ECE 2534

Microcontroller Programming and Interfacing

(formerly called *Microprocessor System Design*)

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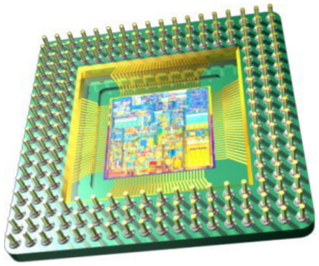


What we expect of you . . .

- An understanding of the basics of
  - *Digital logic*
  - *Binary representations and arithmetic*
  - *C/C++ programming*
  - *Computer organization*

- To do some work:
  - *Laboratory assignments*
  - *Homework / quizzes*
  - *Midterm exams*
  - *Final exam*

- A desire to learn a useful, exciting topic!

What you can expect of us . . .

- To learn about microcontrollers in general, and about the PIC32 in particular
- To learn about embedded systems, as opposed to general-purpose computing
- To learn (more) about the interaction between hardware and software
- To learn programming techniques that “scale up”
  (Many embedded systems have millions of lines of code)

By studying one microcontroller in detail,
you’ll learn valuable principles that apply to <u>any</u>
microcontroller-based system

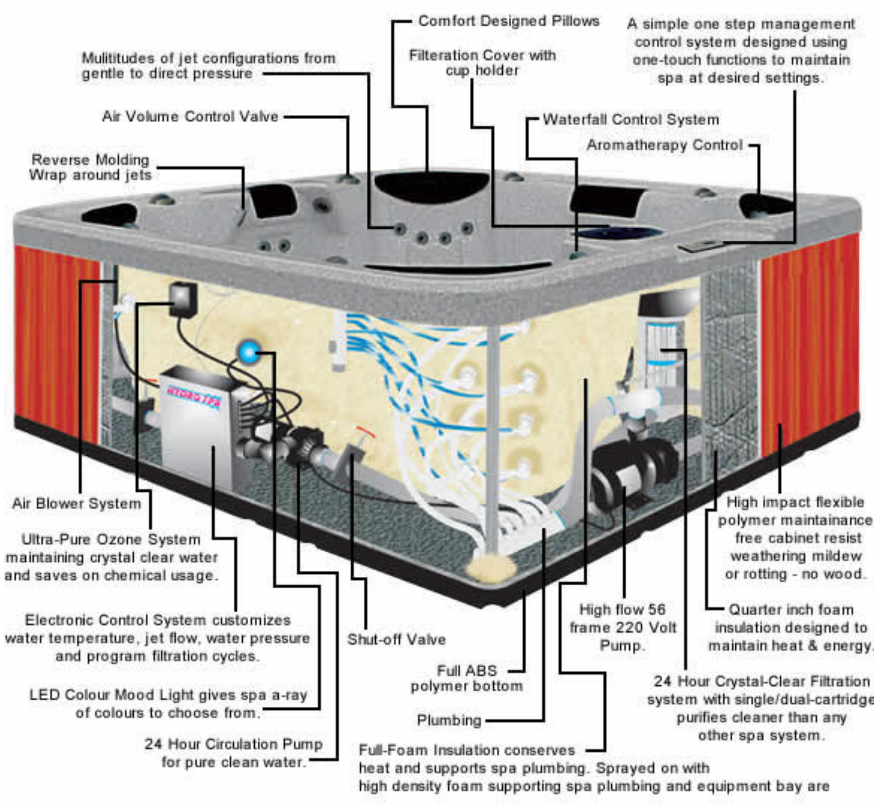
So, what’s an **embedded system**?

Let’s look at an example …

Commercial application: Hot tub design

Source: Wikipedia

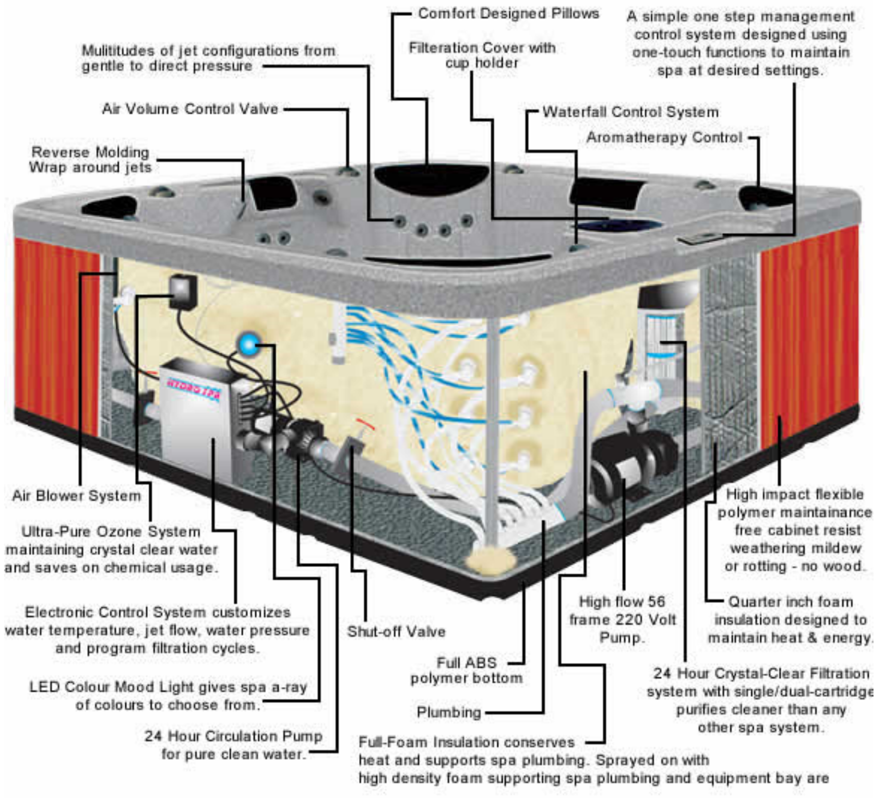
What is the role of a computer in hot-tub design?


