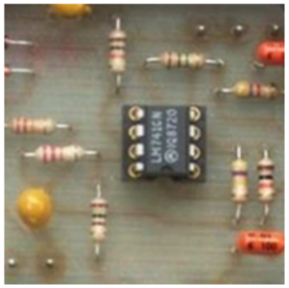
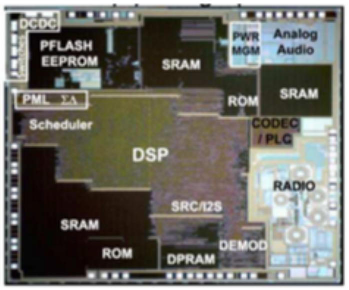
Chapter 1

Electronics I - Introduction

Electronics vs. Microelectronics

- Discrete Circuits vs. Integrated Circuits





- Limit the component count to achieve a small board area
- Available resistors are in the range 1Ω-10MΩ
- Available capacitors are in range 1pF-10mF
- All resistors are within 1-10% of their nominal value
- The utility of discrete transistors is limited. Usually prefer opamps over discrete transistors. Sometime use BJTs if opamps can't do the job. Use MOSFET primarily as switches

- Avoid using resistors and inductors, use as many MOSFET transistors as needed to realize the best circuit implementation
- Available capacitors are in range 1fF-100pF
- The critical parameters in transistors can be made to match within 1%, but vary by more than 30% for different fabrication runs
- Capacitors of similar size can match to within 0.1%, but vary by more than 10% for different fabrication runs

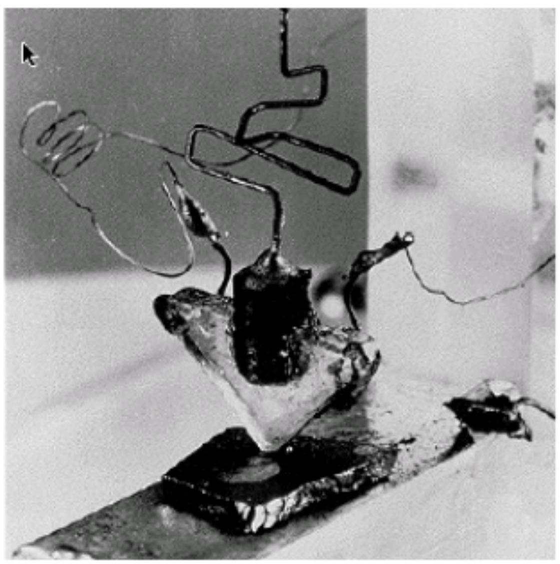
Source: B. Murmann, Stanford

Circuits are Everywhere

Source: B. Murmann, Stanford

In the beginning was …

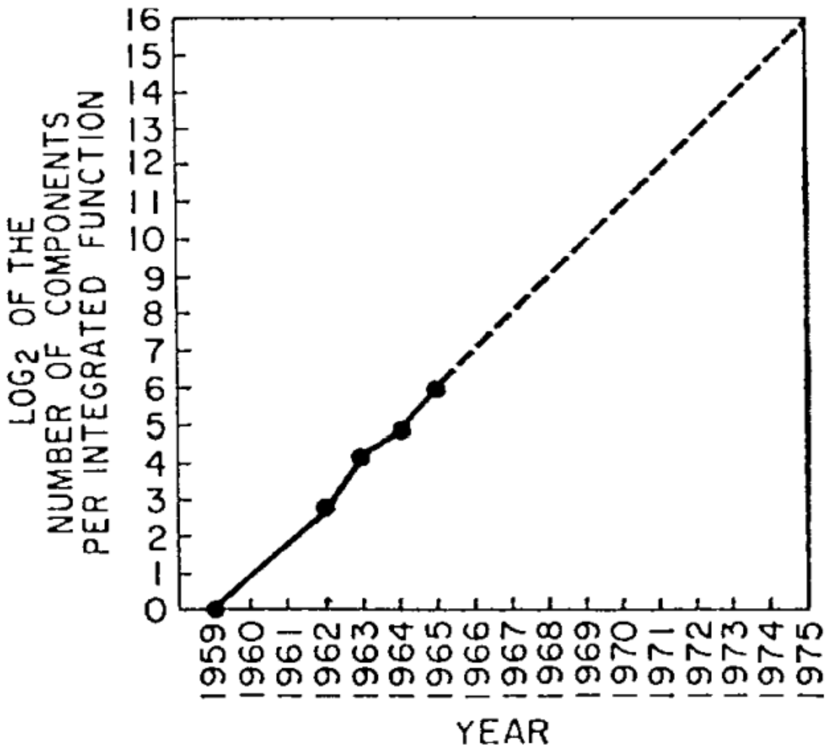
Transistor
Bardeen, Brattain, Shockley, 1948

