application note

Mounting Considerations For Packaged Microwave Semiconductors AN-A006

INTRODUCTION

There are three kinds of connections that must be made when a device is mounted onto a circuit board. A mechanical attachment is needed to physically hold the device to the circuit. Electrical attachments are needed to provide paths for both DC and RF currents to flow. A thermal attachment is needed to provide a path for heat to leave the device so that it can operate reliably. This application note discusses how these connections should be made for packaged microwave devices.

The design of the semiconductor package determines how the above attachments can be made. There are two primary package types: small signal and power.

SMALL SIGNAL DEVICE PACKAGES

Small signal microwave semiconductor packages have designs that come primarily from high frequency electrical performance considerations. Thermal dissipation and heat rise in the package are not major design considerations, due to the small amount of power dissipated (usually less and 100 mW). In general such packages are expected to be used in a microstripline environment. Thus input and output leads emerge from opposite sides of the package, and are usually transmission lines for minimum loss. Two opposing ground leads are also provided, to allow for the shortest, lowest loss path to ground possible. The overall dimensions of the package are kept as small as possible, to minimize its electrical length.

A package of this kind—small in size, with multiple leads, and having no need for a superior thermal path—can use the attachment of the leads to the electrical traces of the circuit board as the sole means of device mounting. Thus, with small signal devices, the lead attachment provides the mechanical, thermal, and electrical connections to the circuit.

Soldering

The most common way of attaching the leads of a package to a circuit board is by soldering. The soldering process can subject devices to two different kinds of potentially dangerous stresses: electrical and thermal.

A transistor of MMIC can suffer permanent electrical damage if any of its breakdown voltages are exceeded. Care must be taken in the soldering process to insure that this doesn't happen. The voltage ratings will vary from one device model to another, and also as a function of across which terminals the voltage is applied. The permissible limits for a particular device will be delineated in the maximum device ratings section of this data sheet.

Voltage breakdowns can be exceeded when soldering equipment is not at ground potential. A multimeter should be used to ensure the portion coming into contact when the semiconductor is at zero volts, both DC and AC. Even voltages smaller in magnitude than the breakdowns can cause problems. Gallium Arsenide Field Effect Transistors (GaAs FETs), for example, are "normally on" devices (i.e. no gate bias voltage need be applied for the device to operate once drain voltage is applied. If the soldering equipment is not at ground potential, accidental operation of such a device can easily result; in the uncontrolled impedance environment of soldering these high gain devices can then easily oscillate and destroy themselves. KEEP ALL SOLDERING EQUIPMENT AT GROUND POTENTIAL.

Electrostatic discharge (ESD) can also generate sufficient voltage to exceed breakdowns and damage microwave devices. GaAs FETs are particularly susceptible to this kind of damage. Anything coming into contact with a static sensitive device must be at ground potential. This includes operators as well as equipment. Static sensitive devices should only be handled by operators wearing static wrist bands working at static free work stations. For more information on ESD protection see Hewlett-Packard application note AN-A004R: ***Electrostatic Discharge Damage and Control.***

Thermal damage of various kinds can result if any of several critical temperatures are exceeded. Alloying temperatures establish the first critical temperature. Extremely high temperatures (above 425°C) will essentially cause new diffusions of the die, resulting in drastically changed electrical performance. Die attach temperatures establish a second critical temperature. Silicon bipolar devices are typically bonded to the package substrate by a fold-silicon eutectic that forms around 400°C. Gallium Arsenite FETs are typically eutectic die attached at 280°C. Heating the package during soldering to above the die attach temperature can "float" the die, and seriously degrade the bond to the substrate. This can result in severe thermal stress on the die during electrical operation. The third critical temperature is established by the maximum temperature the package can endure without damaging the integrity of the seal. Since there are a number of different types of seal (glass, epoxy, plastic, various solders) this temperature can vary from above 400°C to as low as 150°C. Destruction of the package seal can allow penetration of the package by foreign material, which may then alter device electrical performance, either through corrosion or by establishing alternate electrical paths. In general the temperature at which seal degrades is the lowest critical temperature in the die-package system, and establishes the maximum temperature ratings of the device. Each critical temperature is time dependent, and has associated with it a certain "dwell time" above which damage will occur.

Because of the relatively small volumes usually encountered in the microwave industry, hand soldering has been by far the most popular way of attaching a device to a circuit. Avantek recommends the following guideline for this method. HAND SOLDERING SHOULD BE PERFORMED AT 250°C, IN LESS THAN 2 SECONDS PER LEAD. Hand soldering is the ONLY recommended method of soldering for any GaAs FET devices using low temperature solder seals.

Improved manufacturing technology and the advent of several consumer oriented microwave products has raised interest in more automated soldering techniques. These include wave soldering, vapor phase soldering, IR reflow soldering, and laser reflow soldering, to name just a few. Each technique can use any of a whole array of solders, each with different melting temperatures. Rather than try to construct a recommended profile for each package type for each kind of soldering, HP provides the information shown in Figs. 1 through 3 to help the manufacturing engineer design a soldering profile. These curves show maximum recommended time versus temperature for the plastic (04, 05, 08, 23B, 84, 85, 86), ceramic or glass-metal (18, 35, 36) and gold (10, 20, 23A, 50, 70) package families.

