COMPUTER ORGANIZATION AND ARCHITECTURE (COA)

EET 2211

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4TH SEMESTER – CSE & CSIT

CHAPTER 1, LECTURE 3

CHAPTER 1 – BASIC CONCEPTS AND COMPUTER EVOLUTION

TOPICS TO BE COVERED

- The Evolution of the Intel x86 Architecture
- Embedded Systems

LEARNING OBJECTIVES

- Present an overview of the evolution of the x86 architecture.
- Define embedded systems.
- List some of the requirements and constraints that various embedded systems meet.

ALREADY COVERED

- Organization and architecture
- Structure and Function
- A Brief History of Computers.

THE EVOLUTION OF THE INTEL x86 ARCHITECTURE

- ✓Microprocessors have grown faster and more complex.
- ✓Intel used to develop microprocessors every 4 years.

GENERATION	APPROXIMATE DATES	TECHNOLOGY	TYPICALSPEED (operations per second)
1	1946-1957	Vacuum tubes	40,000
2	1957-1964	Transistors	2,00,000
3	1965-1971	Small and medium scale integration	10,00,000
4	1972-1977	Large scale integration	1,00,00,000
5	1978-1991	Very large scale integration	10,00,00,000
6	1991-	Ultra large scale integration	>10,00,00,000

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(a) 1970s Processors

	4004	8008	8080	8086	8088
Introduced	1971	1972	1974	1978	1979
Clock speeds	108 kHz	108 kHz	2 MHz	5 MHz, 8 MHz, 10 MHz	5 MHz, 8 MHz
Bus width	4 bits	8 bits	8 bits	16 bits	8 bits
Number of transistors	2,300	3,500	6,000	29,000	29,000
Feature size (μm)	10	8	6	3	6
Addressable memory	640 bytes	16 KB	64 KB	1 MB	1 MB

(b) 1980s Processors

	80286	386TM DX	386TM SX	486TM DX CPU
Introduced	1982	1985	1988	1989
Clock speeds	6–12.5 MHz	16–33 MHz	16–33 MHz	25–50 MHz
Bus width	16 bits	32 bits	16 bits	32 bits
Number of transistors	134,000	275,000	275,000	1.2 million
Feature size (μm)	1.5	1	1	0.8–1
Addressable memory	16 MB	4 GB	16 MB	4 GB
Virtual memory	1 GB	64 TB	64 TB	64 TB
Cache	—	—	—	8 kB

Table: Evolution of Intel Microprocessors [Source: Computer Organization and Architecture by William Stallings]

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(c) 1990s Processors

	486TM SX	Pentium	Pentium Pro	Pentium II
Introduced	1991	1993	1995	1997
Clock speeds	16–33 MHz	60–166 MHz,	150–200 MHz	200–300 MHz
Bus width	32 bits	32 bits	64 bits	64 bits
Number of transistors	1.185 million	3.1 million	5.5 million	7.5 million
Feature size (μm)	1	0.8	0.6	0.35
Addressable memory	4 GB	4 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	8 kB	8 kB	512 kB L1 and 1 MB L2	512 kB L2

(d) Recent Processors

	Pentium III	Pentium 4	Core 2 Duo	Core i7 EE 4960X
Introduced	1999	2000	2006	2013
Clock speeds	450–660 MHz	1.3–1.8 GHz	1.06–1.2 GHz	4 GHz
Bus width	64 bits	64 bits	64 bits	64 bits
Number of transistors	9.5 million	42 million	167 million	1.86 billion
Feature size (nm)	250	180	65	22
Addressable memory	64 GB	64 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	512 kB L2	256 kB L2	2 MB L2	1.5 MB L2/15 MB L3
Number of cores	1	1	2	6

Table: Evolution of Intel Microprocessors [Source: Computer Organization and Architecture by William Stallings]

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MICROPROCESSOR	DESCRIPTION
8080	➢The world's first general purpose microprocessor. ➢This was an 8-bit machine, with an 8-bit data path to memory. ➢It was used in the first personal computer, ALTAIR.
8086	➢A more powerful 16-bit machine. ➢It has wider data path, larger registers and an instruction cache/queue, that prefetches a few instructions before they are executed. ➢A variant of this processor, the 8088, was used in IBM's first personal computer. ➢It is the first use of x86 architecture.
80286	➢It is an extension of 8086. ➢It enabled addressing a 16-MB memory instead of just 1MB.
80386	➢Intel's first 32-bit machine. ➢The complexity and power of minicomputers and mainframes was introduced. ➢It was the first Intel processor to support multitasking.

