APPLICATION NOTE AN-003

Mounting Circulators and Isolators

Introduction:

This document provides guidelines to properly mount a RFCI circulator or isolator for RF evaluation. Unless otherwise specified, the term “device” will be used synonymously for either a circulator or isolator.

Mechanical Considerations: RFCI devices are matched to 50 ohms impedance and they tend to be less susceptible to RF performance variation due to mechanical placement than components that are matched to lower impedances.

If one is attempting to correlate RF performance to a particular data set such as samples tested at elevated power levels, it is important to consider the following:

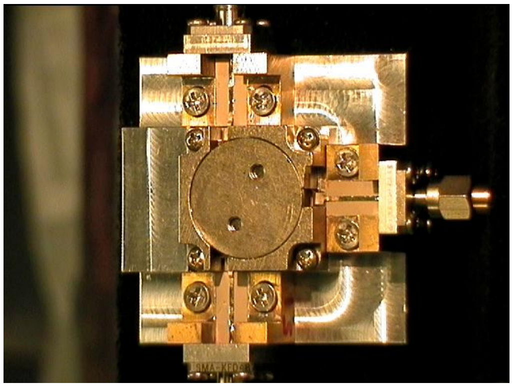
1) **Device Cleanliness**
   All contact surfaces (tabs, housing, PCB traces, and mounting surfaces) should be clean and free of debris/contaminants.
2) **Proximity of The Trace On The System PCB to the Device Housing**
   Often the devices are mounted in a recessed area of a chassis that allows the leads to land at the height of the PCB for soldering. The proximity of the trace on the system PCB to the housing should be considered. Often this trace extends beyond the contact area of the tab. The proximity of the end of the trace to the device should be adequate to minimize the potential for corona if elevated power levels will be used.
3) **Flatness of Cavity**
   The flatness of the cavity is an important consideration as well. Any air (a perfect insulator) gap between the housing and the chassis, particularly in the region area under and proximal to the termination will increase the heat build-up inside the device. As more heat built up inside the device, it reduces the reliability of the device. To assure better reliability, better thermal management is necessary. RFCI device housings are typically specified at 0.03mm for flatness. Adequate clearance should be allowed on all sides of the device to account for the effects of temperature coefficient changes (Cte) as well as any corner radius that may be present on the bottom of the cavity at the wall / floor interface. The housing material has a linear temperature coefficient (Cte) of about 13.5um / m /℃ and a 25.4mm housing will change -0.0154 to +0.0206mm over the typical operating range of -20 to +85℃.
4) **Height of PCB Trace**
   The depth of the cavity should be controlled so that the finished PCB trace height allows the device tabs to rest flat on the PCB trace after all mounting screws have been installed and properly torqued, as shown in **Figure 1** below.

Figure 1 – Tab laying flat on microstrip.

In many applications the circulator will be mounted below the PCB and directly to an Aluminum Chassis. Standard threaded fasteners up to M3 x 0.5 coarse or 6-32 UNC may be used to attach the device to the chassis. For the standard test fixture, 4-40 UNC-2B fasteners are used. Torque values of 0.7 N-m (6 in-lbf) should be used for M3 and 6-32 fasteners with 0.45 N-m (4 in-lbf) reserved for 4-40 fasteners used with RFCI test fixtures.

Electrical / RF Considerations: To maximize repeatability and insure good correlation, screws should be installed in each mounting hole. Typical single junction devices use 4 screws and dual junction devices use 6 screws. **Figure 2** shows a device properly secured on a test fixture with all mounting screws.

Figure 2 – Note the use of all 4 mounting screws



Alignment of the tabs directly over the mating trace on the PCB (typically microstrip) is important as well. Allowing the tabs to overhang the microstrip trace will result in a discontinuity which will affect the performance of the device as well as any attempt at establishing correlation. The tab is typically designed to be narrower than the trace on the system PCB but wide enough to have mechanical integrity. The correct alignment is shown in **Figure 3**.

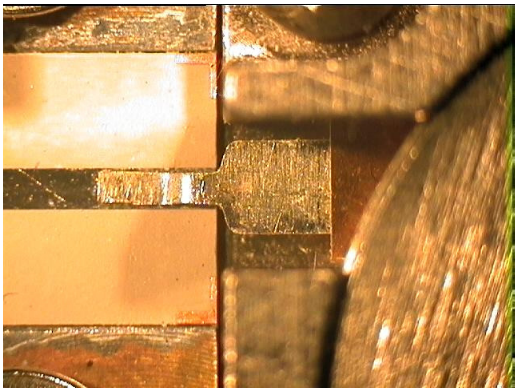


Figure 3 – Tab centered on PCB trace.