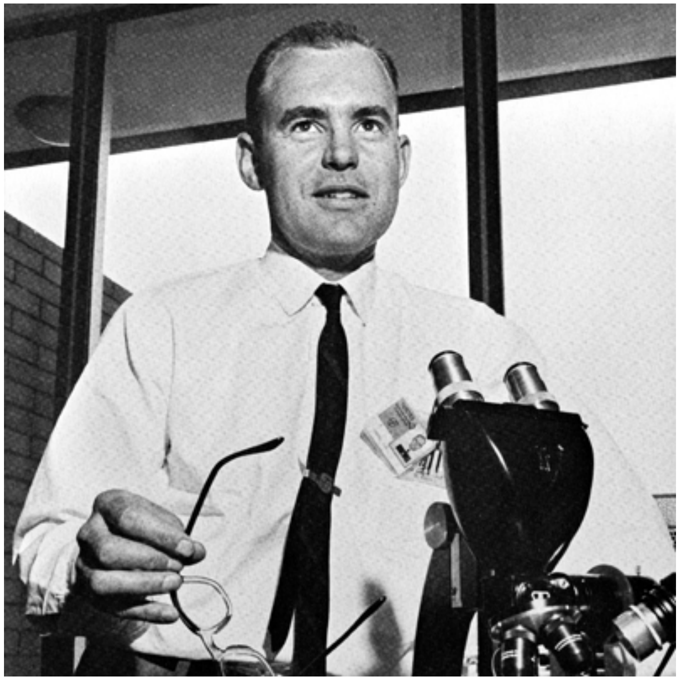


Integrated Circuit
Kilby, 1958

Source: B. Murmann, Stanford

Moore's Law



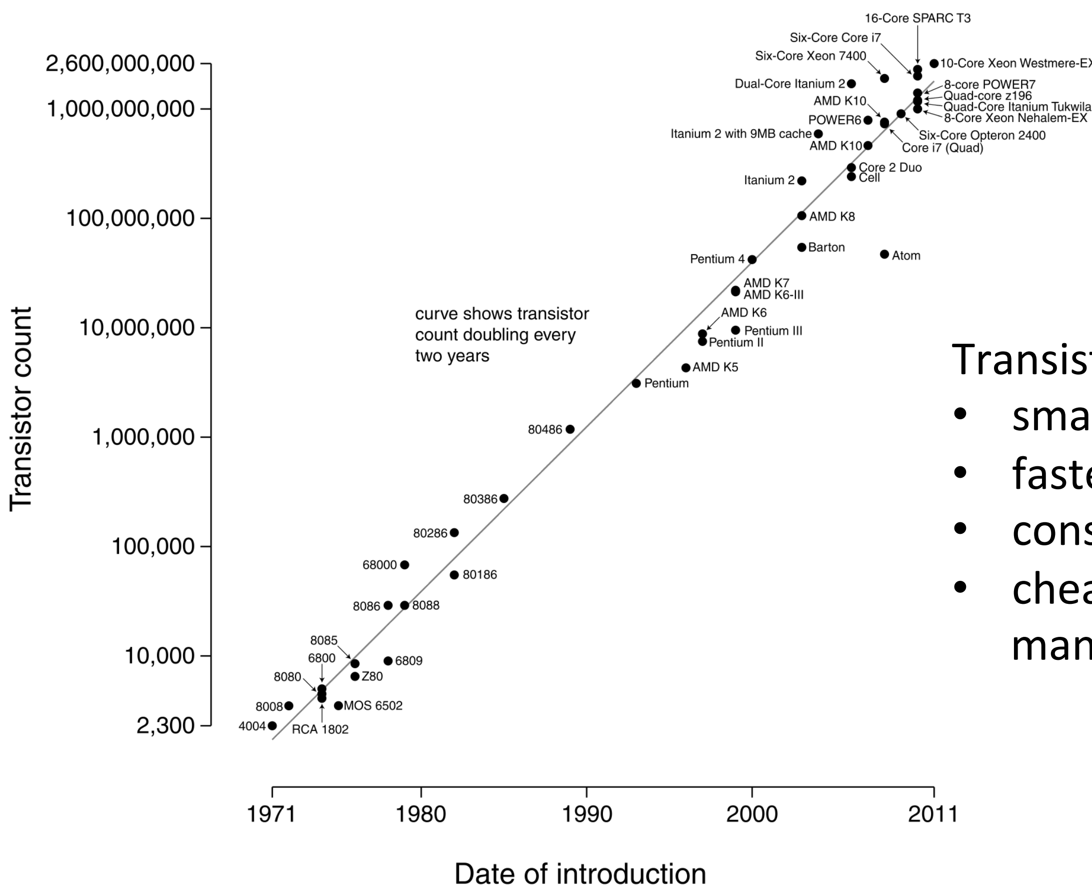


In 1965, Gordon Moore's predicted exponential growth in the number of transistor per integrated circuits

