Introduction To Embedded Systems

CMPN-445

Basem Ibraheem

Basem@eng.cu.edu.eg

Basemibraheem@gmail.com

Intended Learning Outcomes

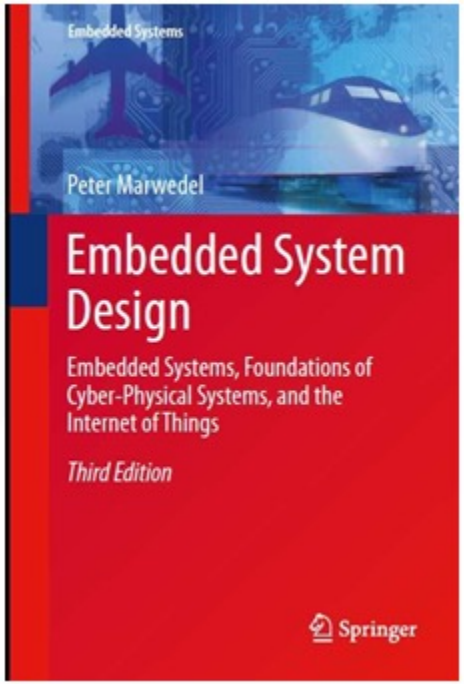
- Develop an understanding of Embedded Systems, theircharacteristics, applications and challenges
- Learn the different methodologies to model embeddedsystems.
- Understand the design metrics and the interplay amongdesign trade-offs, and technology issues.
- Differentiate between general operating systems and real timeones and understand the role of the latter in embedded systems.
- Acquire the design skills necessary for co-designing HW andSW.
- Acquire the understanding and design skills of major embedded system components including sensors, actuators,ADCs, DACs & control loops

Course Contents

- **Embedded Systems Overview**
- **Modeling Embedded Systems**
  - FSMs, Data Flow Diagrams, Petri Nets
- **Embedded Systems Inputs and Outputs**
  - ADCs, DACs, Sensor, Actuators, Storage
- **Processing Units: AVR, PIC, ARM, etc…**
- **Memory Hierarchy and Management**
- **Design Validation**
- **Hardware and Software Engineering**

Course References & Readings

- Embedded System Design
  - Embedded System Design: Embedded Systems, Foundations ofCyber-Physical Systems, and the Internet of Things
  - Peter Marwedel,
  - Springer, 3rd Edition, 2018



Course Grading

- **Tutorials & Assignments (15)**
- **Midterm (20)**
- **Final (40)**
- **Project (20)**
- **Research & Quizzes (5)**

Project Examples

- Face Recognition
- North Seeking Gyro
- Robotic Arm
- Car Parking System
- Logic Analyzer
- RFID Child Safety System
- Remote Home Security and Automation

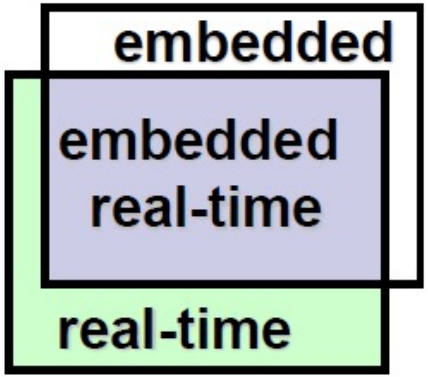
Definition

- **Embedded System is a computerized system that is built for the purpose of a specific application**

  - **“Dortmund“ Definition: [Peter Marwedel]**
  - **Embedded systems are information processing systems embeddedinto a larger product**
  - **Berkeley: [Edward A. Lee]*:***
  - **Embedded software is software integrated with physical processes.The technical problem is managing time and concurrency in computational systems.**
  - **Cyber-Physical (cy-phy) Systems (CPS) are integrations ofcomputation with physical processes [Edward Lee, 2006].**

Characteristics of Embedded Systems

- Application specific
- Efficient
  - energy, code size, run-time, weight, cost
- Dependable
  - Reliability, maintainability, availability, safety, security
- Real-time constraints
  - Soft vs. hard
- Reactive - connected to physical environment
  - sensors & actuators
- Hybrid
  - Analog and digital
- Distributed
  - Composability, scalability, dependability
- Dedicated user interfaces



- Dr.Amr Helmy Slides 2016

Inside the PC

- Custom processors
  - Graphics, sound
- 32-bit processors
  - IR, Bluetooth
  - Network, WLAN
  - Hard disk
  - RAID controllers
- 8-bit processors
  - USB
  - Keyboard, mouse

