Thermal solutions for MMIC line amplifiers in CATV systems

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Introduction

CATV systems require amplifiers with high linearity and high output power to transmit video and data throughout the network. As CATV systems have evolved to incorporate more channels and provide higher data rates, the operating frequency, power levels, and distortion levels have become even more challenging. The most challenging component in the system amplifier is a power doubler line amplifier because it operates at 24 Volts and can dissipate over 10 Watts to achieve the needed performance. Effectively removing the heat generated by these components is critical to ensure optimum performance, long operating lifetimes and high reliability.

A common way to maintain low component operating temperatures is to use a line amplifier hybrid module with a built-in heat sink (Figure 1). This ensures low temperatures because the amplifier components are connected directly to the large aluminum block which is contacted to the system amplifier housing or chassis. This provides a complete solution of electrical performance with thermal performance in a convenient package, and is commonly used in many systems today. The limitations of this approach are the cost, size, and manufacturing complexity.

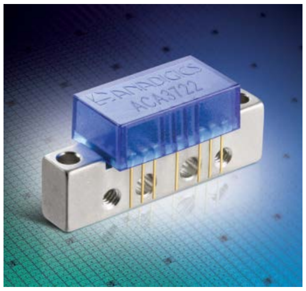

Figure 1: Line amplifier hybrid module

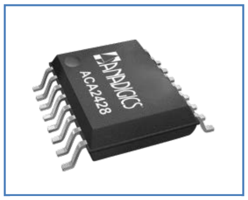

Figure 2: MMIC line amplifier

In order to overcome those limitations, we have developed an easy-to-use, custom solution to adapt the system amplifier chassis, and PCB for a MMIC power doubler line amplifier (Figure 2). The MMIC incorporates the critical components of the amplifier into a compact package that provides low cost, smaller board size and greater manufacturing flexibility. The MMIC is designed with a custom leaded package that includes a heat-slug in order to be able to obtain this performance.

This paper presents solutions that allow MMIC line amplifiers to be used in systems that are currently using line amplifier hybrid modules. We will demonstrate that we can maintain an MMIC operating temperature at or below that of a hybrid module in order to maintain performance and ensure high reliability.

MMIC heat sink solutions

Using MMIC line amplifier power doublers on a PCB requires a heat sink optimized to dissipate at least 10 Watts of power directly beneath the MMIC. There are two approaches to provide this heat sink: 1) directly built into the chassis or, 2) an adapter block. We present three methods below to adapt the chassis that provide an excellent thermal heat sink for the MMIC, are easy to use and allow for low system cost. The methods combine different types of heat sinks (flat or with a pedestal), different ways to attach the PCB to the heat sink block, and different ways to contact the MMIC to the heat sink. A summary of the three methods is shown in Table 1.

Table 1: Summary of heat sink methods

Method	PCB Attachment	MMIC contact
1	Screwed to flat block	Via holes
2	Soldered to flat block	Via holes
3	Screwed to block with pedestal	Direct to block
Reference	Hybrid attached directly to chassis	To hybrid block

Method 1

The MMIC is attached to the PCB using a standard reflow solder attach process and the PCB is designed with vias that provide heat flow through the board. The 32 vias have a 0.89 mm diameter and are in a 4x8 rectangular pattern beneath the custom MMIC heat slug. A flat block is inserted between the PCB and chassis to provide thermal heat sink. Thermal grease is applied between the PCB and block and screws are used to provide additional thermal contact onto a flat block beneath the PCB. Figure 3 shows details of Method 1, including a cutaway view of the die and PCB, as well as the thermal model of the system. The thermal model shows all of the elements that contribute to the thermal resistance in the system.

