Quantifying Shmoo Results: Brain Storm

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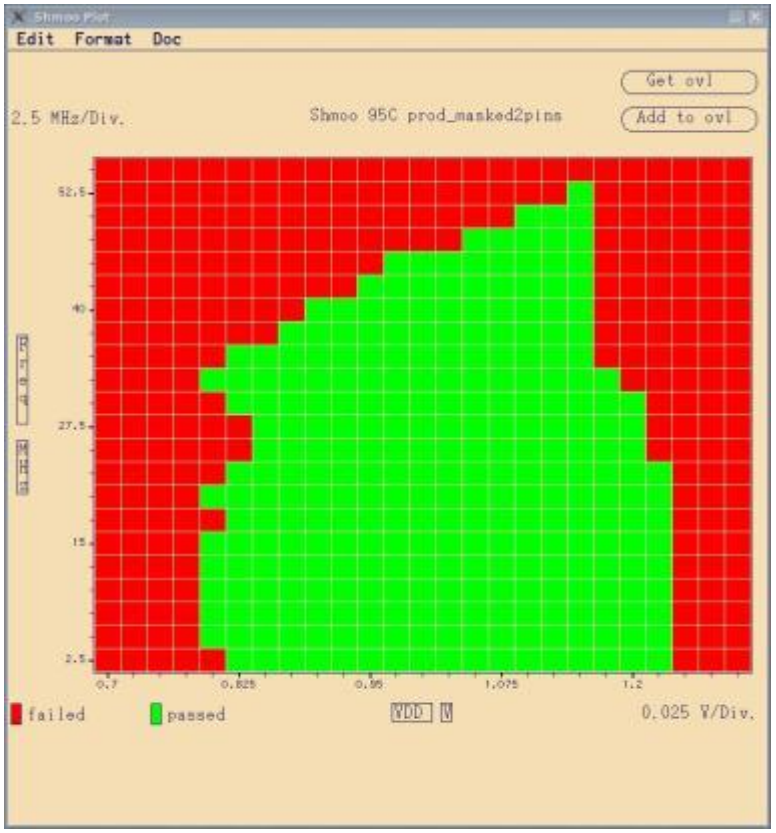
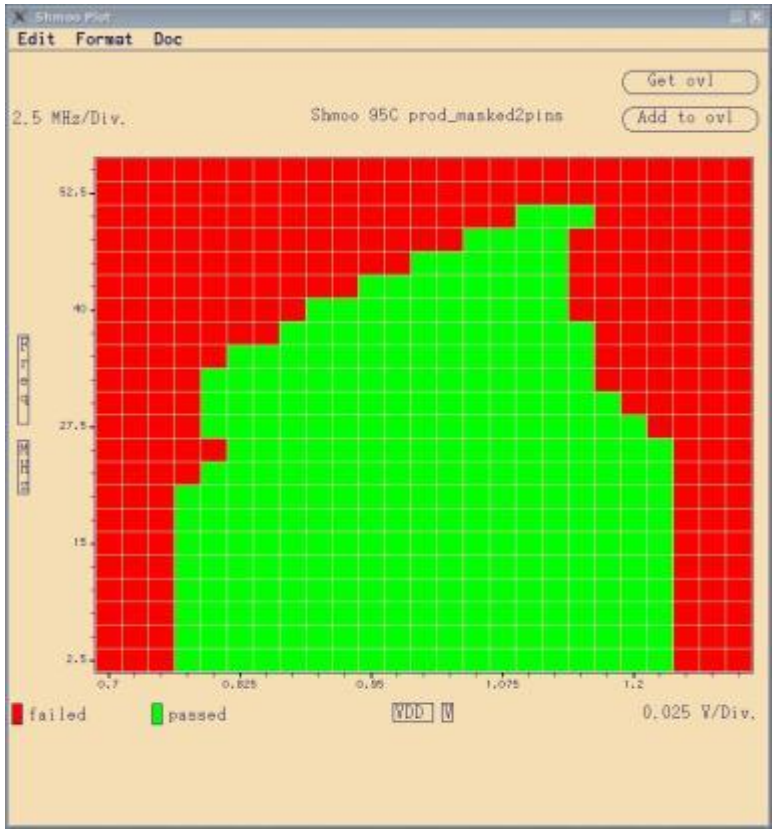
Agenda

- Purposes of Quantifying Shmoo Results
- Definition of Shmoo Results: Shmoo Quality (SQ)
- Test Methods for Shmoo Quality
- Complex Cases of Shmoo plots
- What Are We Going to Achieve?
- Moving from an Analog Parameter Shmoo on an ATE Tester to a Digital Parameter Shmoo on an Internal Register value
- Appendix: An Example of a Shmoo Quality Application
- Credits

Purposes of Quantifying Shmoo Results





- These Left and Right Shmoo plot settings are identical. Can we easily tell which Device has a better (bigger) pass region? (Green is pass.)
- Quantifying Shmoo Results will have great positive impacts on product and test engineering.

Definition of Shmoo Results: Shmoo Quality (SQ)

- When comparing more than one Shmoo plots, we usually compare the X-Dimension and Y-Dimension opening (pass) region. This is the definition of Area: The amount of space inside the boundary of a flat (2-dimensional) surface.
- Shmoo Quality (SQ) is defined as the Area of a Shmoo Plot Pass Region.
- Unit of Shmoo Quality (SQ): X-Dimension unit times Y-Dimension unit. For example, if we Shmoo Voltage (X) vs. Frequency(Y), the SQ unit can be (V * MHz).
- After this definition, we can quantify any Shmoo plot's SQ. Furthermore, we can compare SQ values, datalog SQ, analysis SQ distribution, trends, etc. over process or temperature, etc. by data analysis tools such as Data Conductor.
- In the Shmoo plot, the area of each pass/fail block equals Step_X * Step_Y.
- SQ = total pass block * (Step_X * Step_Y)

Test Methods for Shmoo Quality (SQ)

Property	Value
Test Type	M
Test Method	testmethodlib.ShmooQuantify
Parameters	/projects/OPS-Eagle/FT/eagle/datalogs/eagle/Shmoo, gA
Directory	/projects/OPS-Eagle/FT/eagle/datalogs/eagle/Shmoo
Pin	gAllPins
PassValue	0
VDD_CORE	
Start_X	0.6
Start_Y	2.5
Stop_X	1.3
Stop_Y	55
Step_X	0.02
Step_Y	2.5
Block	0
vector_label	SCAN_BURST_sdc
Debug	ON
Shmoo_X	VDD
Shmoo_Y	Freq
Unit_X	V
Unit_Y	MHz
ShmooTitle	Freq vs. Voltage
CharforPass	+
CharforFail	0
Limits	...

