Combined I-V Table Checking Problem

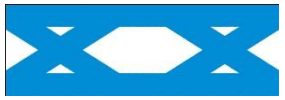
Asian IBIS Summit

Yokohama, Japan, November 22, 2013

Bob Ross
Teraspeed Consulting Group
bob@teraspeed.com

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

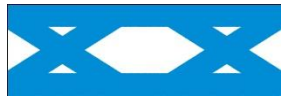
Presented by Anders Ekholm, Ericsson



TERASPEED CONSULTING GROUP

Real Data from BUG140 and Cadence Presentations

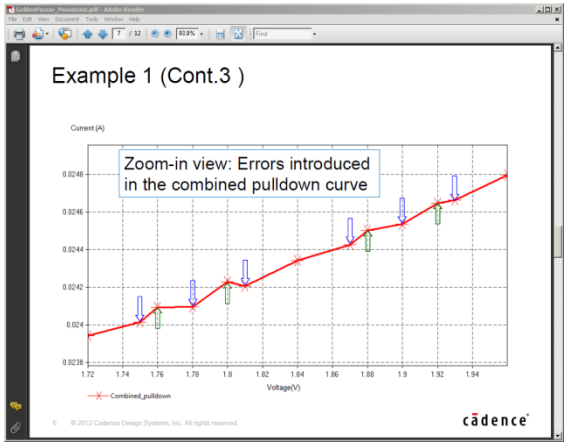
- BUG140: http://www.eda.org/ibis/bugs/ibischk/bug140.txt
- (In all test cases, the [Gnd Clamp] data is 0.0 in the region of interest)
- Presentations
  - "Golden Parser Non-monotonic Warning's Investigation" by Yingxin Sun and Joy Li, November 9, 2012: http://tinyurl.com/byqu7yn (Presented at the IBIS 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)



TERASPEED CONSULTING GROUP

BUG140 Issue

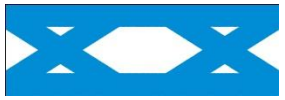
- Unexpected Non-Monotonic Warnings for Combined I-V Tables (derived from monotonic data)



- 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

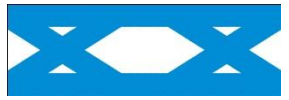
- No specification REQUIREMENT that individual or combined I-V tables be monotonic
- No stated method to sum mismatched voltage points (piecewise linear interpolation is allowed and used)
- Non-monotonicity often occurs outside of normal simulation region – in clamping region and not a problem
- Ibischk5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



TERASPEED CONSULTING GROUP

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



TERASPEED CONSULTING GROUP

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

x	y1 = x^2	y2 = x^2	y1-y2 = 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		

Non-monotonic due to piecewise linear interpolation on both columns

x Step 0.02, Offset by 0.01 (Red: Interpolated Value)

x	y1 = x^2	y2 = x^2	y1-y2
0.00	0.0000		
0.01	0.0002	0.0001	0.0001
0.02	0.0004	0.0005	-0.0001
0.03	0.0010	0.0009	0.0001
0.04	0.0016	0.0017	-0.0001
0.05	0.0026	0.0025	0.0001
0.06	0.0036		

