An Introduction to Spring-Probe Technologies for End-of-Line Test. History, Latest Trends & Applications

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- History of Test Probes for End-of-Line Test
- Variety of Test Probes / by Application
- Existing Challenges PCBA – Wire Harness – Battery Test
- Trends and Future Designs

History of ICT / Test Fixtures

- **In-circuit** test systems date back to the **early seventies**. Engineers at Bell Laboratories are said to have invented so called **“pogo pin” technology** during that time (see note at [PROM])
- **ICT/FCT** is done at the **end of the production-line**
- **Test fixtures** (manual or vacuum are used)

Why do some call it a “pogo pin”?

As little as 3 components. But some probes have 30+ components!

(1) Plunger

- The plunger is the moving part that makes contact with the DUT thru the. It is biased to ensure contact with the barrel.

(2) Barrel

- The barrel houses the spring and is considered the main body. It sits firmly inside a receptacle, also by some known as a “socket”.

(3) Spring

- The spring is the single most important component and allows compression and compliance for usage in test fixtures.

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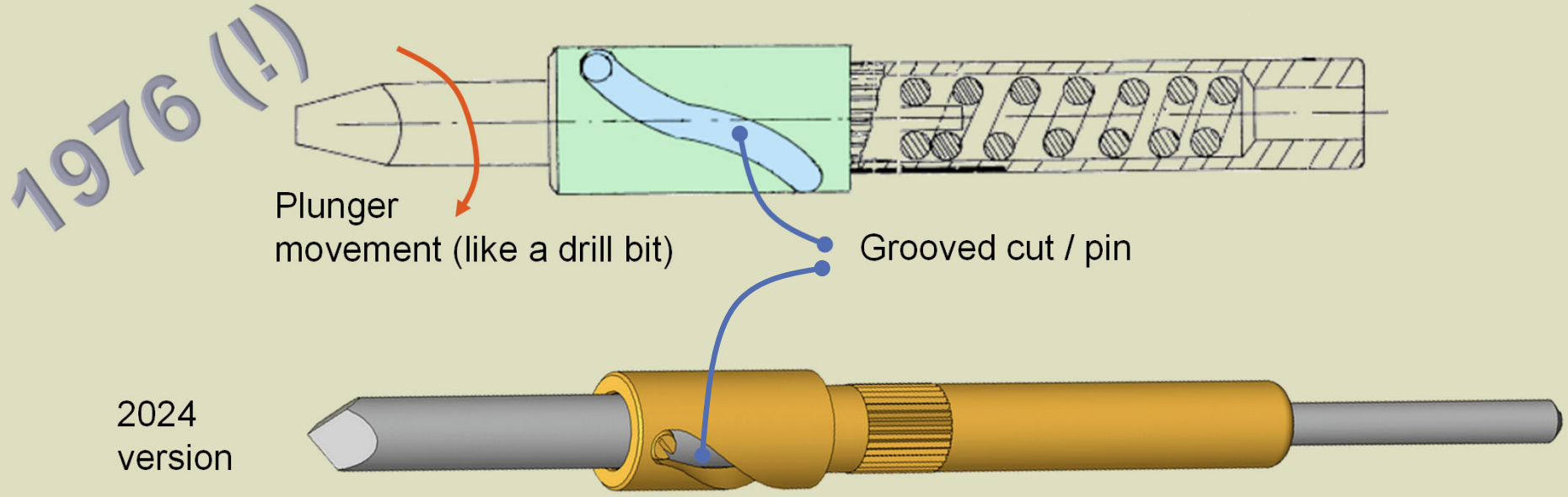
History of Specialty Probes for PCBA - Rotator

- 1st patent on rotating probes in 1976, expired 1982, see [ING75]

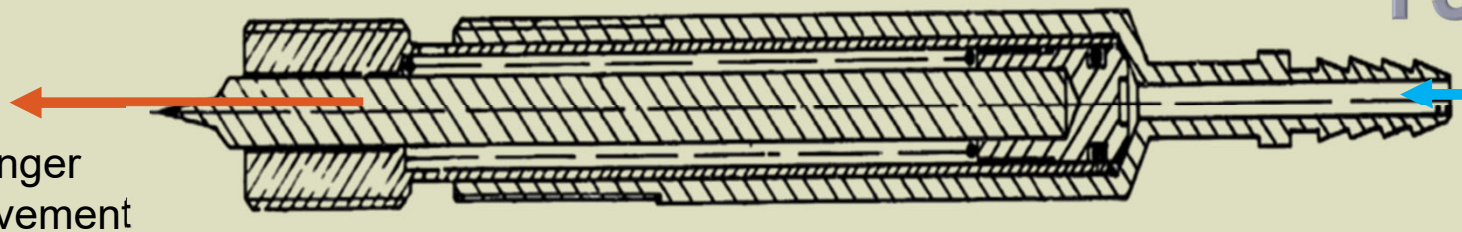


Why is this still very relevant in 2024/2025?
→ oxide layers / battery cell contacting etc.!

History of Specialty Probes for PCBA - Pneumatic

- 1st patent on pneumatic probes in 1984, expired 1990, see [ING84]

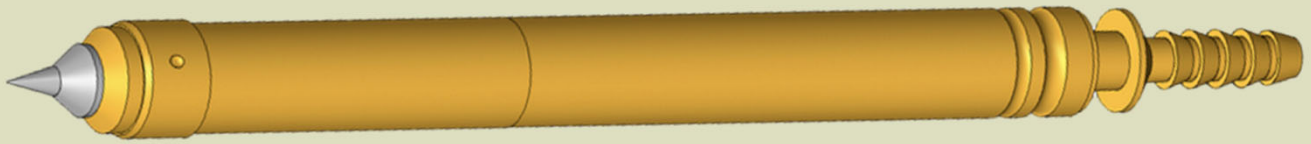
1984 (!)



Plunger movement

Compressed air, 86 psi

2024 version

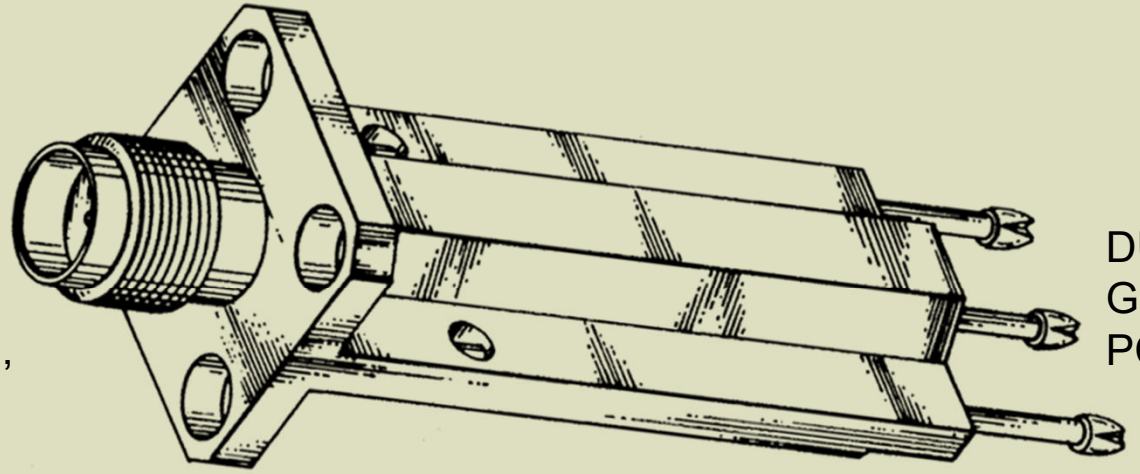


Why is this still very relevant in 2024/2025?
→ Hard to reach components / angular contact / “fake” dual stage / “Serial” testing without activating all probes / “fixtureless” test etc.

History of RF Probes for PCBA

- Earliest design developments started in 1986 by Motorola laboratories, but later commercialized by another company (see [Korn95])
- It started with 3 standard DC probes in a flange-mounted holder, SMA-launch

1986 (!)



