Microprocessors and Micro-controllers

Class 1 and 2

Microprocessor

- Microprocessor is a silicon chip that contains a CPU. In the world of personal computers, the terms *microprocessor* and CPU are used interchangeably.
- A microprocessor (abbreviated **µP**) is a digital electronic component with miniaturized transistors on a single semiconductor integrated circuit (IC).
- One or more microprocessors typically serve as a central processing unit (CPU) in a computer system or handheld device. At the heart of all personal computers and most working stations sits a microprocessor.
- Three basic characteristics differentiate microprocessors:
  1. **Instruction set**: The set of instructions that the microprocessor can execute.
  2. **Bandwidth**: The number of bits processed in a single instruction.
  3. **Clock speed**: Given in megahertz (MHz), the clock speed determines how many instructions per second the processor can execute.
- In both cases, the higher the value, the more powerful the CPU. For example, a 32 bit microprocessor that runs at 50MHz is more powerful than a 16-bit microprocessor that runs at 25MHz.
- In addition to bandwidth and clock speed, microprocessors are classified as being either RISC (reduced instruction set computer) or CISC (complex instruction set computer).

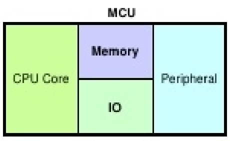
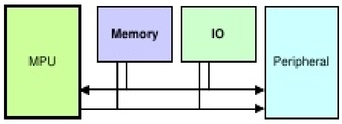
Micro-controller

- Microcontroller is a highly integrated chip that contains all the components comprising a controller. Typically this includes a CPU, RAM, some form of ROM, I/O ports, and timers.
- Unlike a general-purpose computer, which also includes all of these components, a microcontroller is designed for a very specific task - to control a particular system.
- A microcontroller differs from a microprocessor, which is a general-purpose chip that is used to create a multi-function computer or device and requires multiple chips to handle various tasks. A microcontroller is meant to be more self-contained and independent, and functions as a tiny, dedicated computer.
- The great advantage of microcontrollers, as opposed to using larger microprocessors, is that the parts-count and design costs of the item being controlled can be kept to a minimum.

- They are typically designed using CMOS (complementary metal oxide semiconductor) technology, an efficient fabrication technique that uses less power and is more immune to power spikes than other techniques.
- Microcontrollers are sometimes called embedded microcontrollers, which just means that they are part of an embedded system that is, one part of a larger device or system.

- Difference between Microprocessors and Micro-controllers can be studied from the diagram shown below:

MCU and MPU

Classification	MCU	MPU
Chip	Embedded A CPU core, memory, peripherals, IO ... into a single chip.	Contain only the main processor (CPU core)
Block Diagram of a system		
General Application Area	- Self contained to complete a task. - Targeted for small, compact, and low cost system	-Need external memory, peripheral to accomplish a task - Targeted for complex, high performance and expandable system
Processor (CPU) Core	4, 8, 16 bit	32 bit or above
Examples	8051,pic16f887a,M16, H8, SH1/2	SH3/4,8085
Application	Washing machine, car side mirror, air con	Handphone, PDA

