

CLASS LOGISTICS

Two In-Class Examinations (40%)

- Exam 1 – 20%
- Exam 2 – 20%

Required Laboratory (40%)

- Several Experiments
- Meets Weekly (Check online Class Schedule!!!)

Attendance, Homework, and Pop Quizzes (10%)

- Several Assignments
- Homework Assignments on Class Schedule Webpage
- In-class Pop Quizzes are a Possibility (ask questions/interact)

Take-Home Final Design Project (10%)

- Design/project oriented class
- Capstone evaluation diagnostic is a take-home final design and corresponding report

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CLASS GOALS

Microprocessor/Microcontroller Architecture

Microcontroller Instruction Set Architecture

Interfacing

Memory

Busses

Devices and Device Drivers

Embedded System Software Architecture

Standard Embedded System Busses

AMBA

I2C

USB

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Microprocessors & Microcontrollers

Microprocessors

- Rich Instruction Set – General Purpose Computing
- Hardware Support for OS
- General Purpose ALU and Memory/IO Interfaces
- High-Level Languages

Microcontrollers

- Limited Instruction Set – Embedded Systems
- Dedicated Memory/IO Features, Timers, DSP circuits, etc.
- Often Optimized for Power, Specialized IO, On-board Firmware
- Assembler & Low-level Programming

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Microprocessors & Microcontrollers

Microprocessors

- CPU on a chip – Typically with some Local Memory (cache)
- Requires Dedicated Chipset
- External Main Memory
- External IO Support – Interrupt Controller, DMA

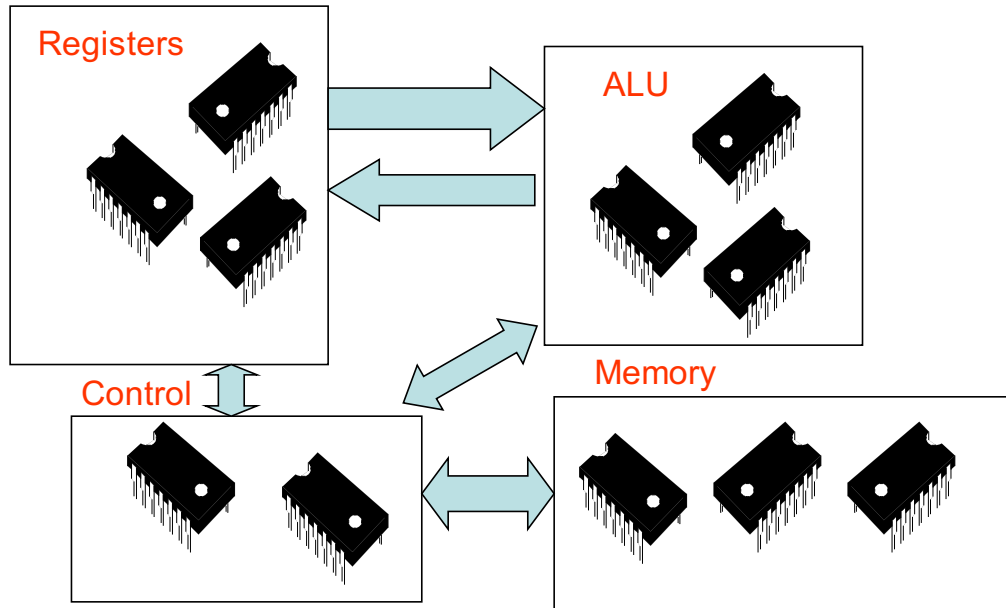
Microcontrollers

- Usually has Memory & IO Support on Same Chip
- Dedicated Support Circuitry – Timers, Multiple IO, Flash Memory
- Data Converters (ADC and DAC) Often on-chip

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Processor Integration

Early computers had many separate chips for the different portions of a computer system



