Combined I-V Table Checks (BUG140)

DesignCon IBIS Summit

Santa Clara, CA, January 31, 2013

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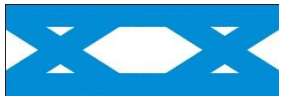

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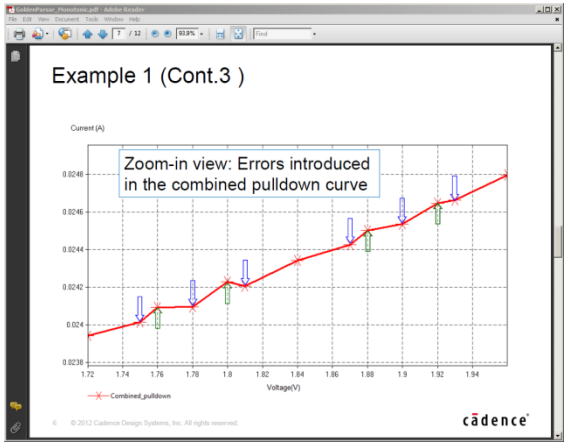
BUG140 Issue

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



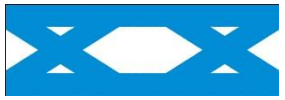
- Combined I-V table checks:
  - [Pulldown] + [Gnd Clamp] + [Power Clamp]
  - [Pullup] + [Gnd Clamp] + [Power Clamp]
- Ibischk5 parser is de facto standard for IBIS model correctness (and ibischk5 is embedded in tools)
- Some companies require 0 Errors, 0 Warnings
- IBIS Quality Spec, recommends 0 Errors and 0 Warnings
- **Warning messages create support issue for model authors or automatic modeling utility**

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)
- Specification recommends individual I-V table parser checking
- Combined checks added with BUG94 (BUG92 dealt with submodels): http://www.eda.org/ibis/bugs/ibischk/
- Non-monotonicity often occurs outside of normal simulation region – in clamping region and not a problem
- Ibischk5 parser is operating 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 with piecewise linear interpolation calculations (if not done right)
    - I-V tables have different V resolution
  - Combination of above cases



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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

Real Data from BUG140 and Cadence Presentation

- "Golden Parser Non-monotonic Warning's Investigation" by Yingxin Sun and Joy Li, Cadence Design Systems, November 9, 2012: http://tinyurl.com/byqu7yn
- Presented at IBIS Quality Committee November 27, 2012
- BUG140: http://www.eda.org/ibis/bugs/ibischk/
- (In all test cases, the [Gnd Clamp] data is 0.0 in the region of interest)

