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LOW COST MMIC INSERTION USING THICK FILM PROCESSING

A. Bettner, B. Hundley, P. Salisbury

Varian Associates, Solid State Microwave Division
3251 Olcott Street
Santa Clara, CA 95054-3095

ABSTRACT

Multilayer thick-film circuits have been developed to provide single supply biasing and reactive matching to MMIC chips. The result is a method of achieving large amounts of gain at extremely low cost.

INTRODUCTION

Newer and better MMIC chips are becoming available with improving technology. Higher gains, smaller chip size, and other features are making the MMIC an attractive alternative to the standard hybrid MIC.

Unfortunately, MMIC chips are small, fragile, and do not interface well with standard SMA type connectors. They are difficult to test or use effectively unless mounted on some type of hybrid MIC structure. In most cases, the MMIC must be mounted in a manner similar to an ordinary MESFET, i.e., in several brazing and die attaching steps.

In this paper, a method will be described which minimizes the cost and labor involved in inserting the MMIC. It will be shown that a multilayer thick-film circuit can provide an effective way to support, bias, and reactively match the MMIC to a given band.

OVERVIEW

Thick-film circuits are not new. They have been used for many years in hybrid circuit manufacturing below 1 GHz. Advantages can be shown to be:

1. Low Cost - wirescreen printing techniques (direct "printing" of circuit patterns)
2. Durability - circuits are fired at temperatures greater than 800°C, causing direct fusion of glass frit with the base (alumina) substrate
3. Multilayer - resistors, capacitors, and multiple layer interconnects can be readily formed
4. Via holes - can be made repeatably and reliably at little added cost

The primary disadvantage for thick-film circuits is their relatively large size, i.e., line definition, line gaps. In the normal manufacturing process, lines or spaces under .005 inches are not readily producible. This means that Lange couplers, the key ingredient in balanced amplifiers, are not readily producible. In addition, edge coupled filters and other similar structures cannot be fabricated. However, elements such as common transmission lines (Z_0 as high as 100 ohms), shorted and open stubs, and even spiral inductors can be realized. It will be shown that using these elements, plus the necessary resistors and capacitors (to properly bias the MMIC) will provide an ideal structure for inserting the MMIC.

BIAS CIRCUIT DESIGN

Because of the source vias present on the MMIC of interest, some method of self-biasing was desired to avoid the need for a separate negative gate supply. Self-biasing has been achieved by mounting the entire MMIC on a thick-film capacitor (grounded through substrate vias), which in turn is shunted by a resistor which provides gate to source bias. Schematically, this is represented in Figure 1.

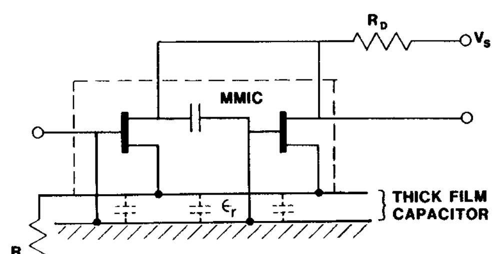

FIGURE 1
BIASING CIRCUIT CONFIGURATION

Grounds to the backside of the capacitor, as was indicated, are provided through via holes which connect the backside capacitor metal to ground. The source resistor (R_S) has been printed between the capacitor top side and a separate via using the thick-film process. A drain resistor (R_D) has also been provided for power adjustment, if desired.

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MATCHING CIRCUIT

In this application, the goal was to maximize gain in the 15 to 17 GHz band. To do this, reactive matching would be used. Developing the matching circuit was done by examining the MMIC S parameters and choosing an appropriate topology to match the input and output impedances. For both the input and output, a series transmission line/open stub topology was chosen. To refine the match, Super Compact (TM) optimization was used. Results predicted a return loss of better than -10 dB over the 15 to 17 GHz band. Matched gain was predicted to be 13.5 ±1 dB. The final topology is shown in Figure 2.

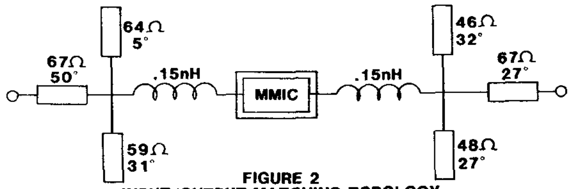

FIGURE 2
INPUT/OUTPUT MATCHING TOPOLOGY

Following the optimization, a layout was generated for a 20 mil alumina (96%) substrate. Because of the glass (SiO_2) content in this material, a slightly lower dielectric constant (er=9.5 vs. the usual 9.8) must be used.

FABRICATION

Once the layout was established, the artworks for the various necessary layers (metal, dielectric, and resistors) were generated. This was done using an in-house CAD layout system. These patterns were then sent to the thick-film vendor where they were reduced, stepped and repeated, and used to make the screens required in the printing process.

