Construction
Hints and Techniques

You just get finished building a Microwave project and it looks beautiful. After admiring it for awhile you decide to spark it up. All of the voltages and currents look good, so you apply RF. Now after a tweak here, a cut there, a component change, and a repaired trace because you burnt it when you forgot to shut the voltage off, you have a mess that still doesn't work up to expectation. If this scenario sounds like the last "Quiet Time " you had in your shack, then the contents of this paper should be of some interest to you.

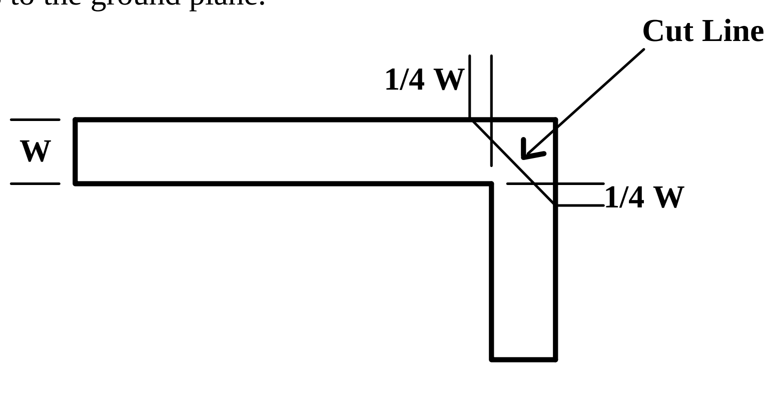
If you have the desire to make a VHF, UHF, or Microwave project work the way it was designed and have it look like a gem when you are done, you will find this compilation of procedures, techniques and ideas helpful. You will also find that good construction practices and techniques not only allows the project to initially work, but will add to the reliability and enable you to repair a mishap with ease so you will be able to keep your pride and joy working for years to come.

Steve Kostro, N2CEI

Circuit boards, transmission lines, and other related stuff

When making your own circuit boards, cut or etch, follow a simple rule for 90 degree bend. Trim the corner as illustrated below. This keeps the impedance as uniform as possible and eliminates reflections that cause radiation.

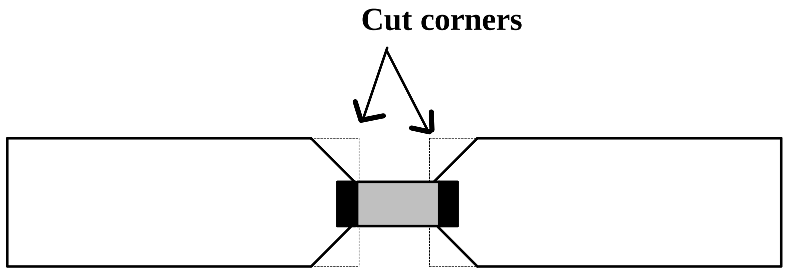
When trimming any circuit during a tuning session with a razor knife, keep track of the discarded material and make clean cuts in the softer type circuit boards. Try to avoid deep cuts to prevent circuit shorts to the ground plane.



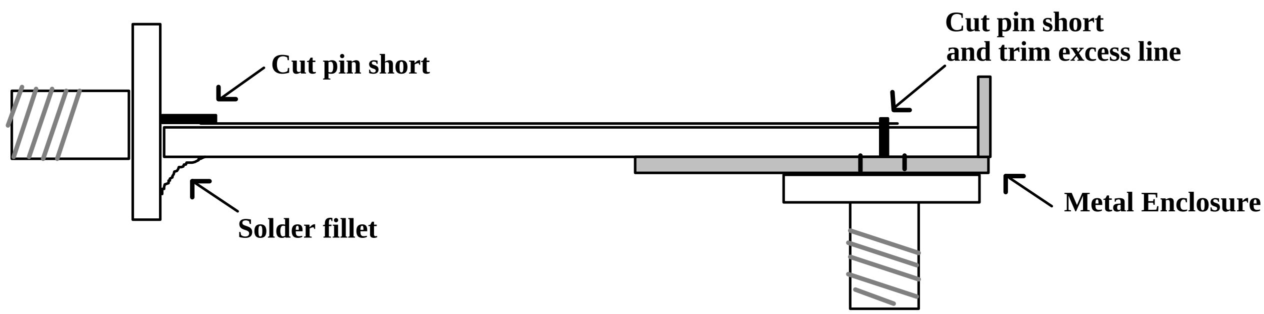
W = Width of transmission line

Straight transmission lines should be chamfered down to accept a lead of active devices or chip components. Loss is hard to measure under 500 MHz. but could be as much as .5 dB at 1.3 Ghz and causes major problems 2 Ghz and up! It is totally dependent on the component used.

