Innovative Test Solution Design and Production Practices for Automotive

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TestConX China

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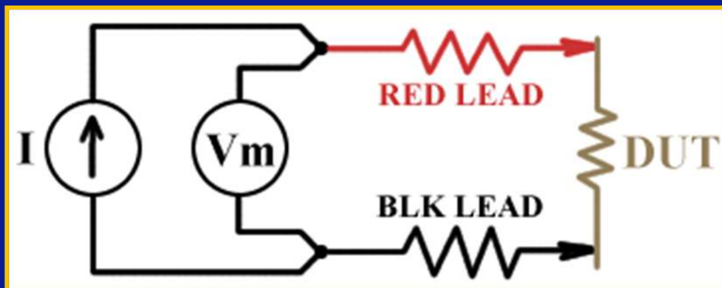
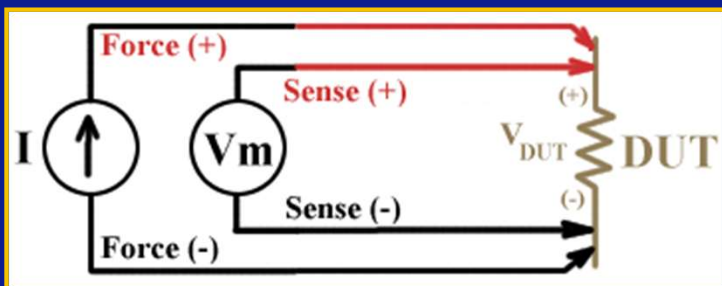
Kelvin

Kelvin Measurement

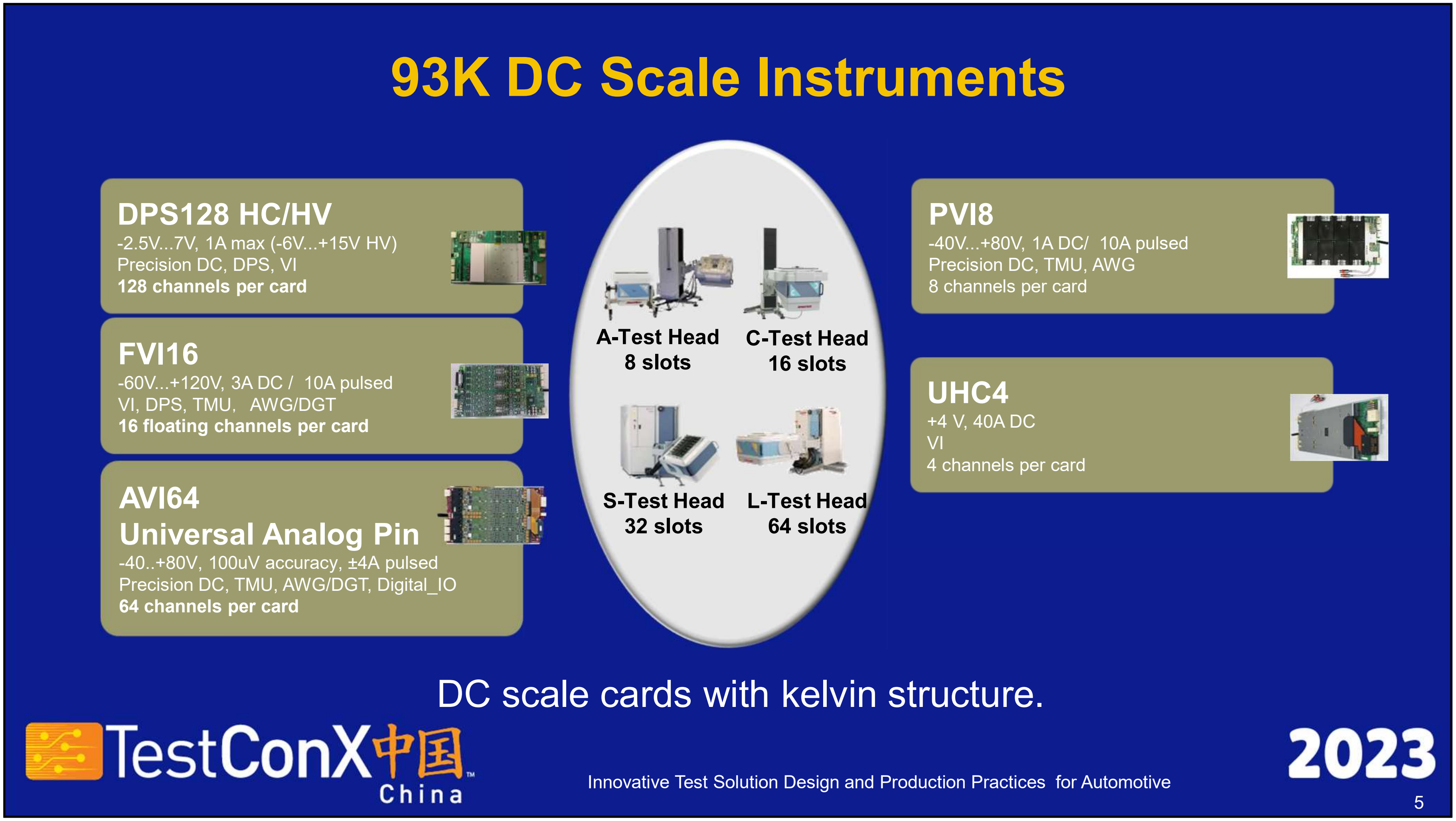


A 2-wire measurement really measures the DUT resistance plus the meter lead resistance



A 4-wire measurement gives you control of where the voltmeter connects
-Called Kelvin Measurement

All voltage drops on the line and connection resistance must be compensated by the regulation loop. Therefore, the sense lines are connected at DUT pins directly.


