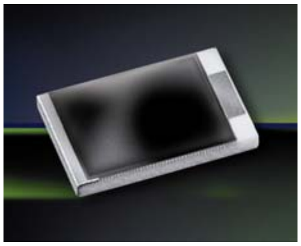


CVD Ultra High Power Resistors and Terminations

Application Note 007

General Description:

There are many applications in RF design where it is necessary to absorb large amounts of RF power. To absorb large amounts of power, resistors and terminations must be constructed on materials that have a high coefficient of thermal conductivity. Commonly used substrates for high power resistors and terminations which have high coefficients of thermal conductivity are Beryllia, Aluminum Nitride, and to a lesser extent, Boron Nitride and Silicon Carbide. While these materials are known for their superior thermal properties, none of them come even close to matching the thermal conductivity of CVD. For example, while Beryllia and Aluminum Nitride have thermal conductivities of 2.5 and 1.7 watts/cm/°C respectively, CVD offers 10 to 18 watts/cm/°C. This is about 3 to 4 times that of copper. This huge increase in thermal conductivity enables RF Component Designers to produce RF components such as resistors, terminations, attenuators, power dividers, and couplers that are smaller, dissipate more power, and can operate at higher frequencies. These devices typically can provide superior RF performance for any specified power level up to 20 GHz and beyond.

But the outstanding thermal properties of CVD are only part of it's allure. CVD is also an incredibly stable material since it is essentially chemically inert at temperatures below 300°C. In air, CVD is unconditionally stable at temperatures up to 600°C while in a vacuum or reducing atmosphere it is unaffected by temperatures exceeding 1,200°C . This makes it unquestionably the material of choice for high reliability and space applications.

Mounting Instructions:

CVD components manufactured by EMC Technology, Inc. are designed to be mounted using conventional mounting techniques. The backside ground plane of the device is sputter coated with a solderable metal and finished with about 150 nm (5.9 micro-inches) of pure gold.

The easiest and preferred method of attaching the device to a heat sink is by soldering the unit with Sn96 solder (96.5% Tin / 3.5% Silver). This is a eutectic alloy that melts at 221°C (430°F). It is permissible to bring the CVD device momentarily to 300°C for 10 seconds or less to ensure adequate wetting of the surface. The heat sink should be constructed of a high thermal conductivity material such as copper. Aluminum heat sinks can also be used, but it should be noted that the thermal conductivity of aluminum is approximately one-half that of copper. In situations where weight is a concern, an acceptable compromise would be to mount the CVD device on a copper heat spreader which is in turn attached to the aluminum heat sink.

The thermal resistance across the attachment interface has a significant affect on the performance of the device. For instance, at 50 watts, the temperature differential across a Sn96 solder interface that is only 0.002 inches thick would be about 39°C for a device measuring 50 mils square. This is greater than the temperature differential across the entire CVD substrate at the same power level. Therefore, it is important to maintain the thickness of the solder to between 1 and 3 mils. For every 1 mil increase in the thickness of the solder, the temperature of the device will increase by approximately 20°C therefore reducing the component's ability to absorb power.

When soldering the CVD device to the heat sink, solder voids must be reduced to the lowest minimum area or eliminated if possible . Even small solder voids can substantially reduce the efficiency of the thermal interface resulting in devices that run considerably hotter than necessary. The integrity of the soldered connection can easily be determined by measuring the temperature of the top surface of the device and comparing it with calculated data. For example, for a 50 mil square resistor running at 50 watts, the top surface of the device would normally measure about 60°C to 70°C higher than the heat sink temperature. If the device temperature is substantially higher than this, the solder interface is suspect and should be evaluated for voids or other discontinuities.

Other silver-tin solder compositions such as Sn95 and Sn94 and many Lead-Free formulations can also be used with no degrading of performance. However, when using Tin-Lead solders such as Sn63 which have a melting temperature of 183°C, the maximum permissible input power or the heat sink temperature should be reduced to prevent the solder from melting. For example, a part rated at 50 watts on a 100°C heat sink should be derated by about 30% to 35 watts maximum when attached with Sn63 solder.

Epoxies can provide a very high-strength mechanical bond, however, they should be used with caution due to their generally poor thermal performance. When epoxies are used, consult with the manufacturer of the epoxy for the coefficient of thermal conductivity. If necessary, de-rate the maximum power rating of the CVD device accordingly.

