

# The Chip Design Game at the End of Moore's Law

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Hot Chips, August 2013





## Best tech exponential improvement trend *ever!*

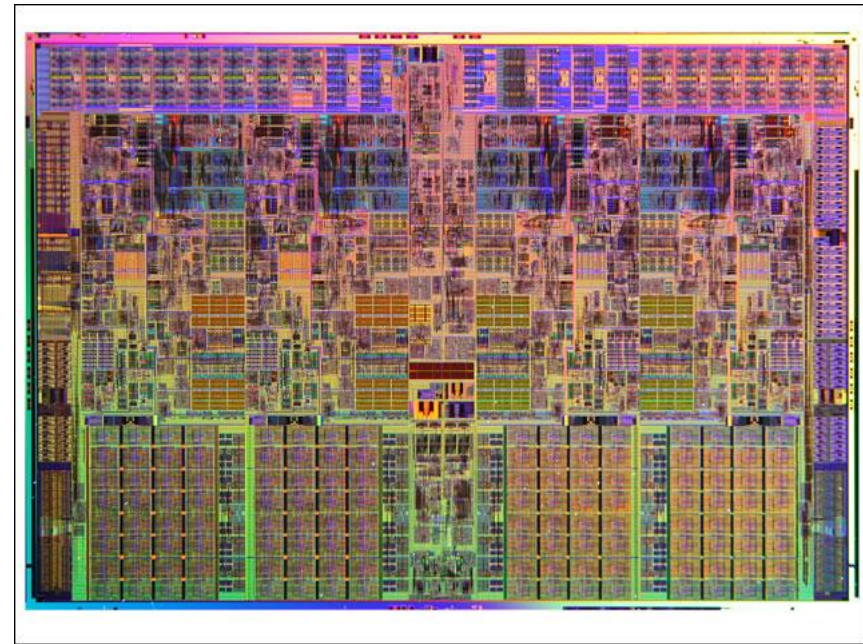
From this...



FIRST  
TRANSISTOR  
RADIO

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**1955**



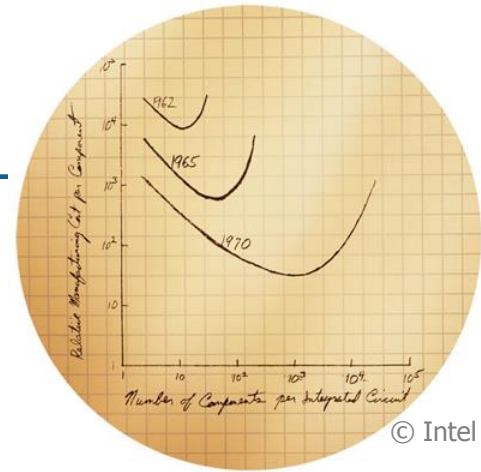
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...to this.

**2010**



# How Did We Do That?



- Separation of concerns
  - ISA, microarchitecture, functional blocks, circuits, placement, routing, layout, silicon, packaging
  - All could be done by specialists
- Tools
  - Checked & enabled this separation of concerns
  - CMOS was just plain beautiful technology
    - Simple, small, reliable, fast, low power, high yield...very hard to beat!

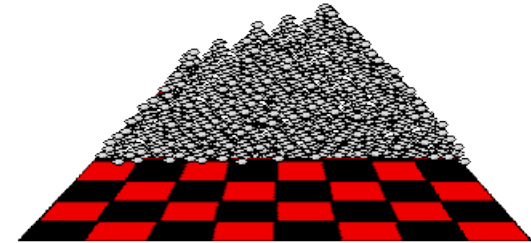


# Electronics Will Go On...

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...but things are changing rapidly!

1. All exponentials must end
  - Or they will “eat the universe”
2. Electronics existed before Moore’s Law
3. There will be electronics after it



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# Canonical "Moore's Law" Chip Designer's Algorithm

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**Given constraints**

**{Si area, schedule, team, tools, power}**

**How can I best design a chip to  
sell huge unit volumes  
at high yields  
and high profits?**

**People need a reason to part with their money.  
It's the chip designer's job to give them that reason.**



## So, is Death of Moore's Law a Big Deal?

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# YES.

