Lecture 2: Technology

Thursday, January 11, 2018 3:35 PM

Announcements

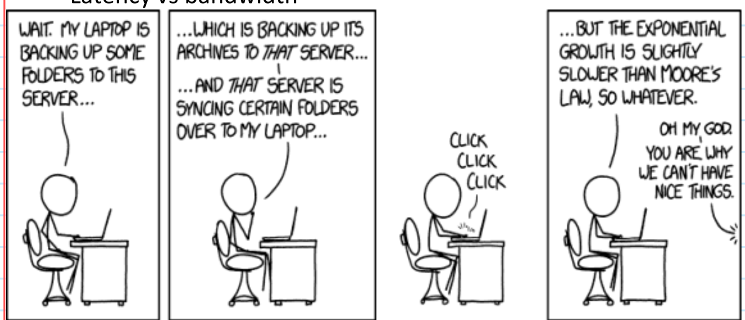
Lab 1 on github

- Minor update for grading

HW 1

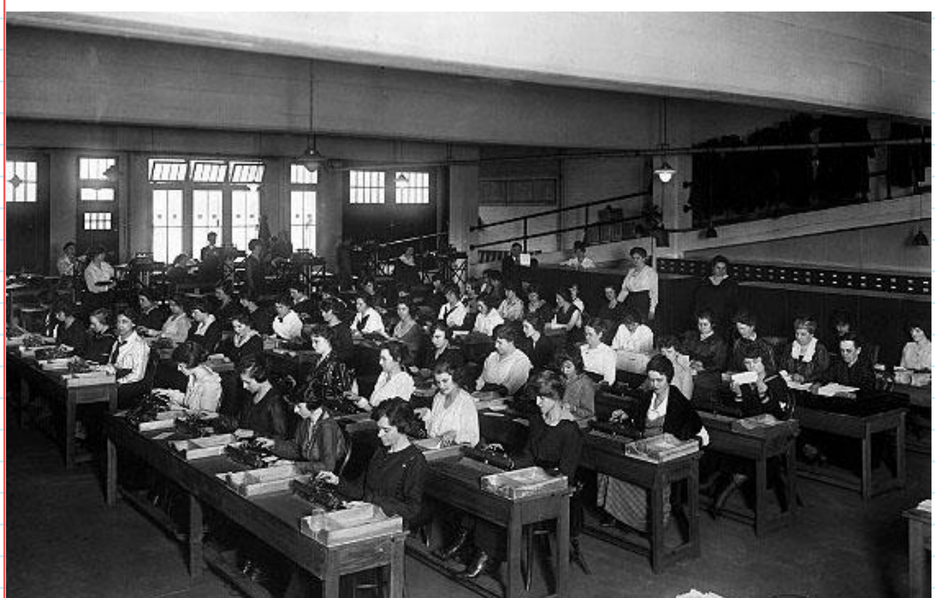
Outline

- History
- Moore's Law & Dennard Scaling
- Energy/Power of CMOS devices
- Technology trends
  - Transistor
  - Integration
- Latency vs bandwidth

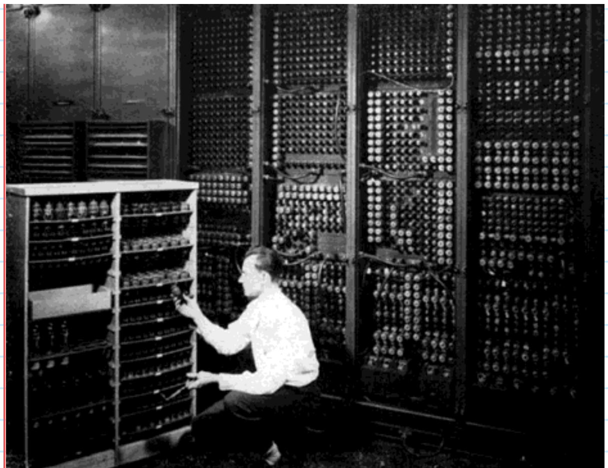


History

What did the first computers look like?



