Computer Organization and Architecture

Performance of Computer

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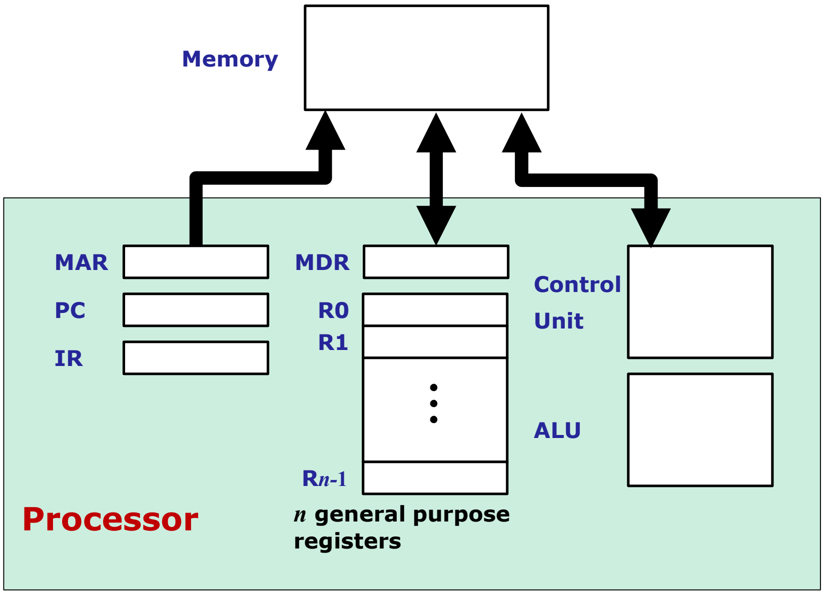
Recap

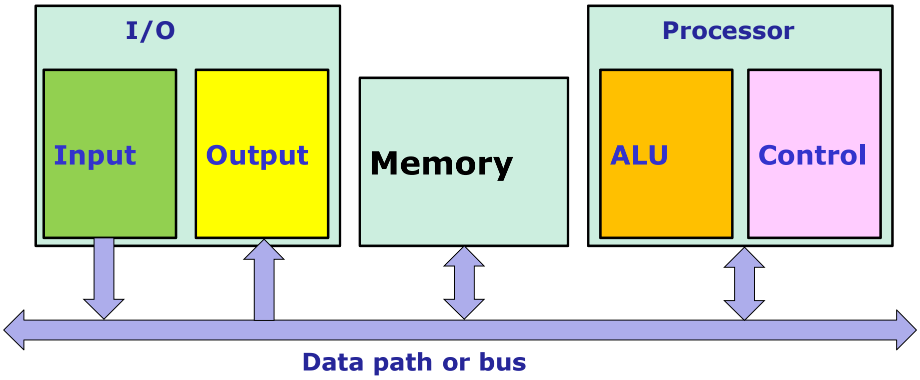
- Functional units
- Basic operational concepts
  - Execution of an instruction
  - Important processor registers

Operational Details



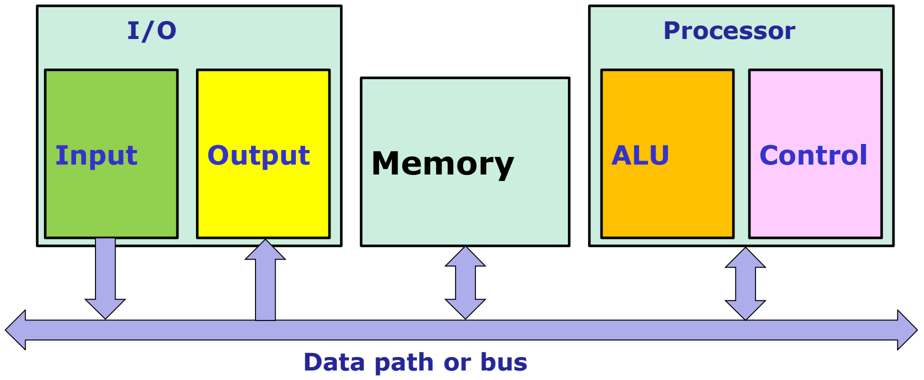
Functional Units

- Suitable connection between the functional units
- Functional units handle one full word of information
  - All the bits in a word are transferred in **parallel** over many wires, lines
  - One bit per line
- **Bus:** group of lines that serve as a connecting path