Embedded system metrics

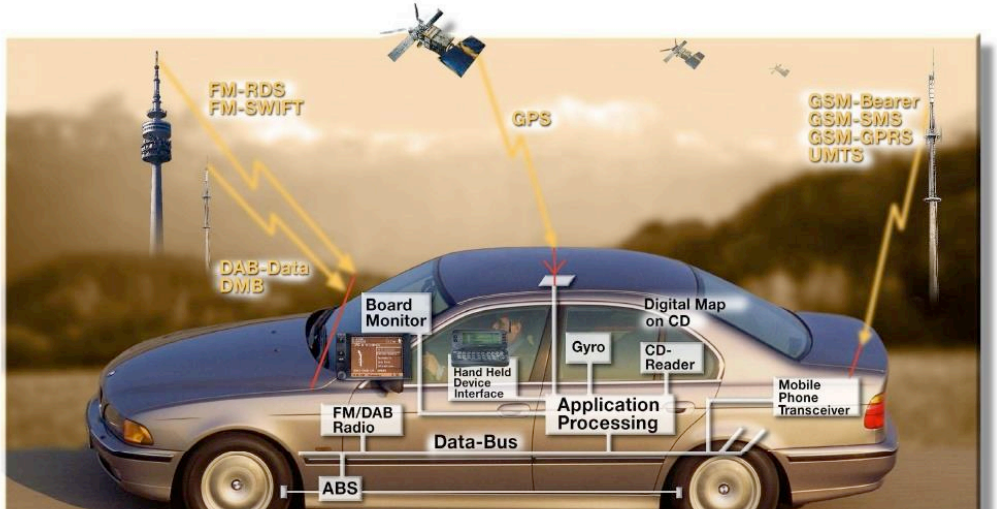
- Some metrics:
  - *performance*: MIPS, reads/sec etc.
  - *power*: Watts
  - *cost*: Dollars
    - Nonrecurring engineering cost, manufacturing cost
  - *size*: bytes, # components, physical space occupied
  - Flexibility, Time-to-prototype, time-to-market
  - Maintainability, correctness, safety
- MIPS, Watts and cost are related
  - technology driven
  - to get more MIPS for fewer Watts
    - look at the sources of power consumption
    - use power management and voltage scaling

