University of San Carlos | Department of
COMPUTER ENGINEERING

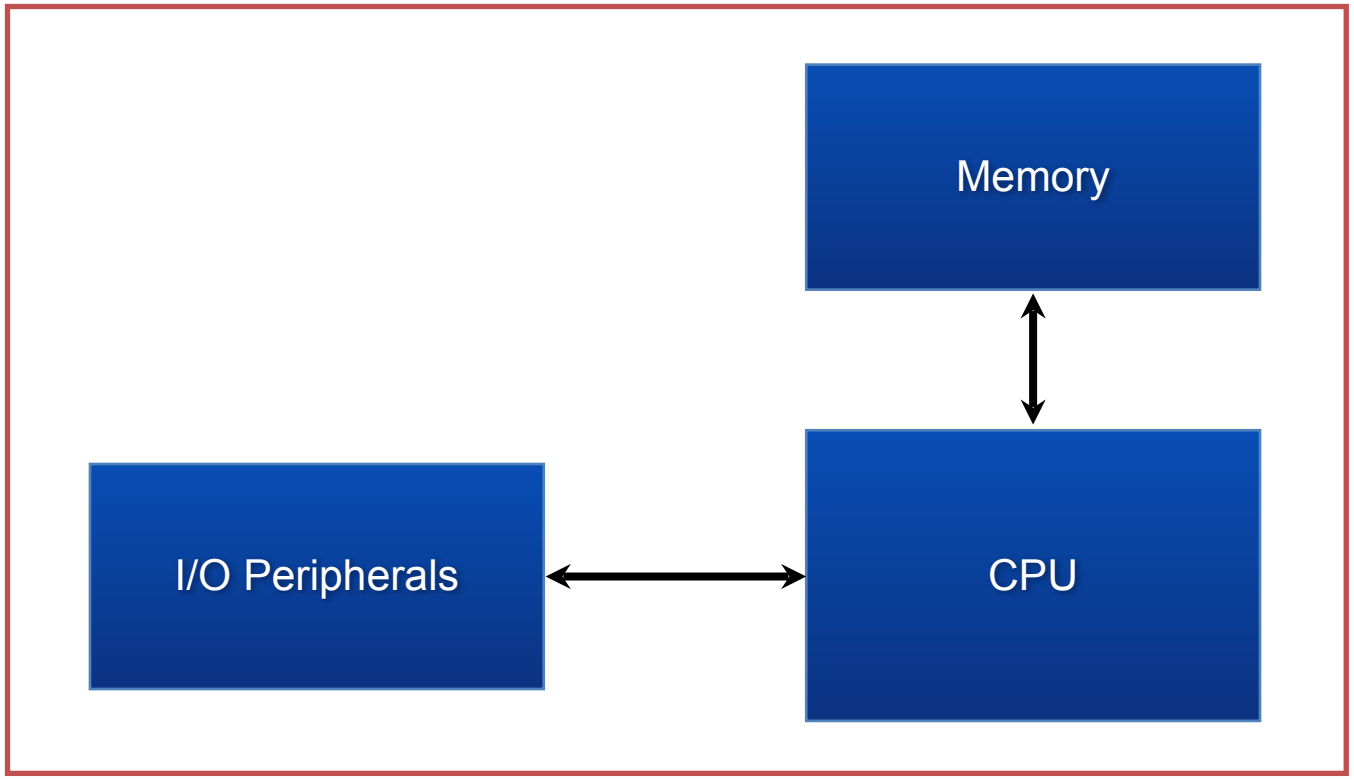
CpE 3201
Embedded Systems

MCU Architecture & Programming

Microcontroller

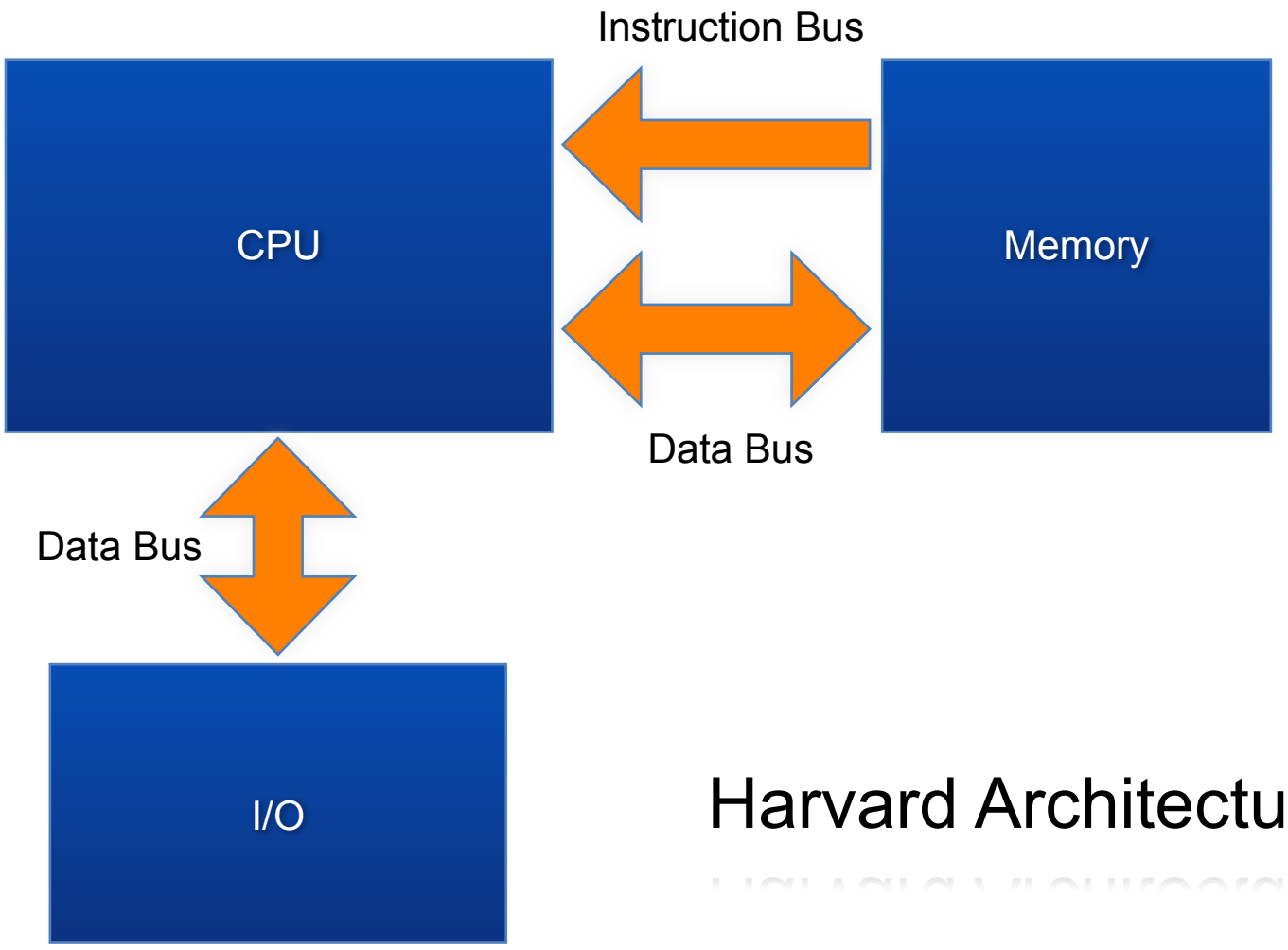
- A small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals

Microcontroller Architecture



Architecture

- some microcontrollers use a Harvard architecture where;
  - separate memory buses for instructions and data, allowing accesses to take place concurrently



Harvard Architecture

Instruction Set

- Most MCUs have a RISC (Reduced Instruction Set Computer) CPU while some have CISC (Complex Instruction Set Computer)

CISC vs RISC

- Emphasis on hardware
- includes multi-clock
- complex instructions
- Memory-to-memory: "LOAD" and "STORE"
- Small code sizes, high cycles per second
- Transistors used for storing complex instructions

- Emphasis on software
- single clock
- reduced instructions only
- Register-to-register: "LOAD" and "STORE"
- Low cycles per second, large code sizes
- Spends more transistors on memory registers

Applications

- automobile engine systems
- implantable medical devices
- remote controls
- office machines
