IMFET Handling and Design Guidelines

Application Note 1083

Introduction
This application note provides basic information on the use and handling of Hewlett-Packard's Internally Matched Power GaAs FETs or IMFETs™. Topics include a brief product description, proper handling, some common mounting methods, and electrical testing. Specific areas covered are ESD precautions, transport, unpacking, storage, test fixtures, mounting methods, heatsinking, and system installation.

Product Description
An IMFET consists of one or more GaAs MESFET power chips and internal circuitry matched to 50 ohms and assembled in a micro-stripline package. All circuits use thin-film hybrid microwave integrated circuit (MIC) construction with ceramic gold-plated substrates. The package flange is made of copper or copper / tungsten for efficient heat transfer. The walls and cover for each model are made of either ceramic or copper. Biasing is external to the IMFET to allow design flexibility. The two industry standard packages have three external connections:

1. The RF input and negative gate voltage bias supply,
2. The RF output and drain voltage bias supply, and
3. The flange which is the ground connection and thermal contact.

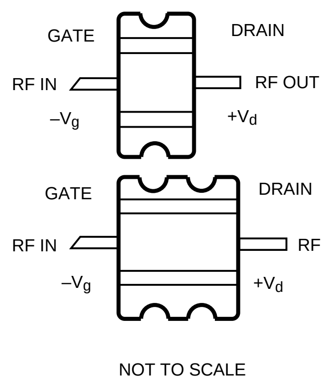

Figure 1. IMFET Configuration.

Handling

General ESD Precautions
Handle IMFETs as Electro Static Discharge (ESD) sensitive devices. ESD damage is not always immediately catastrophic. Because latent ESD damage is often very difficult to detect, you should consider a stressed IMFET's life expectancy to be reduced. ESD damage can occur anywhere in the handling sequence. To minimize the potential for ESD damage, important areas to routinely monitor for destructive voltage potentials include:

- static-controlled work stations,
- work surfaces,
- test equipment,
- cables,
- power supplies,
- test fixtures,
- tools, and
- operators.

In short, anything coming into contact with the IMFET should be at ground potential. Additional information on ESD is available in the HP application note AN-004R (5091-8803E).

Shipping
Each IMFET is shipped in an ESD-static dissipative container. HP recommends keeping these packages for routine transport of the IMFETs.

Local Transport
Each IMFET should be stored in its ESD-static dissipative container until installed. If the IMFET must be handled outside the container, always use clean gloves or finger cots and a grounded wrist strap.

Unpacking
Remove the plastic transport case

cover, leaving the IMFET nested in the base. Using clean finger cots or non-nylon gloves to prevent skin oil contamination, remove the IMFET from the base using clean tweezers. Any contamination can lead to difficulties in subsequent soldering or bonding operations.

Storage

Store the IMFETs in an ESD protected environment. A stable temperature, preferably near 25°C, with relative humidity below 60% is preferred. The IMFETs have been qualified to 85% relative humidity with MIL-STD-202F, Method 103, Condition B. The maximum long term storage temperature is 150°C, a temperature below the attachment process temperatures used to assemble all internal parts.

General Mounting Considerations

Any assembly method must address the mechanical, electrical, and heat factors, as well as lead placement. Mechanical layout requirements are determined by the dimensions of the industry standard package. Electrical performance is specified on the data sheet. Heat transfer and lead alignment considerations are discussed below and apply to all the mounting methods presented in this application note.

Heat Transfer

Good heat or thermal transfer is directly dependent on solid contact between the IMFET flange and the heatsink. Because of the relatively high levels of power dissipation, proper heatsinking must be provided. Failure to do so may result in degraded reliability and shortened mean-time-before-failure (MTBF). The path for the heat flow from the active regions of the FET device is through the bottom of the package. The package bottom is designed to apply maximum pressure under the IMFET devices to improve the heat transfer away from the die. Assembly experience has shown this method provides better heat transfer away from the die through the flange than does a flat case bottom.

