Processing Unit

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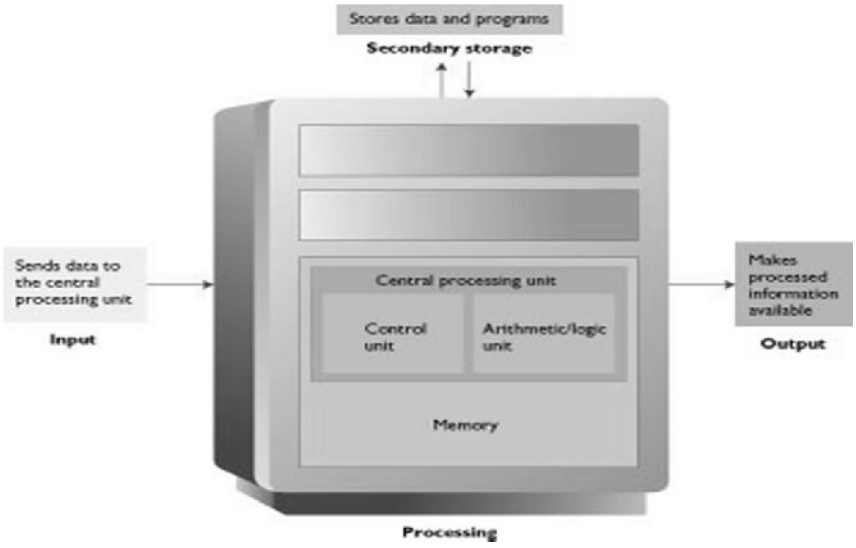
Objectives

- Identify the components of the central processing unit and how they work together and interact with memory
- Describe how program instructions are executed by the computer
- Explain how data is represented in the computer
- Describe how the computer finds instructions and data
- Describe the components of a microcomputer system unit's motherboard
- List the measures of computer processing speed and explain the approaches that increase speed

The CPU



The CPU

- Converts data into information
- Control center
- Set of electronic circuitry that executes stored program instructions
- Two parts
  - –Control Unit (CU)
  - –Arithmetic Logic Unit (ALU)

Control Unit (*CU)*

- Part of the hardware that is in-charge
- Directs the computer system to execute stored program instructions
- Communicates with other parts of the hardware

Arithmetic / Logic Unit (*ALU)*

- Performs arithmetic operations
- Performs logical operations

Arithmetic Operations

Addition

Subtraction

Multiplication

Division

Logical Operations

- Evaluates conditions
- Makes comparisons
- Can compare
  - –Numbers
  - –Letters
  - –Special characters

NOT

AND

OR

= > < <> >= <=

Registers

- Special-purpose
- High-speed
- Temporary storage
- Located inside CPU

Instruction register	*Data register*
Holds instruction currently being executed	Holds data waiting to be processed Holds results from processing

Types of Storage

- Secondary
  - Data that will eventually be used
  - Long-term
- Memory
  - Data that will be used in the near future
  - Temporary
  - Faster access than storage
- Registers
  - Data immediately related to the operation being executed
  - Faster access than memory

Memory (*Many Names)*

- Primary storage
- Primary memory
- Main storage
- Internal storage
- Main memory

Main Types of Memory

- RAM
  Random Access Memory
- ROM
  Read Only Memory

RAM

- Requires current to retain values
- Volatile
- Data and instructions can be read and modified
- Users typically refer to this type of memory

What's in RAM?

