

ICT Fixture Guidelines



Test Techniques and Practices

US/Canada Dial-in #: (877) 809 3723
Int'l/Local Dial-In #: +1 (706) 634 0863



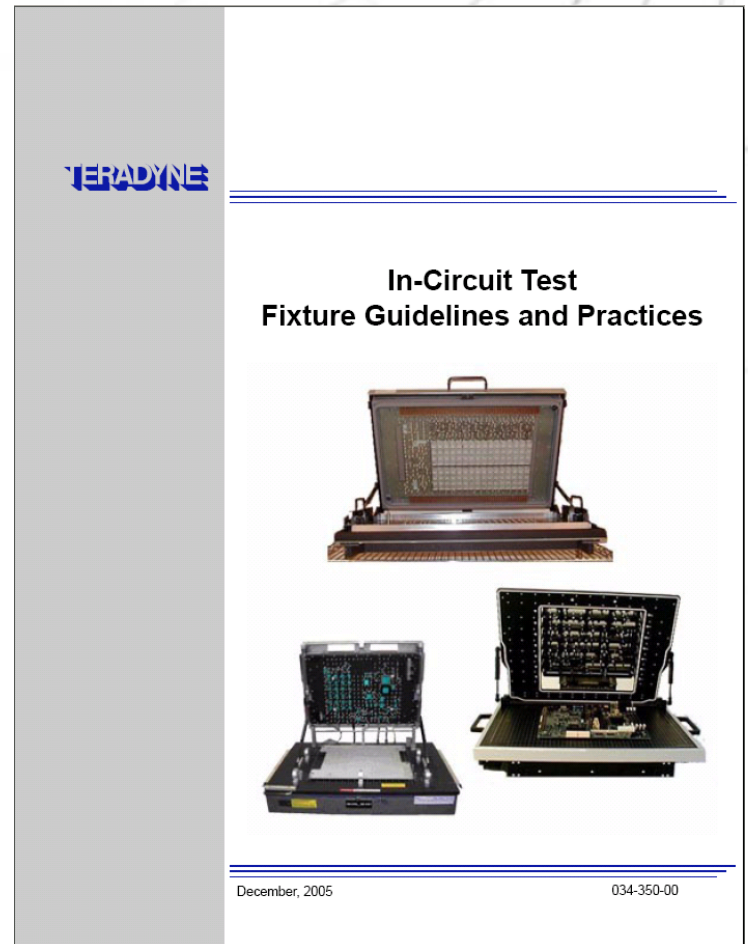
TERADYNE

Michael J Smith
Michael.J.Smith@Teradyne.com

Assembly Test Division

In-Circuit Test Fixture Guidelines

- ICT fixturing can make or break the efficiency of PCB manufacturing test.
- This presentation is based on the Teradyne's new fixturing design guide.

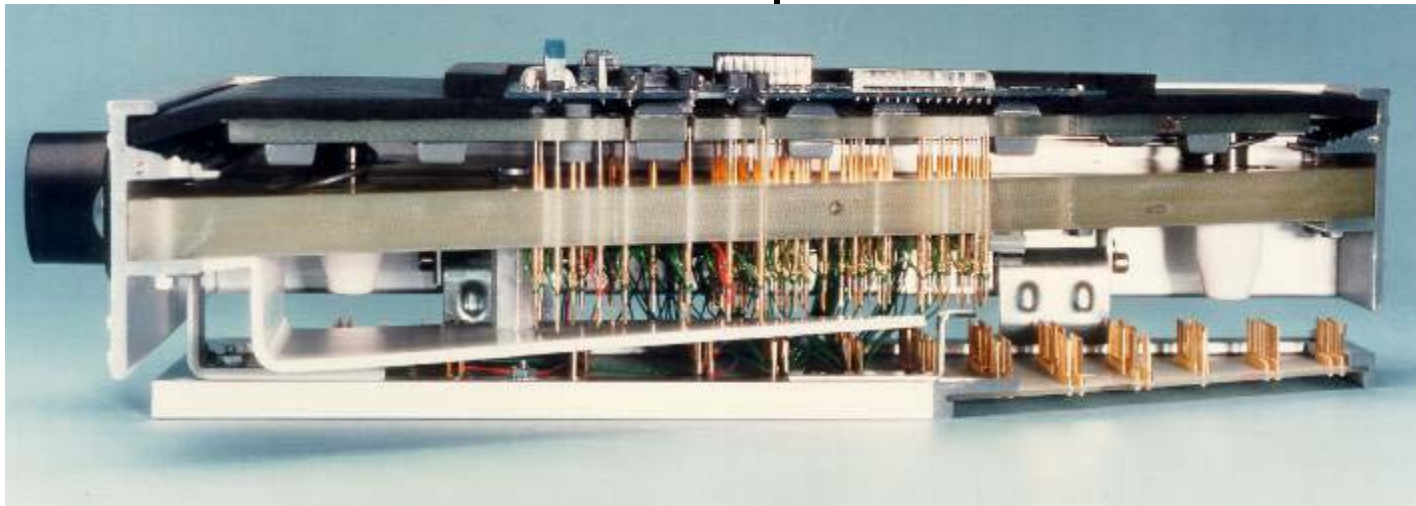
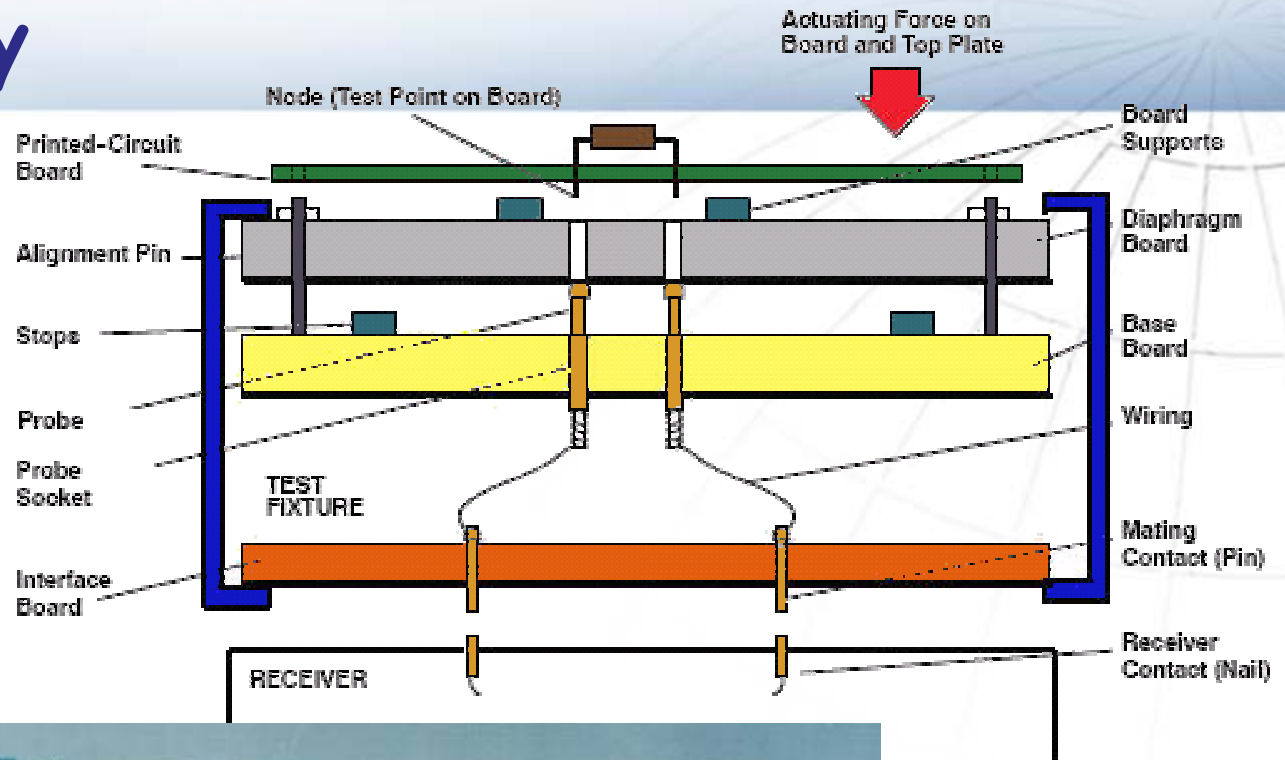


