بسم اللہ الرحمن الرحیم

EE213 COMPUTER ORGANIZATION AND ASSEMBLY LANGUAGE

Spring 2019

Instructor

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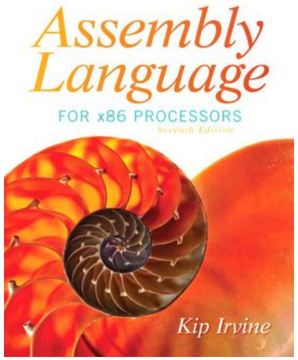
Recommended Text Book



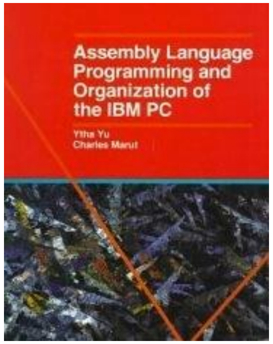
Assembly Language

FOR X86 PROCESSORS

Seventh Edition

Kip R. Irvine

- **Reference Text Book**



Assembly Language Programming and Organization of the IBM PC

Ytha Yu, Charles Marut

MARKS DISTRIBUTION

- MID I (6th Week) : 15 %
- MID II (12th Week) : 15 %
- Quizzes/Assignment(s) : ~20%
- Semester Project : ~ 10%
- Final: ~40% – ~50 %

PREREQUISITES

Digital Logic Design

Programming experience with some high-level language such C, C ++, Java …

COURSE OBJECTIVE

- Covering the basics of computer organization with emphasis on the lower level abstraction of a computer system
- Programming Methodology of low-level languages, the assembly language.
- Accessing computer hardware directly
- Overview of a user-visible architecture (of Intel 80x86 processors)
- Intel 80x86 instruction set, assembler directives, macro, etc.
- *Device handlers*
- How is it possible to interface high-level language and low-level language modules

TEACHING PLAN

- Coverage from ~**12** chapters from recommended book.
- Additional coverage from reference material.
- **Mid I:**
  - Coverage from Ch#1 – Ch#5 (~ 5 Chapters)
  - Quiz I
- **Mid II:**
  - Ch#5 – Ch#8 (~ 4 Chapters)
  - Quiz II
  - Semester Project
- **Finals**
  - Ch#9, Ch#12, Ch#13, Ch#17, Reference Material
  - Quiz III
  - Semester Assignment

ASSEMBLY LANGUAGE (ASM)

- Machine-dependent, low-level language that uses words instead of binary code to program a specific computer system

  - ***Assembler*** is a utility program that converts source code programs from assembly language into machine language.

  - A *linker* is a utility program that combines individual files created by an assembler into a single executable program.

- Strong correspondence between the language and the architecture's machine code instructions.

- Specific to a particular computer architecture.

WHY ASSEMBLY LANGUAGE

- You'll be able to choose better high-level language statements.
- To learn the costs associated with various high-level constructs.
- Direct hardware manipulation
- Access to specialized processor instructions, or to address critical performance issues
- For writing the compilers or device drivers, write some code in assembly language.

COMPUTER ORGANIZATION

- Computer organization describes *how* a task is done by the computer.
  - Usually a high-level description of the logic, memory, etc.

- **Computer Architecture VS Computer's organization**

- Computer architecture is abstract model and are those attributes that are visible to programmer
  - instructions sets, no of bits used for data, addressing techniques.

- Computer organization expresses the realization of the architecture
  - how features are implemented like these registers, those data paths or this connection to memory
  - how different components of computer are linked together to meet the requirements .

- Computer architecture comes before computer organization.

Assembly Language and the Machine Language

- Assembly language has a *one-to-one* relationship with machine language.

High Level Language and the Assembly Language

- High-level languages have a *one-to-many* relationship with assembly language and machine language.

- *Assembly language* consists of statements written with short mnemonics such as ADD, MOV, SUB, and CALL.

Machine Language	Assembly Language	High-Level Language
Collection of binary numbers	Symbolic form of machine language (I.e. symbolic names are used to represent operations, registers & memory locations	Combines algebraic expressions & symbols taken from English language (ex. C++, java, Pascal, FORTRAN, …etc)
Ex. 10100001 00000000 00000000 00000101 00000100 00000000 10100011 00000000 00000000	Ex. **MOV AX, A** **ADD AX, 4** **MOV A, AX**	Ex. **A = A + 4**

The Instruction Set Architecture (ISA)