Cable connection, SMA

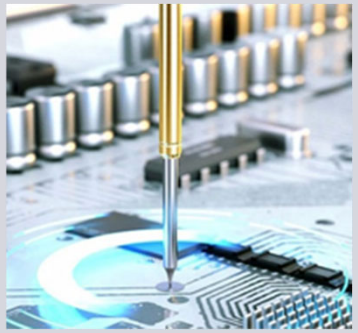
DUT side GSG, e.g. PCBA

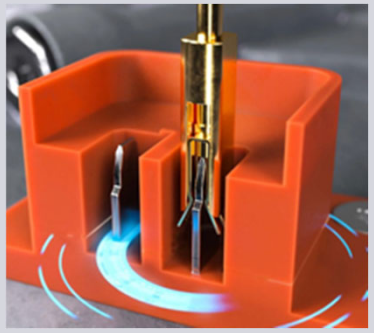
Flange mount

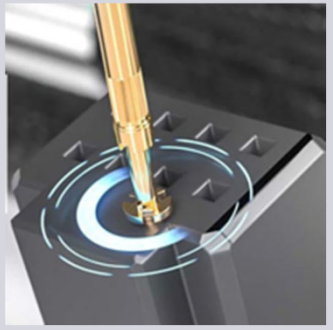
Illustration above from expired patent, see [USPTO95]

Variety of Test Probes

PCBA	Connector	Harness	Battery
-“classic test point” - 40/50/75/100 mil - Use: ICT/FCT - also: RF	- continuity - high current - RF / Wireless - EV / high current	- wire harness - automotive - continuity check	- individual cells - modules / packs

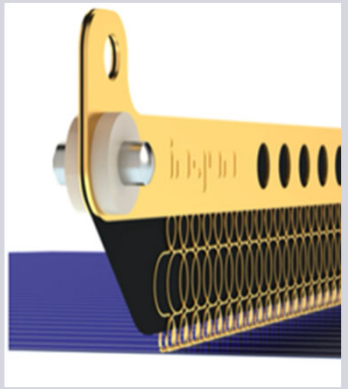


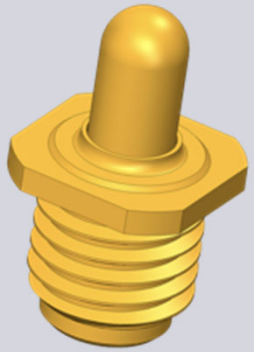


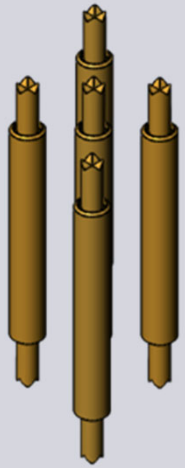


Variety of Test Probes

Solar Cell	Interconnect	Semicon
- solar cells - test with stripes or probes	- Use of probe as “permanent” component in product	- wafer level - socket test





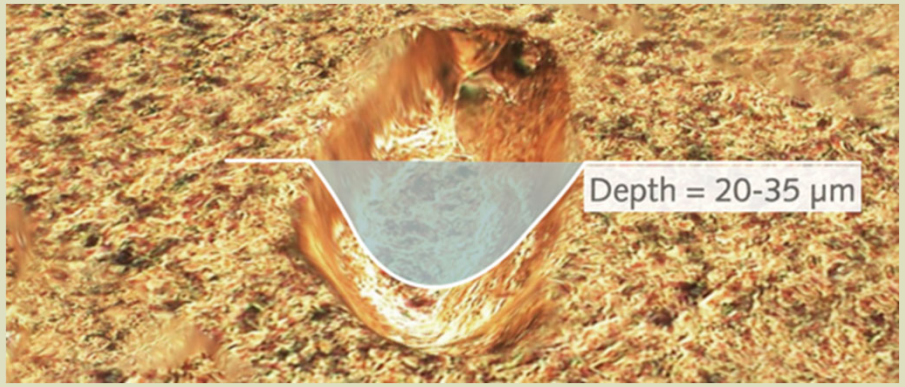


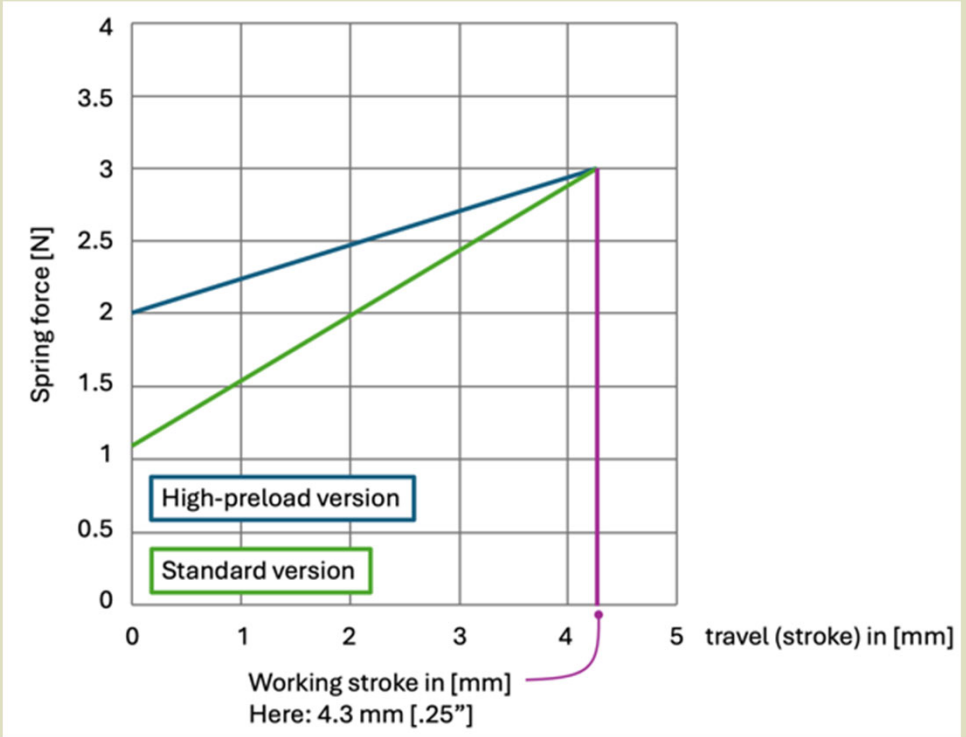
Challenges: PCBA

Challenge OSP residue / solder-Flux residue / other contaminants

Solutions:

