EE105
Microelectronic Devices and Circuits

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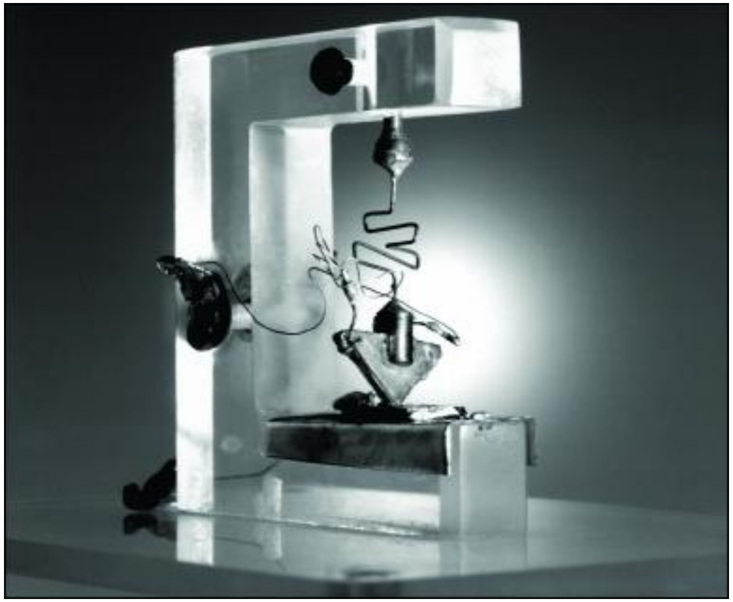
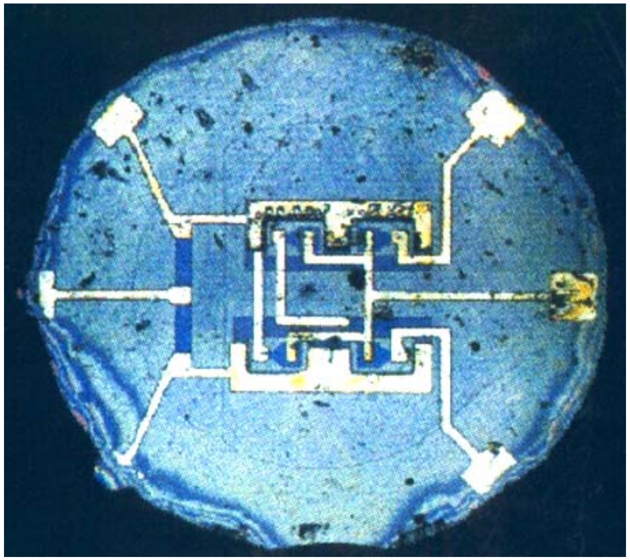
Invention of Transistors - 1947

- Bardeen, Shockley, and Brattain at Bell Labs
- Invented bipolar transistor in 1947
- Nobel prize in 1956
- Shockley sometimes credited as "the man who brought silicon to Silicon Valley"



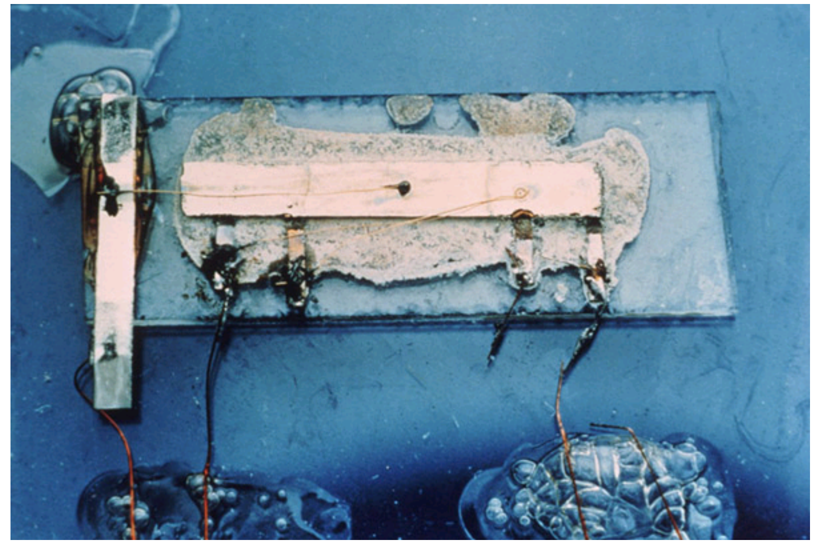
Point contact bipolar transistor (in Germanium)

The First Integrated Circuits - 1958



R. N. Noyce
Fairchild Semiconductor
Co-Founder of both
Fairchild and Intel
(deceased 1990)

"Unitary Circuit" made of Si



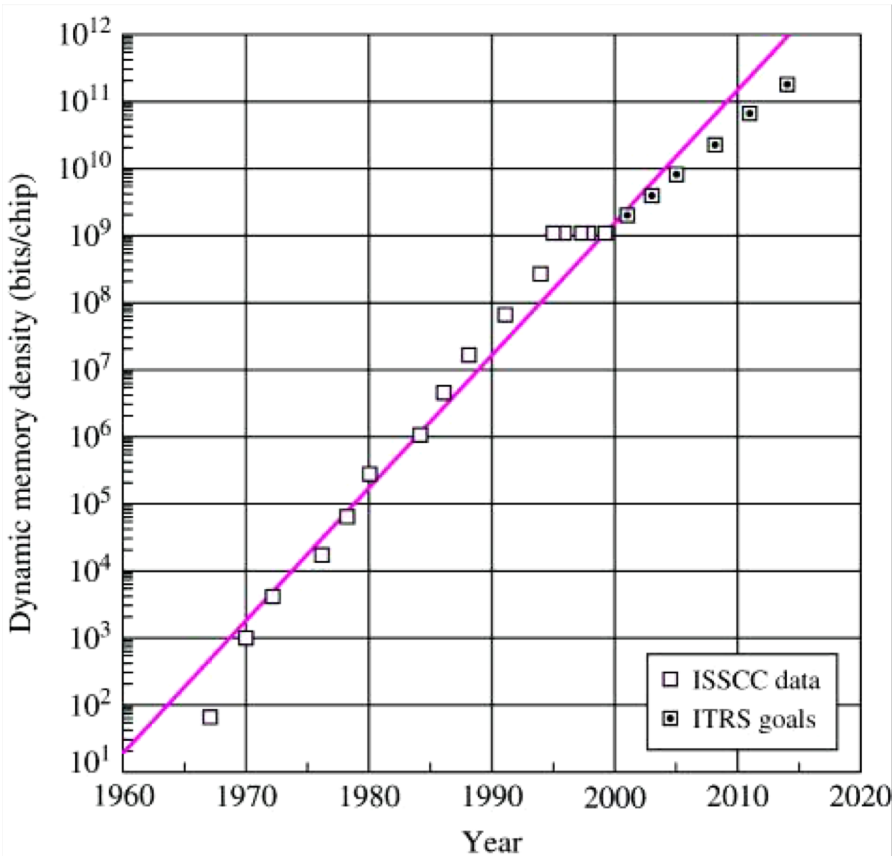
Jack Kilby
Texas Instruments
Invented IC during his first year at TI

