EE 330
Fall 2019

Integrated Electronics

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

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

Lecture: MWF 12:10 –1:00 1312 Hoover

Lab:	Sec 1	Tues	8:00 - 10:50	TA:
	Sec 2	Tues	11:00 - 1:50	TA:
	Sec 3	Wed	5:10 - 8:00	TA:
	Sec 4	Fri	8:00 - 10:50	TA:
	Sec 5	Thur	8:00 - 10:50	TA:
	Sec 6	Wed	8:00 - 10:50	TA:

Labs all meet in Rm 2046 Coover

Labs start this week !

HW Assignment 1 has been posted and is due this Friday

Final Exam: Thursday Dec 19 12:00 PM

Instructor Access:

- Office Hours
  - Open-door policy
  - MWF 11:00-11:50
  - 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 EE 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.

Electronic Circuits in Industry Today

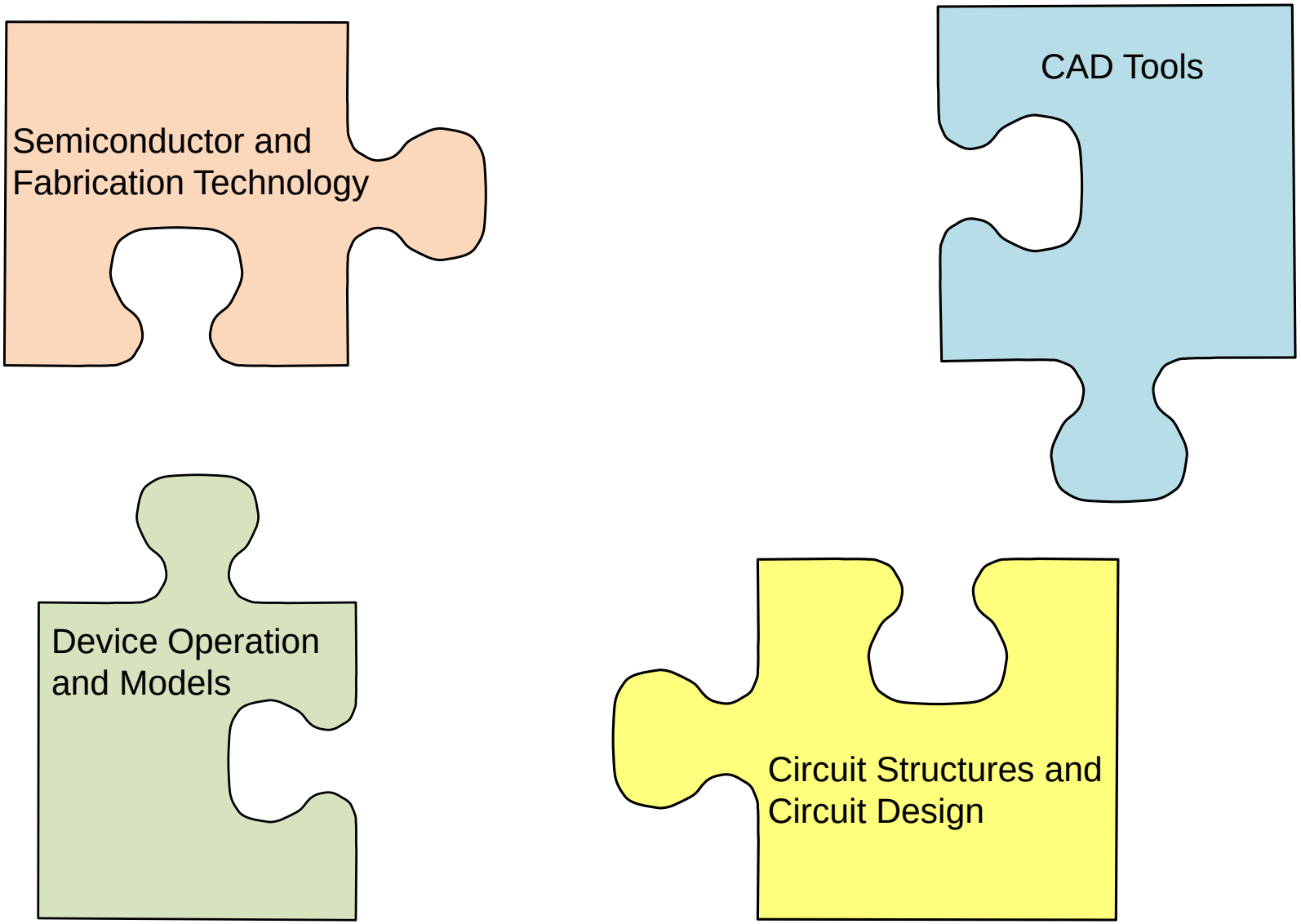
- Almost all electronic circuits are, at the most fundamental level, an interconnection of transistors and some passive components such as resistors, capacitors, and inductors

- For many years, electronic systems involved placing a large number of discrete transistors along with passive components on a printed circuit board
- Today, most electronic systems will not include any discrete transistors but often billions of transistors grouped together into a few clusters called integrated circuits

