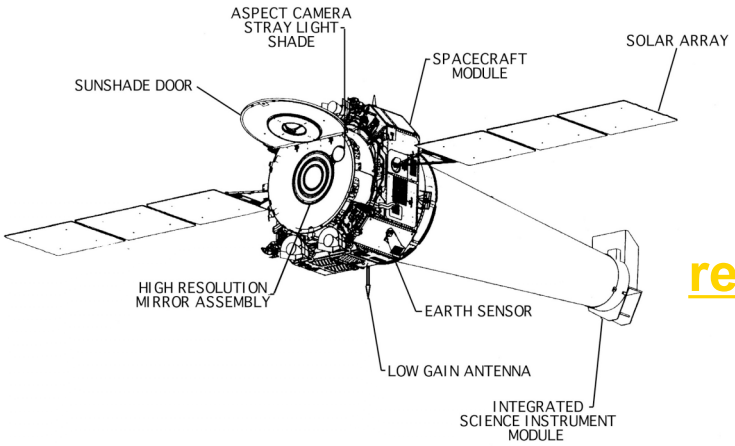
USC Viterbi School of Engineering

Electrical Engineering at USC

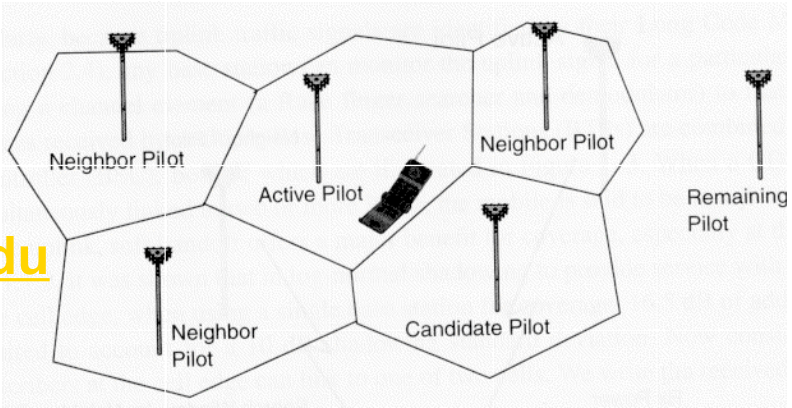
What it means to you…



Mark Redekopp

redekopp@usc.edu

ENGR 101



What is Electrical Engineering

- Harnessing electrical properties of materials to sense, transform, process, and enhance information & matter
  - What it used to be (pre-1950's)…
    - Power generation and delivery
    - Electromagnetics & Circuits (Radio, early TV, Radar)
  - What it is…
    - Computers, integrated circuits, control systems
    - Media Processing Techniques (MP3's, JPG, MPG)
    - Communications (Wireless, Networks, Internet, Error-correction)
    - Lasers, Photonics, Fiber optics
  - What the future holds…
    - Nanoelectronics and Bioelectronics
    - Quantum Computing
    - Pervasive networking and information accessibility
    - Reconfigurable, intelligent, parallel computing systems

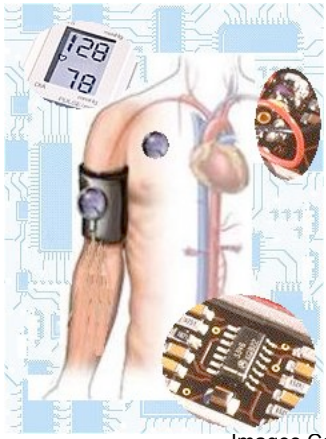
What is Electrical Engineering

- The key partner and enabling driver for many other industries and engineering practices…

Computer Science

Mechanical and Aerospace

EE



Biomedical Devices

Industrial Engineering

Images Courtesy:
- (From "Der neue Mercedes SL". ATZ/MTZ Extra, Special Edition October 2001, Friedr. Vieweg & Sohn Verlagsgesellschaft mbH, Wiesbaden, P. 105)
- http://www.sintef.no/ImageVault/Images/id_775/scope_4/webSafe_1/ImageVaultHandler.aspx

Impact on Society

- **National Academy of Engineering Top Achievements of the 20th Century: <u>The Contributions of Engineers to Society</u>**

1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

In just over 250 years, electrical engineering has become *"the"* key discipline that most profoundly effects technological progress (and our everyday life):

EE Majors

The options you have

- Electrical Engineering, B.S.

  ►Areas of emphasis◄

  Communication, Control, & Signal Processing

  Algorithms and applications for representing and processing information

  Computer Engineering

  Designing computation structures to implement the above

  Electronic Devices and Circuits

  Building and fabricating those computation structures

  Electromagnetics & Solid State

  The cutting edge science/physics of electricity/magnetism

- Electrical Engineering – Integrated Media Systems, B.S.

  Combine computers, human interface, sound, multi-media

- Computer Engineering/Computer Science (CECS), B.S.

- Biomedical/Electrical Engineering (BMEN), B.S.

- Combined EE B.S./M.S. (4+1)