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MICROPROCESSOR	DESCRIPTION
80486	➢It introduced the use of sophisticated and powerful cache technology and instruction pipelining. ➢It also used a built-in math co-processor helpful in offloading complex maths operations from the main CPU.
Pentium	➢Intel introduced the use of superscalar techniques. ➢It allows multiple instructions to execute in parallel.
Pentium Pro	➢It followed the superscalar architecture with use of register renaming, branch prediction, data flow analysis and speculative execution.
Pentium II	➢It incorporated Intel MMX technology which is designed specifically to process video, audio and graphics data efficiently.

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MICROPROCESSOR	DESCRIPTION
Pentium III	➢It incorporates additional floating-point instructions. ➢The Streaming SIMD Extensions (SSE) instruction set extension added 70 new instructions designed to increase performance. ➢E.g. DSP and GP.
Pentium 4	➢It includes additional floating-point and other enhancements for multimedia.
Core	➢It is the first Intel x86 microprocessor with dual core, referring to the implementation of two cores on a single chip.
Core 2	➢It extends the Core architecture to 64-bits. ➢The Core 2 Quad provides four cores on a single chip. ➢An important addition to the architecture was the Advanced Vector Extensions instruction set that provided a set of 256-bit and then 512-bit instructions for efficient processing of vector data.

EMBEDDED SYSTEMS

- It refers to the use of electronics and software within a product.
- E.g. cell phones, digital computers, video cameras, calculators, microwave ovens, home security systems, washing machines, lighting systems, thermostats, printers, various automotive systems, toothbrushes and numerous types of sensors and actuators in automated systems.
- Generally embedded systems are tightly coupled to their environments.