Shmoo Plot Settings

```
New Record Start:  SCAN_CHAIN_Shmoo_QualityV*MHz    LotID: E03322SKF    FabID:
Vector Label is: SCAN_BURST_sdc
X Direction Shmoo Variable is VDD
Y Direction Shmoo Variable is Freq
Start_X=0.6V    Stop_X=1.3V X per step = 0.02V
Start_Y=2.5MHz  Stop_Y=55MHz    Y per step = 2.5MHz

Pass Shmoo Point Represent by Char +    Pass Shmoo Point Represent by Char 0

Freq vs. Voltage    Freq vs. VDD
Y=     55MHz    00000000000000000000000000000000000000
Y=   52.5MHz    00000000000000000000000000000000000000
Y=     50MHz    00000000000000000000000000000000000000
Y=   47.5MHz    00000000000000000000000000000000000000
Y=     45MHz    00000000000000000000000000000000000000
Y=   42.5MHz    00000000000000000000000000000000000000
Y=     40MHz    00000000000000000000000000000000000000
Y=   37.5MHz    00000000000000000000000000000000000000
Y=     35MHz    00000000000000000000++++00000000000000
Y=   32.5MHz    0000000000000000++++++++++0000000000000
Y=     30MHz    000000000000++++++++++++++0000000000000
Y=   27.5MHz    000000000000++++++++++++++0000000000000
Y=     25MHz    000000000000+++++++++++++++000000000000
Y=   22.5MHz    00000000000+++++++++++++++000000000000
Y=     20MHz    00000000000+++++++++++++++000000000000
Y=   17.5MHz    00000000000+++++++++++++++000000000000
Y=     15MHz    00000000000+++++++++++++++000000000000
Y=   12.5MHz    00000000000+++++++++++++++000000000000
Y=     10MHz    00000000000+++++++++++++++000000000000
Y=    7.5MHz    00000000000+++++++++++++++000000000000
Y=      5MHz    00000000000+++++++++++++++000000000000
Y=    2.5MHz    00000000000+++++++++++++++000000000000
        X_Start=0.6V---------->X_End=1.3V

SCAN_CHAIN_Shmoo_Quality    Shmoo Quality:      11.15V*MHz
```

Shmoo Quality Results

TestMethod: Shmoo Quality

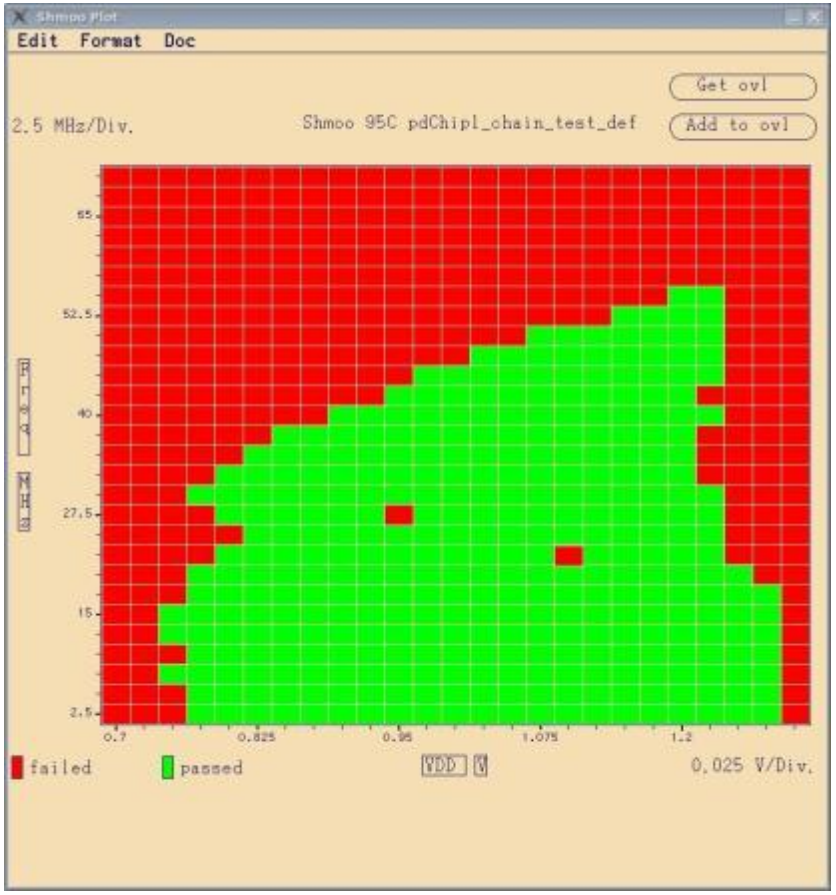
- The left-side picture is the V93K Test Suite inputs and the right- side picture is the V93K UI window and Datalog file format.
- The example showed SQ = 11.15V * MHz on the right-side picture.
- TestMethod will create or append a data file while the UI window shows the same contents.
- STDF datalog will generate a PTR record with a test name as a suite name and the test result will be the SQ value.
- This TestMethod can be used for almost any timing or level variable to Shmoo. The Results datalog file can be postprocessed by Perl to get a colorful picture.
- This TestMethod Shmoo Quality approach is best for lots of parts that need to be SQ tested across many test phases. For example, a Split LOT may have 200 parts to go through SCAN CHAIN, SCAN BURST, and MBIST Shmoo with perhaps 2 – 3 different pattern files. An STDF datalog of SQ value can help get the data analysis work done in minutes.

