



RF Wireless and High Speed Digital
Test Issues and Your
Contactor Supplier

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Abstract

As the world of test changes to meet the needs of RF Wireless and High Speed Digital devices, semiconductor manufacturers should be able to partner with their contactor suppliers to identify the best test solution for their specific applications. Specific challenges that this paper will address include smaller package geometries and other package issues, electrical requirements, grounding and thermal requirements, mechanical and interface requirements, load board considerations, and transfer of the product to offshore production. Each issue is discussed from the contactor supplier point of view, and offers suggestions to semiconductor manufacturers on ways to work more closely with the contactor supplier in order to meet these challenges and achieve the customers' desired business results.

Outline

The outline of this paper will list key issues that must be addressed with respect to RF Wireless and high speed digital test from the viewpoint of the contactor supplier. The list is as follows.

- RF Wireless and high speed digital test challenges
- Packaging considerations
- Electrical considerations
- Grounding/thermal considerations
- Mechanical considerations
- Load board considerations, and a
- Conclusion

RF Wireless and HSD challenges

There are significant issues and challenges that device manufacturers face in testing their devices to specifications. In some instances, they may want to test beyond their specifications to ascertain margins in the electrical performance of a specific device. There are significant factors that wireless device manufacturers and test system component suppliers must consider. A list of crucial factors includes, but is not limited to the following.

- Signal integrity: How well is the signal's shape and performance characteristics preserved within the test system? An ideal test system will transfer the operating parameters of the tester to the device under test (DUT) with a high degree of resolution.
- Low inductance: The entire test system must exhibit a very low inductance, else the response of the DUT will be compromised in a deleterious manner.
- Crosstalk: The crosstalk of the entire test system must be minimized over the test frequency of interest. If it isn't, then the yield of DUTs will suffer.
- Grounding: Ground is the most important factor in any electrical circuit since it serves as reference and shielding. Ground impedance must be low and non-obtrusive.
- Load board design: Properly designed load boards are critical to system test...if the full frequency response capability of RF wireless and HSD devices is to be met.
- Small geometry devices: Since most RF wireless and HSD devices are DFQ/QFN/LCC pad-style, it is essential that the ability to hit small geometry device pads be preserved, if testing is to be successful.
- Increase yields and MTBA: Yield is essential as is MTBA when it comes to performance on the production floor. A test system must be optimized to maximize yield and minimize mean-time-between-assist (MTBA).
- Load board interface: It is absolutely crucial that the load board be closely matched to the test socket and the test system interface in general. If this is not the case, test yield will drop. The system must be properly matched (impedance-wise) to the highest frequency the DUT is capable of operating to.

Packaging considerations

Designers must not only consider the effects of package selection on their application, but must consider the implications packaging has on test. Most device packages are made to JEDEC specifications. Under these circumstances, there is a tolerance in the package/pad/lead/pitch that can cause problems. Also packages may vary slightly with various suppliers. The window on the mechanical tolerance of pads may be “large.” Then there is the issue of sawn vs. molded packages for high frequency devices. One type has clean edges, the other has “ragged” edges. Package material and the composition thereof also enters the discussion. For instance, Pb-free packages have different plating on the pads. Some are 100% matte tin while others are nickel-palladium-gold flash. The performance will be quite different between these two, with respect to contact resistance and MTBA, and must be taken into consideration.

Other issues that contactor suppliers must be able to address with respect to their customer’s unique packages include multiple alignment plates (to accommodate different package sizes) and different contact profiles. In reference to the latter, a contact for use with tin-lead coated pads will be different from one used with Pb-free coated device pads or leads. The reason is that harder materials will demand a different profile to break through the oxides that form on the material. Pb-free plated pad devices will require materials other than the traditional plated BeCu material that comprises contacts for use in non-lead free situations.

Packages and configuring for Pb-free

The migration to Pb-free QFN packages, for example, introduces several contacting challenges that must be addressed. First, there is the problem of harder oxide layers and the plating material. Pure matte tin plating is relatively soft (Knoop hardness of 20 to 30), but tin oxide forms readily and builds up rapidly on the tips of contacts. This translates into higher contact resistance readings and the need to clean the contacts frequently. A positive point is that the soft tin does not wear the tips of the contacts to any degree whereas, the harder nickel-palladium-gold plating (Knoop hardness of 350 to 450) does wear the tips of the contacts. Another item worthy of note is that some device packages (QFN in particular) can have flush to slightly recessed pads. This geometry will effectively reduce the design tolerance for contact-to-device pad registration. One way of coping with this is to use notched contacts.