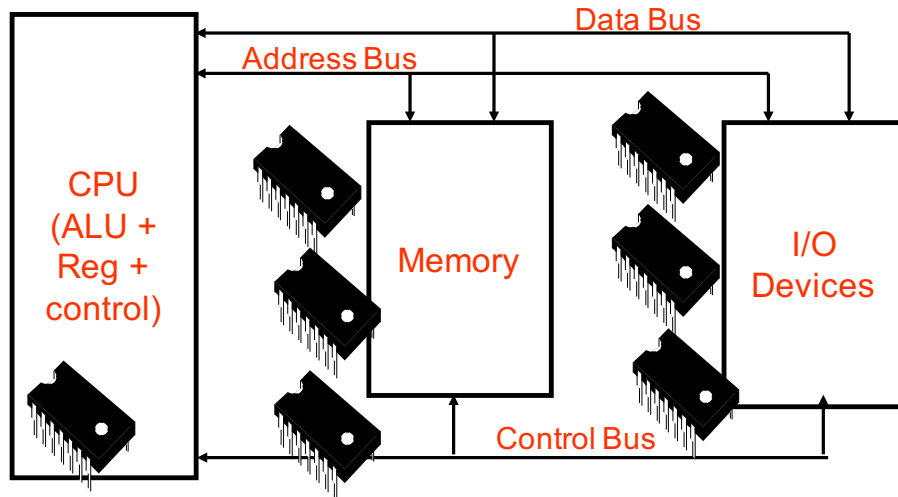
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The Cray-1 supercomputer. (Photo courtesy of Smithsonian.)



Microprocessors

First *microprocessors* placed control, registers, Arithmetic logic unit in one integrated circuit (one chip).



CPU – Central Processing Unit

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FIGURE 1-1 The stored program computer consists of three units: the CPU, memory, and I/O devices.

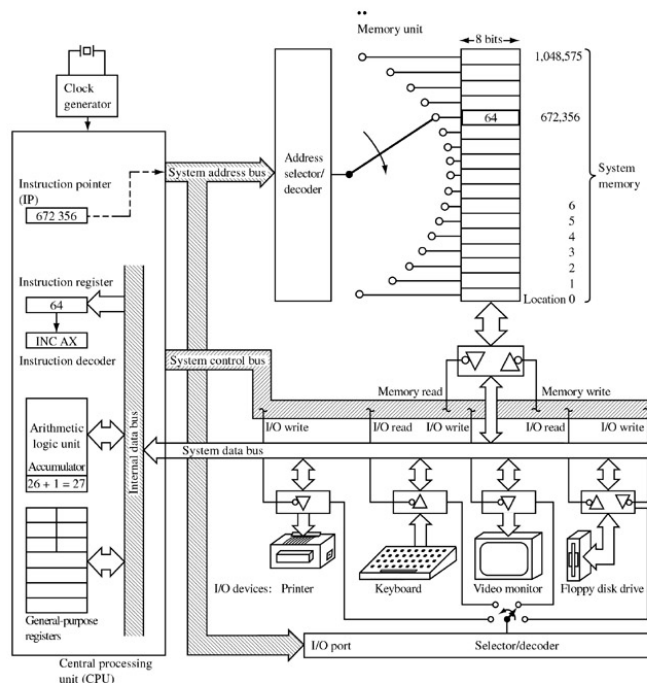
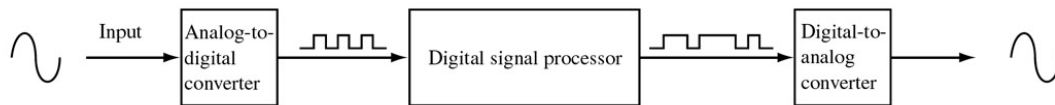


FIGURE 1-9 In a digital signal processing system, analog input signals are converted to digital form, processed by the DSP, and then converted back to analog form.

Typical Embedded System



John Uffenbeck
The 80x86 Family: Design,
Programming, and Interfacing, 3e

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Microcontrollers

Microcontrollers integrate all of the components (control, memory, I/O) of a computer system into one integrated circuit. Microcontrollers are intended to be single chip solutions for systems requiring low to moderate processing power.

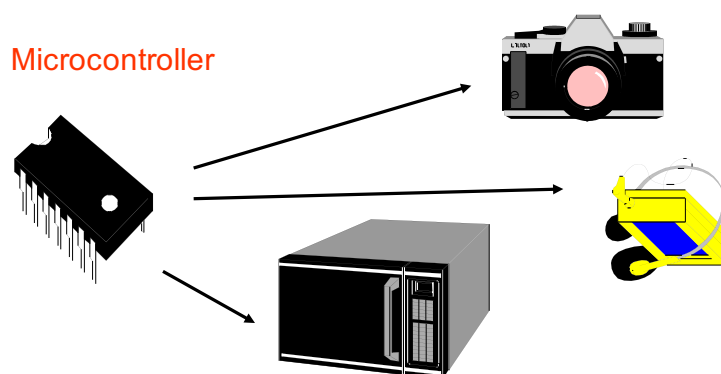


FIGURE 1-6 Microcontrollers are often called “hidden computers.” In this picture there are 14 different microcontrollers. (Reprinted courtesy of Intel Corporation and Microcomputer Solutions.)