- In this course, emphasis will be placed on developing an understanding on how transistors operate, on how they can be combined to perform useful functions on an integrated circuit, and on designing basic analog and digital integrated circuits

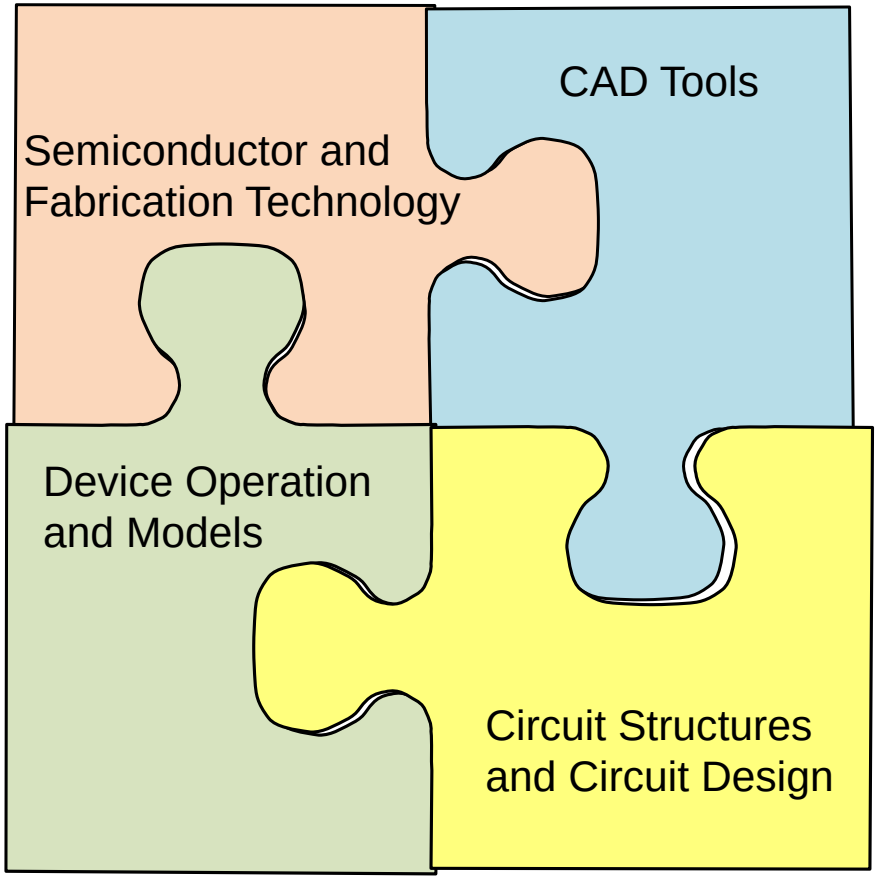
- A basic understanding of semiconductor and fabrication technology and device modeling is necessary to use transistors in the design of useful integrated circuits

How Integrated Electronics will be Approached



How Integrated Electronics will be Approached

After about four weeks, through laboratory experiments and lectures, the concepts should come together

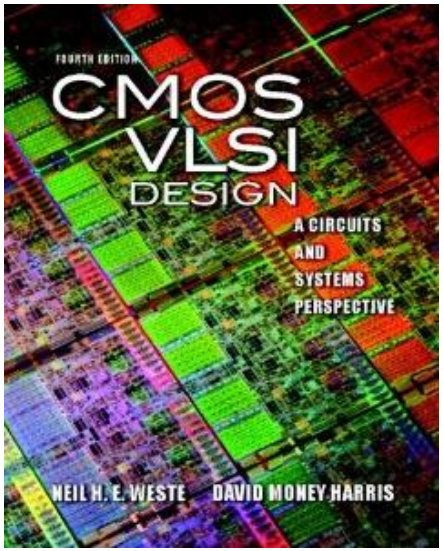


Topical Coverage

- 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

Textbook:

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



- Detailed Course Notes

Extensive course notes (probably over 1800 slides) will be posted

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

Grades from Fall 2016

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

For reference only, grades from Fall 2016, Spring 2017, Fall 2017, and Spring 2018 of students that completed course

	Fall 2016		Spring 2017		Fall 2017		Spring 2018
A	12		8		10		9
A-	4		5		3		8
B+	4		5		7		9
B	5		7		6		4
B-			2		4		
C+	1						
C	3		5		1		4
C-	5				3		
D							2
F			2		1		3

Studying for this course:

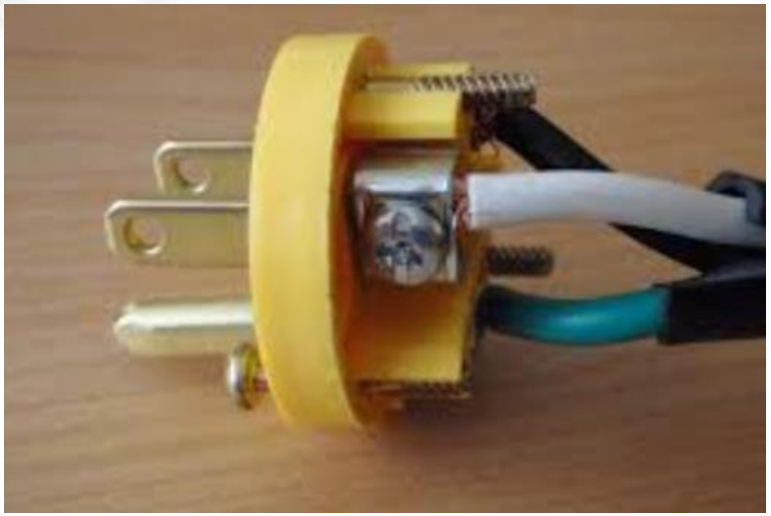
- By focusing on the broad concepts, the details should be rather easy to grasp
- Focusing on the details rather than broad concepts will make this course very difficult
- Read textbook as a support document even when lecture material is not concentrating on specific details in the book
- Although discussing homework problems with others on occasion is not forbidden, time will be best spent solving problems individually
- The value derived from the homework problems is not the grade but rather the learning that the problems are designed to provide

Attendance and Equal Access Policy

Participation in all class functions and provisions for special circumstances including special needs 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 the 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.

Laboratory Safety



Laboratory Safety

- In the laboratory, you will be using electronic equipment that can cause serious harm or injuries, or even death if inappropriately used. However, if used in the appropriate way, the risk of harm is very low. Safety in the laboratory is critical.

- Your TA will go through a laboratory safety procedure and ask you to certify that you have participated in the laboratory safety training.

- Lab Safety guidelines are posted in all of the laboratories

- Be familiar with the appropriate operation of equipment and use equipment only for the intended purpose and in the appropriate way

- Be conscientious and careful with the equipment in the laboratory for your safety and for the safety of others in the laboratory

- Use common-sense as a guide when working in the laboratory

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 unless notified to the contrary in class. 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. Report on the final project will be due at 5:00 p.m. on Friday Dec 13.

Design Project

- Design project will focus on the design of an integrated circuit

- Opportunity will exist to have the integrated circuit fabricated through MOSIS

- Fabricated circuit will not be back from foundry until some time after class is over

- The cost of this fabrication would be many $ thousands if paid for privately

- The final project will be culminated with an oral presentation and a written report

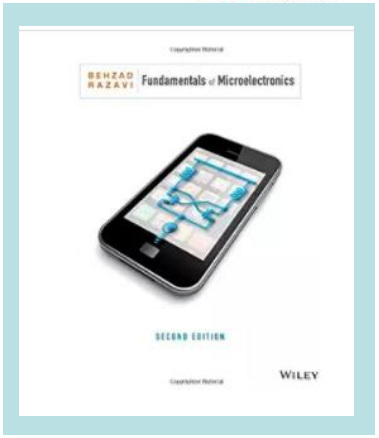
www.mosis.com

From MOSIS WEB site Aug 26, 2019

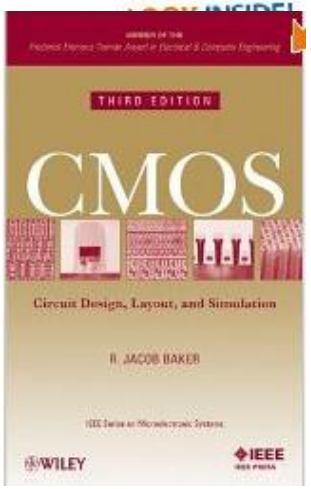
Effective immediately, MOSIS continues to support ON Semi B5 0.5 micron process (formally C5) for VLSI design classes for undergraduate courses under new MOSIS University Support Program. This will be the only free fabrication technology going forward.

Reference Texts:

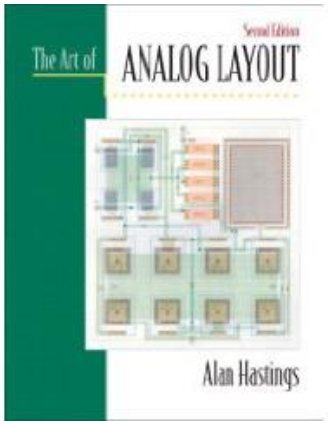
Fundamentals of Microelectronics
by B. Razavi, Wiley, 2013



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

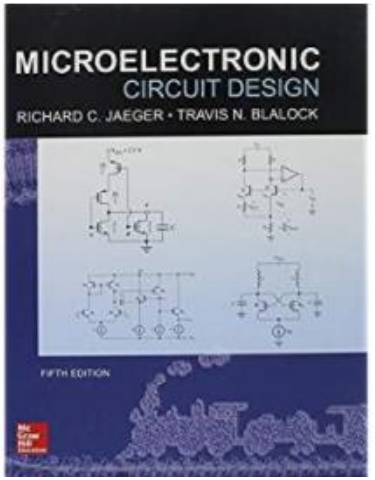


The Art of Analog Layout
by Alan Hastings, Prentice Hall, 2005

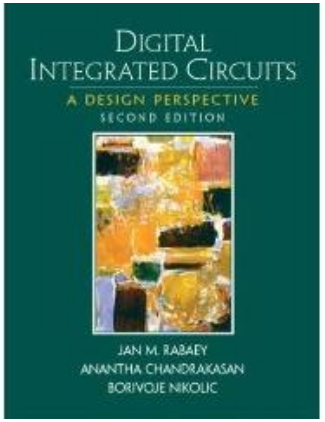


Reference Texts:

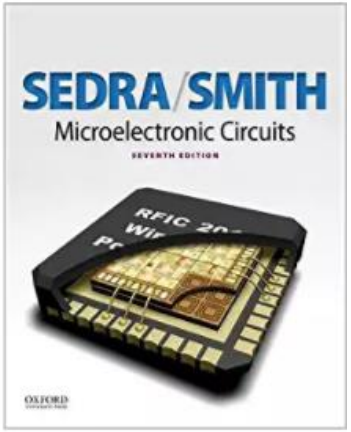
Microelectronic Circuit Design (4th edition)
By Richard Jaeger and Travis Blalock,
McGraw Hill, 2015



Digital Integrated Circuits (2nd Edition)
by Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, Prei
2003

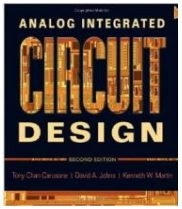


Microelectronic Circuits (7th Edition)
by Sedra and Smith, Oxford, 2014

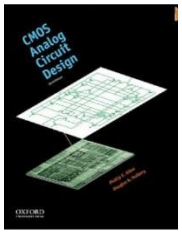


Other useful reference texts in the VLSI field:

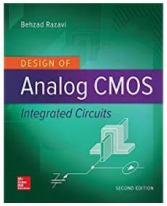
Analog Integrated Circuit Design (2nd edition)
by T. Carusone, D. Johns and K. Martin, Wiley, 2011



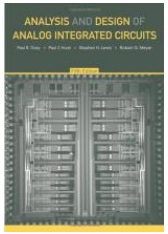
CMOS Analog Circuit Design (3rd edition)
by Allen and Holberg, Oxford, 2011.



Design of Analog CMOS Integrated Circuits
by B. Razavi, McGraw Hill, 2016



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



Untethered Communication Policy

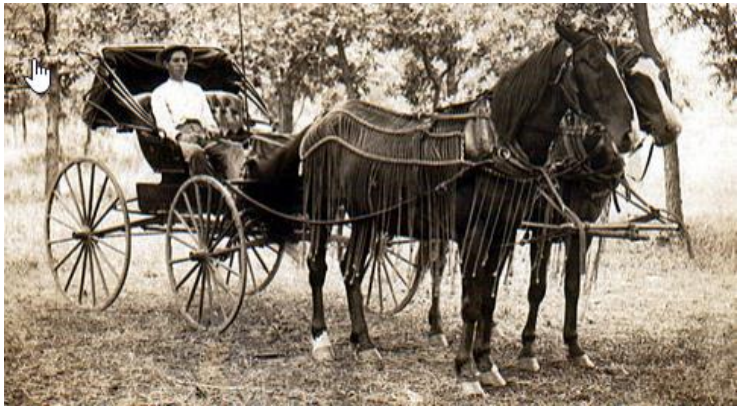
Use them !

Hearing them ring represents business opportunity !

Please step outside of the room to carry on your conversations

Technology Revolution

Obsolete or Current?



Technology Revolution

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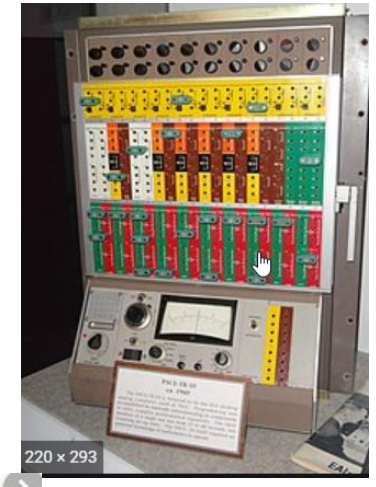

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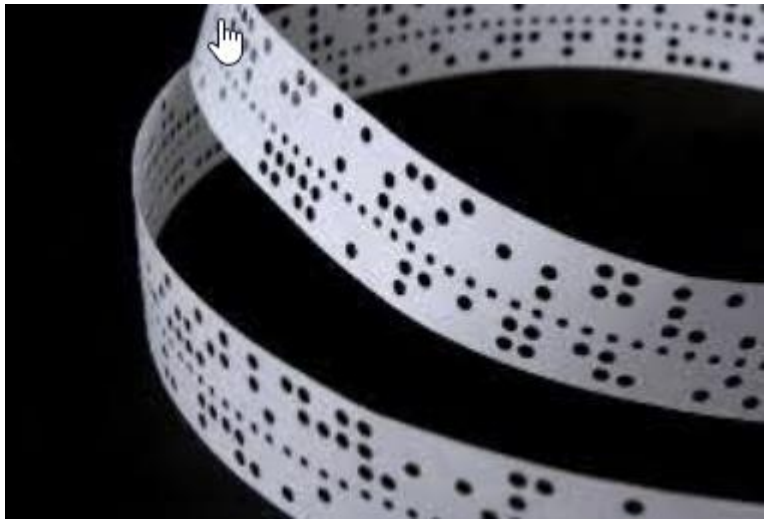


Technology Revolution

Obsolete or Current?