Bus Structures

- Single bus-All units are connected to this bus
- Only one transfer at a time
- Only two units can use at a time

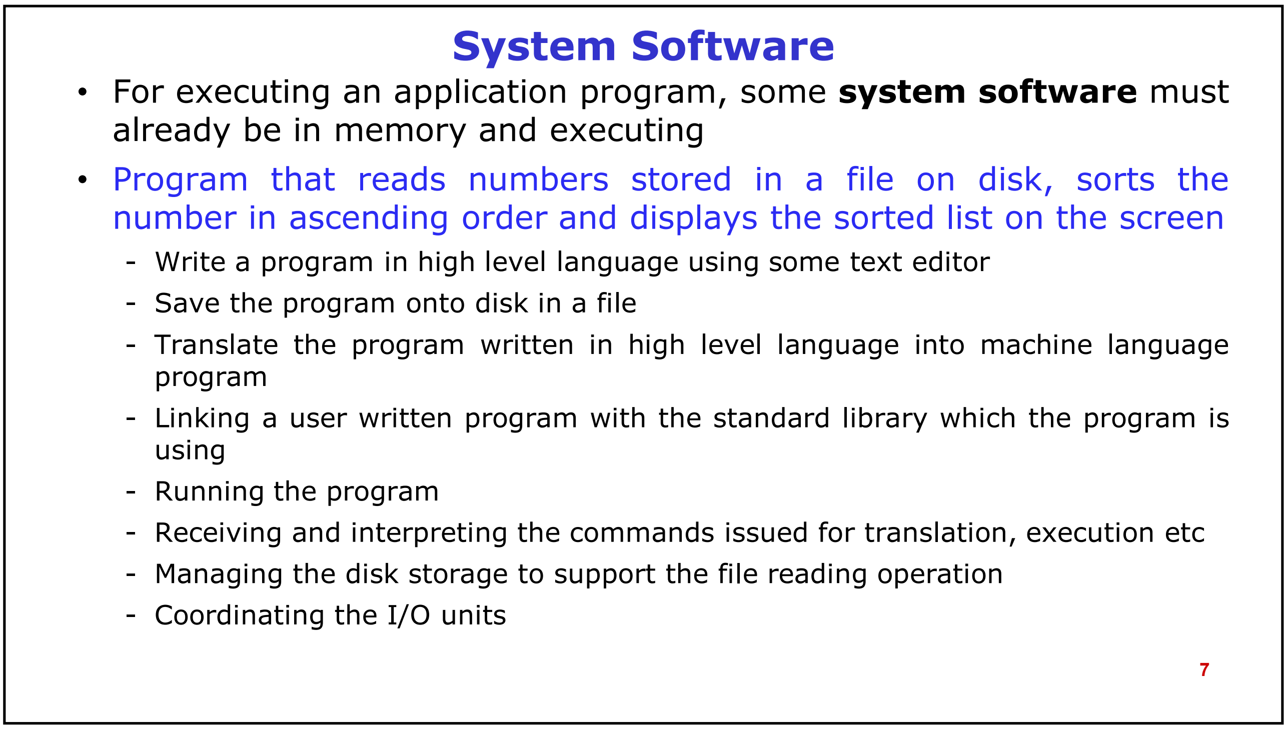


Bus Structures

- **Devices connected to a bus vary widely in speed of operation**
  - Keyboards and printers are relatively slow
    - Electromechanical devices
  - Memory and processor are faster
    - Operate at electronics speed

