depth	Width	Voltage
Compare						
MT41J128M16HA-107G	2Gb	Sampling	Yes	128Mb	x16	1.5V
MT41J128M16HA-125	2Gb	Production	Yes	128Mb	x16	1.5V
MT41J128M16HA-125G	2Gb	Sampling	Yes	128Mb	x16	1.5V
MT41J128M16HA-15E	2Gb	Production	Yes	128Mb	x16	1.5V
MT41J128M8JP-107E	1Gb	EOL Pending	Yes	128Mb	x8	1.5V
MT41J128M8JP-125	1Gb	Production	Yes	128Mb	x8	1.5V
MT41J128M8JP-15E	1Gb	Production	Yes	128Mb	x8	1.5V
MT41J128M8JP-15E IT	1Gb	Production	Yes	128Mb	x8	1.5V
MT41J1G4THD-15E	4Gb	Production	Yes	1Gb	x4	1.5V

Memory Trends

SAMSUNG Products Support About Us

MEMORY > Computing DRAM > DDR3 > Component

- Component »
- Registered DIMM »
- Unbuffered DIMM »

Partnumber	Density	Organization	Voltage(V)	Speed
K4B4G0446A	4G bit	1Gx4	1.5,1.35	F8,H9,K0
K4B4G0846A	4G bit	512Mx8	1.5,1.35	F8,H9,K0
K4B2G0446D	2G bit	512Mx4	1.5,1.35	F8,H9,K0,MA
K4B2G0846D	2G bit	256Mx8	1.5,1.35	F8,H9,K0,MA
K4B2G0446C	2G bit	512Mx4	1.5,1.35	F8,H9,K0
K4B2G0846C	2G bit	256Mx8	1.5,1.35	F8,H9,K0
K4B2G0446B	2G bit	512Mx4	1.5	F8,H9,K0
K4B2G0846B	2G bit	256Mx8	1.5	F8,H9,K0

NAND Flash Memory: Significant developments in NAND flash memory over the past few years, resulting in high-density, low-power, and low-cost storage solutions that are enabling the replacement of traditional hard-disk storage with solid-state disks (SSDs). **Figure 5** shows the observed trend in NAND flash capacities presented at ISSCC in the past 12 years. Note that in 2010, the reduction in process feature sizes, coupled with advanced multi-level cell (MLC) techniques have yielded a 32Gb/chip capacity in a 32nm technology with 2b/cell operation. .