(Nobel Prize 2000)

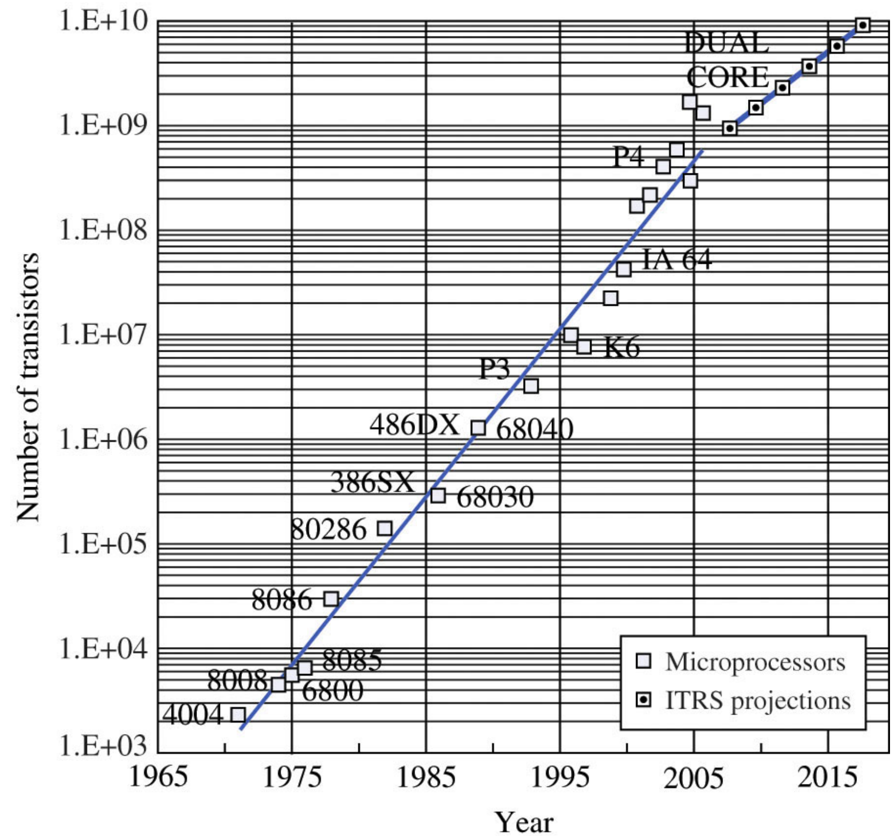
"Solid Circuit" made of Ge

Moore's Law

Memory chip density versus time



Microprocessor complexity versus time



Moore's Paper in 1965

Cramming more components onto integrated circuits

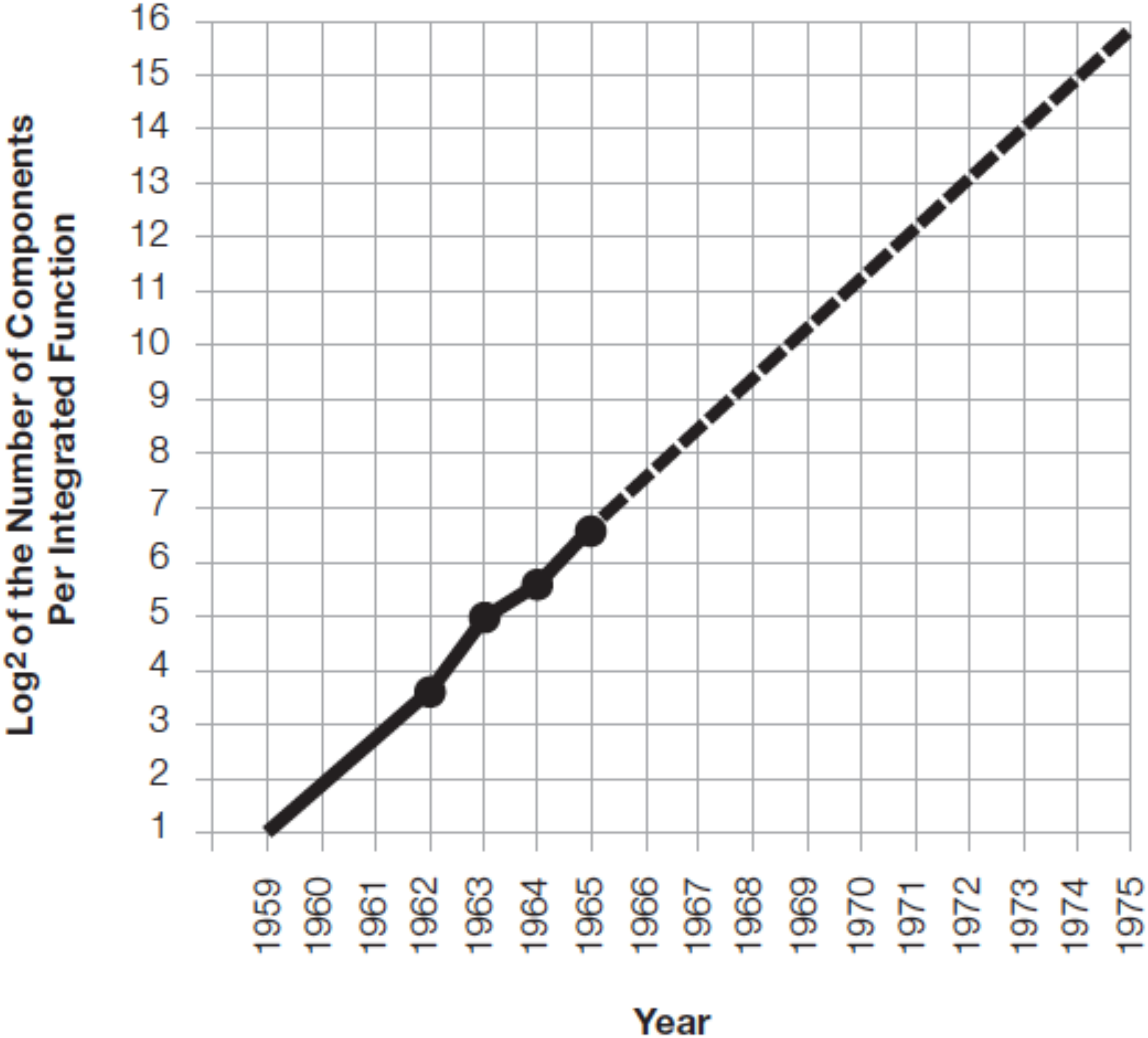
With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip

By Gordon E. Moore

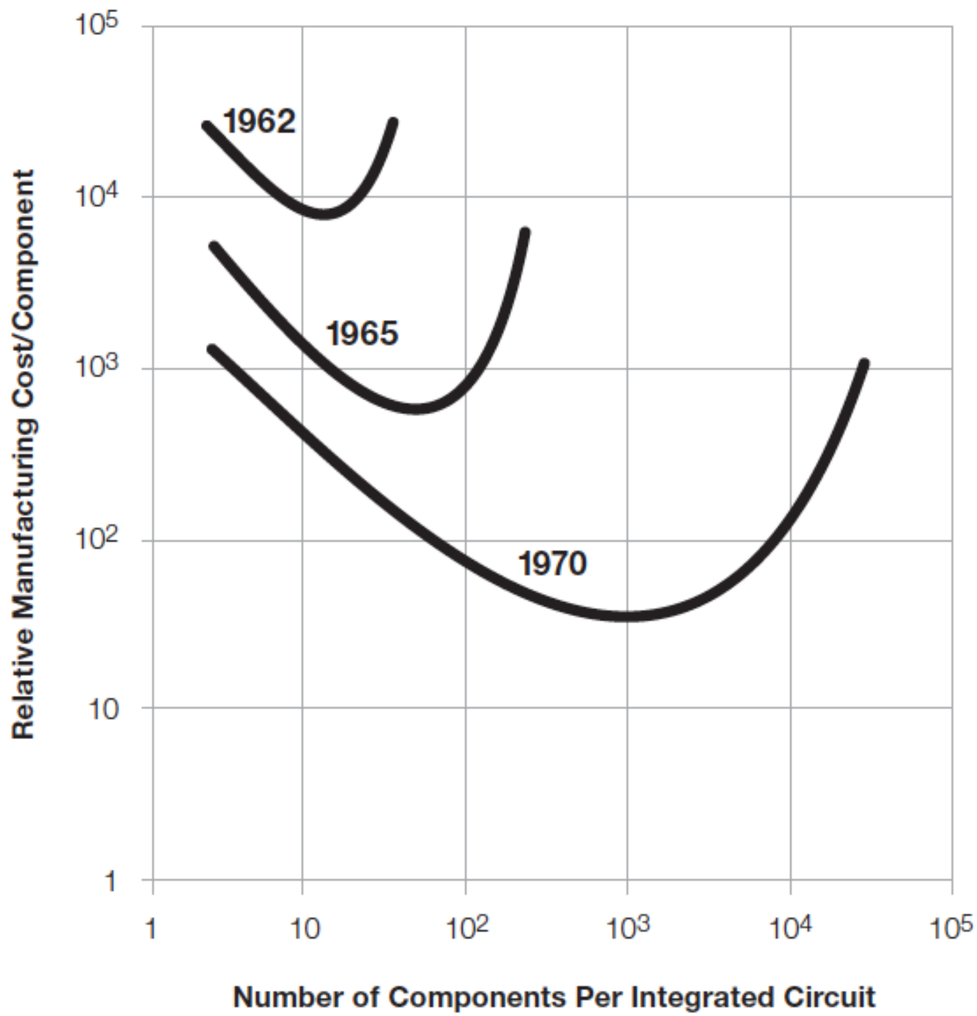
Director, Research and Development Laboratories, Fairchild Semiconductor division of Fairchild Camera and Instrument Corp.

Dr. Gordon E. Moore is one of the new breed of electronic engineers, schooled in the physical sciences rather than in electronics. He earned a B.S. degree in chemistry from the University of California and a Ph.D. degree in physical chemistry from the California Institute of Technology. He was one of the founders of Fairchild Semiconductor and has been director of the research and development laboratories since 1959.

