Inside the Computer System
How Computers Represent Data

• **Binary numbers**
  o Only 0s and 1s

• **Bit**
  o Smallest piece of data a computer can work with
  o Either “on” or “off,” a 0 or a 1
  o Eight bits—**byte**—a single unit of storage
How Computers Represent Data

• Modem’s data transfer rate is in bits per second
  o Example—gigabits per second (Gbps)

• Data storage is in bytes
  o Kilobyte (KB)—one thousand bytes
  o Megabyte (MB)—one million bytes
  o Gigabytes (GB)—one billion bytes
  o Terabyte (TB)—one trillion bytes
How Computers Represent Data

- Computers convert binary numbers into hexadecimal (hex) numbers
  - Which use the numbers 0 through 9, followed by letters A through F

<table>
<thead>
<tr>
<th>Decimal (Base 10)</th>
<th>Binary (Base 2)</th>
<th>Hexadecimal (Base 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0000</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0001</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0010</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0011</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>0100</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>0101</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>0110</td>
<td>6</td>
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<tr>
<td>7</td>
<td>0111</td>
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<tr>
<td>8</td>
<td>1000</td>
<td>8</td>
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<tr>
<td>9</td>
<td>1001</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>1010</td>
<td>A</td>
</tr>
<tr>
<td>11</td>
<td>1011</td>
<td>B</td>
</tr>
<tr>
<td>12</td>
<td>1100</td>
<td>C</td>
</tr>
<tr>
<td>13</td>
<td>1101</td>
<td>D</td>
</tr>
<tr>
<td>14</td>
<td>1110</td>
<td>E</td>
</tr>
<tr>
<td>15</td>
<td>1111</td>
<td>F</td>
</tr>
</tbody>
</table>
How Computers Represent Data

• **Floating point notation**
  - Has no fixed number of digits before or after a decimal point
  - Enables a computer to work quickly with very large or small numbers
  - Requires special processing circuitry
How Computers Represent Data

- **Characters**
  - Letters, numbers, and symbols—converted into numbers the computer understands

