Assembly Level Machine Organization

Introduction

1945: John von Neumann – Wrote a report on the stored program concept, known as the First Draft of a Report on EDVAC – also Alan Turing… Konrad Zuse… Eckert & Mauchly systems.

The basic structure proposed in the draft became known as the "von Neumann machine" (or model).

– a memory, containing instructions and data

– a processing unit, for performing arithmetic and logical operations

– a control unit, for interpreting instructions

Intel 8086

Evolutionary design

– Backwards compatible up until 8086, introduced in 1978

– Added more features as time goes on

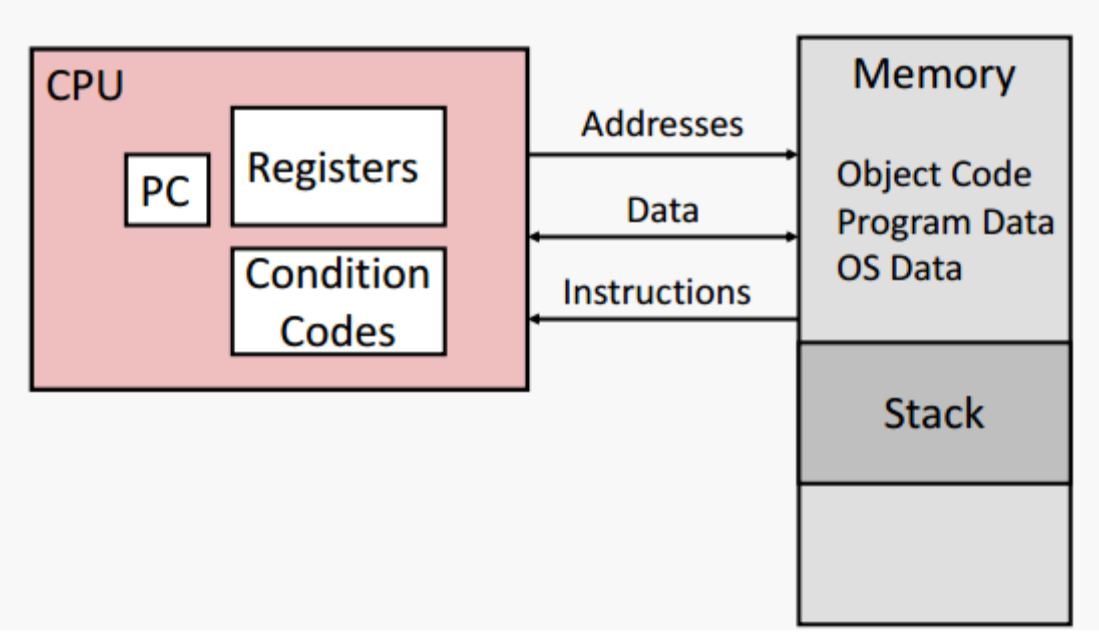
Complex instruction set computer (CISC)

– Many different instructions with many different formats

But, only small subset encountered with Linux programs

– Hard to match performance of Reduced Instruction Set Computers (RISC) –

But, Intel has done just that. In terms of speed. Less so for low power



Programmer-Visible State

– PC: Program counter

Address of next instruction

– Register file

Heavily used program data

– Condition codes

Store status information about most recent arithmetic operation

Used for conditional branching

– Memory

Byte addressable array

Code, user data, (some) OS data

Includes stack used to support procedures

Assembly Language

Translating Languages

English: Display the sum of A times B plus C.

C++: cout << (A * B + C);

Assembly Language:

mov A, Imed1

mul B

add A, C

The Compilation System

1. **Low-level language**
- Each instruction performs a much lower-level task compared to a high-level language instruction
- Most high-level language instructions need more than one assembly instruction
2. **One-to-one correspondence between assembly language and machine language instructions**
- For most assembly language instructions, there is a machine language equivalent
3. **Directly influenced** by the instruction set and architecture of the processor (CPU)