- High energy / high preload probes
- Aggressive cutting action tips





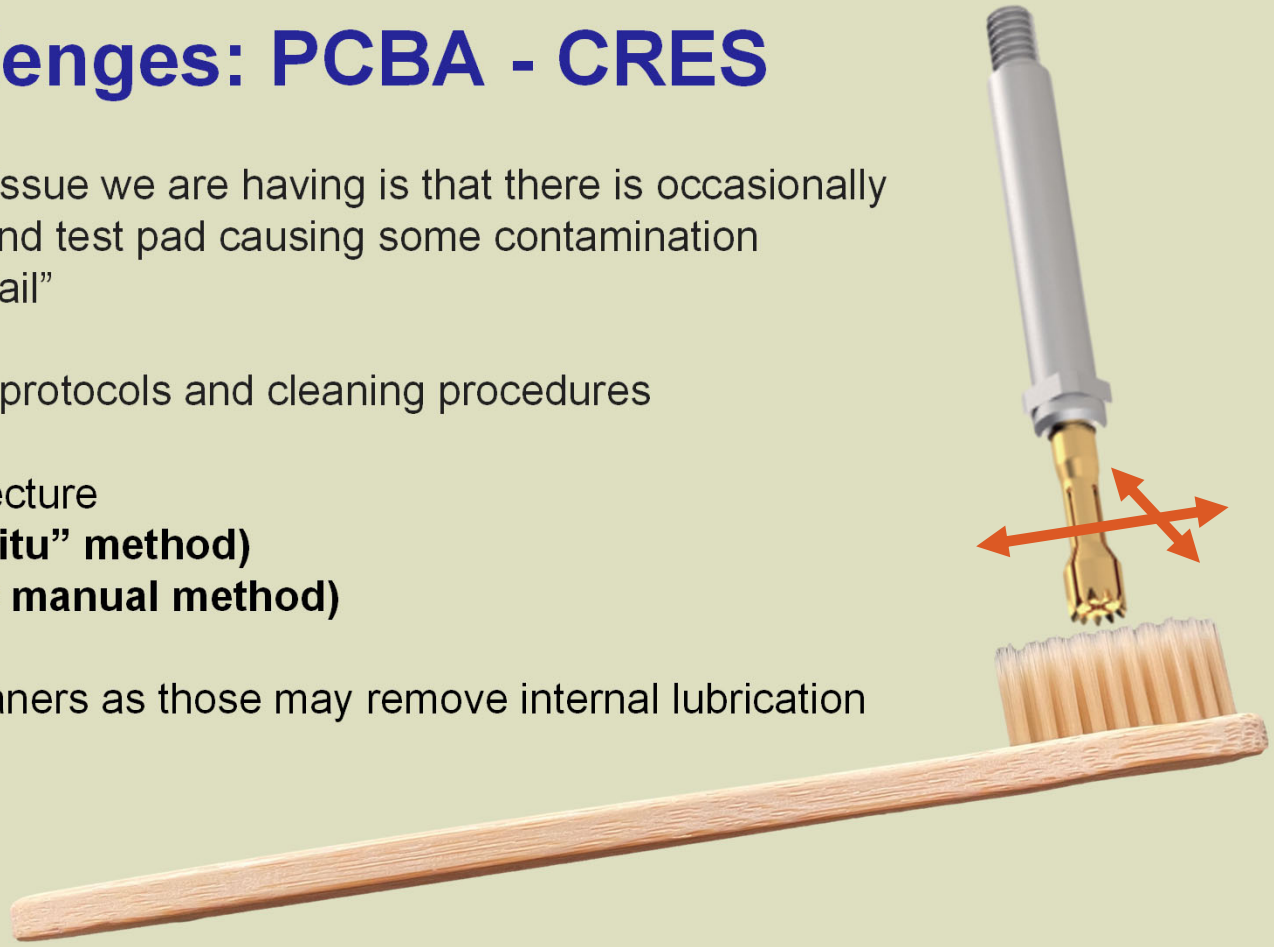
Challenges: PCBA - CRES

A common email request: "The issue we are having is that there is occasionally poor contact between our probe and test pad causing some contamination buildup and tests to occasionally fail"

Need for preventive maintenance protocols and cleaning procedures

Depending on tip style and architecture
- Contact cleaning mats **(= "in-situ" method)**
- Fiberglass cleaning brushes **(= manual method)**

Be careful with solvent-based cleaners as those may remove internal lubrication layer.



Challenges: Connector – High Current

- High current up to 400-500 A (pulsed) or more for some applications.
- Test probe need to be carefully matched to shape of the target (mechanical considerations).
- High contacting force maybe necessary.
- Don’t connect / disconnect under load.
- Safety features on DUT, fixture and preferable also on probe to prevent touching

Left: Photo of a badly burnt probe for round post connectors. The **connector post (DUT)** was **too small** for the contacting blades, which then could not make good contact.

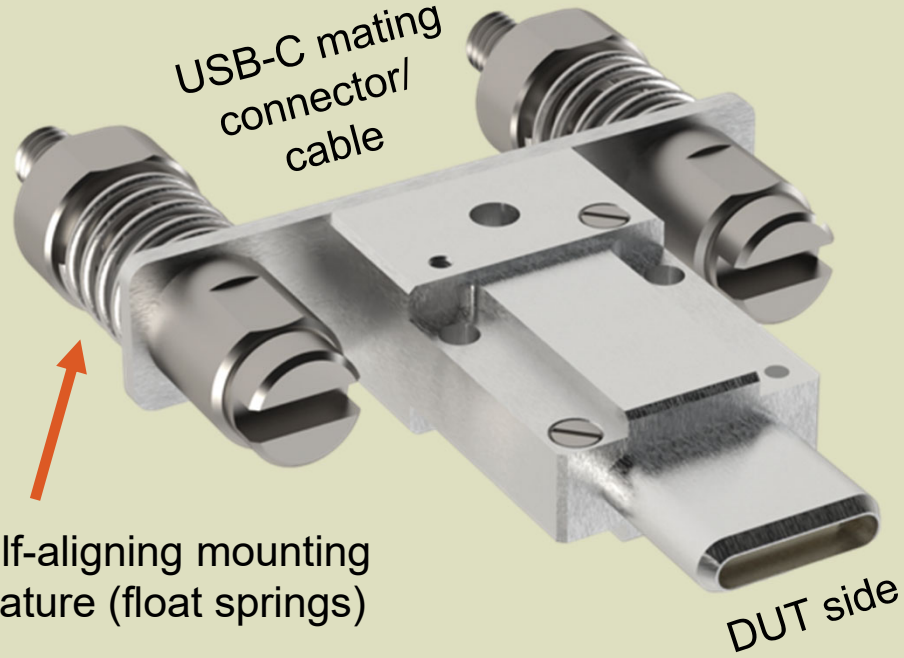
Challenges: Connector – RF / Wireless / High-Speed

Challenge #1 Ever increasing frequency requirements (mechanical features of probe interfere with S-Parameter performance)

Solutions:
- Coaxial designs with short stroke
- Probes with minimized discontinuities inside

Challenge #2 Repeatability and lower return loss (matching) compared to a mating connector

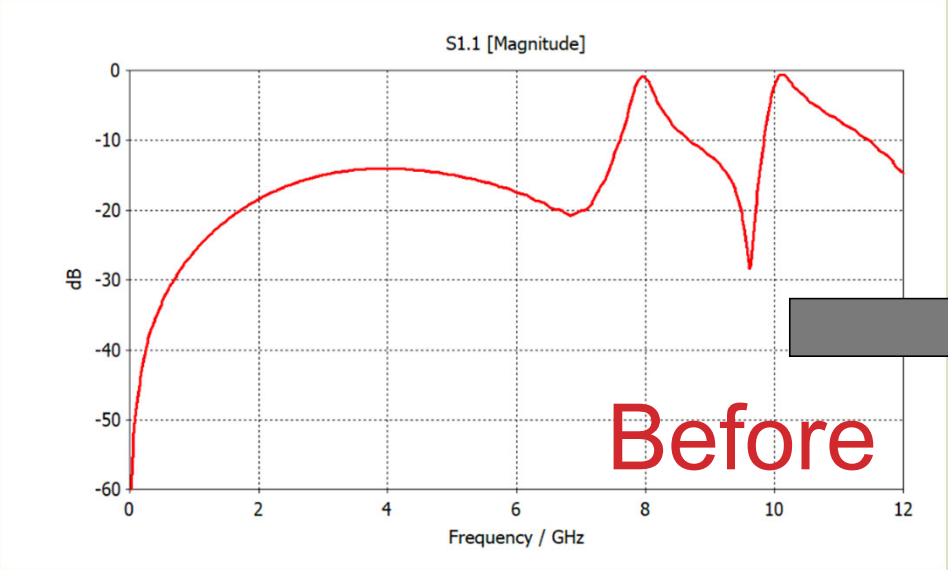
Solutions:
- Test plugs
- Ruggedized slide on / push in test connectors instead of spring-probe

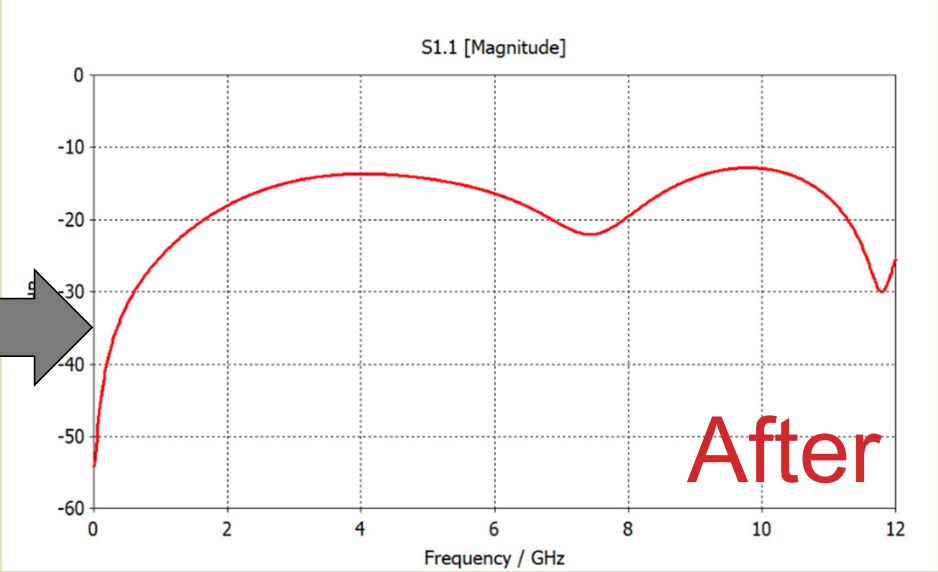


Challenges: Connector – RF / Wireless / High-Speed

RF Simulations help to improve performance

- Necessary for PCB design, probe design and matching these two.
- Here: “Notch-analysis” for the influence of air-gaps on return loss behavior