… and the prediction was right

Microprocessor Transistor Counts 1971-2011 & Moore's Law

source: wikipedia

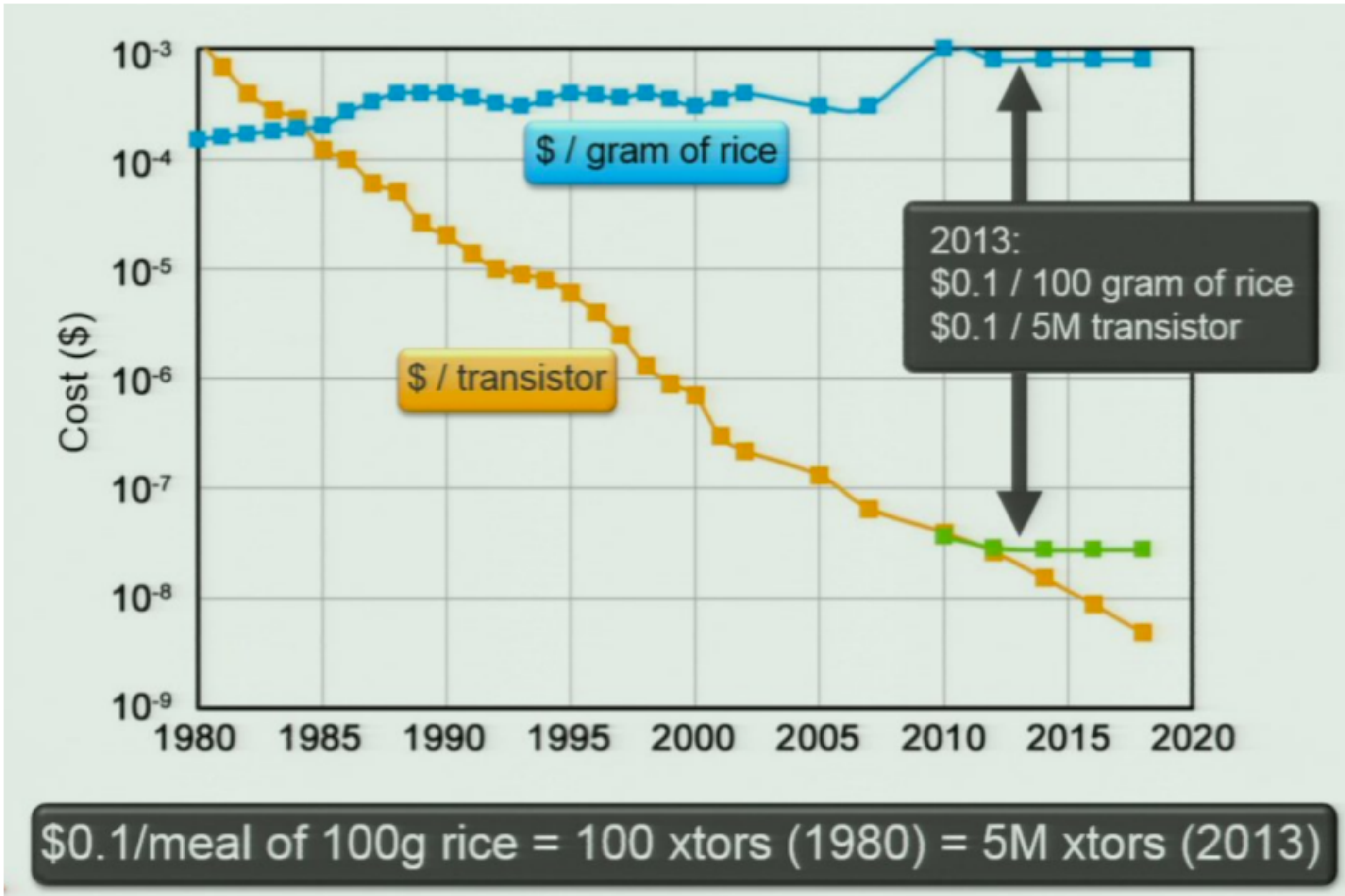


Transistors have become:

- smaller
- faster
- consume less power
- cheaper to manufacture

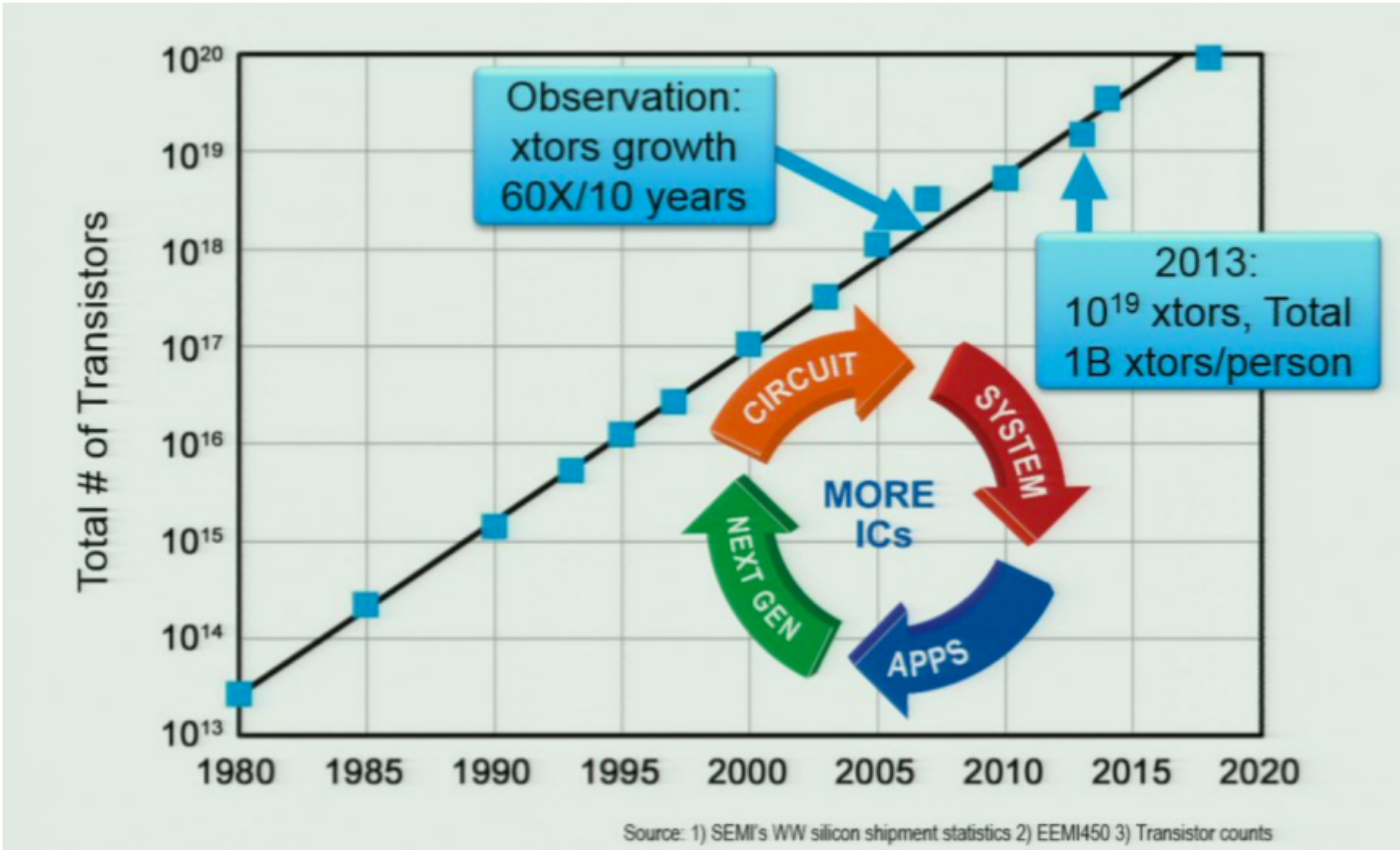
- No other technology has grown so fast so long