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EE Curriculum

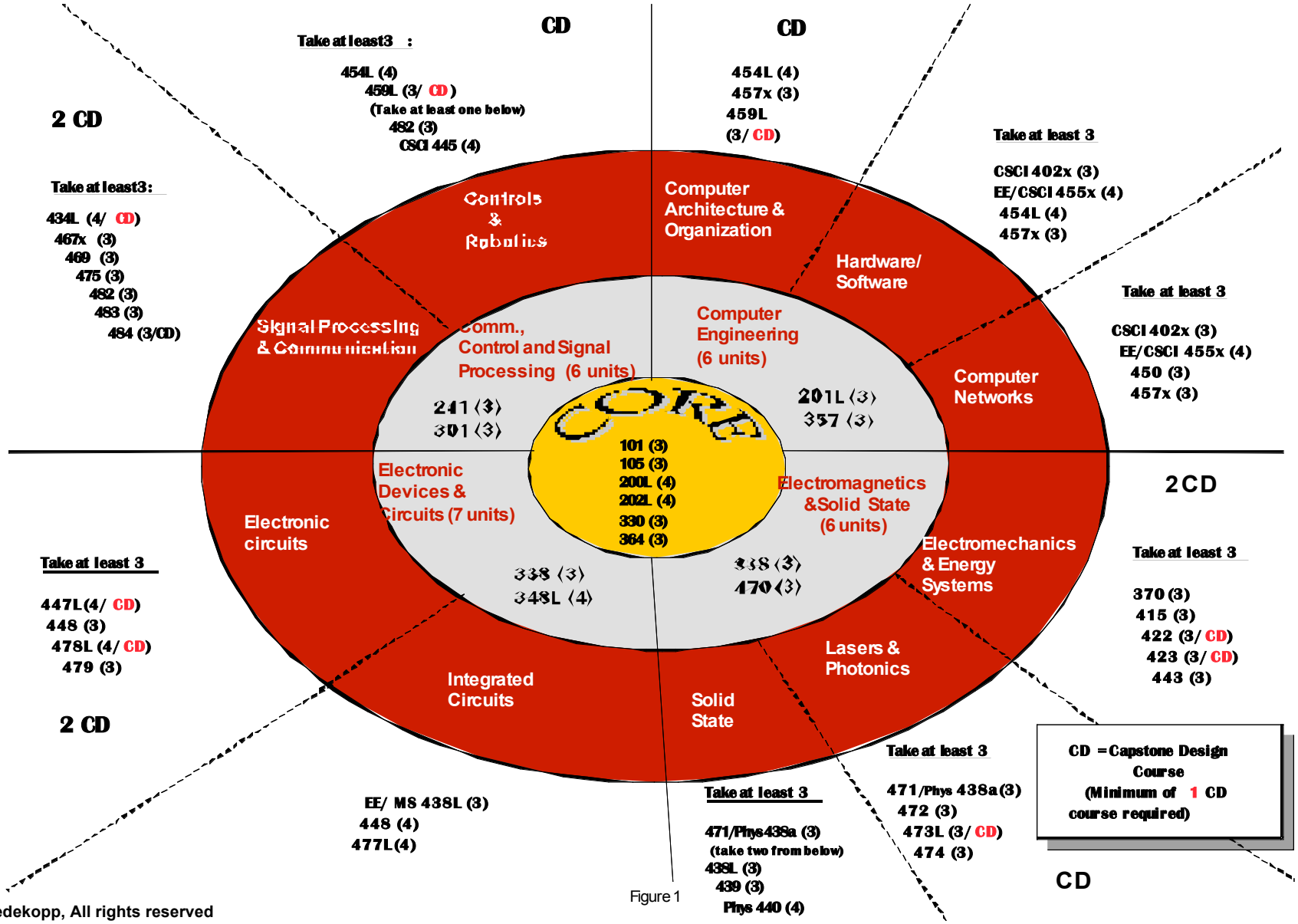


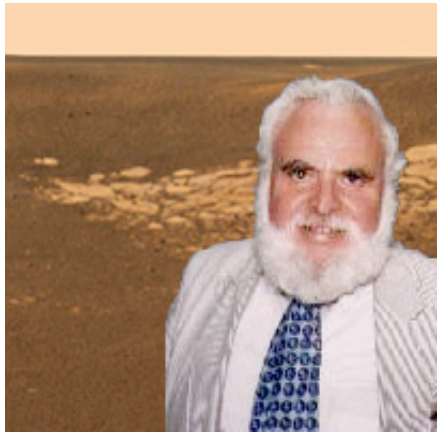
Figure 1

Communications

- Signal Representation, Transmission, Reception
  - WiMax, Fiber-optics, Ultra-wide band radio
- Signal coding for wired and wireless communications
  - Error Correcting Codes (Viterbi algorithm)
- Information Theory
- Quantum Information & Computing
  - Harnesses properties of quantum mechanics to perform calculations too “hard” for classical computers

Communications Example

- Mars rovers use a coding technique authored by USC's Solomon Golomb
  - Image data is translated using Golomb's code to significantly reduce the amount of data that has to be transferred to earth
- Andrew Viterbi's algorithm used in cell phones and many other communications devices
- Irv Reed developed error correcting codes used on all DVDs to correct for scratches and dirt
- Chuck Weber's work used for space shuttle's radar system

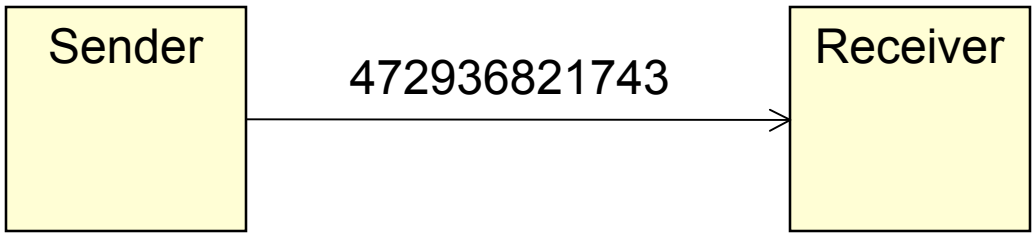


S. Golomb

A. Viterbi

Error Correcting Code Example

- You want to send the following numbers over a communication link. Errors can occur during transmission.
  - Can we include more information to detect a single digit error?
  - Can we include more information to detect AND correct a single digit error?



Error Correcting Code Example

Example: 12 digit number is | 4 7 2 9 3 6 8 2 1 7 4 3 |

Arrange as a 3 x 4 array:

4	7	2	9
3	6	8	2
1	7	4	3

Parity Checks:

4	7	2	9	2
3	6	8	2	9
1	7	4	3	5
8	0	4	4	6

Claim:

12 digits of data requires **8** digits of parity check to achieve automatic **detection** and **correction** of any single error.

