DFT techniques for high density / fine pitch applications with manual and vacuum test fixtures.

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Agenda

01 **Introduction to Test Fixture Designs, Manual – Vacuum – Pneumatic**
Design , Terms , Definitions , General Customization Guidelines

02 **Introduction to General Test Probe Design**

03 **Socketless Probe Design and Fixture Customization**

04 **Rigid Pin Design and Fixture Cassettes**

05 **Probing onto Multipin B2B Connectors**

06 **Board-Level Contacting Blocks / Cartridges and Fine Pitch Probes**

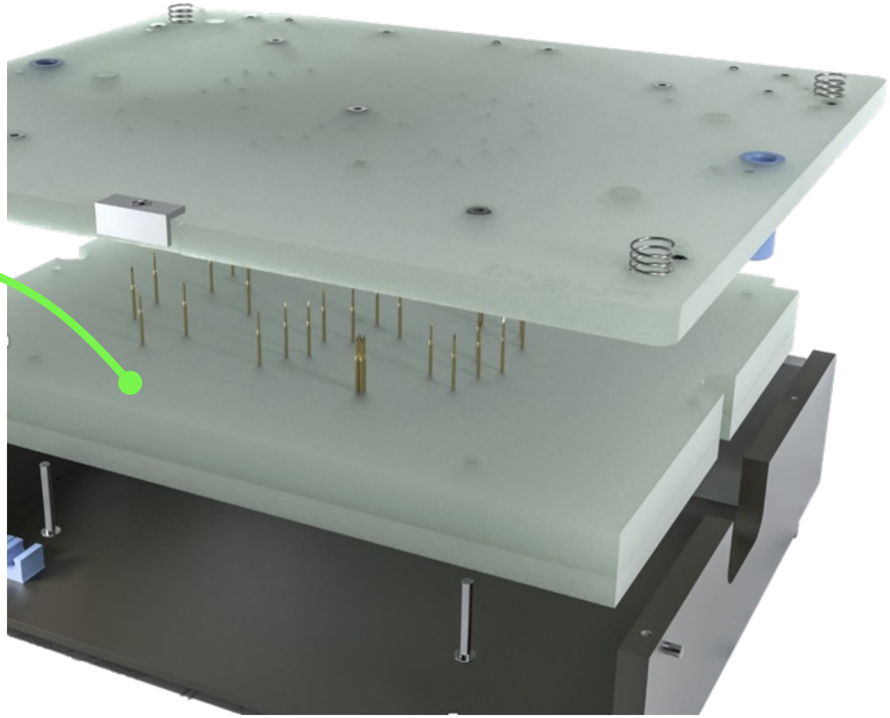
01

Introduction: General test fixture design

1. Manual types

Manual fixtures are used for medium pin counts

Normal spacing: Standard manual fixture

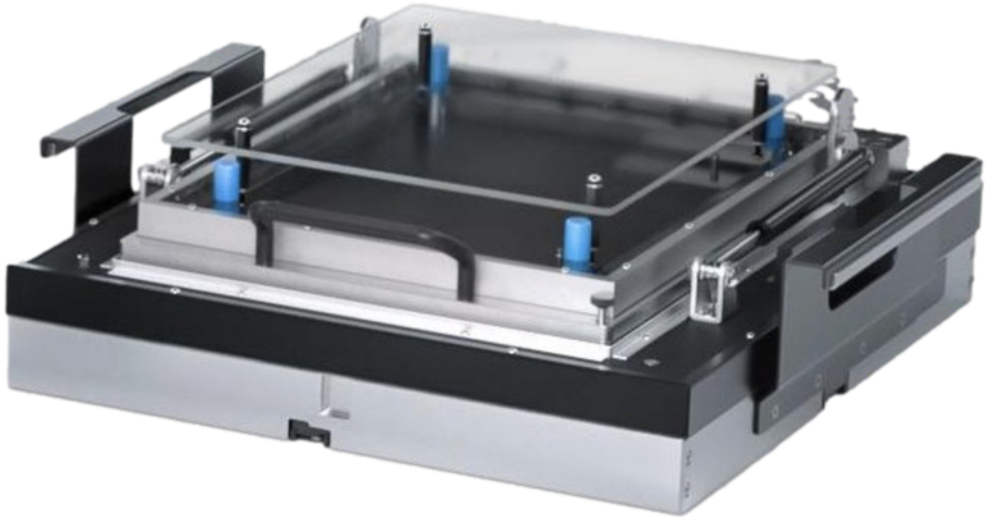


Close centers: Design for socketless probes (only insert shown, fixture frame is same compared to standard version).

1. Vacuum types

Vacuum fixtures are used for high pin counts

Manual fixtures can handle up to ˜2000 Newtons of force, however certain vacuum types can handle 10-11x that Force, depending on size.



Normal spacing: Standard vacuum fixture

Close centers: Rigid pin vacuum

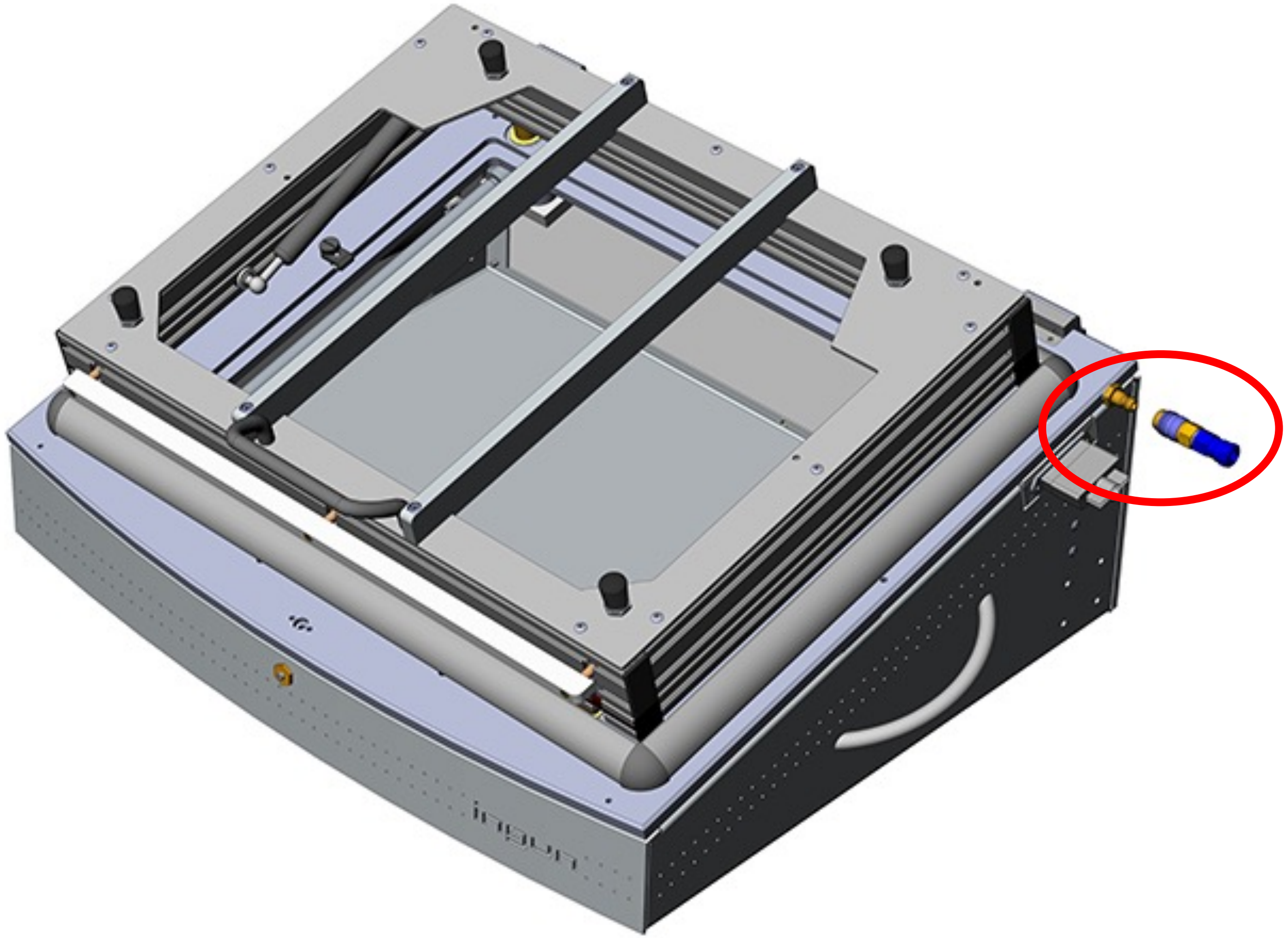
1. Pneumatic types

Pneumatic fixtures are used for medium pin counts

Pneumatic test fixtures are used for contacting electronic assemblies in medium quantities in series testing with a high number of versions.

The fixtures are designed as an interchangeable kit system, are connected to an existing test system, and operated with interchangeable kits that have been specially customized for the electronic assembly under test.

The parallel contact stroke is generated by feeding **compressed air** to a **pneumatically operated lifting cylinder** that directs the pressure plate with the electronics assembly and the test probes into the test field.



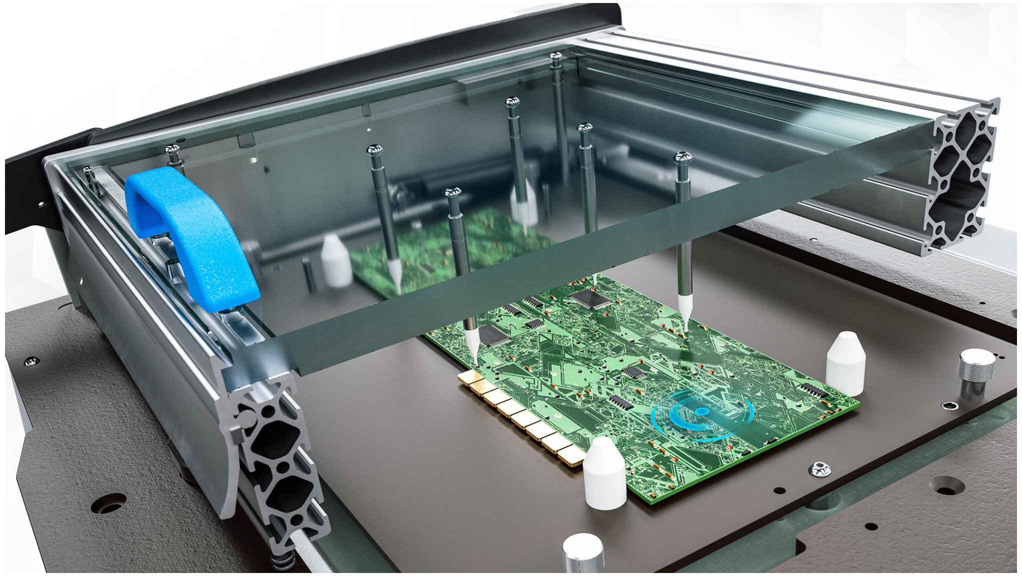
Note: Probe plate / cassette not shown

1. Printed Circuit Board DFT Considerations

Regardless of how impressive a PCB design can be, unless DFT is taken into consideration during development, testing said product can be costly.

Main Pain Points:

- Inadequate Tooling Features
- Poka-Yoke accounted for
- Component Congestion
- Test Pad Size and Spacing



Note: PCB Tooling Cross section

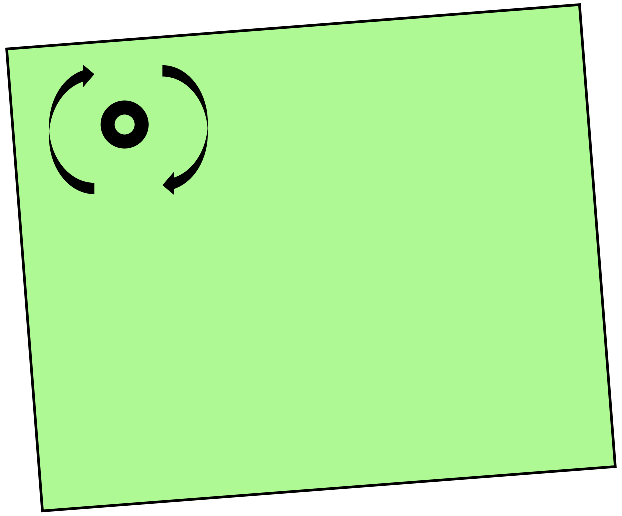
1. Inadequate Tooling Features

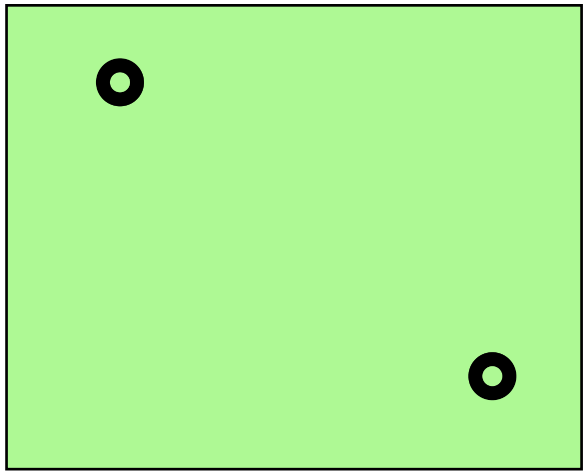
At PCB level the most common practice for tooling a PCB during is to use stainless steel “Tooling Pins” in board tooling holes designated during development.

Proper tooling pin size calculated by subtracting .10 mm from the tooling hole diameter in PCB.

At least 2 tooling pins should be used to control axial movement of the PCB in each axis.

Imagine each tooling pin as a pivot point. More than 1 is needed to stop rotation.





1. Tooling Pins

When selecting tooling pin, always keep into account a **.10 mm** smaller pin diameter to tooling hole diameter.

The goal is to have precise tooling, without having a PCB binding up and getting stuck on the tooling pins when being removed after test.

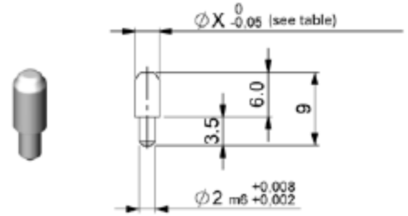
Tooling pins

Customising accessories

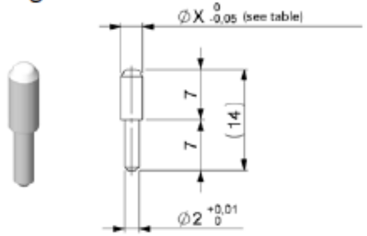
Series: FS
Design: Rigid
Type: Round
Mounting: Press in

Tooling pins (FS)

Tip length: 6.0 mm



Tip length: 7.0 mm



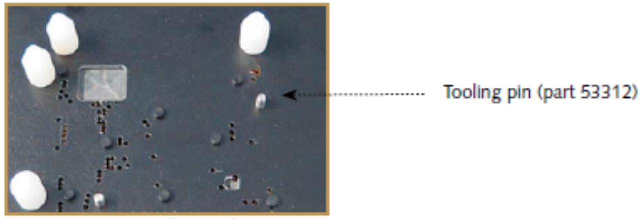
Usage

Tooling pins (FS) are used to mount printed circuit boards to be tested via the tooling holes, and to position them precisely at the contacting level in the probe field. The tooling pins are mounted in a 2H7 hole in the moving plate.

Features

- Simple, quick mounting
- Made from stainless steel, available in non-hardened or hardened version
- Tip lengths 6.0 mm (for ADPs = 4 mm) and 7.0 mm (for ADPs = 8 mm)

Customisation example



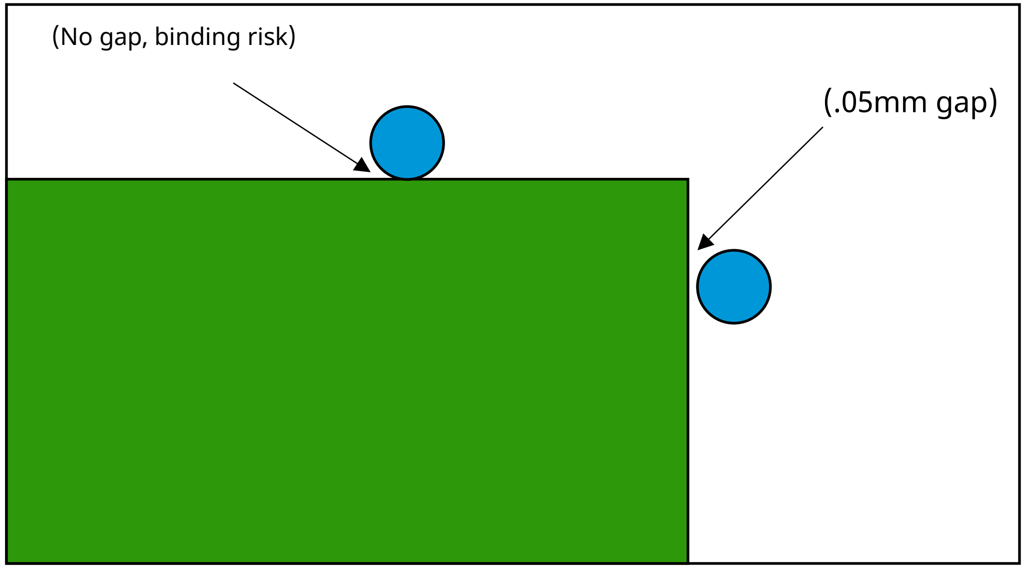
Moving plate with tooling pins (FS)

1. Caging Features / Binding Risk

In some cases, when tooling holes are not available, a PCB will need to tooled by caging the perimeter of the PCB.

Ideally 8 pins are used with 2 in each corner of the PCB. (Assuming square shaped PCB). The same thought process comes into play. The caging pin should not be placed tangent to the PCB, rather a **~.05mm** gap between the PCB edge and the edge of the caging pin.

ONLY place caging pins on routed edges of PCB, break away areas on a PCB do not give a surface with a mechanical tolerance to tool from.