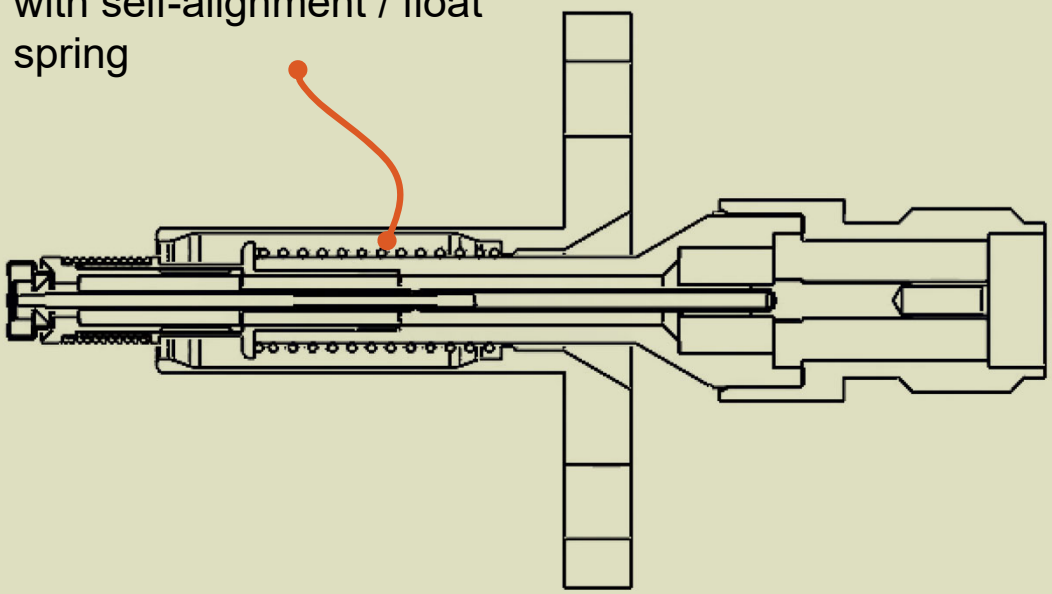


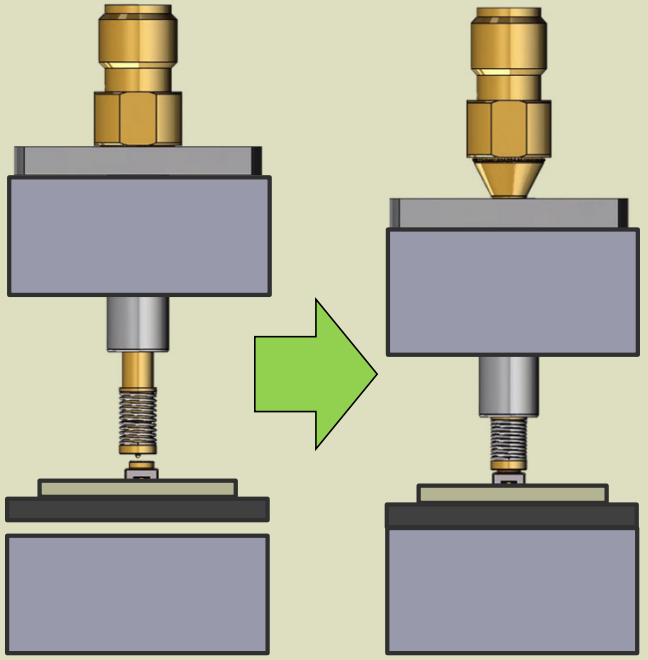


Challenges: Connector – RF / Wireless / High-Speed

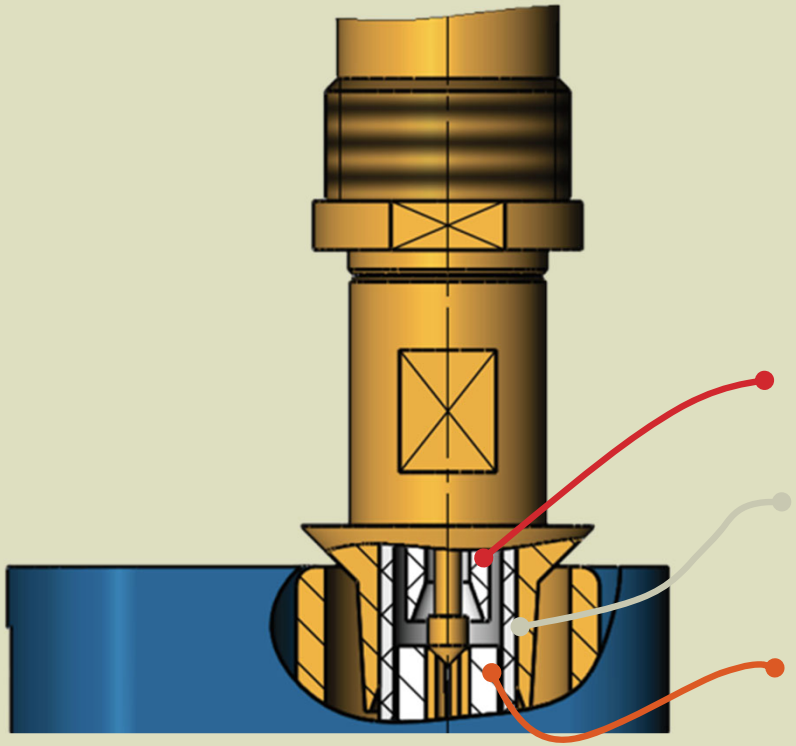
Mechanical installation: Surface mount board connectors never seem to be at the right position ;)

Necessitates use of version with self-alignment / float spring





Challenges: Harness



Challenge #1 Mechanical access into sealed connectors.

Solutions:

- Specialized “tulip”-style tips which expand inside upon actuation

Challenge #2 Hi-pot capability

Solutions:

- Usage of probes with additional insulation material to prevent arching.

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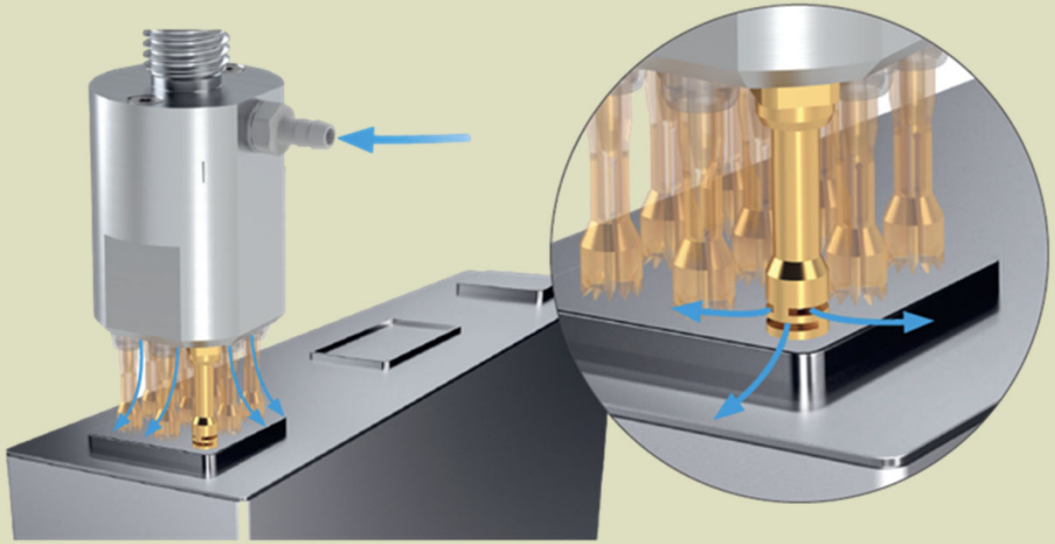
Challenges: Battery

Challenge #1 Materials (aluminum = hard to probe tends to oxidize)