Checking bug140a.ibs

```
IBISCHK5 V5.1.2

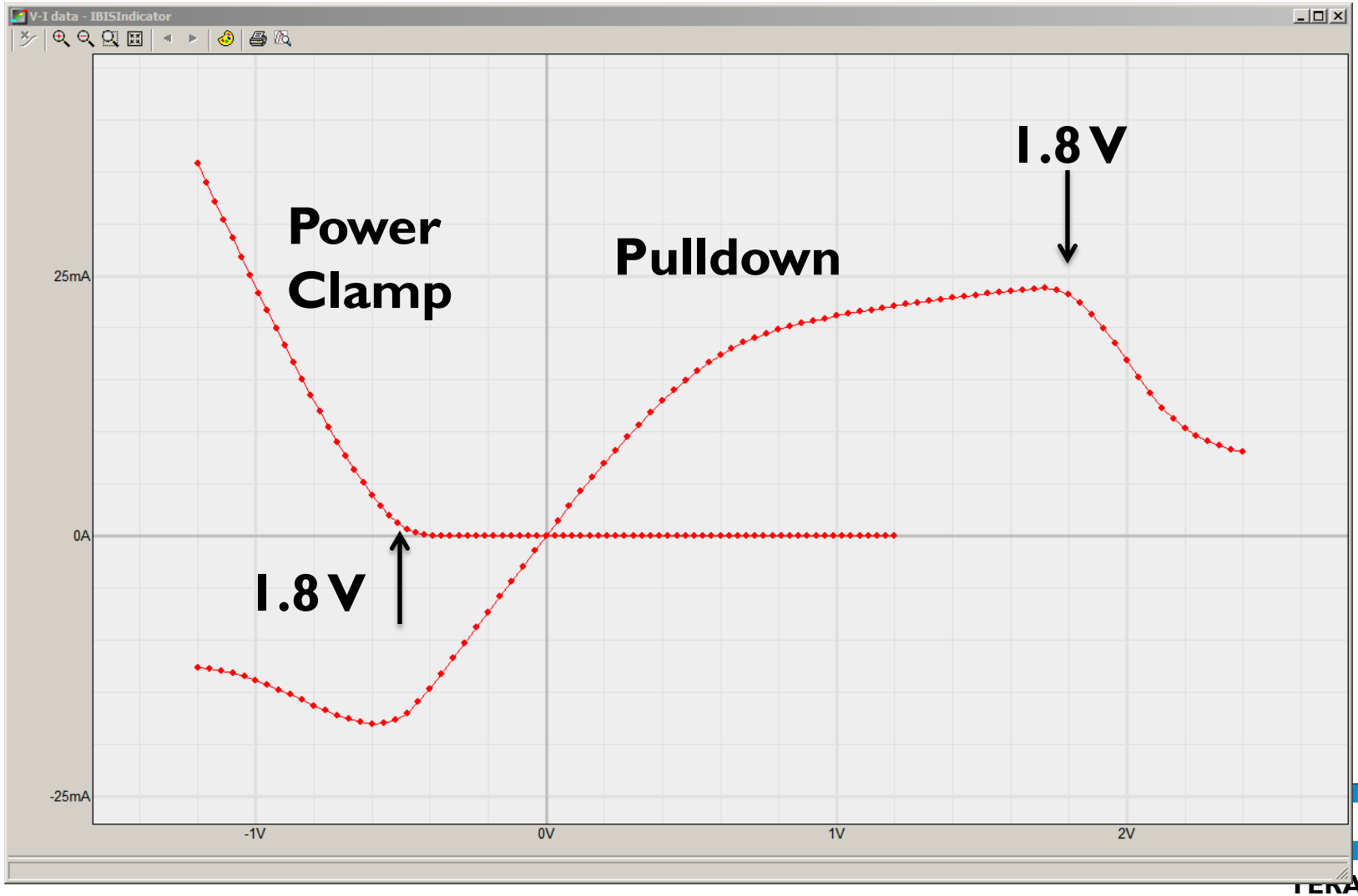
Checking bug140a.ibs for IBIS 3.2 Compatibility...

