EB107

Mounting Considerations for Motorola RF Power Modules

INTRODUCTION

The packaging used for standard Motorola RF Power modules consists of a copper flange on which the substrates are soldered and a non-conductive cover which is either of a "snap-on" or epoxy attached design. The ceramic substrates are either 96% alumina (Al_2O_3), 99.5% alumina or 99% Beryllium oxide (BeO). These substrates are attached to the copper flange using either lead-tin or indium based soft solders. Typical liquidus temperatures of these solders are in the 149°C to 163°C range.

The purpose of this paper is to present the mechanical factors which should be considered in mounting these modules in equipment.

MAJOR MOUNTING FACTORS

There are three major considerations in mounting an RF power module. First, the flange is used for the RF electrical ground reference. Typical inductance of the connection pins used on these modules is about 18 nanohenries per inch or 1.8 nanohenries per 100 mils. Since at 800 MHz a nanohenry has about 5.0 ohms reactance, it is easy to see that it would be almost impossible to achieve a low reactance ground through the use of pins alone. Second, the copper flange provides the thermal path for the removal of the heat produced in the active devices present in the module. Thus, proper thermal handling must be considered in mounting the module. Finally, we must consider the mechanical stresses placed on the module by the mounting techniques used. Here we consider stresses placed on the leads and bending or twisting of the mounting flange which would cause ceramic fractures.

MODULE FLANGE FLATNESS

During the processing of the module, consideration has to be given to the various stresses produced. Through analysis of these stresses and the materials used we can arrive at the maximum allowable flange bending which can be tolerated from a mechanical standpoint. In determining the allowable flange flatness conditions, both analytical and empirical analyses were performed. Agreement between both of these analyses was very good. The theoretical analysis was performed by Motorola Government Electronics Group, Mechanical Engineering Laboratory. GEG was selected to do this work because they have done extensive work in the area of laminate stresses and have available several proven computer programs which apply directly to this problem. The assigned task was to provide an estimate of the maximum amount of initial bow (curvature) in the mounting flange which would not subsequently cause the ceramic substrate to fracture in the final assembled state. For the results of this analysis, see Table 1.

MOUNTING CONSIDERATIONS

The theoretical analysis shows that some of the responsibility for proper mounting rests on the user. Proper consideration should be given to the following items:

1. Flatness of the mounting area must be such that the final mounting of the module will not bend the flange beyond the limits given in Table 1.
2. Attention must be given to surface finish and cleanliness of the mounting surface. For instance, if one mounts the module with thermal compound and uses a dirty work area which allows 3 to 5 mil particles to be present in the compound, a failure mode can be produced.
3. Another consideration is the movement of material around tapped or punched holes. A tapped or punched hole which leaves a burr on the mounting surface can lead to failure modes.
4. In addition, rigidity of the mounting surface and its material should be considered. For instance, the copper flange on an aluminum heatsink will result in a bimetallic system which can create a bending problem. Consideration of the direction of ribs in a heatsink should be made to maximize stiffness in the direction of bending or adequate thickness of the heatsink must be provided to control bending.

It is not desirable to mechanically constrain the ends of the module so that no "slip" is possible between the module flange and its mounting surface. If the ends are constrained and the temperature differential between the module and the heatsink is significant, there can be enough bending of the module flange to break the ceramic. An example calculation is shown below to demonstrate this problem.

Assume that the ends of the flange are constrained at the centerline of the mounting holes. (2.4 inches for MHW612A/MHW710/MHW720 series modules). Assume that the module is mounted on a machined aluminum heatsink.

Thermal expansion coefficients in μinch/inch/°C

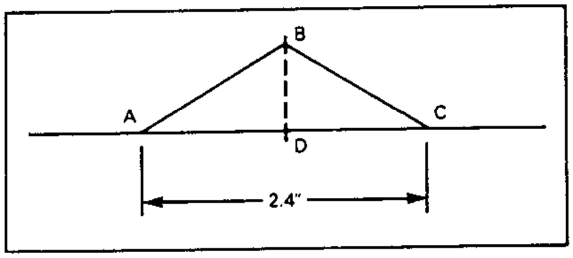
Aluminum 25×10^{-6}

Copper 17×10^{-6}

$L = 2.4$ inches

For a reasonable approximation assume the thermally induced bending creates an isosceles triangle as shown in Figure 1.

