What is a Computer?

A computer consists of a CPU, memory, hard disk, monitor, printer, and communication devices.
CPU

• Central Processing Unit (CPU)
  
  • retrieves instructions from memory and executes them
  
  • the CPU speed is measured in hertz = cycles per second (Hz, MHz = MegaHertz, GHz = Gigahertz)
    
    • 1 megahertz = 1 million pulses per second
Memory

- Stores data and program instructions for CPU to execute

- ordered sequence of bytes (8 bits – binary base unit)

Bus

- Storage Devices: e.g., Disk, CD, and Tape
- Memory
- CPU
- Communication Devices: e.g., Modem, and NIC
- Input Devices: e.g., Keyboard, Mouse
- Output Devices: e.g., Monitor, Printer
How Data is Stored?

• What’s binary?
  • a base-2 number system

• What do humans use?
  • base-10

• Why?

• Why do computers like binary?
  • electronics
    • easier to make hardware that stores and processes binary numbers than decimal numbers
  • more efficient: space & cost

<table>
<thead>
<tr>
<th>Memory address</th>
<th>Memory content</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>01001010</td>
</tr>
<tr>
<td>2001</td>
<td>01100001</td>
</tr>
<tr>
<td>2002</td>
<td>01110110</td>
</tr>
<tr>
<td>2003</td>
<td>01100001</td>
</tr>
<tr>
<td>2004</td>
<td>00000011</td>
</tr>
</tbody>
</table>

Encoding for character ‘J’
Encoding for character ‘a’
Encoding for character ‘v’
Encoding for character ‘a’
Encoding for number 3
<table>
<thead>
<tr>
<th>Number System</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>binary</td>
<td>0, 1</td>
</tr>
<tr>
<td>octal</td>
<td>0, 1, 2, 3, 4, 5, 6, 7</td>
</tr>
<tr>
<td>decimal</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9</td>
</tr>
<tr>
<td>hexadecimal</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F</td>
</tr>
</tbody>
</table>
Number Systems

- Computers use binary numbers internally because storage devices like memory and disk are made to store **0s and 1s**.
  - A number or a text inside a computer is stored as a sequence of 0s and 1s.
  - Each 0 and 1 is called a **bit** (short for **binary digit**)

- Binary numbers are not intuitive, since we use decimal numbers in our daily life.
  - When you write a number like 20 in a program, it is assumed to be a decimal number.
  - Internally, computer software is used to convert decimal numbers into binary numbers, and vice versa.
Number Systems

• The digits in the **decimal number system** are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.
• A decimal number is represented using a sequence of one or more of these digits.
• The value that each digit in the sequence represents depends on its position.
• A position in a sequence has a value that is an integral power of 10.
• e.g., the digits 7, 4, 2, and 3 in decimal number 7423 represent 7000, 400, 20, and 3, respectively:

\[
\begin{array}{cccc}
7 & 4 & 2 & 3 \\
10^3 & 10^2 & 10^1 & 10^0 \\
\end{array}
\]

\[7 \times 10^3 + 4 \times 10^2 + 2 \times 10^1 + 3 \times 10^0 = 7000 + 400 + 20 + 3 = 7423\]

• We say that 10 is the **base** or **radix** of the decimal number system.
• The base of the binary number system is 2 since the binary number system has two digits.
• The base of the hex number system is 16 since the hex number system has sixteen digits.
Number Systems

- Binary numbers tend to be very long and cumbersome:
  - For example: 1010 1010 1010
- Hexadecimal numbers are often used to abbreviate binary numbers:
  - For example: AAA

- The hexadecimal number system has 16 digits:
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F.
  - The letters A, B, C, D, E, and F correspond to the decimal numbers 10, 11, 12, 13, 14, and 15.