Parity digits are generated by Σ modulo$_{10}$ for each column and row, respectively

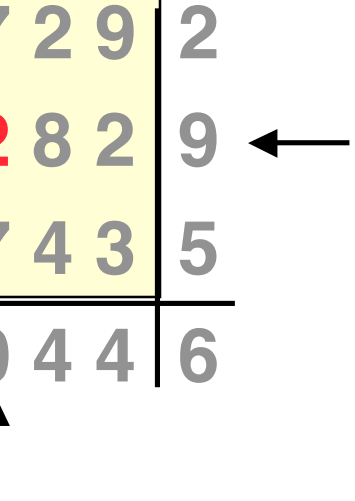
Error Correcting Code Example

Sent

4 7 2 9	2
3 6 8 2	9
1 7 4 3	5
8 0 4 4	6

Received

4 7 2 9	2
3 2 8 2	9
1 7 4 3	5
8 0 4 4	6



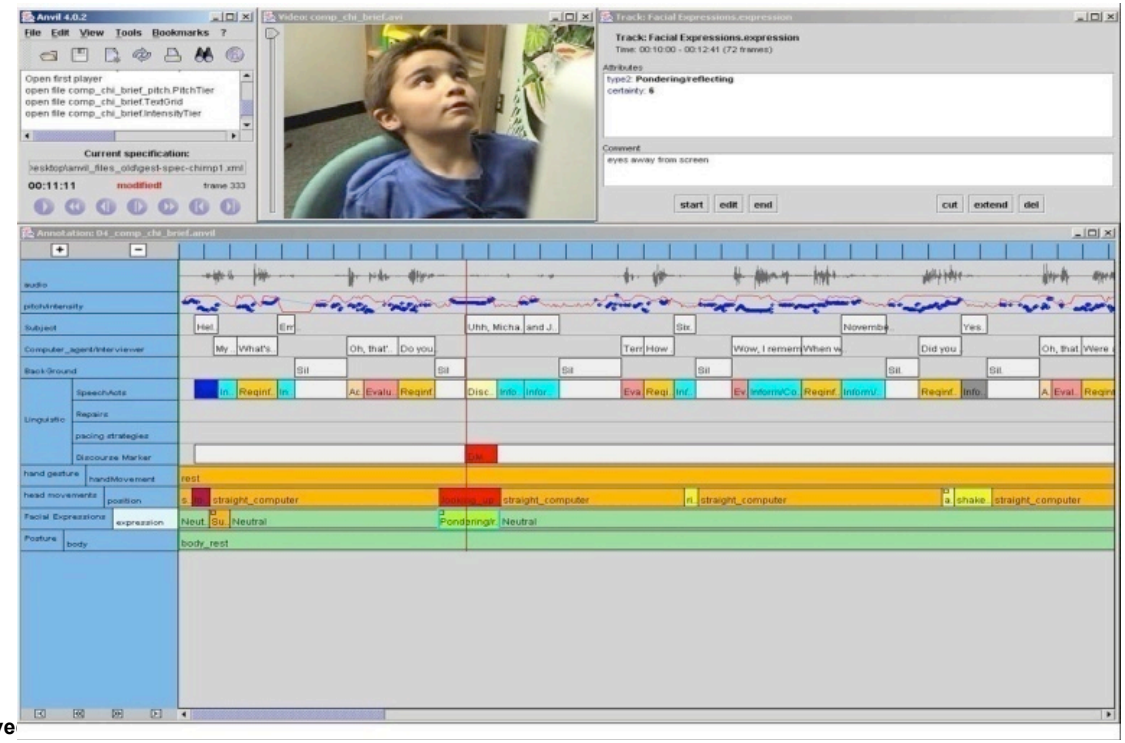
- **Finding the row and column discrepancy allows for detection**
- **Correct by solving row and column sum equations**
- **Binary works the same**
- **Used often in cache memories and on buses in computers, in networks, and other communication links**

Signal & Image Processing

- Feature/Pattern Identification and Extraction (Recognition)
  - Voice/Speech Recognition
  - Image Recognition (Biomarkers, Target Tracking)
- Image (Video) and Audio Transformations (Filtering)
  - Compression & Coding (MP3, MPG, JPG)
  - MRI, CT scans, and other medical imaging
  - Immersive Audio (10.2 Surround Sound)
  - Loudspeaker design
  - Video conferencing and virtual reality

Speech Analysis and Interpretation

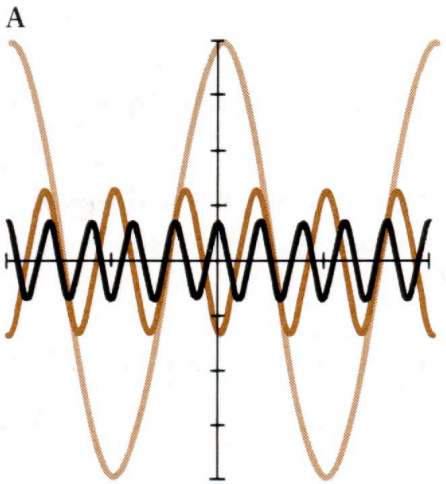
- Analyze children's speech and physical expression to provide better child-computer interaction
- 2-way real-time speech interpretation (English-Farsi)
- Music Database
  - Search music by humming or singing a portion of the song



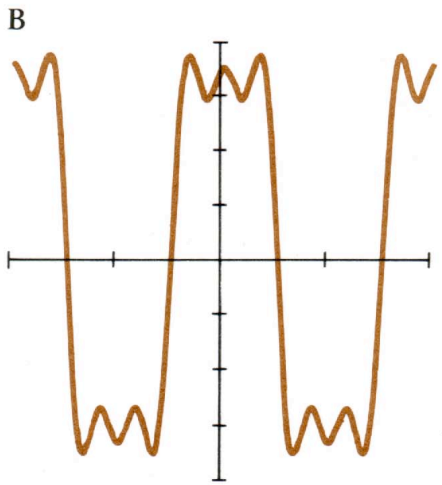
Research by
S. Narayanan

Combining of Signals

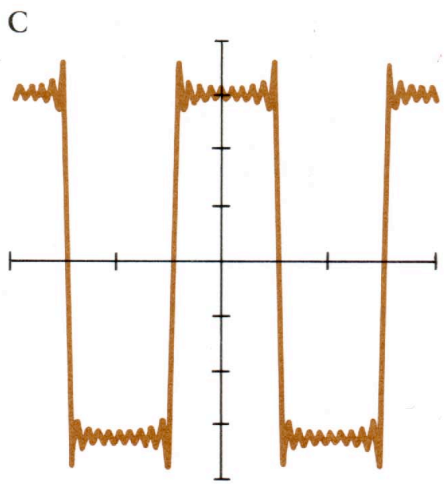
- Fourier's Theorem: any periodic signal (one that repeats over time) can be described as a sum of constituent sinusoids of different frequencies, amplitudes, and phases.
- Thus any signal can be decomposed into its corresponding frequency spectrum



