EB211

Thermal Management and Solder Mounting Method for the MRF286, 60 Watt Power Device in a CuW (Copper Tungsten) Base Package

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MOUNTING METHOD DESIGN AND CONCERNS

The critical aspects of any mounting method design for power devices are 1) how heat is transferred away from the semiconductor and, 2) if the mechanical aspects of the design are constructed such that the package will not come apart or cause a performance failure during normal operations in expected environments. Once these two critical issues have been adequately assessed from a simulation and testing point of view, then both the design team and the customers have reached an important milestone in product robustness. Accelerated life tests can then be performed to enhance the confidence level for long term operation and to predict potential product lifetime.

With the MRF286 device, thermo–mechanical stress models were completed using Ansys 5.3 2D simulation techniques and thermal management modeling was performed on the mounted assembly. After simulation, test structures were built and thermal performance measured to ensure adequate heat transfer under typical conditions. Finally, power life test boards were solder assembled with the MRF286 on an automated surface mount line. These printed circuit boards (PCBs) were fastened to copper plates which were then bolted to fan–cooled, finned aluminum heatsinks with thermal compound on the interface. The assemblies were then powered up at an 80% duty cycle for 12,000 cycles representing 1000 hours of DC operation. Additional boards were submitted to nonpowered temperature cycling of –65°C to +150°C, with electrical tests done before and after 1000 cycles.

Although testing and simulation were done specifically on the MRF286 60 W device (as seen in Figure 1), the mounting method described can be reliably used for similar devices using the same package construction technique and materials from 20 W to 60 W of power dissipation in packages with a 0.040 inch thick CuW base.

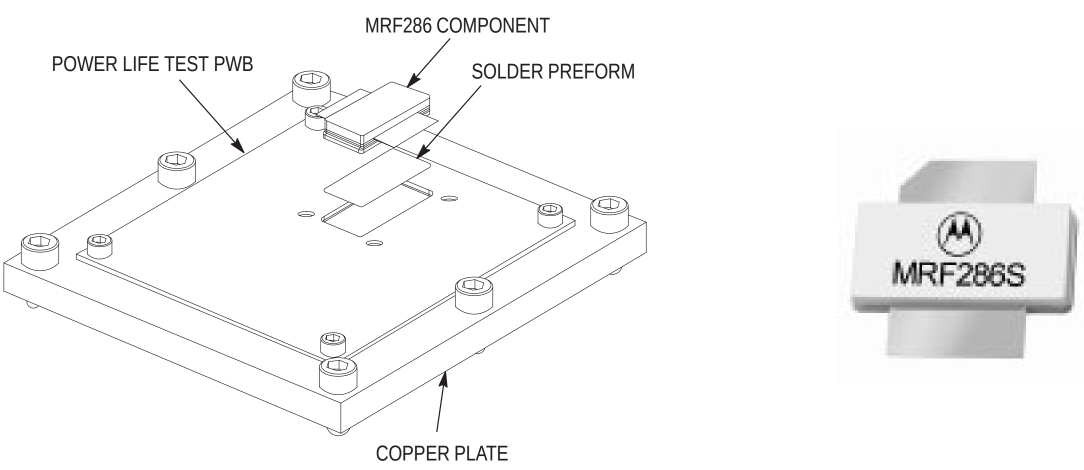

Figure 1. MRF286 60 Watt Power Device

MOUNTING METHOD

The completed power life test assembly is shown in Figure 2. As described in the Mounting Method Design section, the assembly consists of the device solder mounted to a printed circuit board, with the base of the part solder mounted to a copper plate. The copper plate is bolted to an aluminum chassis which is then fan–cooled in order to maintain the die junction temperature at approximately 175°C.

A challenging aspect of high volume manufacturing of any component in a board assembly involves the stack up of tolerances of the completed system. Achievable device tolerances for seating plane height of the component are ±0.005 inches. Achievable tolerances of the printed circuit board are approximately ±0.007 inches. The tolerances of the copper plate can be kept to ±0.003 inches in the recessed area where the component will sit. In the assemblies built for power life test, the recess in the copper plate was machined so that the device leads would be assembled with maximum lead tip deflection of 0.015 inch where the leads attach to the PCB. This was accomplished by utilizing a solder reflow fixture which held the component in place during reflow. The fixture used for this assembly is depicted in Figures 3 and 4. To solder multiple components at one time, a simple fixture can be designed to secure all of the components during the reflow operation. This can be done with several techniques, an array of pins being one example. In the power life test assembly, the varying space tolerance between the backside of the component and the copper plate was filled with solder.