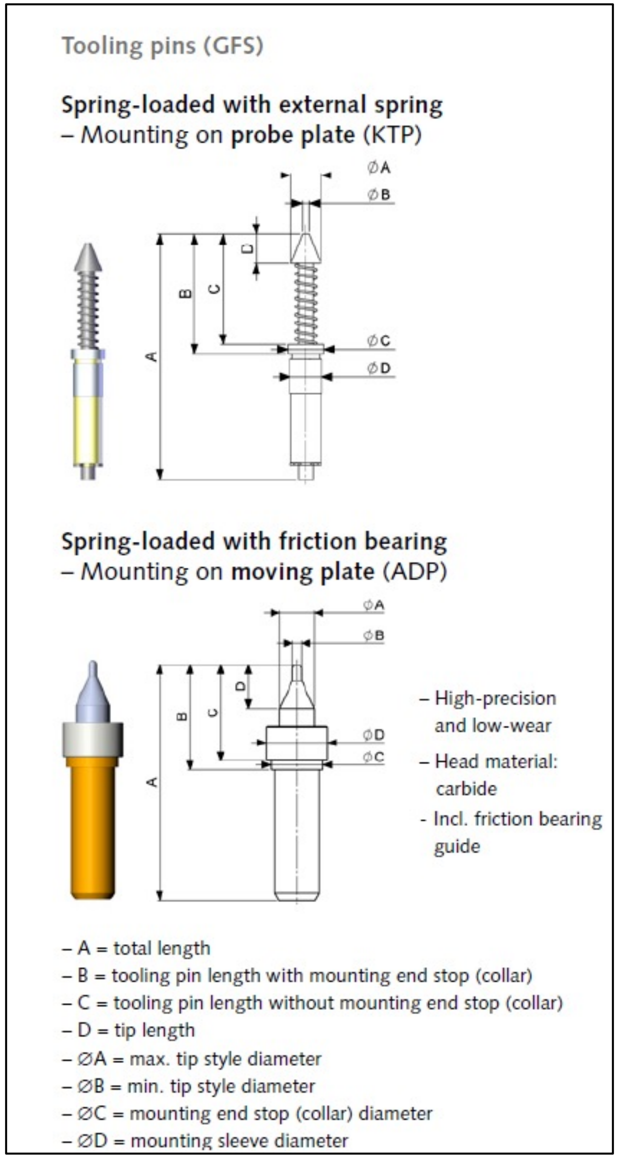


1. Alternative Tooling Options

Spring Loaded Tooling pins with a conical tip work as a self centering tooling option.

This removes the risk of binding and gives variability for PCB tooling hole sizes that may be a non-standard size.

Good option for testing a PCB in plastic housing with the need to tool to plastic housing. Help alleviate the tolerance of molded plastic parts



1. Poka-Yoke - Japanese term for “mistake proofing”

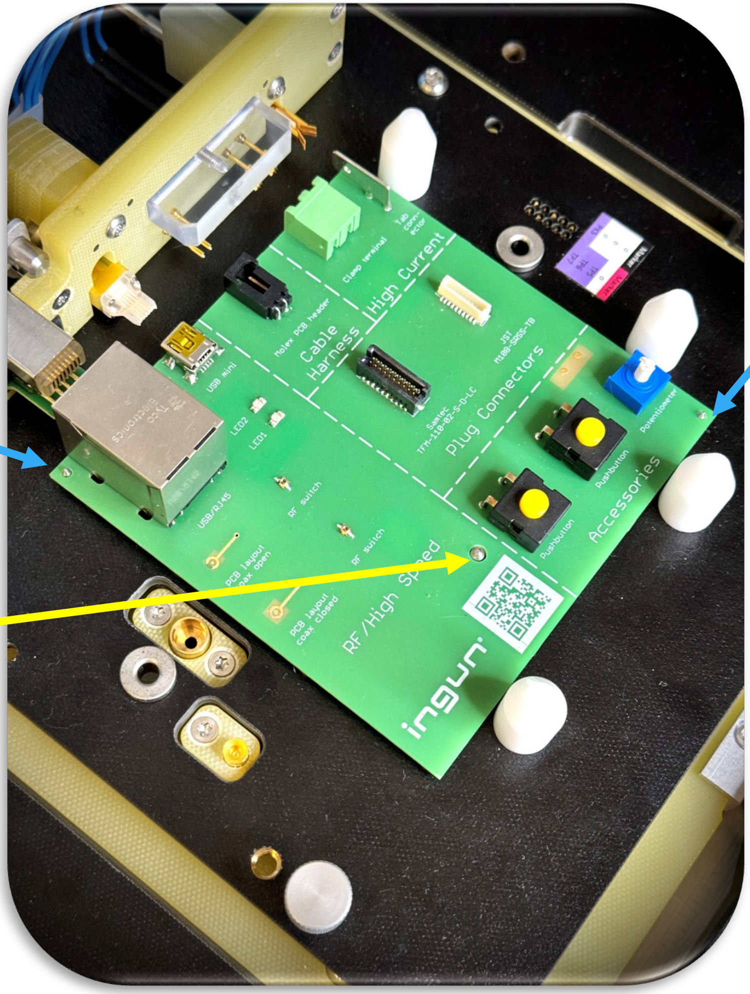
Take into account during design poka-yoke, when the physical product has features that allow for the PCB to be tooled or nested in a way that allows for the PCB to be placed only one way into the test fixture.

Poka-Yoke Features:

- Asymmetric PCB Tooling Holes
- Asymmetric shaped PCB
- Large SMT Connectors (USB, RJ45, HDMI, etc…)
- Opening in PCB for poka-yoke feature

(PCB Tooling Pin)

(Poka-Yoke Pin)



(PCB Tooling Pin)

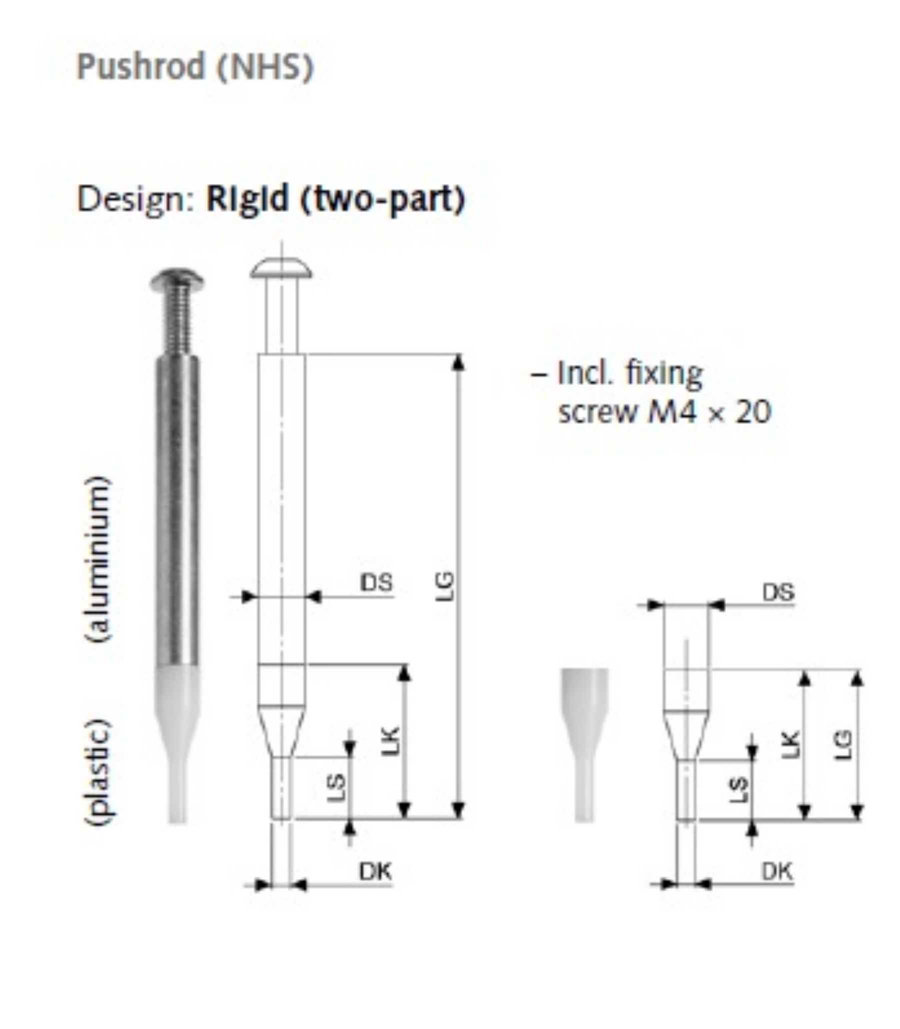
1. Component Congestion

Sometimes PCBs are designed with the mindset of making the smallest physical package as possible.

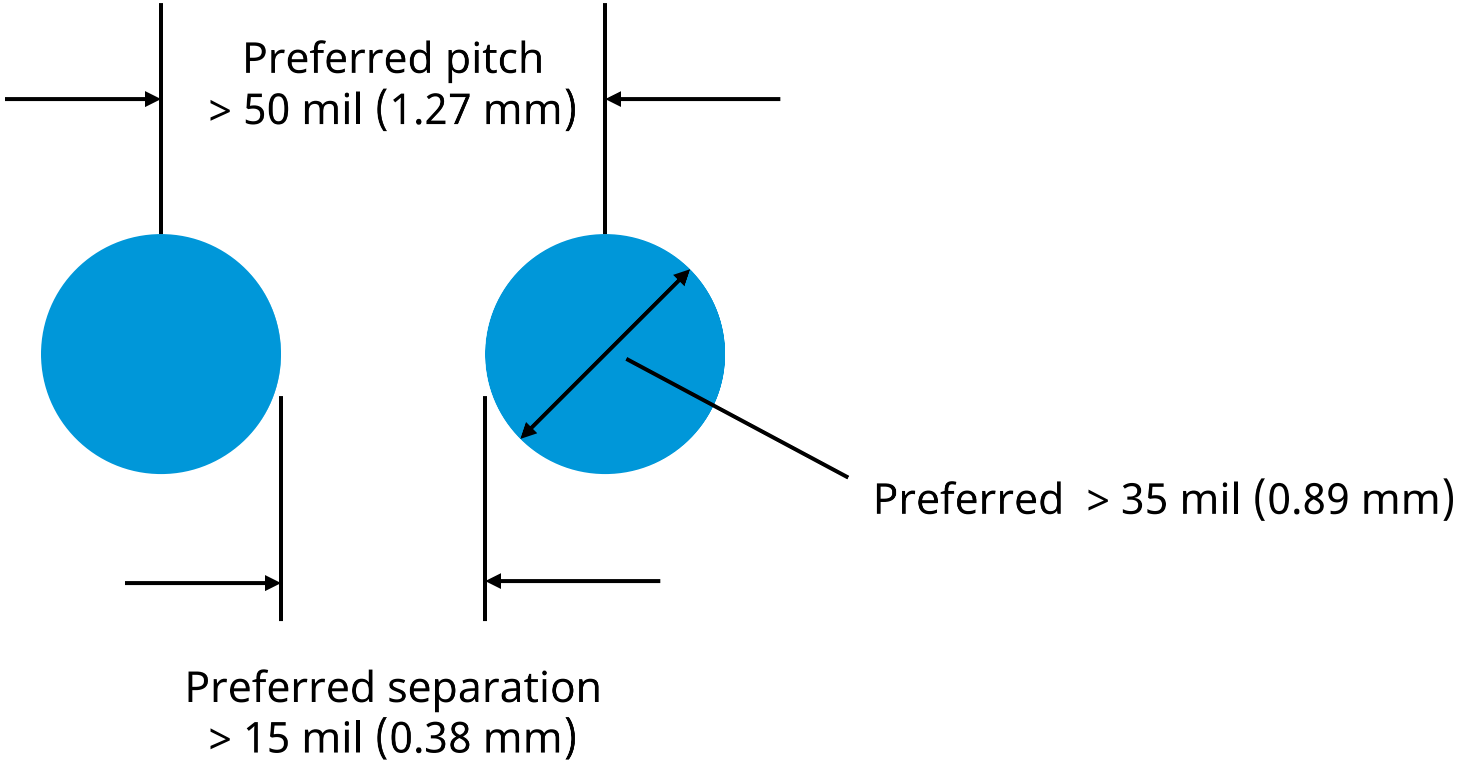
With a bed of nails test fixture, the PCB under test is being pushed down into the spring-loaded test probes. Typical practice is to use push rods that will push on the PCB and counteract the force of all of the test probes.

More “Topside” components = **Less real-estate** to place push rods.

Depending on test probe locations, not being able to place sufficient amount of push rods can greatly increase the risk of stress on the PCB and possibly damage.



1. Minimum Desirable Test Point Size and Clearance



Note: SMTA TP-101E 2014

1. Test Point Minimum Spacing

Center Center: 2.2 mm
In between pads: 0.45 mm

Center Center: 2.0 mm
In between pads: 0.45 mm

Center Center: 1.84 mm
In between pads: 0.45 mm

Center Center: 1.74 mm
In between pads: 0.45 mm

Center Center: 1.8 mm
In between pads: 0.4 mm

Center Center: 1.61 mm
In between pads: 0.4 mm

Center Center: 1.51 mm
In between pads: 0.4 mm

Center Center: 1.27mm
In between pads: 0.25 mm

Center Center: 1.17 mm
In between pads: 0.25 mm

Center Center: 1 mm
In between pads: 0.20 mm

Legend

100 mil

75 mil

50 mil

40 mil

Note: SMTA TP-101E 2014

1. Small Test Pads

When internally or the largest test pad designed into the PCB can save time and cost down the line.

There is no set standard for what test pad size is achievable to contact. This is all based on if this is being done internally or being outsourced out.

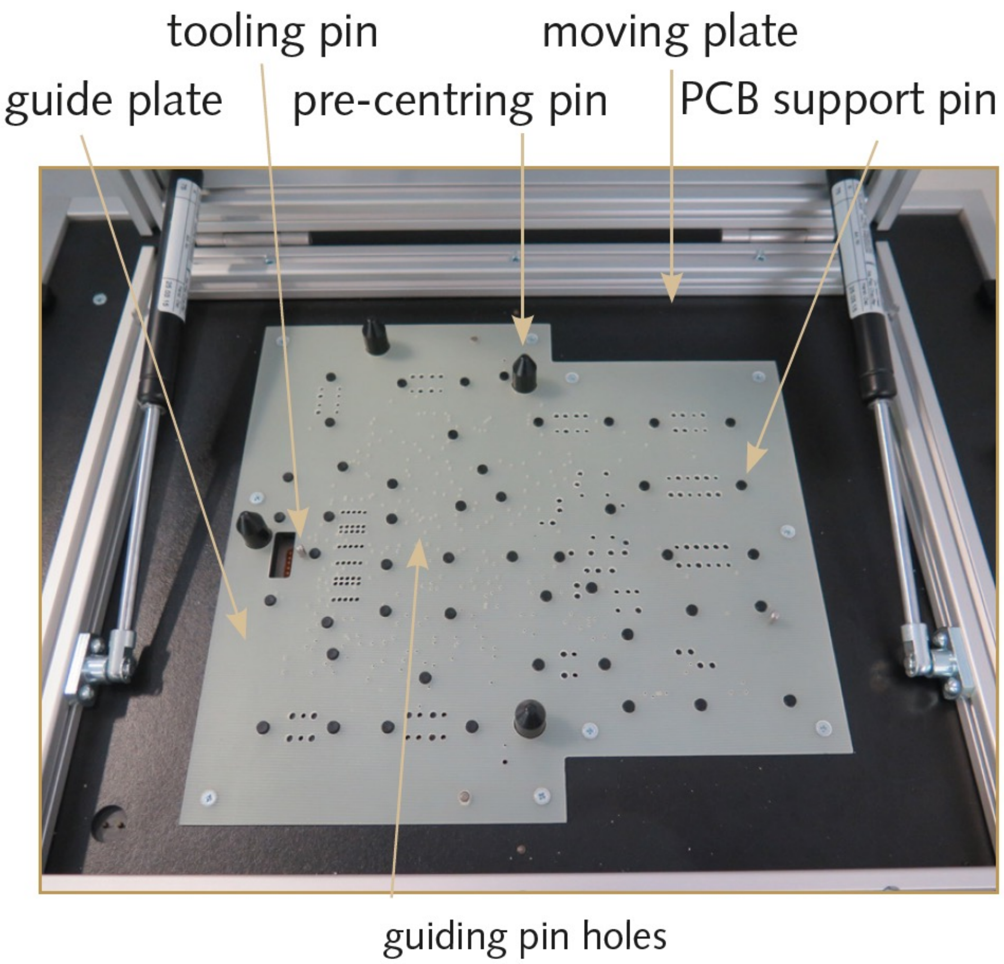
Smaller targets usually indicate a closer probe grid. Smaller probes and receptacles are not only more expensive, as well prone to breaking during installation and maintenance.

With reduced size receptacle size the drill diameter size gets smaller.

- **50 Mil : 0.98 – 1.00mm Hole Size**
- **100 Mil : 1.69 – 1.70mm Hole Size**

More machine expertise is needed the smaller the mounting hole needs to be.

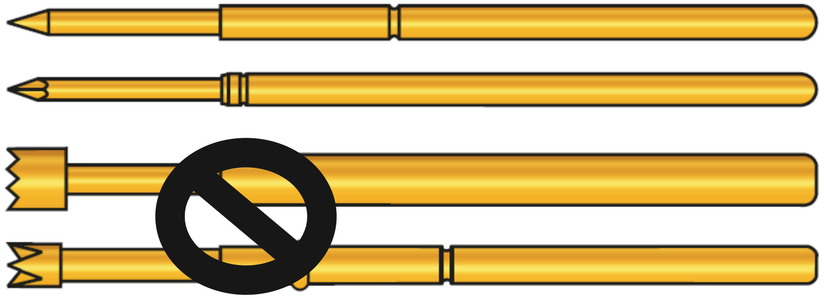
1. Alternative Targeting Method



One option to help probe small targets is to use a **guide plate**.

A guide plate is mounted on the moving plate directly below the PCB being tested. To act as a funnel for the spring-loaded probe targeting the PCB.

The holes will be drilled slightly larger than the spring-loaded probe itself. Only **headless probes** can be used with a guide plate.



02

Introduction: General test probe design

2. General Test Probe Design

<u>Plunger</u> 

The plunger is the **moving part** that contacts the DUT. It is biased to ensure contact through the barrel.