Comfort Designed Pillows
A simple one step management control system designed using one-touch functions to maintain spa at desired settings.
Mulititudes of jet configurations from gentle to direct pressure
Filteration Cover with cup holder
Air Volume Control Valve
Waterfall Control System
Aromatherapy Control
Reverse Molding Wrap around jets
Air Blower System
Ultra-Pure Ozone System maintaining crystal clear water and saves on chemical usage.
Electronic Control System customizes water temperature, jet flow, water pressure and program filtration cycles.
LED Colour Mood Light gives spa a-ray of colours to choose from.
24 Hour Circulation Pump for pure clean water.
Shut-off Valve
Full ABS polymer bottom
Plumbing
Full-Foam Insulation conserves heat and supports spa plumbing. Sprayed on with high density foam supporting spa plumbing and equipment bay are
High flow 56 frame 220 Volt Pump.
High impact flexible polymer maintainance free cabinet resist weathering mildew or rotting - no wood.
Quarter inch foam insulation designed to maintain heat & energy.
24 Hour Crystal-Clear Filtration system with single/dual-cartridge purifies cleaner than any other spa system.

Source: http://malagaspas.com

What is the role of a computer in hot-tub design?

- User interface: read switches, control display
- Read sensors that measure water temperature
- Maintain internal timers
- Control relays that turn heating elements on/off
- Control relays that turn water pumps on/off
- Control relays that open/ close air valves
- Control relays that turn lights on/off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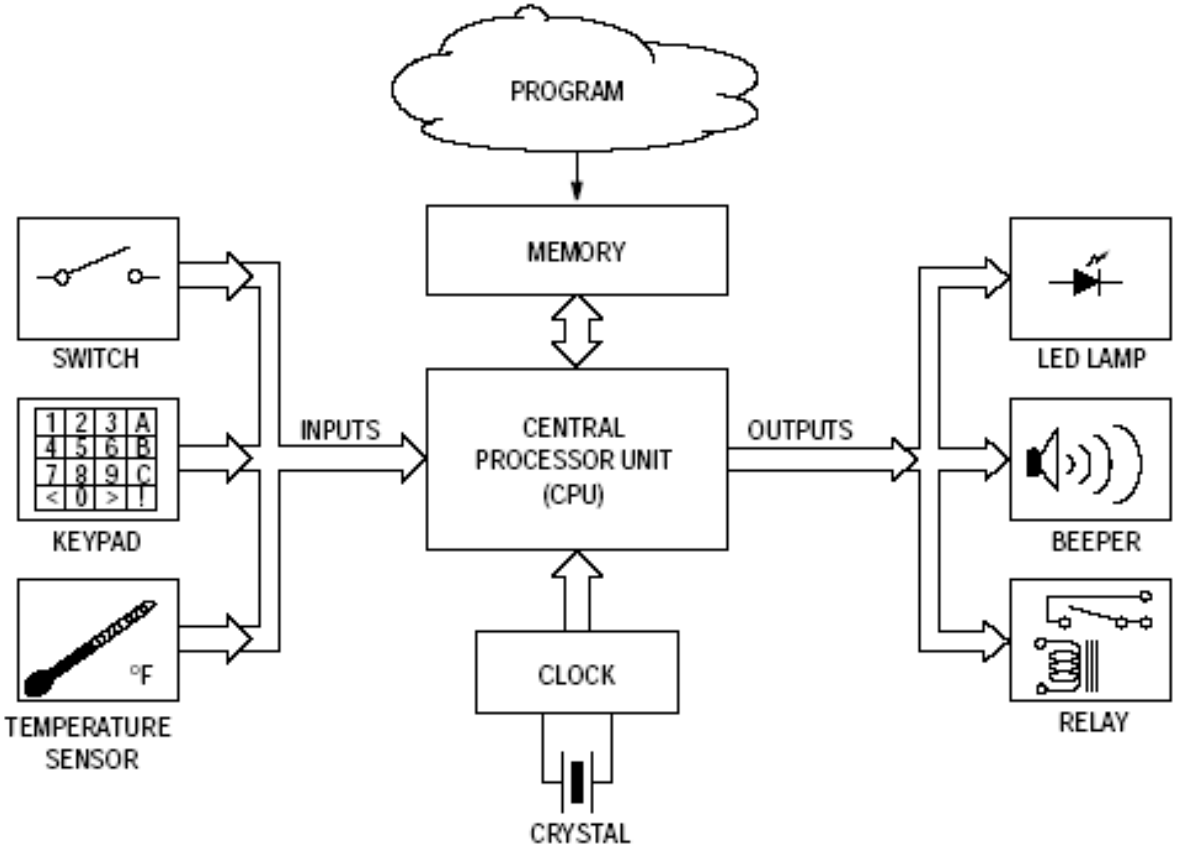
Embedded systems

- An embedded system is a computer-based system that designed to perform particular tasks within a larger system
  - a few dedicated functions: not general-purpose
  - may or may not interact directly with humans

High-level View



Source: Sibigtroth, Understanding Small Microcontrollers

What are some characteristics of an embedded system?