There are several variables that must be taken into consideration in addressing product configuration for Pb-free applications. These include the following.

- **Contact profile:** Different Pb-free platings may require different contact profiles to break through the oxides, maintain an effective scrub, and provide good contact resistance readings.
- **Contact pressure:** The amount of contact pressure may be different according to the type of Pb-free plating on the pads or leads of the DUTs. Required Pb-free contact pressure may be somewhat higher than that for tin-lead coated pads.
- **Surface roughness:** This is a key parameter. Contact pins that have a rough surface (32 to 64 microinches) will tend to fill up with solder material when used with tin-lead coatings. A smoother surface (4 to 8 microinches) will tend to slough off tin-lead material where the contact touches the DUT pad, but the smoother, softer gold finish on the contact may cause galling when in contact with the gold plating of the load board. Contacts made of precious metal material typically have a 16 microinch surface finish...and do not gall because of the hardness of the material.
- **Contact material:** Solid contact material, such as precious metal, wears much better with respect to contact with Pb-free plated pads than its counterpart, namely gold-plated beryllium copper. The latter tends to have its plating worn off with a concomitant higher contact resistance when the plating wears through.

- Contact wipe or scrub on a DUT pad: This is a very important feature of contactors that employ this type of geometric operation. Good scrub is essential for low contact resistance, minimum MTBA, and good contact and load board life.

Electrical Considerations

RF wireless and HSD applications continue to push the envelope of electrical performance. Device packages are becoming smaller, have more transistors per unit area, operate at high speed and power, and must dissipate more heat. This is taxing indeed. Today's I.C. designers require...

- Excellent signal integrity
- Lowest possible inductance
- High bandwidth, and
- Maximum crosstalk immunity

In order for contactor suppliers to meet these challenges they must provide contactors that have low and repeatable contact resistance, the shortest possible contact length (signal path), and proven performance. Examples of package driven contactor technology for shortest electrical length are shown in Figure 1 below. The migration of contacts from left-to-right depicts the result of ever-increasing frequency growth.

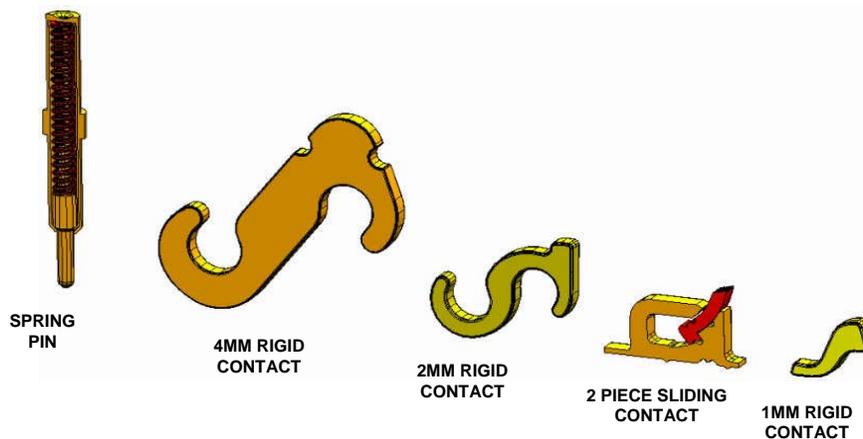


Figure 1. Migration of contactor technology due to ever-increasing frequency.

A major electrical parameter that contactors must provide is low contact resistance. How low is low? That depends upon the device being tested. In many instances, a contact resistance of 100 to 500 milliohms is sufficient. In other cases, the contact resistance must be on the order of tens of milliohms. It is worth noting that contact resistance is the sum of the bulk resistance of the contact pin itself plus the interface resistance at the DUT-contact and the contact-load board pad interfaces. The interface resistance is highly dependent upon the material at the interface, and the pressure thereon. An example of contact resistance variability, at ambient temperature, for a 1mm production contactor for a solder-plated pad interface is shown in Figure 2.