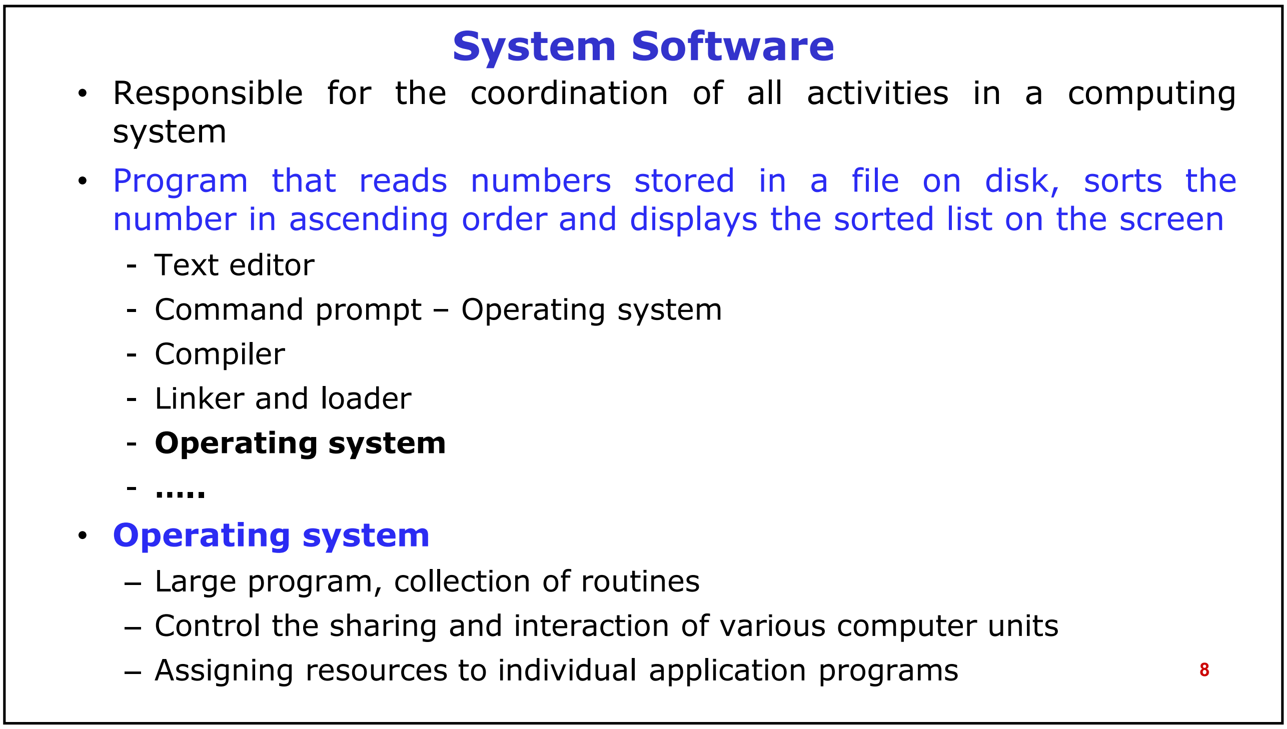
- Communicate with each other over a bus
  - May get constrained by the slow devices

- **Buffer registers**
  - Every device to hold the information during transfers
  - Transfer of a character from processor to a printer
    - Transferred over a bus to the printer buffer
    - Printer can print without further intervention of the bus and the processor



System Software

- For executing an application program, some **system software** must already be in memory and executing
- Program that reads numbers stored in a file on disk, sorts the number in ascending order and displays the sorted list on the screen
  - Write a program in high level language using some text editor
  - Save the program onto disk in a file
  - Translate the program written in high level language into machine language program
  - Linking a user written program with the standard library which the program is using
  - Running the program
  - Receiving and interpreting the commands issued for translation, execution etc
  - Managing the disk storage to support the file reading operation
  - Coordinating the I/O units



System Software

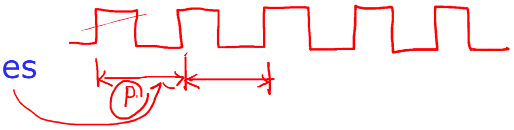
- Responsible for the coordination of all activities in a computing system
- Program that reads numbers stored in a file on disk, sorts the number in ascending order and displays the sorted list on the screen
  - Text editor
  - Command prompt – Operating system
  - Compiler
  - Linker and loader
  - **Operating system**
  - **.....**
- **Operating system**
  - Large program, collection of routines
  - Control the sharing and interaction of various computer units
  - Assigning resources to individual application programs