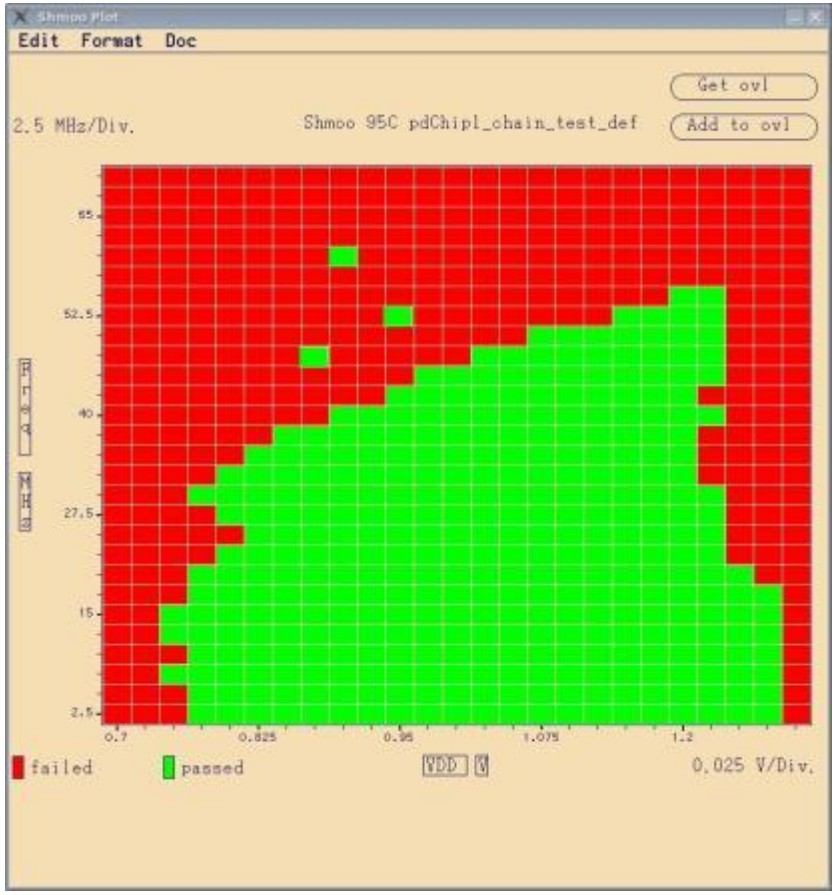
STDF datalog PTR Record

```
PTR Record
  TEST_NUM:     0
  HEAD_NUM:     1
  SITE_NUM:     1
  TEST_FLG:     0x0
  PARM_FLG:     0xC0
  RESULT:           14.000000000
  TEST_TXT:     SCAN_CHAIN_5 MHz_NOM
  ALARM_ID:
  OPT_FLAG:     0xE
  LO_LIMIT:     0.000000010
  HI_LIMIT:     9999999827968.000000000
  UNITS:
  LO_SPEC:      0.0000
  HI_SPEC:      0.0000
```

- We can see the QS results in the STDF file are logged as normal analog results.
- TM controls the test name. In this case, “SCAN_CHAIN_5MHz_NOM” is the test name in the STDF data log.
- We can define Units in TM as well.

Complex Cases of Quantifying Shmoo Qualify





- The left Plot illustrates some fail points in the big pass region.
- The right Plot illustrates some pass points within the failure region.

Algorithmic Definition of Shmoo Results

- We have defined that Shmoo Quality (SQ) is the Area of a Shmoo Plot Pass Region.
- We also observed in the previous slide that the simple Area definition of the pass region may not make sense in some of the real cases.
- We may have to remove some good “pass” block neighborhoods with one isolated “fail” block, or to remove an isolated “pass” block from SQ calculation.
- Engineers usually need to review those special Shmoo plot cases in order to better understand the real situation.
- The sample TestMethod is a simple step to demonstrate the mindset of Quantifying. The TestMethod we are using here can be improved in many ways.

What Are We Going to Achieve?

- We want to quantify everything that we can. Knowing how to analyze those detail differences will help us improve quality, cost, and speed.
- This exercise of creating a test method to generate a Shmoo plot will help us to Shmoo the device internal register value. Under such circumstances, the tester's timing or level settings usually have less influence over those internal register settings.
- We can use this approach to let the ATE program do Shmoo and datalog automatically (avoiding the engineer having to do it manually) as characterization and R&D engineering work with a relatively large numbers of devices. For example, there tests can be done by prober auto sorting, handler auto indexing, or operators.
- This Shmoo plot TM exercise also helps generate the BER Contour Plot by the Shmoo "TX/RX len" internal register setting, and reads back the internal error counter through JTAG or another serial port.

From Analog to Digital Parameter Shmoo

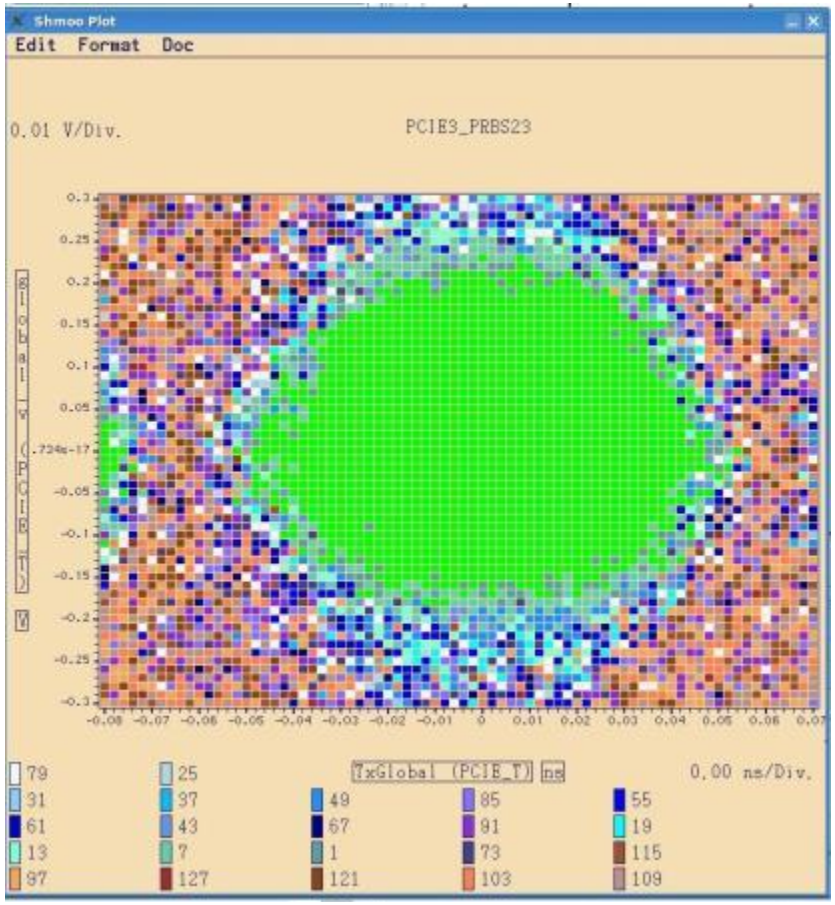
Move from Analog Parameter Shmoo on the ATE Tester to Digital Parameter Shmoo on the Internal Register Value

