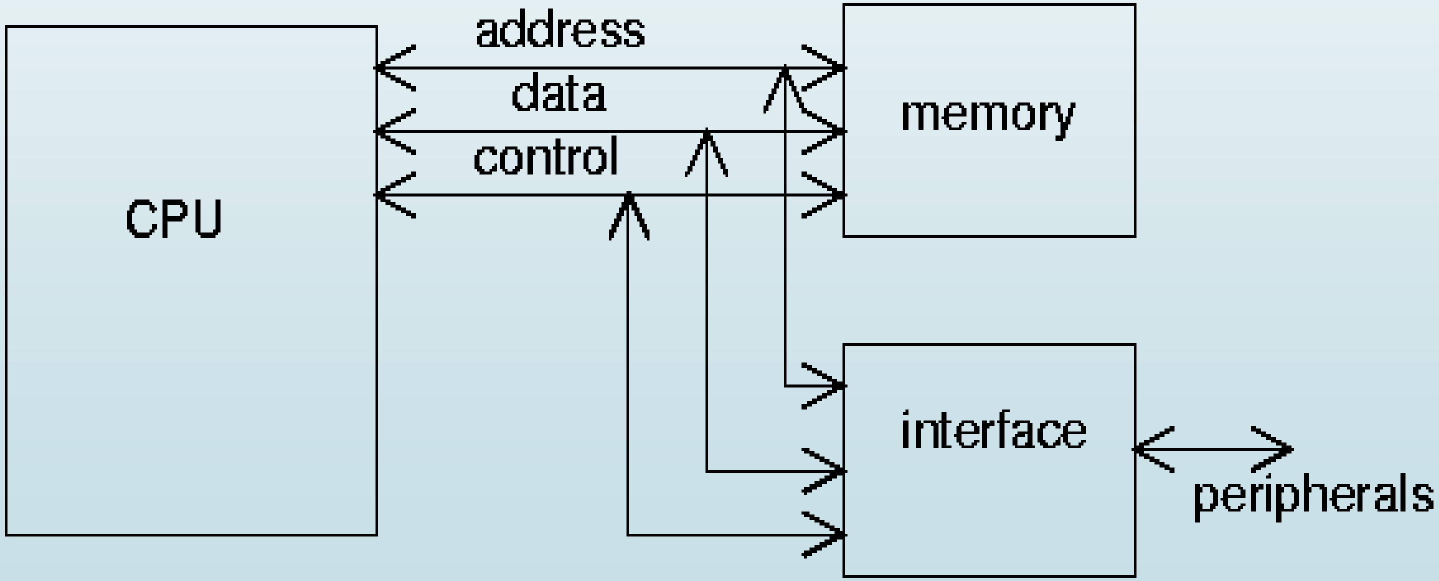
Overview of Computer Organization

What is computer organization

Computer Organization;

- The internal components of the computer, their interconnection and communication between them.



Computer Organization Overview

Microcomputer

- A micro-computer is a computer on a single printed circuit board containing some chips. Used as general purpose computer

Microcontroller

- A single chip computer having processor, memory and I/O components built in it. Used in embedded systems
- **Microprocessor**
- The processor and its control unit.

Computer Organization Overview

The Microprocessor

- Contains the Arithmetic, Logic Unit for arithmetic and logic operations.
- Hosts the groups of registers, a temporary storage area for arithmetic, logic operations and other core functions.
- Processor performs operations on data stored in registers. This requires to load data from main memory in the registers, perform operations on the loaded data and store the result back to the memory.
- Processors generates signals indicating the resulting values of AL operations, whether its negative, zero or an overflow etc. These values are stored in special read only register called the flags register.

