BİL 218-BİLGİSAYAR ORGANİZASYONU

Dr. Öğr. Üyesi İclal Çetin Taş

Syllabus and Performans Evaluation

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1	Organizasyon ve mimari tanımlamaları	
2	Bilgisayarların tarihsel gelişimi	
3	Bilgisayarların genel yapısı ve işleyişi	
4	Aritmetik işlem çeşitleri ve sayı gösterimleri	
5	İşlemci, veriyolu ve kontrol	
6	Önbellek	
7	Makine komutları	
8	Ara-sınav	
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10	CISC mimarisi ve pipeline	
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14	Assembly dili.	
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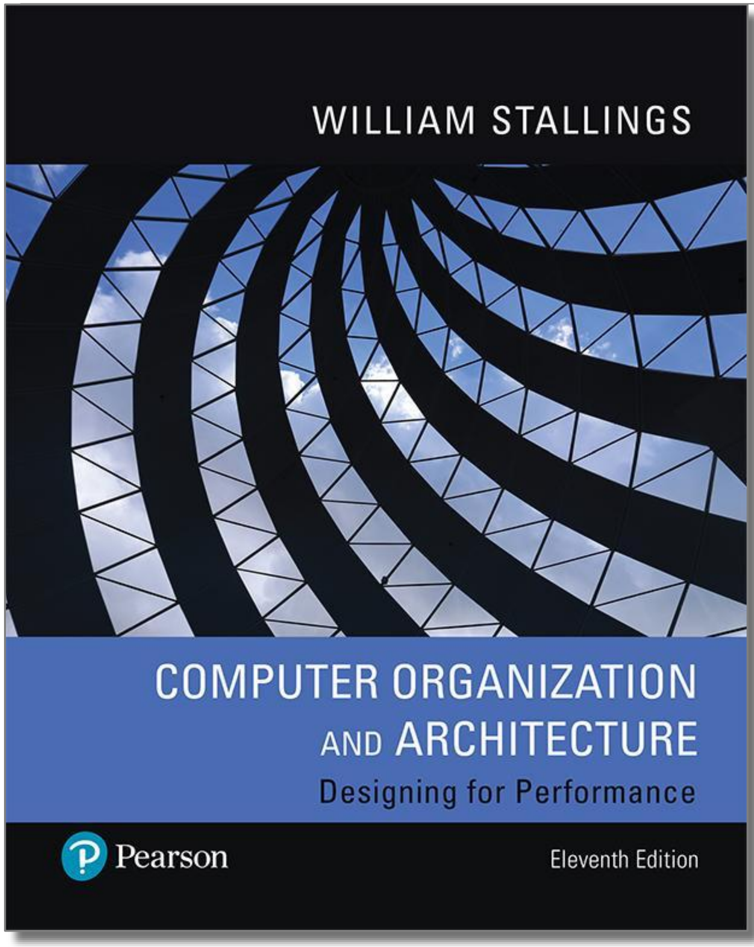
Kriter	Ağırlık
Vize	%30
Ödev	%10
Kısa Sınav	%20
Final	%40

Source

Computer Organization and Architecture
Designing for Performance

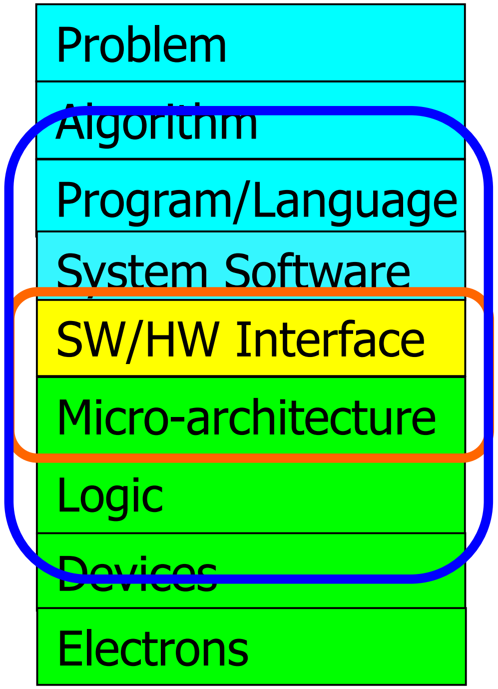
11th Edition



Chapter 1

Basic Concepts and Computer Evolution

The Transformation Hierarchy

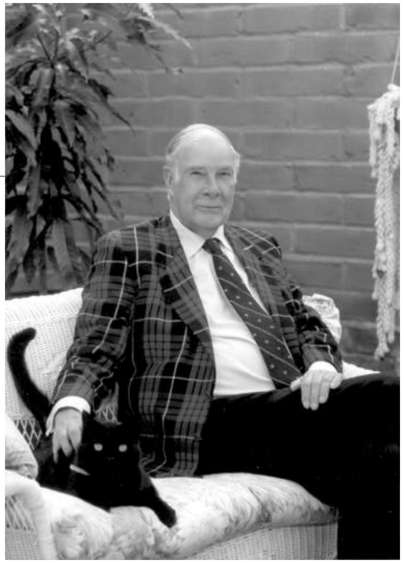


Computer Architecture (expanded view)

Computer Architecture (narrow view)

"The purpose of computing is [to gain] insight" (*Richard Hamming*)
We gain and generate insight by solving problems
How do we ensure problems are solved by electrons?

Levels of Transformation



Algorithm

Step-by-step procedure that is **guaranteed to terminate** where **each step is precisely stated** and **can be carried out by a computer**

- **Finiteness**
- **Definiteness**
- **Effective computability**

Many algorithms for the same problem

Problem
Algorithm
Program/Language
Runtime System (VM, OS, MM)
ISA (Architecture)
Microarchitecture
Logic
Devices
Electrons

ISA
(Instruction Set Architecture)

Interface/contract between SW and HW.

What the programmer assumes hardware will satisfy.

Microarchitecture
An implementation of the ISA

Digital logic circuits
Building blocks of micro-arch (e.g., gates)

Computer Architecture

is the science and art of designing computing platforms (hardware, interface, system SW, and programming model)

to achieve a set of design goals

- E.g., highest performance on earth on workloads X, Y, Z
- E.g., longest battery life at a form factor that fits in your pocket with cost < $$$ CHF
- E.g., best average performance across all known workloads at the best performance/cost ratio
- …

- Designing a supercomputer is different from designing a smartphone → But, many fundamental principles are similar

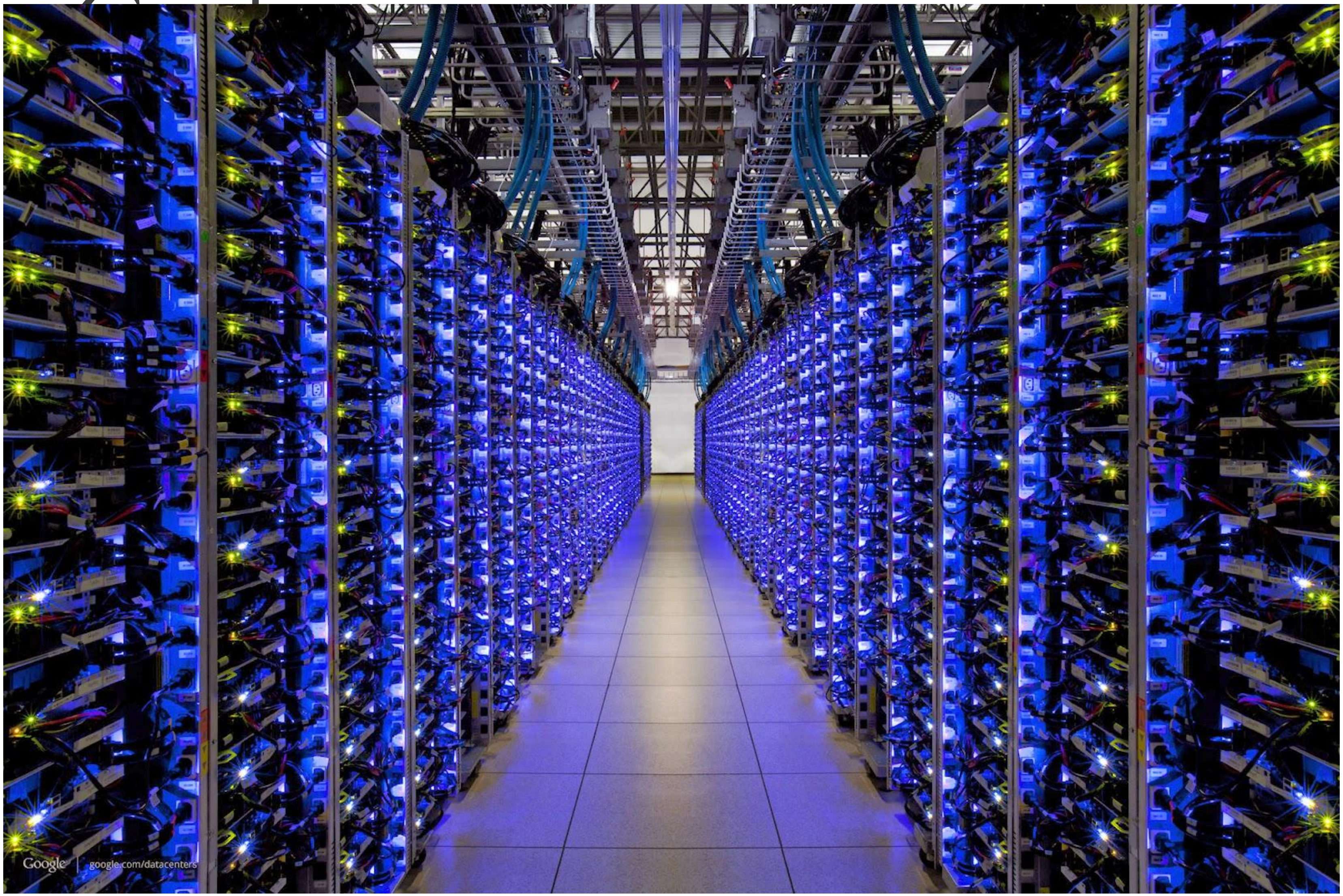
Different Platforms, Different Goals

Source: http://www.sia-online.org (semiconductor industry association)

Different Platforms, Different

Different Platforms, Different Goals

Different Platforms, Different

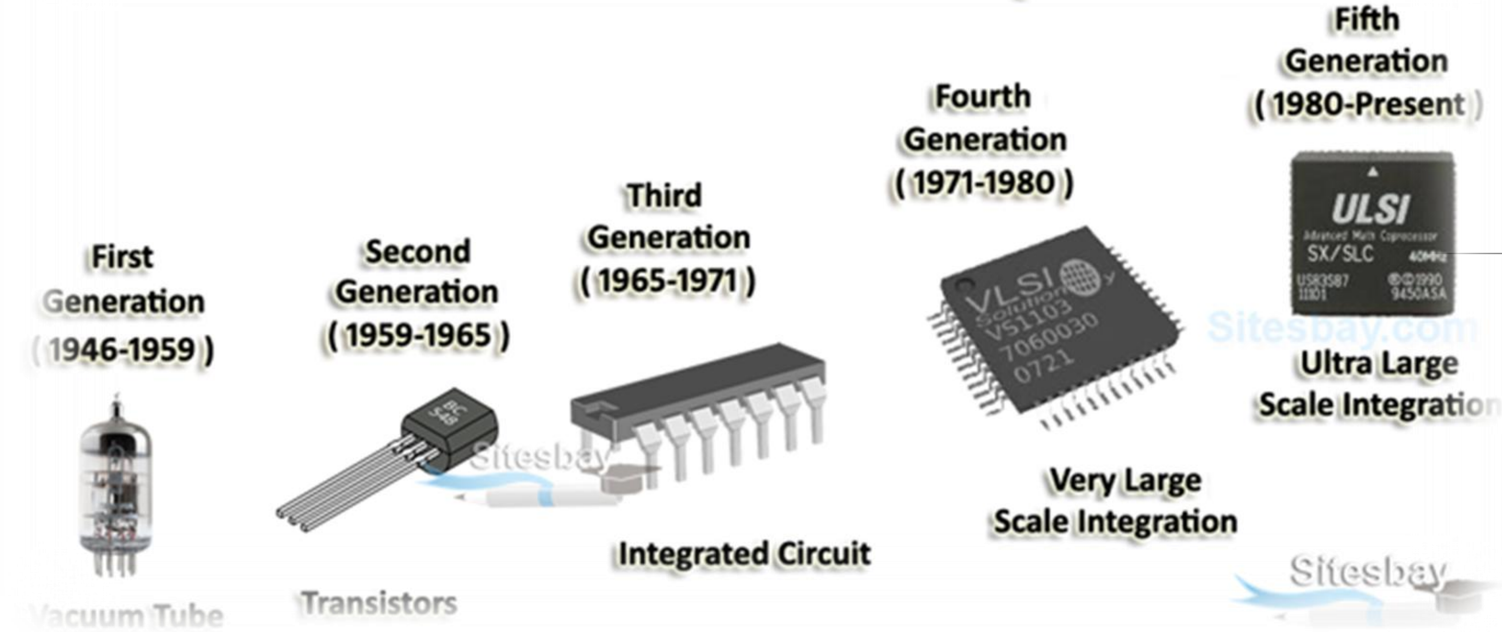


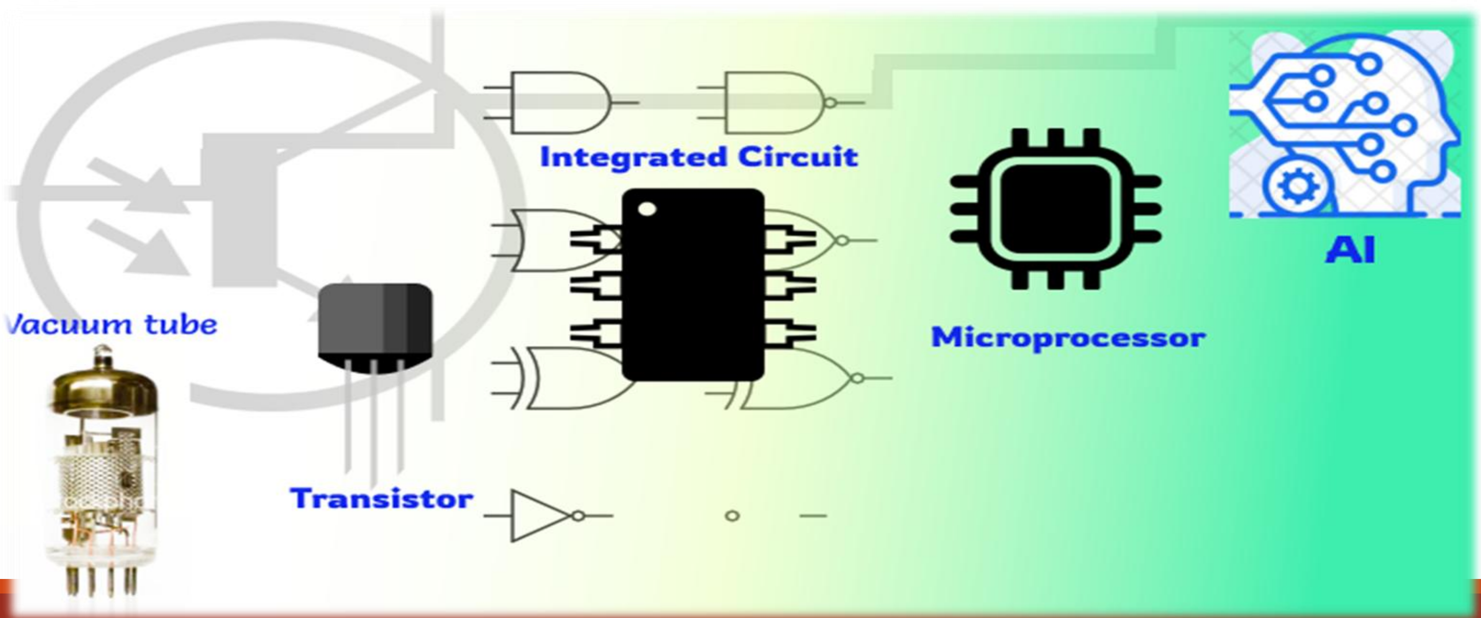
Source: http://datacentervoice.com/wp-content/uploads/2015/10/data-center.jpg

