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Subject Name: **Computer Architecture**

Subject Code: **IT-4005**

Semester: **4th**

UNIT-IV Parallel Processing

Parallel Processing

Instead of processing each instruction sequentially, a parallel processing system provides concurrent data processing to increase the execution time. In this the system may have two or more ALU's and should be able to execute two or more instructions at the same time. The purpose of parallel processing is to speed up the computer processing capability and increase its throughput.

Parallel processing can be viewed from various levels of complexity. At the lowest level, we distinguish between parallel and serial operations by the type of registers used. At the higher level of complexity, parallel processing can be achieved by using multiple functional units that perform many operations simultaneously.

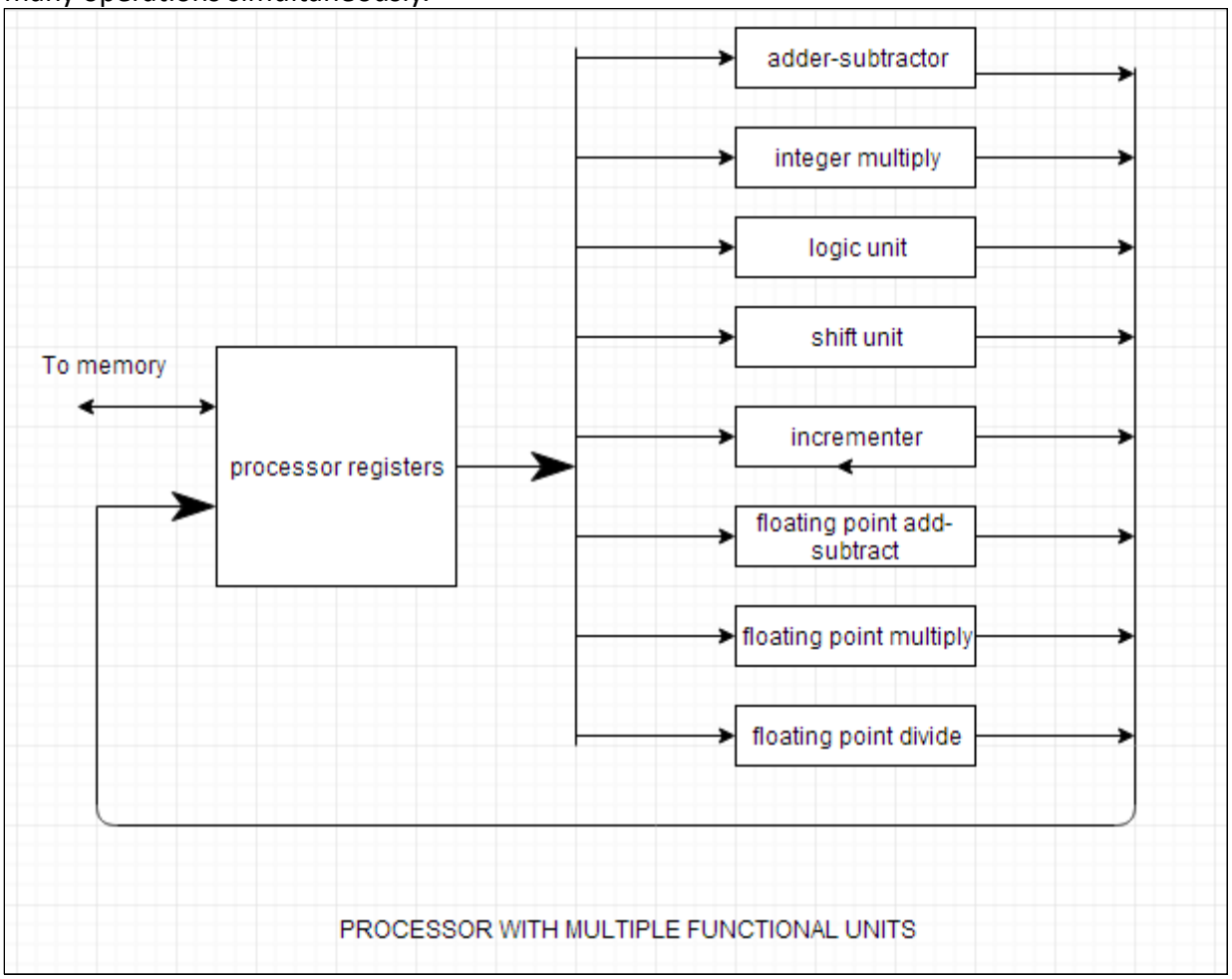

Fig 5.1 processor with multiple functional units

Data Transfer Modes of a Computer System

According to the data transfer mode, computer can be divided into 4 major groups:

SISD (Single Instruction Stream, Single Data Stream)

It represents the organization of a single computer containing a control unit, processor unit and a memory unit. Instructions are executed sequentially. It can be achieved by pipelining or multiple functional units.

SIMD (Single Instruction Stream, Multiple Data Stream)

It represents an organization that includes multiple processing units under the control of a common control unit. All processors receive the same instruction from control unit but operate on

different parts of the data.

They are highly specialized computers. They are basically used for numerical problems that are expressed in the form of vector or matrix. But they are not suitable for other types of computations

MISD (Multiple Instruction Stream, Single Data Stream)

It consists of a single computer containing multiple processors connected with multiple control units and a common memory unit. It is capable of processing several instructions over single data stream simultaneously. MISD structure is only of theoretical interest since no practical system has been constructed using this organization.

MIMD (Multiple Instruction Stream, Multiple Data Stream

It represents the organization which is capable of processing several programs at same time. It is the organization of a single computer containing multiple processors connected with multiple control units and a shared memory unit. The shared memory unit contains multiple modules to communicate with all processors simultaneously. Multiprocessors and multicomputer are the examples of MIMD. It fulfils the demand of large scale computations.

Pipelining

Pipelining is the process of accumulating instruction from the processor through a pipeline. It allows storing and executing instructions in an orderly process. It is also known as **pipeline processing**. Pipelining is a technique where multiple instructions are overlapped during execution. Pipeline is divided into stages and these stages are connected with one another to form a pipe like structure. Instructions enter from one end and exit from another end. Pipelining increases the overall instruction throughput. In pipeline system, each segment consists of an input register followed by a combinational circuit. The register is used to hold data and combinational circuit performs operations on it. The output of combinational circuit is applied to the input register of the next segment.

Pipeline system is like the modern day assembly line setup in factories. For example in a car manufacturing industry, huge assembly lines are setup and at each point, there are robotic arms to perform a certain task, and then the car moves on ahead to the next arm.

