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Upconverting LTCC Mixer Targets Instrumentation Applications

LTCC fabrication and high performance are combined in this passive mixer that upconverts frequencies from 50 to 3300 MHz to an output of 3900-4300 MHz.

Test instrumentation may need to accommodate signals having a wide-percentage frequency bandwidth. For ease of processing such RF signals, the input can be up-converted in order to reduce the percentage bandwidth. To facilitate upconversion ahead of higher frequency receivers, Mini-Circuits (www.minicircuits.com) has developed a high-performance passive mixer that allows original-equipment manufacturers (OEMs) to optimize receiver design.

The company's model SIM-U742MH+ mixer is based on a combination of low-temperature-cofired-ceramic (LTCC) technology, semiconductor technology, and a highly manufacturable circuit layout. The patented combination [1] results in small size, high insensitivity to electrostatic discharge (ESD), excellent stability with temperature and is a part of a growing family of SIM mixers [2,3].

Parameter	Specification
IF range (input)	50-3300 MHz
RF range (output)	3900-4300 MHz
LO range (input)	4100-7400 MHz
LO power (nominal)	13 dBm
Conversion loss (typical)	8.0 dB
LO-RF isolation (typical)	23 dB
LO-to-IF isolation (typical)	17 dB
Compression point (1 dB)	9 dBm
Operating temperature	–40 to 85° C
Storage temperature	–55 to 100°C
Size	0.2×0.18×0.08 in.

Table 1 · SIM-U742MH+ performance.

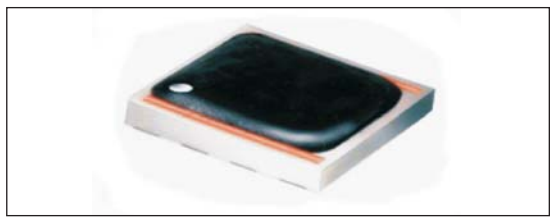

Figure 1 · The SIM-U742MH+ surface-mount mixer is ideal for upconverting signals at 50-3300 MHz to the 3900-4300 MHz band.

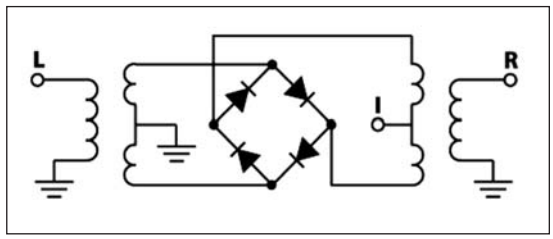

Figure 2 · The SIM-U742MH+ employs a diode quad with patented circuit techniques and proven LTCC circuit materials.

Instrumentation receivers need components, such as mixers and oscillators, that provide stable performance over time and under different environmental conditions, including temperature.

The SIM-U742MH+ mixer (Fig. 1) is built on a LTCC substrate, ideally suited for designs with multilayer circuits. In contrast to conventional planar circuit designs, in which all circuit elements are placed on one side of a single-layer printed circuit board, LTCC circuits can be designed and fabricated in three dimensions, even with embedded components between layers, to save space. The approach results in a mixer that measures just 0.2×

0.18×0.08 in. (5.1×4.6×2.1 mm), which is smaller than some commercial semiconductor-based mixers. While the SIM-U742MH+ mixer incorporates semiconductors to accomplish its frequency-translation function, it is a passive design that operates without DC bias (compared to a standard IC mixer which requires the application of constant DC bias).

The SIM-U742MH+ is a double-balanced mixer (Fig. 2) built around a reliable diode quad. Except for the diodes, the entire structure is implemented in multiple layers of LTCC which is inherently hermetic. By integrating components in LTCC, the mass of the mixer is minimized, making it extremely rugged in terms of withstanding shock and vibration. In fact, the entire mixer structure can withstand the environmental extremes usually associated with tough military components, regarding temperature, humidity, vibration, and mechanical shock.

The mixer is RoHS compliant, constructed without lead-based solder or other hazardous materials. It is also built to withstand severe ESD scenarios under conditions normally hazardous to monolithic semiconductor mixers. The SIM-U742MH+, like other members of the company's SIM mixer line, meets Class 1C ESD requirements: a level of 1000 V when tested per the Human Body Model (HBM), compared to standard semiconductor mixers which are typically rated as Class 1A, 250 V for HBM testing. The SIM-U742MH+ mixer also meets Class M2 ESD requirements (testing at 100 V) according to the ESD Machine Model.

Table 1 summarizes the performance characteristics of the SIM-U742MH+ mixer.

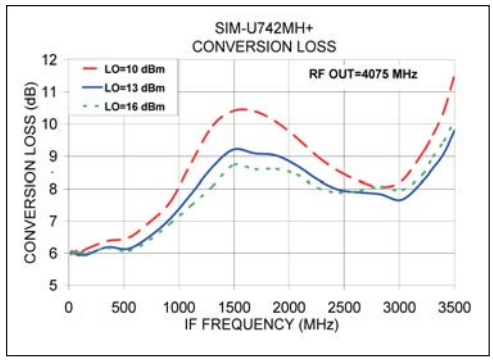

Figure 3 · The SIM-742MH+ mixer exhibits low conversion loss to 500 MHz IF and medium to 3300 MHz. It was tested here at LO drive levels of +10, +13, and +16 dBm.

