EE 3300
Fall 2025

Integrated Electronics

Lecture Instructors:	Randy Geiger 2133 Coover rlgeiger@iastate.edu 294-7745
Course Web Site:	ttp://class.ece.iastate.edu/ee330/
Canvas:	Use primarily for turning in assignments and reports "Grades" generated by Canvas are unrelated to the course grading policy

Lecture: MWF 12:05 –12:55 Rm 1016 Coover

Lab:				
	Sec A	Tues	7:45 AM - 10:50	TA: Yash Gaonkar
	Sec B	Tues	11:00 AM - 1:50	TA: Yash Gaonkar
	Sec D	Fri	7:45 AM - 10:35	TA: Yash Gaonkar

Labs start this week !
HW Assignment 1 has been posted land is due on Friday

Laboratory Instructor:

Yash Gaonkar yashg@iastate.edu

Instructor Access:

- Office Hours
  - Monday, Wednesday, Friday 11:00-11:50
  - By appointment at other times
- Email
  - rlgeiger@iastate.edu
  - Include **EE 3300** in subject
- Class Zoom Link

https://iastate.zoom.us/j/92719380626?pwd=O59cpBSE1kxffSb6kEmSYRFXUblTNT.1

Passcode: 514444

Catalog Description

E E 3300. Integrated Electronics. (Same as Cpr E 3300.) (3-3) Cr. 4. F.S. *Prereq:* 2010, credit or enrollment in EE 2300, Cpr E 2100. 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.

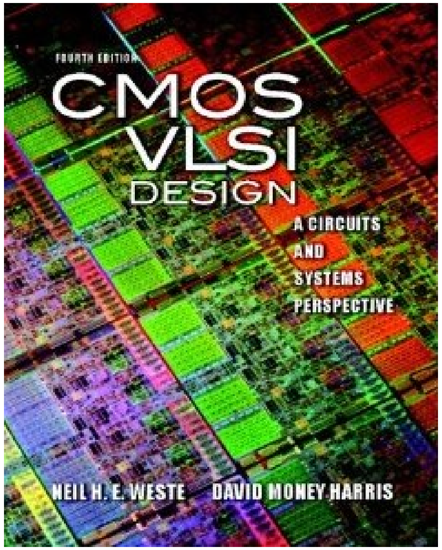
Grading Policy

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

- Attendance based upon in-person presence but under special individually approved circumstances zoom can be used
- A letter grade will be assigned based upon the total points accumulated
- Grade breaks will be determined based upon overall performance of the class (Letter grades that may appear in Canvas should be ignored)

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

Academic Misconduct

Academic misconduct will not be tolerated in this course

- Academic misconduct includes, but is not limited to, representing someone else's work as your own. Some examples of academic misconduct include turning in homework solutions that are copied from someone else, turning in source code prepared by someone else, and copying solutions from someone else on exams.

- Academic misconduct also includes but is not limited to making postings or dissemination of course materials so that the poster or others can take advantage of the work of others. Specifically precluded is posting any homework or exam problems on any forums such as Chegg or similar forums or accessing these forums to see if anyone else has posted or solved problems.

Those that violate the academic conduct guidelines will, at the discretion of the instructor, receive either a grade of 0 for the work where academic misconduct occurred or a grade of F for the course. A grade of F will be assigned to <u>any</u> student where there is evidence that electronic forums such as Chegg (either posting or accessing) are used for any part of this course.

The course will follow Iowa State University's policy on academic dishonesty. Anyone suspected of academic dishonesty will be reported to the Office of Student Conduct.

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 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
- Seek help from the instructor or the TA if help is needed on any topic
- Ask questions in class on any concepts that are not clearly understood

Equal Access Policy

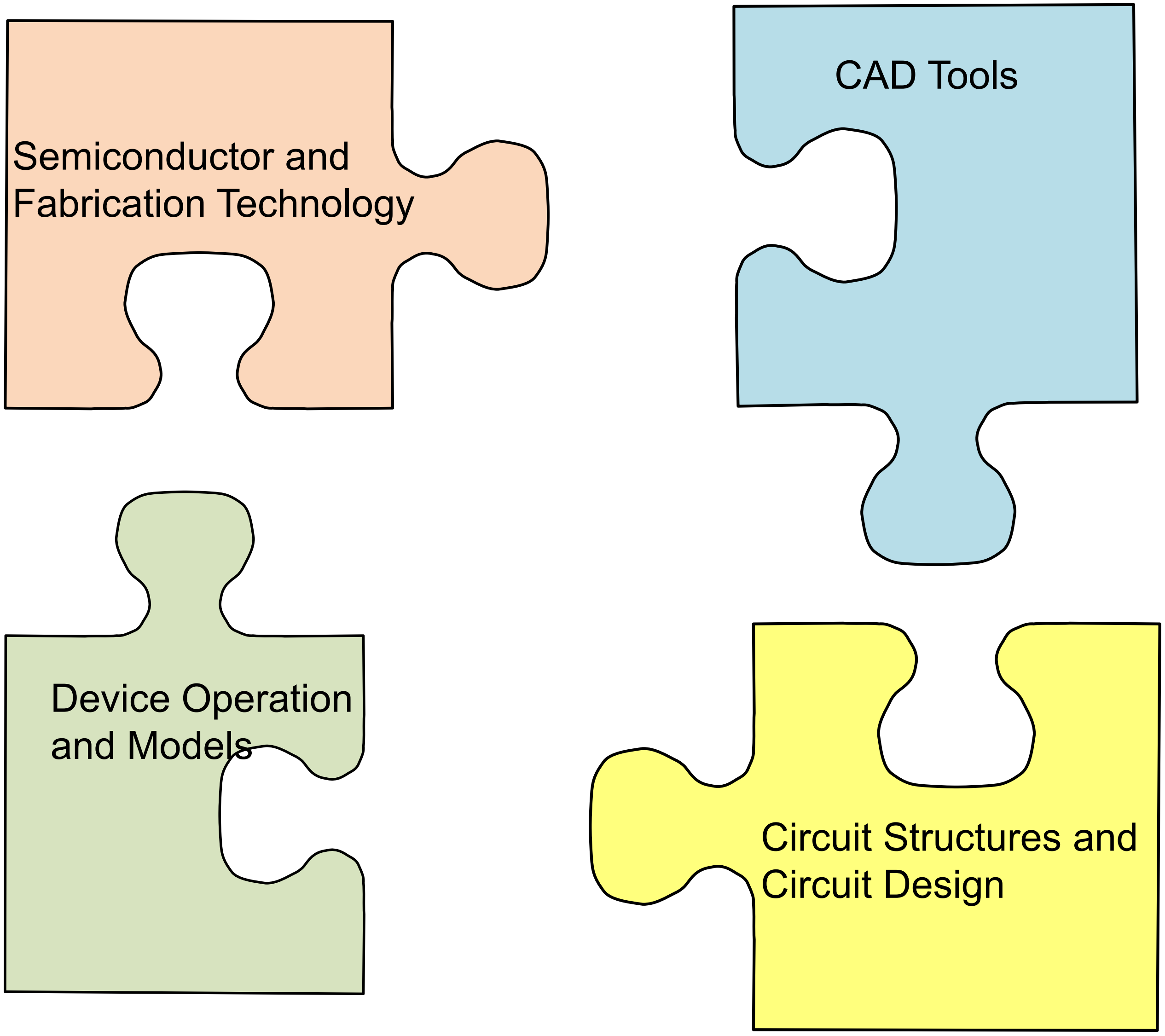
Participation in all class functions and provisions for special circumstances including special needs will be in accord with ISU policy

Participation in any classes or laboratories, turning in of homework, or taking any exams 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 contribute. Successful completion of ALL laboratory experiments 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.