93K DC Scale Instruments
DPS128 HC/HV
-2.5V...7V, 1A max (-6V...+15V HV)
Precision DC, DPS, VI
128 channels per card
FVI16
-60V...+120V, 3A DC / 10A pulsed
VI, DPS, TMU, AWG/DGT
16 floating channels per card
AVI64
Universal Analog Pin
-40..+80V, 100uV accuracy, ±4A pulsed
Precision DC, TMU, AWG/DGT, Digital_IO
64 channels per card
A-Test Head
8 slots
C-Test Head
16 slots
S-Test Head
32 slots
L-Test Head
64 slots
PVI8
-40V...+80V, 1A DC/ 10A pulsed
Precision DC, TMU, AWG
8 channels per card
UHC4
+4 V, 40A DC
VI
4 channels per card
DC scale cards with kelvin structure.
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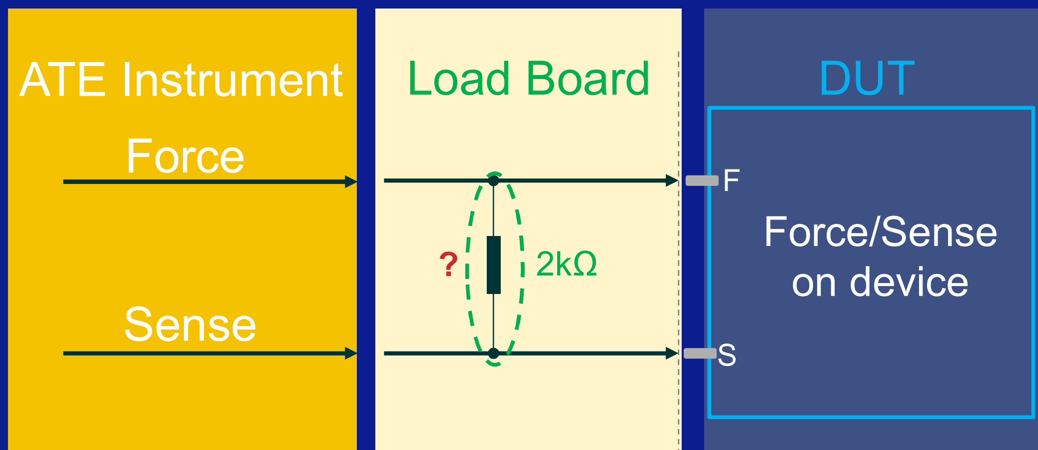
Soft Kelvin Benefits and Considerations

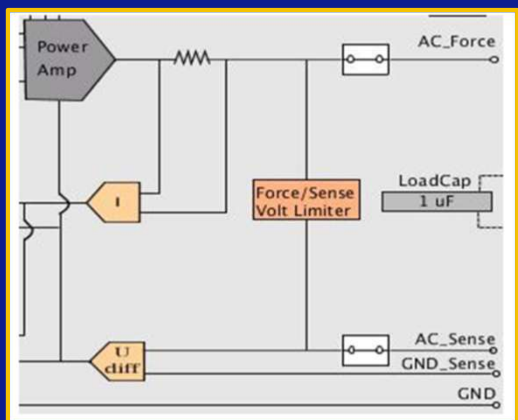


Why do we need the kohm resistor between F/S on load board?
When the force and sense present on device, we may damage device in case of abnormal F/S connection. The resistor was used for “soft kelvin”.

Do we need the resistor when we use 93K DC instruments in production?

Soft Kelvin Benefits and Considerations

DPS128

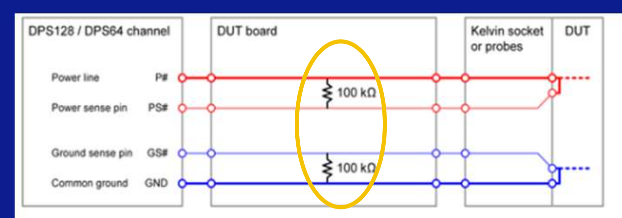


From cookbook:

- ✓ DPS128 does not implement a local sensing safety circuit, but implements a so-called “force / sense voltage limiter” block. This block guarantees a not to be violated maximum distance between force and force-sense and also acts as a safety feature to prevent unpredictable DPS states.
- ✓ For standard force operation the “force / sense voltage limiter” works in a way that it will tie up the sense to the force, as soon as the there is a voltage difference greater than 1 V.

Recommendations,

Add 100 kOhm force to sense bypass resistors on the DUT board to protect against open loop.



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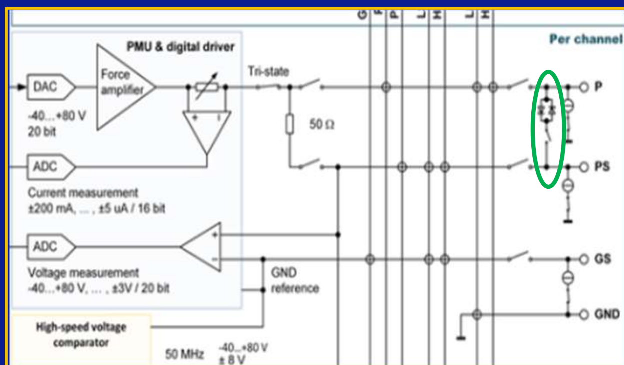
Soft Kelvin Benefits and Considerations

AVI64



- ✓ Each AVI64 channel features a switchable clamp circuitry between the P# pogo pin and the PS# pogo pin. This clamp circuitry limits the voltage difference between the two pins for abnormal operating conditions.
- ✓ An abnormal operating condition is for example an open sense connection on the DUT board if the Kelvin connection scheme is used. The closed FS clamp limits the voltage increase on the force line to about 2 V in this case.