- The octal number system has 8 digits:
  - 0, 1, 2, 3, 4, 5, 6, and 7.
Binary Numbers => Decimals

Given a binary number \( b_n b_{n-1} b_{n-2} \ldots b_2 b_1 b_0 \)
the equivalent decimal value is

\[
b_n \times 2^n + b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + \ldots + b_2 \times 2^2 + b_1 \times 2^1 + b_0 \times 2^0
\]

10 in binary \(1 \times 2^1 + 0 = 2\) in decimal

1010 in binary \(1 \times 2^3 + 0 \times 2^2 + 1 \times 2 + 0 = 10\) in decimal

10101011 in binary \(1 \times 2^7 + 0 \times 2^6 + 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2 + 1 = 171\) in decimal
Decimals => Binary

- To convert a decimal number $d$ to a binary number is to find the binary digits $b_n, b_{n-1}, b_{n-2}, \ldots, b_2, b_1, b_0$ such that

$$d = b_n \times 2^n + b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + \ldots + b_2 \times 2^2 + b_1 \times 2^1 + b_0 \times 2^0$$

- These numbers can be found by successively dividing $d$ by 2 until the quotient is 0. The remainders are $b_n, b_{n-1}, b_{n-2}, \ldots, b_2, b_1, b_0$

For example, the decimal number 123 is 1111011 in binary. The conversion is conducted as follows:

\[
\begin{align*}
2 & \overline{\div} & 123 & = & 61 & \quad \text{Quotient} \\
2 & \overline{\div} & 61 & = & 30 & \downarrow \quad \text{Remainder} \\
2 & \overline{\div} & 30 & = & 15 & \\
2 & \overline{\div} & 15 & = & 7 & \\
2 & \overline{\div} & 7 & = & 3 & \\
2 & \overline{\div} & 3 & = & 1 & \\
2 & \overline{\div} & 1 & = & 0 & \\
\end{align*}
\]

The remainders are 0, 1, 1, 1, 1, 0, and 0, which correspond to the binary digits $b_6, b_5, b_4, b_3, b_2, b_1, b_0$, respectively.
Windows Calculator

The Windows Calculator is a useful tool for performing number conversions. To run it, choose Programs, Accessories, and Calculator from the Start button.
Hexadecimals => Decimals

• The hexadecimal number system has sixteen digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F.
• The letters A, B, C, D, E, and F correspond to the decimal numbers 10, 11, 12, 13, 14, and 15.
• Given a hexadecimal number $h_nh_{n-1}h_{n-2}...h_2h_1h_0$
The equivalent decimal value is

$$h_n \times 16^n + h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + ... + h_2 \times 16^2 + h_1 \times 16^1 + h_0 \times 16^0$$

$7F$ in hex is $7 \times 16^1 + 15 = 127$ in decimal

$FFFF$ in hex $15 \times 16^3 + 15 \times 16^2 + 15 \times 16 + 15 = 65535$ in decimal

• Octal number system is similar, but base is 8.
Decimals => Hexadecimals

To convert a decimal number $d$ to a hexadecimal number is to find the hexadecimal digits $h_n, h_{n-1}, h_{n-2}, ..., h_2, h_1, h_0$ such that

$$d = h_n \times 16^n + h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + ... + h_2 \times 16^2 + h_1 \times 16^1 + h_0 \times 16^0$$

These numbers can be found by successively dividing $d$ by 16 until the quotient is 0. The remainders are $h_0, h_1, h_2, ..., h_{n-2}, h_{n-1}, h_n$

For example, the decimal number 123 is 7B in hexadecimal. The conversion is conducted as follows:

Octal number system is similar, but base is 8.
# Hexadecimals ↔ Binary

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

To convert a hexadecimal number to a binary number, simply convert each digit in the hexadecimal number into a **four-digit** binary number.

To convert a binary number to a hexadecimal, convert every **four binary digits from right to left** in the binary number into a hexadecimal number. For example,

![Binary to Hexadecimal Example](image)

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### Octal <=> Binary

<table>
<thead>
<tr>
<th>Binary</th>
<th>Octal</th>
<th>Decimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>001</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>010</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>011</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>101</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>110</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>111</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

To convert an octal number to a binary number, simply convert each digit in the octal number into a three-digit binary number.

To convert a binary number to an octal number, convert every three binary digits from right to left in the binary number into an octal digit. For example,

```
1 1 1 0 0 0 1 1 0 1
```

- 1 6 1 5
Memory: What goes in each memory segment?