Moore's Law in 1965

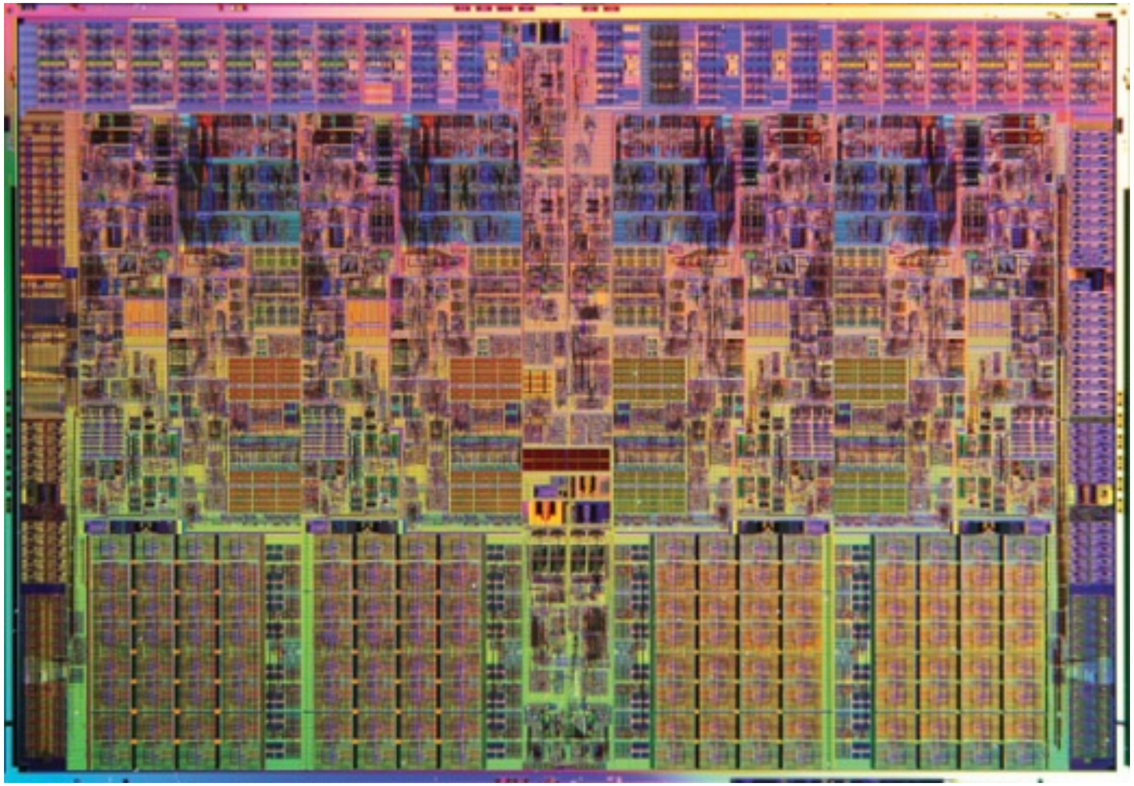


Moore's Argument



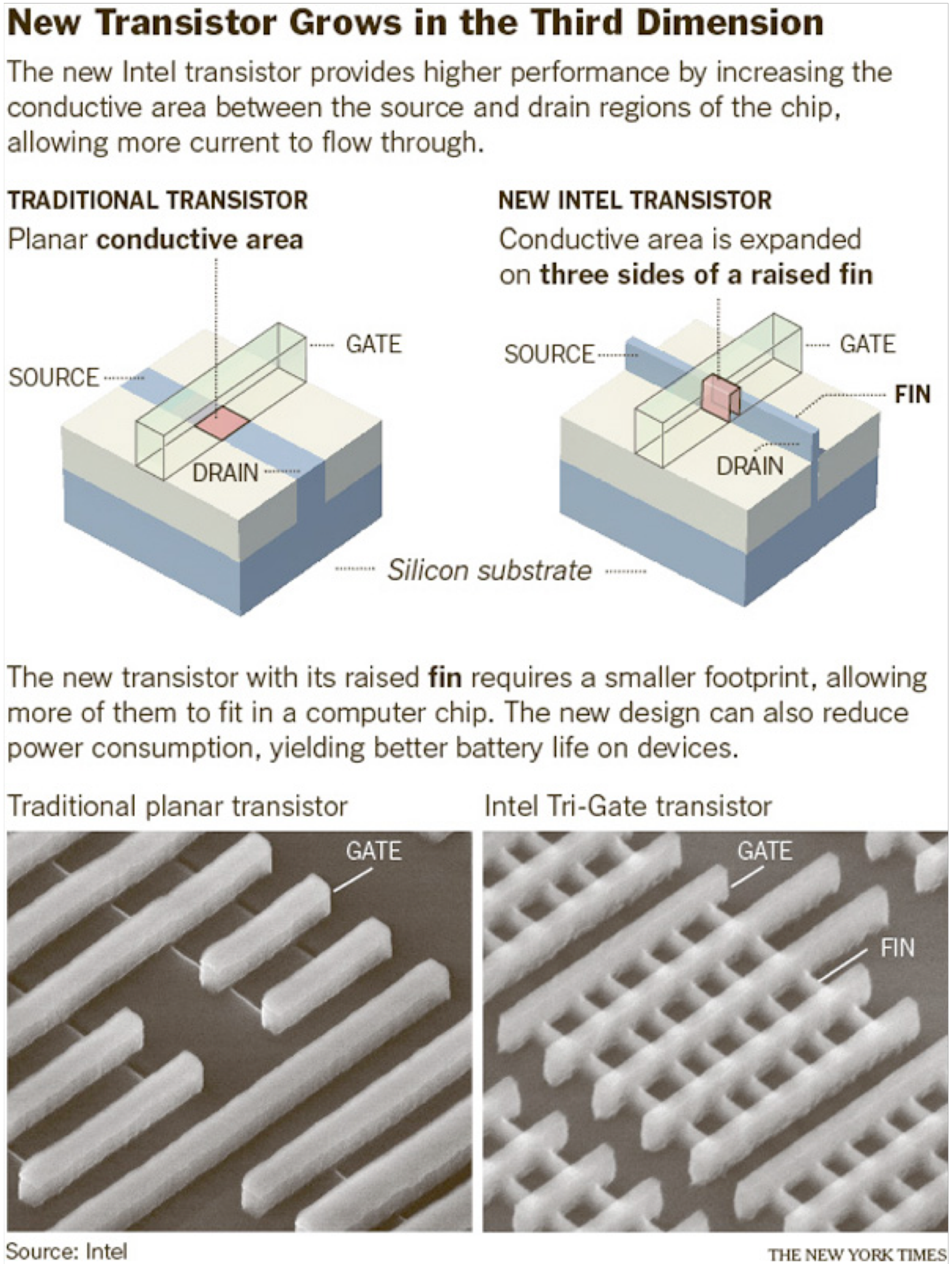
Intel Core i7 Microprocessor (4 Cores)

~ 1.1 Billion Transistors



Most powerful processor has about 10B transistors today.
Most powerful GPU has 20B+ transistors.
http://en.wikipedia.org/wiki/Transistor_count

FinFET

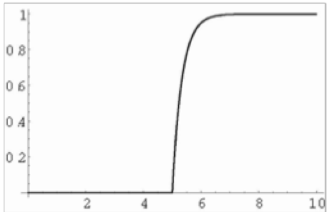


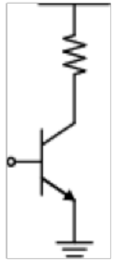
- **Invented at Berkeley !**
- Hisamoto, D.; Wen-Chin Lee; Kedzierski, J.; Takeuchi, H.; Asano, K.; Kuo, C.; Anderson, Erik; Tsu-Jae King; Bokor, J.; Chenming Hu, "FinFET-a self-aligned double-gate MOSFET scalable to 20 nm," *IEEE Transactions on Electron Devices,* 2000

http://www.nytimes.com/imagepages/2011/05/05/science/05chip_graphic.html?action=click&contentCollection=Science&module=RelatedCoverage&region=Marginalia&pgtype=article

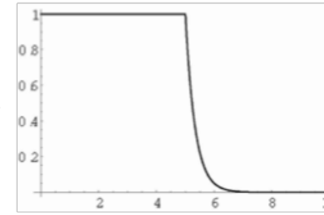
BSAC

Berkeley SPICE





```
* Example netlist
Q1 1 2 0 npnmod
R1 1 3 1k
Vdd 3 0 3v
.tran 1u 100u
```



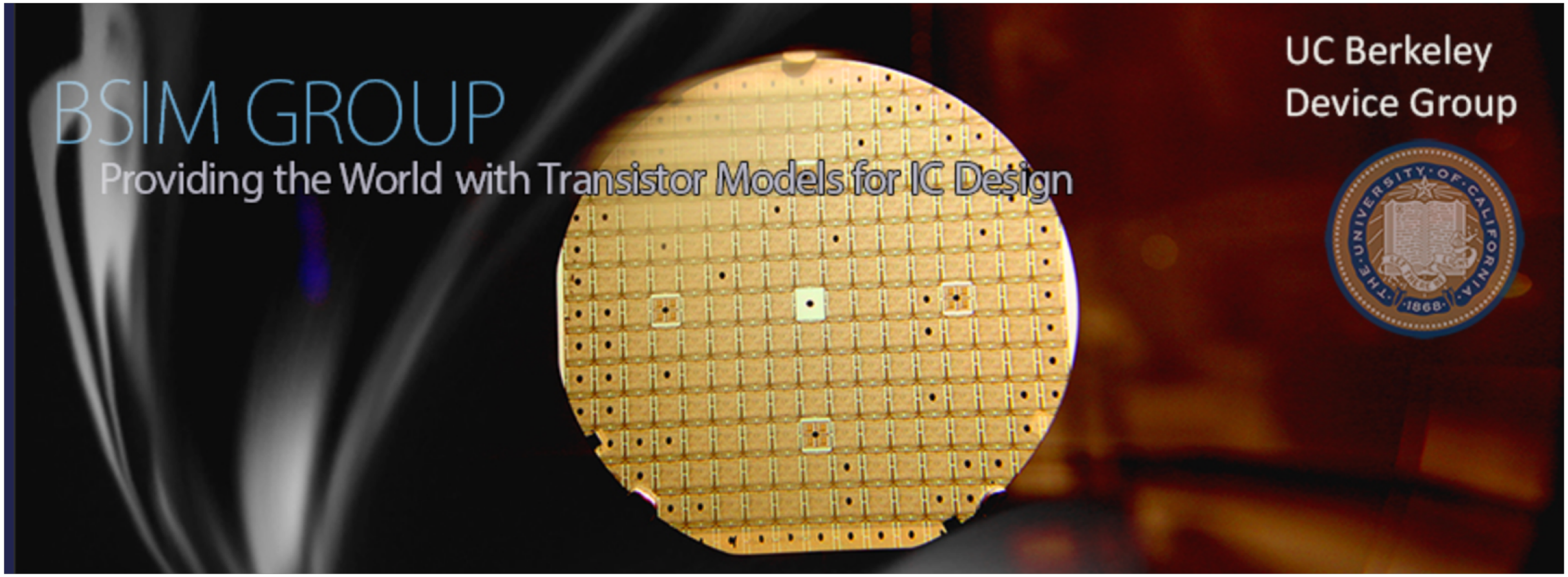
stimulus netlist response

SPICE was developed at the Electronics Research Laboratory of the University of California, Berkeley by Laurence Nagel with direction from his research advisor, Prof. Donald Pederson. SPICE1 …. SPICE1 was first presented at a conference in 1973.

