Bits, Bytes, Words

Digital signal
Digital Signals

• The amplitude of a digital signal varies between a logical “0” and logical “1”.
  – The information in the signal is encoded in the combination:
    • of the length of time that the signal is held at each logical state
    and
    • frequency of the clock (or clock speed), which is the frequency of the fastest oscillation between logical levels that is allowed by the digital system.
A bit

• A single piece of digital information
  – Either a logical “0” or a logical “1”
    • “1101” is a 4 bit number
    • Since digital electronic circuits output voltages not bits, we assign a voltage range to be equal to a logical “0” and a different voltage range to be a logical “1”
      – Different logic families assign a different range of voltages to be equal to a logical “0” and a logical “1”.
      – For example:
        » TTL  “0” → 0 – 0.7V; “1” → 2 – 5V
        » CMOS “0” → 0 – 1.5V; “1” → 3.5 – 5V
Is the data the same or different?

Whether the lower digital signal is “11001100” or “1010” or some other variation on this pattern depends on the clock speed – the minimum length of time that the system can output a logical state as it switches from one state to another.
Base 2

• As there are only two types of bits, “0” and “1”, the number system commonly used in digital electronics is base 2.

  – Task: Convert the following base 10 numbers into the equivalent number in base 2.

<table>
<thead>
<tr>
<th>Base 10</th>
<th>4</th>
<th>11</th>
<th>25</th>
<th>64</th>
<th>257</th>
<th>515</th>
<th>1024</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Observations:
  – Numbers that are odd end with a “1”.
  – Numbers that are divisible by $2^n$ with no remainder are written with a 1 followed by n zeros.
Grouping of Bits

- **Byte**: Composed of 8 bits
- **String**: Sequential set of bits of arbitrary length
- **Nibble**: Composed of 4 bits or half a byte
  - Nibbles are occasionally written as hexadecimals to make the data more readable
  - Hexadecimals are the numbers in base 16
    - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
- **Word**: The standard memory bus width in the microprocessor or computer architecture
  - 16-bit, 32-bit, or 64-bit architecture
ASCII

• American Standard Code for Information Interchange
  – Encodes each of the 26 characters from the English alphabet, numbers between 0-9, a space, symbols (! for example), and other actions that are necessary when typing (e.g., a horizontal) into a 7 bit string
    • ASCII code has 128 different 7-bit strings \(2^7\)
Parity bit

• An extra bit at the beginning or end of a string of bits that is used to check if the data received is reasonably correct
  – 8-bit ASCII has an extra bit added at the beginning of each 7-bit string.
    • In even parity checking, the sum of all bits in the byte will be even and the value chosen for the eighth bit is selected based upon the sum of the other 7 bits.
    • In odd parity checking, the sum of all bits in the byte will be odd and the value chosen for the eighth bit is selected based upon the sum of the other 7 bits.
Parity checking

Choose “0” or “1” for the parity bit for even or odd parity checking.

<table>
<thead>
<tr>
<th>Parity Check</th>
<th>Parity bit</th>
<th>MSB</th>
<th>LSB</th>
<th>ASCII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Even</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Odd</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Even</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<tr>
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<td>0</td>
<td>0</td>
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<td>1</td>
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</tr>
<tr>
<td>Odd</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

MSB: Most significant bit  
LSB: Least significant bit
Chinese Binary

• Chinese binary for transmission of text is based on Chinese Telex
  – It is composed of two bytes where each byte has a parity bit followed by a 7-bit string
Standards Committees

• Standards committees are established to document a system that will be used by all manufacturers so that products can work together.
  – The Institute of Electrical and Electronics Engineers (IEEE), your professional society, organizes standards committees with engineers from various manufacturers’ providing input on the pros and cons of their protocols.
  • For example: There was a standards committee to determine the voltage levels, data transmission speed, maximum current on the bus, and shape of the connectors for products with USB outputs.
Flag

- A flag is a single bit whose state indicates the status of the digital system
  - A state can be:
    - High: the value of the bit is a logical “1”
    - Low: the value of the bit is a logical “0”
  - Sometimes there is an output pin for the flag that is tied (or connected) to an LED.
    - The state of the flag can easily be determined by looking to see if the LED is turned on or off
      - LED: Light-emitting diode