f_o, $3f_o$, $5f_o$



Σ of f_o, $3f_o$, $5f_o$



Pierce pg. 43b

Σ through f_{19}

Controls

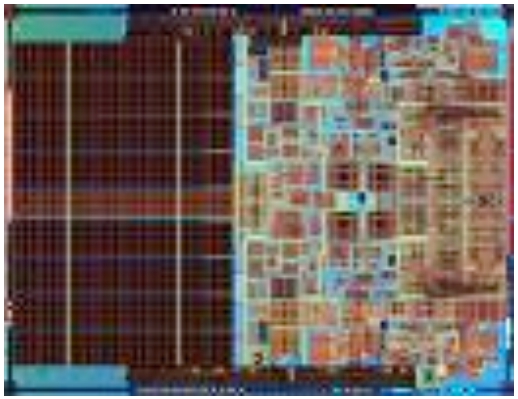
- Feedback Algorithms (Stability)
  - Cruise Control
  - Autopilot
  - Highway traffic control
- Robotics (Automation)
- Fuzzy logic and artificial intelligence
  - Reasoning in an uncertain, non-binary (true/false) world
  - ex. “Drive with the flow of traffic”

Robots in USC Labs

Steve Sample patented control systems found in dishwashers

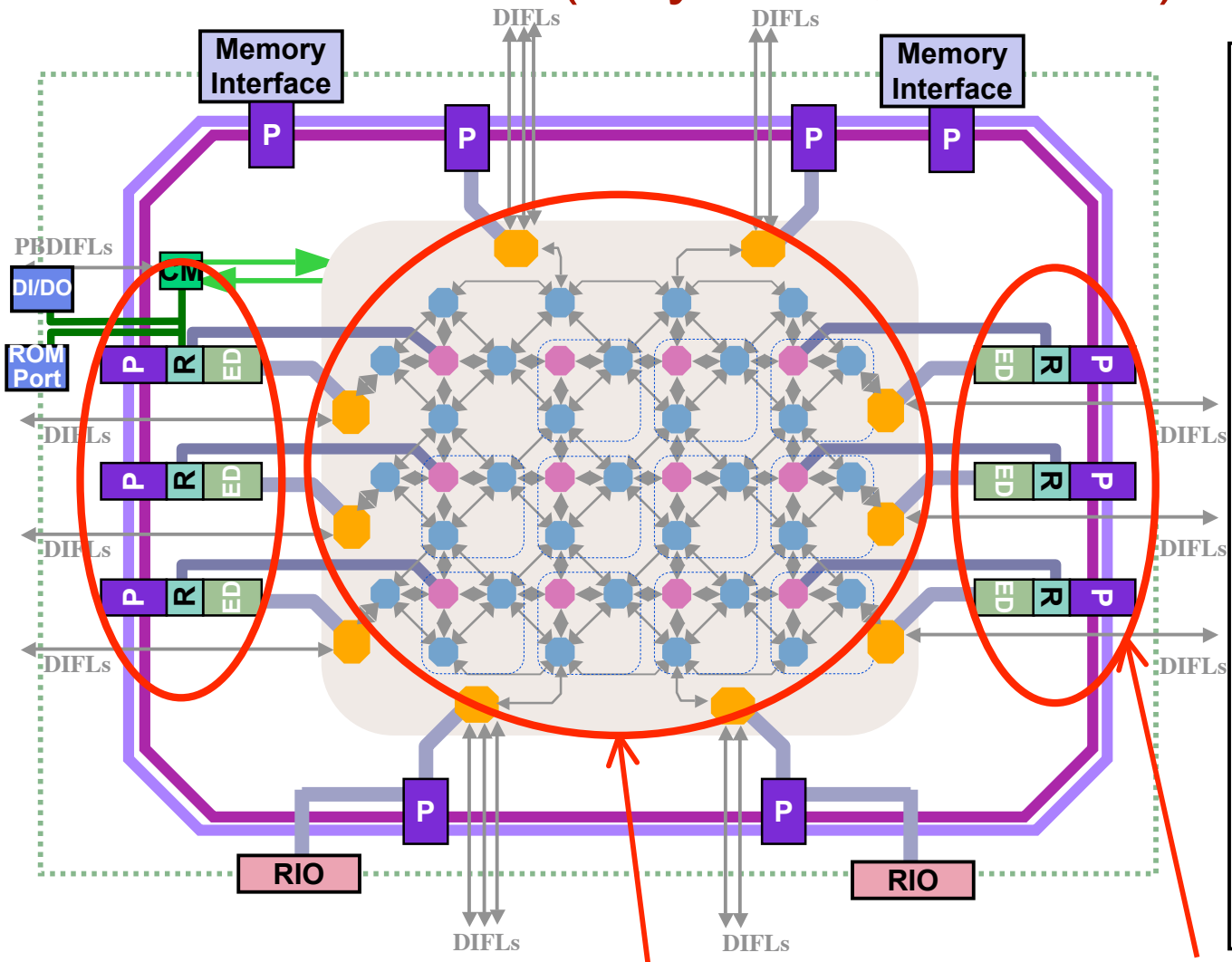
Computer Engineering

- Computer Architecture
  - Multicore processors
  - Reconfigurable processors
  - 3D chip stacking
- Computation Algorithms
  - Parallel processing methods
- Integrated Circuits
  - Low-power consumption
  - Reliability and testing



Core 2 Duo silicon die photo

MONARCH Chip
(Raytheon, USC-ISI)