- Operating System
- Program currently running
- Data needed by the program
- Intermediate results waiting to be output

RAM

- Keeps the instructions and data for current program
- Data in memory can be accessed randomly
- Easy and speedy access
- Volatile
- Erased
- Written over

Types of RAM

DRAM (*dynamic random access memory*)
- Must be constantly refreshed
- Used for most PC memory because of size and cost

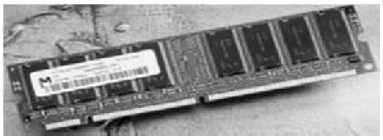
SRAM (*static random-access memory*)
- Retains contents as long as power is maintained
- Faster than DRAM

SDRAM (*synchronous DRAM*)
- faster type of DRAM

Rambus DRAM
- Faster than SDRAM
- Expensive

Adding RAM

- Purchase memory modules that are packaged on circuit boards
- SIMMS – Chips on one side
- DIMMS – Chips on both sides
- Maximum amount of RAM that can be installed is based upon the motherboard design



ROM

- Non-volatile
- Instructions for booting the computer
- Data and instructions can be read, but not modified
- Instructions are typically recorded at factory

ROM

- Programs and data that are permanently recorded at the factory
- Read
- Use
- Cannot be changed by the user
- Stores boot routine that is activated when computer is turned on
- Nonvolatile

PROM

- Programmable ROM
- ROM burner can change instructions on some ROM chips

Executing Programs

- CU gets an instruction and places it in memory
- CU decodes the instruction
- CU notifies the appropriate part of hardware to take action
- Control is transferred to the appropriate part of hardware
- Task is performed
- Control is returned to the CU

Finding Data in Memory

- Each location in memory has a unique address
  - –Address never changes
  - –Contents may change
- Memory location can hold one instruction or piece of data
- Programmers use symbolic names

Coding Schemes

- ASCII
  - Uses one 8 bit byte
  - 2^8 = 256 possible combinations or characters
  - Virtually all PCs and many larger computers
- EBCDIC
  - Uses one 8 bit byte
  - 2^8 =256 possible combinations or characters
  - Used primarily on IBM-compatible mainframes
- Unicode
  - Uses two 8 bit bytes (16 bits)
  - 2^{16} = 65,536 possible combinations or characters
  - Supports characters for all the world's languages
  - Downward-compatible with ASCII

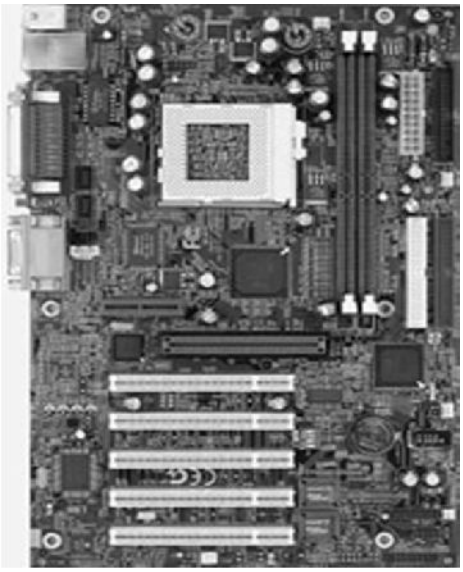
The System Unit

Motherboard

- Microprocessor chip
- Memory chips
- Connections to other parts of the hardware
- Additional chips may be added – math coprocessor

Storage Devices

- Hard drive
- Floppy drive
- CD-ROM drive
- DVD-ROM drive



Microprocessor

- CPU etched on a chip
- Chip size is ¼ x ¼ inch
- Composed of silicon
- Contains millions of transistors
  - –Electronic switches that can allow current to pass through

Microprocessor Components

- Control Unit – CU
- Arithmetic / Logic Unit – ALU
- Registers
- System clock

Building a Better Microprocessor

- Computers imprint circuitry onto microchips
  - –Cheaper
  - –Faster
- Perform functions of other hardware
  - –Math coprocessor is now part of microprocessor
  - –Multimedia instructions are now part of microprocessor

Building a Better Microprocessor

The more functions that are combined on a microprocessor:

- The faster the computer runs
- The cheaper it is to make
- The more reliable it is

Types of Microprocessors

- PowerPC
  - –Cooperative efforts of Apple, IBM, and Motorola
  - –Used in Apple Macintosh family of PCs
  - –Found in servers and embedded systems
- Alpha
  - –Manufactured by Compaq
  - –High-end servers and workstations