- **Stack Segment**
  - temporary variables declared inside methods
  - removed from memory when a method returns

- **Heap Segment**
  - for dynamic data (whenever you use `new`)
  - data for constructed objects
  - persistent as long as an existing object variable references this region of memory

- **Global Segment**
  - data that can be reserved at compile time
  - global data (like static data)
How objects are stored?

• You must understand that in Java, every object/reference variable stores a memory address
  • 32 bit numbers (4 bytes)
  OR
  • 64 bit numbers (8 bytes)

• These addresses point to memory locations where the objects’ data is stored
So Hardware stores 0s & 1s

- 0101010101010101010101010101 ... 

- Data is byte addressable
  - we can access or change any byte (group of 8 bits) independently as needed

- How do we store text?
  - Numerically (using its code)
  - Each character is stored in memory as a number
  - Standard character sets: ASCII & Unicode
    - ASCII uses 1 byte per character
      - ‘A’ is 65
<table>
<thead>
<tr>
<th>Dec</th>
<th>Hx Oct</th>
<th>Char</th>
<th>Dec</th>
<th>Hx Oct</th>
<th>Html</th>
<th>Chr</th>
<th>Dec</th>
<th>Hx Oct</th>
<th>Html</th>
<th>Chr</th>
<th>Dec</th>
<th>Hx Oct</th>
<th>Html</th>
<th>Chr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>000</td>
<td>NUL (null)</td>
<td>32</td>
<td>20 040</td>
<td>#32:</td>
<td>Space</td>
<td>64</td>
<td>40 100</td>
<td>#64:</td>
<td>@</td>
<td>96</td>
<td>60 140</td>
<td>#96:</td>
<td>`</td>
</tr>
<tr>
<td>1</td>
<td>001</td>
<td>SOH (start of heading)</td>
<td>33</td>
<td>21 041</td>
<td>#33:</td>
<td>!</td>
<td>65</td>
<td>41 101</td>
<td>#65:</td>
<td>A</td>
<td>97</td>
<td>61 141</td>
<td>#97:</td>
<td>a</td>
</tr>
<tr>
<td>2</td>
<td>002</td>
<td>STX (start of text)</td>
<td>34</td>
<td>22 042</td>
<td>#34:</td>
<td>&quot;</td>
<td>66</td>
<td>42 102</td>
<td>#66:</td>
<td>B</td>
<td>98</td>
<td>62 142</td>
<td>#89:</td>
<td>b</td>
</tr>
<tr>
<td>3</td>
<td>003</td>
<td>ETX (end of text)</td>
<td>35</td>
<td>23 043</td>
<td>#35:</td>
<td>#</td>
<td>67</td>
<td>43 103</td>
<td>#67:</td>
<td>C</td>
<td>99</td>
<td>63 143</td>
<td>#99:</td>
<td>c</td>
</tr>
<tr>
<td>4</td>
<td>004</td>
<td>EOT (end of transmission)</td>
<td>36</td>
<td>24 044</td>
<td>#36:</td>
<td>$</td>
<td>68</td>
<td>44 104</td>
<td>#68:</td>
<td>D</td>
<td>100</td>
<td>64 144</td>
<td>#100:</td>
<td>d</td>
</tr>
<tr>
<td>5</td>
<td>005</td>
<td>ENQ (enquiry)</td>
<td>37</td>
<td>25 045</td>
<td>#37:</td>
<td>%</td>
<td>69</td>
<td>45 105</td>
<td>#69:</td>
<td>E</td>
<td>101</td>
<td>65 145</td>
<td>#101:</td>
<td>e</td>
</tr>
<tr>
<td>6</td>
<td>006</td>
<td>ACK (acknowledge)</td>
<td>38</td>
<td>26 046</td>
<td>#38:</td>
<td>&amp;</td>
<td>70</td>
<td>46 106</td>
<td>#70:</td>
<td>F</td>
<td>102</td>
<td>66 146</td>
<td>#102:</td>