Electronic Circuits in Industry Today

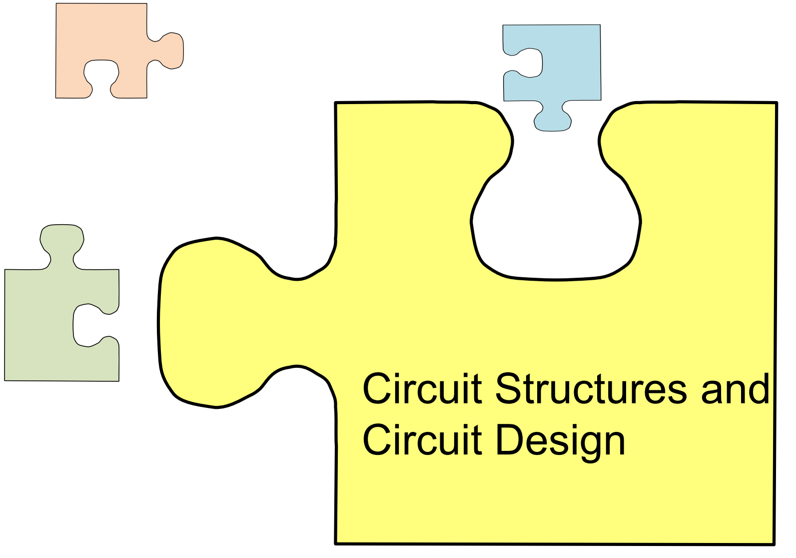
- Almost all electronic circuits are, at the most fundamental level, an interconnection of transistors and some passive components such as resistors, capacitors, and inductors
- For many years, electronic systems involved placing a large number of discrete transistors along with passive components on 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



Will initially bounce back and forth between these topics – but have faith !

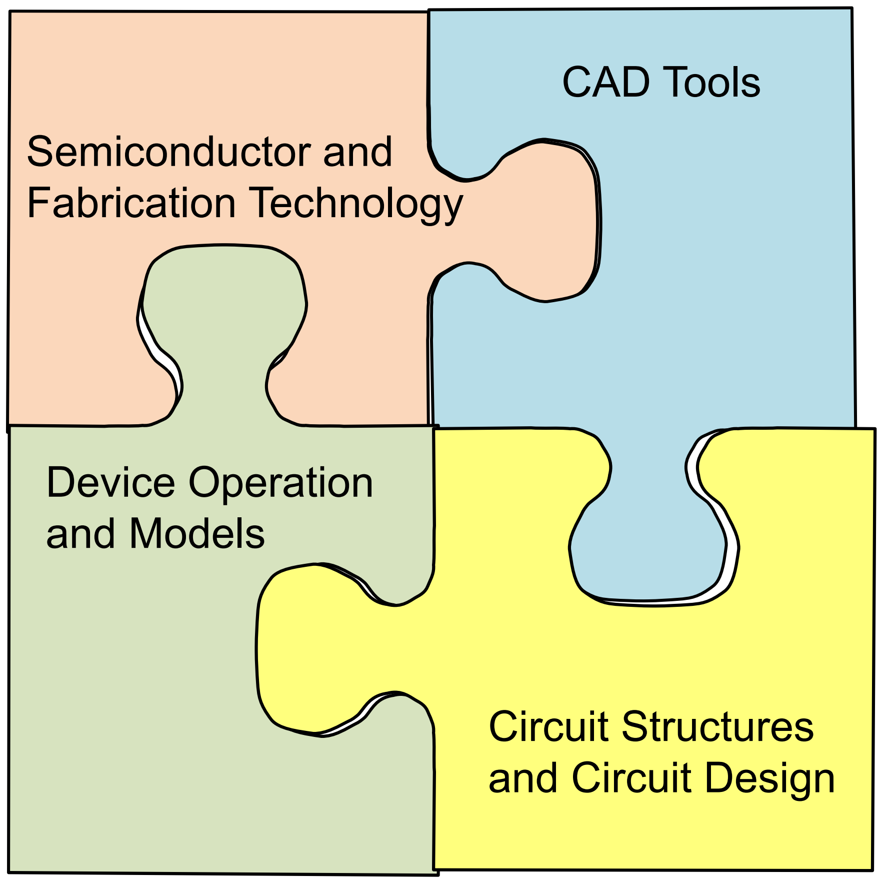
How Electronics was Approached for Decades



Coupling of electronic circuits with fabrication technology was weak and device models were simple

How Integrated Electronics will be Approached

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



The sequencing of laboratory experiments has been intentionally structured so that on some topics, a laboratory investigation will lead a topic in the classroom and in others it will follow

Topical Coverage

- Semiconductor Processes
- Device Models (Diode,MOSFET,BJT, Thyristor)
- Layout
- Simulation and Verification (using commercial state of the art toolsets)
- Basic Digital Building Blocks
- Behavioral Design and Synthesis
  - Standard cells
- Basic Analog Building Blocks

Laboratory Equipment

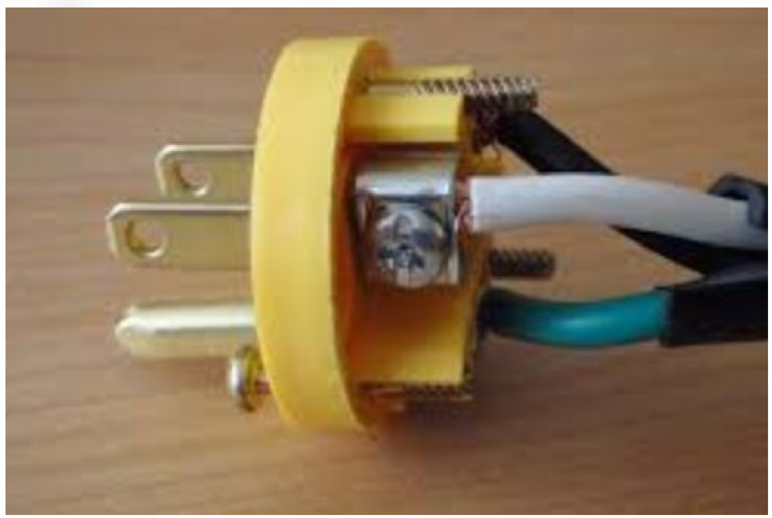
All laboratory equipment and all software used in the laboratory in this course are expected to be fully functional and operate correctly all of the time!

If for any reason it appears that there is an equipment malfunction or an error in software used in this course, bring it to the attention of your TA immediately. If for any reason the issue is not resolved by your TA, bring it to the attention of the course instructor.