Agenda - Fixture Guidelines

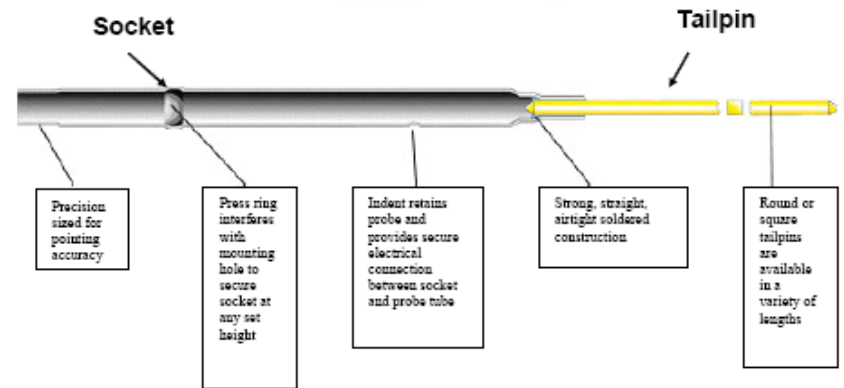
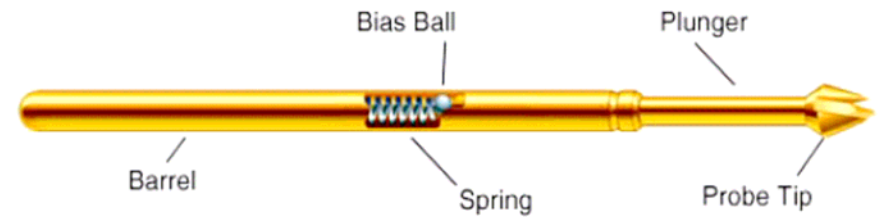
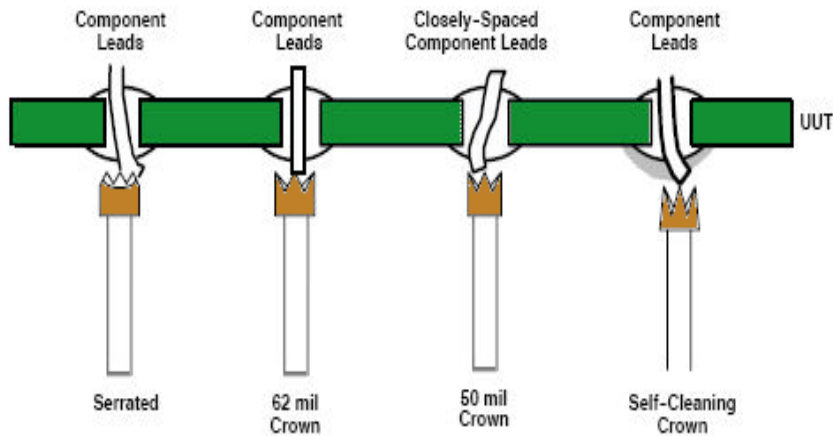
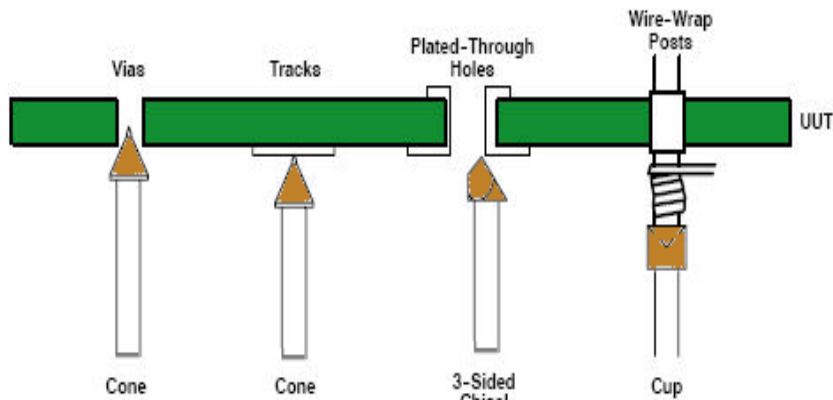
- Terminology
- Fixture Build Process Guidelines
- Fixture Mechanical Guidelines
- Fixture Electrical Guidelines
- Best Practices - Pros and Cons
 - Wireless Fixtures
 - Short-wire Fixtures
 - Long-wire Fixtures.
- Methods of Activation - Pros and Cons

