The Socketless Revolution Larger Probes on Smaller Center Test Targets Application of the Socketless Probe Technology to PCB Manufacturing and In-Circuit Test

Matt Parker
Product Engineer
QA Technology Co. Inc.

Introduction to Socketless Technology

As technology progresses, electronic components that do bigger and better things are hitting the market. At the same time, the size of the PCB is shrinking. While circuit board designers could resolve the issue by building multiple boards into products to accommodate the additional components, they instead are opting to squeeze them onto a single PCB.

To fit more components in a smaller area, designers decrease the size and spacing of test targets commonly used in bed-of nails fixtures. These test targets allow electrical access to the UUT. The challenge is to hit these smaller targets and still achieve accurate test results. To accomplish this, it is only logical that test probes also need to be smaller. While other types of ATE, including flying probes, X-ray, built-in self-test (BIST), boundary scan software, and optical inspection, combine to enhance the testing of high-density PCBs, the bed-of nails fixture continues to offer the best combination of speed and test coverage in a high-volume manufacturing environment.

Since the beginning of automated PCB testing, designers have pushed fixture and probe manufacturing companies to build a better bed-of-nails fixture. However, any new product innovations must be balanced with design for test (DFT) guidelines that have evolved over time to keep pace with the latest advances in PCB and fixture manufacturing. The challenge is getting everyone in the design, manufacturing, and test departments to coordinate their efforts and agree upon the guidelines.

A solution was needed to solve probing issues that were starting to make waves in the in-circuit, bed-of-nails test world. The problem was the reluctance of test managers and technicians to use the “fragile” .050 (1.27) center probes and the insistence of test board designers to put test points on .050 (1.27) and closer centers. The probes designed for .050 (1.27) centers were smaller, harder to work with, had lower spring forces and damaged more easily compared to the widely accepted .100 (2.54) and .075 (1.91) center probes. The new test probe concept was conceived and initially released in February 1998 as a solution.

While the concept of socketless probing isn’t new, the technology wasn’t widely used throughout the industry until the growing demand for smaller test targets started calling for the use of smaller, more delicate test probes. Now, socketless technology is widely recognized for its capability to use larger, longer lasting probes on high-density PCBs. This is made possible by joining two parts: a probe and a termination pin. In the example shown in **Figure 1**, the modified interconnect receptacle at the bottom of the probe tube fits securely onto the interconnect pin at the top of the termination. This effectively removes the conventional socket from the system reducing the overall diameter of the probe and thus allowing that same probe to be mounted on closer centers.

Socketless Design Considerations

- Compatibility with existing fixturing platforms, wired and wireless, with minimal fixture modifications - Conventional probes and sockets were developed for an established network of fixture design houses, fixture end-users, test system manufacturers and others, which incorporate many proven software and hardware designs. The objective with socketless technology is to offer another option with additional benefits.

- Built on the existing “tried and true” Probe and Socket Technology – The goal was to develop a socketless system utilizing existing spring designs, probe tube diameters, point style options and the “industry standard” probe dimensions, while maintaining the web thickness between holes to ensure proper electrical isolation and to make drilling easier.

- Probes designed to be easily replaceable and maintainable - To ensure the long-term performance of a socketless design, the assembly must be able to be repaired and replaced in the field. Furthermore, the design must be able to accept fixture modifications / Engineering Change Orders (ECOs) to an already completed and delivered fixture.

- Adjustable set heights - The socketless assembly must be able to accommodate components on a UUT that are at different heights. This allows a fixture to be designed so that the probes are stroked the same distance regardless of the height of the component. The recommended stroke of a probe is typically 2/3^{rds} of the full working stroke.

• Reliable electrical signal path (see **Figure 2**) - The conventional probe and socket has evolved into a reliable, electrically compliant contact with a proven record regarding electrical system resistance and current flow. The socketless design has met this same criteria.

• Utilize existing fixture wiring techniques – All of the current wired and wireless methods of making electrical connections to the fixture interface must be maintained.

• Lower per-point cost for closely centered probes **-** This is accomplished by using socketless technology, which places larger probes on closer centers. Generally, in a conventional probe and socket fixture, as the test target spacing decreases, the cost-per-probe increases.

• Worldwide availability - By making socketless technology universally available to those who design, build and use test fixtures, it has been widely accepted and well received by fixture houses, board manufacturers and OEMs.

Comparison between Conventional and Socketless
The assembly shown in **Figure 3** is a comparison between conventional and socketless probe technologies.

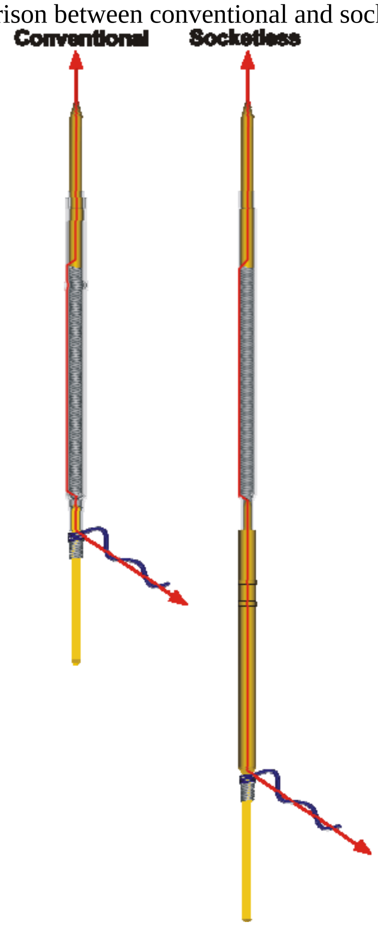

Figure 2 – Same reliable electrical signal path

With conventional technology, a socket is installed in the Probe Plate at a specific set height and a probe is installed into it.

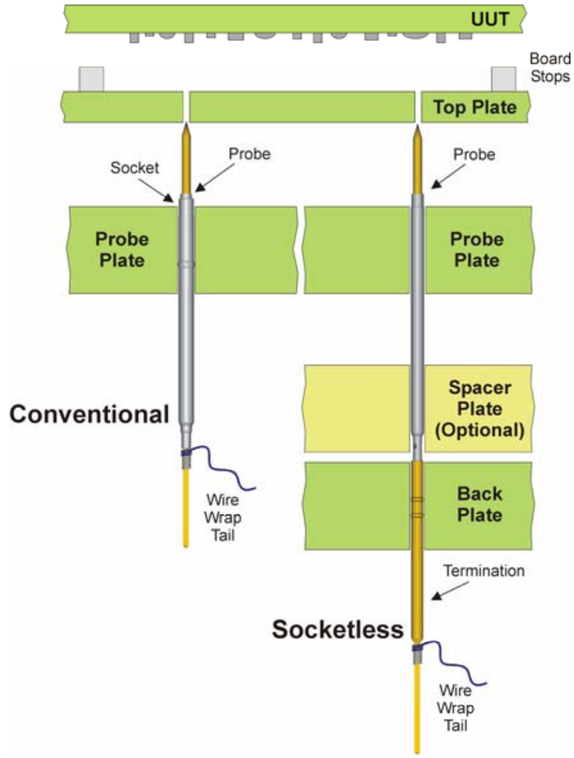

Figure 3 – Comparison between conventional and socketless

When using socketless technology, additional plates are added to accommodate the probe and Termination pin. The upper Probe Plate acts as a guide for the probe. A lower Back Plate is used to mount the Termination pin below the probe. The Termination pin adjusts for the probe set height, providing the electrical path and the wiring connection point. An optional Spacer Plate may be added to fill the gap between the Probe and Back Plates.

By eliminating the socket, a probe of equal size can now be installed on closer centers.

Although there are a variety of different versions of the socketless probe, the basic concept is to eliminate the conventional test socket from the probe/socket system while maintaining the flexibility of wiring and maintenance. All manufacturers currently use a dedicated Termination that connects to the bottom of the probe and incorporates both a probe connection and wire connection method.

In some cases, small areas of larger socketless probes may be added to a conventional fixture to replace areas of smaller probes like those typically found under ball grid arrays, high-density connectors, and other closely centered test points, see **Figure 4.**

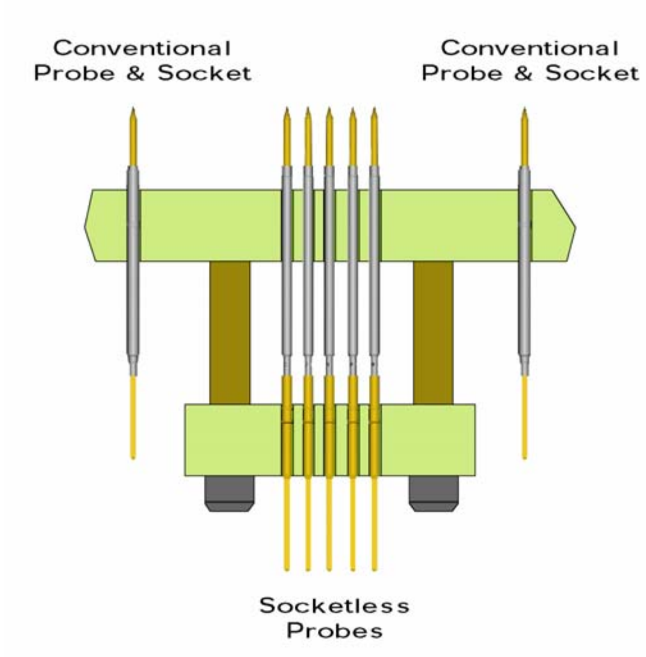

Figure 4 – Typical mixed technology fixture using conventional and socketless probes

Advantages
Socketless probes have greater strength for a given center spacing, because when a larger socketless probe is used to replace a conventional probe on the same centers the probe will be inherently more durable in the application.

Larger probes have larger bearing surface areas compared to smaller center probes. Increased bearing size means less component wear making the larger probe last longer.

Larger diameter probe components will last longer when subjected to similar side loaded stresses when compared to a smaller center probe. In a theoretical application, for a rigidly held probe with a .25 lb (.11 kg) side load force, the plunger will deflect as shown in **Figure 5**. In this example, the .039 (1.00) probe would be permanently damaged (bent) by this sideloading force because the stresses on the plunger exceed the 100,000 PSI (689,476kPa) yield strength of the plunger material and pointing accuracy would be affected. Components that are continually over stressed will eventually fail. By using a larger probe on closer centers the individual component stresses are reduced.