Advantages of Assembly Languages

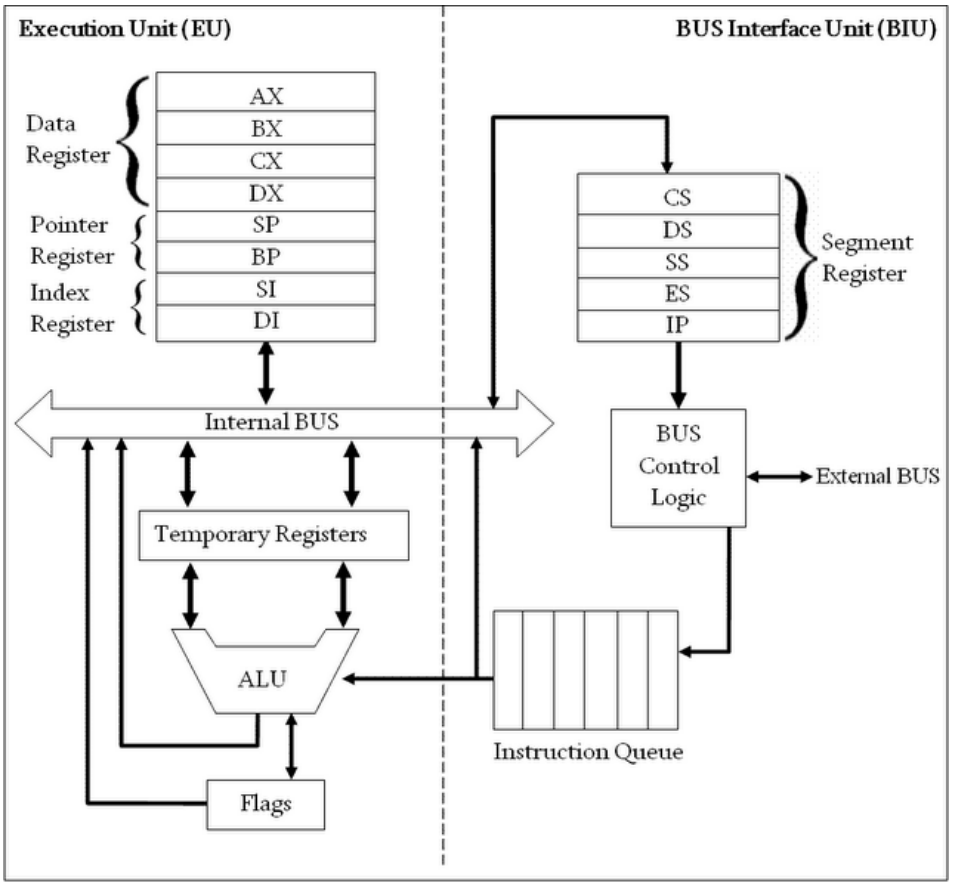
1. Space-efficiency (e.g. hand-held device software, etc)
2. Time-efficiency (e g Real (e.g. Real -time applications etc) time applications, etc)
3. Accessibility to system hardware (e.g., Network interfaces, device drivers, video games, etc)

Advantages of High-level Languages

1. Development
2. Maintenance (Readability)
3. Portability (compiler, virtual machine)

CPU:Bus Interface Unit and Execution Unit

The internal function of 8086 processor are partitioned logically into processing units ,Bus Interface Unit(BIU) and Execution Unit (EU).general block diagram of 8086 processor is shown in figure (4).



Bus Interface Unit(BIU) and Execution Unit (EU).

Execution Unit (EU) : Execution unit receives program instruction codes and data from the BIU, executes them and stores The results in the general registers. It can also store the data in a memory location or send them to an I/O device by passing the data back to the BIU. This unit, EU, has no connection with the system Buses. It receives and outputs all its data through BIU.

Bus Interface Unit : As the EU has no connection with the system Busses, this job is done by BIU. BIU and EU are connected with an internal bus. BIU connects EU with the memory or I/O circuits. It is responsible for transmitting data, addresses and control signal on the busses.

EU is used mainly to execute instructions. It contains a circuit called the arithmetic and logic unit (ALU). The data for operations are stored in circuit called Registers. The EU has eight registers for storing data; their names are AX, BX, CX, DX, SI, DI, BP, SP and FLAGS register. The EU accepts instructions and data that have been fetched by the BIU and then processes the information. Data processed by the EU can be transmitted to the memory or peripheral devices through the BIU. EU has no direct connection with the outside world and relies solely on the BIU to feed it with instruction and data. It is here that instructions are received, decoded, and executed from the instruction queue portion of BIU. The instructions are taken from the top of the instruction queue on the first-in, first-out, or FIFO, basis.