Semiconductor Memory

- Reliable
- Compact
- Low cost
- Low power usage
- Mass-produced economically
- Volatile
- Monolithic
  - All circuits together constitute an inseparable unit of storage

Semiconductor Memory
CMOS

Complementary metal oxide semiconductor

- Uses little electricity
- Used in PC to store hardware settings that are needed to boot the computer
- Retains information with current from battery

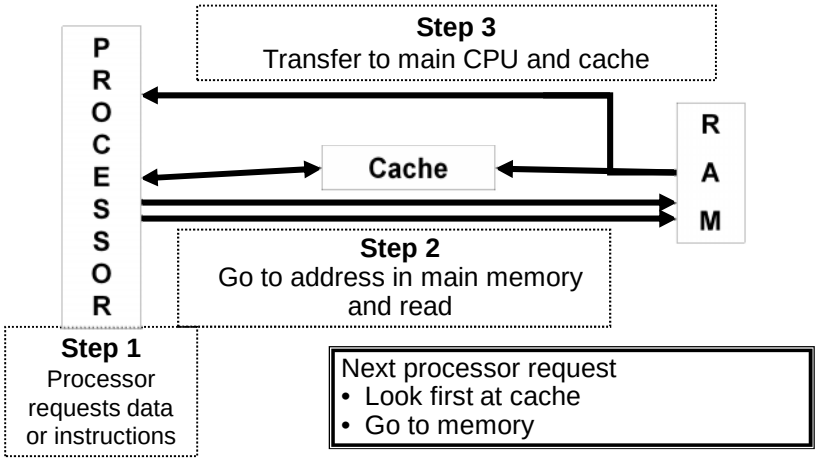
Cache

- Small block of very fast temporary memory
- Speed up data transfer
- Instructions and data used most frequently or most recently

Types of Cache

- Internal cache
  - Level 1 (L1)
  - Built into microprocessor
  - Up to 128KB
- External cache
  - Level 2 (L2)
  - Separate chips
  - 256KB or 512 KB
  - SRAM technology
  - Cheaper and slower than L1
  - Faster and more expensive than memory

Cache



Flash Memory

- Nonvolatile RAM
- Used in
  - –Cellular phones
  - –Digital cameras
  - –Digital music recorders ETC.

Bus Line

- Paths that transport electrical signals
- System bus
  - –Transports data between the CPU and memory
- Bus width
  - –Number of bits of data that can be carried at a time
  - –Normally the same as the CPUs word size
- Speed measured in MHz

Bus Line

Larger bus width	More powerful computer
CPU can transfer more data at a time	Faster computer
CPU can reference larger memory addresses	More memory available

CPU can support a greater number and variety of instructions

Expansion Buses

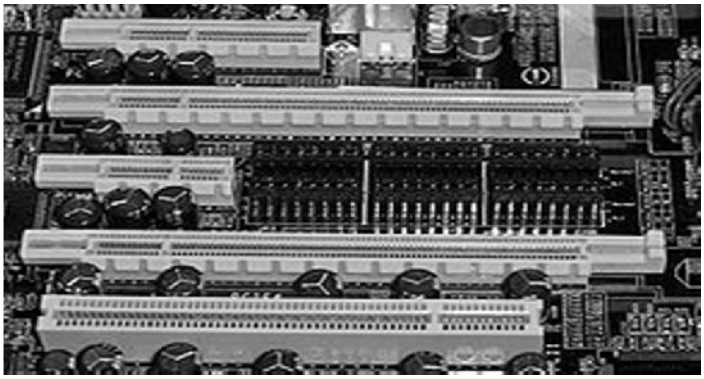
- Connect the motherboard to expansion slots
- Plug expansion boards into slots
  - –interface cards
  - –adapter cards
- Provides for external connectors / ports
  - –Serial
  - –Parallel