Different Platforms, Different

Source: https://fossbytes.com/wp-content/uploads/2015/06/Supercomputer-TIANHE2-china.jpg

Generation of Computer





https://www.sitesbay.com/computer/cf-generation-of-computer

COMPUTER GENERATION

```
#include <stdio.h>
int main(void)
{ int idizi[10]; int id, len; // Dizi boyutunu int veri
türü boyutuna bölerek dizi eleman sayısını bulma len =
sizeof(idizi)/sizeof(int); for (id=0; id<len; id++)
idizi[id] = id+1; // Dizi boyutunu dizinin ilk eleman
boyutuna bölerek dizi eleman sayısını bulma len =
sizeof(idizi)/sizeof(idizi[0]); for (id=0; id<len; id++)
printf("%d ", idizi[id]); return 0; }
```

COMPUTER GENERATION

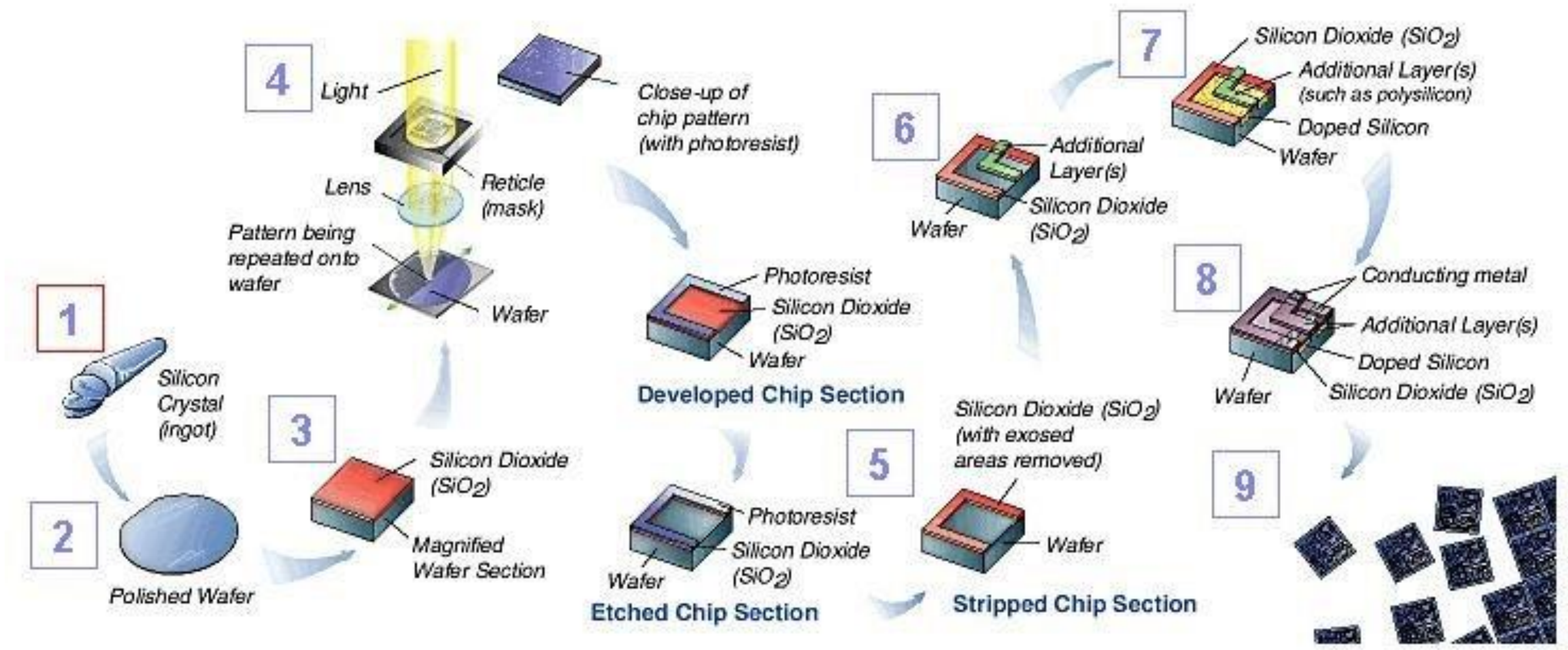
```c
#include <stdio.h>
int main(void)
{ int idizi[10]; int id, len; // Dizi boyutunu int veri
türü boyutuna bölerek dizi eleman sayısını bulma len =
sizeof(idizi)/sizeof(int); for (id=0; id<len; id++)
idizi[id] = id+1; // Dizi boyutunu dizinin ilk eleman
boyutuna bölerek dizi eleman sayısını bulma len =
sizeof(idizi)/sizeof(idizi[0]); for (id=0; id<len; id++)
printf("%d ", idizi[id]); return 0; }
```

D e r l e m e

Ç e v i R i m

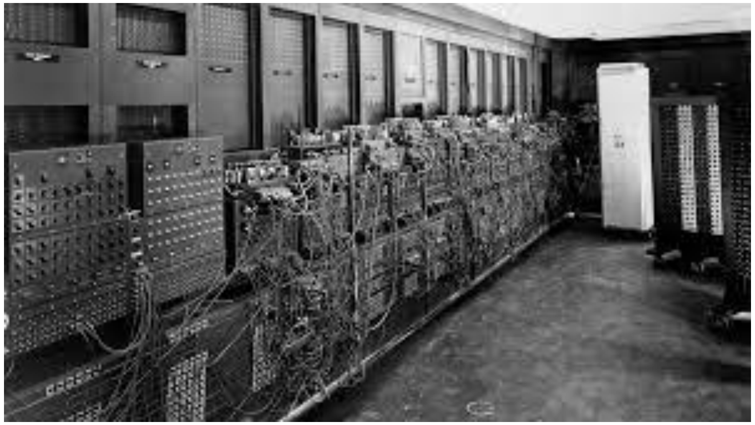

```asm
section .data
    fmt db "%d ", 0  ; Printf için format string
    newline db 10, 0 ; Satır sonu karakteri

section .bss
    idizi resd 10    ; 10 adet integer (4 byte) için yer ayır

section .text
    global main
    extern printf    ; C'deki printf fonksiyonunu kullanabilmek için

main:
    ; RBP ve RSP kaydedicilerini koru
    push rbp
    mov rbp, rsp

    ; Dizi boyutunu hesapla (sizeof(idizi) / sizeof(int))
    mov ecx, 10      ; Dizi uzunluğu (10)
    xor eax, eax     ; id = 0

fill_loop:
    cmp eax, ecx     ; id < len ?
    jge print_loop   ; Eğer id >= len ise yazdırma aşamasına geç
    mov dword [idizi + eax*4], eax  ; idizi[id] = id
    inc eax          ; id++
    jmp fill_loop    ; Döngüyü tekrar et

print_loop:
    xor eax, eax     ; id = 0

print_loop_start:
    cmp eax, ecx     ; id < len ?
    jge end_main     ; Eğer id >= len ise çık
    push rax         ; Argümanları bozmamak için
    push rsi
    push rdi
    mov edi, fmt     ; printf formatı
    mov esi, [idizi + eax*4]  ; Dizi elemanını al
    xor eax, eax     ; printf için sıfırlama (integer argümanı)
    call printf      ; printf çağrısı

    pop rdi
    pop rsi
    pop rax

    inc eax          ; id++
    jmp print_loop_start  ; Döngüyü tekrar et

end_main:
    mov edi, newline ; Satır sonu ekrana bas
    call printf

    ; Çıkış işlemi
    mov eax, 0
    pop rbp
    ret
```

COMPUTER GENERATION



https://www.researchgate.net/figure/Semiconductor-wafer-fabrication-process-flow_fig1_338193528

COMPUTER GENERATION



Alan Turing –Chistopher
İlk özel amaçlı bilgisayar

ENIAC
Ilk genel amaçlı bilgisayar

COMPUTER GENERATION

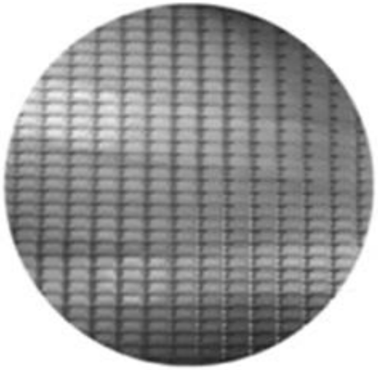
S.N.	Generation & Description
1	**First Generation** The period of first generation: 1946-1959. Vacuum tube based.
2	**Second Generation** The period of second generation: 1959-1965. Transistor based.
3	**Third Generation** The period of third generation: 1965-1971. Integrated Circuit based.
4	**Fourth Generation** The period of fourth generation: 1971-1980. VLSI microprocessor based.
5	**Fifth Generation** The period of fifth generation: 1980-onwards. ULSI microprocessor based

COMPUTER GENERATION

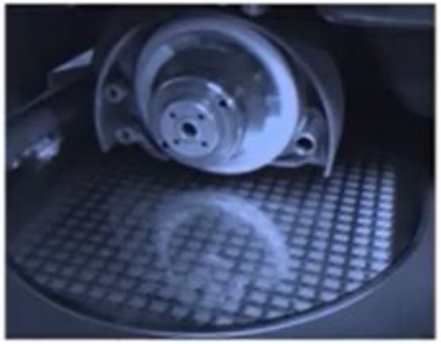
First Generation	Second Generation	Third Generation	Fourth Generation
ENIAC	IBM-1620	IBM-360 Series	DEC-10
EDIVAC	IBM-7094	Honeywell 600 series	STAR-1000
UNIVAC	CDC-1604	PDP(personal data processor)	PDP -11
IBM-701	CDC-3600	IBM-370/168	CRAY-1 (super computer)
IBM-650	UNIVAC-1108	TCD-316	CARY-X-MP (super computer)

COMPUTER GENERATION

Çap artarsa maliyet azalır.



Intel Core i7 Plakası



Bir silikon plakadan yongaların kesilmesi

$$\text{Yonga Maliyeti} = \frac{\text{Plaka Maliyeti}}{\text{Plakadaki Yonga Sayısı} \times \text{Verim}}$$

$$\text{Plakadaki Yongalar} = \frac{\text{Plaka Alanı}}{\text{Yonga Alanı}}$$

$$\text{Verim} = \frac{1}{(1 + (\text{Birim Alandaki Kusurlu Yonga Sayısı} \times \text{Yonga Alanı} \div 2))^2}$$

1 Nanometrede Kaç Silisyum Atomu Var?

- Atomları doğrusal olarak sıraladığımızı varsayarsak:

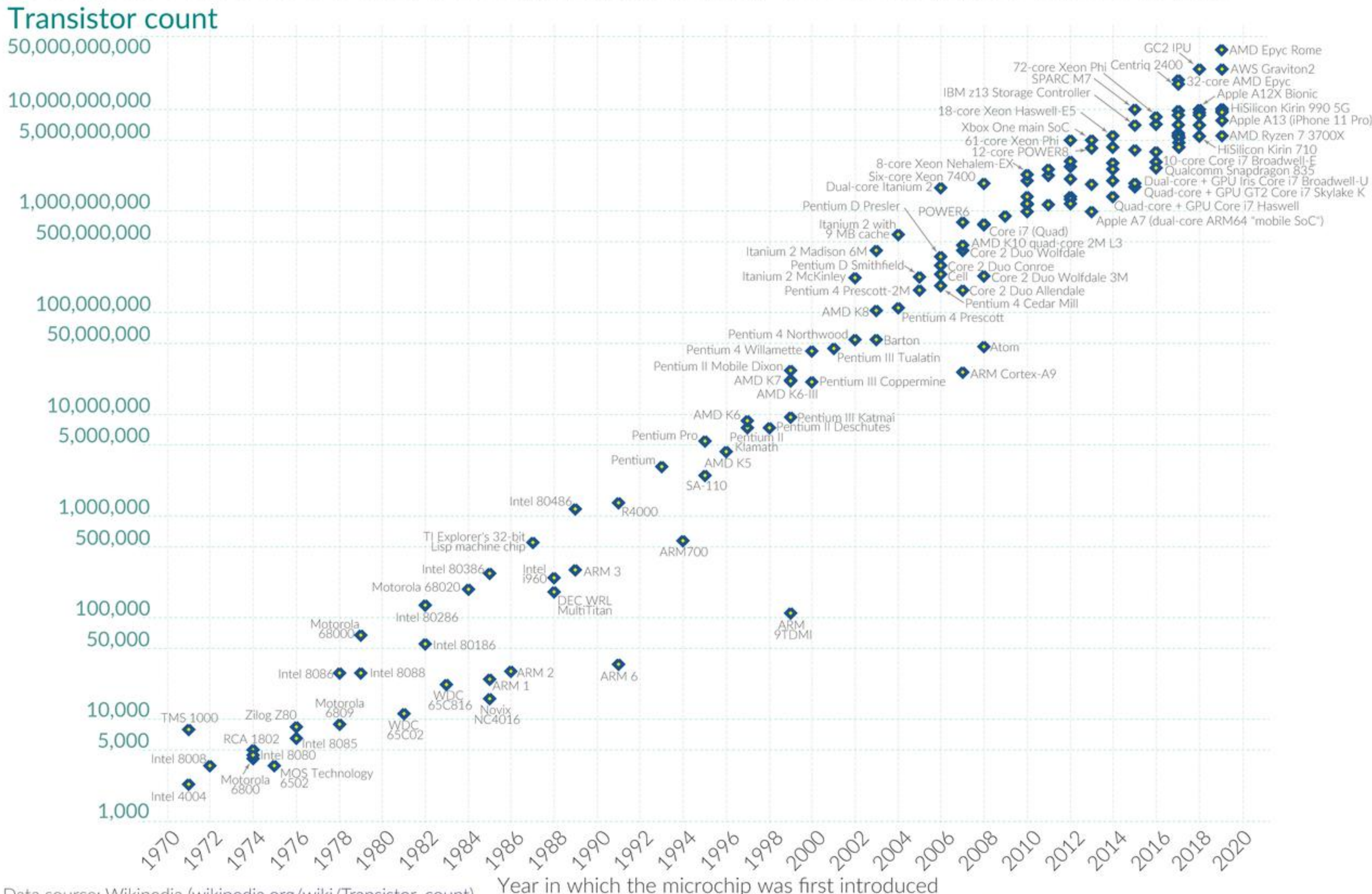
$$\frac{1\ \text{nm}}{0.236\ \text{nm}} \approx 4.24$$

Yani 1 nm içinde yaklaşık 4 silisyum atomu bulunur.