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

Laboratory Safety



Due Dates and Late Reports

Homework assignments will be posted on the class WEB site and turned in on Canvas

Homework assignments will usually be due at 12:05 PM on Fridays but will be accepted without penalty up until 11:59 pm on the due date. In weeks where exams are scheduled or other situations arise, the homework assignment due times will be changed.

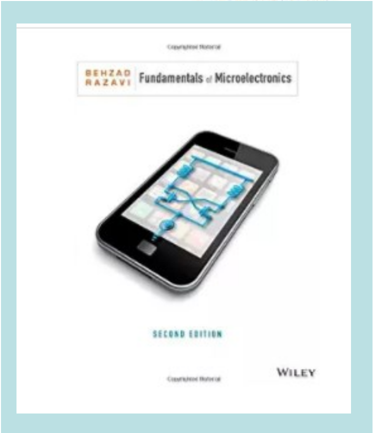
Laboratory reports are due at 11:59 p.m. on the day before the next laboratory experiment is scheduled. Reports will be turned in on Canvas. The last laboratory report will be due one week after the scheduled completion of the experiment.

Design Project

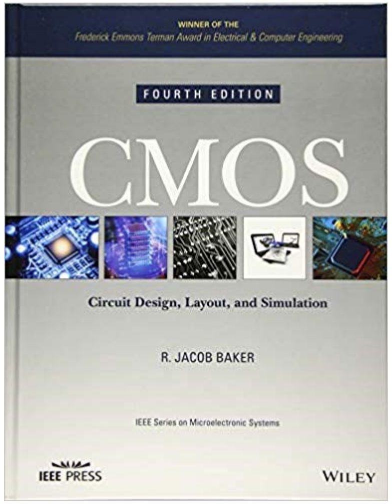
- Design project will focus on the design of an integrated circuit
- The final project will be culminated with an oral presentation and a written report

Reference Texts:

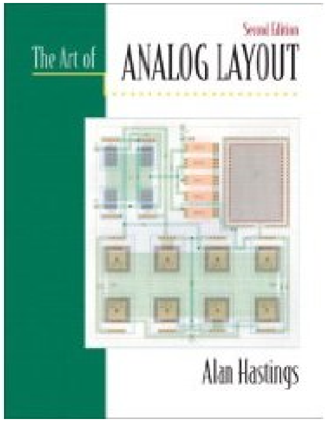
Fundamentals of Microelectronics
by B. Razavi, Wiley, 2013



CMOS Circuit Design, Layout, and Simulation (4th Edition)
by Jacob Baker, Wiley-IEEE Press, 2019.

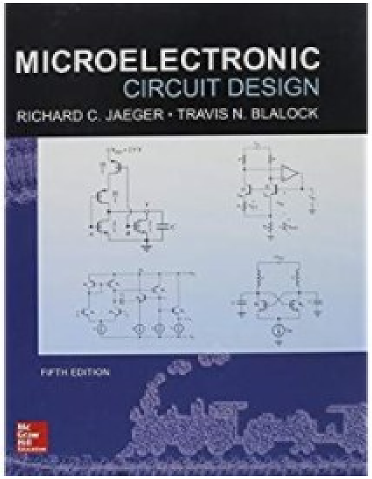


The Art of Analog Layout
by Alan Hastings, Prentice Hall, 2005

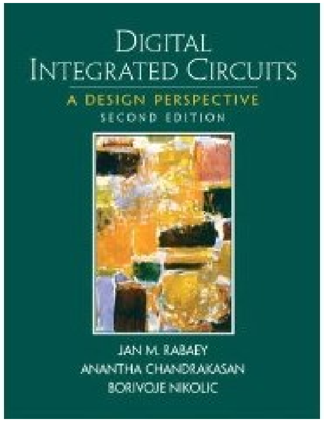


Reference Texts:

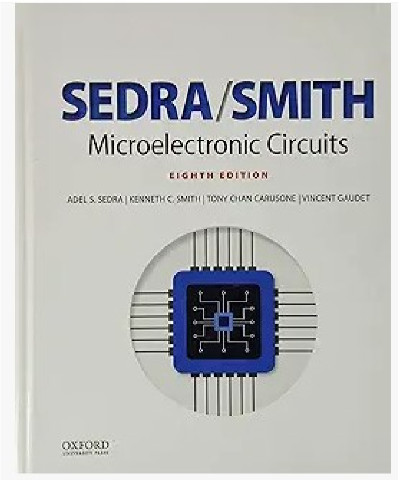
Microelectronic Circuit Design (4th edition)
By Richard Jaeger and Travis Blalock,
McGraw Hill, 2015



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

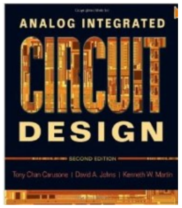


Microelectronic Circuits (8th Edition)
by Sedra and Smith, Oxford, 2019

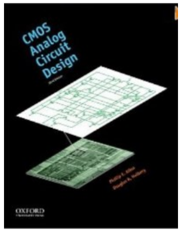


Other useful reference texts in the VLSI field:

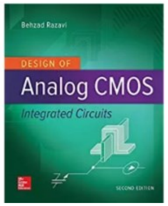
Analog Integrated Circuit Design (2nd edition)
by T. Carusone, D. Johns and K. Martin, Wiley, 2011



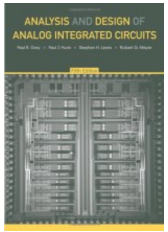
CMOS Analog Circuit Design (3rd edition)
by Allen and Holberg, Oxford, 2011.



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 !

Technology Revolution

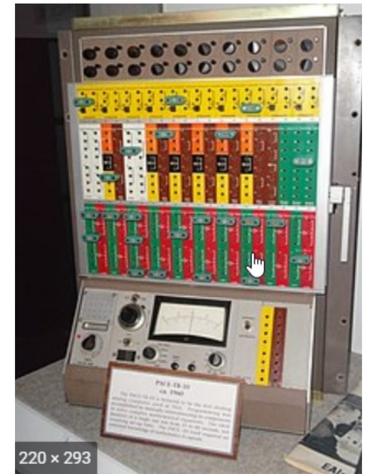
Obsolete or Current?

Technology Revolution

Obsolete or Current?

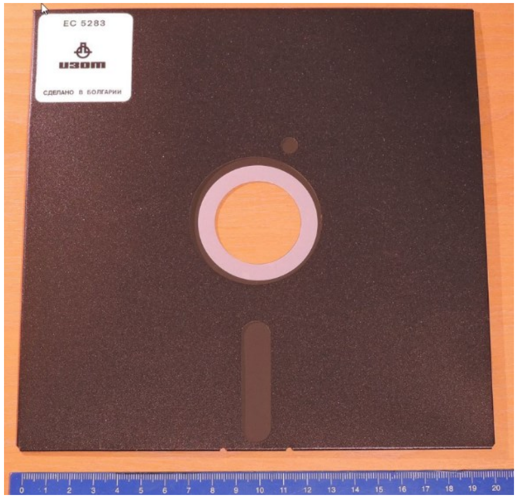
Technology Revolution

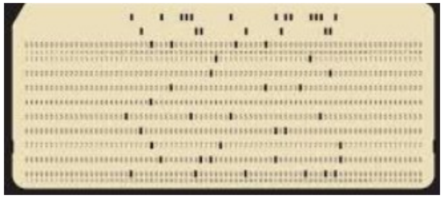
Obsolete or Current?