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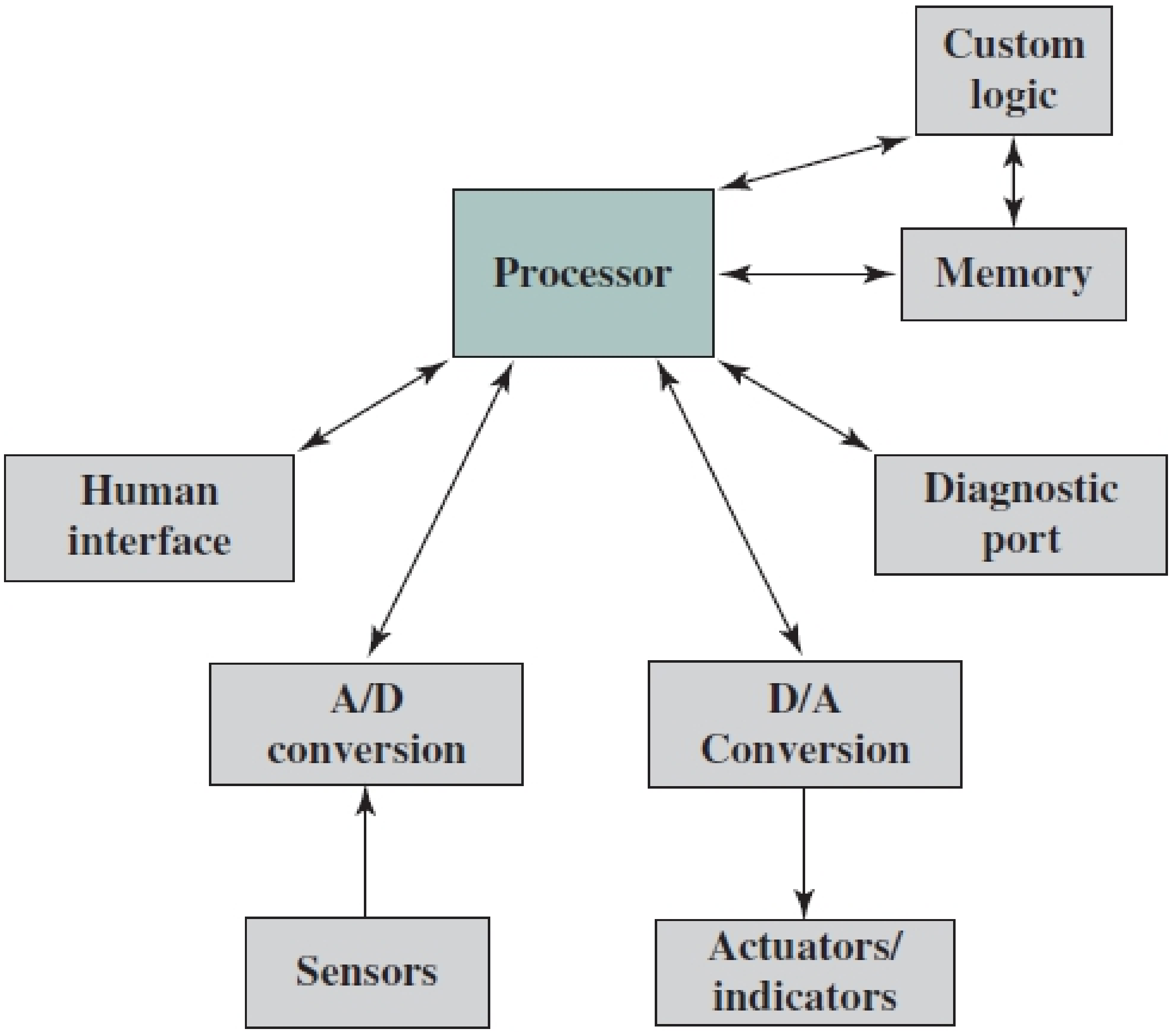

Fig.1: Organization of an Embedded System [Source: Computer Organization and Architecture by William Stallings]

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ELEMENTS THAT ARE DIFFERENT IN AN EMBEDDED SYSTEM FROM TYPICAL DESKTOP/ LAPTOP

1. There may be a variety of interfaces that enable the system to measure, manipulate and interact with the external environment.
2. The human interface can be either very simple or complicated.
3. The diagnostic port may be used for diagnosing the system.
4. Special purpose FPGA and ASIC or non-digital hardware can be used to increase performance.
5. Software often has a fixed function and specific to the application.
6. They are optimized for energy, code size, execution time, weight, dimensions and cost in-order to increase the efficiency.

SIMILARITY BETWEEN EMBEDDED SYSTEMS AND GENERAL PURPOSE COMPUTER

1. Even with nominally fixed function software, the ability to upgrade to fix bugs, to improve security and to add functionality is very important for both.
2. Both support wide variety of apps.

INTERNET OF THINGS

- IoT is a system of interrelated computing devices, mechanical and digital machines provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
- Dominant theme is embedding short range mobile trans-receivers into a wide array of gadgets and everyday items, enabling a form of communication between people and things.
- E.g. embedded systems, wireless sensor networks, control systems, automation (home and building), smart home (lighting fixtures, thermostats, home security systems, appliances).
- It refers to expanding interconnection of smart devices (ranging form appliances to tiny sensors).