As a rule of thumb, the temperature differential across the attachment material should not exceed 40°C at the maximum rated power of the device. It can be calculated by the following expression:

$$\Delta T = \frac{P \times t}{K \times A}$$

where: ΔT = Temperature Differential in °C

t = thickness of the interface in cm

P = Power in watts

A = Area in Square-cm

K = Thermal Conductivity in Watts/cm/°C

Typical values for the Coefficient of Thermal Conductivity of commonly used attachment materials are listed in the table below:

Commonly Used Attachment Materials

Material	Composition	Thermal Conductivity (Watts/cm/°C)	Melting Temperature (°C)
Gold-Tin Solder	80% Gold / 20% Tin	0.58	280
Lead-Free Solder	99.3% Tin – 0.7% Copper	Note (1)	227
Lead-Free Solder	96.5% Tin / 3.5% Silver	0.33	221
Lead-Free Solder	96.5% Tin / 3% Silver / 0.5% Copper	Note (1)	217 - 220
Sn63 Solder	63% Tin / 37% Lead	0.49	183
Conductive Epoxy	Silver Filled	0.01 to 0.02	N/A

Note: (1) Data not available at this writing.

Input Connections:

The top side connections are finished with about 1 micron (39.4 micro-inches) of gold and are designed to be wire bonded using conventional ultrasonic and thermo-compression wedge bonding techniques. The attachment wires can be either 1 mil diameter gold wire or 1x3 mil gold ribbon. Multiple wires should be used to reduce the input inductance and to increase the current capability of the connection.

For applications which require soldering of the input connection, contact our sales department for contact metallization types that would be compatible with the type of solder you are using.

Typical RF Performance:

The RF performance of 4 different parts will be presented here. These are as follows:

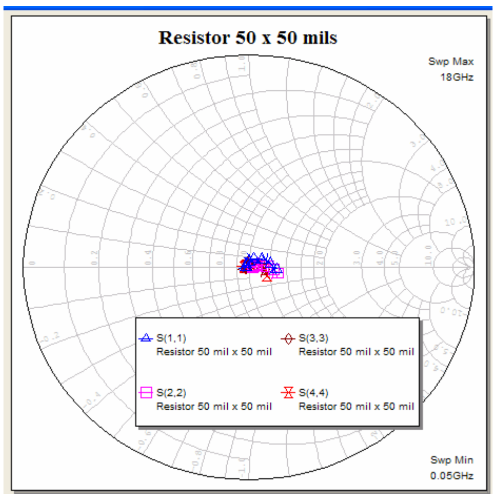
(1) 50 watt, 50 Ohm Resistor measuring 50x50 mils (1.27mm sq.)

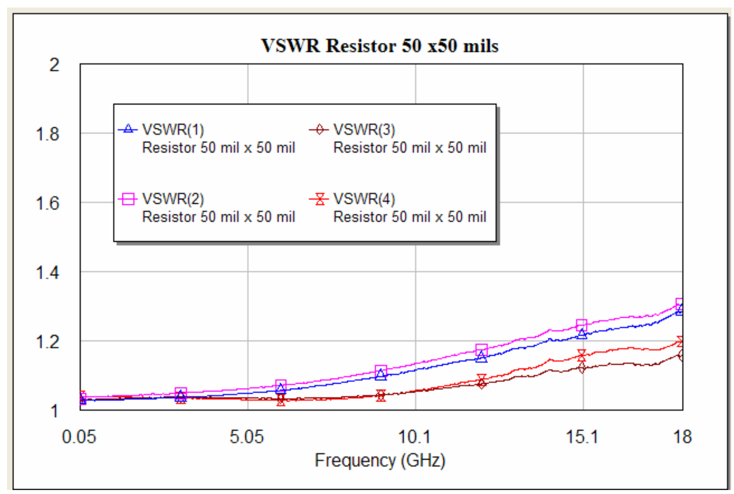
(2) 50 watt, 50 Ohm Termination measuring 50x50 mils (1.27mm sq.)

(3) 150 watt, 50 Ohm Resistor measuring 100x100 mils (2.54 mm sq.)