ALU (Arithmetic & Logic Unit) : This unit can perform various arithmetic and logical operation, if required, based on the instruction to be executed. It can perform arithmetical operations, such as add, subtract, increment, decrement, convert byte/word and compare etc and logical operations, such as AND, OR, exclusive OR, shift/rotate and test etc.

The internal processor bus is needed to transfer data between the various registers and the ALU because the ALU in fact operates only on data in the internal processor memory

Address registers may themselves be somewhat general purpose, or they may be devoted to a particular addressing mode. Examples include; Segment pointers, Index registers, Stack pointer

- **Index Registers**
  1. **SP (Stack Pointer):** This is stack pointer register pointing to program stack. It is used in conjunction with SS for accessing the stack segment.
  2. **BP (Base Pointer):** This is base pointer register pointing to data in stack segment. Unlike SP, we can use BP to access data in the other segments.
  3. **SI (Source Index):** This is source index register which is used to point to memory locations in the data segment addressed by DS. By incrementing the contents of SI one can easily access consecutive memory locations.
  4. **DI (Destination Index):** This is destination index register performs the same function as SI. There is a class of instructions called string operations.

- **Segment Registers :** BIU has 4 segment busses, CS, DS, SS, ES. These all 4 segment registers holds the addresses of instructions and data in memory. These values are used by the processor to access memory locations. It also contains 1 pointer register IP. IP contains the address of the next instruction to execute by the EU.

  1- CS (Code Segment): The code segment register holds the base location of all executable instructions (code) in a program.

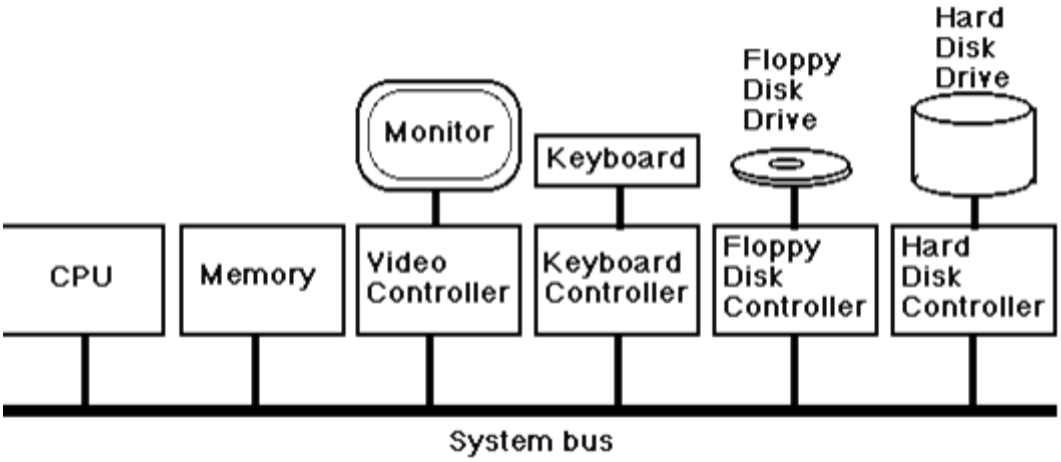
2- DS (Data Segment): the data segment register is the default base location for variables. The CPU calculates their location using the segment value in DS.

3- SS (Stack Segment): the stack segment register contain the base location of the stack.

4- ES (Extra Segment): The extra segment register is an additional base location for memory variables.

1) Input/output

In computing, **input/output** or **I/O**, is the communication between an information processing system (such as a computer) and the outside world, possibly a human or another information processing system. Inputs are the signals or data received by the system, and outputs are the signals or data sent from it. The term can also be used as part of an action; to "perform I/O" is to perform an input or output operation. I/O devices are used by a person (or other system) to communicate with a computer. For instance, a keyboard or a mouse may be an input device for a computer, while monitors and printers are considered output devices for a computer. Devices for communication between computers, such as modems and network cards, typically serve for both input and output.



Figure(3): I/O units communication

Variables

Syntax for a variable declaration:

name **DB** *value*

name **DW** *value*

DB – stays for Define Byte.