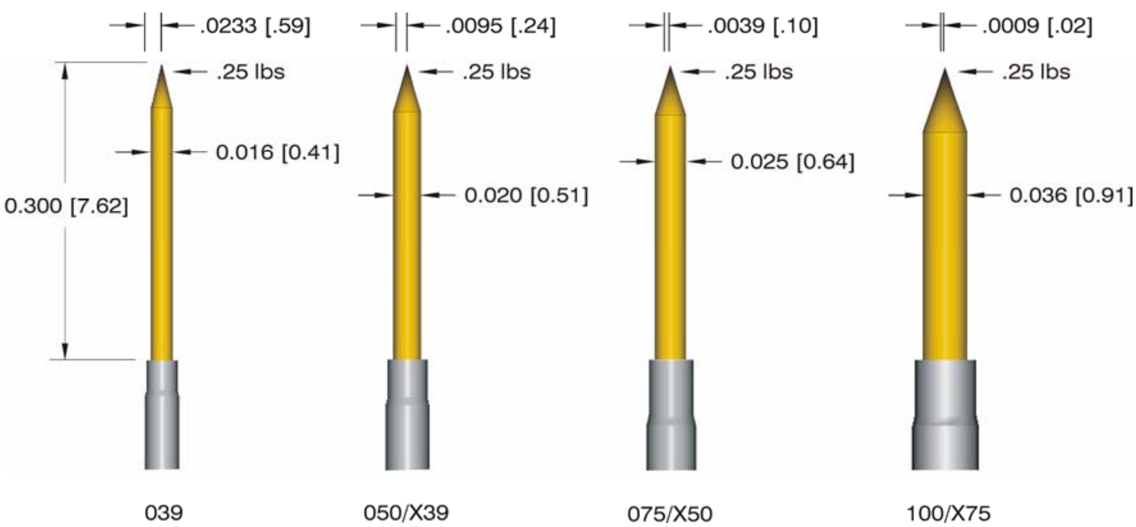

Figure 5 –Plunger Deflection

Probes mounted on .050 (1.27) and .039 (1.00) centers are more delicate requiring extra attention and time when replacements are needed. In addition, smaller probes are more susceptible to damage during the placement and removal of to-be-tested PCB's.

Another potential advantage of larger probes on smaller centers is cost reduction. In general, the larger the probe the lower the cost. Because the majority of test probes sold today are still mounted on .100 (2.54) and .075 (1.91) centers, smaller center probes are expensive by comparison. By increasing the probe size, socketless technology enables cost reduction when smaller center probing is necessary (see **Table 1).**

Table 1 – Cost differences of Conventional vs. socketless

Center Spacing	socketless Cost is More or Less?
.039	Less
.050	Less
.075	Less
.100	More

These costs are reduced for a socketless probe because the larger probe allows for larger manufacturing tolerances. This enables components and assemblies to be more easily manufactured. From the Contract Manufacturers' viewpoint their larger physical size makes the socketless probes easier to install and replace during fixture maintenance minimizing fixture down time.
The larger socketless probes offer a greater number of spring options. When designing test fixtures, these choices are especially important in today's No-clean, OSP and Pb-free test environments (see **Table 2)**.

Table 2 - Comparison of Spring Force Availability for Conventional vs. Socketless

Spring Selection Comparison		
Conventional	**Center Spacing / Stroke**	**Socketless**
3.5 (99) 5.4 (153)	.039 (1.00) / .250 (6.35)	3.0 (85) 4.3 (122) 5.6 (159) 8.0 (227)
3.0 (85) 4.3 (122) 5.6 (159) 8.0 (227)	.050 (1.27) / .250 (6.35)	3.1 (88) 5.5 (156) 7.0 (198) 8.0 (227) 10.1 (286)
Not Available	.050 (1.27) / .400 (10.16)	4.3 (122) 9.3 (264)
3.1 (88) 5.5 (156) 7.0 (198) 8.0 (227) 10.1 (286)	.075 (1.91) / .250 (6.35)	3.5 (99) 5.5 (156) 6.5 (184) 8.0 (227) 8.1 (230) 10.1 (306) 17.1 (485)
4.3 (122) 9.3 (264)	.075 (1.91) / .400 (10.16)	3.0 (85) 5.7 (162) 8.1 (230)
13	**Available Spring Forces**	**21**

By using a larger probe on closer centers we have a greater number of point styles available. This is beneficial for the difficult to contact test points where tip style selection is critical to ensuring a reliable contact.

Table 3 - Comparison of Point Style Availability for Conventional vs. Socketless

Tip Style Selection Comparison		
Conventional	**Center Spacing / Stroke**	**Socketless**
4	.039 (1.00) / .250 (6.35)	15
15	.050 (1.27) / .250 (6.35)	33
Not available	.050 (1.27) / .400 (10.16)	15
33	.075 (1.91) / .250 (6.35)	42
15	.075 (1.91) / .400 (10.16)	27
67	**Available Point Styles**	**132**

By eliminating the socket in the system, we are removing the socket tilt in its mounting hole. By doing this, the pointing accuracy of a socketless probe is 39.5% better than a conventional probe and socket (see **Figure 6**). Pointing accuracy is dependent on a number of variables besides socket tilt; these include but are not limited to hole location, hole straightness, plate alignment and fixturing methods.

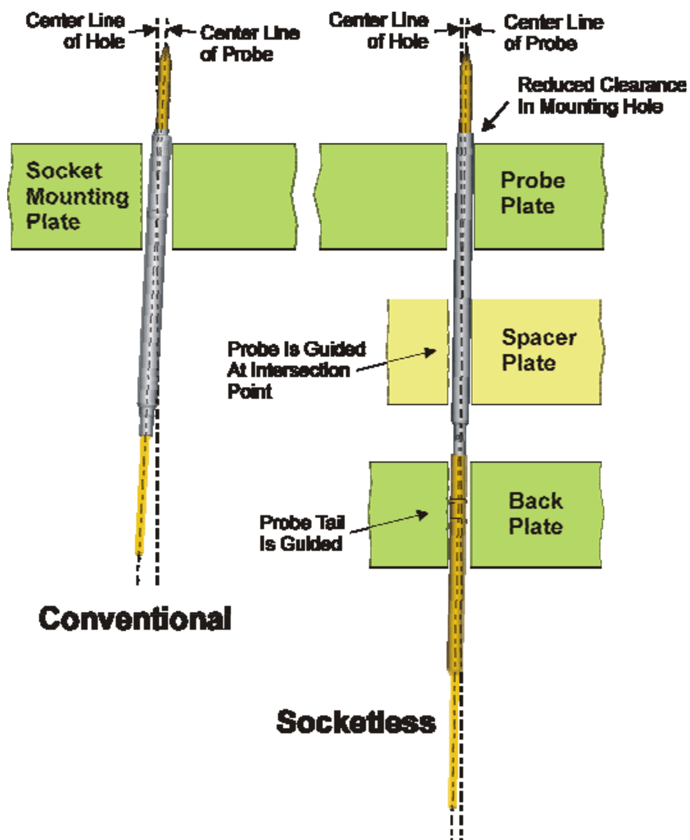

Figure 6 – 39.5% Better Pointing Accuracy

Spring and space restraints limited the plunger stroke and spring force in conventional probe and socket assemblies on closely centered contacts. By putting larger probes on closer centers, a socketless system offers a .039 (1.00) center, .250 (6.35) stroke probe and a .050 (1.27) center .400 (10.16) stroke probe. These combinations were not possible before.

The optional Spacer Plate that is located between the Probe Plate and the Back Plate can act as a stiffener when bolted to the Back Plate. This is especially useful for large high-density fixtures where bowing could occur. Instead of a .500 (12.70) thick plate supporting the probes we now have the equivalent of a greater than 1.000 (25.40) thick plate.

PCB Design, Manufacturing, Testability, Cost
A conventional .039 (1.00) probe has a .016 (.406) diameter plunger. In order for this probe to contact a via, the via diameter would have to be in the .012 (.305) or smaller range. A via larger than .012 (.305) when probed could cause the plunger to stick in the via during the vacuum release. This causes the probe to be pulled from its socket creating testing problems and

additional fixture maintenance. By using a .050 (1.27) probe on .039 (1.00) centers, the plunger diameter is increased to .020 (.508). The via holes can now be specified up to .016 (.406) in diameter. This allows the board designer to specify larger vias when using thick PCB boards which helps to keep the hole depth to drill diameter ratio low.

Drill houses prefer that drilling ratios be kept below 10 to 1 to maintain drilling production throughput.

The fewer the number of board layers for a given PCB design the cheaper and easier it is to manufacture. One of the factors affecting costs of a PCB is the number of board layers. For each additional board layer, the cost increases not only because of the added board layer but also due to the additional vias and traces needed to connect the layers. Because board designers are constantly trying to increase the performance of PCBs, reducing the number of board layers shortens the signal lengths, thus increasing the performance needed for high-speed applications.

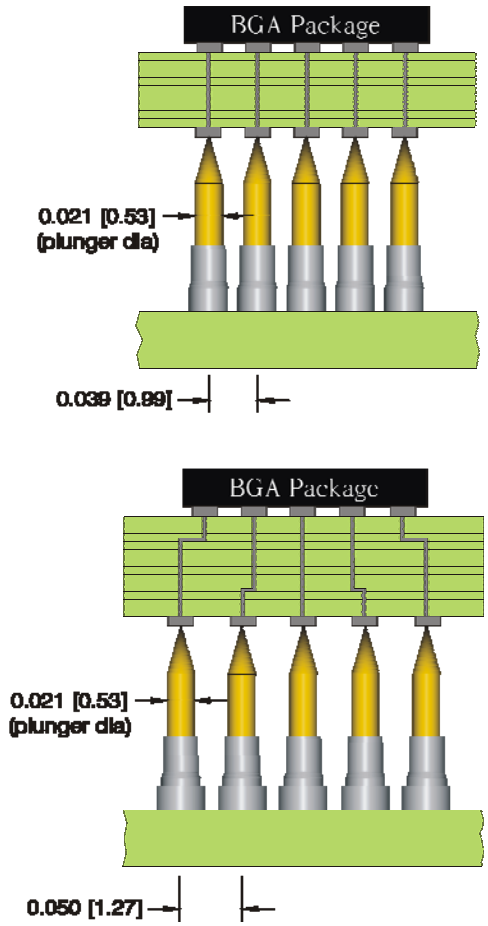

Figure 7 – Direct probing under .039(1.00) center BGA packages

If the only objective of PCB designers were to produce the smallest and cheapest possible board, we would end up with a small board with few layers. Unfortunately, when this design is sent to the Contract Manufacturers for production and test, the Design for Testability (DFT) would be very poor causing the board reliability to be questionable. Being able to test directly underneath component packages on .039 (1.00) centers offer significant advantages over extending the traces and test pads out beyond the package size (see **Figure 7)**. This saves both PCB costs and board space. But probing on .039 (1.00) centers is expensive. By using .050 (1.27) center probes on .039 (1.00) centers, the cost is reduced and the test reliability is increased.