Computer Organization Overview

The Flags Register

|---------------- 8086 Flags Register (16-bits) ----------------|

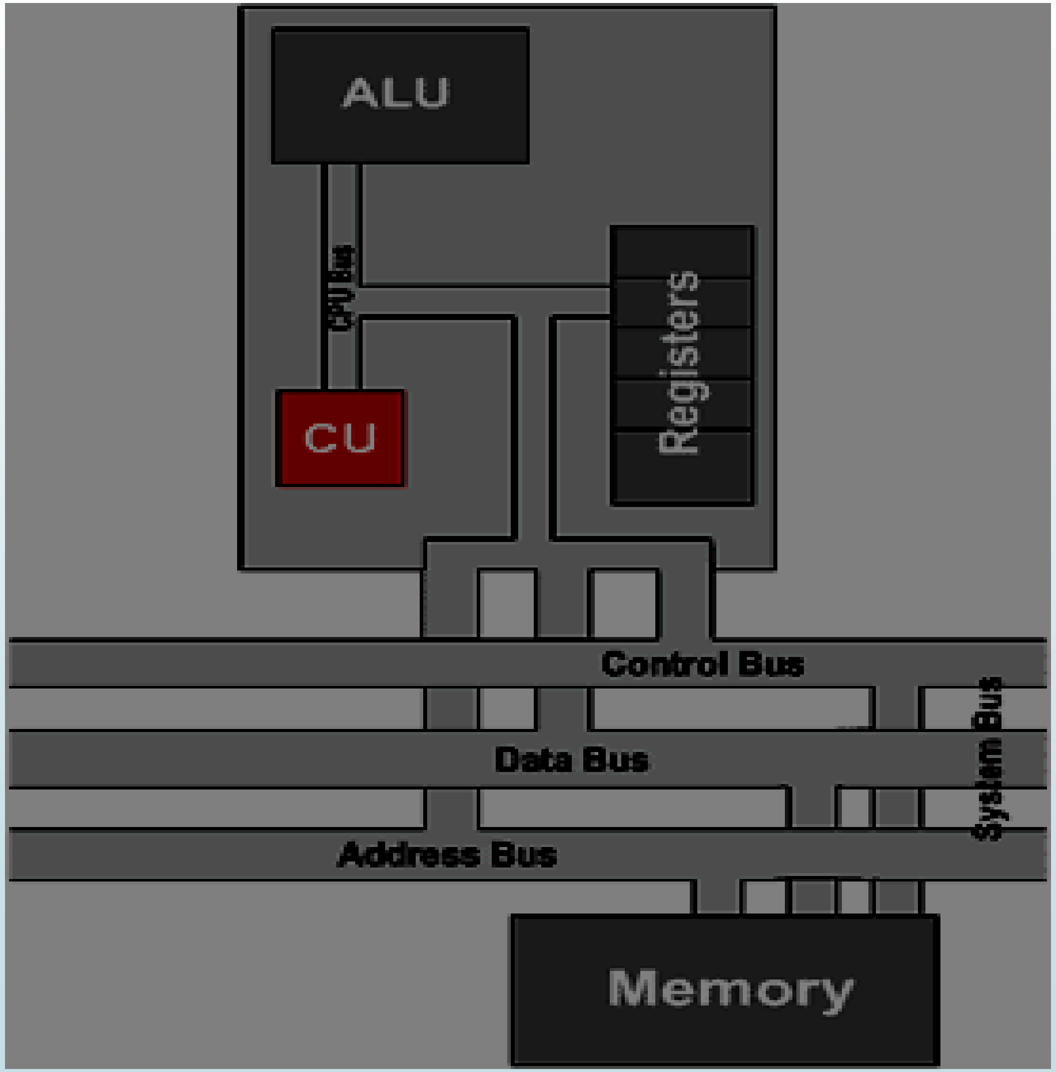
-- -- -- -- OF DF IF TF SF ZF -- AF -- PF -- CF

Computer Organization Overview

The Control Unit (CU)

- Synchronous sequential system that control and coordinates data flow between different units and their operation.
- The sequence of steps and control out of CU depends on the input; the current program instruction,the status outputs of other units, and input/output block.
- Decodes and monitors the execution of instructions. Works as arbiter when various systems compete for CPU and other resources.
- The CU is integral part of CPU.

Computer Organization Overview

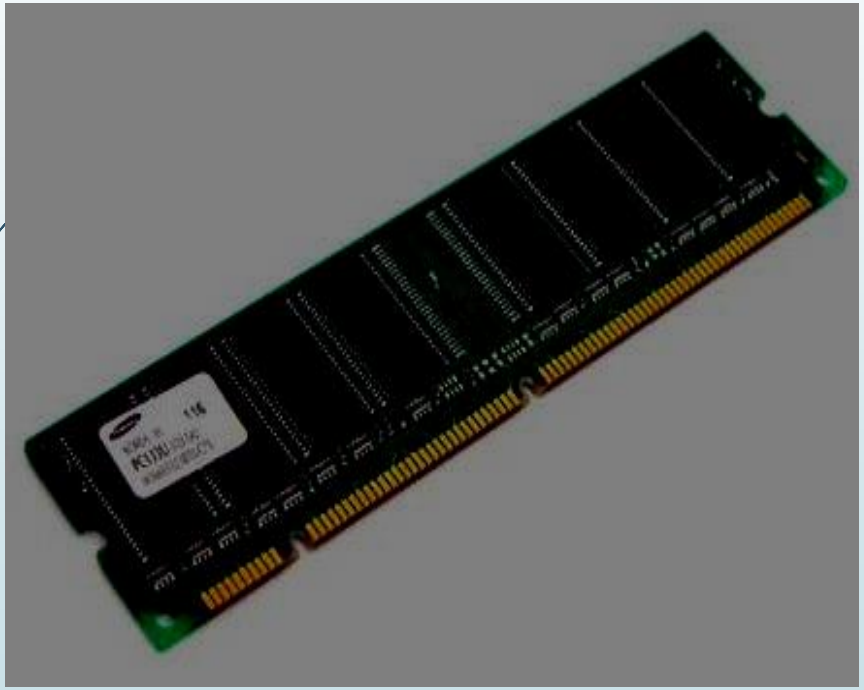


Memory

- Memory refers to some storage area. There are different types of memories in a system, we refer to main memory here.
- Storage area where program data and code is stored.
- A sequential directly addressable 'locations'.
- The number of address available in memory is limited by the number of bits used to represent the address.
- If 16 bits are used for the address, there are 65536 (2^{16}) different addresses available.
- The contents of a given address can be interpreted as one of the two things; Either its Instruction to be executed, or its Data to be operated on.