Terminology

Fixture Basics



Terminology - Probe Basics.



Terminology - Probe styles.

- [1] B Arzadon, et al, "Lead-Free Solder Paste with ICTProbe Penetrable Residues", Proceedings APEX, 2002, Session 5.1.
- [2] D. Suraski, AIM and M. Parker, QA Technology "Considerations for the Pin Probe Testing of No - Clean Solder Paste Residues",
- [3] K. Tellefsen, Alpha Metals CRL "Solder PasteResidue Pin Probability Testing Using a Camalot Dispensing System".
- [4] Rosa D. Reinoso, Hewlett-Packard Company, Effect of Lead Free Solders on In-Circuit Test Process, ITC 2005 Paper 26-3✓

Fixture Build Process Guidelines

- Documented Fixture Assembly Process
 - Design-For-Testability Guidelines - Fixture Manufacturer
 - Statement of Work Document - Customer generated
 - Example in Teradyne Fixture Guidelines
- Fixture Manufacturer Should Provide
 - Pre-Manufacture PCB Analysis
 - Fixture Verification
 - On-Site Installation Services
 - Fixture Warranty
 - Customer Surveys

Mechanical Details for Fixture Kits

- Base pans fabricated using sheet steel or aluminum which meets standard ASTM-A366.
- For large size test fixtures (20" (508mm) x 30" (762mm)),
 - use sheet metal pans with a minimum thickness of .125" (3.2mm).
- For small size test fixtures (20" (508mm) x 24" (610mm)),
 - use sheet metal pans with a minimum thickness of .090" (2.3mm).
- For pan strength and durability, all pan corners must be completely welded and smooth sanded.
- Use electrostatic applied powder coating for pan finish.
 - Do not use painted pans, because paint can crack and chip, potentially leading to oxidation of the pan metal.
- Recommendation for TestStation Wired Fixture kits.
 - For standard sized (Non-L receiver version) wired fixtures, a minimum pan depth of 3.25" (82.6mm) maintain sufficient room for wires and added components.
 - For L receiver size wired fixtures, maintain a minimum pan depth of 5.00" (127mm) to allow sufficient room for wires and added components.
- Etc
- see the Fixture Information Manual, 9007011505

Recommended Top Plate Specifications

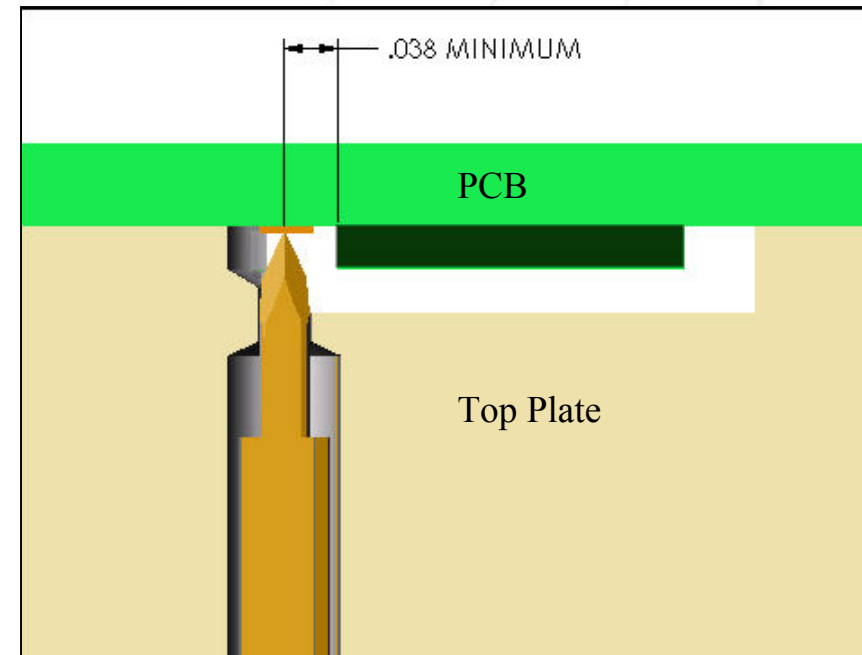
- All top plates are to have a minimum nominal thickness of .192" (4.9mm).
 - Thicker top plates are allowable depending on the application.
- A recommended technique for mounting the top plate to the probe plate is through the use of four locking guide pins, one in each corner, which work to align the top and probe plates.

