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LOW COST TO PACKAGES FOR HIGH SPEED/MICROWAVE APPLICATIONS

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ABSTRACT

A set of low cost, microwave quality packages has been developed for use with both monolithic and hybrid integrated circuits. The packages are modeled after the common TO-style packages, thus allowing the use of an established, cost effective manufacturing base. They are plug-in packages, with pins on 0.100 inch spacings for easy insertion at higher levels. Test results of the TO-8 style package show better than 20 dB return loss through 15 GHz. Isolation between adjacent ports is greater than 50 dB. With package size varying from the small 0.300 inch diameter TO-5 can to the 1.000 inch diameter TO-3 can, applications requiring one GaAs chip, several cascaded chips, or an entire hybrid substrate can be accommodated. The low cost, high performance attributes of these packages make them ideal for high speed, high frequency subsystems.

INTRODUCTION

An essential element to any microwave system is the method in which it is packaged. If not properly designed, the package can become a limiting factor to size, weight and especially performance. When microwave packaging is considered, it often represents a significant contribution to total cost. Although this problem has long been recognized, with the advent of monolithic microwave integrated circuits (MMICs) the necessity of a packaging system which addresses these issues has become a major objective. Previous efforts in this packaging thrust have been the development of WAFFLELINE(1), a unique, high density integration technique, and microwave chip carriers specifically designed for MMICs (2), (3), (4). Our most recent development in this endeavor is low cost, microwave quality TO packages for use with hybrid or monolithic circuits.

TO style packages are a common component in many RF systems which operate at frequencies less than 1 GHz. They represent an established technology, with package specifications which have been standardized to yield low cost, "plug-in" elements. As such, it is desirable to extend this packaging concept and its advantages to high frequency applications. In order to accomplish this, there are a number of factors which must be examined. The primary of these is maintaining RF performance. With these design issues resolved, the result is a set of cost effective, microwave packages which can be used for most monolithic and many hybrid applications today.

DESIGN

As mentioned, the existing low frequency TO technology is an attractive packaging concept due to its low cost and low risk. However, there are certain limitations to the performance of these packages at higher frequencies. These are inadequate RF grounding through the package base or the connector seals, seals which are not 50 ohm matched, and a right angle transition from the pin extending up into the package onto the circuit inside. With these issues addressed, another possible limitation to high frequency performance could be cavity resonance. If the inner diameter of the package is greater than the cavity height, which is the case for all the packages we are developing, the TM_{010} mode has the lowest resonant frequency. Figure 1 shows a plot of radius versus resonant frequency of this mode for an air-filled cavity. Although there will be a slight effect on this calculation due to the inclusion of hybrid substrates, GaAs chips or other small perturbations, these frequencies provide a good estimate of the upper limit of operation. For our baseline package we wanted performance through Ku-band. Therefore we chose a TO-8 size

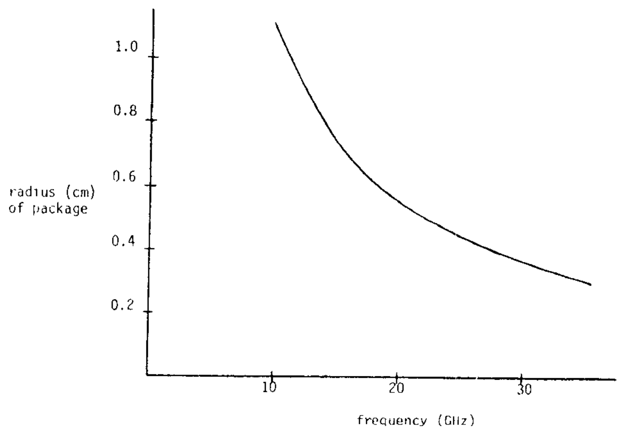

Figure 1. Resonant frequency of TM_{010} mode.

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package, with an inner diameter of 0.525 inches and a resonant frequency 17.1 GHz, as our initial test vehicle. A sketch showing a standard TO-8 package is given in Figure 2.

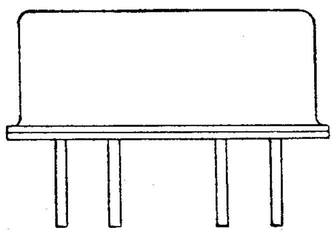


Figure 2. View of a standard TO-8 Package.

The primary concern in the development of our microwave quality TO package was to ensure RF performance. Basically this meant producing a package with 50 ohms in and 50 ohms out at the glass seal interface. Our first step in achieving this goal was to replace the seals used in the low frequency package with high quality glass seals. The dimensioning of these seals has been carefully determined so that the inner pin conductor, the glass dielectric and the outer metallization of the seal look like a 50 ohm characteristic impedance coaxial line at microwave frequencies.