Transistors Cost



Source: Ming-Kai Tsai, CEO MediaTek, ISSCC Plenary Talk 2014 2

Everybody can afford a lot of transistors

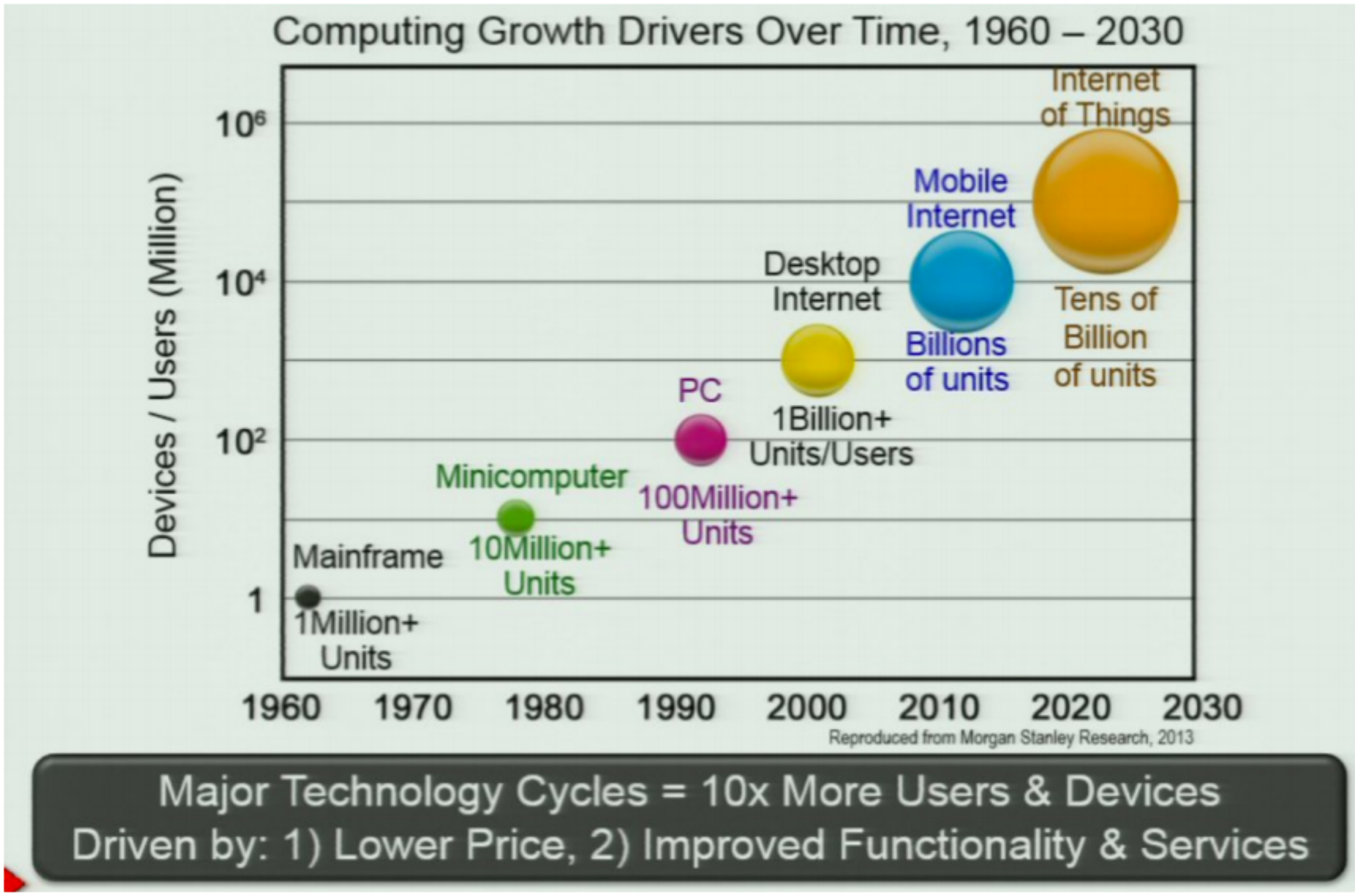


Source: Ming-Kai Tsai, CEO MediaTek, ISSCC Plenary Talk 2014 4

Social Impact

Source: Ming-Kai Tsai, CEO MediaTek, ISSCC Plenary Talk 2014 5

Applications driving the market



Source: Ming-Kai Tsai, CEO MediaTek, ISSCC Plenary Talk 2014

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IoT Trend:
more connected things than people

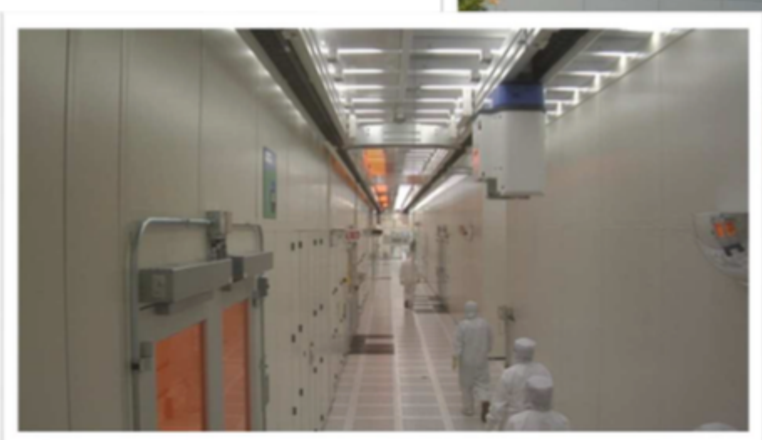
TODAY:
10 Radios/Person
70 Billion Radios

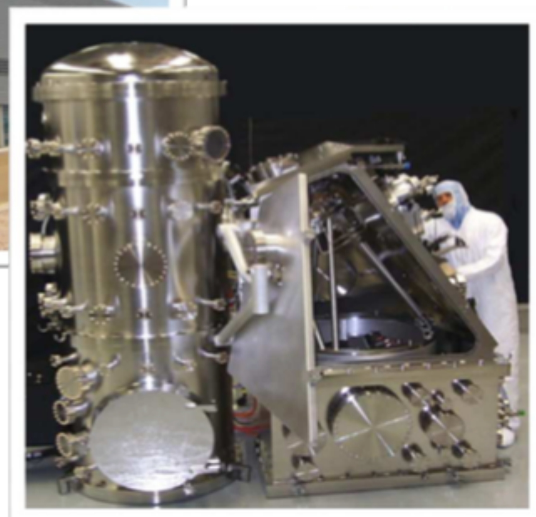
2030:
100 Radios/Person
800 Billion Radios
$100B+ Silicon opportunity

[Tsai, 2014 International Solid-State Circuits Conference (ISSCC), Keynote Talk]