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

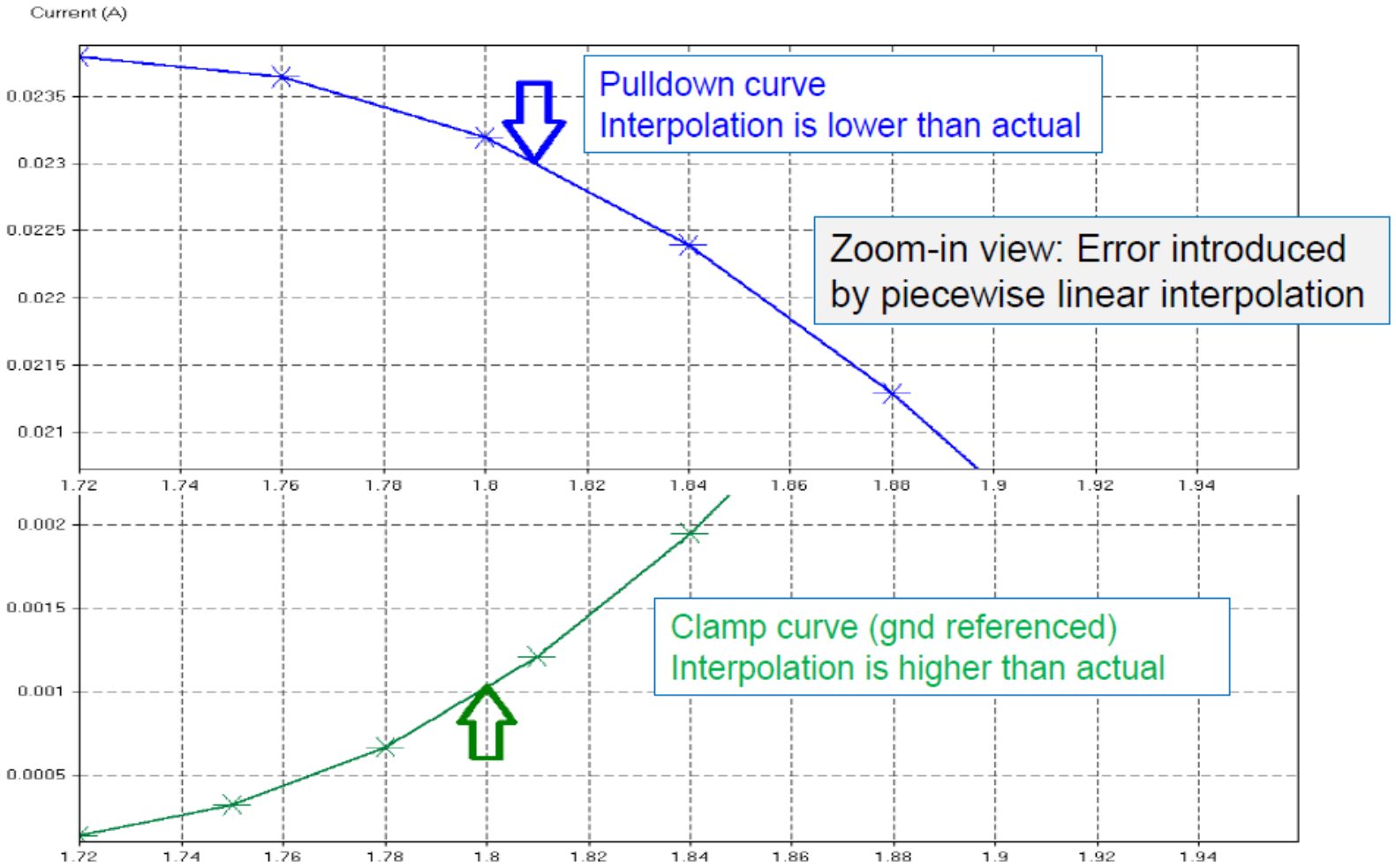
Errors  : 0
Warnings: 1

File Passed
```