Electrical and Thermal Considerations for Small Signal Packages

One extremely important electrical consideration should be kept in mind while mounting any microwave device. Any extra lead length becomes an additional, undesired circuit element at microwave frequencies. This is especially important for ground lead length; seemingly small lengths of lead can result in decibels of lost gain. In general all leads should mount flush with the PC board, with the smallest gap possible left between package body and circuit traces. For packages where the leads are not co-planar with the bottom of the package, it is better to make a hole in the PC board to allow for flush mounting than to bend the device leads.

Thermal considerations involved in the mounting of small signal devices are minimal.. The device lead attachment provides sufficient heatsinking to these semiconductors. The output lead is the primary heat path for bipolar transistors and MODAMP™ MMICs—for these devices the bottom of the die is the collector (output) meaning these devices end to be die attached directly to the output trace. The ground leads are the primary heat path in GaAs FETs since these devices have electrically isolated backsides and, are therefore, usually die attached directly to ground. Note that this means additional lead length not only degrades electrical performance, it also increases the operating temperature of a small signal device by increasing the case-to-ambient thermal resistance. 100 mils of lead length in free air can raise the case-to-ambient thermal resistance of a small signal microwave package to between 150° C/W to 300° C/W. In contrast, properly mounted small signal devices should have case-to-ambient thermal resistances of less than 50° C/W.

For best electrical and thermal performance of small signal devices, KEEP ALL PACKAGE LEAD LENGTHS AS SHORT AS POSSIBLE.

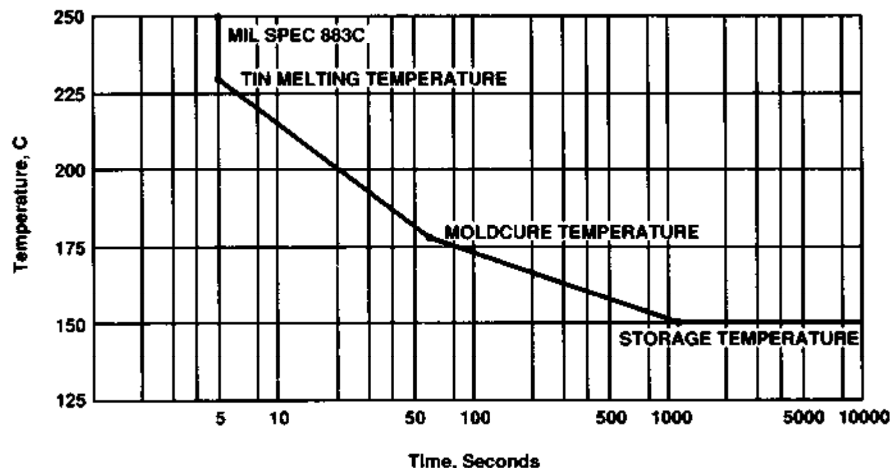

**Figure 1.
Temperature/Solder Graph For Plastic
Packaged Transistors**

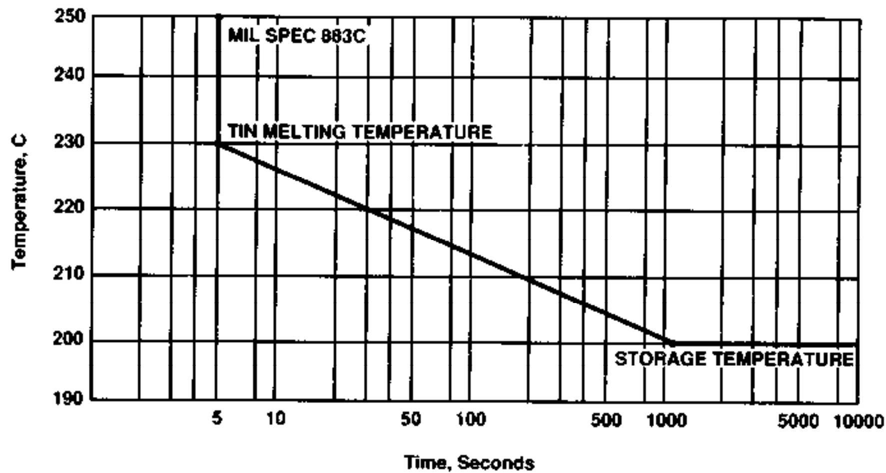

Figure 2.
Temperature/Solder Graph For Ceramic and Glass-Metal Packaged Transistors