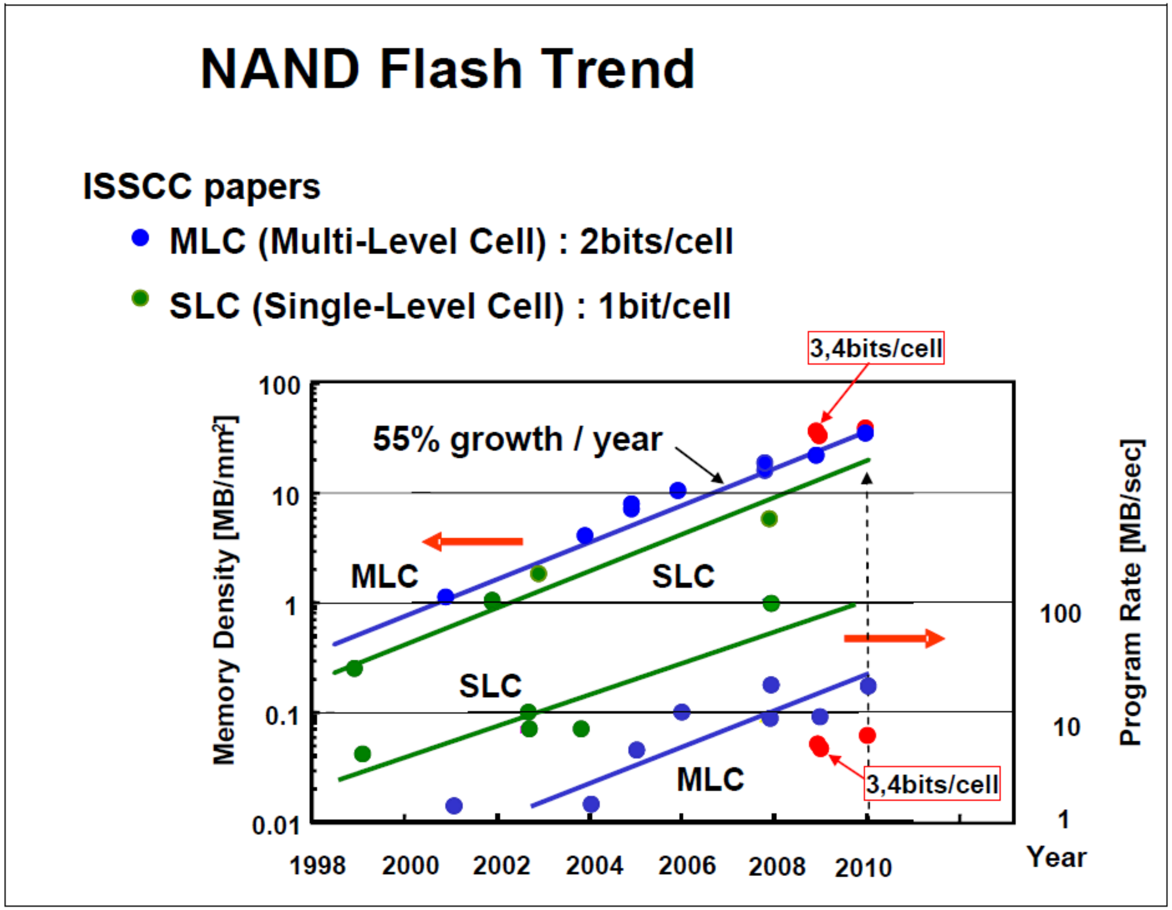


Figure 5. NAND Flash Memory Trends

From ISSCC 2010 Summary

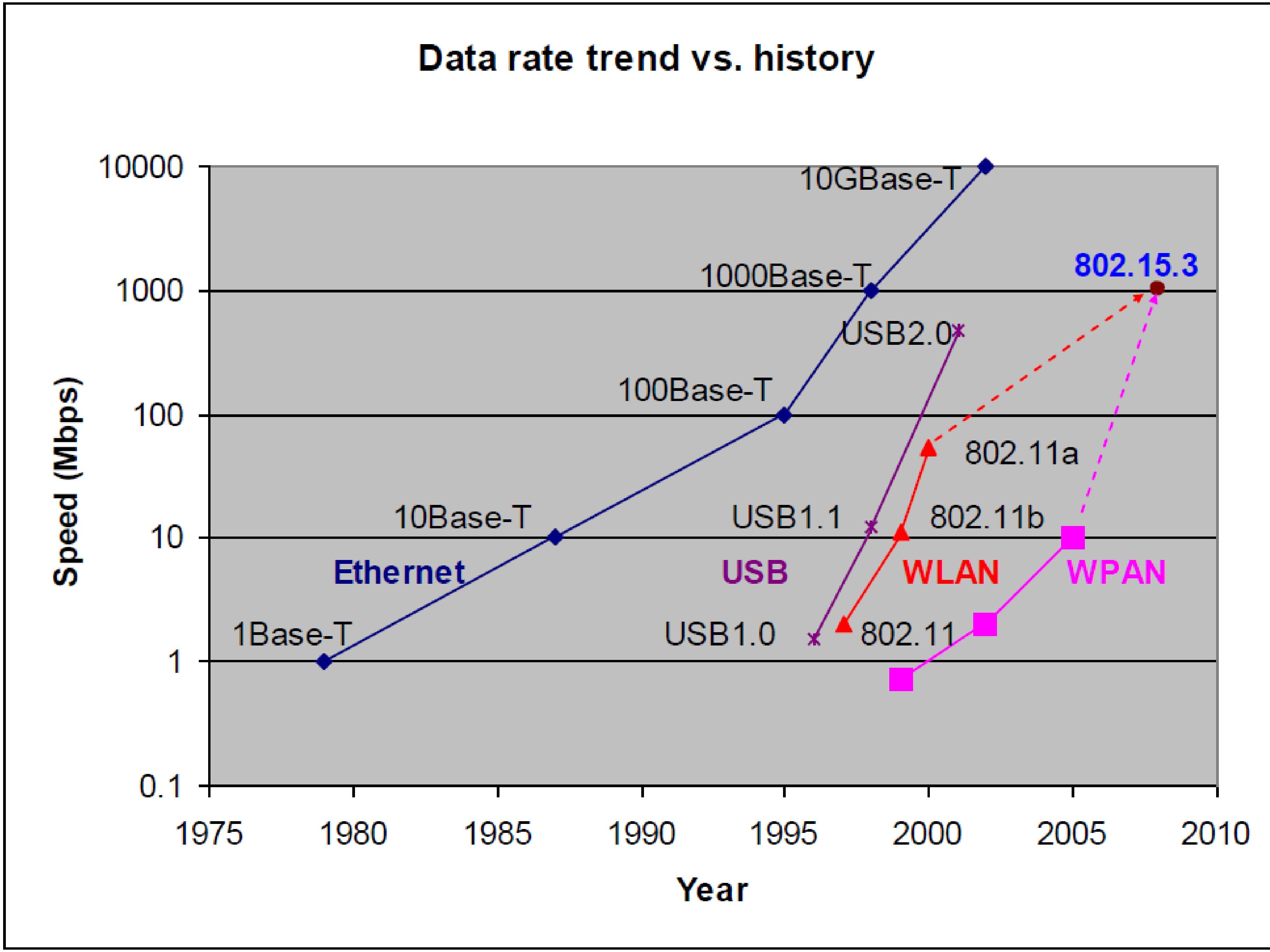


Figure 8. Data Rate Trend Chart

From ISSCC 2010 Summary

Selected Semiconductor Trends

- Microprocessors
  - State of the art technology is now 22nm with over 5 Billion transistors on a chip
- DRAMS
  - State of the art is now 4G bits on a chip which requires somewhere around 4.5 Billion transistors
- FPGA
  - FPGAs currently have over 7 Billion transistors and are growing larger

Device count on a chip has been increasing rapidly with time, device size has been decreasing rapidly with time and speed/performance has been rapidly increasing

