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信号完整性测试

你的产品质检员

一博科技-SI研究部

EDADOC，Your Best Partner

产品出来后怎么判断产品性能，忐忑出货/底气十足？

- 只做功能性测试？
  - 长时间
  - 高低温
- 两条腿走路？——功能性测试+ 信号完整性测试同时进行
  - 波形/眼图
  - 时序
  - 轻载/重载

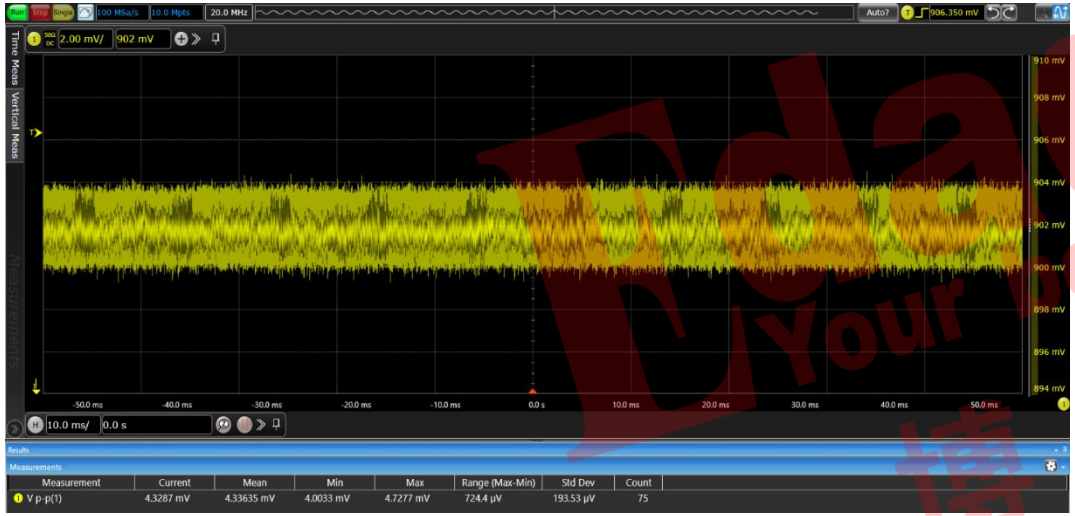
PART 01

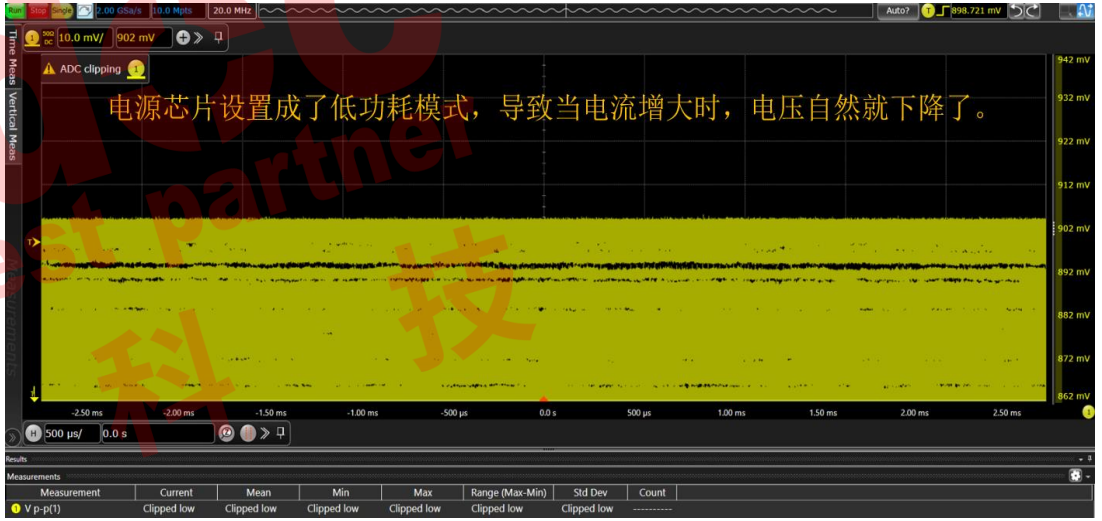
什么时候你想SI测试了

功能出了问题，请测试找原因

客户：对业务端口初始化，温度升高一会儿就挂了，少初始化一些端口就能够建链。业务端口起来的越多，功耗越高，怀疑是纹波过大造成的

- 芯片上电——系统正常，且纹波≤5mVpp
- 所有业务端口初始化起来——系统挂了，电压明显下降，从0.9V降到了0.85V，且不会回到0.9V

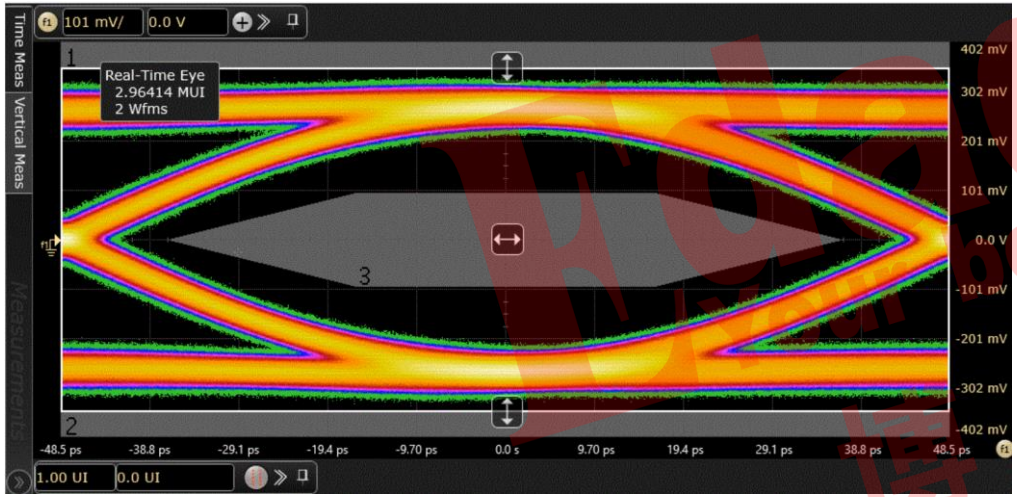




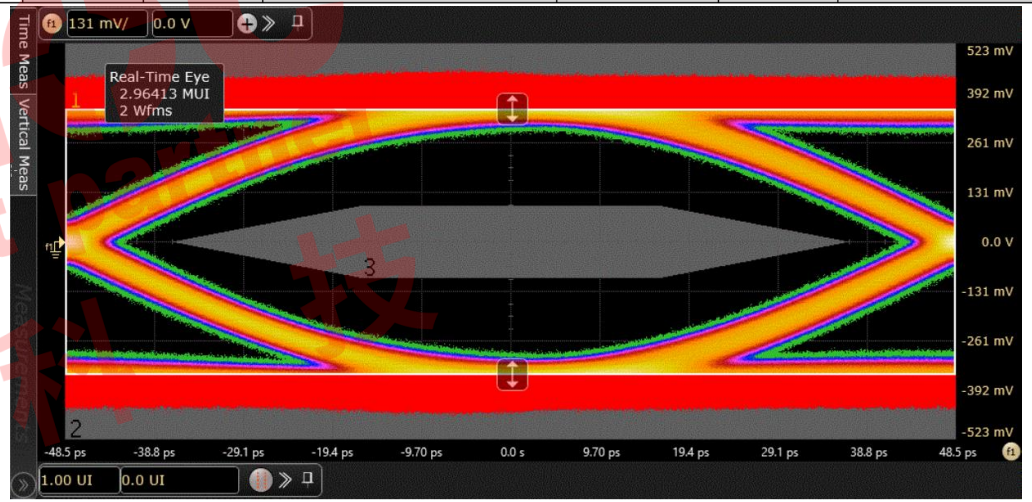
功能没问题，但客户问你要测试报告

- 产品发货两年了，功能没问题，从没测过眼图；现在的客户要求必须见到SI测试报告
- 幅度过大有什么影响？

Pass	# Failed	# Trials	Test Name (click to jump)	Actual Value	Margin	Pass Limits
✓	0	1	Total Jitter (TJ)(p-p)	182.4 mUI	34.9	VALUE <= 280.0 mUI
✓	0	1	Eye Mask Hit Ratio	0.0000000	100.0	VALUE <= 50.0 µ



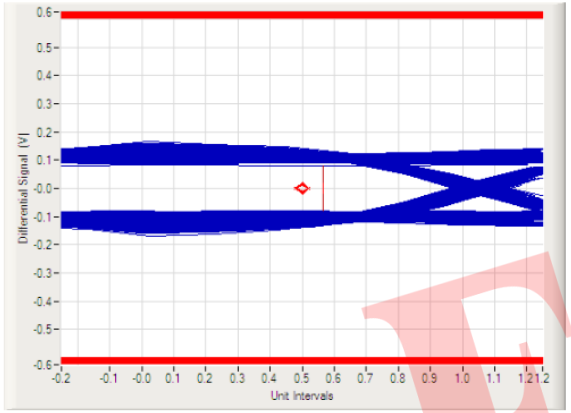
Pass	# Failed	# Trials	Test Name (click to jump)	Actual Value	Margin	Pass Limits
✓	0	1	Total Jitter (TJ)(p-p)	184.6 mUI	34.1	VALUE <= 280.0 mUI
✗	1	1	Eye Mask Hit Ratio	459.1975 m	-918E+03	VALUE <= 50.0 µ