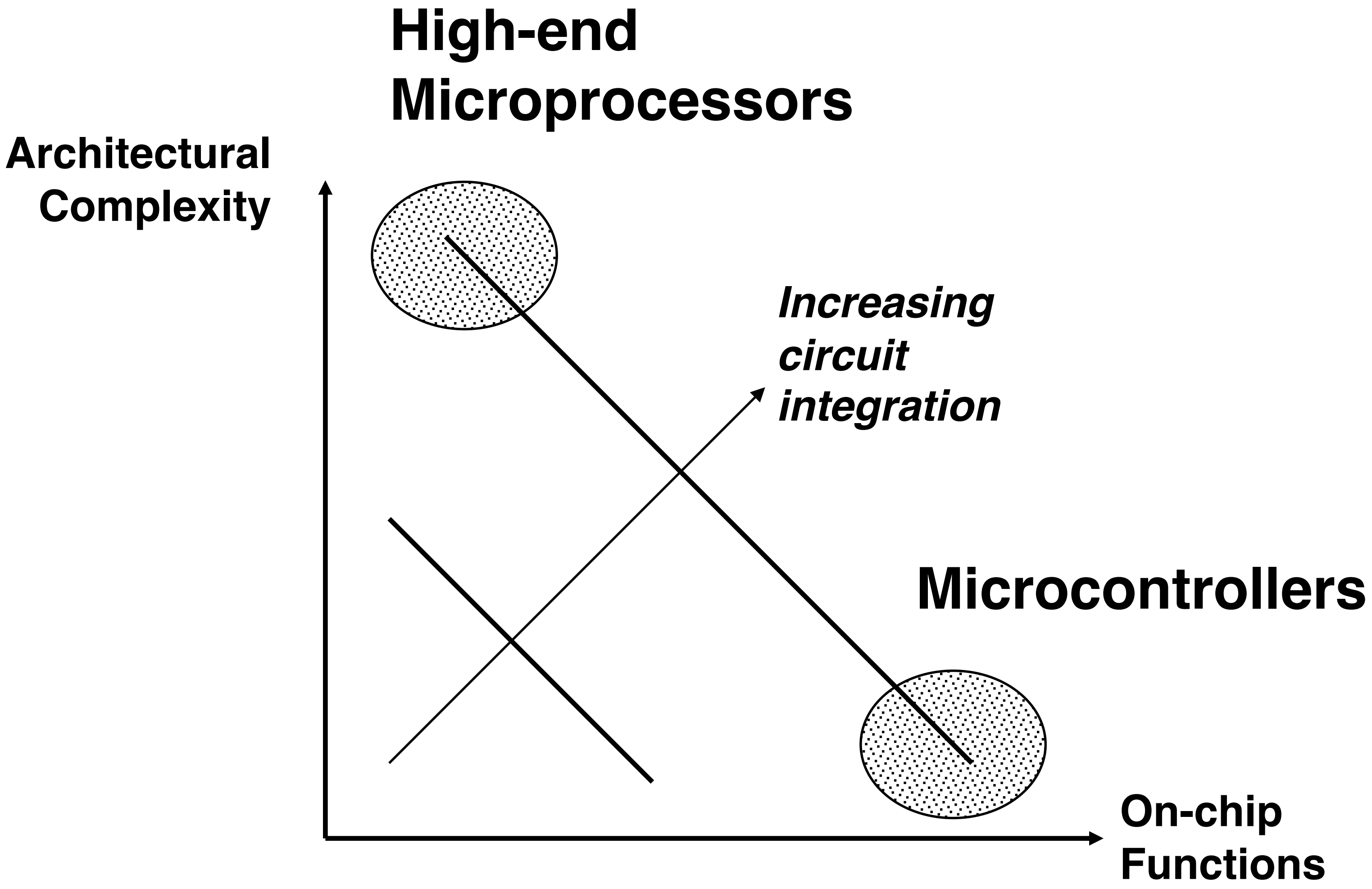
What are some characteristics of an embedded system?

- Possible constraints:
  - Size
  - Weight
  - Power
  - Cost
  - Latency (real-time)
  - Robustness (safety-critical)

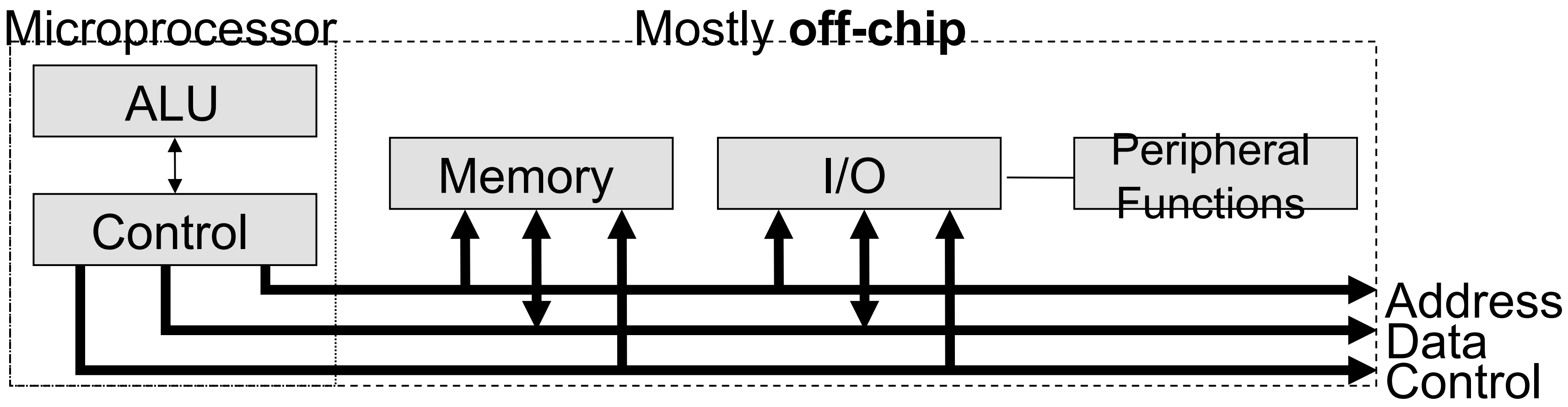
So, what’s a **microcontroller**?