Many contract manufacturers are open to the idea of testing on .039 (1.00) centers if a reliable test method is provided through the use of socketless probing.

Since the beginning of automated PCB testing, designers have pushed fixture and probe manufacturing companies to build test fixtures with high-density probe configurations to the shrinking package sizes. The first logical solution is to put the smaller conventional probes with sockets on closer centers. But this plan must incorporate the DFT guidelines, which have been developed over time to keep pace with the latest advances in PCB and fixture manufacturing. In the past, contract manufacturers have been reluctant to test on .039 (1.00) centers due to the delicate nature of the test probes and statistically lower first past yields. But by taking probes which are typically mounted on .050 (1.27) centers and placing them on .039 (1.00) centers, the contract manufacturer maintains the high degree of reliability they are accustom to. This in turn allows added coverage without expanding the board size and in some cases reducing the number of layers.

Summary

Being able to use a larger probe on closer centers produces many desirable benefits for the OEM, Designer, and Contract Manufacturer. The OEM can satisfy its customer's request for a product that is "cutting edge" by adding features that make it innovative while making it more reliable and more cost effective to produce. The Designer can incorporate the improvements by making the product smaller and more compact while increasing or maintaining the test coverage required to ensure a reliable product. The Contract Manufacturers can incorporate these improvements without adversely affecting the testing requirements or per piece manufacturing costs. In this way, mounting a larger more robust socketless probe on closer centers has greatly revolutionized not only the process of testing the PCBs but also the associated manufacturing and material costs.

About the Author

Matt Parker is employed by QA Technology Co. Inc. as a Product Design Engineer. During his nine years at QA he has focused his efforts on the design and development of probes and sockets for the in-circuit test market for both loaded and bare board PCB assemblies. He is a graduate of the University of New Hampshire with a BS in Engineering and has received two patents for the X Probe Socketless Technology. Matt can be reached at (603) 926-1193 or e-mail: mparker@qatech.com
QA Technology Company, Inc., 110 Towle Farm Rd., Hampton, NH 03842

The Socketless Revolution

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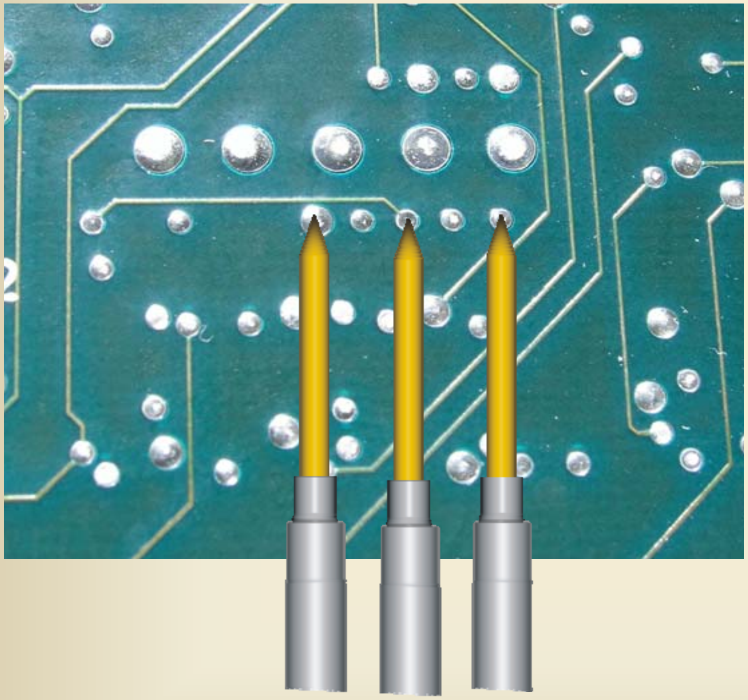
Matt Parker
Product Engineer
QA Technology Co. Inc.
110 Towle Farm Rd.
Hampton, NH 03842
USA

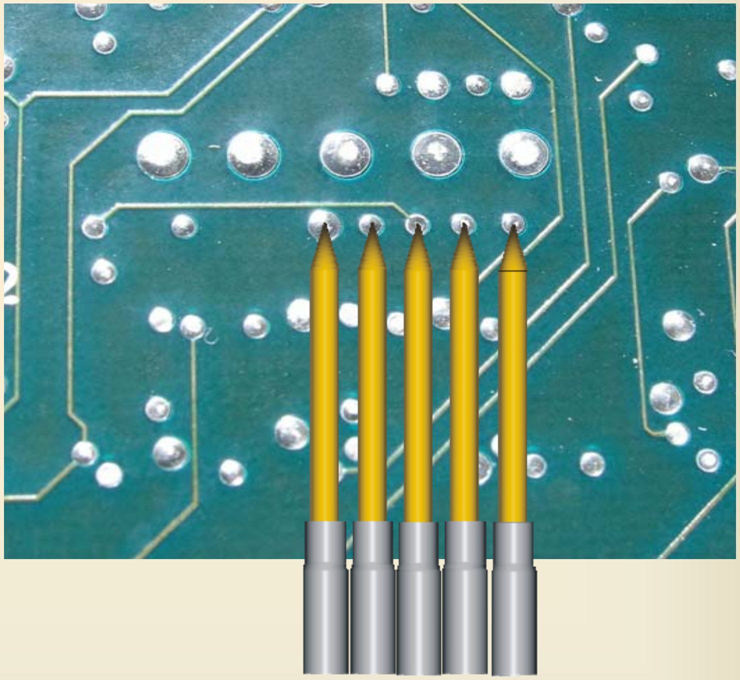
Socketless Probe Technology

- Introduction
- Design Considerations
- Comparisons
- Advantages
- Summary

Socketless Introduction

Smaller PCBs with more capabilities result in smaller test targets, closer test centers and smaller test probes

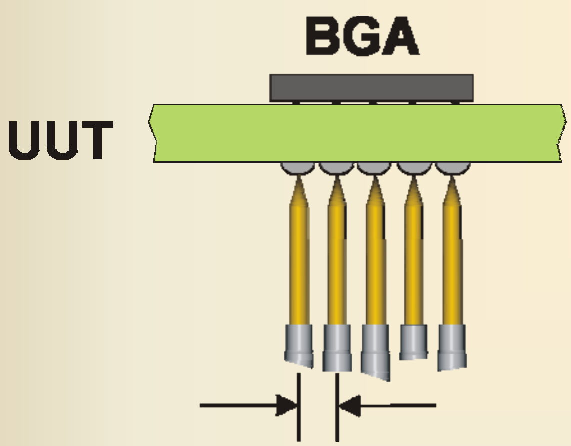




Socketless Introduction

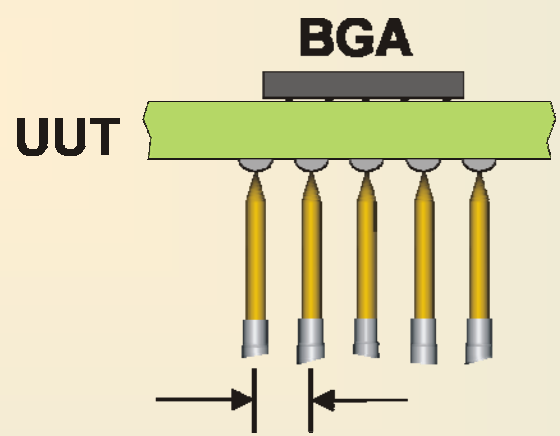
Compact PCB designs mean that center spacing must be reduced. Contract Mfrs and Test Departments are reluctant to test on smaller centers because of test reliability and probe durability.

Designers Want



.050” and smaller center test targets

Test Engineers Want

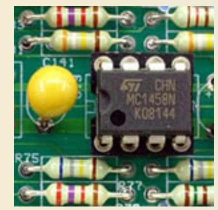


.050” and larger center test probes

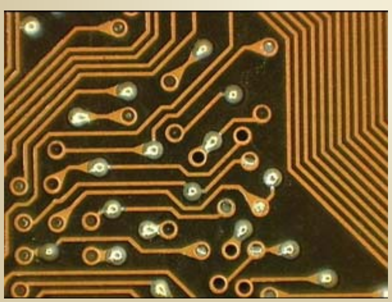
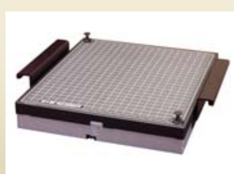
Socketless Design Considerations

Compatible with every existing test platform and current fixture manufacturing techniques.