- appliances
- toys

Why MCU?

- By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes.

General Features

- Low power consumption
  - uses four-bit words and operate as low as 4 kHz
- Ability to retain functionality while waiting for an event such as a button press or any interrupt.

General Features

- Ability for core CPU to sleep thus having as low nano-watts power consumption suitable for battery powered devices.
- Programmable general purpose I/O (GPIO) ports.
  - each port can be programmed to a specific function

General Features

- Programmable Timers
  - Watch-Dog Timer (WDT)
  - Interrupt Timer
  - Programmable Interval Timer (PIT)
  - Time Processing Unit (TPU)

General Features

- Other peripherals such as:
  - A/D and D/A converters for mixed signal systems
  - Pulse-Width Modulation, Capture and Compare Modules

General Features

- Communication Systems
  - UART
  - I2C
  - SPI
  - Com Buses
  - CAN & LIN

Limitations

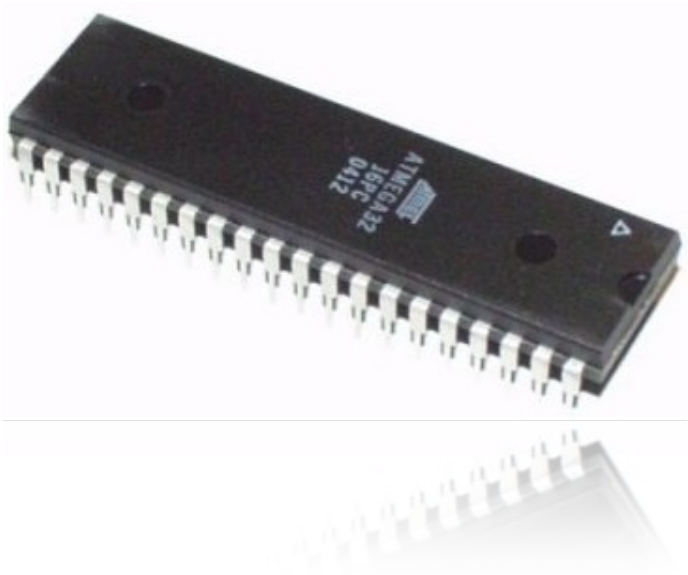
- MCUs does not have a math co-processor or floating point processors like most microprocessor have
- Calculations involving floating point must be done by software