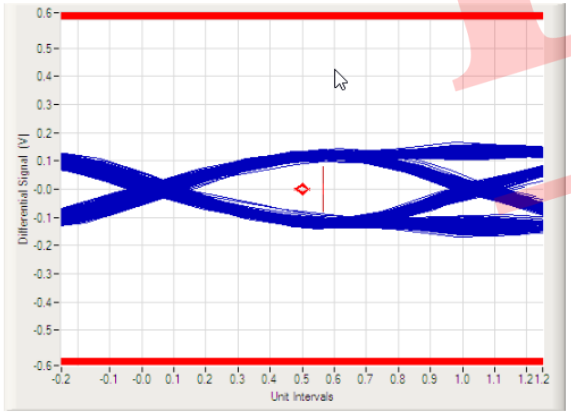
自己测功能没问题，但客户说：挑板

- 无法限制客户使用特定的板卡，只能让自己调整到最优，以补他人之短

Worst Non Transition Signal Eye



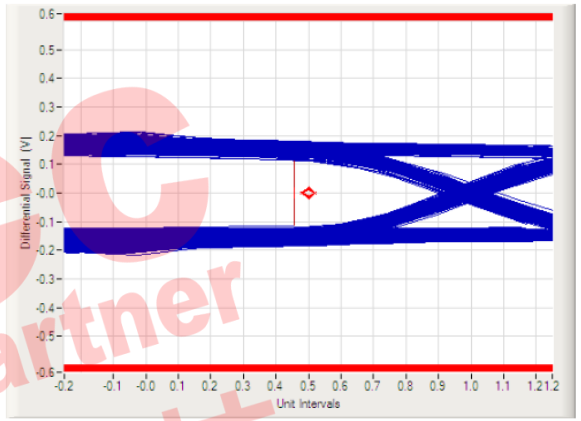
Worst Transition Signal Eye



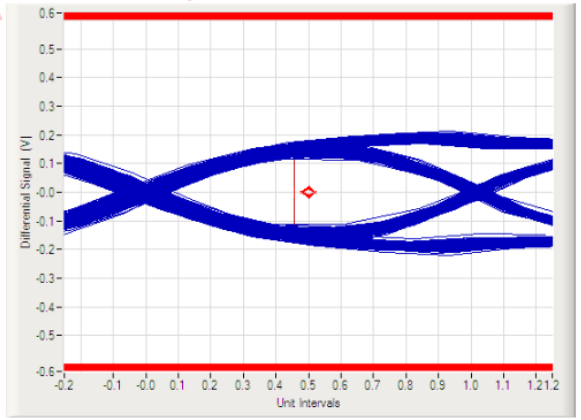
挑出最好的preset

- Overall Sigtest Result: Pass!

Worst Non Transition Signal Eye



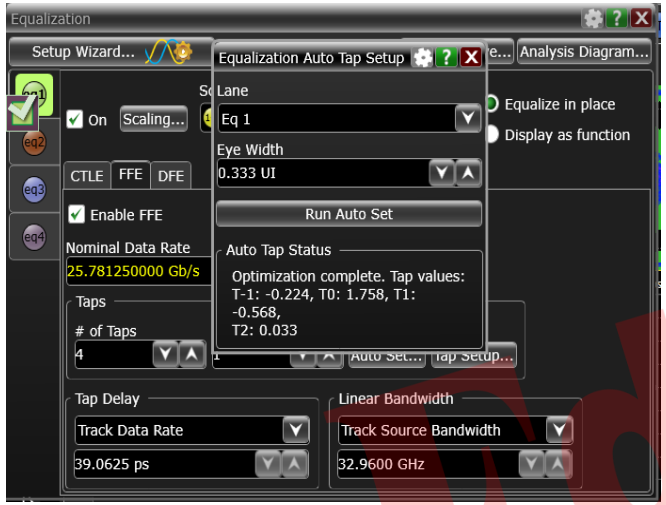
Worst Transition Signal Eye

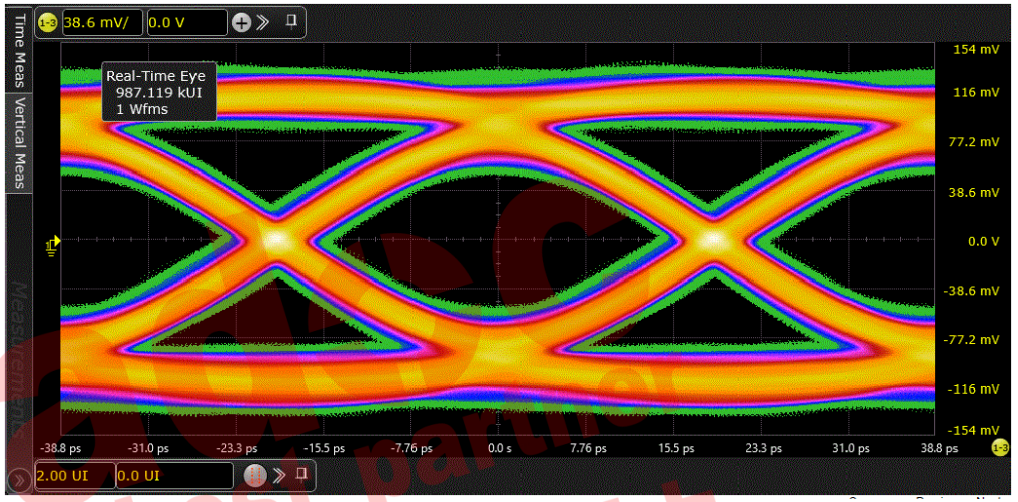


- Overall Sigtest Result: Pass!

按原厂说的参数设了，但适合我吗？

- 按照芯片推荐的值，眼图虽PASS，但裕量≈没有





Summary of Results

Test Statistics	
Failed	0
Passed	4
Total	4

Margin Thresholds	
Warning	< 5 %
Critical	< 0 %

Pass	# Failed	# Trials	Test Name (click to jump)	Actual Value	Margin	Pass Limits
✓	0	1	Signaling Rate	25.781508000 Gbps	45.0	25.778671875 Gbps <= VALUE <= 25.783828125 Gbps
✓	0	1	Eye Height A	95.00 m	0.0	VALUE >= 95.00 m
✓	0	1	Eye Width	729.69 m	58.6	VALUE >= 460.00 m
✓	0	1	Eye Height B	93.10 m	16.4	VALUE >= 80.00 m

财力稳健，谨慎行事

- 有病治病，无病防身

——第一时间发现问题，解决问题，防微杜渐

PART 02

DDR测试

- 波形质量：幅度、斜率、占空比、过冲
- 时序：建立/保持时间
- 眼图

[Table 57] Command, Address, Control Setup and Hold Values

DDR4	1600	1866	2133	2400	2666	2933	3200	Unit	Reference
tIS(base, AC100)	115	100	80	62	-	-	-	ps	VIH/L(ac)
tIH(base, DC75)	140	125	105	87	-	-	-	ps	VIH/L(dc)
tIS(base, AC 90)	-	-	-	-	55	48	40	ps	VIH/L(ac)
tIH(base, DC 65)	-	-	-	-	80	73	65	ps	VIH/L(dc)
tIS/tIH @ VREF	215	200	180	162	145	138	130	ps	

NOTE :
1) Base ac/dc referenced for 1V/ns slew rate and 2 V/ns clock slew rate.
2) Values listed are referenced only; applicable limits are defined elsewhere.

[Table 58] Command, Address, Control Input Voltage Values

DDR4	1600	1866	2133	2400	2666	2933	3200	Unit	Reference
VIH.CA(AC)min	100	100	100	100	90	90	90	mV	VIH/L(ac)
VIH.CA(DC)min	75	75	75	75	65	65	65	mV	VIH/L(dc)
VIL.CA(DC)max	-75	-75	-75	-75	-65	-65	-65	mV	VIH/L(dc)
VIL.CA(AC)max	-100	-100	-100	-100	-90	-90	-90	mV	VIH/L(ac)

NOTE :
1) Command, Address, Control input levels relative to VREFCA.
2) Values listed are referenced only; applicable limits are defined elsewhere.