State of the Art Semiconductor Fab

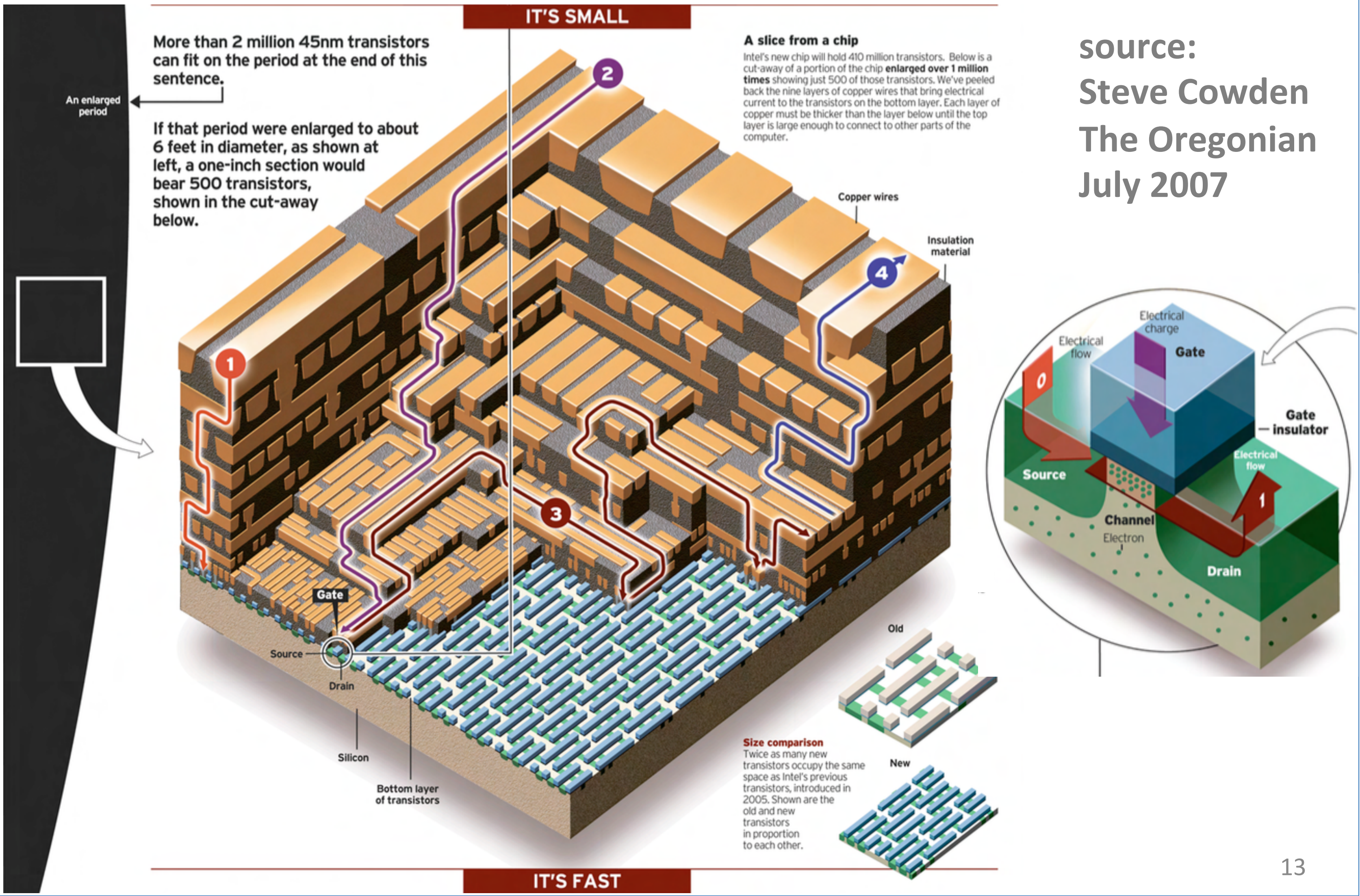
Intel's "Fab 32" (Chandler, Arizona) ~ $3 Billion





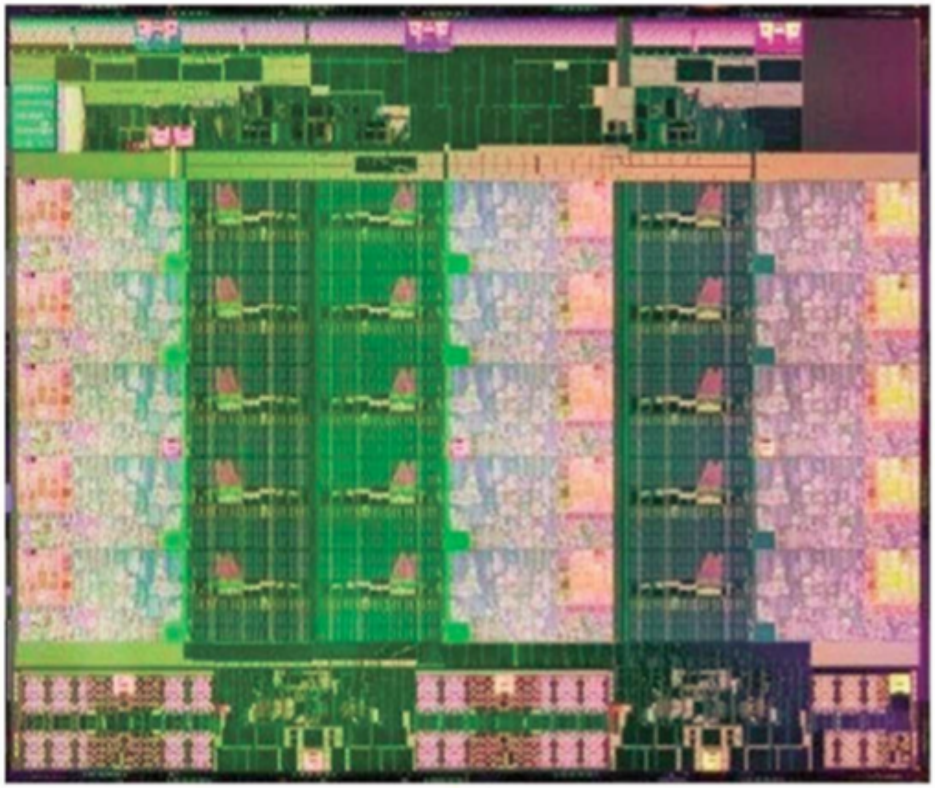
Source: B. Murmann, Stanford

45 nm CMOS Technology (Intel)



