ECE Circuits Curriculum

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Outline

- Why ?
  - Industries with growth == Industries with jobs
  - Salary depends on sub-disciplines
- What ?
  - Context
  - Some simple circuits
- Circuits Curriculum

10 Best Performing Industries MSNBC Sept 17

Industry	% Change One Month
Catalog & Mail Order Houses	14.4%
Semiconductor - Memory Chips	12.5%
Major Airlines	11.8%
Appliances	9.5%
Processing Systems & Products	9.3%
General Entertainment	8.7%
Networking & Communication Devices	8.5%
Electronics Stores	8.5%
Food Wholesale	8.4%
Music & Video Stores	8.2%

Most Profitable – Return on Revenues (Fortune 500)

1	Mining, Crude-Oil Production	29.9
2	Internet Services and Retailing	23.8
3	Commercial Banks	18.3
4	Network and Other Comm. Equipment	15.8
5	Pharmaceuticals	15.7
6	Medical Products & Equipment	13.2
7	Securities	12.7
8	Railroads	12.5
9	Diversified Financials	12.4
10	Publishing, Printing	11.8
11	Household and Personal Products	11.1
12	Insurance: Life, Health (stock)	10.3
13	Homebuilders	9.9
14	Insurance: P & C (stock)	9.0
15	Oil and Gas Equipment, Services	8.7
16	Entertainment	8.4
17	Food Consumer Products	8.4
18	Electronics, Electrical Equipment	8.2
19	Food Services	8.0
20	Computers, Office Equipment	7.5
21	Health Care: Insurance & Managed Care	7.1
22	Hotels, Casinos, Resorts	6.8
23	Industrial & Farm Equipment	6.6
24	Apparel	6.5
25	Petroleum Refining	6.1
26	Utilities: Gas & Electric	6.0
27	Chemicals	5.8
28	Metals	5.6
29	Beverages	5.3
30	Information Technology Services	5.1
31	Aerospace and Defense	4.9
32	Health Care: Medical Facilities	4.6
33	Telecommunications	4.2
34	General Merchandisers	4.1
35	Specialty Retailers	4.0
36	Semi. and Other Electronic Components	3.9
37	Energy	3.0
38	Food Production	2.8
39	Health Care: Pharmacy & Other Services	2.8
40	Wholesalers: Diversified	2.3
41	Engineering, Construction	2.2
42	Wholesalers: Food and Grocery	2.1
43	Food & Drug Stores	1.6
44	Pipelines	1.4
45	Wholesalers: Electronics & Office Equip.	1.4
46	Wholesalers: Health Care	1.3
47	Automotive Retailing, Services	1.1
48	Motor Vehicles & Parts	1.1
49	Packaging, Containers	0.4
50	Airlines	-10.6

Compare Salaries with other sub-disciplines

- IEEE USA Salary Service
- Computer Hardware: 0%
- Applied Physics: 0%
- Computer Software: 0%
- Signals and Systems: 0%

- Solid State Circuits: +7%

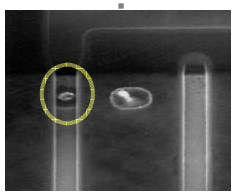
Why study circuits ?

- Some circuits faculty and their cars

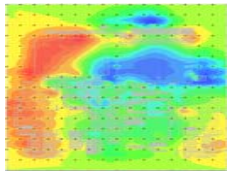
Circuits in Context I

Materials Science & Applied Physics | **Electrical Engineering** | **Computer Engineering** | **Computer Systems**

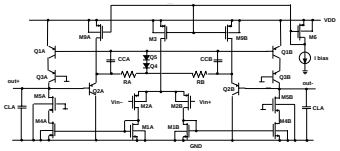
Si System Implementation Spectrum



Modeling & Testing

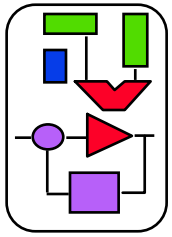


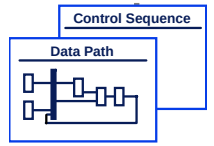
Modeling & Analysis



Circuits

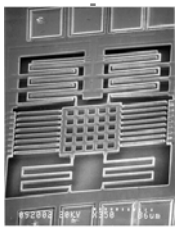
Systems & Architecture



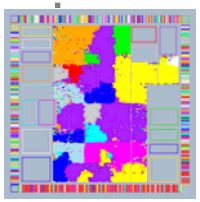


H/S Codesign

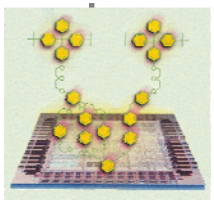
Manufacturing



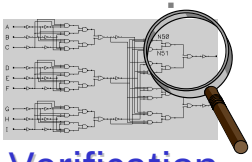
MEMS



Design Automation



Nanotechnology

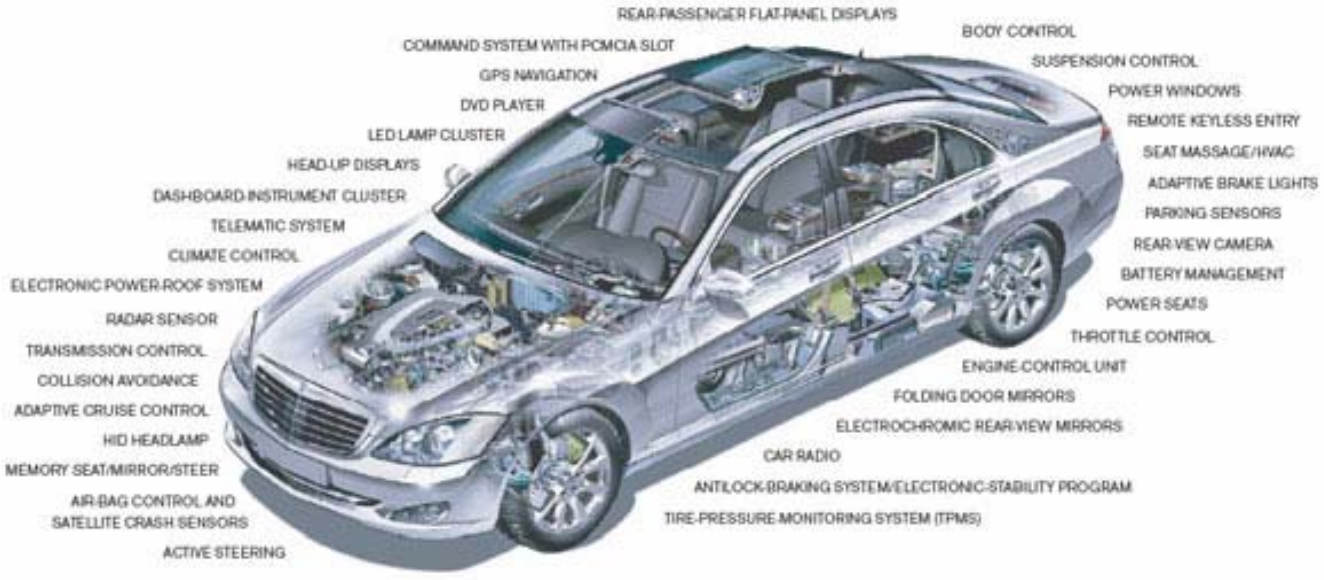


Verification

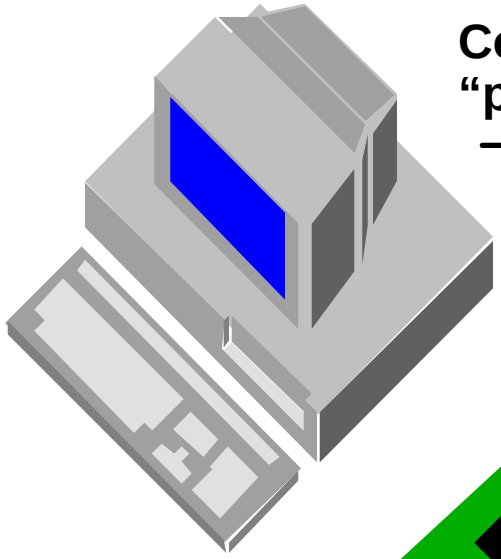
Electronic Circuits in Context II

- Electronics: Gadgets based on electronic circuits

- Electronics also important for other industries (e.g. auto)