- Throughput 64 GOPS peak
- Multiple programming modes
  - Reconfigurable, data flow
  - RISC scalar
  - RISC SIMD (Altivec-like)
- 90 nm bulk CMOS
- Clock 333 MHz
- Power 3-6 GFLOPS/W
- 12 Arithmetic Clusters
  - 96 adders (32 bits) fixed and float
  - 96 multipliers
- 31 Memory Clusters
  - 124 dual port memories
  - 256W x 32 bits each (128KB)
  - 248 address generators
- >72 DMA engines
- 6 RISC processors
- 12 MBytes on chip eDRAM
- 2 Bulk memory interfaces (8 GB/s BW)
- 2 RapidIO (serial) interface
- 17 DIFL ports (2.6 GB/s ea)
- On-chip ring 40 GB/s

Computer Networks

- Internet architecture
  - Network traffic congestion
  - Delivery of media
- Mobile and ad-hoc networks
- Network protocols
  - Reliable, secure data delivery
- Wireless Sensor Networks

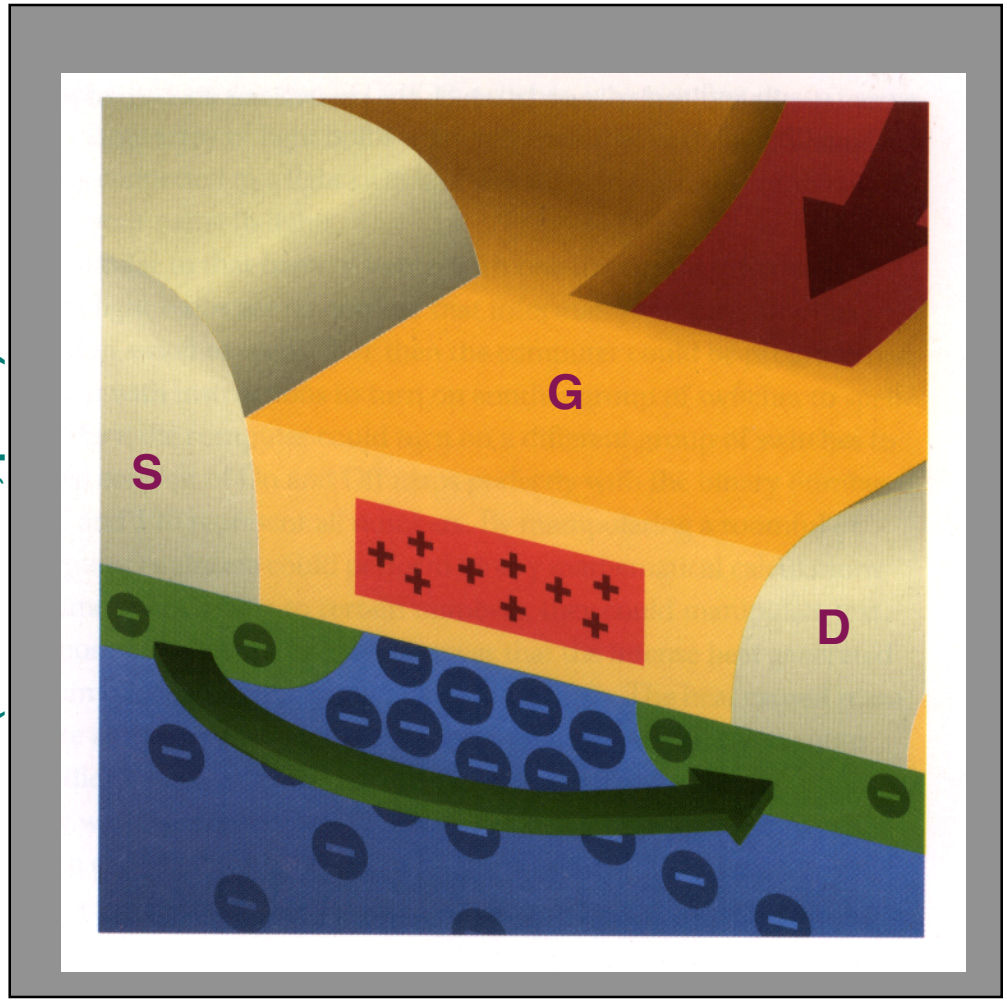
Wireless Sensor Networks

- Large scale unattended wireless networks of small embedded devices, each with sensing, computation and communication capabilities, running on very limited battery supplies.
  - Structural Monitoring (Bridge, Buildings, Airplanes)
  - Environmental Monitoring
  - Military Intelligence

Integrated & Electronic Circuits

- Digital Integrated Circuits
  - Semiconductor Device Physics and Chip Fabrication
- Analog Circuits
  - Wireless communication
  - Cell phones
  - Sound mixing boards

Transistors: Digital Circuit Building Blocks



(from White, p. 27)

How it works

Three Terminal Device (G,S,D)

Small positive charge placed on red electrode (gate, G)

Causes negative charges in the blue region to be attracted to red region

Affects conductivity in material between green regions (source, S and drain, D)

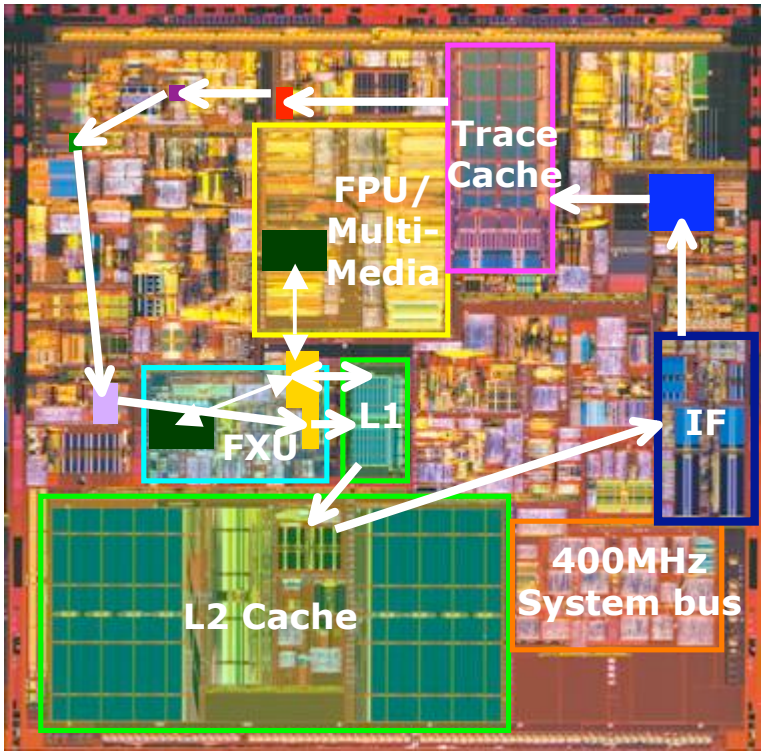
Current from source is now able to travel between source and drain