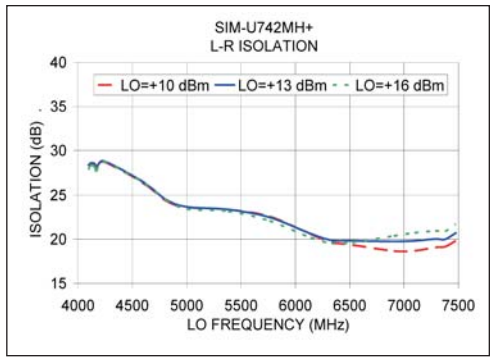

Figure 4 · The isolation between the LO and RF ports was measured at typically 23 dB for the three LO drive levels of +10, +13, and +16 dBm.

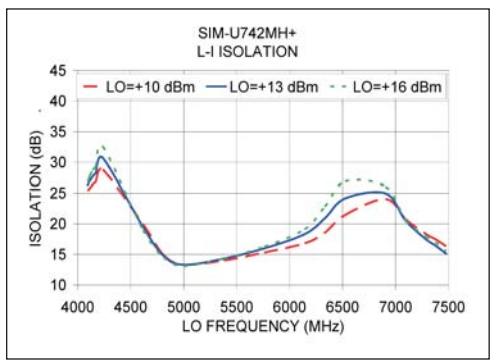

Figure 5 · The isolation between the LO and IF ports was measured as typically 17 dB across the full frequency range of the SIM-U742MH+ mixer.

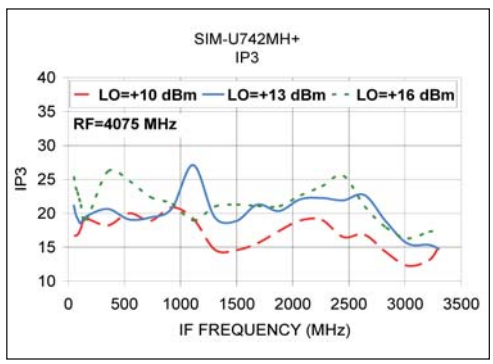

Figure 6 · The measured input third-order intercept performance of the SIM-U742MH+ mixer was in excess of +14 dBm and typically +19 dBm at all frequencies, when LO power was +13 dBm and higher.

Evaluating Performance

The SIM-U742MH+ mixer accepts intermediate-frequency (IF) signals from 50 to 3300 MHz and local-oscillator (LO) signals from 4100 to 7400 MHz and a nominal level of +13 dBm to produce RF output signals from 3900 to 4300 MHz. It performs the frequency upconversion with typical conversion loss of 8.0 dB. The mixer's conversion loss increases with IF frequency. See Fig. 3, which shows test results with LO drive levels of +10, +13, and +16 dBm. Performing swept-frequency testing at different LO drive levels simulates the effects of variations in LO power from unit to unit as well as across wide frequency ranges. The variation in conversion loss with LO drive power is typically +0.1/–0.5 dB across the 3300-MHz measured bandwidth.

The LO-to-RF isolation of the SIM-U742MH+ mixer was evaluated at the three LO drive levels used in the conversion-loss test, to understand the effect of variation in LO power on isolation. As Fig. 4 shows, the LO-to-RF isolation is high (typically 23 dB) and very well behaved at all three LO drive levels. Variation in isolation as a function of LO power is negligible.

Similarly, the LO-to-IF port isola-

tion was also evaluated at the three LO drive levels. The SIM-U742MH+ mixer exhibited typically 17 dB isolation across an LO frequency range of 4100 to 7400 MHz (Fig. 5).

Since wide dynamic range is important in instrumentation applications, the input third-order intercept point (IP3) of the SIM-U742MH+ mixer was also evaluated at the three LO drive levels (+10, +13, and +16 dBm) and an RF output range of 3900 to 4300 MHz. IP3 is consistently about 20 dBm up to 2.5 GHz and then drops to 15 dBm at 3.3 GHz (Fig. 6).

The LTCC double-balanced mixer features typical LO port return loss of 3.5 to 8.5 dB. The return loss measured at the RF port is 5.5 dB typ. while the return loss at the IF port is typically within 5 to 30 dB across the full IF band.

The mixer supports conventional surface-mount applications, and can be supplied in tape-and-reel formats for use with automated assembly equipment. This RoHS-compliant product is designed to withstand high levels of ESD mishandling compared to more sensitive, and often larger, semiconductor mixers.

Mini-Circuits' LTCC mixers have been tested extensively and qualified for environmental conditions such as humidity, shock, and vibration. To evaluate the durability and reliability of their solder joints, 20 of the LTCC mixers were soldered onto FR-4 PCB motherboards and thermally cycled over the operating temperature range of –40 to 85ºC. The DC continuity was measured from the motherboard trace to the top of the LTCC board for 1000 cycles, with no failures found.

References

1. United State Patent No. 7,027,795 (2006).
2. Engineering Staff, Mini-Circuits, "LTCC Launches Miniature, Wideband, Low-Cost Mixers," *Microwaves & RF*, June 2006, pp. 107-110.
3. Mini-Circuits web site, http://www.minicircuits.com (Enter model series prefix SIM to get a list of SIM Mixers).

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