source:
Steve Cowden
The Oregonian
July 2007

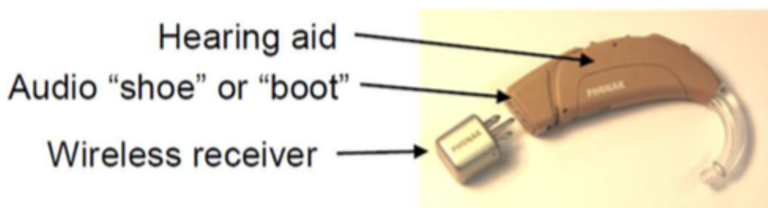
State of the Art Microprocessor

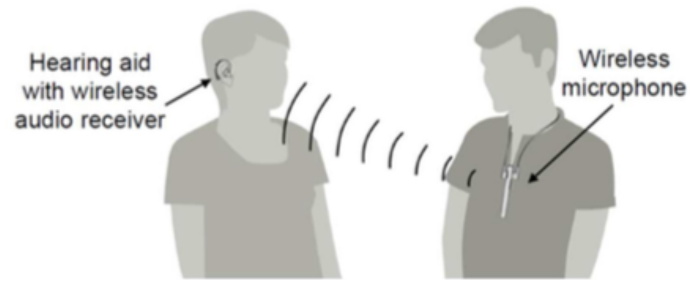


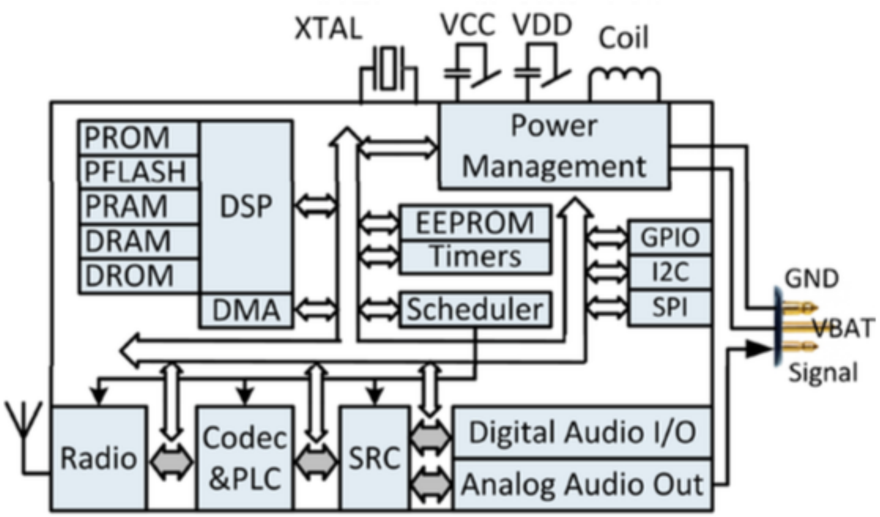
Intel “Ivytown” Processor
15 Cores (64-bit)
22nm Technology
4.31 Billion Transistors
Clock Rate 1.4-3.8 GHz
Power Dissipation 40-150W

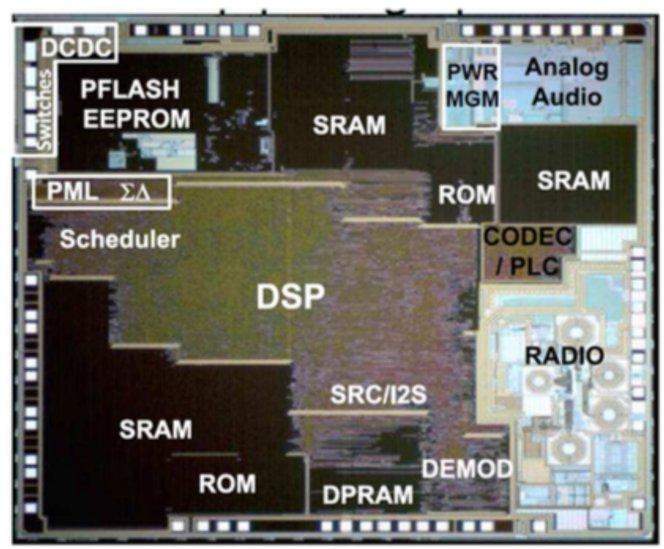
[Rusu, 2014 International Solid-State Circuits Conference (ISSCC)]

Hearing Aid with Wireless Receiver









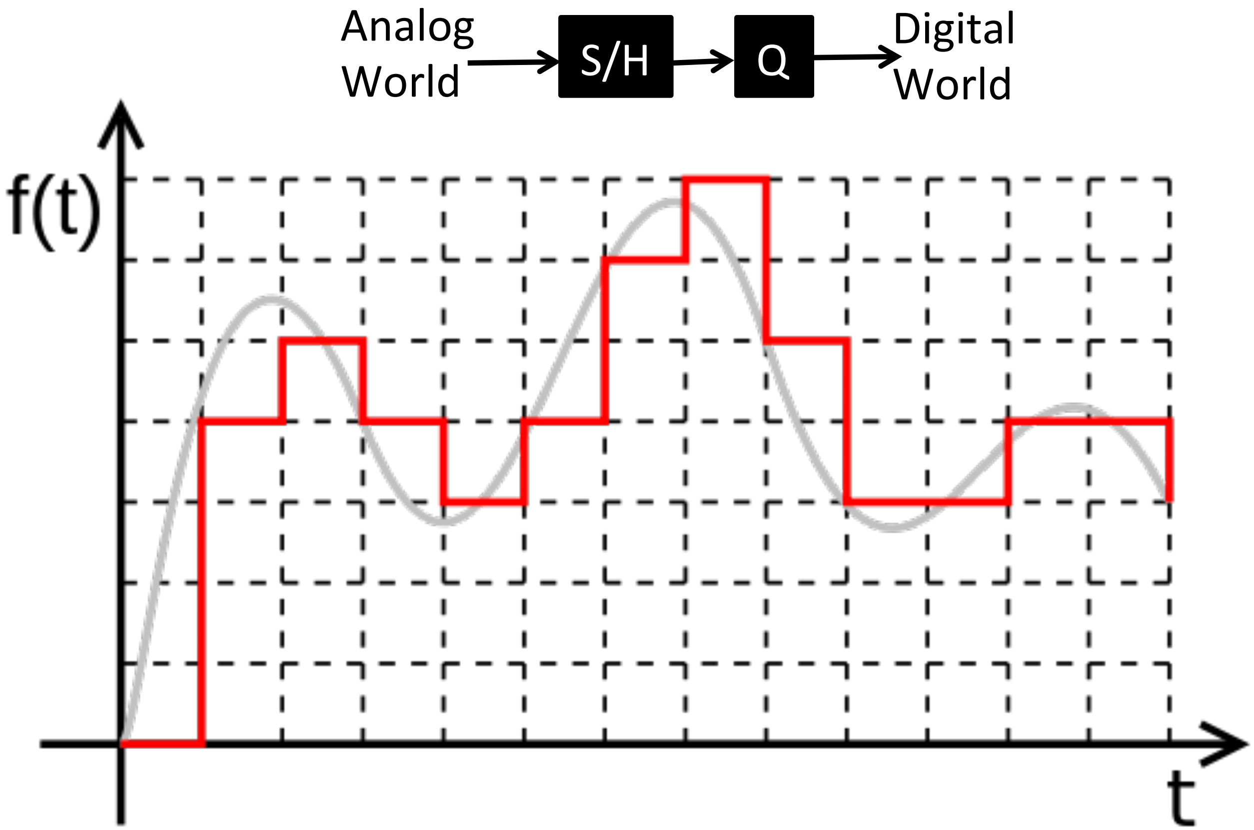
[El-Hoiydi, 2014 International Solid-State Circuits Conference (ISSCC)]