Recommendations,

We recommend connecting the two pins directly at the DUT so that the digital closed loop control is able to compensate the voltage drop on the P# line.

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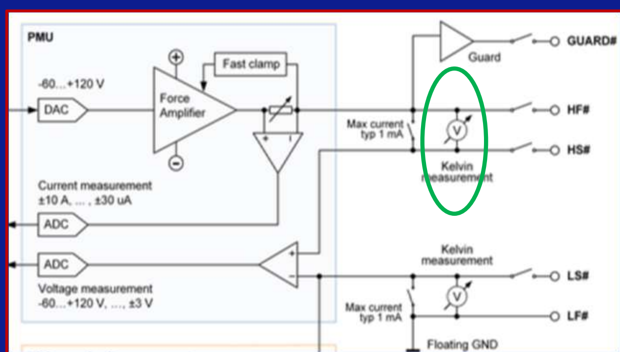
Soft Kelvin Benefits and Considerations

FVI16

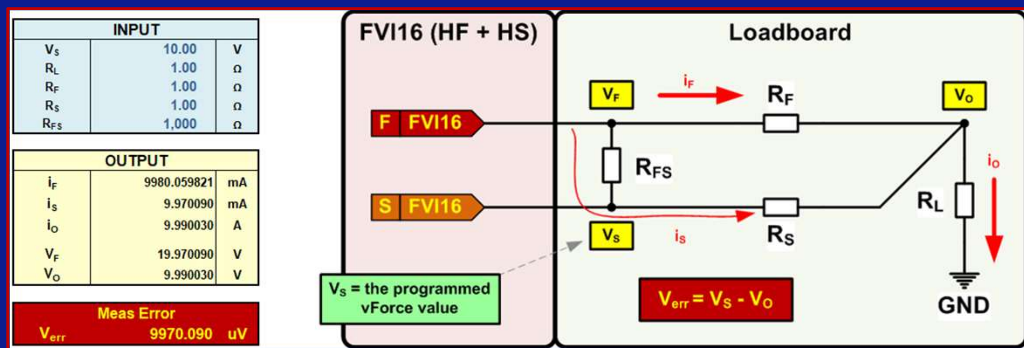


- ✓ Automatic disconnect for weak force to sense connection. To protect probe card needles and test sockets, the VI source output gets automatically disconnected in case a weak force to sense connection leads to a Kelvin voltage drop exceeding the programmed threshold voltage and the VI is set to the 3 A or 10 A range.
- ✓ Disadvantage:
  300mA range is excluded from automatic disconnect

Recommendations,
We recommend a F/S resistor is optional. Generally, recommend a F/S resistor of at ≥ 10kΩ for the FVI16.

Soft Kelvin Benefits and Considerations

FVI16



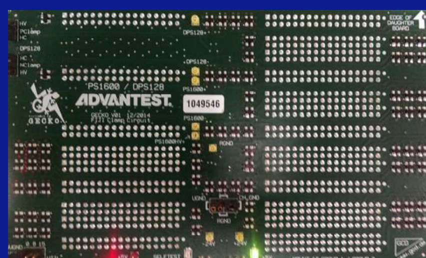
Force Sense Resistor Error Calculator

V_S	R_L	R_F	R_S	R_{FS}	V_F	V_O	V_{err}
5.0 V	5.0 Ω	1 Ω	1 Ω	1 kΩ	5.9978 V	4.9990 V	997.8 µV
5.0 V	5.0 Ω	1 Ω	**10 Ω**	1 kΩ	5.9872 V	4.9901 V	9871.7 µV
5.0 V	5.0 Ω	1 Ω	1 Ω	**10 kΩ**	5.9998 V	4.9999 V	99.9 µV
5.0 V	5.0 Ω	1 Ω	1 Ω	**100 kΩ**	5.9999 V	4.9999 V	10.0 µV
5.0 V	**1.0 Ω**	1 Ω	1 Ω	100 kΩ	9.9998 V	4.9999 V	49.9 µV

Example using the calculator

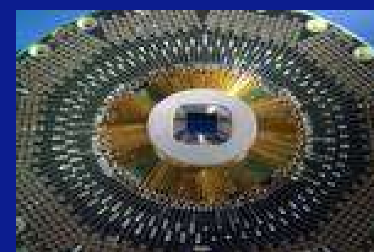
Kelvin Test

Kelvin Connection



Kelvin connection on LB

Kelvin socket



Kelvin prober card

Regulation loop control is able to compensate the voltage drop on the P# line, make sure the voltage presented to DUT