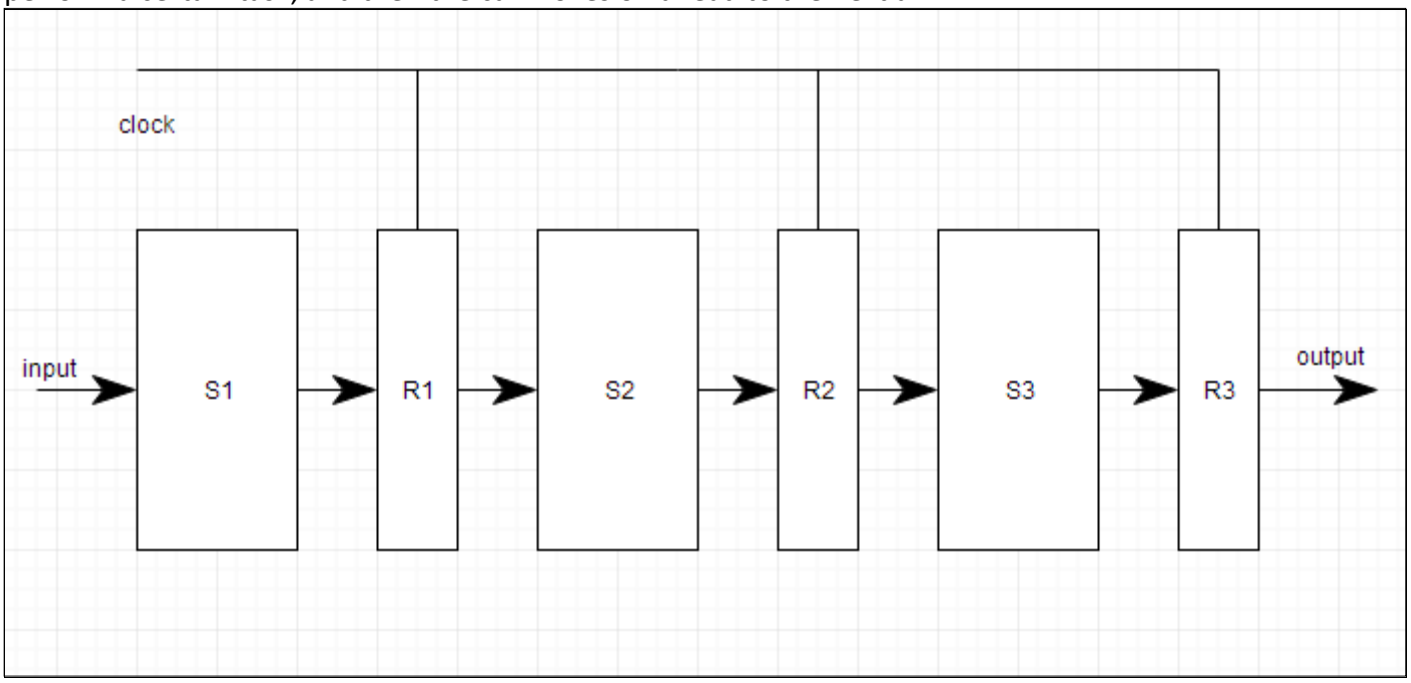

Fig 5.2 pipelining

Types of Pipeline: It is divided into 2 categories:

Arithmetic Pipeline

Arithmetic pipelines are usually found in most of the computers. They are used for floating point operations, multiplication of fixed point numbers etc. For example: The input to the Floating Point Adder pipeline is:

X = A*2^a

Y = B*2^b

Here A and B are mantissas (significant digit of floating point numbers), while **a** and **b** are exponents.

The floating point addition and subtraction is done in 4 parts:

1. Compare the exponents.
2. Align the mantissas.
3. Add or subtract mantissas
4. Produce the result.

Registers are used for storing the intermediate results between the above operations.

Instruction Pipeline

In this a stream of instructions can be executed by overlapping *fetch*, *decode* and *execute* phases of an instruction cycle. This type of technique is used to increase the throughput of the computer system.

An instruction pipeline reads instruction from the memory while previous instructions are being executed in other segments of the pipeline. Thus we can execute multiple instructions simultaneously. The pipeline will be more efficient if the instruction cycle is divided into segments of equal duration.

Pipeline Conflicts

There are some factors that cause the pipeline to deviate its normal performance. Some of these factors are given below:

Timing Variations

All stages cannot take same amount of time. This problem generally occurs in instruction processing where different instructions have different operand requirements and thus different processing time.

Data Hazards

When several instructions are in partial execution, and if they reference same data then the problem arises. We must ensure that next instruction does not attempt to access data before the current instruction, because this will lead to incorrect results.

Branching

In order to fetch and execute the next instruction, we must know what that instruction is. If the present instruction is a conditional branch, and its result will lead us to the next instruction, then the next instruction may not be known until the current one is processed.

Interrupts

Interrupts set unwanted instruction into the instruction stream. Interrupts effect the execution of instruction.

Data Dependency

It arises when an instruction depends upon the result of a previous instruction but this result is not yet available.

Advantages of Pipelining

1. The cycle time of the processor is reduced.
2. It increases the throughput of the system
3. It makes the system reliable.

Disadvantages of Pipelining

1. The design of pipelined processor is complex and costly to manufacture.
2. The instruction latency is more.

Vector (Array) Processing

There is a class of computational problems that are beyond the capabilities of a conventional computer. These problems require vast number of computations on multiple data items that will take a conventional computer (with scalar processor) days or even weeks to complete. Such complex instruction, which operates on multiple data at the same time, requires a better way of instruction execution, which was achieved by Vector processors.

Scalar CPUs can manipulate one or two data items at a time, which is not very efficient. Also, simple instructions like ADD A to B, and store into C are not practically efficient. Addresses are used to point to the memory location where the data to be operated will be found, which leads to added overhead of data lookup. So until the data is found, the CPU would be sitting ideal, which is a big performance issue.