PC Buses and Ports

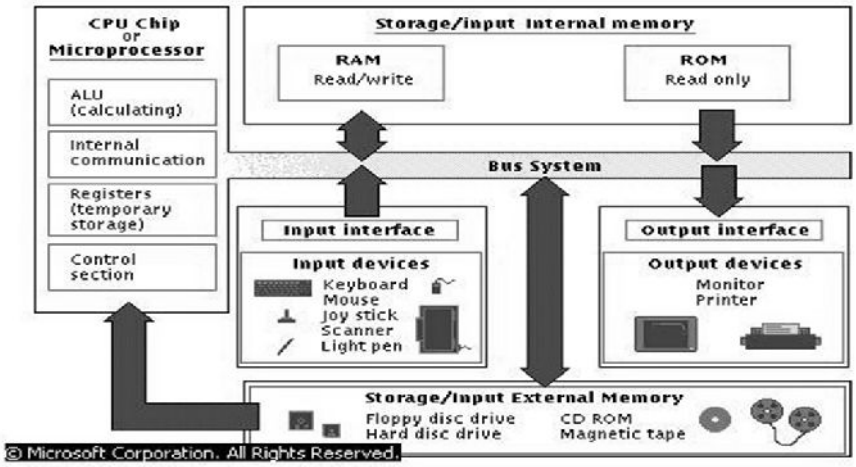
ISA	Slow-speed devices like mouse, modem
PCI	High-speed devices like hard disks and network cards
AGP	Connects memory and graphics card for faster video performance
USB	Supports "daisy-chaining" eliminating the need for multiple expansion cards; hot-swappable
IEEE 1394 (FireWire)	High-speed bus connecting video equipment to the computer
PC Card	Credit card sized PC card devices normally found on laptops

Bus system

A subsystem that transfers data between computer components inside a computer or between computers.



Bus system connection



Data bus

The data bus is 'bi-directional'

- data or instruction codes from memory or input/output are transferred into the microprocessor
- the result of an operation or computation is sent out from the microprocessor to the memory or input/output.

Depending on the particular microprocessor, the data bus can handle 8 bit or 16 bit data.

Address bus

- The address bus is '**unidirectional**', over which the microprocessor sends an address code to the memory or input/output.
- The size (width) of the address bus is specified by the number of bits it can handle.
- The more bits there are in the address bus, the more memory locations a microprocessor can access.
- A 16 bit address bus is capable of addressing 65,536 (64K) addresses.

Control bus

The control bus is used by the microprocessor to send out or receive timing and control signals in order to coordinate and regulate its operation and to communicate with other devices, i.e. memory or input/output.

Speed and Power

What makes a computer fast?

- Microprocessor speed
- Bus line size
- Availability of cache
- Flash memory
- RISC computers
- Parallel processing

Computer Processing Speed

Time to execute an instruction

- Millisecond
- Microsecond
- Nanosecond
  - –Modern computers
- Picosecond
  - –In the future

Microprocessor Speed

- Clock speed
  - –Megahertz (MHz)
  - –Gigahertz (GHz)
- Number of instructions per second
  - –Millions of Instructions Per Second (MIPS)
- Performance of complex mathematical operations
  - –One million floating-point operations per second (Megaflop)