<td>f</td>
</tr>
<tr>
<td>7</td>
<td>007</td>
<td>BEL (bell)</td>
<td>39</td>
<td>27 047</td>
<td>#39:</td>
<td>'</td>
<td>71</td>
<td>47 107</td>
<td>#71:</td>
<td>G</td>
<td>103</td>
<td>67 147</td>
<td>#103:</td>
<td>g</td>
</tr>
<tr>
<td>8</td>
<td>010</td>
<td>BS (backspace)</td>
<td>40</td>
<td>28 050</td>
<td>#40:</td>
<td>(</td>
<td>72</td>
<td>48 110</td>
<td>#72:</td>
<td>H</td>
<td>104</td>
<td>68 150</td>
<td>#104:</td>
<td>h</td>
</tr>
<tr>
<td>9</td>
<td>011</td>
<td>TAB (horizontal tab)</td>
<td>41</td>
<td>29 051</td>
<td>#41:</td>
<td>)</td>
<td>73</td>
<td>49 111</td>
<td>#73:</td>
<td>I</td>
<td>105</td>
<td>69 151</td>
<td>#105:</td>
<td>i</td>
</tr>
<tr>
<td>10</td>
<td>012</td>
<td>LF (NL line feed, new line)</td>
<td>42</td>
<td>30 052</td>
<td>#42:</td>
<td>*</td>
<td>74</td>
<td>4A 112</td>
<td>#74:</td>
<td>J</td>
<td>106</td>
<td>6A 152</td>
<td>#106:</td>
<td>j</td>
</tr>
<tr>
<td>11</td>
<td>013</td>
<td>VT (vertical tab)</td>
<td>43</td>
<td>31 053</td>
<td>#43:</td>
<td>+</td>
<td>75</td>
<td>4B 113</td>
<td>#75:</td>
<td>K</td>
<td>107</td>
<td>6B 153</td>
<td>#107:</td>
<td>k</td>
</tr>
<tr>
<td>12</td>
<td>014</td>
<td>FF (NP form feed, new page)</td>
<td>44</td>
<td>32 054</td>
<td>#44:</td>
<td>,</td>
<td>76</td>
<td>4C 114</td>
<td>#76:</td>
<td>L</td>
<td>108</td>
<td>6C 154</td>
<td>#108:</td>
<td>l</td>
</tr>
<tr>
<td>13</td>
<td>015</td>
<td>CR (carriage return)</td>
<td>45</td>
<td>33 055</td>
<td>#45:</td>
<td>-</td>
<td>77</td>
<td>4D 115</td>
<td>#77:</td>
<td>M</td>
<td>109</td>
<td>6D 155</td>
<td>#109:</td>
<td>m</td>
</tr>
<tr>
<td>14</td>
<td>016</td>
<td>SO (shift out)</td>
<td>46</td>
<td>34 056</td>
<td>#46:</td>
<td>.</td>
<td>78</td>
<td>4E 116</td>
<td>#78:</td>
<td>N</td>
<td>110</td>
<td>6E 156</td>
<td>#110:</td>
<td>n</td>
</tr>
<tr>
<td>15</td>
<td>017</td>
<td>SI (shift in)</td>
<td>47</td>
<td>35 057</td>
<td>#47:</td>
<td>;</td>
<td>79</td>
<td>4F 117</td>
<td>#79:</td>
<td>O</td>
<td>111</td>
<td>6F 157</td>
<td>#111:</td>
<td>o</td>
</tr>
<tr>
<td>16</td>
<td>020</td>
<td>DLE (data link escape)</td>
<td>48</td>
<td>36 060</td>
<td>#48:</td>
<td>0</td>
<td>80</td>
<td>50 120</td>
<td>#80:</td>
<td>P</td>
<td>112</td>
<td>70 160</td>
<td>#112:</td>
<td>p</td>
</tr>
<tr>
<td>17</td>
<td>021</td>
<td>DC1 (device control 1)</td>
<td>49</td>
<td>37 061</td>
<td>#49:</td>
<td>1</td>
<td>81</td>
<td>51 121</td>
<td>#81:</td>
<td>Q</td>
<td>113</td>
<td>71 161</td>
<td>#113:</td>
<td>q</td>
</tr>
<tr>
<td>18</td>
<td>022</td>
<td>DC2 (device control 2)</td>
<td>50</td>
<td>38 062</td>
<td>#50:</td>
<td>2</td>
<td>82</td>
<td>52 122</td>
<td>#82:</td>
<td>R</td>
<td>114</td>
<td>72 162</td>
<td>#114:</td>
<td>r</td>
</tr>
<tr>
<td>19</td>
<td>023</td>
<td>DC3 (device control 3)</td>
<td>51</td>
<td>39 063</td>
<td>#51:</td>
<td>3</td>
<td>83</td>