Recommended Probe Plate Specifications

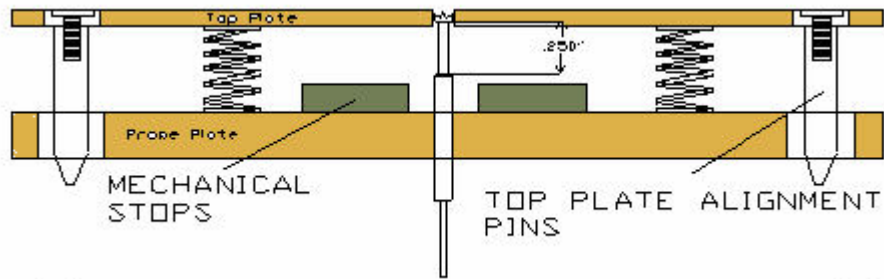
- Fixtures with less than 1000 probes can use a probe plate that has a minimum thickness of .375" (9.5mm).
- Fixtures with more than 1000 probes require a probe plate with a minimum thickness of .50" (12.7mm).
- Fixtures that are going to be testing "no-clean" PCAs require a probe plate with a minimum thickness of .50" (12.7mm).
 - Typically No Clean use higher force probes

Guided Probe Plate

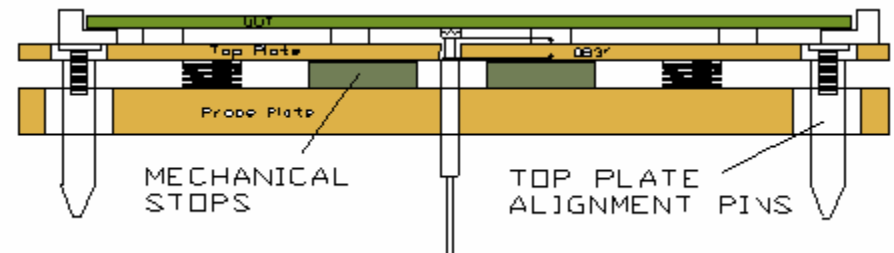
- Guided probe plates are recommended for fixtures using small test pads and spacing, below .028" in diameter.
- One technique is to modify the top plate of the fixture kit to countersink the back side of the top plate to act as a guide.
- Another technique is to mount plates between the probe plate and the top plate that are used to increase the accuracy of smaller test probes.
- Guided probe plates should be manufactured from standard FR-4 or G10.
 - The main difference between NEMA Grades G10 and FR4 is that FR4 is a fire retardant grade of G10



Probe Travel



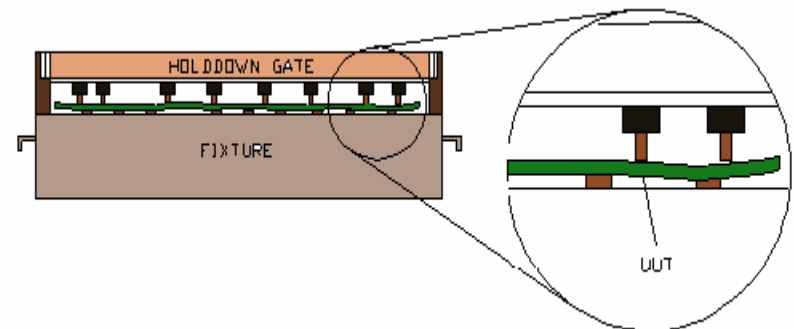
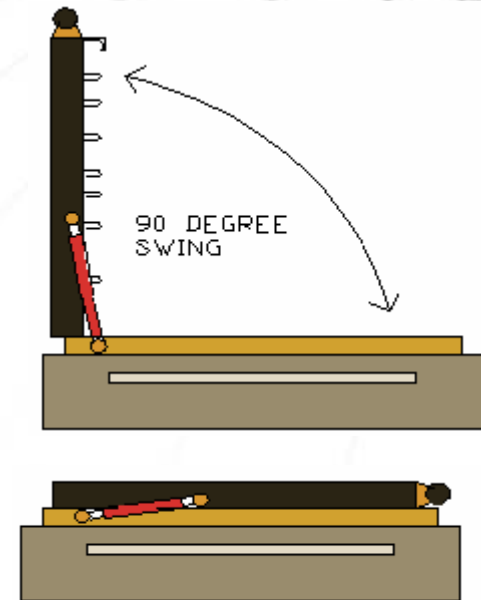
- Allow clearance from UUT contact to probe tips



- The probe shall travel at least $2/3 \pm 20\%$ of its full travel

Hold-down gate

- Hold-down gates require positive force to close but cannot spring up rapidly when opened as it could cause injury.
- Fixtures may require plates that provide extra support at the location of the hold-down gates.
- Hold-down fingers should not make contact with any components, solder joints etc (norm .05" clearance)
- Can use .02" clearance if required for stress mitigation,
- Hold-down gates hold the UUT flat and do not allow it to warp or flare up on the sides.
- Design to reduce the flex of the UUT.

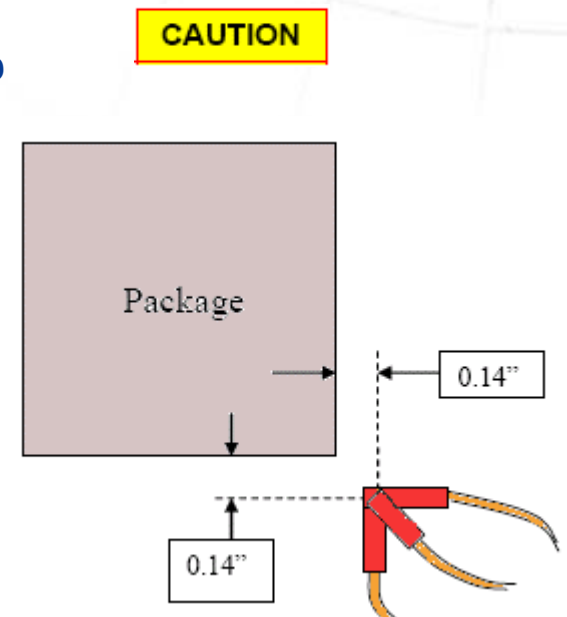


Tooling pin recommendations are:

- For rectangular PCAs, two diagonally opposed tooling pins should be installed in the bottom plate of the test fixture for accurate UUT to bed-of-nails registration.
 - The use of a third tooling pin installed in the top plate is recommended to ensure correct UUT placement on the test fixture.
- Tooling pins should be smaller in diameter (typically 0.003" - 0.005" [0.0762mm - 0.127mm]) than the alignment hole on the UUT with a tolerance of ± 0.001 " ($\pm .0254$ mm)..
- Press fit tooling pins in the probe plate and retain using a fastener
- Use hardened steel at a Rockwell hardness of 55-60 with taper on the end to allow for easy installation of the UUT.
- Design tooling pins for easy removal and replacement because over the life of the fixture these can loosen or wear and require replacement.
- Include tooling pins on single boards within a panel to accommodate break-out boards.
- Do not use plated holes for tooling pins.