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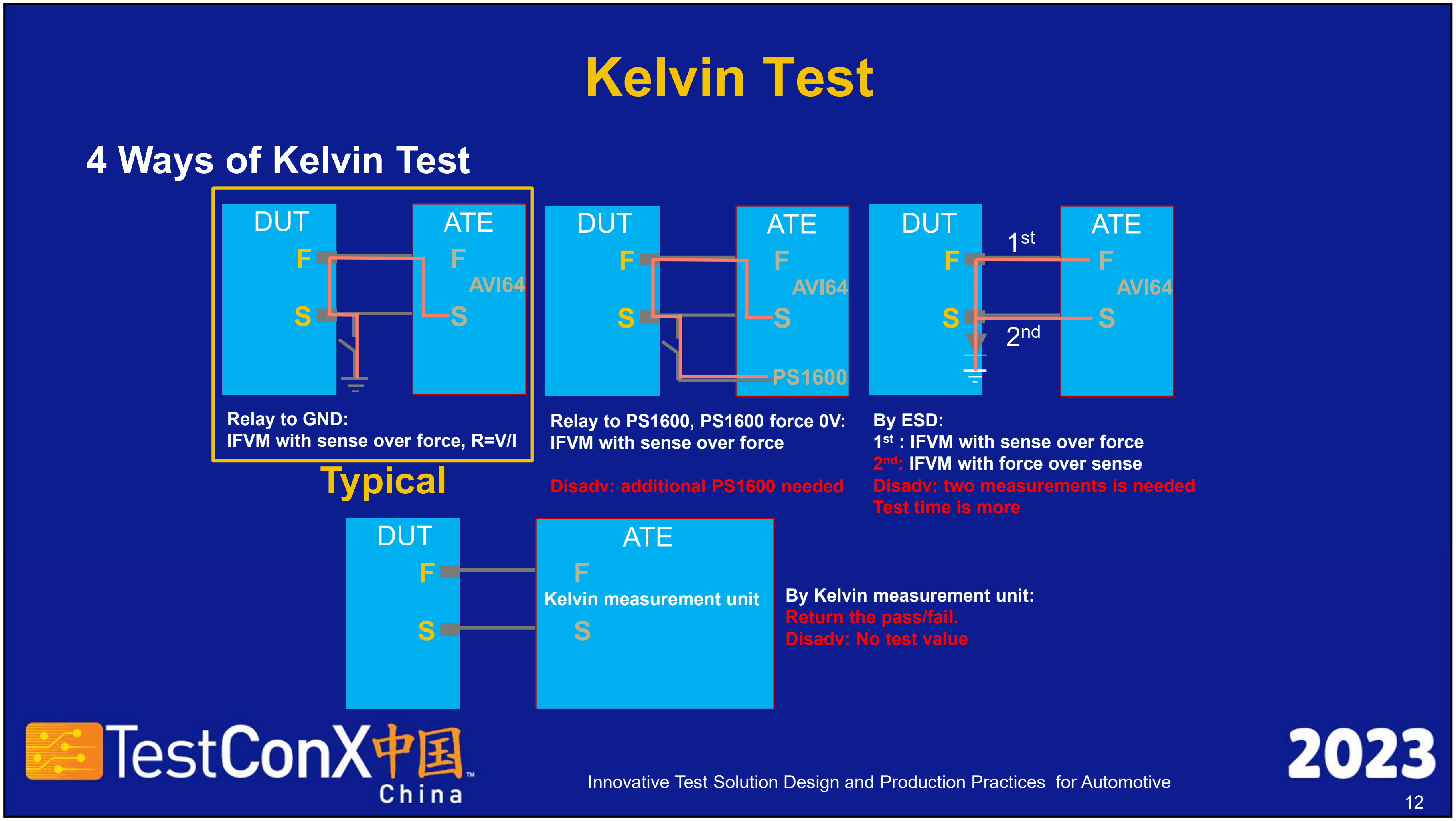

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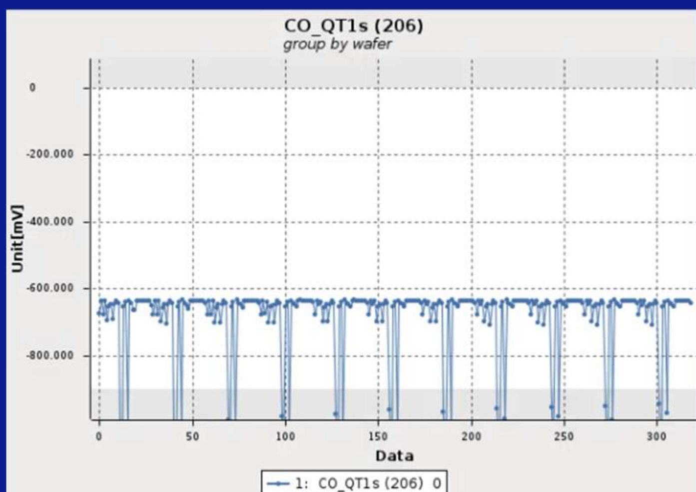
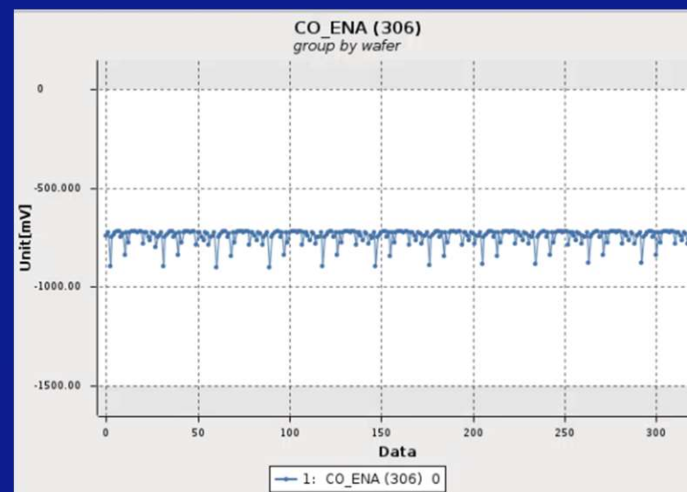
Fritting On Contact

Background

When the prober card was idle for a long time(days) and then used for production, we will encounter the contact problem. Two prober cards both have same behavior.