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Moor's Law

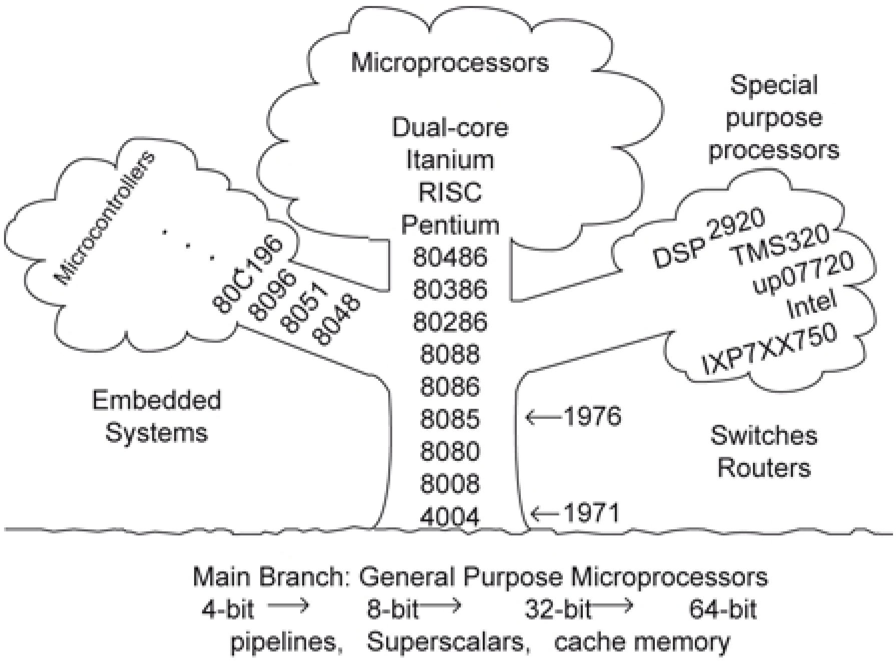
- In 1965, four years after Fairchild Semiconductor Corporation and Texas Instruments Inc. marketed their first integrated circuits, Fairchild research director Gordon E. Moore made a prediction in a special issue of Electronics magazine. Observing that the total number of components in these circuits had roughly doubled each year, he extrapolated this annual doubling to the next decade, estimating that microcircuits of 1975 would contain an astounding 65,000 components per chip.
- History proved Moore correct. His bold extrapolation has since become enshrined as Moore's law—though its doubling period was lengthened to 18 months in the mid-1970s.
- What has made this dramatic explosion in circuit complexity possible is the steadily shrinking size of transistors over the decades. Measured in <u>millimetres in the late 1940s</u>, the dimensions of a typical transistor are typically about <u>10 nanometres during the 1980s</u>, when dynamic random-access memory (DRAM) chips began offering megabit storage capacities.

- At the dawn of the 21st century, these features approached <u>0.1 micron</u> across, which allowed the manufacture of gigabit memory chips and microprocessors that operate at gigahertz frequencies. Moore’s law continued into the second decade of the 21st century with the introduction of three-dimensional transistors that were tens of nanometres in size.

Microprocessor	Year of Introduction	Transistors
4004	1971	2,300
8008	1972	2,500
8080	1974	4,500
8086	1978	29,000
Intel286	1982	134,000
Intel386™ processor	1985	275,000
Intel486™ processor	1989	1,200,000
Intel® Pentium® processor	1993	3,100,000
Intel® Pentium® II processor	1997	7,500,000
Intel® Pentium® III processor	1999	9,500,000
Intel® Pentium® 4 processor	2000	42,000,000
Intel® Itanium® processor	2001	25,000,000
Intel® Itanium® 2 processor	2003	220,000,000
Intel® Itanium® 2 processor (9MB cache)	2004	592,000,000

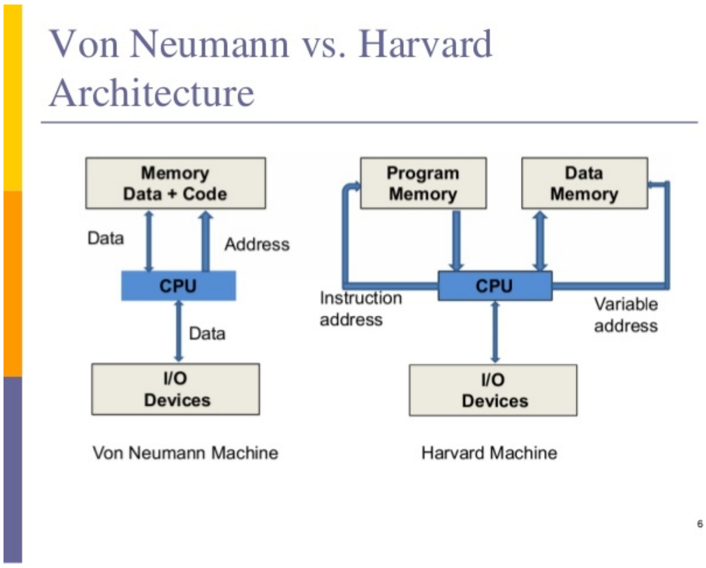
- The first microprocessor chip was 4004, introduced in 1971, had only 2,300 transistors in it. The table above shows that the number of transistors per chip has increased drastically across time and that Moor’s law stands valid in this 21st century as well.