VLSI Chip Design, Layout, and Fabrication

Intel Pentium 4 (Northwood .13μm)

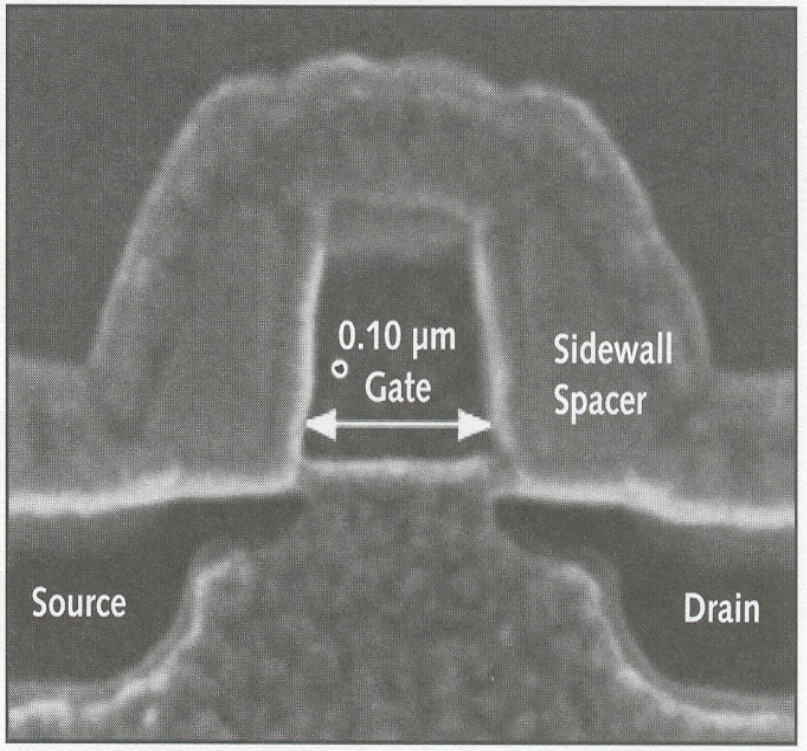
Human Hair = 100,000 nm; Hydrogen atom = 1/10 nm

MPR Feb 2004 pg. 60



- 55 M transistors in 132mm^2
- "city map" logic placement
- 89 Watts @ 3.4 GHz
- 6 metal layers, 423 I/O pins

MPR Sept. 6, 1998 pg 7

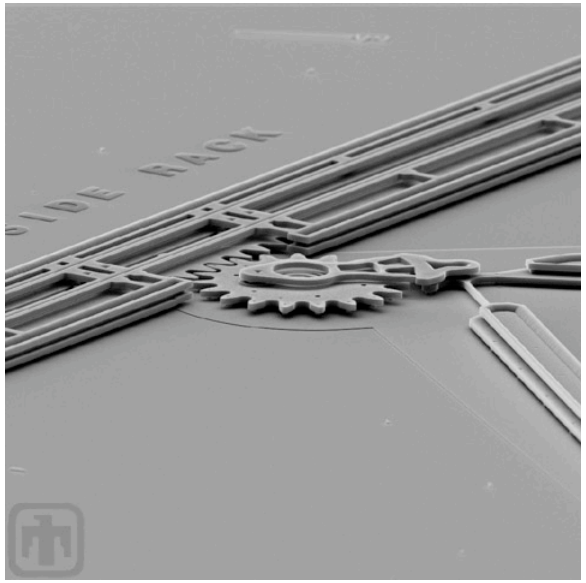


- Cross section of a transistor fabricated in 130 nm technology
- In 2004, 90 nm technology
- In 2006, 65 nm technology
- Soon 45nm (nanotechnology)

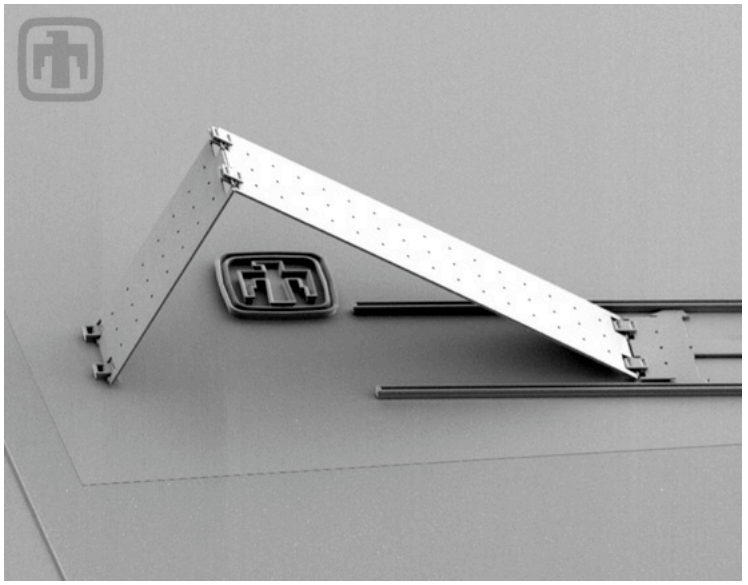
Solid State & Microelectromechanical (MEMS) Systems

- Fabrication of electronic and micro-mechanical devices on a single chip
  - DLP projection
  - Bio-implants