- **Character code**
  - Performs the conversion
    - American Standard Code for Information Interchange (ASCII)
    - Extended Binary Coded Decimal Interchange Code (EBCDIC)
    - Unicode
| Dec | Hex | Oct | Char | Dec | Hex | Oct | Char | Dec | Hex | Oct | Char | Dec | Hex | Oct | Char |
|-----|-----|-----|------|-----|-----|-----|------|-----|-----|-----|------|-----|-----|-----|------|-----|-----|-----|------|-----|-----|-----|------|-----|-----|-----|------|
| 0   | 0   | 0   | 0    | 32  | 20  | 40  | [space] | 64  | 40  | 100 | @    | 96  | 60  | 140 | `    |
| 1   | 1   | 1   | 1    | 33  | 21  | 41  | !     | 65  | 41  | 101 | A     | 97  | 61  | 141 | a    |
| 2   | 2   | 2   | 2    | 34  | 22  | 42  | "     | 66  | 42  | 102 | B     | 98  | 62  | 142 | b    |
| 3   | 3   | 3   | 3    | 35  | 23  | 43  | #     | 67  | 43  | 103 | C     | 99  | 63  | 143 | c    |
| 4   | 4   | 4   | 4    | 36  | 24  | 44  | $     | 68  | 44  | 104 | D     | 100 | 64  | 144 | d    |
| 5   | 5   | 5   | 5    | 37  | 25  | 45  | %     | 69  | 45  | 105 | E     | 101 | 65  | 145 | e    |
| 6   | 6   | 6   | 6    | 38  | 26  | 46  | &     | 70  | 46  | 106 | F     | 102 | 66  | 146 | f    |
| 7   | 7   | 7   | 7    | 39  | 27  | 47  | '     | 71  | 47  | 107 | G     | 103 | 67  | 147 | g    |
| 8   | 8   | 10  |     | 40  | 28  | 50  | (     | 72  | 48  | 110 | H     | 104 | 68  | 150 | h    |
| 9   | 9   | 11  |     | 41  | 29  | 51  | )     | 73  | 49  | 111 | I     | 105 | 69  | 151 | i    |
| 10  | A   | 12  |     | 42  | 2A  | 52  | *     | 74  | 4A  | 112 | J     | 106 | 6A  | 152 | j    |
| 11  | B   | 13  |     | 43  | 2B  | 53  | +     | 75  | 4B  | 113 | K     | 107 | 6B  | 153 | k    |
| 12  | C   | 14  |     | 44  | 2C  | 54  | .     | 76  | 4C  | 114 | L     | 108 | 6C  | 154 | l    |
| 13  | D   | 15  |     | 45  | 2D  | 55  | -     | 77  | 4D  | 115 | M     | 109 | 6D  | 155 | m    |
| 14  | E   | 16  |     | 46  | 2E  | 56  | .     | 78  | 4E  | 116 | N     | 110 | 6E  | 156 | n    |
| 15  | F   | 17  |     | 47  | 2F  | 57  | /     | 79  | 4F  | 117 | O     | 111 | 6F  | 157 | o    |
| 16  | G   | 18  |     | 48  | 30  | 60  | 0     | 80  | 50  | 120 | P     | 112 | 70  | 160 | p    |
| 17  | H   | 19  |     | 49  | 31  | 61  | 1     | 81  | 51  | 121 | Q     | 113 | 71  | 161 | q    |
| 18  | I   | 20  |     | 50  | 32  | 62  | 2     | 82  | 52  | 122 | R     | 114 | 72  | 162 | r    |
| 19  | J   | 21  |     | 51  | 33  | 63  | 3     | 83  | 53  | 123 | S     | 115 | 73  | 163 | s    |
| 20  | K   | 22  |     | 52  | 34  | 64  | 4     | 84  | 54  | 124 | T     | 116 | 74  | 164 | t    |
| 21  | L   | 23  |     | 53  | 35  | 65  | 5     | 85  | 55  | 125 | U     | 117 | 75  | 165 | u    |
| 22  | M   | 24  |     | 54  | 36  | 66  | 6     | 86  | 56  | 126 | V     | 118 | 76  | 166 | v    |
| 23  | N   | 25  |     | 55  | 37  | 67  | 7     | 87  | 57  | 127 | W     | 119 | 77  | 167 | w    |
| 24  | O   | 26  |     | 56  | 38  | 70  | 8     | 88  | 58  | 130 | X     | 120 | 78  | 170 | x    |
| 25  | P   | 27  |     | 57  | 39  | 71  | 9     | 89  | 59  | 131 | Y     | 121 | 79  | 171 | y    |
| 26  | Q   | 28  |     | 58  | 3A  | 72  | :     | 90  | 5A  | 132 | Z     | 122 | 7A  | 172 | z    |
| 27  | R   | 29  |     | 59  | 3B  | 73  | ;     | 91  | 5B  | 133 | [     | 123 | 7B  | 173 | {    |
| 28  | S   | 30  |     | 60  | 3C  | 74  | %     | 92  | 5C  | 134 | \    | 124 | 7C  | 174 | |    |
| 29  | T   | 31  |     | 61  | 3D  | 75  | =     | 93  | 5D  | 135 | |     | 125 | 7D  | 175 | }    |
| 30  | U   | 32  |     | 62  | 3E  | 76  | >     | 94  | 5E  | 136 | ^    | 126 | 7E  | 176 | ~    |
| 31  | V   | 33  |     | 63  | 3F  | 77  | ?     | 95  | 5F  | 137 | `    | 127 | 7F  | 177 |     |
Introducing the System Unit

- **System unit**
  - Case that contains the major hardware components of a computer
  - Come in different styles
  - **Footprints**
    - Amount of space that the unit uses
Introducing the System Unit

- **System unit (con’t.)**
  - Some have embedded biometric authentication devices such as fingerprint readers, retina scanners, and face recognition systems to prevent unauthorized access.
  - **Form factor**—specifies how the internal components are located within the system unit.
Inside the System Unit

- All-in-one system unit
- Notebook system unit
- Desktop system unit
- Smartphone system unit
Inside the System Unit

- System unit main components
  - Motherboard
  - CPU
  - Power supply
  - Cooling fan
  - Internal speaker
  - Drive bays
  - Expansion slots
Inside the System Unit
Inside the System Unit

- Notebook motherboard
- Processor
- Cooling fan
- Power supply
What’s on the Motherboard?