Technology Revolution

Obsolete or Current?





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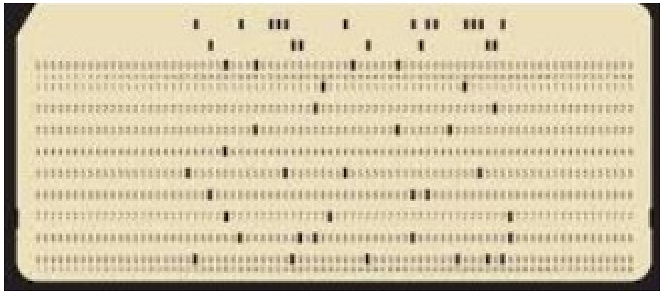

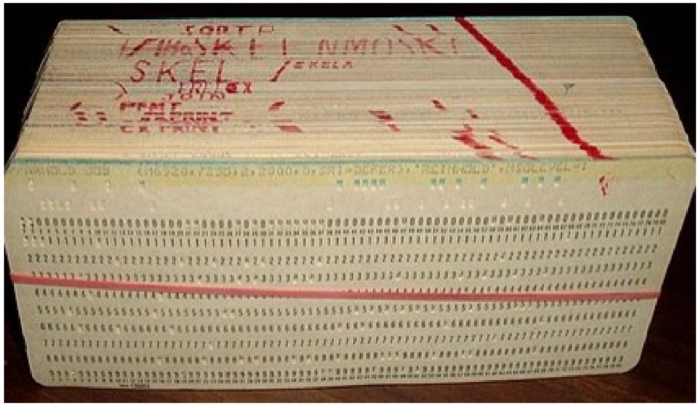

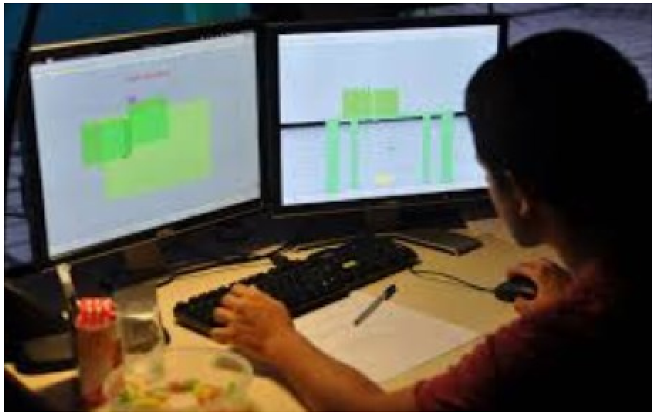

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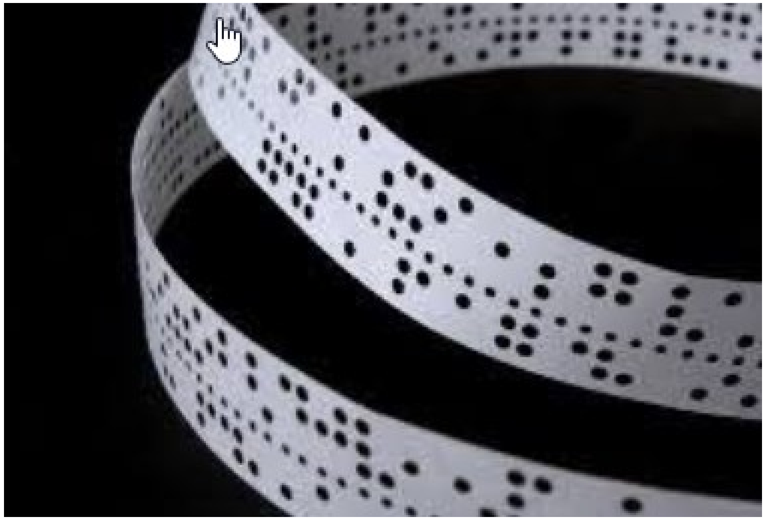

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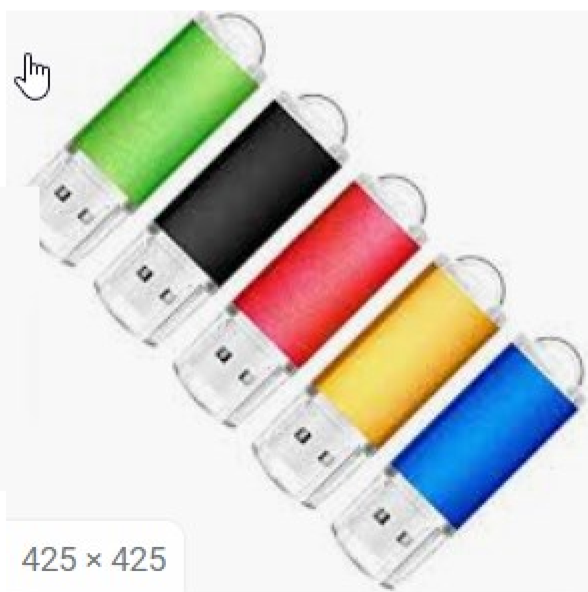

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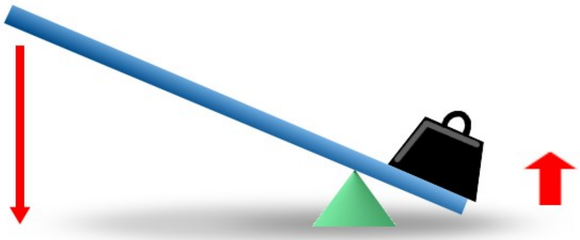