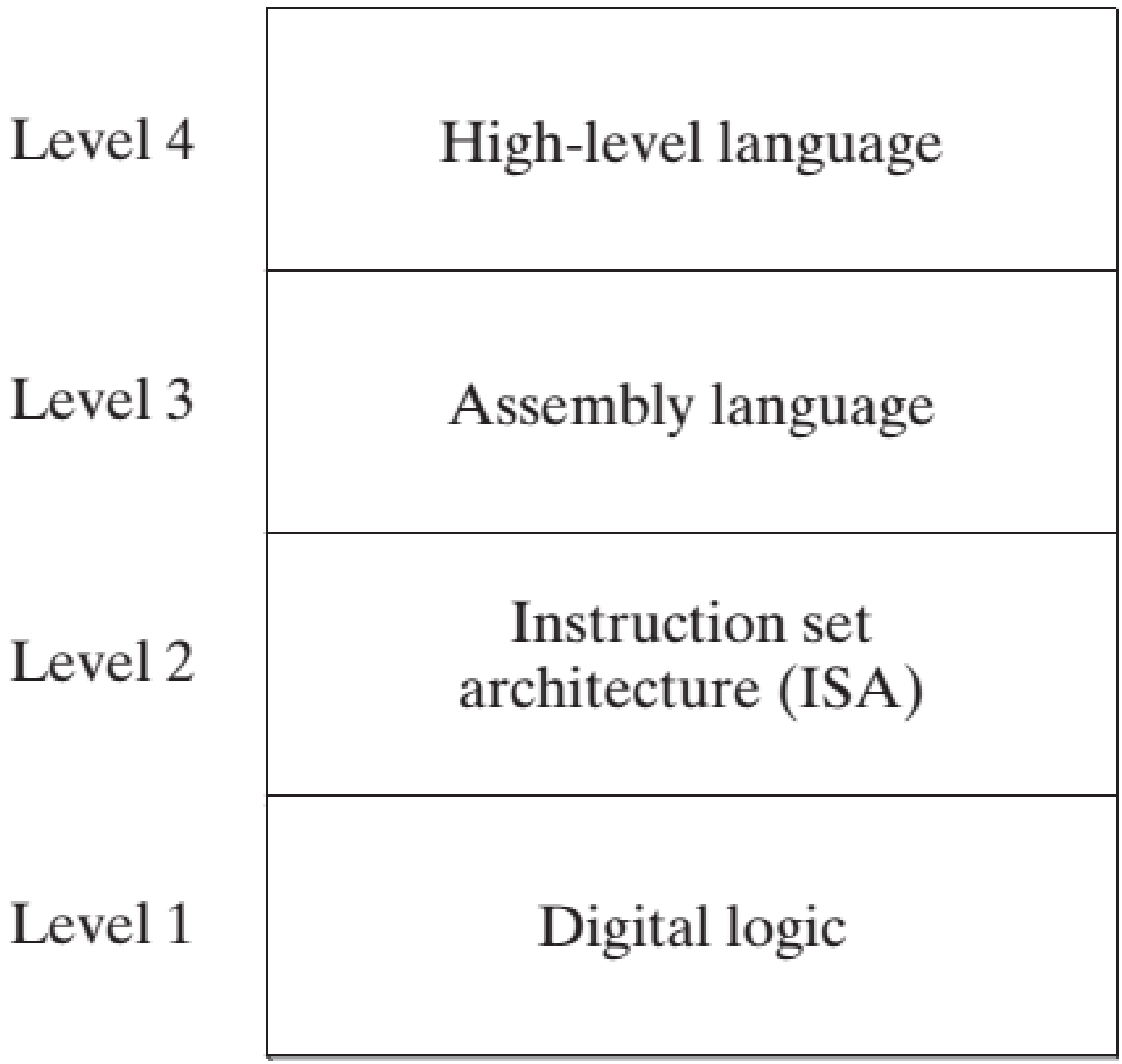
- instruction set, in the processor, to carry out basic operations, such as move, add, or multiply.
  - also referred to as *machine language*.

Assembly Language

- Above the ISA level, assembly language uses short mnemonics which are easily translated to the ISA level.

High Level Languages

- Above the assembly level, their powerful statements are translate into multiple assembly language instructions

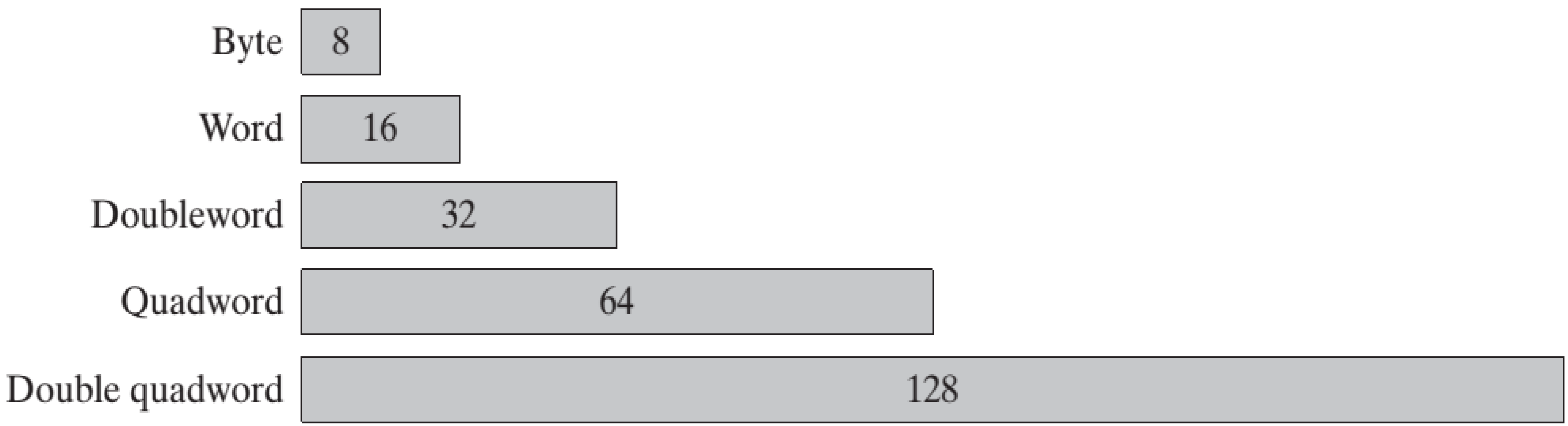

Level 4
High-level language
Level 3
Assembly language
Level 2
Instruction set architecture (ISA)
Level 1
Digital logic

DATA REPRESENTATION

System	Base	Possible Digits
Binary	2	0 1
Octal	8	0 1 2 3 4 5 6 7
Decimal	10	0 1 2 3 4 5 6 7 8 9
Hexadecimal	16	0 1 2 3 4 5 6 7 8 9 A B C D E F