<td>53 123</td>
<td>#83:</td>
<td>S</td>
<td>115</td>
<td>73 163</td>
<td>#115:</td>
<td>s</td>
</tr>
<tr>
<td>20</td>
<td>024</td>
<td>DC4 (device control 4)</td>
<td>52</td>
<td>40 064</td>
<td>#52:</td>
<td>4</td>
<td>84</td>
<td>54 124</td>
<td>#84:</td>
<td>T</td>
<td>116</td>
<td>74 164</td>
<td>#116:</td>
<td>t</td>
</tr>
<tr>
<td>21</td>
<td>025</td>
<td>NAK (negative acknowledge)</td>
<td>53</td>
<td>41 065</td>
<td>#53:</td>
<td>5</td>
<td>85</td>
<td>55 125</td>
<td>#85:</td>
<td>U</td>
<td>117</td>
<td>75 165</td>
<td>#117:</td>
<td>u</td>
</tr>
<tr>
<td>22</td>
<td>026</td>
<td>SYN (synchronous idle)</td>
<td>54</td>
<td>42 066</td>
<td>#54:</td>
<td>6</td>
<td>86</td>
<td>56 126</td>
<td>#86:</td>
<td>V</td>
<td>118</td>
<td>76 166</td>
<td>#118:</td>
<td>v</td>
</tr>
<tr>
<td>23</td>
<td>027</td>
<td>ETB (end of trans. block)</td>
<td>55</td>
<td>43 067</td>
<td>#55:</td>
<td>7</td>
<td>87</td>
<td>57 127</td>
<td>#87:</td>
<td>W</td>
<td>119</td>
<td>77 167</td>
<td>#119:</td>
<td>w</td>
</tr>
<tr>
<td>24</td>
<td>030</td>
<td>CAM (cancel)</td>
<td>56</td>
<td>44 070</td>
<td>#56:</td>
<td>8</td>
<td>88</td>
<td>58 130</td>
<td>#88:</td>
<td>X</td>
<td>120</td>
<td>78 170</td>
<td>#120:</td>
<td>x</td>
</tr>
<tr>
<td>25</td>
<td>031</td>
<td>EM (end of medium)</td>
<td>57</td>
<td>45 071</td>
<td>#57:</td>
<td>9</td>
<td>89</td>
<td>59 131</td>
<td>#89:</td>
<td>Y</td>
<td>121</td>
<td>79 171</td>
<td>#121:</td>
<td>y</td>
</tr>
<tr>
<td>26</td>
<td>032</td>
<td>A (substitute)</td>
<td>58</td>
<td>4A 072</td>
<td>#58:</td>
<td>0</td>
<td>90</td>
<td>5A 132</td>
<td>#90:</td>
<td>Z</td>
<td>122</td>
<td>7A 172</td>
<td>#122:</td>
<td>z</td>
</tr>
<tr>
<td>27</td>
<td>033</td>
<td>ESC (escape)</td>
<td>59</td>
<td>4B 073</td>
<td>#59:</td>
<td>:</td>
<td>91</td>
<td>5B 133</td>
<td>#91:</td>
<td>[</td>
<td>123</td>
<td>7B 173</td>
<td>#123:</td>
<td>{</td>
</tr>
<tr>
<td>28</td>
<td>034</td>
<td>FS (file separator)</td>
<td>60</td>
<td>4C 074</td>
<td>#60:</td>
<td>&lt;</td>
<td>92</td>
<td>5C 134</td>
<td>#92:</td>
<td>\</td>
<td>124</td>
<td>7C 174</td>
<td>#124:</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>035</td>
<td>GS (group separator)</td>
<td>61</td>
<td>4D 075</td>
<td>#61:</td>
<td>=</td>
<td>93</td>
<td>5D 135</td>
<td>#93:</td>
<td>]</td>
<td>125</td>
<td>7D 175</td>
<td>#125:</td>
<td>}</td>
</tr>
<tr>
<td>30</td>
<td>036</td>
<td>RS (record separator)</td>
<td>62</td>
<td>4E 076</td>
<td>#62:</td>
<td>&gt;</td>
<td>94</td>
<td>5E 136</td>
<td>#94:</td>
<td>^</td>
<td>126</td>
<td>7E 176</td>
<td>#126:</td>
<td>~</td>
</tr>
<tr>
<td>31</td>
<td>037</td>
<td>US (unit separator)</td>
<td>63</td>
<td>4F 077</td>
<td>#63:</td>
<td>?</td>
<td>95</td>
<td>5F 137</td>
<td>#95:</td>
<td>_</td>
<td>127</td>
<td>7F 177</td>
<td>#127:</td>
<td>DEL</td>
</tr>
</tbody>
</table>

