Low Rth Device Packaging for High Power RF LDMOS Transistors for Cellular and 3G Base Station Use

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Abstract – Significant performance improvement of RF LDMOS high power devices can be obtained by implementing new low Rth packaging technology and manufacturing techniques for RF high power LDMOS power transistors. This markedly improved performance can be achieved while still maintaining package physical characteristics and cost targets.

INTRODUCTION

Motorola's RF and DSP Infrastructure Division is a world leader in providing RF power amplifier component solutions for the wireless infrastructure market. Its leadership position is not by accident but a result of a directed pursuit to provide the best and most cost effective RF PA solutions to its customers. These solutions include a focus on consistency, reliability, overall performance and ease of use. Furthermore, Motorola has a very rich heritage in servicing the RF power device market for over forty years.

THERMAL MANAGEMENT

Thermal management is an integral part of this pursuit of product performance excellence. Motorola's approach to thermal management is a comprehensive, integrated one from device layout to package material selection, manufacturing process design, and mounting application notes. Creating lower thermal resistance for our RF PA products begins with having a "big picture" view of the technical challenges, understanding the contributions of various constituents (device layout, package material issues, manufacturing processes, and wireless systems applications) which contribute to the total thermal resistance of the end product.

Effective heat spreading in the device has long been recognized as an important factor in creating cooler operating RF PA devices. Through rigorous computer simulations, supported by test data collected on device test structures, we are able to understand the relationships between device layouts and the device contributed thermal resistance. Thermally optimized device layouts are selected which lower overall device thermal resistance, while providing industry leading RF electrical performance.

Conduction-contributed thermal resistance due to die thickness has been well researched. Over the past several years we have reduced Si thickness by nearly a factor of three in our RF PA's and have been shipping volume products with 4 mil thick Si. In addition, we have taken thin die manufacturing to 1 mil for our GaAs RF PA products.

PACKAGE MATERIAL TECHNOLOGY

Package material contributions to overall device thermal resistance has been evaluated extensively and the role of package flange materials and manufacturing processes is well understood. WCu flanges of increasing thermal conductivity (Kth) have been introduced into our products over the past five years. Working with our material suppliers, the Kth of our WCu flanges in our RF PA products has been increased by nearly 35% over this same time period [1].

Next generation products, utilizing Cu laminate flanges with even higher Kth, compared to WCu, have been recently sampled. Such Cu laminate flanges, in concert with a well characterized and highly thermally conductive AuSi die attach, have resulted in thermal resistance (Rth or θjc) reductions of over 20% compared to conventional high thermal conductivity WCu flanges. A comparison of WCu and Cu laminate thermal resistance is shown in Figure 1.

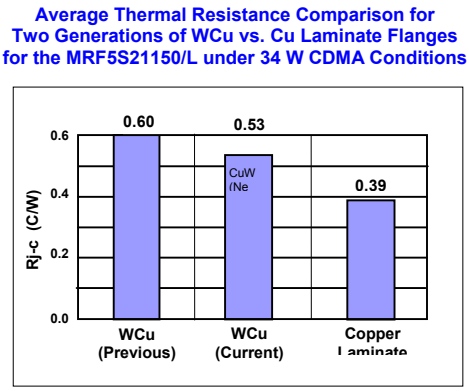

Figure 1. Comparison of WCu and Cu laminate thermal resistance

With these new low Rth Cu laminate systems, equivalent electrical performance is achieved, along with a higher P1dB (1 dB compression point) due to the above-mentioned improved thermal characteristics.

An example of a device in Motorola's new Cu laminate low Rth packaging is shown in Figure 2.

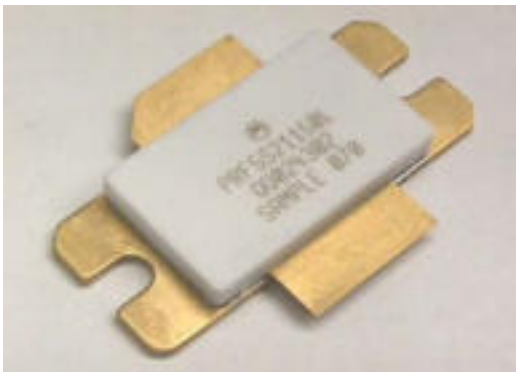

Figure 2. PRF5S21150L 150 W Device in a Cu Laminate Low Rth Package

To help facilitate customer ease of use and to maintain industry leading RF performance, Cu laminate development efforts have focused on utilizing industry standard metal-ceramic package outlines, achieving equivalent or better reliability, and achieving costs comparable to standard packages.