For better correlation between the measured data and the sample data, the tabs should NOT be soldered to the microstrip traces on the RFCI test fixture. Soldering the device in place will include additional parasitic effects and impedance changes to the interface.

Also, repeatable soldering the tabs to the microstrip trace may cause the peeling of copper strip from PCB.

However, if the device will be installed in a system for functional test, it is desirable to solder the leads to the traces on the PCB. The device should always be mounted with 4 screws to the chassis and the tab alignment/flatness should be verified prior to soldering.

For RoHS compliance, a lead-free solder will be required but such solder typically has higher reflow temperatures. In order to avoid applying excessive heat that can damage the trace on the PCB, soldering temperatures must be carefully controlled. Also the use of excessive solder will alter the impedance of the trace and it can degrade the performance of the device. In lead-free applications, the use of excessive solder can cause solder joint reliability problems.

Refer to the latest version of IPC-A- 610 or equivalent for acceptable solder practices that apply to Flat Ribbon, L, Gull Wing or Coined leads for electronic assemblies.

In general, the amount of solder used should allow the shape of the lead to be observed. The solder should tail off at the tail end of the lead and should not extend down the transmission line. The lead should not overhang the edge of the trace if at all possible to minimize RF discontinuities. Solder fillet heights that are at least 50% of the lead thickness should be evident on all sides of the lead. Heel fillet should be equivalent to the solder thickness plus 50% of the lead thickness. Solder should not extend up the lead and should be kept away from the metallic housing of the device to avoid shorting. **Figures 4 and 5** illustrate acceptable solder joints.

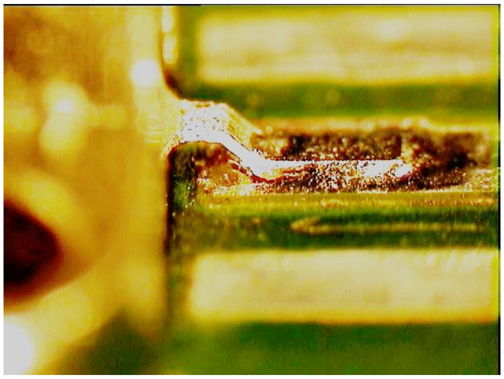


Figure 4 – side view, of a good joint

Note in **Figures 4 and 5** that the outline of the lead is still visible and that the side and toe fillets extend at up at least 50% of the lead thickness. Also notice the heel fillet on the backside under the lead in **Figure 4**.

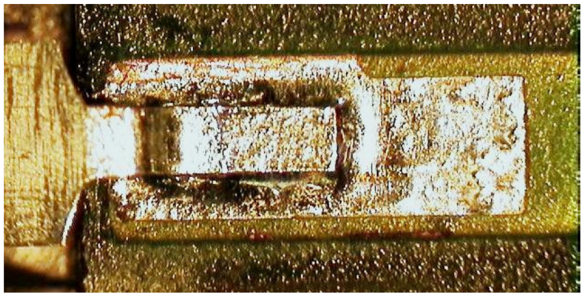


Figure 5 – good solder joint, top view.

Thermal Considerations: To reduce the thermal resistance at a particular interface, many factors such as choice of materials, flatness, surface roughness, pressure, shape, orientation and altitude should be considered. These factors are usually determined by the design, the cost as well as the environment. Additionally, various means may be used to manage the temperature including convection, conduction (either natural or forced) and radiation. One or more of these means may be present but without some forethought and attention to detail can provide for less than ideal thermal management.

In a typical base station application where a device is used as a constant load and provides protection for the power amplifiers (PA), there may be some convection present due to fans used to cool the PA's at the output stage. In most isolator applications, a termination is connected to one of the ports (typically port 3) to absorb reflected energy. The termination is where a lot of heat will be generated when large reflections occur. Under normal operating conditions however, heat will build up in the ‘junction’ of the device due to the average power. For a typical circulator operating at 100W this is about 5 to 10W. At high duty cycles, the device may reach a thermal equilibrium where it will typically operate the majority of the time. For intermittent operation or applications where the duty cycle is reduced, maximizing the thermal conduction will help to maintain a lower average operating temperature allowing for better performance.

Ultimately it is the customers’ responsibility to properly assess what is needed to maintain an operating temperature that is below the maximum for each component in their system. However RFCI does consider what may be done during the design phase of each component to more easily allow our customers to manage heat that can build up in the component.

