Combined I-V Table Checking Problem

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Real Data from BUG140 and Cadence Presentations

• BUG140: http://www.eda.org/ibis/bugs/ibischk/bug140.txt
• (In all test cases, the [Gnd Clamp] data is 0.0 in the region of interest)
• Presentations
  – “Golden Parser Non-monotonic Warning’s Investigation” by Yingxin Sun and Joy Li, November 9, 2012: http://tinyurl.com/byqu7yn (Presented at the IBIS Quality Committee November 27, 2012)
  – “Combined I-V Table Checks (BUG140)”, January 31, 2013 IBIS Summit, Bob Ross, Yingxin Sun, and Joy Li
  – “Ibischk5 Specification and Parser”, May 15, 2013 IBIS Summit, Bob Ross and Mike LaBonte (Signal Integrity Software)
BUG140 Issue

- Unexpected Non-Monotonic Warnings for Combined I-V Tables (derived from monotonic data)

- Combined I-V table checks:
  - [Pulldown] + [Gnd Clamp] + [Power Clamp]
  - [Pullup] + [Gnd Clamp] + [Power Clamp]

- Ibischk5 parser is de facto standard for IBIS model correctness (and ibischk5 is embedded in tools)
- Some companies require 0 Errors, 0 Warnings
- IBIS Quality Spec, recommends 0 Errors and 0 Warnings
- Warning messages create support issue for model authors or automatic modeling utilities

Facts

- No specification REQUIREMENT that individual or combined I-V tables be monotonic
- No stated method to sum mismatched voltage points (piecewise linear interpolation is allowed and used)
- Non-monotonicity often occurs outside of normal simulation region – in clamping region and not a problem
- Ibischk5 parser is working correctly
Observations

- Non-monotonic behavior can occur
  - Combined I-V table slope is small
  - I-V table points are misaligned due to
    - Offset V intervals due to Gnd, Vdd and delta V
    - Different reference voltages (min/max)
    - Extraction done with piecewise linear interpolation calculations (if not done right)
  - Combination of above cases
- Example \((y = x^2)\) next shows monotonic tables yielding non-monotonic summations

Example: x Step 2, Offset by 1
(Red: Interpolated Value)

<table>
<thead>
<tr>
<th>x</th>
<th>y1</th>
<th>y2</th>
<th>y1–y2 = 0?</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>= x^2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>= x^2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5</td>
<td>-1</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>17</td>
<td>-1</td>
</tr>
<tr>
<td>5</td>
<td>26</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Non-monotonic due to piecewise linear interpolation on both columns
### x Step 0.02, Offset by 0.01

**Red:** Interpolated Value

<table>
<thead>
<tr>
<th>$x$</th>
<th>$y_1$</th>
<th>$y_2$</th>
<th>$y_1 - y_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>0.01</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>0.02</td>
<td>0.0004</td>
<td>0.0005</td>
<td>0.0005</td>
</tr>
<tr>
<td>0.03</td>
<td>0.0010</td>
<td>0.0009</td>
<td>0.0001</td>
</tr>
<tr>
<td>0.04</td>
<td>0.0016</td>
<td>0.0017</td>
<td>0.0001</td>
</tr>
<tr>
<td>0.05</td>
<td>0.0026</td>
<td>0.0025</td>
<td>0.0001</td>
</tr>
<tr>
<td>0.06</td>
<td>0.0036</td>
<td>0.0036</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Still non-monotonic with higher resolution data

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### x Steps 0.02 and 0.01, 0.00 Offset

**Red:** Interpolated Value

<table>
<thead>
<tr>
<th>$x$</th>
<th>$y_1$</th>
<th>$y_2$</th>
<th>$y_1 - y_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>0.01</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>0.02</td>
<td>0.0004</td>
<td>0.0004</td>
<td>0.0000</td>
</tr>
<tr>
<td>0.03</td>
<td>0.0010</td>
<td>0.0009</td>
<td>0.0001</td>
</tr>
<tr>
<td>0.04</td>
<td>0.0016</td>
<td>0.0016</td>
<td>0.0000</td>
</tr>
<tr>
<td>0.05</td>
<td>0.0026</td>
<td>0.0025</td>
<td>0.0001</td>
</tr>
<tr>
<td>0.06</td>
<td>0.0036</td>
<td>0.0036</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Different resolution data causes non-monotonic combination
bug140a.ibs Maximum Data 
(Vdd = 1.3 V)

1.8 V

Power Clamp

Pulldown

1.8 V

Example 1 (Cont.2)

Pulldown curve
Interpolation is lower than actual

Zoom-in view: Error introduced by piecewise linear interpolation

Clamp curve (ground referenced)
Interpolation is higher than actual
BUG140 Resolution

- Change WARNING to NOTE
  - Valid solution for user
  - Avoids tool and model developer support issues
- Add “based on piecewise linear interpolation” to message
- No practical fix
  - Still issues with higher resolution or choosing percentage threshold for non-monotonic warning
  - Piecewise linear interpolation is legal, and spline fitting would just hide information
Checking bug140a.ibs

NOTE (line 39) - Pulldown Typical data is non-monotonic
NOTE (line 42) - Pulldown Minimum data is non-monotonic
NOTE (line 42) - Pulldown Maximum data is non-monotonic
NOTE (line 135) - Pullup Typical data is non-monotonic
NOTE (line 137) - Pullup Maximum data is non-monotonic
NOTE (line 138) - Pullup Minimum data is non-monotonic
WARNING - Combined Pulldown for Model: iobuf Maximum data is non-monotonic

Errors : 0
Warnings: 1

File Passed

Fixed bug140a.ibs in Version 5.1.3

NOTE (line 39) - Pulldown Typical data is non-monotonic
NOTE (line 42) - Pulldown Minimum data is non-monotonic
NOTE (line 42) - Pulldown Maximum data is non-monotonic
NOTE (line 135) - Pullup Typical data is non-monotonic
NOTE (line 137) - Pullup Maximum data is non-monotonic
NOTE (line 138) - Pullup Minimum data is non-monotonic
NOTE - Combined Pulldown for Model: iobuf Maximum data is non-monotonic
based on piece-wise linear interpolation

Errors : 0

File Passed
Closure

• For best checking results, use the latest version of ibischk5
• Parser being updated as new BUG reports are submitted and processed.