Review Problem 38

- Create a **truth table** for a circuit which tells if a 3-bit number is evenly divisible by 3 (num/3 leaves no remainder). Have a separate output for the unsigned, 2’s comp, and sign-magnitude versions.

<table>
<thead>
<tr>
<th>B2 B1 B0</th>
<th>Uns</th>
<th>S-M</th>
<th>2’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 0</td>
<td>0 1</td>
<td>+0 1</td>
<td>+0 1</td>
</tr>
<tr>
<td>00 1</td>
<td>1 0</td>
<td>+1 0</td>
<td>+1 0</td>
</tr>
<tr>
<td>01 0</td>
<td>2 0</td>
<td>+2 0</td>
<td>+2 0</td>
</tr>
<tr>
<td>01 1</td>
<td>3 1</td>
<td>+3 1</td>
<td>+3 1</td>
</tr>
<tr>
<td>10 0</td>
<td>4 0</td>
<td>-0 1</td>
<td>4-1 0</td>
</tr>
<tr>
<td>10 1</td>
<td>5 0</td>
<td>-1 0</td>
<td>-3 1</td>
</tr>
<tr>
<td>11 0</td>
<td>6 1</td>
<td>-2 0</td>
<td>-2 0</td>
</tr>
<tr>
<td>11 1</td>
<td>7 0</td>
<td>-3 1</td>
<td>-1 0</td>
</tr>
</tbody>
</table>

Note: The same for values that start U/O
Converting Decimal to Two’s Complement

- Convert absolute value to unsigned binary, then fixed width, then negate if necessary

- Convert \((-9)_{10}\) to 6-bit Two’s Complement

\[-(9)_{10} = -(9) = -(1001) = -(001001) = 110110 + 1 = 110111\]

- Convert \((9)_{10}\) to 6-bit Two’s Complement

\[(9)_{10} = +(9) = +(1001) = +(001001) = 001001\]
Converting Two’s Complement to Decimal

- If Positive, convert as normal;
  If Negative, negate then convert.

- Convert $(11010)_2$ to Decimal

$$11010 = \overline{-11010} = - (00101 + 1) = - (00110) = - (6) = -6_{10}$$

- Convert $(01101)_2$ to Decimal

$$= (8 + 4 + 1) + 13_{10}$$
Sign Extension

- To convert from N-bit to M-bit Two's Complement (N<M), simply duplicate sign bit:

\[ +2 \]

- Convert \((0010)_2\) to 8-bit Two's Complement

\[ \text{Is this} -5? \]

- Convert \((1011)_2\) to 8-bit Two's Complement

\[ = -((-11111011)) = -(00000100+1) \]
\[ = -(00000101) \]
\[ = -5 \]
Solving Complex Problems

- Many problems too complex to build as one system
  - Replace with communicating sub-circuits

- Design process:
  - Understand the problem
  - Break problem into subsystems, identifying connections
  - Design individual subsystems.
Complex Problem Example

- Design a digital clock, which can
  - Display the seconds, minutes and hours
  - Have three inputs
    - Increment hour
    - Increment minute
    - Reset seconds

1 Hz clock

1 Hz clock

Reset - Seconds

0 for the
minutes circuit
Complex Problem Example (cont.)
Complex Problem Example (cont.)

equal to the state encoding
Complex Problem Example (cont.)