<u>Barrel</u> 

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

<u>Spring</u> 

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

2. Different probe types

Main categories:

1. Standard test probes
- Single ended
- Double ended

2. 4-wire test probes
- Two probes in one for Kelvin testing / with center and outer conductor

3. RF and high-speed digital
- Coaxial
- Board to board
- Differential
- Contacting modules

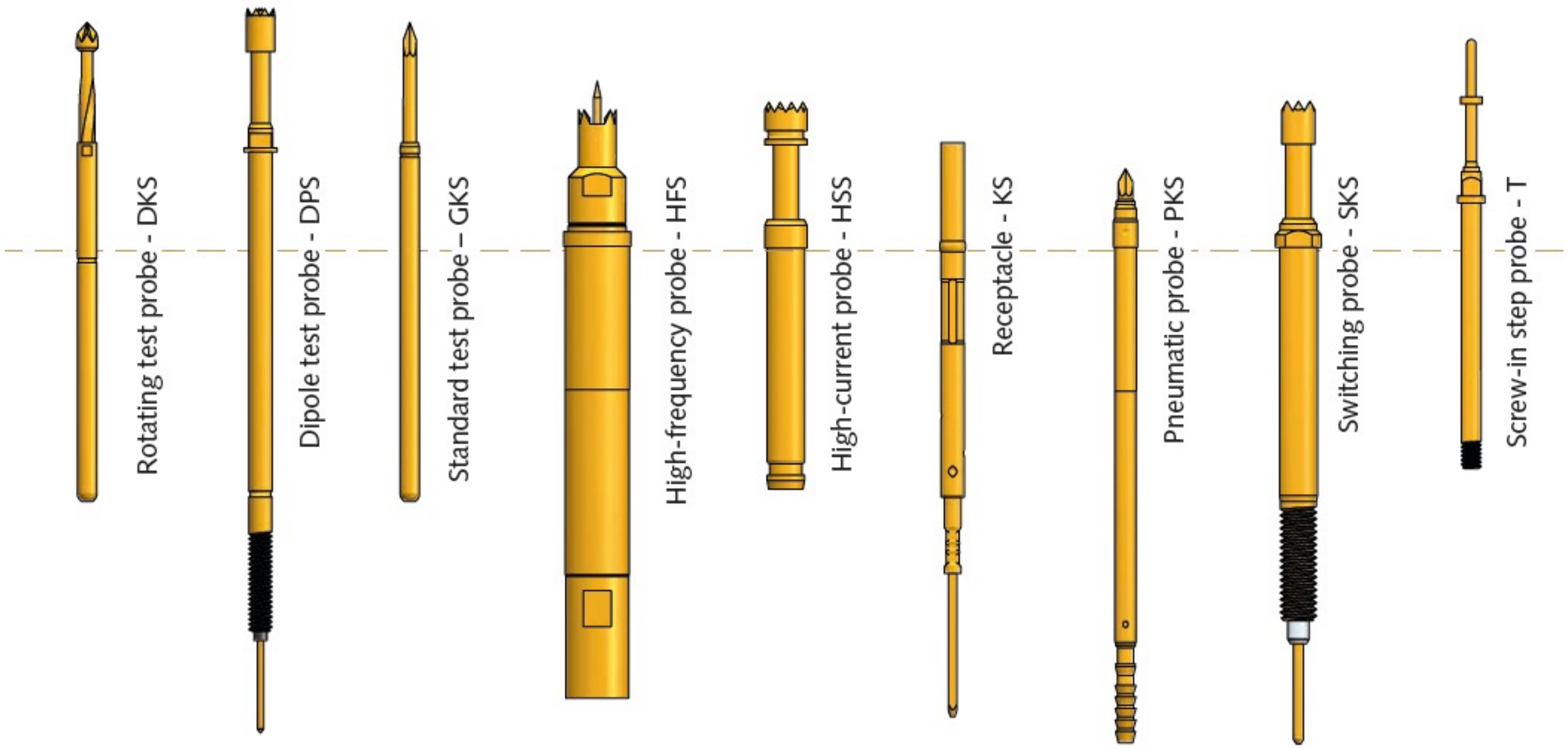
4. Probes with SPST switch

5. Fine pitch versions

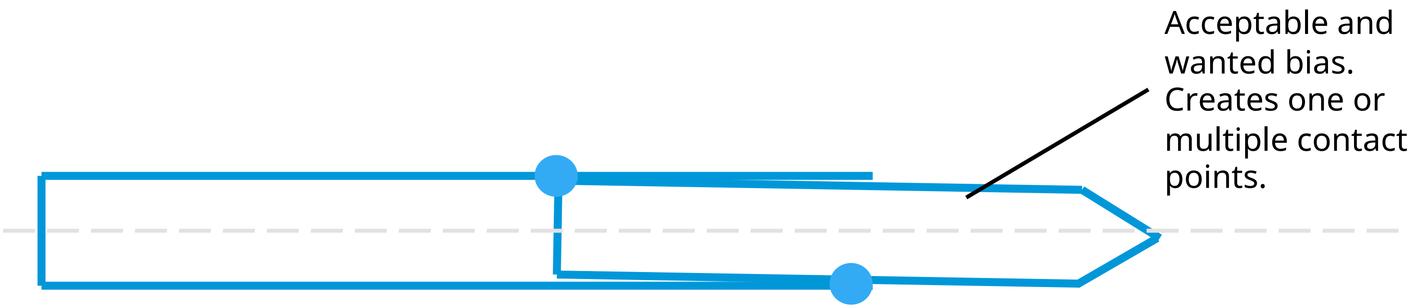
6. Pneumatic probes

7. Wire harness probes

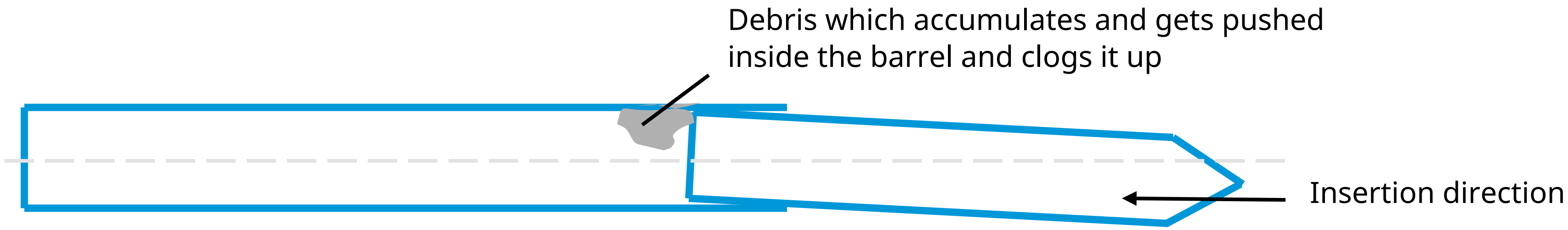
8. Battery cell test probes



2. Different probe types



Proper biasing: If the plunger were to go in 100% straight, no internal contact would be made with the barrel, so biasing is a wanted effect.



Excessive biasing: This can be caused by a clam-shell type fixture that does not have a linear actuator. Heavy side loads are the silent killer of a test probe. For this reason linear action test fixtures should always be used (linear overclamp / drive unit).

2. DFT – Test point sizes per SMTA specs

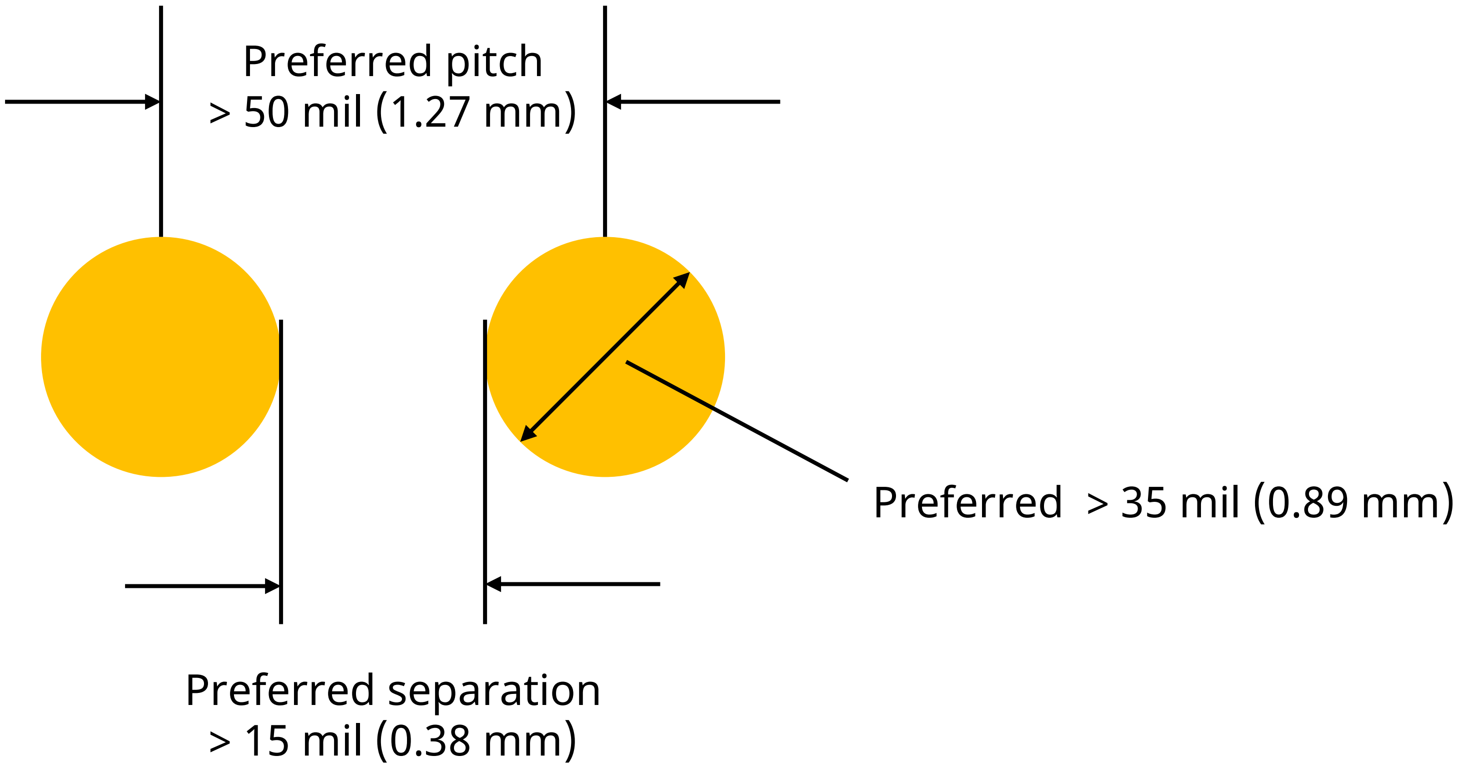
According to SMTA TP-101E 2014

Target size top side probing	Target size bottom side probing	Remarks
35 mil	30 mil	Preferred target size when tooling holes are available. We realize this is more and more difficult to achieve.
25 mil	22 mil	Guided probe platen needed inside test fixture + zero flex. It will increase costs.
20 mil	18 mil	Requires proprietary fixture technology. You can use such small points but at decreased FPY and contact repeatability.
< 20 mil	< 18 mil	Not preferred for standard PCBA testing. Avoid if you can.

2. DFT – Test point sizes per SMTA specs

According to SMTA TP-101E 2014

- SMTA specs call out .89 mm pad for the TP and min. 50 mil pitch
- But many applications these days need <50 mil (25/40 mil)
- Sometimes PCBA probing requirements at down to 0.35 / 0.3 mm (!!) = **11.8 mil**



03

Socketless probes designs and suitable fixture kits

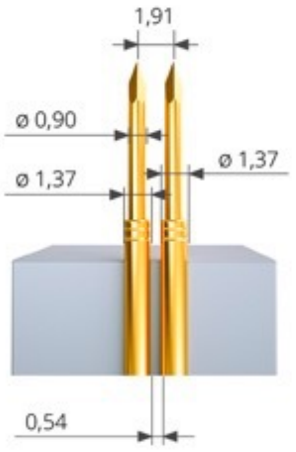
Larger probes in a smaller grid

3. Socketless probe design and fixture customization

Idea: Use larger form factor probes in a smaller grid (by skipping the receptacle)

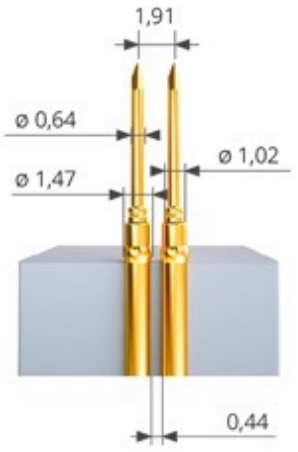
Detail std. 75 mil

(w/o receptacle)



Detail std. 75 mil

(with receptacle)



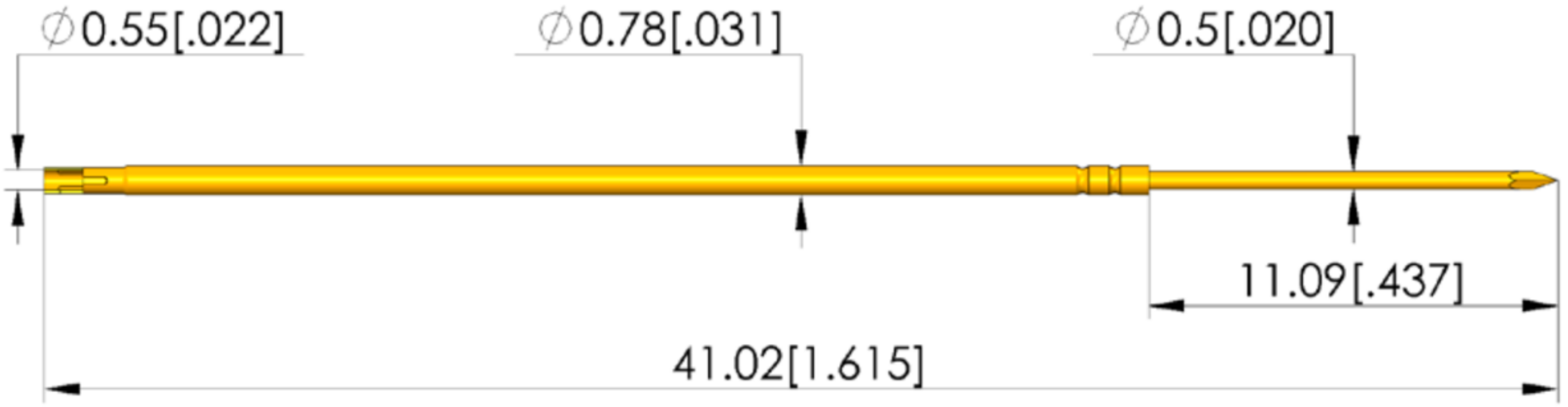
Left: Socketless 75 mil (without receptacle)

Right socketed 75 mil (in receptacle)

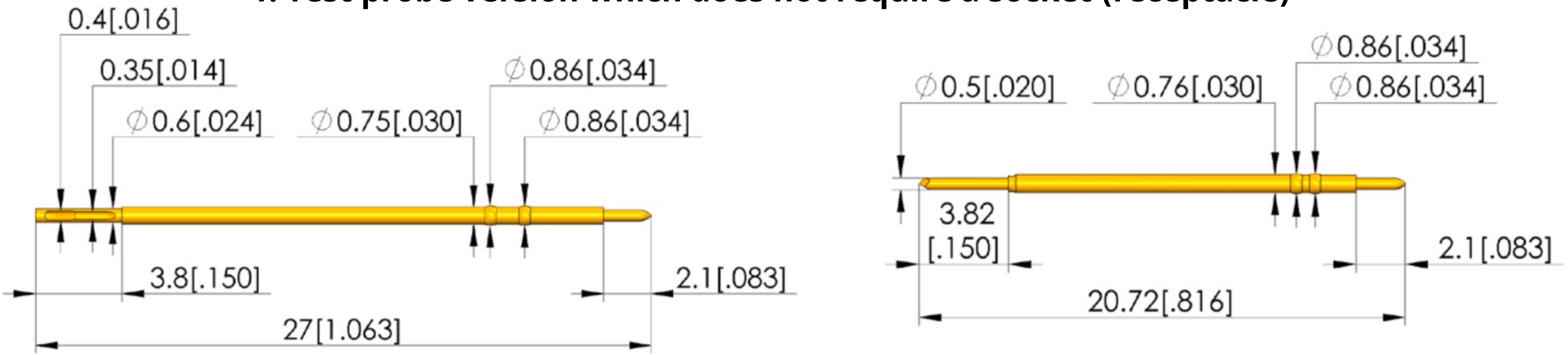
- Larger test probes in common grid sizes compared to conventional test probes with a receptacle.
  - → Mechanically more **durable**, robust test probes
  - → Accurate testing in small grid sizes
  - → More precision and repeatability

- For socketless probes, the pitch distance is determined by the **diameter of the test probe**.

2. Socketless probes



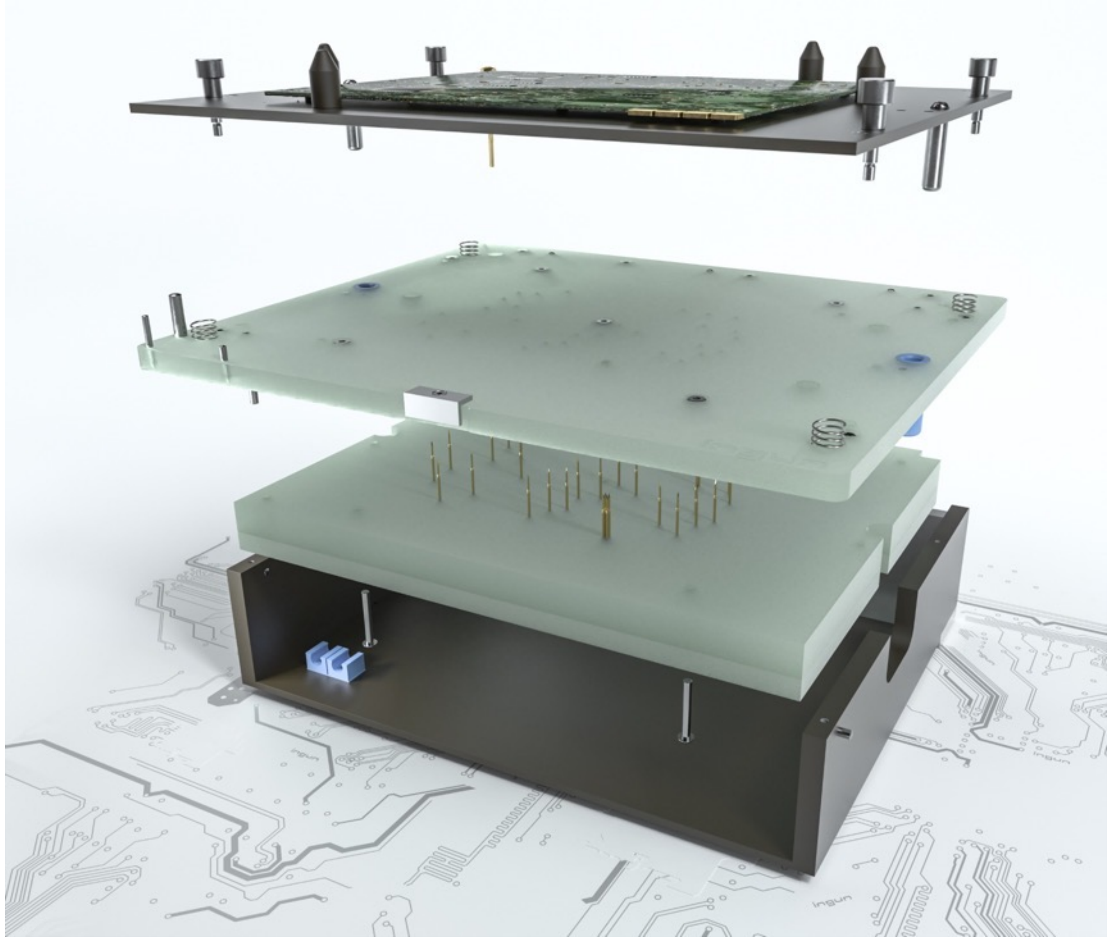
1. Test probe version which does not require a socket (receptacle)



2. Two versions of terminations, wire grip (crimp) = left, spring-loaded = right

3. Fixture design for socketless versions, probe integration

Stacked-plate design



Freely adjustable installation height

The installation height (test probe and contact terminal) is adjusted by varying the insertion depth of the contact terminal in the plate. For this, special insertion tools are used.

