**Technical Challenges**

- Real-time
- Complexity
- Concurrency
- Legacy Languages

**Software complexity growing**

**Size of Typical Embedded System**

- 1985: 13 kLOC
- 1989: 21 kLOC (↓ 44 % per year)
- 1998: 1 MLOC
- 2000: 2 MLOC
- 2008: 16 MLOC \(\approx\) Windows NT 4.0
- 2010: 32 MLOC \(\approx\) Windows 2000


**Digital Camera Block Diagram**

**The Design Challenge**

Design optimal device that meets constraints on:

- Price
- Functionality
- Performance
- Size
- Power
- Time-to-market
- Maintainability
- Safety

**The Time-to-Market Challenge**

Typical time-to-market constraint: 8 months

**Simplified Revenue Model**

Assuming a constant market ramp, on-time revenue is \(\frac{1}{2}bh = \frac{1}{2} \cdot 2W \cdot W^2 = W^3\) and delayed revenue is \(\frac{1}{2}(2W - D)(W - D)\), so fractional revenue loss is \(\frac{D(W - D)}{2W} = O(D^2)\).

Example: when \(W = 26\) and \(D = 11\), fraction lost is about 50%.
Nonrecurring engineering cost: The cost of producing the first one.

- **NRE cost dominates**
  - Low NRE, high production costs
  - High NRE, low production costs

- **Production cost dominates**

**Moore’s Law: Transistors per chip**

“The complexity for minimum component costs has increased at a rate of roughly a factor of two per year. Certainly over the short term this rate can be expected to continue, if not to increase.” — Gordon Moore, 1965

Source: Intel/Wikipedia

**$1000 buys you this many CPS**

Source: Ray Kurzweil, *The Age of Spiritual Machines*

**1918 Sears Roebuck Catalog**


**Spectrum of IC choices**

- **You choose**
  - polygons (Intel)
  - circuit (Sony)
  - wires
  - logic network
  - logic function
  - program (e.g., Pentium)
  - program (e.g., DSP)
  - settings (e.g., Ethernet)
  - part number (e.g., 74LS00)

- **Flexibility**

**Hardware and Software**

- **Hardware**
  - Parallel
  - Synchronous
  - Logic Gates
  - Wire-based communication
  - Fixed topology
  - Low power
  - More detailed
  - High NRE
  - Faster

- **Software**
  - Sequential
  - Asynchronous
  - Stored programs
  - Memory-based communication
  - Highly programmable
  - High power
  - Less detailed
  - No NRE
  - Slower

**Design Tools**

- **Hardware**
  - Logic Synthesis
  - Place-and-route
  - DRC/ERC/LVS

- **Software**
  - Compilers
  - Assemblers
  - Linkers
  - Debuggers
Cost of Designs is Rising

1981: 100 designer-months for leading-edge chip
10k transistors, 100 transistors/month

2002: 30 000 designer-months
150M transistors, 5000 transistors/month

Design cost increased from $1M to $300M

Your Nemesis: The Altera DE2

Class Structure

Three Introductory Labs: 1.5 weeks each
1. Access, modify, and display memory in VHDL
2. An Ethernet chat client (software only)
3. Either (a) an FM audio synthesizer; or (b) a video bouncing ball.

The project: Design-your-own

Projects from 2004

MIDI synthesizer
Line-following robot with video vision
SAE student vehicle telemetry system
Stereo video vision system
Pac-man-like video game
Internet video camera

Projects from 2005

Scrabble Timer
Scorched Earth Video Game
SAE Auto Shifter
Internet Radio Broadcaster
3D Maze Game
Voice-over-IP Telephone
JPEG decoder
Sokoban video game
Rally-X video game

Projects from 2006

Video-guided Lego Robot
360° camera de-warper
Videogame with accelerated line-drawing
Voice recorder
Internet radio
JPEG decoder
Voice over IP tranceiver

More Ideas

Digital tone control
Digital sound effects processor
Real-time audio spectrum analyzer
Speech synthesizer
Internet radio

Custom Project Ideas

Broadly: C + VHDL + peripheral(s)
Video game (e.g., Pac-Man)
Video effects processor
Digital picture frame
Serial terminal
Serial port monitor
Very fancy digital clock (w/ video)
Projects from 2007

- Pac-Edwards (Don’t ask!)
- Button Hero (videogame)
- Digital Picture Frame: SD card with JPEG to VGA
- Networked game of Clue
- Conway’s Game of Life (60 gps!)