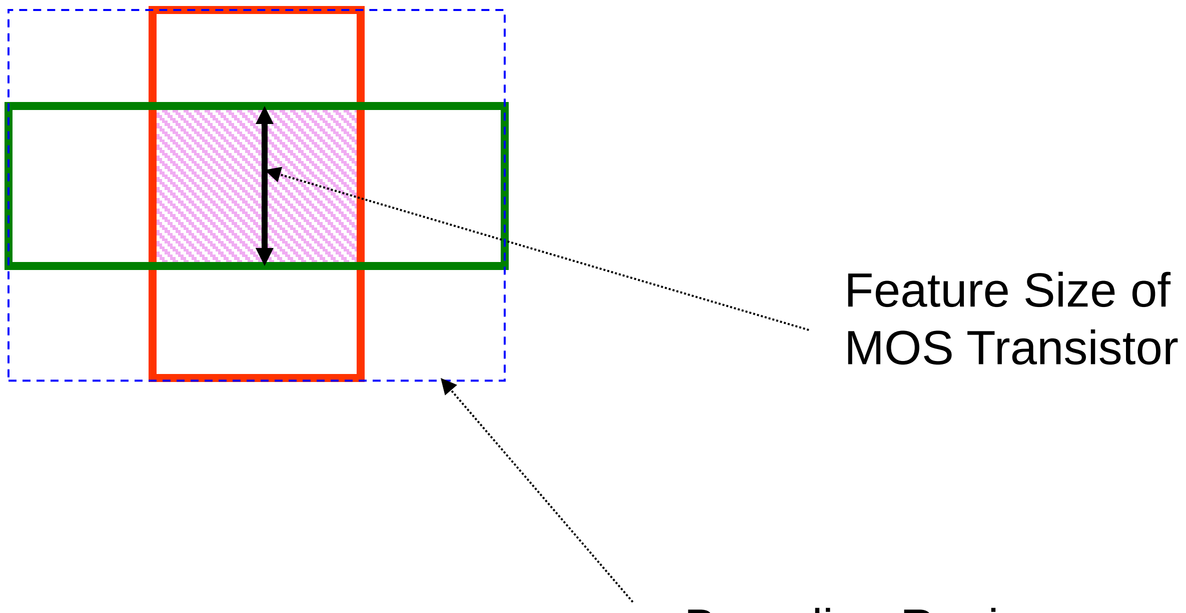
Moore’s Law

From Webopedia

The observation made in 1965 by Gordon Moore, co-founder of Intel, that the number of transistors per square inch on integrated circuits had doubled every year since the integrated circuit was invented. Moore predicted that this trend would continue for the foreseeable future. In subsequent years, the pace slowed down a bit, but data **density has doubled approximately every 18 months, and this is the current