- Memory module (RAM)
- Modem card
- Network interface card
- Sound card
- Video card
What’s on the Motherboard?

• **Motherboard**
  - Printed circuit board that contains the electrical circuitry for the computer
  - The majority of parts found on the motherboard are **integrated circuits**.
    - Includes millions of **transistors** and carries electrical current
      - A switch that is able to control the electrical signal flow to the circuit
What’s on the Motherboard?

• **Central processing unit (CPU)**
  - Integrated circuit chip that processes electronic signals
  - Also known as a microprocessor or processor
What’s on the Motherboard?

• **CPU (con’t.)**
  - Is usually covered by a **heat sink**
    - A heat-dissipating component that drains heat from the chip
  - **Instruction**—An operation performed by the CPU and assigned a specific number
  - **Instruction set**—The list of CPU instructions for the operations

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Operand Number</th>
<th>Operation</th>
<th>Opcode</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDA</td>
<td>1</td>
<td>Load memory data to ACC</td>
<td>0000</td>
</tr>
<tr>
<td>ADD</td>
<td>1</td>
<td>Add ACC data with B register data</td>
<td>0001</td>
</tr>
<tr>
<td>SUB</td>
<td>1</td>
<td>Sub B register data from data in ACC</td>
<td>0010</td>
</tr>
<tr>
<td>OUT</td>
<td>0</td>
<td>Move out the ACC data to the output register</td>
<td>1110</td>
</tr>
<tr>
<td>HLT</td>
<td>0</td>
<td>Stop program</td>
<td>1111</td>
</tr>
</tbody>
</table>
What’s on the Motherboard?

- **CPU (con’t.)**
  - **Control unit**—one of the two main parts
    - Retrieves instructions from memory
    - Interprets and performs those instructions
    - Manages the **machine cycle** or **processing cycle**, the four-part process performed by the CPU
  - **Arithmetic logic unit (ALU)**—one of the two main parts
    - Performs arithmetic and logical operations
      - Involve adding, subtracting, multiplying, dividing
      - Logical operations involve comparisons between two or more data items.
What’s on the Motherboard?

• **Machine cycle**
  
  o **Instruction cycle**
    • **Fetch**: Retrieves program instructions
    • **Decode**: Determines what the program is telling the computer to do
  
  o **Execution cycle**:
    • **Execute**: Performs the requested action
    • **Store**: Stores the results to an internal register

• **Registers**—store data when it must be temporarily stored in the CPU
What’s on the Motherboard?

**INSTRUCTION CYCLE**

1. **Fetch**
   - Retrieves the next program instruction from memory

2. **Decode**
   - Determines what the program is telling the computer to do

**EXECUTION CYCLE**

3. **Execute**
   - Performs the requested instruction

4. **Store**
   - Stores the results to an internal register (a temporary storage location) or to memory
Factors that affect the performance of a CPU include:

- Number of existing transistors
- Data bus width and word size
- Clock speed
- Operations per microprocessor cycle
- Use of parallel processing
- Type of chip
What’s on the Motherboard?

- **Data bus**
  - Group of parallel wires that connect the CPU’s internal components
  - Width measured in bits
  - Maximum number of bits the CPU can process at once is called the **word size**
    - Determines which operating systems and software a CPU can run
What’s on the Motherboard?

• **System clock**
  - Electronic circuit that produces rapid pulses and coordinates the computer’s internal activities.
  - **Clock speed**—measurement of the electrical pulses generated by the system clock, usually measured in gigahertz (GHz)

![Diagram showing processor cycle](image)
What’s on the Motherboard?

• **System clock (con’t.)**
  
  o **Superscalar architecture**—enables the CPU to perform more than one instruction for each clock cycle
  
  o **Pipelining**—enables the CPU to process more than one instruction at a time improving performance

Parallel processing with pipelines

- **pipeline 1**
  - fetch
  - decode
  - execute

- **pipeline 2**
  - decode
  - execute
  - fetch

- **pipeline 3**
  - execute
  - fetch
  - decode

Each pipeline is a separate part of the CPU