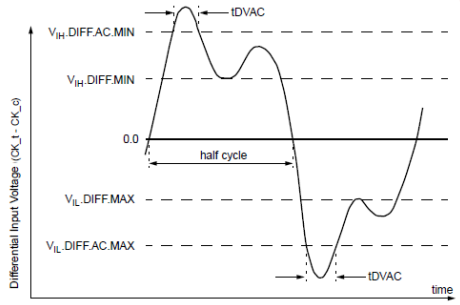


Figure 2. Definition of differential ac-swing and "time above ac-level" t_{DVAC}

Symbol	Parameter	DDR4 -1600/1866/2133		DDR4 -2400		DDR4-2666		DDR4-2933		DDR4-3200		uni t	NOT E
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
V_{IHdiff}	differential input high	+0.150	NOTE 3	+0.135	NOTE 3	+0.135	NOTE 3	+0.125	NOTE 3	TBD	NOTE 3	V	1
V_{ILdiff}	differential input low	NOTE 3	-0.150	NOTE 3	-0.135	NOTE 3	-0.135	NOTE 3	-0.125	NOTE 3	TBD	V	1
V_{IHdiff}(AC)	differential input high ac	2 x (V_{IH}(AC) - V_{REF})	NOTE 3	2 x (V_{IH}(AC) - V_{REF})	NOTE 3	2 x (V_{IH}(AC) - V_{REF})	NOTE 3	2 x (V_{IH}(AC) - V_{REF})	NOTE 3	2 x (V_{IH}(AC) - V_{REF})	NOTE 3	V	2
V_{ILdiff}(AC)	differential input low ac	NOTE 3	2 x (V_{IL}(AC) - V_{REF})	NOTE 3	2 x (V_{IL}(AC) - V_{REF})	NOTE 3	2 x (V_{IL}(AC) - V_{REF})	NOTE 3	2 x (V_{IL}(AC) - V_{REF})	NOTE 3	2 x (V_{IL}(AC) - V_{REF})	V	2

8.7 AC and DC Logic Input Levels for DQS Signals

8.7.1 Differential signal definition

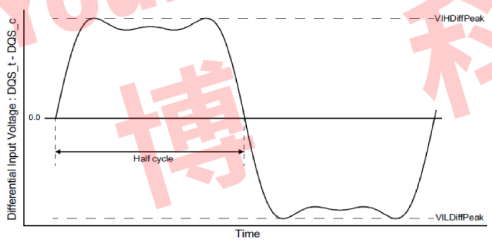


Figure 11. Definition of differential DQS Signal AC-swing Level

8.7.2 Differential swing requirements for DQS (DQS_t - DQS_c)

[Table 17] Differential AC and DC Input Levels for DQS

Symbol	Parameter	DDR4-1600/1866/2133		DDR4-2400		DDR4-2666		DDR4-2933		DDR4-3200		Unit	Note
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
VIHDiffPeak	VIH.DIFF.Peak Voltage	186	Note2	160	Note2	150	Note2	145	Note2	140	Note2	mV	1
VILDiffPeak	VIL.DIFF.Peak Voltage	Note2	-186	Note2	-160	Note2	-150	-145	Note2	-140	Note2	mV	1

NOTE :
1) Used to define a differential signal slew-rate.
2) These values are not defined; however, the differential signals DQS_t - DQS_c, need to be within the respective limits Overshoot, Undershoot Specification for single-ended signals.

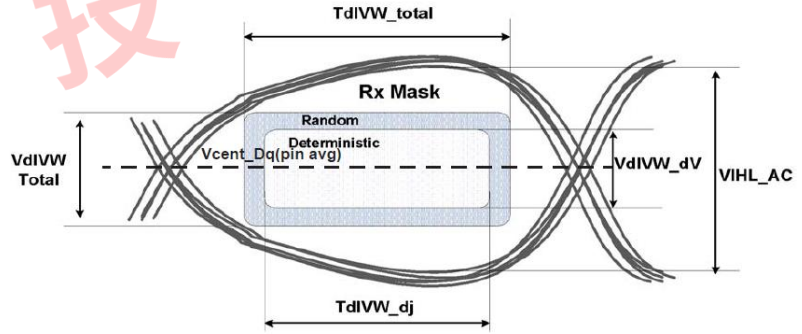


Figure 186 — DQ Receiver(Rx) compliance mask

Symbol	Parameter	1600/1866/2133		2400		2666		2933		3200		Unit	NOTE
		min	max	min	max	min	max	min	max	min	max		
VdIVW	Rx Mask voltage - pk-pk	-	136	-	130	-	120	-	115	-	110	mV	1,2,10
TdIVW	Rx timing window	-	0.2	-	0.2	-	0.22	-	0.23	-	0.23	UI*	1,2,10