Performance vs. functionality

- Microprocessors have evolved in two directions



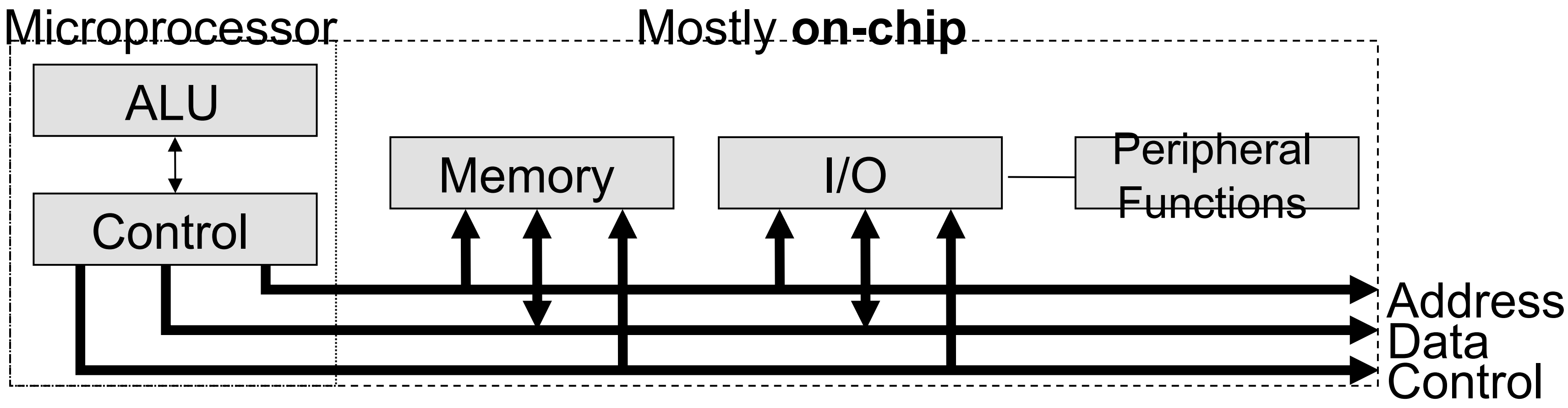
Microprocessors



High performance, general purpose “brains” for PCs and workstations

- Instruction decode and control, arithmetic/logic operations, registers, timing, external control
- Typical cost: $75 -- $500
- Annual demand: Tens of millions

Microcontrollers



Devices with high levels of integration for embedded control

- Microprocessor functions plus on-chip memory and peripheral functions (e.g. ports, timers)
- "Swiss army knife" of the technology
- Typical cost: $1-- $25 each
- Annual demand:
  $5.8 billion in 2006
  $9.5 billion in 2010

Microprocessor vs. Microcontroller

- Not always a clear distinction
  - Today’s microprocessor may be tomorrow’s microcontroller
- Microprocessor
  - Includes memory management unit
  - Lots of cache
  - Performance is most important feature (cost is important, but secondary)
  - Used mainly in desktop/laptop machines
- Microcontroller
  - Integrated RAM and ROM
  - Smaller cache (or no cache)
  - May include lots of on-chip peripherals
  - Used mainly in “embedded” applications
  - Often involves real-time control
  - Low power consumption for battery-powered applications

Comparison to other courses

- Single-threaded applications
- No underlying kernel or RTOS

ECE 4534 looks at multi-threaded applications using an RTOS or thread library

- Microcontroller (rather than CPU) organization

ECE 2500/4504 looks at processor internals

Philosophy

- In this type of course, most of the learning takes place when you work on assignments
  - Lectures are focused on preparing you for labs
  - Instructors prep for this course by creating and implementing labs
- Programming is a skill that improves with practice
  - One of the most important skills for any engineer
  - Requires decomposing large problems into smaller ones
  - The person who best understands the application is the best person to write the software
- Lab assignments are carefully sequenced

Formal Learning Objectives

Having successfully completed this course, the student will be able to

1. develop software for microcontroller systems using a high-level programming language;

2. demonstrate familiarity with common microcontroller subsystems, such as timer modules;

3. demonstrate an ability to use both polling and interrupt-driven approaches for interfacing a microcontroller with peripheral devices;

4. develop and analyze software to interface a microcontroller with common peripheral devices, such as switches, visual displays, digital-to-analog converters, analog-to-digital converters, and flash memory to produce a system to accomplish a specified task;

5. design interfaces to external devices connected to the microcontroller using a standard bus; and