Moore's Law: The number of transistors on microchips doubles every two years

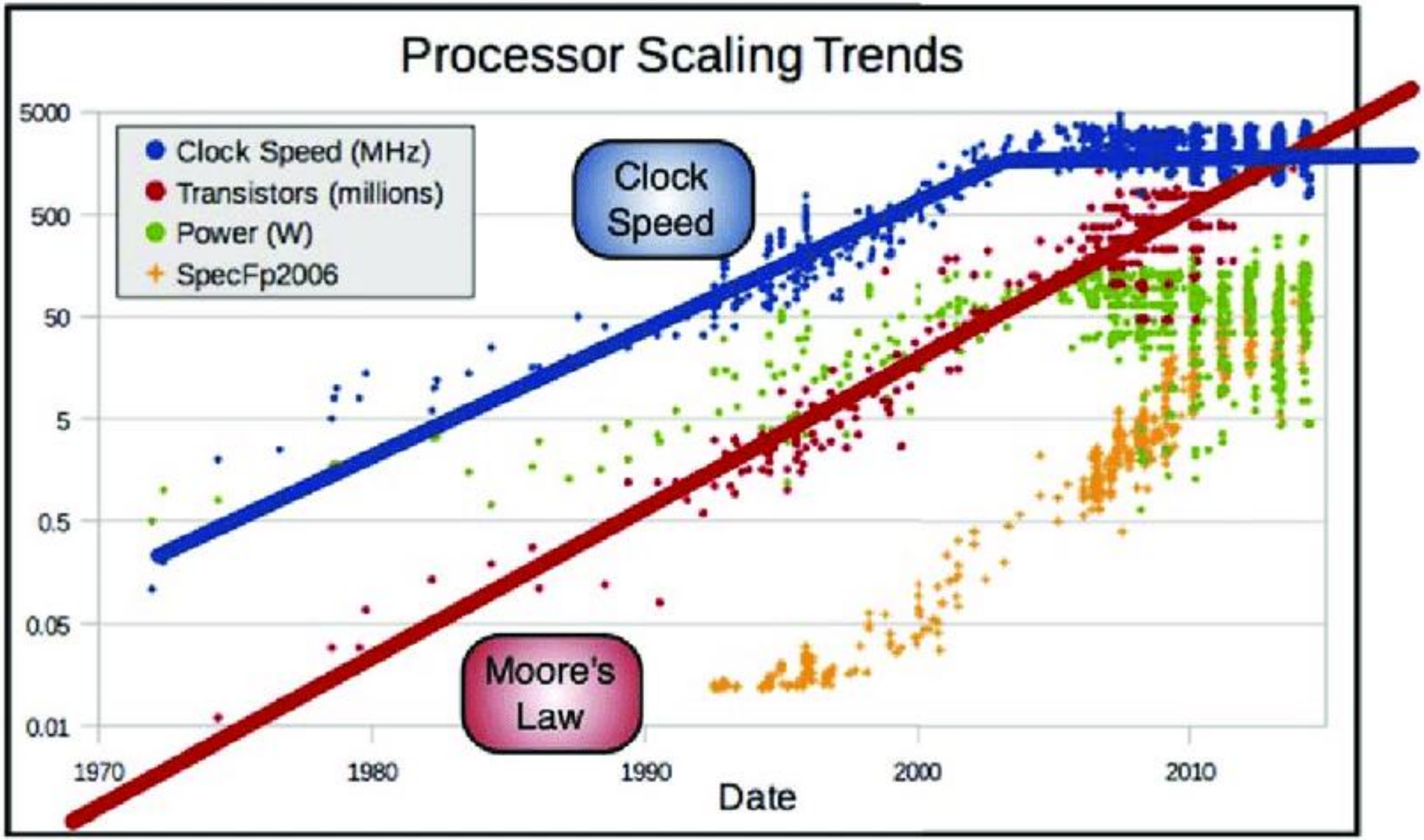
Our World in Data

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years.
This advancement is important for other aspects of technological progress in computing – such as processing speed or the price of computers.

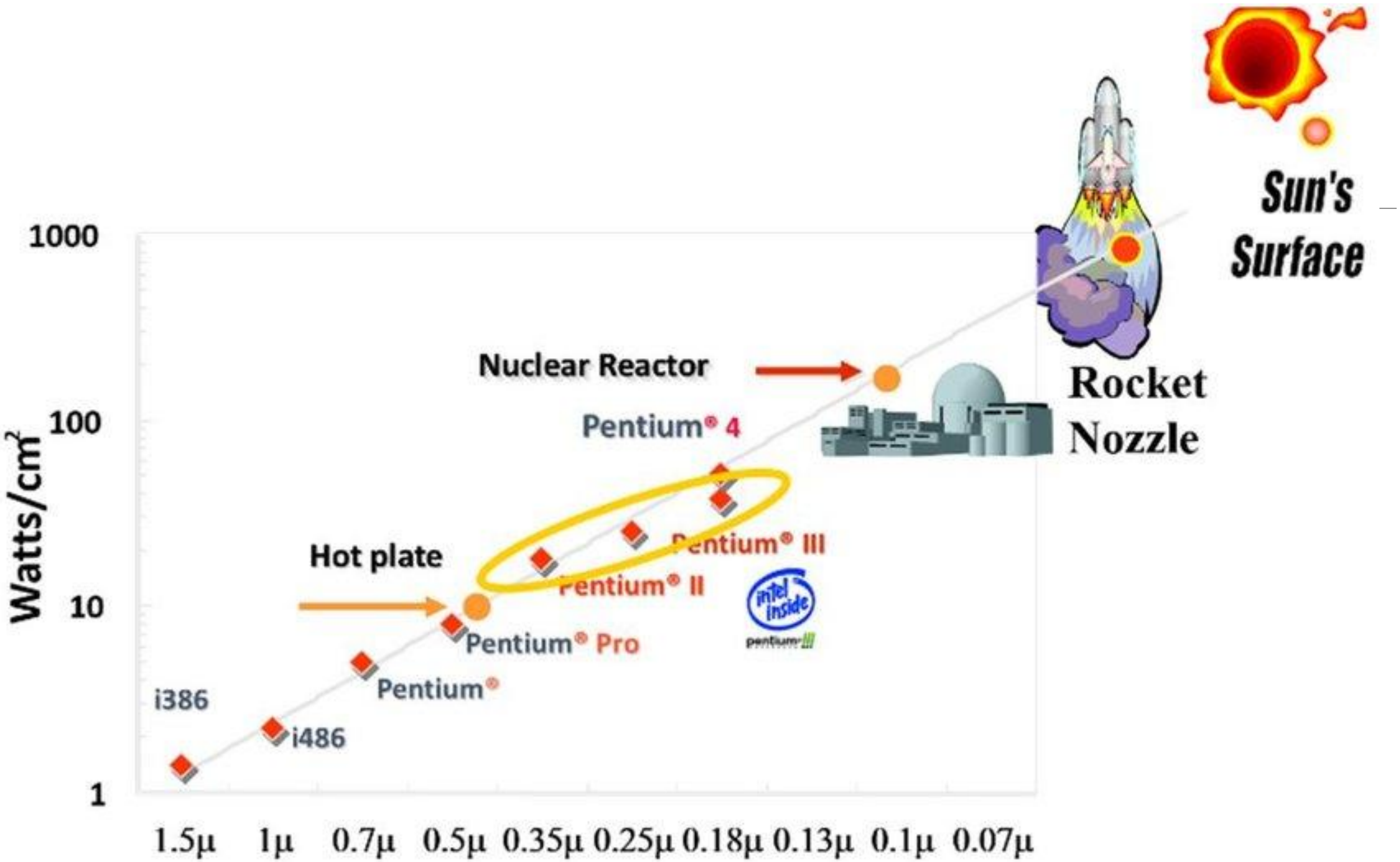


Data source: Wikipedia (wikipedia.org/wiki/Transistor_count)
OurWorldinData.org – Research and data to make progress against the world's largest problems.

COMPUTER GENERATION



https://www.researchgate.net/figure/CPU-transistor-densities-clock-speeds-power-and-performance-from-1970-2015-Courtesy-of_fig1_321233071



https://www.researchgate.net/figure/Power-density-for-successive-nodes-B-Reducing-CPI-and-increasing-IPC-CPI-has-two_fig3_323510528

Computer Architecture

Computer Organization

- Attributes of a system visible to the programmer
- Have a direct impact on the logical execution of a program

Computer Architecture

Architectural attributes include:

- Instruction set, number of bits used to represent various data types, I/O mechanisms, techniques for addressing memory

Organizational attributes include:

- Hardware details transparent to the programmer, control signals, interfaces between the computer and peripherals, memory technology used

Computer Organization

- The operational units and their interconnections that realize the architectural specifications

Pearson

IBM System 370 Architecture

- IBM System/370 architecture
  - Was introduced in 1970
  - Included a number of models
  - Could upgrade to a more expensive, faster model without having to abandon original software
  - New models are introduced with improved technology, but retain the same architecture so that the customer's software investment is protected
  - Architecture has survived to this day as the architecture of IBM's mainframe product line

Structure and Function

- Hierarchical system
  - Set of interrelated subsystems
- Hierarchical nature of complex systems is essential to both their design and their description
- Designer need only deal with a particular level of the system at a time
  - Concerned with structure and function at each level

- Structure
  - The way in which components relate to each other
- Function
  - The operation of individual components as part of the structure

Function

- There are four basic functions that a computer can perform:
  - Data processing
    - Data may take a wide variety of forms and the range of processing requirements is broad
  - Data storage
    - Short-term
    - Long-term
  - Data movement
    - Input-output (I/O) - when data are received from or delivered to a device (peripheral) that is directly connected to the computer
    - Data communications – when data are moved over longer distances, to or from a remote device
  - Control
    - A control unit manages the computer’s resources and orchestrates the performance of its functional parts in response to instructions

Structure

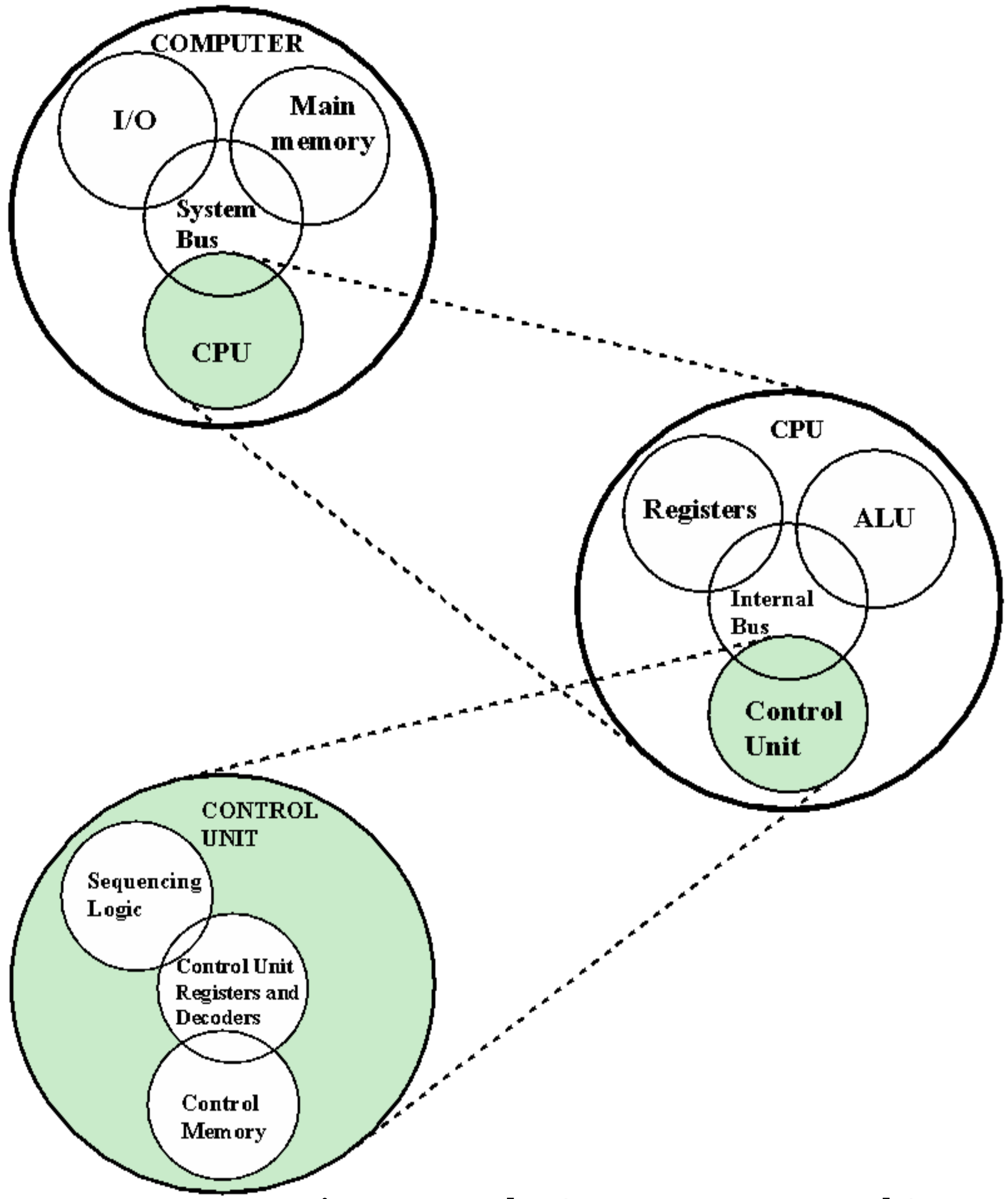


Figure 1.1 The Computer: Top-Level Structure

There are four main structural components of the computer:

- CPU – controls the operation of the computer and performs its data processing functions
- Main Memory – stores data
- I/O – moves data between the computer and its external environment
- System Interconnection – some mechanism that provides for communication among CPU, main memory, and I/O

CPU
Major structural components:

- Control Unit
  - Controls the operation of the CPU and hence the computer
- Arithmetic and Logic Unit (ALU)
  - Performs the computer's data processing function
- Registers
  - Provide storage internal to the CPU
- CPU Interconnection
  - Some mechanism that provides for communication among the control unit, ALU, and registers

Multicore Computer Structure

- Central processing unit (CPU)
  - Portion of the computer that fetches and executes instructions
  - Consists of an ALU, a control unit, and registers
  - Referred to as a processor in a system with a single processing unit
- Core
  - An individual processing unit on a processor chip
  - May be equivalent in functionality to a CPU on a single-CPU system
  - Specialized processing units are also referred to as cores
- Processor
  - A physical piece of silicon containing one or more cores
  - Is the computer component that interprets and executes instructions
  - Referred to as a *multicore processor* if it contains multiple cores

Cache Memory

- Multiple layers of memory between the processor and main memory
- Is smaller and faster than main memory
- Used to speed up memory access by placing in the cache data from main memory that is likely to be used in the near future
- A greater performance improvement may be obtained by using multiple levels of cache, with level 1 (L1) closest to the core and additional levels (L2, L3, etc.) progressively farther from the core

Figure 1.2

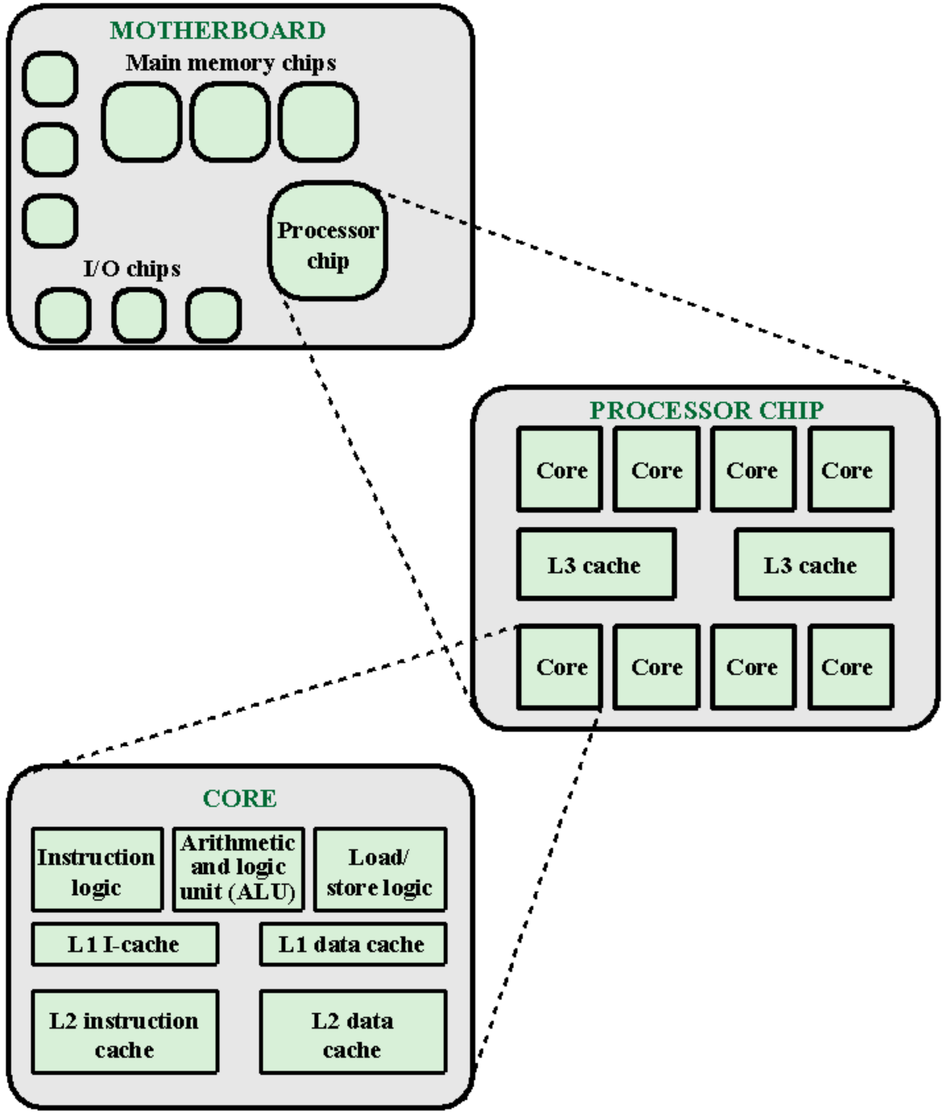
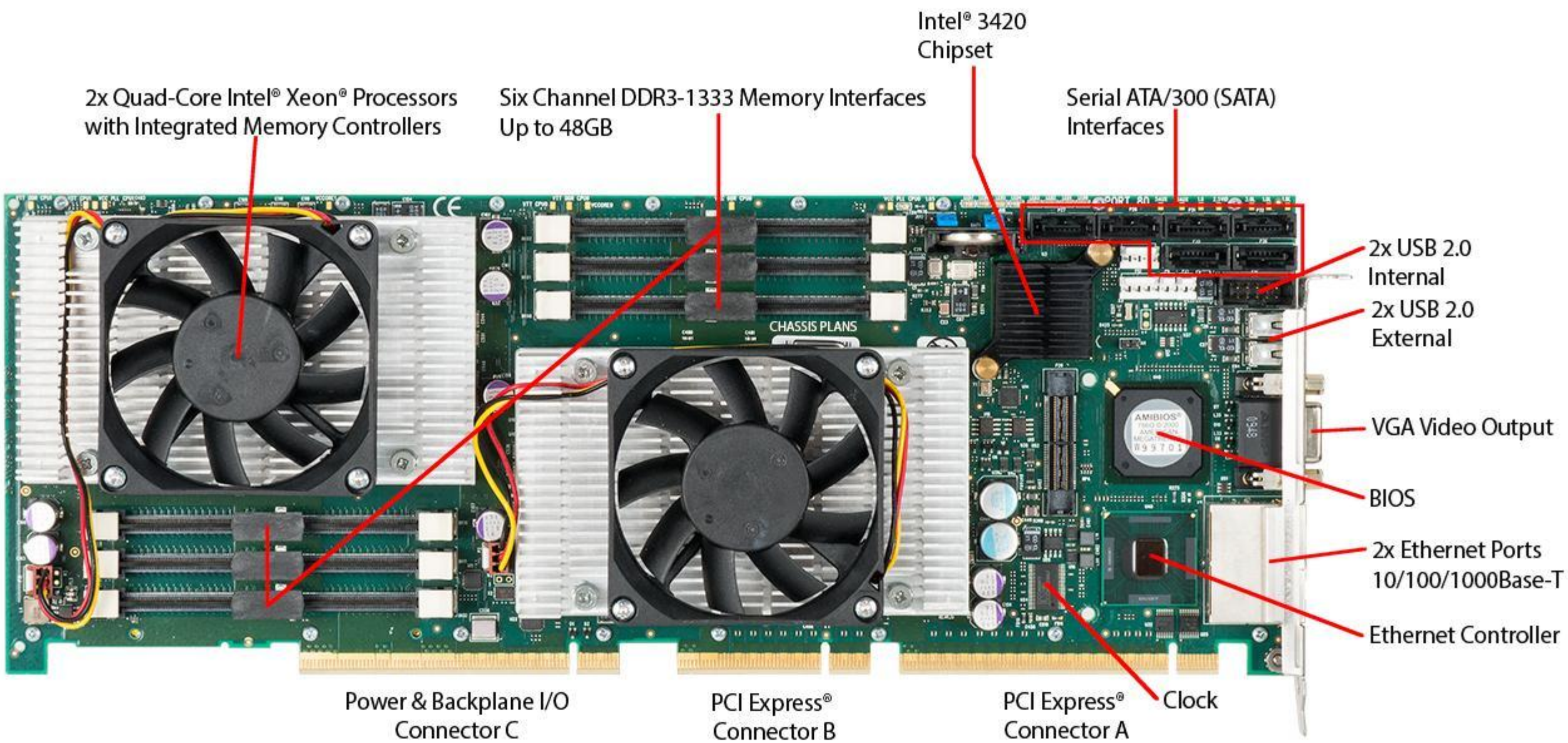


Figure 1.2 Simplified View of Major Elements of a Multicore Computer

Figure 1.3
Motherboard with Two Intel Quad-Core Xeon Processors



Source: Courtesy of Chassis Plans Rugged Rackmount Computers

Figure 1.4

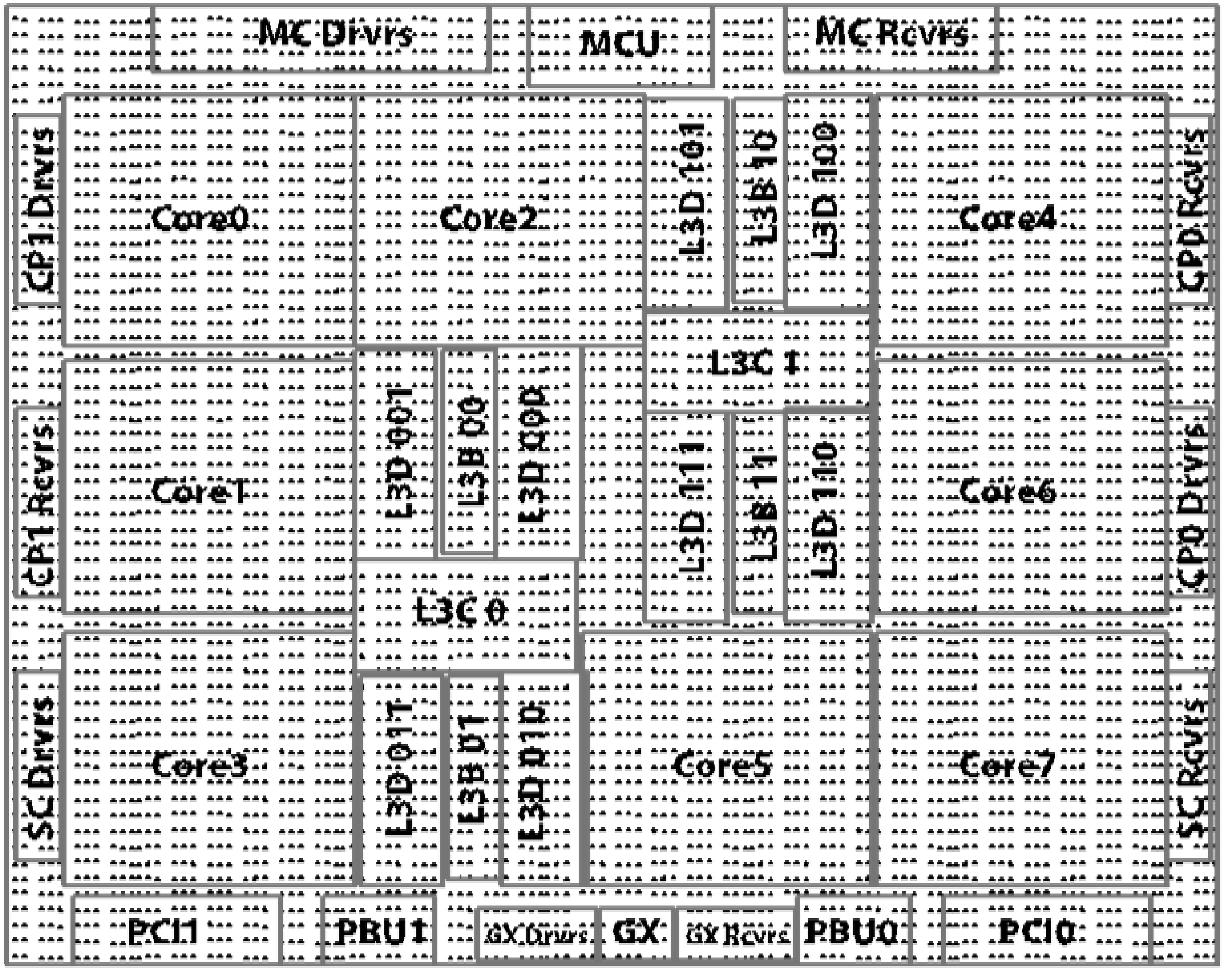


Figure 1.4 IBM z13 Processor Unit (PU) Chip Diagram

Figure 1.5

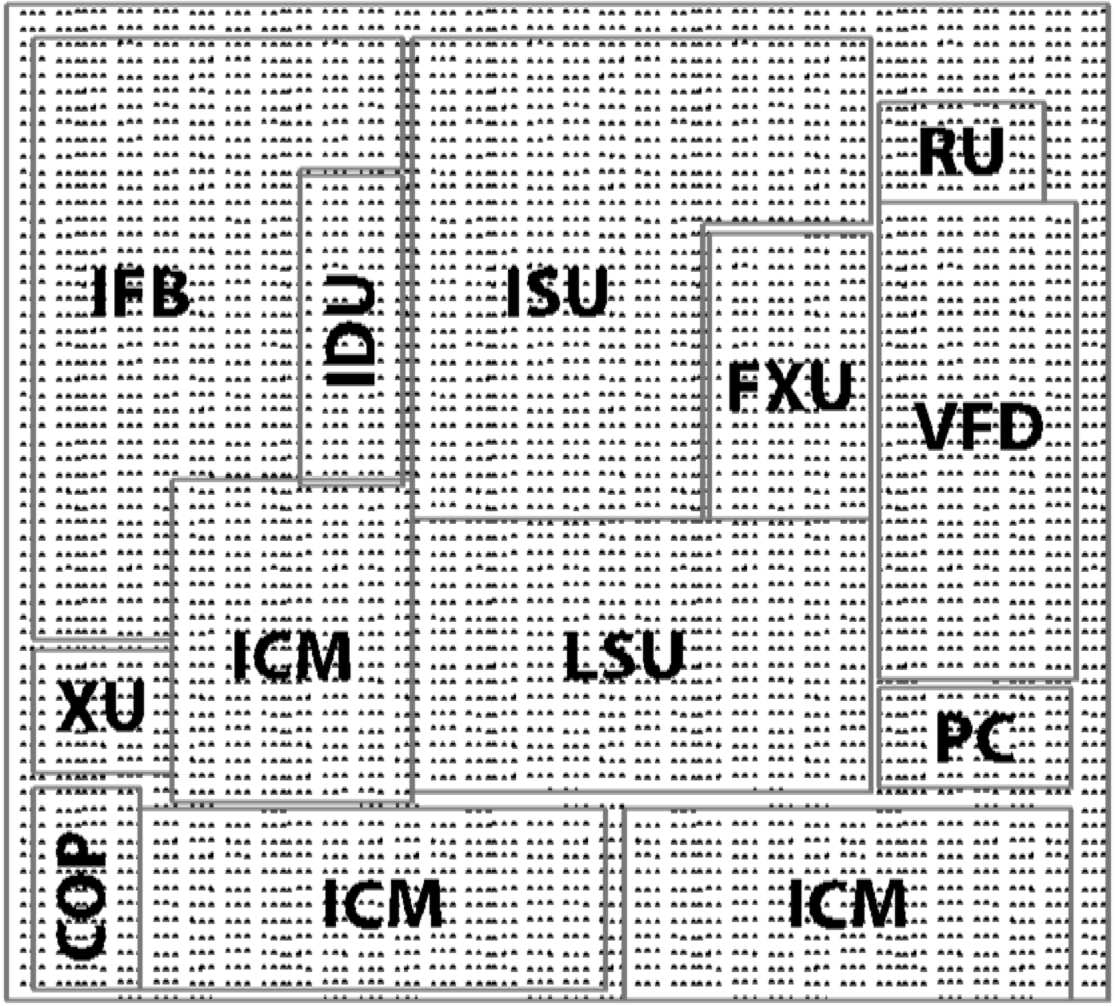


Figure 1.5 IBM z13 Core Layout

History of Computers
First Generation: Vacuum Tubes

- Vacuum tubes were used for digital logic elements and memory
- IAS computer
  - Fundamental design approach was the stored program concept
    - Attributed to the mathematician John von Neumann
    - First publication of the idea was in 1945 for the EDVAC
  - Design began at the Princeton Institute for Advanced Studies
  - Completed in 1952
  - Prototype of all subsequent general-purpose computers