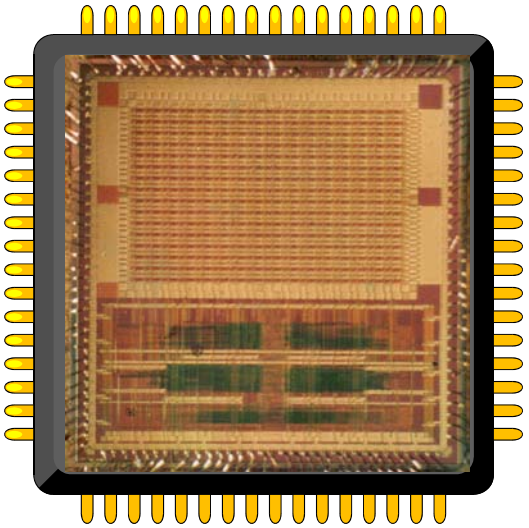


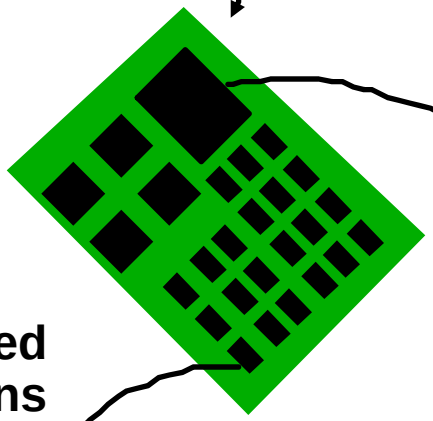
Circuits in Context III: View from Comp. HW



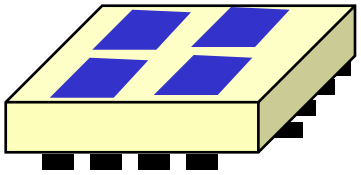
Computer system
"pizza box"

…implemented
as a digital system
on a big circuit board

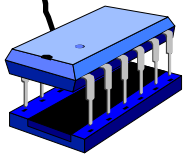




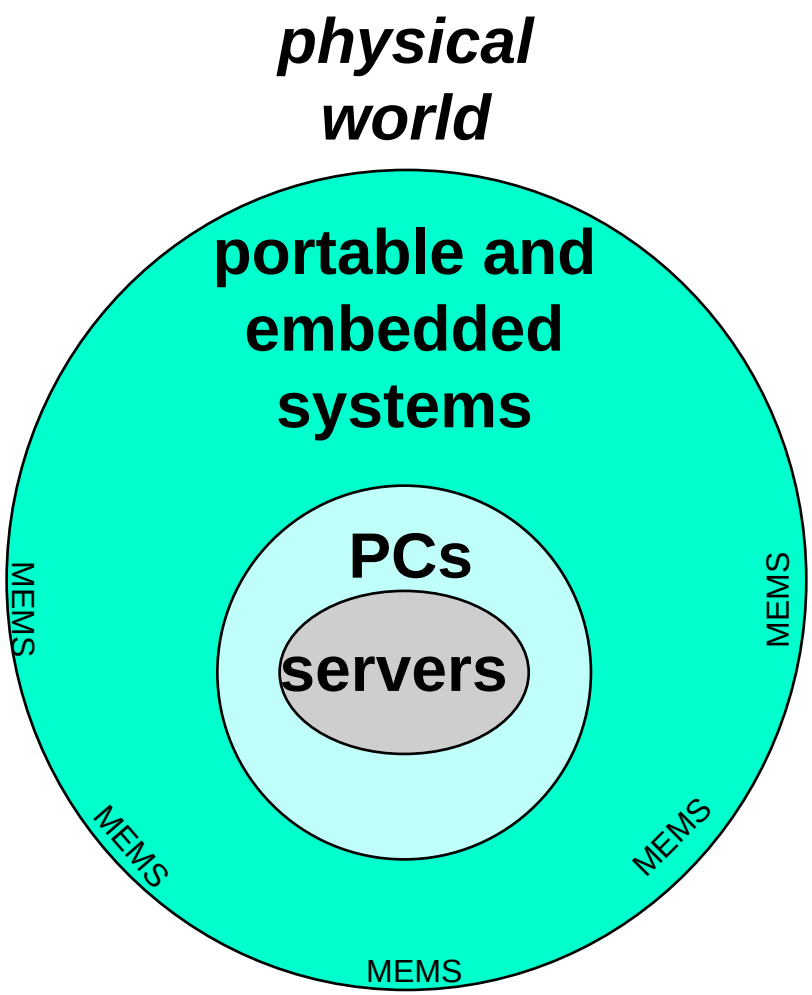
…implemented as atomic
subsystems (e.g. CPU)
on complex packages like
"multichip modules"



…implemented
as digital functions
on individual chips



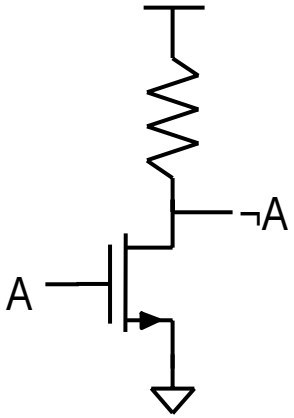
Circuits in Context IV: View from Circuits



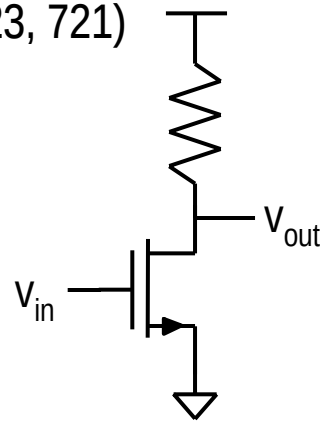
- Increasing number of information systems in our lives
- Embedded in larger systems that need to sense and act as well as compute
- Creating demand for greater diversity of interaction with the physical world
  - mechanical
  - electromagnetic
  - chemical and biological
  - optical
- Need MEMS sensors & actuators
- And Circuits interface to Digital Info World

Some Simple Circuits

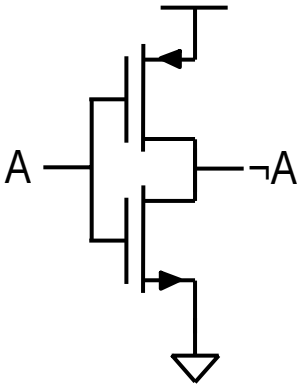
- NMOS Inverter (322, 722)



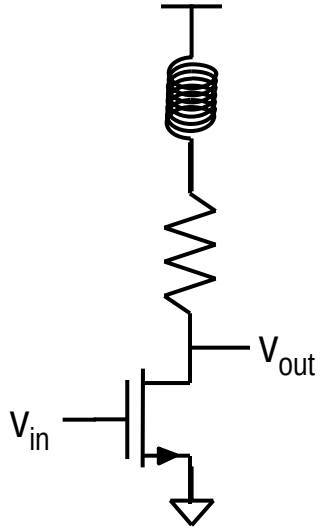
- Common Source Amplifier (321, 623, 721)



- CMOS Inverter (322, 722)



- RF Low Noise Amplifier (723)