- **Designing circuits with dozens of transistors by hand is quickly challenging.**
- **Today we routinely design analog circuits with hundreds to thousands of transistors, and digital circuits with millions**
- **Computer simulation is important for design and verification of these circuits**
  - **SPICE was born at Berkeley and it's the heart of many commercial simulation engines**

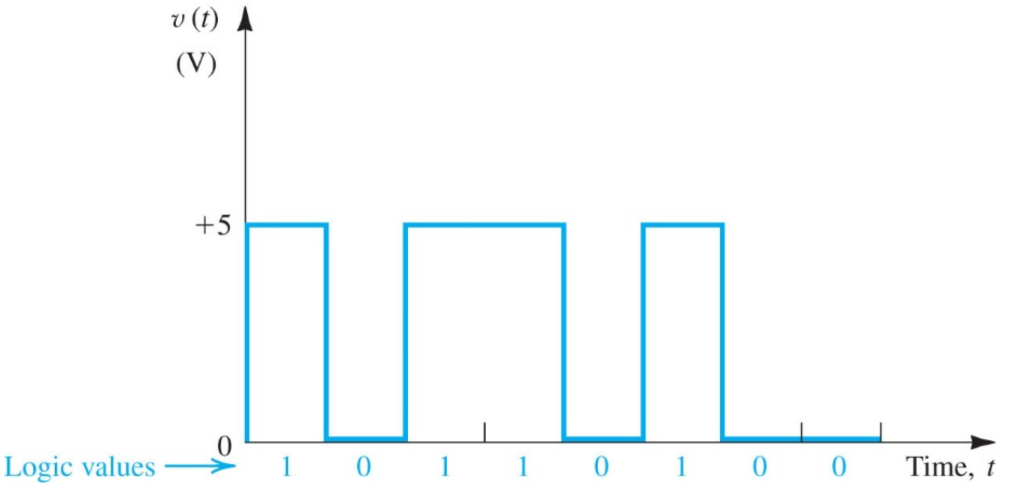
BSAC

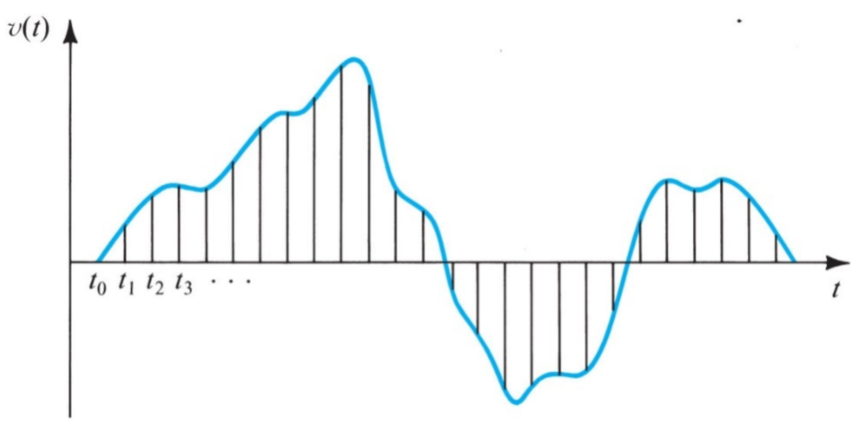
Modeling Transistors



- **Transistors are very complicated if you want all the details ...**
- **In a high level language, a single transistor is described with thousands of lines of code (10X more in a lower level language like "C")**
- ***Berkeley* builds and maintains the world standard compact models for a family of transistors in the BSIM model**