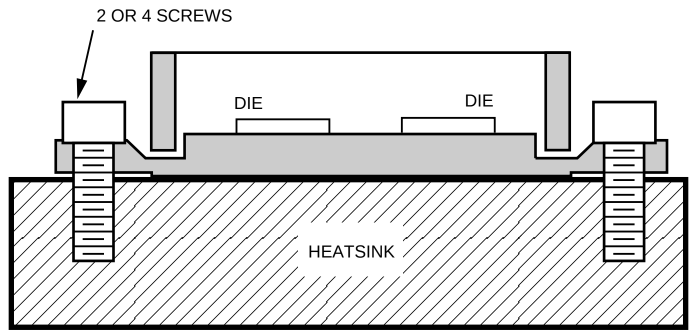

Figure 2. Cross-sectional View of IMFET Mounted on Heatsink.

Repeated exposure to elevated temperatures beyond the time guidelines in Figure 3 can lead to permanent IMFET damage. HP recommends using this graph as a guide for **cumulative** temperature and time exposure.

For example, consider an IMFET exposed to 200°C for 10 seconds. This uses 1/3 of the “maximum cumulative time” of the IMFET (30 seconds at 200°C). The remaining 20 seconds can be used at 200°C, or applied proportionately to some other temperature. For example, if a second process step requires 180°C, a maximum of 80 seconds is available. The 80 seconds is two thirds (67%) of the allowable time at 180°C (120 seconds times 0.67).

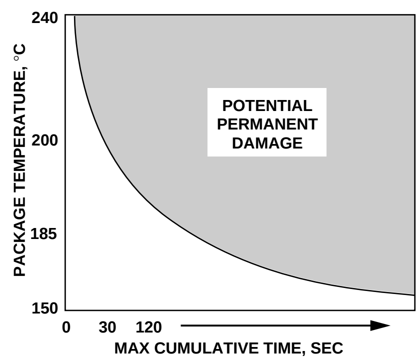

Figure 3. Cumulative Time and Temperature.

Lead Alignment

When mounted into the system, all leads of the IMFET should always be level (coplanar) with, or slightly above, the attachment surface. Figure 4 shows the lead height required for lead stress relief. Stress relief will prevent mechanical damage resulting from thermal expansion or contraction that could result in lead detachment and feedthrough cracking on the IMFET case when assembly is complete. The “A” dimension in Figure 4 is necessary to allow for package width tolerance, thermal expansion over temperature , and space to prevent solder flow / shorting between the lead area and the IMFET package.

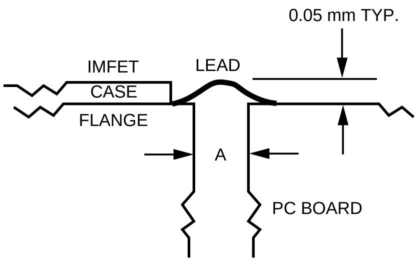

Figure 4. IMFET Lead Height and Stress Relief.

Assembly

There is no universal method for properly mounting an IMFET. Different system configurations require unique considerations that must be managed by the design engineer. Several different methods of mounting are presented in this section. The advantages and disadvantages of each are discussed.

In all mounting methods screw torque values are critical. Correct torque values are shown in Table 1. Over-torquing the screws can bend the package and cause bad RF grounding. Under-torquing can result in poor heat transfer from the IMFET to the heat sink.

Mounting Method #1: Thermal Pad

This method uses a dry, 98% graphite, commercially available [1], 0.20 mm thick pad between the IMFET and the heatsink. When properly placed, and with proper screw torque per Table 1, this method can provide both a low resistance thermal transfer as well as a solid electrical contact. An optional adhesive coating on one side is available, but will significantly increase the thermal resistance.

Advantages:
- Good thermal conductivity, 3.85 $Wm^{-1}K^{-1}$
- Good electrical conductivity, 0.002 Ω-cm
- No outgas
- No drying out
- Minimum mechanical distortion
- Wide temperature range, -200 to +500°C
- No assembly heating required
- Easy IMFET replacement
- Consistent thickness

Disadvantages:
- Additional assembly required
- Possible fulcrum points, if not properly installed
- Less surface conforming than thermal grease, 84 hardness

Procedure:
When used, the recommended steps are:
1. Align the pad on the heatsink surface.[2]
2. Gradually tighten each screw alternately to avoid warping the case (see Figure 5.).
3. Finally, tighten all screws to the appropriate torque as shown in Table 1.