Technology Revolution

Obsolete or Current?

The end of Blu-ray | ZDNet

https://www.zdnet.com › article › the-end-of-blu-ray

Feb 25, 2019 - Thanks to the rise of streaming, Samsung is discontinuing its Blu-**ray** and 4K Blu-**ray** player lines. That's lousy news for people who love older ...

Over 10 years ago, Samsung released the first commercial Blu-ray video disc player. Within a few years, Samsung and other Blu-ray OEMs had defeated their rival HD DVD manufacturers. They were set to dominate the video world. Then, streaming came along and everything changed. Recently, Samsung told *CNET* that, "Samsung will no longer introduce new Blu-ray or 4K Blu-ray player models in the US market."

Technology Revolution

Obsolete or Current?

Blu-ray is dead.

It's not often that an industry's leading OEM quits, but that's what Samsung has done. Samsung had 37 percent of the market, followed by Sony at 31 percent and LG at 13 percent according to market research firm NPD Group. On Amazon, Samsung had four of Amazon's 10 best-selling Blu-ray players including the most popular model.

With its demise, Blu-ray follows Laserdisc, BetaMax, and VHS VCRs into the second-hand stores. DVDs may soon follow. Ted Sarandos, Netflix's longtime head of content told Variety, even though Netflix still has three-million DVD subscribers, "We never spent one minute trying to save the DVD business."

Why? It's all because of streaming.

Technology Revolution

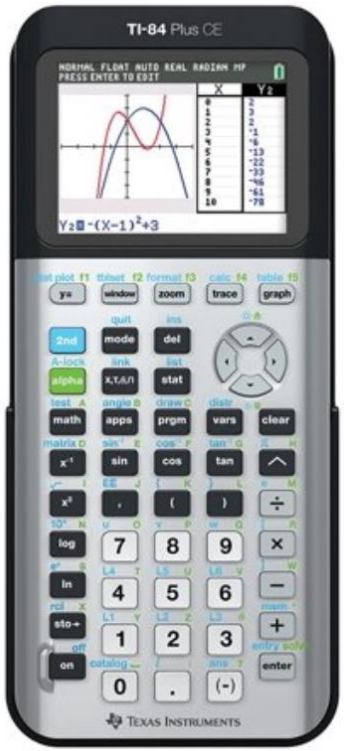
Obsolete or Current?

Technology Revolution

Obsolete or Current?

Technology Revolution

Obsolete or Current?



Graphing calculator

Computing engine

A graphing calculator is a handheld computer that is capable of plotting graphs, solving simultaneous equations, and performing other tasks with variables. Wikipedia

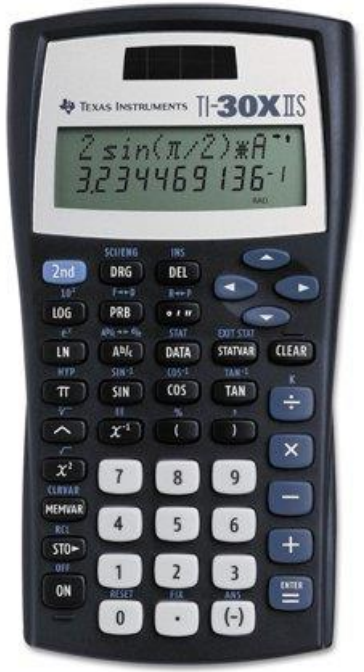
Calculation supported: Equation

Operation supported: Graph of a function, Computer algebra system, Programming

Purpose: Solving simultaneous equations, Plotting graphs

Application: Education, Engineering

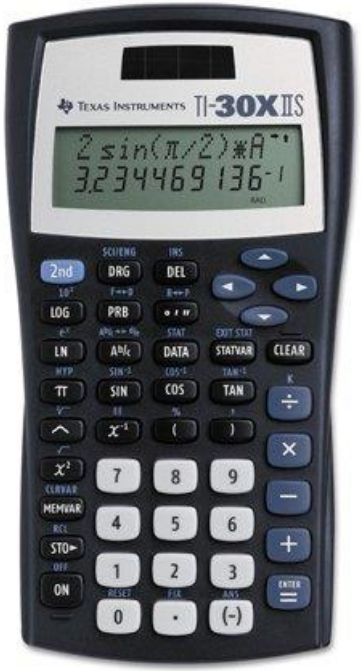
Introduced in school level: High school, GCE Advanced Level