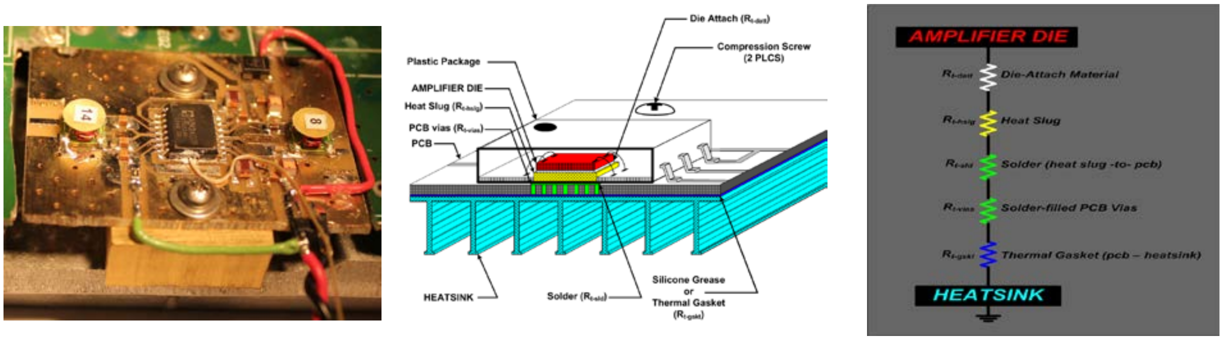

Figure 3: Details of Method 1

Method 2

The MMIC is attached to the PCB using a standard reflow solder attach process and the PCB is designed with vias that provide heat flow through the board. The 32 vias have a 0.89 mm diameter and are in a 4x8 rectangular pattern beneath the custom MMIC heat slug. A flat block is inserted between the PCB and chassis to provide thermal heat sink. The thermal grease is replaced with solder between the PCB and block and screws are again used to provide additional thermal contact onto a flat block beneath the PCB. Figure 4 shows details of Method 2, including a cutaway view of the die and PCB, as well as the thermal model of the system. The thermal model is similar to method 1, with a similar number of components. The overall thermal resistance is lower because the solder that replaces the thermal gasket (grease) has lower thermal resistance.

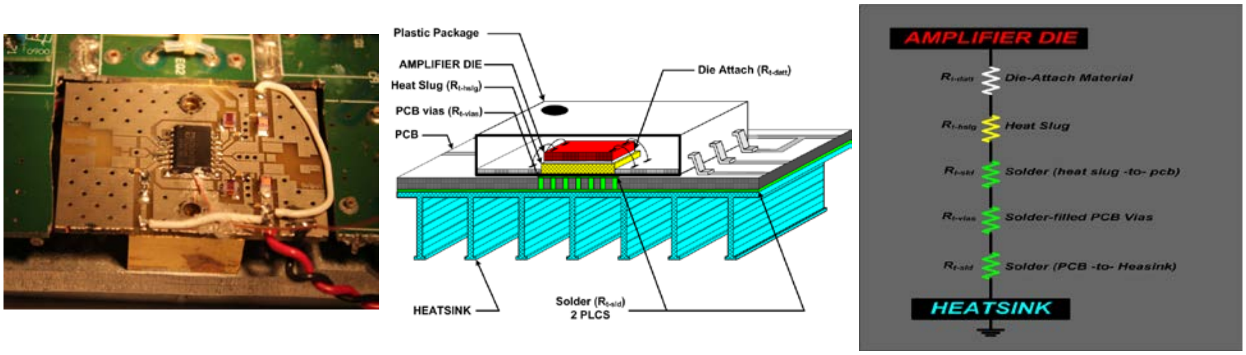

Figure 4: Details of Method 2

Method 3

The MMIC is attached directly to the heat sink through a hole in the PCB. The heat sink has a pedestal that allows for the custom MMIC heat slug to rest flat on the heat sink pedestal with thermal grease providing the thermal contact to the heat sink. Figure 5 shows details of Method 3, including a cutaway view of the die and PCB, as well as the thermal model of the system. This method results in the lowest thermal resistance, as shown in the thermal model, with the fewest thermal resistance components, each with a low value.

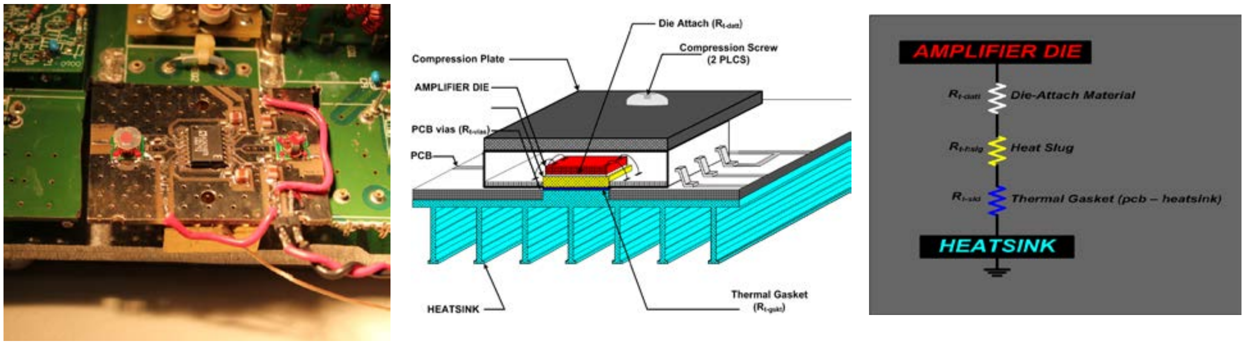

Figure 5: Details of Method 3

Results

Temperature measurements were conducted with an ANADIGICS ACA2407 MMIC line amplifier attached using each of these methods. The MMICs are operated at 24 Volts and 430 mA, with a total power dissipation of 10.32 Watts, on a standard 62 mil thick PCB. The temperature rise is measured near Pin 1 of the MMIC with DC power applied and no RF power. Figure 6 shows the results measured for each of the 3 methods along with the temperature of a hybrid module with similar power dissipation, measured in a similar location. Measurements indicate that all three methods achieve excellent thermal results. Both method 2 and method 3 obtain results similar to that of the reference hybrid module, with method 3 achieving much lower temperature (8.3 °C lower) than the hybrid module.