Digital vs Analog



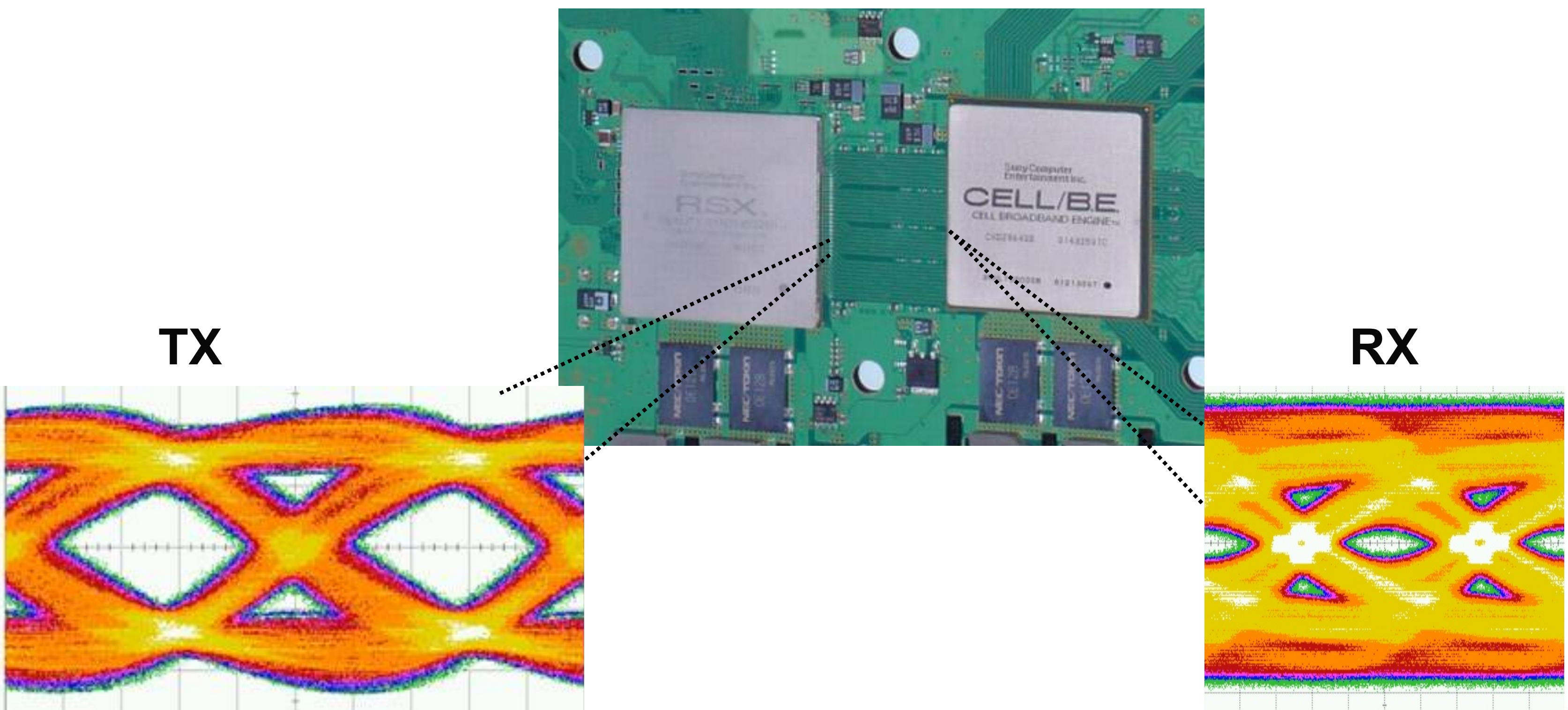


(a)

- **Digital signals appear at discrete levels. Usually we use binary signals with two levels**
- **One level is referred to as logical 1 and logical 0 is assigned to the other level**
- **Analog electrical signals take on continuous values**

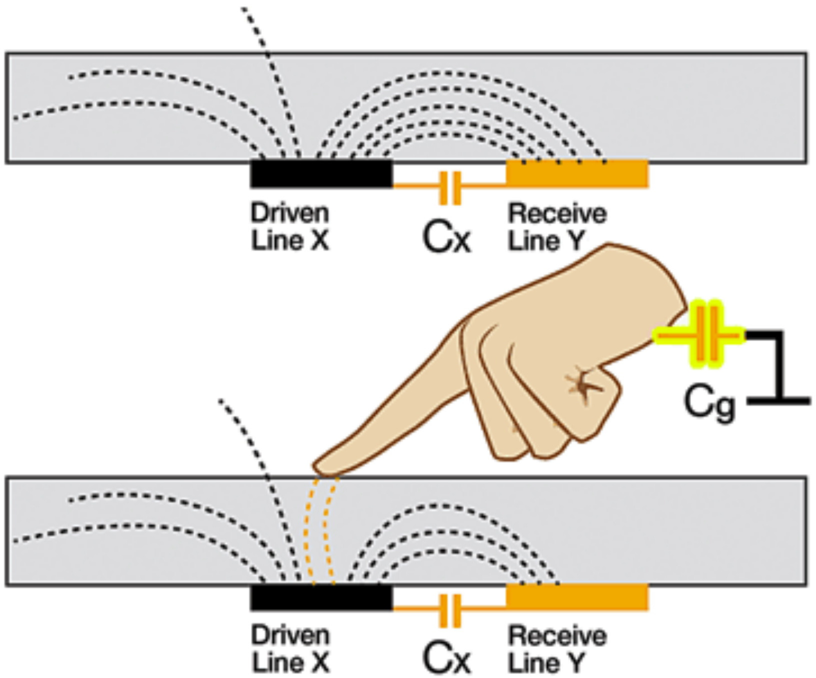
Why Analog?

- **The "real" world is analog**
  - **Analog is required to interface to just about anything**
  - **Even to get two digital chips to talk to each other:**



(Elad Alon)

Sensing



- **Similar to communications – analog needed for signal conditioning**

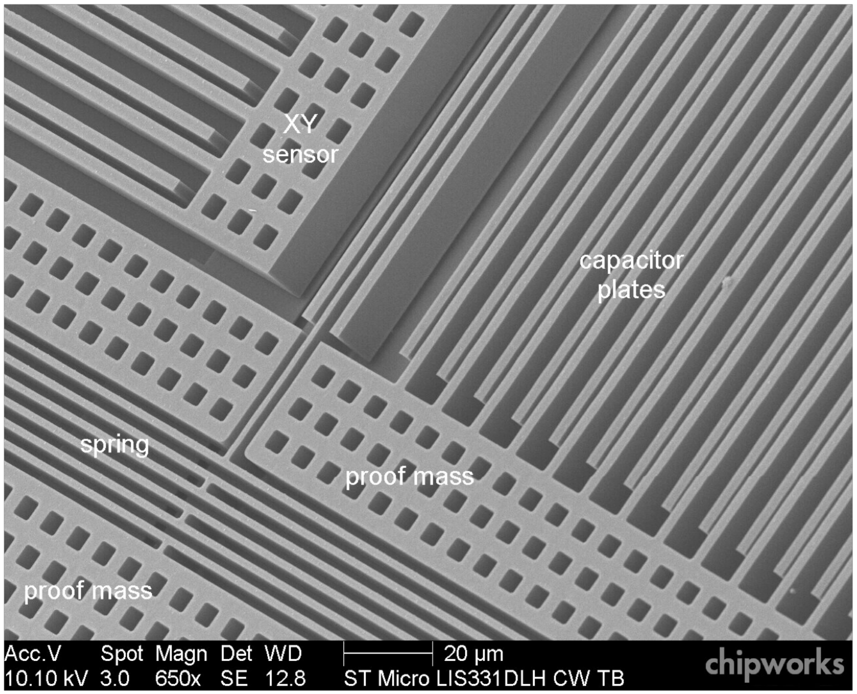
Sensors in a Phone

Lots of sensors:

- **9DoF motion sensing,**
  - **3 axis accelerometer**
  - **3 axis gyroscope**
  - **3 axis compass**
- **3 microphones,**
- **2 image sensors,**
- **ambient light and proximity sensors,**
- **archetypal touch screen sensor.**

MEMS
(Micro-Electro-Mechanical Systems)

- **Accelerometer in iPhone4**

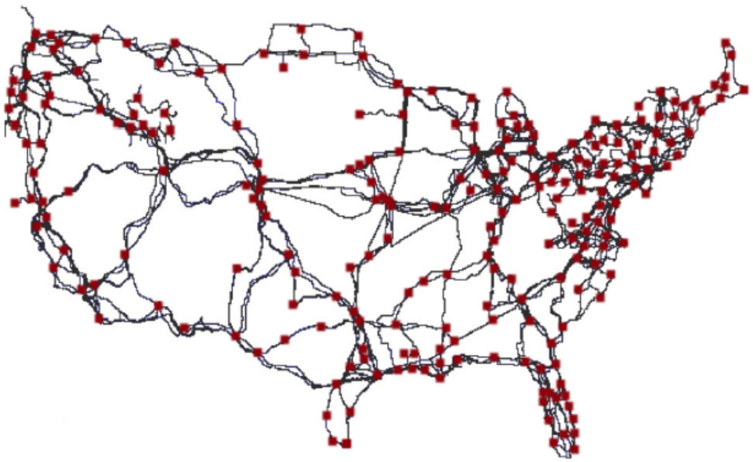


www.memsjournal.com/2010/12/motion-sensing-in-the-iphone-4-mems-accelerometer.html