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Definitions

Microprocessor – A CPU on a single chip containing registers, ALU, instruction decoder, addressing logic, internal busses, and control logic. Typically it cannot be operated in a standalone manner.

Microcontroller – A complete computer system on a chip containing a CPU, memory, IO/interface controllers, timers, and other specialized circuitry. Typically it can be operated in a standalone manner.

Embedded System – A system or device that has a dedicated computer as one of its subsystems. Examples are cell phones, MP3 players, household appliances, etc. They may contain microcontrollers or embedded general purpose processors.

Real-time System – A system or device that is required to respond to external events within a specified time period.

More Definitions

Digital Signal Processors – A chip that includes a CPU and dedicated arithmetic circuitry for processing signals such as fast adders/multipliers or circuits to support operations such as Fourier transforms. Many times they also contain data converters (ADC and DAC).

ADC – Analog to Digital Converter circuit. Input is a continuously varying signal that is sampled and outputs digital values that approximate the continuous signal.

DAC – Digital to Analog converter circuit. Input is a series of digital values that are converted to a continuously varying output signal.

Real-time System – A system or device that is required to respond to external events within a specified time period.

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ARM® Processors

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Processors Market

In 2007:

- 13 billion microprocessors were shipped.
- 3 billion are based on the ARM architecture embedded processor.
- 150 million are for the PC, notebook, and workstation.

By February 2008:

- 10 billion ARM-based processors have been produced.

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A Bit of ARM History

Originally conceived to be a processor for the desktop system (Acorn®)

- now entrenched in embedded markets

First well-known product

- Apple®'s Newton™ PDA (1993)
based on an ARM6 core



Significant breakthrough

- Apple®'s iPod® (2001)
based on an ARM7 core



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ARM Ltd

- Founded in November 1990
 - Spun out of Acorn Computers
- Designs the ARM range of RISC processor cores
- Licenses ARM core designs to semiconductor partners who fabricate and sell to their customers.
 - ARM does not fabricate silicon itself
- Also develop technologies to assist with the design-in of the ARM architecture
 - Software tools, boards, debug hardware, application software, bus architectures, peripherals etc



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Intellectual Property

- ARM provides hard and soft views to licensees
 - RTL and synthesis flows
 - GDSII layout
- Licensees have the right to use hard or soft views of the IP
 - soft views include gate level netlists
 - hard views are DSM (Deep SubMicron Layouts)
- OEMs must use hard views
 - to protect ARM IP

ARM Processor Architecture

ARM stands for “Advanced RISC Machine”.

- based on Reduced Instruction Set Computer (RISC) architecture
 - trading simpler hardware circuitry with software complexity (& size)
 - but latest ARM processors utilize more than 100 instructions

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RISC Philosophy

Original RISC design (e.g., MIPS)

- aims for high performance through
 - reduced number of instruction classes
 - large general-purpose register set
 - load-store architecture
 - fixed length instructions
 - pipelines
- enables simpler hardware; hence, scalable to higher operating frequencies

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ARM Processor

ARM processor

- targeted for embedded applications as a processor embedded for system-on-chip devices
- not a pure RISC architecture (e.g., supports both 16-bit and 32-bit instruction sets)

Also emphasizes the following:

- low power consumption
- small die size
- cost effectiveness

Biggest market for ARM-based processors

- mobile phones and smart phones

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ARM Powered Products



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ARM Partners

The ARM processor is not sold as a processor chip but as a hardware IP license.

Licensees add their own logic and customized peripherals and then manufacture the silicon processor chip.