These new low Rth devices will also have a new solderable lead finish. Thinner gold will provide an opportunity to eliminate costly tin dipping operations intended to remove excess gold from the leads prior to equipment assembly. This program of comprehensive thermal management will be complemented with extensive application notes on package mounting and power dissipation issues.

Figures 3 through 6 show the thermal performance of the MRF5S21150/L device in standard WCu and Cu laminate low Rth packaging. The Cu laminate based low Rth device has nearly 29% reduction in θjc and a more uniform temperature distribution across the die compared to the standard WCu based device. The improved thermal performance allows the new low Rth version of the device to have 10 to 15% higher P1dB compared to the standard device.

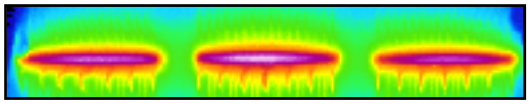

Figure 3. IR temperature profile of the MRF5S21150 device at 34 W CDMA output power at 70° C. case temperature in a standard WCu package. Peak die temperature: 124°C with a θjc of 0.52° C/W.

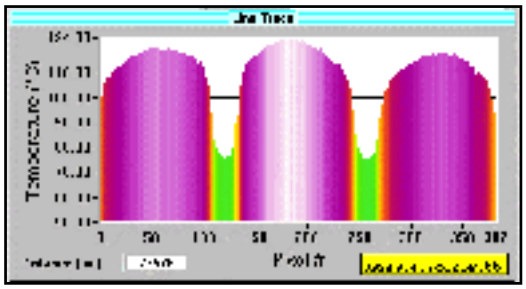

Figure 4. Line profile of the temperature of the die of the MRF5S21150 in the standard WCu package at the operating conditions above.

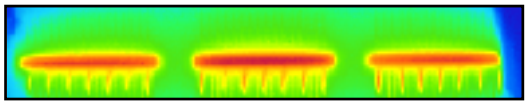

Figure 5. IR temperature profile of the PRF5S21150L device at 34 W CDMA output power at 70° C. case temperature in a Cu laminate, low Rth package. Peak die temperature: 107°C with a θjc of 0.37° C/W.

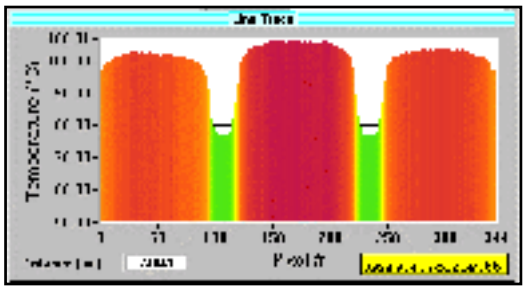

Figure 6. Line profile of the temperature of the die of the PRF5S21150L in the Cu laminate, low Rth package at the operating conditions above.

Working with customers and understanding their applications is important in providing industry-leading solutions. Controlling the flange flatness of our RF PA products to a tight distribution is another important factor and has enabled our customers to reduce the header-to-heatsink interfacial thermal resistance to a small and consistent value.

Finally, Motorola has developed the industry's leading edge thermal measurement methodology [2] and we have continuously shared this methodology with our customers [3]. We have solicited their input, and incorporated their needs into our products. We rigorously scrutinize our thermal data and our customers have shown a high level of confidence in that data.

Commercial introduction of the new low Rth device portfolio will focus on die technologies from our current HV5 and the new HV6 families of LDMOS products.

CONCLUSION

Thermal management in RF PA devices is a complex issue, requiring a comprehensive approach in order to provide solutions with industry leading performance. Device design and layout, package material selection, manufacturing process technology, and end application design are all important factors in achieving an optimized thermal solution. Motorola's comprehensive approach to RF PA thermal management incorporates all these important factors into optimized products for wireless infrastructure systems.

REFERENCES

[1] M. Mahalingam, "Material Requirements in Wireless Communication", *General Session - Materials in the Future, PM^{2}TEC, World Congress, Metal Powder Industries Federation, June 20, 2002*

[2] M. Mahalingam and E. Mares, "Infrared Temperature Characterization of High Power RF Devices", *Proceedings of IEEE MTT-S International Microwave Symposium, May 2001.*

[3] M. Mahalingam and E. Mares, "Thermal Measurement Methodology of RF Power Amplifiers", *Motorola Application Note, June 2002.*

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