Analog and Digital Signals

- Analog = signals that occurs in nature are continuous in time and continuous in amplitude

- Digital (abstraction) = signal can take only a finite number of values and can changes only at fixed points in time

Analog and Digital Signals



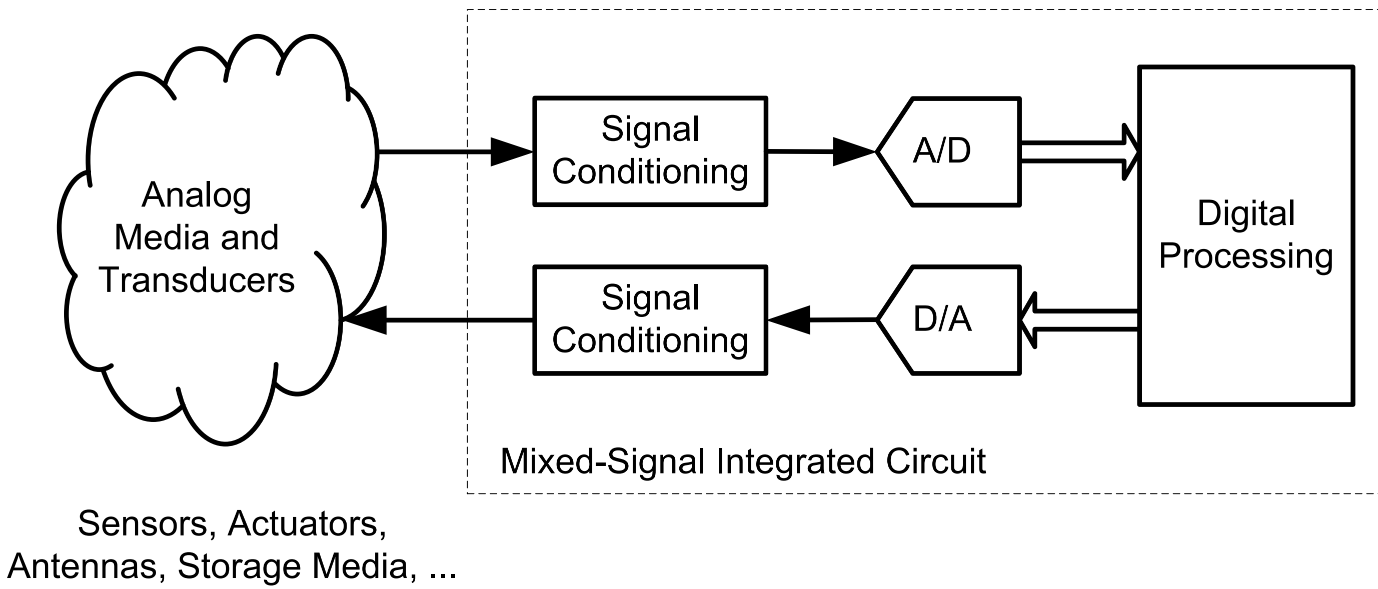
The digital signal (red) is the sampled and rounded representation of the grey analog signal

Source: wikipedia

Analog & ~~vs.~~ Digital

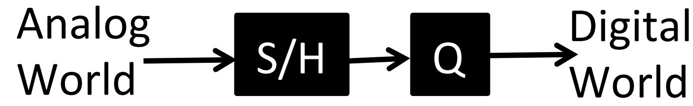
- **Analog Circuits Advantages**
  - Require fewer devices
  - Better to deal with low signal amplitudes
  - Better to deal with high frequencies
- **Digital Circuits Advantages**
  - Better immunity to noise
  - More “adaptable” (e.g. microprocessors)
  - Design can be done at more abstract level
  - Better economic (easier to implement as ICs)