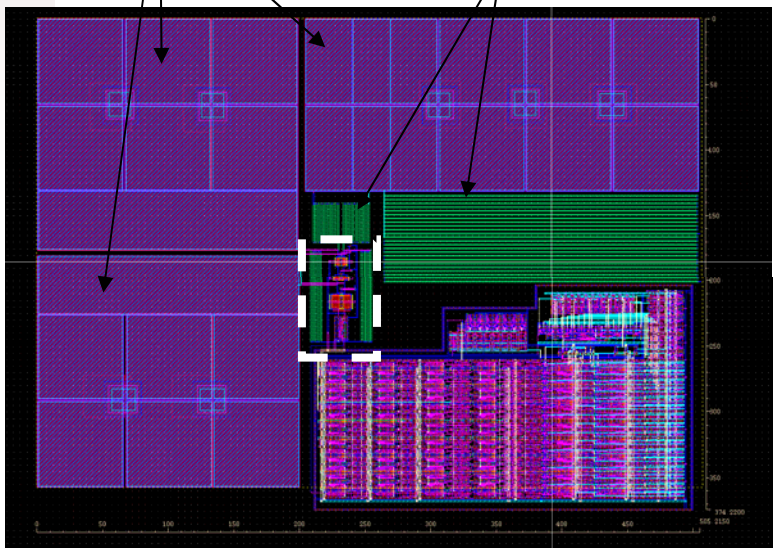


Layout Interface to Manufacturing

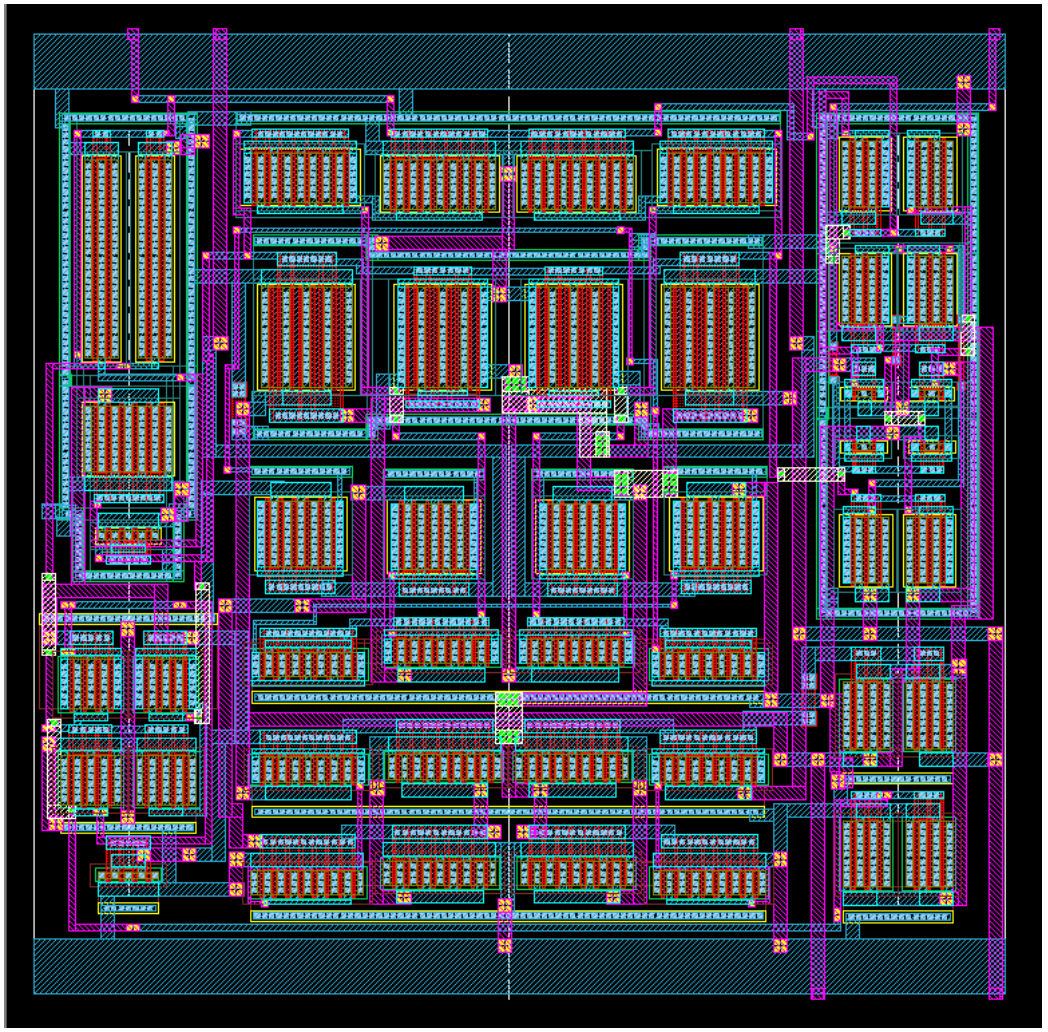
- Red over Green
  == Transistor

Capacitors

Resistors

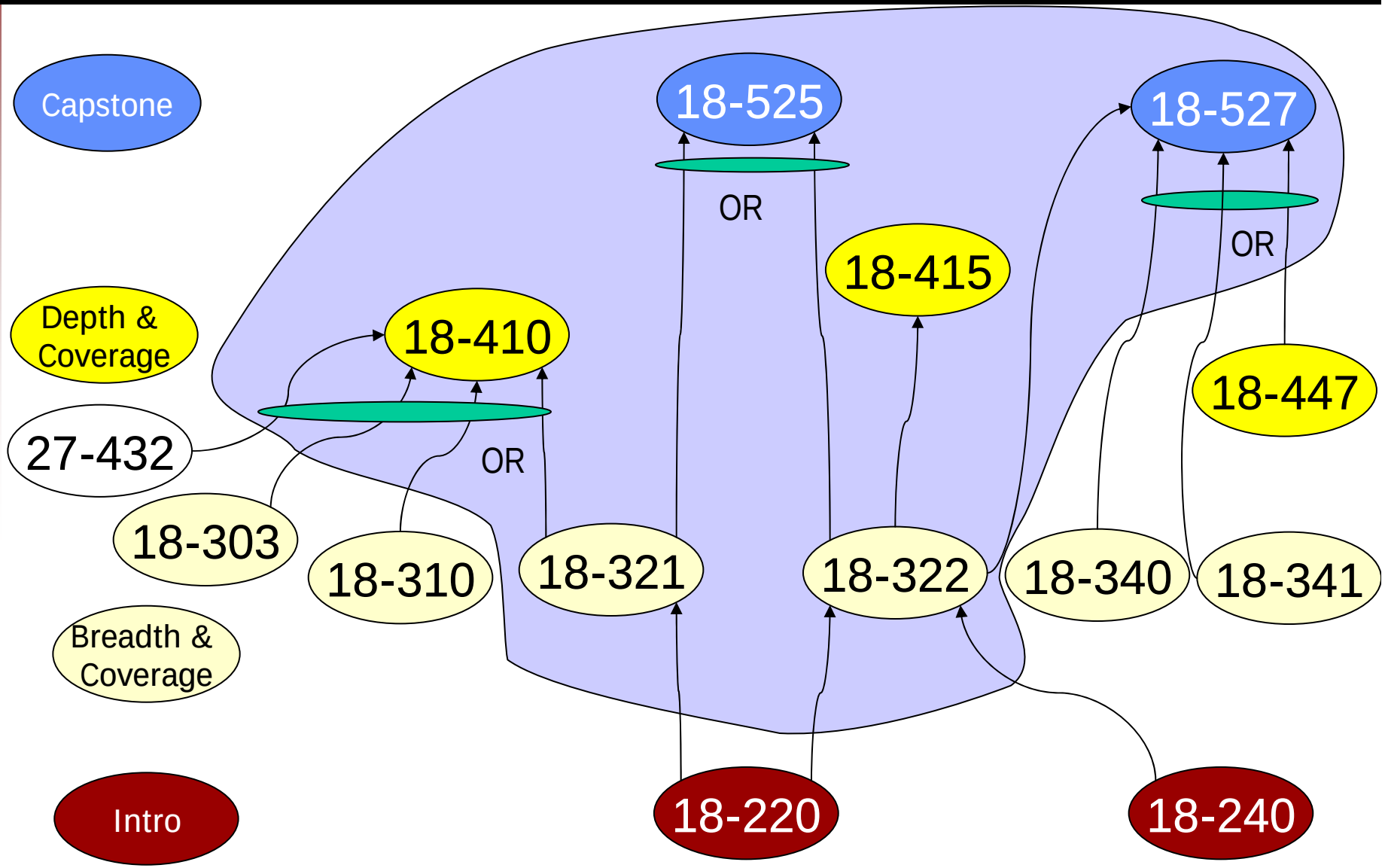


Sigma Delta Converter

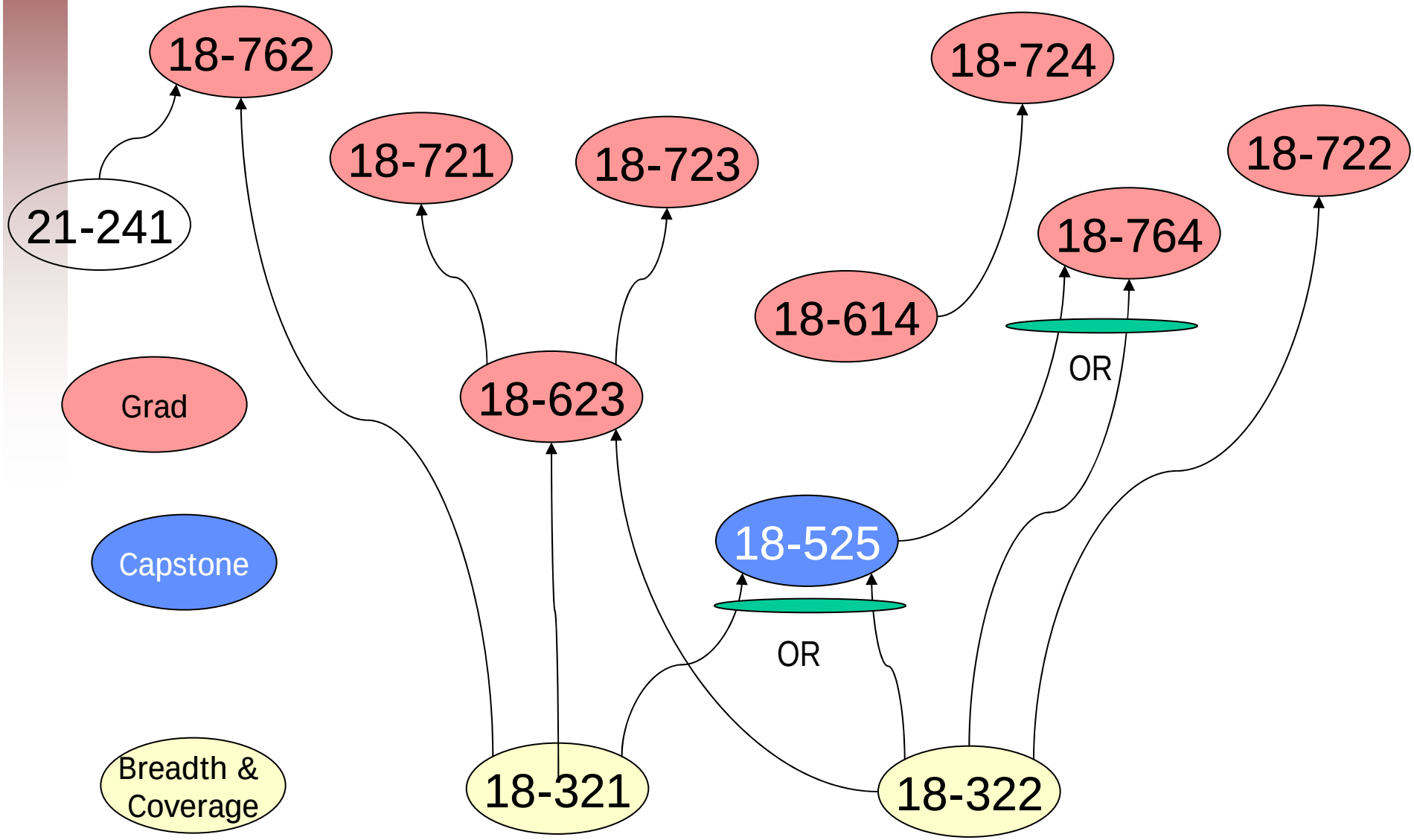


50 transistor fully differential OpAmp

Pre-requisite Tree: Undergraduate



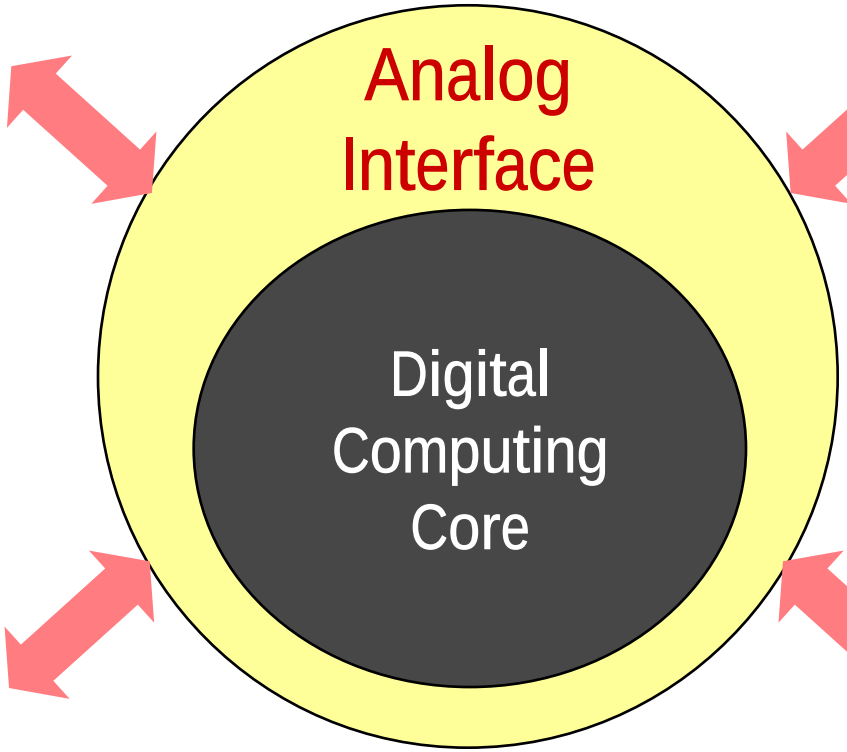
Pre-requisite Tree: Graduate