FIGURE 1



Assume that the module flange changes temperature from 25°C to 50°C and the heatsink changes temperature from 25°C to 30°C in the same time (obviously the heat input to the system comes from the copper flange — more on this later).

$$\text{Heatsink } \triangle\, L \text{ (aluminum)} = 2.4'' \times 5°\text{C} \times 25 \times 10^{-6} = 0.0003''$$

$$\text{Flange } \triangle\, L \text{ (copper)} = 2.4 \times 25°\text{C} \times 17 \times 10^{-6} = 0.00102''$$

$$\text{So length ABC} = 2.40102,\ \text{AB} = 1.20051''$$

$$\text{length AC} = 2.4003'',\ \text{AD} = 1.20015$$

$$\text{And } \text{AB}^2 = \text{AD}^2 + \text{BD}^2$$

$$\text{BD} = \sqrt{\text{AB}^2 - \text{AD}^2}$$

So BD = 0.029397 inches which far exceeds the allowable flange bend.

This analysis also points out the advantage of keeping the heatsink and the flange at lowest possible temperature differential through the use of thermally conducting compounds between the surfaces.

For instance, in the example given above with an aluminum/copper system, the copper flange will remain in tension at any temperature *above* the temperature at which the system was constrained as long as the temperature ratio between the heatsink and flange is kept less than the ratio of the thermal expansion coefficients or 25/17. Incidentally, this assumes that the heat input source to the system originates in the copper flange. This situation points out the folly in some types of temperature cycling testing. For instance, if the aluminum/copper system is constrained at 25°C and is uniformly heated to say 125°C, the copper remains in tension — if the system is cooled below 25°C, the copper will go into compression. This is exactly the opposite situation obtained when the heat input to the system comes from the copper flange.

The above is a rather elementary analysis of the thermal effects on the module/heatsink system. Many other factors are involved such as relative strengths of the materials involved, bending of the mounting screws and so forth.

What should be derived from this discussion is that the design of the mounting for the module/heatsink system is not a simple one and should not be done in a casual manner.

Our recommendation is that a mock version of the system be constructed early in the equipment design and thermal cycling performed both with external heat input to the system and with heat input to the system from the module. This is a very effective "analog computer" and direct measurements of the flange/heatsink deflections can be made. In this manner the actual expected flange excursions can be compared to the recommended maximum flange bending to determine whether the design is adequate. Incidentally, the recommended maximum deflection values given in Table 1 have a safety factor of approximately 2. That is, the deflection required to crack the ceramic is approximately twice the value given. Table 1 includes data showing the empirical deflections required to fracture a ceramic board in the module.

5. We strongly recommend the use of a good thermal compound between the mounting surface. Sufficient material must be used to fill all gaps which may be present. We have not been able to create any mechanical problem with excess compound as long as there is a path for the excess material to escape as the module is tightened down with the mounting screws. At this point it should be pointed out that unless both the module flange and the heatsink were lapped to absolute gauge block flatness, there will always be a significant air gap between areas of the flange and the heatsink. Since it is obviously not practical to achieve a lapped surface of this quality, this portion of the mounting problem resolves to one of mechanical rather than thermal considerations. As an aside, some of the Motorola modules also have machined surfaces which may be oxidized to some degree. Infrared thermography of the active die was performed to see if there was any thermal degradation due to this oxide layer and no degradation could be found. This has also been found true on lapped discrete transistor flange mount parts.

Several manufacturers of thermally conductive heatsink compound exist. We have used products from Wakefield and Dow Corning with success.

MOUNTING HARDWARE

Obviously an ideal mounting hardware scheme would be one in which the clamping pressure remained constant with age. One way of achieving this is through the use of conical washers — one trade name is Belleville washers. Another possibility is "wavy" washers. Proper selection of mounting hardware and torque is also necessary. We recommend the following mounting hardware sizes and torques:

4–40	3 in/lb
6–32	5 in/lb
8–32	5 in/lb

TIGHTENING SEQUENCE

A very important factor to be considered in mounting the module is the proper torquing sequence. The personnel involved in mounting the modules should be given careful instruction and their procedures monitored at regular intervals. Since the flanges are punched from a roll of material, there can sometimes be a small "roll-up" at the end of the mounting flange. If one considers what can happen if the mounting hardware were tightened completely at one end first, it is easy to see that the other end could be "lifted" off the mounting surface well in excess of the allowable flange bending tolerance.