DW – stays for Define Word.

name – can be any letter or digit combination, though it should start with a letter. It's possible to declare unnamed variables by not specifying the name (this variable will have an address but no name).

value – can be any numeric value in any supported numbering system (hexadecimal, binary, or decimal), or "**?**" symbol for variables that are not initialized.

EX: MOV AL, var1

MOV BX, var2

RET ; stop the program (end)

Var1 DB 7

Var2 DW 1234h

Interrupts

Interrupts can be seen as a number of functions. These functions make the programming much easier, instead of writing a code to print a character you can simply call the interrupt and it will do everything for you. There are also interrupt functions that work with disk drive and other hardware. We call such functions **software interrupts**. Interrupts are also triggered by different hardware, these are called **hardware interrupts**. Currently we are interested in **software interrupts** only.

To make a **software interrupt** there is an **INT** instruction, it has very simple syntax:

INT value

Where **value** can be a number between 0 to 255 (or 0 to 0FFh), generally we will use hexadecimal numbers.

Each interrupt may have sub-functions. To specify a sub-function **AH** register should be set before calling interrupt.

Each interrupt may have up to 256 sub-functions (so we get 256 * 256 = 65536 functions). In general **AH** register is used, but sometimes other registers maybe in use. Generally other registers are used to pass parameters and data to sub-function.

1. INT 10h

The following example uses **INT 10h** sub-function **0Eh** to type a "Hello!" message. This functions displays a character on the screen, advancing the cursor and scrolling the screen as necessary.

```
ORG 100h
MOV AH, 0Eh
MOV AL, 'H' ;          ASCII code: 72
INT 10h ; print it!
MOV AL, 'e' ;          ASCII code: 101
INT 10h ; print it!
MOV AL, 'l' ;          ASCII code: 108
INT 10h ; print it!
MOV AL, 'l' ;          ASCII code: 108
INT 10h ; print it!
MOV AL, 'o' ;          ASCII code: 111
INT 10h ; print it!
MOV AL, '!' ;          ASCII code: 33
INT 10h ;              print it!
RET ;                  returns to operating system.
```

2. INT 21h

INT 21h use many sub-functions **such as:**

- **01h** to read one value of character from keyboard
- **02h** to write one character on the screen.

Every sub-function value was include in AH register

EX1: INT 21h for 01h sub-function

```
MOV AH, 01
INT 21H

Ret
```

In this program, if we read a character key this character was display on the screen, otherwise 0 value was display on screen (such as F1, F4, etc.)

EX2: INT 21h for 02h sub-function

Input: load 02 into AH register

Load ASCII code into DL register

Output: Copy ASCII code into AL register

```
MOV AH , 02H
MOV DL , „?‟
INT 21H
```

……

EX:

```
MOV AH, 1              ; read a character
INT 21H
MOV BL, AL             ; save input character into BL
MOV AH, 2              ; carriage return
MOV DL, 0DH
INT 21H
MOV DL, 0AH            ; line feed
INT 21H
MOV AH, 2              ; display the character stored in BL
MOV DL, BL
INT 21H
MOV AH, 4CH            ; return control to DOS
INT 21H
```

……..

EX:

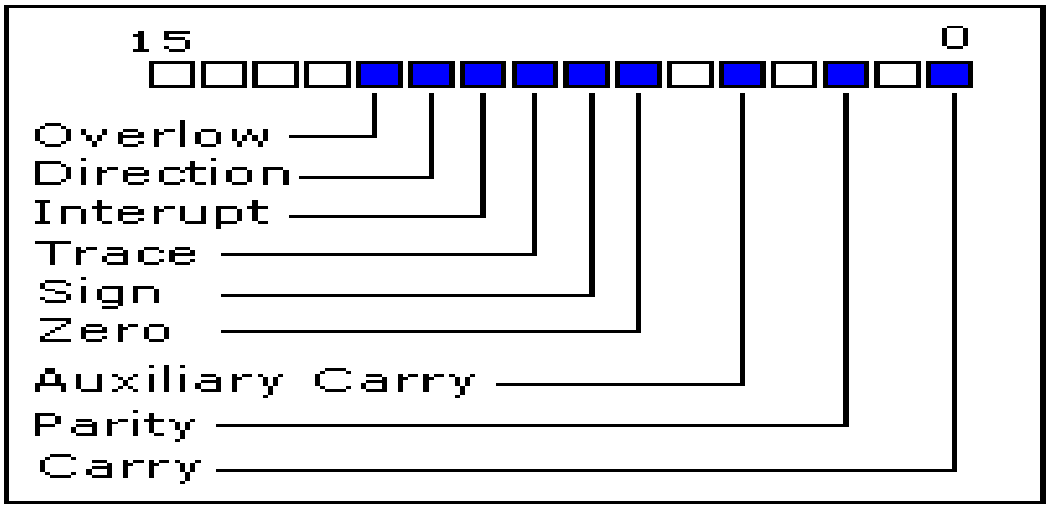
```
MOV ah, 1h ;     keyboard input subprogram
int 21h ;        read character into al
MOV dl, al ;     copy character to dl
MOV ah, 2h ;     character output subprogram
int 21h ;        display character in dl
```