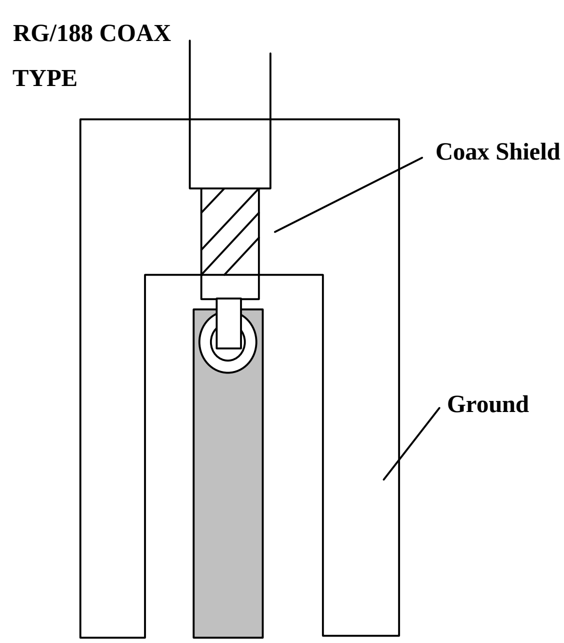
Be careful with tuned circuits. This is for Transmission lines only!



Connectors soldered to transmission lines need to be short and clean. Keep the impedance uniform by trimming the connector to fit the board. Wick off excess solder on the pin. Make a good ground connection. NO GAPS!!!! Gaps in the ground plane cause discontinuities. For LNA's remember that all losses equate to increase in Noise Figure. If the connector needs to go through a wall for mounting,(in a box or on a panel), use the insulator diameter for the hole size. The connector is still coax until the pin intersects with the circuit line. This technique becomes "Black Magic" above 4 Ghz. and alternative methods should be examined. For home made enclosures please review Russ Healy, NJ2L, paper on "Building Enclosure for Microwave Circuits".



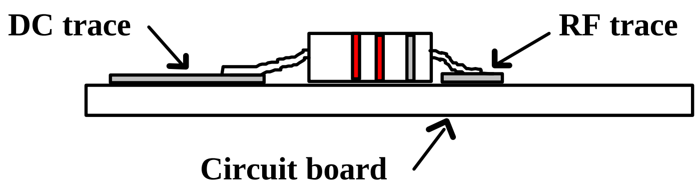
When interconnecting circuit boards with coax, Good quality coax (Teflon, or other high temp dielectric) should be used. Attach the shield to ground as close to center conductor as possible. Do not pigtail coax above 450 MHz. Stop using coax after 3.5GHz



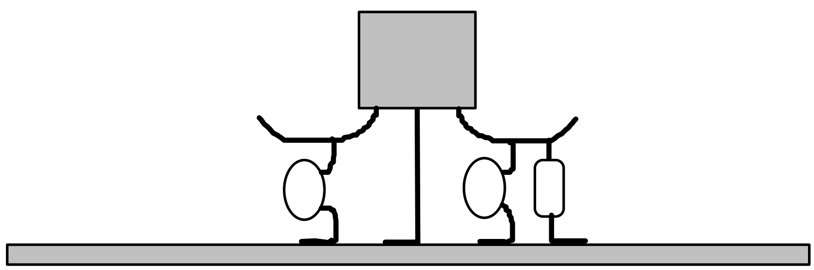
Surface mounting non SMD components

When surface mounting radial or axial components, pre-form and fit before soldering. Be careful not stress the lead at the body of the component. Keep components as close to circuit board as possible. All leads that attach to RF circuits should be as short as possible. Composition of resistors becomes important at 1.3 Ghz and above. (use carbon comp not carbon film) Using leaded components at 5 Ghz and above is CRAZY at best!