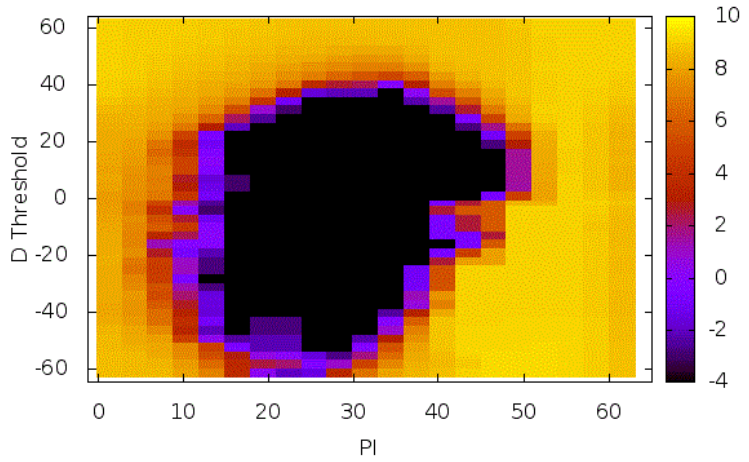
```
00000000000000000000++++00000000000
0000000000000++++++++++0000000000
00000000000+++++++++++++++0000000000
00000000000+++++++++++++++0000000000
00000000000+++++++++++++++000000000
0000000000+++++++++++++++000000000
000000000+++++++++++++++000000000
000000000+++++++++++++++0000000000
00000000+++++++++++++++0000000000
00000000+++++++++++++++0000000000
000000000+++++++++++++++000000000
00000000+++++++++++++++000000000
00000000+++++++++++++++000000000
000000000+++++++++++++++000000000
```

- In the left-side data array, each x-y point can store a Error Count value (from 0 – infinite).
- Use Perl scripts to generate a BER contour plot. At each point, a color will represent the Error Bit Count.
- Usually X-Dimension is the Chip Internal Phase Delay sampler position and Y-Dimension is the digital threshold value.
- The Error-Free Area is the targeted value we want to get.

2-D Shmoo Plot with Error Count

From Tester to IC Built-In Digital Register Value Shmoo

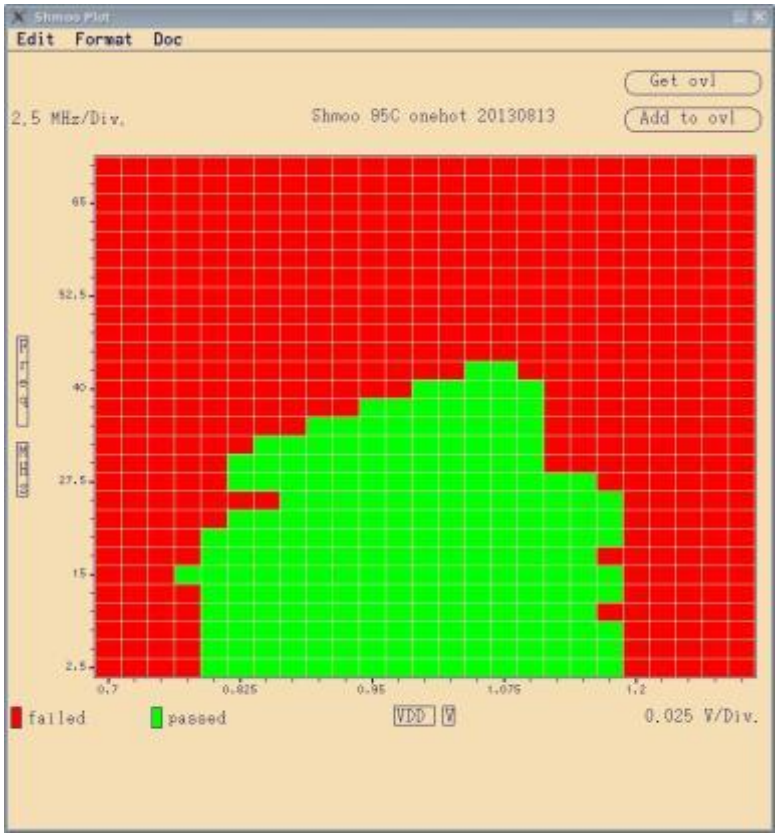


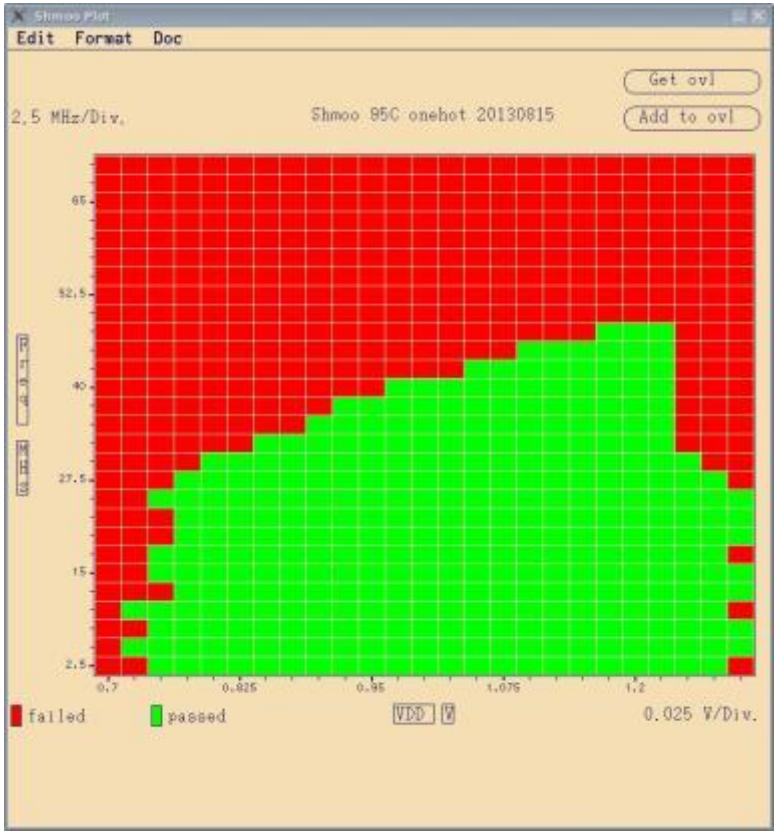


- Left-side plot is the V93K PS9G receiver's view in an 8G PCIe Gen3 signal.
- Right-side plot is the IC internal PCIe receiver's view of the signal. The ATE tester only can control the register setting through JTAG. This is the challenge.