18-321: Analysis & Design of Analog ICs

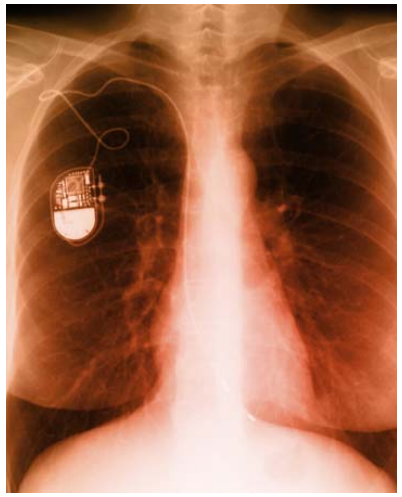
Telecom

Consumer



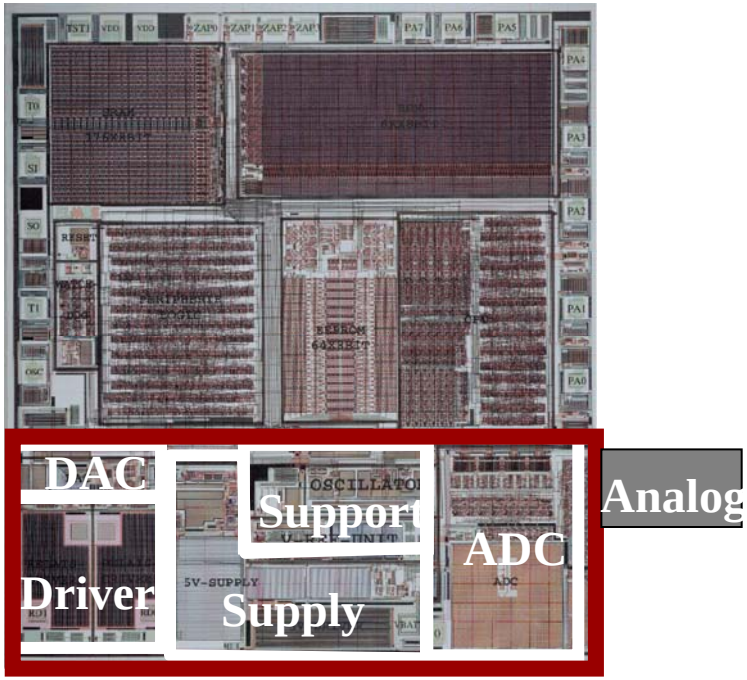
Automotive

Medical



Modern Systems have
Analog Interfaces

18-321: Analysis & Design of Analog ICs

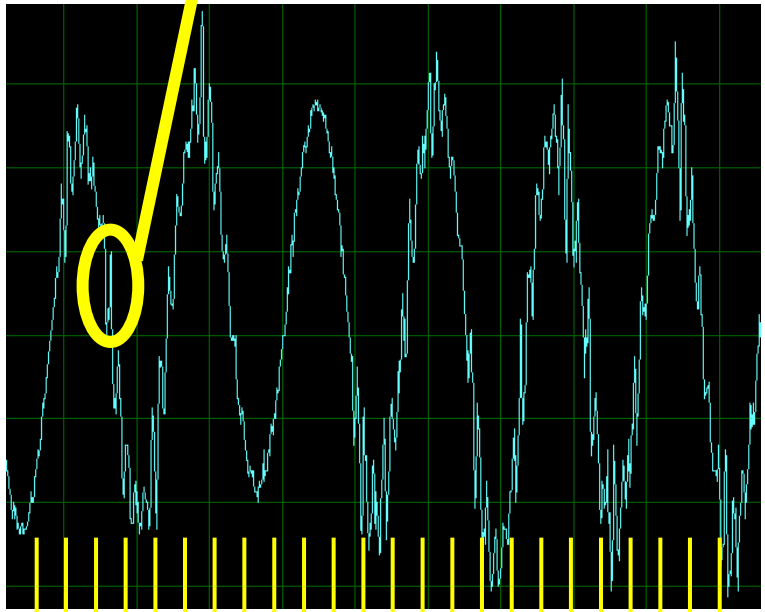


Automotive IC

- Lots of nominally digital circuits are really doing analog things today

- Analog Circuits connect to, manipulate continuous-valued, arbitrary signals