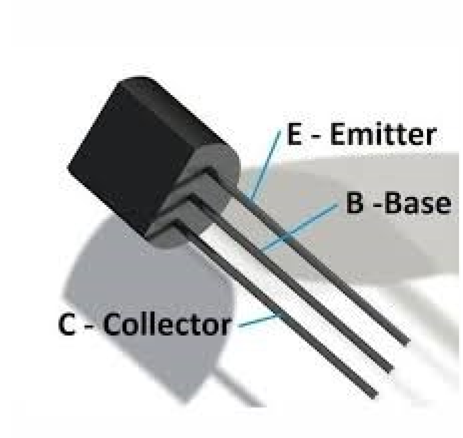

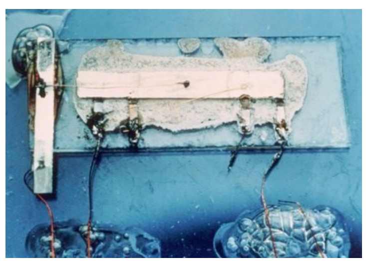

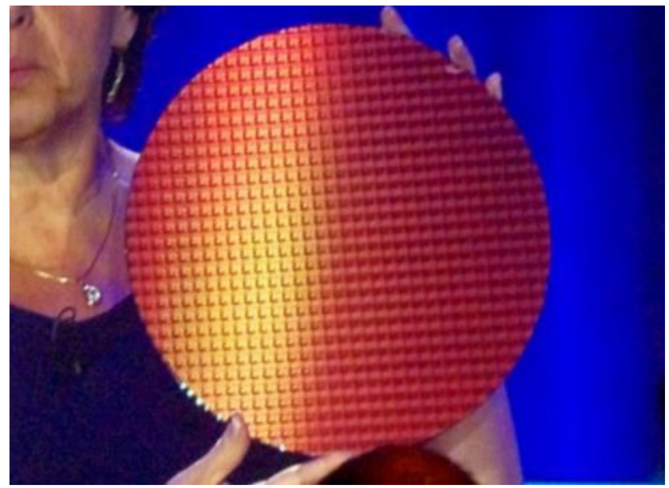

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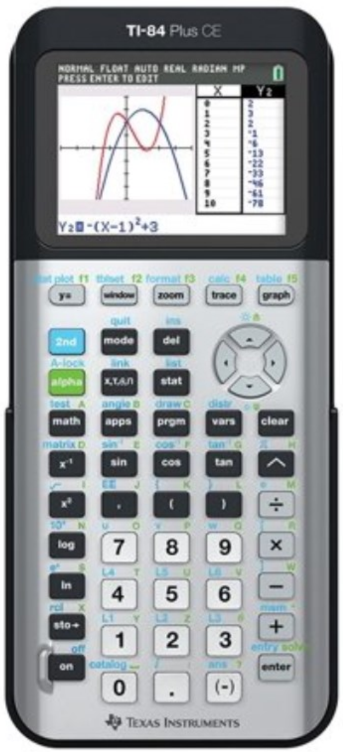


Graphing calculator

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

Technology Revolution

- Electronics technology is the driving factor in this technology revolution

- Electronics technology will play an even larger role in the technology revolution of the next two decades !

- Electronics technology often referred to microelectronics technology or semiconductor technology of Very Large Scale Integration (VLSI)

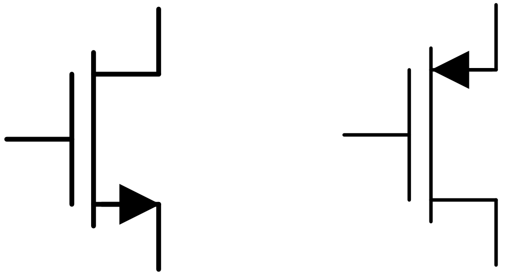
Semiconductor Industry Today is in a Major State of Turmoil !

- Impact on Global Society

  (AI, machine learning, data science)
- Who will be the key players
- How is will be distributed across the planet
- Impact on Economy
- Impact on Commerce and Military
- Stakes are high !
- Incredible opportunities in the Field !!

The Semiconductor Industry

The semiconductor industry from a technical viewpoint involves little more than connecting groups of transistors (usually very small) together to make circuits that perform useful functions



Partitioning of the Semiconductor Industry into 3 Major Sectors

- Semiconductor Fabrication Technology
- CAD Tools
- Circuit Design

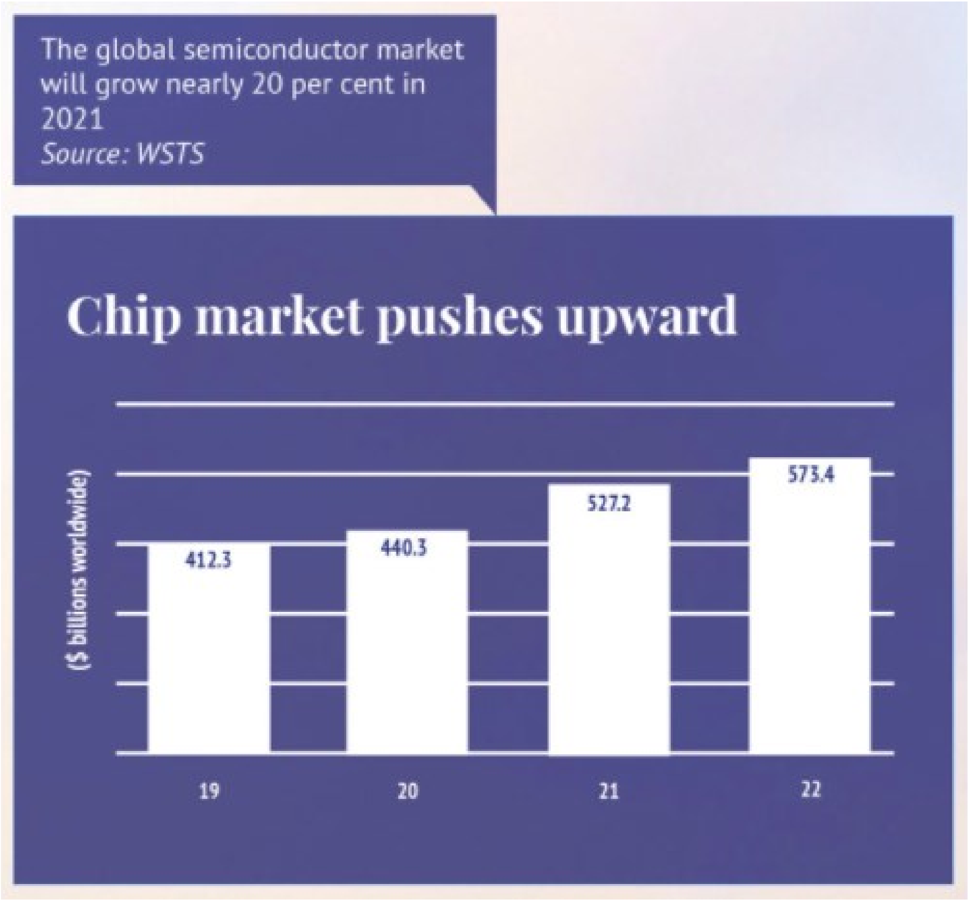
The Semiconductor Industry

(just the “chip” part of the business)

How big is it ?