Contact on some pins failed



Contact on some pins pass but outliers

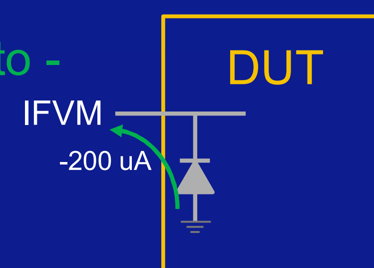
Some Trials and Significant Improvements

1. LB check passing and checked the inside of prober card, no significant findings;
2. Did needle alignment, no help;
3. Cleaned prober tips and adjusted over drive, no help;
4. Switched to another tester and did calibration, no help;
5. Debugged the test method, no help;

…

A significant trial as below improved the contact.

Increase the current to -5 mA and then decrease to -200uA, improved the stability of contact.



Fritting Theory

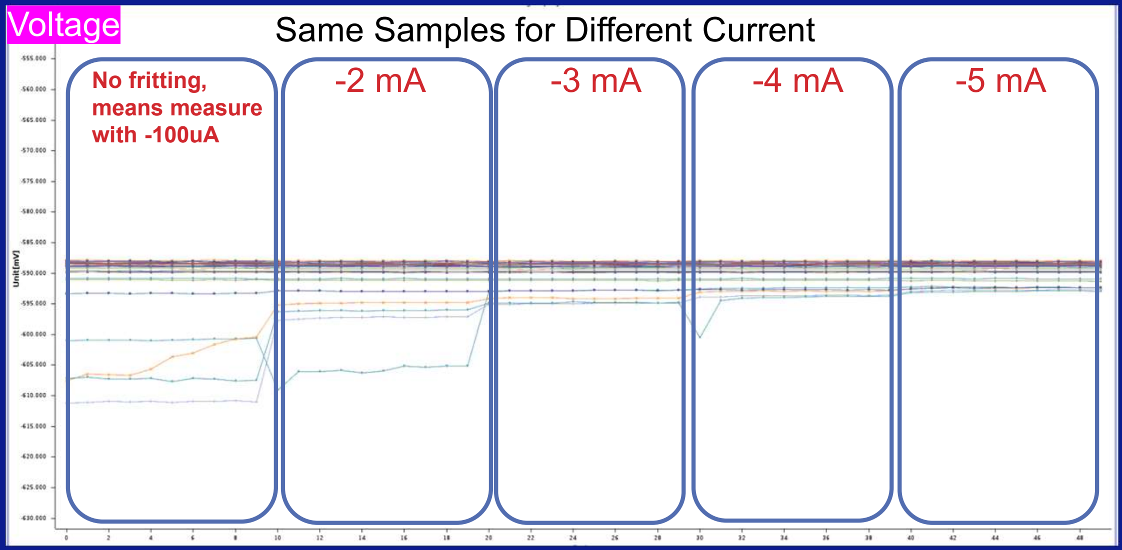
Theory of electric contact:
two conductors in mechanical contact, separated by thin insulating layer (e.g., probe needle on Al-pad separated by layer of native oxide)

Fritting Theory:
- Fritting is used for the electric contact.
- The higher current is supposed to do a kind of fritting.
- Certain pulse time with the higher current is sufficient.

Experiment about Fritting Parameter

Current experiment

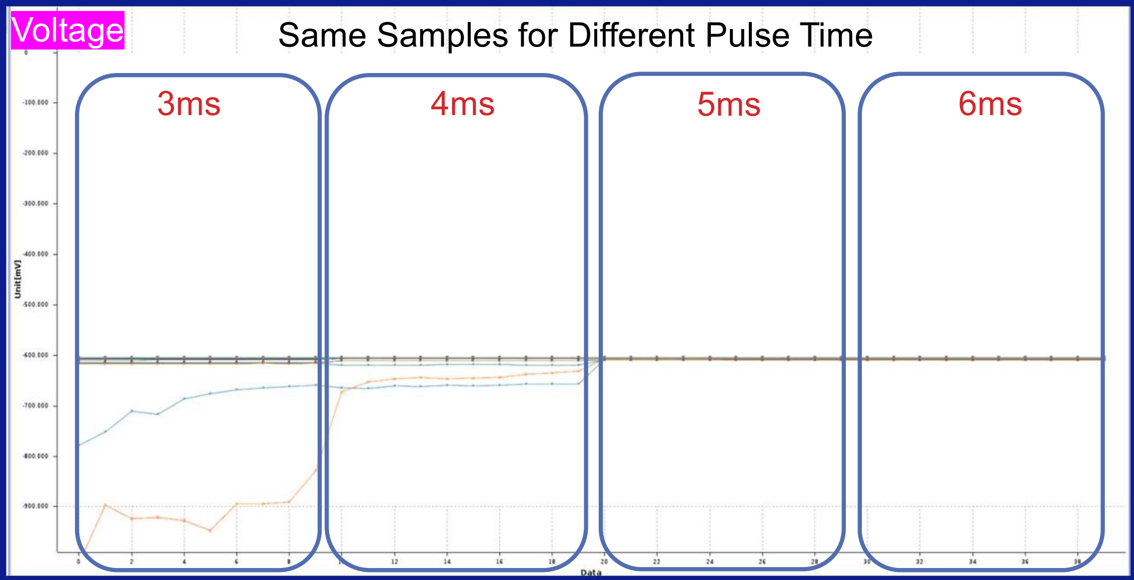
Change current for fritting, providing pulse time = 5 ms.