Solutions:
- Bifurcated spreader tip probes with
- High preload version

Challenge #2 Current rating requirements

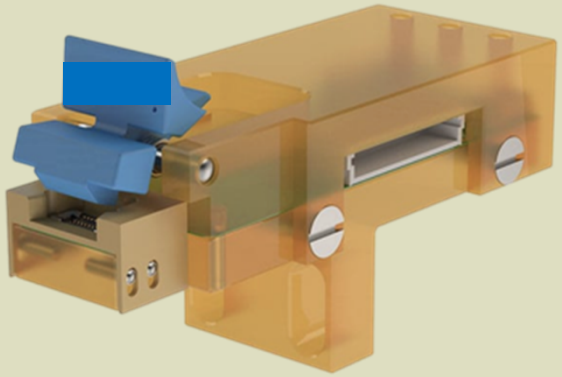
Solutions:
- Active air-cooling features
- Thermal sense probes
- Use of probe blocks vs. single probes



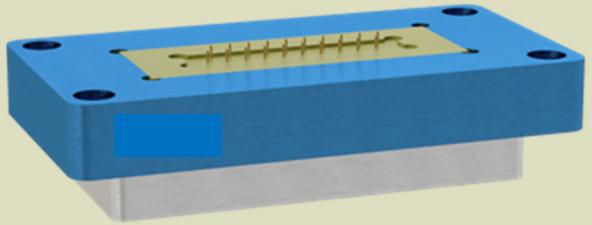
Active cooling, also see 2024 in-depth Battery Presentation at TestConX from the same author [ZAP24]

Trends/ Future Applications: RF/ Wireless/ High-Speed

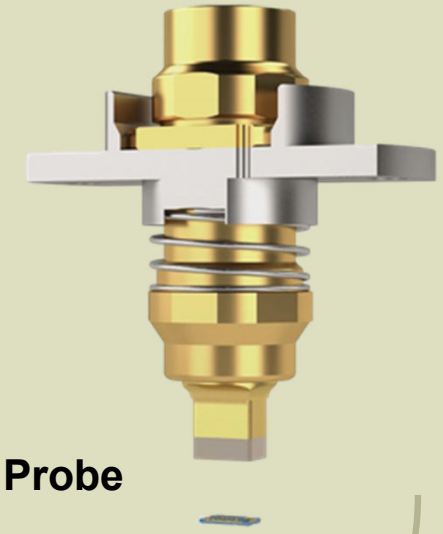
Trend #1 – Higher frequencies / data-rates **Trend #2** – Multisignal connectors



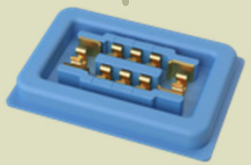
Interposer (Clamp)



Socket

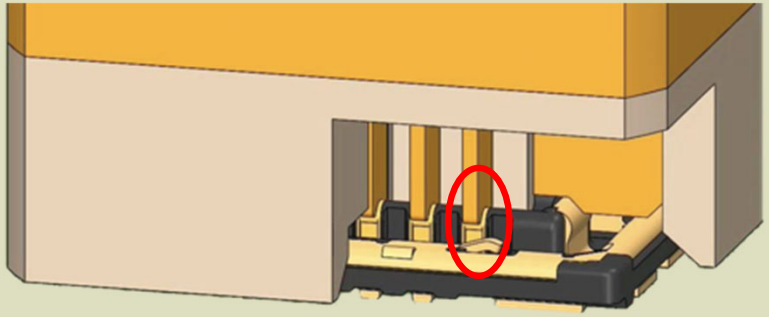


Probe

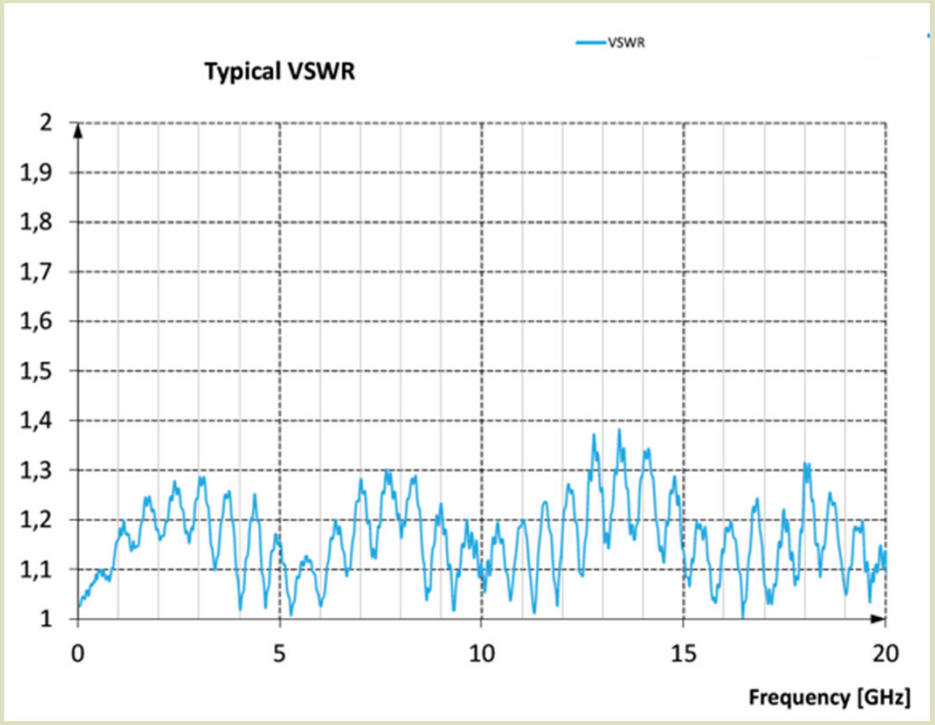


B2B connector (RF+DC)

Trends/ Future Applications: RF/ Wireless/ High-Speed

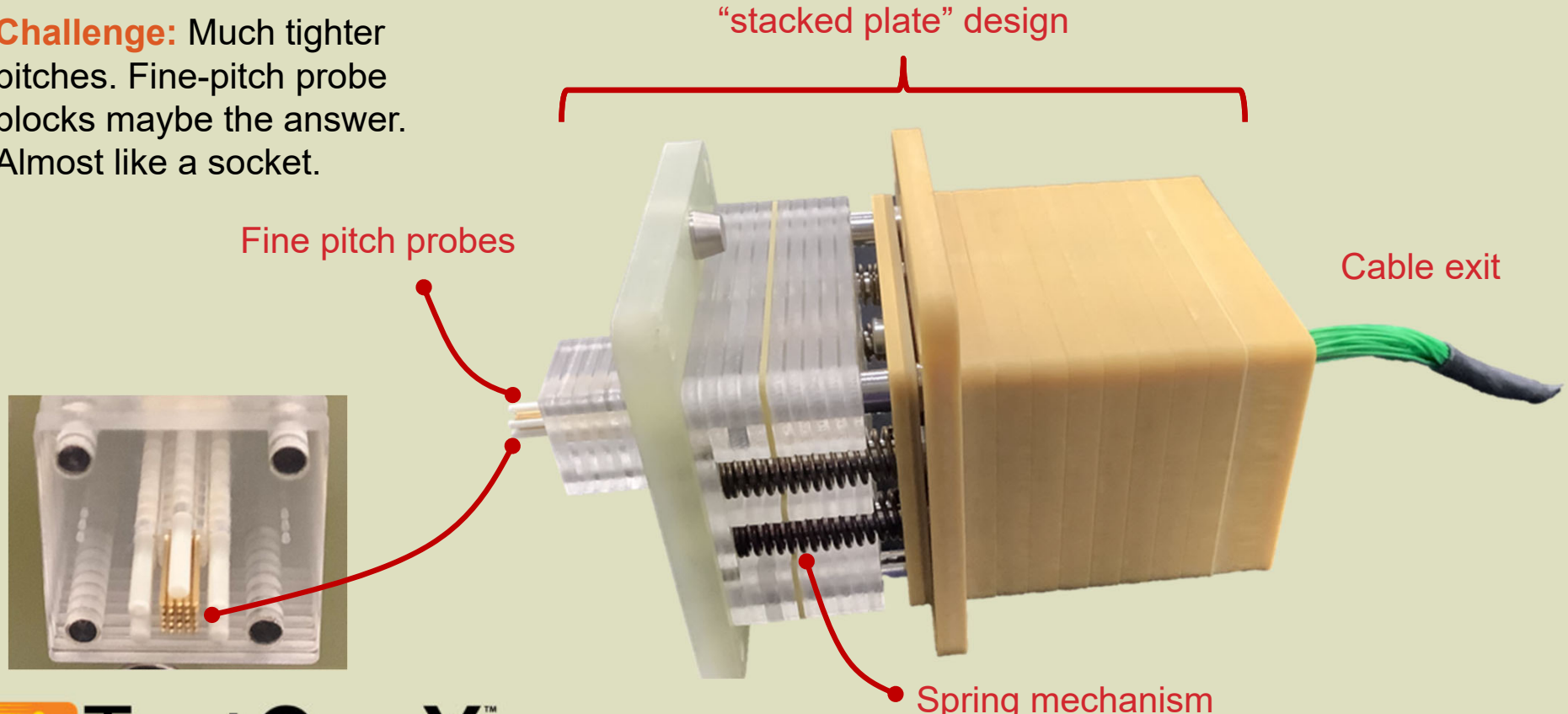


- Contacting example of a blade-pin version onto a B2B connector
- Chamfered “catcher’s mitt” + float mount installation allows the DUT to be caught even in case of positioning tolerances (within some limits of course!)



