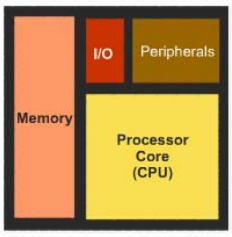
MCU

Εισαγωγή - Σύνοψη

What is a Microcontroller?



- Microcontroller
  - Single-chip device
  - System decisions based on external signals
  - Controls the behavior of a system
- Always contains:
  - Processor core
  - Memory (RAM, ROM)
  - Input/Output (I/O) capability
    - Serial I/O interfaces
  - Various on-chip peripherals such as:
    - Timers
    - Analog to digital convertors
    - Pulse width modulators
    - Many others

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Where are Microcontrollers?

- Everywhere . . .
  - Any Application that has Real World Inputs & Outputs
- Examples
  - Industrial Process Control Equipment, Robotics
  - Security Alarms, Utility Meters
  - Automotive (Airbag Control, Engine Control, Anti-lock Brakes, Instrument Cluster)
  - White Goods (Washing Machines, Dryers, Microwaves, Food Processors)
  - Consumer (Glucose Monitors, Blood Pressure Devices, Clock Radios)
  - Internet Appliances, Routers
  - Networking Equipment
  - Toys

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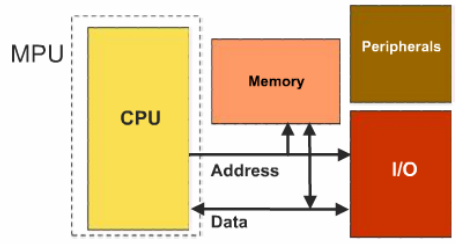
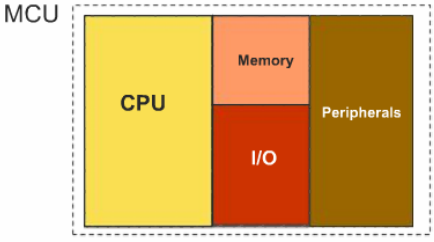
What is the difference between a microcontroller and a microprocessor?



- Microprocessors (MPU): CPUs that connect to external memory and peripherals



- Microcontrollers (MCU): have CPU core with memory, I/O and peripherals integrated on-chip

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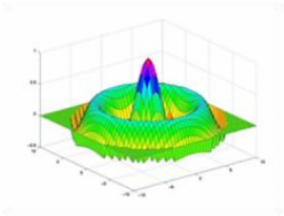
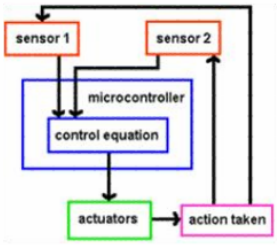
What is the difference between a microcontroller and a DSP?

Digital Signal Processors (DSP): Performs complex mathematical functions.



Source: Michael Dewar

Microcontrollers (MCU): are used when control of a system is required.



Source: www.societyofrobots.com

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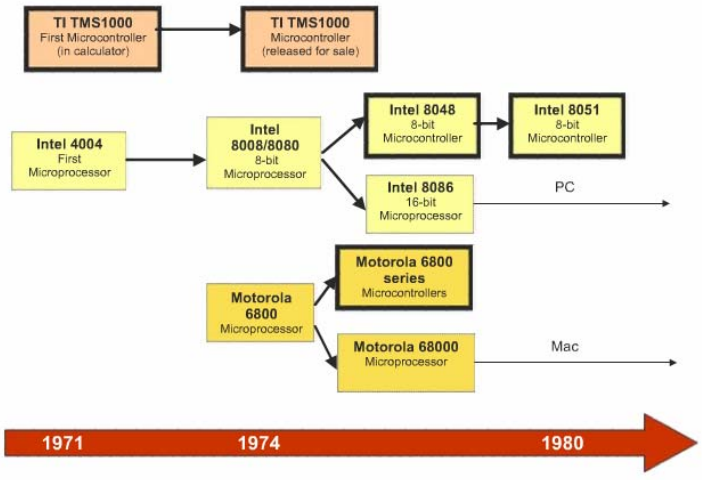
History of the Microcontroller: Early Timeline



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History of the Microcontroller: Other Early Entries

- General Instruments
  - The famous PIC
  - Spun out chip division - Microchip
- Hitachi
  - 6300 line
  - Combined with Mitsubishi Electric to form Renesas
- Zilog
  - First the Z-80 processor, then Z-8 MCU