The finish on RFCI device housings is typically specified at 32 micro inches or less. This helps to maximize thermal transfer via metal to metal contact. Depending on the surface of the heat sink and other variables (i.e. RF grounding requirements at high frequencies) thermal joint compound may reduce the thermal resistance of the device to heatsink interface. In general, RFCI recommends heatsink compound when mounting the device to a heatsink or chassis. Regarding heatsink compound, however, more is not better! All that is required is a thin consistent layer to fill the air gaps between the metal layers. Maintaining metal to metal contact is essential to maximizing heat transfer. Excessive heatsink compound will increase the thermal resistance of the interface and may cause RF grounding problems, negatively impacting performance. Additionally, the use of excessive compound may result in “bowing” of the housing with could cause damage or at the very least alter the RF performance. The proper use and amounts of thermal compound between two materials is presented in **Figure 6**.

A fairly well documented method exists whereby something equivalent to the scenario shown in the bottom most picture of **Figure 6** where good metal to metal contact exists and all air gaps have been replaced by thermal compound. Thermal compound is applied to each metallic surface and spread around using an applicator that is free of contaminants such as lint, oils or other debris that could become lodged in the compound resulting in air gaps. The applicator should be softer than the surface onto which the compound is being applied so as not to mar it in any way. A few mils is all that is necessary as most of it will be removed, leaving compound in only the “valleys” of the surface. Using a single edged razor held at a 45° angle remove the excess heatsink compound from the backside of the device as well as the chassis or heatsink to which it will be mounted. Make sure the device tabs are free of compound as this will be problematic when the tabs are soldered to the PCB later. Place the device onto the heatsink aligning the mounting holes with the threaded holes in the heatsink. The device can be gently “scrubbed” back and forth with some downward pressure to help “squeeze out” excess compound that may still exist. Finally align tabs and torque mounting screws to the proper level.

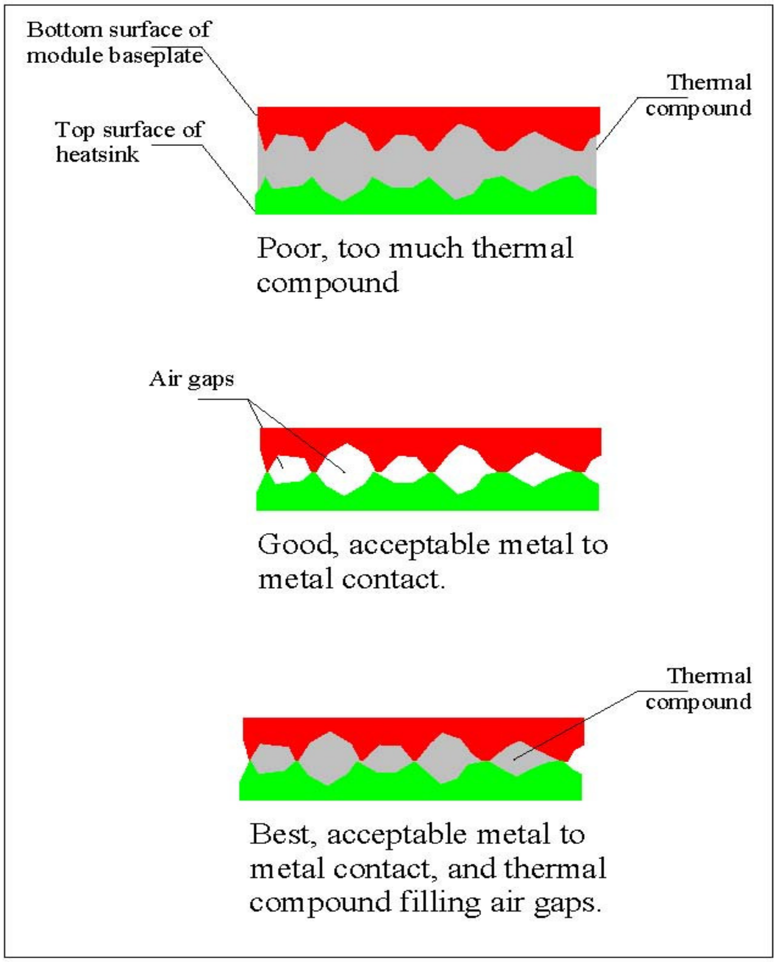


Figure 6 – proper use and amounts of thermal compound.