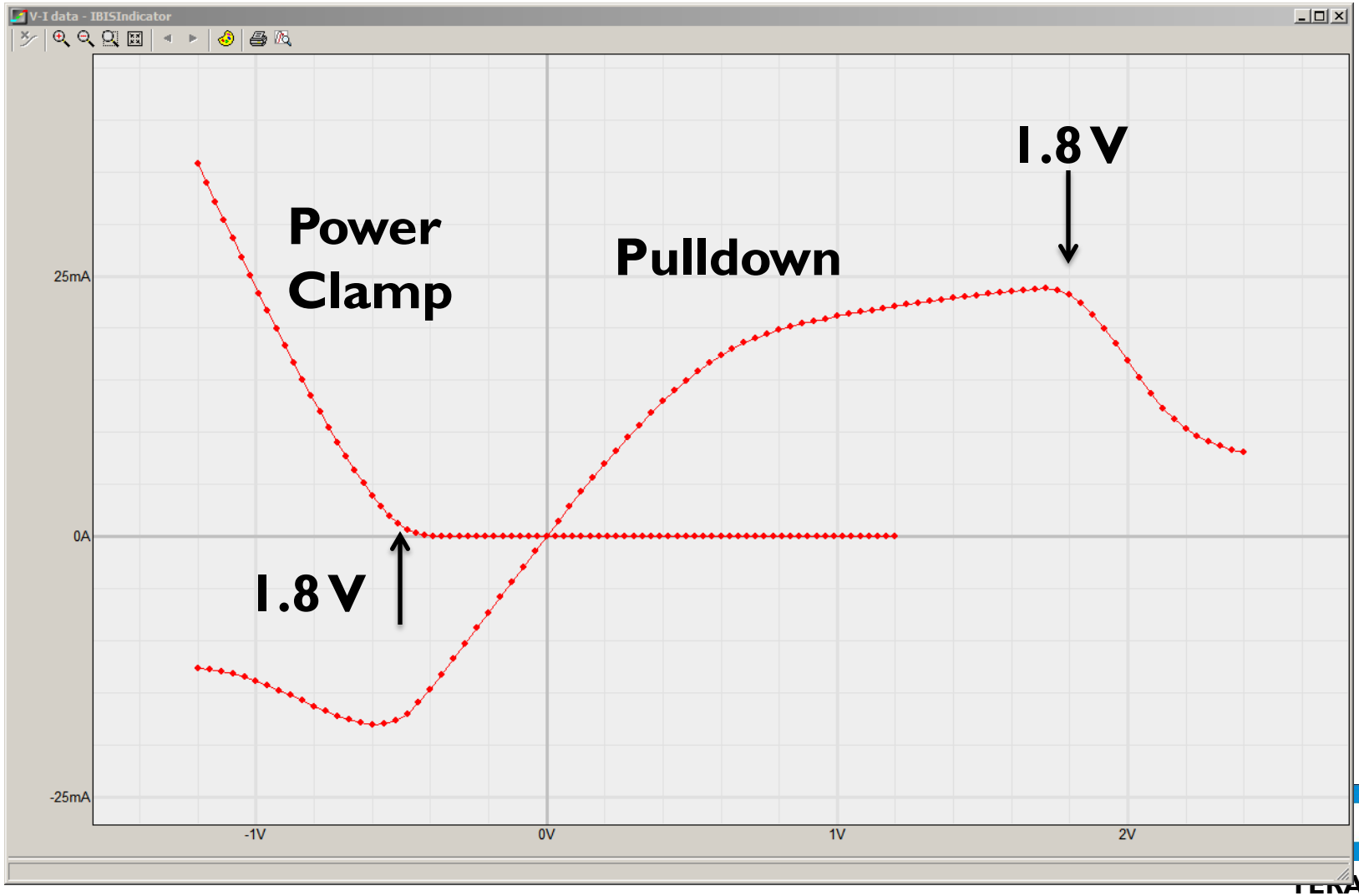
Still non-monotonic with higher resolution data

x Steps 0.02 and 0.01, 0.00 Offset (Red: Interpolated Value)