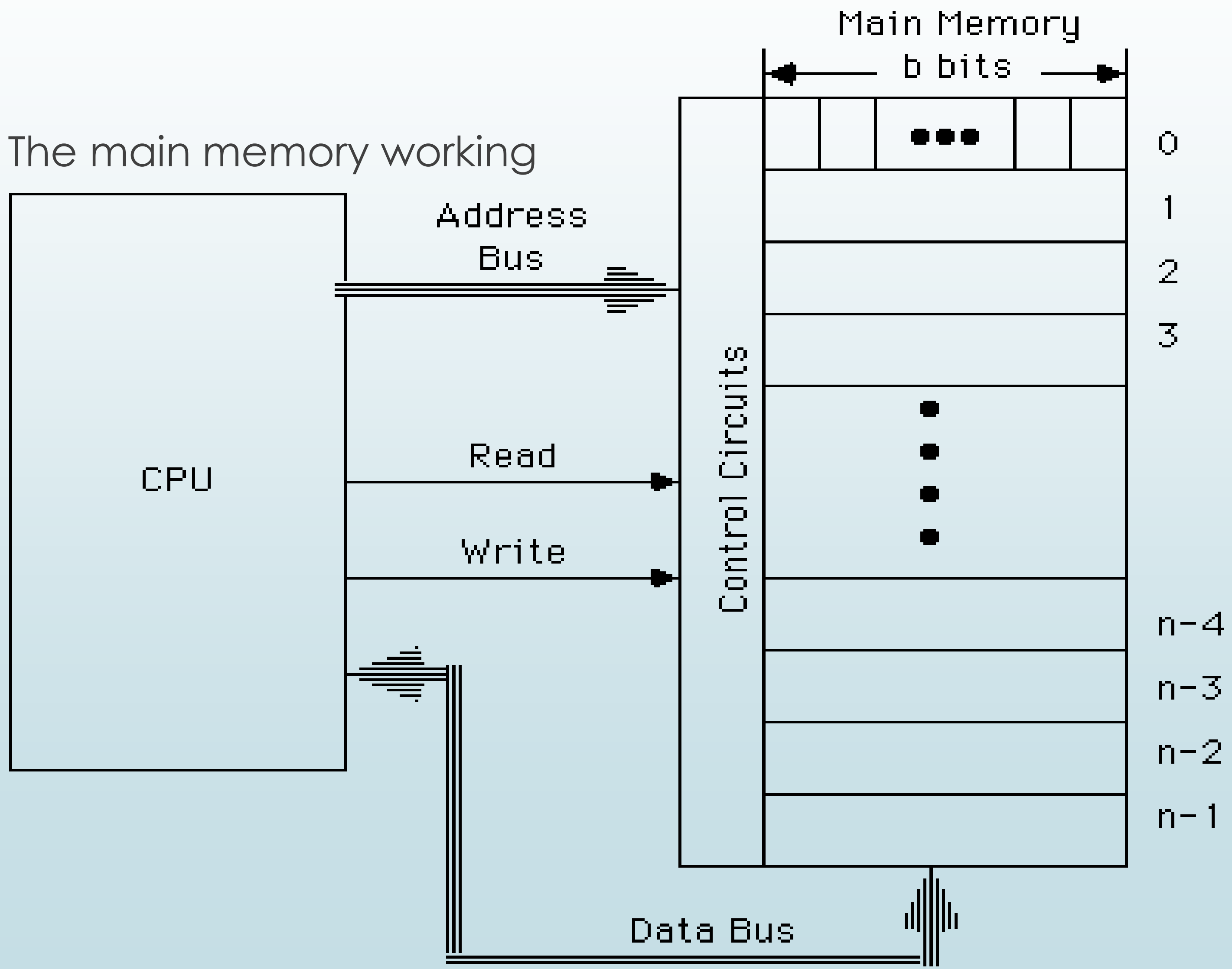
RAM

RAM unit



CPU Memory Communication

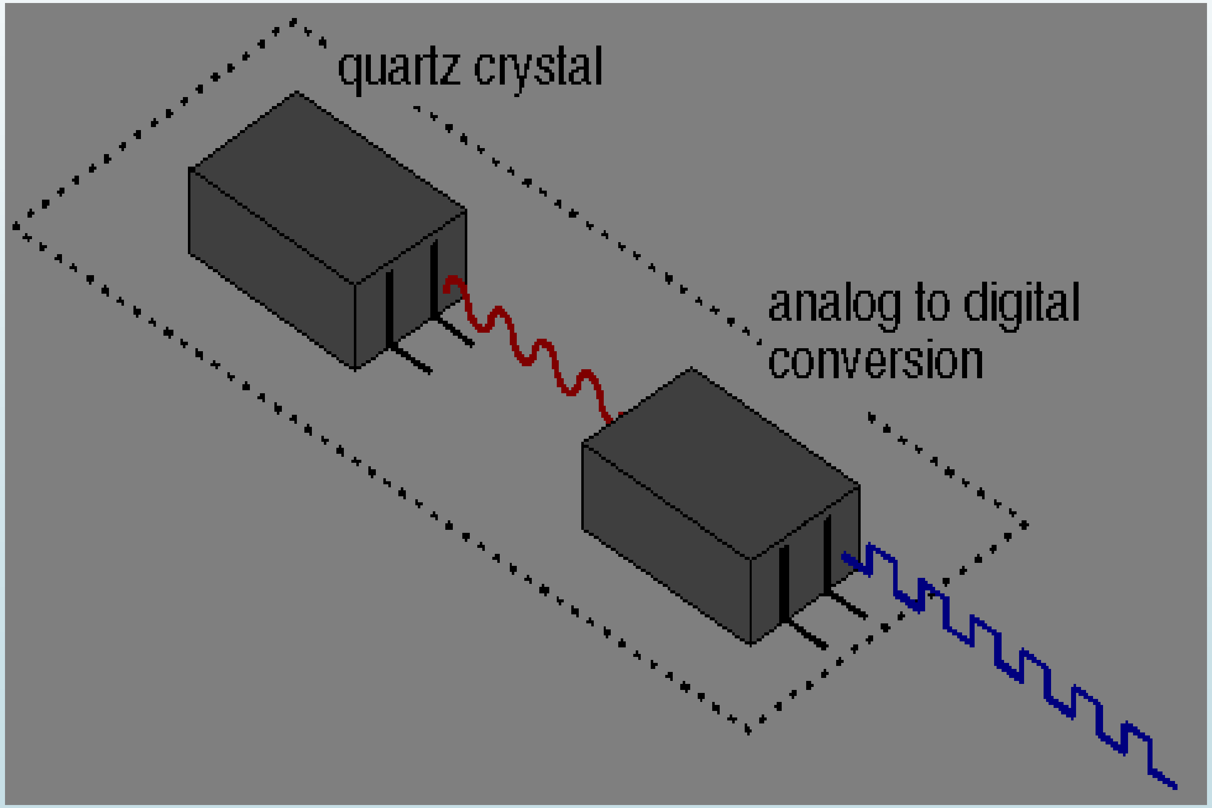
- The main memory working



Digital System Clock

- A microchip that generates periodic signals for the sequential machine.
- The signals are digital signals.
- Operation is performed when the signal value is 1. When its 0, no operation is performed.
- Used by different system units to synchronize themselves with other units.