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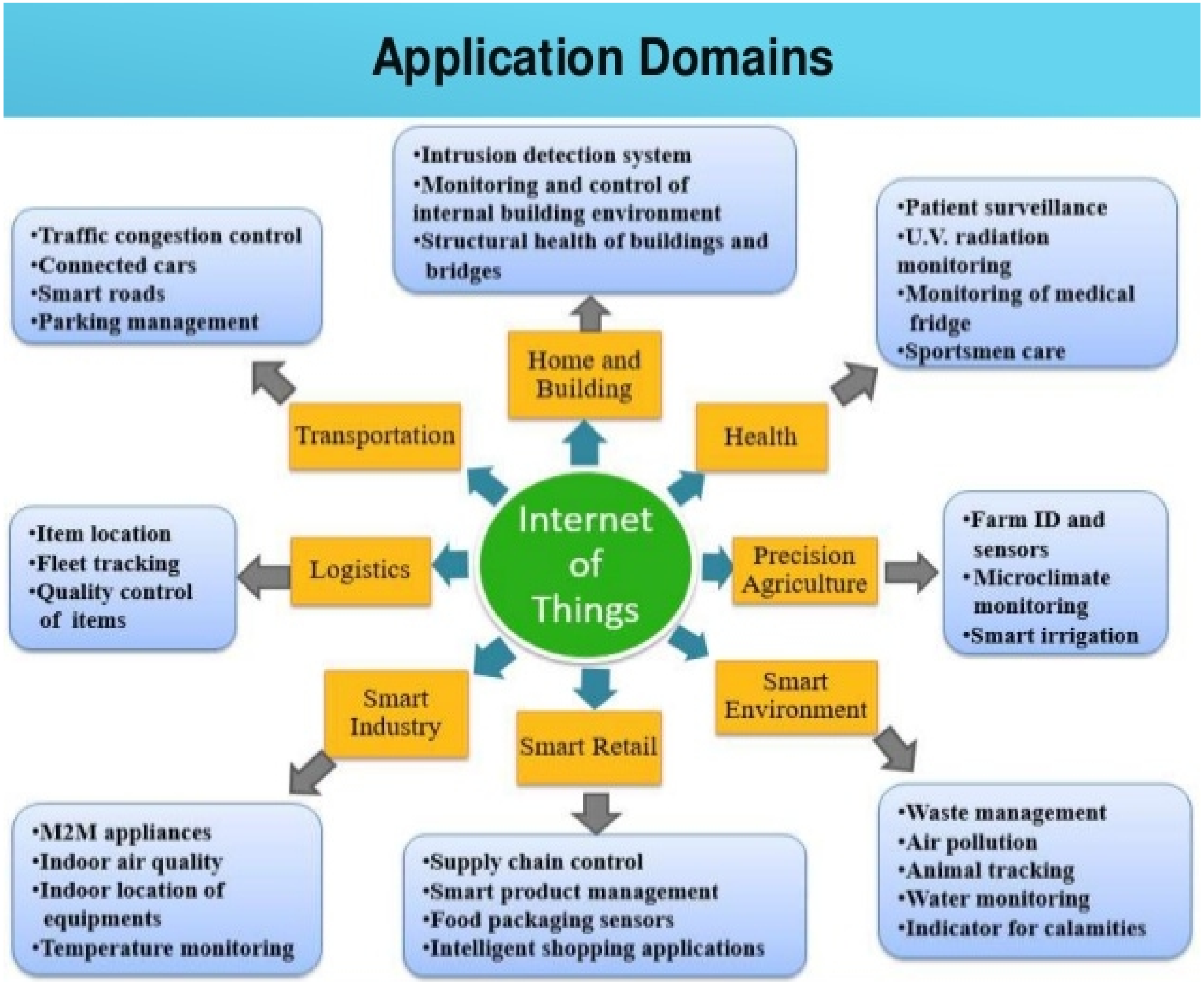
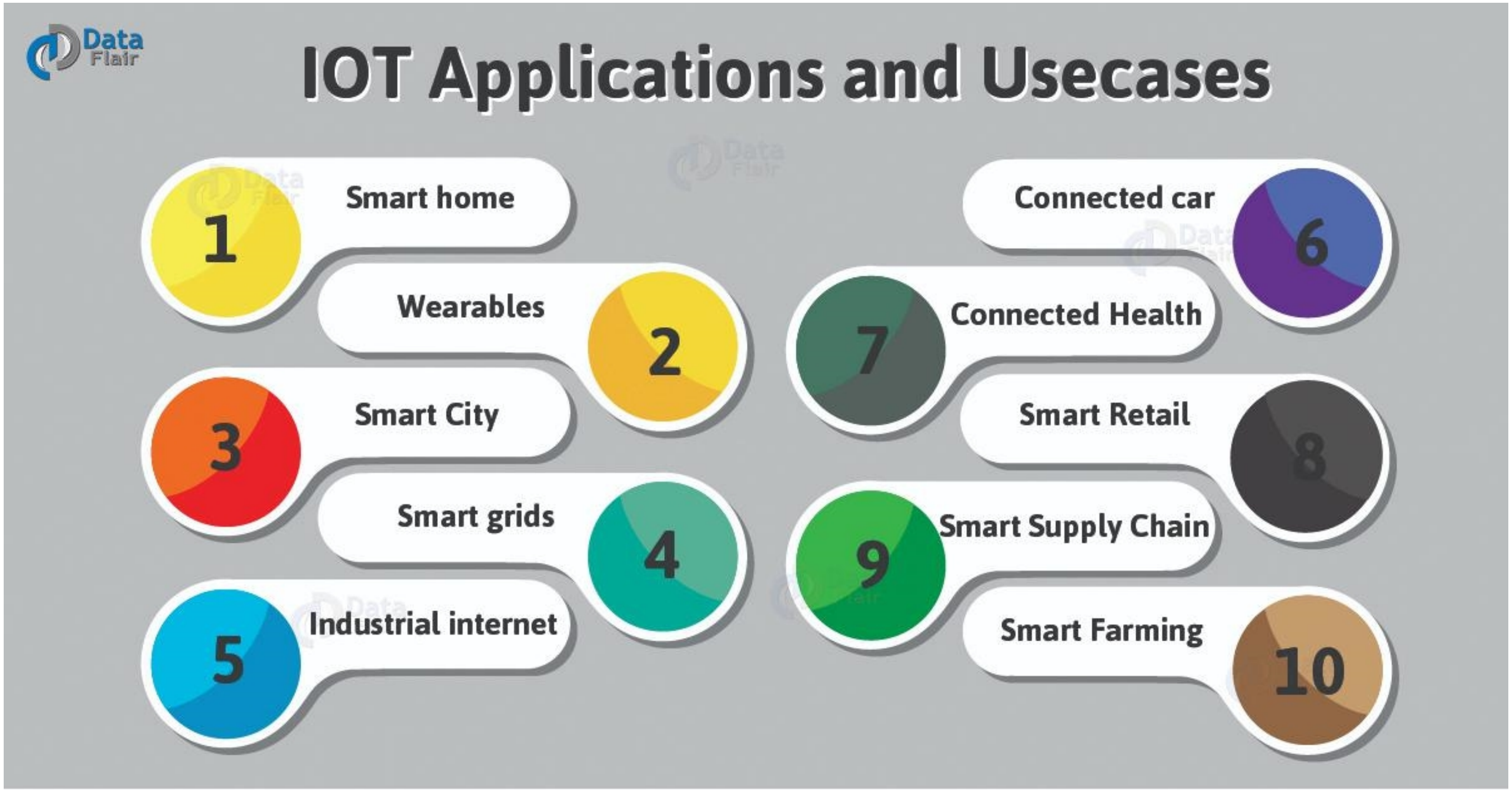