The next transition which needed to be matched was the metal pin extending approximately 0.010 inch into the interior of the package for bonding to the circuit. As is, this pin looks inductive, limiting high frequency performance. Matching this transition was achieved through use of a metal ridge, as shown in Figure 3. The ridge is taller than the

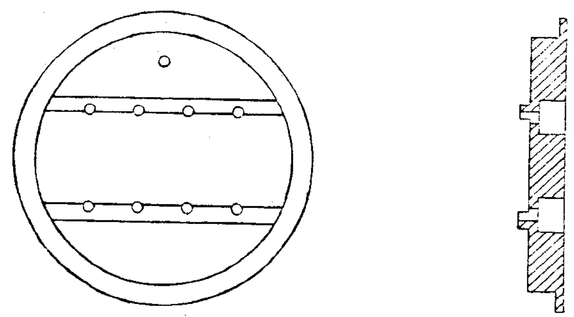


Figure 3. View of package showing ridge.

extension of the pin into the package and almost encircles the pin. It provides capacitance around the pin, thereby matching out the inductance. Initial plans were to determine the amount of capacitance needed, i.e. ridge dimensioning, in an iterative process, as this interface is critical to performance. The only area around the pin which is not enclosed by the ridge is where ribbon bonds or bond wires must come out to make connection to the circuit. Obviously, the cut-out in the ridge is necessary in order to make this connection. However, the manner in which the ridge comes close to the ribbon or wire bonds helps to match them, too, as they are also inductive. The ridge is low and there are no wall obstructions, so the package is compatible with standard hybrid and monolithic wire bonding and die attach equipment.

Other factors which were determined during the design phase involve interface with higher level packaging. As well as a 50 ohm match at the glass seal interface of the package, it is also necessary to match the external launch of the pins into the next level of integration. Obviously, a knowledge of the type of packaging which the TO package is to be used with is required to provide this match. We chose WAFFLELINE. As shown in Figure 4, the body of

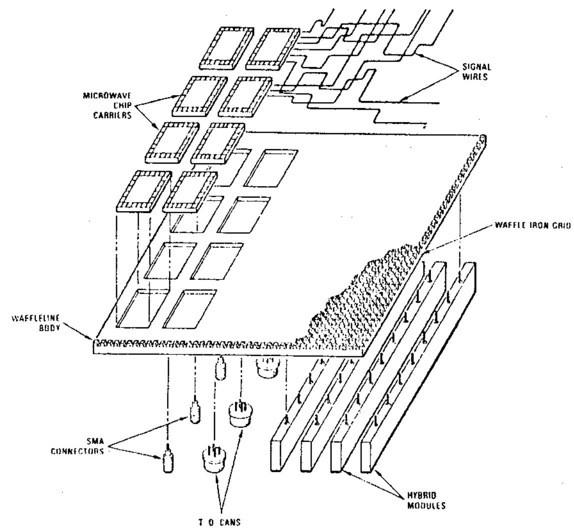


Figure 4. WAFFLELINE assembly.

the WAFFLELINE structure resembles a waffle iron-like grid. Dielectric coated signal wires lie in the channels defined by the grid and are used to connect the various packages assembled in WAFFLELINE. The structure is completed with a top metal foil covering to isolate interior wires from outside RF signals and from each other. Since the transition of the external TO pin is made through the body of the WAFFLELINE, a 50 ohm characteristic impedance coaxial line can be simulated. The external TO pin, 0.012 inch in diameter, is the center conductor, a teflon sleeve with a dielectric constant of 2.0, is the dielectric medium, and the WAFFLELINE provides the outer conductor. The TO package could also be mounted in other packaging schemes, such as stripline or microstrip. If mounted in stripline, a matching technique would have vias from the bottom ground to the top ground surrounding the high frequency pins. The vias would be spaced a certain radius from the package pin to capacitively match its inductance. Mounted in microstrip, the package pins could come up against the edge of the substrate, with matching provided by a metal ridge, similar to the one described previously, located on the other side of the pins.

A major consideration in the interface with the next level of integration is to provide good RF ground for the TO package. This is accomplished by mounting the package in a cavity up configuration onto the next level ground. An additional cover or clamp to the TO package, with screw holes along its lip, is then placed on top of the standard lid and screwed into the ground surface. A pressure contact such as this provides good RF ground to the package if the mounting surfaces are maintained at a specified flatness. This clamping scheme allows easy, low risk part replacement, an important factor in the repair of higher level assemblies. Only the ends of each pin need to be soldered, thus greatly reducing the risk of destruction of adjacent parts when compared with solder attached ceramic LCCs.