Hence, the concept of **Instruction Pipeline** comes into picture, in which the instruction passes through several sub-units in turn. These sub-units perform various independent functions, for example: the first one decodes the instruction, the second sub-unit fetches the data and the third sub-unit performs the math itself. Therefore, while the data is fetched for one instruction, CPU does not sit idle; it rather works on decoding the next instruction set, ending up working like an assembly line.

Vector processor, not only use Instruction pipeline, but it also pipelines the data, working on multiple data at the same time. A normal scalar processor instruction would be ADD A, B, which leads to addition of two operands, but what if we can instruct the processor to ADD a group of numbers(from 0 to n memory location) to another group of numbers(lets say, n to k memory location). This can be achieved by vector processors. In vector processor a single instruction, can ask for multiple data operations, which saves time, as instruction is decoded once, and then it keeps on operating on different data items.

Applications of Vector Processors

The following are some areas where vector processing is used:

1. Petroleum exploration.
2. Medical diagnosis.
3. Data analysis.
4. Weather forecasting.
5. Aerodynamics and space flight simulations.
6. Image processing.
7. Artificial intelligence.

Memory interleaving

It is a technique for increasing memory speed. It is a process that makes the system more efficient, fast and reliable. For example: In the above example of 4 memory banks, data with virtual address 0, 1, 2 and 3 can be accessed simultaneously as they reside in separate memory banks, hence we do not have to wait for completion of a data fetch, to begin with the next. An interleaved memory with n banks is said to be **n-way interleaved**. In an interleaved memory system, there are still **two**

banks of DRAM but logically the system seems one bank of memory that is twice as large.
In the interleaved bank representation below with 2 memory banks, the first long word of bank 0 is flowed by that of bank 1, which is followed by the second long word of bank 0, which is followed by the second long word of bank 1 and so on.
Types:
There are two methods for interleaving a memory:

- 2-Way Interleaved: Two memory blocks are accessed at same time for writing and reading operations.
- 4-Way Interleaved: Four memory blocks are accessed at the same time.

Multiprocessor system

A multiprocessor system is an interconnection of two or more CPU, with memory and input-output equipment. As defined earlier, multiprocessors can be put under MIMD category. The term multiprocessor is sometimes confused with the term multicomputer. Though both support concurrent operations, there is an important difference between a system with multiple computers and a system with multiple processors. In a multicomputer system, there are multiple computers, with their own operating systems, which communicate with each other, if needed, through communication links. A multiprocessor system, on the other hand, is controlled by a single operating system, which coordinate the activities of the various processors, either through shared memory or interprocessor messages.
The advantages of multiprocessor systems are:
·Increased reliability because of redundancy in processors
·Increased throughput because of execution of multiple jobs in parallel portions of the same job in parallel

Characteristics of Multiprocessors

A multiprocessor system is an interconnection of two or more CPUs with memory and input-output equipment.

- The “processor” may be either a central processing unit (CPU) or an input-output processor (IOP).
- Multiprocessors are *multiple instruction streams, multiple data stream* (MIMD) systems
- Multiprocessing can enhance performance by decomposing a program into parallel executable tasks.
- The user can explicitly declare that certain tasks of the program to be executed in parallel.
- This must be done prior to loading the program by specifying the parallel executable segments.
- Other is to provide a compiler with multiprocessor software that can automatically detect parallelism in a user’s program.
- A multiprocessor system with *common shared memory* is classified as a *shared-memory* or *tightly coupled multiprocessor*.
- Each processor element with its own *private local memory* is classified as a *distributed-memory* or *loosely coupled system.*
- when the interaction between tasks is minimal it is most efficient
- Multiprocessing improves the reliability of the system
- In a multiprocessor organization, multiple independent jobs can be made to operate in parallel.
- Also partition of a single job into multiple parallel tasks.
- The similarity and distinction between multiprocessor and multicomputer :
- Both support concurrent operations Distinction

- The network consists of several autonomous computers; communication with each other may or may not take place.
- A multiprocessor system is controlled by one operating system which provides interaction between processors and all the components of the system

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