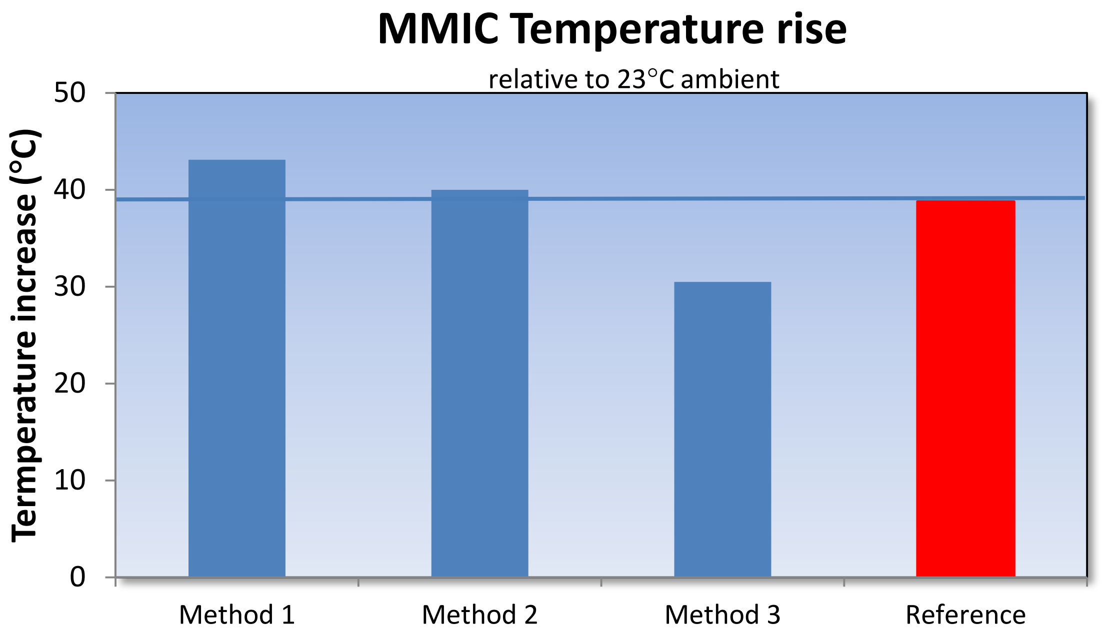

Figure 6: Results of MMIC heat sink tests

Summary

Method 3, with the die attached directly through the PCB with the PCB screwed to the pedestal heat sink, provides the lowest temperature MMIC and lower temperature than a hybrid module. Table 2 summarizes the thermal performance of each method compared with the reference hybrid module.

Table 2: Summary of results

Method	Temperature Increase (°C)	Thermal Performance	Manufacturability	Cost
1	43.1	Good	Easy	Low cost
2	40	Better	Difficult	Moderate
3	30.5	Best	Easy	Low cost
Reference	38.8	Better	Easy	High

In addition to providing excellent thermal performance, method 3 is also an easy solution to implement in a manufacturing environment and provides the lowest cost solution. Each method provides very good thermal performance and a high reliability solution that allow flexibility in the design and manufacturing of system amplifiers. Each of these methods of attaching the MMIC to the heat sink is also applicable if the heat sink is cast directly into the chassis.

Additional improvement in thermal performance can be achieved with a custom reinforcement bar that clamps the MMIC to the heat sink and provides better thermal contact. This approach is illustrated in Figure 7 with a reinforcement bar is optimized to the size of the MMIC, PCB layout and heat sink solution.

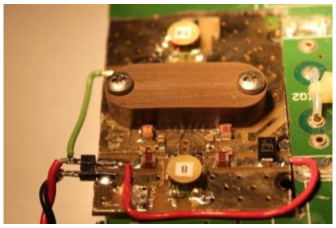

Figure 7: MMIC with reinforcement bar

Conclusion

We have presented manufacturing solutions to implement line amplifier power doubler MMICs with low operating temperature and high reliability. These solutions allow for system amplifiers to accommodate MMIC amplifiers with either a built-in heat sink or adapters and provide for a low cost alternative to hybrid module line amplifiers that are easy to manufacture.