Trends / Future Applications: ICT/FCT

Challenge: Much tighter pitches. Fine-pitch probe blocks maybe the answer. Almost like a socket.



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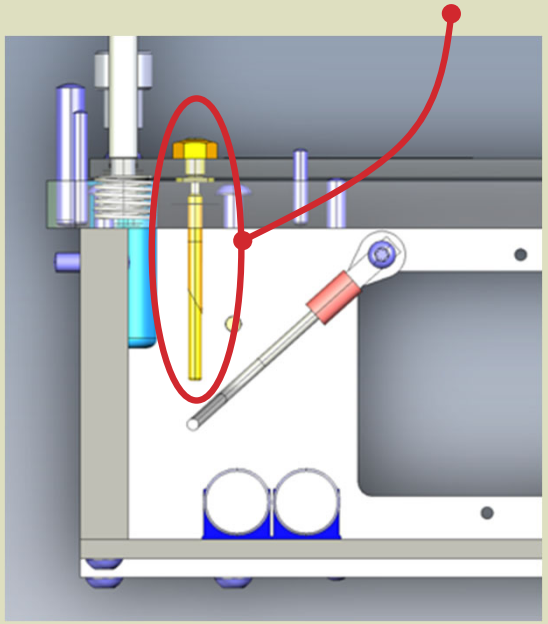
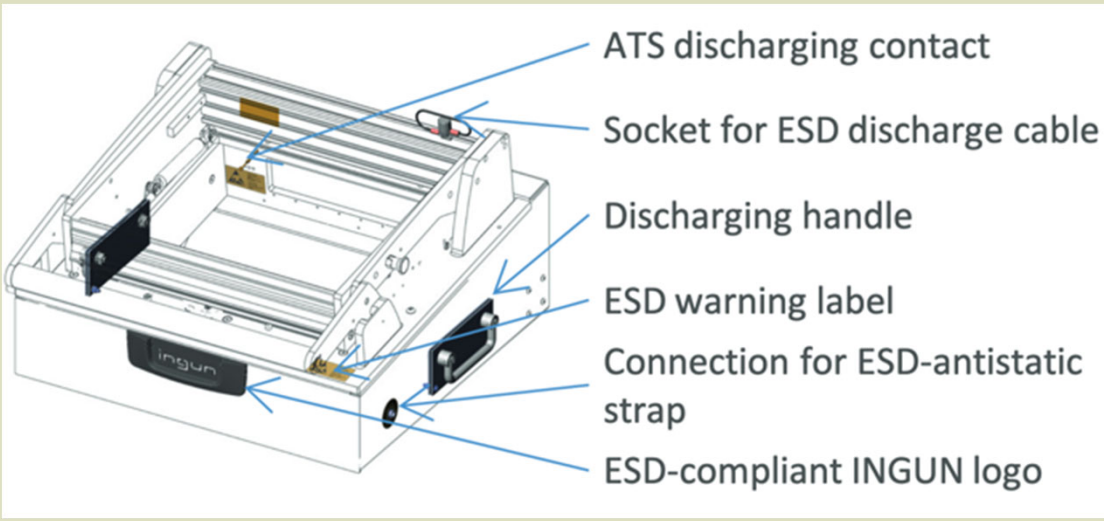
20 2025

Trends / Increased Susceptibility for ESD Events

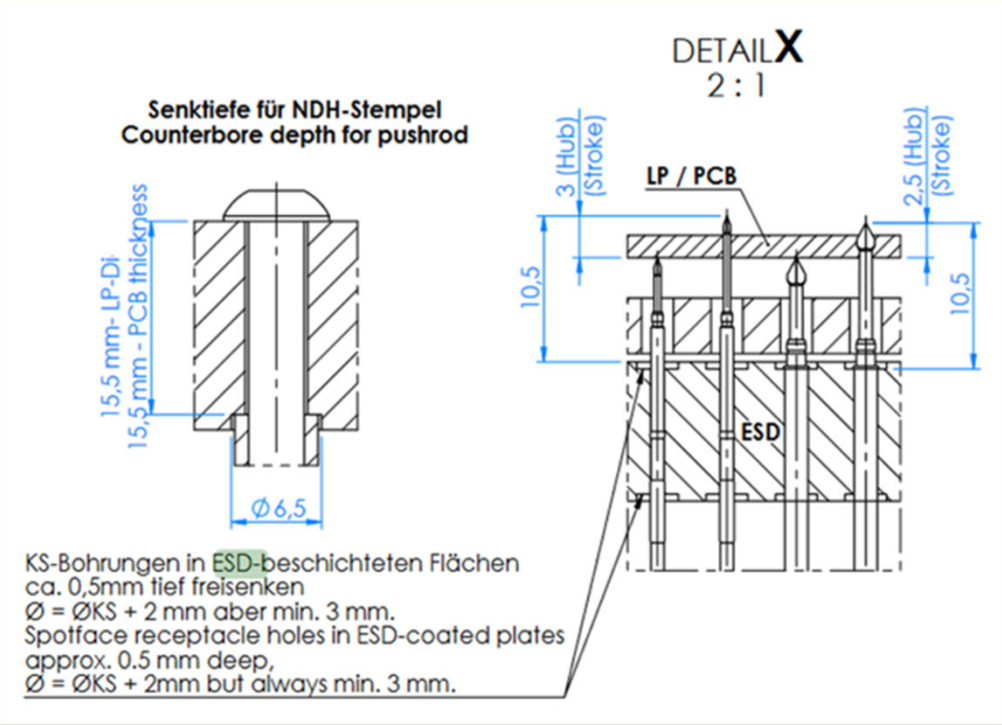
Latent ESD events are a serious problem. Mitigation measures for test include the following:

- on fixture side → ESD compliant probe plate / top plate – dissipative path to ground
- Usage of ESD discharge probes





Trends / Increased Susceptibility for ESD Events



- It is advisable to have ESD control on the probe-plate, best top and bottom
- Typically, the probe plate is then painted with **ESD-coating** (spray-on)
- To install probes, a **counterbore** is needed.
- This means the probe is **seated slightly lower**, calculate for difference in spring-force and choose higher force as necessary

Don't short out the probes! Retrofit to add "cutouts/counterbores" with already installed receptacles is next to impossible (unless every receptacle is extracted)/

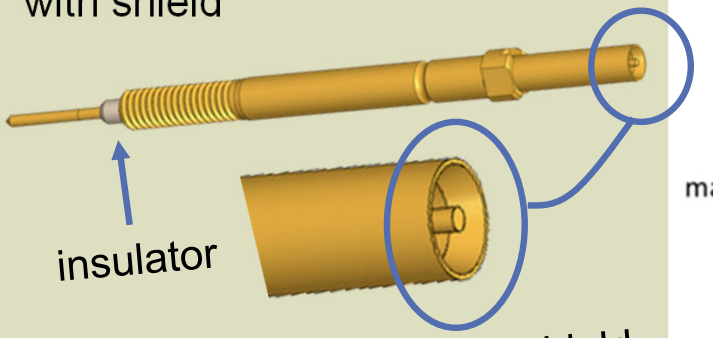
Left: Example from a customization drawing for use inside ESD-compliant test fixture.