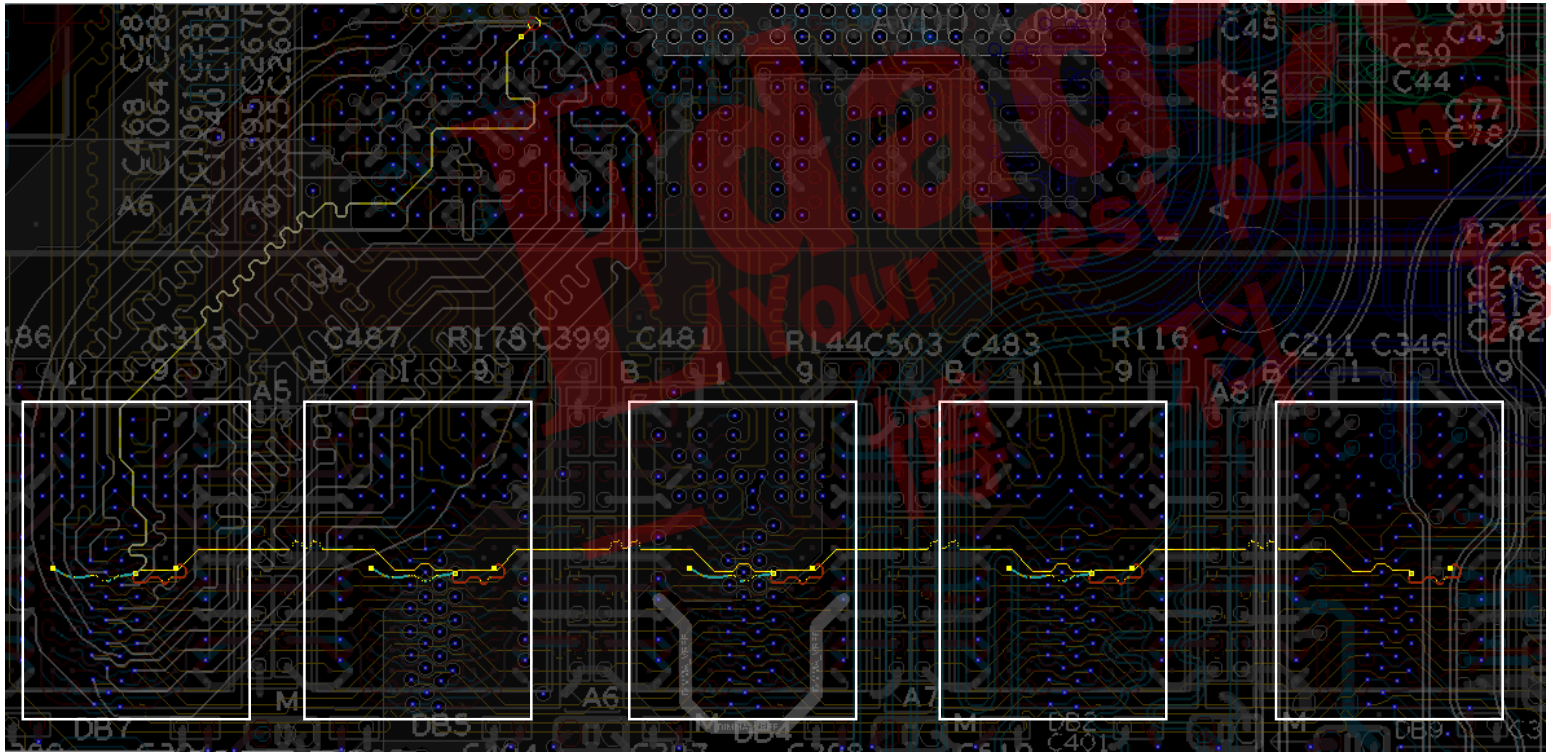
测试难点

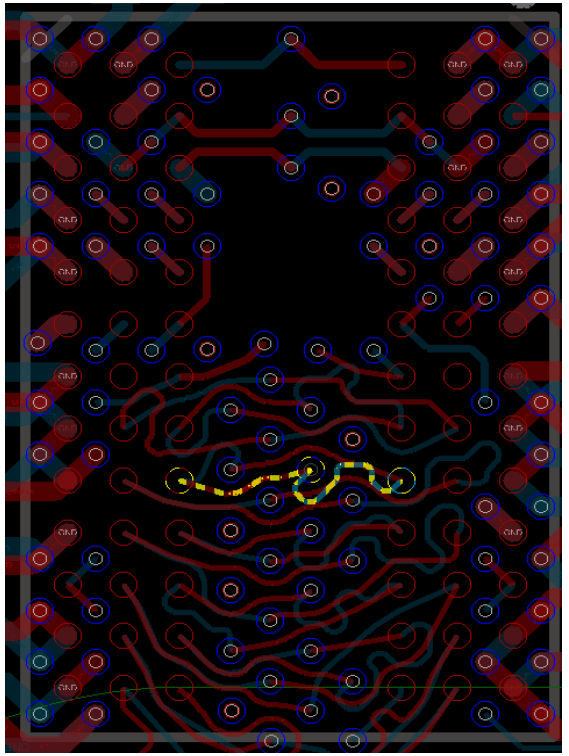
- 拓扑结构：1拖多，测几颗颗粒？每个颗粒测几对网络？

——人工测、人工判决、人工整理数据成报告，工作量大、时间长

- 颗粒正反贴，没有任何测试点

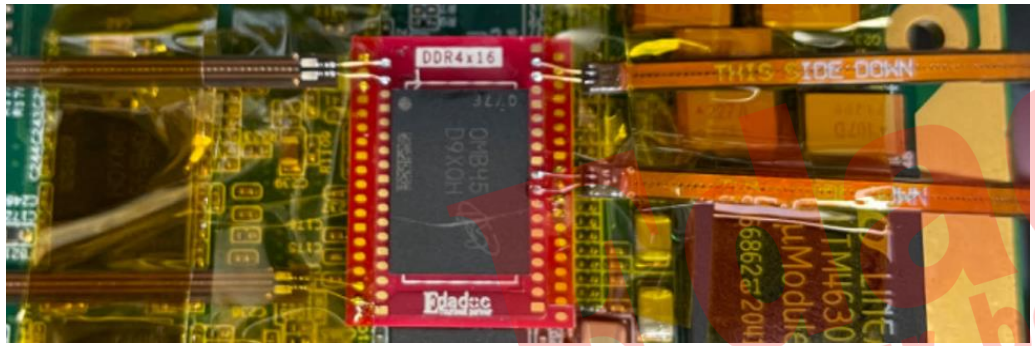
——没法接到示波器，测不了

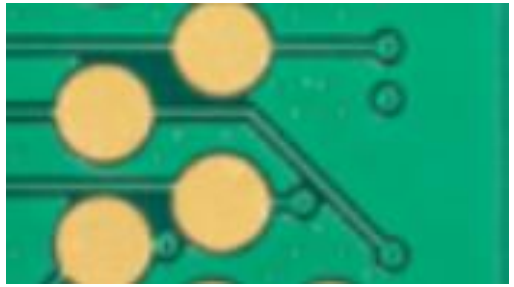


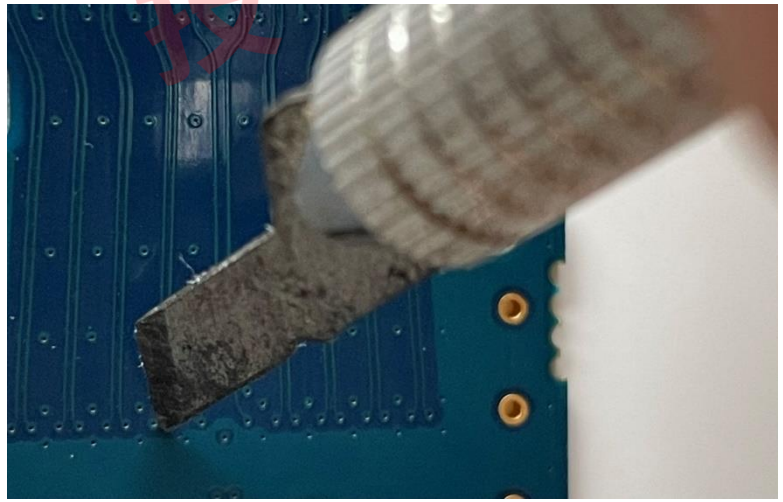


测试点

- 留了测试点
- 没留测试点，但有些信号可以刮孔测试
- 无测试点，无孔可刮，怎么办？



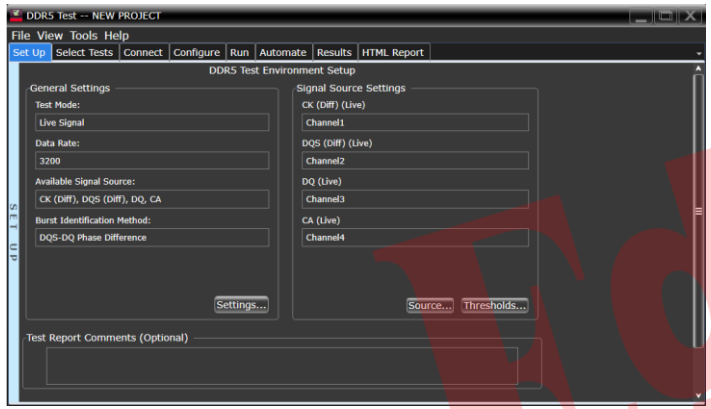


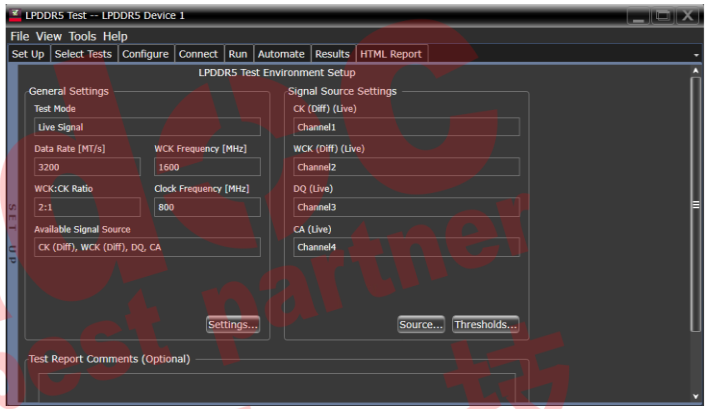


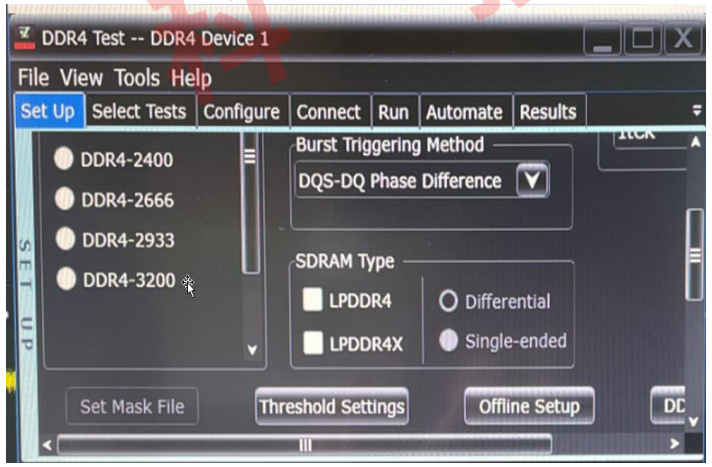
我们怎么测DDR

- 一致性测试软件：DDR4/DDR5/LPDDR5
- 自动生成的测试报告

DDR4 5 test report







PART 03

串行总线测试

- 无源SPEC——前期评估、仿真

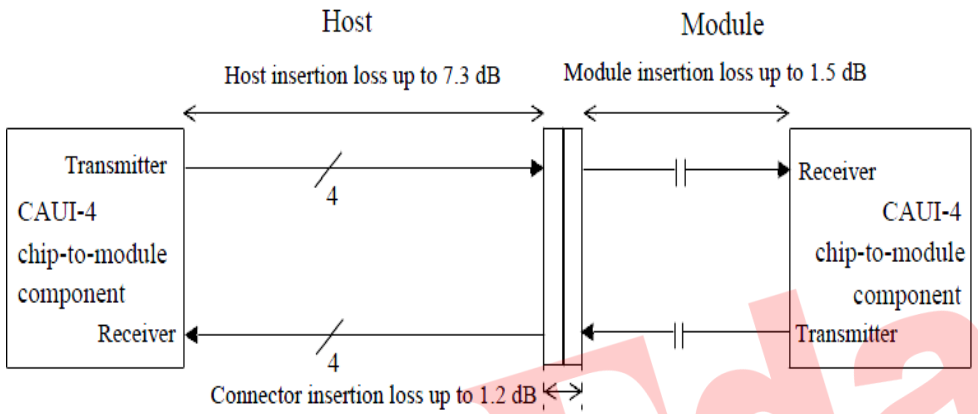
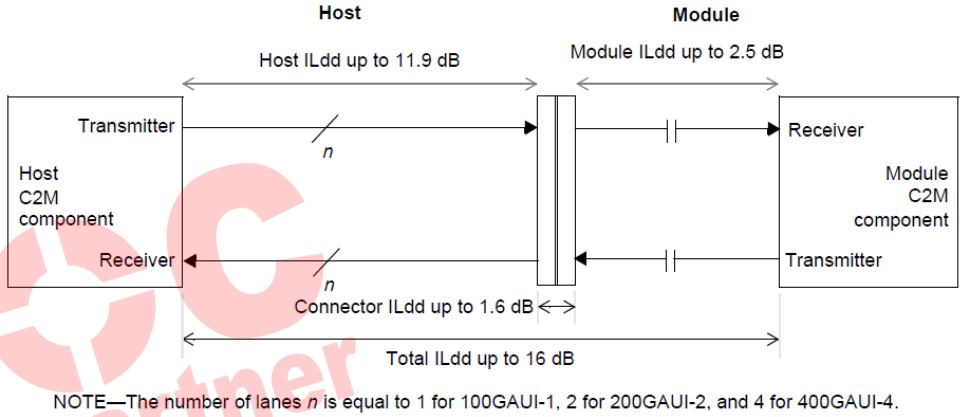


Figure 83E–2—Chip-to-module insertion loss budget at 12.89 GHz



NOTE—The number of lanes *n* is equal to 1 for 100GAUI-1, 2 for 200GAUI-2, and 4 for 400GAUI-4.