Experiment about Fritting Parameter

Pulse time experiment

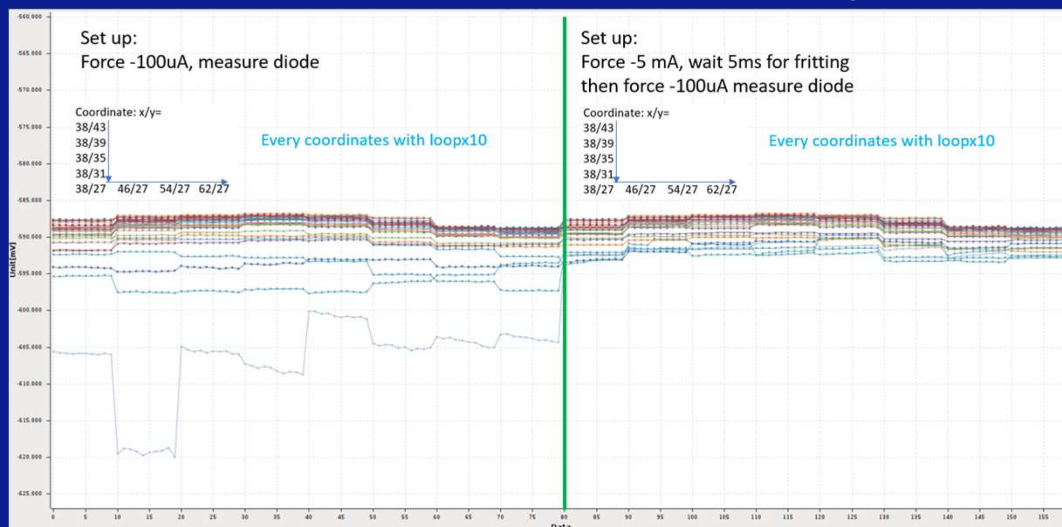
Change pulse time for fritting, providing current = -5 mA.



Experiment about Fritting Parameter

Current + Pulse time

The combination of current and current pulse time

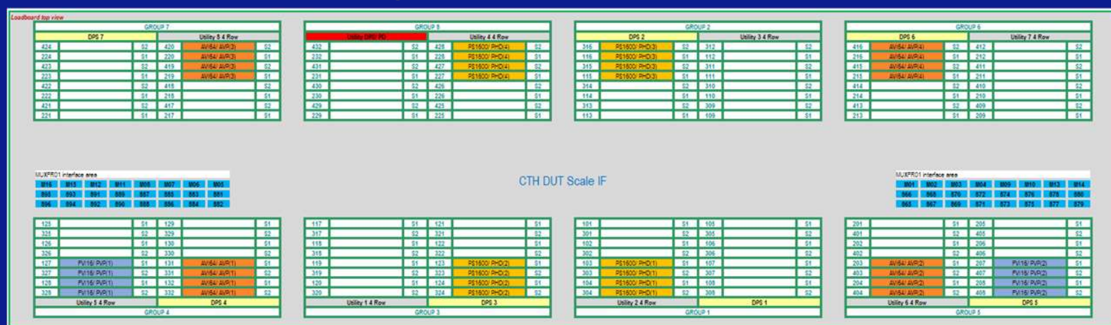


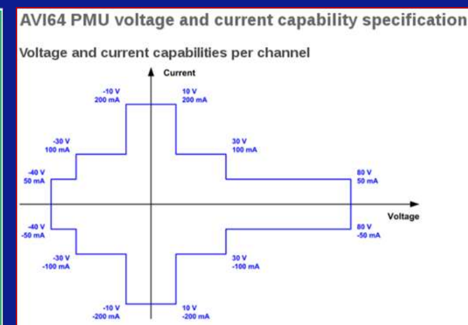
We used the combination for common fritting in production eventually.

FVI16 for Floating Power Supply

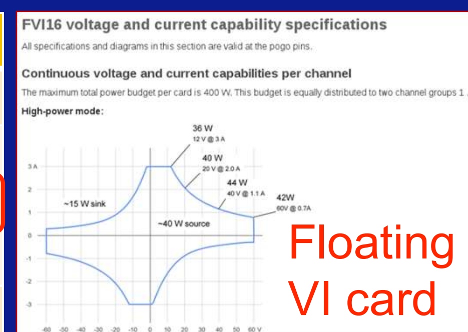
Configuration and Test Spec.

Production Configuration for 32 sites





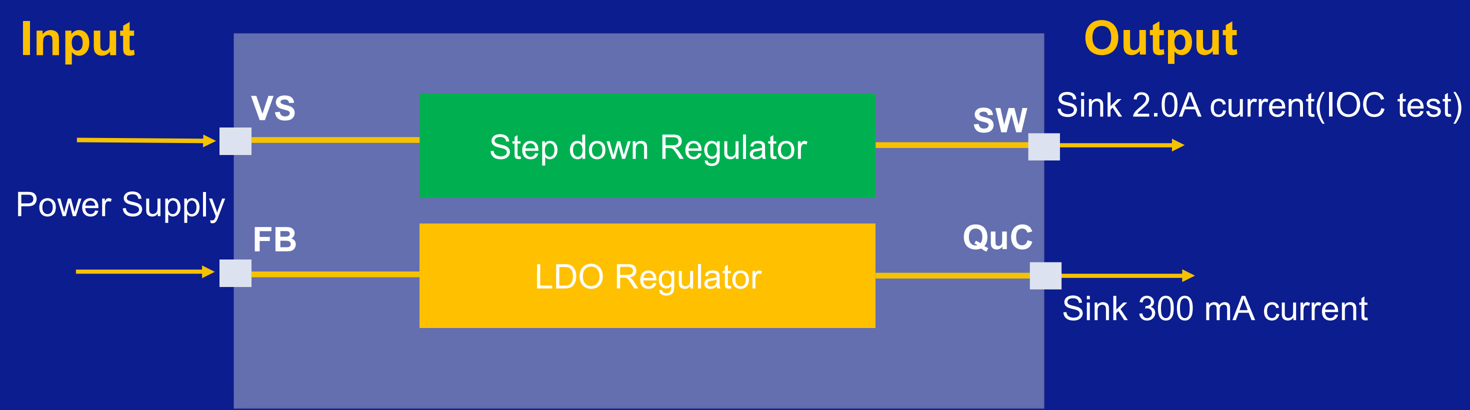
Card	Num.	Total Channels	Per site
PS1600	4	512	16
AVI64	4	256	8
FVI16	2	32	1
PMUX	16	192(1:4 MUX)	6(1:4 MUX)
Utility	1	256	NA



Floating VI card

Configuration and Test Spec.