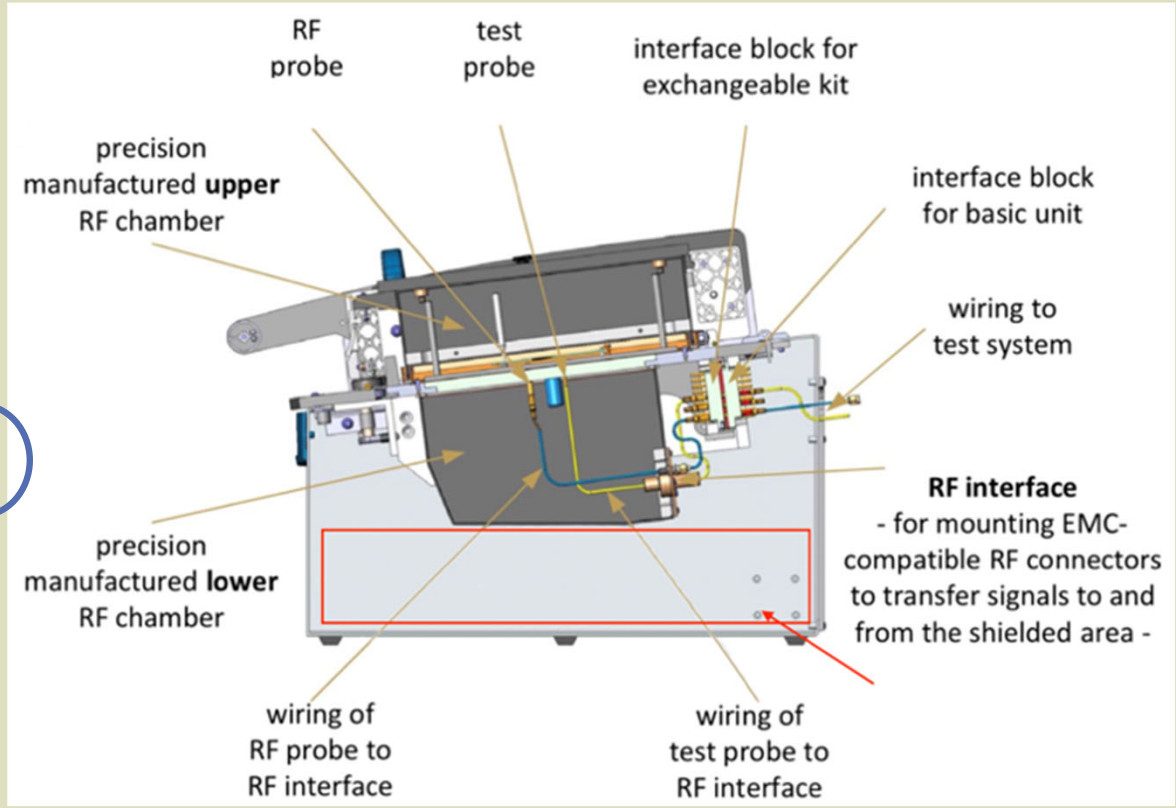
Trends / Increased Susceptibility for EMI

Challenge: **E**lectro**m**agnetic **I**nterference (EMI)

Mitigation:

- Fixture side → Usage of shielded enclosures
- Probe side → coaxial probes with shield





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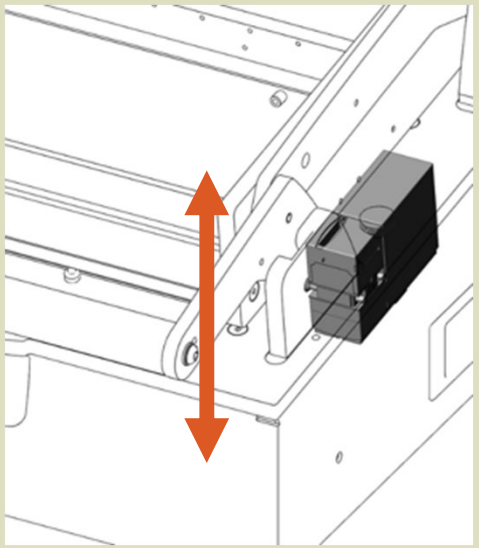
Trends / Future Applications: High Current

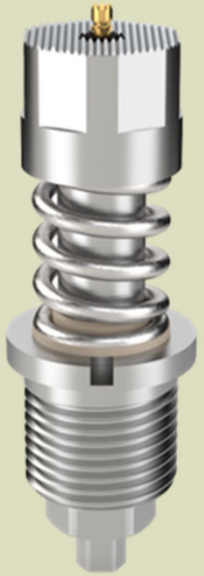
Challenge 500 A … 1 kA and more, pulsed current that far exceeds connector specs.

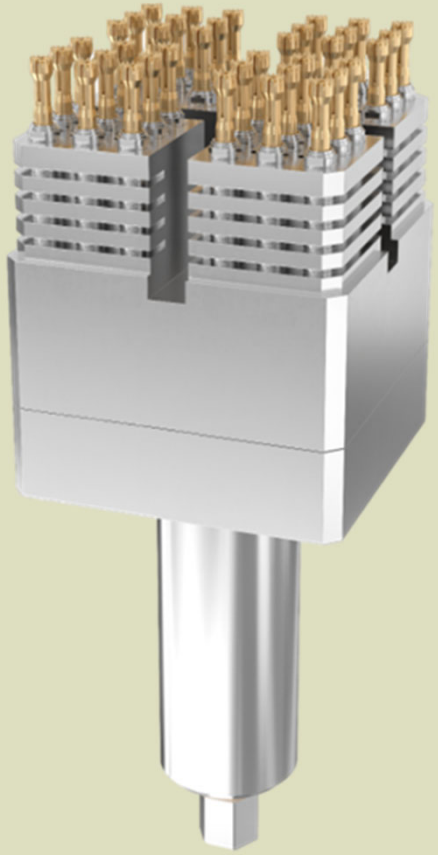
Safety concerns!

Solutions:

- Safety switches and interlocks in fixtures
- Larger form factor probes and multi-pin probe blocks
- Out-of-spec pulsed current test