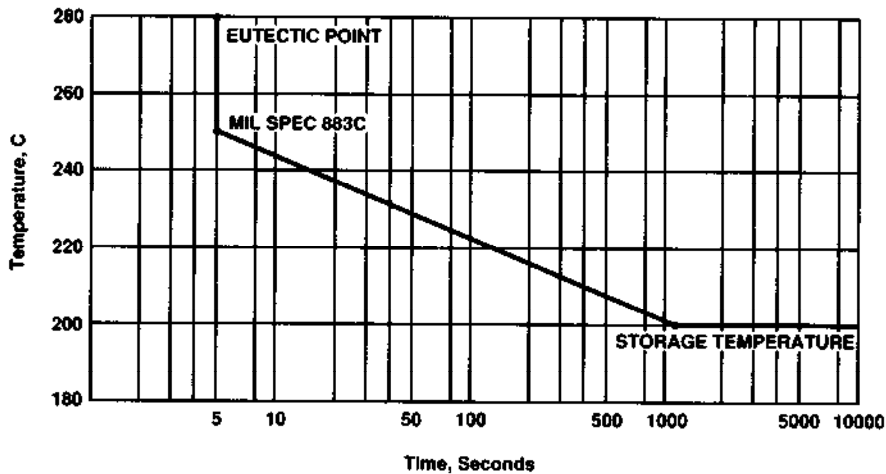

Figure 3.
Temperature/Solder Graph For Gold Plated Packaged Transistors

POWER DEVICE PACKAGES

Higher power devices come in specially designed packages that provide sufficient thermal conductivity to allow for reliable device operation at higher power dissipation levels. Packages for devices with bottom side electrical contacts (e.g., bipolar transistors) usually incorporate a Beryllium Oxide (BeO) ceramic substrate for superior thermal conductivity. Devices with electrically isolated backsides (e.g. GaAs FETs) do away with substrates under the die altogether, and mount directly to a metallic rib of the heatsink brought up through the package for this purpose. Typically power packages are much larger than are the small signal packages, due to the need for heat spreading. Thus such packages often incorporate some additional mechanical means of mounting beyond lead attachment, e.g. mounting screws, in a metal flange.

Electrical and Thermal Considerations for Power Packages

Electrical attachment of power packages is accomplished in the same manner as for small signal packages, i.e., through soldering of the leads. The same hand soldering guideline of 2 seconds per lead at 250°C applies. The graph of time versus temperature for gold packages applies to the power packages as well. Mechanical and thermal attachment vary with the package style.

The 20 style package has an electrically isolated area of metalization on the bottom of the package. It is intended that this area be attached to the circuit heatsink, either by soldering, or using a good thermal conductive epoxy. Soldering should follow the time-temperature guidelines of the "gold" packages (see Fig. 3). Although the soldering of the leads to the circuit board is sufficient for mechanical attachment of this package, this bottom connection is necessary for proper thermal operation.

Most other power devices come in packages with flanges that can be bolted directly to the circuit heatsink. For best thermal conductivity, the bottom of the flange should be coated with a THIN layer (10 mils or so) of thermal conductive grease. This will result in the lowest possible case-to-ambient thermal resistance (θ_{CA})—usually giving a value less than 5° C/W. Note that a thick layer of thermal grease is almost as bad as an air gap and would result in much higher values for θ_{CA}. Additionally, many flange packages use the flange as the ground connection to the device (see individual data sheets for terminal configuration) and excessive grease could degrade this important electrical contact.

Occasionally indium foil will be substituted for heat grease. While indium foil is less messy than heat grease, it is not as desireable as a thermal conductor. In addition, oxidized indium foil is a poor electrical conductor, so the foil must be cleaned prior to installation if the flange of the semiconductor is also the ground terminal. Use of oxidized indium foil can result in significant loss of high frequency gain. The piece of foil used must at least reach past the screw holes in the flange of the semiconductor. A short piece of foil will hold the middle of the flange away from the heatsink when the edges of the flange are bolted down, causing bowing of the semiconductor package. This will compromise device heatsinking, and can also result in cracking of substrates or die. Like all gap fillers used to improve heatsinking, the piece of in foil use should be as thin as possible. Gap fillers usually are much poorer thermal conductors than either the heatsink material or the package material, and the heat transfer path across them should be kept as short as possible. Such materials are used only because they are better thermal conductors than air. Their purpose is to fill in the small air gaps that exist in the flange-heatsink interface.

Mechanical Considerations for Power Packages

Improper mounting techniques can mechanically damage power device packages. HP suggests that the following methods be used when a power device is installed in a circuit.

When bolting a flange device into the circuit, it is important to tighten both bolts only until they are finger tight, then ALTERNATELY tighten until the flange is secured to the heatsink. Never tighten one bolt fully before inserting the second bolt; doing so can bow the package, resulting in miserable thermal contact or a cracked substrate.

It is also acceptable to solder the flange of a power device to the heatsink. The time versus temperature guidelines for "gold" packages should be used when soldering power devices in gold metalized packages (see Fig. 3).

Leads of power devices should be soldered to the circuit traces only after the body of the device has been mechanically attached to the circuit. When a semiconductor already soldered to a PC board is bolted to a heatsink, extreme vertical shear forces can result at the package lead brace, fracturing the braze joint where the lead meets the package.

Following the above guidelines will help ensure that your circuits built with HP transistors and MMICs have the best possible longevity and reliability.

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Printed in U.S.A. Data Subject to Change Obsoletes 300320 (9/90) 5091-8696E (8/93)
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