Performance

- How quickly programs can be executed
- **Best performance**
  - Compiler, machine instruction set, hardware
- **Elapsed time**
  - Total time required to execute a program
  - Measure of entire computer system
  - Affected by the speed of the processor, disk and peripherals like printers
- **Processor time**
  - Performance of the processor
  - Periods during which the processor is active
  - Depends on the hardware involved in the execution of individual machine instruction
    - Processor and memory

Processor Clock

- **Timing signal** that controls the processor circuit
- Periodic signal
  - Regular time intervals- clock cycles



- Execution of an instruction
  - Divide into a sequence of basic steps
  - Each basic step can be completed in one clock cycle
- Length of one clock cycle: *P*
  - Clock rate $R = {}^{1}/_{P}$ cycles per second
  - Hertz (Hz), Mega (M) Hz-Million, Giga (G) Hz-Billion
    - 500 million cycles per second-500 MHz
      - 2 nanoseconds (ns)
    - 1250 million cycles per second—1.25 GHz
      - 0.8 ns

Basic Performance Equation

- **T:** The processor time required to execute a program that has been prepared in high level language
- **N: Actual** number of machine language instructions required to execute a program written in high level language

High level language

```
scanf("%d, %d", a,b);
c=a+b;
printf("&d", c);
```

Machine language

```
IN PORTA, LOCA
IN PORTA, LOCB
LOAD LOCA, R0
ADDM LOCB, R0
STORE R0, LOCC
OUT PORTB
```

Basic Performance Equation

- **N: Actual** number of machine language instructions required to execute a program written in high level language

High level language

```
FOR ( i = 0; i < N; i++)
        A[i] = B[i] + C[i];
```

Machine language

```
            SUB      R0, R0, R0; R0 has value of loop index i
                     LEA      R1, A;  Load the effective address of A in R1
                     LEA      R2, B
                     LEA      R3, C
                     LOAD     R4, N
        Loop_Begin:  CMP      R0, R4
                     JEQ      Loop_End
                     LOAD     R5, [R2][R0]
                     LOAD     R6, [R3][R0]
                     ADD      R7, R5, R6
                     STORE    [R1][R0], R7
                     INC      R0
                     JMP      Loop_Begin
          Loop_End:
```

N×8 + 5

Basic Performance Equation

- *T*: The processor time required to execute a program that has been prepared in high level language
- *N*: **Actual** number of machine language instructions required to execute a program written in high level language
  - Loop-instructions get executed multiple times
  - Condition execution-some instructions may not get executed
- *S*: Average number of basic steps needed to execute one machine instruction
  - Each basic step is completed in one clock cycle
- *R*: Clock rate
- Program execution time

$$T = \frac{N \text{ x } S}{R}$$

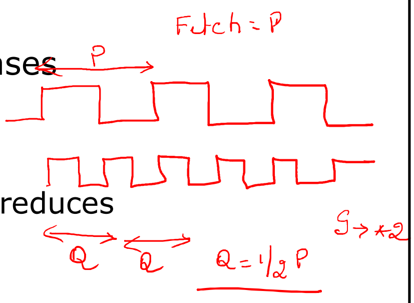
High Performance

$$T = \frac{N \text{ x } S}{R}$$

ADDM LOCB RO ✓

ADD R1, RO ✗

- Reduce the value of *T*
  - Reduce *N* and *S*
  - Increase *R*
- Reduction in *N* – complexity of instruction increases
  - *S* increases
- Increasing *R*-using higher frequency clock
  - Time required to complete a basic execution step reduces



- *N,S*, and *R* are not independent parameters
  - Changing one may affect the other
- **Attempt to improve performance only by overall reduction of *T***

Reference

- Carl Hamacher, Zvonko Vranesic and Safwat Zaky, "Computer Organization", 5th Edition, Tata McGraw Hill, 2002

Thank You