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…
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)
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
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?
Example: 12 digit number is

Arrange as a 3 x 4 array:

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

Parity Claims:
Checks:

<table>
<thead>
<tr>
<th></th>
<th>4 7 2 9</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 7 2 9</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3 6 8 2</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>1 7 4 3</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

8 0 4 4 6

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 $\sum \text{modulo}_{10}$ for each column and row, respectively.
Error Correcting Code Example

<table>
<thead>
<tr>
<th>Sent</th>
<th>Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 7 2 9 2</td>
<td>4 7 2 9 2</td>
</tr>
<tr>
<td>3 6 8 2 9</td>
<td>3 2 8 2 9</td>
</tr>
<tr>
<td>1 7 4 3 5</td>
<td>1 7 4 3 5</td>
</tr>
<tr>
<td>8 0 4 4 6</td>
<td>8 0 4 4 6</td>
</tr>
</tbody>
</table>

• 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.
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

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

(from White, p. 27)

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VLSI Chip Design, Layout, and Fabrication

Intel Pentium 4 (Northwood .13μm)

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

- 55 M transistors in 132mm²
- “city map” logic placement
- 89 Watts @ 3.4 GHz
- 6 metal layers, 423 I/O pins

- 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*
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
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
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

## Combined EE disciplines = 26%

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

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