Area 3: Analog and Digital Electronics

D.A. Johns
1970 – 2012 Tech Advancements

Everything but Electronics:
- Roughly factor of 2 improvement
  - Cars and airplanes: 70% more fuel efficient
  - Materials: up to 50% lighter

Electronics:
- Transistors/chip improvement: 500,000
- Clock speed of microprocessor: 30,000
- Signs of slowing down but still much more to go
Integrated Circuits 1950-60

- Transistor invented 1947 (Bell Labs)
- Discrete components during 1950s
- Integrated circuit invented in 1959
  - Jack Kilby (Texas Instruments)
  - Robert Noyce (Fairchild) (then Intel)
- 1961 was first manufactured IC
- Bell Labs thought putting multiple transistors together in same device a bad idea due to increased failure rate
Integrated Circuits 1970s

- Intel 4004 processor
  - Introduced 1971
  - Initial clock speed: 108 KHz
  - Number of transistors: 2,300
  - Manufacturing technology: 10μ

- Intel 8080 processor
  - Introduced 1974
  - Initial clock speed: 2 MHz
  - Number of transistors: 4,500
  - Manufacturing technology: 6μ

- Intel 8088 processor
  - Introduced 1979
  - Initial clock speed: 5 MHz
  - Number of transistors: 29,000
  - Manufacturing technology: 3μ
Integrated Circuits 1980s

Intel® 286 processor
Introduced 1982
Initial clock speed
6 MHz
Number of transistors
134,000
Manufacturing technology
1.5μ

Intel386™ processor
Introduced 1985
Initial clock speed
16 MHz
Number of transistors
275,000
Manufacturing technology
1.5μ

Intel486™ processor
Introduced 1989
Initial clock speed
25 MHz
Number of transistors
1,200,000
Manufacturing technology
1μ
### Integrated Circuits 1990s

<table>
<thead>
<tr>
<th>Processor</th>
<th>Introduced Year</th>
<th>Initial Clock Speed</th>
<th>Number of Transistors</th>
<th>Manufacturing Technology</th>
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</thead>
<tbody>
<tr>
<td>Intel® Pentium® processor</td>
<td>1993</td>
<td>66 MHz</td>
<td>3,100,000</td>
<td>0.8µ</td>
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<tr>
<td>Intel® Pentium® II processor</td>
<td>1997</td>
<td>300 MHz</td>
<td>7,500,000</td>
<td>0.25µ</td>
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<td>Intel® Pentium® III processor</td>
<td>1999</td>
<td>500 MHz</td>
<td>9,500,000</td>
<td>0.18µ</td>
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</table>
Integrated Circuits 2000s

**Intel® Itanium® 2 processor**
- Introduced 2002
- Initial clock speed: 1 GHz
- Number of transistors: 220,000,000
- Manufacturing technology: 0.13μ

**Intel® Pentium® D processor**
- Introduced 2005
- Initial clock speed: 3.2 GHz
- Number of transistors: 291,000,000
- Manufacturing technology: 65nm

**Quad-Core Intel® Xeon® processor (Penryn)**
- Dual-Core Intel® Xeon® processor (Penryn)
- Quad-Core Intel® Core™2 Extreme processor (Penryn)
- Introduced 2007
- Initial clock speed: > 3 GHz
- Number of transistors: 820,000,000
- Manufacturing technology: 45nm
Integrated Circuits 2012

- Intel Ivy Bridge quad core
- 3.5 GHz clock speed
- 1.4B transistors
- 22nm technology (tri-gate)
- 77W of power
Analog Electronics

- Learn basics of analog circuit design at transistor and board level
- Much more of the world is analog than people realize
- Most integrated circuits have significant analog
Digital Electronics

- Learn basics of digital system design at transistor and architecture levels
- Required skill for anyone thinking of hardware career
Career Opportunities

- **Graduate School:** Circuit design is a rich area of Electronics with many research challenges and opportunities.