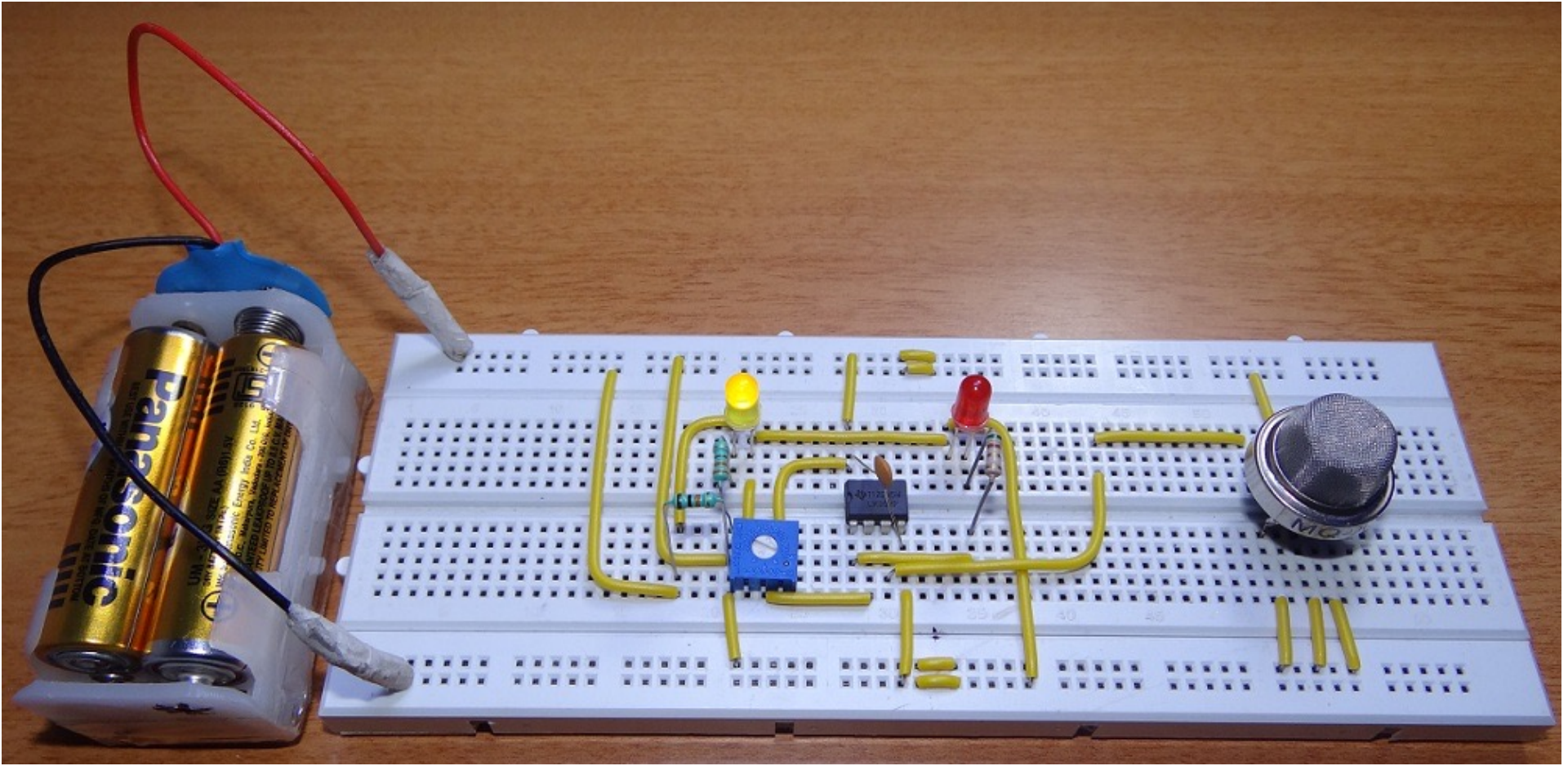
Dr.Amr Helmy Slides 2016

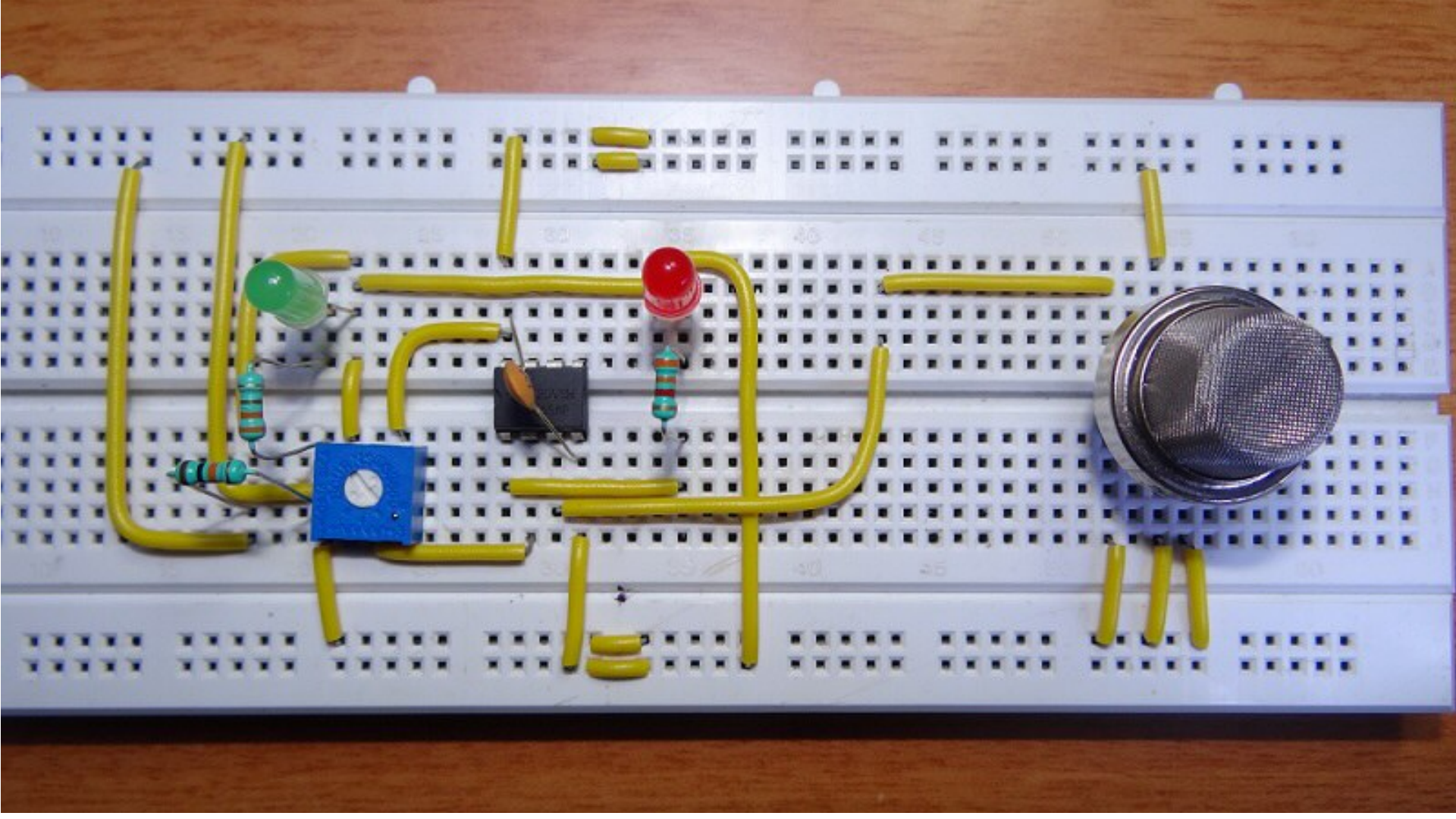
Source: MS HPL

Projects review

- **The Hatcher**
- **Cell Phone Towers**
- **Networks**




Panasonic



Microcontroller Refreshment

What is a microcontroller?

- A microcontroller is an integrated circuit that is programmed to do a specific task.

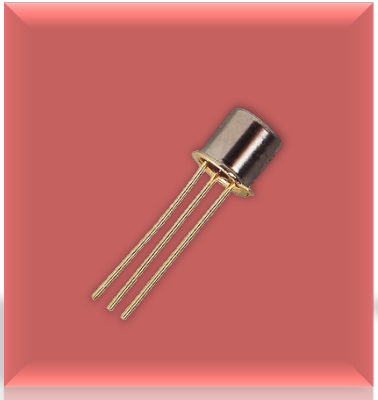
- Microcontrollers are really just "mini-computers".

Where do you find them?

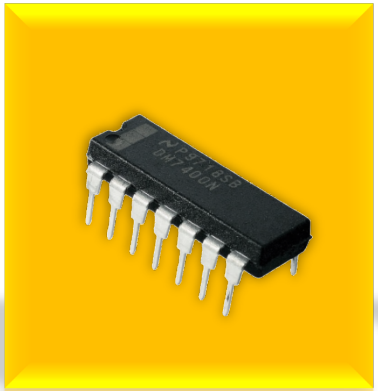
- Microcontrollers are hidden in tons of appliances,gadgets, and other electronics.
  - They're everywhere!