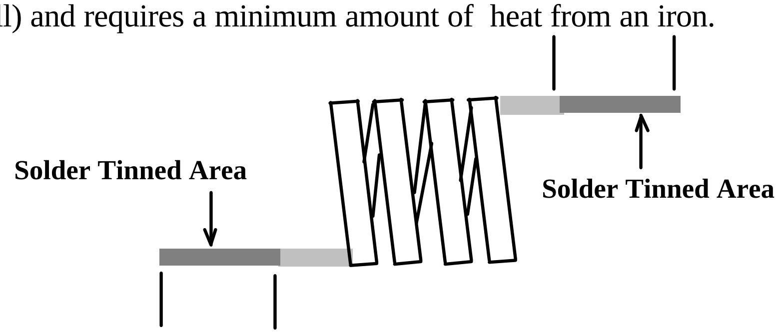
Leads soldered to PCB surface

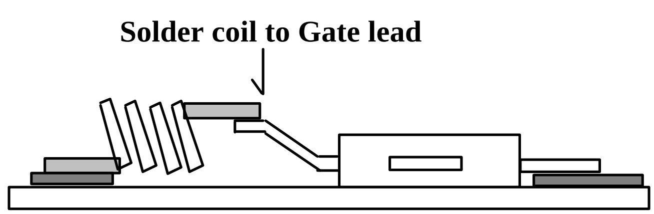


When using "Dead Bug" style assembly , pre-form all ground connections before soldering. These connections support the circuit and keep it from shifting around . Its the backbone of the circuit so build it strong!

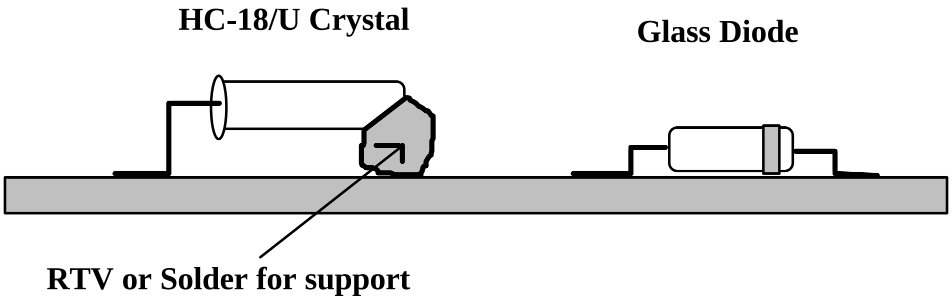


Tin all enamel wire inductors before installing. The input inductors on LNA's are hanging in the air and are supported by the gate lead. A good solder connection is needed to withstand a stretching and compressing session during tune-up. A clean well tinned lead will solder with a minimal amount of solder (if any at all) and requires a minimum amount of heat from an iron.



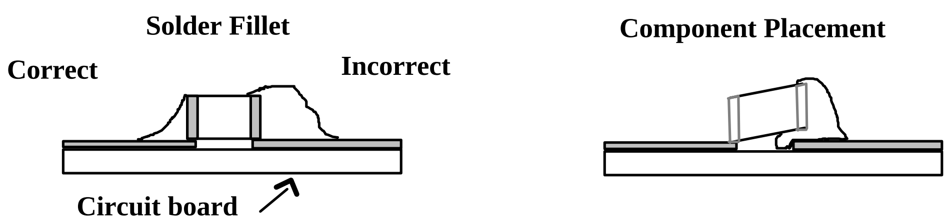


When installing crystals and glass diodes, DO NOT bend the leads at the body! Pre-form before soldering. Always support components such as crystals to prevent unwanted bending and flexing after assembly.



Surface mount components

Never soldered a surface mount component before? Or maybe you might want to check you technique? I think Paul Husby, W0UC, has correctly put it in words in this article from the "ARRL UHF/Microwave Projects Manual".



Surface-Mount Soldering

By Paul D. Husby, WØUC

(From *QST*, June 1991)

Surface-mount devices and boards are a great invention and a joy to work with once you get comfortable handling and soldering the tiny devices. My soldering routine is slightly different from that suggested by Bryan Bergeron, NU1N[1]. Tinning both pads may lead to an installation in which the device is not flat and close to the board. Or, worse, a fragile chip device may be left physically stressed. I prefer this routine:

- Tin only one of the pads, and let it cool.
- Set the device in place. While pressing the device very slightly with a toothpick, reheat the tinned pad until the device

second terminal, touching the iron only to the pad.

- After the device has again cooled, touch up the first solder joint as necessary.
- Use silver solder.

