Embedded System Design

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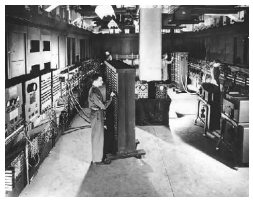
Spot the Computer



Hidden Computers

Casio Camera Watch

Nokia 7110 Browser Phone

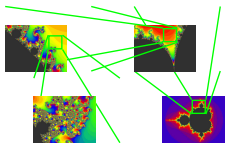
Sony Playstation 2

Philips DVD Player

Philips TiVo Recorder

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	≈ Windows NT 4.0
2010	32 MLOC	≈ Windows 2000

Source: "ESP: A 10-Year Retrospective," Embedded Systems Programming, November 1998

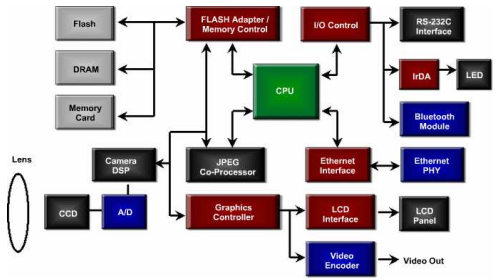
Written in stone-age languages

"Which of the following programming languages have you used for embedded systems in the last 12 months?"

C	81%
Assembly	70%
C++	39%
Visual Basic	16%
Java	7%

Source: "ESP: A 10-Year Retrospective," Embedded Systems Programming, November 1998

Digital Camera Block Diagram



The Design Challenge

Design optimal device that meets constraints on

Price

Functionality

Performance

Size

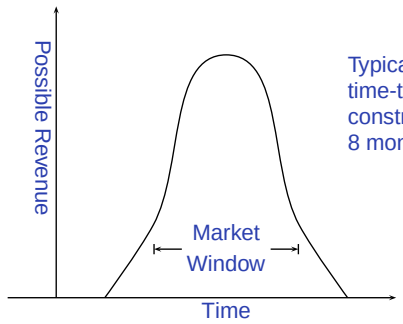
Power

Time-to-market

Maintainability

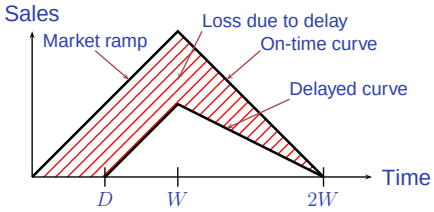
Safety

The Time-to-Market Challenge



Typical time-to-market constraint: 8 months

Simplified Revenue Model



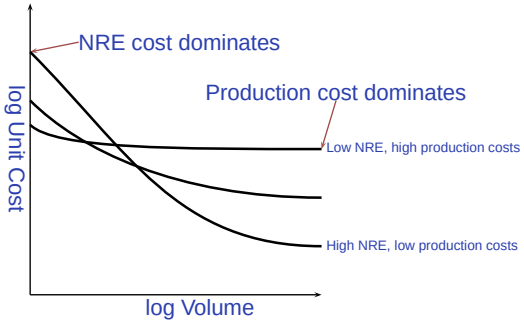
Assuming a constant market ramp, on-time revenue is $\frac{1}{2}bh = \frac{1}{2} \cdot 2W \cdot W = W^2$ and delayed revenue is $\frac{1}{2}(2W - D)(W - D)$ so fractional revenue loss is

$$\frac{D(3W - D)}{2W^2} = O(D^2)$$

Example: when $W = 26$ and $D = 10$, fraction lost is about 50%.

NRE

Nonrecurring engineering cost:
The cost of producing the first one.



Embedded System Technologies


Integrated Circuits


Processing elements


Design tools

IC Technology

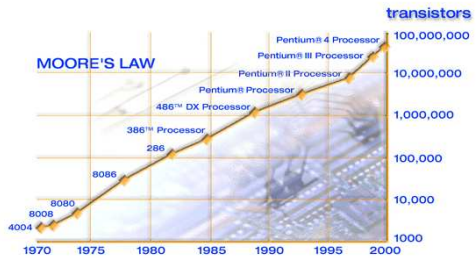

1947: First transistor (Shockley, Bell Labs)


1958: First integrated circuit (Kilby, TI)


1971: First microprocessor (4004: Intel)