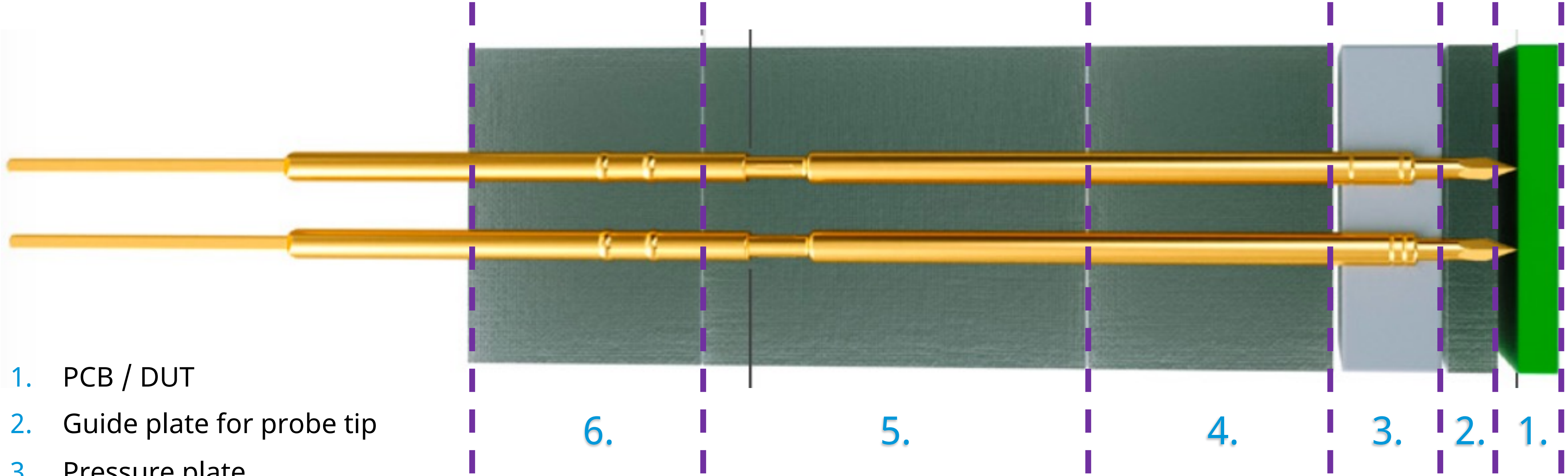
Contacting accuracy / contact reliability

Usage of two press rings ensures centric alignment of the contact terminal in the mounting hole.

Integration and installation in common test fixture designs:

Standard as well as long stroke versions for dual-stage applications can be implemented

3. Stacked plate design / “nomenclature” / definitions

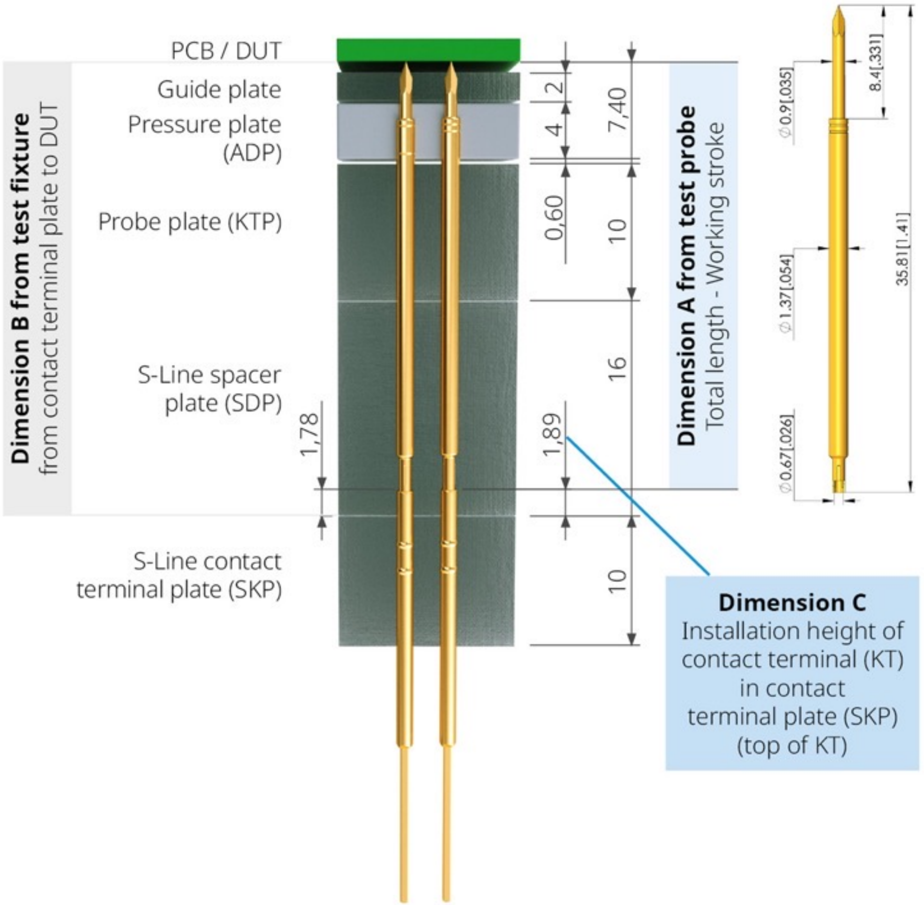


1. PCB / DUT
2. Guide plate for probe tip
3. Pressure plate
4. Probe plate
5. Spacer plate
6. Contact terminal plate

- Conventional fixture: 1 probe plate + stripper plate (optional but recommended)
- Socketless fixture: 5 plates in total (more complexity, but smaller pitches possible)

3. Calculation of the correct installation height of the contact terminal for optimum contact

75 mil version



Calculating the contact terminal's necessary installation depth (dimension C) in the probe plate:

Dimension A:	Length of test probe at working stroke (Total length test probe minus working stroke)
Dimension B:	Distance from to top side of the contact terminal plate's (SKP) to bottom side of DUT when the test fixture is closed (actuated at working stroke)
Dimension C:	Installation depth of contact terminal = **Dimension B – Dimension A** (Exemplary calculation, may vary with different manufacturers)

The thicknesses of plates used in the test fixture should be dimensioned so that both press rings of the contact terminal sit at least 0.5 mm in the contact terminal plate (measured from both the top and the bottom of the contact terminal plate).

3. Connection techniques improved connection reliability

1. Wire-Wrap

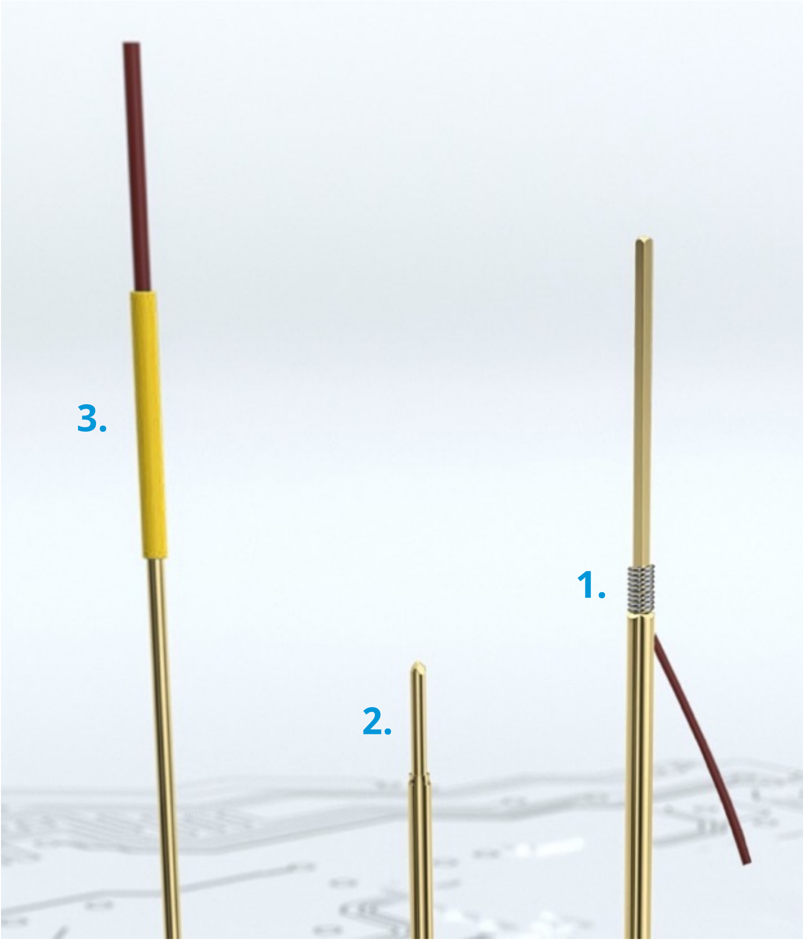
- Cable wire is wrapped around a square post at the base of the contact terminal.

2. Wireless

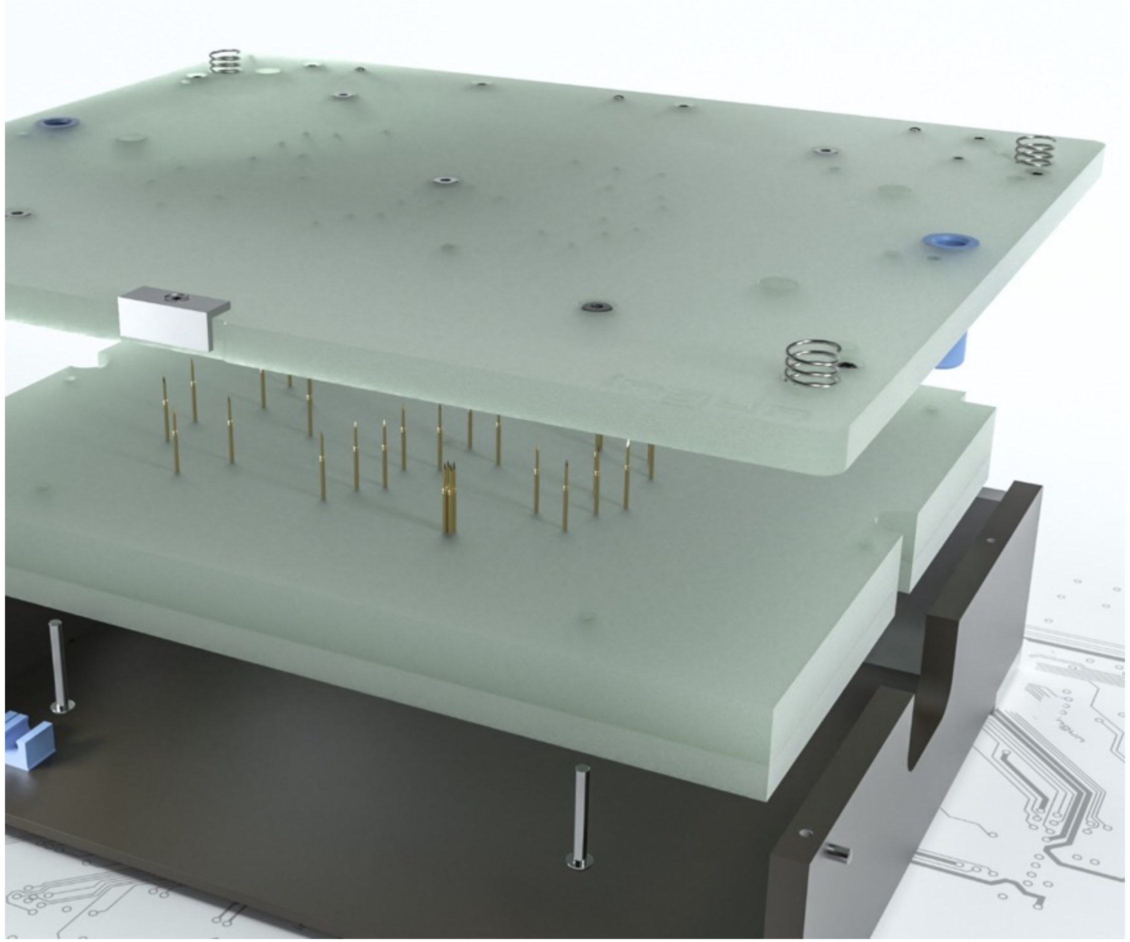
- Signal transmission is created by contacting spring-loaded plunger onto a printed circuit board (translator board) from above.

3. Wire-Grip

- The wire is inserted into the slot at the lower end of the contact terminal and securely connected with the help of a polyamide tube.



3. Correct installation of test probes and contact terminals



Probe plate installation and test probe insertion (step-by-step)

- The required contact terminals are pressed into the mounting holes in the contact terminal plate. The previously calculated insertion depth must be observed.
- The spacer plate and guide plate are installed in the guide bores using the alignment pins.
- The test probes are inserted and pressed onto the pin of the contact terminals.
- Finally, the probe plate and any additional guide plates are installed.

3. Installation tools for probes and contact terminals

Usage of proper tools is required. Hand tools are used for the following:

CONTACT TERMINALS:

1. **Insertion tool:** Inserting the contact terminal into the probe plate
2. **Wiring tool:** Used to apply polyamide tube to the contact terminal
3. **Extraction tools:** Can be used to remove defective contact terminals

PROBES:

A. **Insertion tool "only":** For headless probes / to insert into probe plate

B. **Insertion/ extraction tool "combo":** For headed probes to insert and extract

1. 2. 3. A. B.

3. Requirement for fixture houses and what to look at when choosing a fixture kit and probes

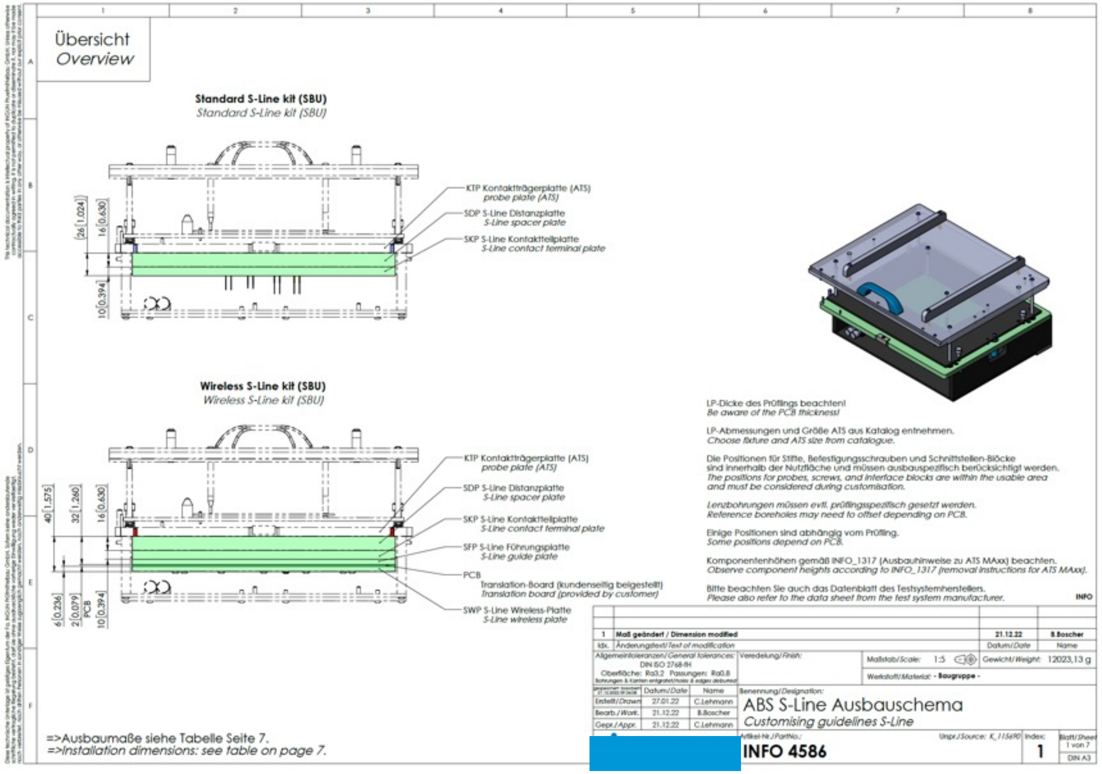
Socketless fixtures are typically customized by more experienced fixture houses, as the installation is not for the faint of heart.

For probe suppliers:

- Check if the probe supplier has detailed instruction guidelines for both the probe and the fixture.

For fixture houses:

- Is the fixture house experienced with receptacle / socketless architectures? Can they handle multiple plates
- Does the fixture house have on-site support capabilities in your region?
- Is the fixture house versed with fixture kits from various suppliers or do just use their own solutions?