Ideally, a contactor or test socket should be transparent to the test system over the frequency range of test. However, this cannot be the case in the physical world since losses will occur in the transmission of electrical signals through the device. A measure of goodness of any contactor is its insertion loss, return loss, and crosstalk performance. Insertion loss is the degree of energy lost to a signal passing through the contactor and is expressed as a log ratio. The energy lost is dissipated in the form of heat. Normal practice is to consider insertion loss of $\leq 1\text{dB}$ at a frequency of interest as acceptable. Another electrical parameter to consider strongly is return loss. Return loss is a log ratio of the amount of signal reflected from a junction to the amount transmitted through the junction. A return loss $\geq 20\text{dB}$ at the frequency of interest is very acceptable. Another example RF performance

of a contactor to consider is crosstalk. Unless it is intentional, crosstalk is very deleterious to the performance of an electrical circuit. It originates when an electrical signal in a transmission line is coupled into an adjacent transmission line or circuit due to proximity effects. Crosstalk can cause timing errors in digital devices and can cause performance degradation in RF wireless devices. As a general rule, induced crosstalk should be at least 20dB or more below the level of the desired signal. Figures 3, 4, and 5 depict insertion loss, return loss, and crosstalk in selected contactors.

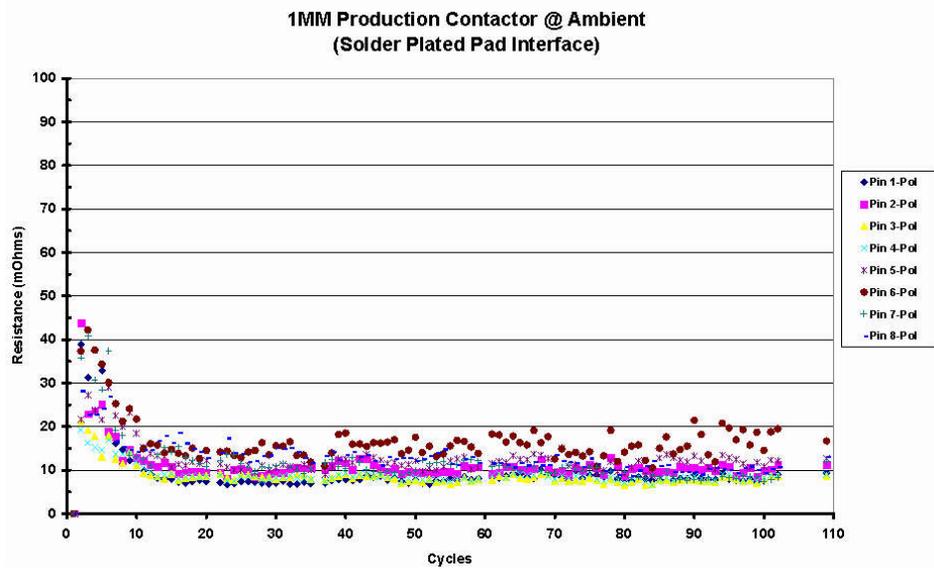


Figure 2. Electrical considerations – contact resistance vs. insertion cycles For 1mm production contactor at ambient temperature

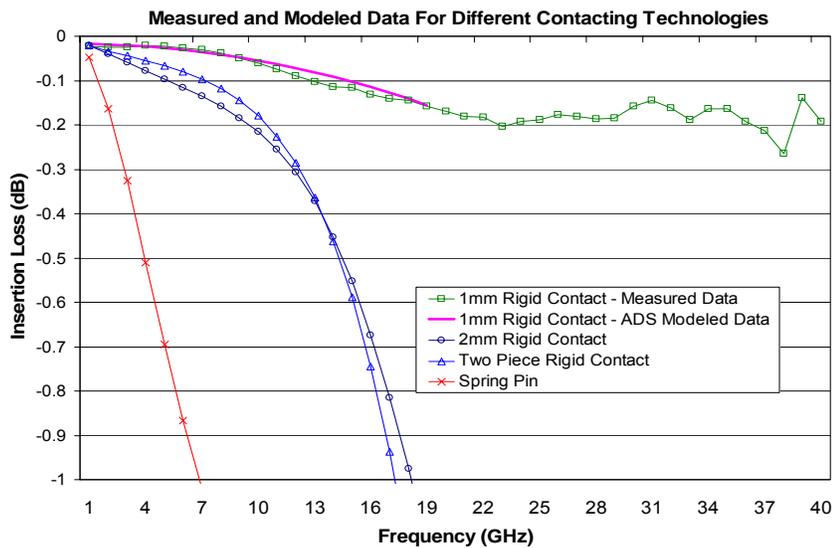


Figure 3. Insertion loss data vs. frequency for various contactors.