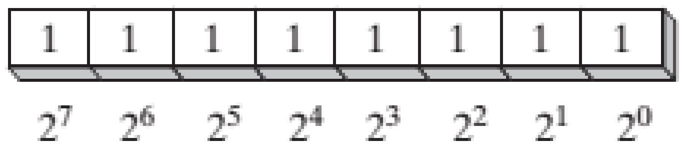
MSB		LSB	
	1 0 1 1 0 0 1 0 1 0 0 1 1 1 0 0		
15		0	Bit number

STORAGE SIZES

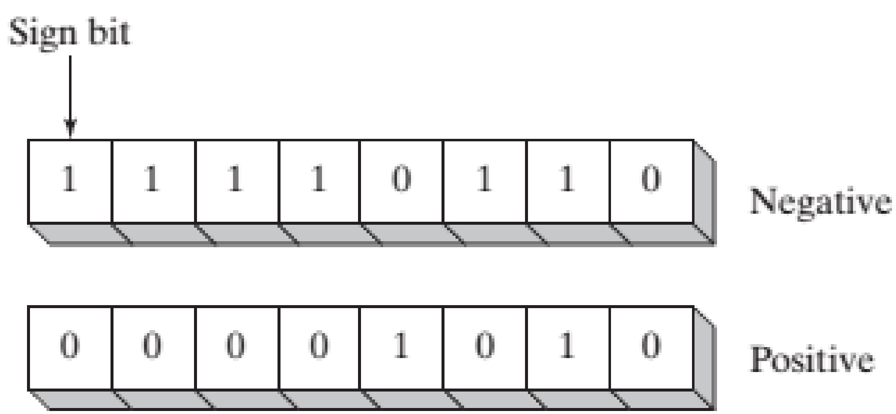


SIGNED VS UNSIGNED

- Unsigned



- Signed



TWO'S-COMPLIMENT REPRESENTATION

- Negative integers use *two's-complement* representation.

Starting value	00000001
Step 1: Reverse the bits	11111110
Step 2: Add 1 to the value from Step 1	11111110 +00000001
Sum: Two's-complement representation	11111111

BOOLEAN EXPRESSIONS

- NOT

X	$\neg$X
F	T
T	F

- AND

X	Y	X $\wedge$ Y
F	F	F
F	T	F
T	F	F
T	T	T

- OR

X	Y	X $\vee$ Y
F	F	F
F	T	T
T	F	T
T	T	T

2
X86 Processor Architecture

OUTLINES

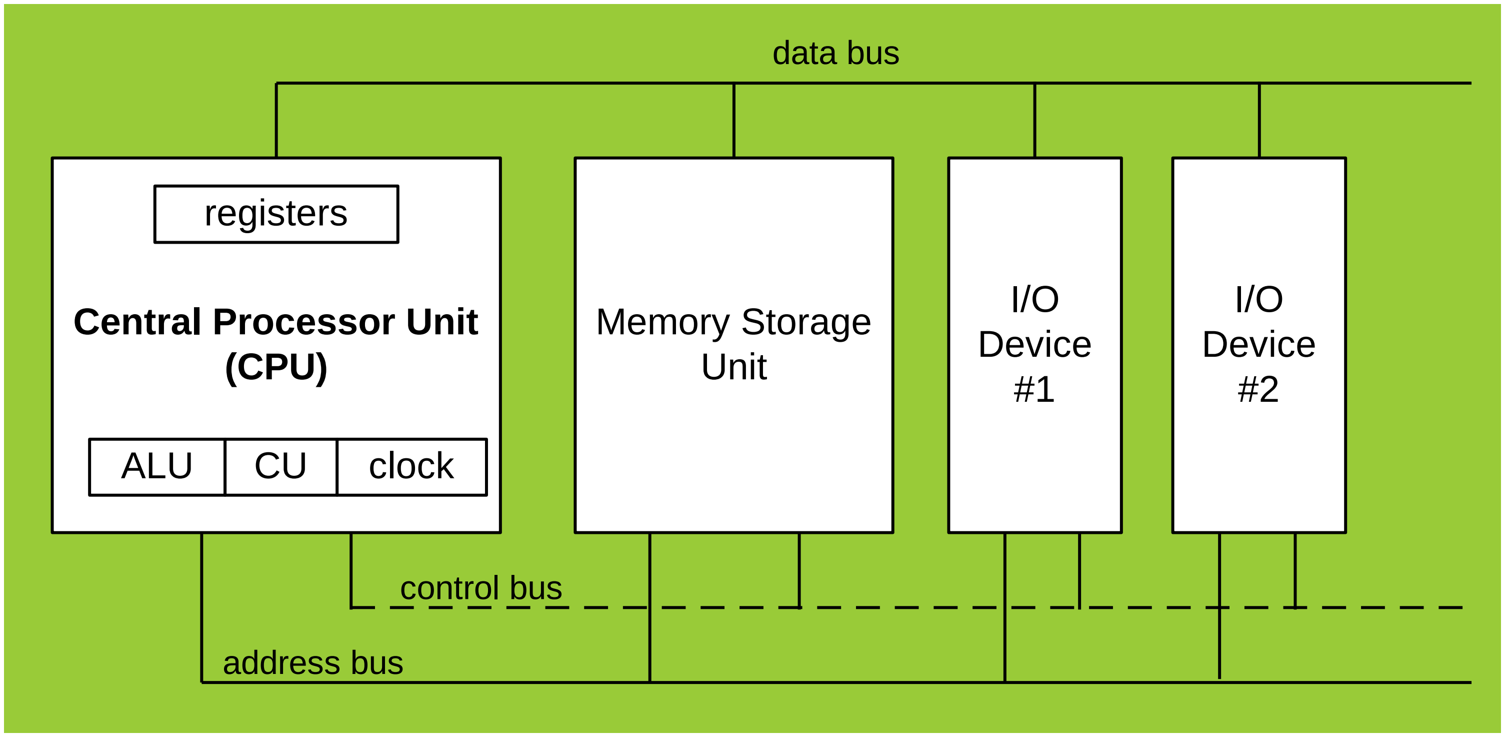
- General Concepts
- 32-Bit x86 Processors
- Components of a Typical x86 Computer