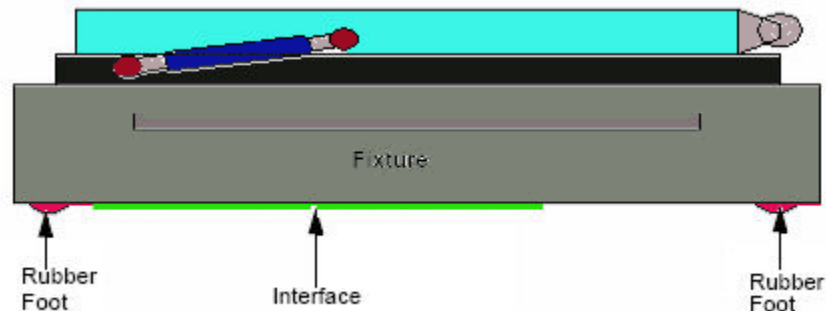
Strain - Board Flex

- To a large extent the location of the gauges is determined by the design of the card and the test fixture.
- In general quality strain measurement requires 3 axes stacked rectangular strain gauges located in the following places.
 - The 4 corners of any large BGA package on the top side (size > 27mm x 27mm).
 - The 4 corners of any large BGA package on the bottom side.
 - The 4 corners of any Chip on board (COB) type package.
 - Any location where there is a high density of ICT probe pins.
- A good resource for learning more about strain and measurement techniques is the Vishay Measurements Group's website (www.measurementsgroup.com).



Fixture Cover Plates and Fixture Protection

- It is recommended that a cover plate of 0.125" (3.175mm) lexan stock, cut to the dimensions of the PCA, be used when the fixture is not in use.
- Another cover plate, made of identical stock, can be provided to protect the receiver/fixture interface pins on the bottom of the test fixture.
- Install rubber feet to protect the fixture during handling.
 - If you are going to use the fixture with adapter plates on other test systems beware of the use of rubber feet. Rubber feet can cause the adapter plate and the fixture not to seal to each other and cause connectivity problems.



CAUTION

Fixture Electrical Guidelines

- Ground Planes

- Ground planes **must** be used on PWAs with a significant amount of digital circuitry.
- Ground planes must be installed on the bottom of the fixture probe plate and on the receiver/fixture interface.
- Ground connections between the ground plane on the probe plate and the ground plane on the receiver/fixture interface must be made by soldering a **minimum of two braided copper wire straps**, each with a minimum width of 3/8".
- Ground planes must have holes drilled with sufficient clearance between installed probe barrels and the ground plane.

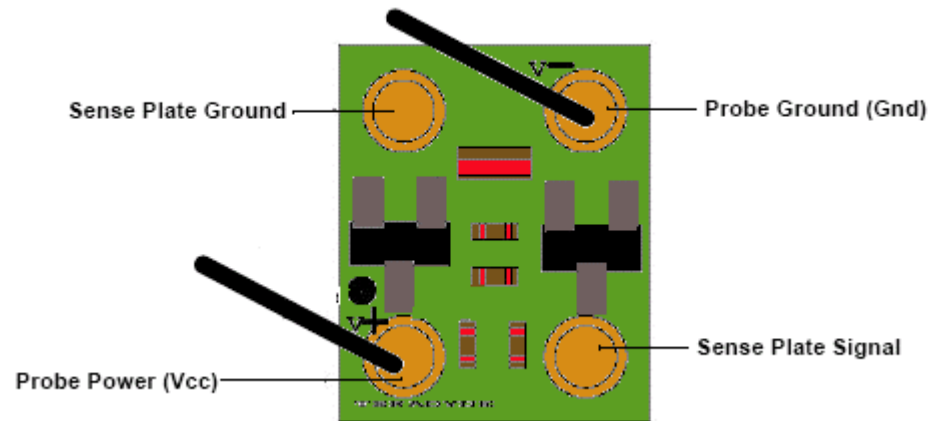
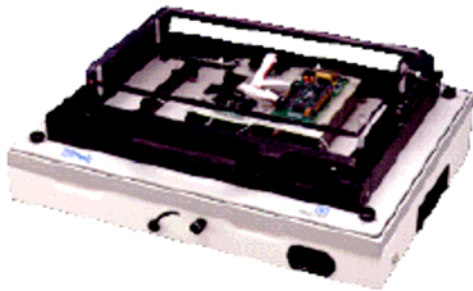
CAUTION

Fixture Electrical Guidelines

- Pin Electronics Wiring
 - Pin Electronics Wire: Kynar/Teflon coated solid wire wrap wire, 26-28 awg
 - Adjacent rows of wires on the receiver/fixture interface should be different colors. Wire colors can repeat after all available colors have been used.
 - Twisted pair wiring is preferred on all pins high speed digital devices.
 - Twisted pair ground wires should be black with 4-8 twisted per inch.
 - Suggested Wire wrapping specification:
 - 7 loops of bare wire contacting the probe socket post
 - 1 $\frac{1}{2}$ Loops of insulated wire around top of probe socket post
 - Do not bundle wires.
 - Do not "daisy chain" any wires
 - Do not dress wires in-between receiver/fixture interface pins.
- Power Supply Wiring (PS, SVS, UPS)
 - see guide