Figure 1.6

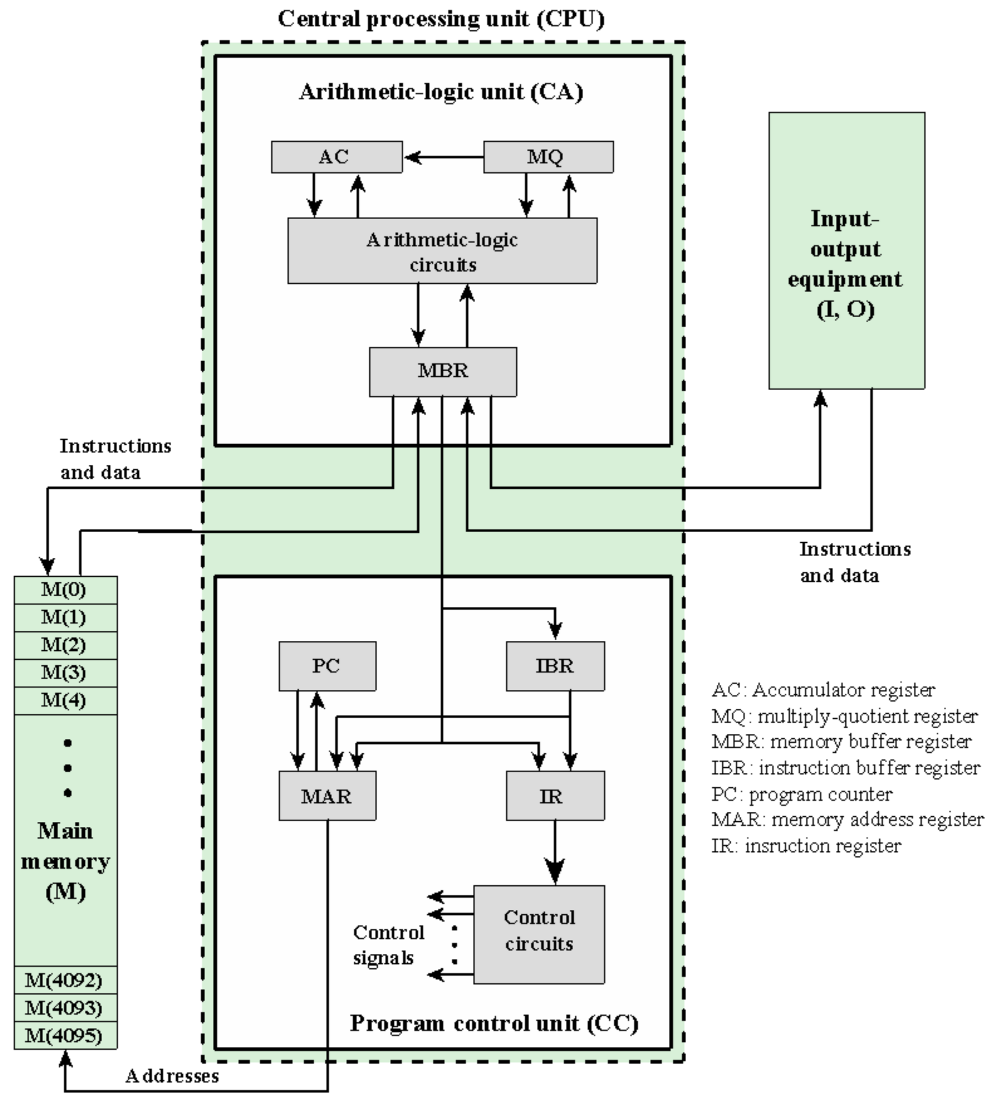


Figure 1.6 IAS Structure

Figure 1.7

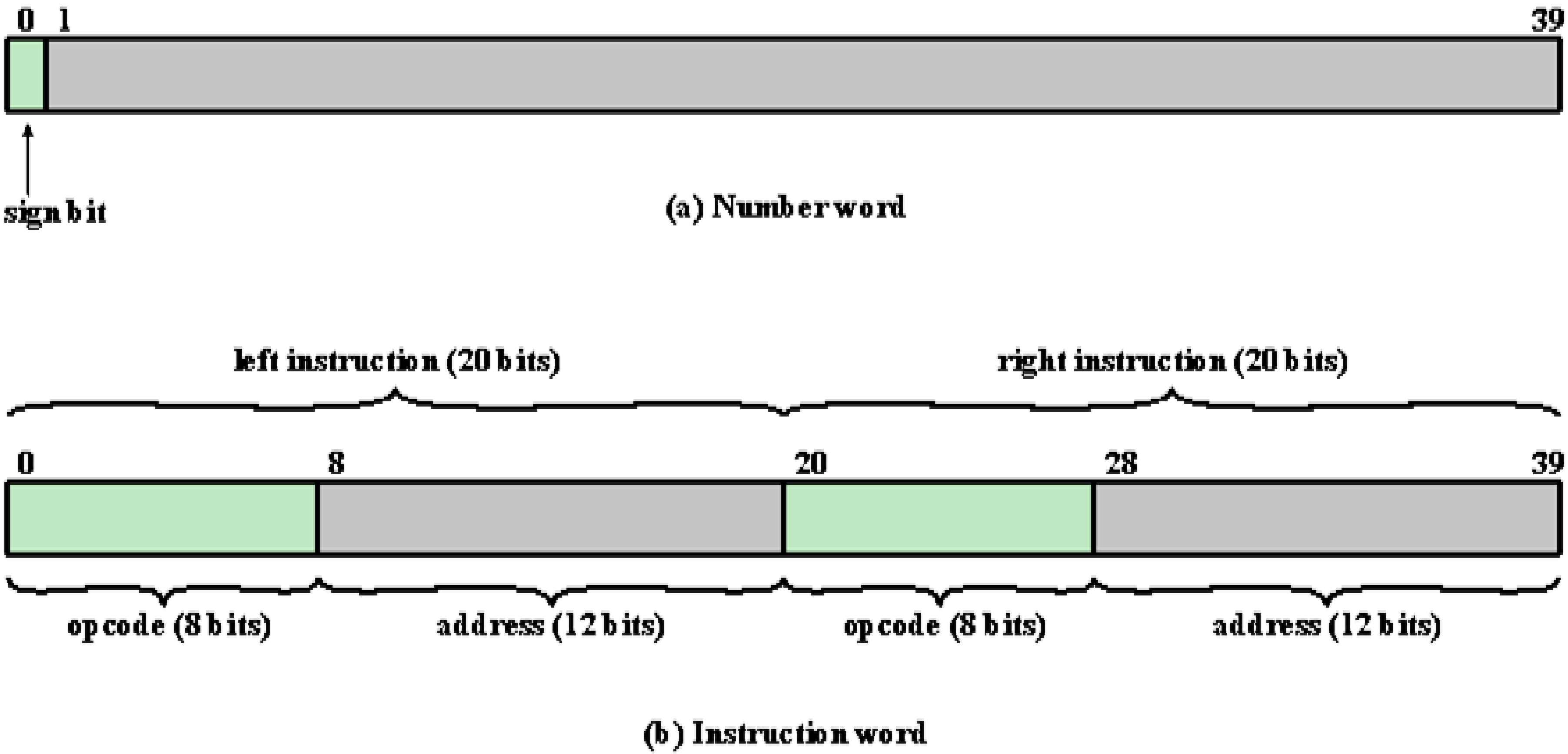


Figure 1.7 IAS Memory Formats

Registers

Memory buffer register (MBR)	• Contains a word to be stored in memory or sent to the I/O unit • Or is used to receive a word from memory or from the I/O unit
Memory address register (MAR)	• Specifies the address in memory of the word to be written from or read into the MBR
Instruction register (IR)	• Contains the 8-bit opcode instruction being executed
Instruction buffer register (IBR)	• Employed to temporarily hold the right-hand instruction from a word in memory
Program counter (PC)	• Contains the address of the next instruction pair to be fetched from memory
Accumulator (AC) and multiplier quotient (MQ)	• Employed to temporarily hold operands and results of ALU operations

Figure 1.8

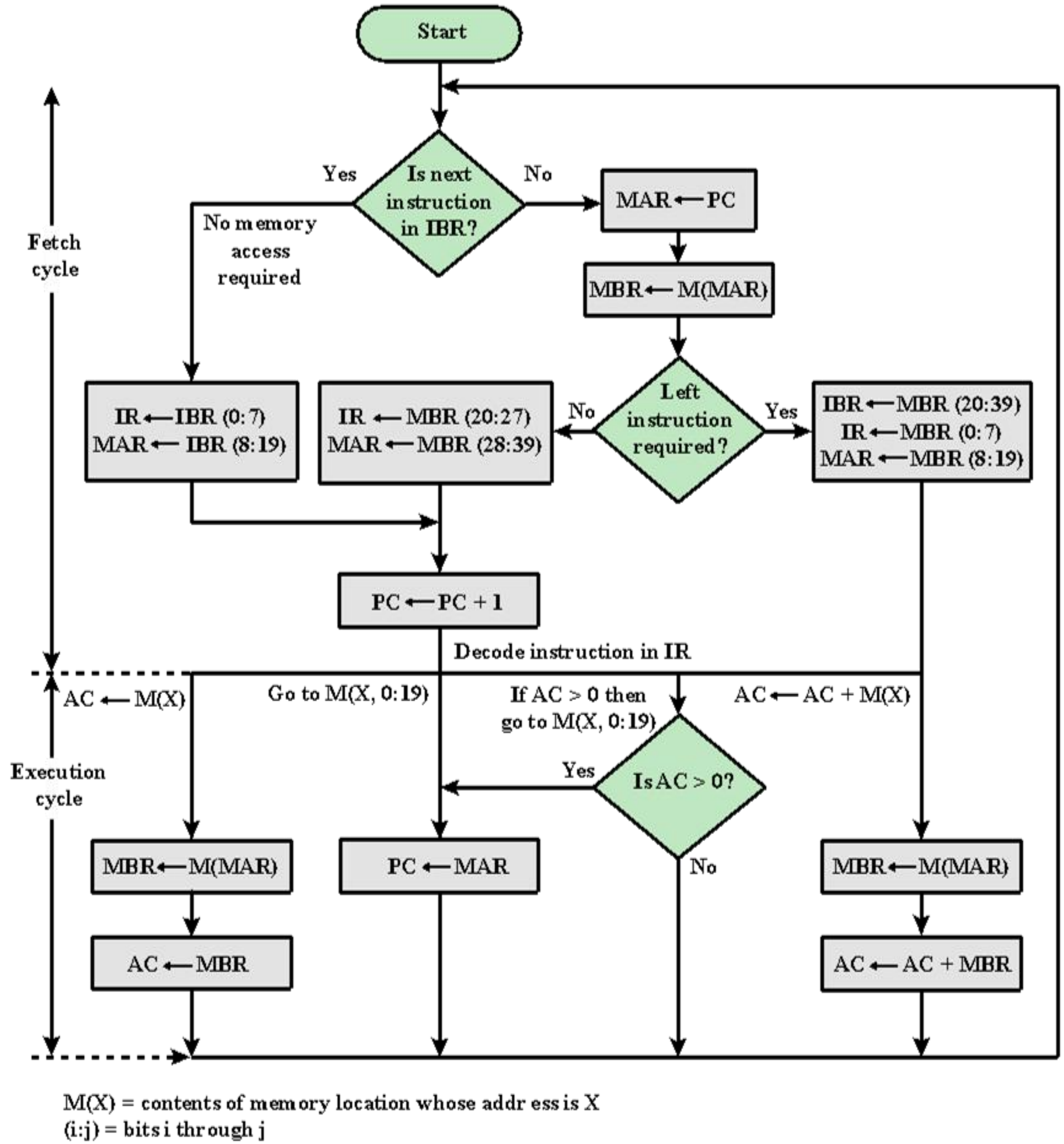


Figure 1.8 Partial Flowchart of IAS Operation

Table 1.1 The IAS Instruction Set

Instruction Type	Opcode	Symbolic Representation	Description
Data transfer	00001010	LOAD MQ	Transfer contents of register MQ to the accumulator AC
	00001001	LOAD MQ,M(X)	Transfer contents of memory location X to MQ
	00100001	STOR M(X)	Transfer contents of accumulator to memory location X
	00000001	LOAD M(X)	Transfer M(X) to the accumulator
	00000010	LOAD –M(X)	Transfer –M(X) to the accumulator
	00000011	LOAD |M(X)|	Transfer absolute value of M(X) to the accumulator
	00000100	LOAD –|M(X)|	Transfer –|M(X)| to the accumulator
Unconditional branch	00001101	JUMP M(X,0:19)	Take next instruction from left half of M(X)
	00001110	JUMP M(X,20:39)	Take next instruction from right half of M(X)
Conditional Branch	00001111	JUMP + M(X,0:19)	Take next instruction from right half of M(X)
	00010000	JUMP + M(X,20:39)	If number in the accumulator is nonnegative, take next instruction from right half of M(X)
Arithmetic	00000101	ADD M(X)	Add M(X) to AC; put the result in AC
	00000111	ADD |M(X)|	Add |M(X)| to AC; put the result in AC
	00000110	SUB M(X)	Subtract M(X) from AC; put the result in AC
	00001000	SUB |M(X)|	Subtract |M(X)| from AC; put the remainder in AC
	00001011	MUL M(X)	Multiply M(X) by MQ; put most significant bits of result in AC, put least significant bits in MQ
	00001100	DIV M(X)	Divide AC by M(X); put the quotient in MQ and the remainder in AC
	00010100	LSH	Multiply accumulator by 2; that is, shift left one bit position
	00010101	RSH	Divide accumulator by 2; that is, shift right one position
Address modify	00010010	STOR M(X,8:19)	Replace left address field at M(X) by 12 rightmost bits of AC
	00010011	STOR M(X,28:39)	Replace right address field at M(X) by 12 rightmost bits of AC

(Table can be found on page 16 in the textbook.)