*Courtesy Sandia National Laboratory



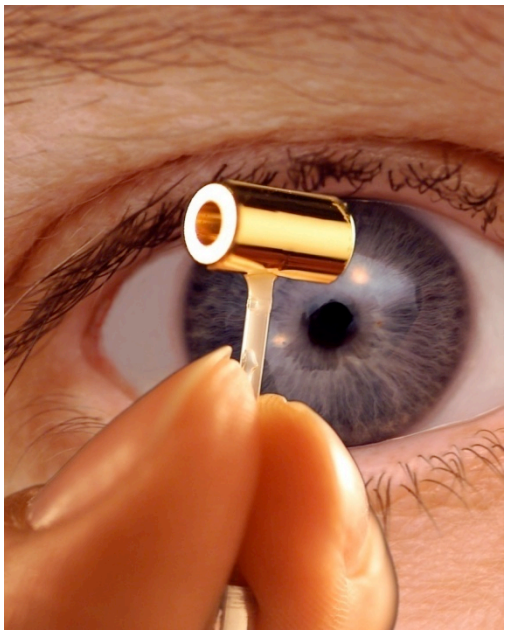
Rotary Drive

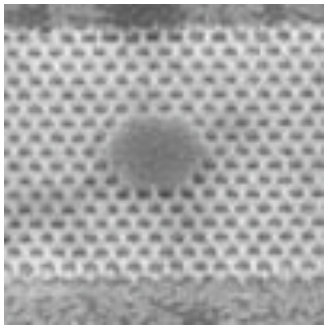


Micro Mirror Assembly

Lasers and Photonics

- Photonics
  - Optical (light) communication and processing techniques
- Lasers
  - Laser-driven fusion?
  - Nanolasers

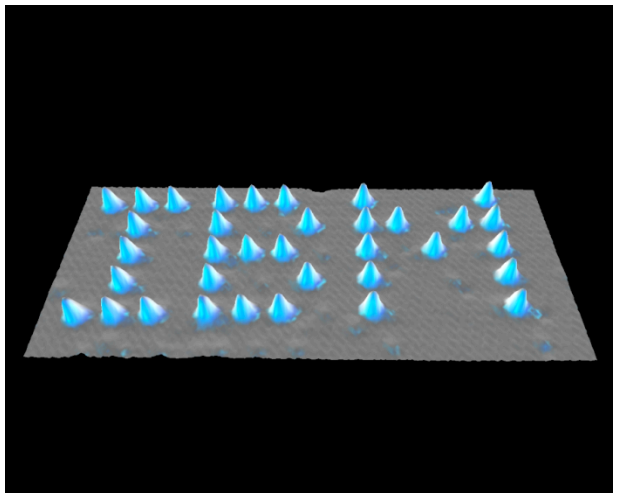




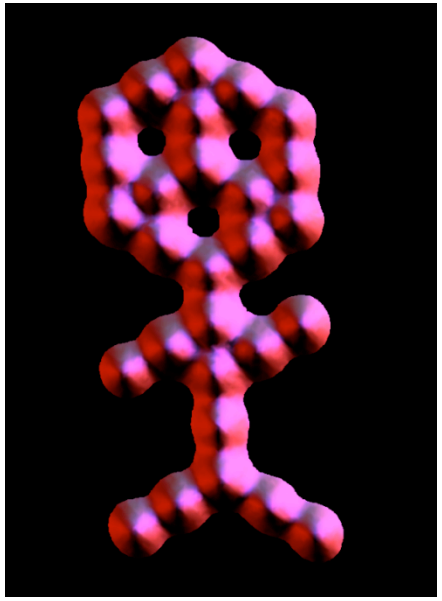
World's smallest laser (500nm, USC)
The nano-laser

Nanotechnology

- Start with very, very small structures and build up entirely new electronic circuits, electronic materials, energy sources, etc.
- Carbon nanotubes and nanowires
  - Nanotube transistors



