### **Embedded System Design**

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## **Spot the Computer**

### **Hidden Computers**







Casio Camera Watch

**Nokia 7110** Browser Phone

Playstation 2



**Philips** 

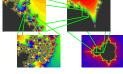
Philips DVD Player

TiVo Recorder

### **Technical Challenges**



Real-time



Complexity



Concurrency



Legacy Languages
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### Software complexity growing

### **Size of Typical Embedded System**

1985 13 kLOC

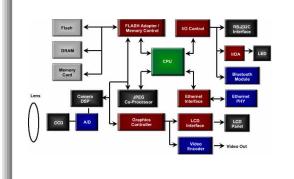
1989 21 kLOC ↓ 44 % per year

1 MLOC 1998 2 MLOC 2000

2008 16 MLOC ≈ Windows NT 4.0 2010 32 MLOC ≈ Windows 2000

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





Functionality



Performance







Time-to-market

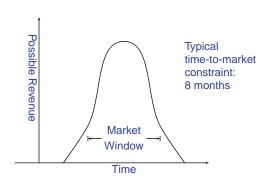


Maintainability

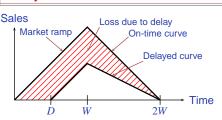


### Safety

### The Time-to-Market Challenge



### 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. -NRE cost dominates Production cost dominates Unit Cost ow NRE, high production costs High NRE, low production costs log Volume

### **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: eight wire layers, 45 nm features

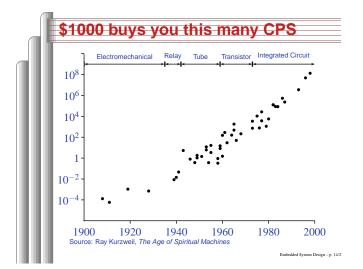
### Moore's Law: Transistors per chip "The complexity for minimum component costs has increased at a rate of roughly a factor of two per year. Certainly over the short term this rate can be expected 100M to continue, if not to increase." 10M 1M 100k

1990

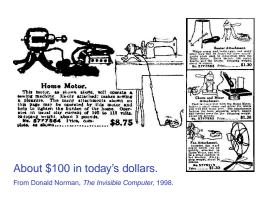
2000

10k

2010



### 1918 Sears Roebuck Catalog



### Spectrum of IC choices

1980

1970

Source: Intel/Wikipedia



### **Hardware and Software**

Hardware	Software	
Parallel	Sequential	
Synchronous	Asynchronous	
Logic Gates	Stored programs	
Wire-based	Memory-based	
communication	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

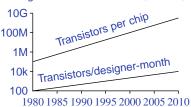
### **Cost of Designs is Rising**

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



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### **Your Nemesis: The Altera DE2**



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# USB USB USB Blaste Device Host Mic Line Line Video VGA Video 10100M Styl DC Power Styley Cornector 27-Mitz Oscillator 27-Mitz Oscillator 27-Mitz Oscillator 27-Mitz Oscillator 27-Mitz Oscillator 27-Mitz Oscillator 28-Mitz Oscillator 28-Mit

### **Class Structure**

Three Introductory Labs: 1.5 weeks each

- 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

### **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

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### **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

### 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!)

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