Computer Organization

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IV

The Variety Of Processors And Computational Engines

Definition

The terms *processor* and *computational engine* refer broadly to any mechanism that drives computation

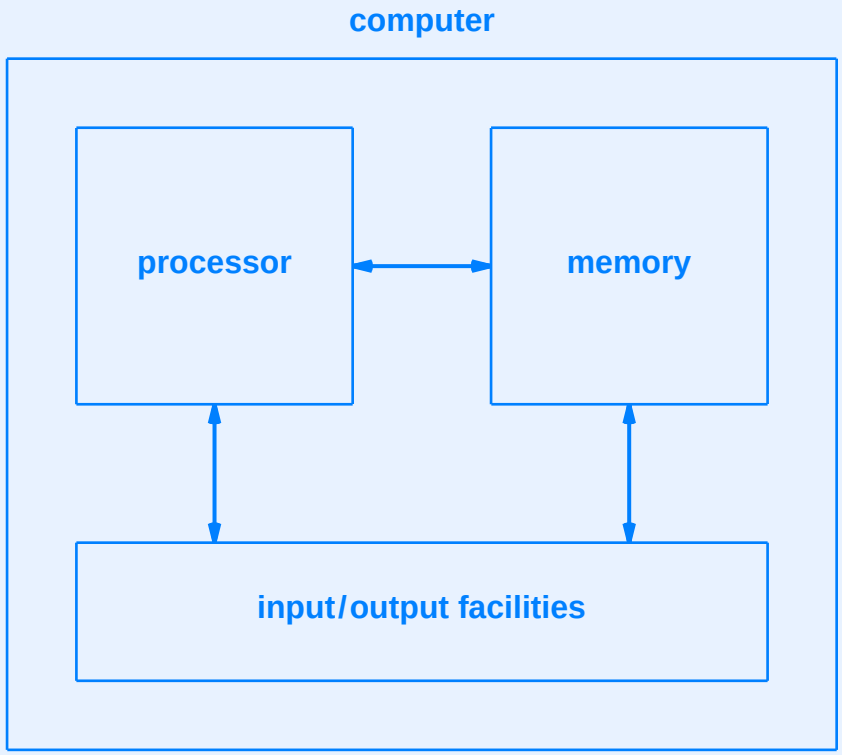
Von Neumann Architecture

- Characteristic of most modern processors
- Reference to mathematician John Von Neumann who was one of the computer architecture pioneers
- Central idea is *stored program*

Three Basic Components Of Von Neumann Architecture

- Processor
- Memory
- I/O facilities
- All interact to form a complete computer

Illustration Of Von Neumann Architecture



Processor

- Digital device
- Performs computation involving multiple steps
- Building blocks used to form computer system

Range Of Processors

- Wide variety of capabilities
- Various mechanisms
  - Fixed logic
  - Selectable logic
  - Parameterized logic
  - Programmable logic

Fixed Logic Processor

- Least powerful
- Performs a single operation
- Functionality hardwired (cannot be changed)
- Example: processor that computes *sine*

Selectable Logic Processor

- Slightly more powerful than fixed logic
- Can perform more than one function
- Exact function specified each time processor invoked
- Example: compute *sine* or *cosine*

Parameterized Logic Processor

- Accepts set of parameters that control computation
- Parameters set for each invocation
- Example
  - Compute hash function, *h(x)*
  - Parameters specify constants *p* and *q* used in computation