History of Microcontrollers

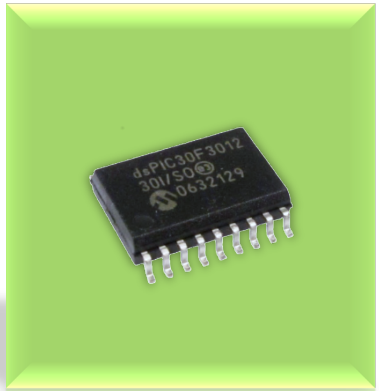
Vacuum Tube
1939



Transistor
1947



Logic Gate
1960



Microcontroller
1971

Microprocessor –vs- Microcontroller

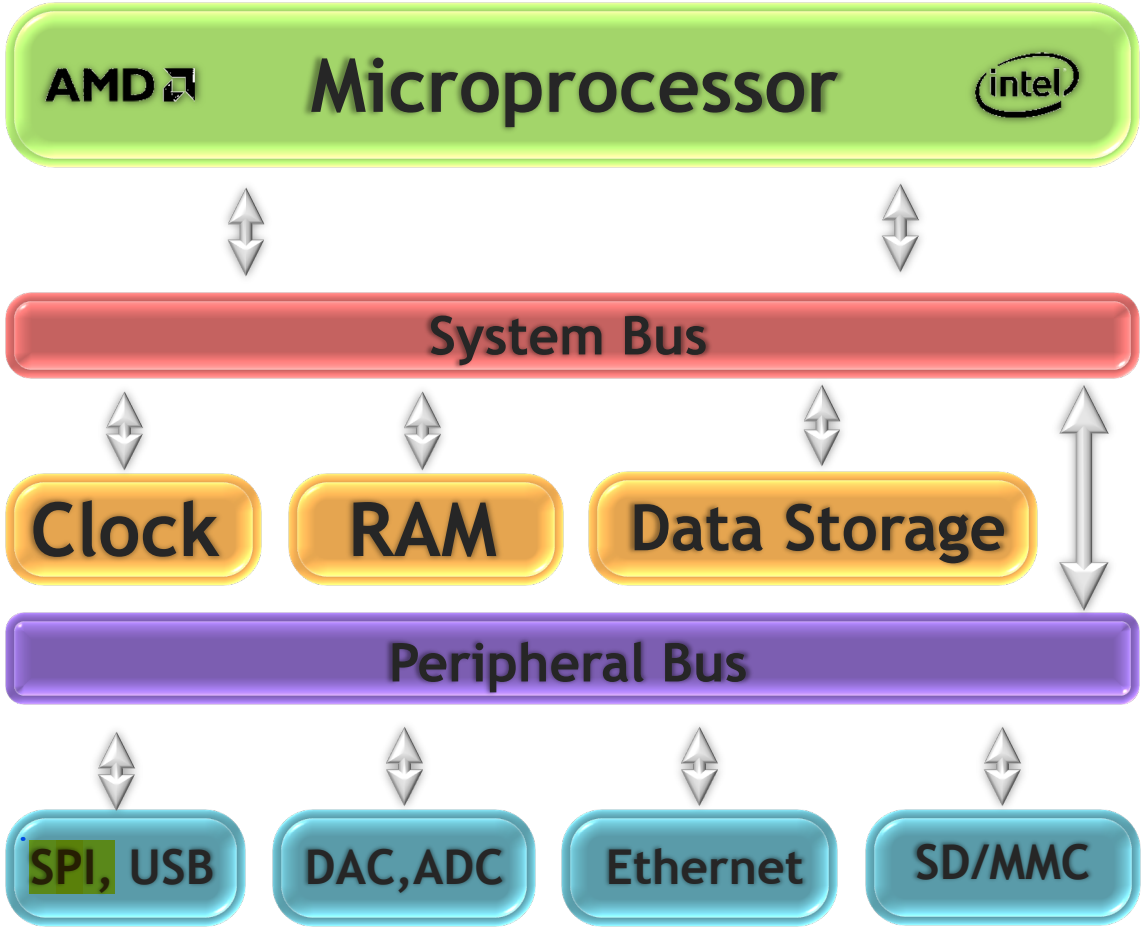
"Is there a difference between a microprocessor and microcontroller?"