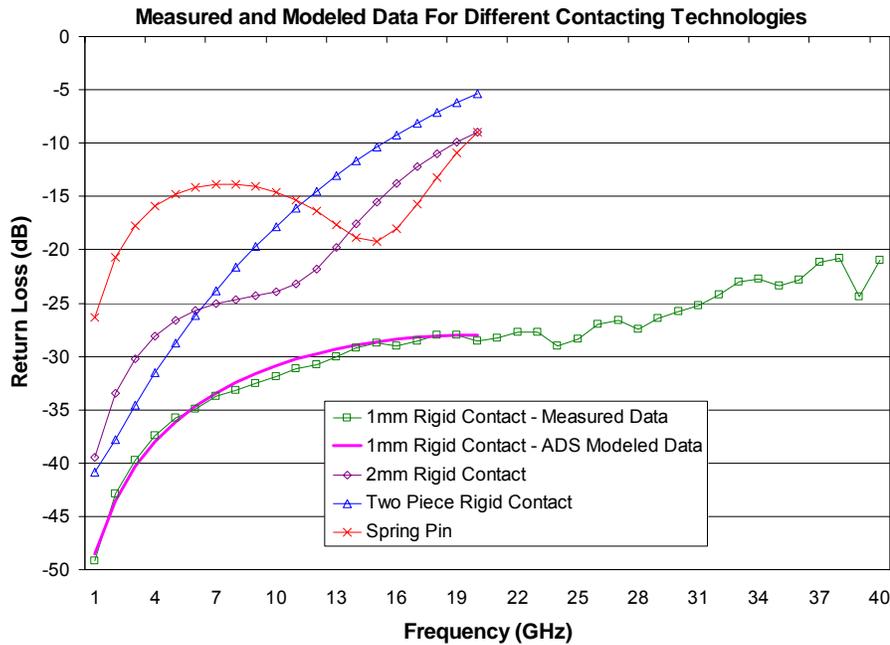


Figure 4. Return loss data vs. frequency for various contactors.

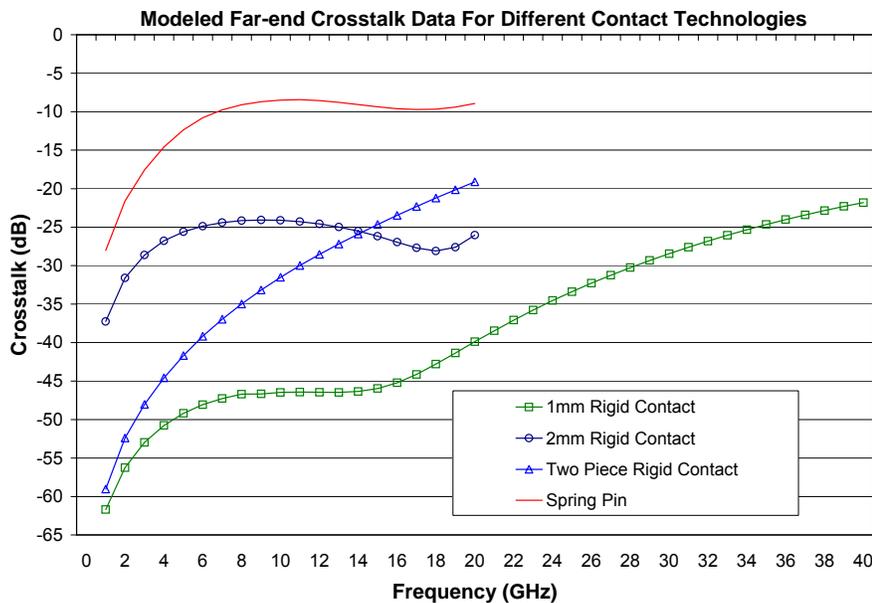


Figure 5. Crosstalk data vs. frequency for various contactors.