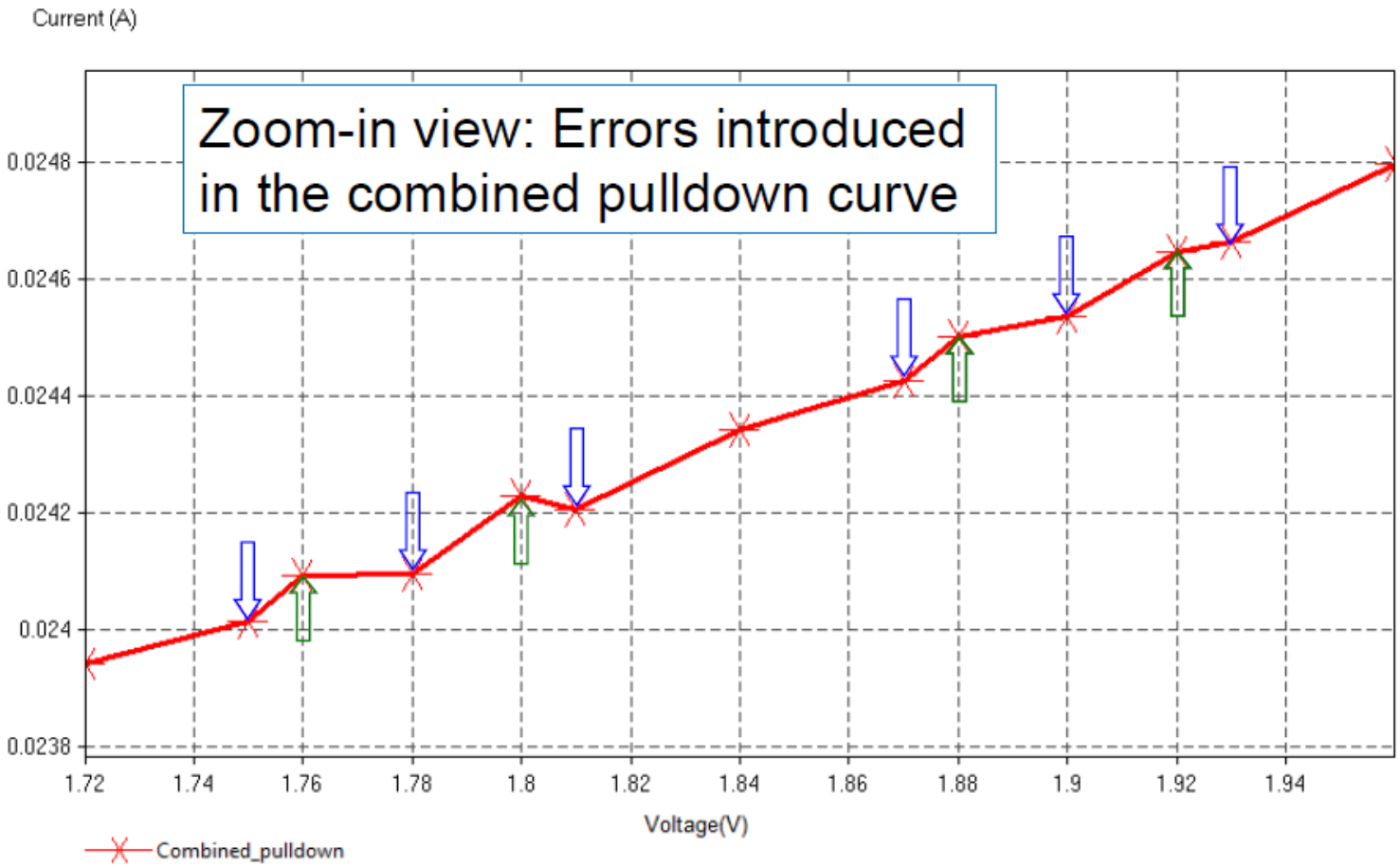
bug140a.ibs Maximum Data (Vdd = 1.3 V)