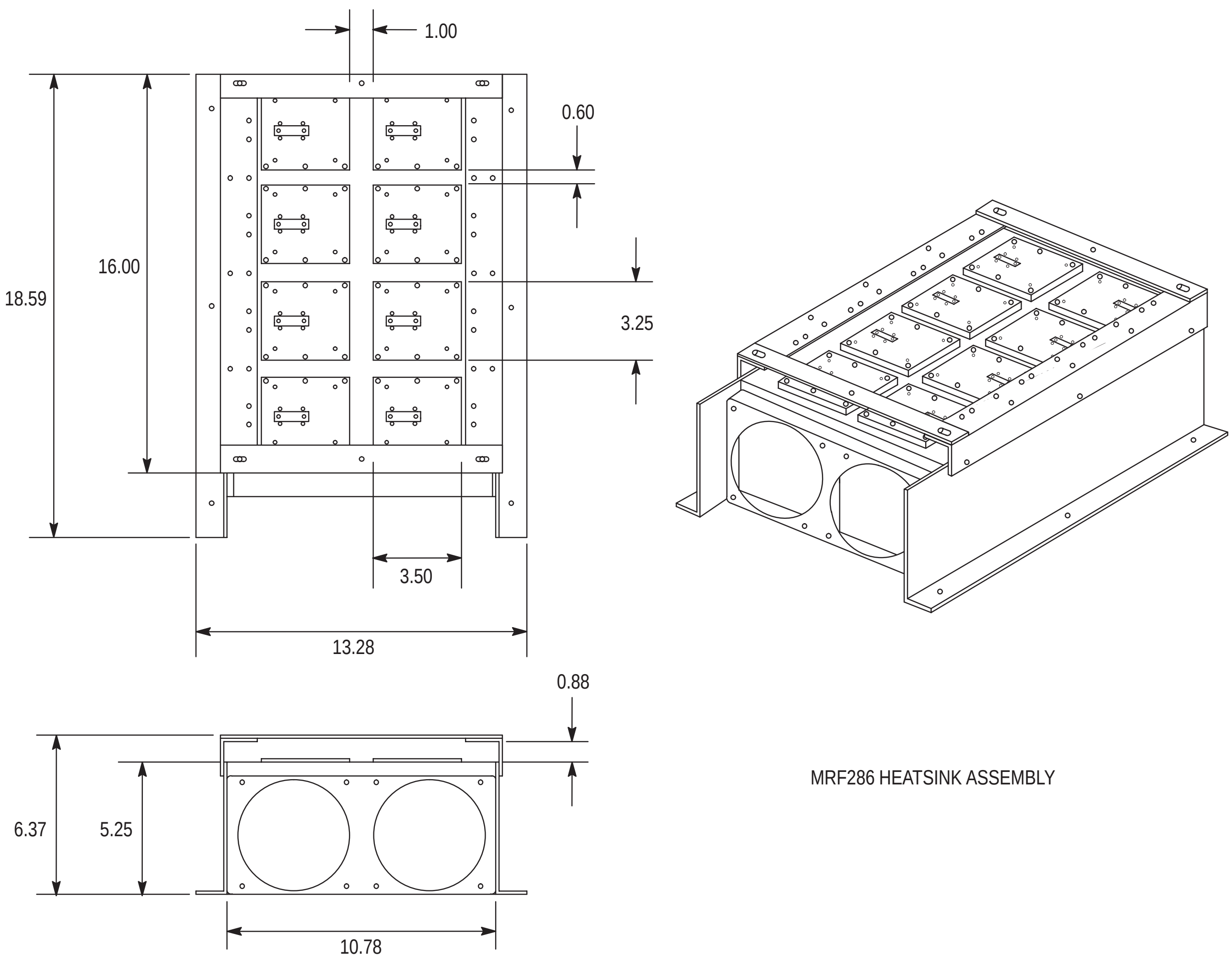

Figure 2. Power Life Test Assembly

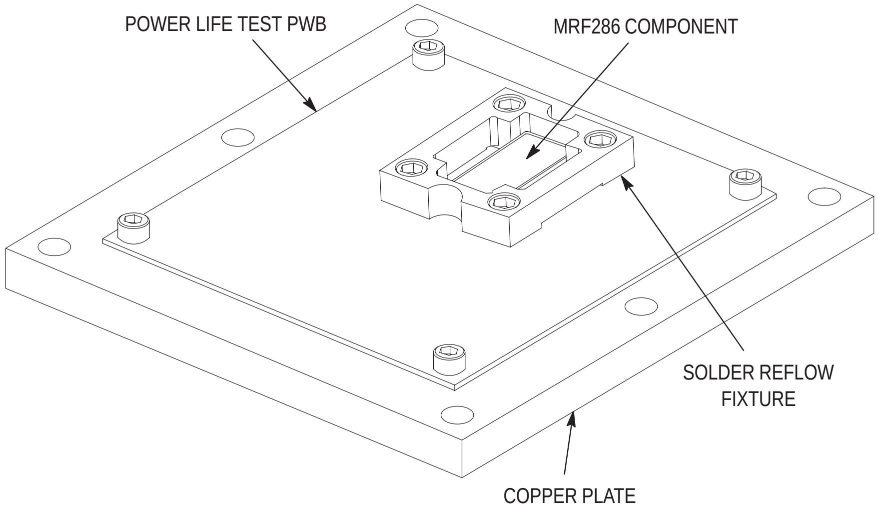

Figure 3. MRF286 Component Assembled with Solder Reflow Fixture

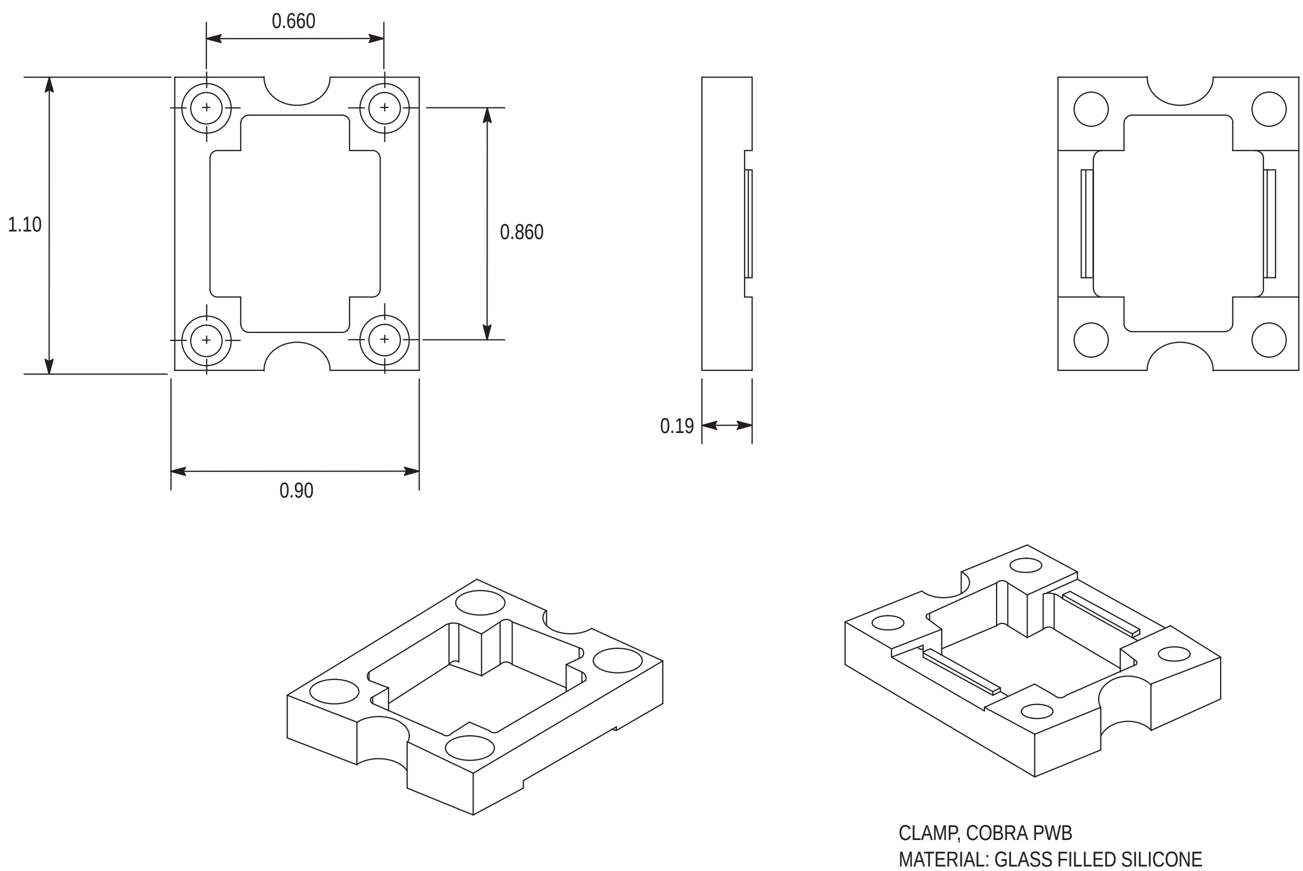

Figure 4. Component Fixture used for Reflow

Prior to proceeding with assembly of the PCB, it is necessary to insure that the level of gold within the solder joint does not exceed 4% by volume. This can be accomplished in a number of ways. Once this was accomplished for our power life test assemblies, the PCB was then screen printed with Sn/Pb/Ag solder paste using a stainless steel stencil, 0.006 inches thick. It was then secured to a copper plate using four #4–40 socket head cap screws. The copper plates were plated with approximately 1,000 to 1,500 microinches of electroless nickel. The plates contain a recessed cavity in which the components were then placed. Prior to placing the component, two .002 inch thick solder preforms were set into the recess. Two drops of no clean flux were placed on the preforms prior to placement of the device. The solder reflow fixture shown in Figure 3 was then fixed in place over the part using four #4–40 screws. Finally, the entire assembly was placed in a BTU convection reflow furnace. In the reflow step, the board is preheated to 150°C and held constant for a minimum of one minute to stabilize the board temperature. Best reflow characteristics are achieved by a “spike” above the 183°C liquidus. Peak temperature of the furnace is at 215°C ±10°C. Maximum time above the liquidus temperature is 90 seconds with 30–60 seconds typical. Maximum time above 150°C is 5.5 minutes. After reflow, the solder reflow fixture was removed by removal of the four screws. The completed, reflowed board/plate assemblies were screw mounted to the aluminum heatsink after evenly spreading the backside of the copper plate with 0.0005–0.001 inches of thermal compound.