Figure 1.9

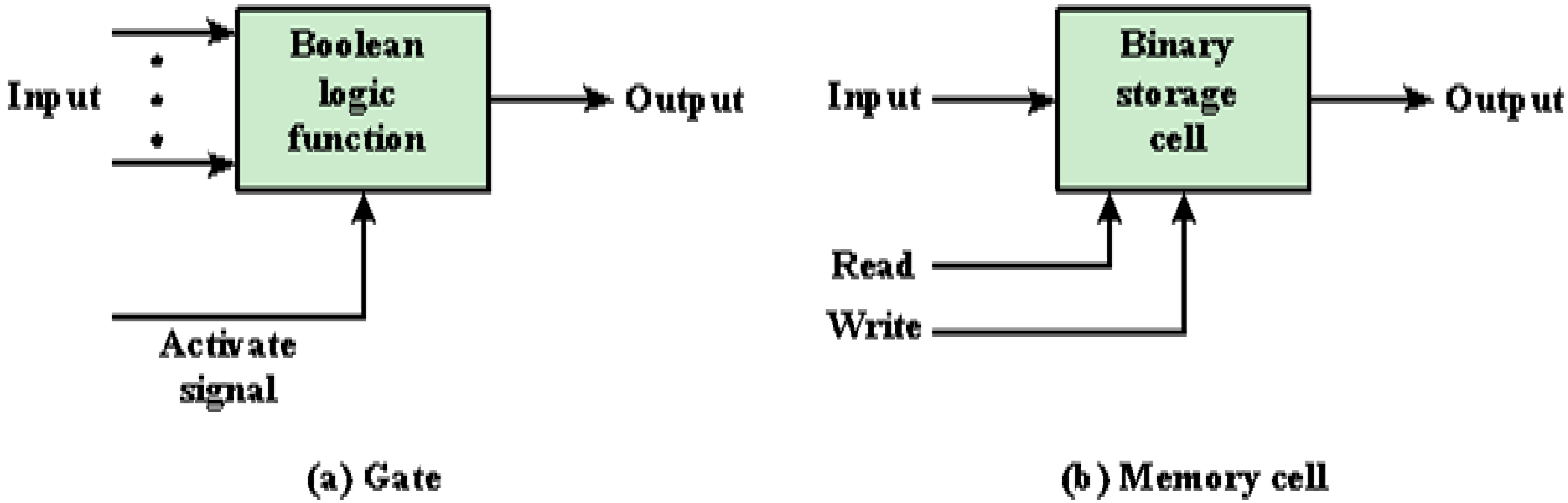


Figure 1.9 Fundamental Computer Elements

Integrated Circuits

- Data storage – provided by memory cells
- Data processing – provided by gates
- Data movement – the paths among components are used to move data from memory to memory and from memory through gates to memory
- Control – the paths among components can carry control signals

- A computer consists of gates, memory cells, and interconnections among these elements
- The gates and memory cells are constructed of simple digital electronic components
- Exploits the fact that such components as transistors, resistors, and conductors can be fabricated from a semiconductor such as silicon
- Many transistors can be produced at the same time on a single wafer of silicon
- Transistors can be connected with a processor metallization to form circuits

Transistors

- The fundamental building block of digital circuits used to construct processors, memories, and other digital logic devices
- Active part of the transistor is made of silicon or some other semiconductor material that can change its electrical state when pulsed
  - In its normal state the material may be nonconductive or conductive
  - The transistor changes its state when voltage is applied to the gate
- Discrete component
  - A single, self-contained transistor
  - Were manufactured separately, packaged in their own containers, and soldered or wired together onto Masonite-like circuit boards

Figure 1.10

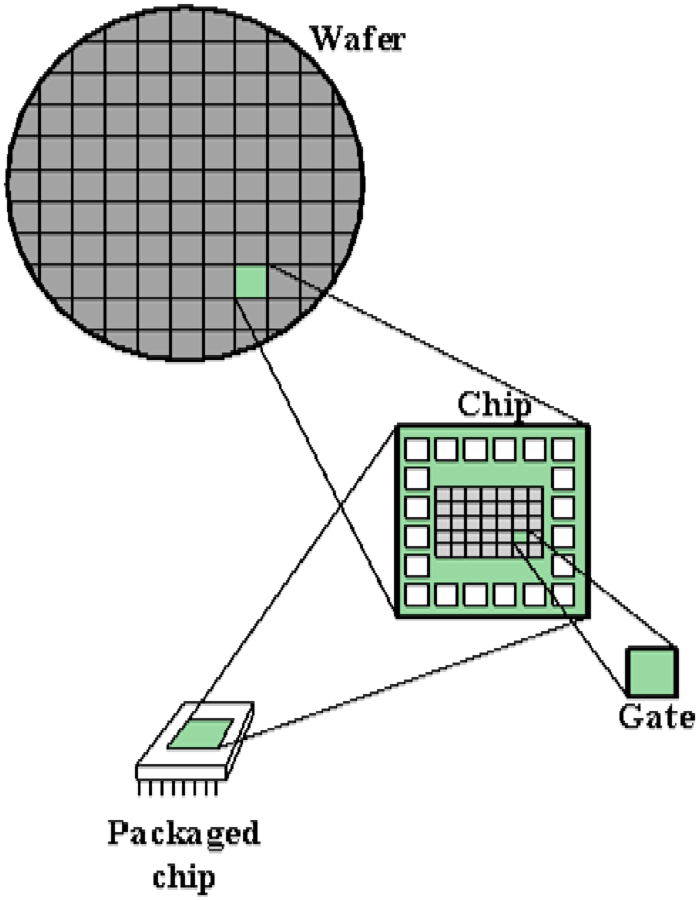
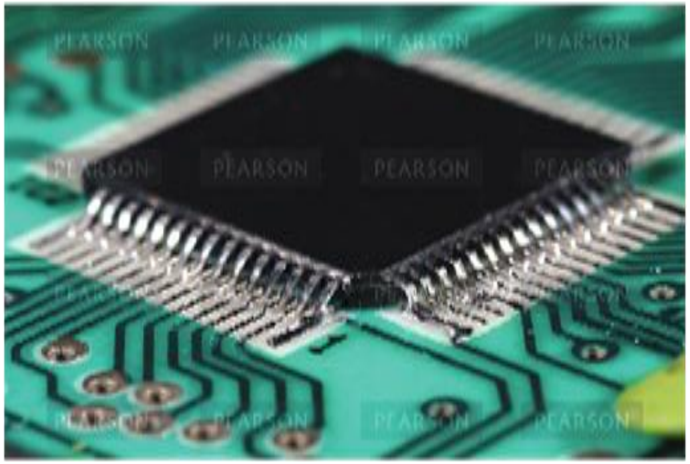
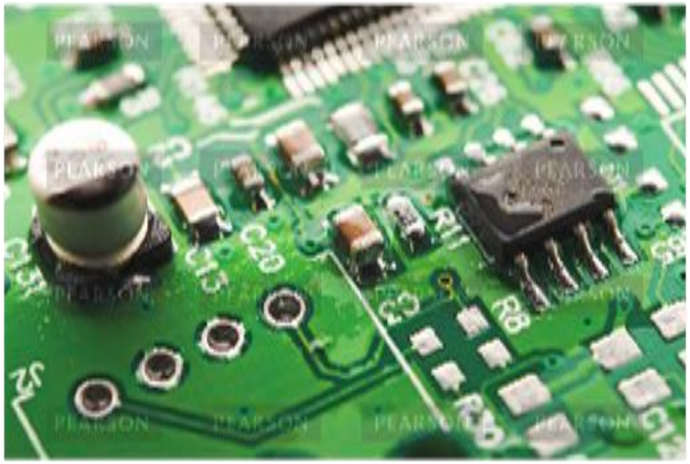


Figure 1.10 Relationship Among Wafer, Chip, and Gate

Figure 1.11



(a) Close-up of packaged chip



(b) Chip on motherboard

Figure 1.11 Processor or Memory Chip on Motherboard

Figure 1.12

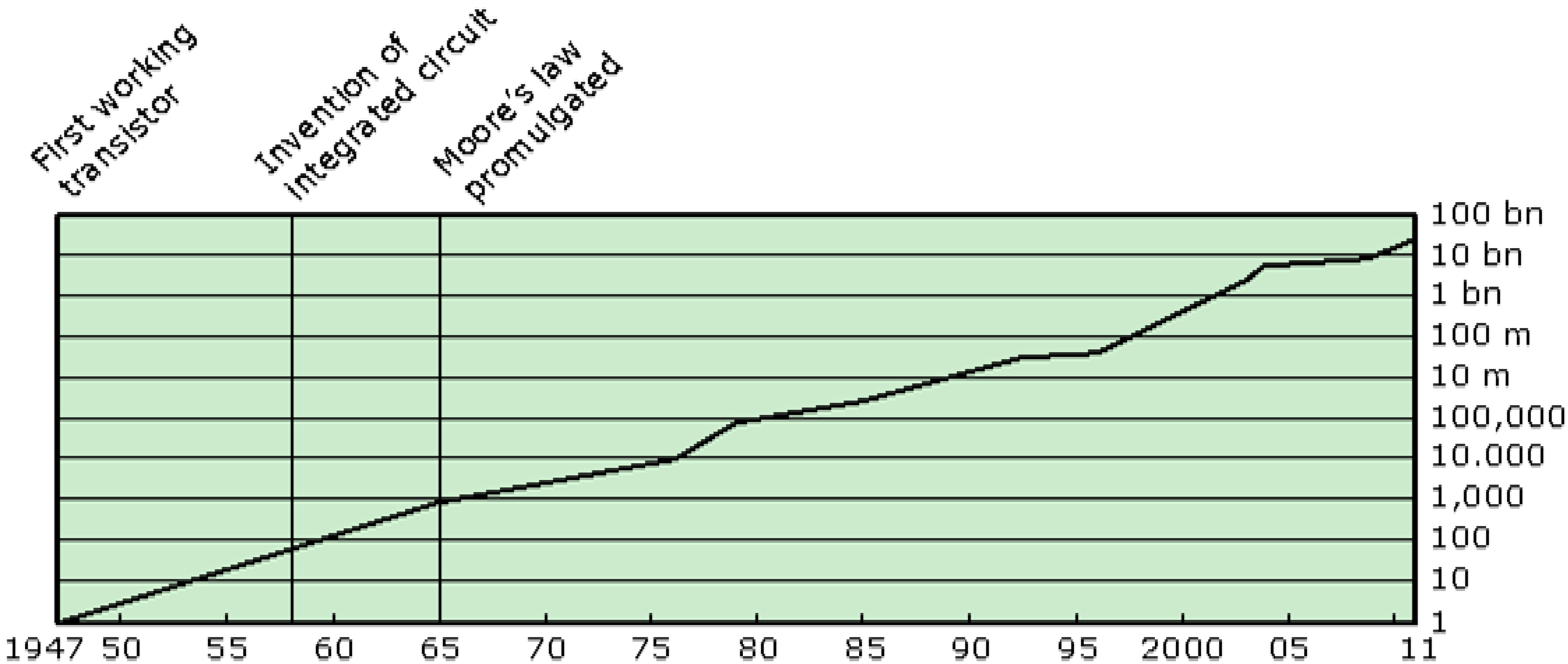


Figure 1.12 Growth in Transistor Count on Integrated Circuits (DRAM memory)

Moore's Law

1965; Gordon Moore – co-founder of Intel

Observed number of transistors that could be put on a single chip was doubling every year

The pace slowed to a doubling every 18 months in the 1970's but has sustained that rate ever since

Consequences of Moore's law:

- **The cost of computer logic and memory circuitry has fallen at a dramatic rate**
- **The electrical path length is shortened, increasing operating speed**
- **Computer becomes smaller and is more convenient to use in a variety of environments**
- **Reduction in power and cooling requirements**
- **Fewer interchip connections**

Figure 1.13

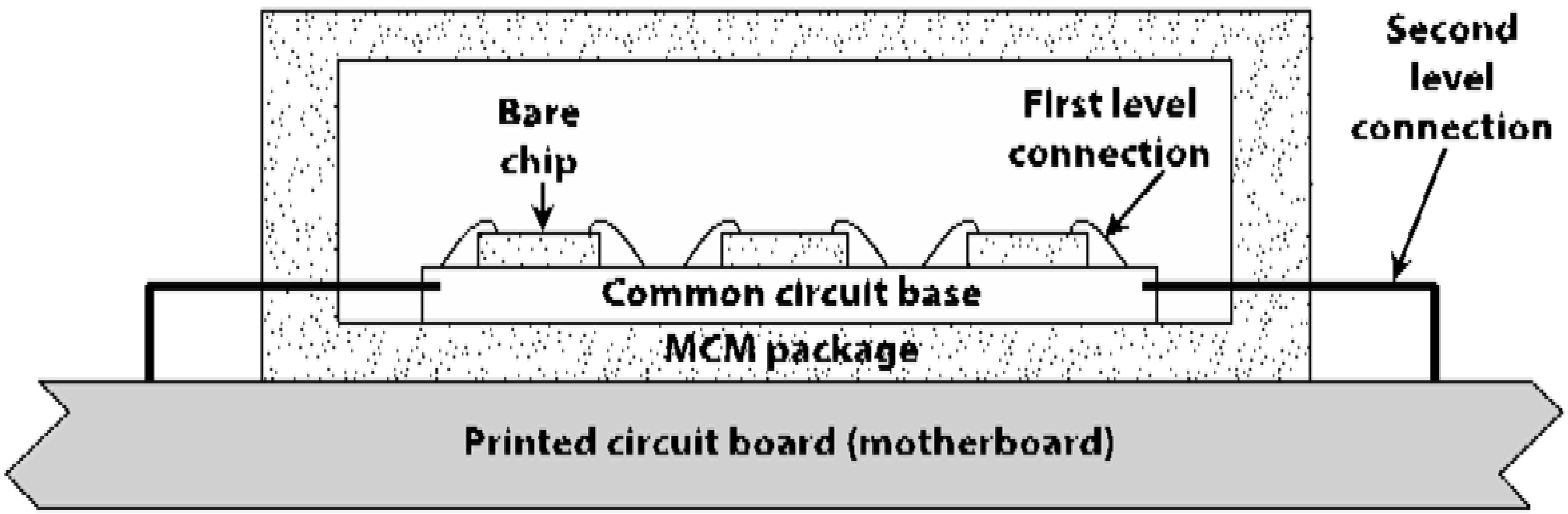


Figure 1.13 Multichip Module

Evolution of Intel Microprocessors (1 of 4)