Example 1 (Cont.2)



Example 1 (Cont.3)



Checking bug140b.ibs

```
IBISCHK5 V5.1.2

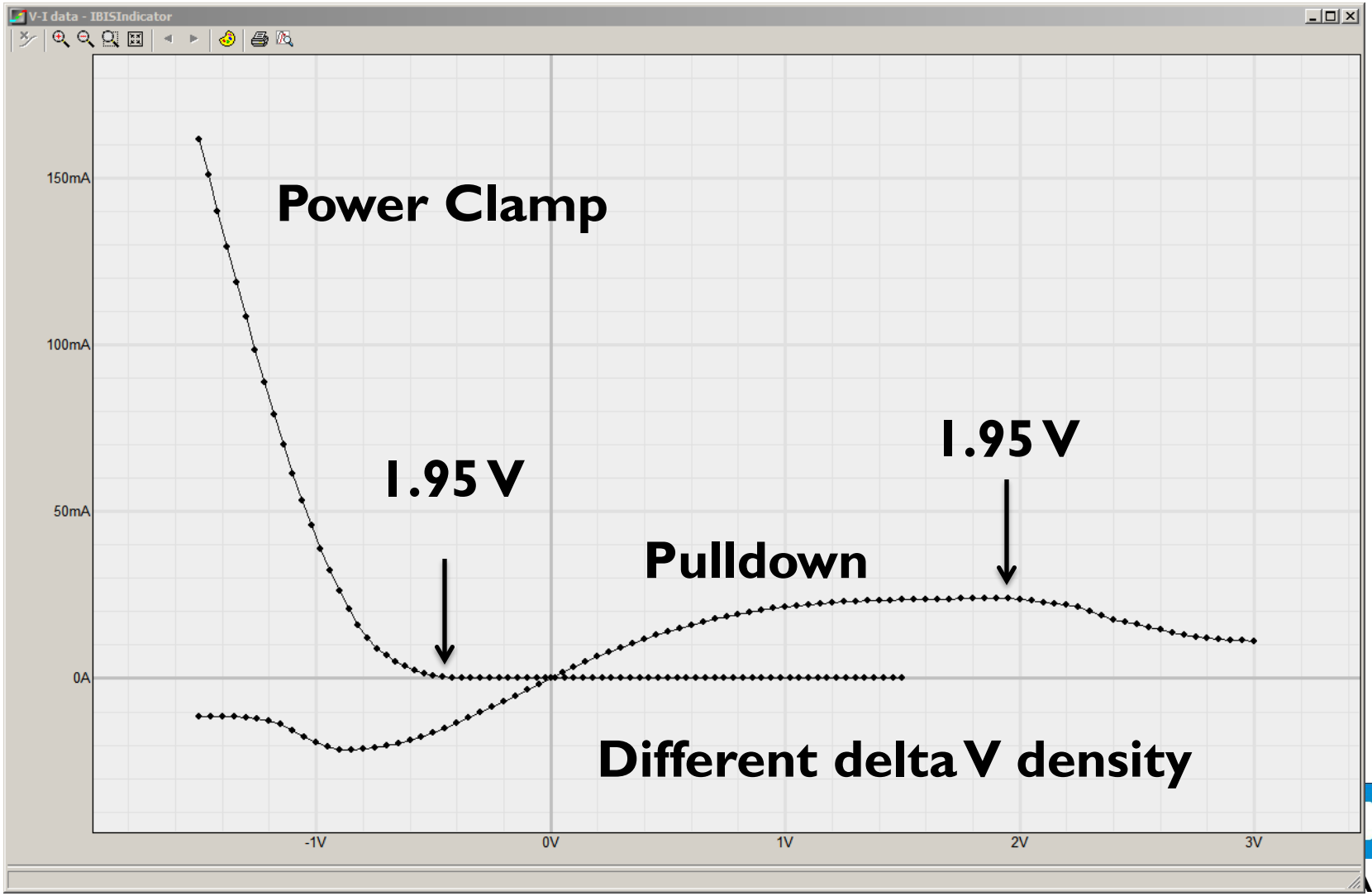
Checking bug140b.ibs for IBIS 4.2 Compatibility...

NOTE (line   40) - Pulldown Minimum data is non-monotonic
NOTE (line   51) - Pulldown Maximum data is non-monotonic
NOTE (line   52) - Pulldown Typical data is non-monotonic
NOTE (line  135) - Pullup Typical data is non-monotonic
NOTE (line  146) - Pullup Maximum data is non-monotonic
NOTE (line  202) - Pullup Minimum data is non-monotonic
WARNING - Combined Pulldown for Model: model_with_warning Typical data is non-
monotonic
WARNING - Combined Pulldown for Model: model_with_warning Maximum data is non-
monotonic

Errors   : 0
Warnings: 2

File Passed
```

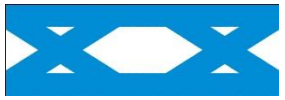
bug140b.ibs Typical Data (Vdd = 1.5V)



Combined Pulldown Data with Aligned Vdd (Different Delta V's)

```
1.850  2.395370e-002
1.880  2.397163e-002
1.900  2.401136e-002
1.920  2.401229e-002
1.950  2.411007e-002 <--
1.960  2.411006e-002 <--
2.000  2.432631e-002
2.040  2.472520e-002
2.050  2.489275e-002
2.080  2.539300e-002

10 nA (0.000041%) non-monotonicity
```

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Checking bug140b.ibs for IBIS 4.2 Compatibility...