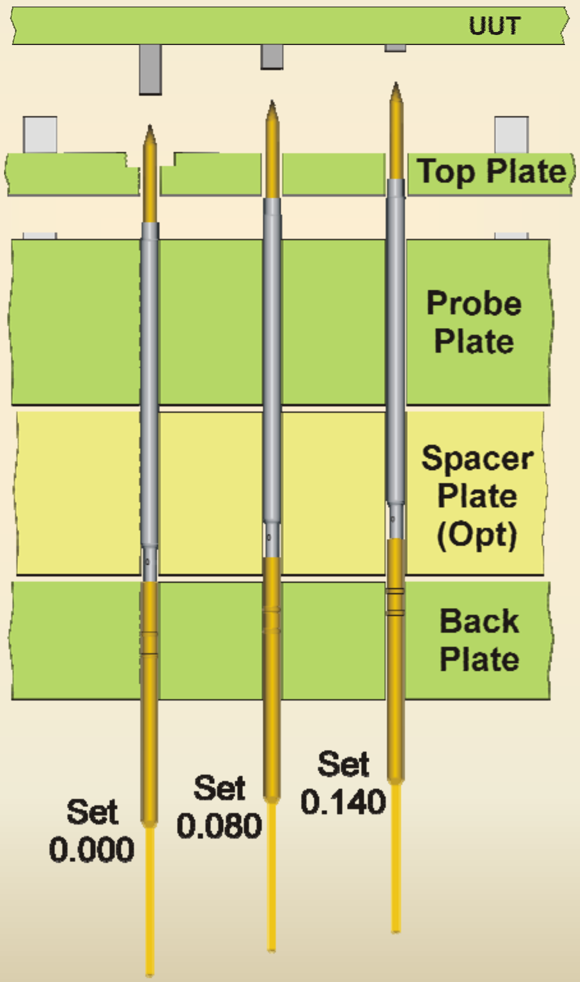





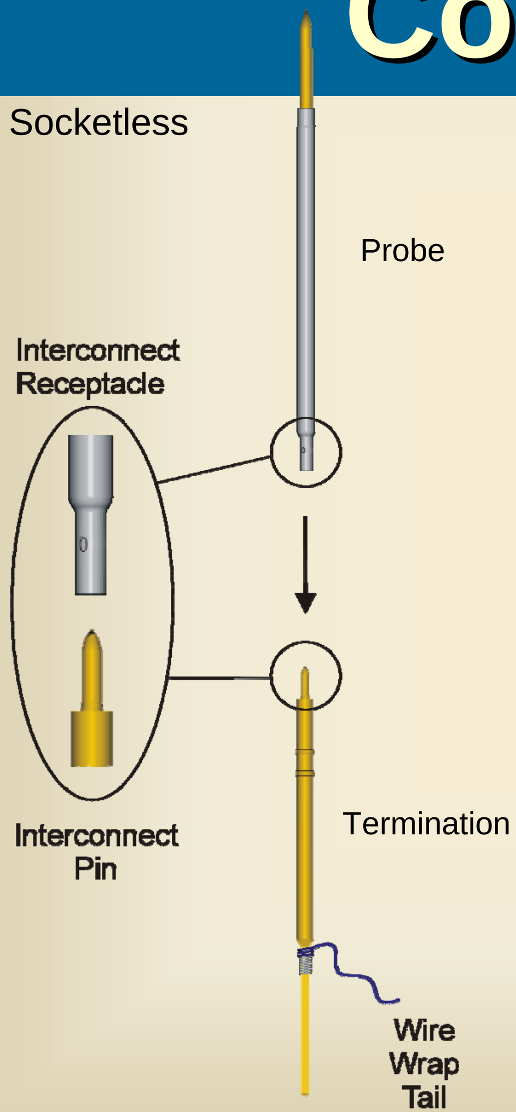





Socketless Design Considerations

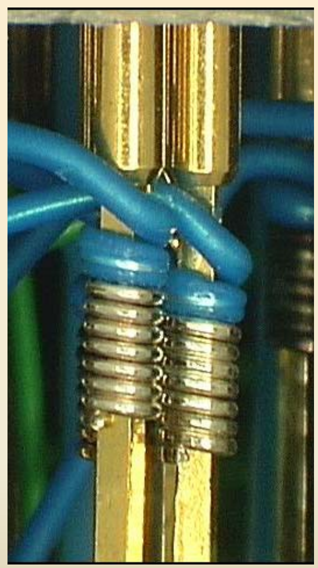
Adjustable set heights to accommodate components of different heights