CISC - vs - RISC

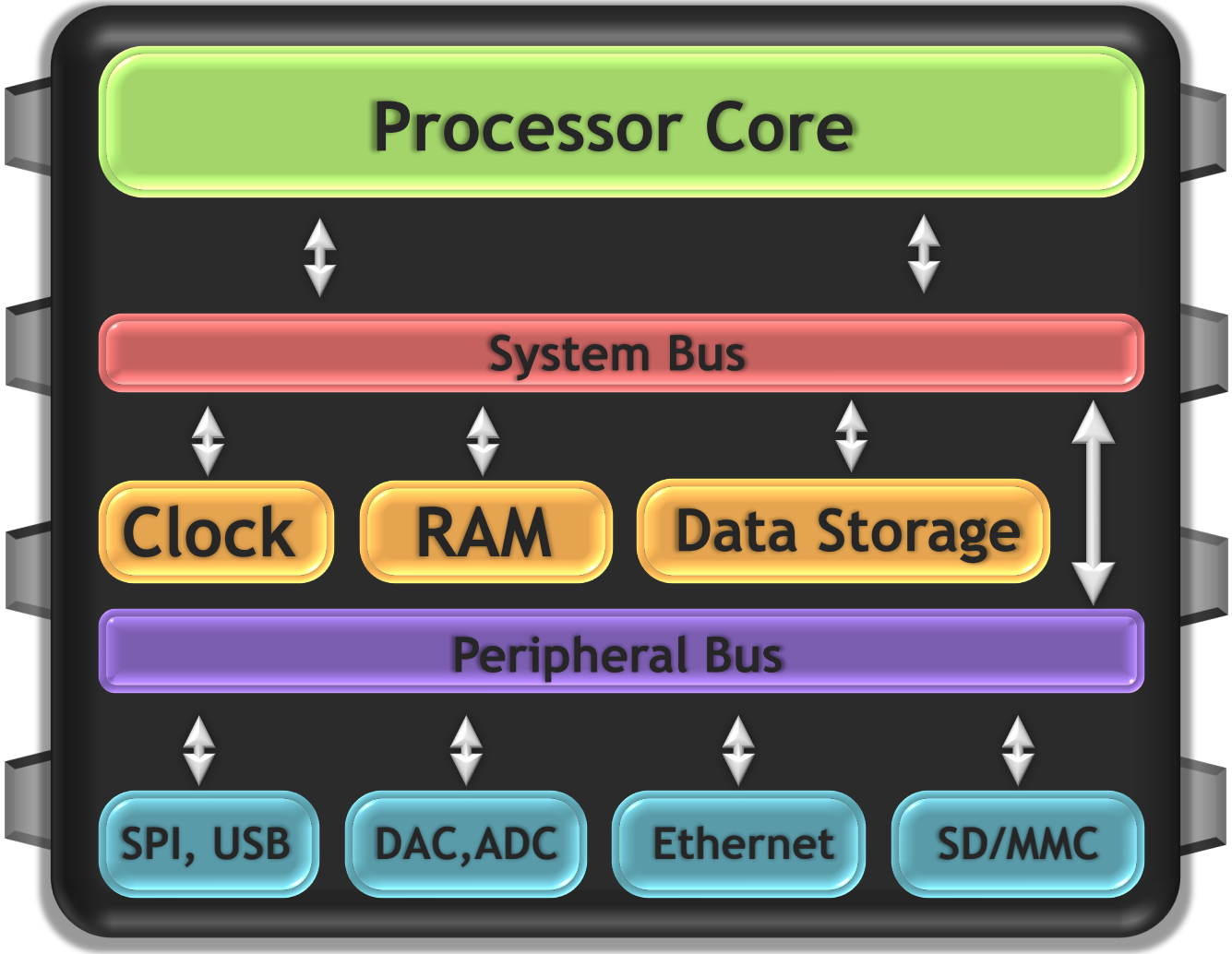
Microprocessor –vs- Microcontroller

CISC	RISC
Emphasis on hardware	Emphasis on software
Includes multi-clock	Single-clock
complex instructions	reduced instruction only
Memory-to-memory: “LOAD” and “STORE” incorporated in instructions	Register to register: “LOAD” and “STORE” are independent instructions
high cycles per second, Small code sizes	Low cycles per second, large code sizes

	Microprocessor	Microcontroller
Applications	General computing (i.e. Laptops, tablets)	Appliances, specialized devices
Speed	Very fast	Relatively slow
External Parts	Many	Few
Cost	High	Low
Energy Use	Medium to high	Very low to low
Vendors	  	   



Microprocessor



Microcontroller

Basic Principles of Operation

- Microcontrollers are used for specific applications.
- They do not need to be powerful because most applications only require a clock of a few MHz and small amount of storage.
- A microcontroller needs to be programmed to be useful.
- A microcontroller is only as useful as the code written for it. If you wanted to turn on a red light when a temperature reached a certain point, the programmer would have to explicitly specify how that will happen through his code.

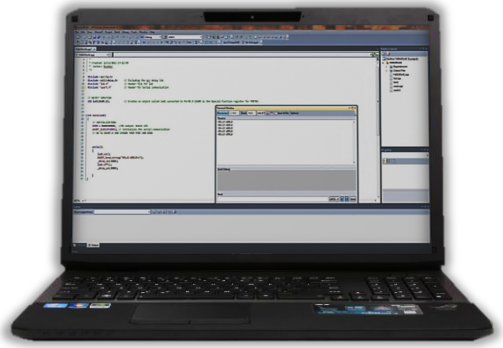
Microcontroller Programming

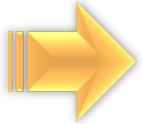
1.) Code is written for the microcontroller in an integrated development environment, a PC program. The code is written in a programming language. (e.g. C, BASIC or Assembly).