definition of Moore's Law, which Moore himself has blessed. Most experts, including Moore himself, expect Moore's Law to hold for at least another two decades.**

Feature Size

The feature size of a process generally corresponds to the minimum lateral dimensions of the transistors that can be fabricated in the process



Bounding region often a factor of 10 or more larger
Than area of transistor itself

Moore's Law

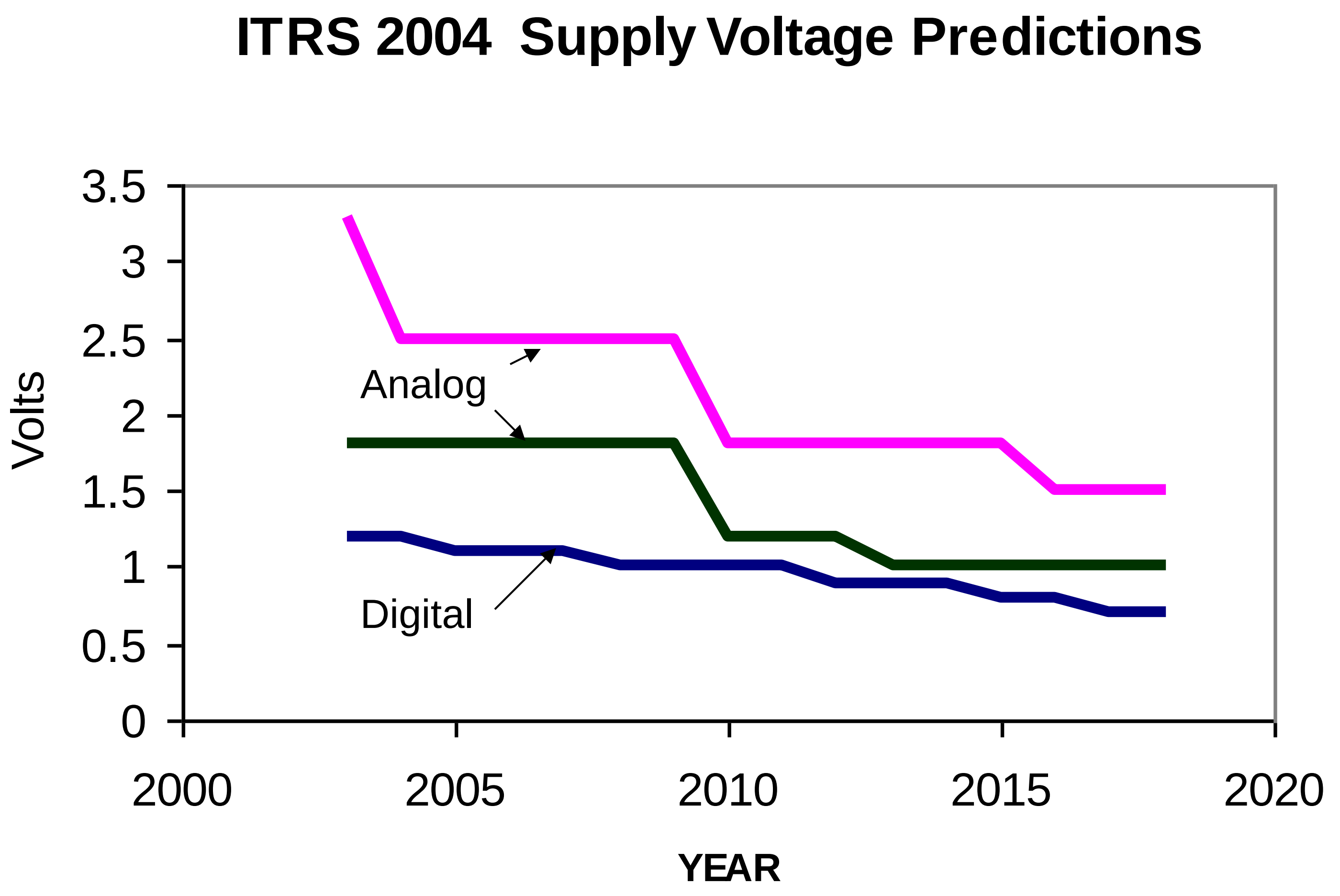
(from Wikipedia)