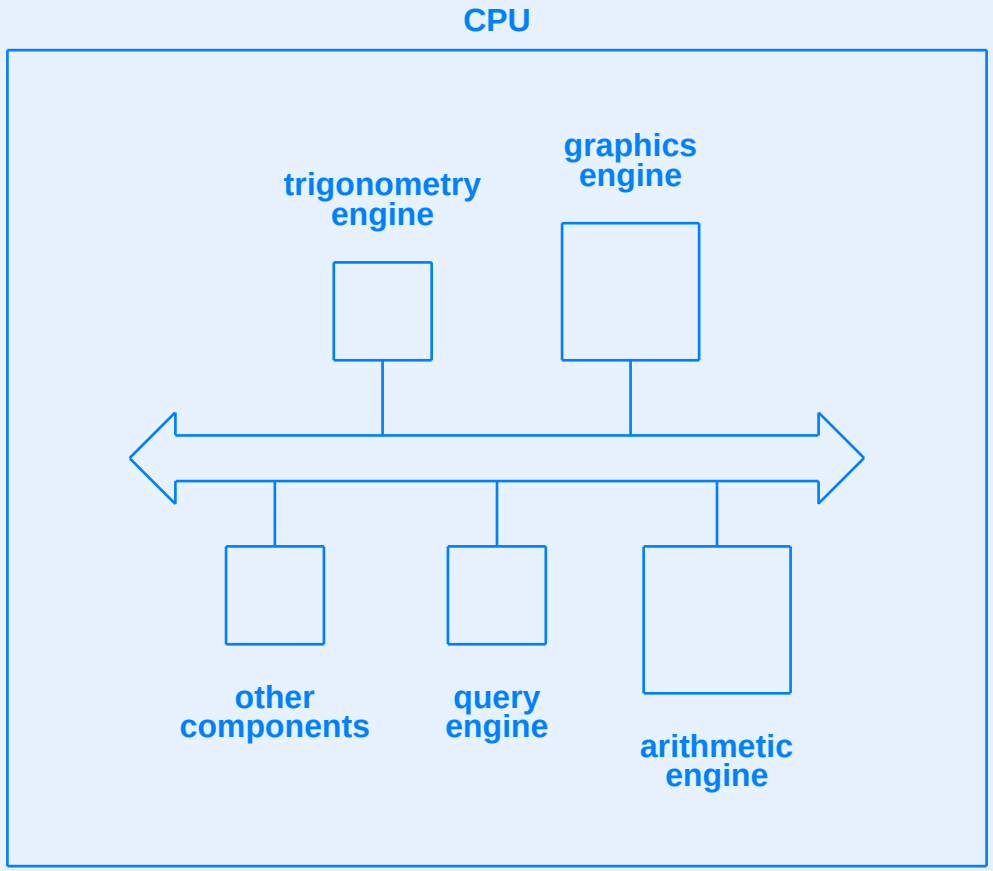
Programmable Logic Processor

- Greatest flexibility
- Function to compute can be changed
- Sequence of steps can be specified for each invocation
- Example: conventional CPU

Hierarchical Structure And Computational Engines

- Most computer architecture follows a hierarchical approach
- Subparts of a large, central processor are sophisticated enough to meet our definition of processor
- Some engineers use term *computational engine* for subpiece that is less powerful than main processor

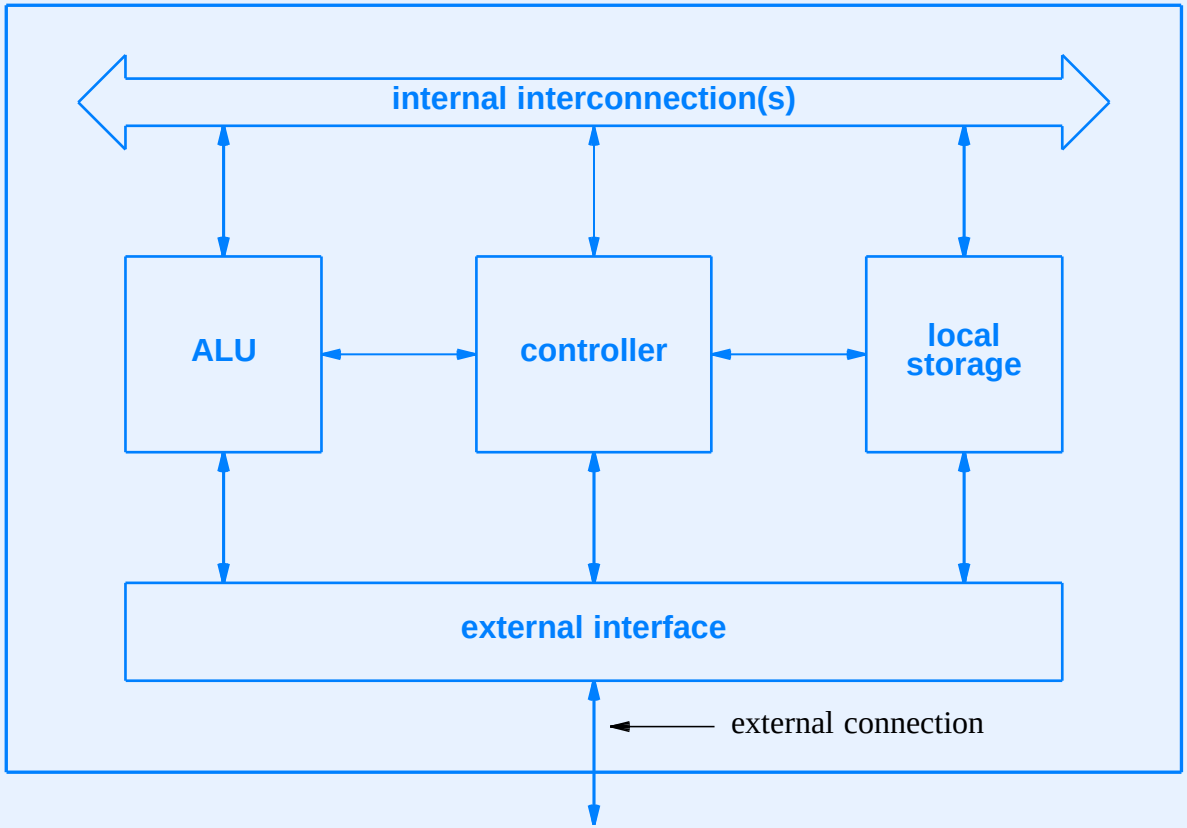
Illustration Of Processor Hierarchy



Major Components Of A Conventional Processor

- Controller
- Computational engine (ALU)
- Local data storage
- Internal interconnection(s)
- External interface