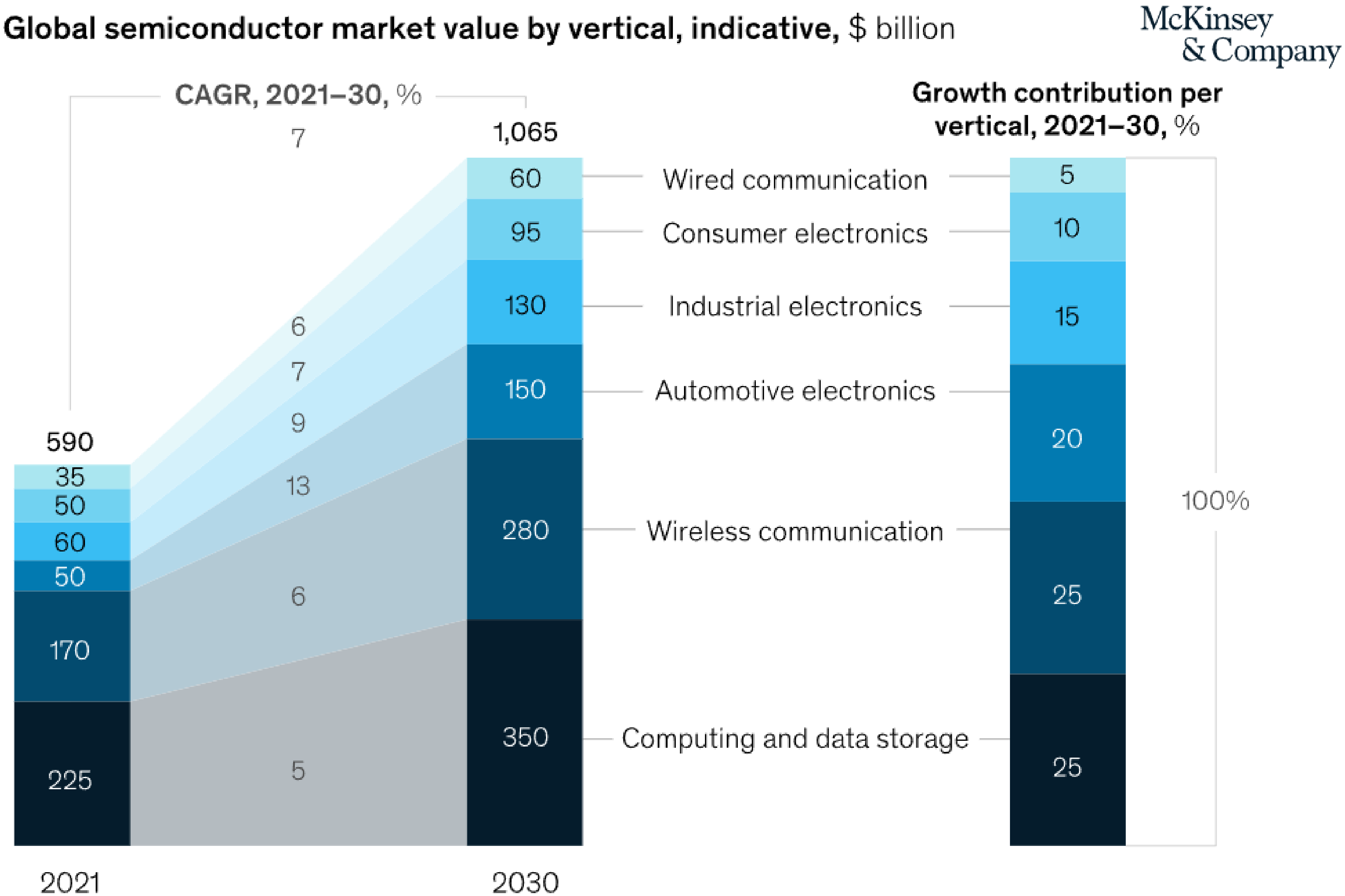
How does it compare to other industries?

How big is the semiconductor industry?



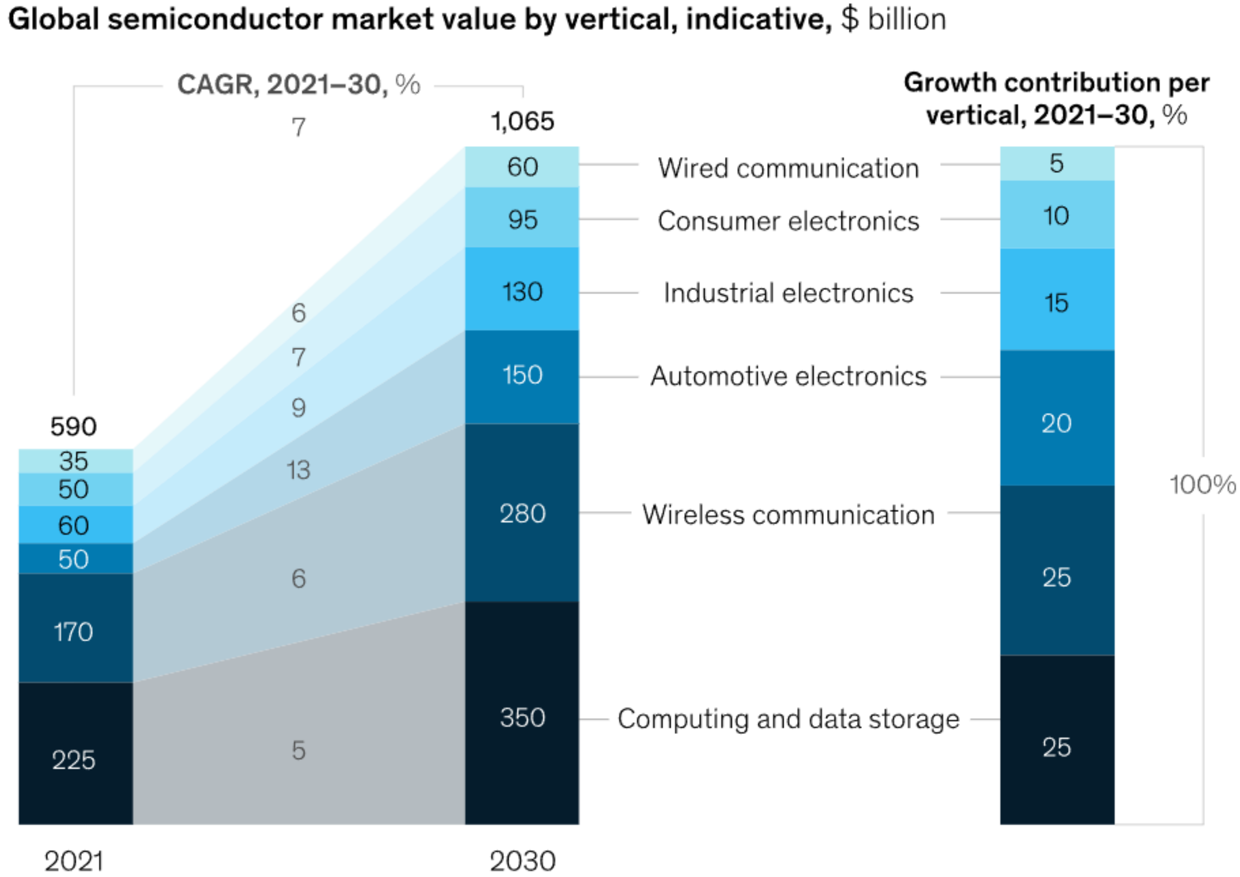
$585B in 2024 with 7.5% annual growth predicted for next decade

How big is the semiconductor industry?



https://www.mckinsey.com/industries/semiconductors/our-insights/the-semiconductor-decade-a-trillion-dollar-industry

What is driving the growth?