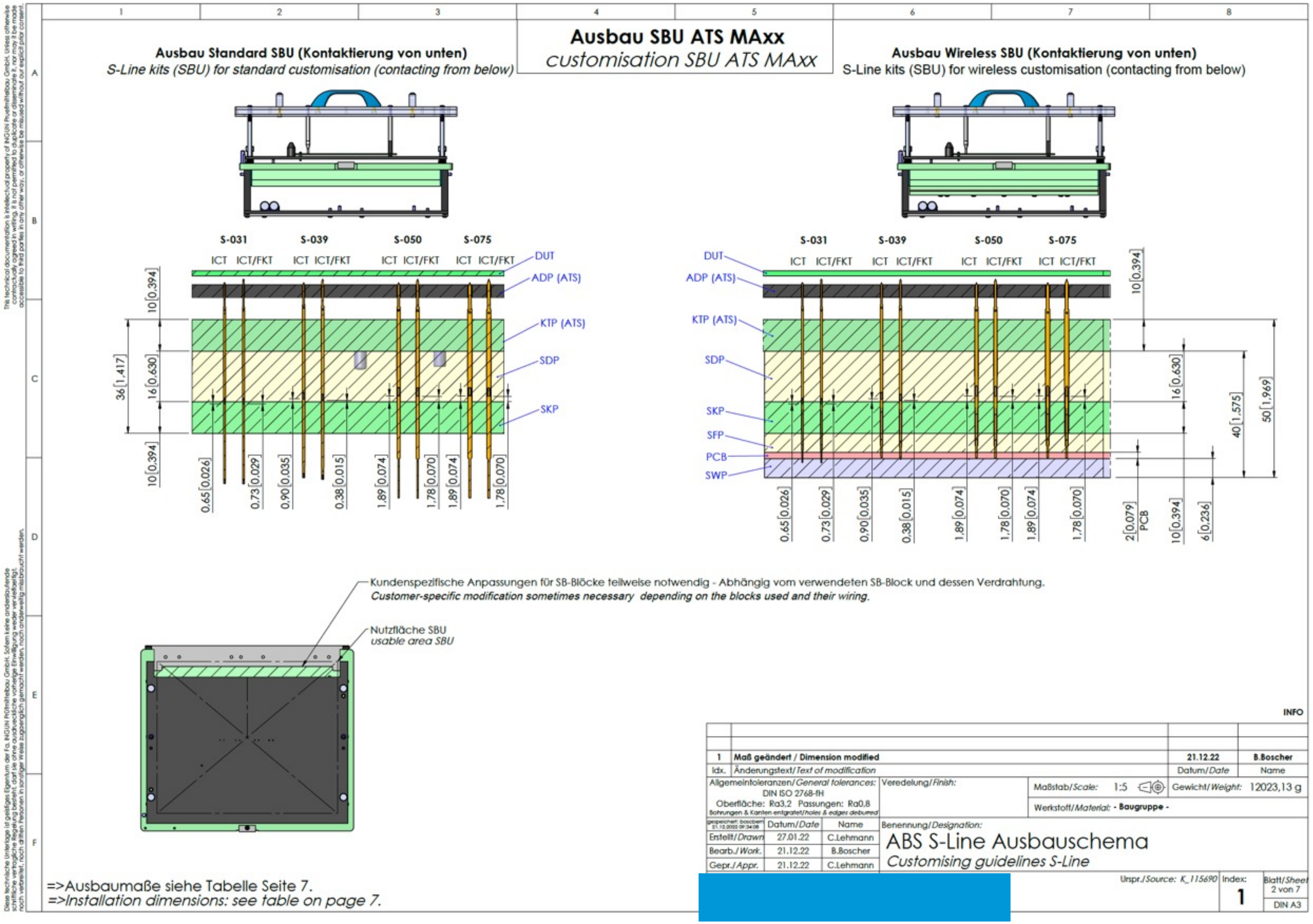
3. Excerpt from customization document

This is an excerpt from a 10-page customization document.

For socketless installation make sure you follow every step carefully with regards to spacing, installation heights etc.

Retrofits on a stacked plate design are very difficult, if not impossible.

Make sure the supplier has documentation for the fixture of your choice (for example manual fixture OR vacuum fixture etc.



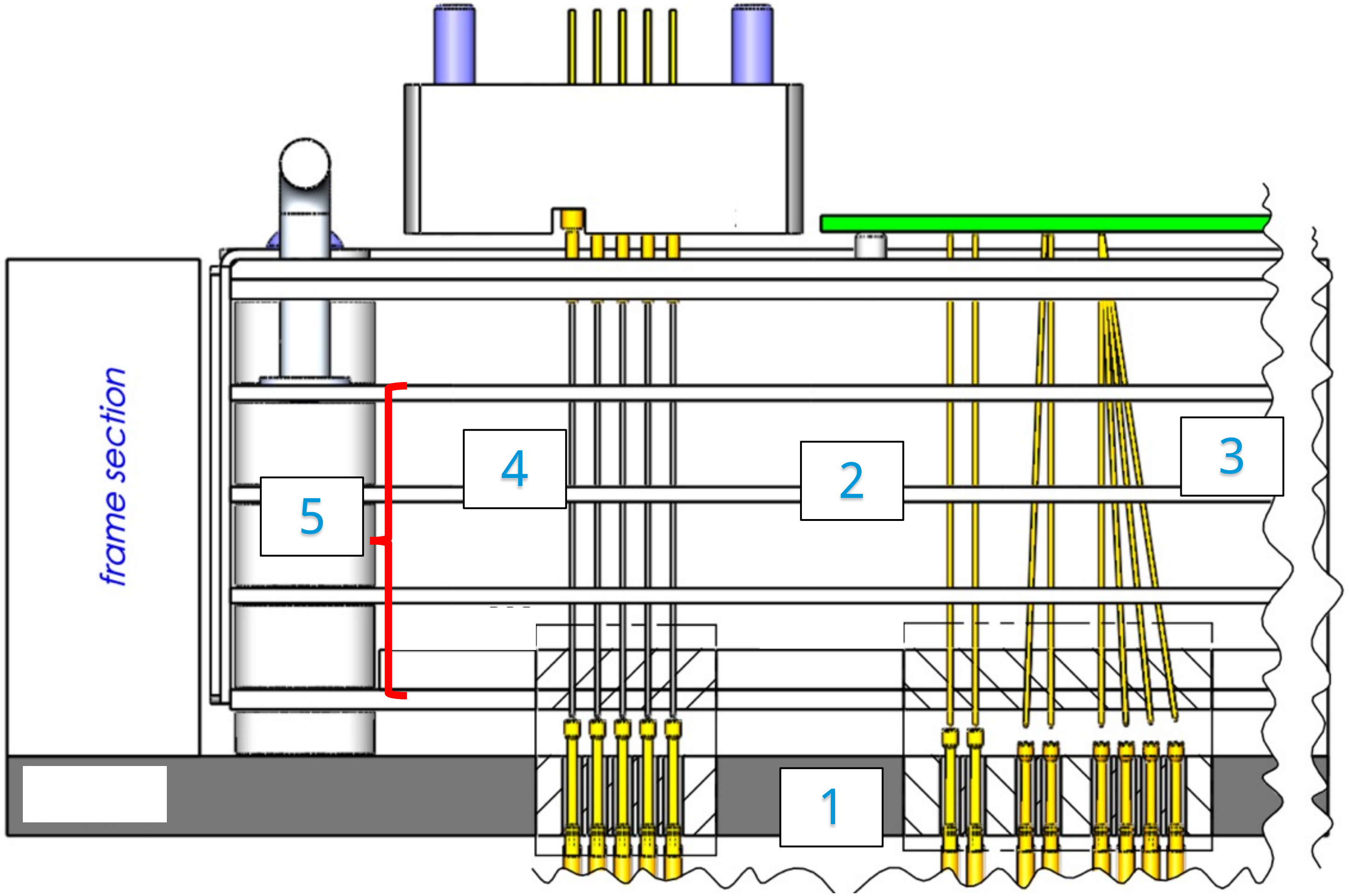
04

Rigid pin designs

Rigid needles with a driver pin

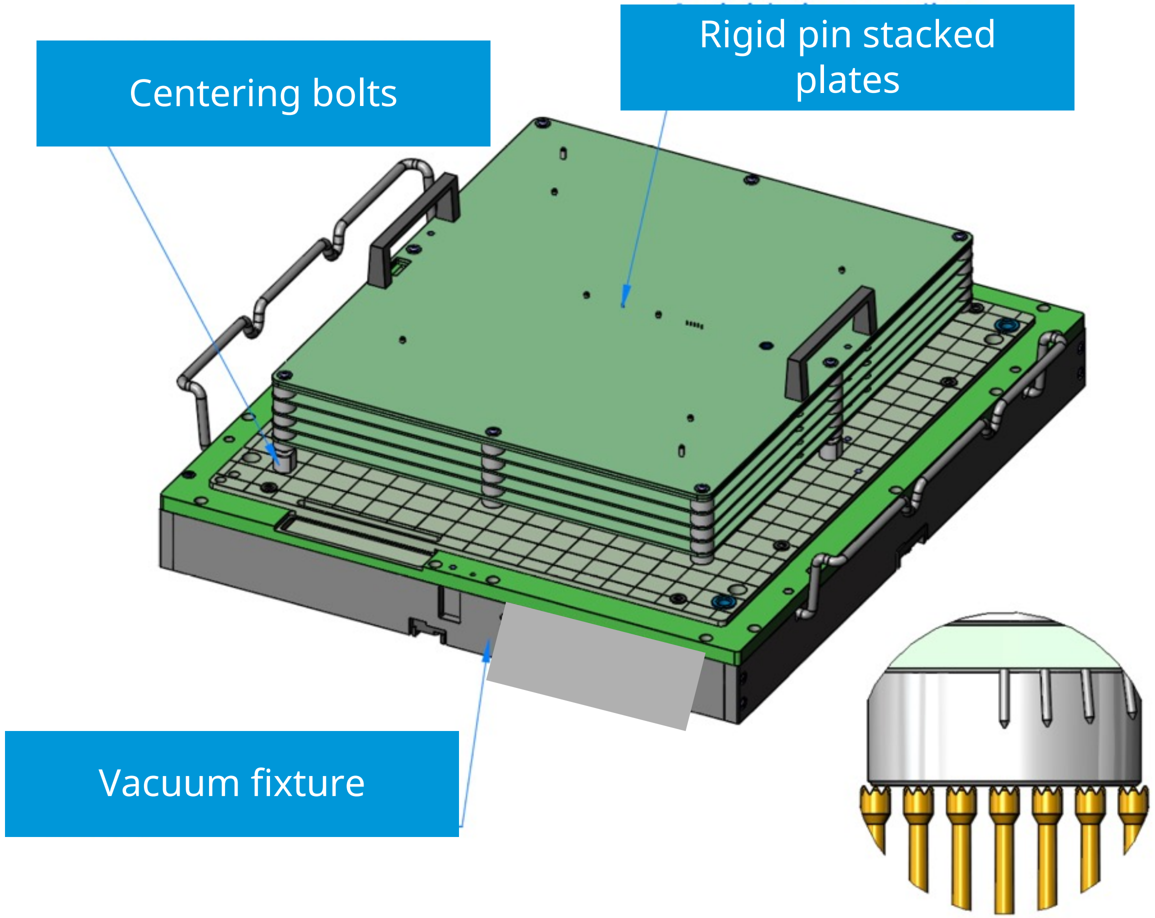
2. Rigid pin + driver pin concept

1. Driver pins, standard grid size, spring-loaded
2. Rigid pins in standard grid to access the board not installed at an angle
3. Rigid pins in reduced grid, installed at an angle
4. Rigid pins in standard grid to access a transfer pin block etc.
5. Stacked plate fixture design, for vacuum or manual fixtures



2. Rigid pins with a vacuum fixture

This design can be used on any kind of vacuum fixture, but it is especially interesting for legacy 3070 and other platforms which are still in heavy use in the industry for ICT test.



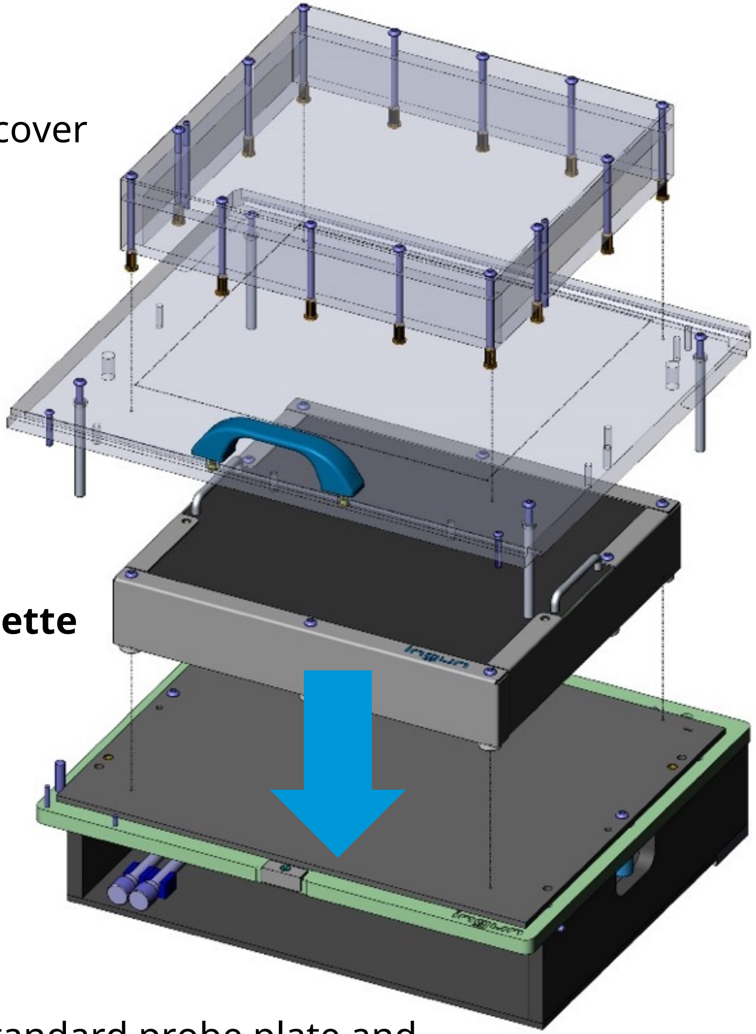
2. Rigid pin cassette for manual test fixtures

- Contacting area diameter: Ø = 0.30 mm
- Minimum standard grid: 0.50 mm (˜ 20mil)

Due to the long rigid pins:
- Optional rigid needle covers maybe needed to customize standard height overclamps

- the rigid pin cassette houses the needles
- In the cassette, the pins are deflected at a certain angle to reduce pitch by one standard grid size or more

Top: Rigid pin cover



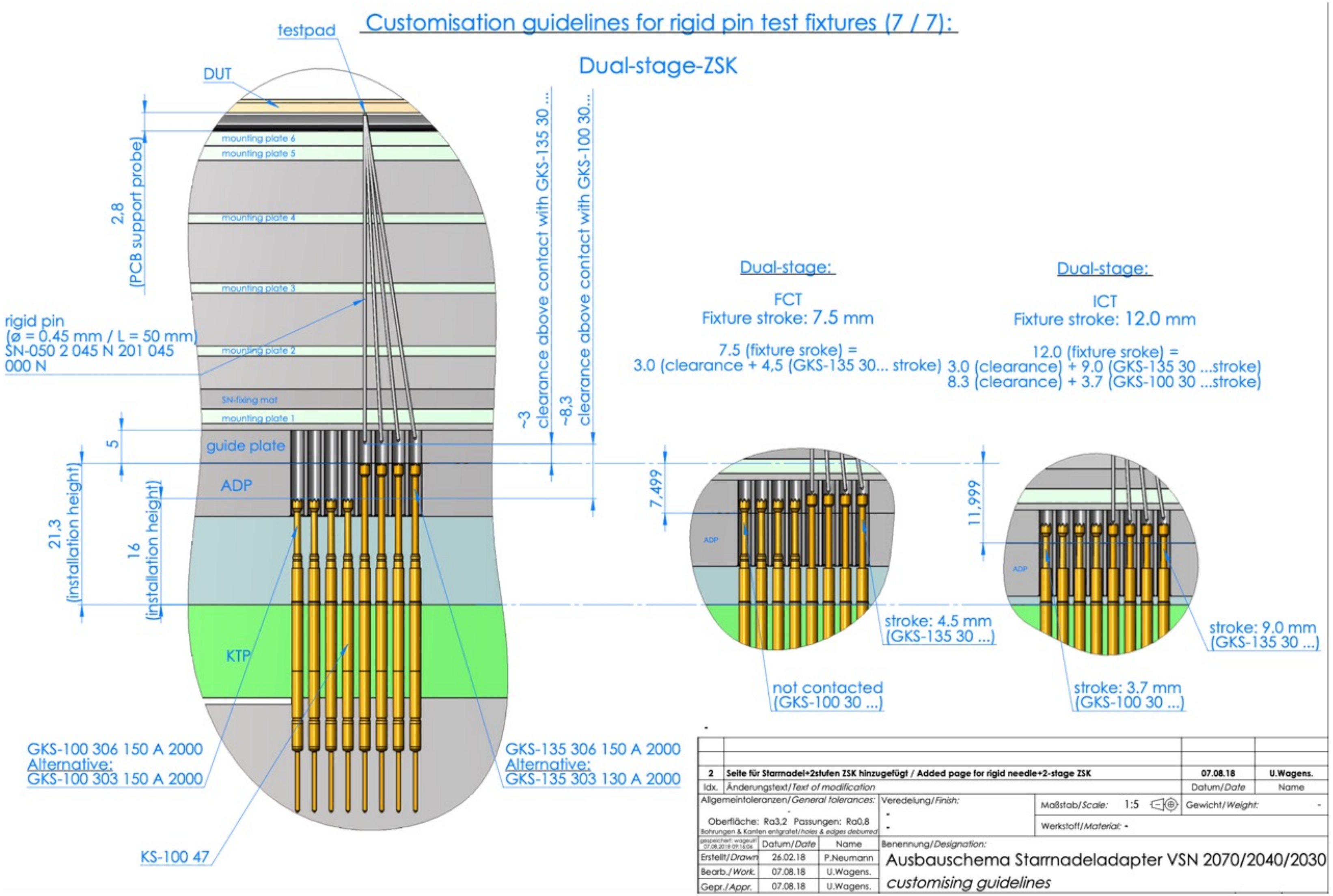
Center:

Rigid pin cassette

Bottom: Standard probe plate and stripper plate for driver pin

2. Rigid pins, a closeup view of plates and more (excerpt from customization document)

Notice the fixing plate and mounting plate design. Here shown for dual stage ICT/FCT