Figure 120G–2—100GAUI-1, 200GAUI-2, and 400GAUI-4 C2M differential-mode to differential-mode insertion loss budget at 26.56 GHz

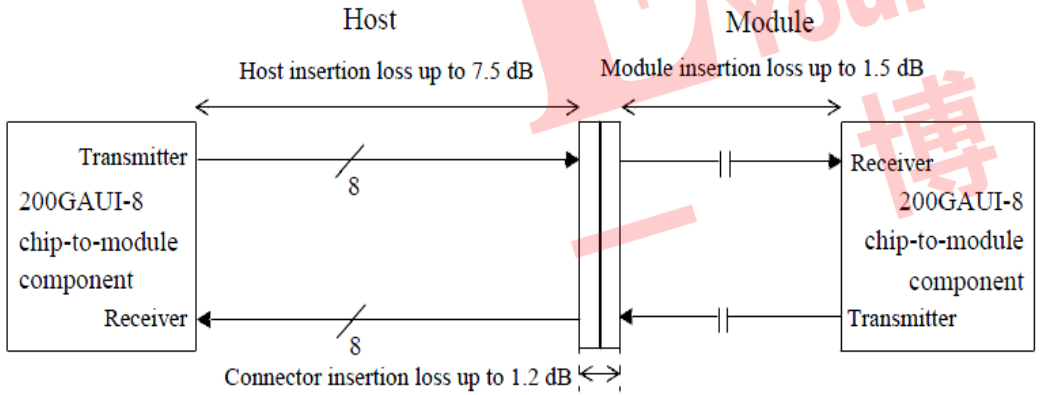


Figure 120C–2—200GAUI-8 chip-to-module insertion loss budget at 13.28 GHz

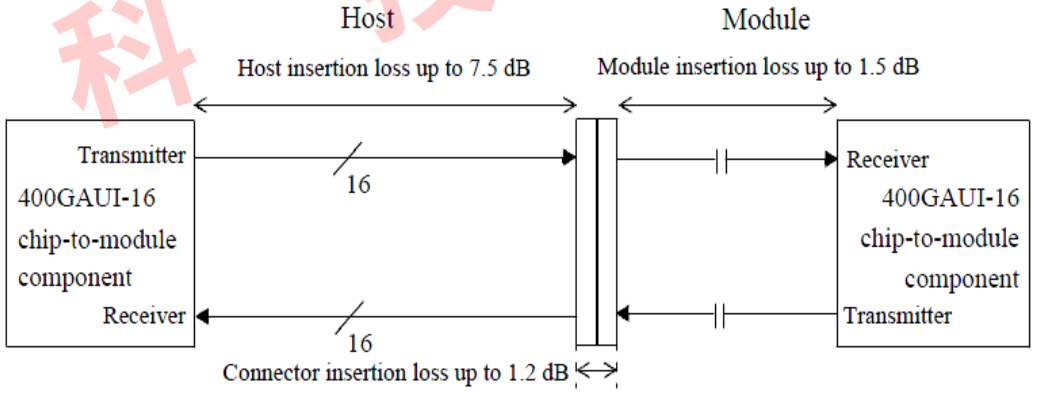
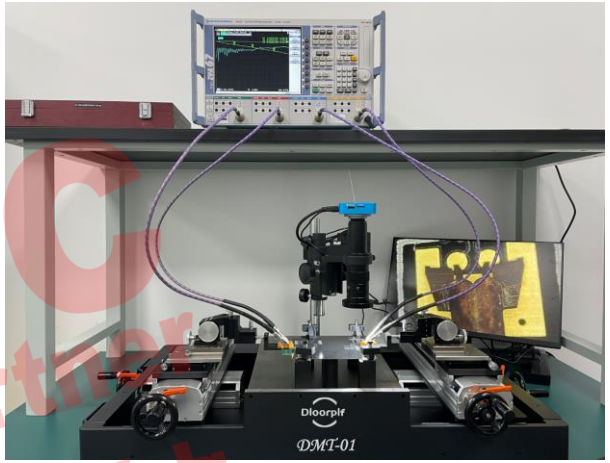
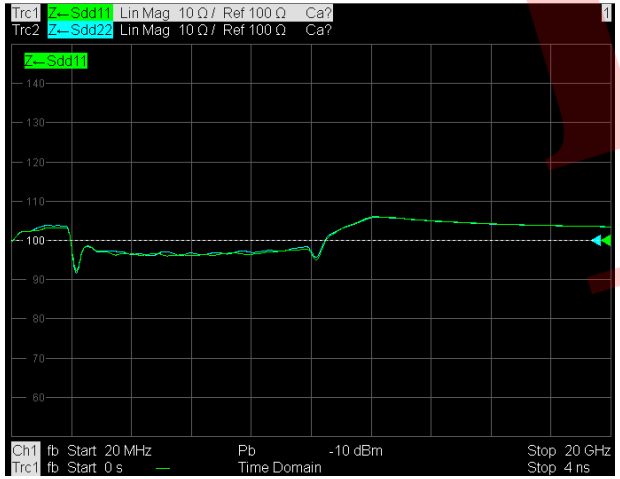


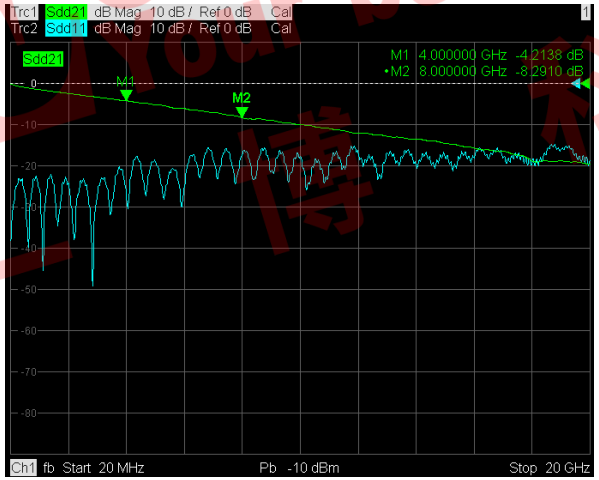
Figure 120C–3—400GAUI-16 chip-to-module insertion loss budget at 13.28 GHz

无源测试

- 光板
- PCBA

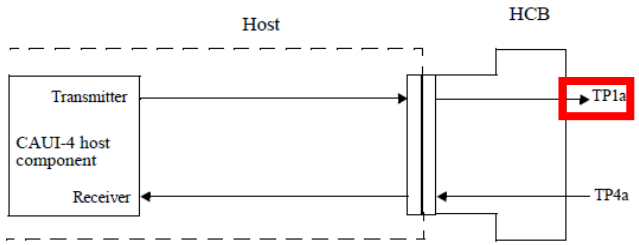


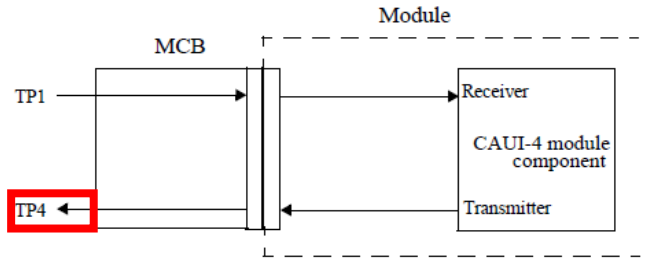




有源协议

- 有源SPEC





28G-VSR

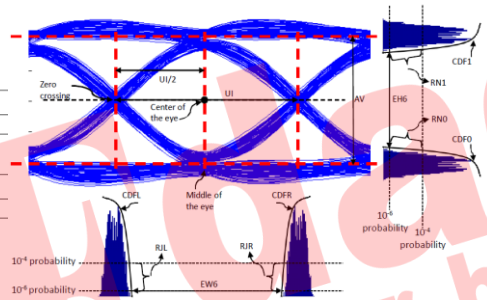
Table 13-1. Host-to-Module Electrical Specifications at TP1a (host output)

Parameter	Min.	Max.	Units	Conditions
Differential Voltage pk-pk	-	900	mV	

Table 13-4. Module-to-Host Electrical Specifications at TP4 (module output)

Parameter	Min.	Max.	Units	Conditions
Differential Voltage, pk-pk	-	900	mV	

Figure 13-9. TP1a and TP4 jitter and Eye Height parameters



56G-VSR-PAM4

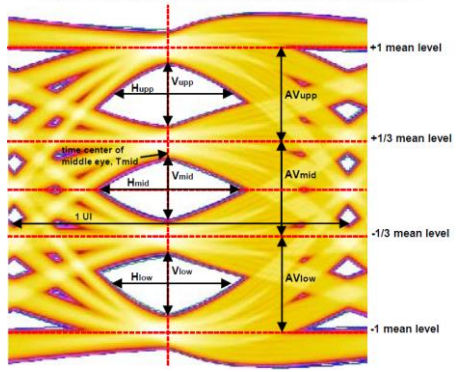
Table 16-1. Host-to-Module Electrical Specifications at TP1a (host output)

Parameter	Min.	Max.	Units	Conditions
Differential Voltage pk-pk	-	880	mV	See Note 1

Table 16-4. Module-to-Host Electrical Specifications at TP4 (module output)