Bits are *bumps* on sine waves

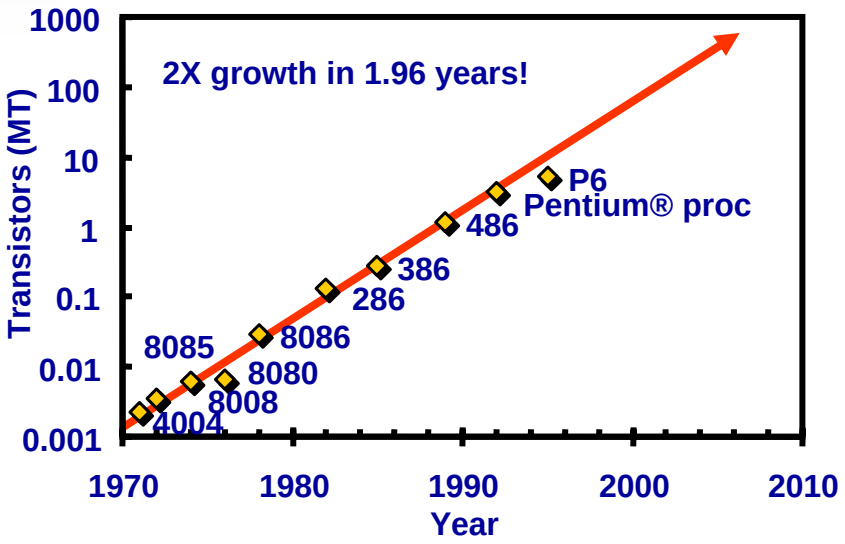


10101010101010101010101

Courtesy Jim Bain CMU

18-322: Analysis & Design of Digital ICs

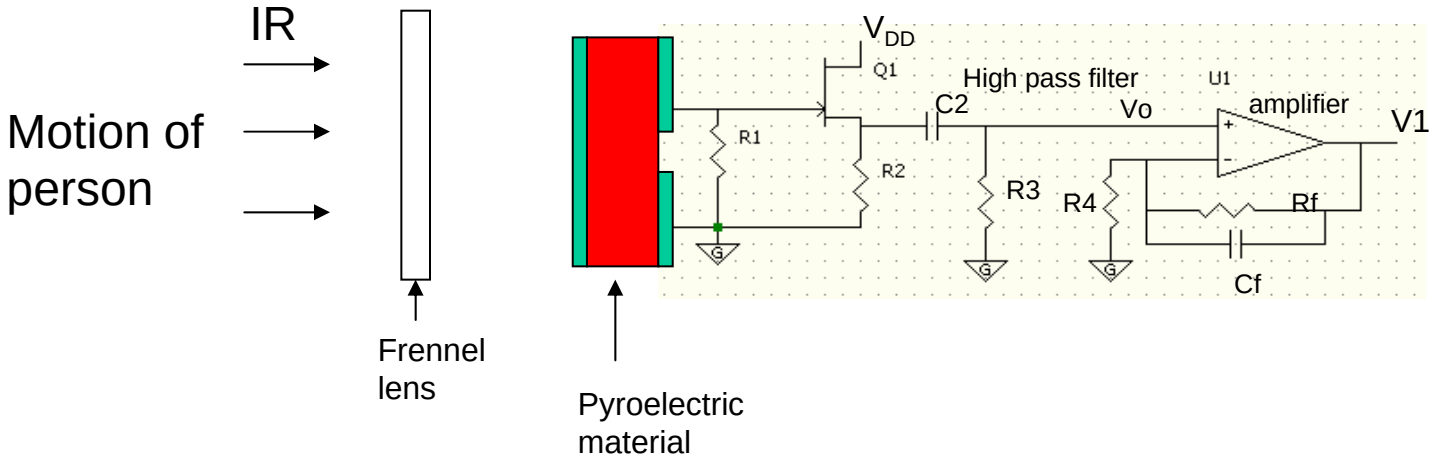
Independently invented by Jack Kilby and Robert Noyce, the integrated circuit was first available commercially in 1961. It led to smaller, inexpensive, mass-produced electronic circuits, revolutionizing the computer industry.