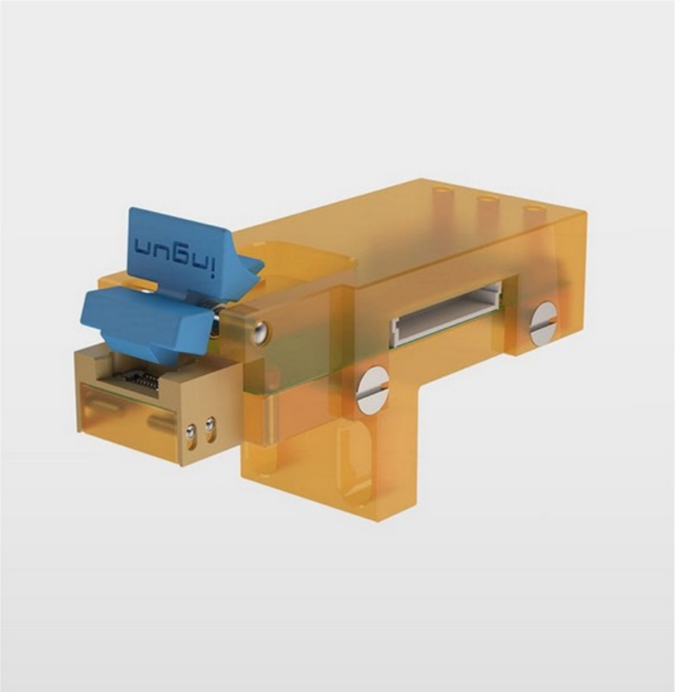


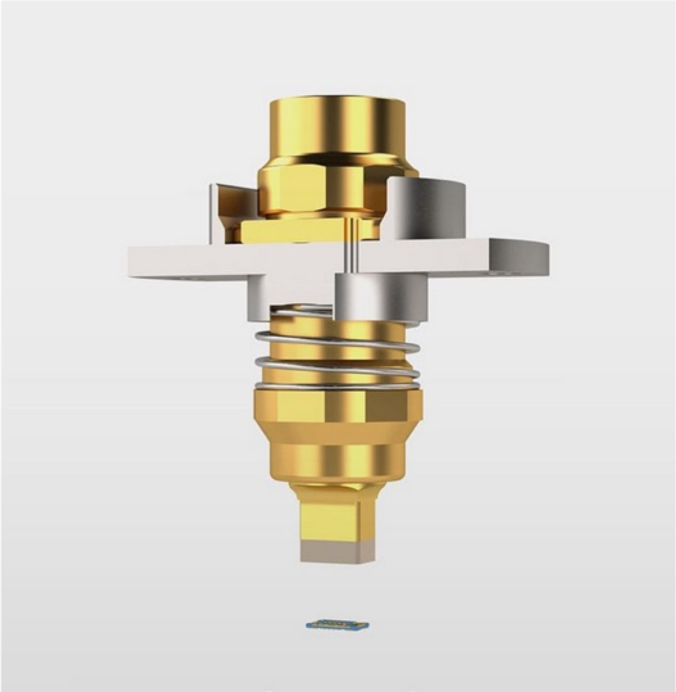
05

Probing onto connectors: Multi-Pin Designs

For connector contacting

5. Probing onto B2B Connectors / Multi-Pin Designs



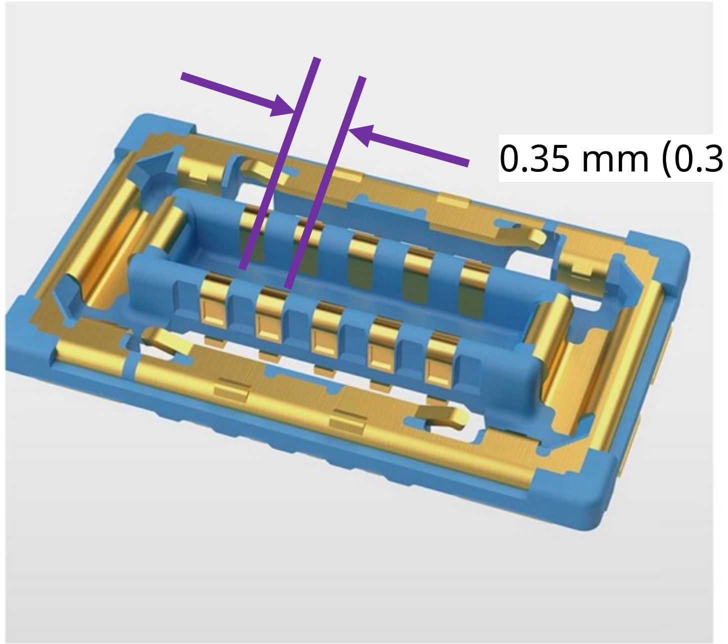


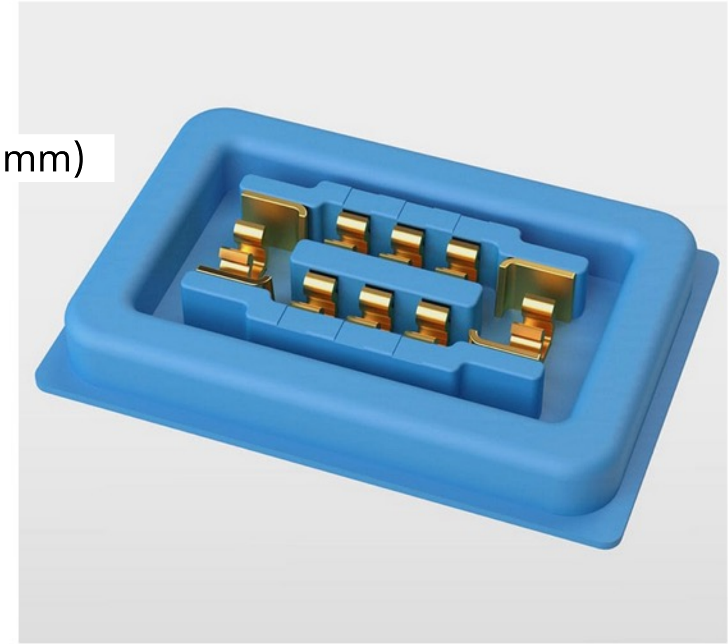
Advanced probe designs for RF and wireless test for use with small pitches:

- interposer (left) – does not require “conventional” test fixture. Acts as a clamp.
- test socket (middle)
- test probe with blade-pins (right)

5. Probing onto B2B Connectors / Multi-Pin Designs

Target connectors



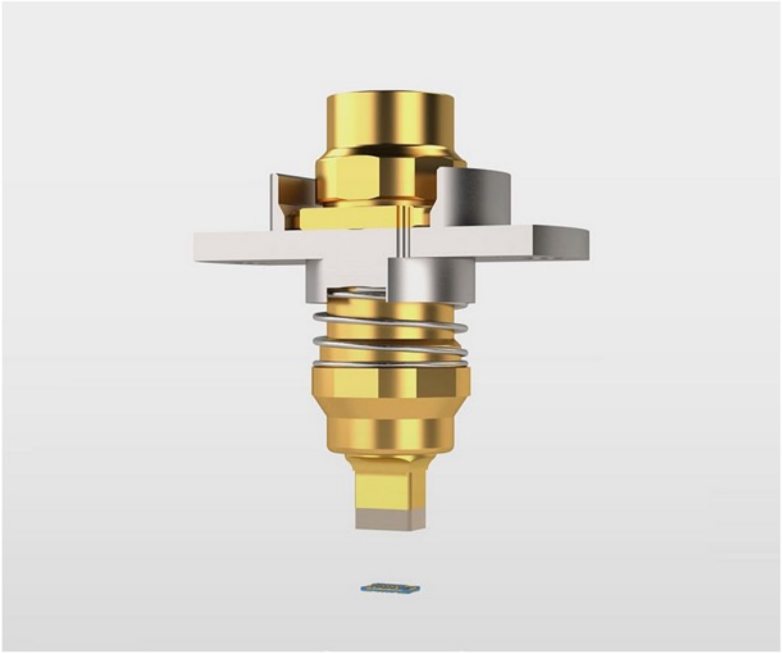


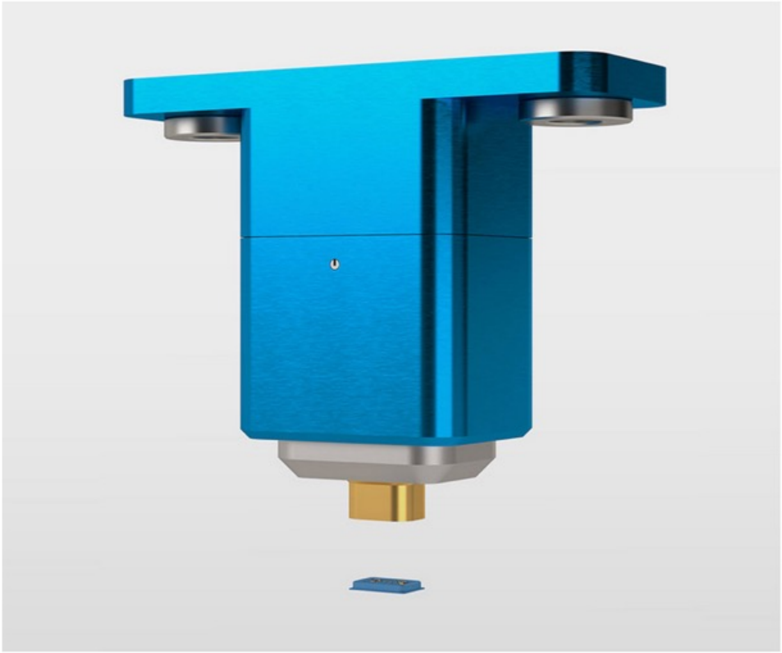
Left: **First-generation B2B connector:** The contacts are arranged in two rows.
Right: **Second-generation B2B connector:** Front-end RF contacts ensure good RF isolation (crosstalk)

Pitches: 0.35 mm standard, 0.3 mm also available

5. Probing onto B2B Connectors / Multi-Pin Designs

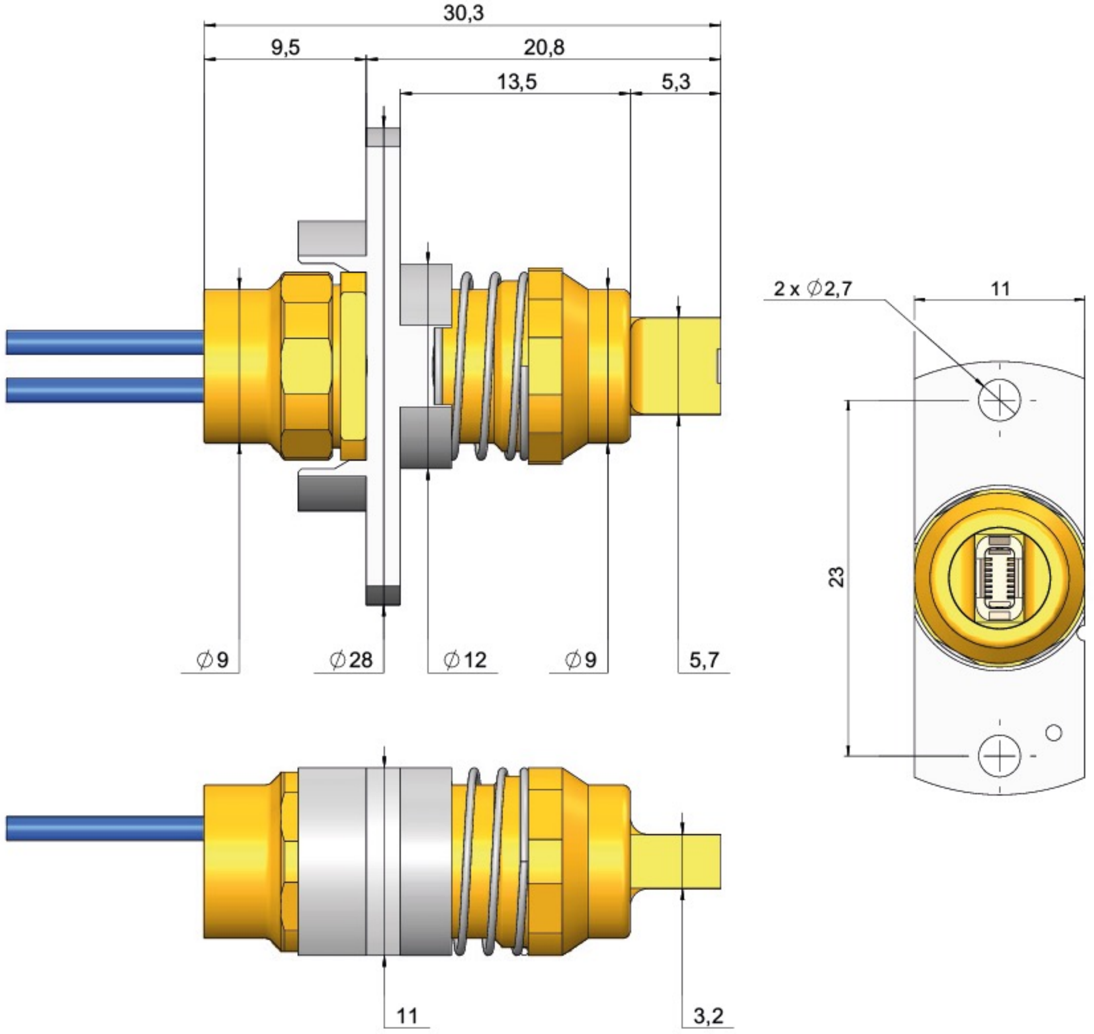
Designs

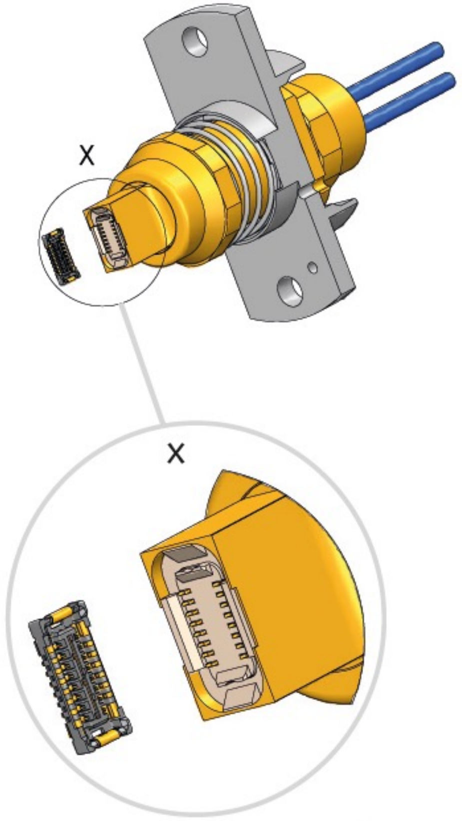




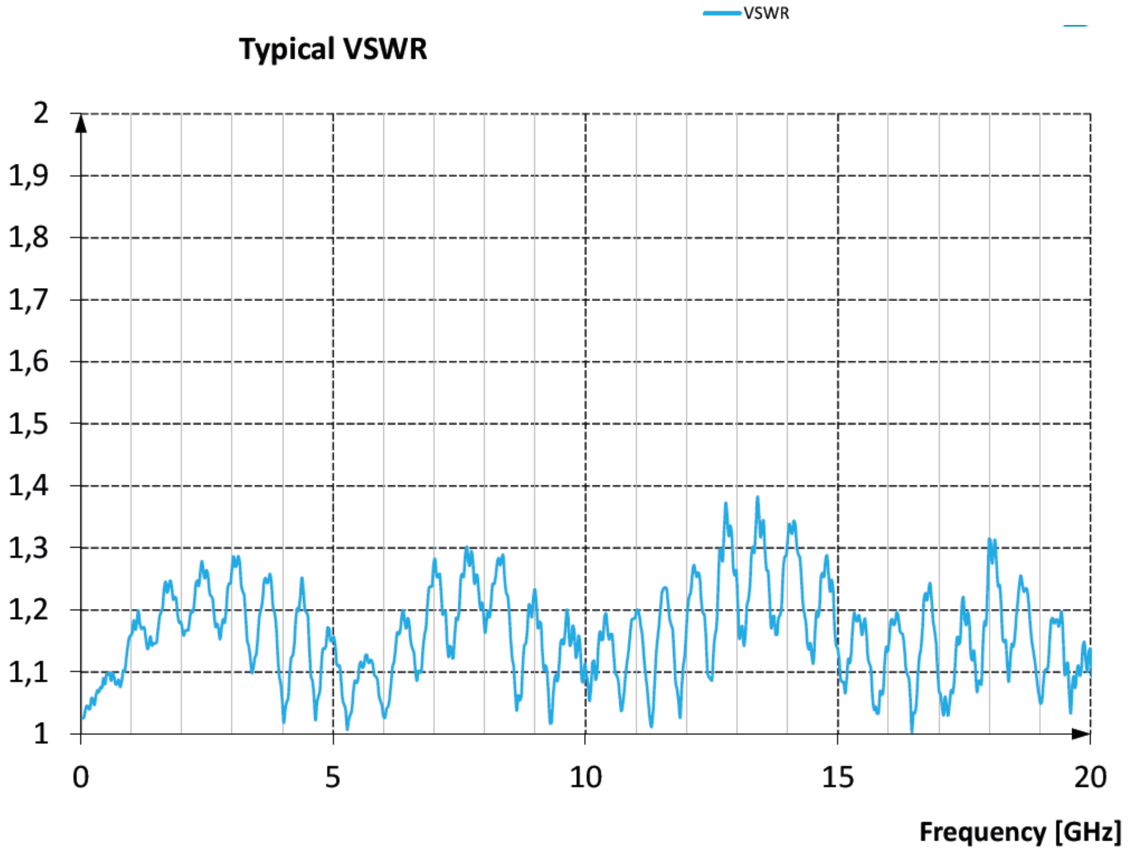
- Equipped with blade-pins (electroformed) or “traditional” fine pitch probes
- Architecture: “RF **probe-style**” (left) with flange mount and outer spring for self-alignment OR “RF **test plug** style” (right)

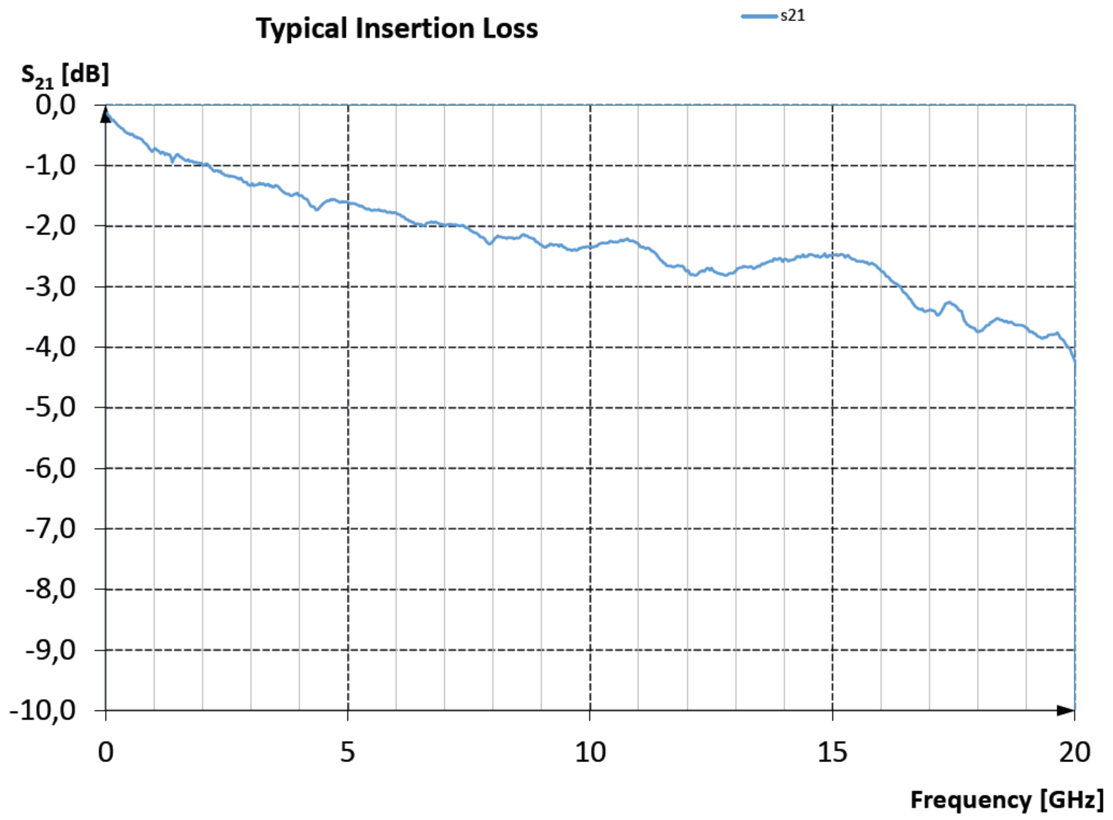
5. Probing onto B2B Connectors / Multi-Pin Designs