MECHANICAL ANALYSIS

A two dimensional plane strain finite element model was created to analyze the stresses in the MRF286 package resulting from deflection of the Alloy 42 leads. During assembly it was expected that the lead deflections could be as much as 0.010 inch to 0.015 inch. From the mechanical analysis it was concluded that the leads would undergo plastic deformation during assembly but would not break, and the CuSil (copper–silver) braze joints and alumina seal ring would not yield or break. Therefore, there should not be any problems with the MRF286 device during assembly to the PCB if the leads are deflected to a maximum of 0.015 inches. Table 1 lists maximum stresses in the lead, braze joint and alumina seal ring at various lead deflection levels.

Table 1. Lead Deflection versus Stress

Material Strengths: (MPa)	Alloy 42 (25°C) Yield/Ultimate 280/494	CuSil (25°C) Yield Stress 162	Alumina Tensile/Flex 193/359	Alumina Tensile/Flex 193/359
Lead Deflection (inches)	**Maximum Lead Stress Seqv (MPa)**	**Maximum CuSil Stress Seqv (MPa)**	**Deflection Down Maximum Alumina Stress S1 (MPa)**	**Deflection Up Maximum Alumina Stress S1 (MPa)**
0.005	214	113	13	45
0.01	287	141	18	65
0.015	301	155	21	77

THERMAL MANAGEMENT AND POWER LIFE TEST