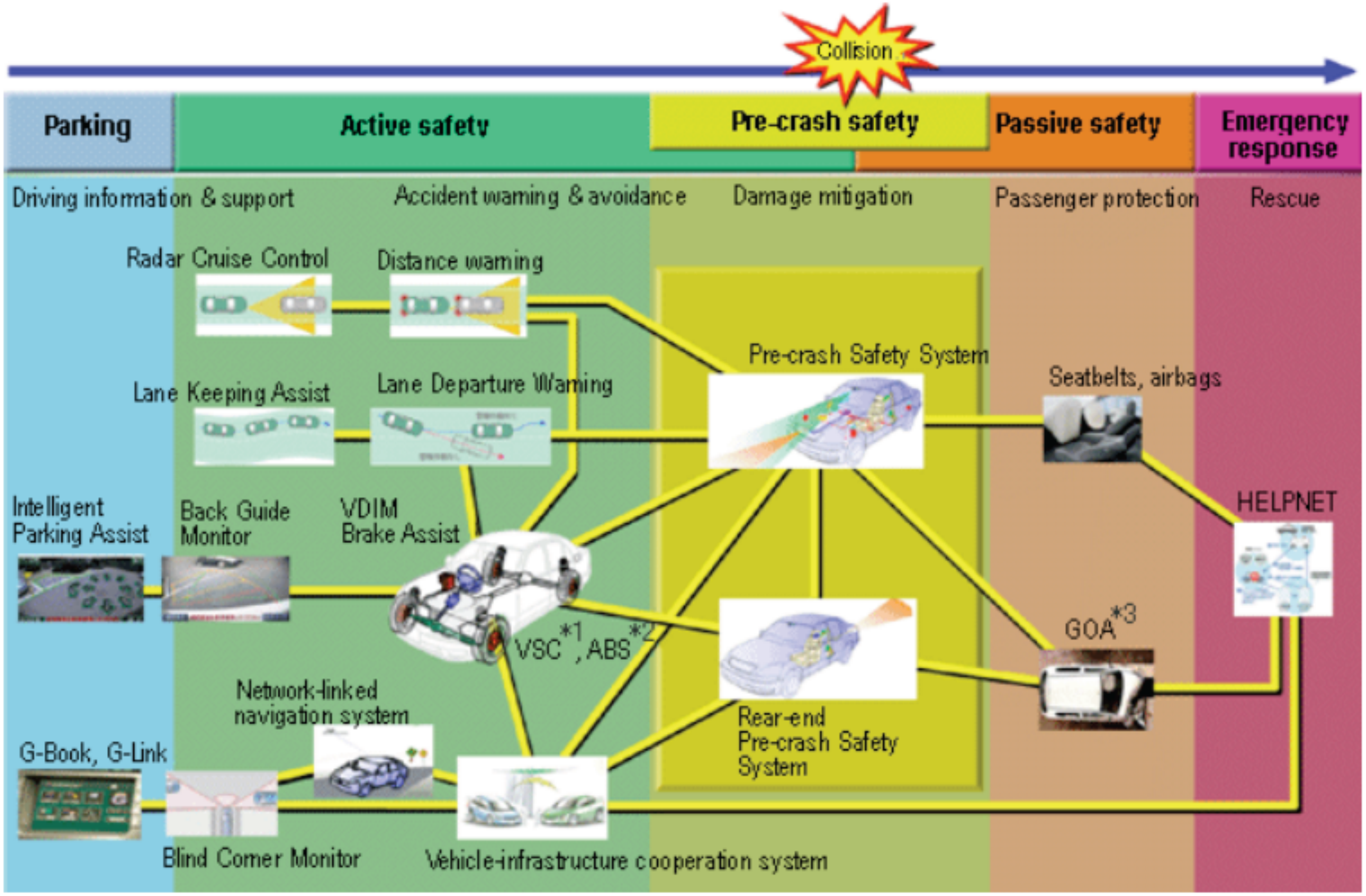
6. describe the roles of microcontrollers in contemporary systems, including common consumer products.

Some types of embedded systems

- Communications
  - E.g. cellphones, routers, wireless infrastructure
- Consumer electronics
  - E.g. TV, Xbox, TiVo, watches, digital cameras, ovens, coffee makers, vacuum cleaners, washing machines, garage-door openers, . . .
- Automotive
  - E.g. antilock brakes, air bags, engine control
- Industrial
  - E.g. SCADA, robotics, flow meters
- Medical
  - E.g. pacemakers, automatic defibrillators
- Defense
  - E.g. drones, satellites

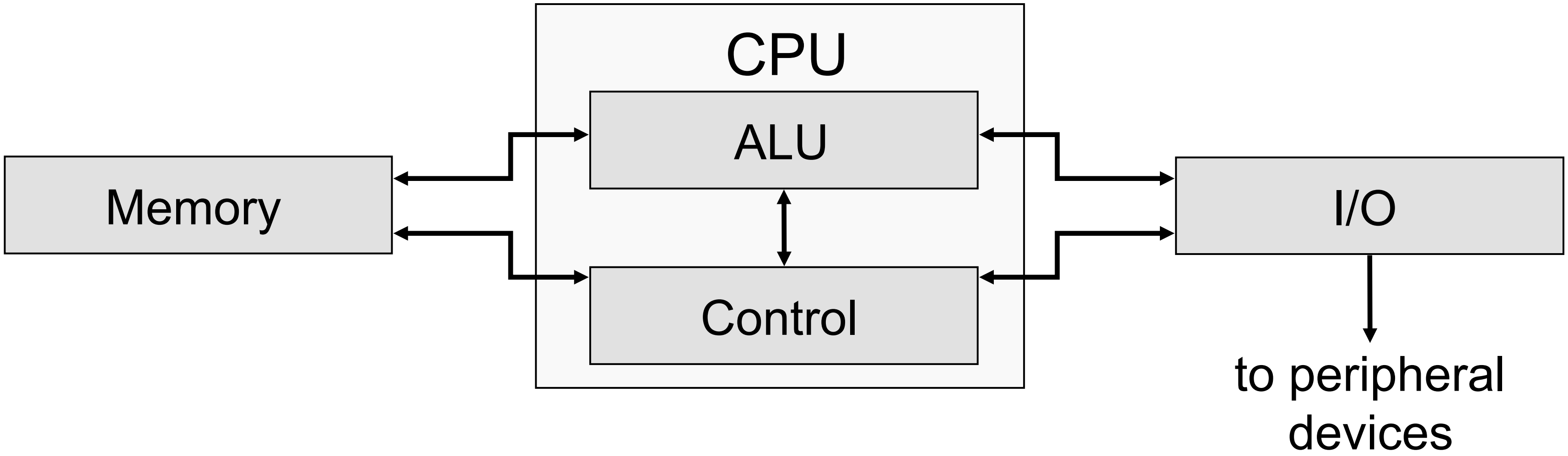
The modern car is stuffed with microcontrollers