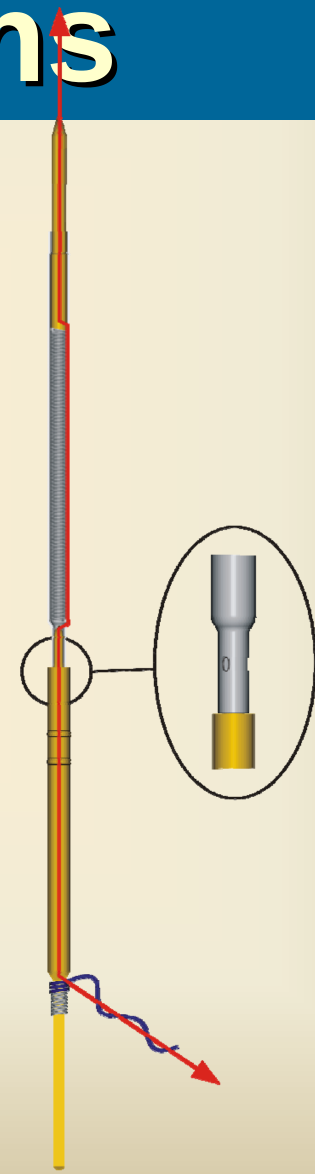


Socketless Design Considerations

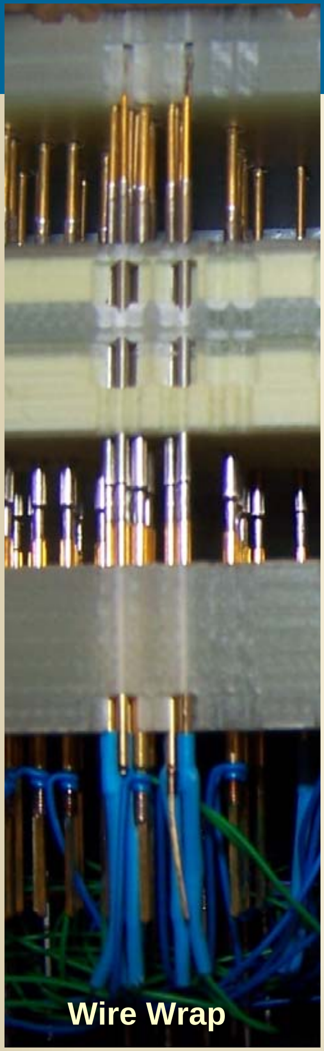


Reliable electrical path

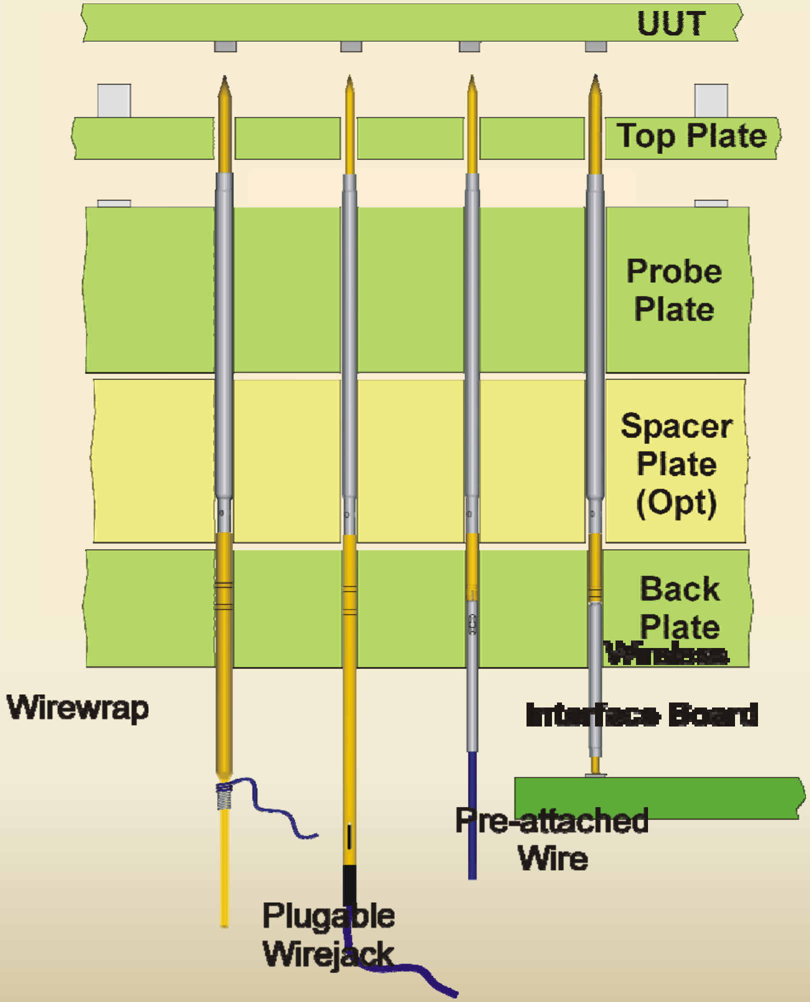


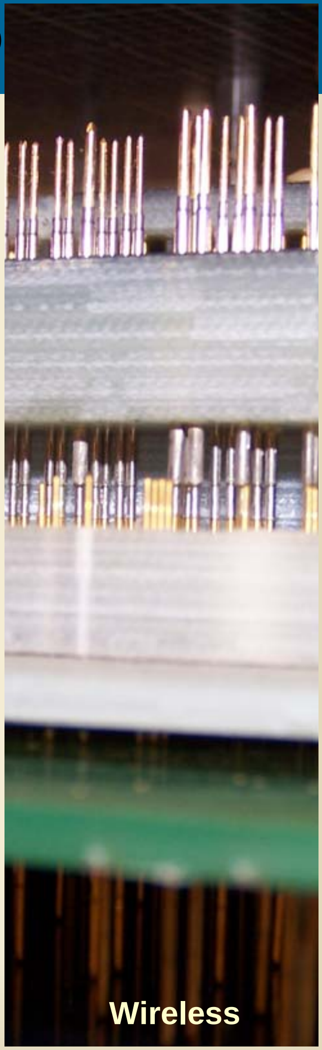


Socketless Design Considerations



Existing Wiring/Wireless Connection Methods





Socketless Design Considerations

Small Probes = Manual Assembly Methods = Higher Costs, Lower Production

Socketless Design Considerations

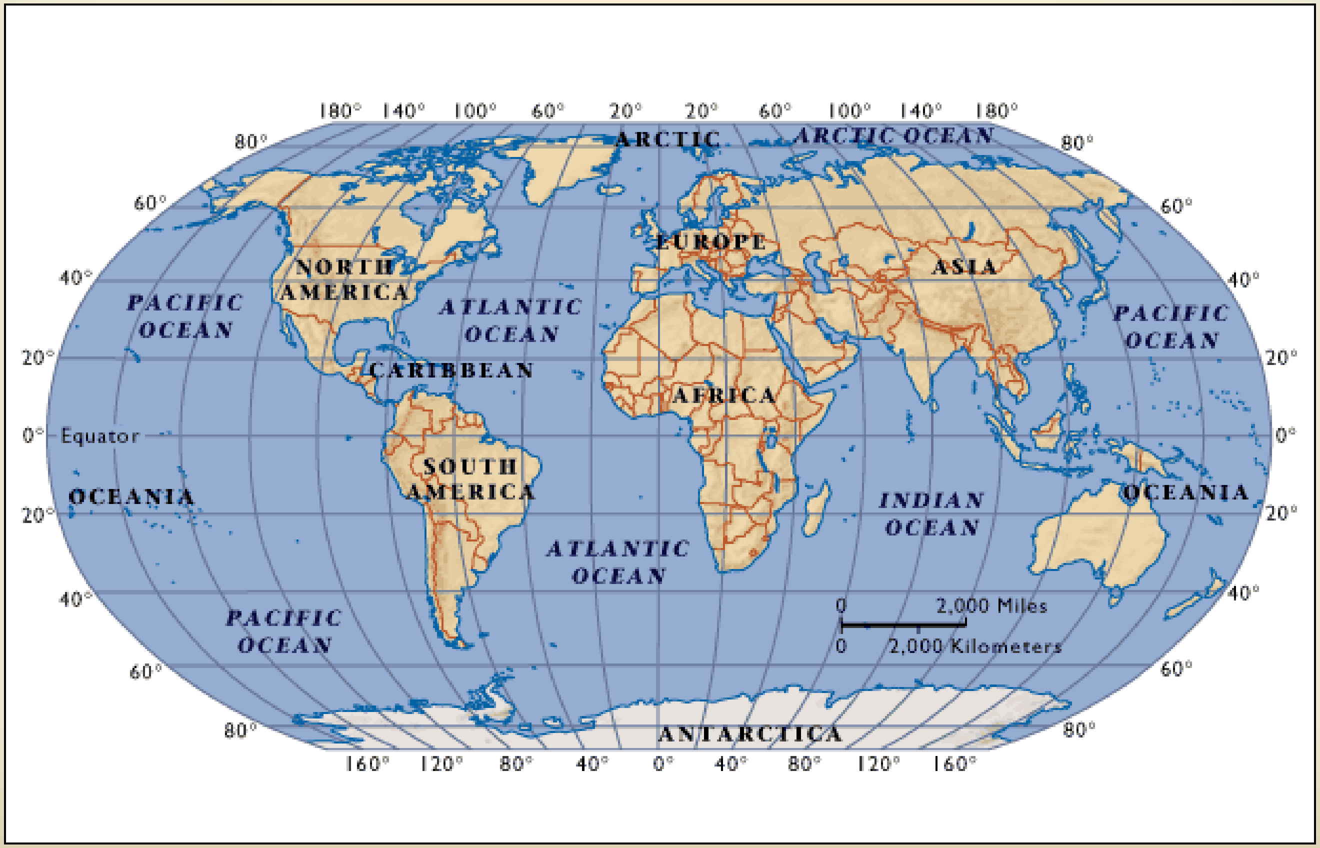
Mid-size Probes = Semi-Automatic Assembly Methods = Moderate Production

Socketless Design Considerations

Larger Probes = Fully-Automatic Assembly Methods = Lower Costs, Higher Production

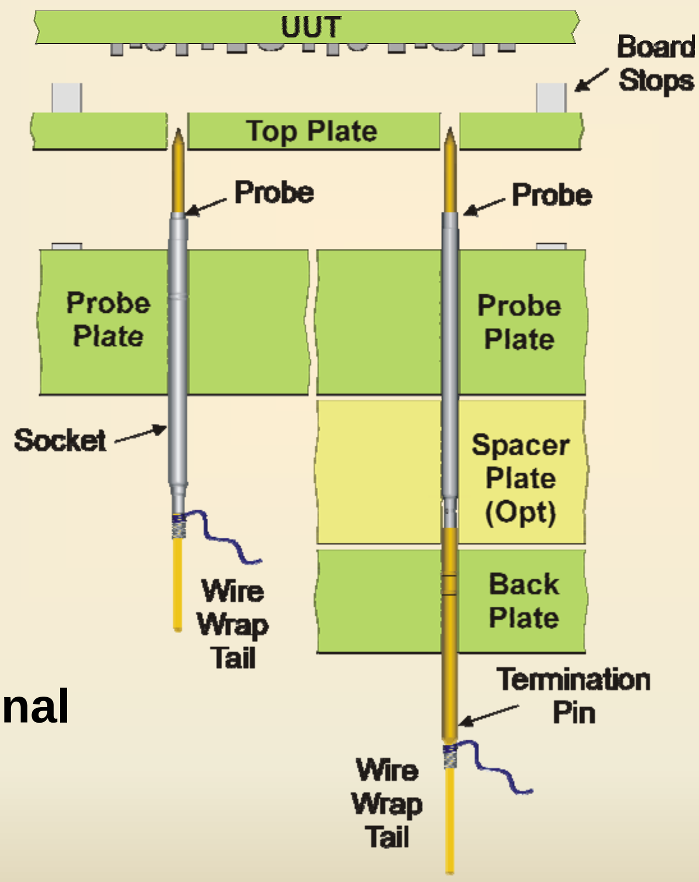
Socketless Design Considerations

Worldwide Availability



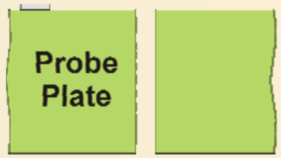
Comparisons

Comparison between conventional probe/socket vs. socketless



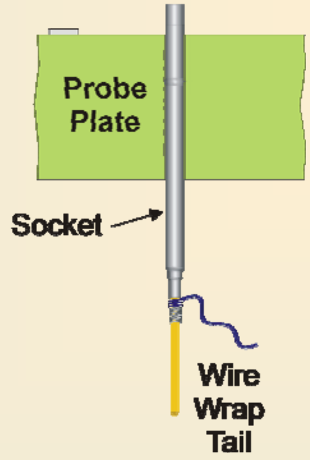
Conventional **Socketless**

Comparisons



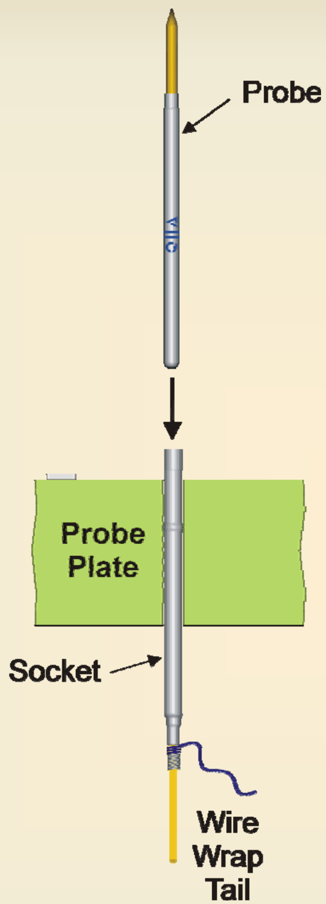
Conventional

Comparisons



Conventional

Comparisons



Conventional

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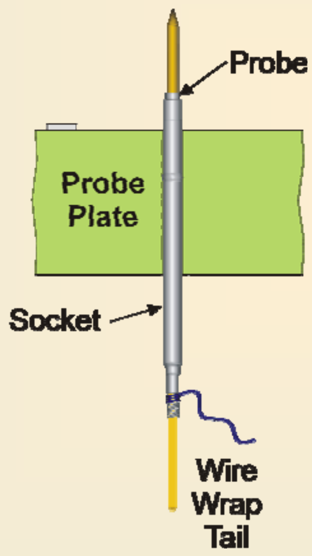

Conventional

Comparisons

Socketless

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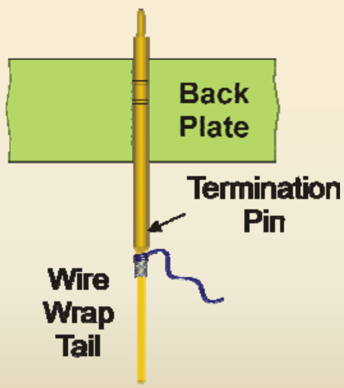

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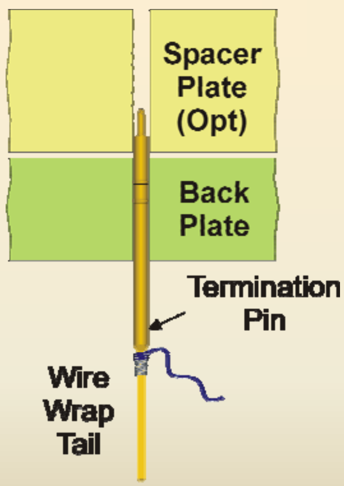

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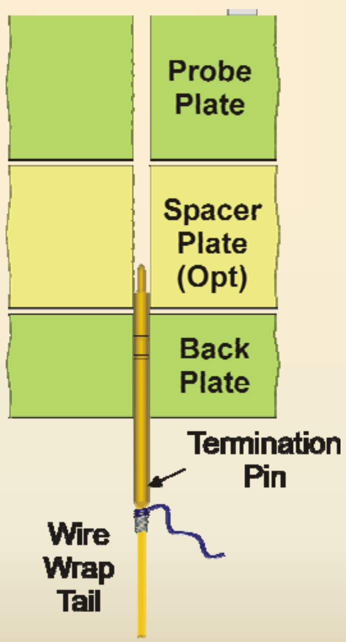

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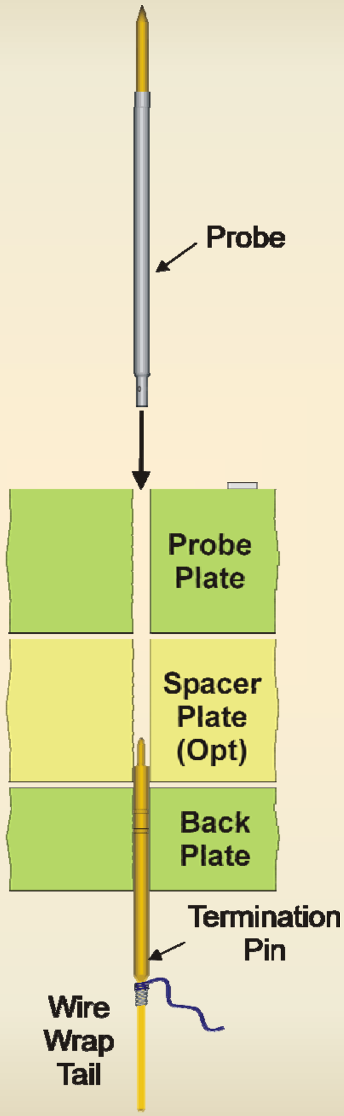

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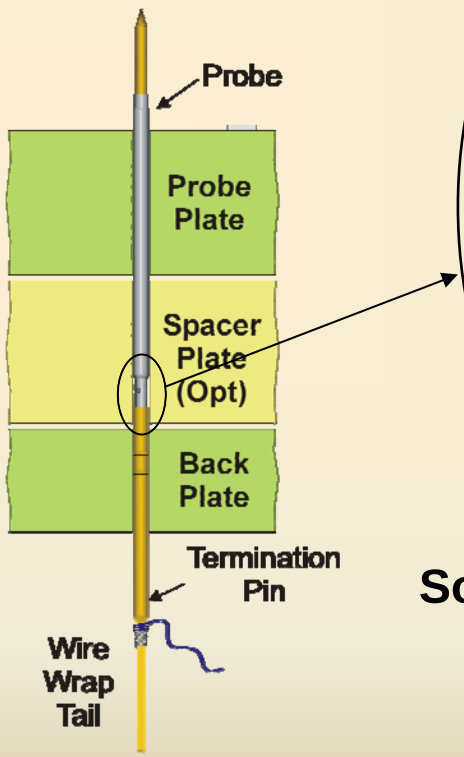