Illustration Of A Conventional Processor



Parts Of A Conventional Processor

- Controller
  - Overall responsibility for execution
  - Moves through sequence of steps
  - Coordinates other units
- Computational engine
  - Operates as directed by controller
  - Typically provides arithmetic and Boolean operations
  - Performs one operation at a time

Parts Of A Conventional Processor
(continued)

- Local data storage
  - Holds data values for operations
  - Must be loaded before operation can be performed
  - Typically impelmented with *registers*
- Internal interconnections
  - Allow transfer of values among units of the processor
  - Sometimes called *data path*

Parts Of A Conventional Processor
(continued)

- External interface
  - Handles communication between processor and rest of computer system
  - Provides connections to external memory as well as external I/O devices

Arithmetic Logic Unit (ALU)

- Main computational engine in conventional processor
- Complex unit that can perform variety of tasks
- Typical ALU operations
  - Integer arithmetic (add, subtract, multiply, divide)
  - Shift (left, right, circular)
  - Boolean (*and*, *or*, *not*, *exclusive or*)

Processor Categories And Roles

- Many possible roles for individual processors in
  - Coprocessors
  - Microcontrollers
  - Microsequencers
  - Embedded system processors
  - General-purpose processors

Coprocessor

- Operates in conjunction with and under the control of another processor
- Usually
  - Special-purpose processor
  - Performs a single task
  - Operates at high speed
- Example: floating point accelerator

Microcontroller

- Programmable device
- Dedicated to control of a physical system
- Example: run automobile engine or grocery store door

Example Steps A Microcontroller Performs (Automatic Door)

```
do forever {
        wait for the sensor to be tripped;
        turn on power to the door motor;
        wait for a signal that indicates the
                door is open;
        wait for the sensor to reset;
        delay ten seconds;
        turn off power to the door motor;
}
```

Microsequencer

- Similar to microcontroller
- Controls coprocessors and other engines within a large processor
- Example: move operands to floating point unit; invoke an operation; move result back to memory

Embedded System Processor

- Runs sophisticated electronic device
- Usually more powerful than microcontroller
- Example: control DVD player, including commands from a remote control

General-Purpose Processor

- Most powerful type of processor
- Completely programmable
- Full functionality
- Example: CPU in a personal computer

Processor Technologies

- Originally: discrete logic
- Later: single circuit board
- Now: single chip

Definition Of Programmable Device

To a computer architect, a processor is classified as programmable if at some level of detail, the processor is separate from the program it runs. To a user, it may appear that the program and processor are integrated, and it may not be possible to change the program without replacing the processor.

Fetch-Execute Cycle

- Basis for programmable processors
- Allows processor to move through program steps automatically
- Implemented by processor hardware
- Note:

At some level, every programmable processor implements a fetch-execute cycle.

Fetch-Execute Algorithm

Repeat forever {

Fetch: access the next step of the program from the location in which the program has been stored.

Execute: Perform the step of the program.

}

- Note: we will discuss in more detail later

Clock Rate And Instruction Rate

- Clock rate
  - Measure of underlying hardware speed
  - Rate at which gates are clocked
- Instruction rate
  - Measure of time required for *execute* portion of fetch-execute cycle
  - Varies because some instructions take more time than others

Clock Rate And Instruction Rate
(continued)

The fetch-execute cycle does not proceed at a fixed rate because the time required to execute a given instruction depends on the operation being performed. An operation such as multiplication requires more time than an operation such as addition.

Stopping A Processor

- Processor runs fetch-execute indefinitely
- Software must plan next step
- When last step of application program finishes
  - Embedded system: processor enters a loop
  - General purpose system: operating system executes an infinite loop

Starting A Processor

- Hardware reset stops fetch-execute
- Digital logic holds reset on power-up until processor initialized
- Process known as *bootstrap*

Summary

- Processor performs a computation involving multiple steps
- Many types of processors
  - Coprocessor
  - Microcontroller
  - Microsequencer
  - Embedded system processor
  - General-purpose processor
- Arithmetic Logic Unit (ALU) performs basic arithmetic and Boolean operations

Summary
(continued)

- Hardware in programmable processor runs fetch-execute cycle
- Most processors now consist of single integrated circuit


Questions?