Mounting Method #2: Soft Metal Gaskets

This method uses a soft metallic material (a “gasket”) placed between the IMFET flange and the heatsink to provide thermal transfer.

There are several gasket materials available on the market, each with a different thermal coefficient of expansion. This coefficient of expansion is likely different from that of the IMFET flange, the heatsink, and the fasteners (usually screws). With subsequent IMFET heating and cooling, the gasket material may compress. This compression may leave air gaps between the flange, the gasket material, and the heatsink that will increase the resistance of the thermal path. Any material or gasket placed between the IMFET and the heatsink will degrade the flow of heat from the IMFET. Because the effective use of gasket material is heavily dependent on both the type of material and the mounting process, HP does not recommend the use of gaskets in mounting IMFETs.

Notes:
1. Warth International, Limited, Birches Industrial Estate, East Grinstead, Sussex RH19 1XH, England, Tel. 01342-315044
2. Pads available pre-cut, custom ordered, or in sheets.

Table 1. Recommended Maximum Torque Values

Screw	Torque Values
1.4 mm	2.25 kgf cm 0.22 Nm 31 oz in.
2.0 mm	2.75 kgf cm 0.27 Nm 38 oz in.
3.0 mm	5.50 kgf cm 0.54 Nm 76 oz in.
# 2	2.80 kgf cm 0.28 Nm 39 oz in.
# 4	5.40 kgf cm 0.50 Nm 73 oz in.

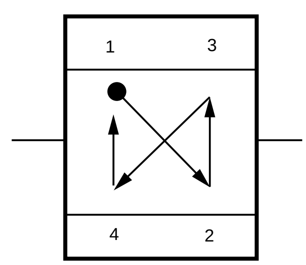

Figure 5. IMFET Tightening Sequence.

Mounting Method #3: Low Temperature Solder

This method attaches the flange of the IMFET to the heatsink using a low temperature, Indium based solder, using process temperatures below 175°C.

Advantages:

- Provides an excellent contact between the case and mounting surface.

Disadvantages:

- If reflowed, the entire assembly must be heated (unless sophisticated spot heating equipment is available).
- Difficult to remove and replace the IMFET (some solder may remain on the mounting surface and interfere with subsequent attachment).
- May introduce a fulcrum point if the recommended sequence for tightening the mounting screws is not followed carefully. (See Figure 5.)
- May easily develop pockets of air that will degrade the thermal path.

Procedure:

If this mounting method is used, the recommended steps are:

1. Ground the heater block. Voltage between the heater block and the IMFET package can degrade or destroy the IMFET.

2. Use a sheet of 0.75 mm, +0.25 / -0.0 (0.03 in.,+0.01/-0.0) thick solder alloy. Form a shim the same size as the IMFET's foot print.

3. Place the alloy shim under the IMFET and gradually tighten each screw alternately to avoid warping the case (see Figure 5).

4. Finally, tighten all screws to the appropriate torque as shown in Table 1.

Mounting Method #4: Mechanical Attachment Without Thermal Compounds or Solder Alloys

Mechanical attachment to the surface of the housing / heatsink using only screws is another common method of attachment.

Advantages:

- No additional heating of the assembly.
- Eliminates excessive flange flexing (if attached properly) due to the absence of any fulcrum points during the tightening of the screws.
- Easiest to remove and replace.

Disadvantages:

- May not provide the most complete contact between the case and the mounting surface.

The mechanical attachment must be configured to ensure good thermal and electrical performance of the IMFET. The package flanges have an 0.20 mm (0.008 in.) maximum elevation above the case bottom. When the torque from Table 1 is properly applied to the mounting screws, the gold plated case will transfer heat appropriately.

Initially finger-tighten each screw. Next, tighten each screw with the crisscross pattern shown in Figure 5 to avoid warping the case. Finally, tighten to the appropriate torque value. This pattern applies to both two and four screw packages. The four screw package would go from corner to corner and the two screw package would alternate sides.

The C24A IMFET package is flat to within 3 mils. The C21A IMFET package is flat to within 2 mils. The mounting surface should be clean and smooth to less than 3.0 µm (0.12 mils), flat to less than 50 µm (2 mils), and free of burrs and protrusions to less than 13 µm (0.5 mils). The recommended maximum torque values for socket head or filister screws are given in Table 1.