Technological change: Electronic computers



ENIAC: Vacuum tubes

Vacuum tubes → ~1000 ft^3

transistors → 10 ft^3 3 ft^3

100

1000

Power

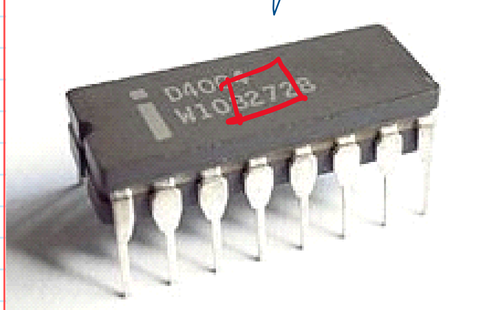
ENIAC → 160 KW

→ 100W

TRADIC: Transistors

CMOS transistors

Intel 4004



Transistors?

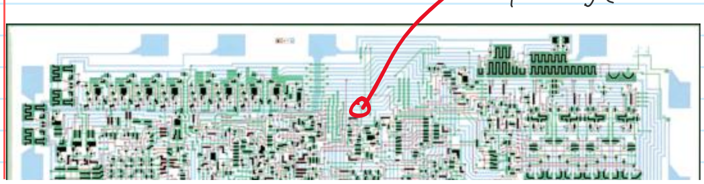
transistor
~10 μm

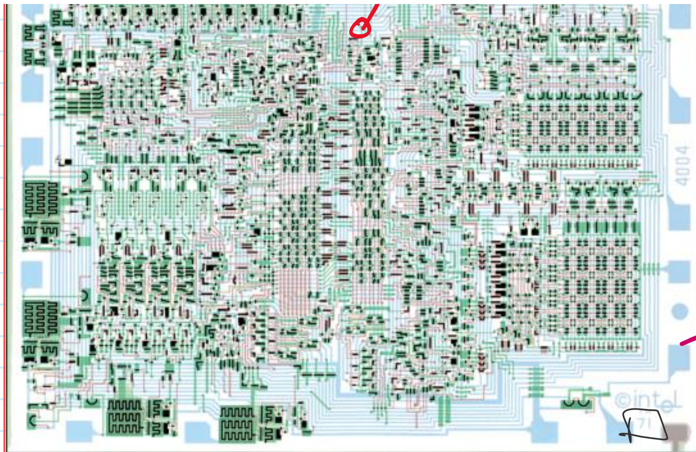
Intel 4004

1 billion

1000

4004



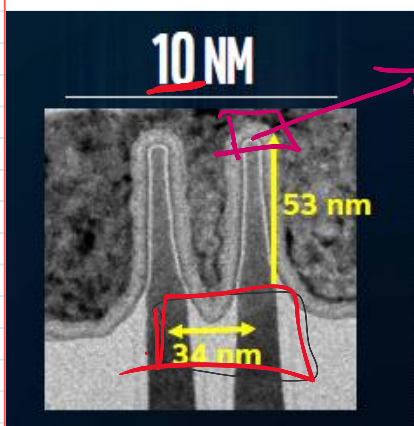


1000

4004

2300 transistors

Today



printing resolution

up

light → 180nm

20nm

core

AMD Threadripper
Transistors?

10 billion

1 trillion

100 million

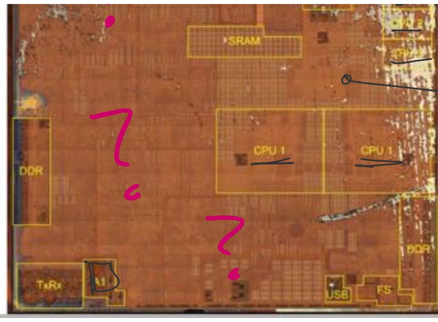
100, 000

?

SoC

System on a chip

~14



Chip

~14nm

Apple A11 in the iPhone 8 & X
Transistors?

4.3 billion

Moore's Law

Cramming More Components onto Integrated Circuits

'68

GORDON E. MOORE, LIFE FELLOW, IEEE

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65 000 components on a single silicon chip.

The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.

Integrated circuits will lead to such wonders as home computers—or at least terminals connected to a central computer—automatic controls for automobiles, and personal portable communications equipment. The electronic wristwatch needs only a display to be feasible today.

But the biggest potential lies in the production of large systems. In telephone communications, integrated circuits

Each approach evolved rapidly and converged so that each borrowed techniques from another. Many researchers believe the way of the future to be a combination of the various approaches.

The advocates of semiconductor integrated circuitry are already using the improved characteristics of thin-film resistors by applying such films directly to an active semiconductor substrate. Those advocating a technology based upon films are developing sophisticated techniques for the attachment of active semiconductor devices to the passive film arrays.