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Programing Languages

Machine Language  Assembly Language  High-Level Language

- Machine language is a set of instructions executed directly by a computer's central processing unit (CPU).
- A program called assembler is used to convert assembly language programs into machine code.

For example, to add two numbers, you might write an instruction in assembly code like this:

```
ADDF3 R1, R2, R3
```

---

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Programming Languages

Machine Language  Assembly Language  High-Level Language

**assembly:** Far easier to use than binary

**BUT:** not very user friendly, very low-level operations, programming is time consuming

High Level programming Languages (HLL):
– more user friendly, easy to use
– more flexible
– platform independent
Popular High-Level Languages

• COBOL (CCommon Business Oriented Language)
• FORTRAN (FORmula TRANslation)
• BASIC (Beginner All-purpose Symbolic Instructional Code)
• Pascal (named for Blaise Pascal)
• Ada (named for Ada Lovelace)
• C (whose developer designed B first)
• Visual Basic (Basic-like visual language developed by Microsoft)
• Delphi (Pascal-like visual language developed by Borland)
• C++ (an object-oriented language, based on C)
• C# (a Java-like language developed by Microsoft)
• Java
 Compiling Source Code

What’s a compiler?

• A software program
  • Input: High Level Language source code
  • Output: Assembly Code
• It is typically integrated with an assembly
  • together they can make an executable or binary program
The *operating system* (OS) is a program that manages and controls a computer’s activities.

- Windows XP, Vista, 7 and 8
- Mac OsX
- Android
- Linux
Why Java?

Java is somewhat different

Java has a principle, “write once, run anywhere”

What does that mean?

Platform independence for compiled Java code

How?

The Java Virtual Machine

Java programs are compiled into Java bytecode

bytecode is executed by the

Java Virtual Machine (JVM)
Java, JVM, Web, and Beyond

- **Java Virtual Machine**
  - A program that runs Java programs and manages memory for Java programs.

- **Why?**
  - Each platform is different (Mac/PC/Linux/etc.)
  - Java can be used to develop Web applications.
  - Java Applets
  - Java Web Applications
  - Java can also be used to develop applications for hand-held devices such as Palm and cell phones
JDK Versions

- JDK 1.02 (1995)
- JDK 1.1 (1996)
- JDK 1.2 (1998)
- JDK 1.3 (2000)
- JDK 1.4 (2002)
- JDK 1.5 (2004) a. k. a. JDK 5 or Java 5
- JDK 1.6 (2006) a. k. a. JDK 6 or Java 6
- JDK 1.7 (2011) a. k. a. JDK 7 or Java 7
- JDK 1.8 (2014) a. k. a. JDK 8 or Java 8
JDK Editions

- **Java Standard Edition (J2SE)**
  - J2SE can be used to develop client-side standalone applications or applets.