GENERAL CONCEPTS

- Basic microcomputer design

- Instruction execution cycle

BASIC MICROCOMPUTER DESIGN



Clock synchronizes CPU operations

Control Unit (CU) coordinates sequence of execution steps

ALU performs arithmetic and bitwise processing

- **Memory Storage Unit**: primary memory
- **I/O Devices**: Input/Output devices
- **Data Bus**: moves data between memory, i/o, and registers
- **Control Bus**: determines where data comes from and goes, and ALU activities
- **Address Bus**: selects where data comes from or goes to

INSTRUCTION EXECUTION CYCLE

- An instruction is not executed all at once, the CPU has to go through the *Instruction Execution Cycle* (a sequence of steps) to execute a machine instruction:

1. CPU has to **fetch the instruction** from an area of memory called the *instruction queue.*
2. Next, the CPU **decodes** the instruction by looking at its binary bit pattern.
3. If operands are involved, the CPU **fetches the operands** from registers and memory.
4. Next, the CPU **executes** the instruction, using any operand values it fetched during the earlier step.
5. Finally, if an output operand was part of the instruction, the CPU **stores the result** of its execution in the operand.

INSTRUCTION EXECUTION CYCLE

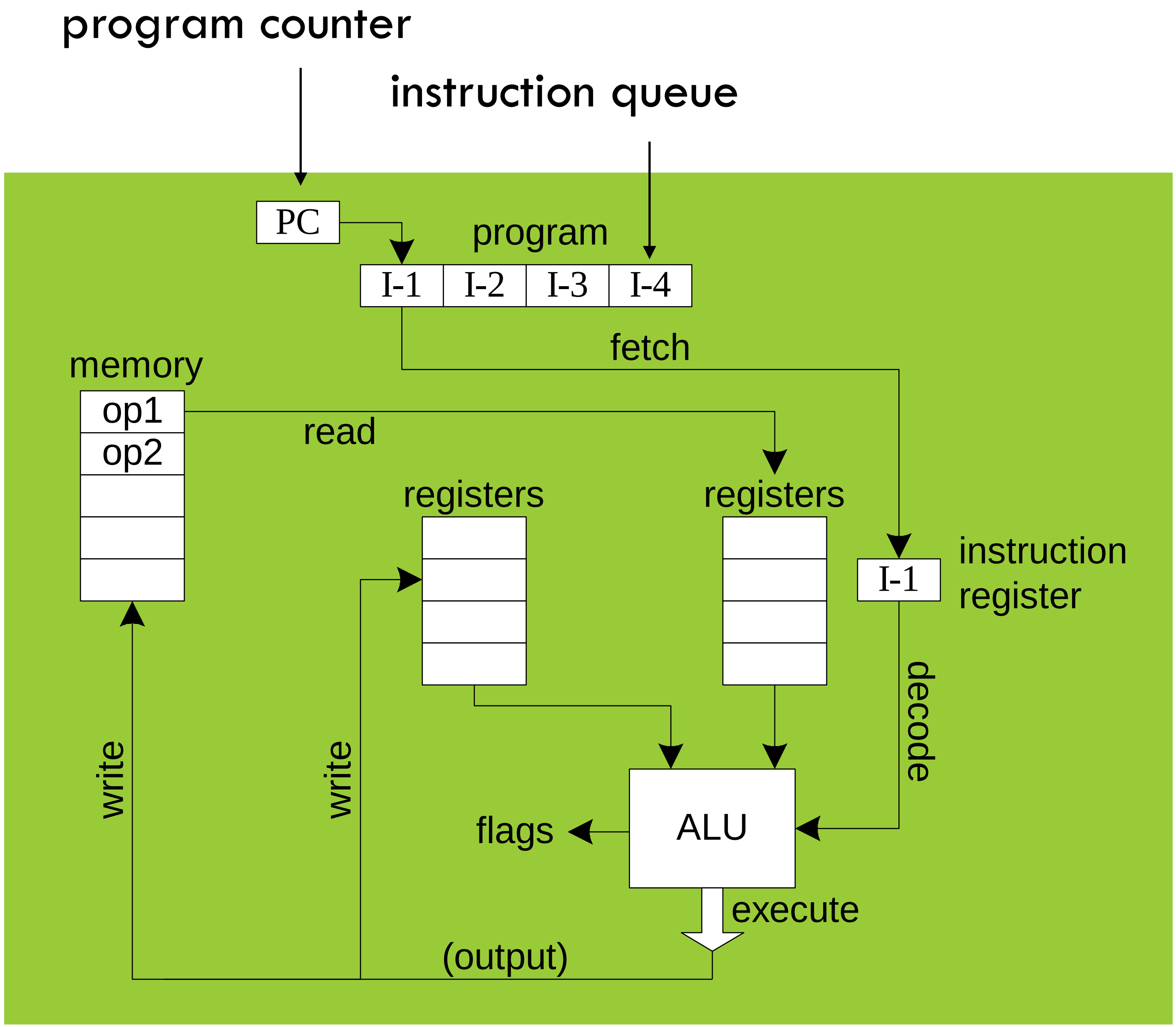
Fetch

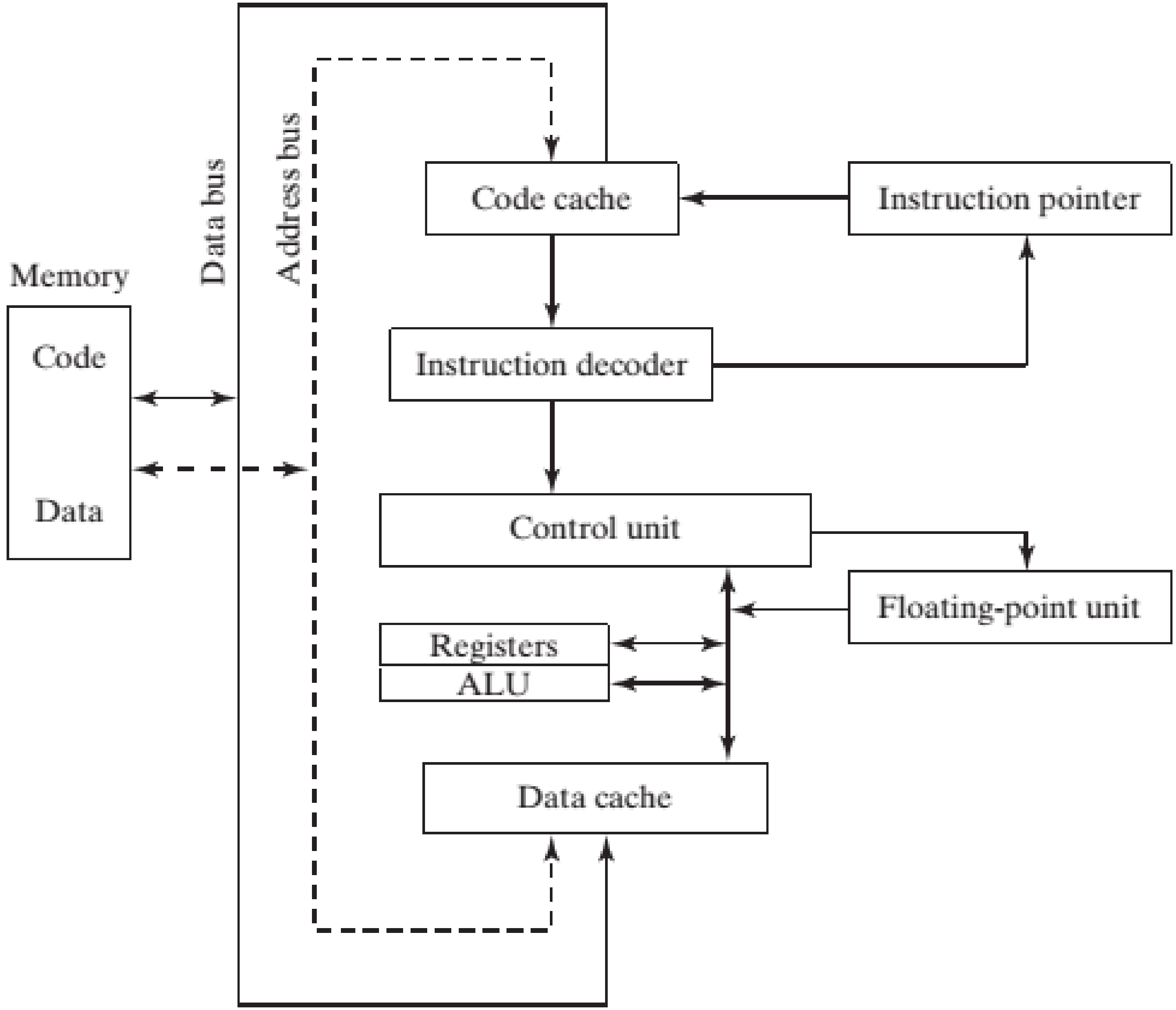
Decode

Fetch operands

Execute

Store output




Memory
Code
Data
Data bus
Address bus
Code cache
Instruction pointer
Instruction decoder
Control unit
Floating-point unit
Registers
ALU
Data cache

