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


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%


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

Possible Revenue

Market Window

Time
Simplified Revenue Model

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

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

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

IC Technology

1947: First transistor (Shockley, Bell Labs)
1958: First integrated circuit (Kilby, TI)
1971: First microprocessor (4004: Intel)
Today: six wire layers, 100 nm features

1918 Sears Roebuck Catalog

About $100 in today's dollars.

Spectrum of IC choices

Full Custom: You choose 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)

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

$1000 buys you this many CPS

Source: Ray Kurzweil, The Age of Spiritual Machines

Moore's Law

Gordon Moore, 1965: Exponential growth in the number of transistors per IC
Source: Intel
### 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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### Custom Project Ideas

Broadly: C + VHDL + peripheral(s)

- Video game (e.g., Pac-Man)
- Simple video effects processor
- Digital picture frame
- Serial terminal
- Serial port monitor
- Very fancy digital clock (w/ video)

### Class Structure

First half of course: Five 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

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

### I/O Resources

The Digilent board is simple:

- 8-color VGA display
- RS-232 serial port
- PS/2 port
- 1MB SRAM
- Switches and LEDs

Interesting projects will include video and the keyboard and/or serial port.