- **Java Enterprise Edition (J2EE)**
  - J2EE can be used to develop server-side applications such as Java servlets and Java ServerPages.

- **Java Micro Edition (J2ME)**.
  - J2ME can be used to develop applications for mobile devices such as cell phones.

Our textbook uses J2SE to introduce Java programming.
A Simple Java Program

//This program prints Welcome to Java!
public class Welcome {
    public static void main(String[] args) {
        System.out.println("Welcome to Java! ");
    }
}

Creating, Compiling, and Running Programs

Source code (developed by the programmer)

```java
public class Welcome {
    public static void main(String[] args) {
        System.out.println("Welcome to Java!");
    }
}
```

Byte code (generated by the compiler for JVM to read and interpret, not for you to understand)

```
... 
Method Welcome() 
  0 aload_0 
  ... 
Method void main(java.lang.String[]) 
  0 getstatic #2 ... 
  3 ldc #3 <String "Welcome to Java!"> 
  5 invokevirtual #4 ... 
  8 return 
... 
```

Create/Modify Source Code

Saved on the disk

Run Byteode

i.e., java Welcome

Result

If compilation errors

If runtime errors or incorrect result
//This program prints Welcome to Java!
public class Welcome {
    public static void main(String[] args) {
        System.out.println("Welcome to Java!");
    }
}

Welcome to Java!
Compiling and Running Java from the Command Window

- Set path to JDK bin directory
  
  ```
  set PATH=c:\Java\jdk1.8.0\bin
  ```

- Set classpath to include the current directory
  
  ```
  set CLASSPATH=.
  ```

- Compile your source code:
  
  ```java
  javac Welcome.java
  ```

- Run your bytecode:
  
  ```java
  java Welcome
  ```
Running Programs in Eclipse
//This program prints Welcome to Java!
public class Welcome {
    public static void main(String[] args) {
        System.out.println("Welcome to Java!");
    }
}

Enter main method
//This program prints Welcome to Java!
public class Welcome {
    public static void main(String[] args) {
        System.out.println("Welcome to Java!");
    }
}
Trace a Program Execution

//This program prints Welcome to Java!
public class Welcome {
   public static void main(String[] args) {
      System.out.println("Welcome to Java!");
   }
}

print a message to the console
Anatomy of a Java Program

- Comments
- Reserved words
- Modifiers
- Statements
- Blocks
- Classes
- Methods
- The main method
Comments

• Three types of comments in Java.

_Line comment_: A line comment is preceded by two slashes (//) in a line.

_Paragraph comment_: A paragraph comment is enclosed between /* and */ in one or multiple lines.

_javadoc comment_: javadoc comments begin with /*** and end with */. They are used for documenting classes, data, and methods. They can be extracted into an HTML file using JDK's javadoc command.
Reserved Words (Keywords)

- Reserved words or keywords are words that have a specific meaning to the compiler.

- Cannot be used for other purposes in the program.

- Example: `class`

  - The word after `class` is the name for the class.
Java Keywords

abstract, assert, boolean, break, byte, case, catch, char, class, const, continue, default, do, double, else, enum, extends, false, final, finally, float, for, goto, if, implements, import, instanceof, int, interface, long, native, new, null, package, private, protected, public, return, short, static, strictfp, super, switch, synchronized, this, throw, throws, transient, true, try, void, volatile, while

http://docs.oracle.com/javase/tutorial/java/nutsandbolts/_keywords.html
Modifiers

Java uses certain reserved words called modifiers that specify the properties of the data, methods, and classes and how they can be used.

- Examples: public, static, private, final, abstract, protected
- A public datum, method, or class can be accessed by other programs
- A private datum or method cannot be accessed by other programs
Statements

A statement represents an action or a sequence of actions

System.out.println("Welcome to Java!");

is a statement to display the greeting "Welcome to Java!"