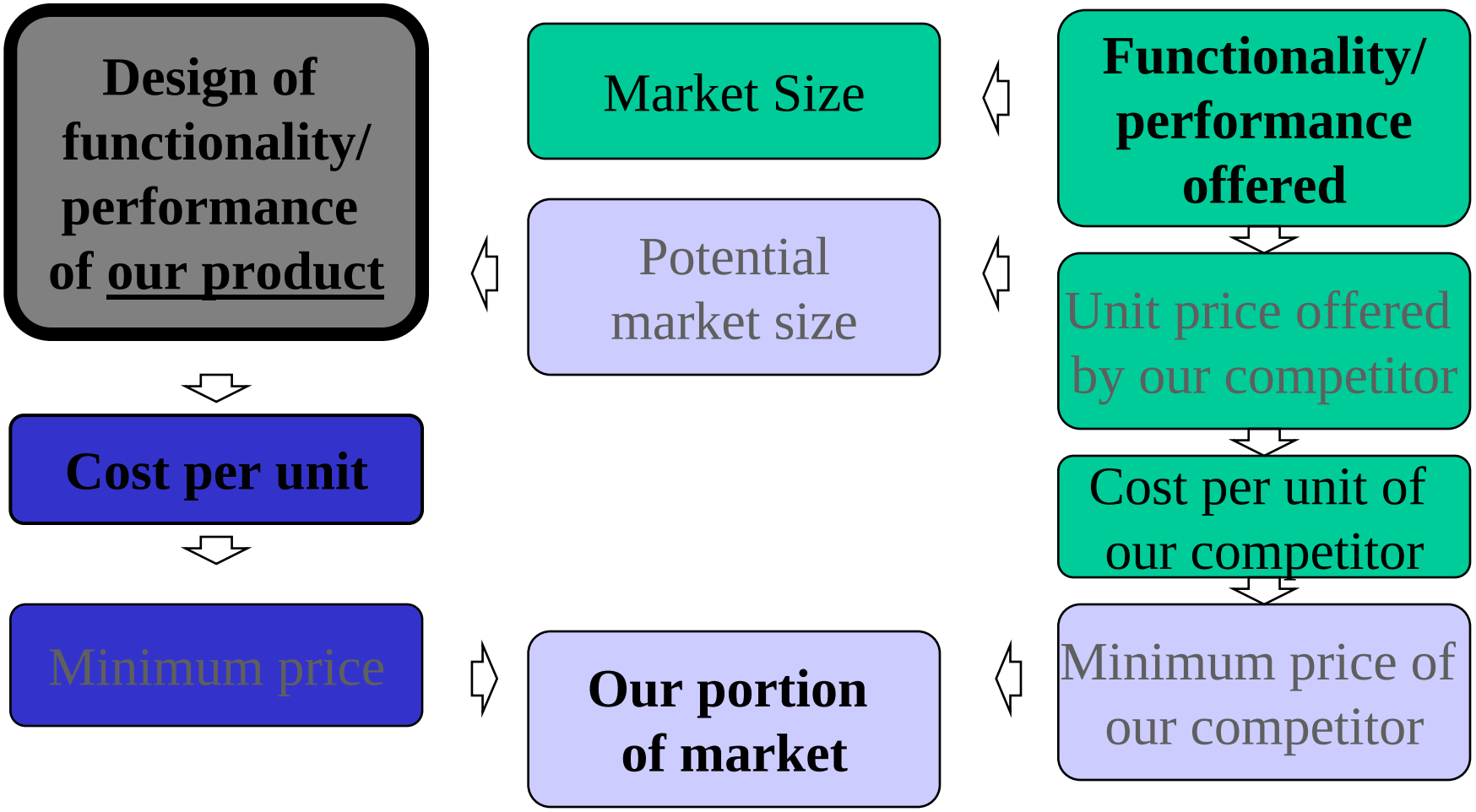
- Design the circuit and layout for a "chip"
  - Understand, design, and optimize digital ckts
  - Metrics speed, area, power dissipation, etc.
  - Use CAD tools. Full custom design flow
- Analysis & design of digital components and interconnect
  - Random logic, registers, arithmetic circuits…
  - Understand and use CMOS technology (transistor models & interconnect parasitics)
- Bottom line: You'll realize that there is much more than 0's and 1's in digital design!

18-410: Physical Sensors, Transducers and Instrumentation

- "There are many many sensor technologies ..... which is best to use?
- Taught both via the 'case method' and via student projects
- How various technologies work and when to apply them to various applications
- Analyze application requirements and understand device physics and technology limitations
- Students select, and report upon, sensor systems of their choice.
- Example: Optical sensor technology
  - Pyroelectric: Motion sensors…temperature monitor



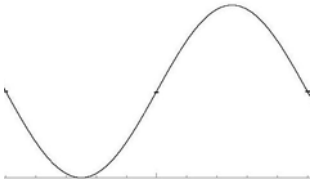
Problem to be solved in 18-415



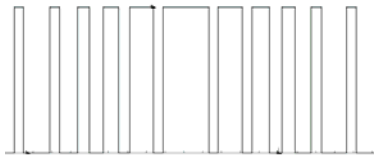
DESIGNED Computed "Invented" "Discovered"

18-525: IC Design Project

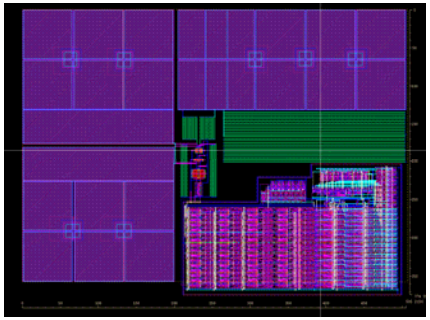
- Example Spring 2006 project: ADC for Digital Voice Processor