Appendix: An Example of Shmoo Quality (SQ)

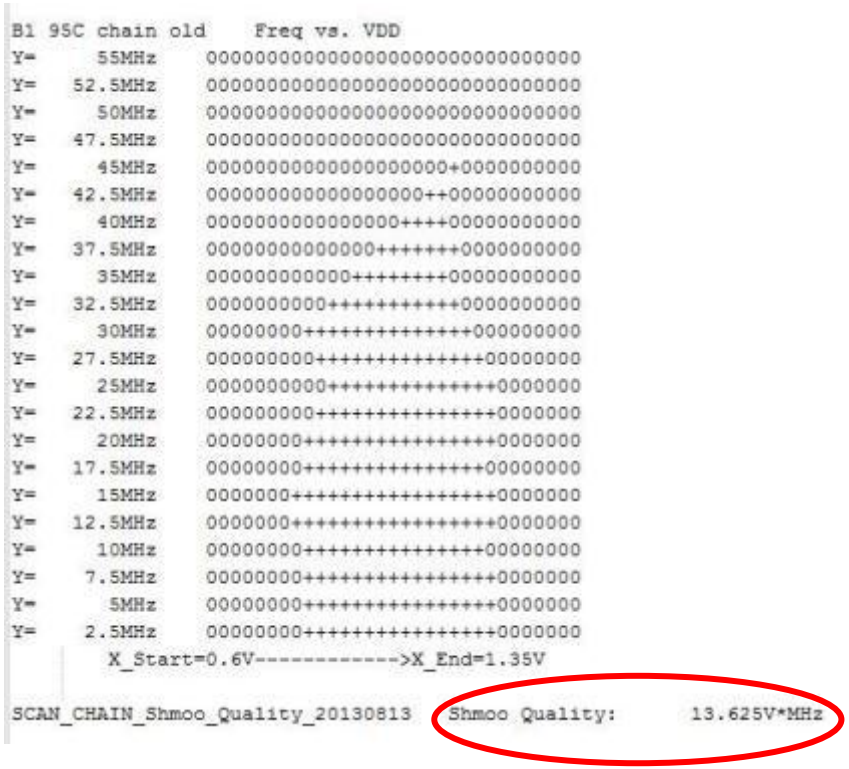
Application Golden Device 1, Nonquantified SQ

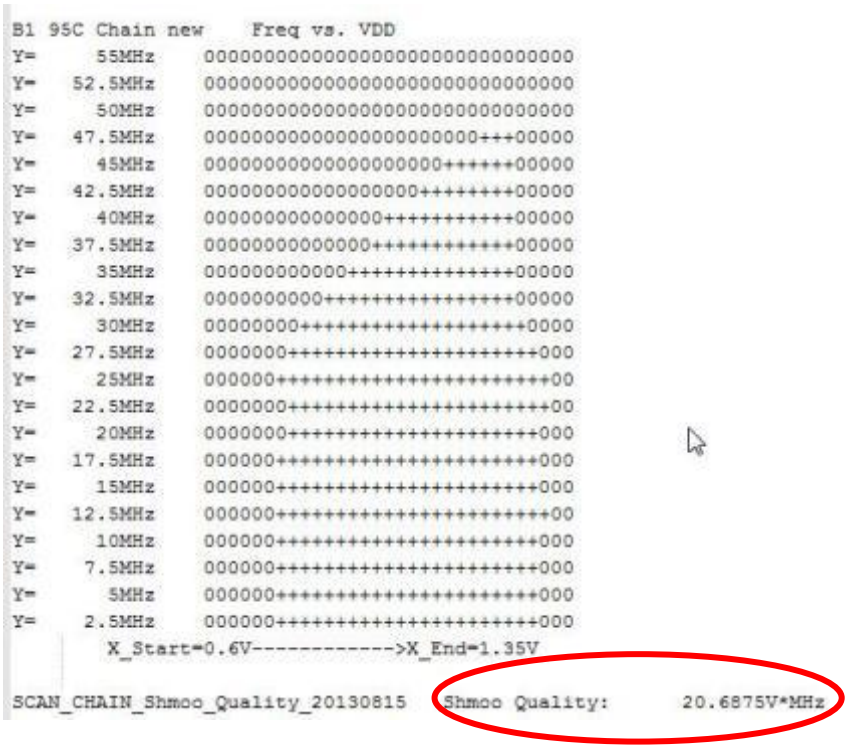




- The Golden Device 1 old (left) and new (right) patterns show a difference in the Shmoo Plot, but the SQ is not quantified.