- Every statement in Java ends with a semicolon (;)
A pair of braces in a program forms a block that groups components of a program.
Block Styles

• We use end-of-line style for braces.

```java
class Test {
    public static void main(String[] args) {
        System.out.println("Block Styles");
    }
}
```

End-of-line style

```java
class Test {
    public static void main(String[] args) {
        System.out.println("Block Styles");
    }
}
```

Next-line style
Variable, class, and method names

- **What’s an API?**
  - Application Programming Interface
  - a library of code to use

- **Names**
  - **For Variables, Classes, and Methods**
  - From 2 sources:
    - your own classes, variables, and methods
    - the Oracle/Sun (or someone else’s) API

- **Your Identifiers (Names) – Why name them?**
  - they are your data and commands
  - you’ll need to reference them elsewhere in your program
  
  ```
  int myVariable = 5; // Declaration
  myVariable = myVariable + 1; // Using the variable
  ```
Rules for Identifiers

- Should contain only letters, numbers, & '_'
  - '$' is allowed, but only for special use
- Cannot begin with a digit!
- Uppercase and lowercase letters are considered to be different characters

Examples:
- Legal: `myVariable`, `my_class`, `my4Var`
- Illegal: `4myVariable`, `my class`, `my!Var`, `@#$myClass`
Common Java Naming Conventions

• Variables & Methods start with lower case letters: \( \text{x, toString} \)
• Classes start with upper case letters: \( \text{Person} \)
• Variables and Class identifiers should generally be nouns
• Method identifiers should be verbs
• Use Camel notation: \( \text{myVariable, MyClass} \)
• Although it is legal, do not begin with ‘_’ (underscore).
• Use descriptive names: \( \text{LinkedList, compareTo} \)

\[
\text{area} = \pi \times \text{radius} \times \text{radius};
\]
Programming Errors

- Syntax / Compiler Errors
  - Detected by the compiler
- Runtime Errors
  - Causes the program to abort
- Logic Errors
  - Produces incorrect result
public class ShowSyntaxError {
    public static void main(String[] args) {
        i = 30; // Detected by the compiler
        System.out.println(i + 4);
    }
}
public class ShowRuntimeError {
    public static void main(String[] args) {
        int i = 1 / 0;  // Division with 0
    }
}
public class ShowLogicError {
    // Determine if a number is between 1 and 100 inclusively
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        int number = input.nextInt();
        // Display the result
        System.out.println(
            "The number is between 1 and 100, inclusively: " +
            ((1 < number) && (number < 100)) );
        // Wrong result if the entered number is 1 or 100
        System.exit(0);
    }
}
Logic Errors Debugging

• Logic errors are called *bugs*

• The process of finding and correcting errors is called *debugging*

• Methods:
  • hand-trace the program (i.e., catch errors by reading the program),
  • insert print statements in order to show the values of the variables
  • for a large, complex program, the most effective approach for debugging is to use a *debugger utility*
Debugger

Debugger is a program that facilitates debugging. You can use a debugger to:

- Execute a single statement at a time.
- Trace into or stepping over a method.
- Set breakpoints.
- Display variables.
- Display call stack.
- Modify variables.
public void refreshDisplay(String option) {
    System.out.println("Option: "+option);
    if (option.equals("b41") || option.equals("b42") || option.equals("b43") || option.equals("b44") || option.equals("b52")) {
        bet = 5;
    } else if (option.equals("b41")) {
        bet = 1;
    } else if (option.equals("b42")) {
        bet = 2;
    } else if (option.equals("b43")) {
        bet = 3;
    } else if (option.equals("b44")) {
        bet = 4;
    } else bet = 5;
    l1.setText("Round "+rounds+" +"+Act);
    l1.setText("Bet: "+bet);
    b41.disable();
    b42.disable();
    b51.enable();
    b6.disable();
} else if (option.equals("b52")) {
    // implement second step of baccarat
System.out.println("Option: "+option);

if (option.equals("b41") || option.equals("b42")) {
    bet = 1;
} else if (option.equals("b44") || option.equals("b45") || option.equals("b51") || option.equals("b6") || option.equals("background") || option.equals("backgroundEraseDisabled") || option.equals("ColorUIResource")) {
    ...