	4004	8008	8080	8086	8088
Introduced	1971	1972	1974	1978	1979
Clock speeds	108 kHz	108 kHz	2 MHz	2 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

(a) 1970s Processors

Evolution of Intel Microprocessors (2 of 4)

	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

(b) 1980s Processors

Evolution of Intel Microprocessors (3 of 4)

	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

(c) 1990s Processors

Evolution of Intel Microprocessors (4 of 4)

	Pentium III	Pentium 4	Core 2 Duo	Core i7 EE 4960X	Core i9-7900X
Introduced	1999	2000	2006	2013	2017
Clock speeds	450–660 MHz	1.3–1.8 GHz	1.06–1.2 GHz	4 GHz	4.3 GHz
Bus width	64 bits	64 bits	64 bits	64 bits	64 bits
Number of transistors	9.5 million	42 million	167 million	1.86 billion	7.2 billion
Feature size (nm)	250	180	65	22	14
Addressable memory	64 GB	64 GB	64 GB	64 GB	128 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB	64 TB
Cache	512 kB L2	256 kB L2	2 MB L2	1.5 MB L2/ 1.5 MB L3	14 MB L3
Number of cores	1	1	2	6	10

(d) Recent Processors

Highlights of the Evolution of the Intel Product Line: (1 of 2)

8080

- World's first general-purpose microprocessor
- 8-bit machine, 8-bit data path to memory
- Was used in the first personal computer (Altair)

8086

- A more powerful 16-bit machine
- Has an instruction cache, or queue, that prefetches a few instructions before they are executed
- The first appearance of the x86 architecture
- The 8088 was a variant of this processor and used in IBM's first personal computer (securing the success of Intel

80286

- Extension of the 8086 enabling addressing a 16-MB memory instead of just 1MB

80386

- Intel's first 32-bit machine
- First Intel processor to support multitasking

80486

- Introduced the use of much more sophisticated and powerful cache technology and sophisticated instruction pipelining
- Also offered a built-in math coprocessor

Highlights of the Evolution of the Intel Product Line: (2 of 2)

Pentium

- Intel introduced the use of superscalar techniques, which allow multiple instructions to execute in parallel

Pentium Pro

- Continued the move into superscalar organization with aggressive use of register renaming, branch prediction, data flow analysis, and speculative execution

Pentium II

- Incorporated Intel MMX technology, which is designed specifically to process video, audio, and graphics data efficiently

Pentium III

- Incorporated additional floating-point instructions
- Streaming SIMD Extensions (SSE)

Pentium 4

- Includes additional floating-point and other enhancements for multimedia

Core

- First Intel x86 micro-core

Core 2

- Extends the Core architecture to 64 bits
- Core 2 Quad provides four cores on a single chip
- More recent Core offerings have up to 10 cores per chip
- An important addition to the architecture was the Advanced Vector Extensions instruction set

Embedded Systems

- The use of electronics and software within a product
- Billions of computer systems are produced each year that are embedded within larger devices
- Today many devices that use electric power have an embedded computing system
- Often embedded systems are tightly coupled to their environment
  - This can give rise to real-time constraints imposed by the need to interact with the environment
    - Constraints such as required speeds of motion, required precision of measurement, and required time durations, dictate the timing of software operations
  - If multiple activities must be managed simultaneously this imposes more complex real-time constraints

Figure 1.14

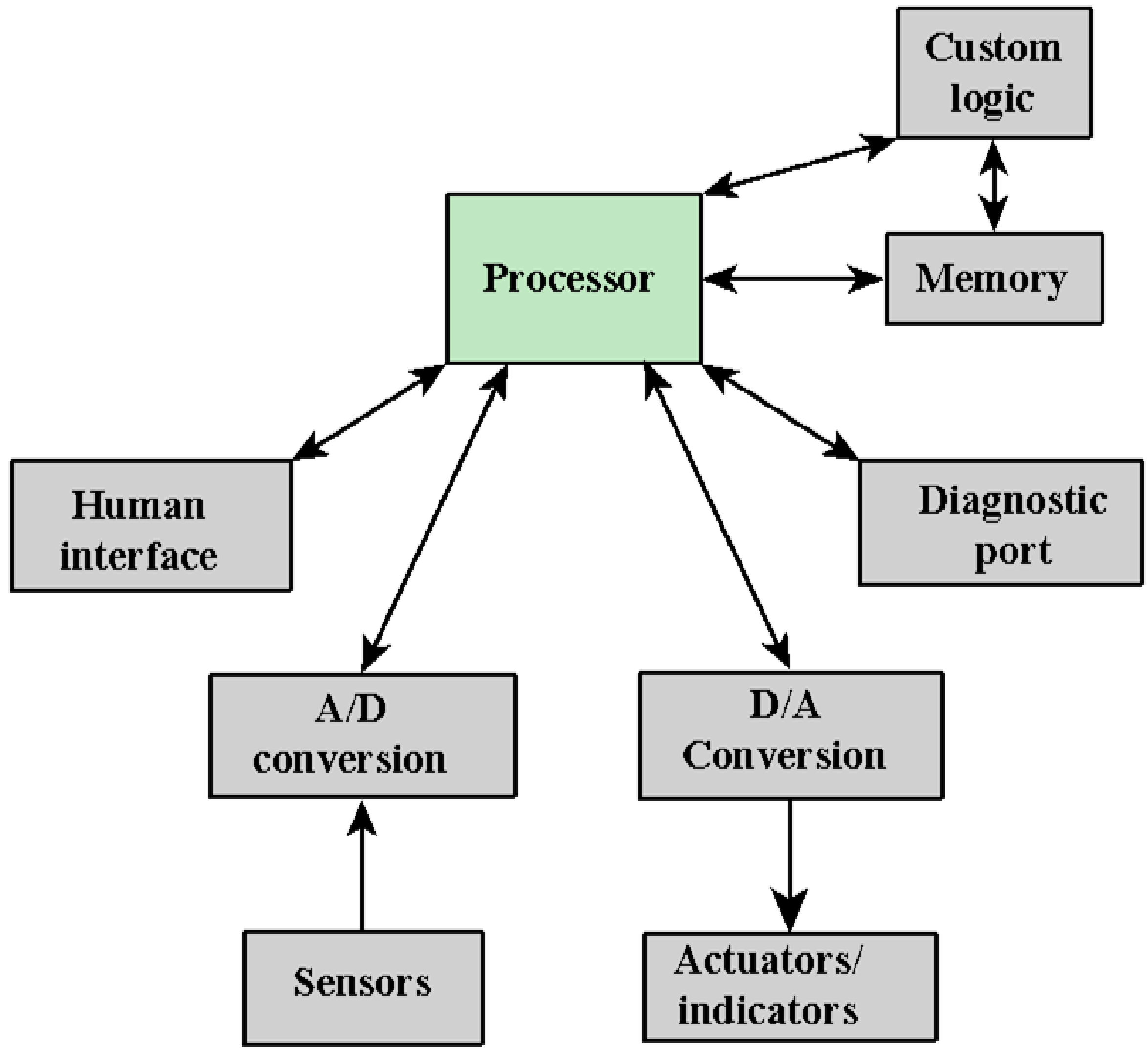
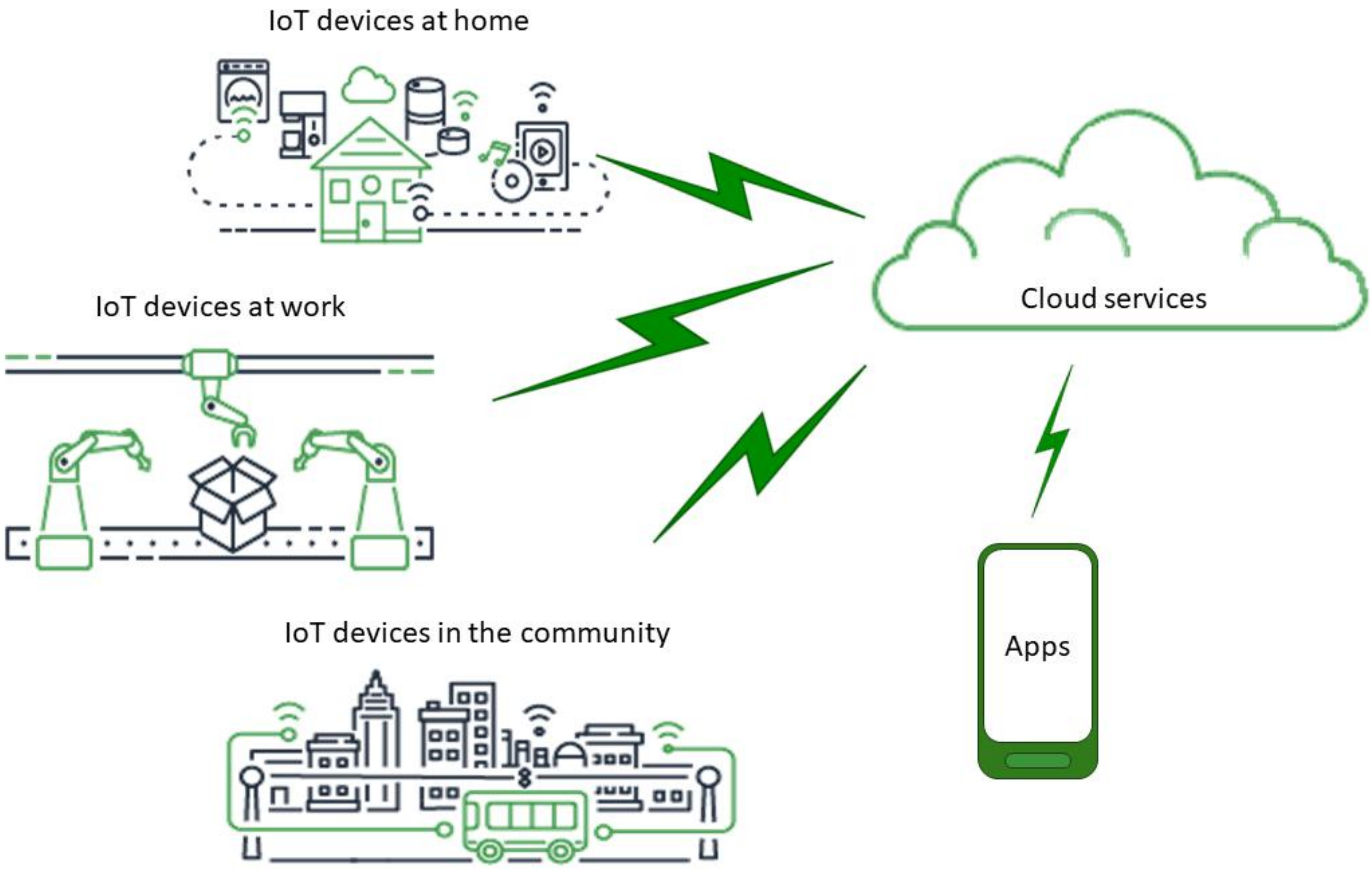


Figure 1.14 Possible Organization of an Embedded System

Internet of Things (IoT)



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The Internet of Things (IoT)

- Term that refers to the expanding interconnection of smart devices, ranging from appliances to tiny sensors
- Is primarily driven by deeply embedded devices
- Generations of deployment culminating in the IoT:
  - Information technology (IT)
    - PCs, servers, routers, firewalls, and so on, bought as IT devices by enterprise IT people and primarily using wired connectivity
  - Operational technology (OT)
    - Machines/appliances with embedded IT built by non-IT companies, such as medical machinery, SCADA, process control, and kiosks, bought as appliances by enterprise OT people and primarily using wired connectivity
  - Personal technology
    - Smartphones, tablets, and eBook readers bought as IT devices by consumers exclusively using wireless connectivity and often multiple forms of wireless connectivity
  - Sensor/actuator technology
    - Single-purpose devices bought by consumers, IT, and OT people exclusively using wireless connectivity, generally of a single form, as part of larger systems
- It is the fourth generation that is usually thought of as the IoT and it is marked by the use of billions of embedded devices

Embedded Operating Systems

- There are two general approaches to developing an embedded operating system (OS):
  - Take an existing OS and adapt it for the embedded application
  - Design and implement an OS intended solely for embedded use

Application Processors versus Dedicated Processors

- Application processors
  - Defined by the processor's ability to execute complex operating systems
  - General-purpose in nature
  - An example is the smartphone – the embedded system is designed to support numerous apps and perform a wide variety of functions
- Dedicated processor
  - Is dedicated to one or a small number of specific tasks required by the host device
  - Because such an embedded system is dedicated to a specific task or tasks, the processor and associated components can be engineered to reduce size and cost