Parameter	Min.	Max.	Units	Conditions
Differential Voltage, pk-pk	-	900	mV	

Figure 16-7. TP1a and TP4 Eye Width, Eye Height and Eye Amplitude



112G-VSR-PAM4

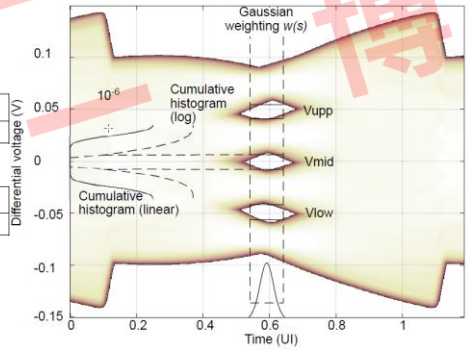
Table 25-1. Host-to-Module Electrical Specifications at TP1a (host output)

Parameter	Min.	Max.	Unit	Conditions
Differential Voltage pk-pk	-	860	mV	See 25.3.4

Table 25-4. Module-to-Host Electrical Specifications at TP4 (module output)

Parameter	Min.	Max.	Unit	Conditions
Differential Voltage, pk-pk	-	860	mV	See 25.3.4

Figure 25-5. TP1a and TP4 Eye Height parameters



10G SFP+

Eye Mask	X1	Mask hit ratio of 5×10^{-5}, See D.2 and Figure 19	0.12	UI
Eye Mask	X2		0.33	UI
Eye Mask	Y1		95	mV
Eye Mask	Y2		350	mV

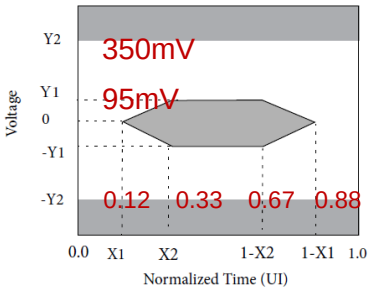
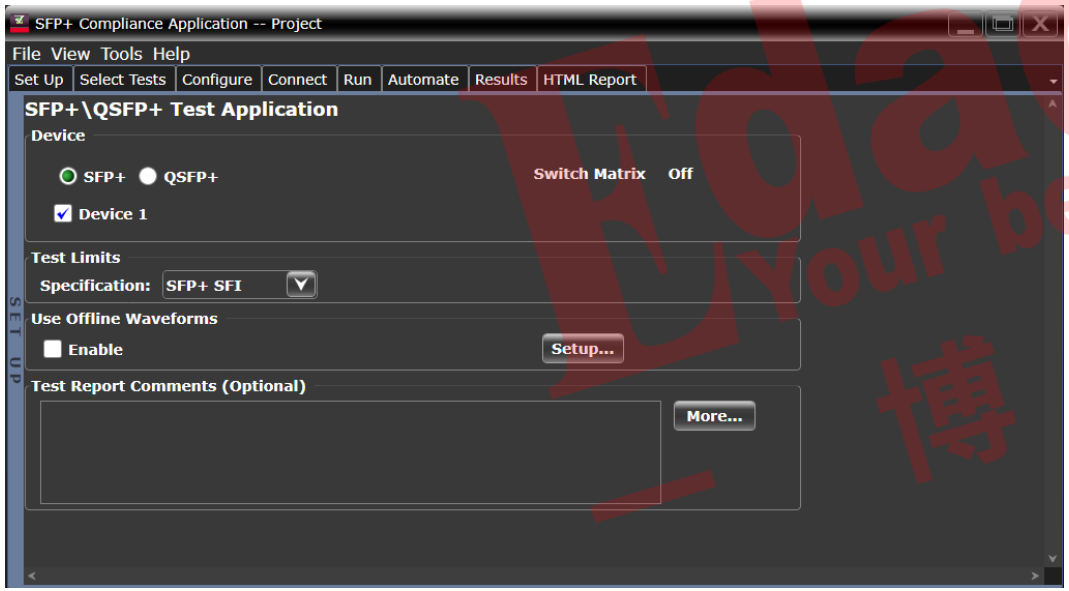
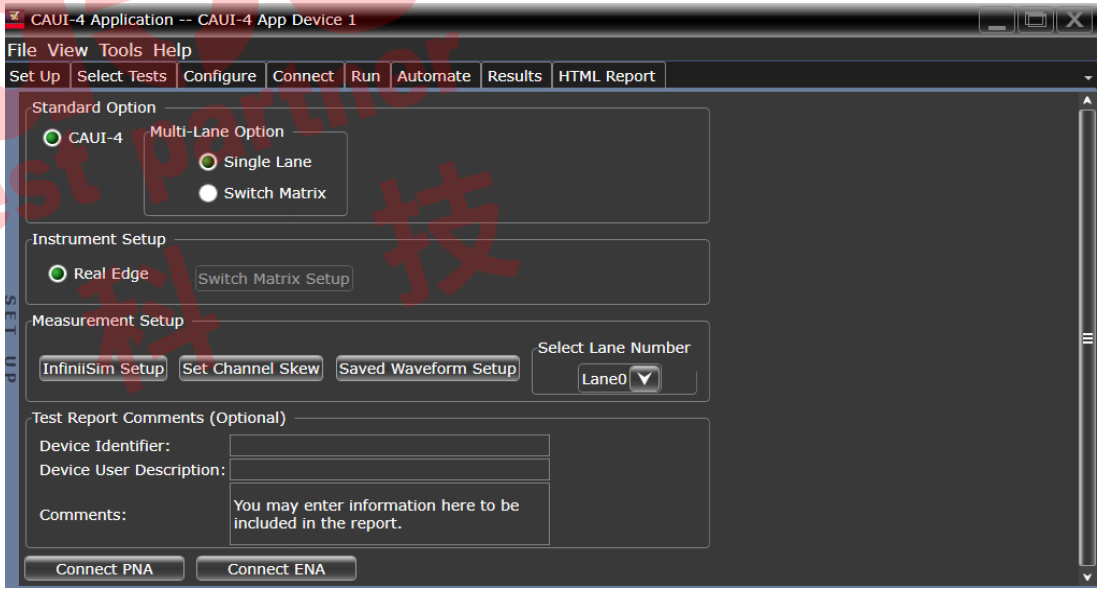