- Typically 50 to 100 embedded systems
- 10 to 15 million lines of C code



Toyota example

Common Computer Organization



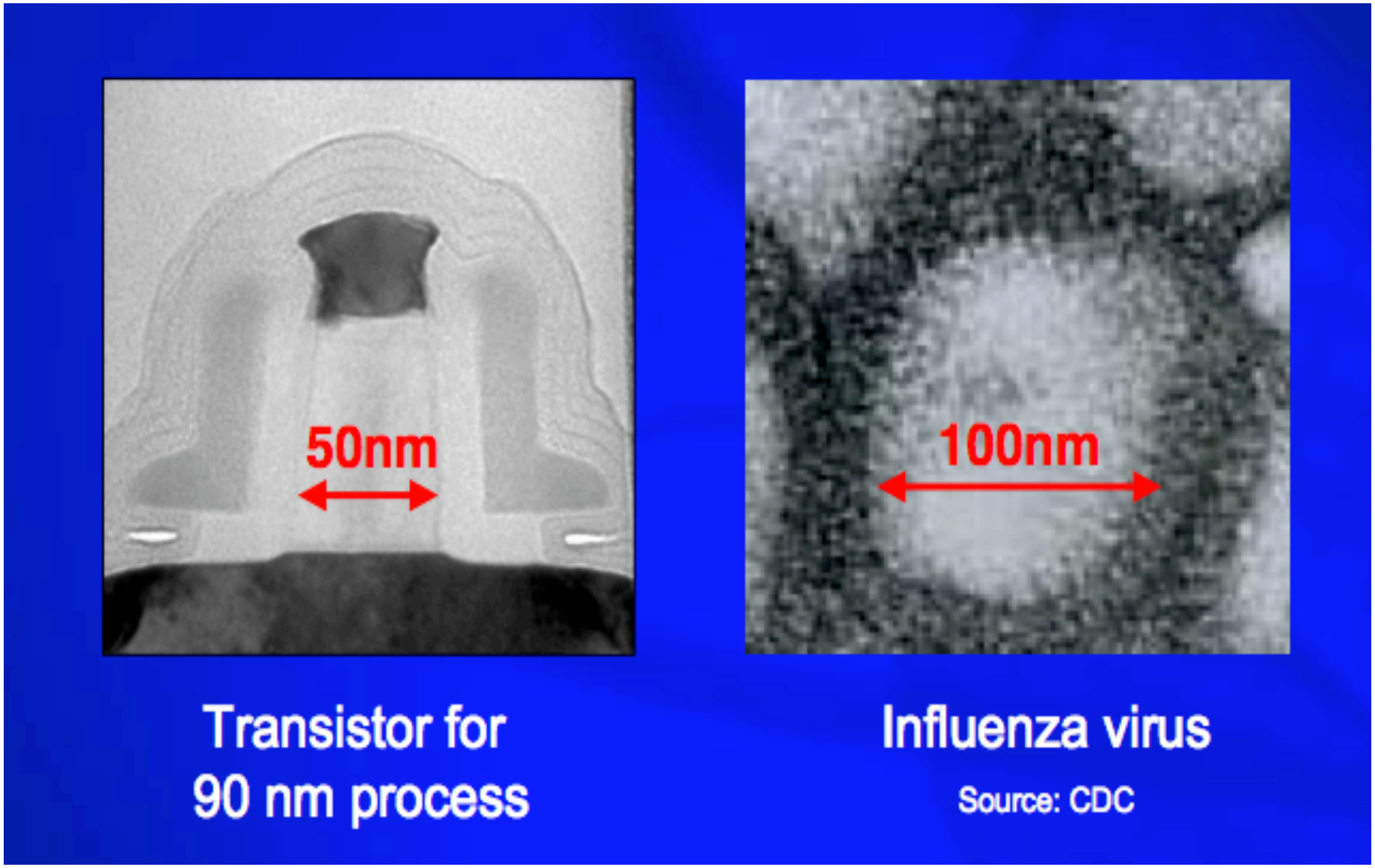
- **Memory** - Stores programs and data
- **CPU** - Central Processing Unit
- **ALU** - Arithmetic & Logic Unit
- **Control Unit** - Sequences data transfers and other operations
- **I/O Unit** - Communicates with the "outside world"

Microprocessor progression (Intel)

Name	Date	Transistors	Microns	Clock speed	Data width	MIPS
8080	1974	6,000	6	2 MHz	8 bits	0.64
8086	1978	29,000	3	5 MHz	16 bits	
80286	1982	134,000	1.5	6 MHz	16 bits	1
80386	1985	275,000	1.5	16 MHz	32 bits	5
80486	1989	1,200,000	1	25 MHz	32 bits	20
Pentium	1993	3,100,000	0.8	60 MHz	32 bits 64-bit bus	100
Pentium II	1997	7,500,000	0.35	233 MHz	32 bits 64-bit bus	~300
Pentium III	1999	9,500,000	0.25	450 MHz	32 bits 64-bit bus	~510
Pentium 4	2000	42,000,000	0.18	1.5 GHz	32 bits 64-bit bus	~1,700
Pentium 4 "Prescott"	2004	125,000,000	0.09	3.6 GHz	32 bits 64-bit bus	~7,000

Source: http://computer.howstuffworks.com/microprocessor2.htm
(Compiled from The Intel Microprocessor Quick Reference Guide and TSCP Benchmark Scores)