Figure 1.15

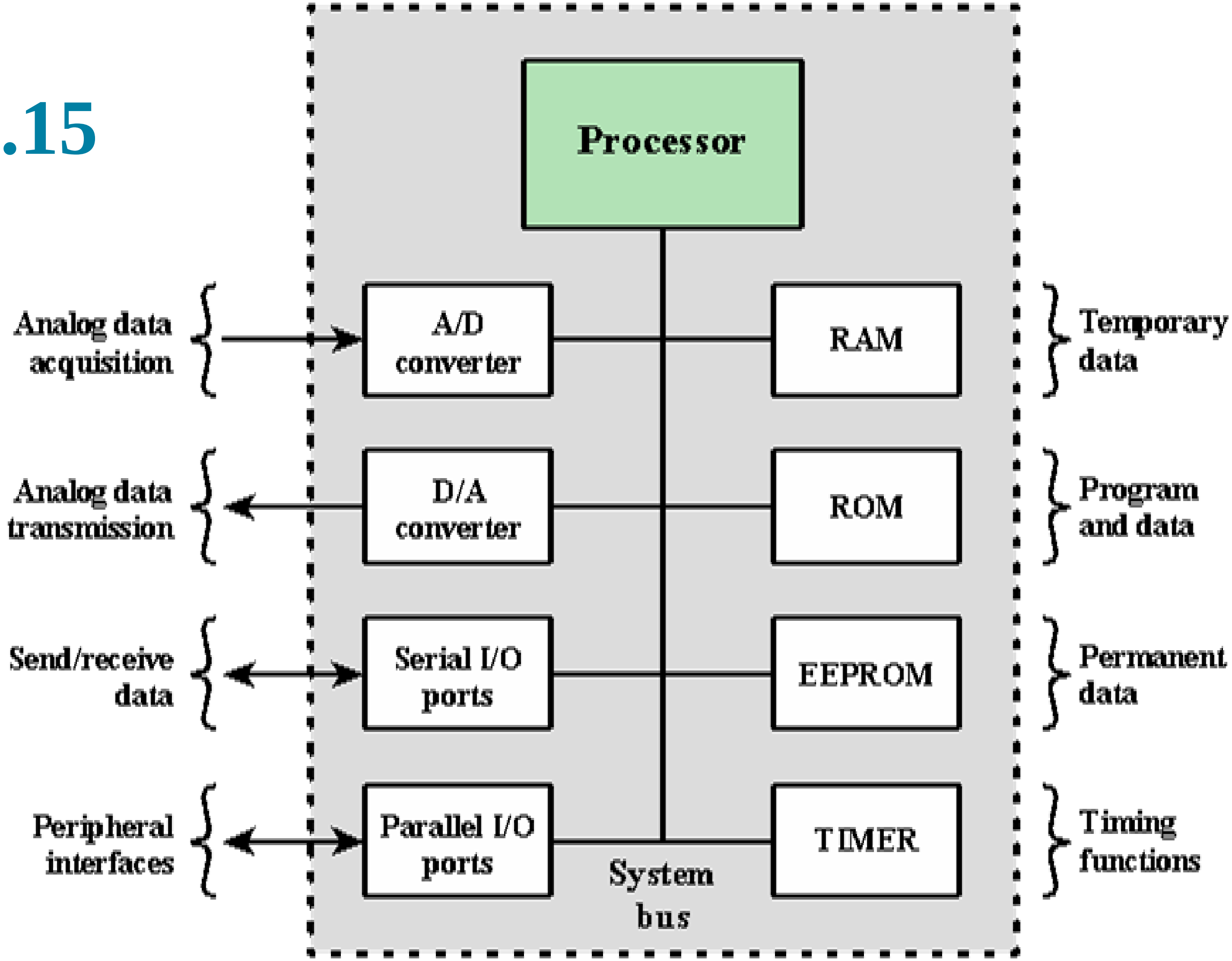
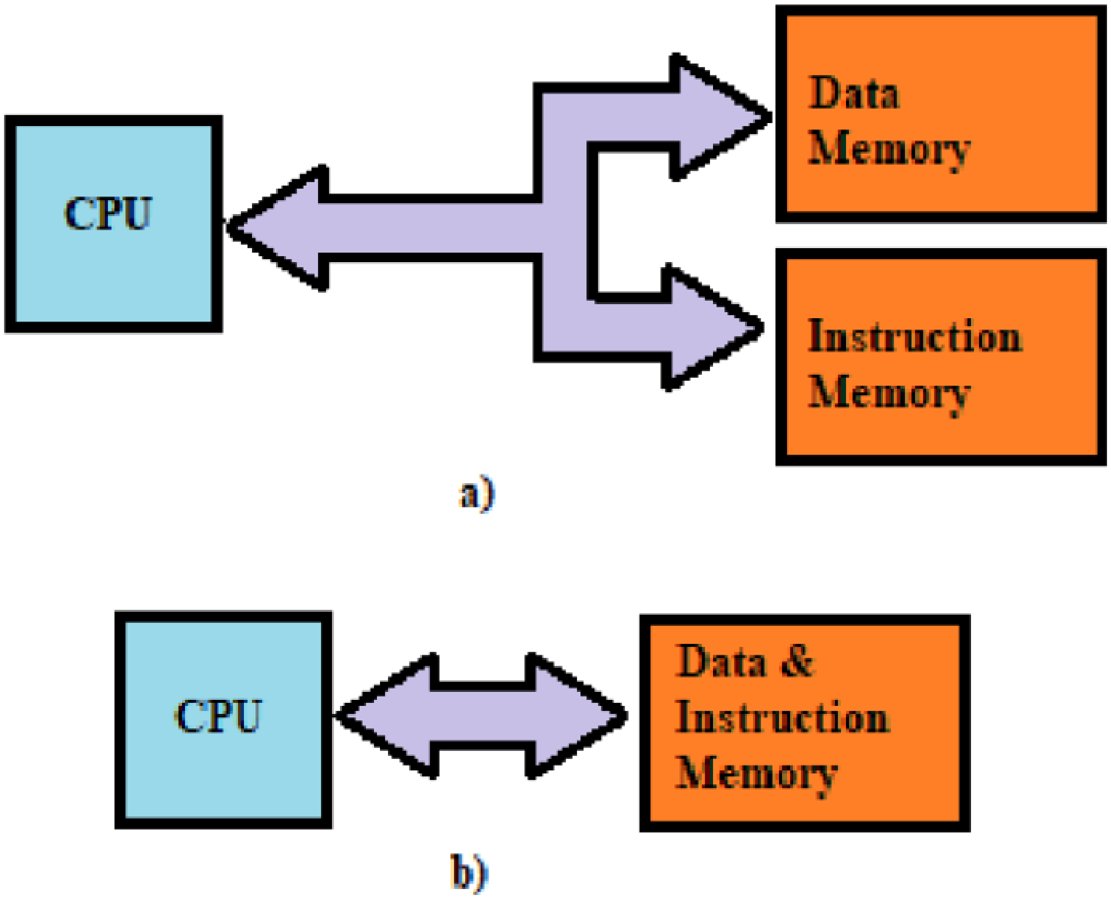


Figure 1.15 Typical Microcontroller Chip Elements

Deeply Embedded Systems

- Subset of embedded systems
- Has a processor whose behavior is difficult to observe both by the programmer and the user
- Uses a microcontroller rather than a microprocessor
- Is not programmable once the program logic for the device has been burned into ROM
- Has no interaction with a user
- Dedicated, single-purpose devices that detect something in the environment, perform a basic level of processing, and then do something with the results
- Often have wireless capability and appear in networked configurations, such as networks of sensors deployed over a large area
- Typically have extreme resource constraints in terms of memory, processor size, time, and power consumption

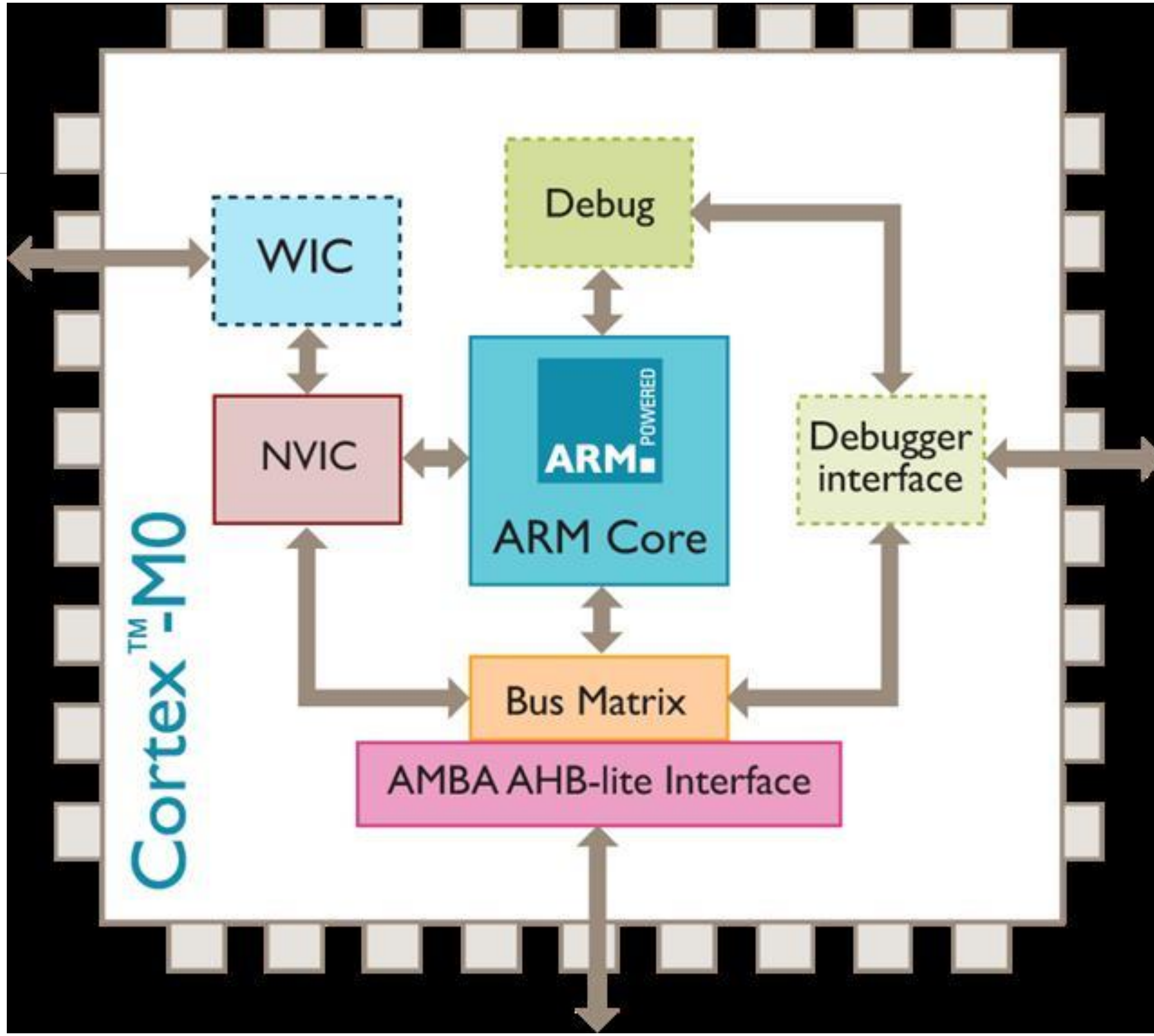
Von Neumann veHarward Mimarileri



https://www.researchgate.net/figure/a-Harvard-Architecture-b-Von-Neumann-Architecture_fig2_372114908

ARM

- Refers to a processor architecture that has evolved from RISC design principles and is used in embedded systems
- Family of RISC-based microprocessors and microcontrollers designed by ARM Holdings, Cambridge, England
- Chips are high-speed processors that are known for their small die size and low power requirements
- Probably the most widely used embedded processor architecture and indeed the most widely used processor architecture of any kind in the world
- Acorn RISC Machine/Advanced RISC Machine



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ARM Products

Cortex-A

Cortex-R

Cortex-M

- Cortex-M0
- Cortex-M0+
- Cortex-M3
- Cortex-M4
- Cortex-M7
- Cortex-M23
- Cortex-M33

Figure 1.16

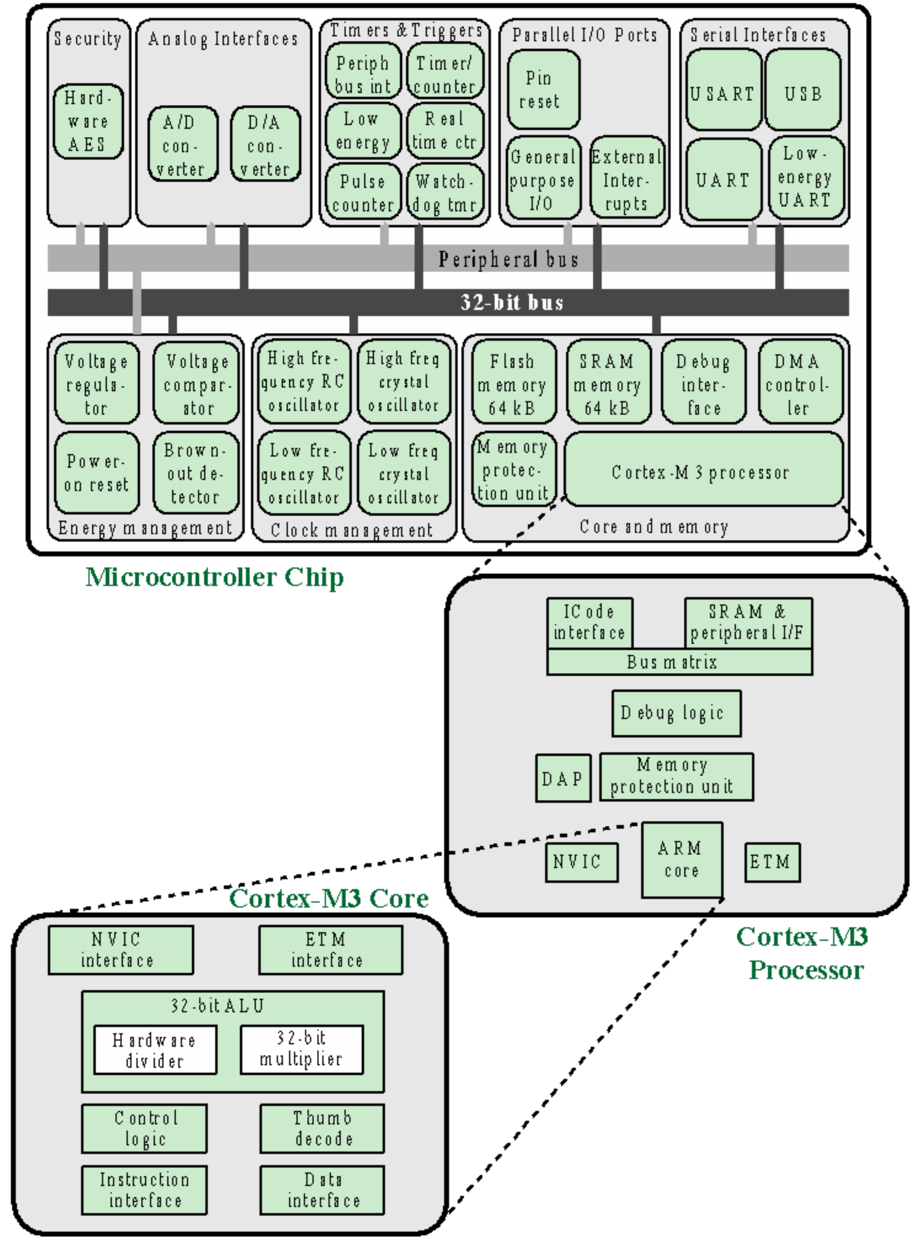

Figure 1.16 Typical Microcontroller Chip Based on Cortex-M3

Summary

Chapter 1

Basic Concepts and Computer Evolution

- Organization and architecture
- Structure and function
- The IAS computer
- Gates, memory cells, chips, and multichip modules
  - Gates and memory cells
  - Transistors
  - Microelectronic chips
  - Multichip module
- The evolution of the Intel x86 architecture
- Embedded systems
  - The Internet of things
  - Embedded operating systems
  - Application processors versus dedicated processors
  - Microprocessors versus microcontrollers
  - Embedded versus deeply embedded systems
- ARM architecture
  - ARM evolution
  - Instruction set architecture
  - ARM products

Additional References

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