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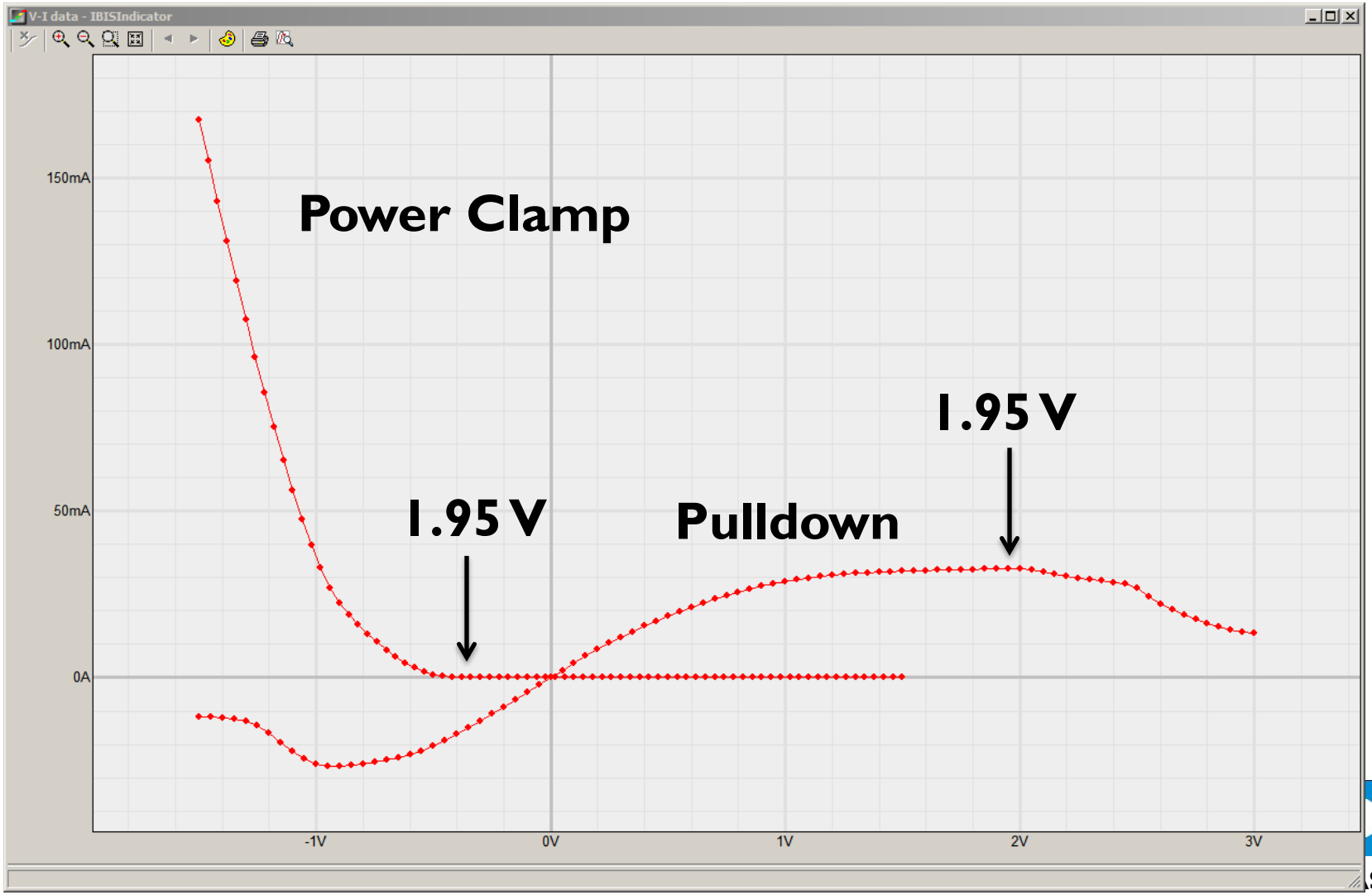
monotonic
WARNING - Combined Pulldown for Model: model_with_warning Maximum data is non-
monotonic