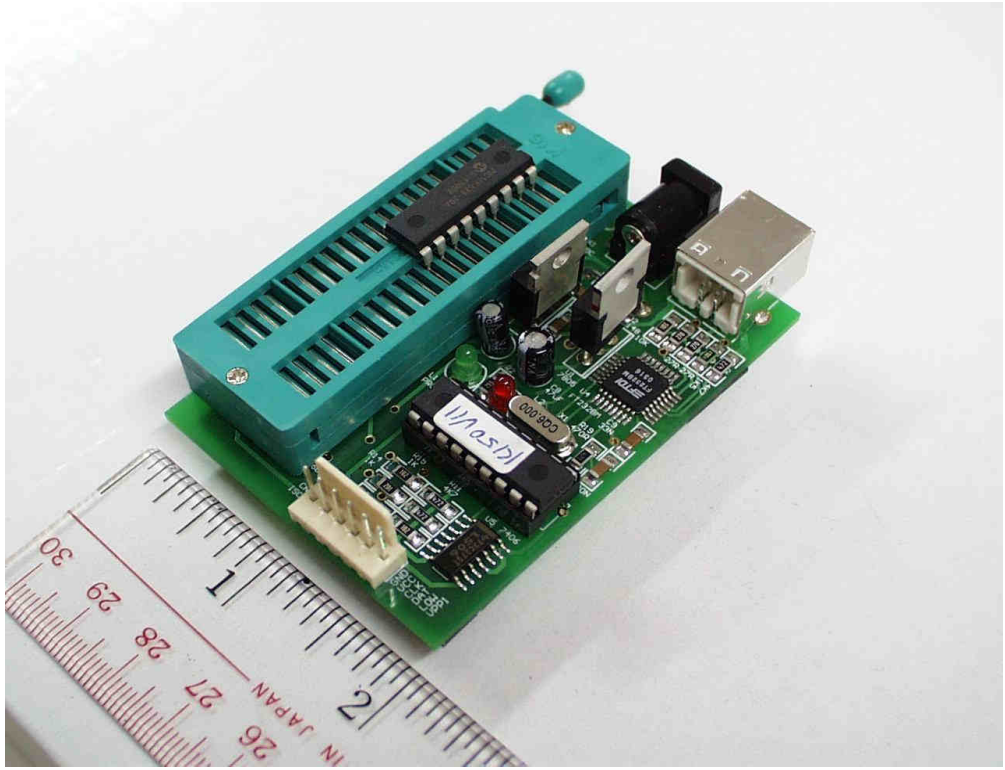
2.) The IDE debugs the code for errors, and then compiles it into binary code which the microcontroller can execute.

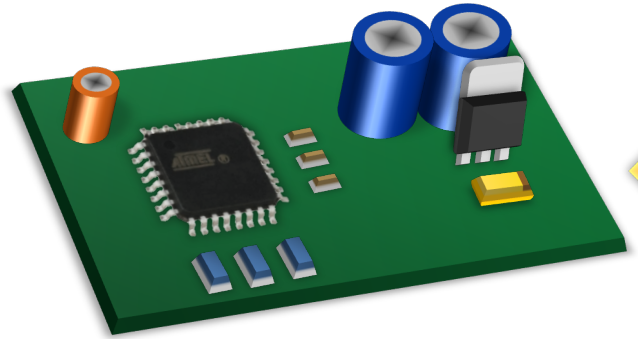
3.) A programmer (a piece of hardware, not a person) is used to transfer the code from the PC to the microcontroller. The most common type of programmer is an ICSP (In-circuit serial programmer).

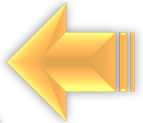
Microcontroller Programming











The Analog to Digital Converter (ADC)

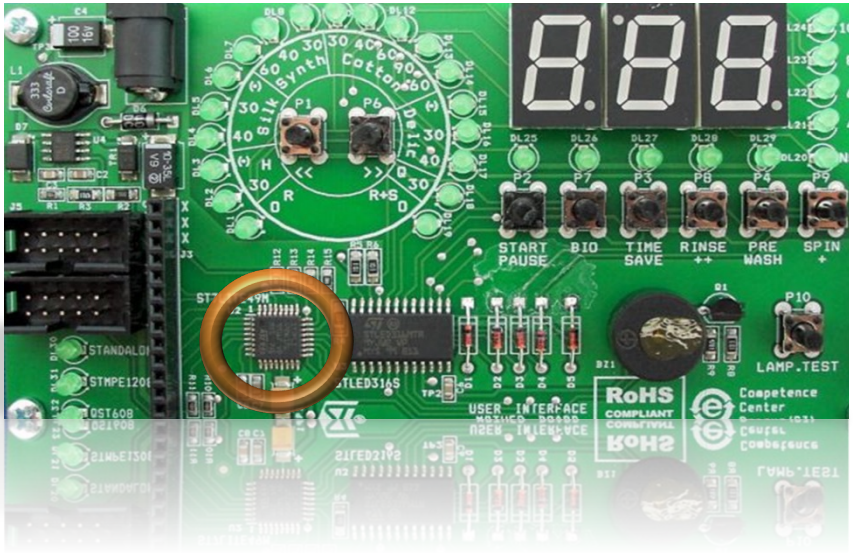
- Just about every modern microcontroller contains an ADC(s).

- It converts analog voltages into digital values.

- These digital representations of the signal at hand can be analyzed in code, logged in memory, or used in practically any other way possible.

Microcontroller Applications

- This is the controller board for a washing machine. If a button is pushed or if a knob is turned, the microcontroller knows how to react to the event.

