Power Device Mounting Considerations

A consistent question asked is how to mount SEDI high power devices. SEDI recommends the use of graphite film, many customers want to know the effects of this and other interface materials.

Example Amplifier

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Article Features

• Torque Values
• Flatness Requirements
• Recommended Properties of Interface Materials
• Starting Point for Customer evaluation of such materials
The use of high power devices requires careful attention to thermal transfer from the part in both design and assembly. This article addresses one aspect of that issue, how to mount a high power microwave device into a housing.

The question of best thermal way to mount devices, with or without thermal grease, comes up often. Screw torque is critical whatever the interface material is. I attach part of page 668 of 2001 SEDI catalog (also on the website. http://www.fcsi.sedi.com) in appendix I with Torque values, with suggested screw sizes added to the table. SEDI recommends the use of graphite or carbon film under power devices whenever possible.

Soldering the part down is another recommended solution. This will be discussed in detail later.

Flatness

Mating surface flatness needs to be around .001 inch/inch. Recommended finish smoothness (surface finish, specified as RMS roughness in micrometers in the USA), is 16 microinches or better (standard American machining surface is usually 32-64 microinches, so this flatness is an extra cost requirement). While flatness and smoothness of the housing is machined in, flatness of parts should be checked before installing.

Mounting Screw Torque

The biggest cause of thermal problems is over-torqueing the mounting screws. This deforms the mounting flange and lifts the center of the part into the air, sometimes considerably. Thermal grease will not make up for an air gap such as that produced by a warped device flange.

Most SEDI parts are to be torqued at 2.5 Kg-cm (2.2 lb-in). Torque-limiting screwdrivers should be used to prevent over-torque (one vendor of such tools is Mountz, Inc; see http://ns.etorque.com.)

Thermal Grease

SEDI recommends some thermal compounds and limited interface materials. However, any use of such materials is done at the customer's own risk and must be properly evaluated. In spite of this disclaimer customers still want to know how thermal grease and other interface materials will affect SEDI devices if they choose to use such material. Below is information that is intended as a starting point in customer's evaluations of using thermal interface materials to mount devices.

The highest risk in using thermal grease is long term; if the oil in the thermal grease dries out the result is much worse thermal conductivity than if no grease is used. Thermal grease must be investigated for its dry out properties.

Some silver-filled thermal greases claim much better thermal conductivity and electrical conductivity than ceramic filled thermal grease. SEDI has tried silver filled thermal greases, but the pressure induced by the screw clamping forces precipitated the silver into a solid, which then damaged both the device and the housing. The high DC current would also increase silver precipitation. Finally the possible RF eddy currents in the ground plane and at the edge of the device would be expected to produce silver dendrite growth around the part, likely shorting out the device with time. If the grease dries out the unit may be coated with silver particles, which could affect device operation. SEDI DOES NOT RECOMMEND SILVER-FILLED GREASE ON ANY RF PART OR ANY CURRENT CARRYING JOINT.

The next significant risk is that standard ceramic-filled grease is an electrical insulator, which can lead to RF grounding problems (surprisingly for some applications at some frequencies this effect may be small). SEDI has seen fresh ceramic-filled thermal grease cause RF measurement differences due to resultant poor grounding. On a 0.1-3 GHz broadband MMIC, differences were seen around 1.6 GHz and at 2.5 GHz and above with S-parameter data. The greatest difference was actually around 1.6 GHz, where S11 went to a Rh=1 condition with thermal grease but was .4 without it. Such effects are unpredictable, depending on the device dimensions, housing configuration, and surrounding circuit.

If thermal grease is determined to have acceptable RF effects and used, the principle is to use the minimum amount of thermal grease possible. Thermal grease is not a good thermal conductor (around 200 times worse than copper thermal conductivity; see Table I). Anything is better than an air gap (see air, still, in table I). The aim with thermal grease is to fill in air voids between metal-to-metal contacts, not fill large gaps with grease.

Compressible Interface Materials

Copper foil is used as a shim. If it is being used as an interface between incompatible finishes it can be useful. Since it deforms very little, copper adds another layer for no significant gain in thermal interface.

Lead Foil will deform slightly under the screw pressure, but does not melt or flow to fill gaps. It is not as electrically or thermally conductive as Indium, another foil solution. It is completely reworkable as it does not form a solution with gold or nickel. If the problem is a gap it will not solve it. Lead foil can oxidize and lose conductivity.