Grounding and thermal considerations

Ground is the most important element in any electrical circuit. Ground serves as reference datum for the overall circuit, and it provides shielding and isolation. When dealing with cutting edge high frequency wireless and HSD applications, extreme attention must be paid to grounding (and thermal) techniques. There are several reasons for this, namely to,

- Reduce the potential for oscillation
- Reduce the potential for “ground bounce”
- Provide the lowest ground impedance
- Provide repeatable ground contact, and
- Provide the ability to tune the load board to the “nth” degree

The customer must insist that contactor suppliers provide for excellent grounding and thermal performance of their contactors by...

- Offering a variety of grounding and thermal options to meet the need of the application
- Providing the smallest footprint possible, and
- Providing close decoupling

In many high-frequency devices, a pad located in the center of the underside of the package serves as ground, thermal exit to the environment or both. Under these circumstances, the contactor must provide a good path to the load board for ground and for heat dissipation. The customer must work closely with the test socket supplier to ensure that these criteria are met. A poor ground or thermal connection will reduce device yield during test on the production floor and could cause damage to the DUT. An example of the thermal performance of a 1mm production contactor is shown in Figure 6.

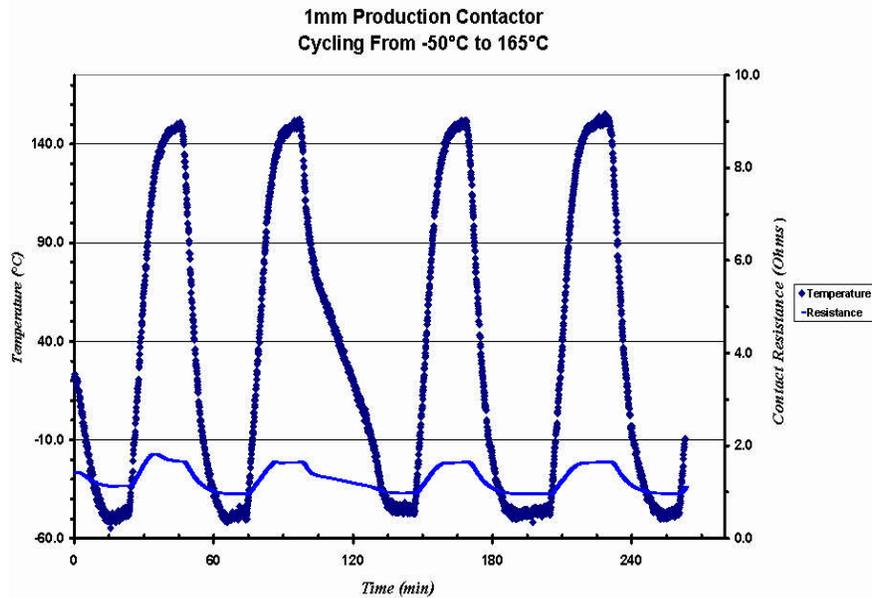


Figure 6. Thermal cycling vs. time for specific 1mm production contactor.

Mechanical considerations

To help reduce time-to-market, customer test system designers should consider all production test requirements early in the production cycle. Things to take into consideration include the handler platform to be used in the production test environment. Different handlers have different performance characteristics in how accurately they present the DUT to the contactor. Now one is into the area of the test interface and certain requirements that must be met, including...

- Load board to contactor
- Docking plate to contactor and docking plate to handler
- Device to nest/work-press and nest/work-press to contactor
- Package contact surfaces to contact elements

To ensure optimum operation of the test system, the contactor supplier and the customer must work closely together. This may also involve getting the handler manufacturer into the picture. Reliable contactor suppliers must provide interface support (pre-sale, post-sale, maintenance, inspection, etc.) and they must provide multiple configurations to lower the cost of test.