With this method, I get a 100% success rate of devices that are flat, straight and well-soldered.

Finding silver solder can be a problem in some locations. (Radio Shack carries 62/36/2 solder [RS 64-013].)

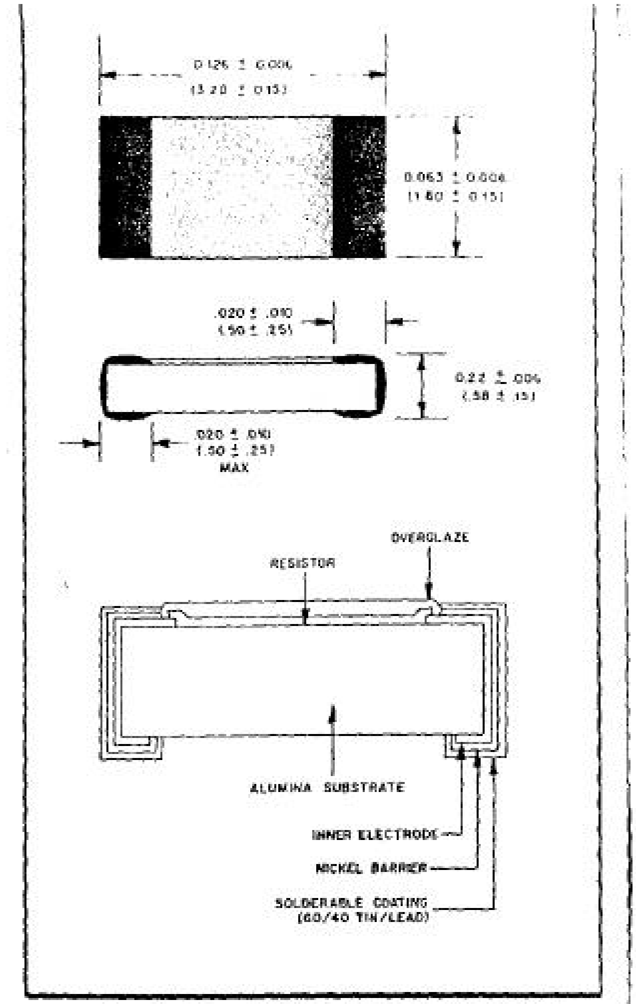
[1]B. Bergeron, "A Surface-Mount Technology Primer—*Part 2*,"

Additional Comments:

Silver solder isn't necessary. The silver content in the solder makes the joint look nice but it raises the melting temperature. It also makes the final connection more brittle. Some of the newer solders on the market now have organic resins and some are "NO-CLEAN" and low temperature.

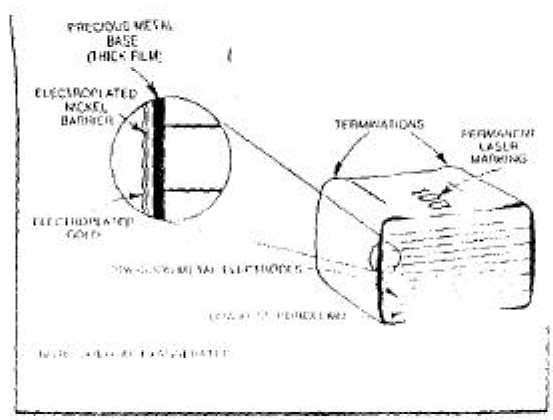
All SMD resistors are all basically the same. After reviewing their construction, it is easy to see where their problems come from. It is easy to think that a SMD resistor is installed correctly only to find it to be an open circuit. If it is open, replace it! You may think you can fixed it by re-soldering, but it won't last!

This picture of a typical 1206 type chip resistor was taken from the "ARRL UHF/Microwave Experimenter's Manual".



—Construction detail of a typical chip resistor.

SMD Capacitors- Why are the inexpensive ones so cheap and the good ones so expensive? Good quality porcelain chip caps are made of layers of interwoven plates much like air variable capacitors. Then the plates are bonded to the metal end caps. The lesser quality SMD capacitors are made of a epoxy mixtures between two plates which are the end caps . They are not very good for high frequency work. Some of the problems are loss, tolerance, effects of temperature and series resonance. Examples are discussed in Bob Atkins', KA1GT, article from the ARRL UHF/Microwave Projects Manual, "Caveats for Choosing Microwave Capacitors".