Figure 19 Transmitter Differential Output Compliance Mask at B and B″

有源测试——软件

- 10G
- 25G
- 56G
- 112G

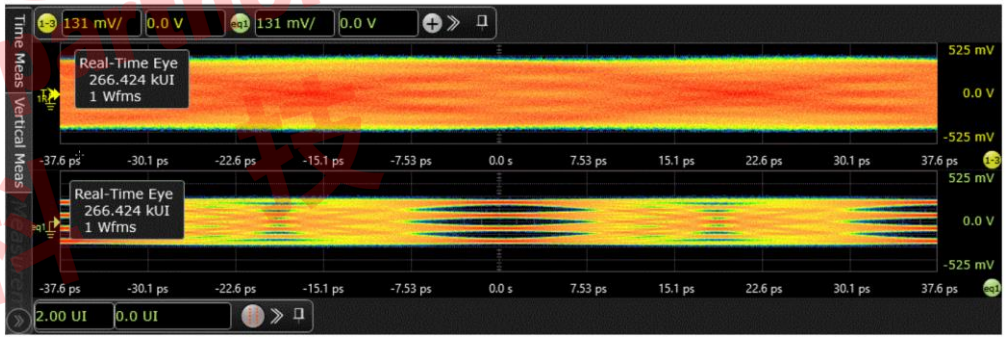




有源测试——夹具

- 目前用的比较多的两种接口
- 56G PAM4测试

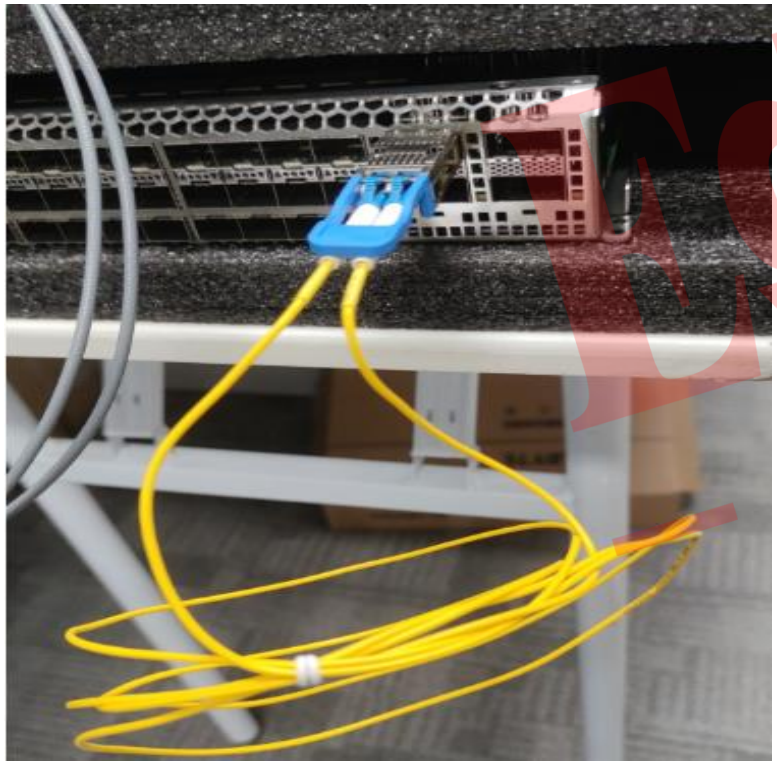
56G PAM4 test report

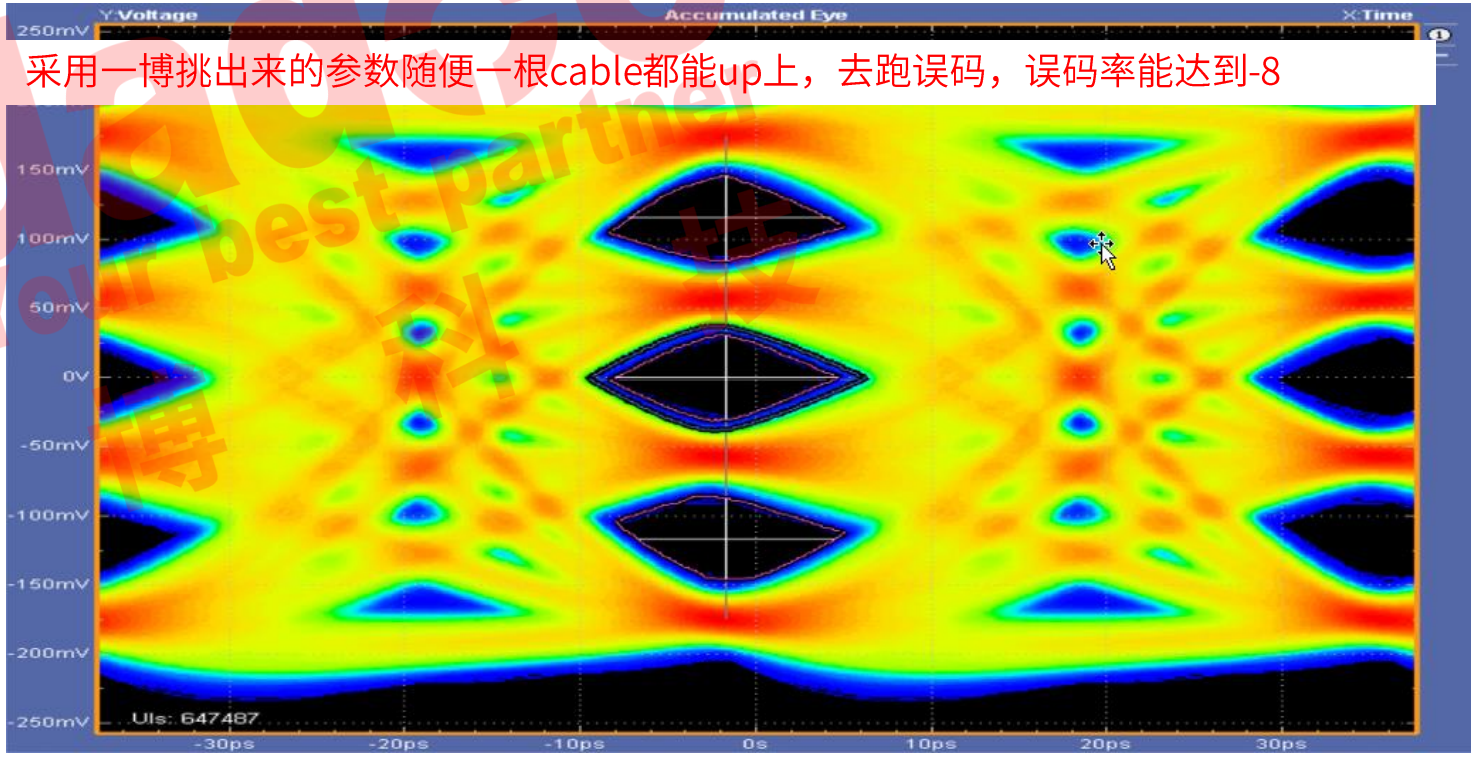


有源测试案例

- 光口信号长度不同、出线层不同，无法用统一的参数
- 环回有误码
- 56G PAM4光口电测试：光环回，用厂家给的参数所有口用任何光纤都link不上，但用在厂家的 Demo板上测试结果很好