Digital System Clock



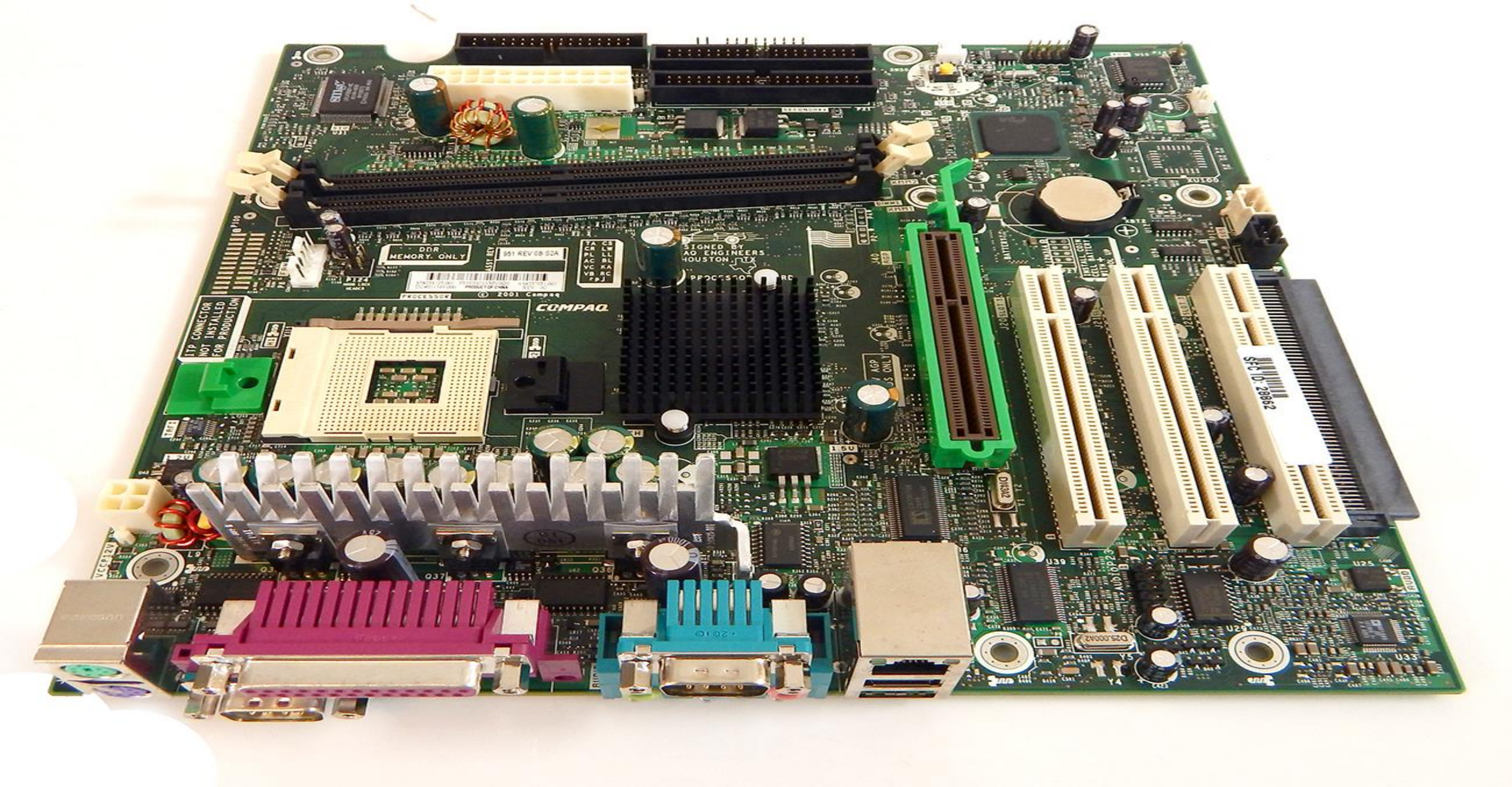
System Buses

- Paths must be provided to transfer information from one register to another and between memory and registers
- A more efficient scheme for transferring information in a system with many registers is to use a common bus.

The System Board

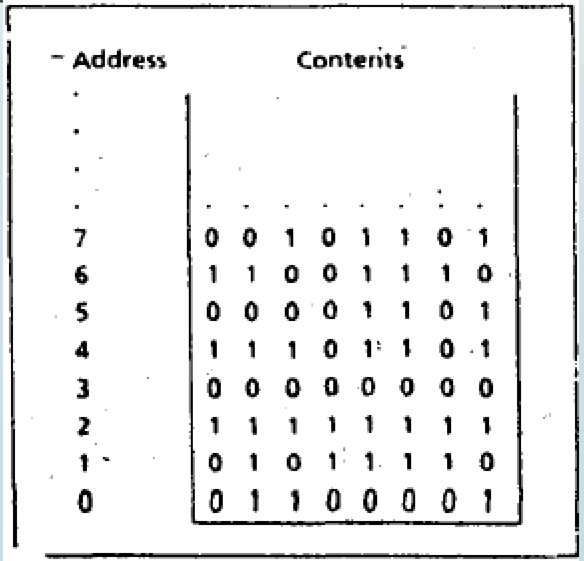
- Inside PC unit is a main circuit board called the system board, which contains the microprocessor and memory circuits.
- It is also called motherboard
    - it contains expansion slots, for additional circuit boards called add-in boards
- I/0 circuits are usually located on add-In cards

The System Board



Address and Memory

- The address of a memory byte is *fixed* and is different from the address of any other memory.
- The contents of a memory byte are not unique and they change, donating the data currently stored.
- Figure below shows the organization of memory bytes.



Address and Memory

- **The number of bits in an address depends on the processor.**
- For example, the Intel 8086 microprocessor assigns a 20-bit address, and the Intel 80286 microprocessor uses a 24~bit address.
- The number of bits used In the address determines the number of bytes that can be accessed by the processor.