Putting 0.09 microns in perspective

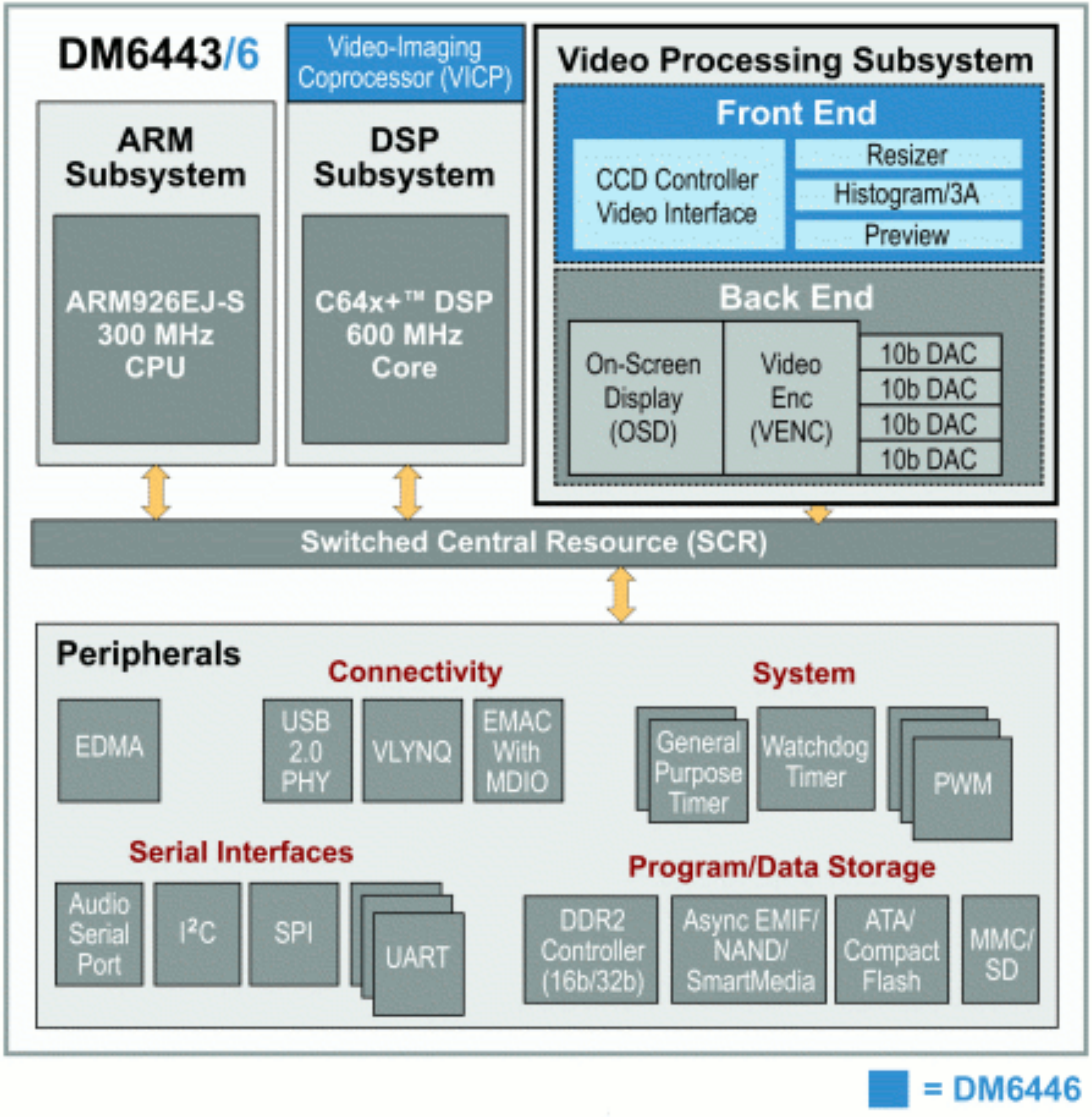


Transistor for 90 nm process

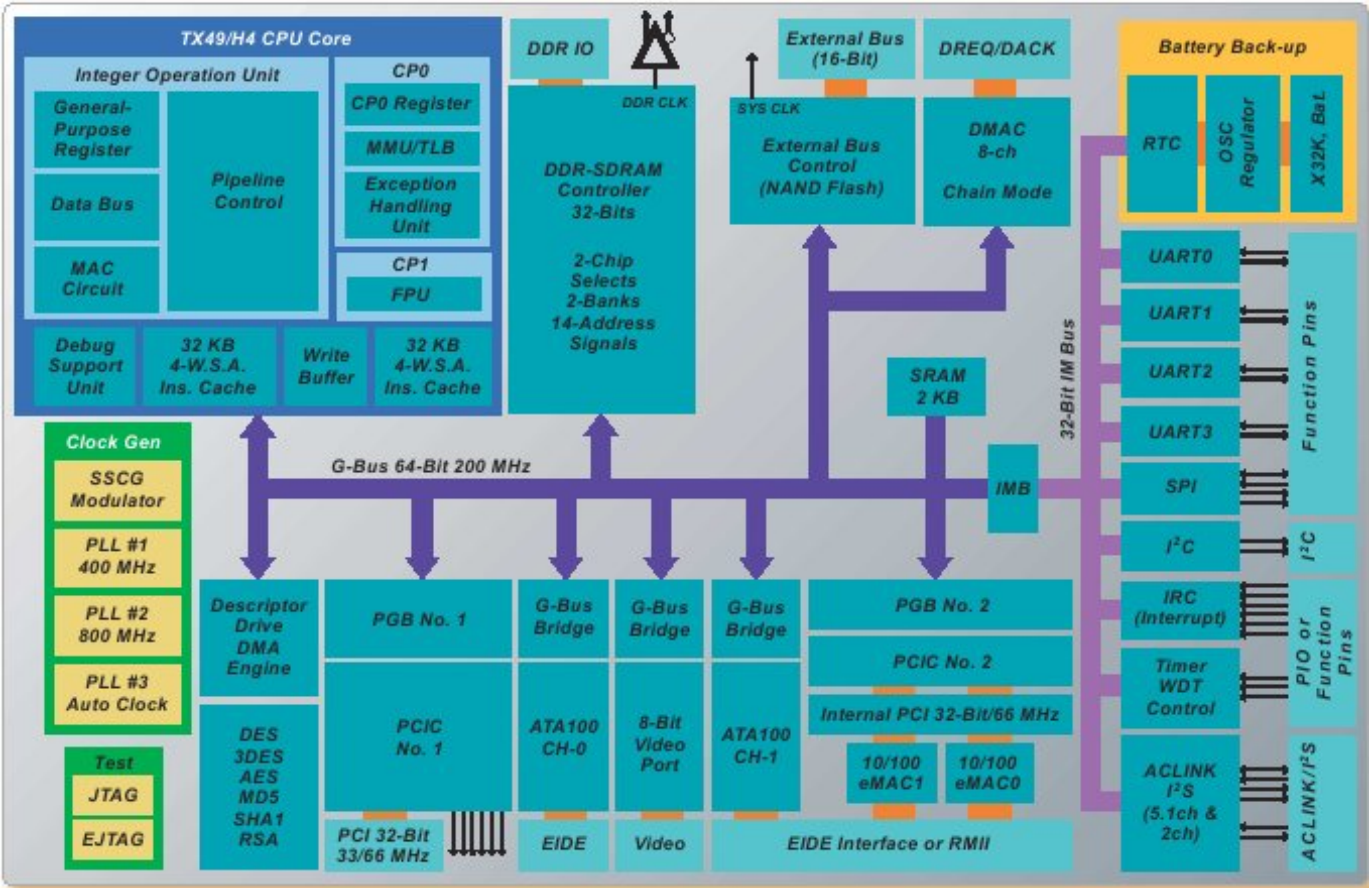
Influenza virus

Source: CDC

Texas Instruments *DaVinci* Processor