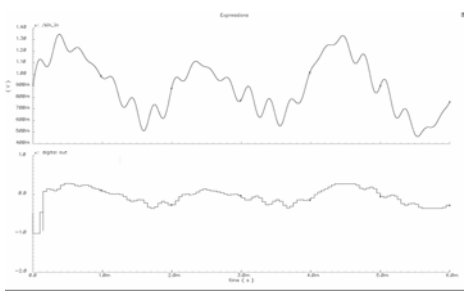
Analog Voice Input



Digitized Signal



Final Layout

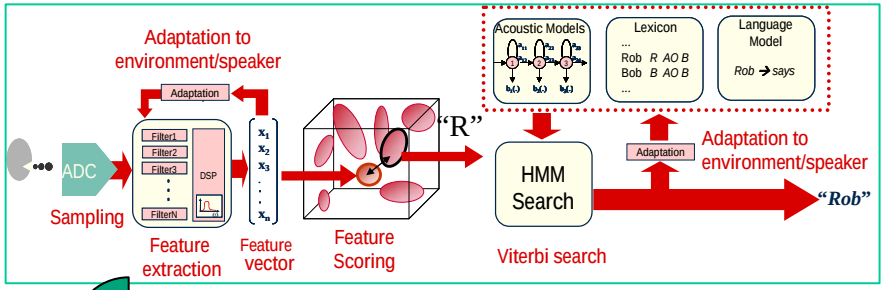


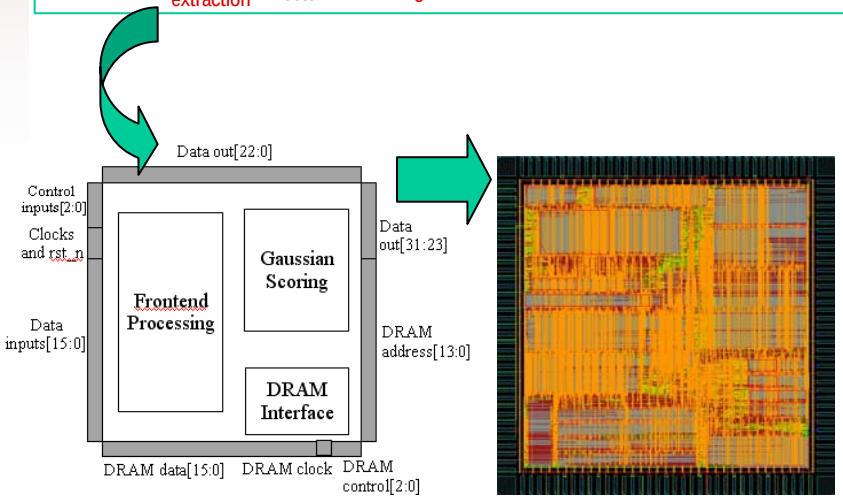
Verification waveforms

- Capstone design class for VLSI *transistor-level* design
  - Analog, Digital, RF, MEMS
  - ~20,000 transistors
- Take a large, realistic application and translate it into silicon
  - Verilog design/simulation
  - Logic design
  - Floorplanning / Layout design
  - Extraction and verification
  - Speed, timing, power optimization

18-527: Advanced Digital IC Design

- Spring 2006 project: components of silicon speech recognizer chip

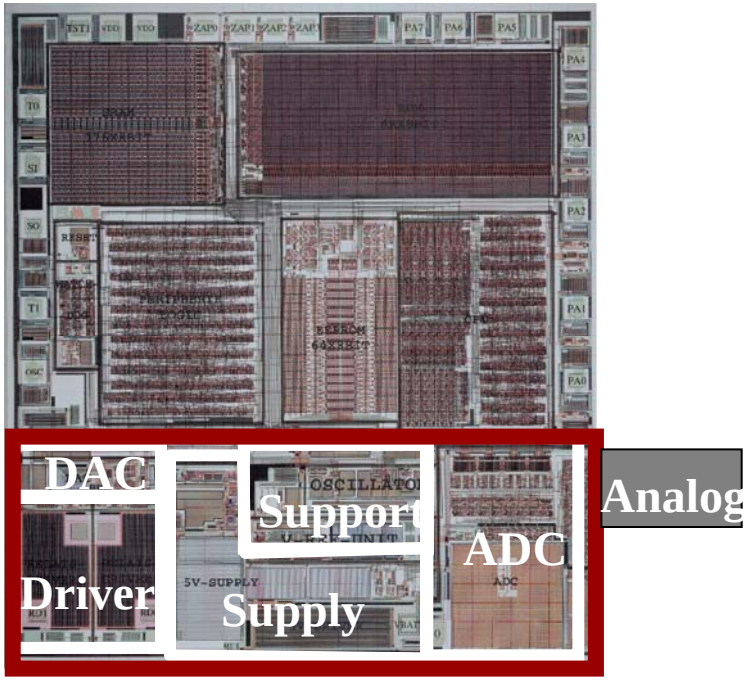




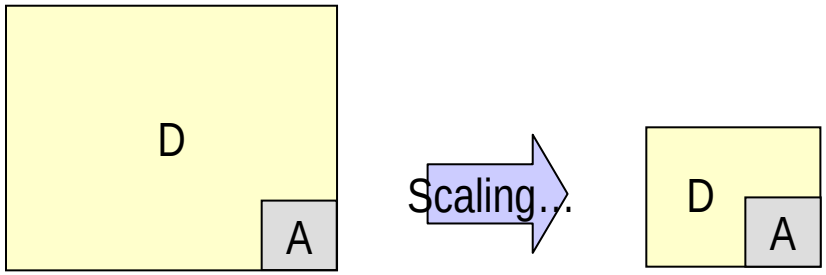
Floorplan Final Layout

- Capstone design class for VLSI *system-level* design
  - Less about transistors, more about large-scale logic, memory
  - 100,000+ gate, 1Mb+ designs
- Take a large, realistic application and translate it into silicon
  - RTL/Verilog design/simulation
  - Logic synthesis
  - Layout synthesis
  - Speed, timing, power optimization

18-623: Analog Integrated Circuit Design



- Unlike 321 focus heavily on design
- Individual design problems (not a capstone – no team)



Automotive IC

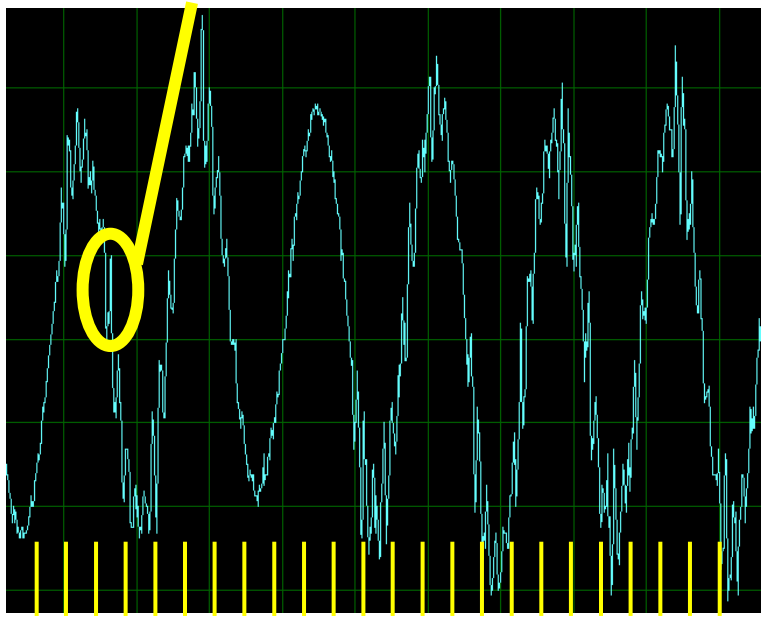
- 623 is
- Review of 18-321, plus
- CMOS layout from 18-322 plus
- Analog Design in digital IC technology

- Scaling Challenges
  - Reduced VDD
  - Increased Variations

18-721: Advanced Analog VLSI Design

- Analog Filtering & Data Conversion

Bits are *bumps* on sine waves



Courtesy
Jim Bain
CMU

- Tremendous market
  - Data Converters: 15% growth rate

18-722: Advanced Digital VLSI Design

Advanced transistor-level design of digital logic

- Design of logic gates and clocked sequential elements
- Design of arithmetic units and memories
- Clock and power distribution
- Low power design
- Variability and signal integrity

Logistics

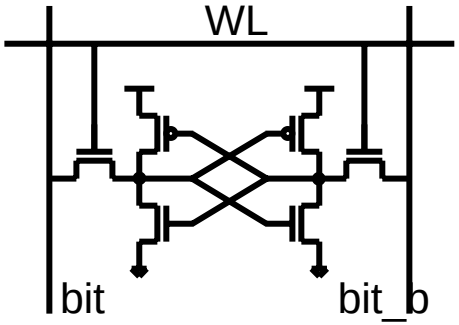
- Problem sets, midterm, project
- Pre-requisite = 18-322 (18-525 recommended)
- Typically 2/3 grad, 1/3 undergrad