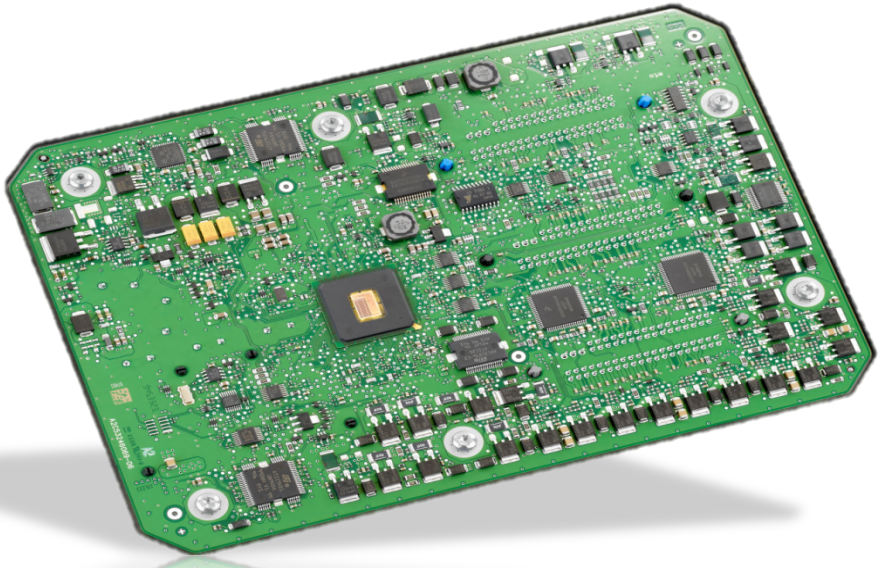


- Ex. If “start” is pushed, the microcontroller knows to switch a relay which starts the motor.

Microcontroller Applications

- This is the main controller from a Buick Regal. This board has several microcontrollers each for a specific task.

- Ex. A microcontroller may handle dashboard controls or it may even control something more complex like the ignition system.



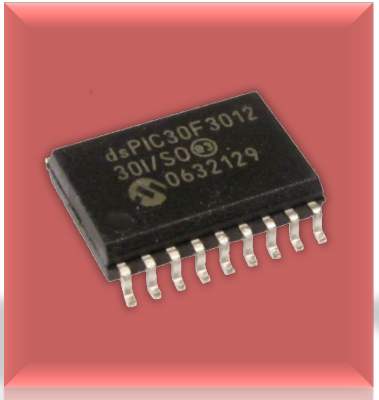
Microcontroller Applications

- Many robots use microcontrollers to allow robots to interact with the real world.

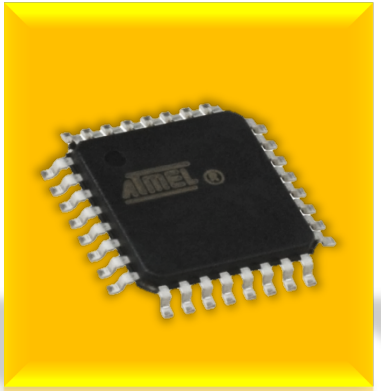
- Ex. If a proximity sensor senses an object near by, the microcontroller will know to stop its motors and then find an unobstructed path.

Microcontroller Packaging

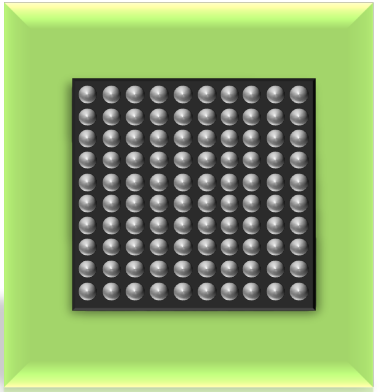
DIP
(Dual Inline Package)
Through hole
8 pins
9mm x 6mm
0.15pins/mm^2