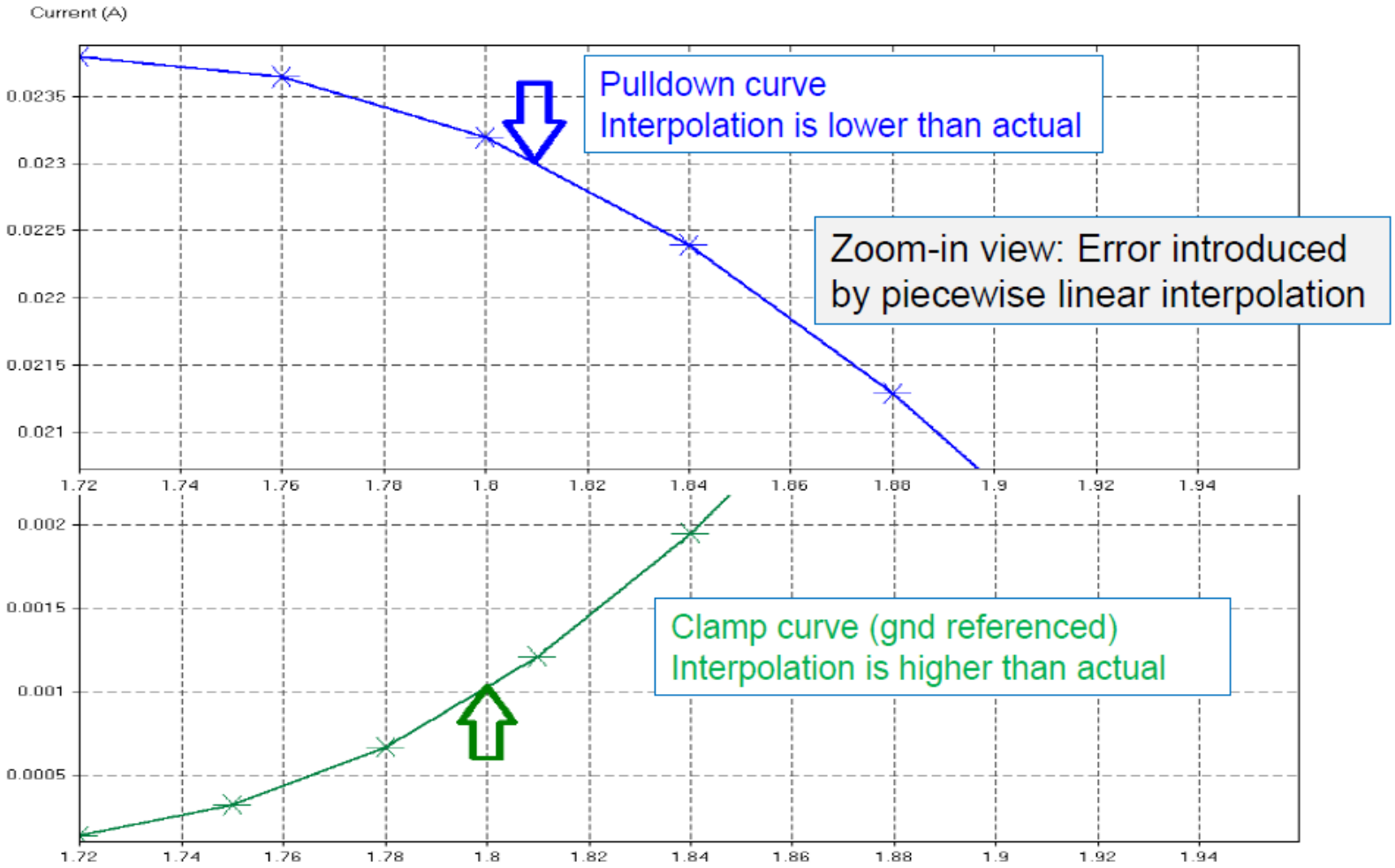
x	y1 = x^2	y2 = x^2	y1-y2
0.00	0.0000	0.0000	0.0000
0.01	0.0002	0.0001	0.0001
0.02	0.0004	0.0004	0.0000
0.03	0.0010	0.0009	0.0001
0.04	0.0016	0.0016	0.0000
0.05	0.0026	0.0025	0.0001
0.06	0.0036	0.0036	0.0000

Different resolution data causes non-monotonic combination

bug140a.ibs Maximum Data (Vdd = 1.3 V)