Fixture Electrical Guidelines

- OpensXpress and FrameScan FX



OpensXpress and FrameScan FX

- Probe plates must be covered with a material that will insulate them from shorting device pins.
- Probe plates must be fully supported in such a way that it is difficult for them to become misaligned and minimizes radial play with respect to the component they are to contact.
- Shield electrical connection to the opens test probe plate in order to ensure signal integrity and stable, accurate measurements.
 - Using coaxial cable is the preferred method for shielding the signal but at a minimum twisted pairs
- Wherever appropriate, multiple opens test probes that need to be mounted as one unit.
 - This insures that the probes will stay in place with respect to one another.
- Label opens test probes with the reference designator of the device they test.
- Transfer pins for opens test circuitry must make electrical contact at all times (for example, when the fixture is actuated AND when it is not actuated).
- Consider using different size and shape probe plates to achieve a larger good signal pin.
 - For example, consider using a L-shaped or U-shaped plate instead of a flat probe plate on connector components to match the geometry of the device being tested

FrameScan FX - Best Practice

- Proper Probe Amplifier Placement:
 - It is strongly recommended that the probe amplifier be mounted directly to the probe sense plate.
- Remote Probe Amplifier Placement:
 - Although mounting the amplifier any distance away from the sensor plate is not recommended, if the amplifier has to be mounted away from the sensor plate, a number of extra precautions are necessary to ensure proper operation.
 - The sensor amplifier will require electrostatic shielding.
 - The conducting material that shields the probe must be connected to the probe amplifier's ground terminal.
 - Other fixture signals in the vicinity of the FrameScan FX probe or probe hangers can interfere with the low level measured signals.
 - It is important to make sure that the remote probe wiring is not tightly bundled with other fixture wires that could interfere with the measured signal and that the wire length is kept to an absolute minimum.

FrameScan FX - Best Practice

- Fixture Wire Bundling:
 - Isolate FrameScan FX wiring from other fixture wiring.
- Probe Plate Travel and Force:
 - Limit FrameScan FX probe travel on spring hangers such that the probe plate will not contact the PCB, should the part being tested is missing from the PCB. Also, it is important to set a probe force that is high enough to ensure that there is full contact between the face of the probe sensor and the device under test, but not so much force as to accidentally cause an open solder joint to close and cause a false pass condition.
- Probe Plate Contact Repeatability:
 - The FrameScan FX should contact the device under test in a consistent and repeatable manner. As the result, make sure that the probes are well supported and are not "wobbly".
- Probe Plate Mounting:
 - The preferred method of mounting the FrameScan FX probe and amplifier to a fixture top or bottom plate is to use two spring loaded probe plate hangers. In fixturing situations where it is not possible to use hangers, alternative methods such as form may need to be used.

Fixture Best Practice

- There are three different methods of wiring a fixture, based on the way the fixtures are wired,
 - Wireless fixtures
 - Short wire fixtures
 - Long wire fixtures
- The appropriate type of wiring for the fixture depends on:
 - The number of electrical nodes to be tested on a given board.
 - The number of boards to be tested.
- Wireless fixtures are preferable when the node count is high and the board is a non-prototype board. In case of very low node counts and prototype boards, wired fixtures are preferred

Wireless Fixtures

- Wireless Fixtures
 - Wireless fixture technology is a mature and economical technology and is especially applicable in high node count, low voltage scenarios and non-prototype boards.



Wireless Fixtures

- **Advantages**
 - Reliable wiring because manual wiring errors are eliminated.
 - Duplicate fixtures perform identically.
 - The internal fixture electronics are neat and clean.
 - Fixture height is low making the fixture compact.
 - Electrical parameters are constant, excellent for low voltage requirements.
 - Probing accuracy is enhanced because there are no lateral loads on sockets.
 - Small scale ECOs are easy to manage even in high pin count scenarios.
 - Fixture size and weight are independent of probe count making wireless fixtures well suited to high pin count scenarios.
 - Multiple copies are extremely compatible and more economical.

Wireless Fixtures

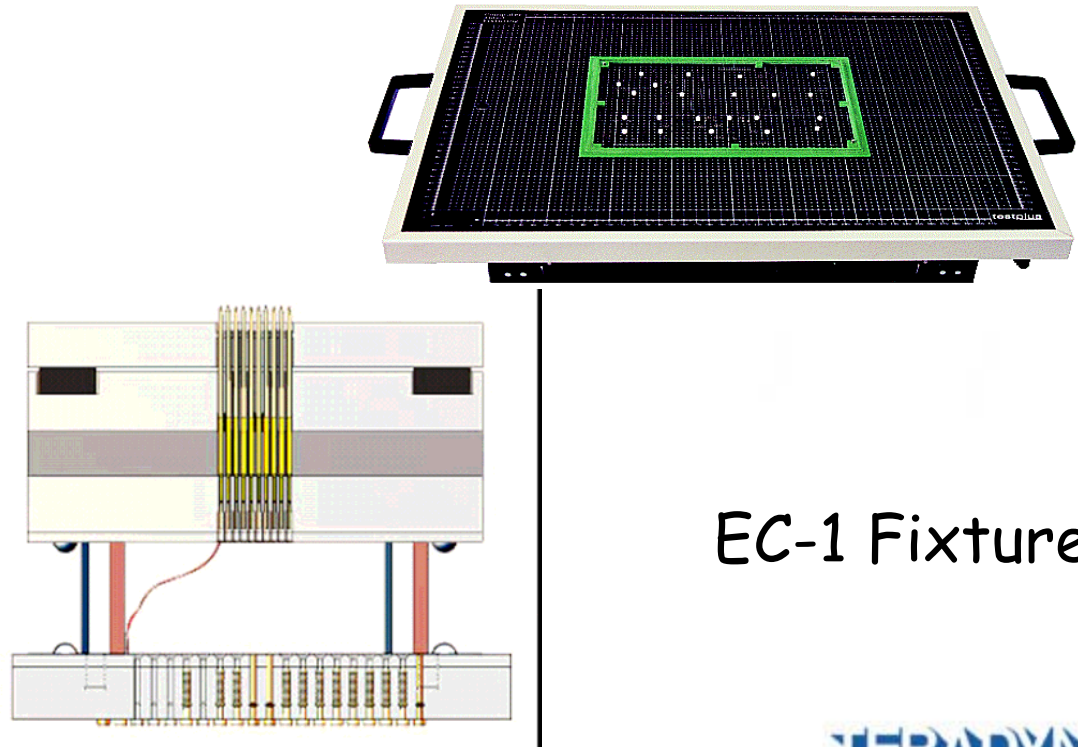
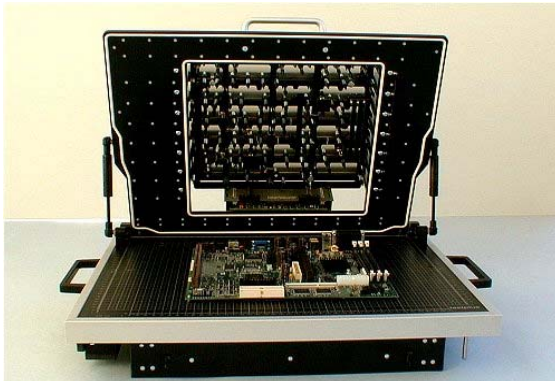
- Limitations

