
Area 3: Analog and Digital Electronics

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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

10 μ



Intel® 8080 processor
Introduced 1974
Initial clock speed

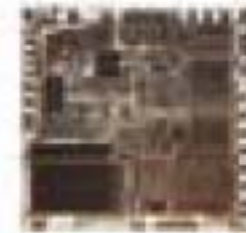
2 MHz

Number of transistors

4,500

Manufacturing technology

6 μ



Intel® 8088 processor
Introduced 1979
Initial clock speed

5 MHz

Number of transistors

29,000

Manufacturing technology

3 μ



Integrated Circuits 1980s



Intel® 286 processor
Introduced 1982
Initial clock speed

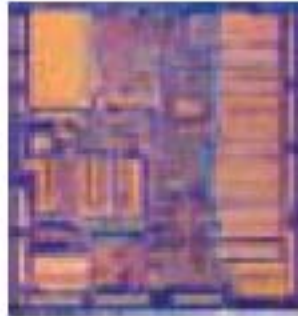
6 MHz

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



Intel® Pentium® processor
Introduced 1993
Initial clock speed

66 MHz

Number of transistors

3,100,000

Manufacturing technology

0.8 μ



Intel® Pentium® II processor
Intel® Pentium® II Xeon® processor
Introduced 1997
Initial clock speed

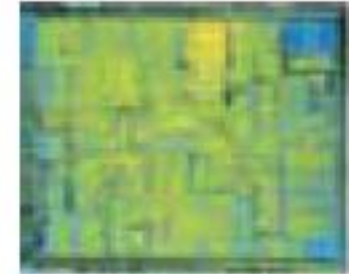
300 MHz

Number of transistors

7,500,000

Manufacturing technology

0.25 μ



Intel® Pentium® III processor
Intel® Pentium® III Xeon® processor
Introduced 1999
Initial clock speed

500 MHz

Number of transistors

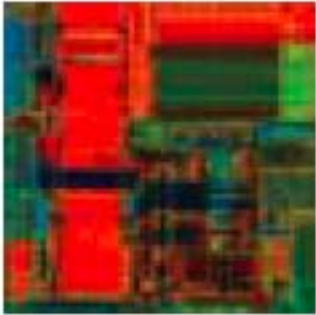
9,500,000

Manufacturing technology

0.18 μ



Integrated Circuits 2000s



Intel® Itanium® 2 processor
Introduced 2002
Initial clock speed

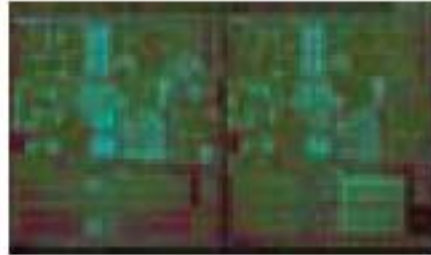
1 GHz

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



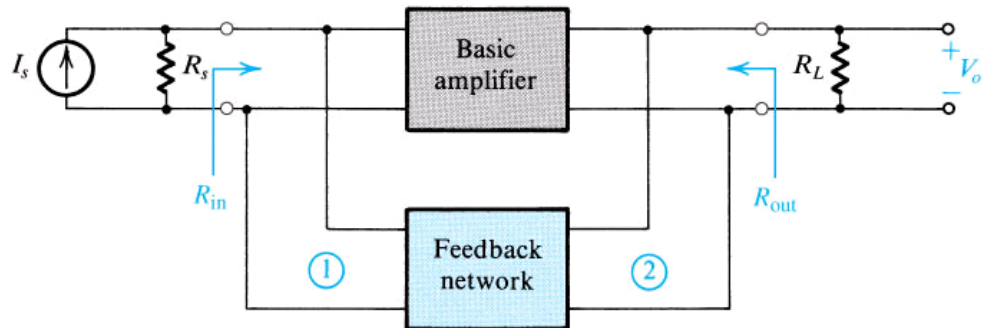
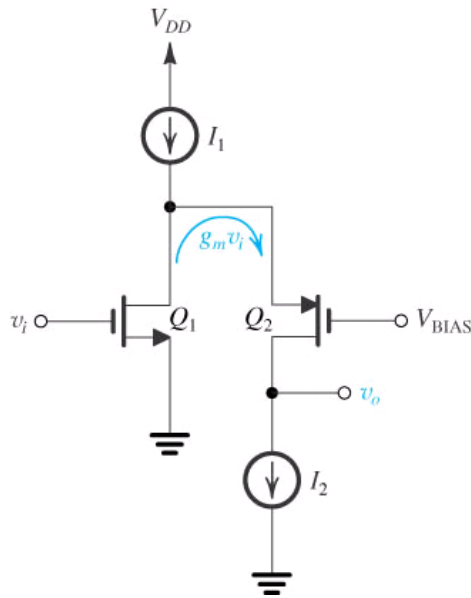
Integrated Circuits 2012