32-BIT X86 PROCESSORS

- Modes of Operation
- Basic Execution Environment
- x86 Memory Management

MODES OF OPERATION

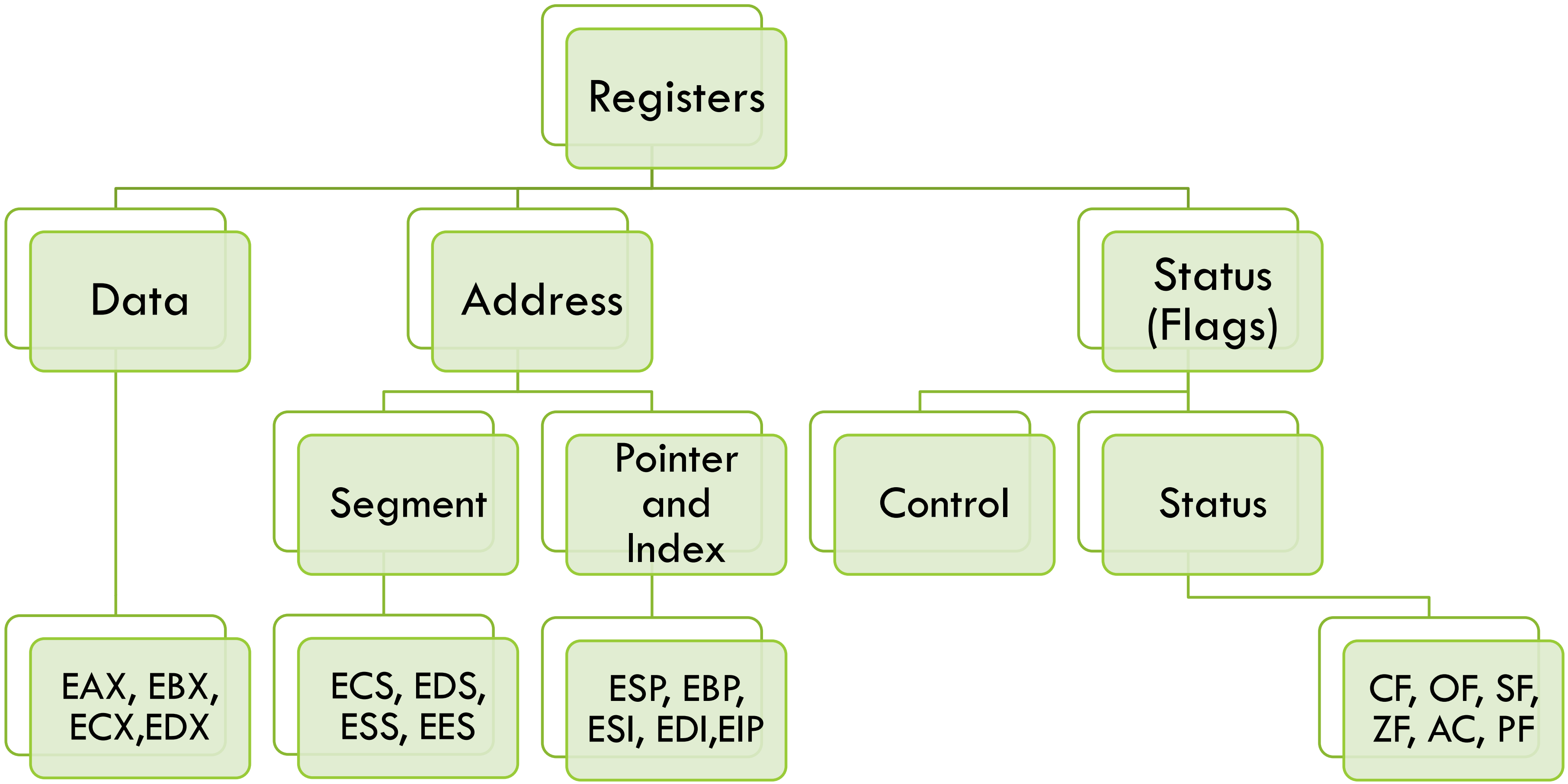
- The *CPU privilege levels.*
- ***Protected Mode****:* all instructions are available.
- **Real-address Mode:** implements programming environment of Intel8086 processor
- **System Management Mode:** provides OS for power management, system security, diagnostics etc.
- **Virtual-8086 mode**
  - hybrid of Protected
  - each program has its own 8086 computer

BASIC EXECUTION ENVIRONMENT

Basic Program Execution Registers

- *Registers* are high-speed named storage locations directly inside the CPU.

- The registers are classified according to the functions they perform:
  - **Data/General Purpose Registers** hold data for an operation
  - ***Address registers*** hold the address of an instruction or data
  - **Status register** keeps the current status of the processor.


Registers
Data
Address
Status (Flags)
Segment
Pointer and Index
Control
Status
EAX, EBX, ECX,EDX
ECS, EDS, ESS, EES
ESP, EBP, ESI, EDI,EIP
CF, OF, SF, ZF, AC, PF

- **Data Registers (EAX, EBX, ECX, EDX)**: These four registers are available to the programmer for general data manipulation.
  - The high and low bytes of the data registers can be accessed separately.

  - **EAX** (Extended Accumulator Register) is preferred to use in in arithmetic, logic and control instructions.

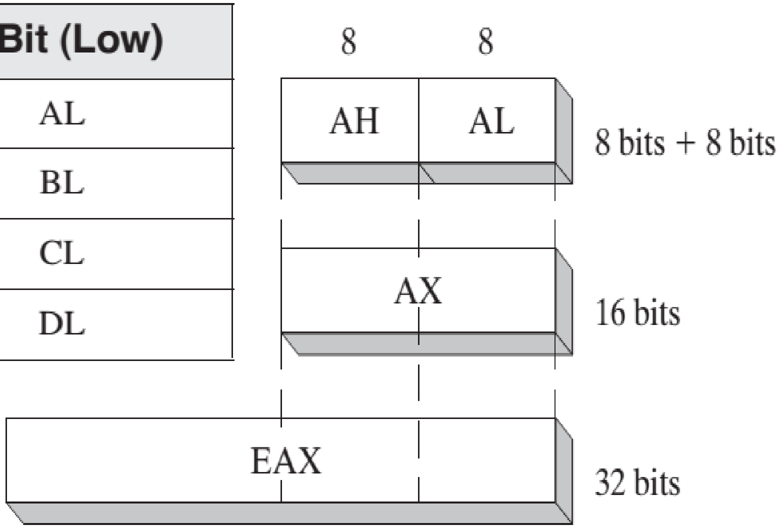
  - **EBX** (Extended Base Register) is used to serve as an address register.

  - **ECX** (Extended Counter Register) serves as loop counter.