SEDI recommends as a possible solution carbon film, also called graphite sheet. It is a more compressible interface material than the others mentioned. SEDI uses Panasonic carbon graphite sheet for mounting our devices (currently available from Digikey). Please see http://www.panasonic.com/industrial/components/pdf/pgs_info_0105.pdf for more details. Our recommended sheet is EYGS182310. Recommended thickness is .1mm. Thermal conductivity is about 700W/mK in the x-y direction. In the Z direction it is about 15 W/mK.

Another possible source is Kerafol, in Germany. Keraotherm® - Graphite 90/25. However, Keratherm Thermal conductivity is about 400W/mK. In Z direction it is about 7.5 W/mK. Find information at www.kerafol.de and search for "graphite films." Minimum thickness is .140mm.

Laird Technologies is another source, currently available from Digikey. x-y
thermal conductivity is about 200W/mK, Z direction is 5 W/mK. Min thickness is .125mm.

Also it is important to consider the Coefficient of Thermal Expansion. This characteristic must be evaluated by the end user. Only Panasonic gives this information. And only Panasonic PGS is recommended at this time.

Carbon film has thermal conductivity better than thermal grease or epoxy, with electrical conductivity similar to stainless steel or conductive epoxy. It does add a very small resistive term in the source circuit, which can affect some applications and may require investigation.

Carbon Film has thermal conductivity that is directional, being very good in the horizontal dimensions and not so good in the vertical dimension. Thus the material is an excellent spreader but not so good a conductor. This improves somewhat with the clamping force on the part, but using the minimum thickness possible is important.

Vendors can supply either film or die cut patterns as required. It is soft and easily cut to shape.

**Gap Filler Interface Materials**

For larger parts or to guarantee thermal properties other interface materials can be investigated. These materials are more expensive and can be difficult to apply. The ideal gap filling material should be both thermally and electrically conductive. It must flow to fill the gaps and rough spots, but not sufficiently to cause electrical problems. Currently these come as refloable materials and must be heated to flow before becoming effective.

The only gap filler pad material I am aware of that is both thermally and electrically conductive, plus reworkable as well, is Phase Change Thermal Interface Material (PCTIM). I am aware of 2 sources: AI Technology Cool Pad 8550 (http://www.aitechnology.com) and Loctite Silverstrate (with a .002 inch aluminum substrate providing conductivity) see (www.loctite.com/electronics).

Phase change material flows when heated to 51 or 60 ºC and fills small gaps readily. Minimum thickness is .003 inch (.075mm). The AI technology material has no substrate; the material itself is conductive. The Loctite approach uses non-conductive compounds but the substrate provides conductivity. The presence of non-conductive material makes this more risky. The need to reflow this material at and elevated temperature is a drawback to this approach.

Conductive silver filled epoxy as a film or paste is a good gap filler. But it is very difficult to rework, requiring both heat and mechanical force to separate. It is not as thermally and electrically conductive as solder. Typically it can be cured to a thinner bond line than a PCTIM material.

Indium Foil is a gap filler although since it also has solder properties it is discussed under solder.

**Solder Interface: The Best Gap Filler**

Tin Based and Tin-Lead Solder

Soldering the part in place with tin based solder such as lead-tinSn63/Pb37 or similar solder (example is Sn96/Ag4/Cu) is a superior solution to the thermal problem, and fully electrically conductive as well. Soldering is a recommended SEDI solution. It requires heating the mounting surface above solder melt temperatures (186ºC for Sn63 Eutectic solder). Solder flux is necessary and very difficult to clean out of the part. Rework is difficult as the solder must be re-melted to get the part out. SEDI outlines the method and gives caution in section B2 in Appendix I. Thermal coefficient of expansion mismatches can cause problems in long term use and should be thoroughly investigated before using this solution.

Lead free solder must be investigated by the user. SEDI has no recommendations for that process, though many customers have solved the problem to become RoHS compliant.

**Indium Solder**

Pure Indium foil is technically a solder, though it behaves more like a gap filler. Indium is a solder that flows at a lower temperature (around 156ºC for pure Indium). Indium flows when heated past its melting point to fill gaps. A drawback is that it tends to form alloys with the gold on the back of the part, so is not completely removable from the part after rework. Since Indium is very soft the part is still easily removable from the installation even without reheating the part. Indium can be obtained in any thickness from .001 inch (.025 mm) and up. It is available from Indium Corp of America http://www.indium.com or AIM Technology http://www.aimsolder.com/ among others.