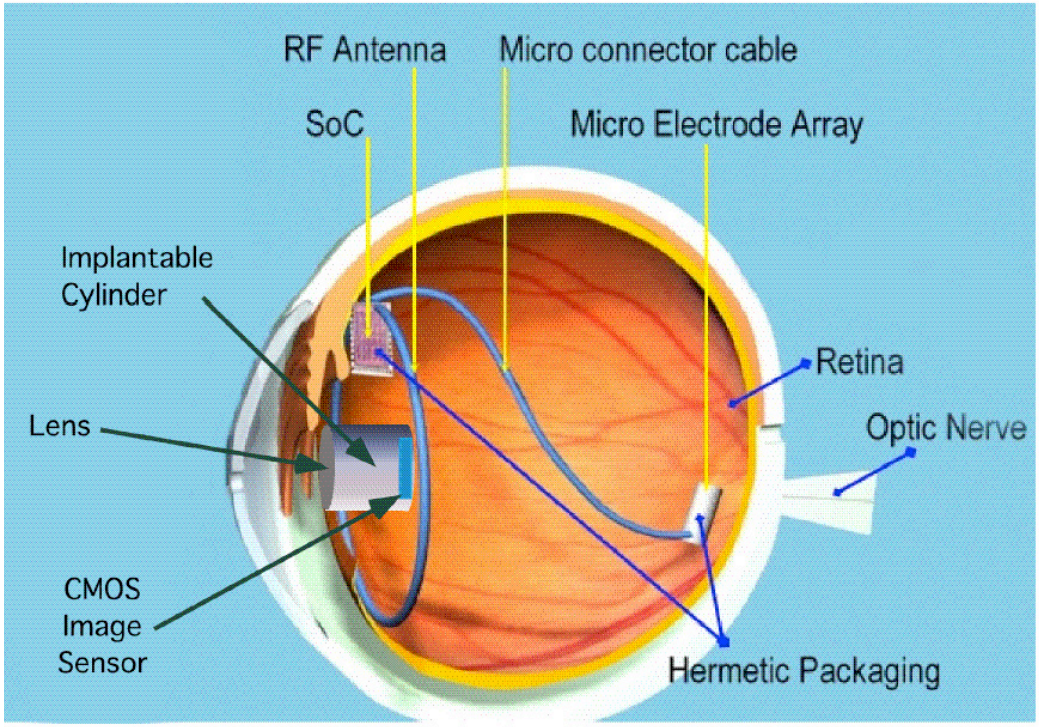
35 xenon atoms on nickel crystal



CO Man

Bioelectronics

- Implantable systems
- MRI
  - 3D MRI
  - Brain activity
- CT Scans



Intraocular Camera for Retinal Prostheses: Eyes for the Blind

A joint project between Electrical Engineering, Medical School, Mann Institute

USC Viterbi School of Engineering

EE Curriculum

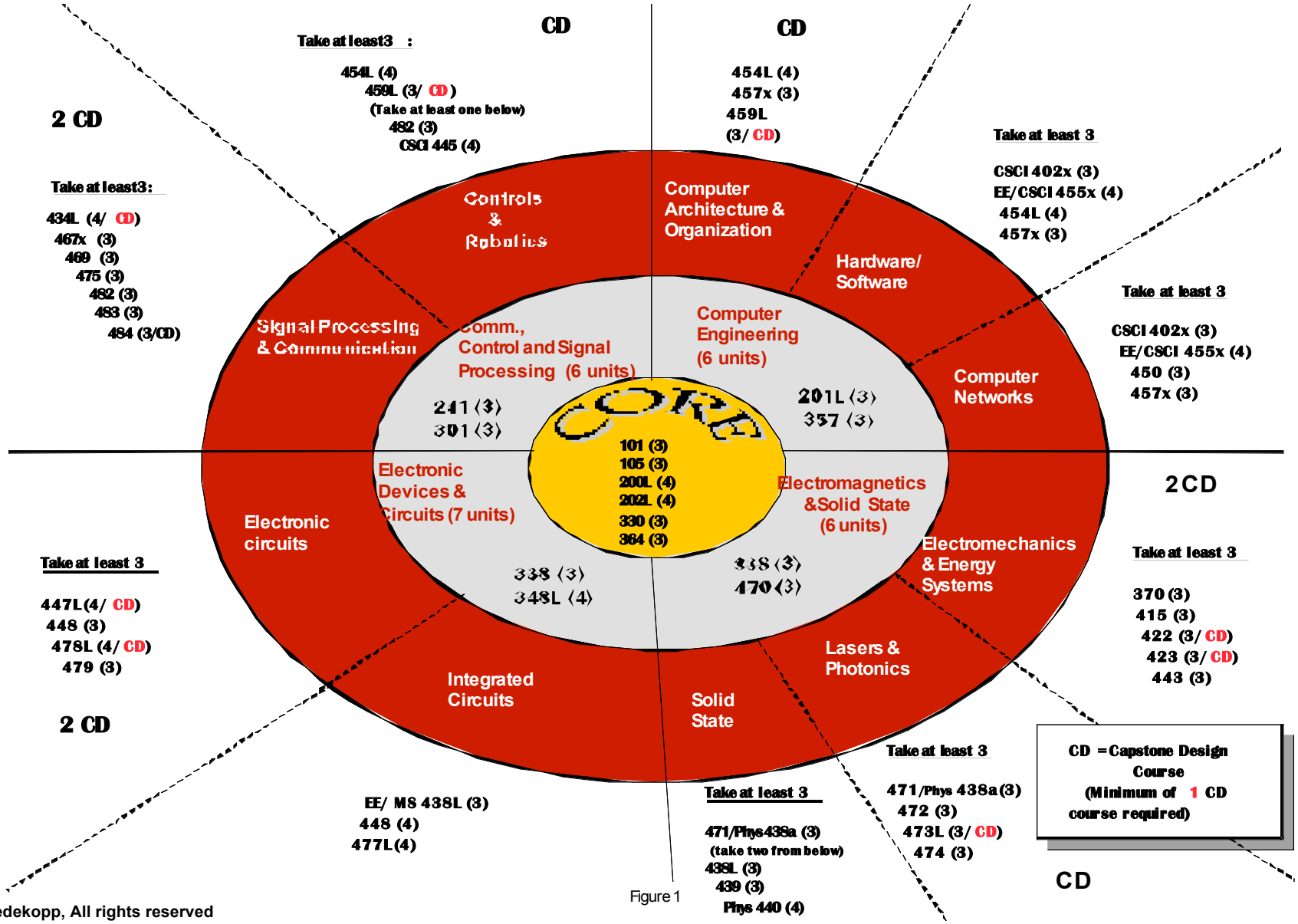


Figure 1

EE Student Organizations

- Institute of Electrical and Electronics Engineers
  - EE Professional Society
- Association of Computing Machinery (ACM)
  - Computer Professional Society
- Eta Kappa Nu
  - EE Honor Society
- Competition Robotics
  - Autonomous Submarine

Beyond USC

Employers & Graduate Schools

- Semiconductor & Computing
  - Cypress Semiconductor
  - Intel
  - Hewlett-Packard
  - Microsoft & Apple
- Communications & Networking
  - Nokia
  - Cisco Systems Inc.
  - DirectTV
  - Conexant
- Aerospace
  - Boeing
  - Raytheon
  - Northrop-Grumman
  - Space Exploration Technologies
- Chevron
- Walt Disney Imagineering
- Alcon (Biomed)

- Sample Graduate Schools
  - Stanford
  - Berkeley
  - Georgia Tech.
  - Duke
  - UPenn
  - Columbia

Engineering Job Market

Civil	237,000	16.4
Mechanical	226,000	15.6
Industrial	177,000	12.2
Electrical	156,000	10.8
Electronics, except computer	143,000	9.9
Computer hardware	77,000	5.3
Aerospace	76,000	5.2
Environmental	49,000	3.4
Chemical	31,000	2.1
Health and safety	27,000	1.8
Materials	21,000	1.5
Nuclear	17,000	1.2
Petroleum	16,000	1.1
Biomedical	9,700	0.7
Marine engineers	6,800	0.5
Mining and geological	5,200	0.4
Agricultural	3,400	0.2
All other engineers	172,000	11.8

Combined EE disciplines = 26%

Source: Department of Labor, Bureau of Labor Statistics
http://www.bls.gov/oco/ocos027.htm

EE was good enough for these guys…

Steven Sample
President of USC

Andrew Viterbi
Founder Qualcomm,
Namesake of USC
Engineering School

C.L. Max Nikias
Provost of USC

Ming Hsieh
Founder Cogent Systems,
Namesake of EE Dept.

The Last Word…

- Pick a major that interests you and that you enjoy…
  - A career is a long time
  - Money doesn't buy happiness
  - Find ways to integrate your different passions

The END