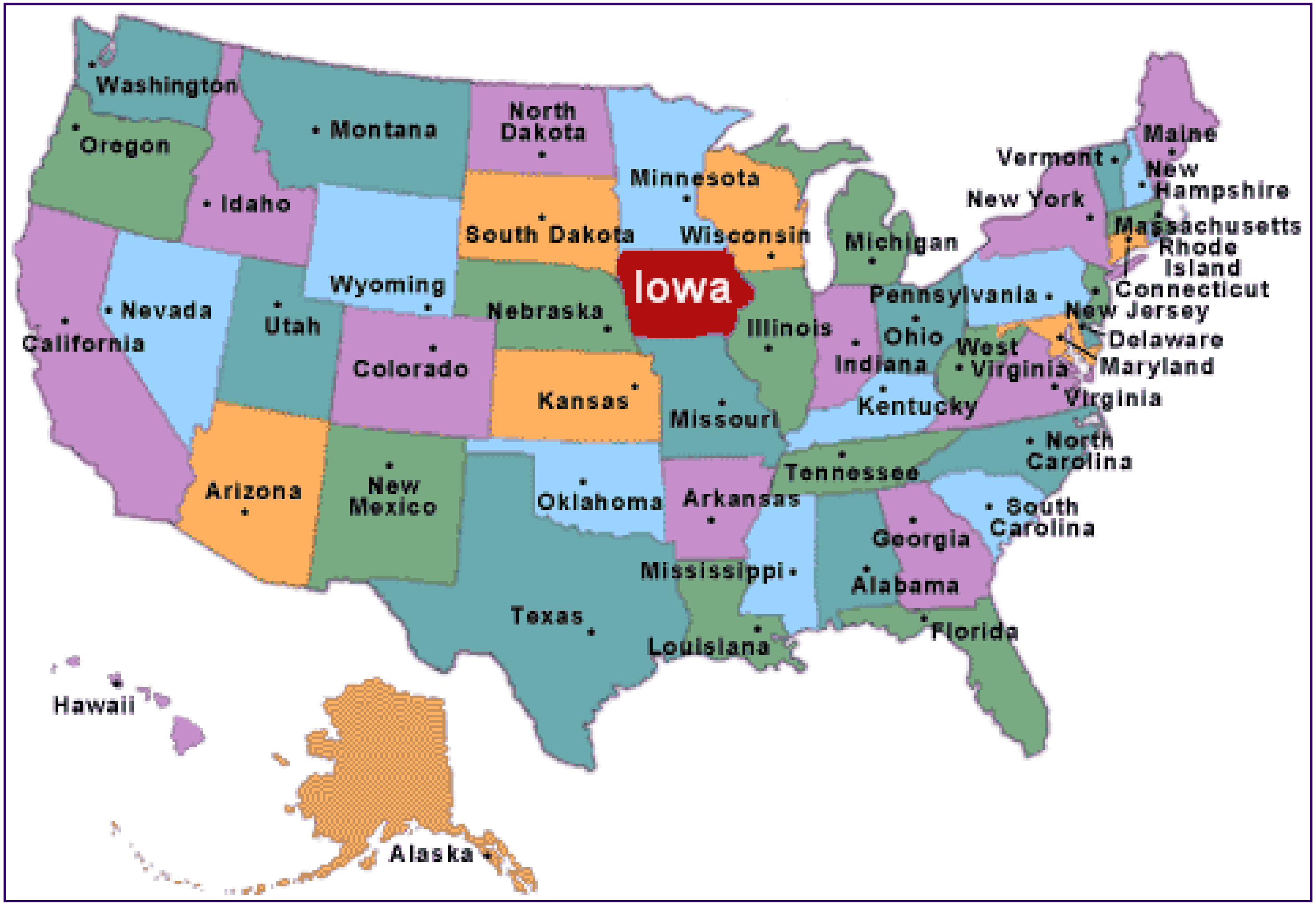
- Automotive
- Wireless Communications
- Computing and Data Storage

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
Second in Soybean production
First in Egg production
First in Hog production (nearly 3x 2^{nd} rank)
First in Red Meat production (2020)

Updated August 2023

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**

LANDUS COOPERATIVE

Not secure | www.landuscooperative.com/grain-bids/

Based upon Aug 24, 2024 markets in Boone Iowa

	Corn	Soybeans
Aug 2024 delivery	3.73	9.63

Value of Agricultural Commodities

(Based upon commodity prices in Boone Iowa on Aug 25, 2024)

(simplifying assumption: value constant around world)

Corn Production

	Bushels (Billions)	Value (Billion Dollars)
Iowa	**2.2**	**$8.2**
United States	**12**	**$45**
World	**23**	**$79**

Soybean Production

	Bushels (Millions)	Value (Billion Dollars)
Iowa	**340**	**$3.3**
United States	**3,100**	**$30**
World	**8,000**	**$77**

Projected world 2024 semiconductor sales of $611B about 400% 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 $610B/Year and expected to exceed $1T/Year by 2030

How does it compare to Iowa-Centric Commodities?

Larger than major agricultural commodities (almost 4X)

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

And the electronics industry which embeds the semiconductor devices is much larger

The Key Players

Rank	Company		Revenue	Net Income	Market Cap	Location
				In $Billions		
1	Samsung		202	15	275	S. Korea
2	Nvidia		80	43	3300	USA
3	TSMC	*	72	28	930	Taiwan
4	Intel		55	4	130	USA
5	Broadcom		43	10	840	USA
6	Qualcomm		36	8	250	USA
7	SK Hynix		29	3.5	29	S. Korea
8	ASML	*	28	8	420	Netherlands
9	Applied Materials	*	27	7	205	USA
10	AMD		23	1.1	250	USA
11	Micron		21			USA
12	ASE	*	17			Taiwan
13	Infineon		16			Germany
14	Texas Instr		16			USA
15	Media Tek		16			Taiwan
16	STMicro		15			Switzerland
17	Lam Res	*	14			USA
18	NXP		13			Netherlands
19	Tokyo Elec	*	13			Japan
20	Analog Devices		10			USA

Rank 1-10 From: Invesotpedia   Updated July 31, 2024

*   Not semiconductor sales

Note: Sales of Nvidia alone exceeds value of all corn and beans produced in the US

