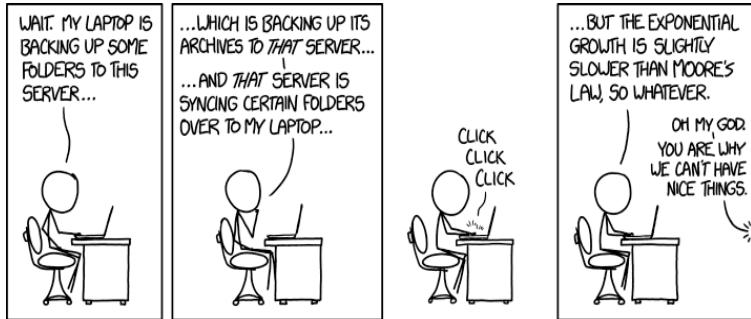


Lecture 2: Technology

Wednesday, January 9, 2019 7:45 AM

Outline

- Turing Lecture
- Moore's Law and Dennard Scaling
- Energy/Power of CMOS devices
 - Transistor
 - Integration



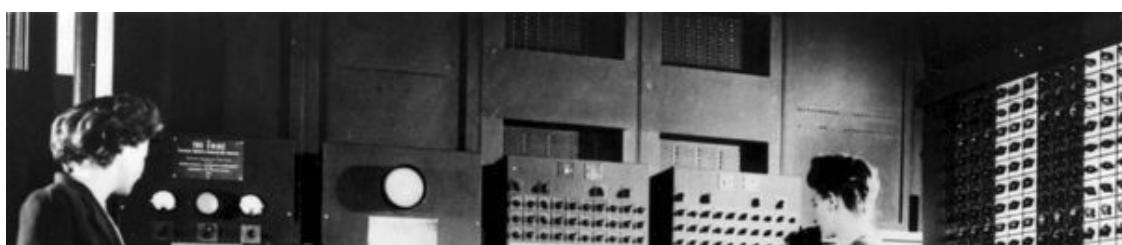
Turing Lecture

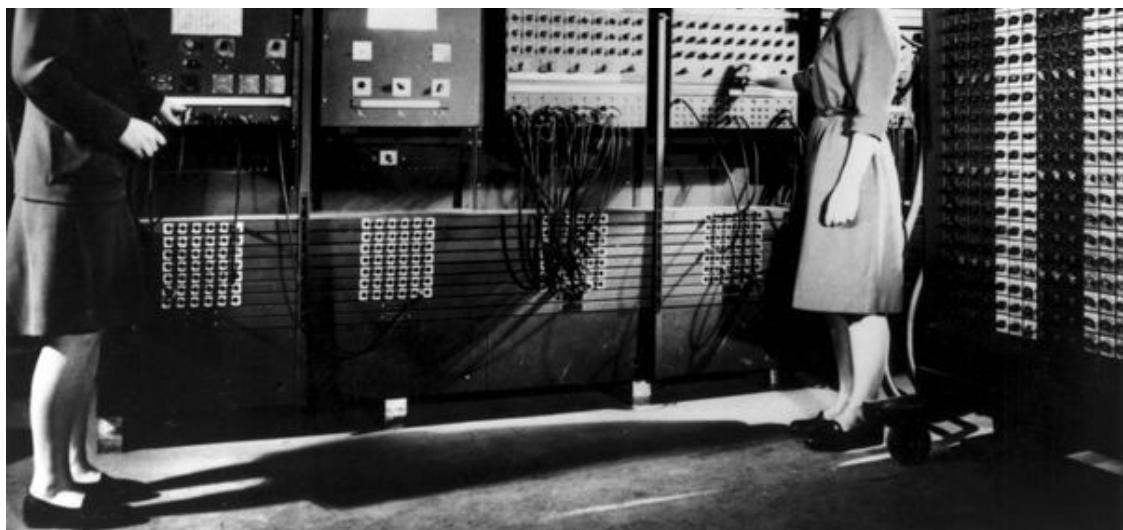
Conclusion: A New Golden Age

- End of Dennard Scaling and Moore's Law
⇒ architecture innovation to improve performance/cost/energy
- Security ⇒ architecture innovation too
- Domain Specific Languages ⇒ Domain Specific Architectures
- Free, open architectures and open source implementations
⇒ everyone can innovate and contribute
- Cloud FPGAs ⇒ all can design and deploy custom "HW"
- Agile HW development ⇒ all can afford to make (small) chips
- Like 1980s, great time for architects in academia & in industry!

History

- The first computers?



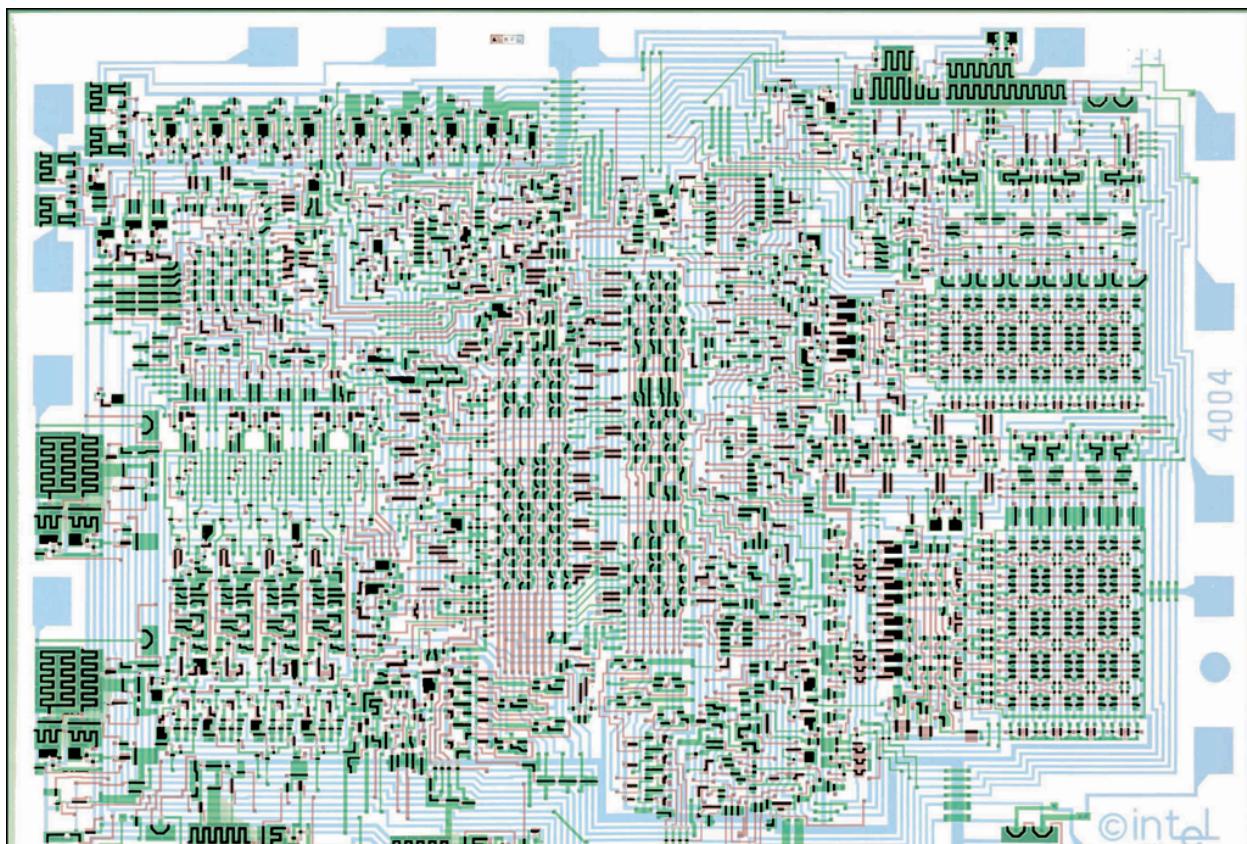


ENIAC: Vacuum tubes (<https://www.computerhistory.org/revolution/birth-of-the-computer/4/78/317>)

<https://d34zi8nxray0rk.cloudfront.net/102695698-01-480.mp4>

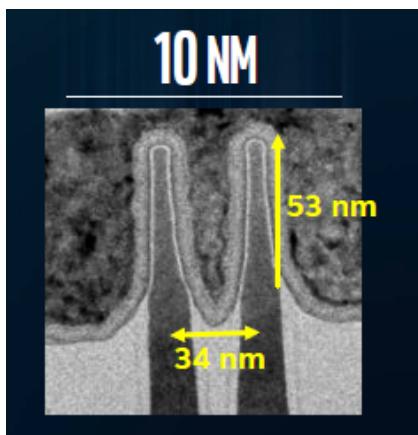
Intel 4004

Integrated circuits: CMOS transistors

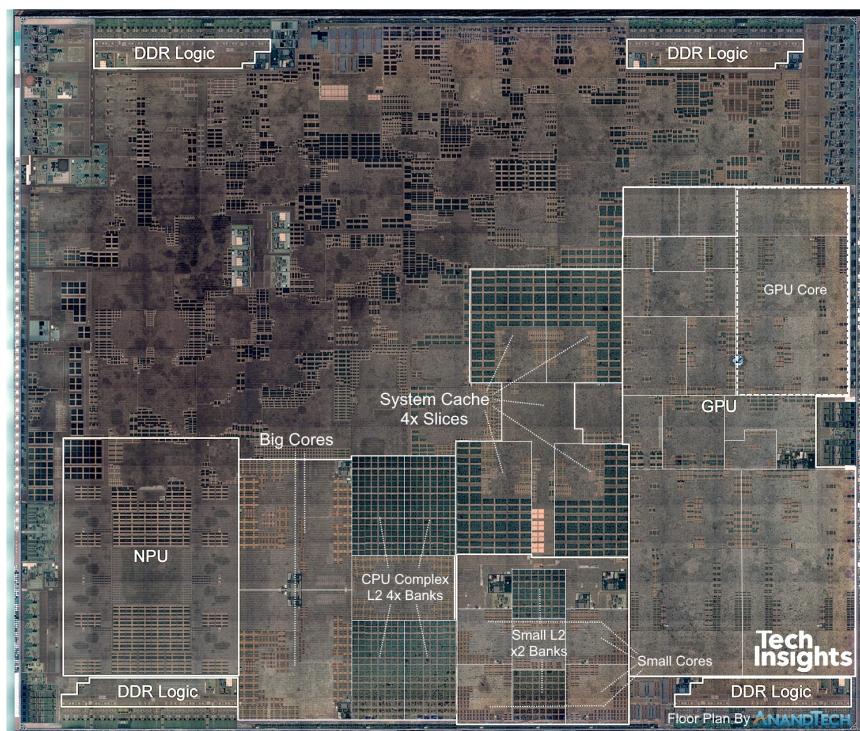




Today



AMD Threadripper: Transistors?



Apple A12 in iPhone X and XS
Transistors?

Moore's Law

Cramming More Components onto Integrated Circuits

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.

What is Moore's Law?

The 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 |

What happens when Moore's Law slows???

[John Hennessy and David Patterson 2017 ACM A.M. Turing Award Lecture](#)

John Hennessy and David Patterson 2017 ACM ...



Energy and Power of CMOS devices

How do energy and power relate?

Energy =

Static energy:

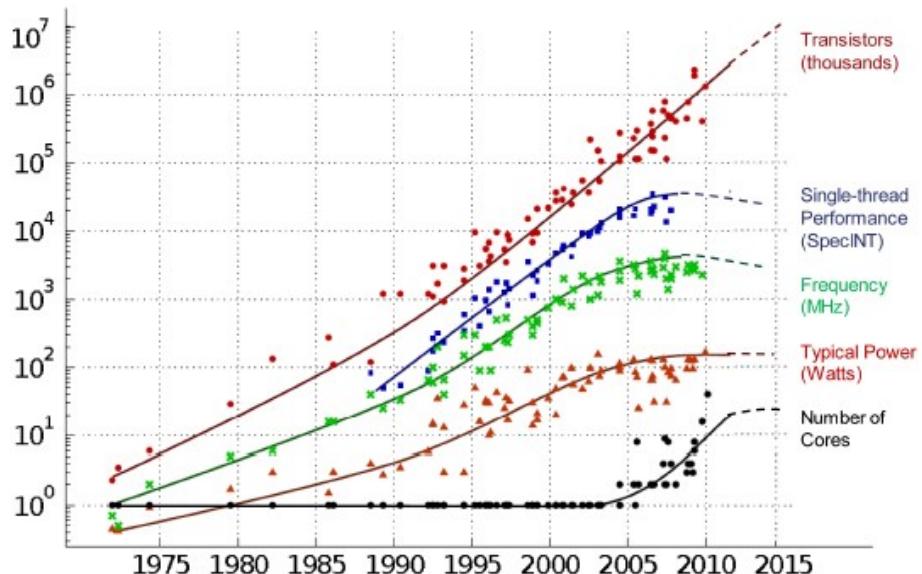
Dynamic energy:

Power:

If we are power/energy constrained: How do we reduce power/energy?

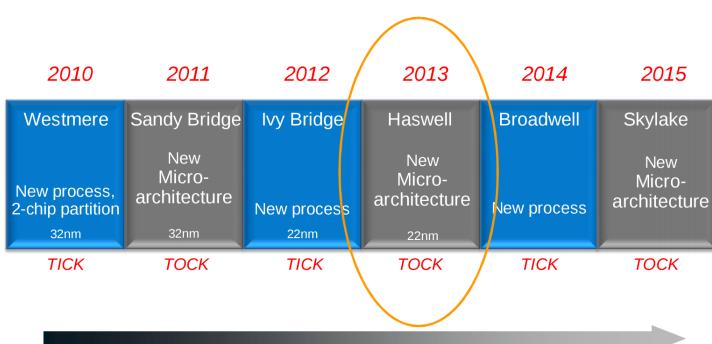
Trends

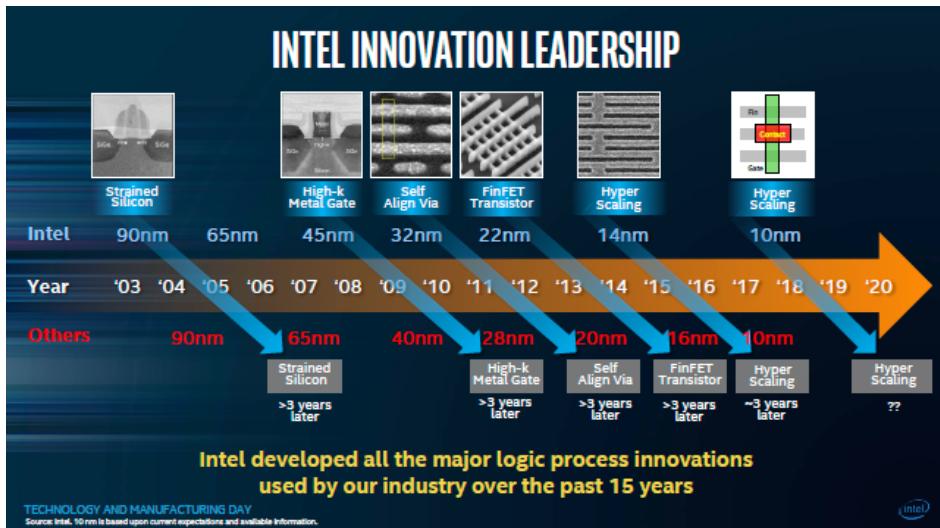
35 Years of Microprocessor Trend Data



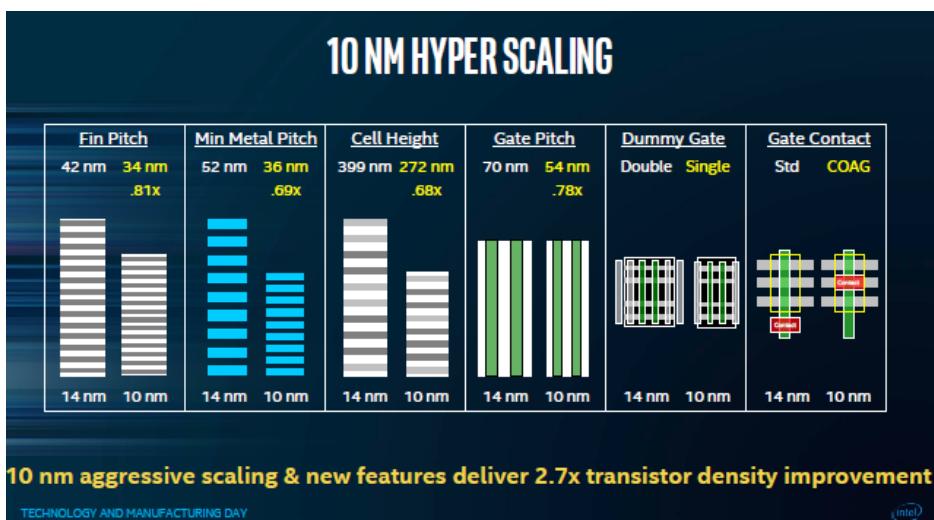
Slides from Intel

Intel Tick-Tock Model





TECHNOLOGY AND MANUFACTURING DAY
Source: Intel. 10 nm is based upon current expectations and available information.



TECHNOLOGY AND MANUFACTURING DAY
Source: Intel