Both approaches have worked well and are being used in equipment today.

an observation not a law
↳ economics

What is Moore's Law?

Double transistors per area every 12 mo.
↳ 18
24

Technology growing exponentially
Double speed every 18 months

Driver behind Moore's Law: Dennard Scaling

Table 1
Scaling Results for Circuit Performance

Device or Circuit Parameter	Scaling Factor
Device dimension t_{ox}, L, W	$1/\kappa$
Doping concentration N_a	κ
Voltage V	$1/\kappa$
Current I	$1/\kappa$
Capacitance $\epsilon A/t$	$1/\kappa$
Delay time/circuit VC/I	$1/\kappa$
Power dissipation/circuit VI	$1/\kappa^2$
Power density VI/A	1

reduce transistor size
" " power
increase speed

$\sqrt{2}$

implication ⇒ same unit area
double transistors
go faster
use the same power

Energy and power of CMOS

How does power and energy relate?

Power

Energy

How does power and energy relate?

Power	Energy
consuming over time	cost
cool	carbon footprint
power input	finite
	Battery

Energy = $P \cdot t$

= static + dynamic

Static energy: ~~As~~ smaller transistors more leakage

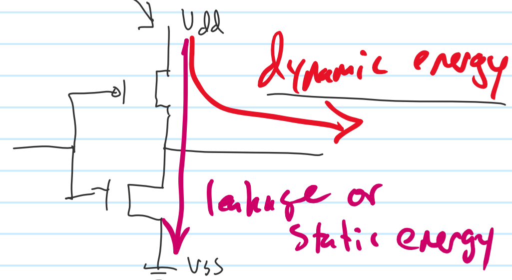
Dynamic energy:

$E = c\,V^2$ → voltage

↳ capacitance → how many transistors

Power =

→ $P = \frac{1}{2} c\,V^2 \cdot f$ → frequency

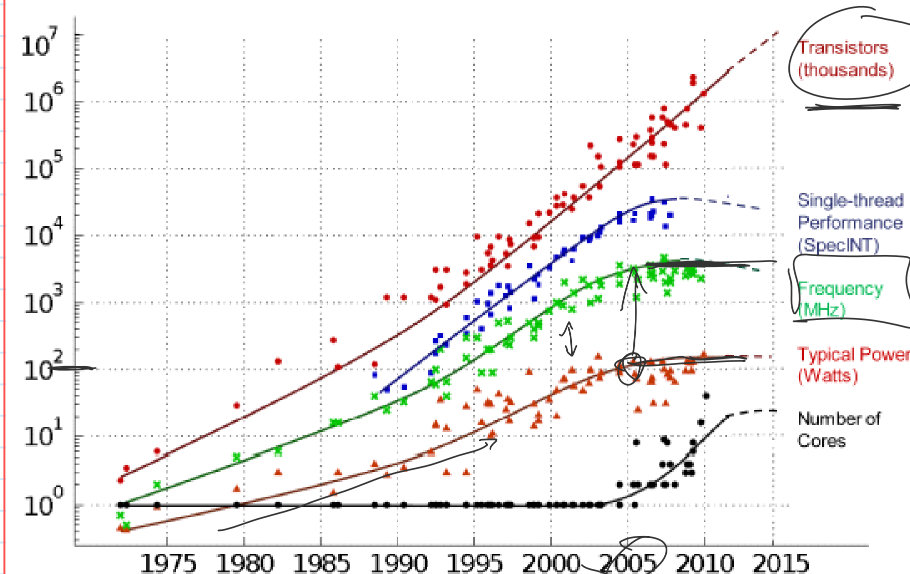


What is the most effective way to reduce (dynamic) power?