Today: six wire layers, 90 nm features

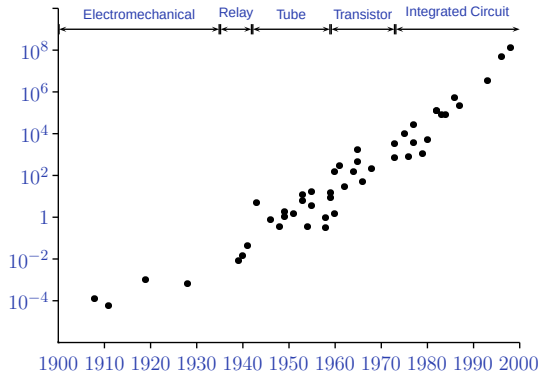
Moore's Law



Gordon Moore, 1965: Exponential growth in the number of transistors per IC

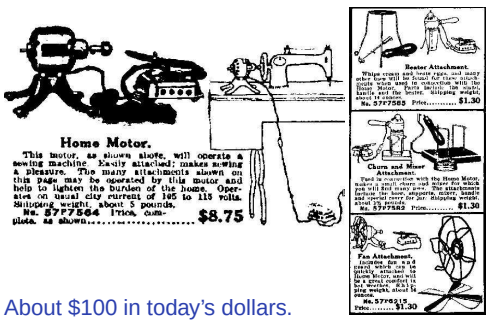
Source: Intel

$1000 buys you this many CPS



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

1918 Sears Roebuck Catalog



About $100 in today's dollars.

From Donald Norman, *The Invisible Computer*, 1998.

Spectrum of IC choices

	You choose
Full Custom	polygons (Intel)
ASIC	circuit (Sony)
Gate Array	wires
FPGA	logic network
PLD	logic function
GP Processor	program (e.g., Pentium)
SP Processor	program (e.g., DSP)
Multifunction	settings (e.g., Ethernet)
Fixed-function	part number (e.g., 74LS00)

Flexibility ↑

Hardware and Software

Hardware	Software
Parallel	Sequential
Synchronous	Asynchronous
Logic Gates	Stored programs
Wire-based communication	Memory-based communication
Fixed topology	Highly programmable
Low power	High power
More detailed	Less detailed
High NRE	No NRE
Faster	Slower

Design Tools

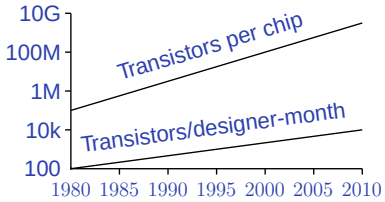
Hardware	Software
Logic Synthesis	Compilers
Place-and-route	Assemblers
DRC/ERC/LVS	Linkers
Simulators	Debuggers

Cost of Designs is Rising

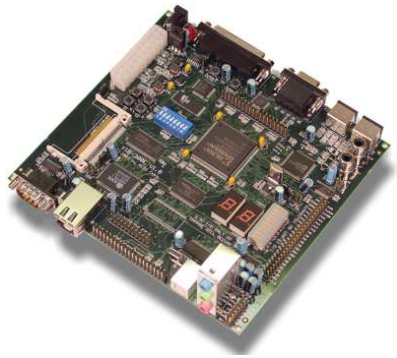
1981: 100 designer-months for leading-edge chip
10k transistors, 100 transistors/month

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

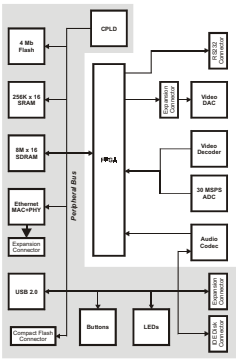
Design cost increased from $1M to $300M



Your Nemesis: The XESS XSB-300E



Block Diagram



XC2S300E FPGA
XC9572 CPLD
256K x 16 SRAM
8M x 16 SDRAM
512K x 8 Flash
6-channel NTSC video decoder
12-bit, 30 MSPS ADC
80 MHz, 30-bit video DAC
20-bit, 4-input, 1-output stereo codec
Microphone/line-in/line-out jacks
10/100 Ethernet MAC+PHY
USB 2.0 peripheral port
Six pushbuttons, DIP switch
Two LED digits, bargraph
Three programmable oscillators
Two expansion headers w/ 75 I/O pins
Peripheral header w/ 18 I/O pins
Parallel and Serial port
Compact Flash interface
IDE hard disk interface

Class Structure

First half of course: Six Introductory Labs:

1. Count in C on the 7-segment display
2. Serial Terminal in C
3. VHDL system reverse-engineering
4. Sum the contents of a small memory in VHDL
5. Create a simple peripheral
6. Build an OPB interface to off-chip SRAM

Second half project: **Design-your-own**

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)

More Ideas

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

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