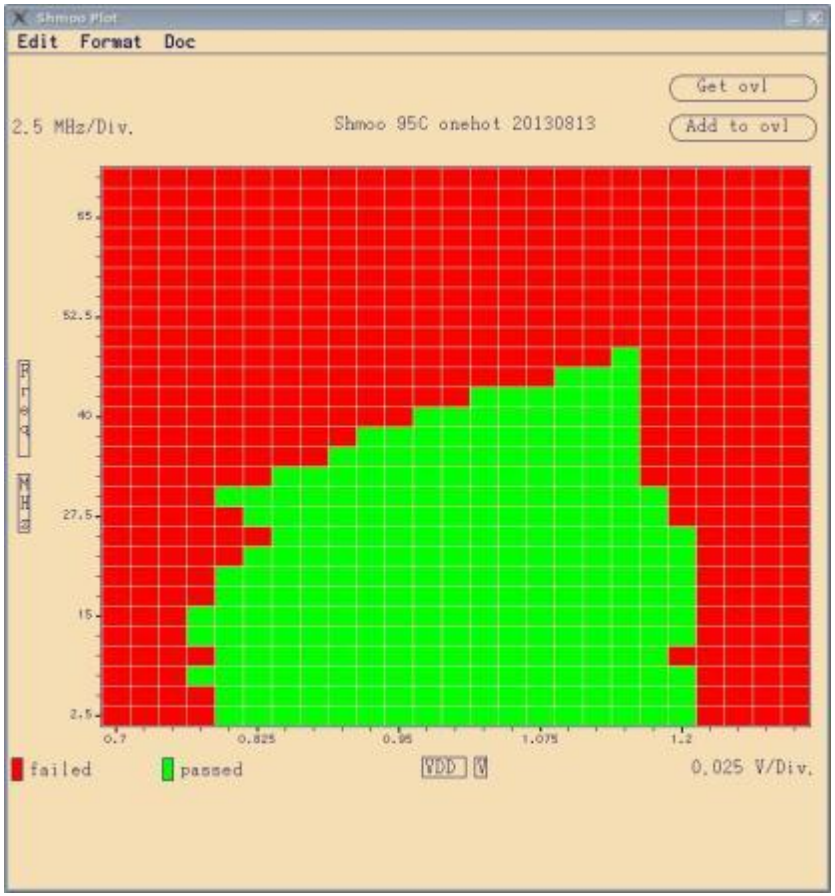
Golden Device 1, Quantified SQ

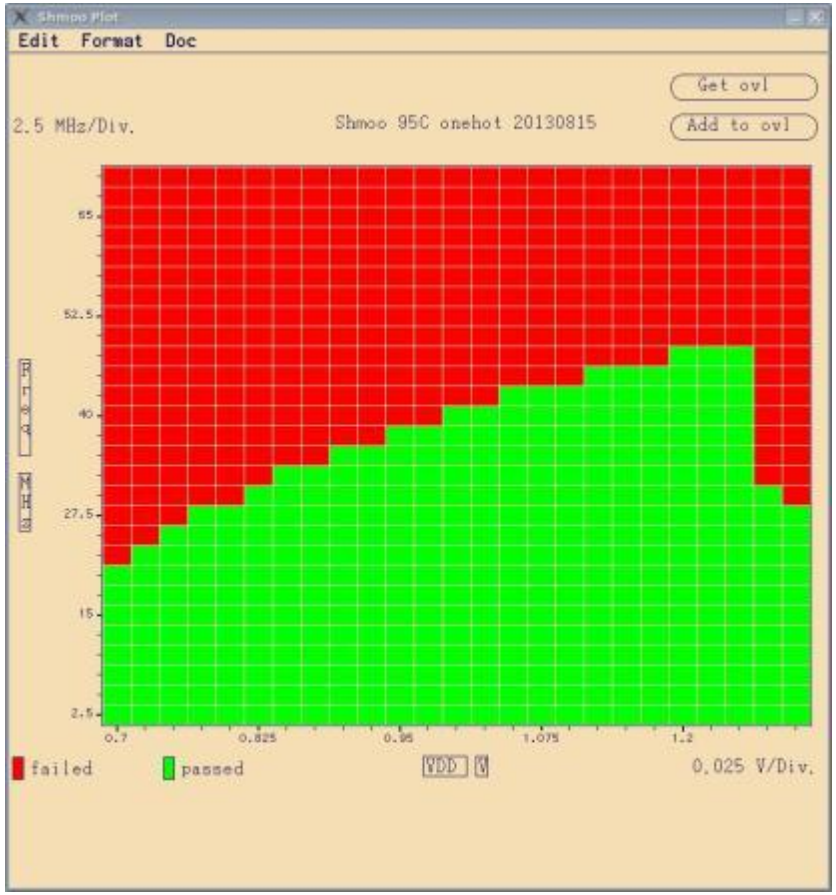




- The Golden Device 1 old (left) and new (right) patterns show a difference on the Shmoo Plot, with a quantified SQ.
- Improved Shmoo Quality = SQ (new) / SQ (old) = 20.6875 / 13.625 = 151.8%