Limitations

- Unlike non-integrated systems, MCUs have limited amount of RAM and Program ROM, though can be expanded with external memories

MCU Organization

- central processing unit - ranging from small and simple 4-bit processors to complex 32- or 64-bit processors
- volatile memory (RAM) for data storage
- ROM, EPROM, EEPROM or Flash memory for program and operating parameter storage

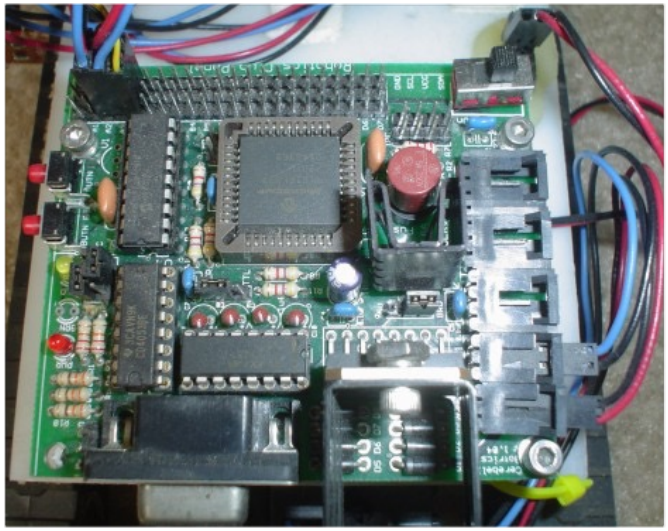


MCU Organization

- discrete input and output bits, allowing control or detection of the logic state of an individual package pin
- serial input/output such as serial ports (UARTs)
- other serial communications interfaces like I²C, Serial Peripheral Interface and Controller Area Network for system interconnect
- peripherals such as timers, event counters, PWM generators, and watchdog

MCU Organization

- clock generator - often an oscillator for a quartz timing crystal, resonator or RC circuit
- many include analog-to-digital converters, some include digital-to-analog converters
- in-circuit programming and debugging support



Programming

- Microcontrollers were originally programmed only in assembly language, but various high-level programming languages are now also in common use to target microcontrollers
- The most common high-level language being used is C

Assembly vs High-Level

```
MOVLW 03H
MOVWF PORTA
```

```
PORTA = 0x03;
```

Code to assign a literal value 03 to register PORTA

*Programming for PIC16F84A

Assembly vs High-Level

- assembly language has a lower memory footprint than high-level language
- high-level language is much easier to code than assembly;
- also allows hardware abstraction which makes programs portable to a different MCU architecture

Types of Microcontrollers

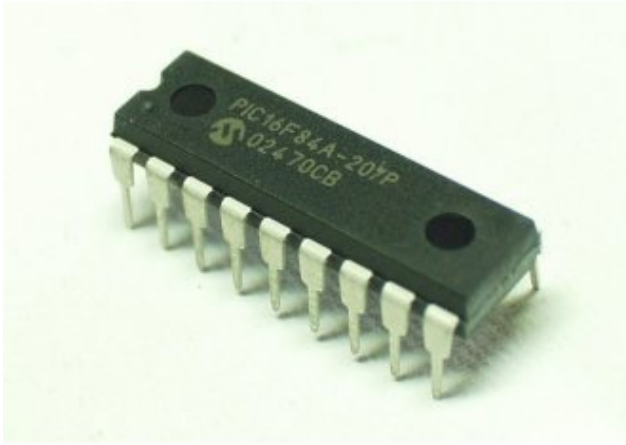
- Freescale 68HC11 (8-bit); Freescale ColdFire (32-bit) and S08 (8-bit)
- ARM processors (from many vendors) using ARM7 or Cortex-M3 cores are generally microcontrollers

Types of Microcontrollers

- Zilog eZ8 (16-bit), eZ80 (8-bit)
- NXP Semiconductors [2] LPC1000, LPC2000, LPC3000, LPC4000 (32-bit), LPC900, LPC700 (8-bit)
- Atmel AVR (8-bit), AVR32 (32-bit), and AT91SAM (32-bit)

Types of Microcontrollers

- PIC (8-bit PIC16, PIC18, 16-bit dsPIC33 / PIC24)



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End of Lecture

References:

- Jonathan W. Valvano. Embedded Microcomputer Systems Int'l, 3rd ed. Connecticut: Cengage Learning, 2011.
- Ian McLoughlin. Computer Architecture: An Embedded Approach. New York: McGraw-Hill Education (Asia), 2011.
- Ramesh S. Gaonkar. Fundamentals of Microcontrollers and Applications in Embedded Systems. Thomson Delmar Learning, 2007.