Electronic Components For Exams

- No electronic communications
- No graphing calculators
- No smart phones

Scientific Calculator Permitted



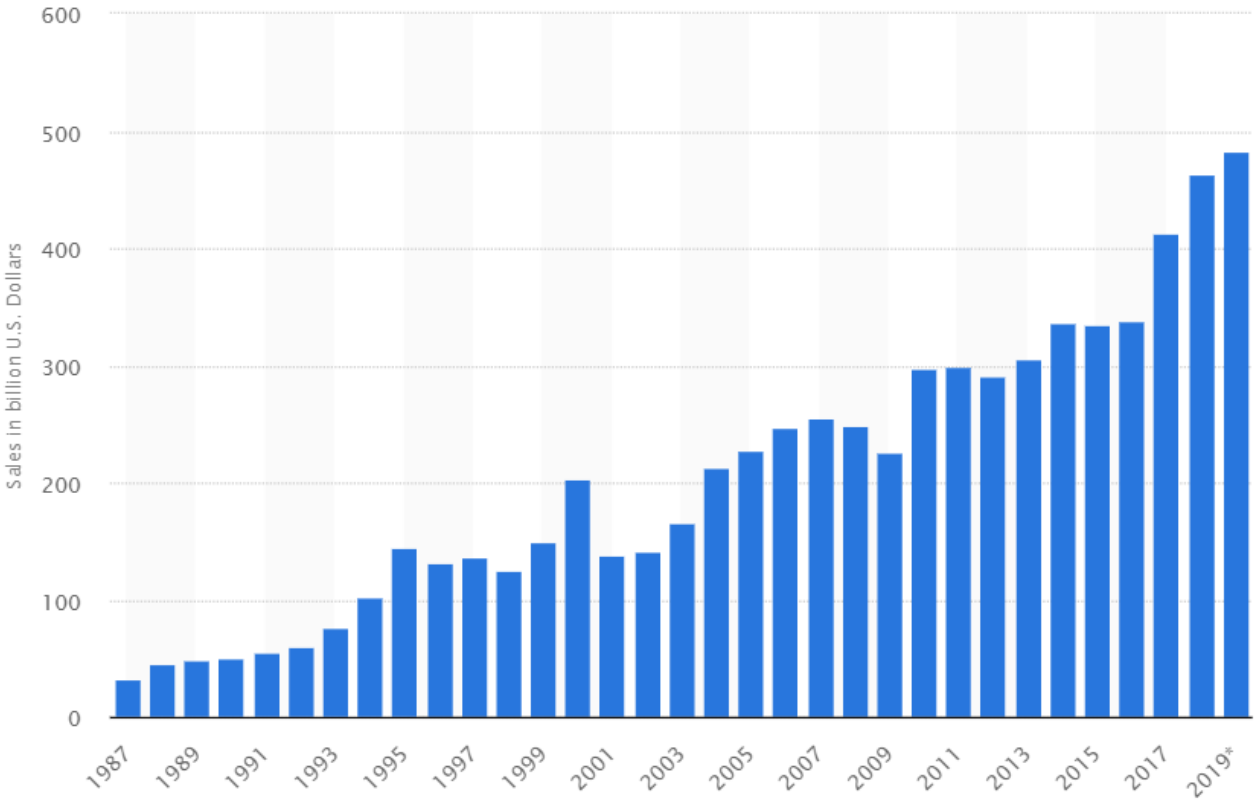
The Semiconductor Industry

(just the “chip” part of the business)

How big is it ?

How does it compare to other industries?

How big is the semiconductor industry?