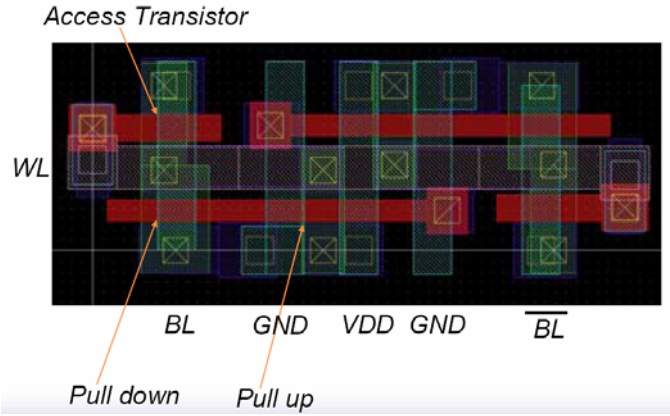
Tools

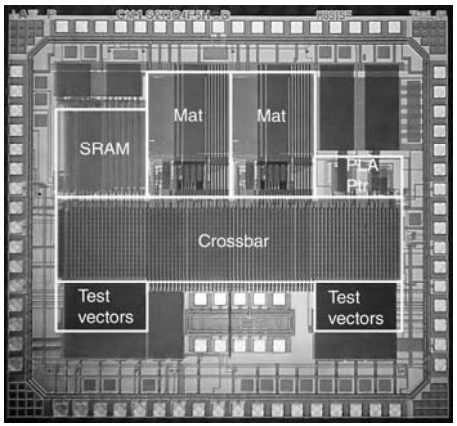
- Schematic capture (Composer)
- Transistor-level simulation (Spectre, HSIM)
- Some HDL (Verilog) and some layout (Virtuoso)

Project

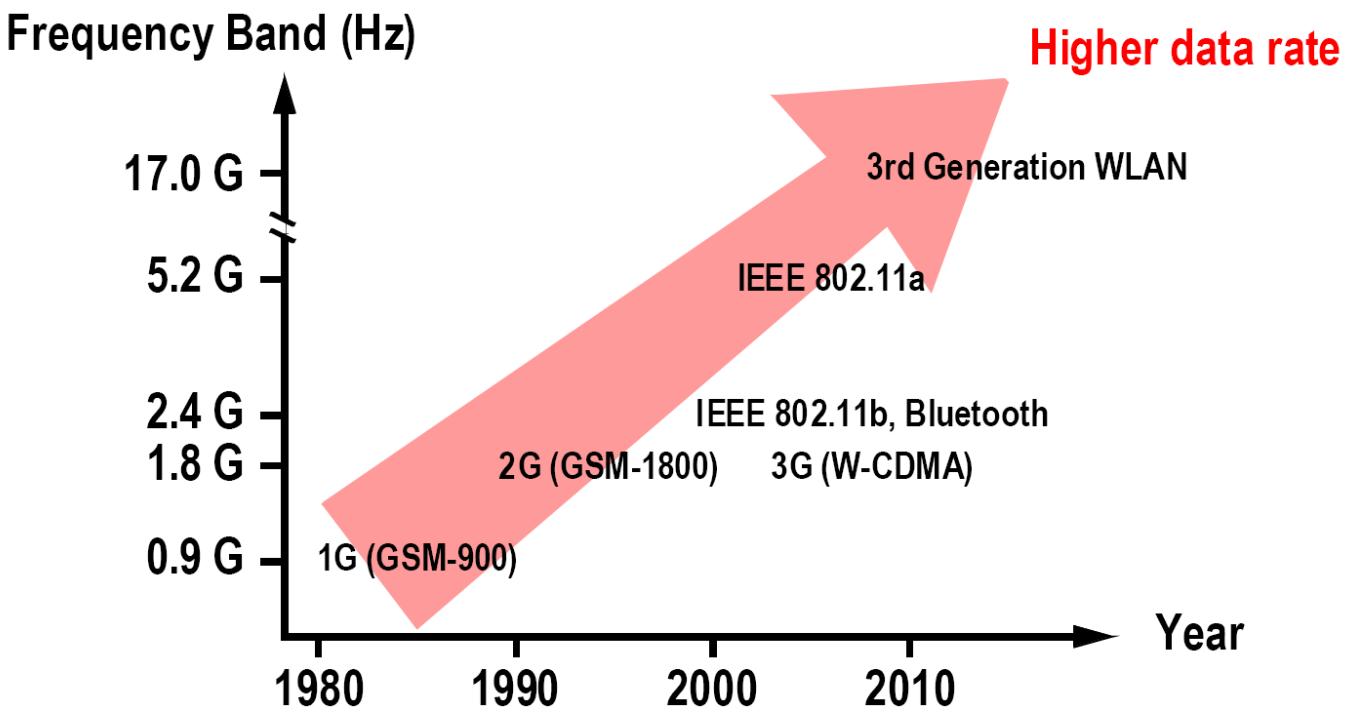
- Design of a large microprocessor sub-block
- 1Mb SRAM
- 64b integer adder







18-723: RF Integrated Circuit Design



- Tremendous market
  - Cellular phones: 15% growth rate
  - Wireless LAN cards: 40% growth rate

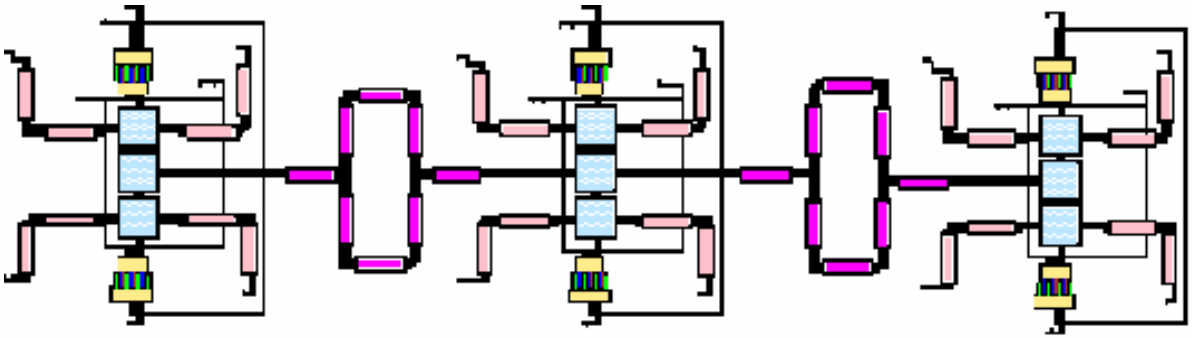
18-724 Microelectromechanical System Design

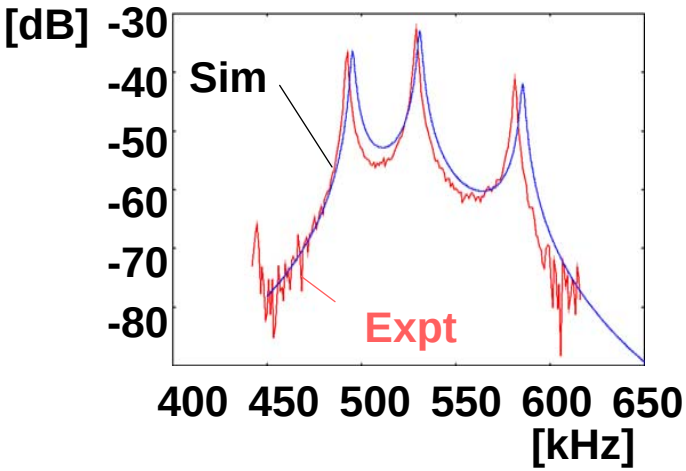
- Sensors and Actuators
- Integrated directly in CMOS
- Mechanical Design on a chip
- Readout Circuit Design

- Logistics
  - Problem sets, midterm, project
  - Pre-requisite = 18-614 (18-623 recommended)
  - Typically 90% PhD, 10% IMB

- Tools
  - Schematic capture (Composer)
  - Transistor-level mechanical simulation (Spectre)
  - Some HDL (Verilog-A) and some layout (Virtuoso)

- Project: e.g. high-Q mechanical filter design





Summary

- Electronics increasingly a part of our life
- IC Design (Solid State Design) has tremendous growth
- Lots of jobs especially in Analog and RF (for IMB)
- Higher salaries than your peers