- **Status and Control register:**

1- IP (Instruction Pointer): The instruction pointer register always contain the offset of the next instruction to be executed within the current code segment. The instruction pointer and the **code segment** register combine to form the complete address of the next instruction.

2- The Flag Register: is a special register with individual bit positions assigned to show the status of the CPU or the result of arithmetic operations.

Flag Register Statues



Flag Register Statues

There two basic types of flags: (control flags and status flags)

1- <u>Control Flags</u>: individual bits can be set in the flag register by the programmer to control the CPU operation , these are:

1. The **Direction Flag (DF):** affects block data transfer instructions, such as **MOVS, CMPS, SCAS**. The flag values are **0 = up** and **1 = down**.
2. The **Interrupt flag (IF):** dictates whether or not a system interrupt can occur. Such as keyboard, disk drive, and the system clock timer. A program will sometimes briefly disable the interrupt when performing a critical operation that cannot be interrupted. The flag values are **1 = enable**, **0 = disable**.
3. The **Trap flag (TF):** Determine whether or not the CPU is halted after each instruction. When this is set, a debugging program can let a programmer to enter single stepping (trace) through a program one instruction at a time. The flag values are **1 = on**, **0 = off**. The flag can be set by **INT 3** instruction.

2- <u>Status Flags</u>: The status flags reflect the outcomes of arithmetic and logical operations performed by the CPU, these are:

1. The **Carry Flag (CF):** is set when the result of an unsigned arithmetic operation is too large to fit into the destination for example, if the sum of 71 and 99 where stored in the 8-bit register AL, the result cause the carry flag to be 1. The flag **values = 1 = carry**, **0 = no carry**.
2. The **Overflow (OF)**: is set when the result of a signed arithmetic operation is too wide (too many bits) to fit into destination. **1 = overflow**, **0 = no overflow**.

3. **Sign Flag (SF):** is set when the result of an arithmetic of logical operation generates a negative result, **1= negative, 0 = positive**.
4. **Zero Flag (ZF):** is set when the result of an arithmetic of logical operation generates a result of zero, the flag is used primarily by jump or loop instructions to allow branching to a new location in a program based on the comparison of two values. The flag **value = 1 = zero, & 0 = not zero**.
5. **Auxiliary Flag**: is set when an operation causes a carry from bit 3 to bit 4 (or borrow from bit 4 to bit 3) of an operand. The flag **value = 1 = carry, 0 = no carry**.
6. **Parity Flag**: reflect the number of 1 bits in the result of an operation. If there is an **even number** of bit, the parity is **even**. If there is an **odd number** of bits, parity is **odd**. This flag is used by the OS to verify memory integrity and by communication software to verify the correct transmission of data.

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H/W

Q: Write an 8086 assembly language program (with flag register status) to

1. Load (FC54H) into memory location started at [2001]
2. Copy the data from memory location [2002] into AH register.
3. Load (FFFFH) into BX register.
4. Replace the data between BX register and AX register.
5. Addition AX register data with memory location data at [2001] and [2002]

Store the result reduced from step 5, into memory location started at [BX].

- Q: Write an 8086 assembly language program (with flag register status) to :
- Load (50H) into memory location started at [3000].
- Load (F1H) into memory location started at [3001].
- Replace the data between memory location [3000] and AH register.
- Load (2000H) into BX register.
- Subtract BX register data from memory location data at [3000] and [3001]
- Store the result reduced from step 5, into AX register