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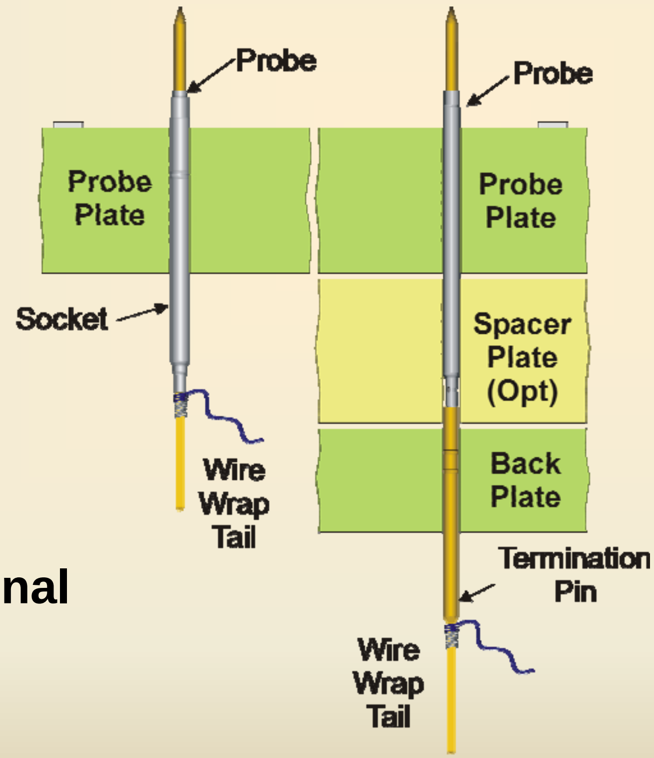

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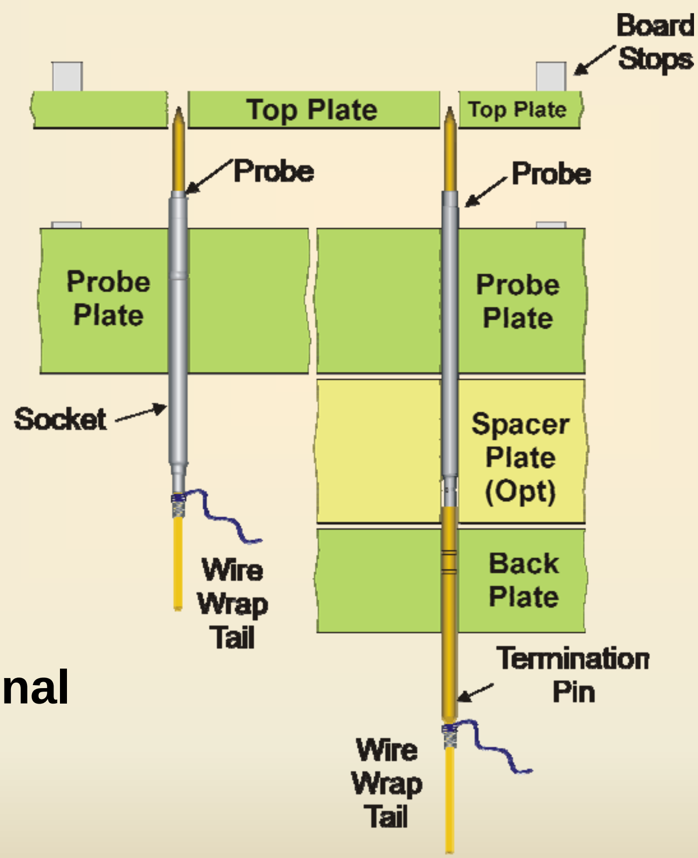

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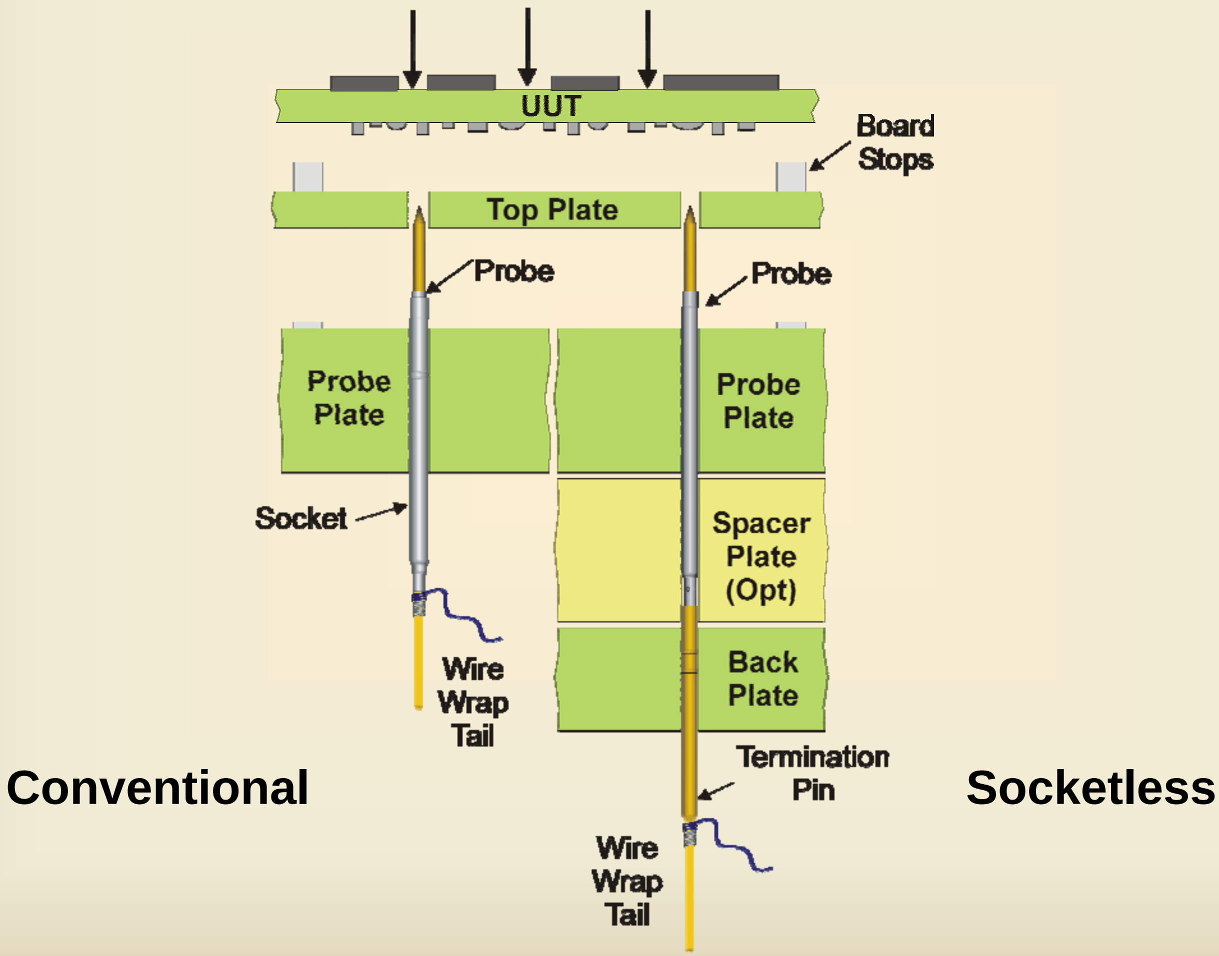

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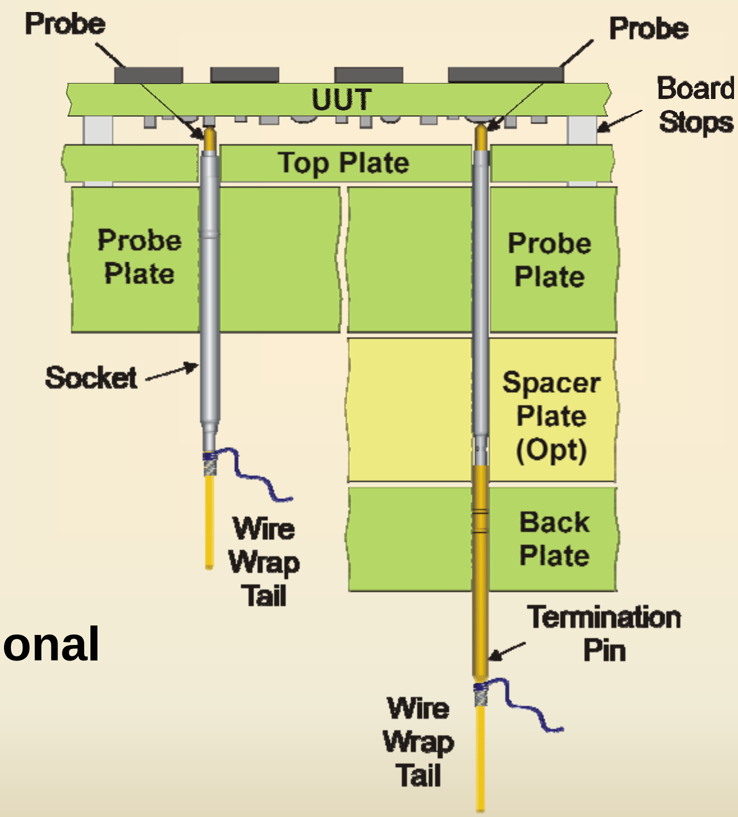
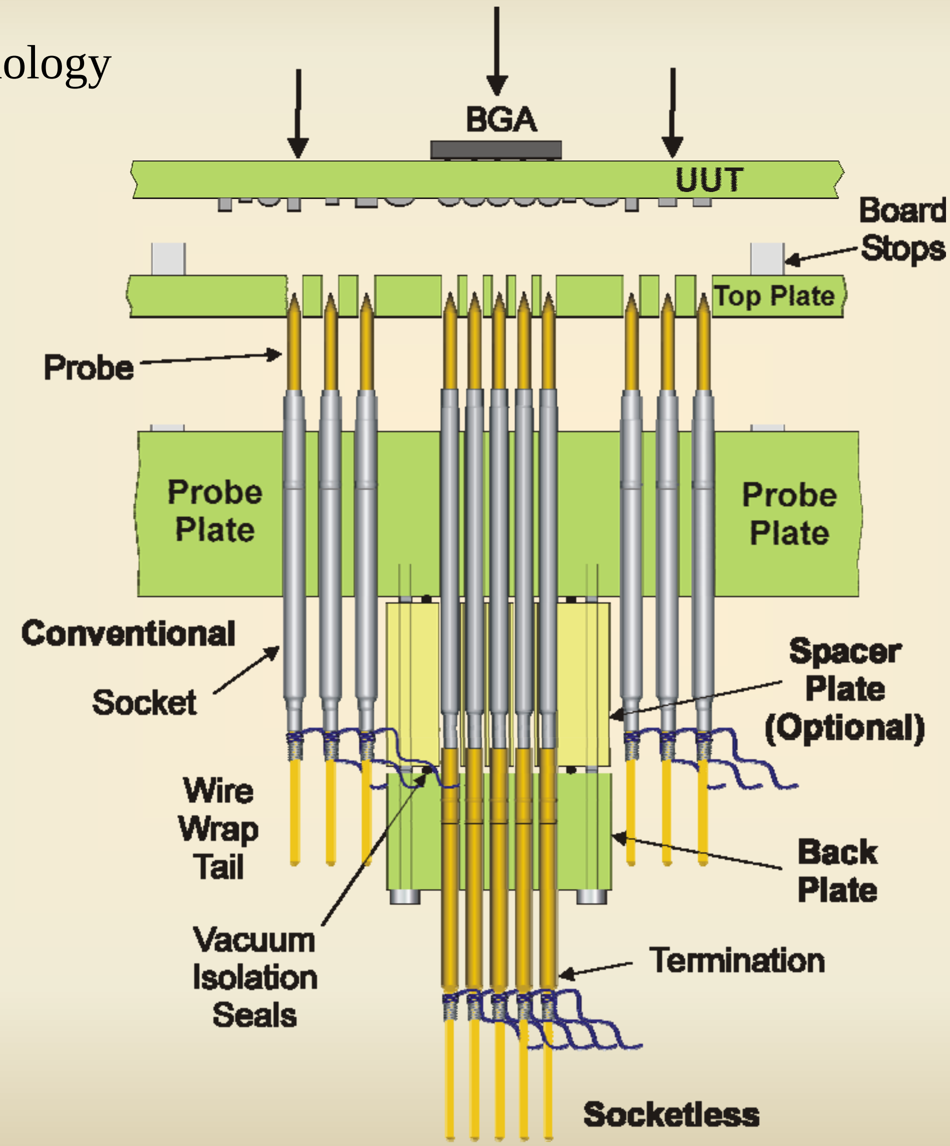