Mounting Method #5: Mechanical Attachment With Thermal Compounds

This method uses a thermal conductive compound between IMFET flange and the heatsink to improve thermal transfer.

Table 2. Effect of Mounting Screw Torque on Contact Thermal Resistance with and without Thermal Compound

Torque			Contact R_{TH} (Rc)	
			No Th.C.	Th.C.
Nm	Oz. in.	Ft. lb.	°C/W	°C/W
0.06	8.5	0.04	0.32	0.18
0.11	15.6	0.08	0.27	0.15
0.17	24.0	0.12	0.26	0.14
0.23	32.6	0.17	0.25	0.13
0.28	39.6	0.20	0.24	0.13
0.34	48.1	0.25	0.23	0.12
0.40	56.6	0.29	0.22	0.11
0.45	63.7	0.33	0.22	0.11
0.51	72.2	0.37	0.22	0.11
0.57	80.7	0.42	0.21	0.11

Advantages:
- Reduces the thermal resistance at the case/mounting surface junction.
- The IMFET is easy to remove and replace.

Disadvantages:
- Some high-thermal-conductivity compounds may degrade with use and result in an increase in thermal resistance between the IMFET case and the mounting surface.
- Thermal compound is rarely a good electrical conductor between the base of the package and ground.

Table 2 represents the thermal contact of the C24A package to the heat sink versus torque in two different cases: without and with thermal compound. Note the minimum torque is 0.40 Nm (57 oz. in.) to obtain the best thermal contact.

Mounting Method #6: Epoxy Attachment

Another method of IMFET attachment is to use an adhesive film or epoxy along with screws.

Advantages:
- May provide adequate contact between the case and mounting surface.

Disadvantages:
- Typically does not possess adequate thermal and electrical conductivity required for guaranteed performance.
- Difficult to remove and replace.
- Requires prolonged curing times at elevated temperature.

As epoxy attachment material and processes continue to improve, we can expect these disadvantages to lessen. At this time, however, HP does not recommend any specific IMFET epoxy attachment process.

Conclusion

The advantages and disadvantages covered in this assembly section are not intended to encompass every mounting consideration. Any decision regarding mounting method must take into account the mechanical, electrical, and thermal factors.

Heatsinking

An IMFET converts RF and DC input power into RF output power and waste heat. The power that is converted to heat should be transferred through a low resistance thermal path to a well designed heatsink.

Thermal factors such as desired operating temperature, power dissipation and IMFET thermal impedance dictate how much heat the mounting surface will need to remove, and therefore the permissible value of the case-to-ambient thermal resistance. Mechanical factors such as the heatsink material, the mounting method used (including torque if applicable) and surface flatness will influence the value of the case-to-ambient thermal resistance. (The best material for a heatsink is copper; aluminum alloy or similar thermally conductive materials also work well.) It is also important that mechanical stresses from thermal expansion not damage the IMFET, so factors such as thermal coefficients of expansion and expected temperature range are also important.

All of the above parameters vary both by design and by process. Each system configuration will require its own unique thermal design. If you need assistance designing a proper heatsink, HP recommends consulting a professional thermal analysis and design company.

Preliminary Testing

Customers may choose to RF test IMFETs before assembling them into the final system. For this testing, soldering the leads into a test fixture will stiffen the leads and may make future system assembly more difficult. HP recommends using a test fixture which uses pressure contacts for the leads. This method limits the lead mechanical stress and the potential for solder damage.

Potential Problem Areas

There are several potential problem areas associated with accurate and repeatable testing of IMFETs. The first is the test fixture itself. Important areas to carefully monitor include:
- correct test fixture machining,
- excessive wear,
- consistent positioning of the device under test (DUT) within the test fixture,
- proper grounding between all components, and
- any contamination that may affect measurements or the thermal path.
- sufficient gate current supply
- IMFET case temperature

A schematic of the test fixture set-up HP uses is shown in Figure 6.

