Combined I-V Table Checking Problem

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Bob Ross
Teraspeed Consulting Group
bob@teraspeed.com

Yingxin Sun and Joy Li
Cadence Design Systems
sunyx@cadence.com
joyli@cadence.com

Presented by Anders Ekholm, Ericsson
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
(\textcolor{red}{\textbf{Red: Interpolated Value}})

\begin{tabular}{ccc}
\textbf{x} & \textbf{y}_1 & \textbf{y}_2 & \textbf{y}_1 - \textbf{y}_2 = 0? \\
0 & 0 & 0 & 0 \\
1 & 2 & 1 & 1 \\
2 & 4 & 5 & -1 \\
3 & 10 & 9 & 1 \\
4 & 16 & 17 & -1 \\
5 & 26 & 25 & 1 \\
6 & 36 & & \\
\end{tabular}

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>y1 = x^2</th>
<th>y2 = x^2</th>
<th>y1−y2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.0000</td>
<td></td>
<td></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>-0.0001</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></td>
<td></td>
</tr>
</tbody>
</table>

Still non-monotonic with higher resolution data
x Steps 0.02 and 0.01, 0.00 Offset

(Red: Interpolated Value)

<table>
<thead>
<tr>
<th>x</th>
<th>y1</th>
<th>y2</th>
<th>y1 - y2</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)
Example 1 (Cont.2)

- **Pulldown curve**
  Interpolation is lower than actual

- **Zoom-in view**: Error introduced by piecewise linear interpolation

- **Clamp curve (gnd referenced)**
  Interpolation is higher than actual
Example 1 (Cont.3)

Zoom-in view: Errors introduced in the combined pulldown curve.
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

**IBISCHK5 V5.1.2**

Checking bug140a.ibs for IBIS 3.2 Compatibility...

**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

IBISCHK5 V5.1.3

Checking bug140a.ibs for IBIS 3.2 Compatibility...

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.