- The generation of the microprocessor, micro-controllers and other special purpose processors can be studied from the microprocessor tree, shown below:



Internal architecture of 8085 microprocessor

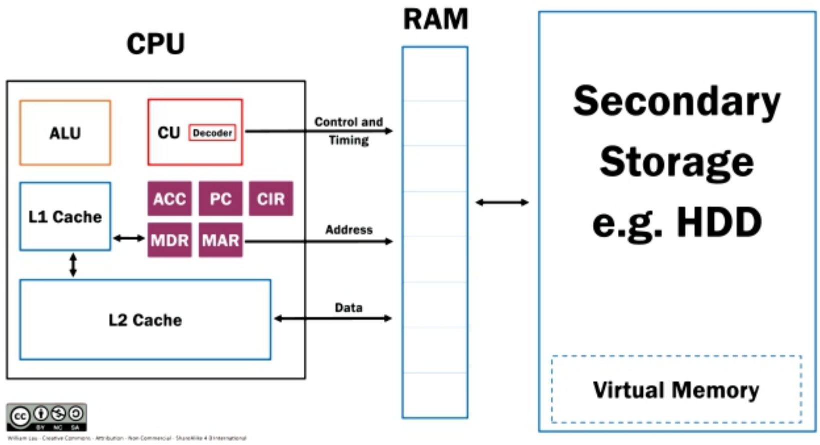
- In Von Neumann Architecture, both the data and instructions are stored in the Read/Write memory (RAM). This is also called Stored Program Architecture.
- The other architecture followed is the Harvard Architecture, where the program memory and data memory are separately accessed by the CPU.



- Von Neumann Machine Architecture is followed by the microprocessors, although it has several disadvantages.
- The Characteristics of Von Neumann Architecture include

  1. The program and data are stored in the same memory, in other words, the memory is shared by program and data.
  2. The contents of the memory are accessed by its location.
  3. The instructions are accessed and executed sequentially, from one instruction to the next.
- This is a great model for designing algorithms and at one point, this described real computers but now a days, it is a useful abstraction for computation.
- The main disadvantage of this architecture is the execution of one instruction at a time. This problem is overtaken by the process of simulating parallel execution by the operating system.

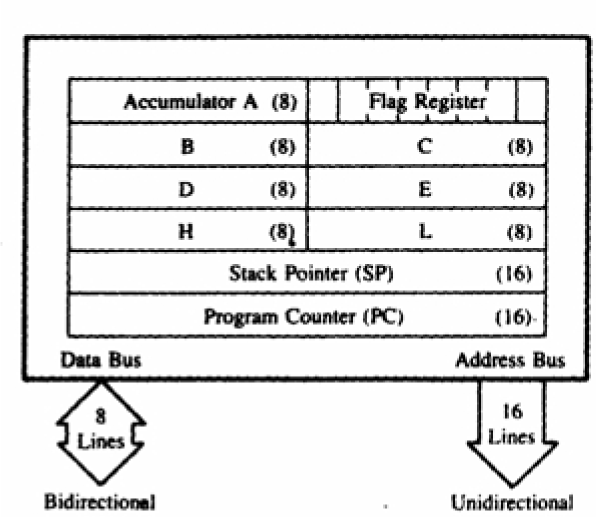
Computer Systems - Von Neumann Architecture



Registers in 8085 Microprocessors

- The 8085/8080A-programming model includes six registers, one accumulator, and one flag register. In addition, it has two 16-bit registers: the stack pointer and the program counter. They are described briefly as follows.