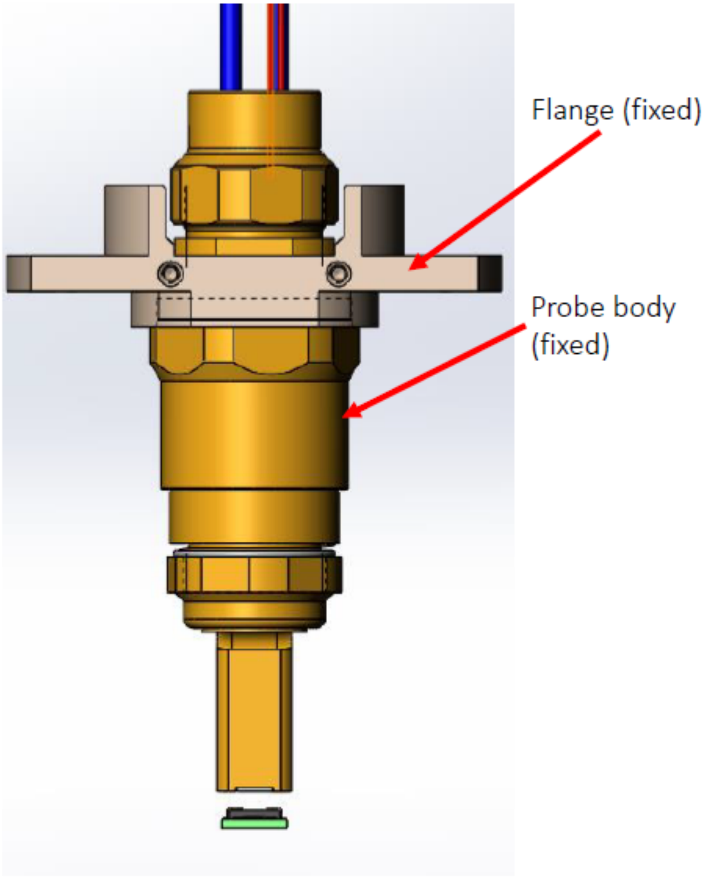


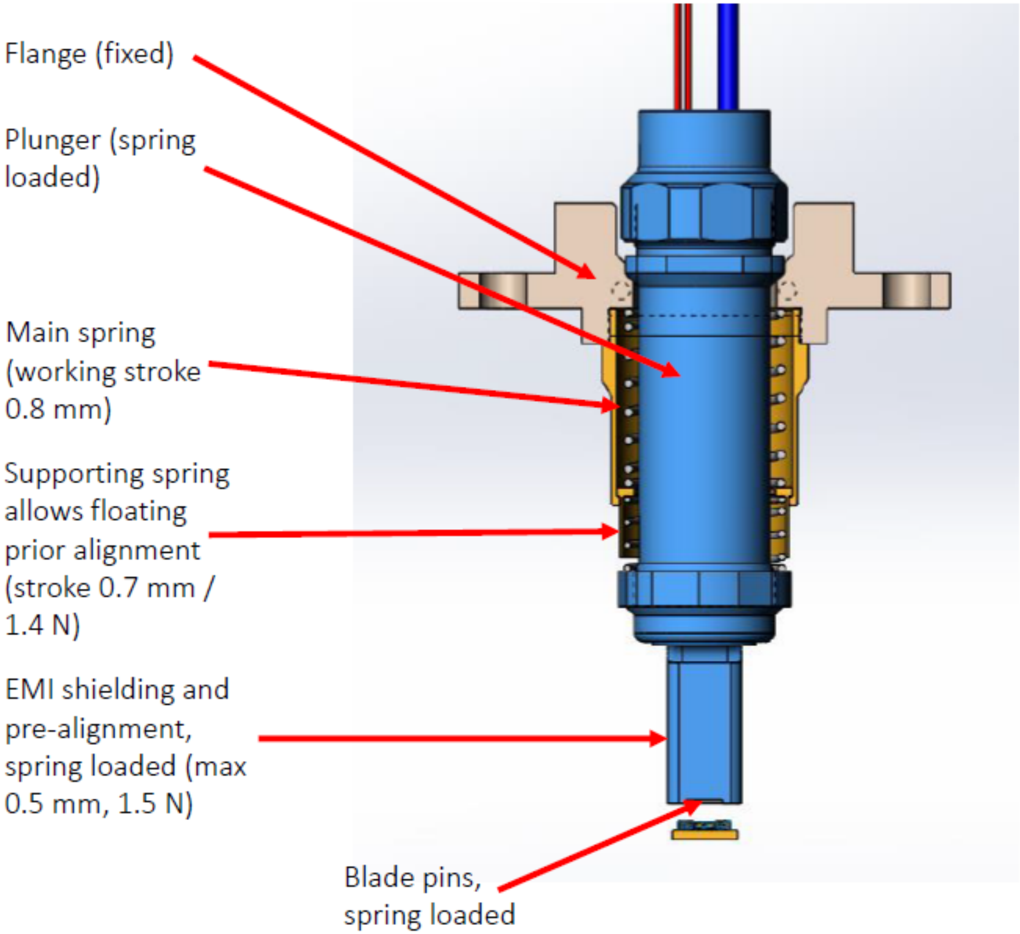
5. Probing onto B2B Connectors / Multi-Pin Designs



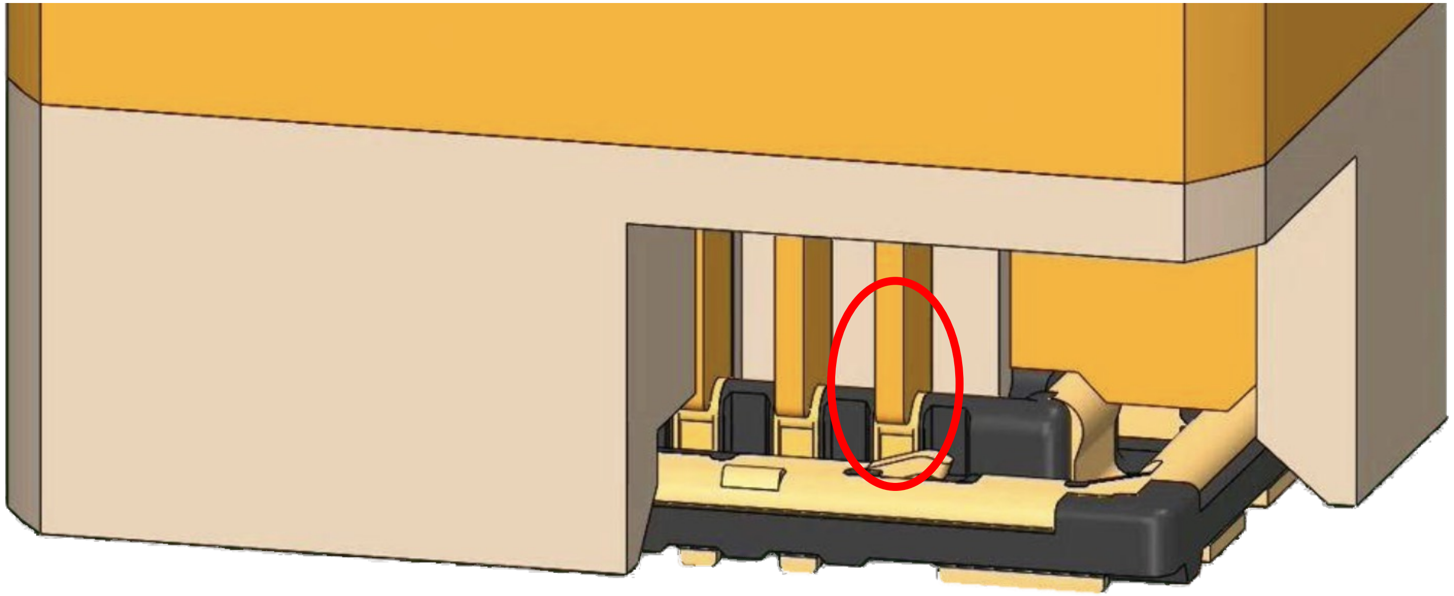


5. Probing onto B2B Connectors / Multi-Pin Designs





5. Probing onto B2B Connectors / Multi-Pin Designs

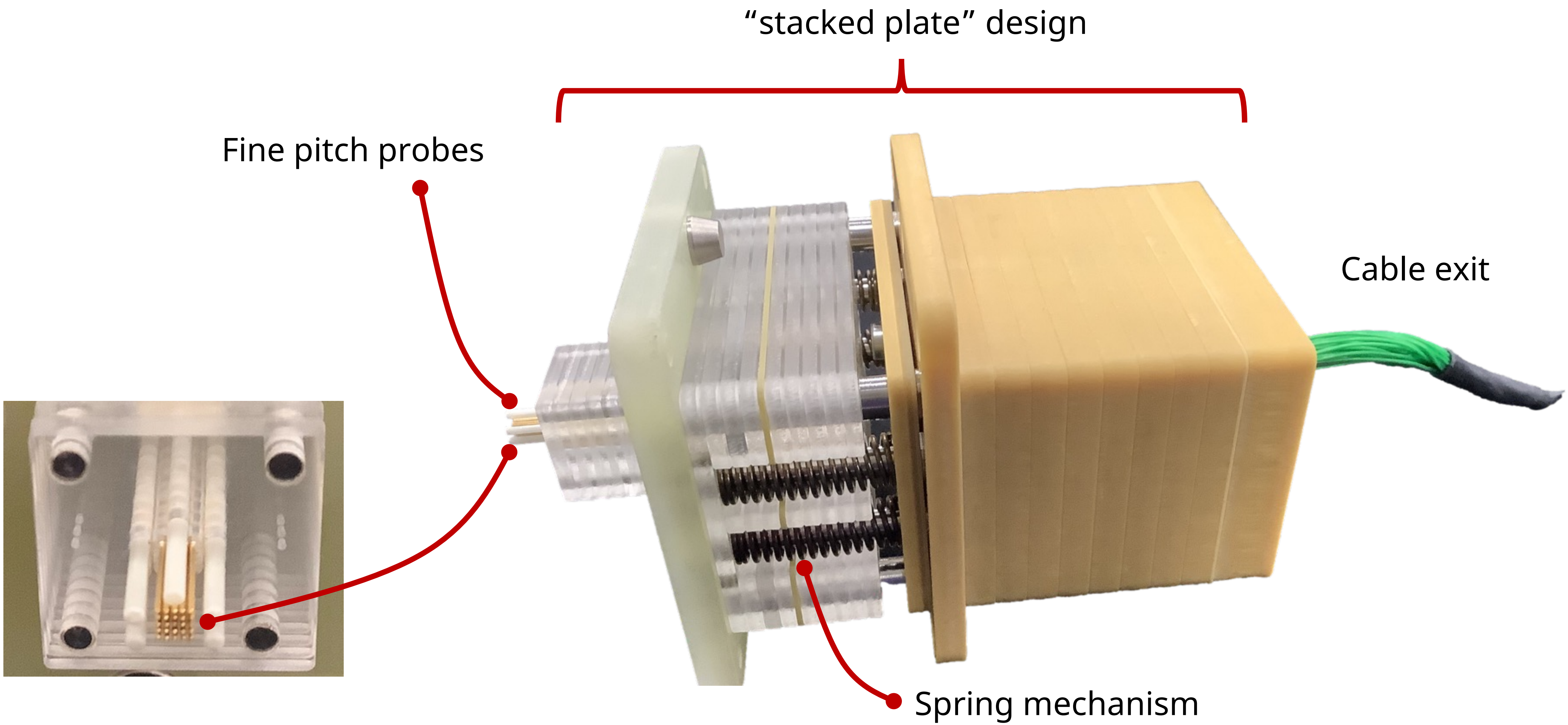


- Contacting example of a blade-pin version onto a B2B connector
- Chamfered “catcher’s mitt” + float mount installation allows the DUT to be caught even in case of positioning tolerances (within some limits of course!)

06

Contact blocks and cartridges and individual fine pitch probes

6. Contacting blocks and cartridges

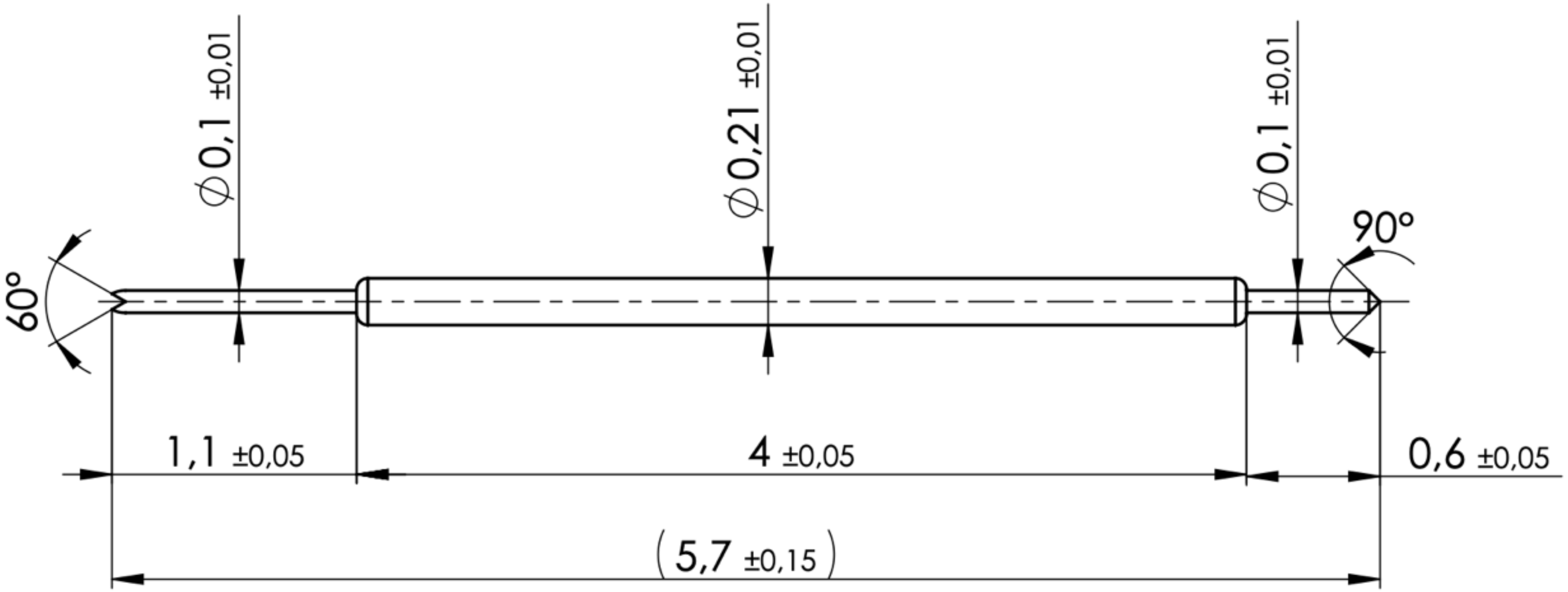


6. Fine Pitch Probes

- Traditionally used for socket applications (semiconductor-test)
- However, these parts now make its way into the PCBA test world for close center applications
- Contacting block, socket-type insert or similar required to use in conventional fixture.
- Double-ended probe designs

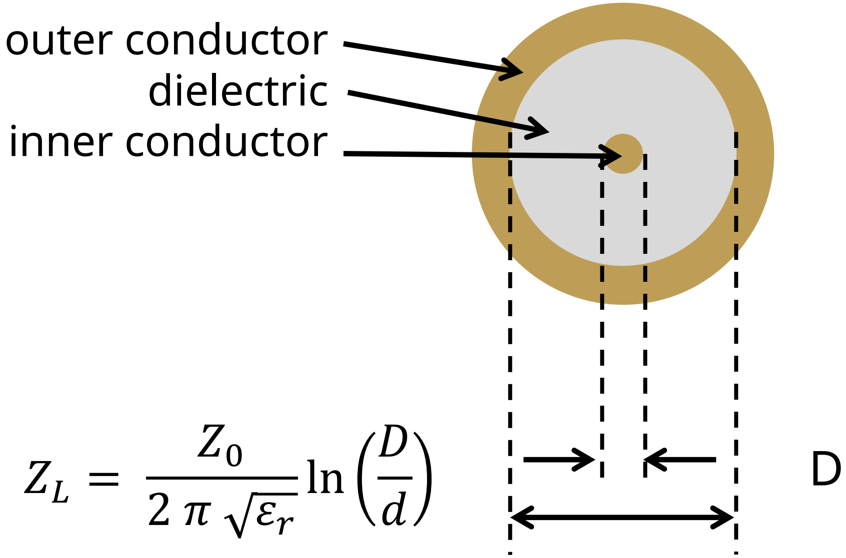
Specs:

Maximum stroke: 1.0 mm
Recommended working stroke: 0.65 mm
Spring force at working stroke: 0.11 N ± 15%
Current rating: 1.0A
Ri typical: ≤ 150 mΩ
Oerating temperature: -40°C up to +120°C

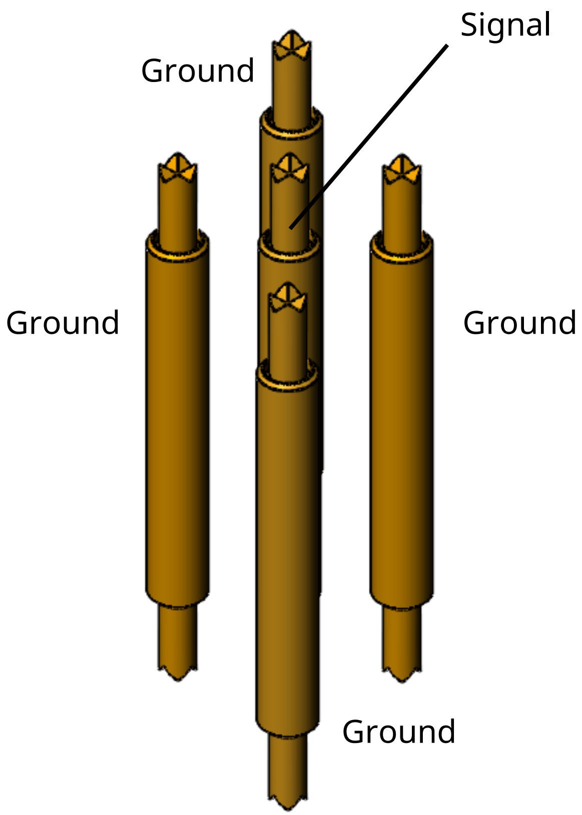


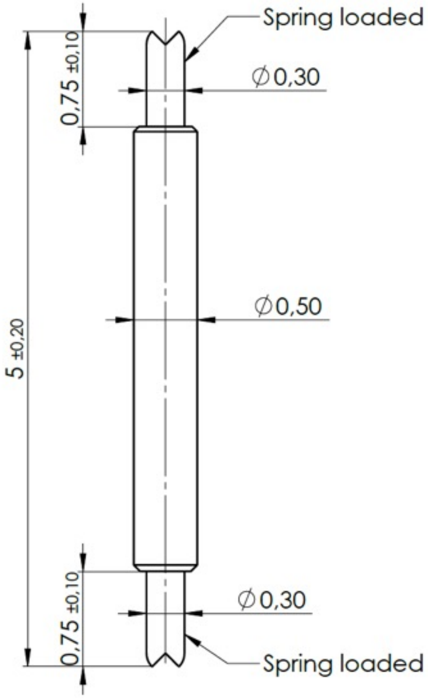
6. Fine Pitch Probes

- For RF, such probes are arranged in a “coax” pattern.
- For impedance calculations, the formular for a coaxial connector can be used to approximate performance.



