Giuseppe Iannaccone

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@iannak1

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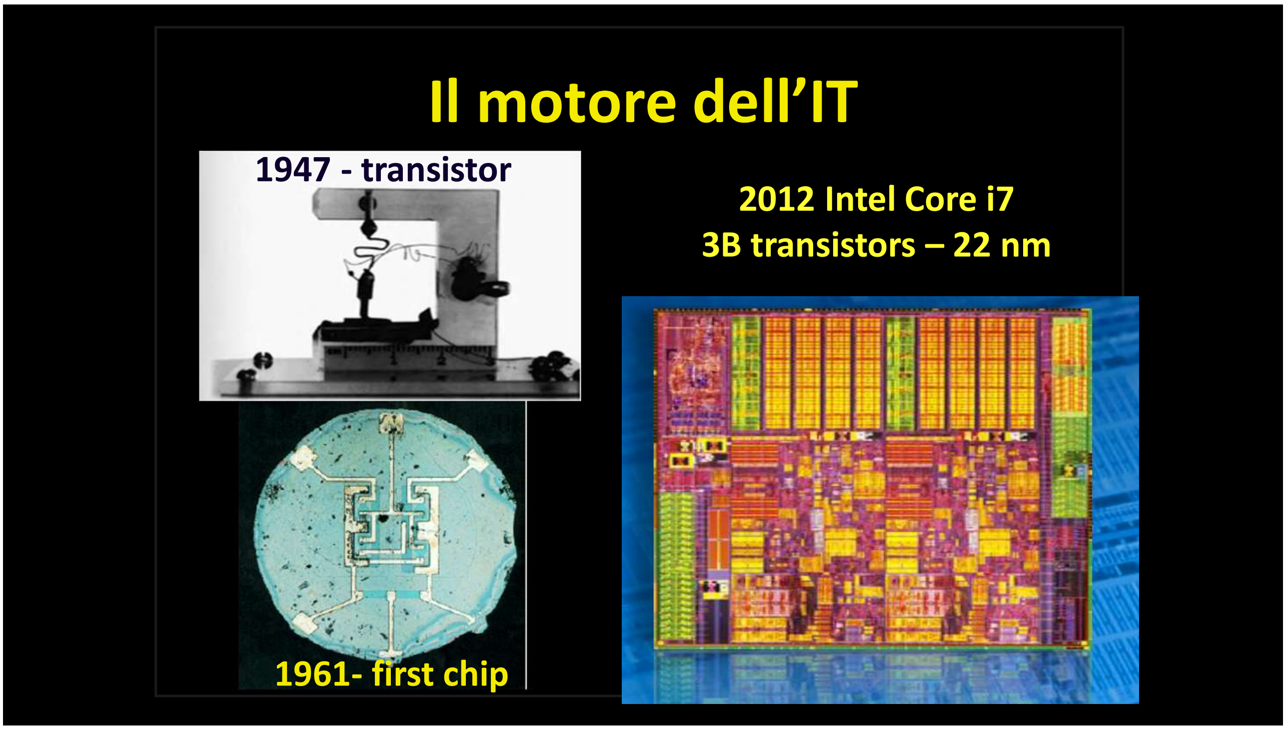
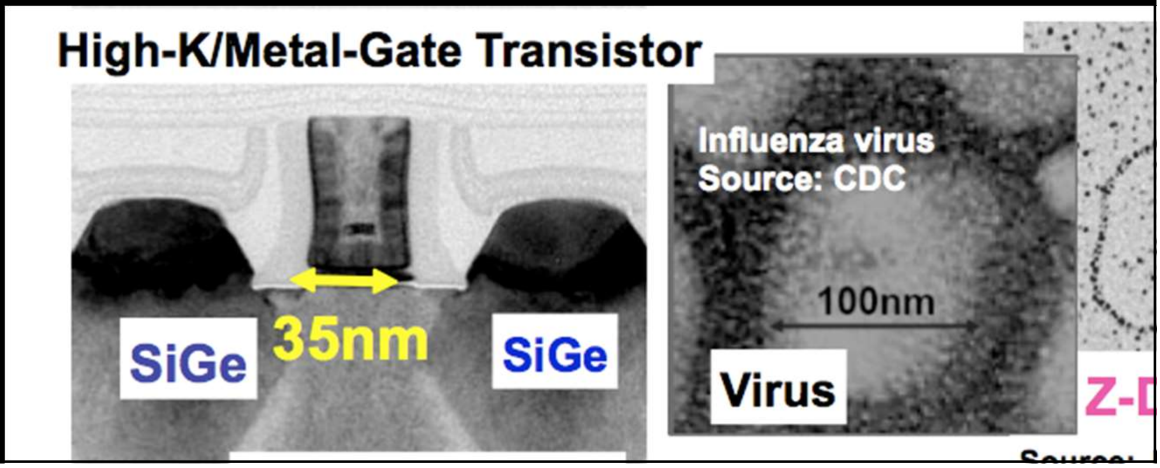


2

Nanotransitors are smaller than a virus

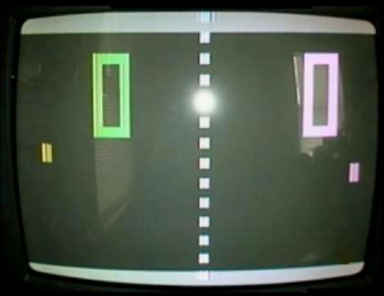


3

Why do we need all these transistors?

4

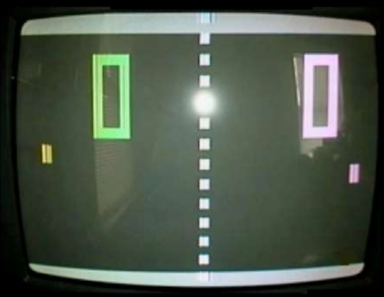
Why do we need all these transistors?



Atari PONG (1976)
3000 transistors

5

Why do we need all these transistors?

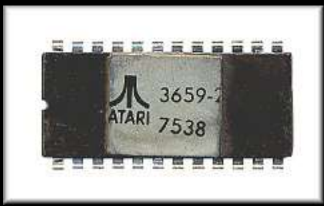


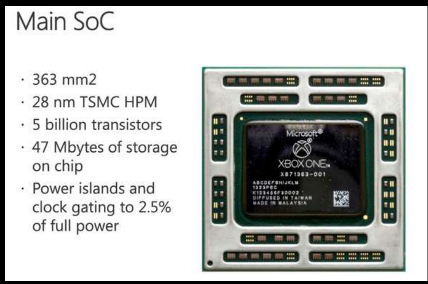
Atari PONG (1976)
3000 transistors

FIFA 14
(2013)
500+ milions transisors

6

Why do we need all these transistors?





Atari PONG (1976)
Atari 3659-1C
3000 transistors

http://www.pong-story.com

FIFA 14 (2013)
XBox one – PSP 4
5 Billion transistors
8 Jaguar cores

7

1833 - Michael Faraday – natural philosopher

First observation of semiconductor effect

I have lately met with an extraordinary case … which is in direct contrast with the influence of heat upon metallic bodies … On applying a lamp … the conducting power rose rapidly with the heat … On removing the lamp and allowing the heat to fall, the effects were reversed.

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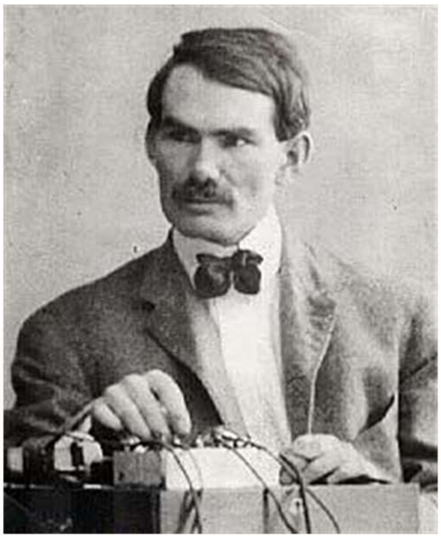
Vacuum Diode - John Fleming – 1904

http://history-computer.com/ModernComputer/Basis/diode.html

9

“Audion” (triode) – Lee De Forest - 1906



http://history-computer.com/ModernComputer/Basis/audion.html

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1920 – Westinghouse Radio Station KDKA (AM)

11

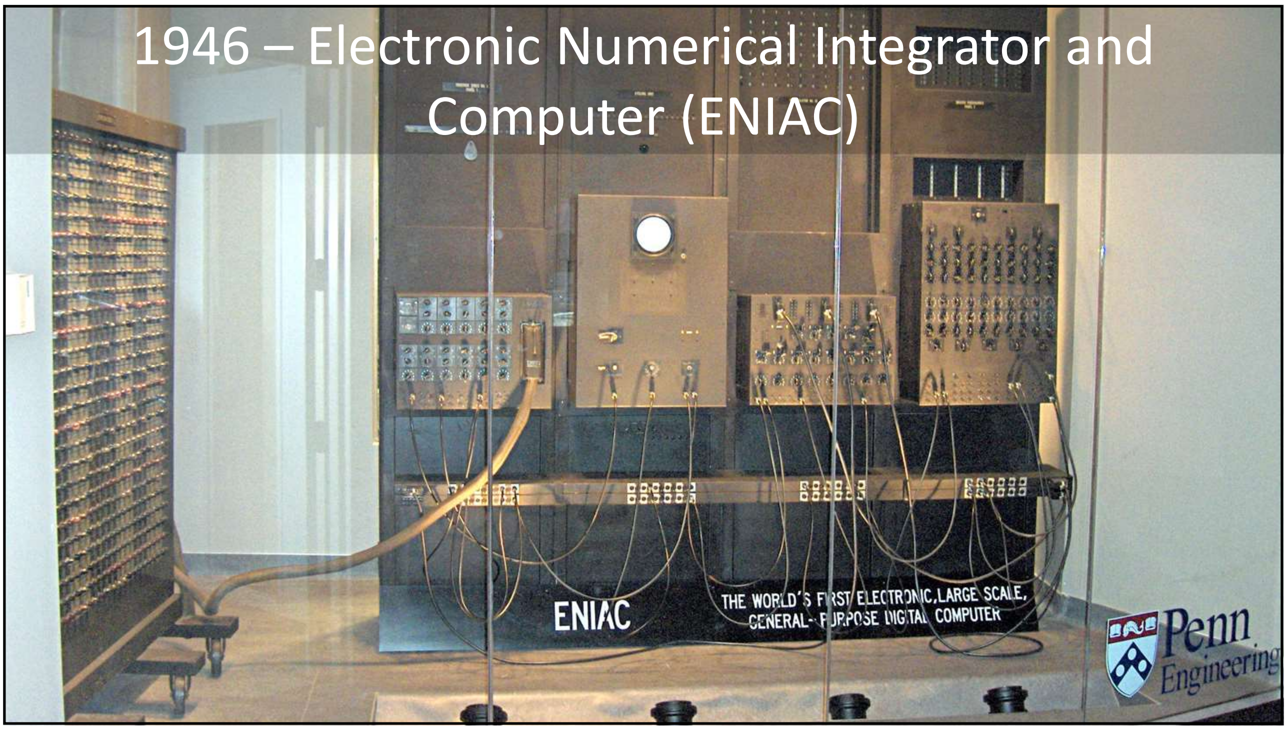

1929 Electronic Television

12

1940 Magnetron (for long-range Radar)

13

1946 – Electronic Numerical Integrator and Computer (ENIAC)



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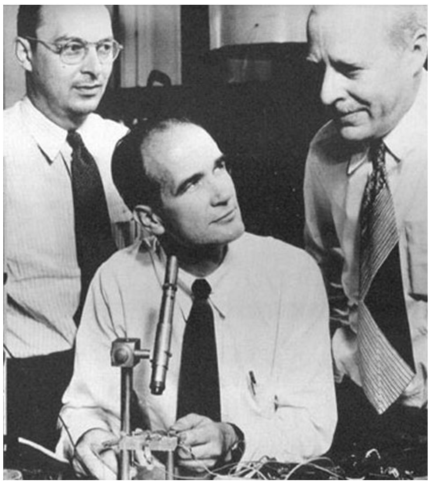
Point-contact Transistor –
Bardeen, Brattain, Schockley – 1948



http://history-computer.com/ModernComputer/Basis/transistor.html

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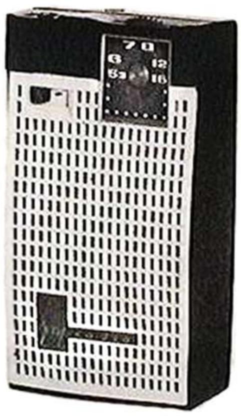
First transistor applications

Hearing aid 1952



TR52 Transistor Radio, 1955

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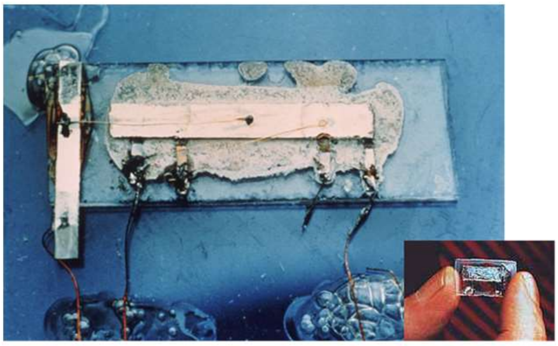
Integrated Circuit– 1958
J. Kilby (Nobel 2000), R. Noyce



http://history-computer.com/ModernComputer/Basis/IC.html

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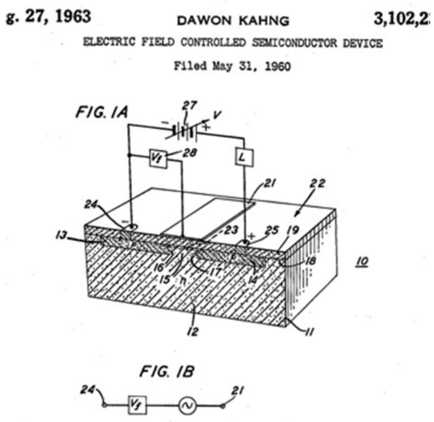
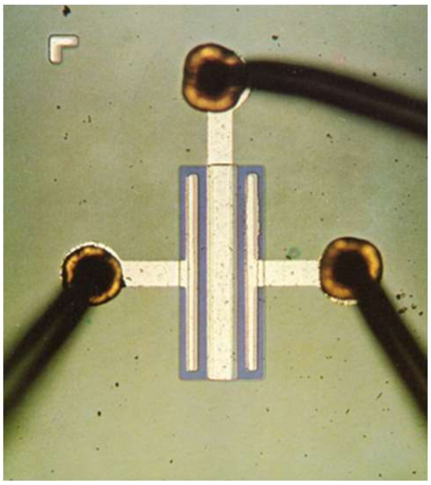
MOSFET demonstrated 1960,
Atalla & Kahng





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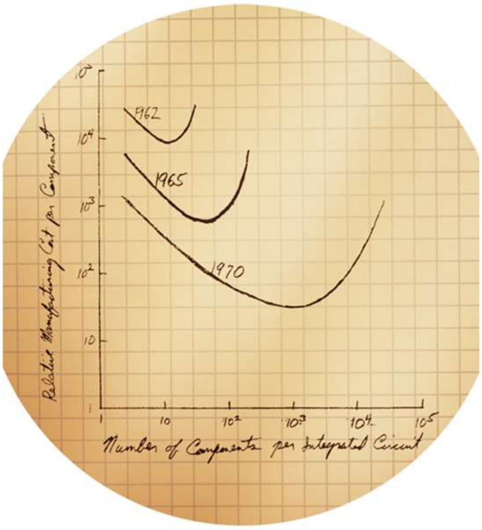
Moore’s law, 1965



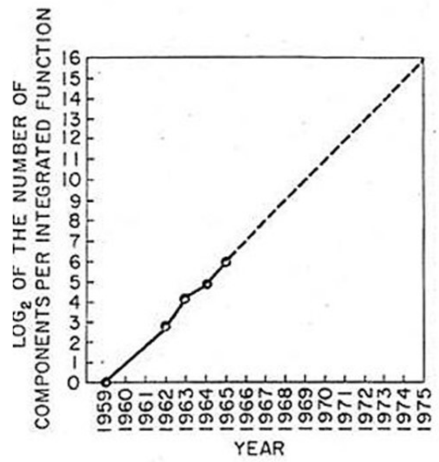


Fig. 2 Number of components per integrated function for minimum cost per component extrapolated vs time.

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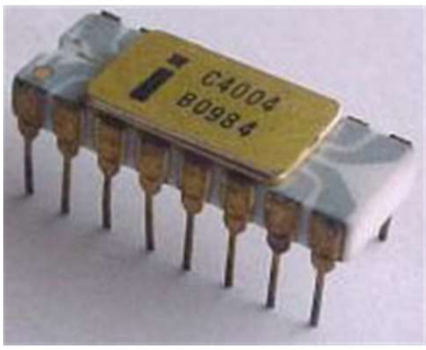
4004 Microprocessor – 1970 – Intel (Hoff, Faggin, Mazor)

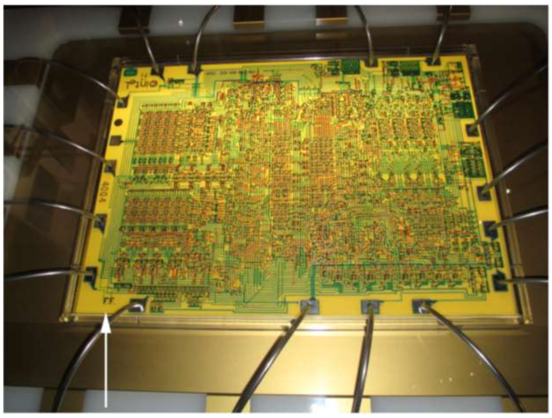


4004
2300 PMOS – 10 µm process
108 KHz
3 mm x 4 mm

http://history-computer.com/ModernComputer/Basis/microprocessor.html

20

4004 Microprocessor – 1970 – Intel (Hoff, Faggin, Mazor)



4004
2300 PMOS – 10 μm process
108 KHz
3 mm x 4 mm
http://www.intel4004.com/sign.htm

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Busicom 141-PF calculator (NCR 18-36)

http://www.vintagecalculators.com/html/busicom_141-pf_and_intel_4004.html

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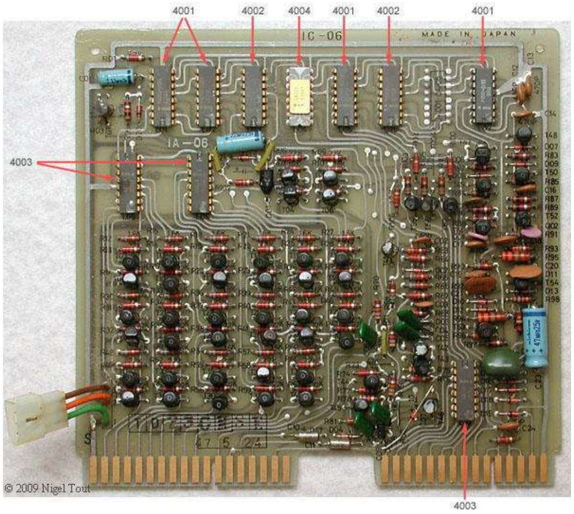
Busicom 141-PF board



- 4 x 4001
- (2048-bit ROM, mask programmable)
- 2 x 4002 (320-bit RAM).
- 3 x 4003, 10-bit shift register
- 4004, 4-bit CPU

http://www.vintagecalculators.com/html/busicom_141-pf_and_intel_4004.html

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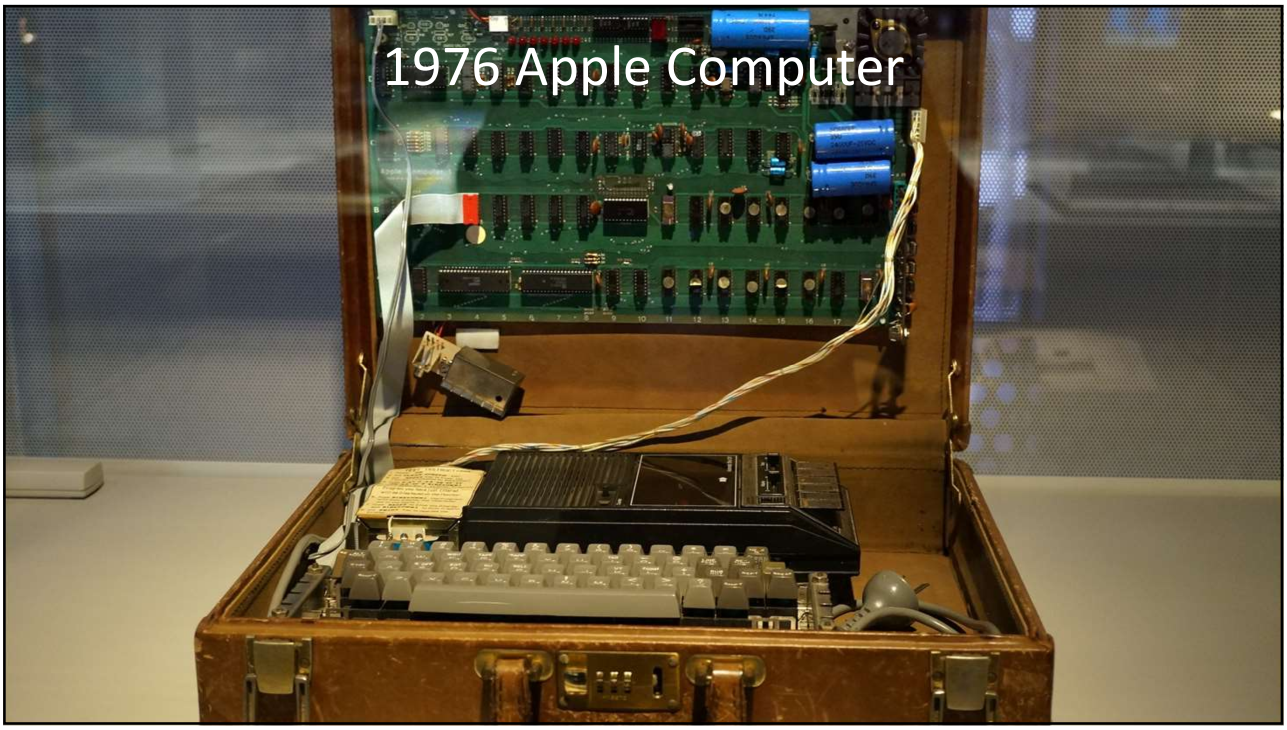

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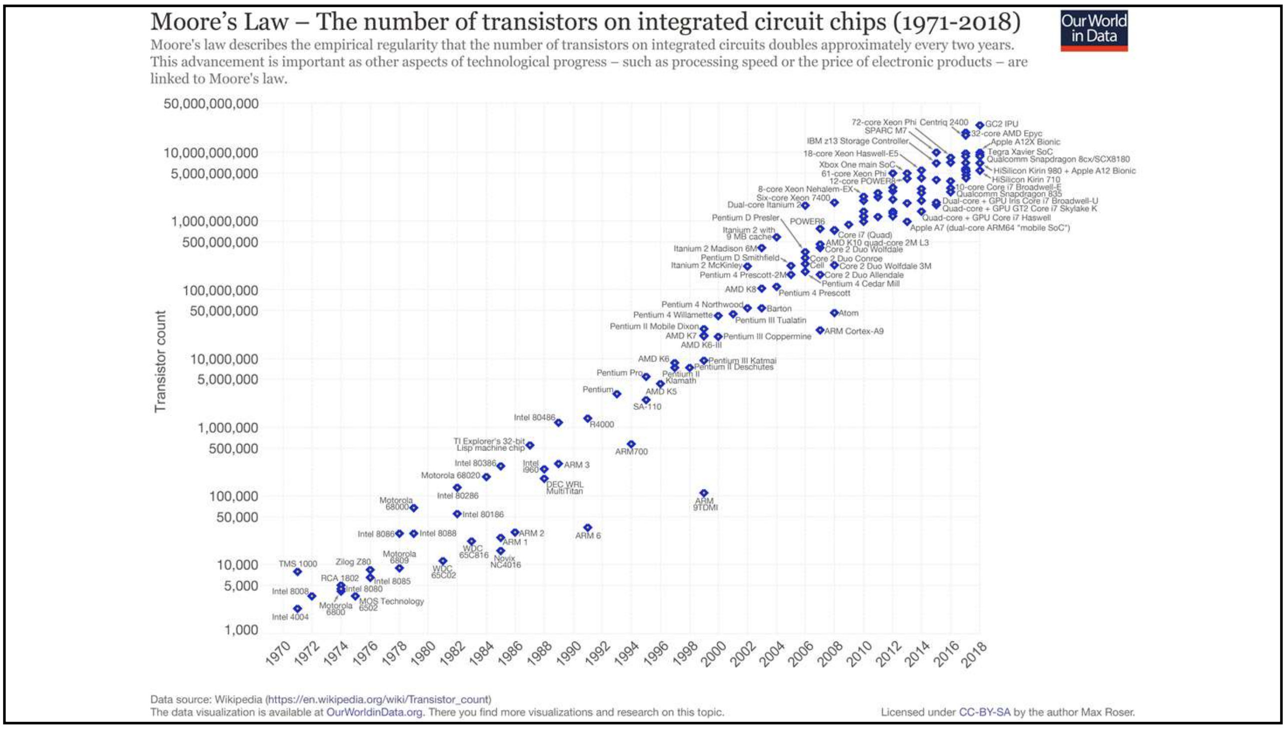

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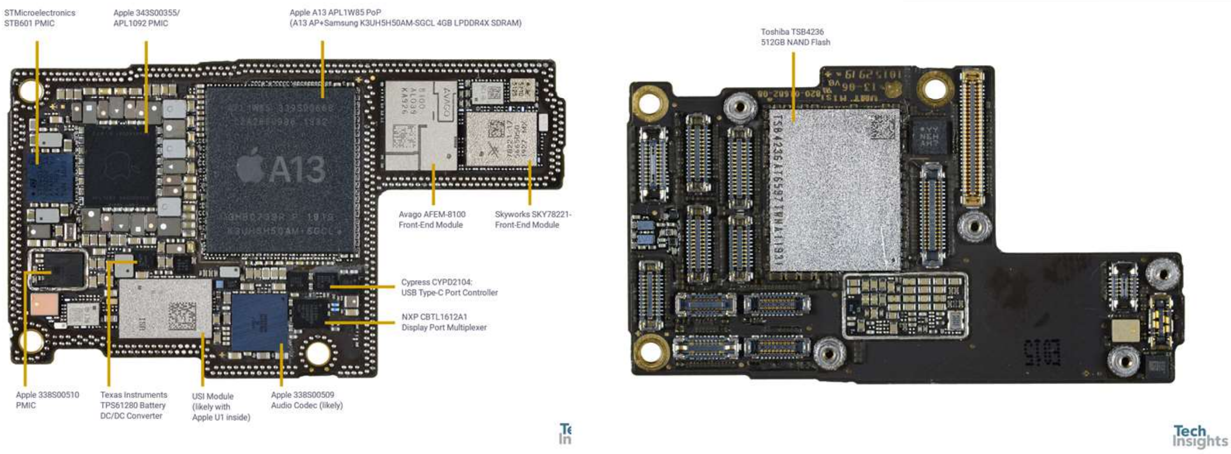
iphone 11 pro teardown



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Dennard's scaling rules

Parameter	Sensitivity	Dennard Scaling
L: Length		1/S
W: Width		1/S
t_{ox}: gate oxide thickness		1/S
V_{DD}: supply voltage		1/S
V_t: threshold voltage		1/S
NA: substrate doping		S
β	$W/(Lt_{ox})$	S
I_{on}: ON current	$\beta(V_{DD}-V_t)^2$	1/S
R: effective resistance	V_{DD}/I_{on}	1
C: gate capacitance	WL/t_{ox}	1/S
τ: gate delay	RC	1/S
f: clock frequency	$1/\tau$	S
E: switching energy / gate	CV_{DD}^2	$1/S^3$
P: switching power / gate	Ef	$1/S^2$
A: area per gate	WL	$1/S^2$
Switching power density	P/A	1
Switching current density	I_{on}/A	S

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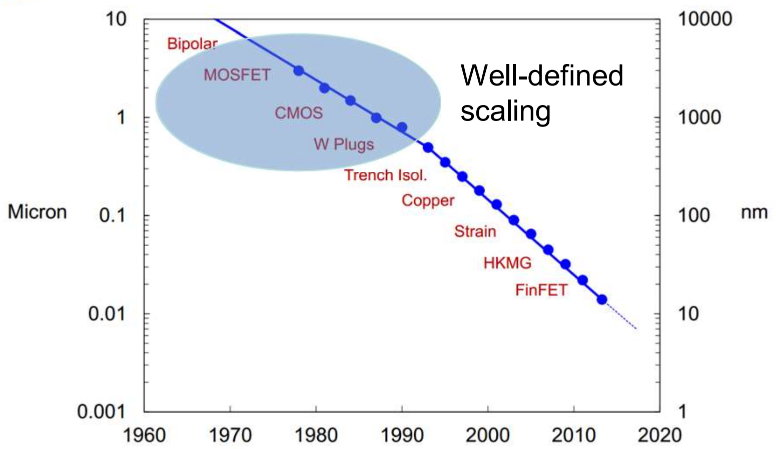
Well-defined scaling for 30 years

(EP1) Moore's Law Challenges Below 10nm: Technology, Design and Economic Implications



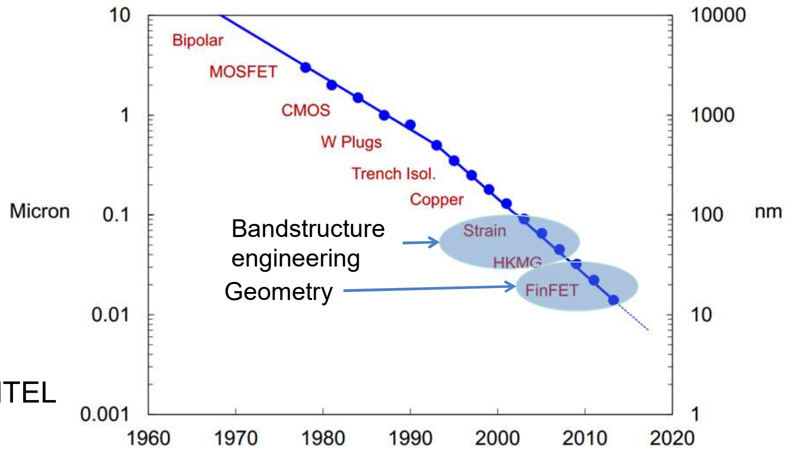
Courtesy of INTEL

Process/device innovation has always been an indispensable part of scaling

28

[nano]scaling needs innovation in materials/geometry

(EP1) Moore's Law Challenges Below 10nm: Technology, Design and Economic Implications



Courtesy of INTEL

Process/device innovation has always been an indispensable part of scaling

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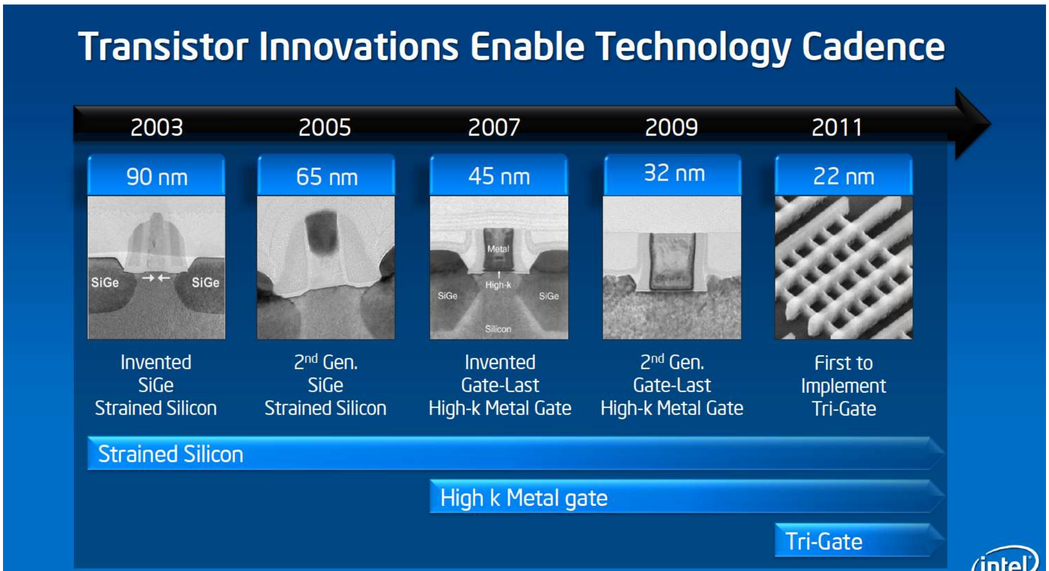
Materials and geometry innovation are common in silicon technology (courtesy of INTEL)



At the nm scale boundaries between materials and device are blurred

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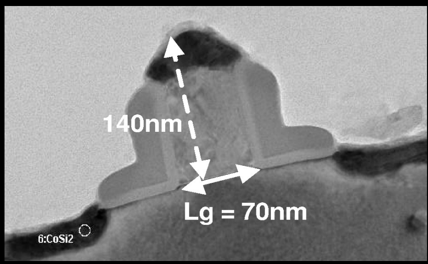
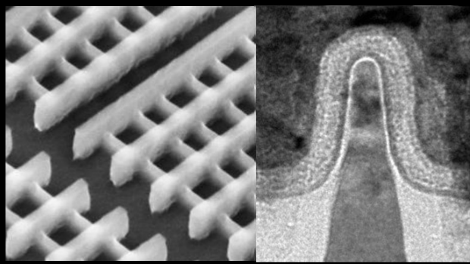
Not your dad's transistor

(neither your elder brother's one)





2001
130 nm
Silicon
SiO_2 – poly gate
Planar [2D]

2011
22 nm
Strained silicon/Ge
High K/Metal gate
3D

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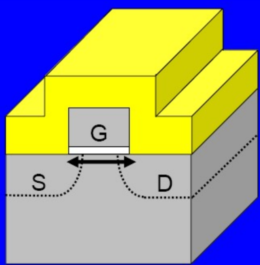
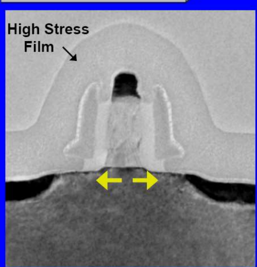
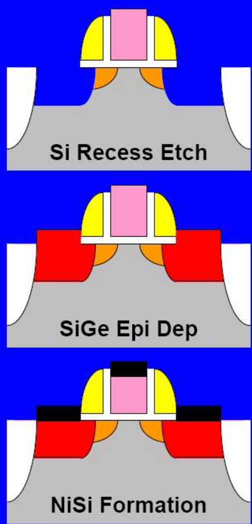
Strained silicon

nMOSFET tensile uniaxial





pMOSFET compressive uniaxial



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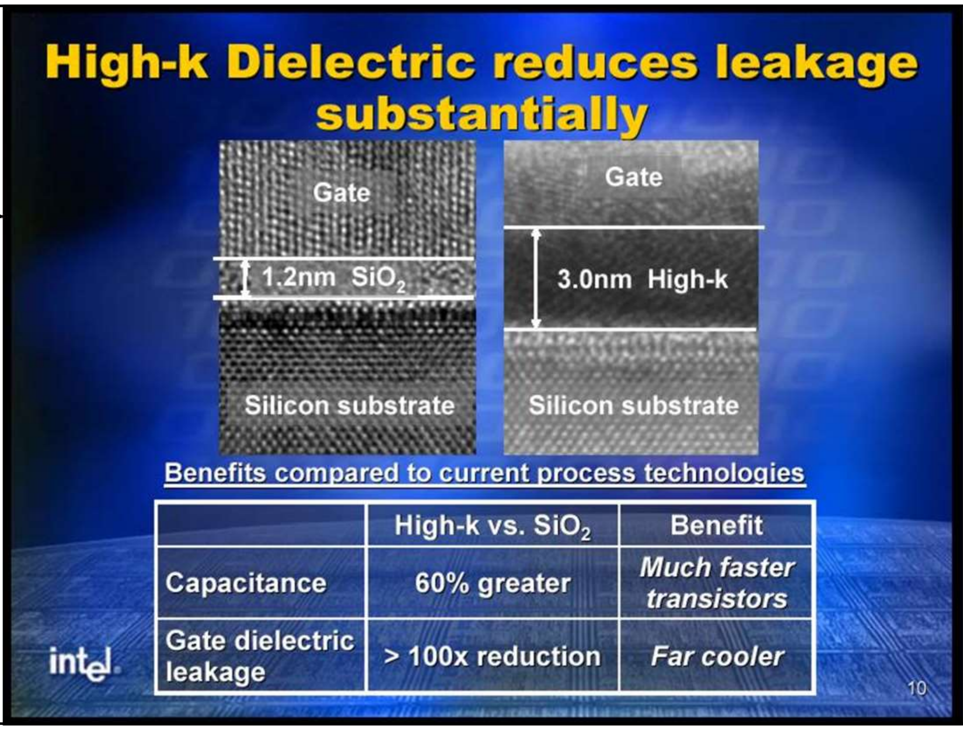
• You



	High-k vs. SiO_2	Benefit
Capacitance	60% greater	*Much faster transistors*
Gate dielectric leakage	> 100x reduction	*Far cooler*

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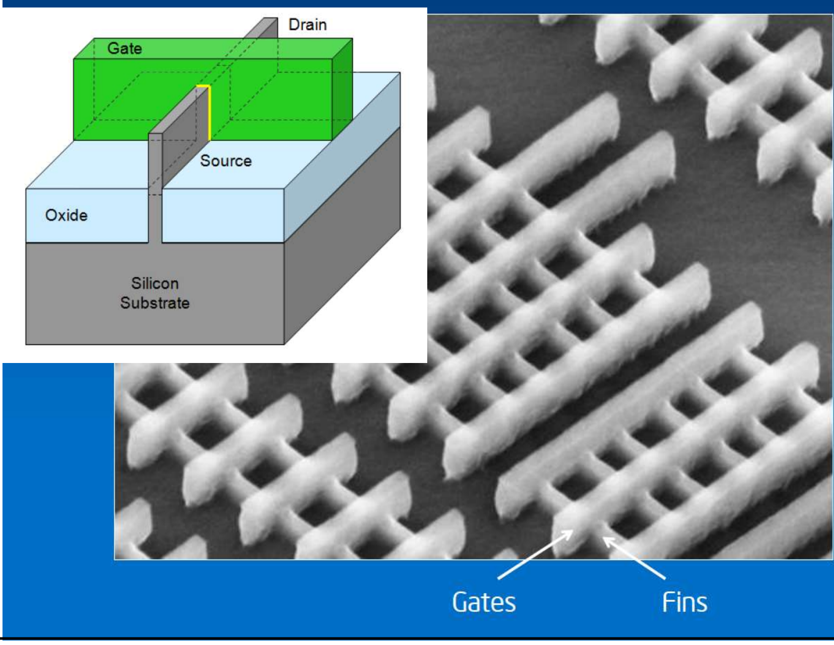
22 nm 3-D Tri-Gate Transistor



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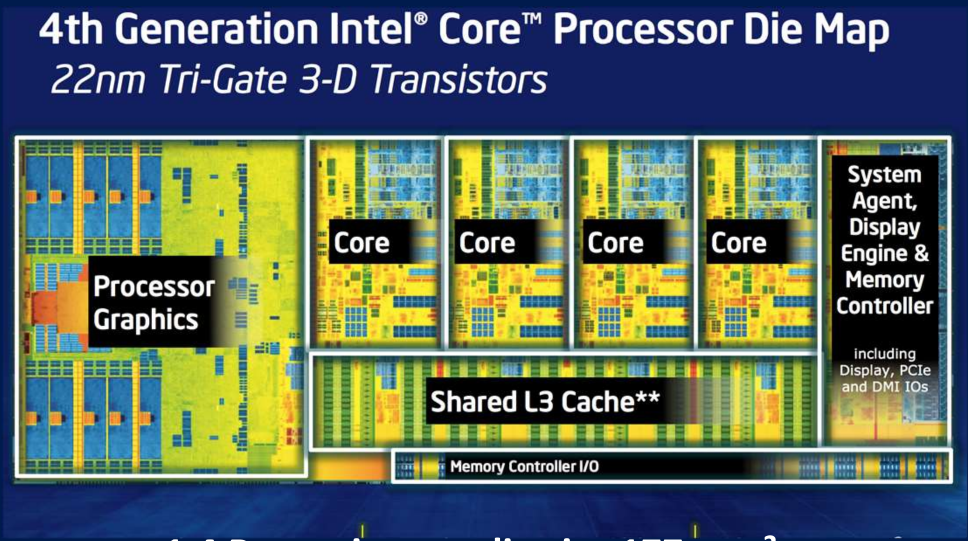

1.4 B transistors - die size 177 mm²

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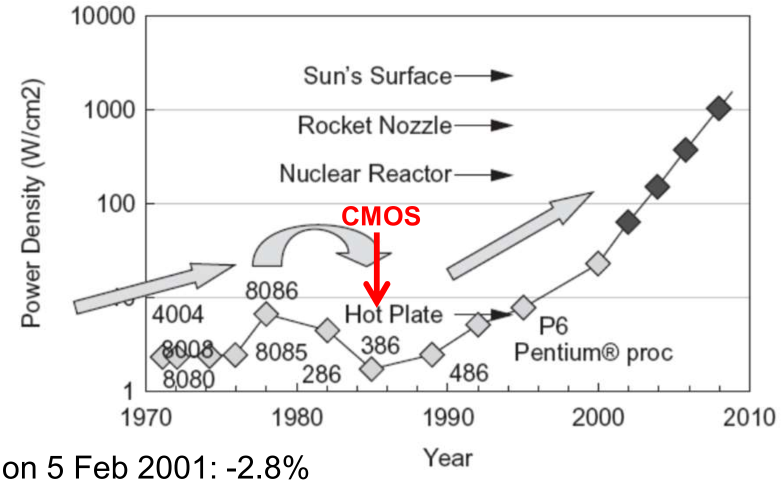
Power panic !

Intel VP Patrick Gelsinger (ISSCC 2001): "*If scaling continues at present pace, by 2005, high speed processors would have power density of nuclear reactor, by 2010, a rocket nozzle, and by 2015, surface of sun.*"



INTC close on 5 Feb 2001: -2.8%

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Power consumption of microprocessor: 1985-2009

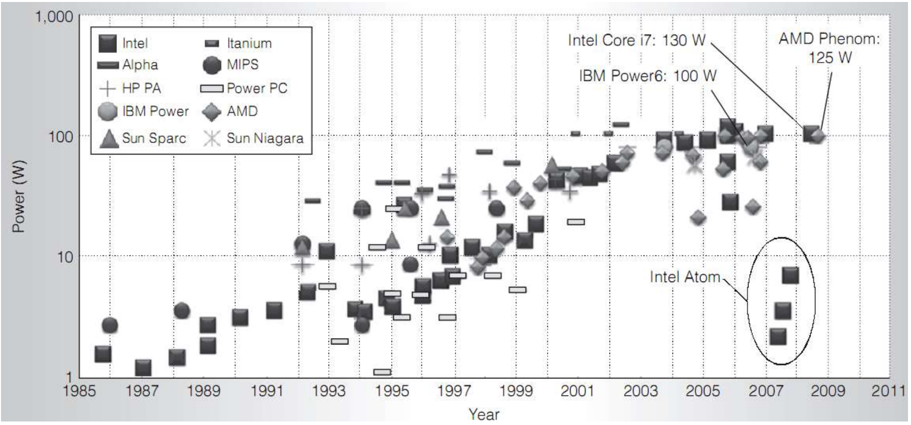

Figure from: O. Shacham et al., "Rethinking digital design: why design must change", IEEE Micro, pp. 9-24 Nov.-Dic. 2010.

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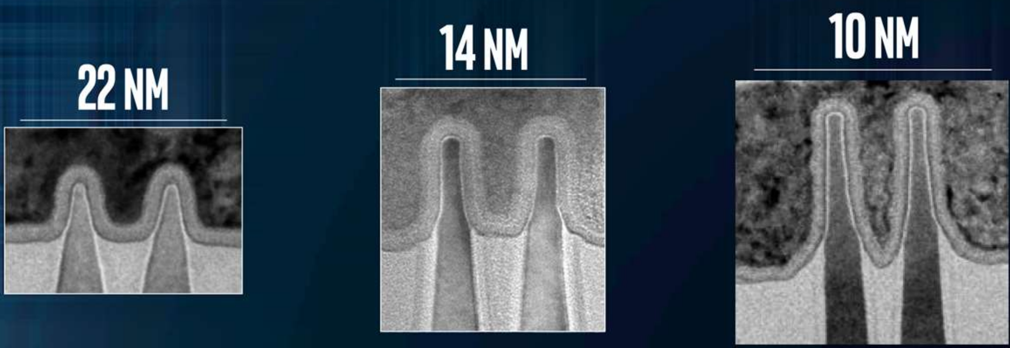
3RD GENERATION FINFETS



10 nm Fins are ~25% taller and ~25% more closely spaced than 14 nm

TECHNOLOGY AND MANUFACTURING DAY

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