Test Spec.



Challenge:

- ✓ Only FVI16 instrument can meet the request above according to V/I capability.
- ✓ But one FVI16 channel per site.

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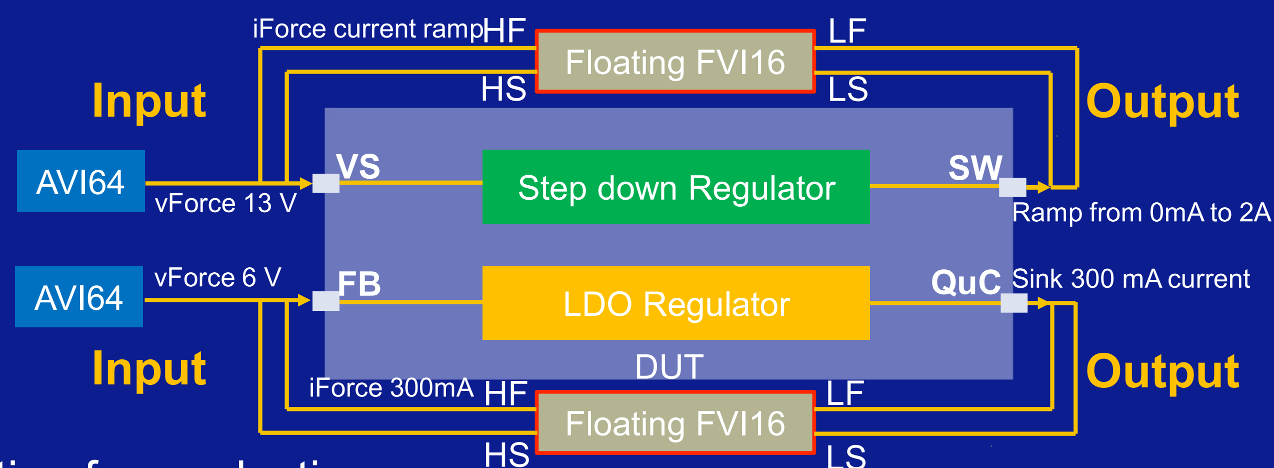
Theory of Test Solution



Solution for production:
Use FVI16 Floating structure. Step down and LDO regulator can share one FVI16 channel per site meanwhile.

FVI16 Unregulated Mode

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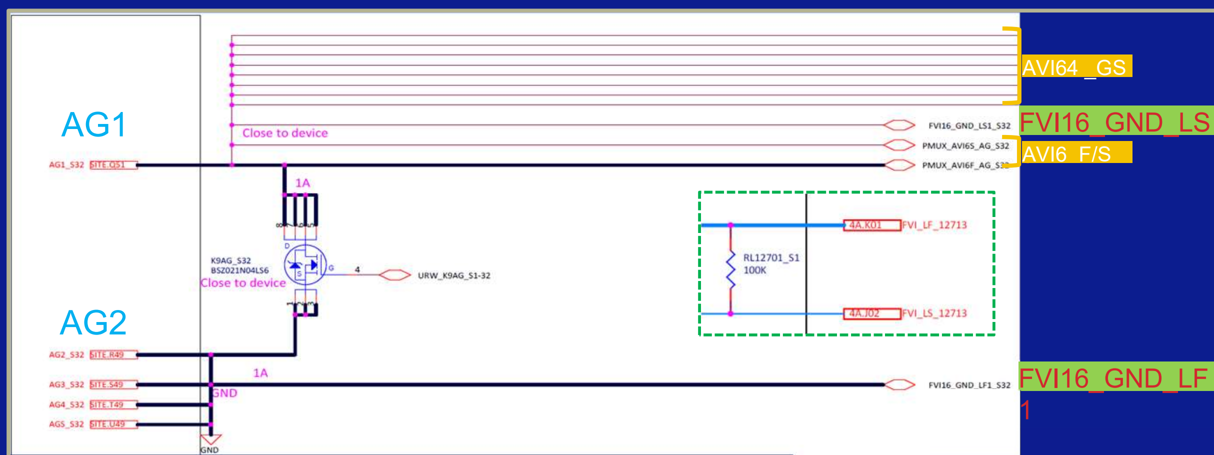
Background

AGx is device ground and pads above are presented on silicon. Test plan request the kelvin test between AG1 and AG2 inside silicon.



LB design bug:

If the kelvin between AG1 and AG2 is defective, we would not use FVI16 and AVI64 regulated mode to test the kelvin.