$$Z_L = \frac{Z_0}{2\,\pi\,\sqrt{\varepsilon_r}} \ln\left(\frac{D}{d}\right)$$



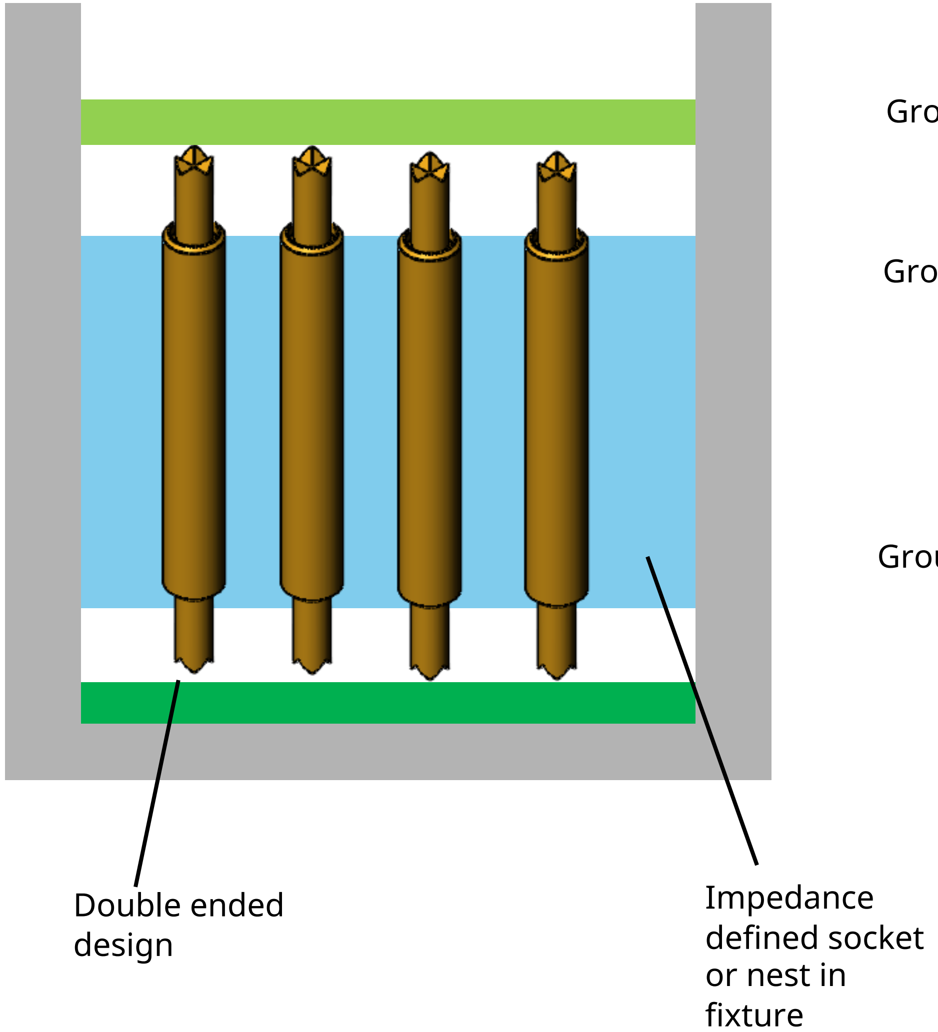


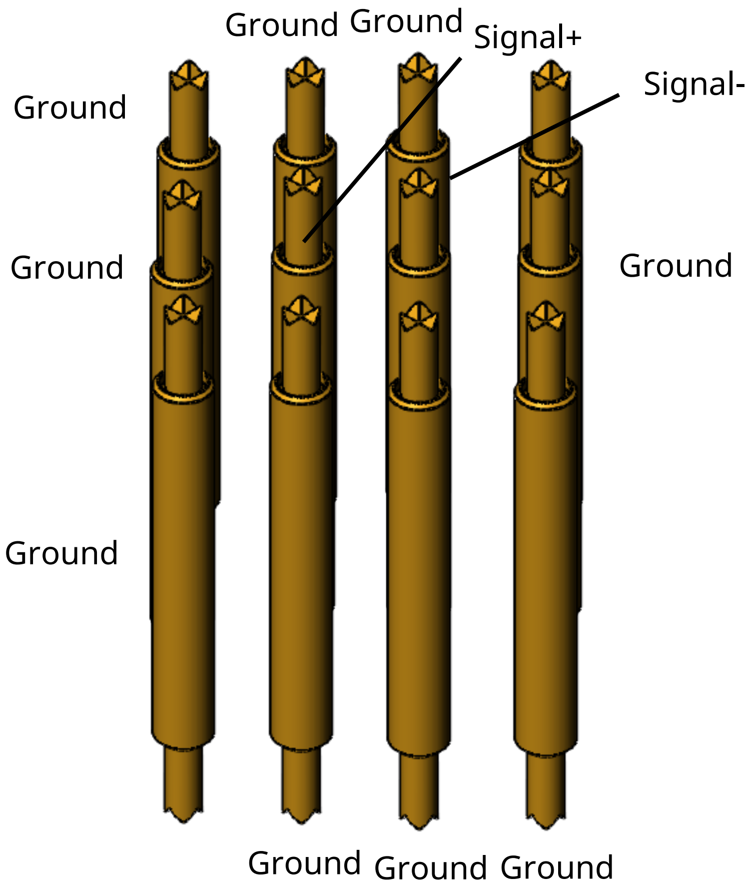
Maximaler Hub: 1,5 mm Empfohlener Arbeitshub: 1,0 mm Federkraft bei Arbeitshub: 0,2 N ± 15%
Maximum stroke: 1.5 mm Recommended working stroke: 1.0 mm Spring force at working stroke: 0.2 N ± 15%

15:1

6. Fine Pitch Probes

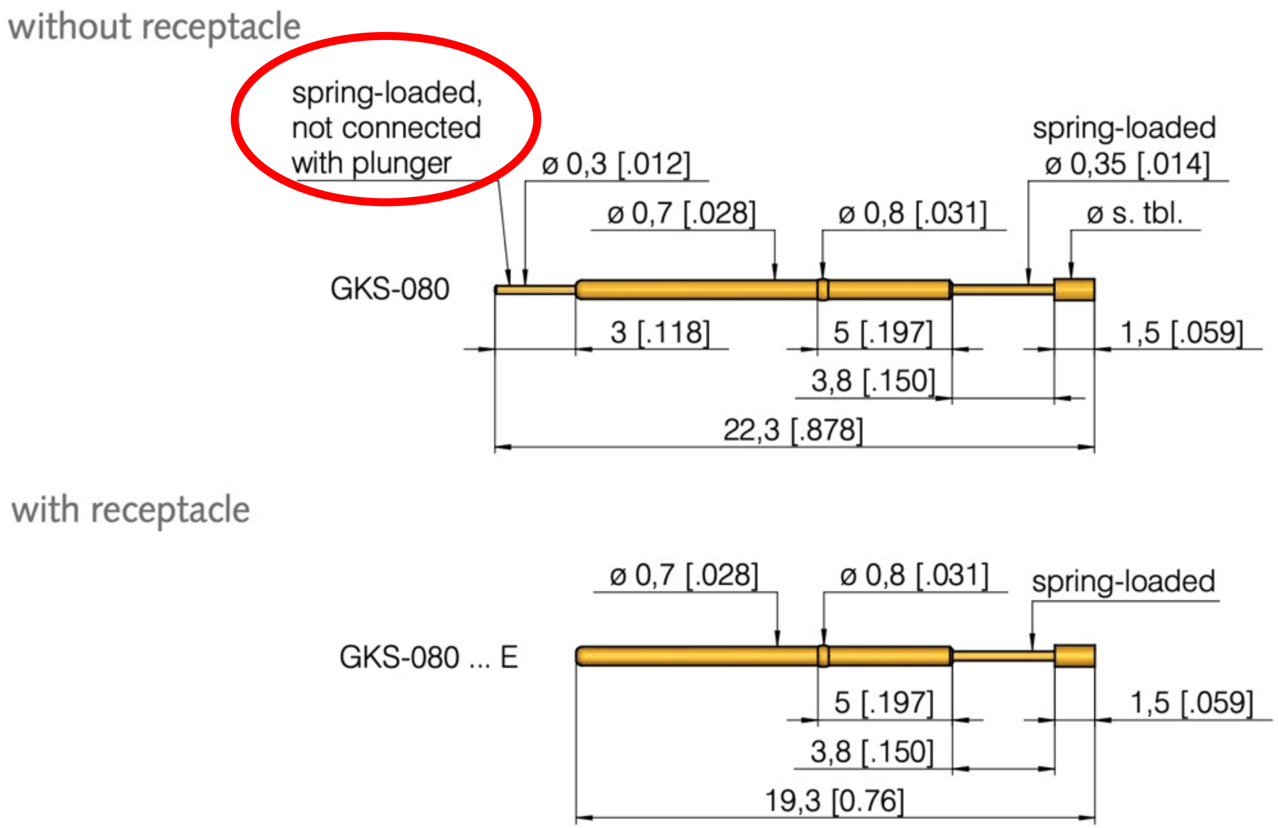
More options for use at RF/high speed. Here: For differential signaling with.

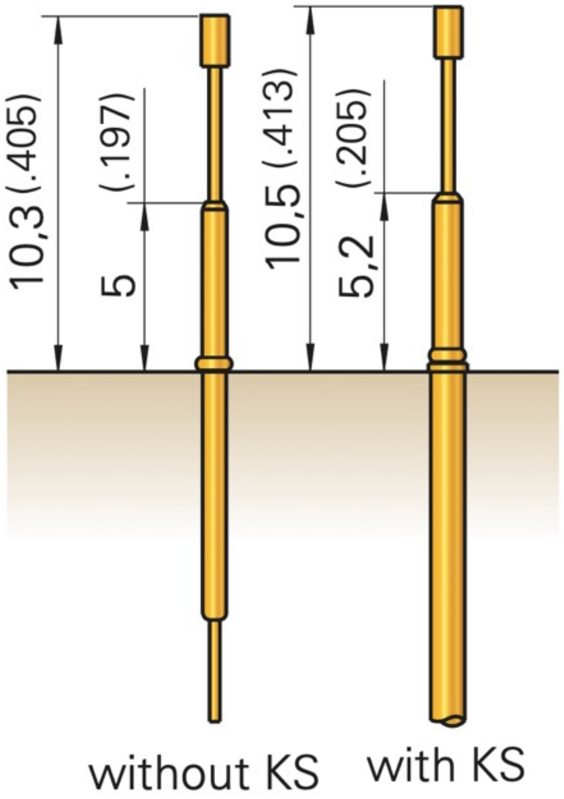




6. Fine Pitch Probes

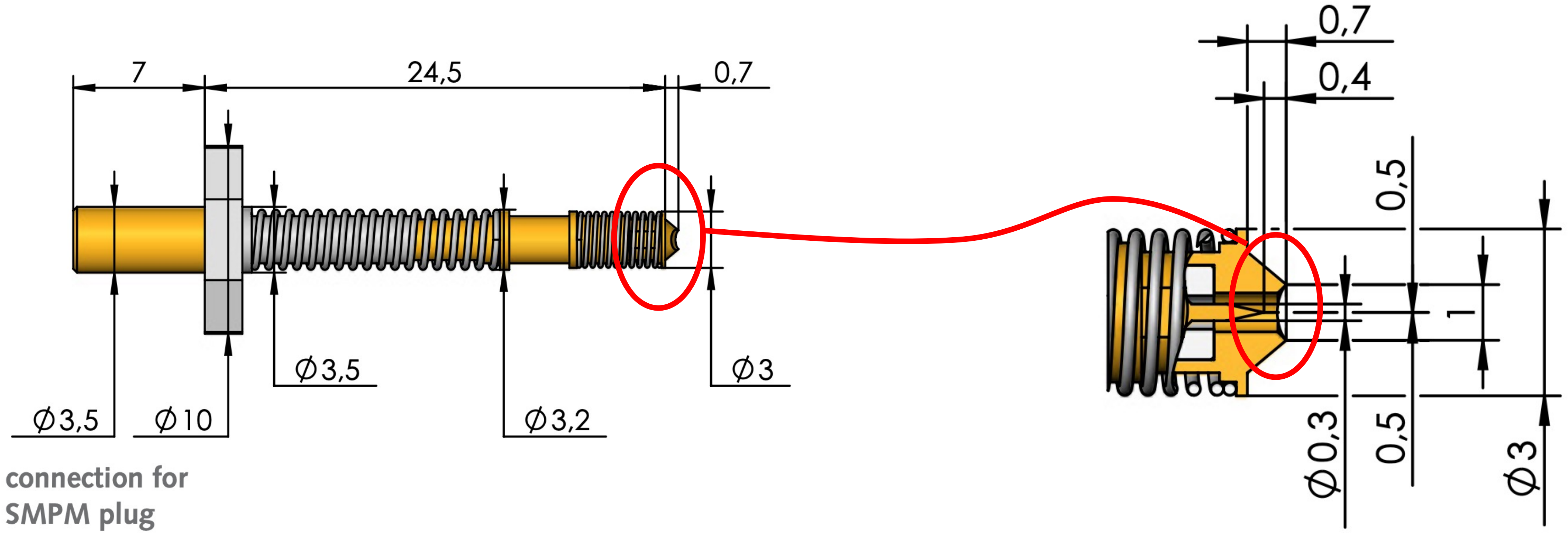
Single ended vs. double ended types. Here: 40 mil versions.





6. Coaxial probes with narrow pitch head

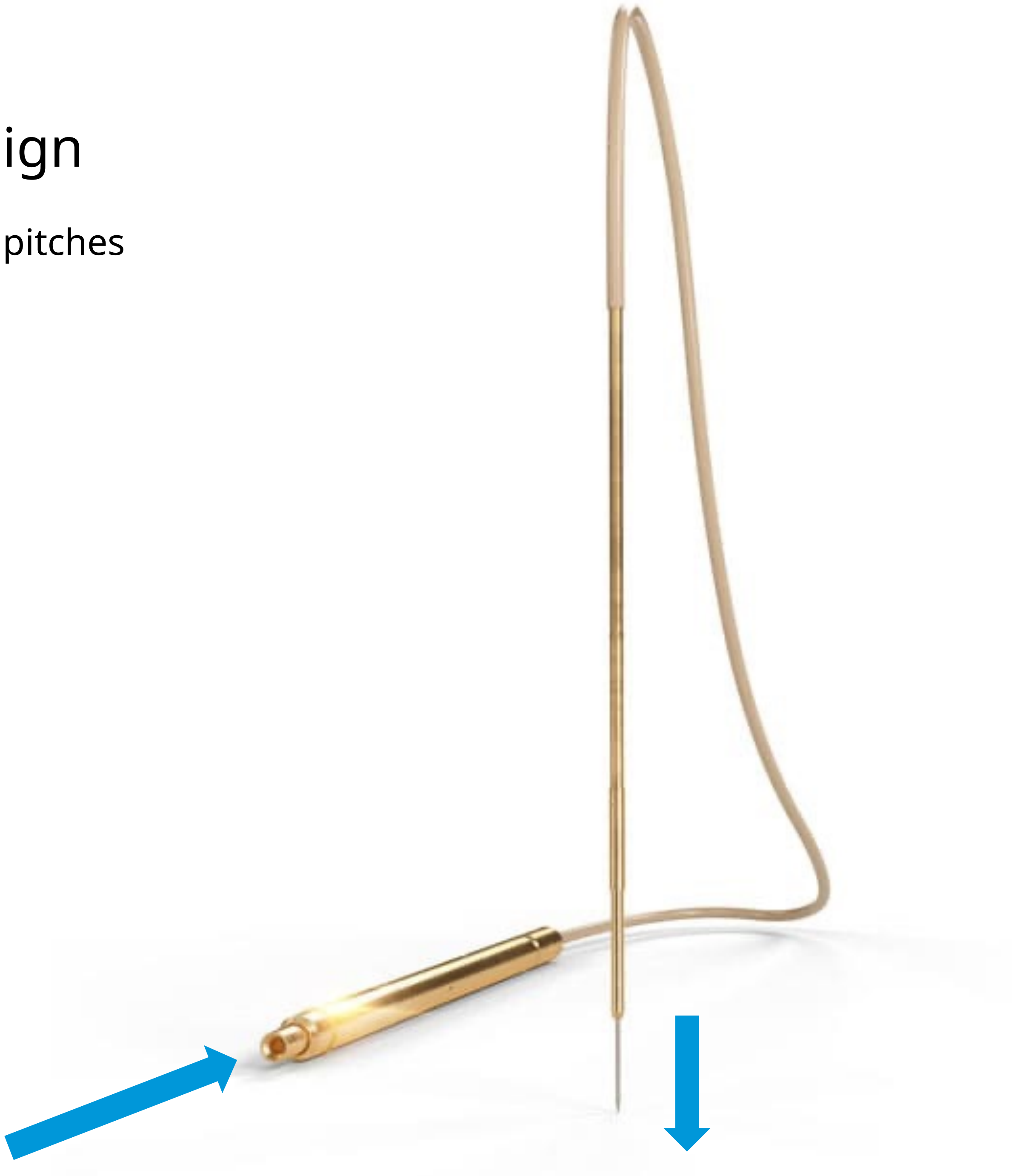
While the probe body is not a fine pitch version “per se”, the probe head is shaped to hit 500 um centers



6. "…One More Thing" – Sleeve probe Design

Uses a "driver" pin and flexible shaft to narrow down to 30 mil pitches

- Penetrates solder flux and OSP
- 360° multi-dimensional contacting
- Durability of a standard test probe
- Contacting: Pads with 0.2 mm [0.008 in]
- Grid size: 0.76 mm [30 mil]
- Contact force: Up to 3 N [10.7 ozf]
- Working stroke: 3.2 mm [0.126 in]
- Total length: 288.3 mm [11.35 in]



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