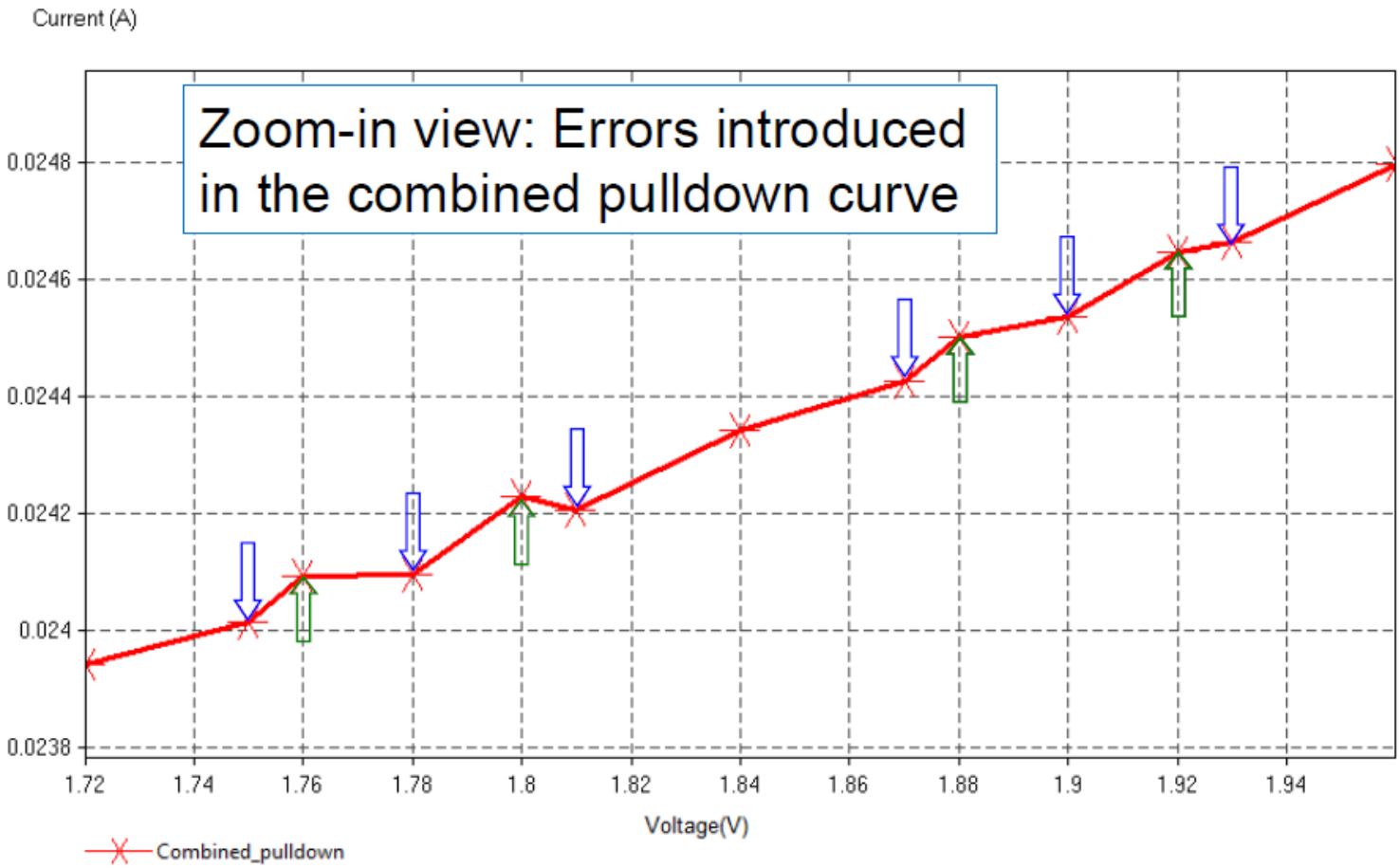


Example 1 (Cont.2)



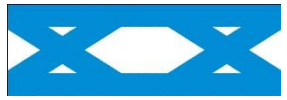
cadence

Example 1 (Cont.3)



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



TERASPEED CONSULTING GROUP

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.