Two-inch by two-inch substrates were used for the first prototype circuits. This produced thirty-six circuits per substrate using step and repeat. For production quantities, a three-inch substrate would reduce costs even further. A total of seven layers were required to realize the circuit. These included

1. Backside metal
2. Vias and frontside base metal (including RF transmission lines)
3. First dielectric (capacitors)
4. First metal (bias line capacitors, DC crossover metal)
5. Second dielectric (DC crossover isolation layer)
6. Second metal (source capacitor top metal)
7. Resistors

A cross sectional view of these layers is shown in Figure 3.

Following thick-film processing (screenprinting and firing), the circuits were laser scribed, DC probed, and checked for proper capacitance values. Circuits not meeting minimum criteria were automatically marked by the probing machine.

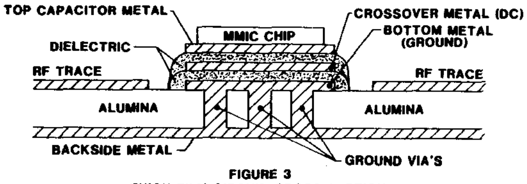

FIGURE 3
THICK FILM CIRCUIT-CROSS SECTION

ASSEMBLY AND TESTING

Before assembling, the processed circuits were retested in-house to confirm proper DC specifications and capacitance values. They were then brazed to a test carrier for MMIC mounting and assembly. The MMIC chip was mounted using conductive silver epoxy and then wirebonded to the appropriate DC and RF traces of the thick-film circuit. (See photo, Figure 4)

Testing was done using a conventional module test fixture where measurements of gain, VSWR, and power could be readily accomplished.

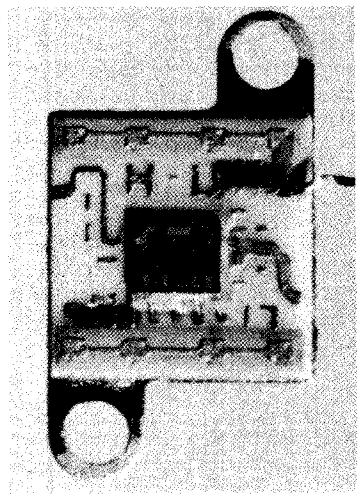

FIGURE 4

THICK-FILM MODULE ASSEMBLY

PERFORMANCE RESULTS

RF tests indicate that the thick-film processes (capacitors included) are fully functional at the frequencies being considered (up to 19 GHz). No resonances were seen, and gain flatness was well within acceptable limits. Figure 5 shows the swept results for gain and return loss. Power (P1dB) was measured to be 15 ±2 dB over the 6 to 18 GHz band. In the band of specific interest (15 to 17 GHz) gain flatness was better than ±.2 dB; return loss was less than -11 dB at the input, less than -12 at the output.

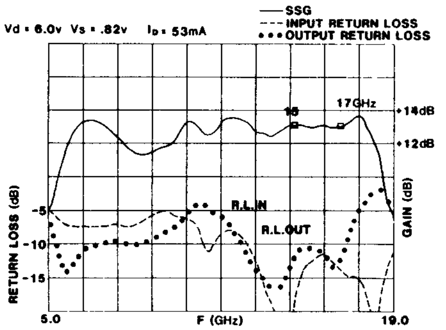

FIGURE 5 TEST RESULTS - THICK FILM MMIC MODULE

OTHER CIRCUITS BEING DEVELOPED

In addition to the thick-film circuit just described, a number of other circuits are being studied in thick-film form. These include the following:

1. Spiral Inductors
2. Power Splitters
3. Feedback Amplifiers
4. DC Circuits (regulators) and other low frequency applications

Data on spiral inductors developed using the thick-film process shows some definite promise. A successful prototype circuit has been evaluated in the 2 to 6 GHz band and appears useful at greater than octave bandwidths. Data has also been taken on a power splitter designed for the 2 to 8 GHz band. Results were equal to or better than a thin-film equivalent which was also tested. A low cost feedback amplifier using these components is currently being studied. Although complete data is yet to be obtained, it appears as though these circuits have definite potential in reducing the cost of MIC amplifiers.

CONCLUSION

A technique for biasing and matching a broadband MMIC using thick-film technology has been presented. This technique allows a dramatic reduction in components and assembly time per module. Using the thick-film technique can potentially reduce the assembly operation to little more than a simple epoxy die attach step followed by the wire-bonding of the MMIC to the thick-film circuit. This concept can be expected to find application in a variety of systems requiring high gain, low cost microwave amplification.

REFERENCES

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2. A. Pavio, L. Cook, "A Comparison of Thin Film Ku Band Amplifiers," IEEE Microwave and Millimeter-Wave Monolithic Circuits Symposium Digest Papers, 1986, pp. 431-432.