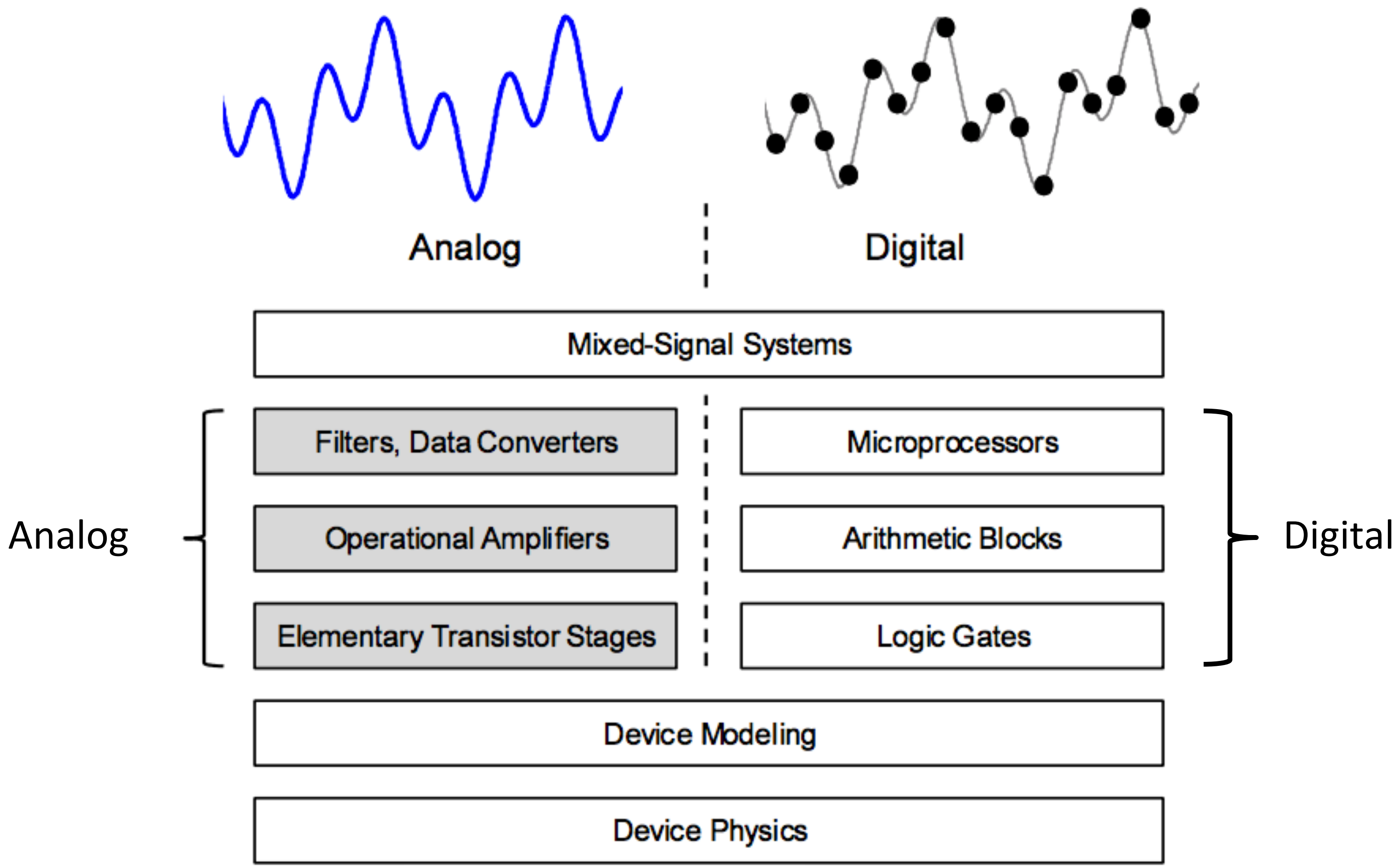
Mixed Signal System



signal conditioning = signal scaling (amplification or attenuation) and shifting

Managing Complexity: Levels of Abstraction



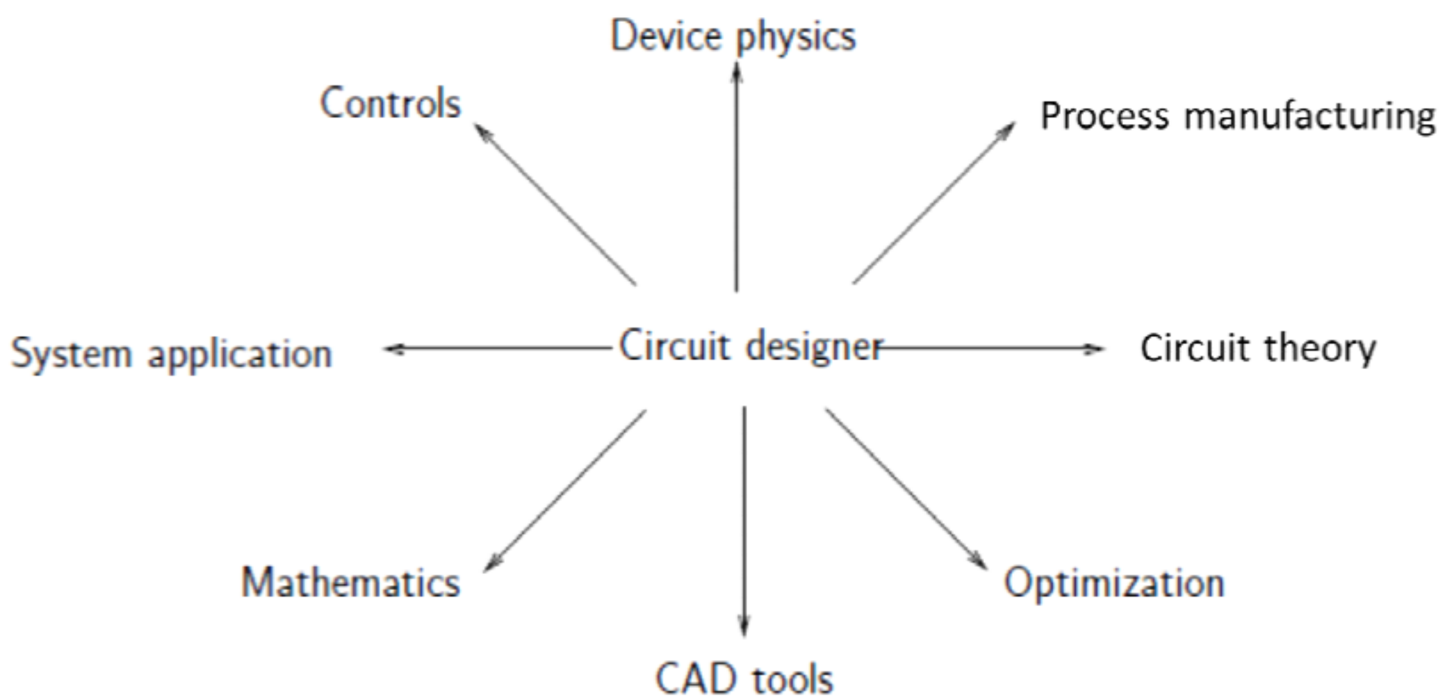


Source: B. Murmann, Stanford

Common Analog Blocks

- Power supplies
- Amplifiers
- Filters
- Signal generators (oscillators)
- Wave-shaping circuits
- Converters (ADC and DAC)

Circuit designers must be broad



Source: B. Murmann, Stanford

Course Topics

- Physics of Semiconductors
- Diode models and application circuits
- Basics of Amplifiers
- Circuit Simulation
- Transistors (BJTs and MOSTs)
- Biasing of Transistors
- Single stage Amplifiers (atoms of analog design)
- Multi stage Amplifiers
- Current Sources and Mirrors
- Frequency Response of Amplifiers
- Op amp based feedback circuits

Prerequisites

- Lumped vs. distributed circuits
- Kirchhoff's Rules
- Independent and dependent sources
- Superposition principle
- Thevenin and Norton equivalents
- Constitutive equations of R, L and C
- Sinusoids and complex exponentials
- LTI systems and their properties
- Fourier transform and Laplace transform
- Frequency and time-domain response of LTI systems
- First and second order linear circuits (transient and steady state response)