- The 8085/8080A has six general-purpose registers to store 8-bit data; these are identified as B,C,D,E,H, and L as shown in the figure. They can be combined as register pairs - BC, DE, and HL - to perform some 16-bit operations. The programmer can use these registers to store or copy data into the registers by using data copy instructions.



Accumulator

The accumulator is an 8-bit register that is a part of arithmetic/logic unit (ALU). This register is used to store 8-bit data and to perform arithmetic and logical operations. The result of an operation is stored in the accumulator. The accumulator is also identified as register A.

Flags

The ALU includes five flip-flops, which are set or reset after an operation according to data conditions of the result in the accumulator and other registers. They are called Zero(Z), Carry (CY), Sign (S), Parity (P), and Auxiliary Carry (AC) flags; they are listed in the Table and their bit positions in the flag register are shown in the Figure below. The most commonly used flags are Zero, Carry, and Sign. The microprocessor uses these flags to test data conditions.

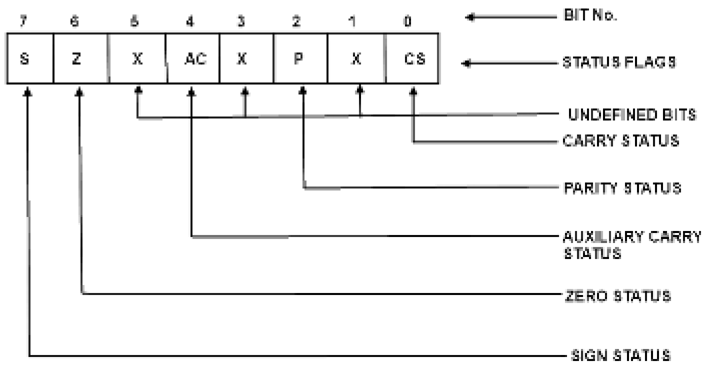


Figure 2: Status Flags of Intel 8085

For example, after an addition of two numbers, if the sum in the accumulator is larger than eight bits, the flip-flop uses to indicate a carry -- called the Carry flag (CY) -- is set to one. When an arithmetic operation results in zero, the flip-flop called the Zero(Z) flag is set to one.

Five bit positions out of eight are used to store the outputs of the five flip-flops. The flags are stored in the 8-bit register so that the programmer can examine these flags (data conditions) by accessing the register through an instruction.

These flags have critical importance in the decision-making process of the micro- processor. The conditions (set or reset) of the flags are tested through the software instructions. For example, the instruction JC (Jump on Carry) is implemented to change the sequence of a program when CY flag is set. The thorough understanding of flag is essential in writing assembly language programs.

Program Counter (PC)

This 16-bit register deals with sequencing the execution of instructions. This register is a memory pointer. Memory locations have 16-bit addresses, and that is why this is a 16-bit register.

The microprocessor uses this register to sequence the execution of the instructions. The function of the program counter is to point to the memory address from which the next byte is to be fetched. When a byte (machine code) is being fetched, the program counter is incremented by one to point to the next memory location

Stack Pointer (SP)

The stack pointer is also a 16-bit register used as a memory pointer. It points to a memory location in R/W memory, called the stack. The beginning of the stack is defined by loading 16-bit address in the stack pointer.

Instruction Register (IR)/Decoder

Temporary store for the current instruction of a program. Latest instruction sent here from memory prior to execution. Decoder then takes instruction and 'decodes' or interprets the instruction. Decoded instruction then passed to next stage.

Memory Address Register (MAR)