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



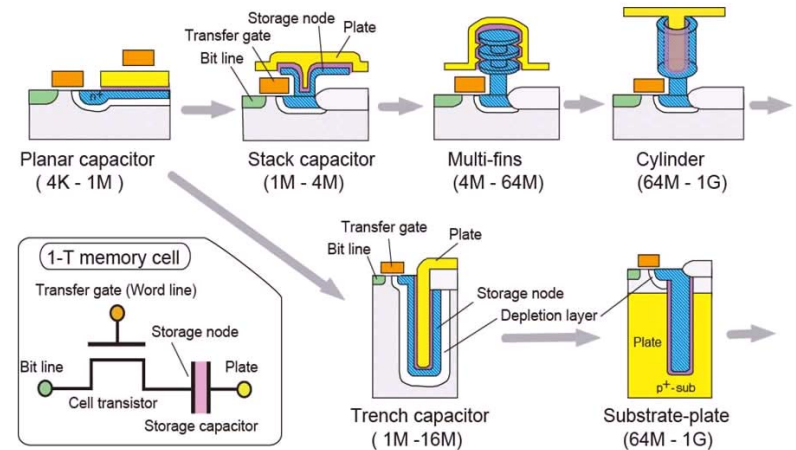
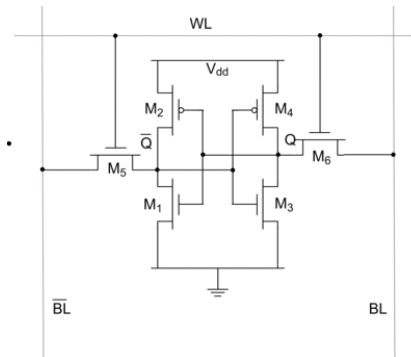
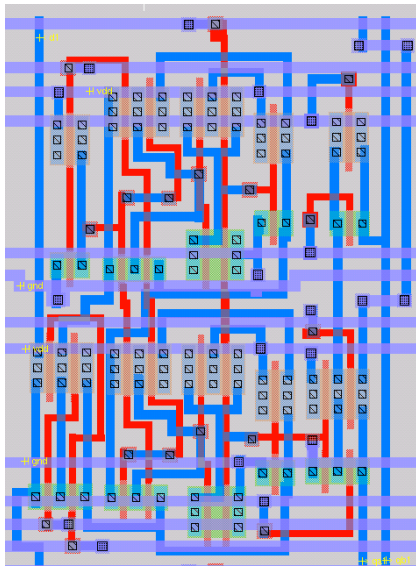
Analog Electronics

- 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

Fall Term - Year 3 or 4		Lect.	Lab.	Tut.	Wgt.	
KERNEL COURSES						
Analog Electronics	ECE331H1	F	3	1.50	1	0.50
Digital Electronics	ECE334H1	F	3	1.50	1	0.50
TECHNICAL ELECTIVES						
Sensory Communication	ECE446H1	F	3	1.50	1	0.50
Analog Signal Processing Circuits	ECE512H1	F	3	-	2	0.50
Integrated Circuit Engineering	ECE534H1	F	3	3	-	0.50

Winter Term - Year 3 or 4		Lect.	Lab.	Tut.	Wgt.	
KERNEL COURSES						
Analog Electronics	ECE331H1	S	3	1.50	1	0.50
Digital Electronics	ECE334H1	S	3	1.50	1	0.50
TECHNICAL ELECTIVES						
VLSI Systems and Design	ECE451H1	S	3	3	-	0.50
Analog Integrated Circuits	ECE530H1	S	3	1.50	1	0.50
Digital Systems Design	ECE532H1	S	3	3	-	0.50



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, modelling, 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