—Construction detail of a typical chip capacitor

Caveats For Choosing Microwave Capacitors

By Bob Atkins, KA1GT

(From *QST*, August 1989)

Physically, chip capacitors are simply small, leadless capacitors. But all physically small, leadless capacitors are not necessarily microwave-quality components. Very small chip capacitors have become much more common as a result of their use in miniaturized circuits. Circuits that operate at only a few megahertz (or tens of megahertz) can get by using inexpensive chip capacitors; the problem is that the dielectric materials used in inexpensive chip capacitors show very low loss at VHF/ UHF, but are entirely unusable at 10 GHz.

One necessary characteristic of microwave-rated components is low dielectric loss at microwave frequencies. A second characteristic of all capacitors—including chip versions—that comes into play is the presence of undesired series and parallel inductances that result from the device packaging. These inductances not only have reactances; they also result in series and parallel device resonances. Where capacitors are used as bypass or dc-blocking devices, series resonances aren't a problem because impedance is minimized. Parallel resonances, however, can be highly detrimental to circuit performance. A third consideration when chip capacitors are used in microstripline circuits is that they create physical discontinuity, and cause some reflection of incident power as a result. This, too, can give rise to losses. Well-designed circuits use capacitors that cause minimal impedance discontinuities.

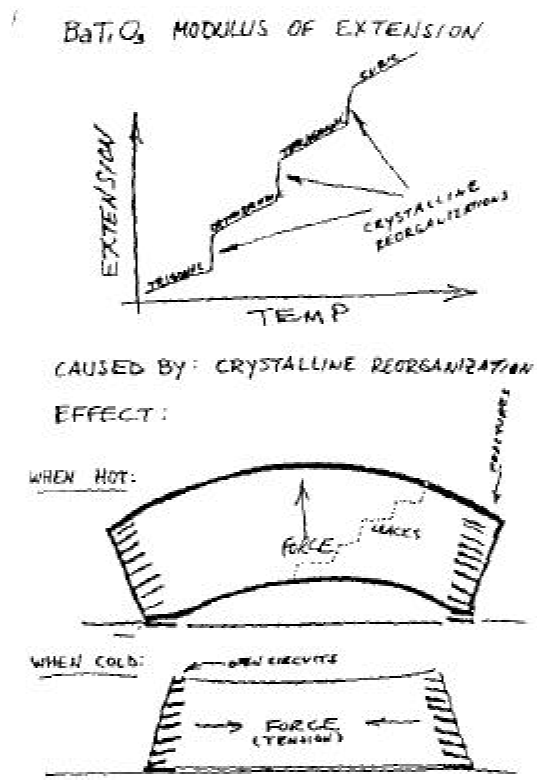
When a circuit calls for a particular type and value of capacitor, use of the specified component may be critical to circuit performance. Thorough designers take into account the factors discussed above, and select capacitors with low loss when designing equipment.

Loss data on a capacitor can be obtained by testing its effect when used as a dc block in a microstripline circuit. To do this, etch a board with a microstripline of the desired impedance, and leave a small gap in the line. The gap can be bridged by either the capacitor under test or a length of copper foil. First measure the circuit loss when the gap is bridged by the copper foil; then with the capacitor in place of the foil. The difference in attenuation is the additional loss caused by the capacitor.

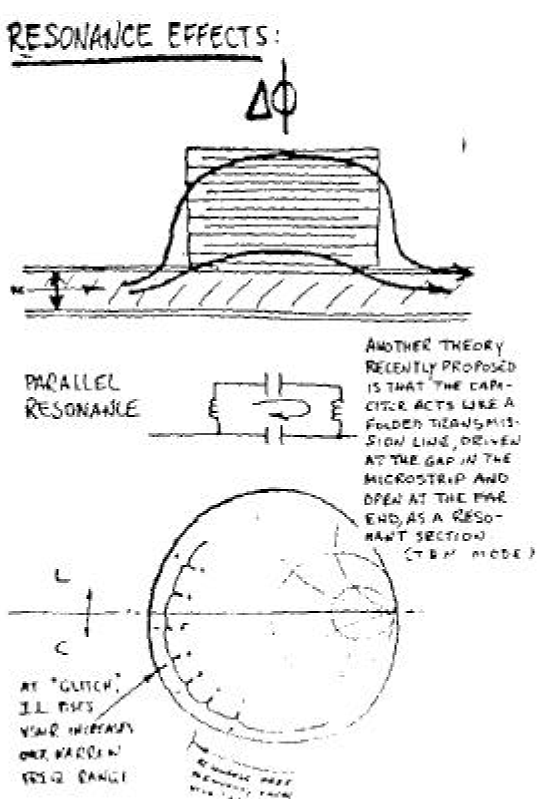
Loss data for one line of commercial microwave chip capacitors rated for use at frequencies up to 4.2 GHz shows that one particular 120-pF capacitor has a loss of almost 0.4 dB at 3 GHz. A 100-pF capacitor from the same series shows less than 0.05 dB loss at that frequency. In this case, substitution of the 120-pF capacitor for the 100-pF capacitor would result in considerable performance degradation in a 3-GHz circuit—not from the change in capacitance, but from associated packaging effects. This also applies to nominally equivalent capacitors from different manufacturers. If you make substitutions without knowledge of these factors, you may find yourself in unexpected trouble.