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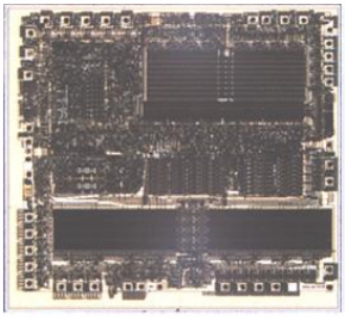
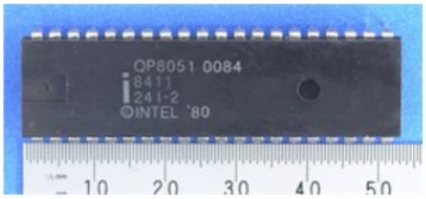
History of the Microcontroller: Early Microcontroller Die and Package





Source: Semiconductor Insights

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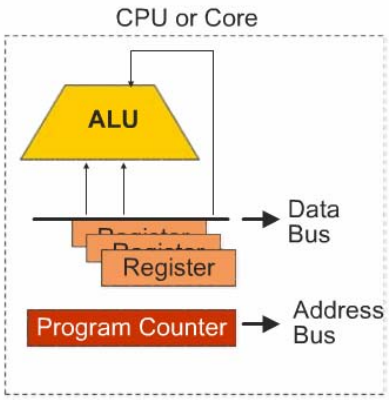
Processor Core

- Core
  - Reads and stores data
  - Performs basic math functions
  - Performs logical functions (e.g. AND, OR, etc.)
  - Controls flow of program execution



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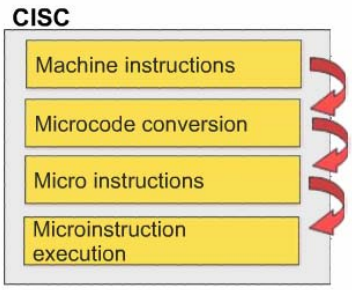
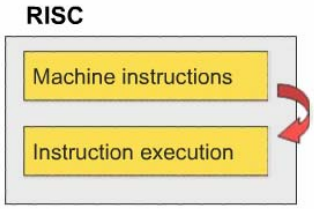
CISC vs. RISC





- **C**omplex **I**nstruction **S**et **C**omputer
- **R**educed **I**nstruction **S**et **C**omputer

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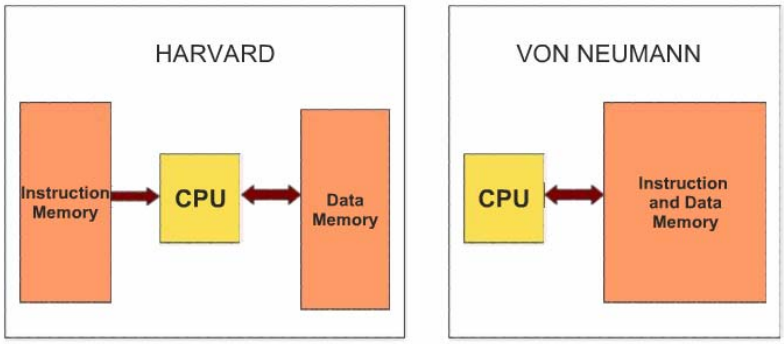
Harvard vs. von Neumann

- Memory Usage and Bus Configuration



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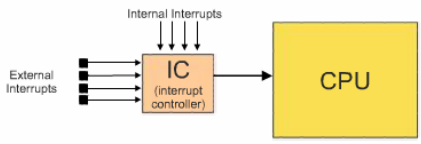
Interrupt Controller

- Hardware to handle interrupt signals.
- Important in real-time systems.
- Interrupt Latency is important to consider.
  - Hardware and software (OS) determine interrupt latency.
  - Interrupt Service Routine (ISR) is part of OS.



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System Memory: ROM

ROM - Read-Only Memory - for Program Storage

- **Masked ROM**
  - Programmed during manufacture
- **PROM**
  - Programmed by blowing fuse after manufacture
- **EPROM - Erasable Programmable Read-Only Memory**
  - Electrically programmed – Erased by UV light.
- **OTP - One-Time Programmable**
  - PROM
  - Or EPROM that is encapsulated
- **EEPROM - Electrically Erasable Programmable Read-Only Memory**
  - Electrically programmed – erased with higher voltages
- **Flash**
  - Similar to EEPROM
  - Write/Read/Erase in large blocks

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System Memory: RAM

RAM - Random Access Memory

- Volatile or Non-Permanent Memory
- Can Be Written To Many Times
- Stores Temporary or Changeable Data
- "Embedded" in MCUs

Types of RAM

- **SRAM**
  - Static RAM
  - Fast Access Times / More Silicon Area
  - Common in MCUs
- **DRAM**
  - Dynamic RAM
  - Slower Access Times / Less Silicon area
  - Less Common in MCUs