- For very low pin count or prototype boards
 - designing a PCB meant to route signals to the appropriate probes becomes expensive
- Continuity can be checked
 - But wiring cannot be checked or traced visually.
- Large-scale ECOs
 - may require a new wireless PCB.
- Component heights on the bottom of the UUT can be limited
 - Depends on design

Short-wire Fixtures

- Short-wire Fixtures

- Short-wire fixturing is aimed at eliminating the disadvantages of the long-wire method while keeping the benefits of the wireless approach.



EC-1 Fixture

Short-wire Fixtures

- **Advantages**

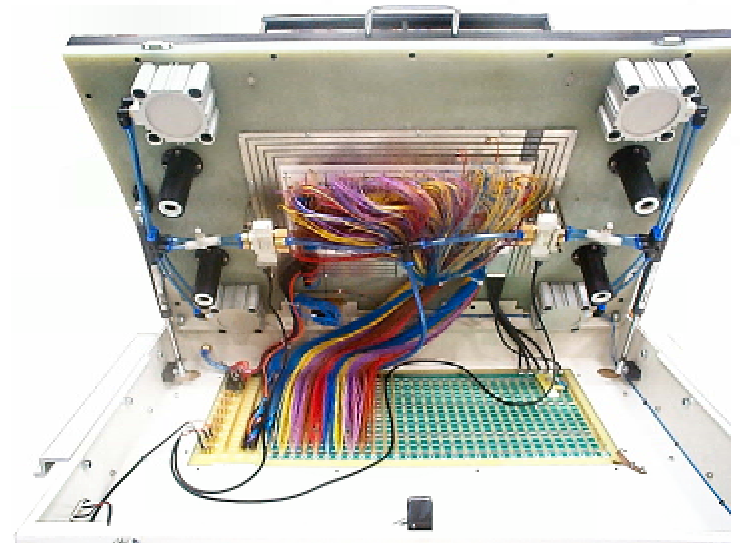
- It is easy to implement ECOs
- The signal integrity is much higher than in the case of long-wire fixtures.
- Such fixtures are lightweight and easy to handle.
- Initial fixture costs are slightly higher but subsequent fixtures of the same design are cheaper.

- **Limitations**

- Even though there are guide plates, there may be some lateral load on interface pins as they are guided to make contact with the grid PCB.
- On low node counts and prototype boards, short-wire fixtures become expensive due to the additional PCB and high precision guide plates that are required.

Long-wire Fixtures

- Long-wire Fixtures
 - These fixtures are widely used and accepted.
 - Long wires are used to establish contact between interface nails (that make contact with the tester receiver) and the bed of nails that makes contact with test points on the board.
 - Wiring is done using manual or semi-automatic wire wrapping procedures.



Long-wire Fixtures

- **Advantages**

- Long-wire fixtures have been tried and tested over time even up to high node counts of around 5000-7000 nodes.
- Higher signal integrity and low cross talk may be obtained by using twisted-pair wiring (with one wire in each pair connected to ground)
- In instances of very low-node count (500-1000) or when in-circuit testing is desired on prototype boards (where the board design is subject to change), long-wire fixtures work out more economically because wiring and fixture-verification costs are low
- These fixtures are larger and roomier.
 - There is more room available to place actuation mechanisms.
 - Probes can be longer, which facilitates wire wrapping.
- Large-scale rework can be incorporated with little loss in investment, especially in low and medium pin counts.
- Wiring can be visually traced and checked.

Long-wire Fixtures

- Limitations

- Duplicate fixtures will not always perform identically.
- Moving wires inside a fixture can cause numerous problems.
 - It can be difficult to control the amount of cross talk and coupling between signals.
 - This may result in unstable in-circuit tests.
- The wire-wrap endings of probe receptacles may cause wires to get nicked and may result in shorts.
- Unauthorized or undocumented wiring changes are extremely difficult to spot.
- It is not always easy to incorporate ECOs
 - High pin count applications
- Fixture weight increases with increase in node count.

Methods of Actuation

- Fixtures can also be classified based on the method of actuation used to establish reliable contact between the bed of nails and the actual test points on a PCB.
 - Vacuum actuation
 - Pneumatic actuation
 - Mechanical actuation

Vacuum Actuation

- In vacuum actuated fixtures, contact between test points on the board and the probes are established by vacuum suction.
- In theory, vacuum can be successfully used to establish contact between test nodes on a board and test probes on a fixture if the downward force caused by the difference in the atmospheric pressure (on the topside) and the vacuum on the bottom side is greater than the upward force exerted by the probes.