There are other mechanical issues to visit also. These fall under the category of system components and how they interface to the contactor. First there is the device package. The package must have consistent physical measurements and tightly held tolerances for proper device presentation to the contactor. Next is the handler. Some things that must be met with handlers include device

presentation, co-planarity, and device-to-contact presentation velocity. These are critical factors and must be understood from the interconnect perspective in order to reduce errors and jam rates, and to increase test yield. Another factor is the load board which must be carefully laid out using best engineering practice in order to optimize the overall performance of the test system. Some contactor suppliers have the in-house expertise to help customers with the layout of their load boards. Many customers have this talent at their own facility.

Load board considerations

Proper load board layout, especially for RF wireless and high speed digital applications, is best done with engineers or designers who have RF experience. Technicians with this talent know that significant attention must be paid to such things during the design of the load board as the location of traces, vias, grounds, and how to tune the load board for optimum performance. On the other hand, contactor suppliers must support good load board design by,

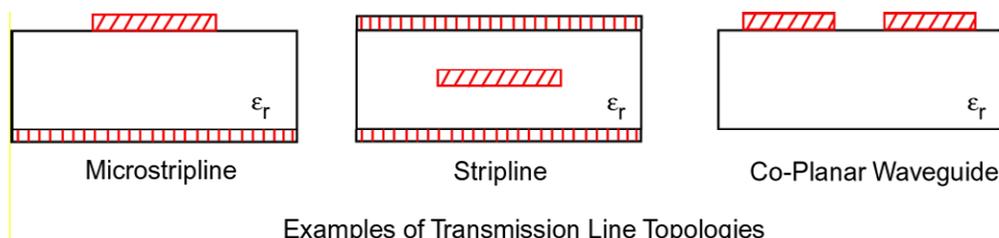
- Understanding the application and its requirements
- Providing the smallest footprint possible, and
- Allowing close decoupling

High frequency load boards are possibly constructed in a sandwich manner. This means the outer layers are high-frequency substrate material glued to inner layers of common FR4 material. RF traces are situated on the outer high-frequency material whereas the inner layers carry power, ground, low-frequency signals and things of that nature. A table of the properties of several common load board materials is shown below.

Table 1. Load board materials and characteristics

Load Board Material	Dielectric Constant	Loss Tangent
FR4	4.30 ±0.2	0.0180
Getek	3.90	0.0120
RO4003	3.38	0.0027
TMM3	3.27	0.0016
TMM4	4.50	0.0017
RO4350	3.48	0.0040

High frequency load board traces usually act as transmission lines and must be designed with certain topologies and in accordance with specific transmission lines rules. The principles can be found in many good RF design textbooks. Common examples of various types of transmission line topologies are depicted below in cross-section views.



A summary of microstripline and coplanar effects as they pertain to the transmission line topologies shown above are as follows. The equations are available in any good transmission line handbook.

Microstripline effects, parameter vs. impedance:

Substrate thickness	↓	Impedance	↑
Trace width	↓	Impedance	↑
Permittivity (ϵ_r)	↓	Impedance	↑
Trace thickness	↓	Impedance	↑
Add air gap above trace (cutout in housing)		Impedance	↑
Place housing on trace		Impedance	↓

Co-planar effects, parameter vs. impedance:

Spacing (pitch)	↓	Impedance	↓
Add ground plane		Impedance	↓

There are numerous rules of thumb for RF load board design. It is worth noting those listed below.

- Eliminate right angles
- Eliminate changes in line width
- Separate high frequency traces with ground
- Move clock traces away from other signal lines
- Place de-coupling components close to the device
- Use matched impedance traces up to the device or test contactor
- Avoid using vias on high frequency lines
- Keep trace lengths short
- Optimize the load board to the contactor

There are more design rules to utilize which are explained in any good textbook on printed circuit design.

Conclusion

In conclusion, the major aspects of this paper can be summarized as follows.

- Contactor manufacturers need to fully understand the impact of packaging trends and geometry.
- Contactor manufacturers must fully understand the customer's performance requirements and be truthful in sharing data with the customer.
- Contactor manufacturers need to work closely with the customer in order to fully understand and meet grounding and thermal requirements.
- Mechanical interface is critical to success; the contactor manufacturer must work with the handler supplier, kit supplier, load board supplier, tester supplier, and customer to ensure good performance results.
- Contactor manufacturers must take into account new load board design issues and load board tuning requirements.