State Encoding

- **Encoding**: Assigning a unique bit representation to each state
- Different encodings may optimize size, or tradeoff size and performance
- Consider 3-Cycle Laser Timer...
  - Example 3.7's encoding: 15 gate inputs
  - Try alternative encoding
    - \( x = s_1 + s_0 \)
    - \( n_1 = s_0 \)
    - \( n_0 = s_1' + s_1's_0 \)
  - Only 8 gate inputs

### One-Hot Encoding Example: Three-Cycles-High Laser Timer

- Four states – Use four-bit one-hot encoding
  - State table leads to equations:
    - \( s = s_3 \cdot s_2 \cdot s_1 \cdot s_0 \)
    - \( n_3 = s_2 \)
    - \( n_2 = s_1 \)
    - \( n_1 = s_0' \cdot s_3 \)
    - \( n_0 = s_0' \cdot s_3 + s_3 \)
  - Smaller:
    - \( 3(n_0+n_1+n_2+n_3) = 8 \) gate inputs
    - Earlier binary encoding (Ch 3): 15 gate inputs
  - Faster
    - Critical path: \( n_0 = s_0' \cdot s_3 \)
    - Previously: \( n_0 = s_1's_0' + s_1's_0's_0' \)
    - 2-input AND slightly faster than 3-input AND

Output Encoding

- **Output encoding**: Encoding method where the state encoding is same as the output values
  - Possible if enough outputs, all states with unique output values
**Mealy vs. Moore Example: Beeping Wristwatch**

- **Button b**
  - Sequences must select lines 0, 01, 10, and 11.
  - Each value displays a different internal register.
  - Each unique button press should cause a 1-cycle beep, with p=1 being beep.
  - Must wait for button to be released (b) and pushed again (c) before sequencing.

- Note that Moore requires unique state to pulse p, while Mealy pulses p on every input.
- Tradeoff: Moore's pulse on p may not test one full cycle.

**Mealy vs. Moore Tradeoff**

- Mealy outputs change mid-cycle if input changes.
  - Note earlier soda dispenser example.
  - Mealy had fewer states, but output d not 1 for full cycle.
  - Represents a type of tradeoff.

**Mealy vs. Moore FSMs**

- Moore: 3 states; Mealy: 2 states.

**Mealy vs. Moore Example: Beeping Wristwatch**

- Inputs: enough
- Outputs: clear

**Mealy vs. Moore Tradeoff**

- Moore vs. Mealy Tradeoff:
  - Mealy outputs change mid-cycle if input changes.
    - Note earlier soda dispenser example.
    - Mealy had fewer states, but output d not 1 for full cycle.
    - Represents a type of tradeoff.

**Mealy vs. Moore**

- Q: Which is Moore, and which is Mealy?
  - A: Mealy on left, Moore on right.
    - Moore outputs on arcs, meaning outputs are function of state AND inputs.
    - Mealy outputs in states, meaning outputs are function of state only.

**Mealy vs. Moore Example: Beeping Wristwatch**

- Button b
  - Sequences must select lines 0, 01, 10, and 11.
    - Each value displays a different internal register.
    - Each unique button press should cause a 1-cycle beep, with p=1 being beep.
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- Note that Moore requires unique state to pulse p, while Mealy pulses p on every input.
- Tradeoff: Moore's pulse on p may not test one full cycle.
Implementing a Mealy FSM

- Straightforward
  - Convert to state table
  - Derive equations for each output
  - Key difference from Moore: External outputs (d, clear) may have different values in same state, depending on input values

Inputs: enough (bit)
Outputs: d, clear (bit)

<table>
<thead>
<tr>
<th>Input</th>
<th>enough</th>
<th>d</th>
<th>clear</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Wait

Init

enough'/d=0
enough/d=1
/d=0, clear=1

Mealy and Moore can be Combined

- Final note on Mealy/Moore
  - May be combined in same FSM

Inputs: b; Outputs: s1, s0, p

Time

Alarm

Date

Stop

Stp

Ch

b'/p=0
b/p=1
s1s0=00
s1s0=01
b/p=1
s1s0=10
b/p=1
s1s0=11

Combined Moore/Mealy FSM for beeping wristwatch example

Design Challenge

- Design Challenge
  - Convert the following Moore FSM to the nearest Mealy FSM equivalent.

Due Next Lecture (as announced in class)
1 point extra credit (Homework)