Complements — Not really in Text

The meaning of complement is something required to make a thing complete. For example, salsa complements tortilla chips, beer complements pizza, an ice cream cone complements a hot summer day, and apple sauce complements pork chops. A key concept to explore is how two things complement each other. For example, when a piece of pizza is removed from a whole pizza the piece complements what is left behind and vice versa. Each of the 4 following complements use the same concept except in different bases and what is considered a complete number in that base.

Diminished Radix Complement

The diminished radix complements are called by the \( radix - 1 \). The diminished complement for a decimal number is the 9's complement and 1's complement for a binary number.

9's Complement

The 9's complement finds whatever is needed to make an entire set of 9's. This is shown in the example below.

Finding the 5 digit 9's complement of 1357

\[
\begin{array}{c|c}
\text{All 9's} & 99999 \\
\text{Initial Value} & -01357 \\
9's \text{ Complement} & 98642 \\
\end{array}
\]

The 5 digit 9's complement of 1357 is 98642

1's Complement

The 1's complement finds whatever is needed to make an entire set of 1's. This is shown in the example below.

Finding the 8 digit 1's complement of 01101100

\[
\begin{array}{c|c}
\text{All 1's} & 11111111 \\
\text{Initial Value} & -01101100 \\
9's \text{ Complement} & 10010011 \\
\end{array}
\]

The 8 digit 1's complement of 01101100 is 10010011

Radix Complement — 1.4.6 in Text

The radix complements are called by their \( radix \). The radix complement for a decimal number is the 10's complement and 2's complement for a binary number. The value that is considered the whole part is \( radix^{digit} \).
10's Complement

Finding the 5 digit 10's complement of 1357

\[ \text{radix}^5 \]
\[ \text{Initial Value} \quad -01357 \]

\[ 10's \text{ Complement} \quad 98643 \]

The 5 digit 10's complement of 1357 is 98643

2's Complement

Finding the 8 digit 2's complement of 01101100

\[ \text{radix}^8 \]
\[ \text{Initial Value} \quad -01101100 \]

\[ 2's \text{ Complement} \quad 10010100 \]

The 8 digit 2's complement of 01101100 is 10010100

Subtracting by Adding — 1.4.6 in Text

A key use of complements is to do subtraction. Building an adder in hardware is fairly easy, but a subtracter is much more difficult. Using the following mathematical property subtraction can be avoided. \( A - B = A + (-B) \) The following example shows how adding the radix complement can give an identical result as subtraction.

Showing how to do 72532 - 3250 Normal Way Using Complements

<table>
<thead>
<tr>
<th>Initial Value</th>
<th>Normal Way</th>
<th>Using Complements</th>
</tr>
</thead>
<tbody>
<tr>
<td>72532</td>
<td>72532</td>
<td>72532</td>
</tr>
<tr>
<td>Adding a 10's complement</td>
<td>-3250</td>
<td>+96750</td>
</tr>
<tr>
<td>Difference</td>
<td>69282</td>
<td>169282</td>
</tr>
</tbody>
</table>

Note the answer has a positive carry out. This means that the difference is positive. If the carry out was 0, then the difference would be a negative number. Taking the radix complement of this negative number indicates the magnitude of the negative number.

Logic Gates — 1.5 in Text

This section covers the background information necessary to understand how binary values and functions are represented and some information about the analog traits of a digital signal.

Boolean Algebra Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>'and'</td>
<td>( \times )</td>
</tr>
<tr>
<td>'or'</td>
<td>+</td>
</tr>
<tr>
<td>'not'</td>
<td>( x' ) or ( \bar{x} )</td>
</tr>
</tbody>
</table>

Logic Gate Symbols

Figure shows more logic gates. Circles on the inputs or outputs represent inverters attached to the gates. Gates can also be built with multiple inputs, up to 8.
Beneath the Digital Abstraction — 1.6 in Text

Threshold Voltages

The voltage being read into a gate is an analog signal, but the gate acts in a digital manner. This is accomplished by using thresholds to compare the incoming signal. Higher than a threshold is considered a high voltage and is assigned to a $1_2$. Lower than a voltage is considered a low voltage and assigned to a $0_2$. If there is a voltage between the two thresholds then it is considered a metastable input and the uncertain input is assigned an 'X'. The images in figure 3 are all from the 74HC08 Quad 2-Input And Gate.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Test Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IH}$</td>
<td>High Level Input Voltage</td>
<td>$V_{CC}$ (V)</td>
<td>$T_A = 25^\circ C$</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>4.3</td>
<td></td>
<td>3.15</td>
<td>3.15</td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>4.2</td>
<td>4.2</td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>Low Level Input Voltage</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td>4.5</td>
<td></td>
<td>1.35</td>
<td>1.35</td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>1.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>

CMOS Transistors — 1.7 in Text

Figure 4 and 5 show how gates can be constructed in integrated circuits.
Figure 4: Example schematic of a commonly used logic gate.

Figure 5: Example layout of a commonly used logic gate.

Figure 4 and 5 both show one of the gates listed in 2. Which gate is it? The tutorial that describes the layout tool is located here:

http://web.engr.oregonstate.edu/~moon/ece423/cadence/example2.html