Fig.2: IoT applications



Data Flair
IOT Applications and Usecases
1
Smart home
2
Wearables
3
Smart City
4
Smart grids
5
Industrial internet
6
Connected car
7
Connected Health
8
Smart Retail
9
Smart Supply Chain
10
Smart Farming

Contd.

- The objects deliver sensor information, act on the environment, and modify themselves to create overall management of a larger system.
- These devices are low-bandwidth, low-repetition data-capture and low-bandwidth data-usage appliances that communicate with each other and provide data through user interface.
- With reference to end systems supported, the internet has gone through roughly four generations of deployment culminating in the IoT:

  1. Information technology (IT) : PCs, servers, routers, firewalls, IT devices bought by enterprise IT people and primarily using wired connectivity.

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2. Operational technology (OT): machines/appliances with embedded IT built by non-IT companies, such as medical machinery, SCADA(Supervisory Control & Data Acquisition System), process control and Kiosks, bought as appliances by enterprise OT people and primarily using wired connectivity.
3. Personal technology : Smartphones, tablets and eBook readers bought as IT devices by consumers exclusively using wireless connectivity.
4. Sensor/Actuator technology : Single-purpose devices bought by consumers, IT and OT people exclusively using wireless connectivity generally of a single form.

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EMBEDDED OPERATING SYSTEMS

1. First approach is to take an existing OS and adapt it for the embedded application. E.g. there are embedded versions of LINUX, Windows, MAC and other commercial operating systems specialized for embedded systems.
2. Second approach is to design and implement an OS intended solely for embedded use. E.g. TinyOS (widely used in wireless sensor networks)

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APPLICATION PROCESSORS VERSUS DEDICATED PROCESSORS

- Application processors are defined by the processors ability to execute complex operating systems such as LINUX, Android and Chrome.
- They are general-purpose in nature.
- E.g. use of embedded application processor is the Smartphone.
- Dedicated processors are dedicated to one or a small number of specific tasks required by the host device.
- The associated components as are dedicated to a specific task can be engineered to reduce size and cost.

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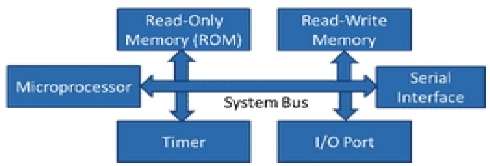
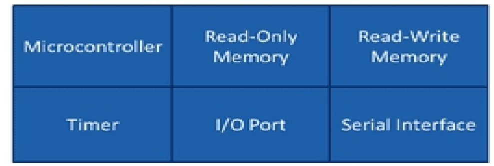
MICROPROCESSORS vs MICROCONTROLLERS





Microprocessor	Micro Controller
Microprocessor is heart of Computer system.	Micro Controller is a heart of embedded system.
It is just a processor. Memory and I/O components have to be connected externally	Micro controller has external processor along with internal memory and i/O components
Since memory and I/O has to be connected externally, the circuit becomes large.	Since memory and I/O are present internally, the circuit is small.
Cannot be used in compact systems and hence inefficient	Can be used in compact systems and hence it is an efficient technique
Cost of the entire system increases	Cost of the entire system is low
Due to external components, the entire power consumption is high. Hence it is not suitable to used with devices running on stored power like batteries.	Since external components are low, total power consumption is less and can be used with devices running on stored power like batteries.
Most of the microprocessors do not have power saving features.	Most of the micro controllers have power saving modes like idle mode and power saving mode. This helps to reduce power consumption even further.
Since memory and I/O components are all external, each instruction will need external operation, hence it is relatively slower.	Since components are internal, most of the operations are internal instruction, hence speed is fast.
Microprocessor have less number of registers, hence more operations are memory based.	Micro controller have more number of registers, hence the programs are easier to write.
Microprocessors are based on von Neumann model/architecture where program and data are stored in same memory module	Micro controllers are based on Harvard architecture where program memory and Data memory are separate
Mainly used in personal computers	Used mainly in washing machine, MP3 players