Projected at $483 Billion in 2019

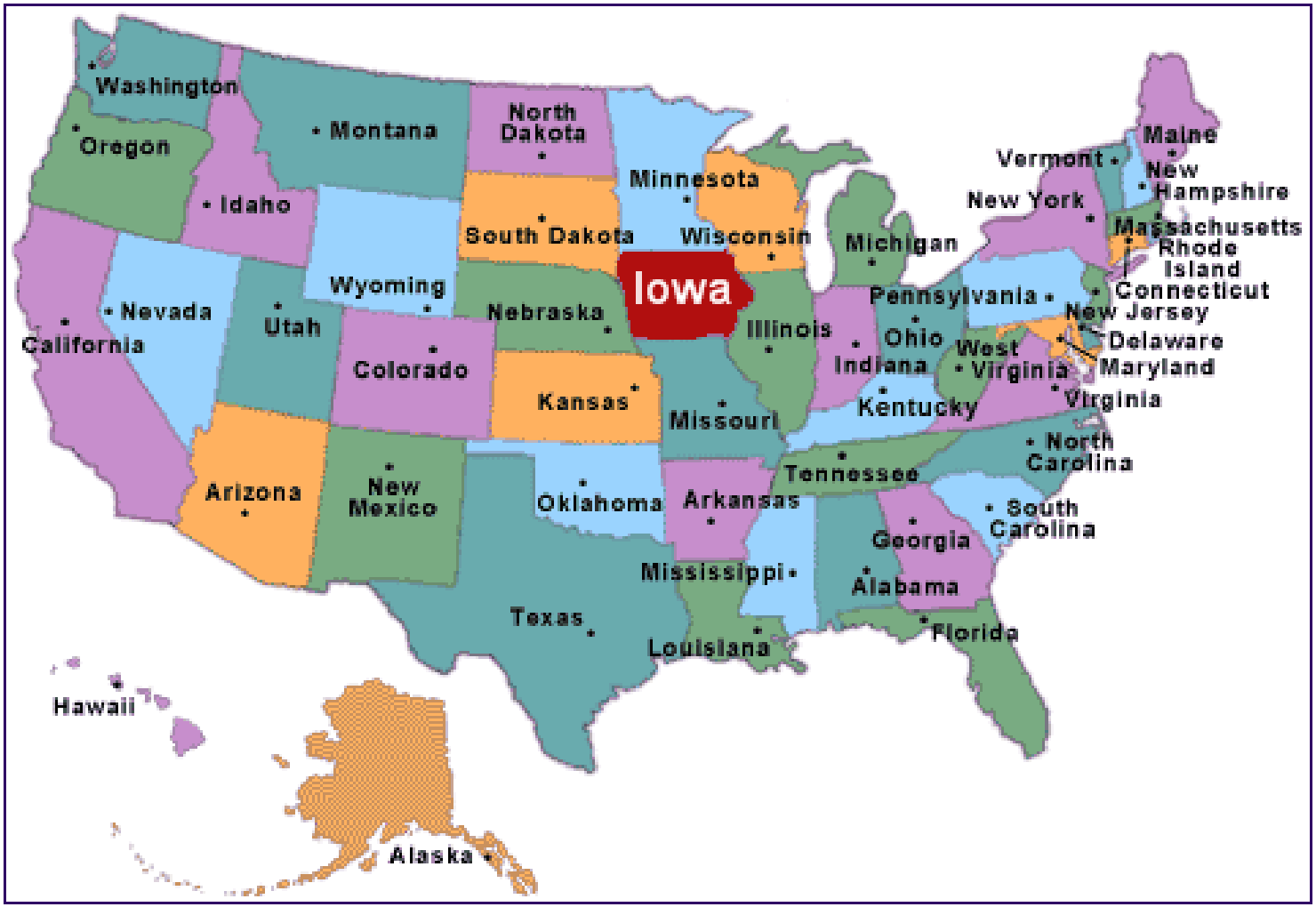
Semiconductor sales do not include the sales of the electronic systems in which they are installed and this marked is much bigger !!

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 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 17, 2018 closing markets in Boone Iowa

	Corn	Soybeans
Aug 2018	3.28	8.11

Value of Agricultural Commodities

(Based upon commodity prices in Boone Iowa on Aug 17 2018)

(simplifying assumption: value constant around world)

Corn Production

	Bushels (Billions)	Value (Billion Dollars)
Iowa	**2.2**	**$7.2**
United States	**12**	**$39**
World	**23**	**$75**

Soybean Production

	Bushels (Millions)	Value (Billion Dollars)
Iowa	**340**	**$2.8**
United States	**3,100**	**$25**
World	**8,000**	**$65**

Projected world 2019 semiconductor sales of $483B about 345% 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 $470B/Year and growing

How does it compare to Iowa-Centric Commodities?

Larger than major agricultural commodities (close to 3.5X)

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?

Worldwide Ranking of the Top-10 Suppliers of Semiconductors in 2017
(Ranking by Revenue in Millions of U.S. Dollars)

2016 Rank	2017 Rank	Company Name	2016 Revenue($)	2017 Revenue($)	Revenue Percent Change	Revenue Percent of Total	Revenue Cumulative Percent
2	1	Samsung Electronics	40,389	62,031	53.6%	14.5%	14.5%
1	2	Intel	54,980	61,406	11.7%	14.3%	28.8%
5	3	SK Hynix	14,699	26,638	81.2%	6.2%	35.0%
7	4	Micron Technology	12,710	22,843	79.7%	5.3%	40.3%
4	5	Broadcom Limited	14,979	17,375	16.0%	4.0%	44.3%
3	6	Qualcomm	15,405	16,872	9.5%	3.9%	48.3%
6	7	Texas Instruments	12,836	14,525	13.2%	3.4%	51.7%
8	8	Toshiba	9,904	11,864	19.8%	2.8%	54.4%
9	9	NXP	9,306	8,864	-4.7%	2.1%	56.5%
13	10	nVidia	6,030	8,578	42.3%	2.0%	58.5%
		Top 10 Companies	**191,238**	**250,996**	**31.2%**	**58.5%**	
		All Others	**161,356**	**178,112**	**10.4%**	**41.5%**	
		Total Semiconductor	**352,594**	**429,108**	**21.7%**	**100.0%**	

Source: IHS Markit Q1 2018 Competitive Landscaping Tool

1Q-2018 Top 15 Semiconductor Sales Leaders

May 15, 2018, anysilicon

Dramatic Dynamic Changes Ongoing

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7	4	Micron Technology	12,710	22,843	79.7%	5.3%	40.3%
4	5	Broadcom Limited	14,979	17,375	16.0%	4.0%	44.3%
3	6	Qualcomm	15,405	16,872	9.5%	3.9%	48.3%
6	7	Texas Instruments	12,836	14,525	13.2%	3.4%	51.7%
8	8	Toshiba	9,904	11,864	19.8%	2.8%	54.4%
9	9	NXP	9,306	8,864	-4.7%	2.1%	56.5%
13	10	nVidia	6,030	8,578	42.3%	2.0%	58.5%
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ElectronicsWeekly.com

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

How Do Engineers Working in the Semiconductor Industry Get Rewarded?