2021_光口信号一误码，怎么调都不





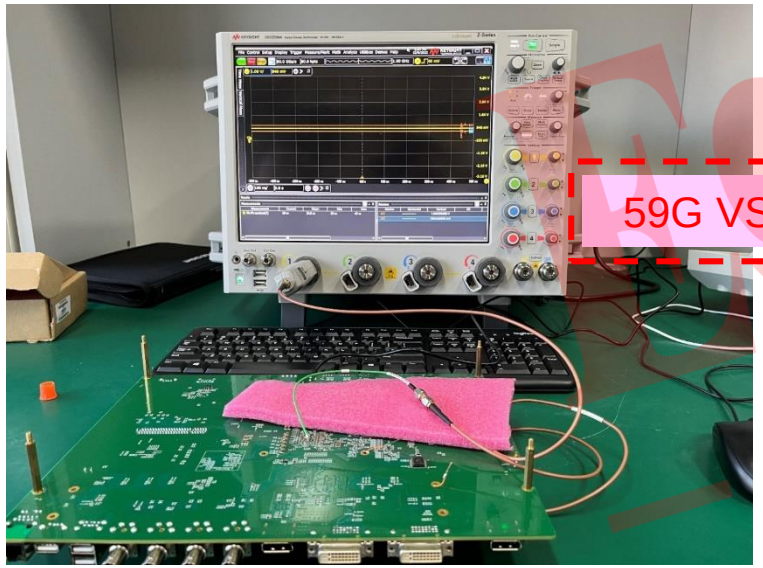
采用一博挑出来的参数随便一根cable都能up上，去跑误码，误码率能达到-8

PART 04

电源测试

电源测试三要素

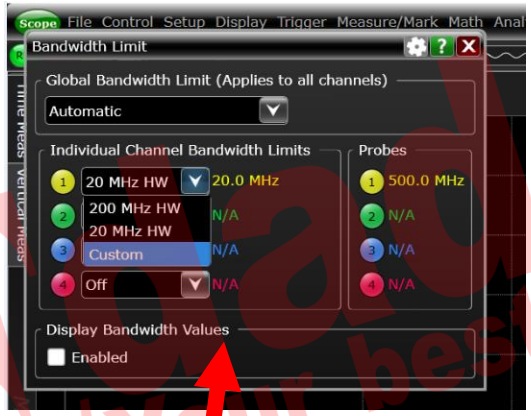
- 示波器：带宽
- 探棒
- 测试手法/设置：人

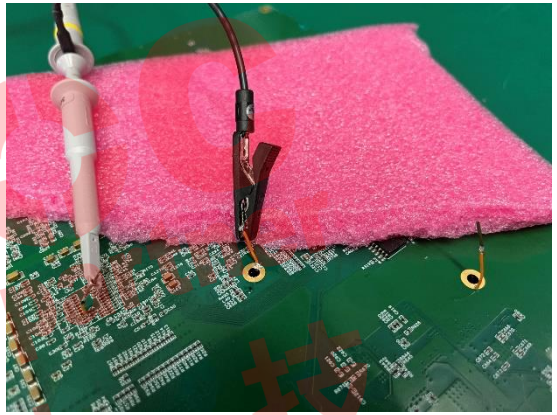


59G VS. 2.5G

电源测试三要素——探棒

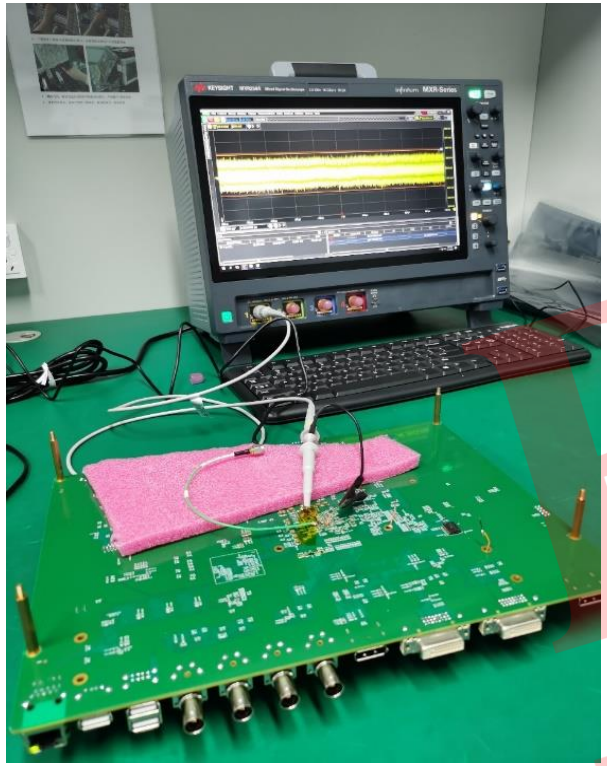
- 示波器
- 探棒
- 测试手法/设置：人

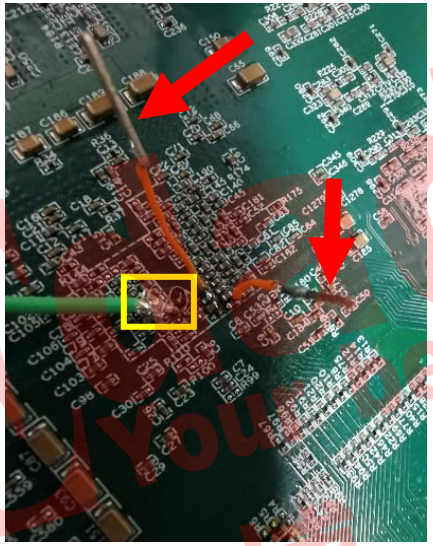


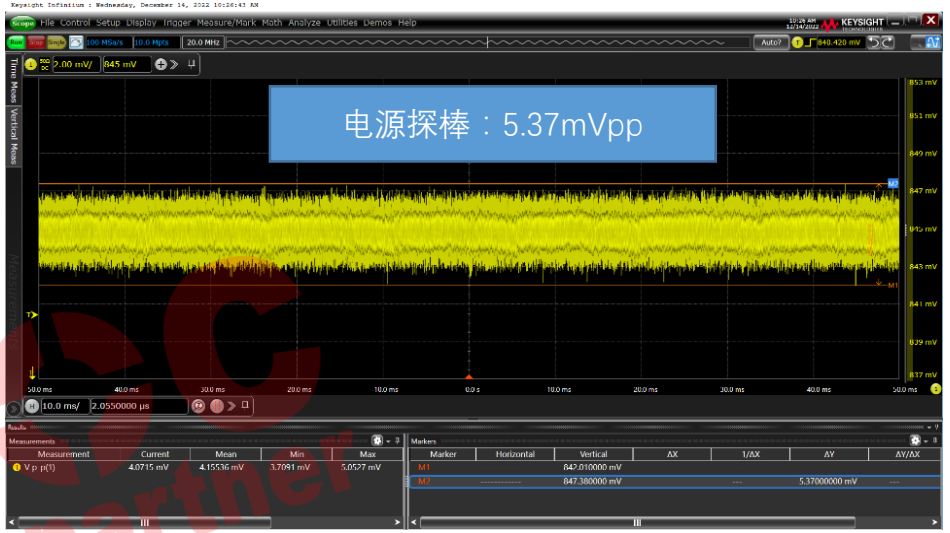


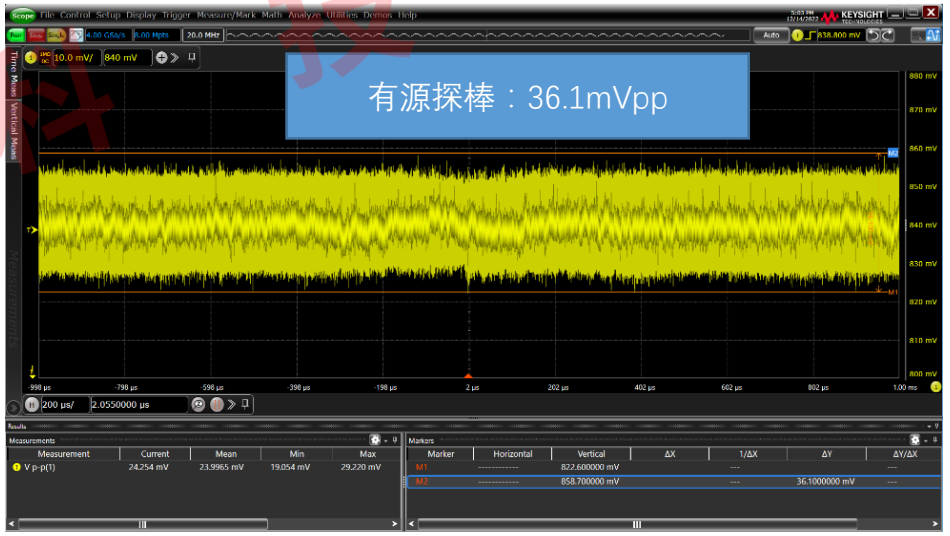
探棒PK

- 10:1无源探棒 vs.1:1电源探棒



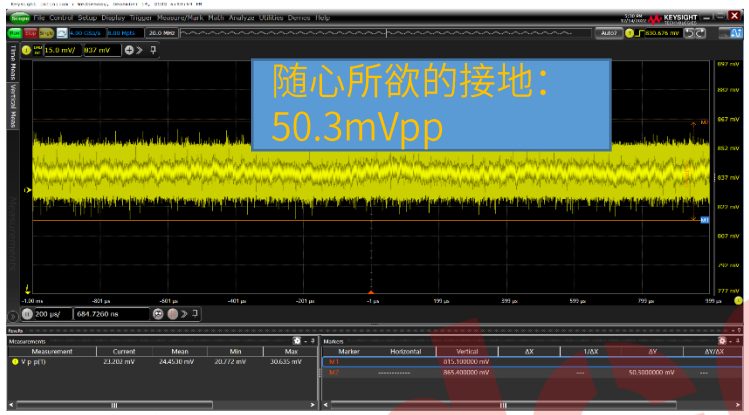


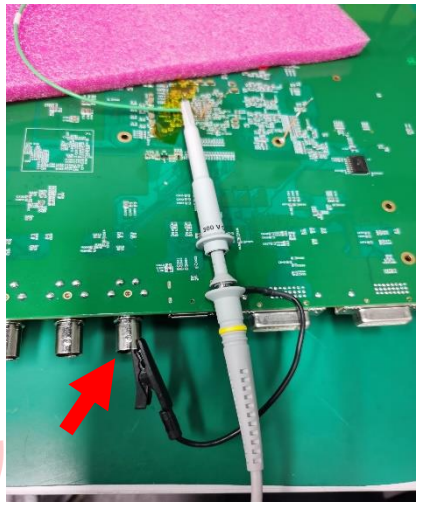


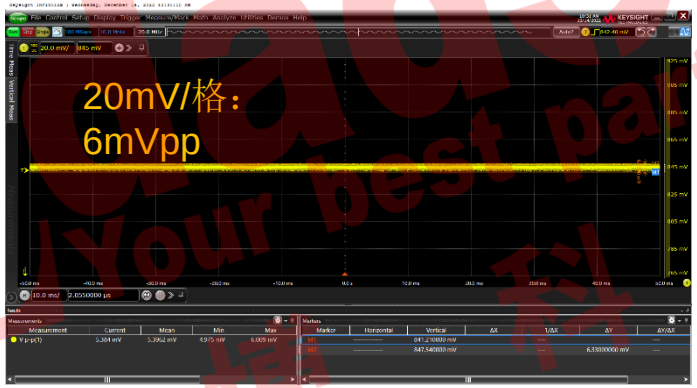


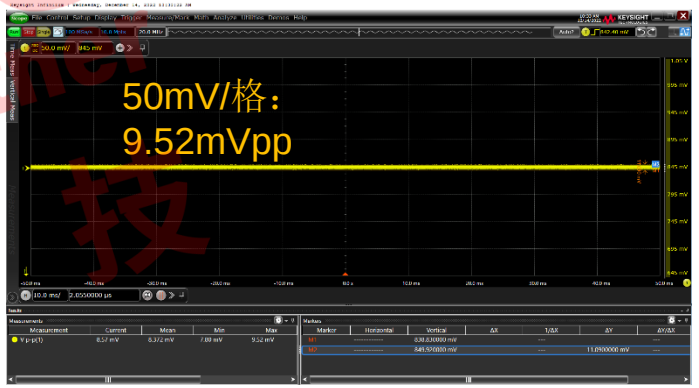
电源测试三要素——测试手法

- 示波器
- 探棒
- 测试手法/设置：人
  - ➢刻度
  - ➢接地









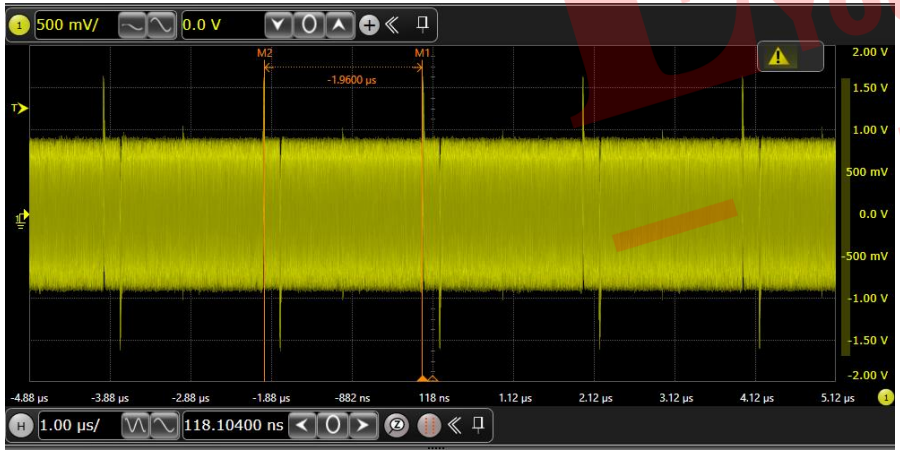
PART 05

总结

Edadoc Your best partner 一博科技

天时地利人和

- 天时：你越来越重视SI测试
- 地利：我有得心应手的装备
- 人和：我们会测试、能分析



- 仪器
  - 67G矢网
  - 64G误码仪
  - 59G示波器
  - 33G示波器
  - 6G示波器
  - 2.5G示波器
  - 500M示波器
- 两地实验室
  - 深圳
  - 珠海

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Thank you!

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