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I/O: Serial Interfaces

- Allow communication with other devices
  - USB (**U**niversal **S**erial **B**us)
  - CAN (**C**ontroller **A**rea **N**etwork)
  - SPI (**S**erial **P**eripheral **I**nterface)
  - I2C (**I**nter **I**ntegrated **C**ircuit)
  - UART (**U**niversal **A**synchronous **R**eceiver / **T**ransmitter)
  - LIN (**L**ocal **I**nterconnect **N**etwork)
  - Ethernet
  - Also wireless interfaces
    - ZigBee
    - Bluetooth

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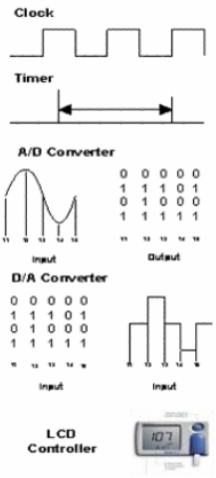
On-Chip Peripherals



Common On-Chip MCU Peripherals

- Timer
- LCD Controller
- Touchscreen Controller
- Keypad Controller
- GPIO pins
- A/D Converter
- D/A Converter
- Analog Comparator
- Pulse Width Modulator (PWM)

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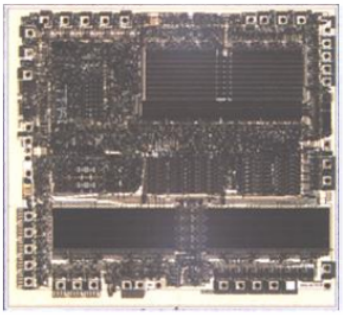
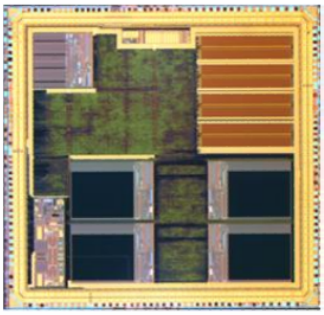
Microcontroller Trends

- Higher Integration
  - More features incorporated.





Source: Semiconductor Insights

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Microcontroller Trends

- 32-bits
  - More processing power
- Flash Memory
  - And more of it
- DSP Functionality
  - DSP or Microcontroller?
- Multi-core
  - Not just for PCs

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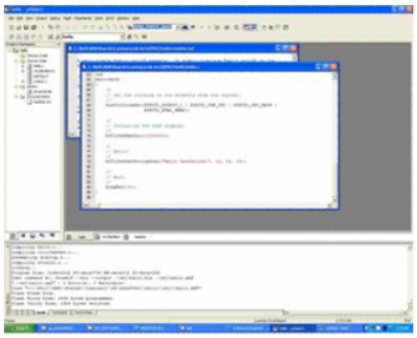
Microcontroller Development Tools

- Editor: Text-based window for editing high-level language.
- Compiler: Converts source code to object code.
- Assembler: Converts assembly code to binary code
- Linker: Joins separate object code files for download.
- Simulator: Runs linker output on a simulation of the MCU on host PC.
- Debugger: Allows engineer to monitor and halt program execution



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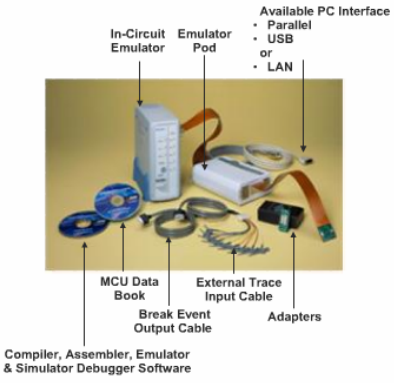
Microcontroller Development Tools

- Integrated Development Environment: Software package that contains all software tools integrated.
- In-Circuit Emulator: Replaces MCU with tool to allow viewing and control of program as seen within the chip.
- JTAG: Interface for test and debug.
- Evaluation / Development Kits: Low-Cost, Easy-to-Use Evaluation and Development Tool
- 3rd Party Tools: Various tools by non-MCU vendor that help in all aspects of development including development kits and JTAG debuggers.



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Operating System

- A software platform which manages tasks created by user
  - Design team may write their own OS
- Drivers handle details of using I/O & peripherals
  - Makes programming easier; just call on driver for I/O
  - Makes programs reusable; MCU hidden from designer
  - Drivers control peripherals; simply pass data to them
- Real-time operating system (RTOS)
  - Designed to execute multiple tasks with definite time constraints and priorities

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Code Development

- Highly integrated microcontrollers make circuit design easy, but…
  - must be programmed in order to perform a function
  - code development is more than half the product development effort
- A program is a sequence of instructions using the microcontroller's unique instruction set
  - Families of MCUs may have a common instruction set
  - Typical instructions include:
    - Adding two numbers and saving the result
    - Comparing two numbers and branching to different subroutines if equal or not equal
    - Reading the value of an external pin