- typically sold as ASIC/SOC for embedded applications

Some of the present and past licensees (ARM calls them Partners) include:

- Texas Instruments, Philips, Analog Devices, Qualcomm
- Intel (StrongARM® and XScale®)
- Atmel – its processor is used on the ARM9 board

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ARM Partnership Model



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ARM Processor Main Features

Typical ARM processors:

- run at a relatively slow clock cycle (few hundred MHz).
[But new and upcoming family, like the dual-core Cortex™-A9 Osprey is capable of achieving up to 2 GHz clock.]
- 32-bit instructions, with extension to support 16-bit Thumb® & Thumb-2 instructions.
- single unified memory address space (i.e. all peripherals and I/O are accessed like normal memory, at certain specific memory locations).
- relatively low power consumption.

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ARM Processor Families

a) ARM7TDMI family (E.g. NXP's ARM7)

- Based on ARMv4T architecture with 3-stage pipeline
- supports the 16-bit Thumb instruction set
- supports the JTAG Debugger
- includes a fast Multiplier to support DSP algorithm
- supports the In-Circuit Emulation interface

b) ARM9TDMI family (E.g. Atmel's ARM9)

- Based on ARMv4T with Harvard cache architecture
- 5-stage pipeline
- ARM920T is based on ARM9TDMI with a memory management unit (MMU)

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ARM Processor Families (cont' d)

c) ARM9E family (E.g. Intel' s XScale)

- Based on ARMv5E architecture
- Enhanced with DSP instructions
- Hardware support of Java™ bytecodes execution

d) ARM10 family

Based on ARMv5E with MMU

e) ARM11 family

- Based on ARMv6 architecture
- Supports SIMD instructions

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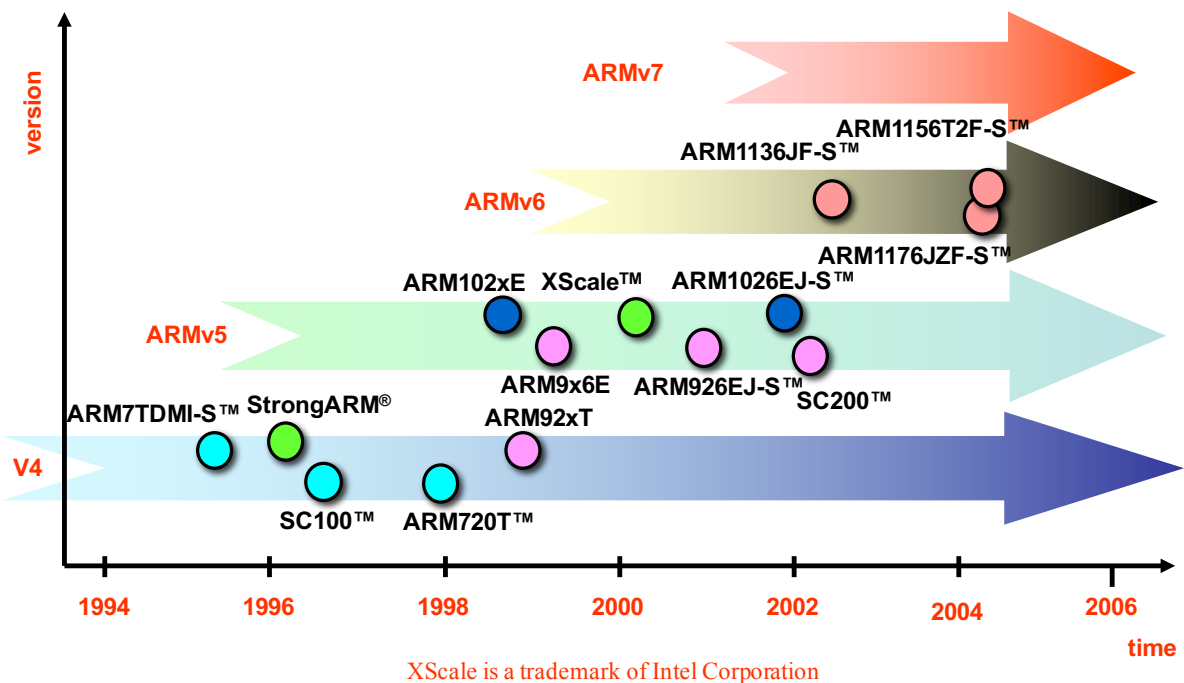
ARM Processor Families (cont' d)

f) Cortex families

- Based on ARMv7 architecture
- Supports the new Thumb-2 instruction set
- Cortex-A: For complex OS based applications
- Cortex-R: For real-time embedded applications
- Cortex-M: For deeply embedded, microcontroller type cost sensitive applications
- Only executes Thumb-2 codes