- **MEMS technology, pioneered here (Berkeley Sensor and Actuator Center, *BSAC*), uses the same process to fabricate silicon ICs to build low cost sensors**

- **Mechanical signals can be coupled readily into the electrical domain**
  - **Accelerometers, pressure, chemical, gyroscopes, microphones, resonators and filters…**

Photonics



Fiber Optic Network

Data Centers

Apple Face ID

- **Laser diodes can create coherent light and modulate the amplitude (and phase) to carry information**
- **Semiconductor lasers and photodiodes are p-n junction diodes**
- **Fiber optic communication is the most efficient way to send information across a long distance**
  - **Accross oceans, continents, cities, campus, data centers, even between computers**

Medical Electronics

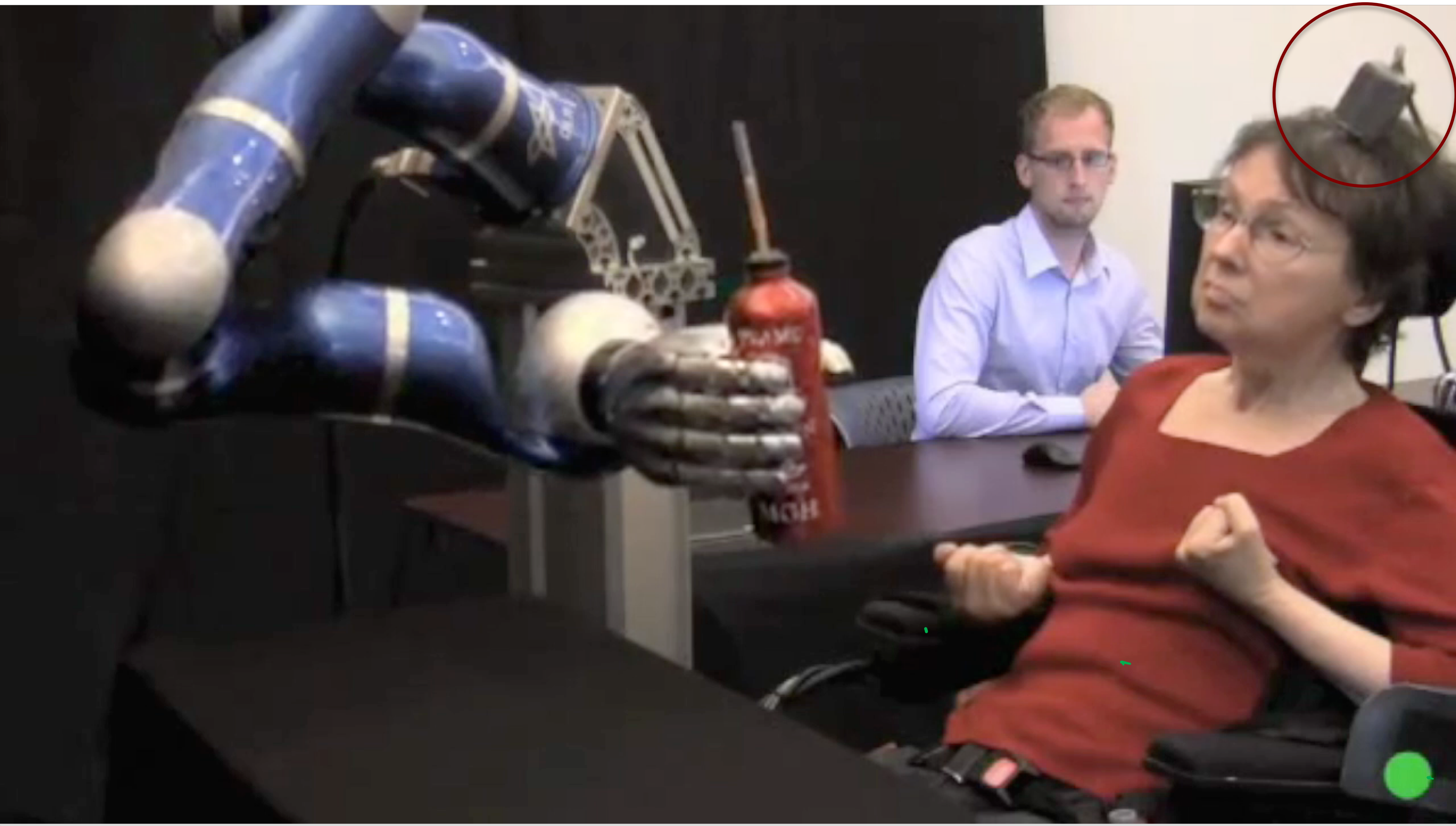
- **Inside every medical device, you will find a range of sensors and interface electronics**

ECG / SpO2



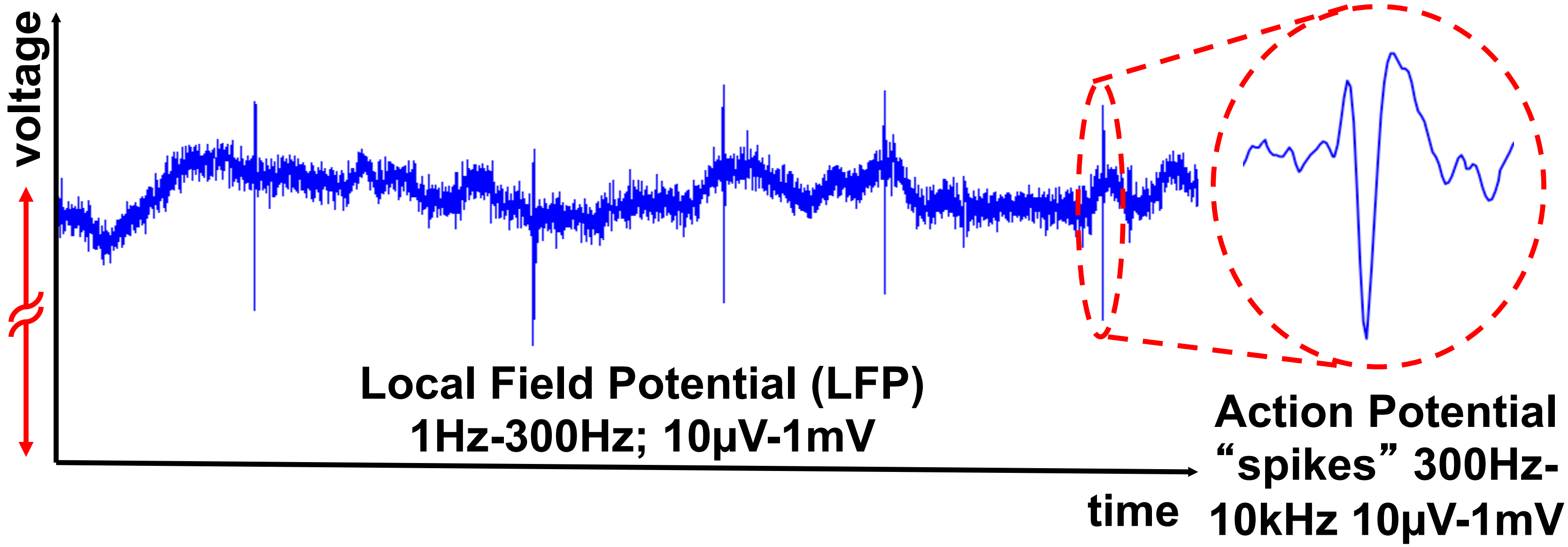
- Two commonly used devices to monitor patient health are Electrocardiogram (ECG) and Blood Oximetry (SpO2) sensors
- ECG uses a bunch of op-amps to amplify a weak signal that can be used to diagnose the health of the heart
- SpO2 uses light / infrared diodes and photosensors + interface electronics to measure blood oxygen levels