  - **EDX** (Extended Data Register) is used in multiplication and division.

- Portions of some registers can be addressed as 8-bit values.
  - For example, the AX register has an 8-bit upper half named AH and an 8-bit lower half named AL.

32-Bit	16-Bit	8-Bit (High)	8-Bit (Low)
EAX	AX	AH	AL
EBX	BX	BH	BL
ECX	CX	CH	CL
EDX	DX	DH	DL



- **Segment Registers:**

- **Memory Segment**: A memory segment is a block of consecutive memory bytes. Each segment is identified by a segment number, staring with 0.

- Within a segment, a memory location is specified by giving an **off- set**. This is the number of bytes from the beginning of the segment.

- A memory location may be specified by providing a segment number and an offset, written in the format **segment:offset**.
- E.g. **A4FB:4872h** means offset **4872h** within segment **A4FBh.**

- The program's code, data, and stack are loaded into different memory segments, we call them the **code segment**, **data segment**, and **stack segment.**
  - Stack segment holds local function variables and function parameters

- To keep track of the various program segments, segment register are used.

- The ECS (Extended Code Segment), EDS (Extended Data Segment), and ESS (Extended Stack Segment) registers contain the code, data, and segment numbers respectively.

  - If a program needs to access a second data segment, it can use the EES (Extended Extra segment) register.

- **Pointer and Index Register (ESP, EBP, ESI, EDI)**
- The registers ESP, EBP, ESI, and EDI normally point to (contain the offset addresses of) memory locations.
- Unlike segment registers, the pointers and index registers can be used in arithmetic and other operations.
  - **ESP (Extended Stack Pointer):** this register is used in conjunction *with ESS for accessing* the stack segment.
  - **EBP (Extended Base Pointer):** these registers are used to access data on the stack and other segments.
  - **ESI (Extended Source Index):** these registers are used to point to memory locations in the data segment addressed by EDS.
  - **EDI (Extended Destination Index):** these registers perform the same functions as ESI, these are used to access memory location addressed by EES.

- **Extended Instruction Pointer (EIP):**
- The memory registers covered so far are for data access.
- To access instructions, x86 uses the ECS and EIP registers.
- The ECS contain the number(base address) of next instruction to be executed and EIP contains the offset.
  - EIP is updated every time an instruction is executed so that it will point to the next instruction.

- **FLAGS Register**
- The purpose of the FLAGS register is to indicate the status of the microprocessor. It does this by the setting of individual bits called *flags*.
  - A flag is *set* when it equals 1; it is *clear* (or reset) when it equals 0.

- There are two kinds of flags: **control flags** and **status flags**.
- The control flags enable or disable certain operations of the processor.
  - for example, if the IF (interrupt flag) is cleared (set to 0), inputs from the keyboard are ignored by the processor.
- The status flags reflect the result of an instruction executed by the processor.
- For example, when a subtraction operation results in a 0, the **ZF** (zero flag) is set to 1 (true).
- **Carry Flag**: set when the result of an *unsigned* arithmetic operation is too large to fit into the destination.
  - **CF = 1** if there is a carry out from the most significant bit (msb) on addition, or there Is a borrow into the MSB on subtraction.
- The **Overflow** flag (OF) is set when the result of a *signed* arithmetic operation is too large or too small to fit into the destination.
  - **OF = 1** if signed overflow occurred, otherwise it is 0

- The **Sign** flag (SF) is set when the result of an arithmetic or logical operation generates a negative result.
  - **SF = 1** if the msb of a result is 1; **SF = 0** if the msb is 0

- The **Zero** flag (ZF) is set when the result of an arithmetic or logical operation generates a result of zero.

- The **Auxiliary Carry** flag (AC) is set when an arithmetic operation causes a carry from bit 3 to bit 4 in an 8-bit operand.

- The **Parity** flag (PF) is set if the least-significant byte in the result contains an even number of 1 bits.

- In x86 processors, there are:
  - eight general-purpose registers
  - six segment registers
  - a processor status flags register (EFLAGS)
  - an instruction pointer (EIP).

- **General Purpose Registers:** These are primarily used for arithmetic and data movement.

Data Registers:

- EAX
- EBX
- ECX
- EDX

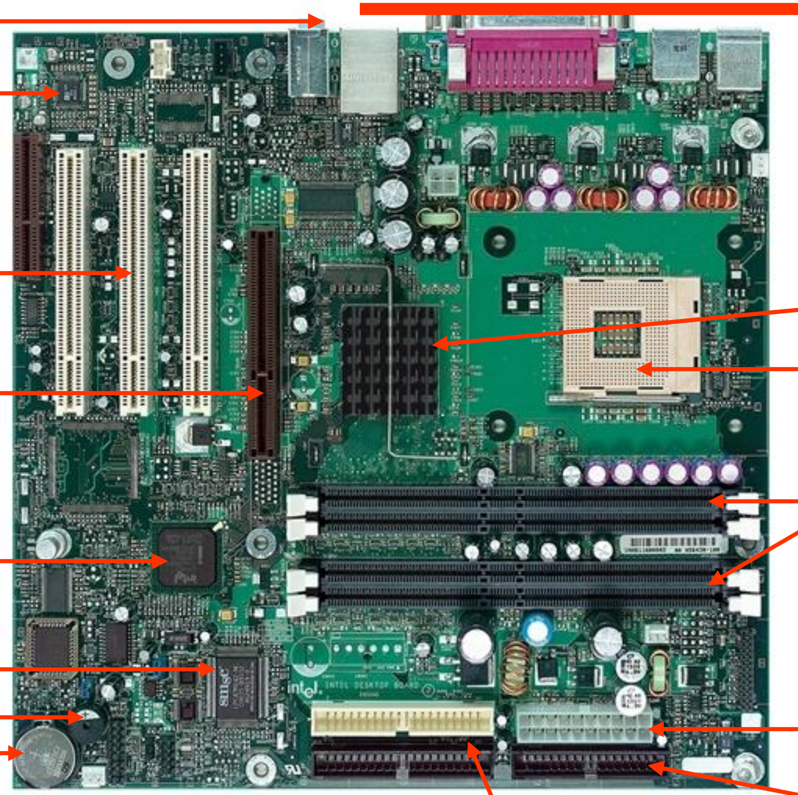
Address Registers:

- ESI
- EDI
- EBP
- ESP

2.4 COMPONENTS OF A TYPICAL X86 COMPUTER

Motherboard

- Heart of microcomputer, having following components:
  - CPU Sockets
  - Memory Slots (or RAM slots)
  - BIOS (*basic input–output system)* computer chips.
  - CMOS (Complementary metal–oxide–semiconductor) RAM.
  - Connectors for mass-storage devices
  - USB connectors for external devices
  - Keyboard and mouse ports
  - PCI (Peripheral Component Interconnect) bus connectors for sound cards, graphics cards, etc.



Source: Intel® Desktop Board D850MD/D850MV Technical Product Specification

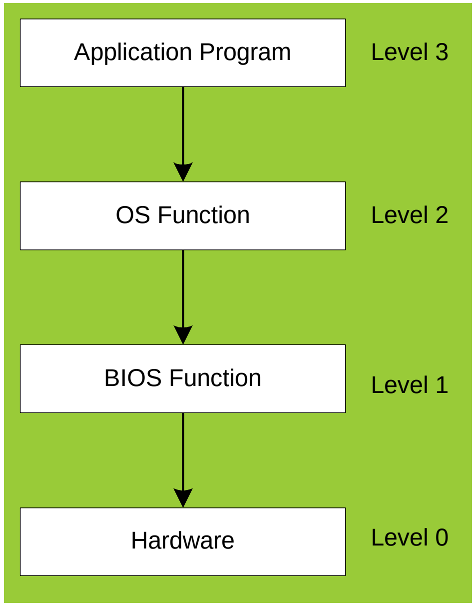
Memory

- Several basic types of memory are used in Intel-based systems:
  - **Read Only Memory (ROM)**: is permanently burned into a chip and cannot be erased.
  - **Erasable Programmable Read-Only Memory (EPROM):** can be erased slowly with ultraviolet light and reprogrammed
  - **Dynamic Random-Access Memory (DRAM)**: it is where programs and data are kept when a program is running. Must be refreshed constantly.
  - **Static RAM (SRAM)**: expensive; used for cache memory; no refresh required.
  - **Video RAM (VRAM):** holds video data. optimized for constant video refresh.
  - **CMOS (complimentary metal oxide semiconductor) RAM**: stores system setup information.

2.5 INPUT–OUTPUT SYSTEM

- I/O need not be accomplished by directly accessing hardware.
- I/O is available at different access levels:
  - **High Level Language Functions:** HLL contain function to perform I/O
  - **Operating system:** Programmers can call operating system functions from a library known as the API (*application programming interface*).
  - **BIOS:** The *basic input–output system* is a collection of low-level subroutines that communicate directly with hardware devices. Drivers that communicate directly with devices
- Device Drivers *Device drivers* are programs that permit the operating system to communicate directly with hardware devices and the system BIOS.

DISPLAYING A STRING OF CHARACTERS

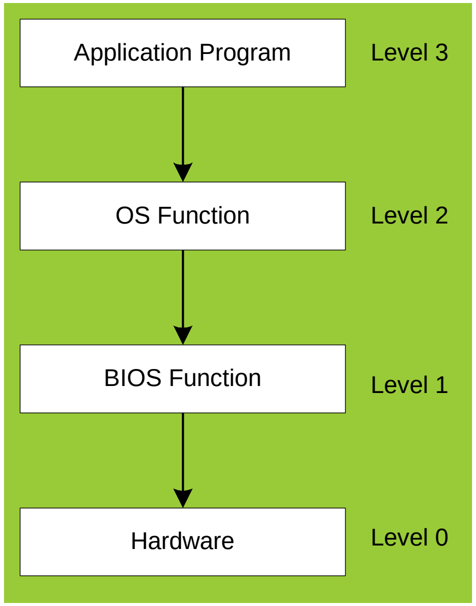


When a HLL program displays a string of characters, the following steps take place:

Level 3: The library function of HLL calls an operating system function, passing a string pointer.

Level 2: The operating system function uses a loop to call a BIOS subroutine, passing it the ASCII code and color of each character. The operating system calls another BIOS subroutine to advance the cursor to the next position on the screen.

DISPLAYING A STRING OF CHARACTERS



Level 1: The BIOS subroutine receives a character, maps it to a particular system font, and sends the character to a hardware port attached to the video controller card.

Level 0: The video controller card generates timed hardware signals to the video display that control the raster scanning and displaying of pixels.

SUMMARY

Assembly Language and its Objective(s)

Computer Organization VS Computer Architecture

High Level, Low Level, Machine Language

Instruction Set Architecture

Data Representation

Storage Sizes

Signed VS Unsigned Values

Two’s Complement

Boolean Expressions

SUMMARY

Central Processing Unit (CPU)

Arithmetic Logic Unit (ALU)

Instruction execution cycle

Real mode and Protected mode

Base vs Offset Address

Registers

Motherboard components

Memory types

Input/Output and access levels