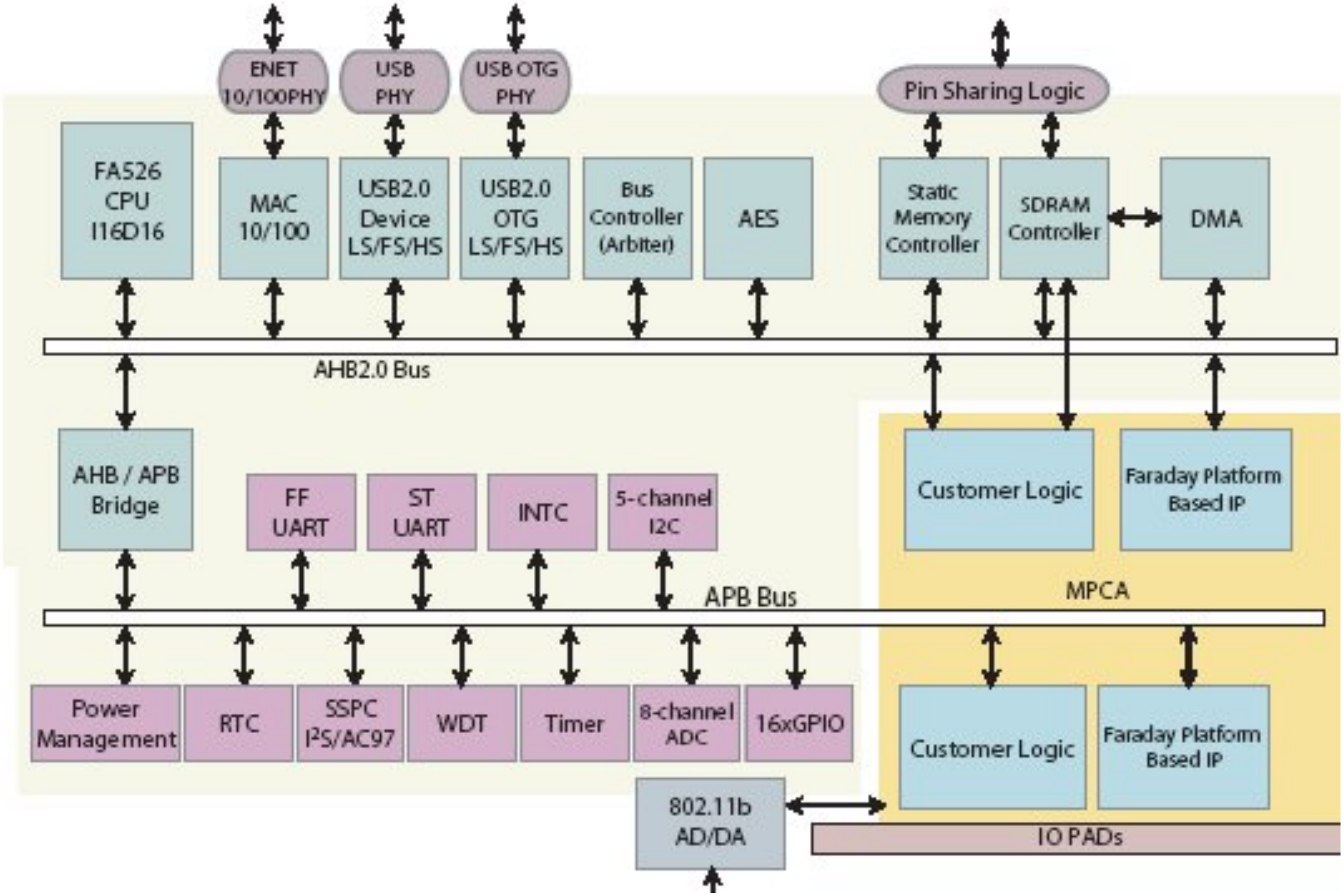


Toshiba TX4939XBG-400



Packet 1

Faraday Technology StructuredC



Summary

- Embedded systems are very important for all EEs and CPEs
- Need to know a “good mix” of hardware and software