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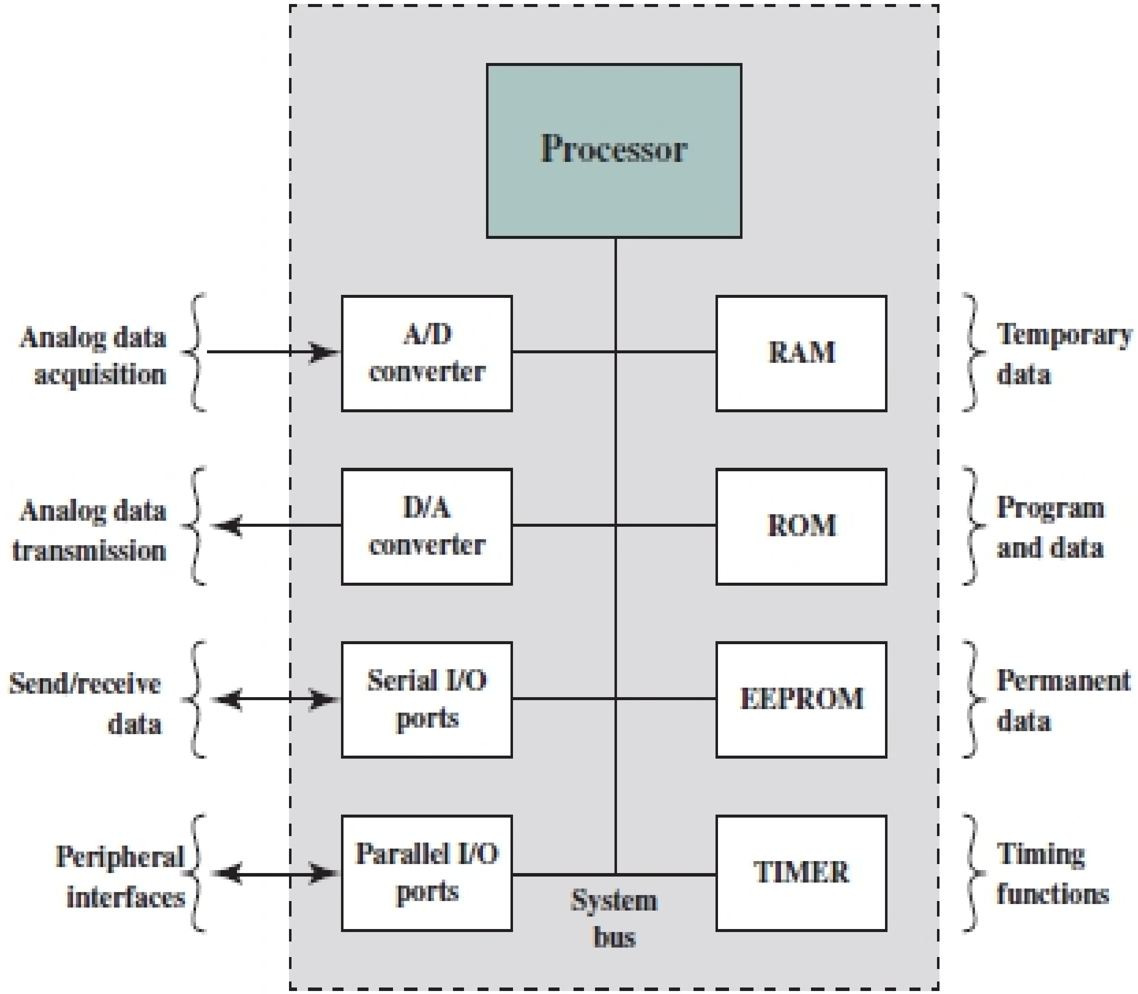

Fig.3: Typical Microcontroller chip Elements [Source: Computer Organization and Architecture by William Stallings]

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EMBEDDED vs. DEEPLY EMBEDDED SYSTEMS

- ✓ Deeply embedded systems are dedicated, single purpose devices.
- ✓ They have wireless capability and appear in networked configurations (network of sensors over a large area like factory or agricultural field).
- ✓ They have extreme resource constraints in terms of memory, processor size, time and power consumption.

QUESTIONS

For each of the following examples determine whether this is an embedded system, explaining why or why not?

a) Are programs that understand physics and /or hardware embedded? For example, one that uses finite-element methods to predict fluid flow over airplane wings?
b) Is the internal microprocessor controlling a disk drive an example of an embedded system?
c) I/O drivers control hardware, so does the presence of an I/O driver imply that the computer executing the driver is embedded?
d) Is a PDA (Personal Display Assistant) an embedded system?
e) Is the microprocessor controlling a cell phone an embedded system?
f) Are the computers in a big phased-array radar considered embedded? These radars are 10-storey buildings with one to three 100-foot diameter radiating patches on sloped sides of the building.
g) Is a traditional flight management system (FMS) built into an airplane cockpit considered embedded?
h) Are the computers in a hardware-in-the-loop (HIL) simulator embedded?
i) Is the computer controlling a pacemaker in a person's chest an embedded computer?
j) Is the computer controlling fuel injection in an automobile engine embedded?

THANK YOU