Address and Memory

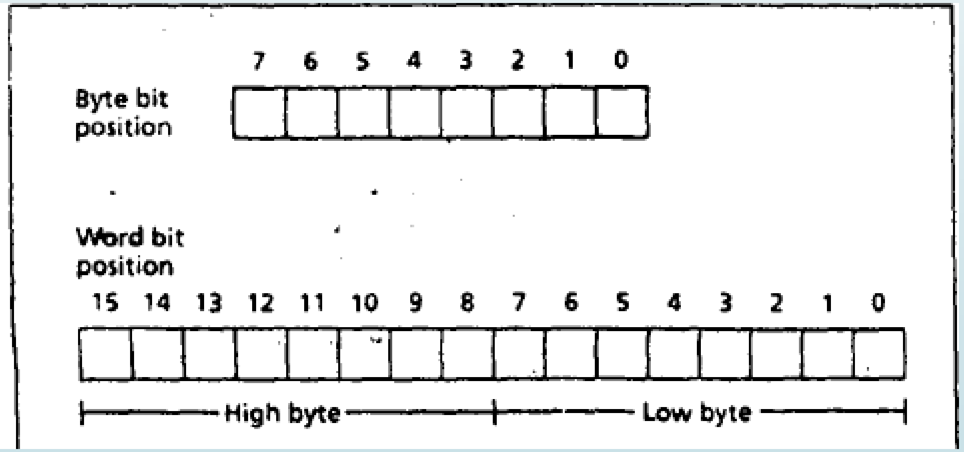
- Problem: How many memory bytes can be accessed for A processor that uses 20 bits for an address?
- **Solution**: A bit can have two possible values, so In a 20-blt address there can be 2^{20} or 1,048,576 different values, with each value being address of a memory byte.
- Number 2^{20} is called 1 mega. Thus, a 20-bit address can be used to address 1 megabyte or 1 MB.

Memory Word

- Two bytes form a word.
- IBM PC allows any pair of successive memory bytes to be treated as a single unit, called a memory word.
- Thus the memory word with the address 2 Is made up of the memory bytes with the
- addresses 2 and 3.

Bit Position

- In a word, the bits 0 to 7 form low byte and the bits 8 lo 15 form high byte.
- For a word in memory, its low byte comes from the memory byte with the lower address and Its high byte Is from the memory byte with the higher address.



Memory Operations

- The processor can perform two operations on memory:
  - read (fetch) and write (store).
- In a read operation, the processor only gets a copy of the data; the original contents of the location are unchanged.
- In a write operation, the data written become the new contents of the location; the original contents are lost.

RAM and ROM

- Program instructions and data are loaded Into RAM memory.
- However, the contents of RAM memory are lost when the machine is turned off.
- ROMs retain their values even when the power Is off.
- ROM is used by the manufacturers to store system programs, called firmware.
- They programs are responsible for loading start-up programs from disk and self-testing the computer when it is turned on.

Buses

- A processor communicates with memory and I/O circuits using signals that travel along a set of wires or connections called buses that connect the different components.
- There are three kinds of signals: address, data, and control.
  - So there are three buses : address bus; data bus, and control bus.
- To read the contents of a memory location, the CPU places the address of the memory location on the address bus, and It receives the data, sent by the memory circuits, on the data bus.
- A control signal is required to inform the memory to perform a read operation. The CPU sends the control signal on the control bus.
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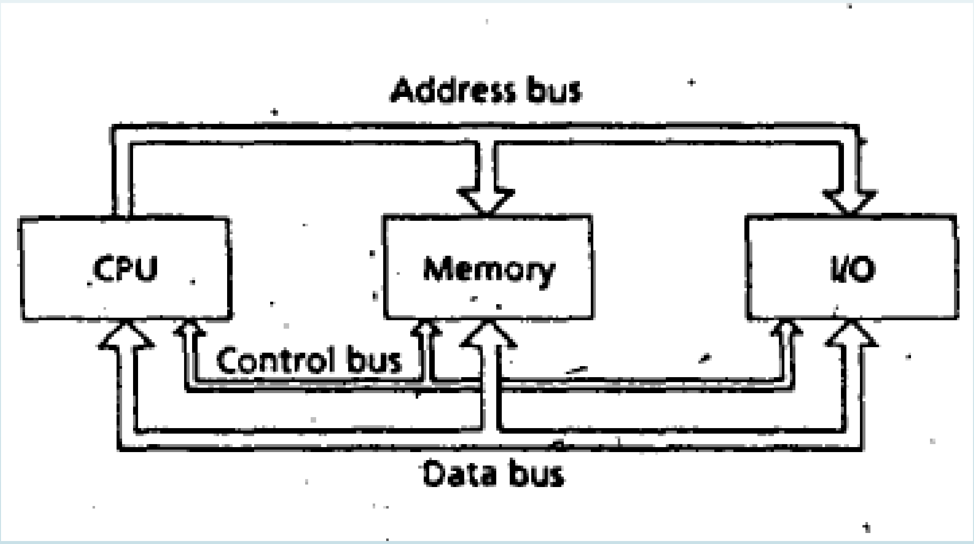
Bus Connections