- Moore's Law silicon improvements are "for free" to designers
- Chip architect's job was to remove obstacles from Moore's Law silicon bounty
  - System perf =  $f(\text{CPU clock, CPU uArch, sys})$
  - From 1980 to 2010, clocks are 3,500x faster
  - What did Arch/uArch achieve beyond that? Maybe 50x?
- **Can we continue to crank out successful new chips with only 10% wins per new gen?**
  - Remaining generations of silicon down to 7nm are not nearly as good as previous gens
  - we're already power-constrained...that won't improve





## What I Do NOT Agree With

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“We may be getting close to the end of Moore's law as far as single chip performance but I think it will be a long time before we see the end of Moore's law. While CPU's and GPU's may be getting close to their physical limits, there are other ways computers can still be made faster... **Ultimately, I think that Moore's Law should never stop. Computer builders will just find other methods to make computers faster and more efficient.** If there is a demand I think we will find a way to make it work.”

<http://www.pcworld.com/article/2032913/the-end-of-moores-law-is-on-the-horizon-says-amd.html>



“The end of Moore’s Law is always 10 years away,” said Intel's lead research director. “And yes, it’s true.”

But real issue is attitude. Truth is, we don’t know what our technology is good for. We build it, then watch as the world figures that out.

...said you have liked us to stop back when telephones had to plug into walls? Didn’t think so.

Harrie  
2 Fans

12:46 on 2

The com... OK  
keep getting better?

re it





# All Post-Moore's-Law Roads Are Not Blocked

- a) 3D stacking & improved packaging
- b) Better cooling, longer battery life
- c) Software, uArch, Arch, I/O, memory
- d) New apps
- e) Resilience (tough sell)
- f) Alternative switch technologies
- g) DARPA PERFECT & UPSIDE: beyond convention
- h) Better system features (sensors, wireless, displays, human interface)...whatever works
- i) Marketing (don't laugh, you *will* see this)



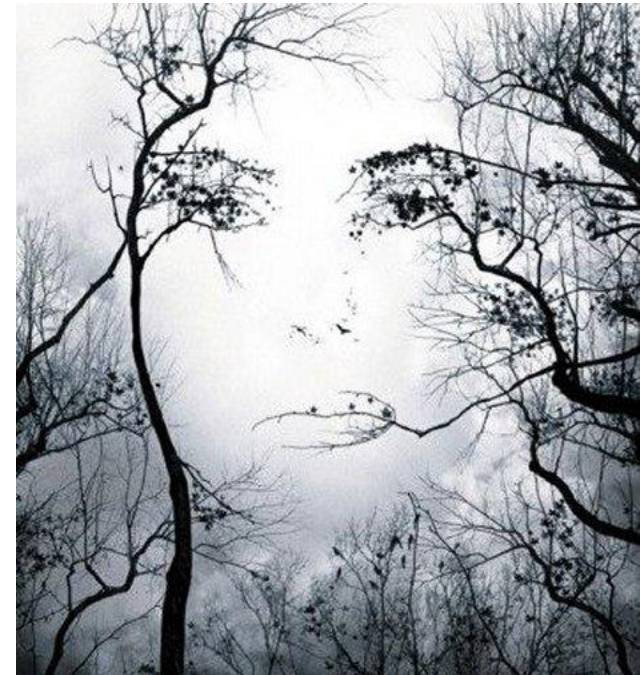
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## But It Will Be Anything But Easy

CMOS has given us the illusion of binary digital crispness for several decades, but the game's up

- Transmission lines, high-frequency design
- Ground bounce, ground loops, power supply design, VRegs
- Electromagnetics (inductances)
- Crosstalk
- Metastability
- Thermals
- Resilience and software handlers
- EFI and RFI



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## No more helpful separation of concerns



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- Resilience, thermals, battery life, complexity, validation, performance, schedule, risk...
  - Have to juggle them all at once, *pre-silicon* (but remember i432!)
  - Meanwhile RTL correctness is just as hard as ever
- Specialized HW to go after 2-3 orders of magnitude boost in efficiency/perf may again become viable
  - Dedicated blocks, approx computing, analog



# Future Designers Must Master Chips AND "*Neighboring Technologies*"

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## Must absorb more of overall value proposition

- Lesson of “Intel Inside”: get buyer to relate perceived value to *your* part of final product
- Lessons from Apple: iTunes, white earbuds
- This requires expertise beyond chip/CPU design