Vacuum Actuation

- Advantages:
 - Tried and tested over time especially in low and medium node-count applications.
 - Vacuum fixtures have also been successfully used up to 6500 nodes
 - They are lighter because of the absence of heavy mechanisms.
 - This makes vacuum actuated fixtures easy to handle.
 - Handling time between two boards and fixture change time between production runs is minimized.
 - There are several variations
 - the board can be placed under vacuum (by using a vacuum-box)
 - the top plate can be pulled down by vacuum and push fingers can be used to prevent the board from moving up (due to the upward force exerted by the probes) once contact is established with the probes.

Vacuum Actuation

- Disadvantages

- leakage from gasket seals needs to be considered
- safety issues
- number of probes effects the amount of vacuum
- As the area of a board increases, addition vacuum is needed
- Vacuum lines can become contaminants
- Vacuum fixtures are an inherent source of electrostatic discharge (ESD) caused by movement of air across insulating surfaces during fixture actuation

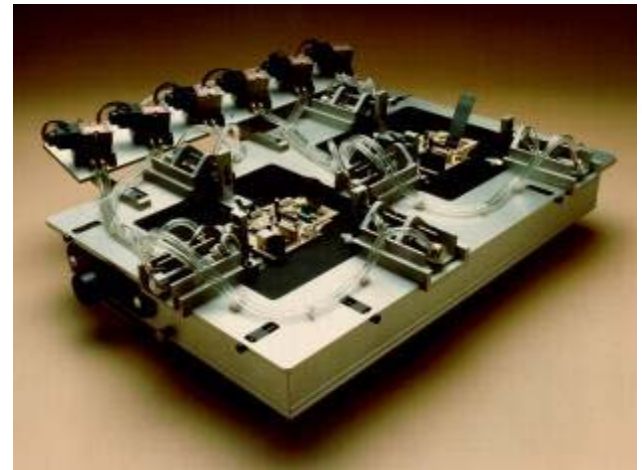
Vacuum Actuation

- Board Stress
 - localized stresses are induced in areas where probe density is high.
- Overheating
 - If a top hat or top probing is used with out air flow (prevent ESD) then the UUT may overheat



Pneumatic Actuation

- Pneumatic actuation is also a very popular means of establishing contact between fixture probes and nodes on a UUT. Pneumatic cylinders placed at different points in a fixture are used to push a board down and establish contact between test points and test probes.



Pneumatic Actuation

- **Advantages**

- With pneumatic actuation it is possible to distribute forces more evenly.
- Boards with holes or vias, as holes facilitate the movement of air, which may induce undesirable static electricity and damage components.
- A higher, vacuum may not be available on the shop floor.
- Use in an environment that is not clean where vacuum would lead to contaminants drawn into the fixture.
- More reliable contact and a lower false-failure rate due to less board flex

Pneumatic Actuation

- Disadvantages

- It should be noted that the higher the amount of force required to establish proper contact, the larger a pneumatic fixture
 - When boards get bigger and more complex and the number of nodes (and hence probes) need to test a board increases, the number of pneumatic cylinders needed to exert the downward acting force increases.
 - If fewer cylinders are used, then the size of each cylinder increases. All in all, the fixture weight and volume increases, making the fixture difficult to handle. This affects the handling time between two boards and the fixture change time.
- The lead-time involved in building a pneumatic fixture will be higher than the lead-time for vacuum actuated fixtures.
- Pneumatic fixtures are marginally more expensive when compared to vacuum actuated fixtures.
- In addition, if the fixture employs the long-wire technique, cost, weight and complexity increase and reliability decreases.

Mechanical Actuation

- Screw mechanisms or levers are used to apply the required force to push the board down and establish contact between test points and test probes.
- The reusable actuation mechanism can be repeatedly used for different fixtures (and different boards).
- Mechanically actuated fixtures can combine the advantages of vacuum and pneumatic fixtures.



Mechanical Actuation

- **Advantages:**
 - The complexities involved with vacuum actuated fixturing such as board and component damage due to board flexing, contact problems due to flexing, ESD issues and the need to maintain enough suction in the line are eliminated.
 - Test repeatability is higher and fixture induced retest or false failures are lower.
 - Mechanically actuated fixtures can be less expensive because individual actuation mechanisms do not have to be incorporated into every fixture.
 - Lead-time is much lower as compared to pneumatic fixtures and also the cost is much lower.
 - Permits Bi Level control for tests requiring two-stage fixturing.

Mechanical Actuation

- Disadvantages:
 - There would be a substantial one-time investment involved
 - Mobility to other fixturing techniques is difficult because the mechanical press itself would be heavy.
 - subsequent fixtures would have to be compatible (in other words, they all would have to be mechanically actuated fixtures).

And more....

- Case Study:
 - Comparison Between Different Test/Fixturing Strategies
 - One 3500-node Tester 2 x 3200-node Wired Vacuum Fixtures
 - 7680-node Tester, 6246-node Wired, Pneumatic Fixture
 - 7680-node Tester, 6517-node Wireless, Vacuum Fixture
- Sample Fixture Statement of Work
- Other references
 - TestStation Vectorless Test Techniques User's Guide 900740909
 - Test Fixture Manual (Small, Medium, Large) Pin Count Test Systems 9007510003/0604/1204
 - Fixture Information Manual 9007011505

More Information:-

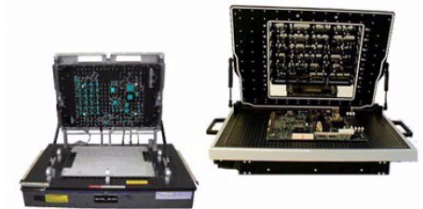
<http://www.teradyne.com/atd>

Your local sales engineer or Teradyne
account representative

Michael.J.Smith@Teradyne.com

TERADYNE

In-Circuit Test Fixture Guidelines and Practices



December, 2005

034-350-00

TERADYNE

Assembly Test Division