Note: Society has a monstrous appetite for electronic devices and gadgets

Applications of Electronic Devices

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

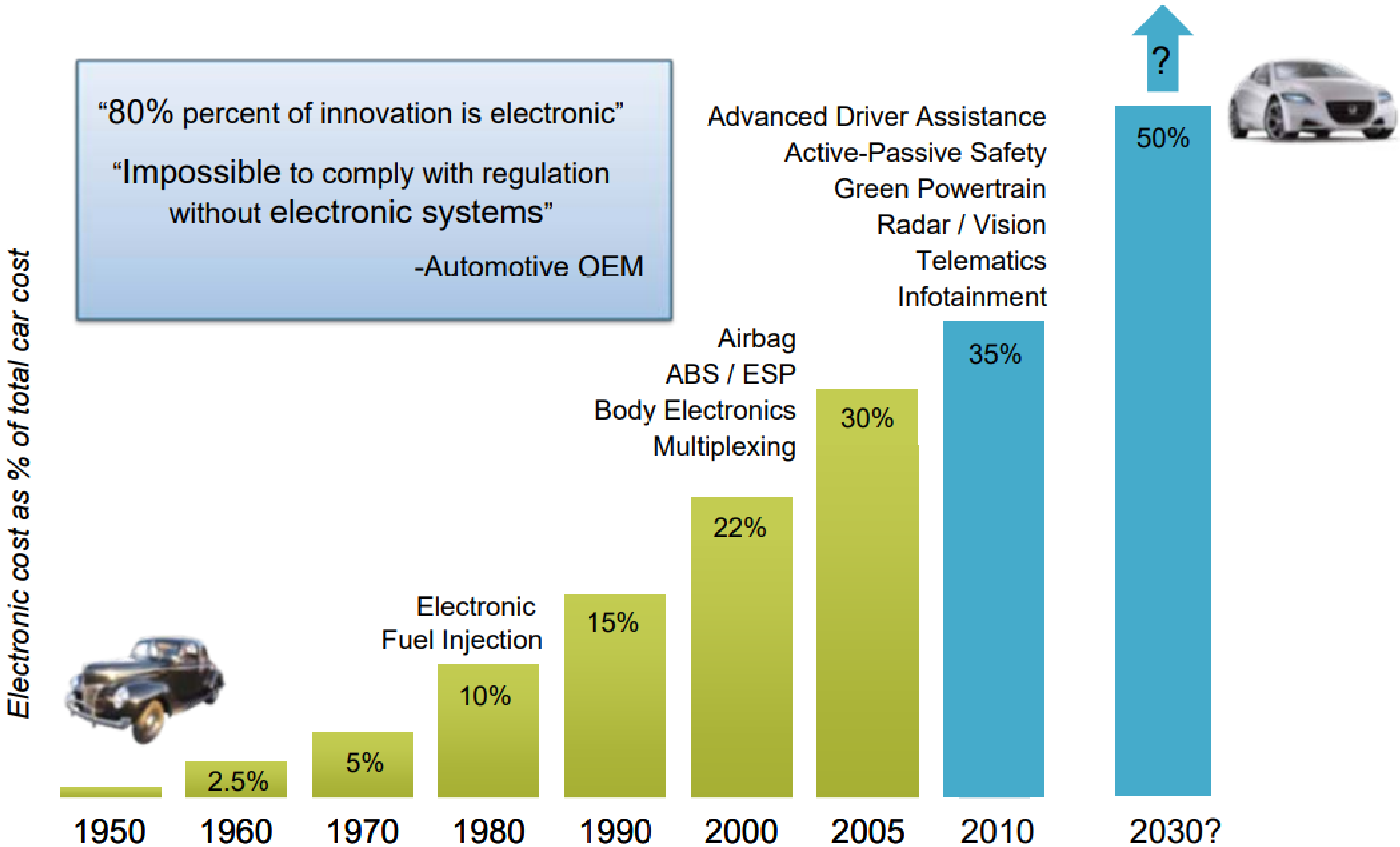
Applications often incorporate several classical application areas

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

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

Is an automobile an electronics “gadget”?

Automotive Electronic Content Growth



Opportunities in the Electronics Field

- A lot has happened in the field in the past 4 decades

- Are there still opportunities?

But be realistic about the difference between what can be done and what can be done profitably

How many of you stream high definition video on smart phones?

If not, how many would like to?

Consider Television Sets and Monitors

8K UHD Television

Pixels: 7680 Horizontal and 4320 Vertical

But: No 8K broadcast channels available in the US and none on the horizon at this time (Aug 2024) and little 8K media available !

Consider Television Sets and Monitors

4K UHD Television

Pixels: 3840 Horizontal and 2160 Vertical

Best Buy Jan 2022

Samsung - 43" Class 7 Series LED 4K UHD Smart Tizen TV

Model: UN43TU7000FXZA **SKU:** 6401740

(6,738)

Price Match Guarantee

$329.99

Save $70 Was $399.99

An example of electronic opportunities

Consider High Definition Television (HDTV)

Video:

Frame size: 3840 x 2160 pixels (one UHD TV frame size)

Frame rate: 120 frames/second (one HDTV frame rate)

Pixel Resolution: 12 bits each RGB plus 12 bits alpha (48 bits/pixel) (no HDTV standard)

RAW (uncompressed) video data requirements: (3840*2160)*120*(48) = 48 G bits/sec
(some references show 36 G bits/sec)

8K UHD RAW (uncompressed) video data requirements: 144 G bits/sec

Audio:

Sample rate: 192 K SPS (44.1 more common)

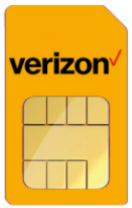
Resolution: 24 bits (16 bits or less usually adequate)

Number of Channels: 2 (Stereo)

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

- RAW video data rate approximately 5000X the RAW audio data rate
- Are RAW video data rates too large to be practical ??

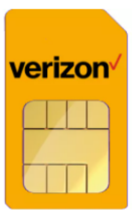
What does data really cost today (Aug 2021)?



Verizon 5GB shared data: from $55 per month

Verizon's shared data plans start with a 5GB allowance plan for $55 a month. The pric
but it's worth noting that 5GB doesn't go a long way, so if you're planning on sharing \
make sure you're both only using it for browsing and checking emails. This plan incluc
the Verizon premium network, but no streaming service or cloud storage perks.

1-line: $55/mo | **2-line:** $80/mo | **3-line:** $105/mo



Verizon 10GB shared data: from $65 per month

The second shared data plan is a 10GB option, which we'd recommend for most peop
their plan across multiple users or devices. Again, 10GB doesn't go that far, but it's a f
helping for most non-streaming tasks. This plan includes full 5G access on the Verizor
but no streaming service or cloud storage perks.

1-line: $65/mo | **2-line:** $90/mo | **3-line:** $115/mo

Effective data rates: $2/GB

How much would it cost to download a 2-hour 4K UHD TV "movie" using RAW audio and video on a Verizon Smart Phone today?

Assume Data Cost us $2/GB

(to keep reasonable bandwidth without throttling)

RAW (uncompressed) video data requirements = 48 G bits/sec

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

Total bits: 48x60x120 Gb = 346,000 Gb

Total bytes: 48x60x120/8 GB = 43,000 GB = 43 TB

Total cost: $86,000

- Moving audio and video data is still expensive and still challenging !
- Be careful about what you ask for because you can often get it!

What can be done to reduce these costs?

An example of electronic opportunities ?

Consider High Definition Television (HDTV) instead of UHD

Video:

(reduced to 24 frames/sec   32 bits/pixel)

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

An example of electronic opportunities ?

Consider High Definition Television (HDTV) instead of UHD

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

Cost for HDTV movie with compression @ $2/GB?

$$\text{Bytes} = 14\frac{\text{MB}}{\text{sec}} \text{x} 60 \frac{\text{sec}}{\text{min}} \text{x} 120 \,\text{min} = 101 \text{ GB}$$

Total cost for two-hour HDTV movie about $200

Challenge to Students

- Become aware of how technology operates
- Identify opportunities where electronics technology can be applied
- Ask questions about how things operate and why

Stay Safe and Stay Healthy !

End of Lecture 1