**Thermal Conductivity**

Some thermal conductivities of materials used in power amplifier manufacture are listed in table I. Note that these are approximations only and manufacturers should be consulted to get the correct data for the materials use.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity W/(cm*ºC)</th>
<th>Reworkability when material used to install device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>4.0</td>
<td>Good</td>
</tr>
<tr>
<td>Aluminum</td>
<td>1.7</td>
<td>Poor</td>
</tr>
<tr>
<td>Copper Tungsten (i.e. Thermkon)</td>
<td>1.67-1.9 depending on formulation</td>
<td></td>
</tr>
<tr>
<td>Kovar</td>
<td>0.16</td>
<td>Excellent</td>
</tr>
<tr>
<td>FR-4 PCB</td>
<td>0.003</td>
<td>Excellent</td>
</tr>
<tr>
<td>Teflon-Fiberglass PCB</td>
<td>0.0026</td>
<td>Excellent</td>
</tr>
<tr>
<td>Indium</td>
<td>0.83</td>
<td>Good</td>
</tr>
<tr>
<td>Carbon Film, PGS</td>
<td>0.15 (?) z(x-y)</td>
<td>Excellent</td>
</tr>
<tr>
<td>Cool Pad 8550</td>
<td>0.09</td>
<td>Good</td>
</tr>
<tr>
<td>Solder (Pb-Sn)</td>
<td>0.51</td>
<td>Poor</td>
</tr>
<tr>
<td>Lead</td>
<td>0.34</td>
<td>Excellent (foil under part)</td>
</tr>
<tr>
<td>Thermal Grease</td>
<td>0.016</td>
<td>Excellent</td>
</tr>
<tr>
<td>Silver-Filled Epoxy</td>
<td>0.016</td>
<td>Poor</td>
</tr>
<tr>
<td>Loctite Silverstrate</td>
<td>0.077</td>
<td>Good</td>
</tr>
<tr>
<td>Air, still</td>
<td>0.000004</td>
<td></td>
</tr>
</tbody>
</table>

Source is Agilent’s Appcad program (manufacturers for graphite film, Indium, Thermkon, and Cool Pad).
Appendix I: Excerpt from SEDI website (modified slightly to show typical screw sizes used with packages)

B. CIRCUIT INSTALLATION

1) Screw Mounting
The flange may be attached using screws. Recommended torque and screw size is given in the table below.

<table>
<thead>
<tr>
<th>Package</th>
<th>Slot, Hole nom dia mm(inch)</th>
<th>Screw Size metric(SAE)</th>
<th>Recommended torque</th>
<th>Maximum torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB, VT</td>
<td>3.2 mm</td>
<td>M3 (#4-40)</td>
<td>4.5 Kg-cm(3.9 lb-in)</td>
<td>5.0 Kg-cm (4.3 lb-in)</td>
</tr>
<tr>
<td>IK, IL, IP, IQ, IU, MK, VF*</td>
<td>2.6 mm</td>
<td>M2.5 (#2-56) M2.2 (#2-56)</td>
<td>2.5 Kg-cm(2.2 lb-in)</td>
<td>3.0 Kg-cm (2.6 lb-in)</td>
</tr>
<tr>
<td>GJ, IA, ME, MG, MH **</td>
<td>2.5 mm</td>
<td>M2.0 OK</td>
<td>2.5 Kg-cm(2.2 lb-in)</td>
<td>3.0 Kg-cm (2.6 lb-in)</td>
</tr>
<tr>
<td>WF, WG</td>
<td>1.6 mm</td>
<td>M1.4 (#0-80)</td>
<td>0.8 Kg-cm(0.7 lb-in)</td>
<td>1.5 Kg-cm (1.3 lb-in)</td>
</tr>
</tbody>
</table>

Notes: * VF is 2.4mm nominal. M2.2 is not common, M2.0 may be more available. ** #1-72 will be close on MH package, 0-80 may be safer.

2) Solder Mounting
The recommended soldering procedure is as follows:

a. The amplifier case or heat sink should be made of copper or aluminum and its surface nickel or tin plated.
b. Prior to soldering, the FET and the amplifier case should be cleaned using acetone followed by an isopropyl alcohol rinse.
c. Recommended solder is Sn62 Tin-Lead solder (Tin 62%).
d. Recommended soldering temperature is 220~230 °C for 10~20 seconds with appropriate pre-heating. Do not exceed 260 °C for 20 sec.
e. During reflow, pressure on the FET is recommended to minimize solder thickness. The gate terminal and drain terminal should be electrically shorted to the source to prevent ESD problems.
f. Type R or RMA flux is recommended. After soldering, the flux residue should be removed by appropriate cleaning methods.

CAUTION: Silicone based heat sink compounds should not be used. They cause poor grounding of the source flange, contamination and long term degradation of thermal resistance between the FET package and heat sink.