Solid State Devices

Signal Processing

Electronics

Power and Energy

Microelectronics

Communications

Control

2015 IEEE-USA Salary Survey: First, the Good News...

BY HELEN HORWITZ
Posted: 19 Oct 2015

2015 Major Results

Engineers in the general PATC of Communications Technology (Broadcast Technology, Communications, Consumer Electronics and Vehicular Technology) continue to enjoy the highest median earnings—$150,000, according to the 2015 Survey. The lowest median income in a broad PATC category is for those in Energy and Power Engineering—at $116,175. Other especially lucrative subspecialties include Information Theory, Solid-State Electronics, Lasers and Electro-Optics, and engineering management—all at median salaries of $150,000, or more, a year. The only subspecialties this year with median annual salaries less than $100,000 were Education and the Social Implications of Technology.

The differences are significant !!

Is an automobile an electronics “gadget”?

e2af.com/trend/071210.shtml

Automotive industry seeking electronic solutions to four main issues

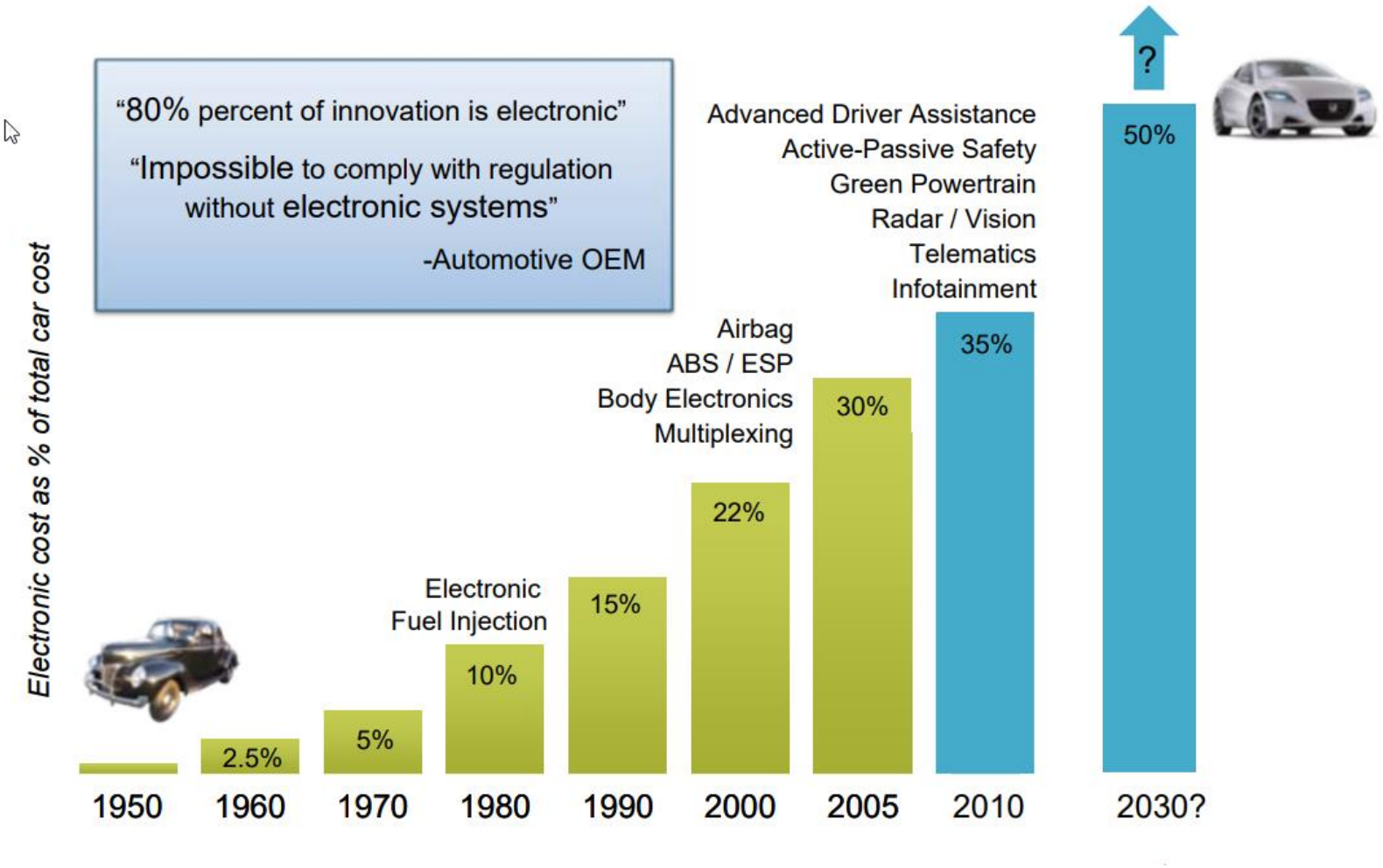
Part.1

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.

Automotive Electronic Content Growth



End of Lecture 1