TEST RESULTS

For evaluation purposes, the TO-8 package with the 0.525 inch diameter was examined in a WAFFLELINE test fixture. A 0.010 inch alumina substrate with 50 ohm through lines was used as a test substrate. Testing was performed with a time domain reflectometer (TDR) and a network analyzer. Use of both pieces of equipment allows a complete analysis of the package. With the TDR, individual interfaces can be examined, mismatches defined, and improvements at these areas seen. The network analyzer supplies accurate return loss and isolation measurements for easy determination of package performance.

Return loss measurements were made by launching into the WAFFLELINE via a K connector, from the WAFFLELINE into the TO package, onto the through substrate, out of the TO package into the WAFFLELINE, out of the WAFFLELINE via another K connector, and into a precision 50 ohm load. For reference, return loss of a through line in WAFFLELINE with launches made via K connectors is given in Figure 5. This shows a smooth transition through 18 GHz. As demonstrated in Figure 6, return loss of the TO-8 package was measured at greater than 20 dB through 16 GHz. Viewed on the TDR individual transitions were seen and imrpoved. The worst transition occurred during the launch through the external pin/WAFFLELINE coaxial configuration. It was found that controlling the characteristic impedance of this transition to 50 ohms is very dependent on maintaining a good teflon fit between the two metal conductors. Of course, keeping bond ribbons and wires to a minimum length and maintaining good RF ground also improves performance.

Using a test set-up similar to the one described for return loss, isolation between adjacent signal ports in the TO package was

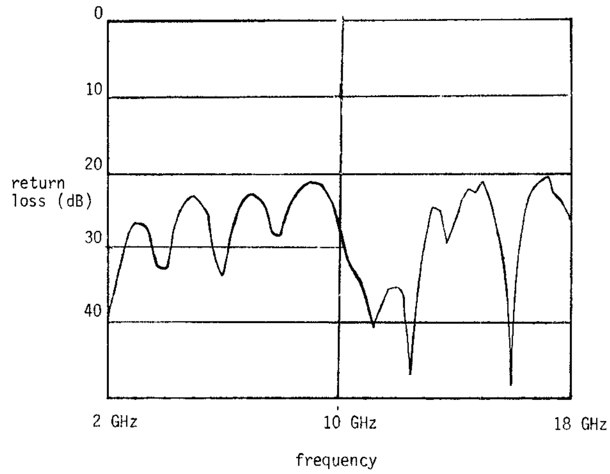
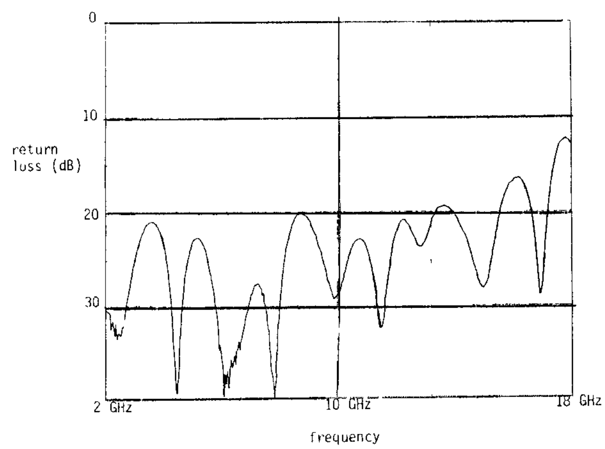


Figure 5. Return loss of WAFFLELINE through.



Fiqure 6. Return loss of TO package.

measured. Here an additional port in the WAFFLELINE was connected to one of the pins adjacent to the through line in the package. Isolation was measured at better than 50 dB through 15 GHz.

OTHER PACKAGES

As well as the 0.525 inch diameter TO-8 package, several other TO cans are currently being developed. For high speed digital chips, a forty pin TO-3 size can is being fabricated. Since projected bandwidth of this package is 5 GHz, its lower resonant frequency of approximately 10 GHz is acceptable. With the narrower bandwidth requirement, the metal ridge used for extended matching can be eliminated. Connections from the package pins to the chip bond pads are made via a 0.005 inch thick duroid interconnect substrate and bond wires. Unlike standard pin grid array ceramic packages, which are usually solder mounted on a multi-layer printed wiring board, this package is capable of thermal dissipation from the chip directly into the mounting structure, for our case WAFFLELINE. This thermal dissipation capability is another advantage of TO type packaging. The result of this effort is a package specifically intended for GaAs circuits where a large number of high speed, densely spaced I/O s are required. Other packages being developed are variations on the TO-8 can, the smaller, TO-5 size cans and square or rectangular packages.

CONCLUSION

The microwave quality TO packages are an excellent packaging option for hybrid and monolithic circuits. Their RF performance is only limited to their cavity resonant frequency, which, dependent on package size, can extend through K-band. As they are modeled after an existing manufacturing technology, production should be low cost and low risk. For many applications, these TO packages provide a cost effective alternative to MCCs and hybrid modules.

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