Conventional

Socketless

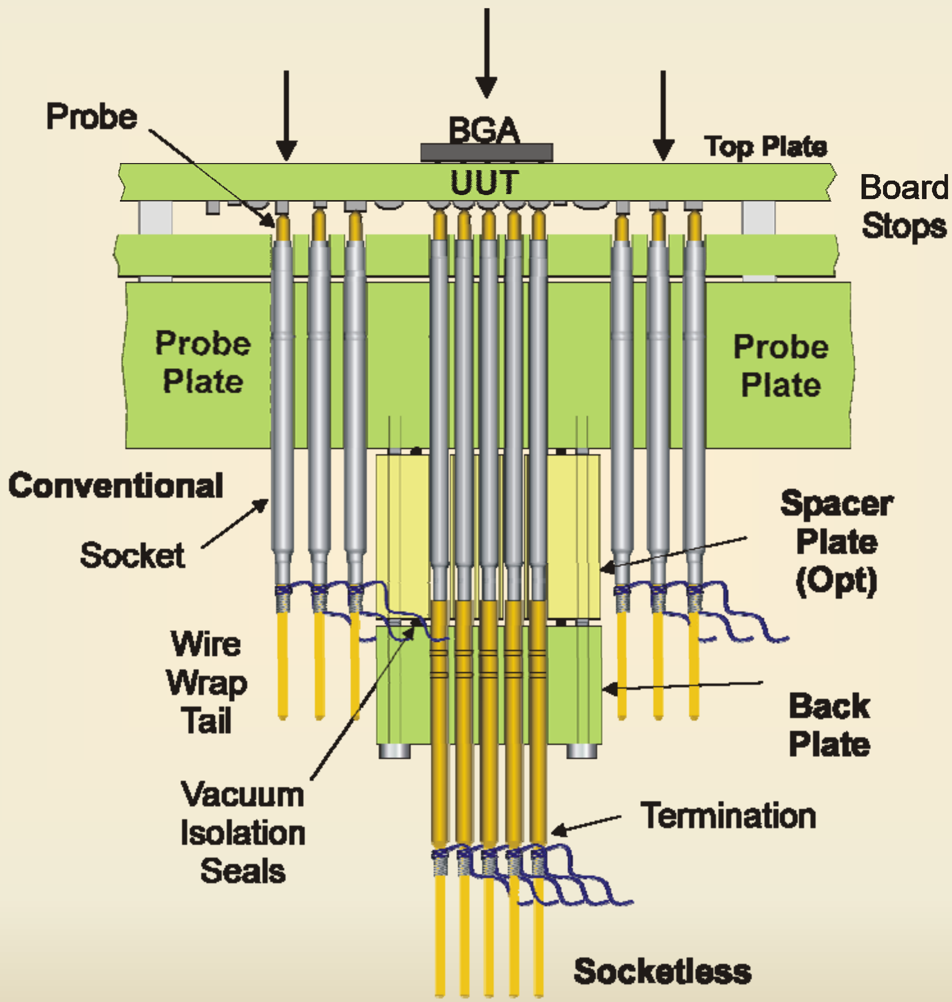
Comparisons

Mixed probe technology



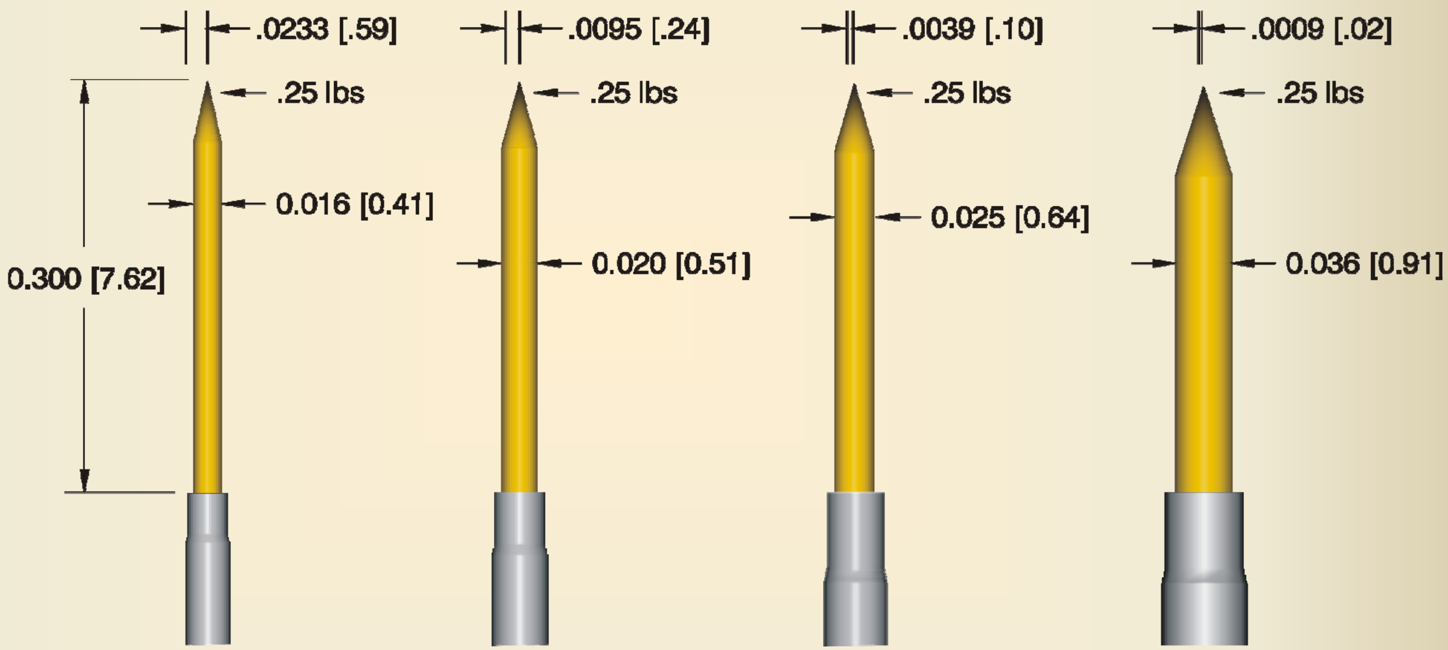
Comparisons

Mixed probe technology



Socketless Advantage

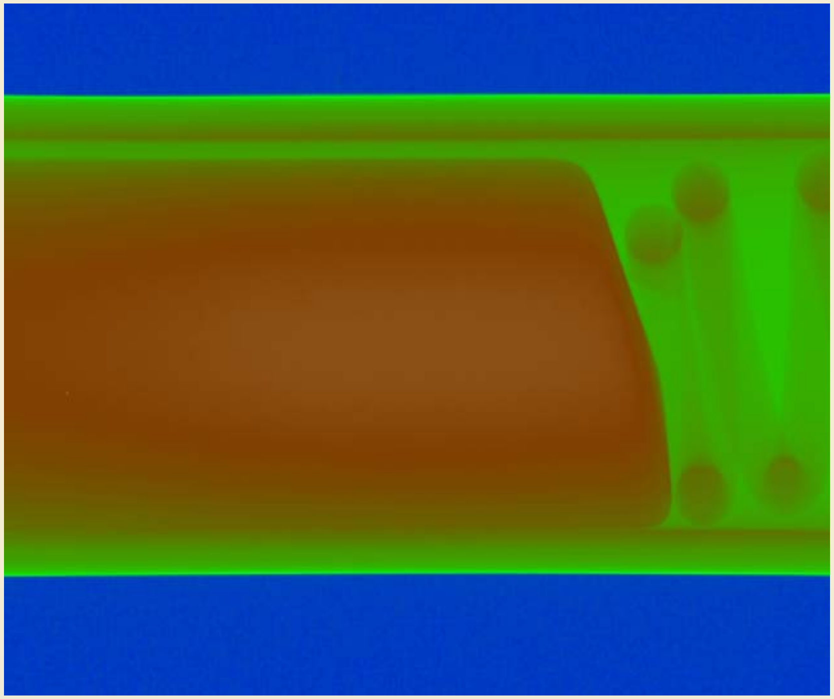
Greater strength – a larger probe on closer centers is more durable when compared to a conventional probe on the same center spacing