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Code Development

Programs May Be Written Two Ways

Assembly Language

Code words standing for individual instructions in the set

```
LDAA #x40
DEC A
BNE 1:
```

High-Level Language (C/C++)

English-like words that correspond to a series of instructions

```
for(int i = 0; i < 10; i++)
{
    cout << "Count: "<< i << endl;
}
```

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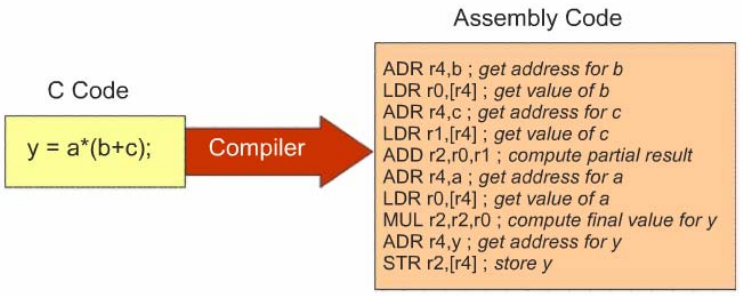
Compiler

- Converts high level language to assembly language.



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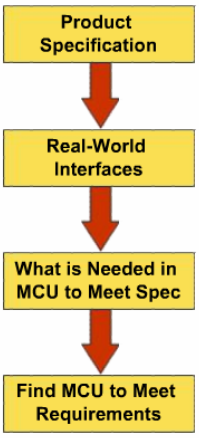
Basics of Designing a System



- Marketing Analyzes Market Needs/Drivers & Develops New Product Specification
- Environment Sensors, Motors, LCD Display, Keypad, etc.
- Engineering Determines What Functions Required of Microcontroller to Meet Specification
- Engineering Team Searches for MCU & Other System Components that Will Deliver End System to Specification

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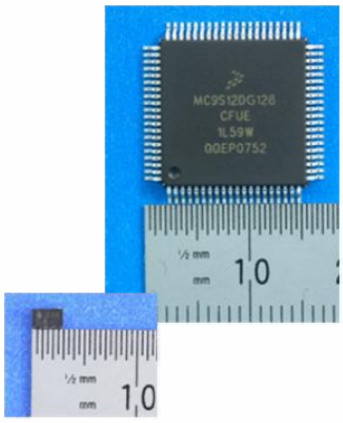
Choosing a Microcontroller: Parametric Aspects

- Features / On-chip Peripherals
  - ADC
  - DAC
  - Analog comparator
  - PWM
  - LCD Control
  - Timers
  - JTAG
  - I/Os
- Communication Interface
  - SPI
  - CAN
  - UART
  - USB
  - others…
- Package
  - Size
  - Pins



Source: Semiconductor Insights

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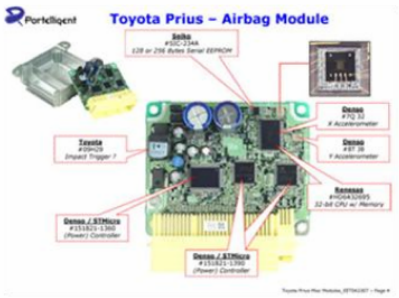
Choosing a Microcontroller: Parametric Aspects

- Power
  - Sleep modes
  - Voltage
  - Current
- Speed
  - Clock Frequency
  - Critical Instructions
  - Interrupt Latency
- Reliability
  - Application Demands
- Memory
  - Size
  - Type



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Choosing a Microcontroller: Other Aspects

- Familiarity
  - Personal Experience
  - Senior Engineer
- Price
  - Device
  - Volume
  - SoftwareTools
    - Integrated Development Environment (IDE)
    - Debug
    - Compiler
    - OS
- Available Kits
  - Evaluation
  - Development
  - Reference Design

Source: Luminary Micro www.LuminaryMicro.com

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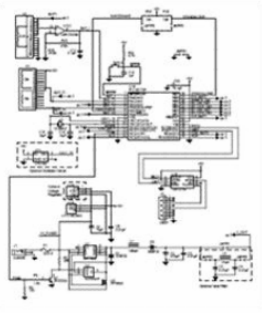
Choosing a Microcontroller: Other Aspects

- Support
  - Documentation
    - White Papers
    - Reference Designs
    - Example Code
    - User Guide
    - Errata
  - Apps Engineers
    - Response Times
  - Community
- Portability / Scalability
  - Roadmap
  - Large Family
  - Abstraction Layer



Source: Microchip Technology Inc.

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Conclusion

- Microcontroller is:
  - Processor core with memory, I/O, peripherals all incorporated in device.
- Microcontroller provides:
  - Control of a system

Source: Semiconductor Insights

LINKS

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TechOnline University

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