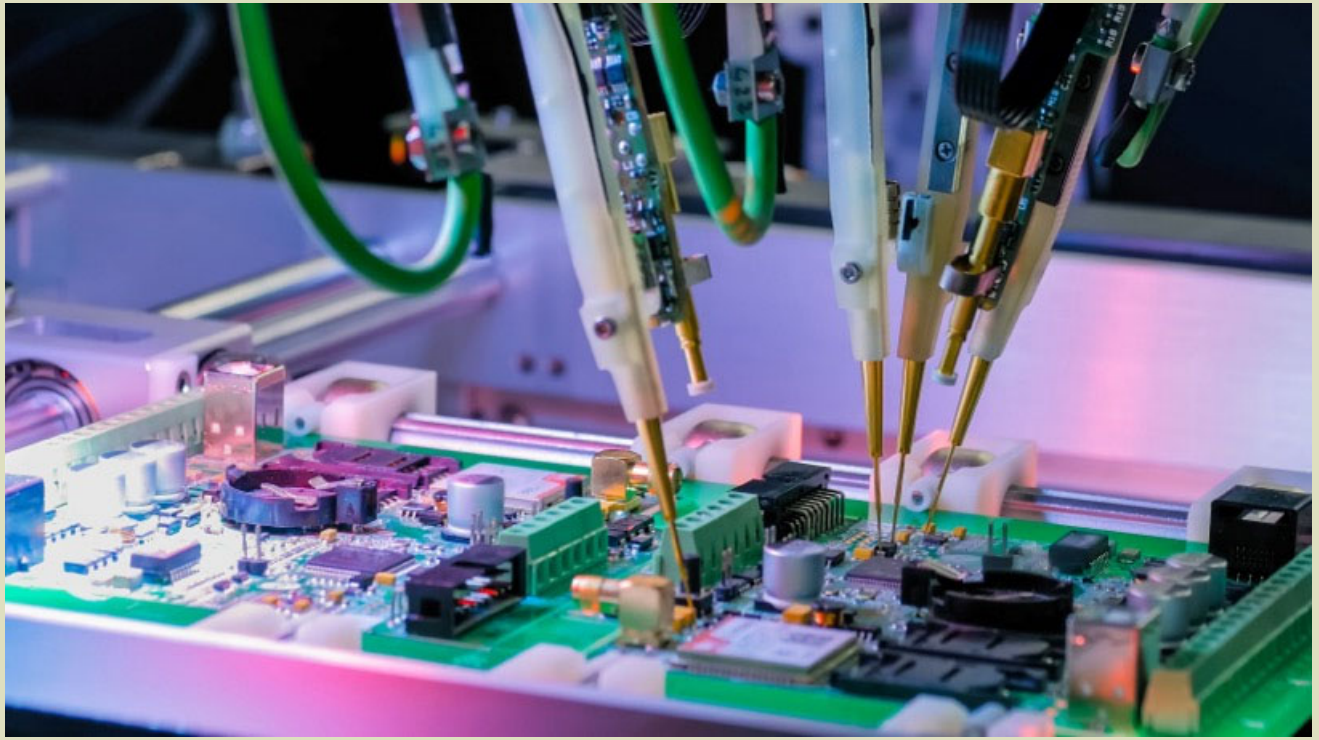




Trends / Future Applications: Even More Massive use of “Flying Probe” - Systems

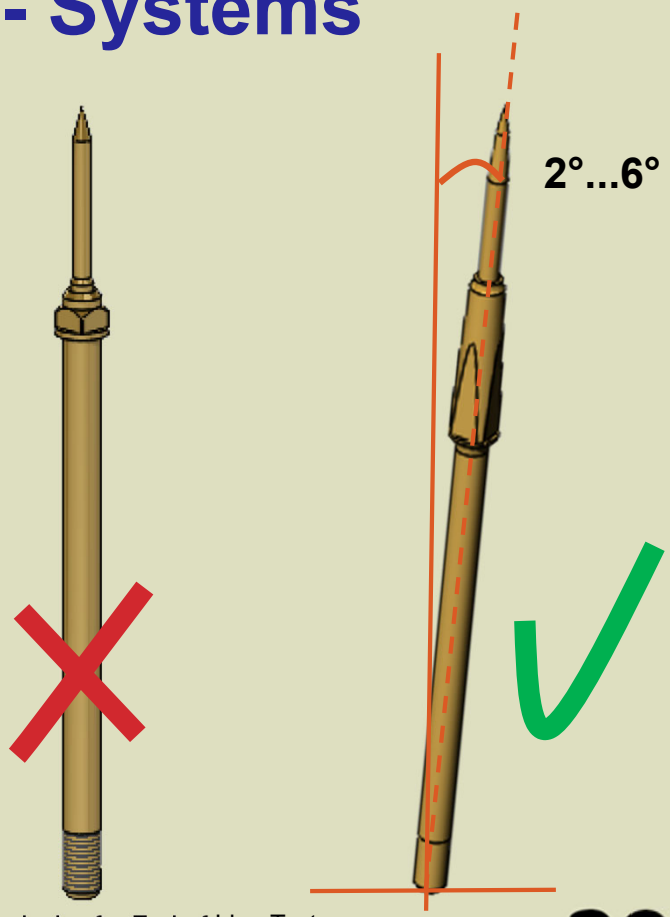
Contrary to all the nay-sayers, “traditional” ICT and FCT is NOT dead!

However, there is no denying, that use of so-called “flying probe”-systems has **increased dramatically** over the years (especially for battery pack and module test).



Trends / Future Applications: Even More Massive use of “Flying Probe” - Systems

- Quite often, this necessitates the use of specialty probe needles, which can be used at an angle (absorbing the side-load caused by such installation)
- Left pin (100 mil) and right pin look very similar. The devil is in the details. The right pin handles side-loading well (reinforced guide-section), the one on the left would suffer from premature wear and tear and ultimately spring- and plunger failure.



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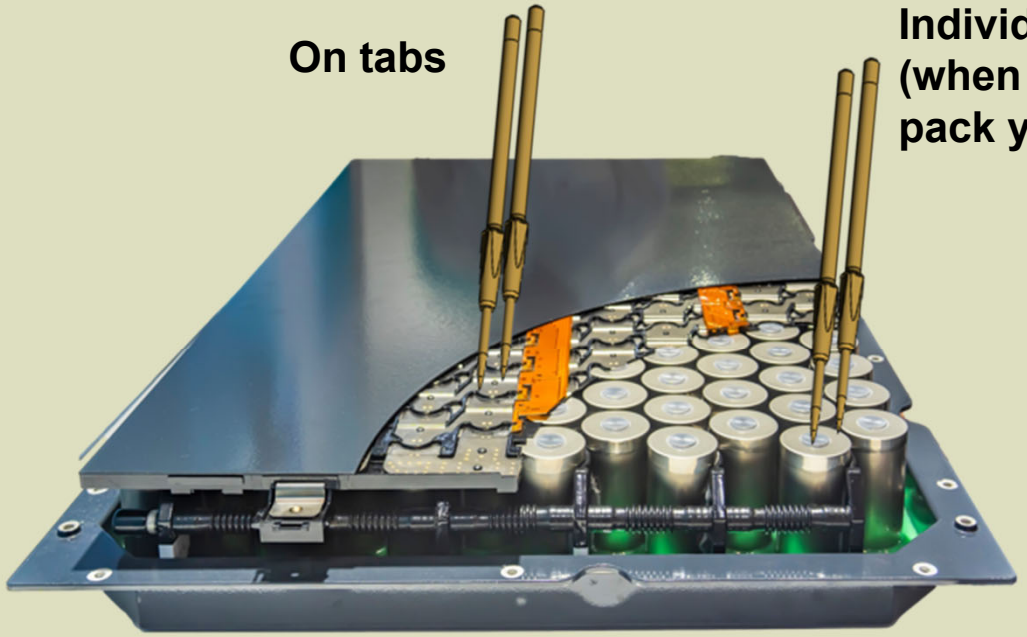
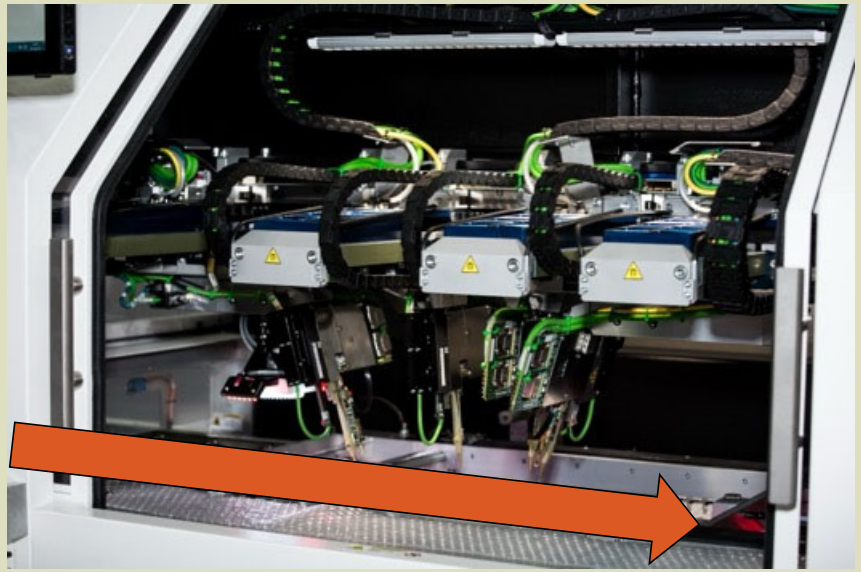
On tabs



Individual cell test (when not in module/ pack yet)

module test, e.g. with in-line flying probe tester



Weld joint test, OCV, ACIR and more

Literature

- **[ING76]** Patent: Rotating Test Probe https://tinyurl.com/maw2jxvc
- **[ING84]** Patent: Pneumatic Test Probe https://tinyurl.com/skxvj97c
- **[Korn95]** Kornowski, Robert R.: The K-50L Coaxial Probe: Its Origin, Applications and Benefits. In: 45th ARFTG Conference Digest-Spring, 1995, p. 46 – 55
- **[PROM]** https://promaxpogopin.com/professional/the-wonders-of-pogo-pin-technology-what-it-is-and-how-you-can-use-it/
- **[USPTO95]** Kornowski, Robert R. et. al.: Coaxial Probe. https://patents.google.com/patent/USD343802S/en?oq=d343802
- **[ZAP24]** Zapaka, Matthias : Production Test of Battery Cells and Packs using Spring-Probes and Contacts. In: Proceedings of TestConX Conference, Mesa, AZ (USA), March 2024

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