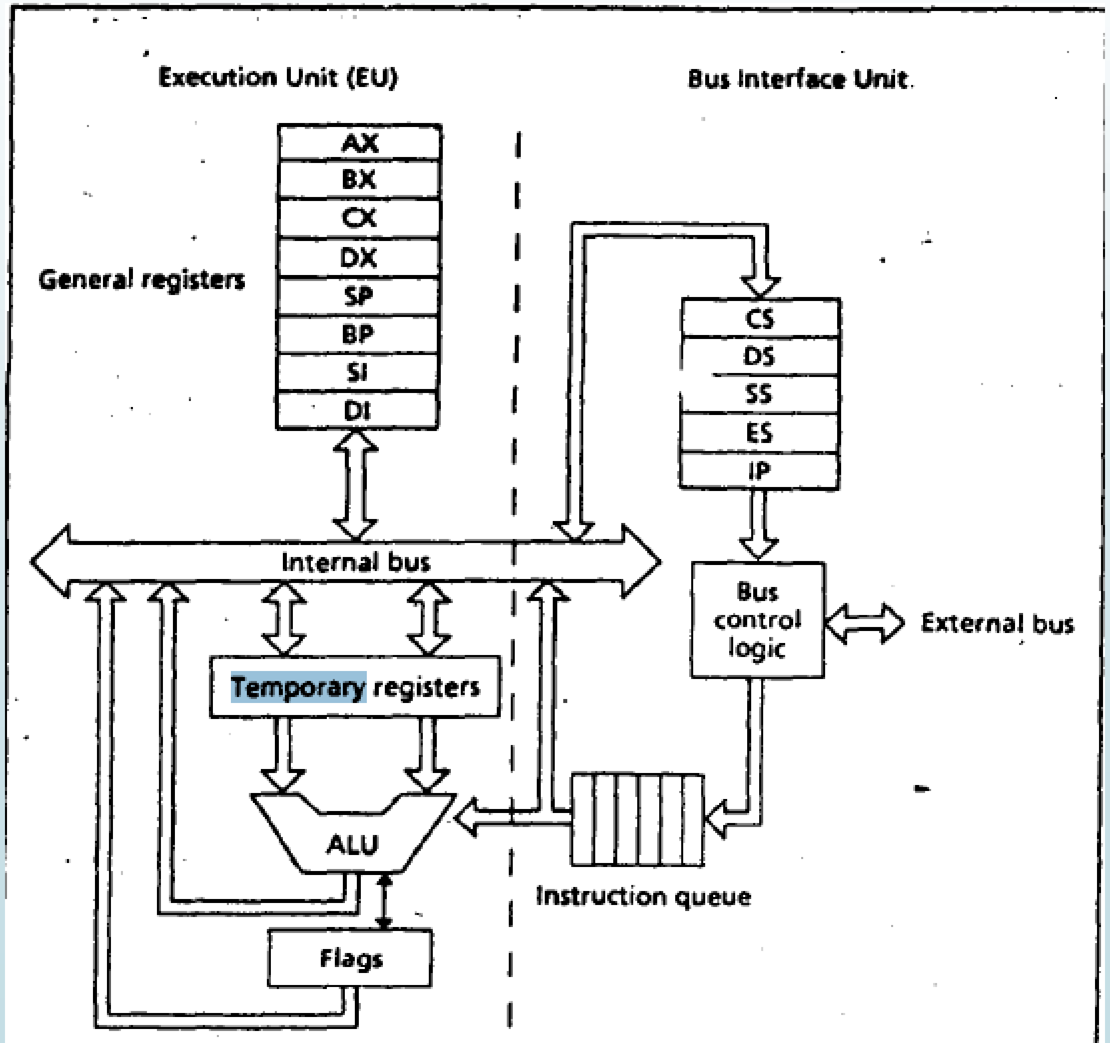
- The figure below shows the bus connections.



CPU

- CPU is the computing brain of a computer that executes instructions.
- An instruction that the CPU executes Is a bit string (for the Intel 8086, instructions are from one to six bytes long). This language of O's and 1 's is called **machine language.**

Intel 8086 CPU organization



Instruction Set

- The instructions performed by a CPU are called its instruction set, and the Instruction set for each CPU is unique.
- Machine language Instructions are designed to be simple; for example, adding two numbers or moving a number from one location to another.
- Computers performing incredibly complex tasks are just a sequence of very basic operations.

Execution Unit (EU)

- Execution unit executes instructions.
- It contains a circuit called the arithmetic and logic unit (ALU).
- The ALU can perform arithmetic (+, - , x ,I) and logic (AND, OR, NOT} operations.
- The data for the operations are stored in circuits called registers.
- A register is a memory location but is referred by a name rather than a number.
- The EU has eight registers for storing data; their names arc AX, BX, CX, DX, SJ, DI, Br, and SP.
- In addition, the EU contains temporary registers for holding operands for the ALU, and the FLAGS register whose individual bits reflect the result of a computation.