This should be avoided by first lightly alternately snubbing down the mounting hardware "finger-tight." Next, the hardware can be torqued to its final specification again in at least two sequential steps.

THE IMPORTANCE OF THIS TORQUING SEQUENCE CANNOT BE STRESSED TOO HIGHLY

LEADS

The leads used on the standard Motorola RF Power Modules are of either tinned copper, gold or silver plated KOVAR, or pure silver strap, typically 5 to 10 mils thick and 15 to 20 mils wide. The leads are intended for making electrical connections to the modules *only* and are not intended to support the module at any time in the assembly process. Consideration should be given to the stresses which may occur during mounting or testing. Poorly designed test fixtures can create lead stresses far above those encountered in the end-use equipment. It is recommended that the fixture be designed so the leads are always clamped after the flange is clamped and the tolerances be such that an upward force is never placed on the leads, even as the fixture wears. Motorola's specification for lead pull in shear and peel are 908 gm shear and 454 gm peel for BeO boards and 1500 gm shear and 750 gm peel for alumina boards. Modules from PC86, 90, and 91 product lines use BeO boards. Modules from the PC87, PC103 line use one alumina and one BeO board. PC41, PC64, and PC104 use alumina boards.

DEFLUXING

These modules are designed to be manually soldered into an assembly. The modules have a silicone die coat over the active die, MOS capacitors, and nichrome resistors. The die coat used will not withstand the normal flux removal fluids and severe reliability problems could be incurred if the flux removal fluids or solder fluxes penetrate the inside of the module. We recommend a flux activity of no more than R or RMA be used.

CONCLUSION

In mounting RF power modules, the following major areas should be considered:

1. Heatsink flatness.
2. Use thermal compound — eliminate dirt or grit in the compound or on mounting surfaces, use an adequate amount to fill gaps.
3. Tighten modules down in an alternate manner "finger-tight" before final torquing.
4. Be careful with defluxing operations.
5. Consider lead stresses, both in mounting and testing.

TABLE 1 — Maximum Deflection

DEVICES	LINE	THEORETICAL DEFLECTION TO BREAK	***EMPIRICAL DEFLECTION TO BREAK		MAXIMUM RECOMMENDED DEFLECTION COMBINED HEATSINK & FLANGE		OUTGOING QA SPEC. (MAX)	
			MIN	AVG	CONVEX	CONCAVE	CONVEX	CONCAVE
MHW709, 710	PC41	0.015	0.0190	0.0218	0.008	0.010	0.005	0.005
MHW720 *	PC64	0.015	0.0190	0.0206	0.008	0.010	0.005	0.005
MHW720 **	PC64	0.011	0.0075	0.0079	0.007	0.0085	0.003	0.005
MHW720A	PC104	—	0.0190	0.0206	0.008	0.010	0.005	0.005
MHW612, 613†	PC86	0.0025	0.0019	0.0028	0.0015	0.002	0.001	0.002
MHW612A, 613A†	PC87	0.011	0.0103	0.0108	0.007	0.0085	0.003	0.005
MHW808	PC90	—	0.0025	0.0034	0.0015	0.002	0.001	0.002
MHW808A	PC103	—	0.0065	0.0070	0.0035	0.004	0.0015	0.0025
MHW820	PC91	0.005	0.0073	0.0084	0.004	0.005	0.002	0.003

ALL UNITS IN INCHES

* PC64 was changed to alumina board — BeO carrier transistor construction similar to PC41 in February, 1983. All product with date code .883 and after has this construction.

** Old construction of PC64 with total BeO output board.

*** Measured deflection to break a substrate within 3 to 5 seconds of application of force.

† These devices will be obsolete on September 30, 1983. Contact Motorola for the current availability and recommended discrete transistor replacement lineup.