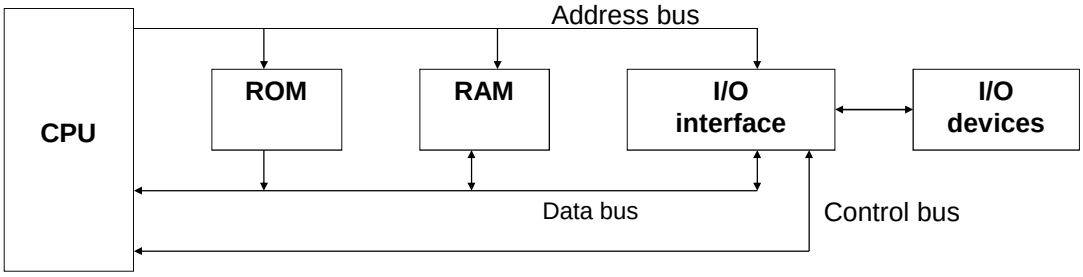
Types of Processing

- Serial processing
  - – Execute one instruction at a time
  - – Fetch, decode, execute, store
- Parallel Processing
  - – Multiple processors used at the same time
  - – Can perform trillions of floating-point instructions per second (teraflops)
  - – Ex: network servers, supercomputers

- Pipelining
  - Instruction's action need not be complete before the next begins
  - Fetch instruction 1, begin to decode and fetch instruction 2

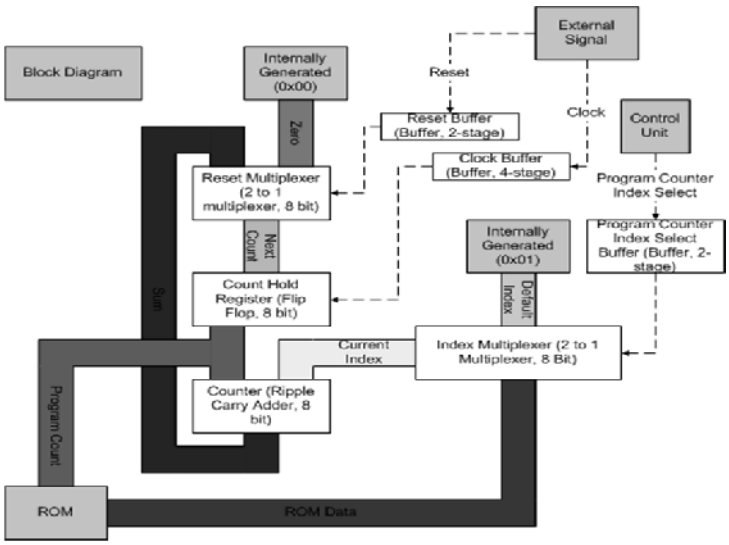
BLOCK DIAGRAM OF A BASIC COMPUTER SYSTEM

Basic computer system consist of a Central processing unit (CPU), memory (RAM and ROM), input/output (I/O) unit.

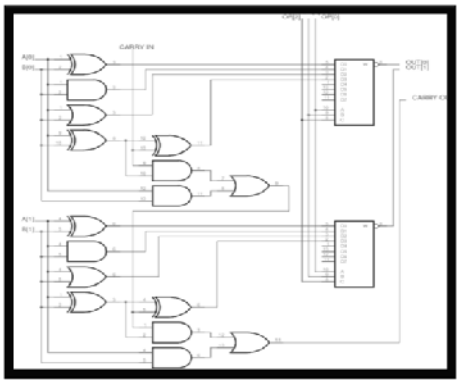


Block diagram of a basic computer system

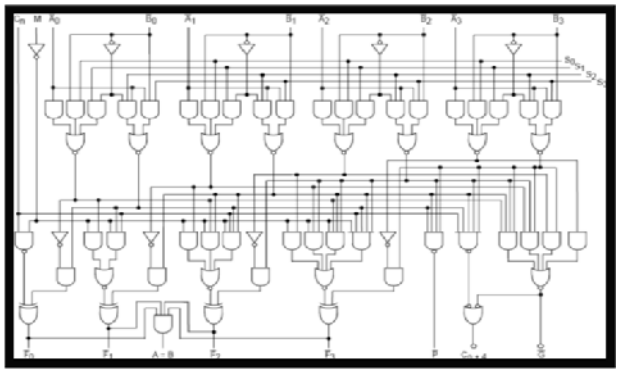
Internal structure of PC



Internal structure of ALU



2 bits of ALU



4 bits of ALU

Internal structure of control unit