lower voltage has biggest effect on power

Trends

35 Years of Microprocessor Trend Data



→ Moore's law

→ faster transistors

100W power wall
150W

$P = \frac{1}{2} C\,V^2\,f$

reduction in voltage → no longer able to reduce voltage

"solution" → multicore → hard to program

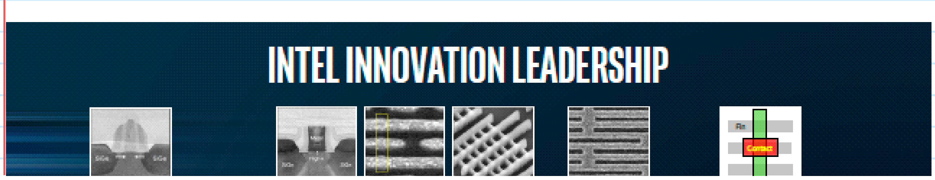
" → specialization

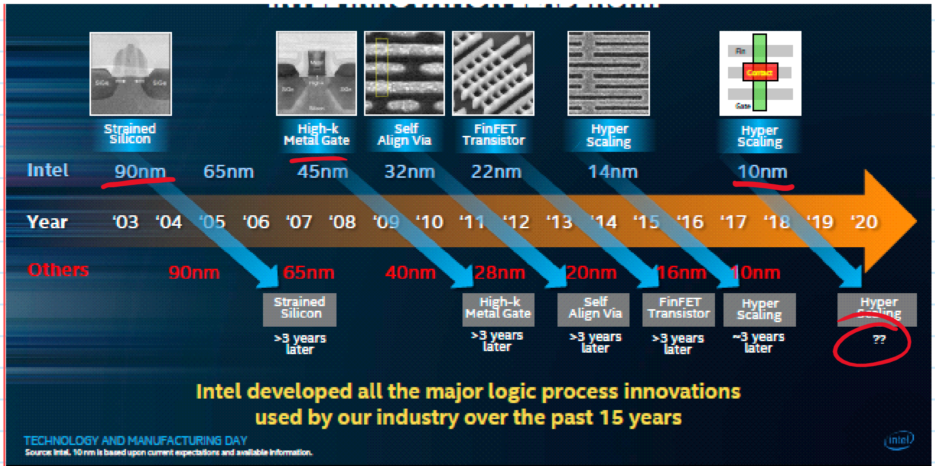
→ Dark silicon → Dim silicon

Slides from Intel

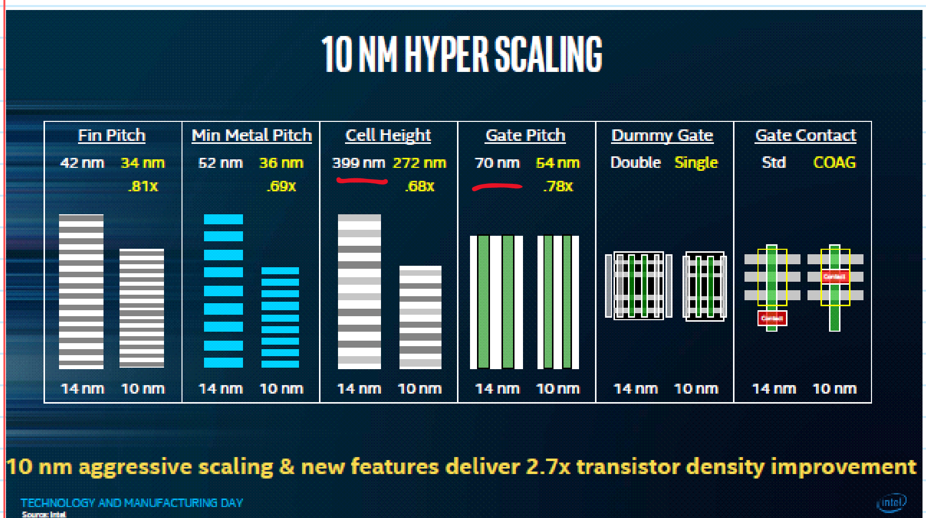
Chips are manufactured at a fabrication plant or Fab