**1. Communications**

**2. Biology**

**3. Physics & Materials**

**4. Control Theory**

**5. What else that no one's thought of yet**



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- Everything *communicates*

- Radio, networks, fiber
- Once, faster processors would win; now designers need to know end *applications*
- Comms theory, signals, modulation techniques, propagation, noise, regulations
  - All information is probabilistic, with some error rate
  - Make system accomplish its mission anyway

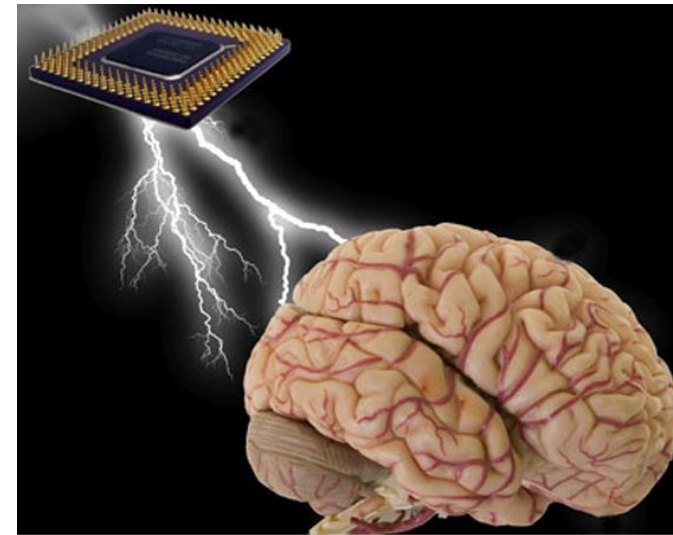


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# Neighboring Technologies: Physics/Bio



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**NO**

**Maybe**

- Physics & Materials
  - Photonics, lasers, infrared
  - Materials (phase-change, flash)
  - MEMS
  - Whatever devices follow CMOS
- Electronics at the meso and atomic scale
- Bio, genetics, human anatomy
  - Engineered bio
  - Brain/human interfacing



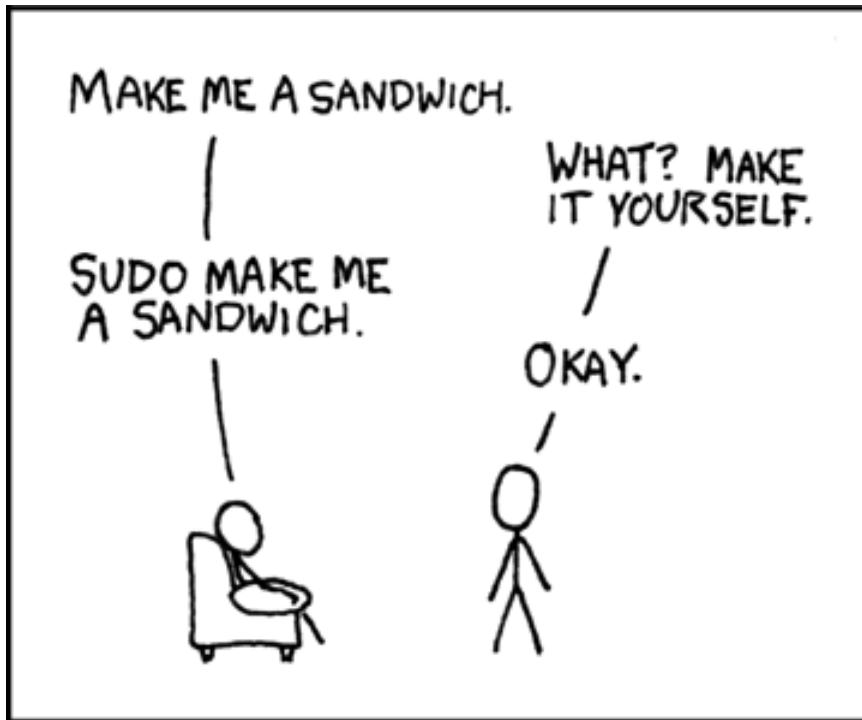


End of Moore's Law revives  
special purpose designs

But please! Heed lessons of past.  
Don't design unprogrammable  
engines!

**When Moore's Law ends, it will  
be economics that stops it, not  
physics. Keep your eye on the  
money...**





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