In order to perform accelerated life testing under duty cycle, it was necessary to fully understand the thermal performance of the device under system mounting conditions described previously. Both thermal analyses and empirical tests using infrared scanning were completed to assure that the cooling conditions would adequately assess performance without subjecting the part to a runaway thermal condition. The guideline used for the MRF286 was to keep the die junction temperature as close as possible to 175°C during the testing cycle. The assemblies were powered up under DC conditions at 26 volts at an 80% duty cycle for 12,000 cycles, which is comparable to 1000 hours of life operating at the maximum average junction temperature expected for the device.

From the thermal testing, it was determined that the heat sink should be cooled to a temperature of approximately 110°C in order to keep die junctions at or near 175°C during the four minutes on, one minute off operation.

There were no failures for the full 12,000 cycles of DC operation at 80% duty cycle. Additional assemblies were subjected to temperature cycling for 1000 cycles at –65°C to +150°C with less than a half minute between temperatures. All assemblies were visually inspected and electrically tested before and after the temperature cycles. There were no failures experienced during temperature cycling.

SUMMARY

A process for mounting the MRF286 60 W power device was presented in conjunction with the methodology used for development of that procedure. The component package was constructed of a CuW (copper tungsten) base with an alumina seal ring and Alloy 42 leads. Although the example described is specific to the MRF286 device, the mounting method is applicable to packages with the same type of construction and materials for power devices ranging from 20 W dissipated power to 60 W dissipated power.

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