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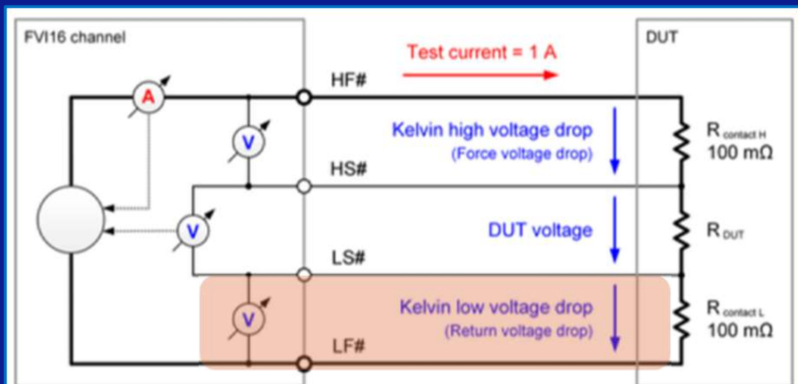
FVI16 Specification



Low force Kelvin drop voltage (Return drop voltage)

Voltage range	Condition	Programmable range	Accuracy	Example and comment
±3 V		±7 V	$\pm$ (20 mV * I_{force}/A + 10 mV)	e.g. @ 1 A = ±30 mV e.g. @ 10 A = ±210 mV
±10 V	Kelvin return threshold + $\lvert V_{force}\rvert \le 14$ V	±7 V	$\pm$ (20 mV * I_{force}/A + 10 mV)	e.g. @ 1 A = ±30 mV e.g @ 10 A = ±210 mV
	Kelvin return threshold + $\lvert V_{force} > 14$ V	< 7 V see left diagram below		$V_{force} \triangleq V_{clamp}$ for I_{force} operation, a kelvin low flag is set in case of violation
±30 V		±7 V	$\pm$ (20 mV * I_{force}/A + 10 mV)	e.g. @ 1 A = ±30 mV e.g @ 10 A = ±210 mV
±60 V	$\lvert V_{force}\rvert \le 48.5$ V	±7 V	$\pm$ (20 mV * I_{force}/A + 10 mV)	e.g. @ 1 A = ±30 mV e.g @ 10 A = ±210 mV
	$\lvert V_{force}\rvert > 48.5$ V	< 7 V see right diagram below		$V_{force} \triangleq {}_{clamp}$ for I_{force} operation
-60 V ... + 120V		N/A	N/A	

setting

measurement

Functionality	Member function	Mode
Set the maximum voltage drop on the force (HF#) line	rdi.dc().forceDropMax()	C + P
Set the maximum voltage drop on the return (LF#) line	rdi.dc().returnDropMax()	C + P
Measure the voltage drop on the force (HF#) line	rdi.dc().vMeasForceDrop()	C + P
Measure the voltage drop on the return (LF#) line	rdi.dc().vMeasReturnDrop()	C + P
Transfer and upload the available ADC values from the last measurement	rdi.dc().vMeasForceDrop(TA::WITH_LAST) rdi.dc().vMeasReturnDrop(TA::WITH_LAST)	C + P

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Production Implementation

...	Test	Test#	Type	Low...	Upper	Unit	Min	Max	Mean	Sdev	Cpk	Cpl	Cpu
	KSW	102	Parametric	0	44.4000	Ohm	30.0845	33.9183	32.0257	0.907362	4.54588	11.7651	4.54588
	KQCo	103	Parametric	0	19.9000	Ohm	3.87976	4.66847	4.24399	0.207335	6.82307	6.82307	25.1702
	KQVR	106	Parametric	0	19.9000	Ohm	3.37914	4.07307	3.70040	0.176401	6.99242	6.99242	30.6114
	KQuC	107	Parametric	0	19.9000	Ohm	2.37248	2.78969	2.54308	0.109027	7.77506	7.77506	53.0660
	KFBS	108	Parametric	0	44.4000	Ohm	27.6942	31.1551	29.2185	0.758298	6.67348	12.8439	6.67348
	KFB45	109	Parametric	0	14.9000	Ohm	3.52344	4.42563	3.89491	0.224327	5.78756	5.78756	16.3528
	KAG1_2	112	Parametric	0	14.9000	Ohm	1.25488	1.46973	1.33528	0.0595955	7.46857	7.46857	75.8710
	KPG1S	118	Parametric	0	44.4000	Ohm	28.6246	32.4729	30.5970	0.875848	5.25318	11.6447	5.25318
	KPG1F	119	Parametric	0	14.9000	Ohm	2.38280	2.87175	2.58798	0.119715	7.20594	7.20594	34.2814

Results
when device is good

Test	Test#	Lower	Upper	Unit	Min	Max	Mean	Sdev	Cpk	Cpl	Cpu
K24FVIQUC_OFF	990017	-10.0000	10.0000	uA	-0.0599366	0.777691	0.332379	0.170116	18.9432	20.2458	18.9432
K24FVIQUC_ON	990018	800.000	1200.00	uA	984.833	1016.96	999.357	4.91012	13.5338	13.5338	13.6211
K25FVISW1_OFF	990019	-10.0000	10.0000	uA	-0.0347777	0.524626	0.276471	0.107477	30.1568	31.8717	30.1568
K25FVISW1_ON	990020	800.000	1200.00	uA	957.482	1089.11	995.502	14.9859	4.34858	4.34858	4.54867
K9AG_ON	990021	800.000	1200.00	uA	995.725	1005.53	1000.34	1.87081	35.5753	35.6949	35.5753
K9AG_OFF	990022	90.0000	110.000	kOhm	95.2555	97.1273	96.4020	0.423854	5.03475	5.03475	10.6939
K1VSTOFF	990023	-10.0000	10.0000	uA	-0.873886	1.72705	0.525030	0.472882	6.67888	7.41907	6.67888
K1VSTON	990024	800.000	1200.00	uA	992.030	1005.37	1000.22	2.03207	32.7716	32.8429	32.7716

Results
when device is defective

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Summary

- **Kelvin**
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  - Trials
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