Embedded Systems
CSEE W4840
Prof. Stephen A. Edwards
Columbia University

Technical Challenges

Spot the Computer

Hidden Computers

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

Typical time-to-market constraint: 8 months

The Time-to-Market Challenge
Simplified Revenue Model

Assuming a constant market ramp, on-time revenue is \[ \frac{1}{2}W \cdot W = W^2 \]
and delayed revenue is \[ \frac{1}{2}(2W - D)(W - D) \] so fractional revenue loss is
\[ \frac{D(W - D)}{2W^2} \propto O(D^2) \]
Example: when \( W = 26 \) and \( D = 10 \), fraction lost is about 50%.

NRE

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

Production cost dominates Low NRE, high production costs

Log Unit Cost

log Volume

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

Moore’s Law

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

Spectrum of IC choices

Full Custom You choose Flexibility
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
### 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

![Graph showing Transistors per chip](image)

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**Your Nemesis: The XESS XSB-300E**

**Block Diagram**

- XC2S300E FPGA
- XC9572 CPLD
- 256K x 16 SRAM
- 8M x 16 SRAM
- 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
- Parallel and Serial port
- Compact Flash interface
- IDE hard disk interface

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**Class Structure**

First half project: **TV Typewriter**. Six Labs:

1. Count in C on the 7-segment display
2. Hello World in C to video display
3. TV Typewriter in C
4. Count in VHDL on the 7-segment display
5. Character Generator in VHDL
6. TV Typewriter in HW/SW

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

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**Custom Project Ideas**

- Broadly: C + VHDL + peripheral(s)
- Digital tone control
- Digital sound effects processor
- Real-time spectrum analyzer
- Simple video effects processor
- Speech synthesizer
- Digital picture frame
- Internet radio