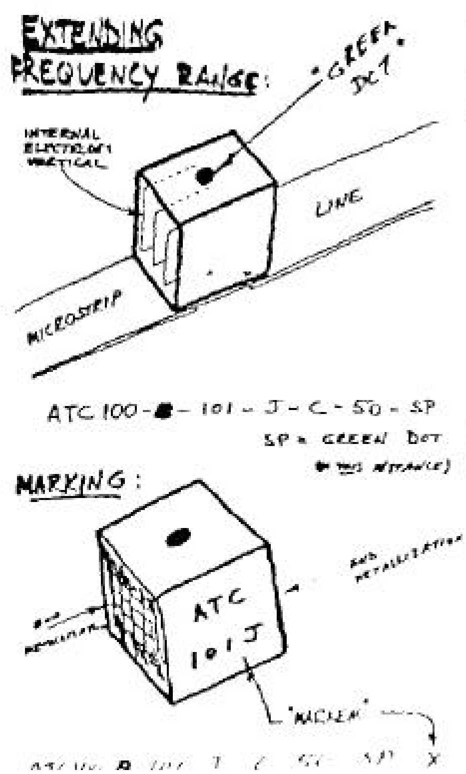
Further references to microwave components and microstrip circuitry can be found in the "New Frontier" columns in January 1981, December 1981, April 1982 and June 1988 *QST*.

Even good high quality chip caps have problems. Over time, with temperature, the plates break away from the end caps which causes the capacitor to have less capacitance. This is shown in this diagram from the "RF Capacitor Handbook" published by American Technical Ceramics Corp.



Another problem at the upper Ghz. frequencies is <u>parallel resonance</u> (*Not the series resonance problem*). This problem is fixable. The reasoning and one solution is shown below. Another solution is practiced all the time. Decrease the value of the cap! Diagrams below are from the "RF Capacitor Handbook" published by ATC Corp.





REPAIRING AND REPLACING COMPONENTS

1. When removing a leaded component, first cut as many leads from its package as possible. It is easier to desolder one lead at a time from the circuit board.

2. Surface mounted active components can be removed by cutting their leads with a razor knife first then desolder the leads from the circuit board.

3. Surface mount resistors and caps can be removed with a large tip iron (bridge the gap and heat on both sides) or use two soldering irons.

4. Leadless disc caps. leach easily. Keep heating to a minimum. Be careful not to pull to hard on the lead that you are trying to cut that is soldered to a leadless disc cap.

5. Wick off all extra solder from circuit board before installing a new component. Treat installation as if it was the first time.

6. Clean replacement area and check for stray pieces or extra solder globs or splashes produced by the repair procedure.

Is The Job Done?

1. Make sure all Fluxes and Resins are removed from the entire project. It will keep oxidizing anything it is in contact with. Examples of problems caused:

It will seep into non hermetic active devices and attract moisture and become more active than before.

It will penetrate porous materials such as epoxy chip caps, and G-10 circuit board, then degrade their quality rapidly.

It will oxidize copper or copper tinned surfaces such as PCB ground plane to housing contact points creating voltage differential on a once common Ground!

2. Be sure all mechanical connections are tight. After a few cycles of heating and cooling, thermal compound may spread and leave a gap between a Hybrid power module and heat-sink. Also, some degreasers used for washing flux, may remove thermal compound.

3. The Rattle Test! Give it a good shake after assembly.