Moore's law is the empirical observation that the complexity of integrated circuits, with respect to minimum component cost, doubles every 24 months[1]. It is attributed to Gordon E. Moore[2], a co-founder of Intel.

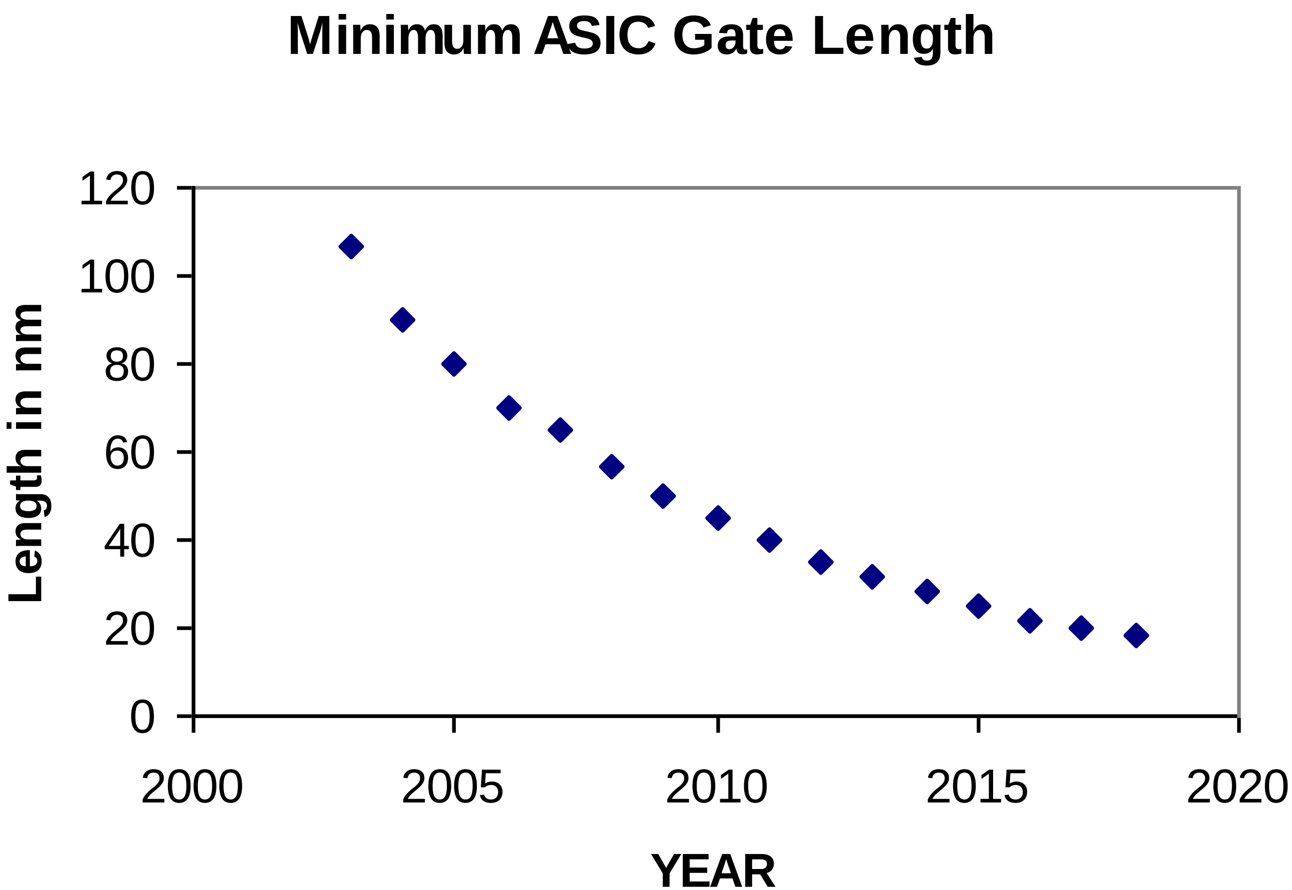
- Often misinterpreted or generalized
- Many say it has been dead for several years
- Many say it will continue for a long while
- Not intended to be a long-term prophecy about trends in the semiconductor field

Device scaling, device count, circuit complexity, … will continue to dramatically improve for the foreseeable future !!

ITRS Technology Predictions



ITRS Technology Predictions



Challenges

- Managing increasing device count
- Short lead time from conception to marketplace
- Process technology advances
- Device Performance Degradation
- Increasing variability
- Increasing pressure for cost reduction
- Power Dissipation

Future Trends and Opportunities

- Is there an end in sight?

No ! But the direction the industry will follow is not yet known and the role semiconductor technology plays on society will increase dramatically!

- Will engineers trained in this field become obsolete at mid-career ?

No ! Engineers trained in this field will naturally evolve to support the microelectronics technology of the future. Integrated Circuit designers are now being trained to efficiently manage enormous levels of complexity and any evolutionary technology will result in even larger and more complexity systems with similar and expanded skills being required by the engineering community with the major changes occurring only in the details.

Future Trends and Opportunities

- Will engineers trained in this field be doing things the same way as they are now at mid-career?

No ! There have been substantive changes in approaches every few years since 1965 and those changes will continue. Continuing education to track evolutionary and revolutionary changes in the field will be essential to remain productive in the field.

- What changes can we expect to see beyond the continued geometric growth in complexity (capability) ?

That will be determined by the creativity and marketing skills of those who become immersed in the technology. New "Gordon Moores", "Bill Gates" and "Jim Dells" will evolve.

Creation of Integrated Circuits

Most integrated circuits are comprised of transistors along with a small number of passive components and maybe a few diodes

This course will focus on understanding how transistors operate and on how they can be interconnected and possibly combined with a small number of passive components to form useful integrated circuits

End of Lecture 1