The second area to monitor is the test system, including:
- source and load impedance presented to the DUT,
- return losses,

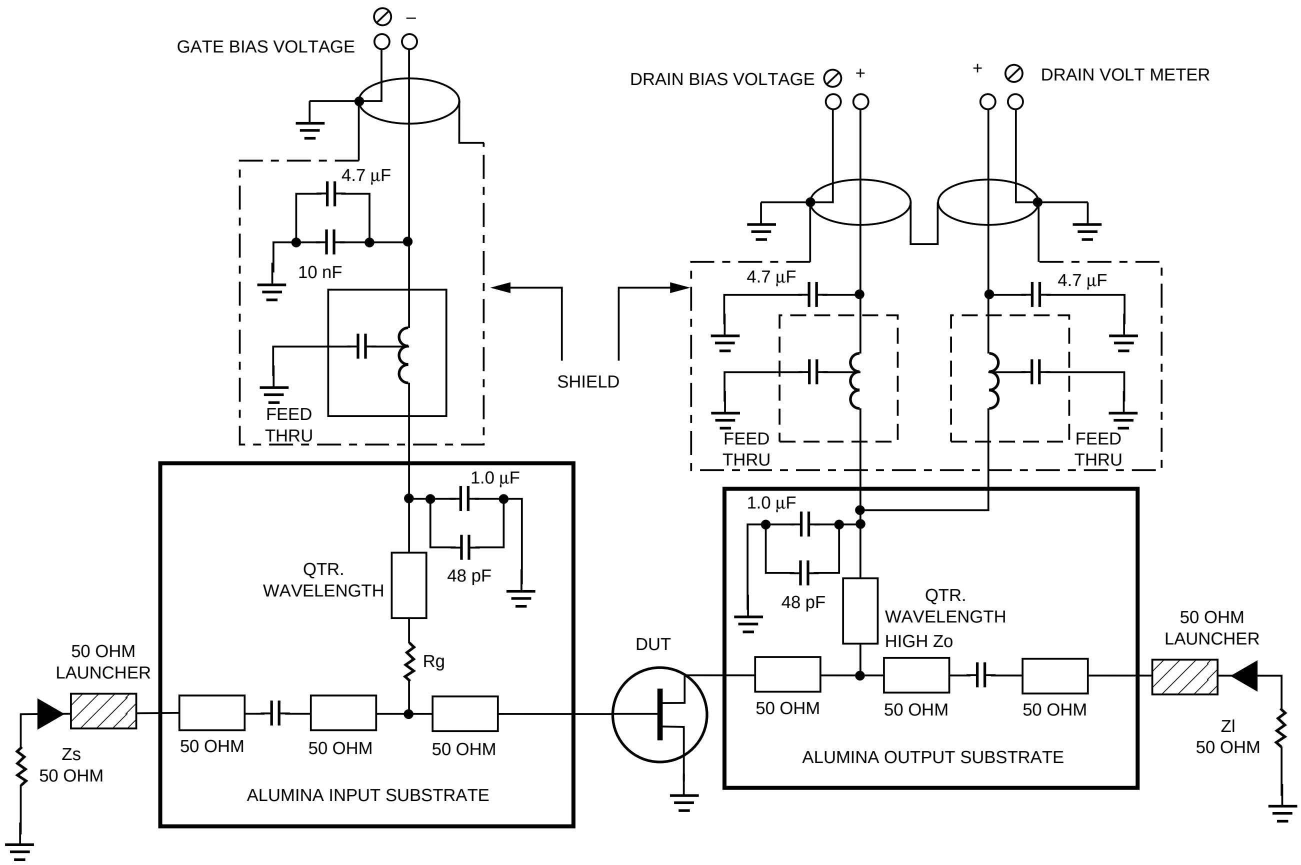

Figure 6. IMFET Test Fixture.

- power levels,
- biasing shifting, particularly of the gate bias.

Any of these can significantly affect measurement results.

These problems can also cause variations in the testing of the components or subassemblies where IMFETs are used. Every precaution must be taken to minimize these effects.

RF Grounding

Solid RF grounding through a clean, flat contact of the IMFET flange to the heatsink surface will provide the best performance from the IMFET. Poor grounding can reduce frequency bandwidths, shift output levels, and cause destructive self-oscillations.

Applying Bias

The sequence of voltage application to the IMFET is ***CRITICAL***. If the drain voltage is applied before the gate voltage, the IMFET can draw excessive current (I_{DSS}) and destroy the IMFET. For manual testing, the slope of the gate and drain voltage ramp is not critical. For automated testing, the voltage ramp slope is only limited by the stability and overshoot limitations of the automated power supplies.