5 ish

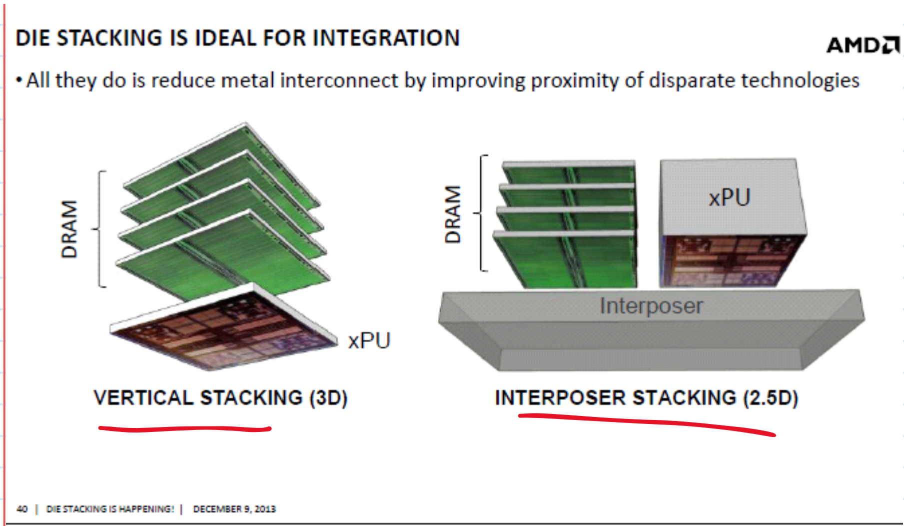


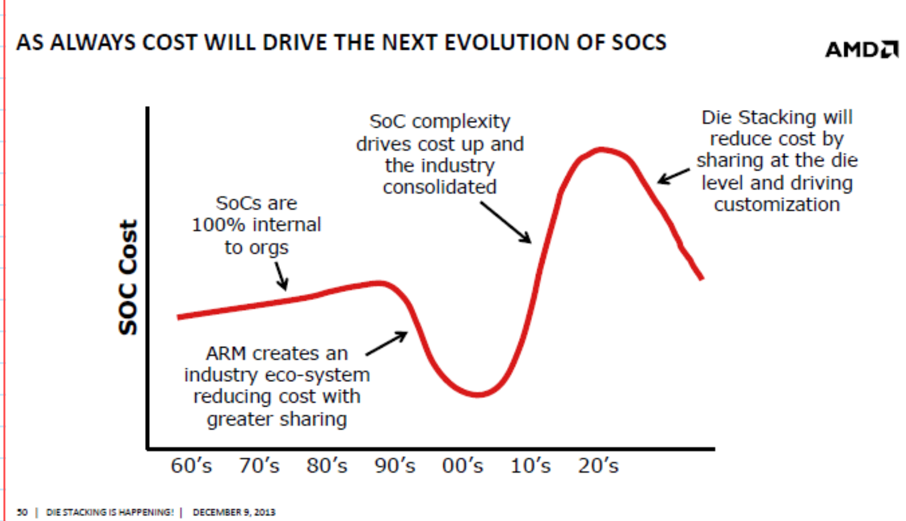


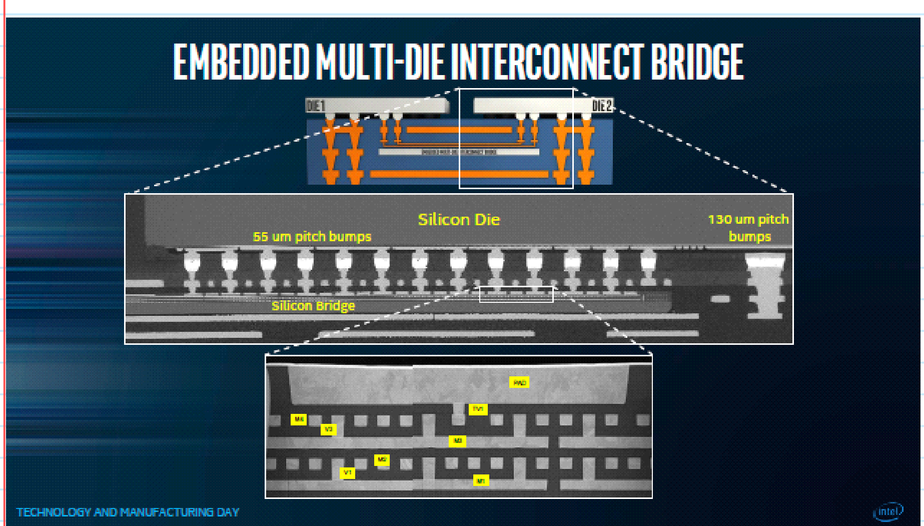
5 ish



Other trends







Latency vs bandwidth: Moving data around

[Grace Hopper - Nanoseconds](https://youtu.be/JEpsKnWZrJ8)
SeHouMusic

https://youtu.be/JEpsKnWZrJ8

Trends

Bandwidth:

Latency:

Little's Law: