FPGA BASED SYSTEM DESIGN

Dr. Tayab Din Memon
tayabuddin.memon@faculty.muet.edu.pk

Lecture 1 & 2

Books

- Recommended Books:
- Text Book: FPGA Based System Design by Wayne Wolf
- Verilog HDL by Samir Palnitkar.
- Advanced Digital Design with the Verilog HDL by Michael D. Ciletti
- Will tell you about other books in coming weeks.
- http://www.waynewolf.us/fpga-book/Overheads/index.html

Course Organization

- **Course material:**
  - All the course material will be provided in power point slides format
- **Course Instructor**:

  Dr. Tayab Din Memon

  Office: TQCIC Lab – II, IIT Building

  tayabuddin.memon@faculty.muet.edu.pk

Course Objectives & Scope

After taking this course, you will:

- Learn how to design ***digital*** circuits with HDL
- Have an understanding
  - VLSI: Fabrication, circuits, interconnects
  - FPGA based design techniques
  - FPGA fabrics
  - FPGA optimization for size, speed, and power consumption
  - VHDL
  - The structure of large digital circuits
  - Large scale platform and multi-FPGA systems
- Understand some of the important ideas for designing more complex systems.

Course Outline

- In this course most of the stuff is recommended from a book "*FPGA Based System Design*" that is given below:
  - FPGA Based Systems
  - VLSI Technology
  - FPGA Fabrics
  - Combinational Logic
  - Sequential Machines
- Some of the material will be covered from other books as:
  - Introduction to HDL and different modes of writing VHDL programming.

REVIEW OF VLSI AND EMBEDDED SYSTEMS

Lecture 1, 2 & 3

Introduction

- Integrated circuits: many transistors on one chip.
- *Very Large Scale Integration* (VLSI): very many
- *Complementary Metal Oxide Semiconductor*
  - Fast, cheap, low power transistors
- How to build your own simple CMOS chip
  - CMOS transistors
  - Building logic gates from transistors
  - Transistor layout and fabrication

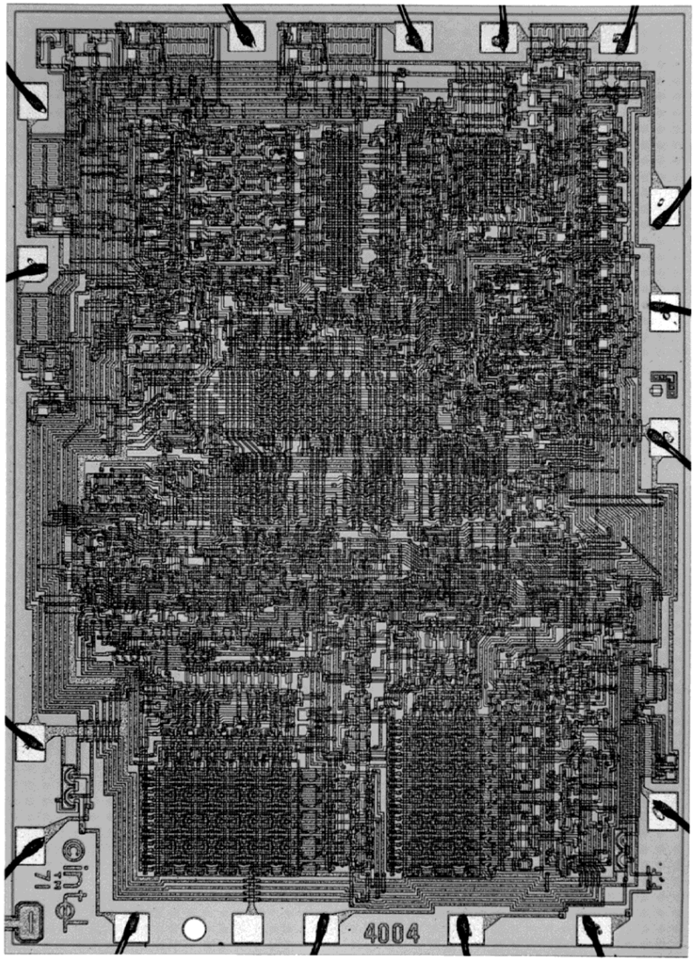
VLSI:Very Large Scale Integration

- Integration: Integrated Circuits
  - multiple devices on one substrate
- How large is Very Large?
    - SSI (small scale integration)
      - 7400 series, 10-100 transistors
    - MSI (medium scale)
      - 74000 series 100-1000
    - LSI 1,000-10,000 transistors
    - VLSI > 10,000 transistors

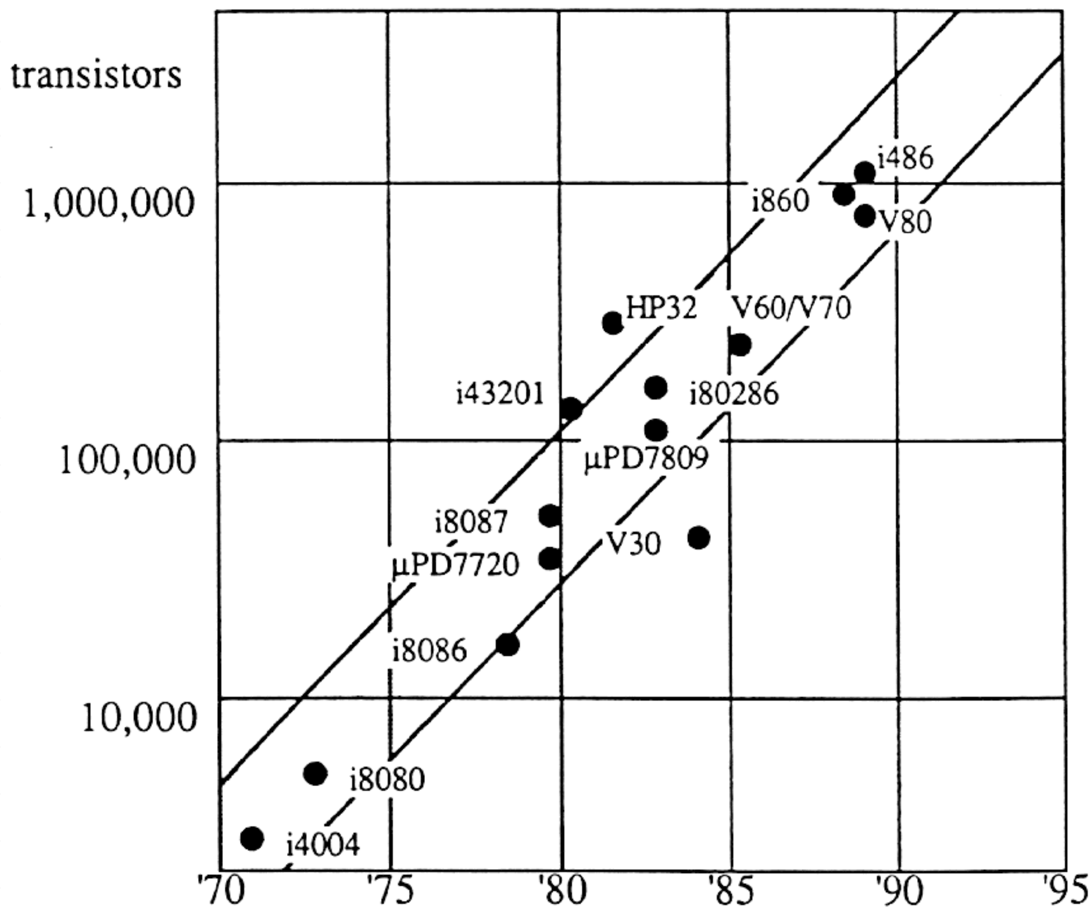
A Brief History

- 1958: First integrated circuit
  - Flip-flop using two transistors
  - Built by Jack Kilby at Texas Instruments
- 2003
  - Intel Pentium 4 μprocessor (55 million transistors)
  - 512 Mbit DRAM (> 0.5 billion transistors)
- 53% compound annual growth rate over 45 years
  - No other technology has grown so fast so long
- Driven by miniaturization of transistors
  - Smaller is cheaper, faster, lower in power!
  - Revolutionary effects on society

Intel 4004 Micro-Processor

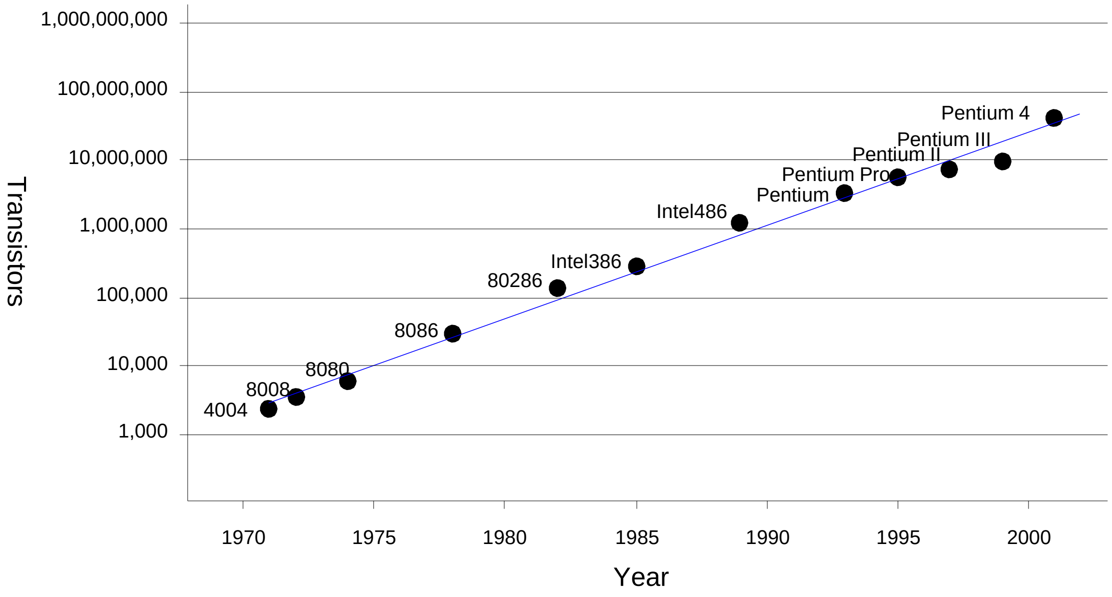


Evolution in Transistor Count



Moore's Law

- 1965: Gordon Moore plotted transistor on each chip
  - Fit straight line on semilog scale
  - Transistor counts have doubled every 26 months



Integration Levels

SSI: 10 gates

MSI: 1000 gates

LSI: 10,000 gates

VLSI: > 10k gates

VLSI Design

- But the real issue is that VLSI is about designing systems on chips.
- The designs are complex, and *we need to use structured design techniques and sophisticated design tools to manage the complexity of the design*.
- We also accept the fact that any technology we learn the details of will be out of date soon.

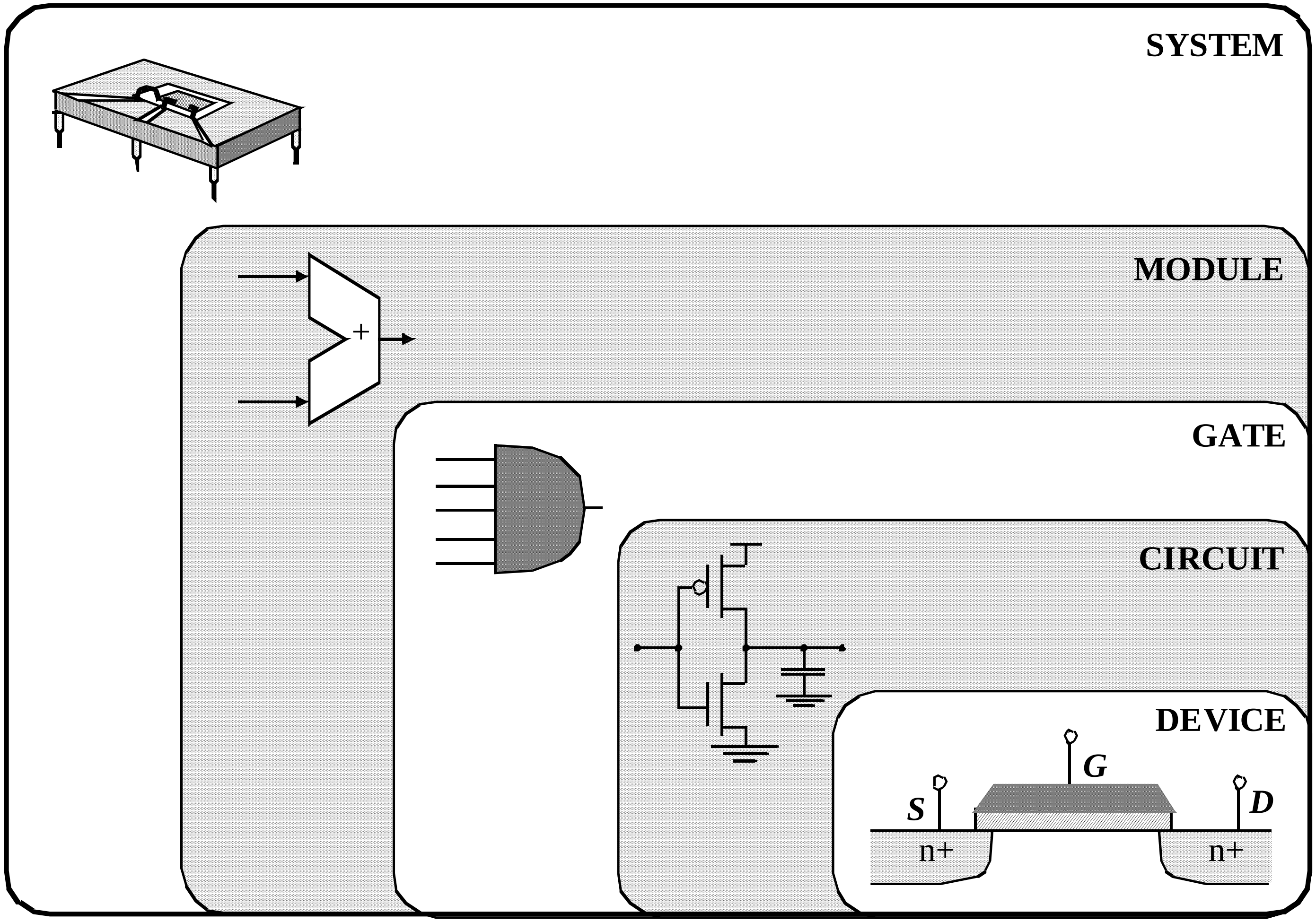
The Process of VLSI Design:

Consists of many different representations/Abstractions of the system (chip) that is being designed.

- System Level Design
- Architecture / Algorithm Level Design
- Digital System Level Design
- Logical Level Design
- Electrical Level Design
- Layout Level Design
- Semiconductor Level Design (possibly more)

Each abstraction/view is itself a *Design Hierarchy of refinements which decompose the design*.

Design Abstraction Levels



Help from Computer Aided Design tools

- Tools
  - Editors
  - Simulators
  - Libraries
  - Module Synthesis
  - Place/Route
  - Chip Assemblers
  - Silicon Compilers
- Experts
  - Logic design
  - Electronic/circuit design
  - Device physics
  - Artwork
  - Applications - system design
  - Architectures

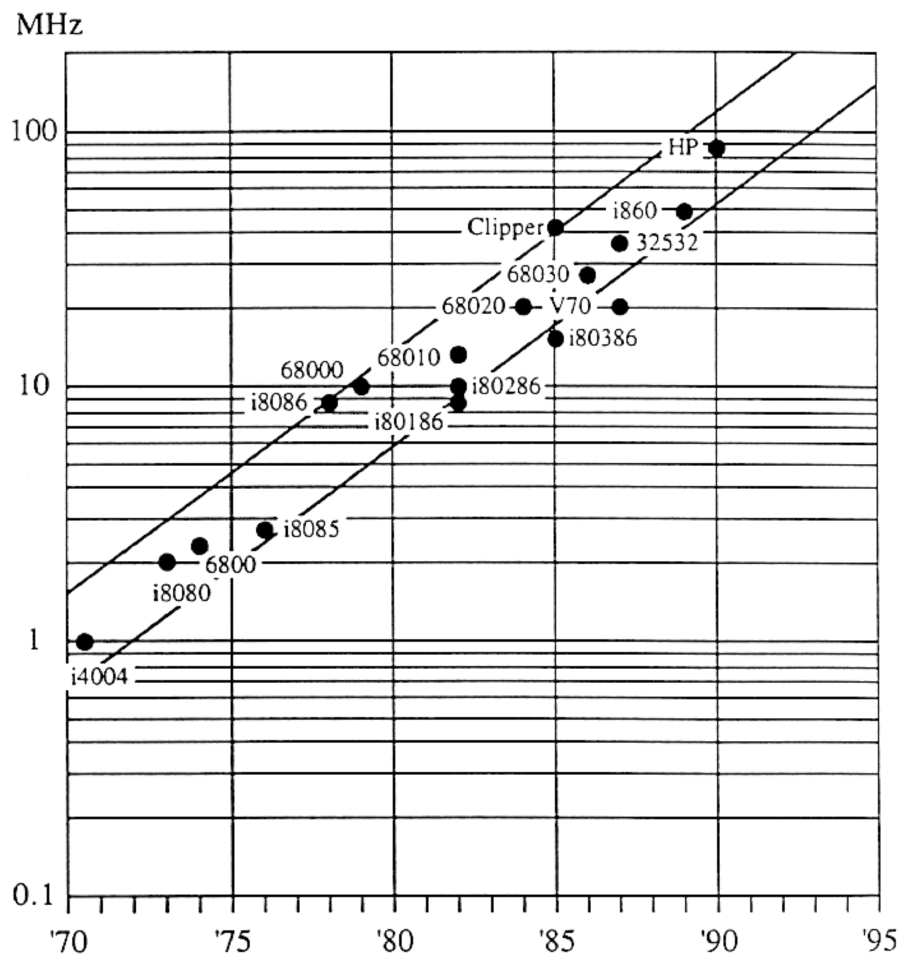
New Design Methodologies

- Methodologies which are based on:
  - System Level Abstractions v.s. Device Characteristic Abstractions
    - Logic structures and circuitry change slowly over time
      - trade-offs do change, but the choices do not
  - Scalable Designs
    - Layout techniques also change slowly.
      - But the minimum feature size steadily decreases with time (also Voltage, Die Size, etc.)

Design Approaches

- Custom
  - full control of design
  - best results, slowest design time.
- Semi-custom (std cell)
  - use Cell libraries from vendor
  - cad tools, faster design time
- Gate Array
  - fastest design time
  - worst speed/power/density
  - best low volume (worst high volume)
- EPLA/EPLD - FPGA - electrically programmable (in the field) -

Evolution in Speed/Performance



Embedded Systems Overview

Embedded Systems :-

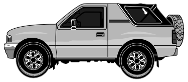
Application-specific systems which contain hardware and software tailored for a particular task and are generally part of a larger system (e.g., industrial controllers)

- Characteristics
  - Are dedicated to a particular application
  - Include processors dedicated to specific functions
  - Represent a subset of reactive (responsive to external inputs) systems
  - Contain real-time constraints
  - Include requirements that span:
    - Performance
    - Reliability
    - Form factor

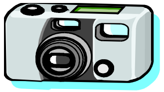
Embedded systems overview

- Embedded computing systems
  - Computing systems embedded within electronic devices
  - Hard to define. Nearly any computing system other than a desktop computer
  - Billions of units produced yearly, versus millions of desktop units
  - Perhaps 50 per household and per automobile

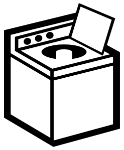
Computers are in here...

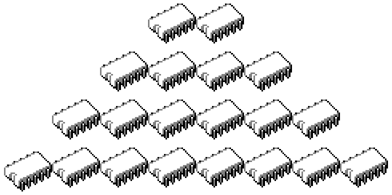


and here...



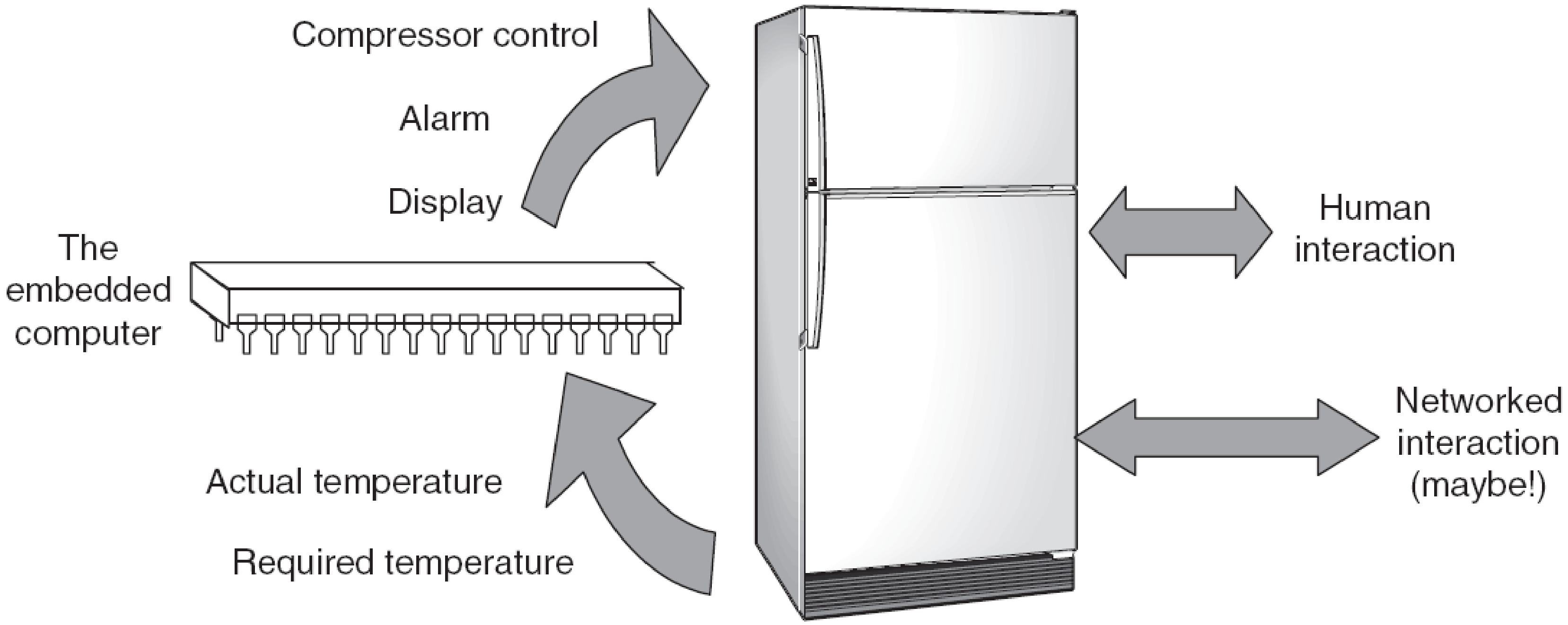
and even here...



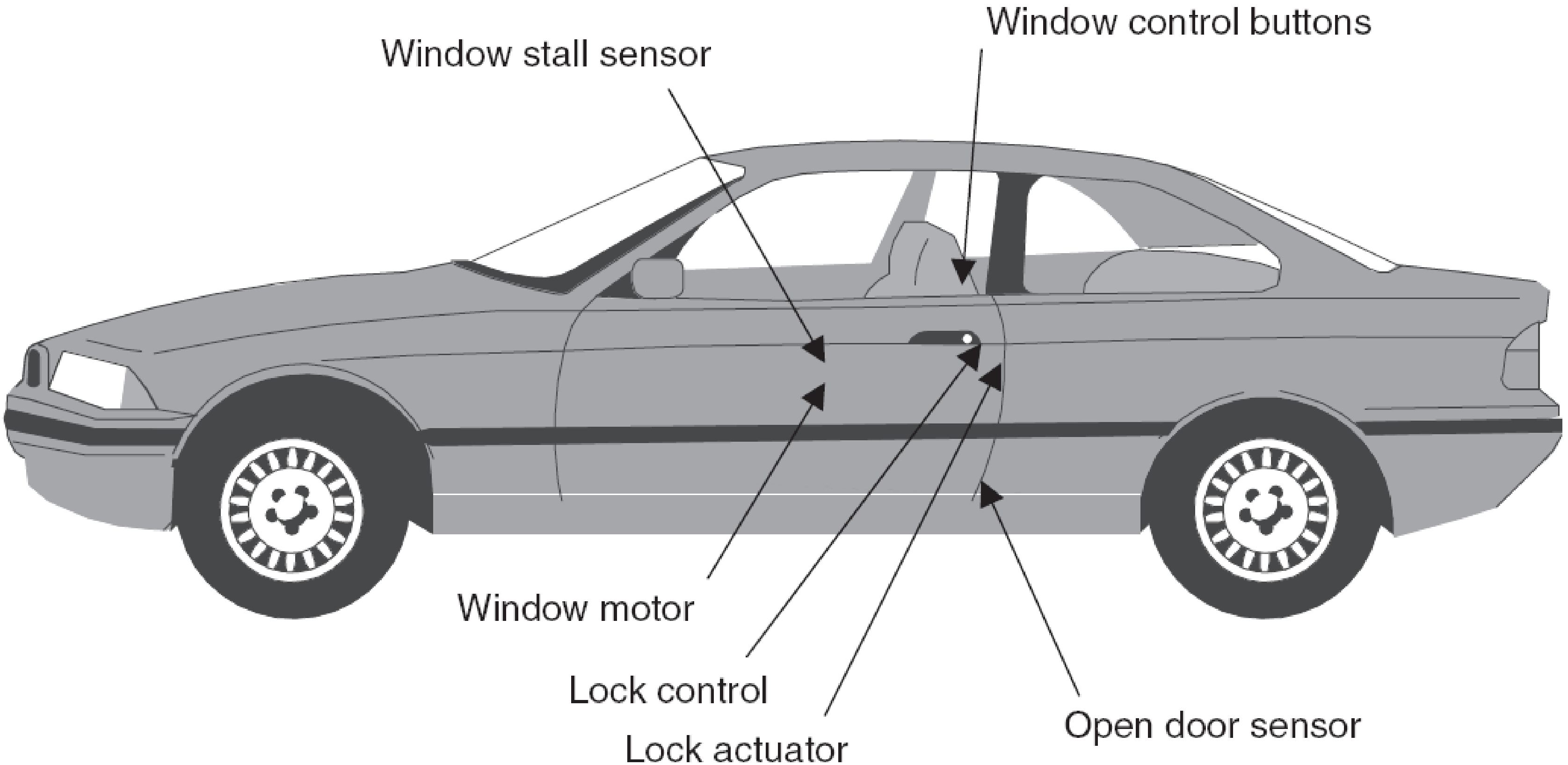


Lots more of these, though they cost a lot less each.

Examples: Refrigerator



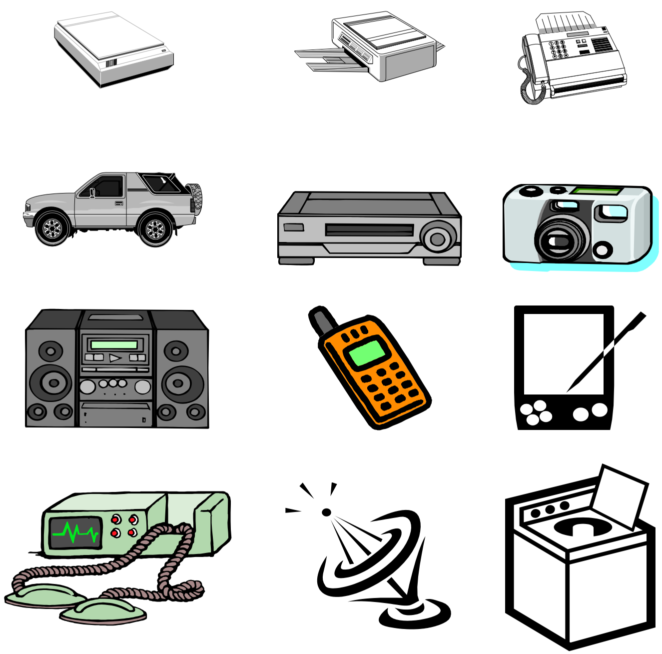
Examples: Car Door



A “short list” of embedded systems

Anti-lock brakes
Auto-focus cameras
Automatic teller machines
Automatic toll systems
Automatic transmission
Avionic systems
Battery chargers
Camcorders
Cell phones
Cell-phone base stations
Cordless phones
Cruise control
Curbside check-in systems
Digital cameras
Disk drives
Electronic card readers
Electronic instruments
Electronic toys/games
Factory control
Fax machines
Fingerprint identifiers
Home security systems
Life-support systems
Medical testing systems

Modems
MPEG decoders
Network cards
Network switches/routers
On-board navigation
Pagers
Photocopiers
Point-of-sale systems
Portable video games
Printers
Satellite phones
Scanners
Smart ovens/dishwashers
Speech recognizers
Stereo systems
Teleconferencing systems
Televisions
Temperature controllers
Theft tracking systems
TV set-top boxes
VCR’s, DVD players
Video game consoles
Video phones
Washers and dryers



And the list goes on and on

Concepts of co-design

- Codesign
  - The meeting of system-level objectives by exploiting the trade-offs between hardware and software in a system through their concurrent design
- Key concepts
  - Concurrent: hardware and software developed at the same time on parallel paths
  - Integrated: interaction between hardware and software developments to produce designs that meet performance criteria and functional specifications

Essential components and considerations

- Essential components :-

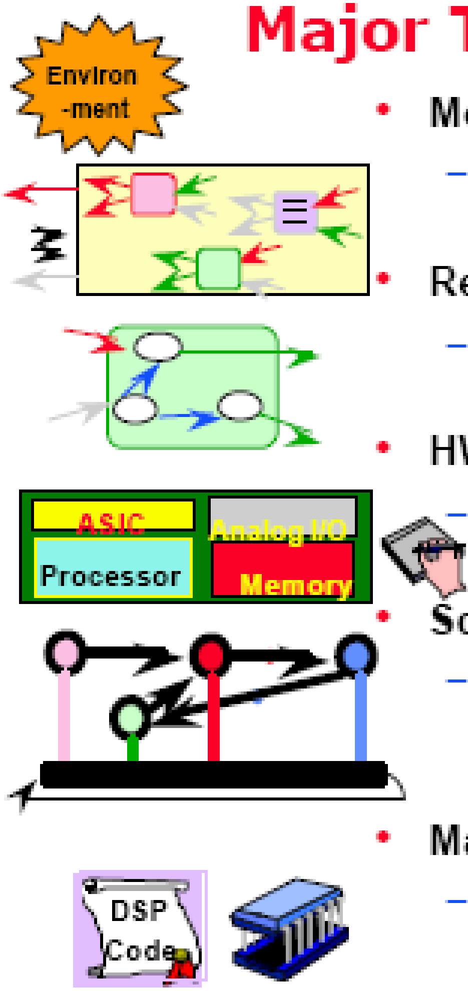
  - Microprocessor / DSP core
  - Sensors
  - Converter (A-D and D-A)
  - Actuators
  - Memory (on-chip and off-chip)
  - Communication path with interfacing environment

- Essential considerations :-

  - Response time ;- (Real time system)
  - Area, Cost, Power, Portability, Fault-tolerance

Design-flow in ES Design

Major Tasks in ES Design



- Modelling
  - the system to be designed, and experimenting with algorithms involved;
- Refining (or "partitioning")
  - the function to be implemented into smaller, interacting pieces;
- HW-SW partitioning: Allocating
  - elements in the refined model to either HW units, or SW running on custom hardware or a uP.
- Scheduling
  - the times at which the functions are executed. This is important when several modules in the partition share a single hardware unit.
- Mapping (Implementing)
  - a functional description into (1) software that runs on a processor or (2) a collection of custom, semi-custom, or commodity HW.

THANKS FOR YOUR PATIENCE

End of Lecture 1 & 2