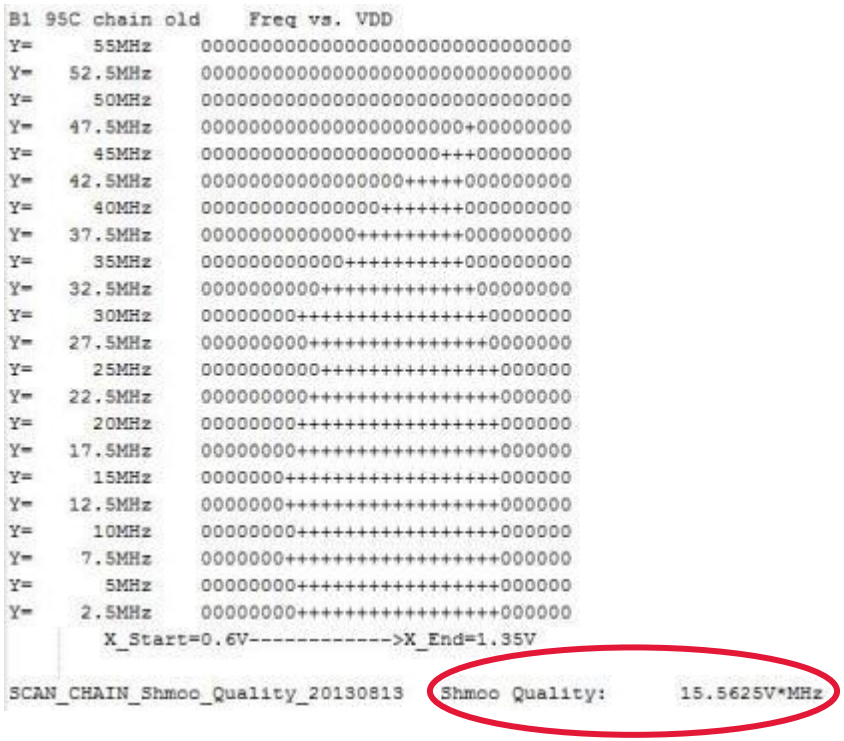
Golden Device 2, Nonquantified SQ

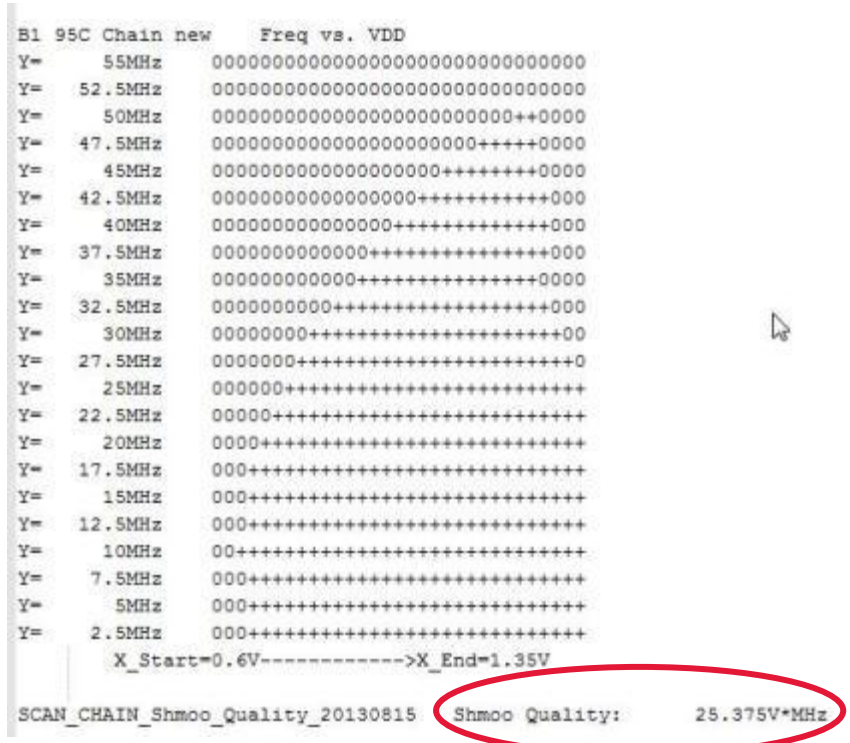




- Golden Device 2 old (left) and new (right) patterns show a difference on the Shmoo Plot, but SQ is not quantified.

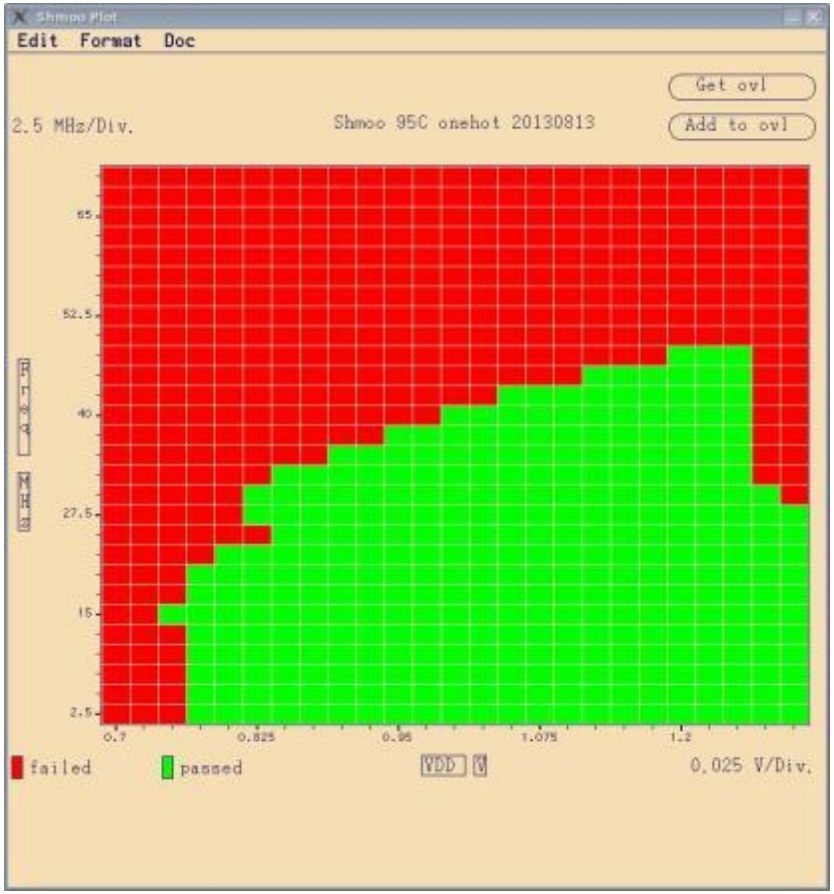
Golden Device 2, Quantified SQ

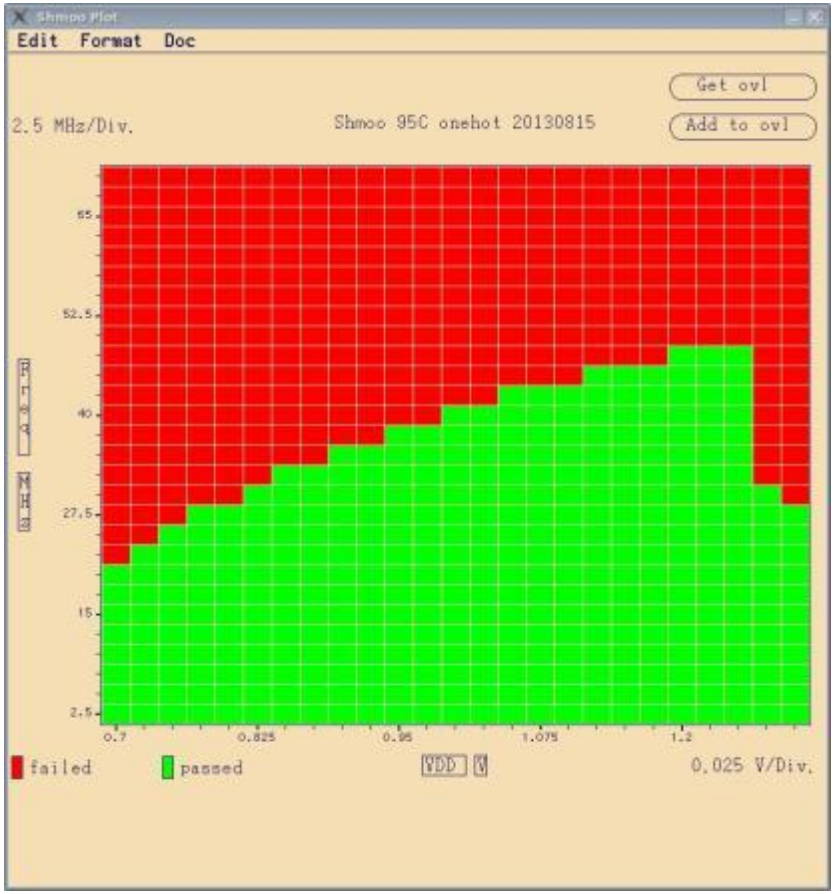




- Golden Device 2 old (left) and new (right) patterns show a difference on Shmoo Plot, with a quantified SQ.
- Improved Shmoo Quality = SQ (new) / SQ (old) = 25.375 / 15.5625 = 163.1%

