Integration trends of 10 GHz and above

Techniques benefits communications, military, and aerospace applications

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RF/microwave system engineers are seeking higher levels of integration because of tremendous pressure to cut cost, reduce size, lower power consumption, reduce time to market, and at the same time provide higher performance. These drivers are causing engineers to evaluate new ways to integrate high-frequency analog and digital circuitry on a single board. High-frequency mixed-signal integration offers tremendous benefits to the communications, military, and aerospace industries.

Traditional problems with integration

High-level integration at very high frequencies (10 to 65 GHz) presents a number of challenges. These include controlling thermal buildup, unwanted crosstalk, controlling the microwave signal, cavity resonances, and adapting manufacturing and test equipment to handle the high density of components in a small area.

Some of the specific challenges include:

- Analog leakage into the RF channel since the circuits are close together
- Dissipating the heat through the board since the components are mounted on the substrate
- High density, which makes bonding wires in the housing difficult

Selecting substrate

Reducing size and cost are of major importance in today's environment. Design engineers can use multilayer thick film and LTCC to achieve the target size and cost savings.

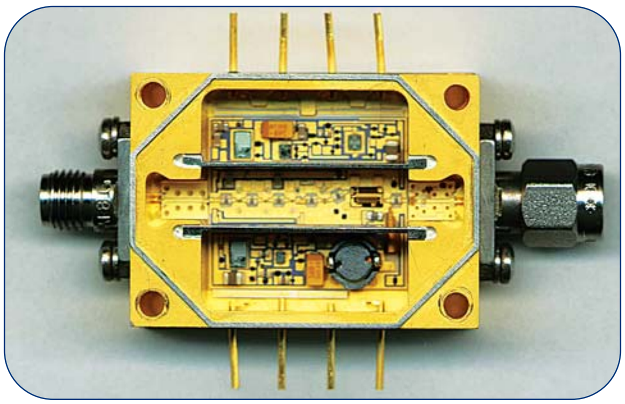

Fig. 1. A 24-dBm medium power amplifier module is an example of mixed-signal integration at high frequencies.

The example for this industry trend is a 24-dBm medium-power amplifier module (see *Fig. 1*) for which thick film was selected, because it allowed the use of multiple conductor layers. The primary microwave conductors were printed directly onto the alumina substrate, which provided the shortest ground returns and most efficient thermal sinks for RF components.

The addition of a layer on which the bulk of the analog traces were printed had the effect of isolating the microwave trace from the control circuit and thus preventing unwanted signal interactions. Interconnecting vias were used to bring desired control signals to the pertinent nodes. Nested layering translates into a three-dimensional architecture, which maximizes the potential for circuit density in a minimal area.

Various resistor inks (see *Fig. 2*)—ranging from 50 Ω to 100 kΩ per square and laser trimmable to within 1% accuracy—allow one to print both microwave biasing resistors and control circuitry onto a single circuit. These resistors are substitutes for their discrete counterparts, providing cost savings and fewer bond wires.

Controlling thermal buildup and crosstalk

One of the big challenges is with keeping heat away from the components and the control circuits. The circuit dissipated a total of 4 W of dc power and 24 dBm of RF power. Additional vias were positioned under all critical die to extract as much heat from the components as possible. The vias proved to be robust and allowed the modules to survive a 1,000-hour burn-in at a 125°C fully powered on.

In today's mixed-signal modules, interference and crosstalk are a major concern because of high gain and high frequency—up to 65 GHz. Two approaches can be taken to direct the propagation of the microwave signals and to prevent interference or crosstalk from control signals.

The primary microwave trace can be constructed using a coplanar waveguide topology, which has a twofold effect: it permits a convenient linear cascade of gain blocks

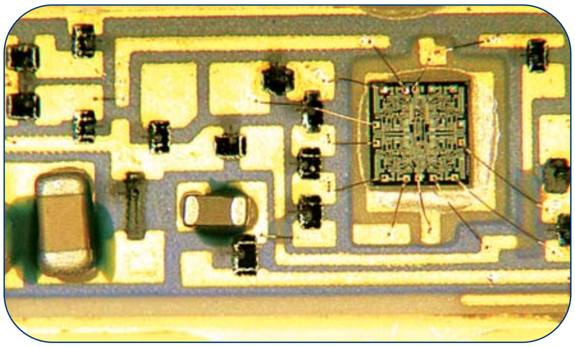

Fig. 2. Resistor links substitute their discrete components for additional cost savings and fewer bond wires.

and isolates the onboard control circuitry from interfering or interacting with the carrier signal. Designers can liberally distribute grounded vias within close proximity of the microwave trace, which serves to maintain the coplanarity of the circuit and to act as a grounded wall, thereby isolating the trace from any interference from the control circuitry.

Internal dimensions of the housing can be simulated to prevent cavity resonances. Slots can be machined into the housing to accommodate the insertion of conductive walls.

Additional grounding vias can be positioned on the substrate to align with these walls, thereby creating a grounded enclosure within the housing itself. This provides for additional isolation between microwave and analog signals and serves to prevent any higher order modes from propagating.

The payoff

There are several benefits of mixed-signal integration at high frequencies:

1. Lower cost. Fewer parts, one housing, and a one-board approach allow boards to be entirely populated external to any housing. The units can then be subjected to a fully automated testing process using techniques similar to those for testing wafers, which allows one to be assured that units fully comply with customer specs before they are installed into their respective housings.

2. Reduced size. A substantial size saving can be achieved by multilayer substrates with printed components.

3. Lower power consumption and increased reliability. There are no losses due to connectors or long transitions between analog and digital circuitry. Eliminating the connectors and lowering the power provides higher reliability.

4. Higher performance. This is achieved because of shorter bonds, fewer transitions, and better thermal management. EP