SOIC
(Small Outline IC)
Surface Mount
18 pins
11mm x 7mm
0.23pins/mm^2



QFP
(Quad Flat Package)
Surface Mount
32 pins
7mm x 7mm
0.65pins/mm^2



BGA
(Ball Grid Array)
Surface Mount
100 pins
6mm x 6mm
2.78pins/mm^2

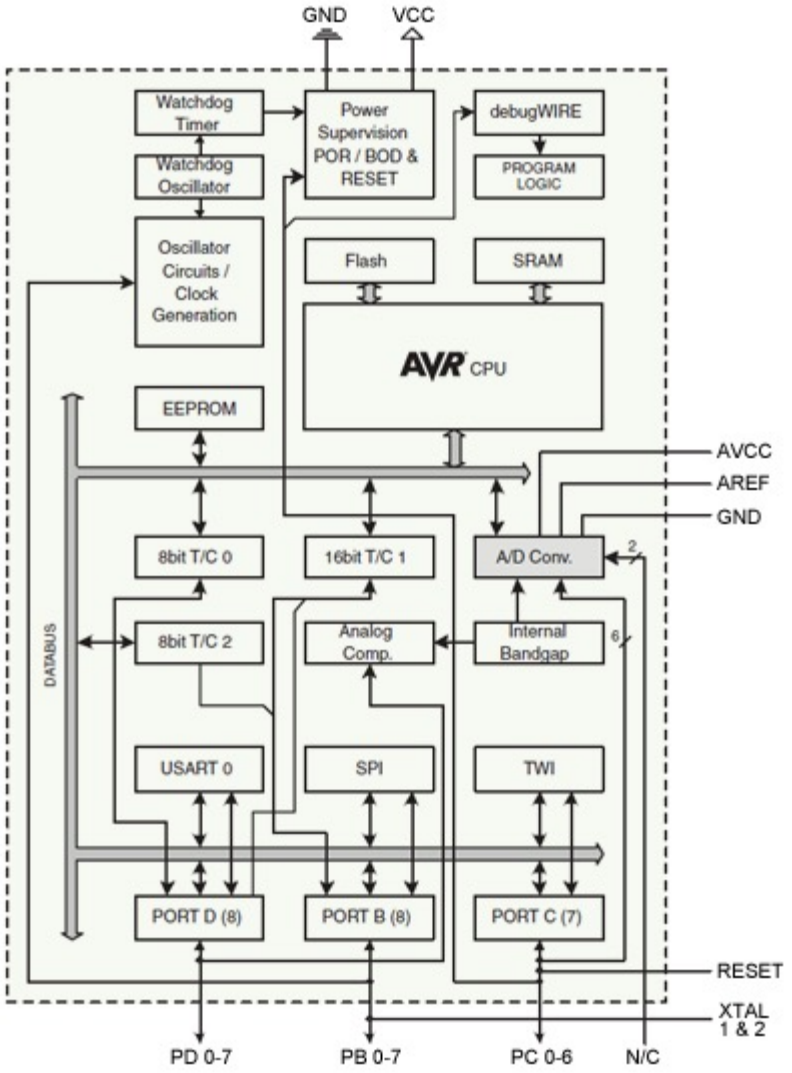
Lab Kits

Arduino Uno
Microcontroller Chip
Atmega 328p

Atmega 328p

The Insides

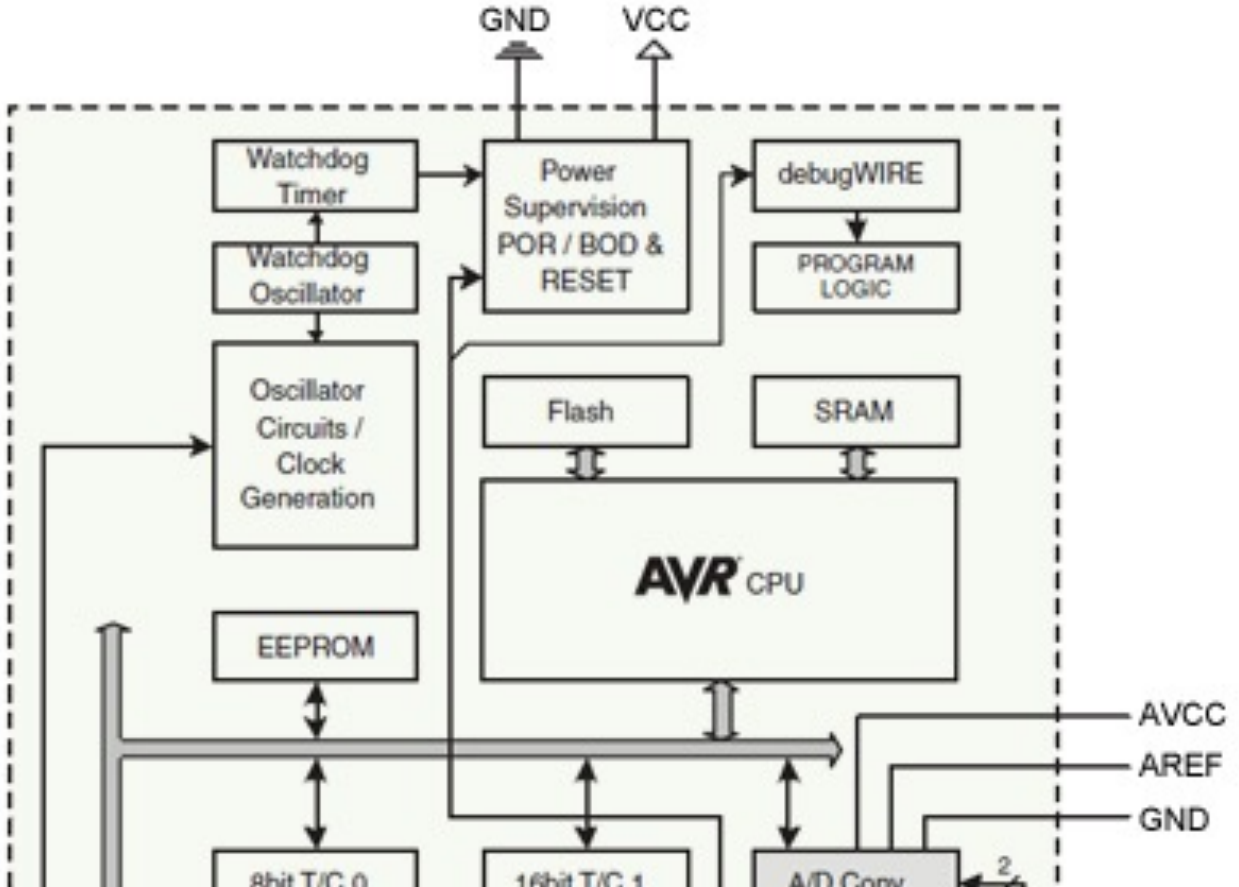
The Data Sheet



Atmega 328p

The Insides

The Data Sheet



Atmega 3

The Insides

The Data Sheet