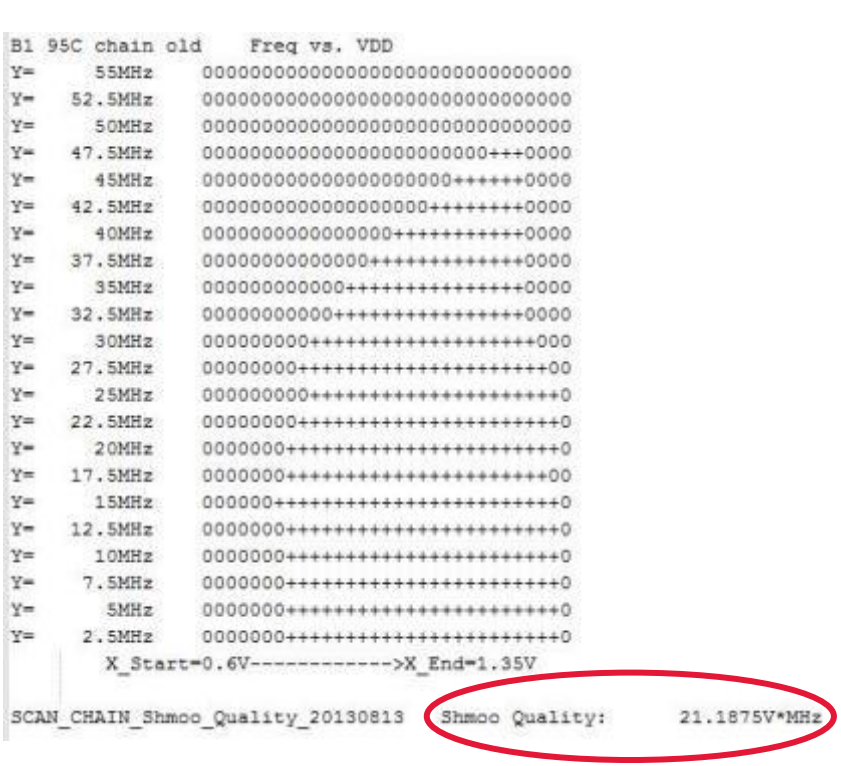
Golden Device 3, Nonquantified SQ

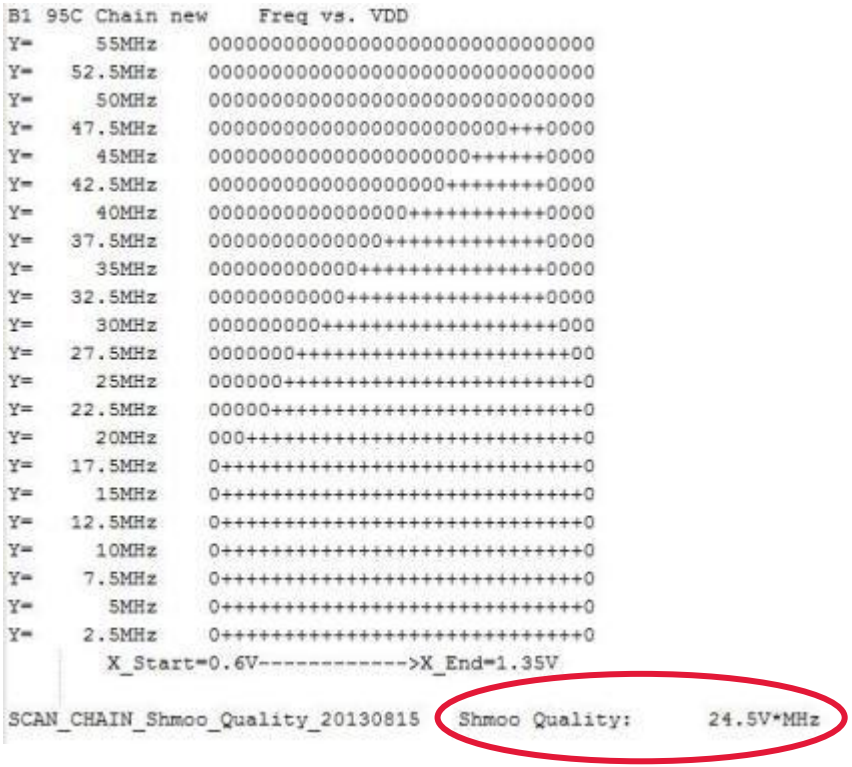




- Golden Device 3 old (left) and new (right) patterns show a difference on the Shmoo Plot, but SQ is not quantified.

Golden Device 3, Quantified SQ





- Golden Device 3 old (left) and new (right) patterns show a difference on the Shmoo Plot, with a quantified SQ.
- Improved Shmoo Quality = SQ (new) / SQ (old) = 24.5 / 21.1875 = 115.6%

Three Devices' Shmoo Results Summary

Shmoo Quality (SQ) Summary Table: Unit (V*MHz)			
Device SN	Old Pattern	New Pattern	Improvement (%)
1	13.625	20.6875	151.83%
2	15.5625	25.375	163.05%
3	21.1875	24.5	115.63%

- We can easily generate a statistic analysis report based on the quantified Shmoo results.

Credits

I want to express my thanks to managers and fellow colleagues:

- Ken Chow encouraged me to write down my ideas.
- Ricky Biton helped me understand the challenges of project “Eagle,” so I got the Eagle Platform to try new things.
- Tik Gwan Kang shared V93K test methods and libraries, and helped me to convert patterns.
- Quinlam Tong helped me arrange easier tester access.
- Kevin Li and his DFT team, Gefu Xu, Harprateek Manocha, and Verra Pappula provided lots of pattern files for me to play with.
- And many others.