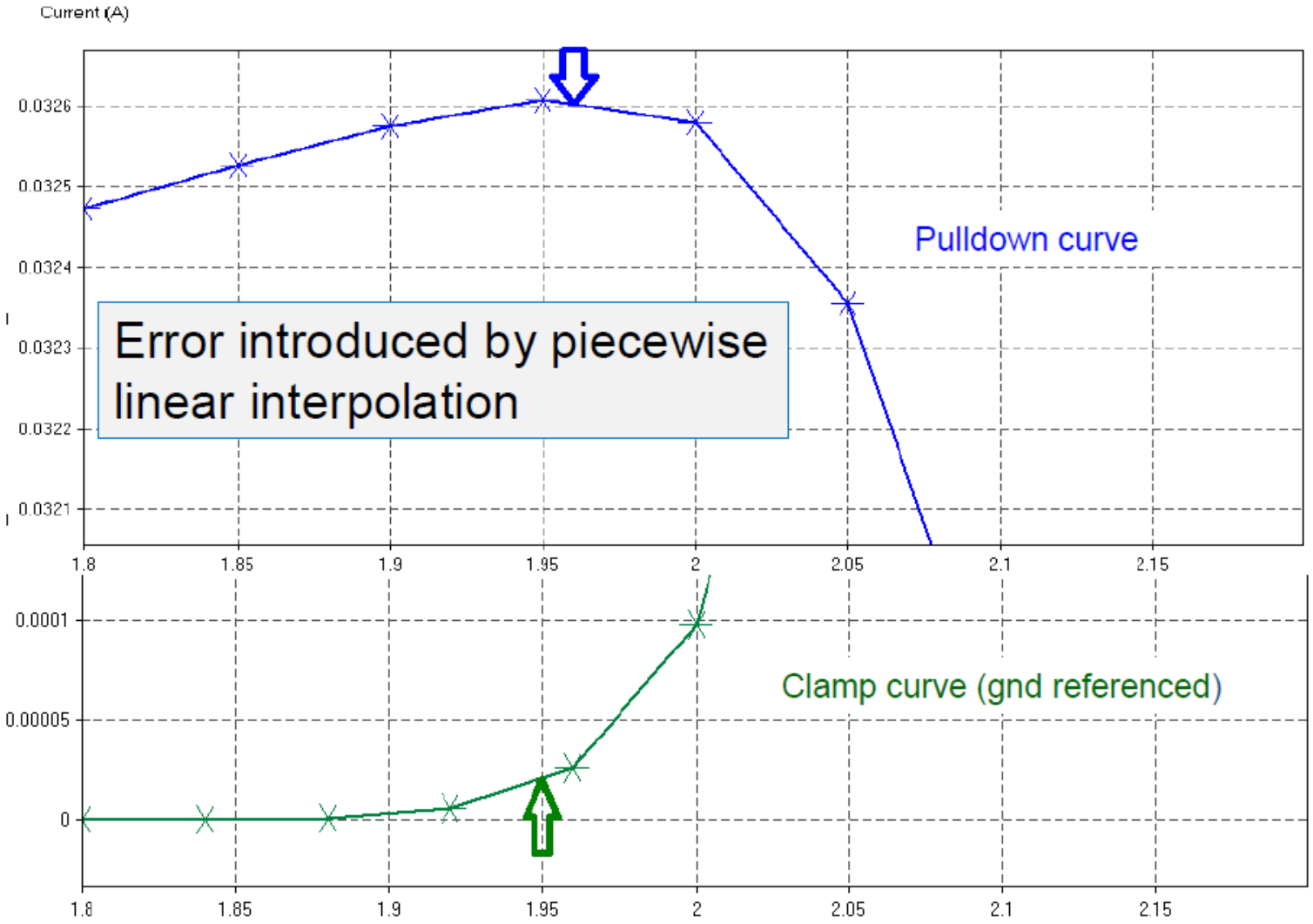
Errors   : 0
Warnings: 2

File Passed
```

bug140b.ibs Maximum Data (Vdd = 1.58 V)



Example 2 (Cont.2)



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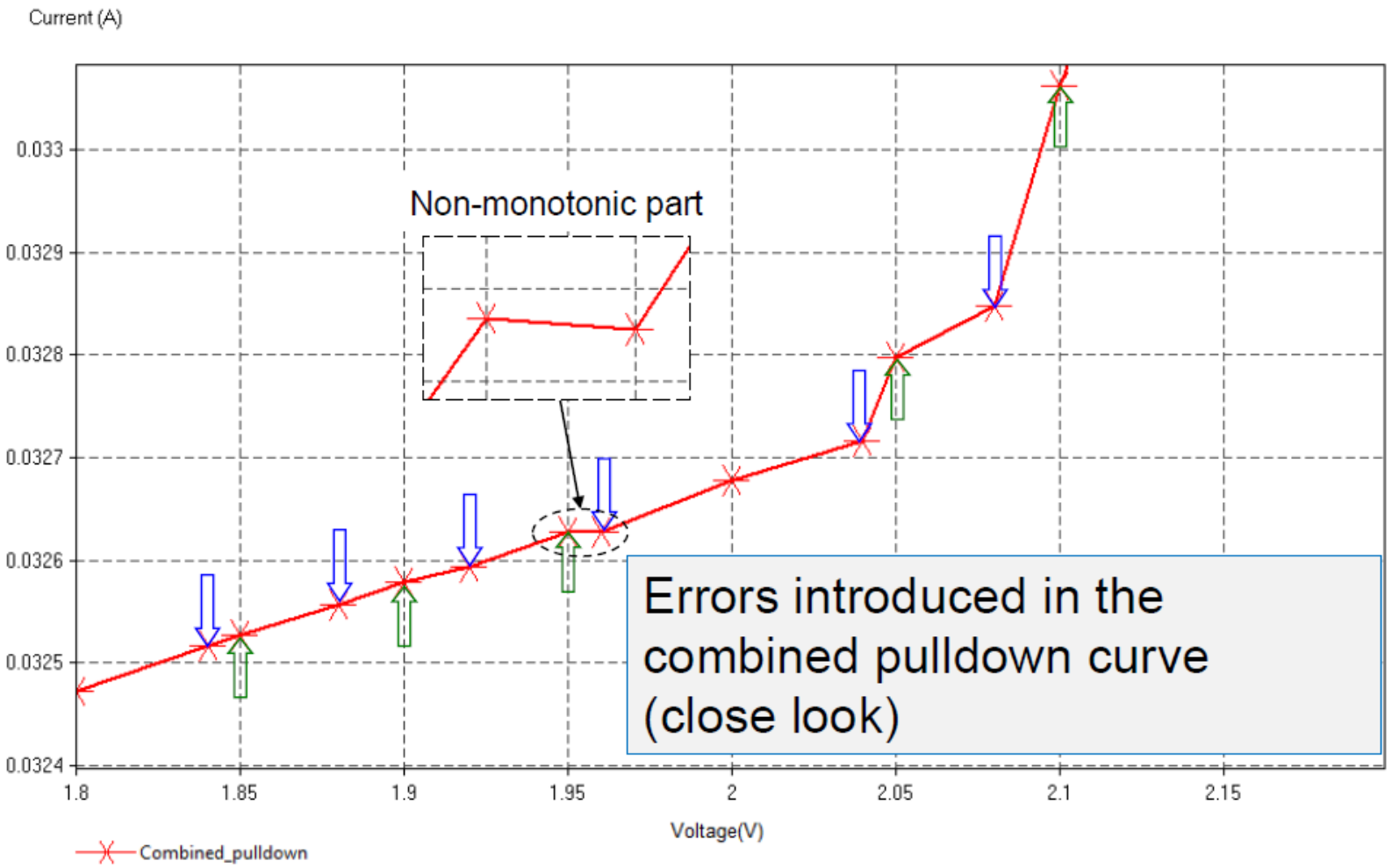
Example 2 (Cont.3)



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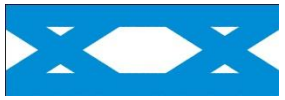
BUG140 Resolution

- 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
  - Piecewise linear interpolation is legal, and spline fitting would just hide information



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