Bus Interface Unit (BIU)

- The bus Interface unit (BIU) facilitates communication between the EU and the memory or I/0 circuits.
- It is responsible for transmitting addresses, data, and control signals on the buses.
- Its registers are named CS, OS, ES, SS,. and IP; they hold addresses of memory locations.
- The IP(instruction pointer) contains the address of the next instruction to be executed by the EU.
- EU and BIU are connected by an internal bus and they work together.
- While the EU is executing an instruction, the BIU fetches up to six bytes of the next instruction and places them in the instruction queue.
- This operation is called **instruction prefetch**, to speed up the processing.
- If the EU needs to communicate with memory or the peripherals, the BIU suspends instruction prefetch.

I/O Ports

- I/0 devices are connected to the computer through I/0 circuits, called I/0 ports.
- The I/O ports have addresses and are connected to the bus system.
- However, these addresses are known as I/O addresses and can only be used in input or output instructions, allowing the CPU to distinguish between an I/O port and a memory location.
- I/0 ports function as transfer points between the CPU and I/0 devices.
- Data to be input from an I/0 device arc sent to a port where they can be read by the CPU.
- On output, the CPU writes data to an I/0 port.
- The I/0 circuit then transmits the data to the I/0 device.

Serial and Parallel Ports

- The data transfer between an I/0 port and an I/0 device can be l bit at a time (serial), or 8 or 16 bits at a time (parallel).
- A parallel port requires more wiring connections, while a serial port is slower.
- Slow devices, like the keyboard connect to a serial port, and fast devices, like the disk drive connect to a parallel port.
- Some devices, like the printer, can connect to either a serial or a parallel port.

Instruction Execution

- A machine instruction has two parts: an opcode and operands.
- The opcode specifies the type of operation, and the operands are often given as memory addresses to the data to be operated on.
- CPU goes through the following steps (cycle) to execute a machine instruction:
- Fetch
  - Fetch an instruction from memory.
  - Decode the Instruction to determine the operation.
  - Fetch data from memory if necessary.
- Execute
  - Perform the operation on the data.
  - Store the result in memory if needed.

Example

- Suppose we look at the instruction that adds the contents of register AX to the contents of the memory word at address 0.
- Steps are given next.

Step 1: Fetch the instruction

- To start the cycle, BIU places a memory read request on the control bus and the address of the instruction on the address bus.
- Memory responds by sending the contents of the location specified-namely, the instruction code over the data bus.
- Because the instruction code Is four bytes and the 8086 can only read a word at a time, this involves two read operations.
- The CPU accepts the data and adds four to the JP so that the IP will contain the address of the next instruction.

Step 2: Decode the instruction

- Next, decoder in the EU decodes the instruction and determines that it is an ADD operation involving the word at address 0.

Step 3: Fetch data from memory

- The EU informs the BIU to get the contents of memory word 0.
- BIU sends address 0 over the address bus and a memory read request is again sent over the control bus.
- The contents of memory word 0 arc sent back over the data bus to the EU and arc placed In a holding register.

Step 4: Perform Operation

- The contents of the holding register and the AX register arc sent to the ALU circuit, which performs the required addition and holds the sum.

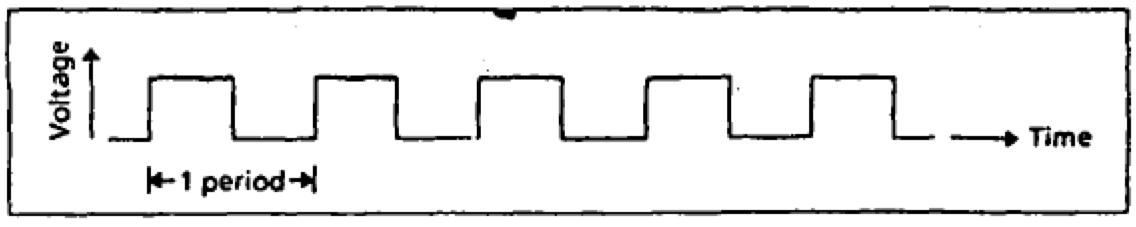
Step 5: Store the Results

- EU directs the BIU to store the sum at address 0.
- BIU sends out a memory write request over the control bus, the address 0 over the address bus, and the sum 10 be stored over the data bus.
- The previous contents of memory word 0 are overwritten by the sum.

- The cycle is now repeated for the next instruction whose address is in IP.

Timing

- The machine instructions are very simple, but their execution is actually complex.
- To ensure that the steps arc carried out in an orderly fashion, a clock circuit controls the processor by generating clock pulses.
- The interval between two pulses is clock period, and the number of pulses per second is the clock rate or clock speed, measured in hertz.
- One megahertz Is 1 million cycles (pulses) per second.



The Clock

- The computer circuits are activated by the clock pulses; perform an operation only when a clock pulse is present.
- Each step in instruction fetch and execution cycle requires one or more clock periods.
- For example, the 8086 takes four clock periods to do a memory read and a multiplication operation may take more than seventy clock periods.
- If we speed up the clock circuit, a processor can be made to operate faster .
- However each processor has a rated maximum clock speed beyond which it may not function properly.