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Architecture Revisions



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Data Sizes and Instruction Sets

- The ARM is a 32-bit architecture.
- When used in relation to the ARM:
 - **Byte** means 8 bits
 - **Halfword** means 16 bits (two bytes)
 - **Word** means 32 bits (four bytes)
- Most ARM's implement two instruction sets
 - 32-bit ARM Instruction Set
 - 16-bit Thumb Instruction Set
- Jazelle cores can also execute Java bytecode

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Example Development Tools

Compilation Tools

ARM Developer Suite (ADS) –
Compilers (C/C++ ARM & Thumb),
Linker & Utilities



RealView Compilation Tools (RVCT)

Debug Tools

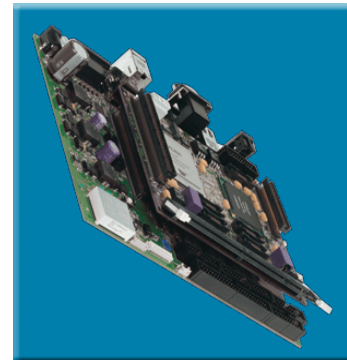
AXD (part of ADS)
Trace Debug Tools
Multi-ICE
Multi-Trace



RealView Debugger (RVD)
RealView ICE (RVI)
RealView Trace (RVT)

Platforms

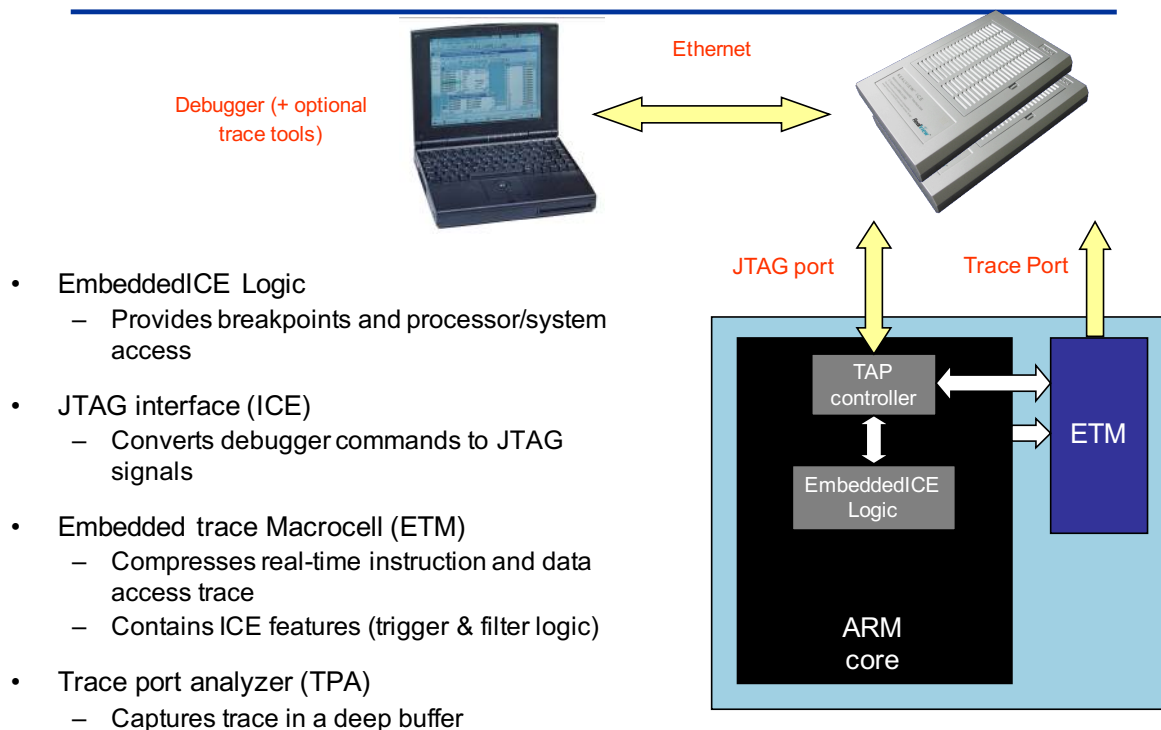
ARMulator (part of ADS)
Integrator™ Family



RealViewARMulator ISS (RVISS)

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ARM Debug Architecture



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