Probe Centers				
Conventional	.039" [1.0 mm]	.050" [1.27 mm]	.075" [1.91 mm]	.100" [2.54 mm]
Socketless	.030" [.80 mm]	.039" [1.0 mm]	.050" [1.27 mm]	.075" [1.91 mm]

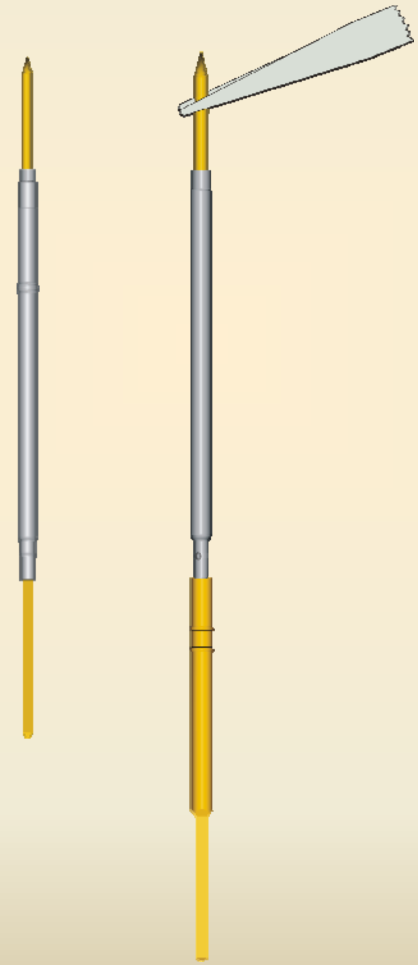
Socketless Advantage

Larger diameter components increases probe life and reduces electrical resistance



Socketless Advantage

Less susceptible to damage during replacement and maintenance



Socketless Advantage

Cost – Larger probes on closer centers typically cost less because

- Larger manufacturing tolerance
- Faster, more automated manufacturing process
- Easier to install
- Volume purchasing of components

Center Spacing	Socketless cost compared to Conventional
.039” [1.00 mm]	Less
.050” [1.27 mm]	Less
.075” [1.91 mm]	Less
.100” [2.54 mm]	More

Socketless Advantage

Spring force availability

Conventional	Center Spacing / Stroke	Socketless
0 *	.039” /.250”	5
5	.050” / .250”	5
0	.050” / .400”	2
5	.075” / .250”	7
2	.075” / .400”	3
12	**Total**	**22**

* Conventional .039” is only available in .160” Stroke

Socketless Advantage

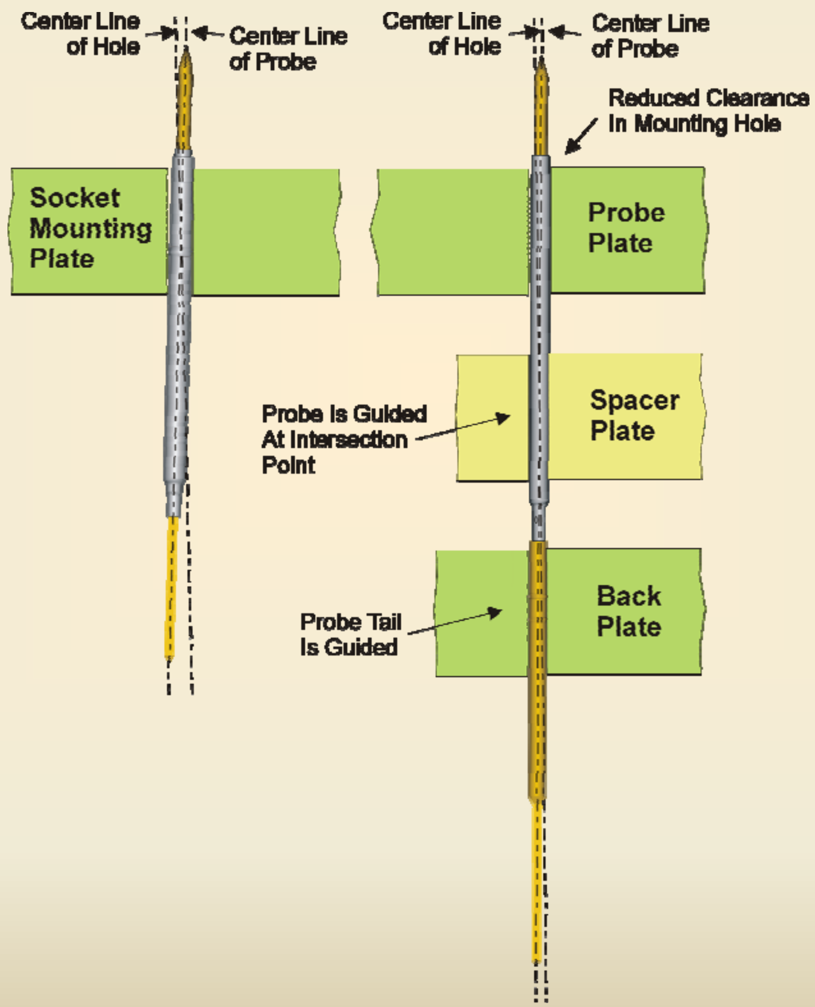
Tip style availability

Conventional	Center Spacing / Stroke	Socketless
0*	.039” /.250”	15
15	.050” / .250”	32
0	.050” / .400”	15
32	.075” / .250”	42
15	.075” / .400”	27
62	**Total**	**131**

* Conventional .039” is only available in .160” Stroke

Socketless Advantage

Improved Pointing Accuracy – 39.5% better pointing accuracy by design



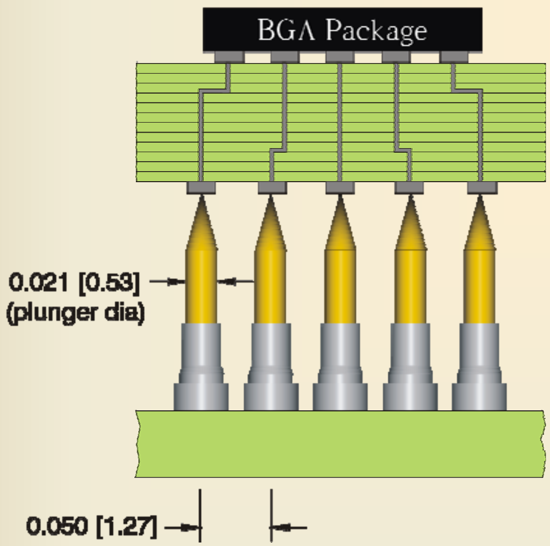
Socketless Advantage

PCB Design, Manufacturing, Testability, Cost

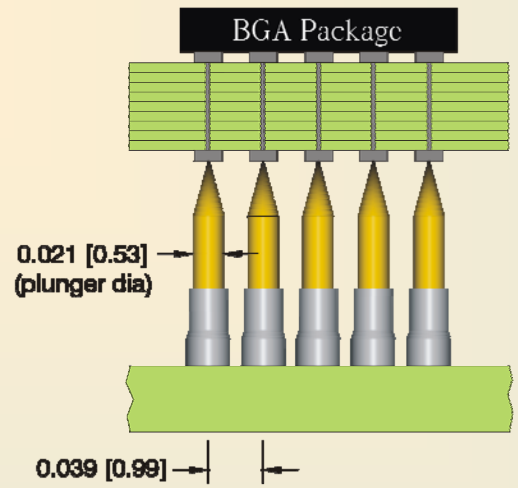
Direct probing under .039” [1.0 mm] BGA packages reduces the number of board layers required.

High density board designs without compromising test coverage.

Conventional



Socketless

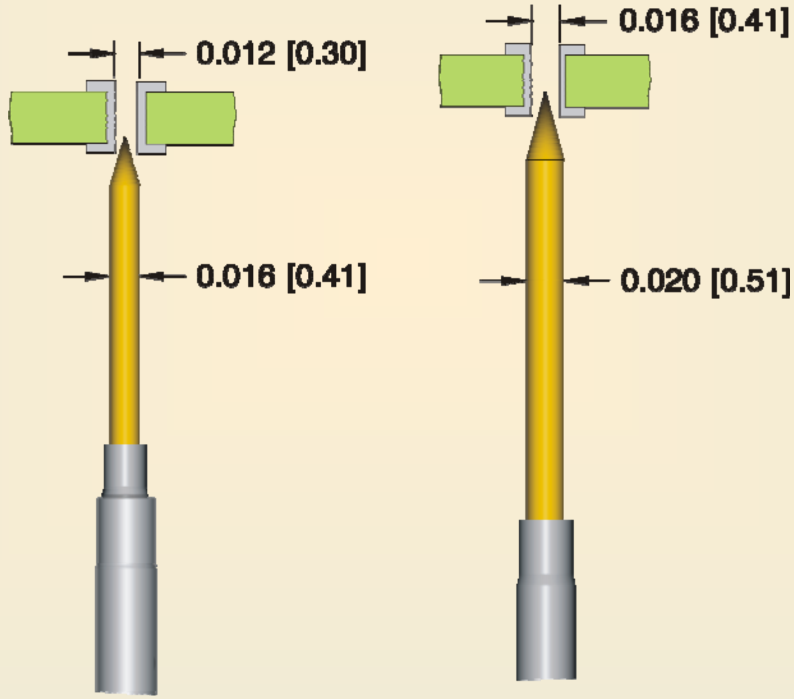


Socketless Advantage

PCB Design, Manufacturing, Testability, Cost

Larger vias on closer centers are now testable.

Conventional



Socketless

.039” [1.0 mm] Conventional

.039” [1.0 mm] Socketless

Socketless Summary

- Socketless probes are designed to be compatible with existing fixture manufacturing and wiring methods.
- For small center test targets, the lower costs of Socketless Probes have an advantage over Conventional probes.
- A greater number of spring force and tip style selections are available.
- For close centered targets, the larger more robust Socketless Probes ease maintenance and increase test reliability for board manufacturers.
- Increased pointing accuracy of the Socketless Probe over a Conventional Probe helps increase first pass yields.
- Socketless Probes allow Board Designers to place test access on closer centers thus reducing board space and layers.
- By allowing larger vias on closer centers the drilling efficiency is improved by keeping the hole depth to hole diameter low.

The Socketless Revolution

Larger probes on smaller center test targets

Thank You

Questions?

Matt Parker
Product Engineer
QA Technology Co. Inc.
110 Towle Farm Rd.
Hampton, NH 03842
USA