- **Join industry:** Anywhere in the world: Canada, US, Europe, Japan, China
### Courses

#### AREA 3 - ANALOG & DIGITAL ELECTRONICS

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<tr>
<th>Fall Term - Year 3 or 4</th>
<th>Lect.</th>
<th>Lab.</th>
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<td>ECE331H1</td>
<td>F</td>
<td>3</td>
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<td>Digital Electronics</td>
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<td>Sensory</td>
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<tr>
<td>Communication</td>
<td>ECE446H1</td>
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<tr>
<td>Analog Signal Processing Circuits</td>
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<td>F</td>
<td>3</td>
<td>-</td>
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<tr>
<td>Integrated Circuit Engineering</td>
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<td>F</td>
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<td>VLSI Systems and Design</td>
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Electronics – Kernel Courses

- **ECE331: Analog Electronics**
  (extension of 2’nd year analog electronics course)
  - Transistor amplifiers (inside an opamp)
  - Biasing techniques
  - Frequency response
  - Feedback analysis and stability

- **ECE334: Digital Electronics**
  (Transistor and gate level circuit design)
  - Transistor models and spice simulation
  - IC fabrication basics and layout
  - CMOS gate design and transient response
  - Latches, registers, adder cells
  - Memory design (SRAM, DRAM, ROM, FLASH)
Electronics – Depth Courses

- **ECE530: Analog Integrated Circuits (analog)**
  - Opamp design, comparators, A/D and D/A converters
- **ECE512: Analog Signal Processing Circuits (analog)**
  - Filters, oversampling, noise in analog circuits.
- **ECE451: VLSI Systems and Design (digital)**
  - Complex digital systems (eg. Microprocessor)
- **ECE532: Digital Systems Design (digital)**
  - Hard/software interfacing, memory interfaces, ...
- **ECE534: Integrated Circuit Eng. (analog or digital)**
  - IC fabrication, modeling, packaging, yield, …
Analog Electronics – Related Courses

- ECE334 Digital Electronics *(kernel)*
  - most integrated circuits contain both digital and analog

- ECE302 Probability & Applications
- ECE431 Digital Signal Processing
- ECE316 Communication Systems
  - Signal processing and communications closely related

- ECE335 Introduction to Electronic Devices
- ECE535 Advanced Electronic Devices
Possible Analog Path

3rd year
- ECE316 Communication Systems (k)
- ECE331 Analog Electronics (k)
- ECE335 Introduction to Electron Dev (k)
- ECE320 Fields & Waves (k)
- ECE302 Probability & Applications (d)
- ECE334 Digital Electronics (k)
- ECE311 Dynamic Systems & Control (k)
- ECE472 Engineering Economic Analysis
Possible Analog

4th year
- ECE496 Design Project
- ECE512 Analog Signal Processing (d)
- ECE534 Integrated Circuit Engin (d)
- ECE431 Digital Signal Processing (d)
- ECE451 VLSI Systems and Design (d)
- ECE530 Analog Integrated Circuits (d)
- ECE422 Radio and Microwave Wireless Systems (d)
- ECE496 Design Project
Digital Electronics – Related Courses

- ECE342 Computer Hardware
- ECE452 Computer Architecture
  Digital design at the upper architecture level

- Any number of software courses. Digital chips these days are done with verilog/VHDL, system C, etc.
- Good digital designers are good software designers (but they can’t make errors – even more rigorous testing)
Possible Digital Path

- **3rd year**
  - ECE316 Communication Systems (k)
  - ECE344 Operating Systems (k)
  - ECE334 Digital Electronics (k)
  - CSC444 Software Eng I (d)
  - ECE361 Computer Networks (k)
  - ECE 342 Computer Hardware (k)
  - ECE345 Algorithms and Data Structures (k)
  - ECE472 Engineering Economic Analysis
Possible Digital Path

- 4th year
  - ECE496 Design Project
  - ECE534 Integrated Circuit Eng (d)
  - ECE552 Computer Architecture (d)
  - ECE454 Computer Systems Programming (d)
  - ECE431 Digital Signal Processing (d)
  - ECE451 VLSI Systems and Design (d)
  - ECE532 Digital Systems Design (d)
  - ECE496 Design Project