Brain-Machine Interfaces



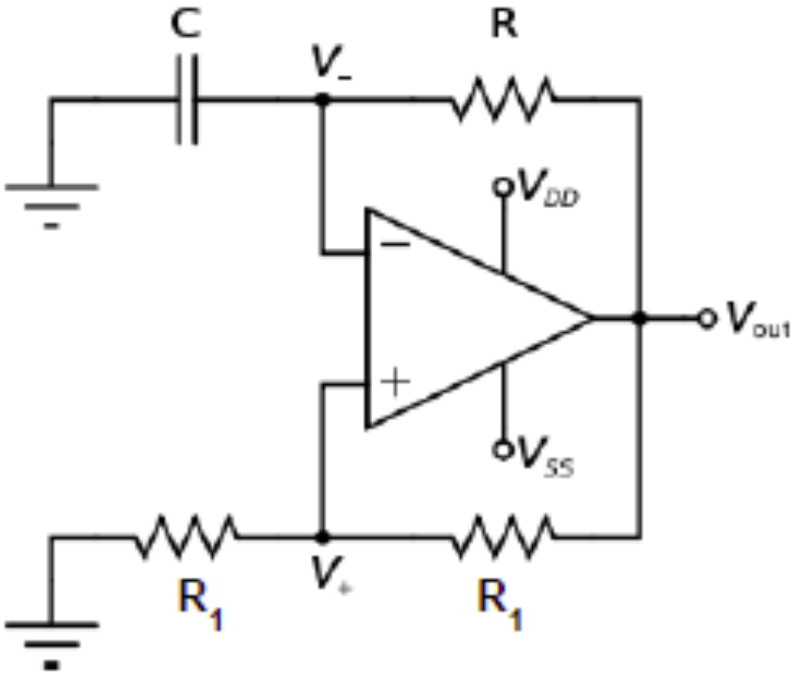
Source: Hochberg et al., *Nature* ‘12

Brain-Machine Interfaces



- **Similar to ECG, the goal of a brain-machine interface is to record the small-amplitude neural signals and pick out the meaningful signals from the “noise”.**
- **These signals are then decoded to create trajectories, movements, and speeds for controlling prostheses, computers, etc.**

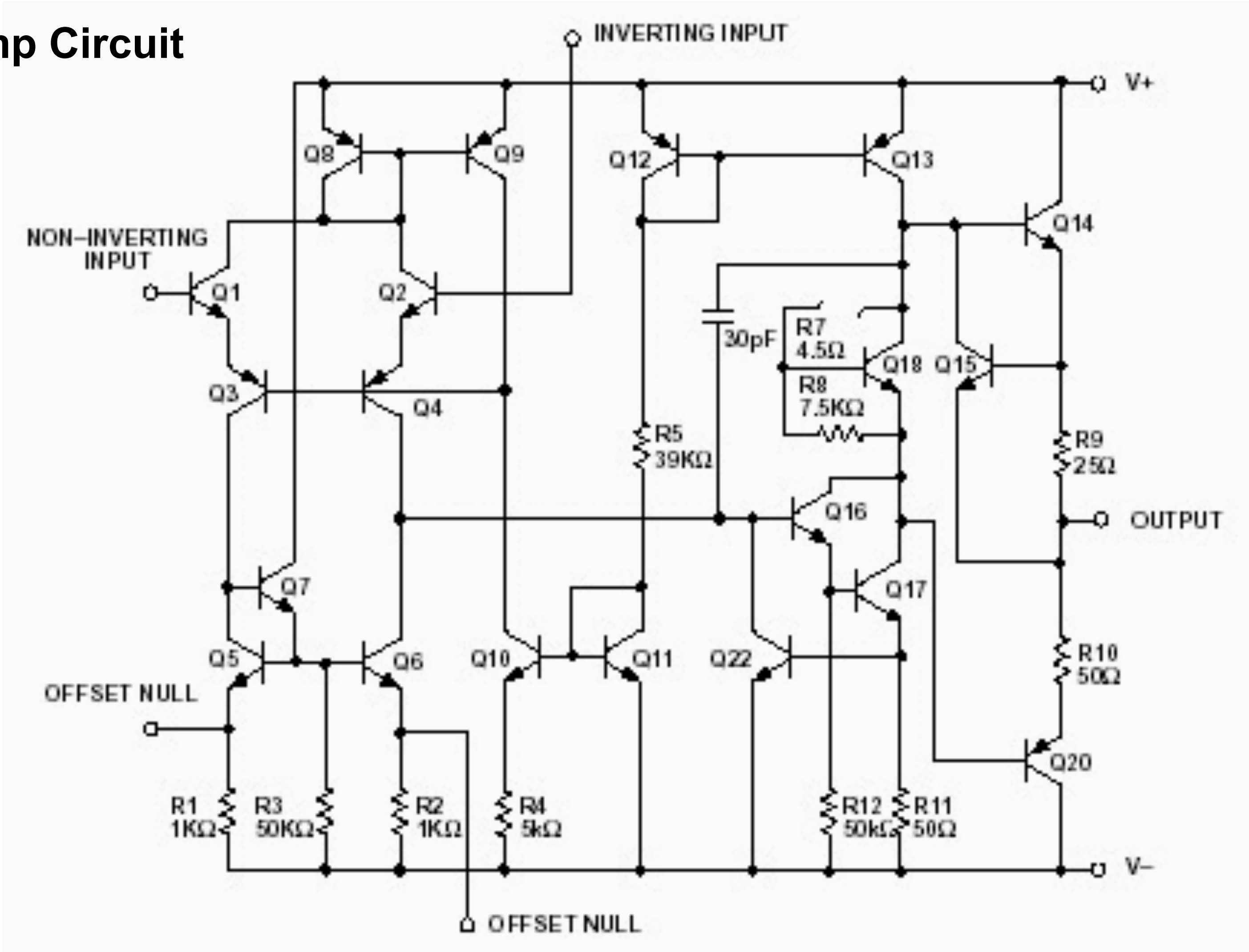
What You Learned in EE16



- Resistors, capacitors, inductors
- KCL, KVL
- Ideal OP Amp
- Time/frequency domain analysis
- Bode Plot

What You Will Learn in EE 105: Some Building Blocks of OP Amp

Op Amp Circuit



EECS Course Map