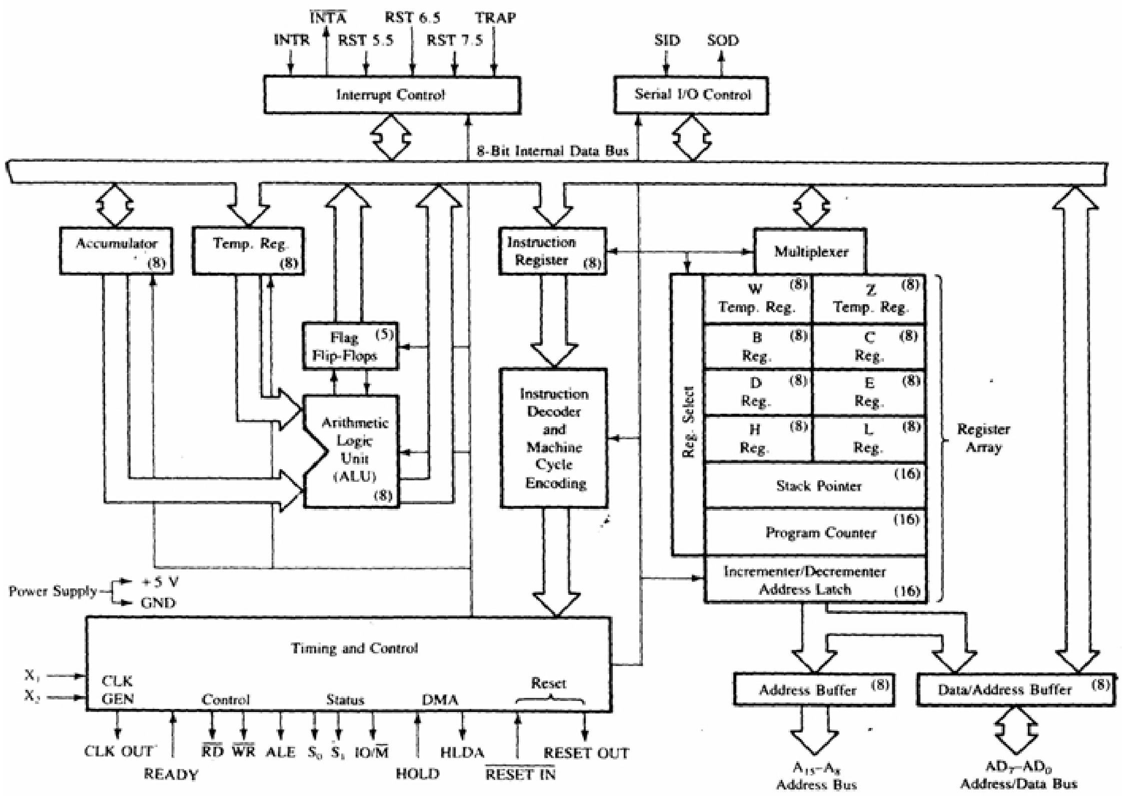
Holds address, received from PC, of next program instruction. Feeds the address bus with addresses of location of the program under execution.

Control Generator

Generates signals within **µP** to carry out the instruction which has been decoded. In reality causes certain connections between blocks of the **µP** to be opened or closed, so that data goes where it is required, and so that ALU operations occur.

Register Selector

This block controls the use of the register stack in the example. Just a logic circuit which switches between different registers in the set will receive instructions from Control Unit.



INTA
RST 6.5
TRAP
INTR
RST 5.5
RST 7.5
Interrupt Control
SID
SOD
Serial I/O Control
8-Bit Internal Data Bus
Accumulator (8)
Temp. Reg. (8)
Flag Flip-Flops (5)
Arithmetic Logic Unit (ALU) (8)
Instruction Register (8)
Instruction Decoder and Machine Cycle Encoding
Multiplexer
W (8) Temp. Reg.
Z (8) Temp. Reg.
B (8) Reg.
C (8) Reg.
D (8) Reg.
E (8) Reg.
H (8) Reg.
L (8) Reg.
Reg. Select
Stack Pointer (16)
Program Counter (16)
Incrementer/Decrementer Address Latch (16)
Register Array
Power Supply
+5 V
GND
Timing and Control
X_1
X_2
CLK GEN
Control
Status
DMA
Reset
CLK OUT
READY
$\overline{RD}$
$\overline{WR}$
ALE
S_0
S_1
IO/$\overline{M}$
HOLD
HLDA
$\overline{RESET\ IN}$
RESET OUT
Address Buffer (8)
Data/Address Buffer (8)
A_{15}–A_8 Address Bus
AD_7–AD_0 Address/Data Bus