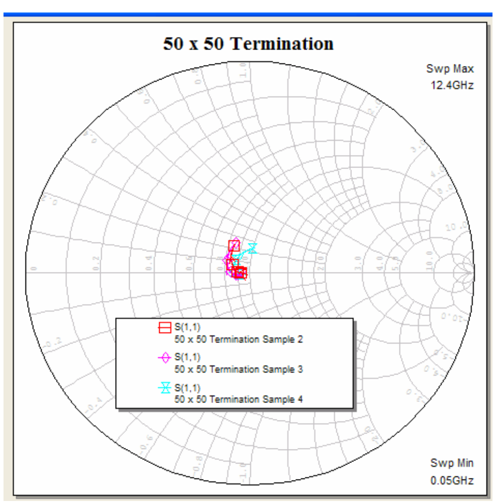
(4) 150 watt, 50 Ohm Termination measuring 125 x100 mils (3.18mm x 2.54mm)

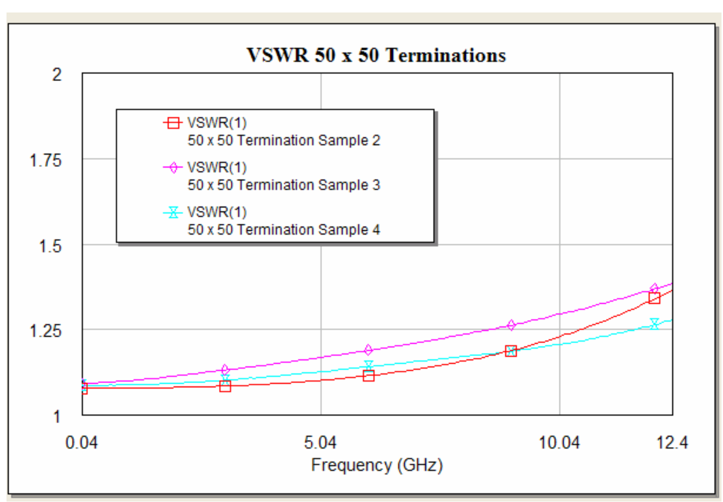
50 watt, 50 Ohm Resistor



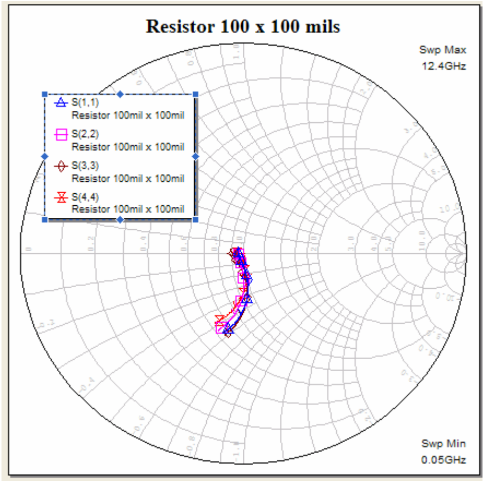


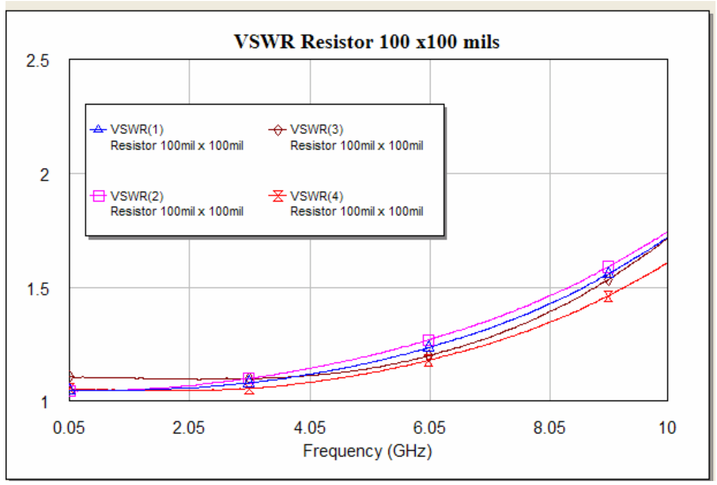
50 watt, 50 Ohm Termination





150 watt, 50 Ohm Resistor





150 watt, 50 Ohm Termination