A word of caution is needed here: the overshoot of an automated power supply can usually be compensated within 10 to 30 milliseconds but may not settle to its final value for 100 milliseconds. For IMFETs this is long enough to permanently damage the device. If you have concerns about your power supply, contact your local HP sales office.

For the following example of how to apply bias, a +10 V drain bias voltage and a -5 V gate bias voltage are used.

Turn on:
1. Carefully insert the IMFET into the test fixture (TF). The TF must be grounded to the power supply.

2. Connect input and output of the TF to the 50 ohm source and load. Both source and load should have a return loss of at least 20 dB.

3. Set the gate voltage to 0.0 V, then connect the negative voltage supply to the TF gate bias connection.

4. Set the drain voltage to 0.0 V, then connect the positive voltage supply to the TF drain bias connection.

5. FIRST, decrease the gate voltage down to -5.0 V,

6. THEN, increase the drain voltage up to the rated voltage (+10.0 V).

7. Increase the gate voltage from -5.0 V towards 0.0 V until the drain to source current specified on the data sheet is reached.

8. Apply the input RF power per the data sheet.

Turn-off :
1. Switch off the RF input power.

2. FIRST, decrease the drain voltage to 0.0 V,

3. THEN, increase the gate voltage to 0.0 V.

4. Remove the IMFET from the TF, remembering to follow all ESD precautions for handling.

System Installation

Before soldering the IMFET into the system, HP strongly recommends pre-tinning the leads of the IMFET and the external interconnect (for example, a PC board). This will reduce the time the solder must be heated to assure a clean fillet and minimize the IMFET lead heating.

IMFET Lead Preparation for Soldering

Procedure:
1. Remove the IMFET from the transport case. Avoid any contact with the RF/DC leads (if cleaning is required, use isopropyl alcohol and a cotton swab).

2. Mask the IMFET body with a water soluble solder mask or Kapton tape. Leave the leads exposed.

3. Solder dip the IMFET leads twice. First, use a Rosin Mildly Activated (RMA) flux. Second, use SN 62 or SN 63 solder at 257°C -5, +2°C for a maximum of 5 seconds per dip.

4. Remove the masking material.

5. Clean the case and leads with isopropyl alcohol and cotton swabs, as required.

Final Installation

This manual method is included only to show the steps necessary for final installation into a typical system. Mass production methods and applicable re-work should include the steps presented here.

Procedure:
1. Mount the IMFET to the board or circuitry as described in the Assembly and Lead Alignment sections of this application note. Figure 4 shows the recommended spacing (the stress relief shown will have minimal impact on the RF performance).

2. Place the pre-tinned leads directly on top of the interconnect surface or trace.

3. Place a small amount of RMA flux on top of the lead / interconnect contact area.

4. Use a clean, pre-tinned solder iron at 300°C ±10°C for a maximum of 5 seconds. Using SN 62 or SN 63 solder, allow the solder to smoothly flow between the lead and interconnect. Rosin Core Wire Solder can be added, as required, to create a clean, bright fillet.

5. Verify the solder connection between the IMFET lead and the external interconnect is not shorted. This can be done either visually or with an ohm meter. If you use an ohm meter be sure it is properly grounded to avoid damage to the IMFET gate/drain.

Conclusions

In review, handle IMFETs as ESD sensitive devices to avoid potential degradation or complete failure. The case mounting methods and assembly processes should be selected to balance the mechanical, electrical, and heating factors with particular attention to heat transfer. Heatsink design is a major consideration for any systems design and may require expert consultants. Consistent test results require routine inspection of both the test fixture and the test system. Using the guidelines presented in this application note will help deliver optimum IMFET performance.

Additional Information:

For information regarding choke network design and troubleshooting, refer to Hewlett-Packard Application Note AN-A001, "Notes on Choke Network Design", publication number 5091-8824E.

For technical assistance or the location of your nearest Hewlett-Packard sales office, distributor or representative call:

Americas/Canada: 1-800-235-0312 or (408) 654-8675

Far East/Australasia: (65) 290-6305

Japan: (81 3) 3335-8152

Europe: Call your local HP sales office.

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