Application Report
SLWA039–June 2005

A Planar, Balanced Approach to Increase Transmitter Linearity

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ABSTRACT

The TI TRF1123 MMIC transmitter chip is a highly linear power amplifier with digital gain control, mute control, and output power detection for use in MMDS/MDS/WCS applications. With a typical P_{1dB} of 31 dBm and a third-order intercept point of 46 dBm, the TRF1123 makes an excellent output stage for communication systems, particularly those that employ high-order modulation schemes such as 64 QAM and OFDM.

In applications with higher output power and/or higher linearity requirements, two TRF1123s can be combined in a balanced configuration to increase the P_{1dB} and third-order intercept points. An ideal balanced configuration provides low input and output VSWR in addition to a 3 dB improvement of the power and linearity performance. Typical microstrip balanced power combiners use a *Lange* type combiner, which, although effective, has the disadvantage of a non-planar implementation. This application note documents a novel design approach for a planar, balanced power combiner and presents results using the TRF1123 transmitter chip.

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1 The Traveling-Wave Divider/Combiner

The Traveling-Wave Divider/Combiner[(1)] is a planar structure used to increase output power by combining parallel amplifier stages. The simplest implementation is a 2-way *Wilkinson* type divider/combiner with a 90° transmission line in one arm. The Wilkinson divider provides an equal-power, equal-phase power split and the transmission line shifts the phase of one path by 90° so at the output of the divider we have two equal power signals in quadrature (phase shifted by 90°) as shown in Figure 1. Two identical power amplifiers with gain *A* are placed in each arm. Any reflected power at the input to the amplifier is

(1) Alain Bert and Didier Kaminsky, *The Traveling-Wave Divider/Combiner*, *IEEE Trans. on Microwave Theory and Techniques*, vol. MTT-28, No. 12 December, 1980.

terminated in the 100-Ω isolation resistor, since the reflected power of the two arms at the resistor is 180° out of phase. A combiner with similar properties is placed at the output to combine both output signals from the amplifiers, but the extra 90° line is placed in the opposite arm so that the output signals add in phase through the combiner. Assuming no loss and perfect combining, the 2-way combiner will increase output power and linearity by 3 dB. Given a *real life* application, the typical increase is 2.5 dB.

Even though this power combiner is comprised of multiple quarter-wave lines, the *Wilkinson* type divider/combiner with a 90° transmission line has a broad bandwidth, significantly wider than a branch-line type combiner, and has low loss. Since the combiner is planar, it is much easier to fabricate using standard PCB technology. The example we show in Figure 1 has a 50-Ω impedance at the amplifier input. However, lower impedances can be achieved by increasing the transformation ratio in the quarter wave lines. Unlike branch line or *Lange* type combiners, the *Wilkinson* type divider/combiner easily scales to 4-way combining for even higher power.

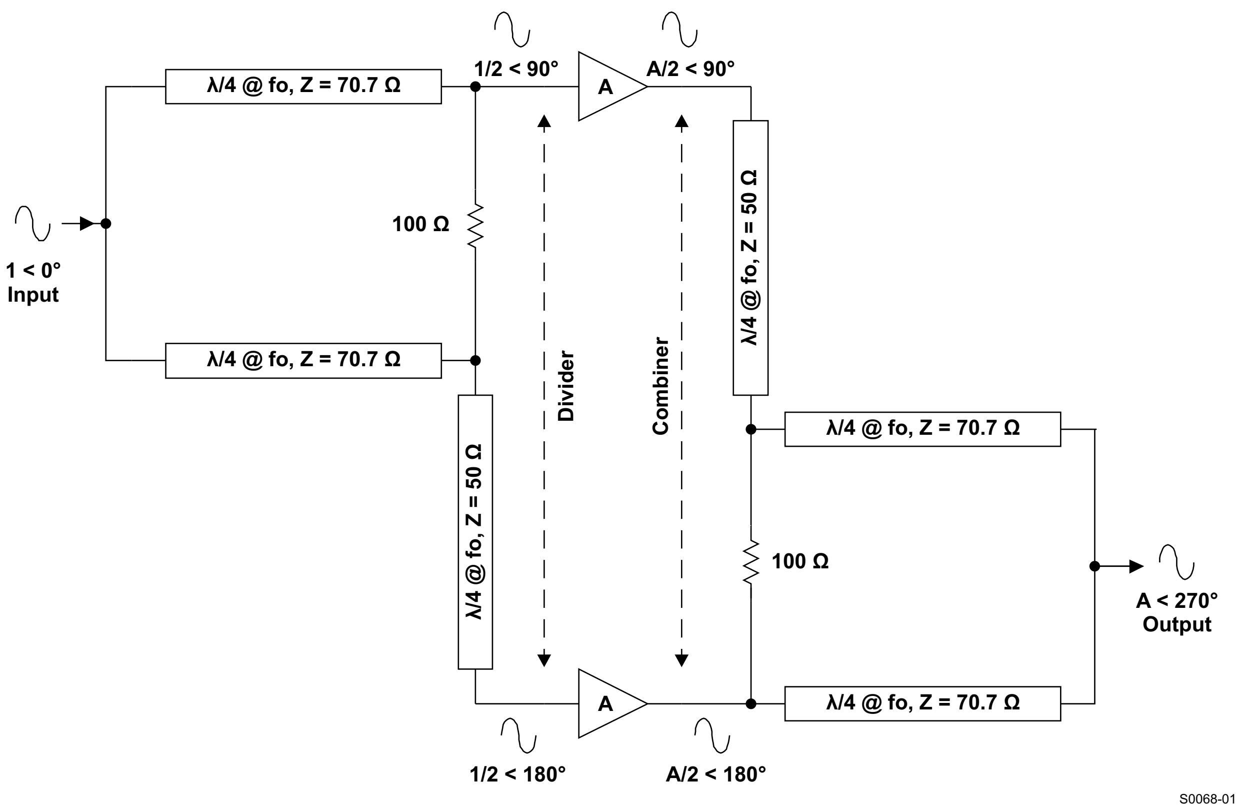

Figure 1. 2-Way Traveling Wave Divider/Combiner Architecture

2 Balanced TRF1123 Design and Layout

A balanced stage using the two-way divider/combiner and TRF1123s was constructed and tested. The layout, shown in Figure 2, was designed on Park-Nelco N4000-13, a low-cost, high-performance FR4 PCB material. The board consisted of four layers: an RF layer (top), an RF ground layer, a trace interconnect layer, and another ground layer (bottom). The RF layer and RF ground layer are fabricated using a Park-Nelco N4000-13 0.01” mil core. The trace interconnect (3rd layer) and bottom ground layer are fabricated using a 0.01” thick FR4 core for cost reasons. The two cores are bonded together with an 0.008” prepreg layer. Starting copper thickness is 1 oz (to help thermal dissipation) resulting in an overall board thickness of 0.035”. The TRF1123 has thermal vias under the package to lower thermal resistance.

The layout and bias circuitry details for the TRF1123 can be found in the data sheet. Proper attention to the layout guidelines listed is required.

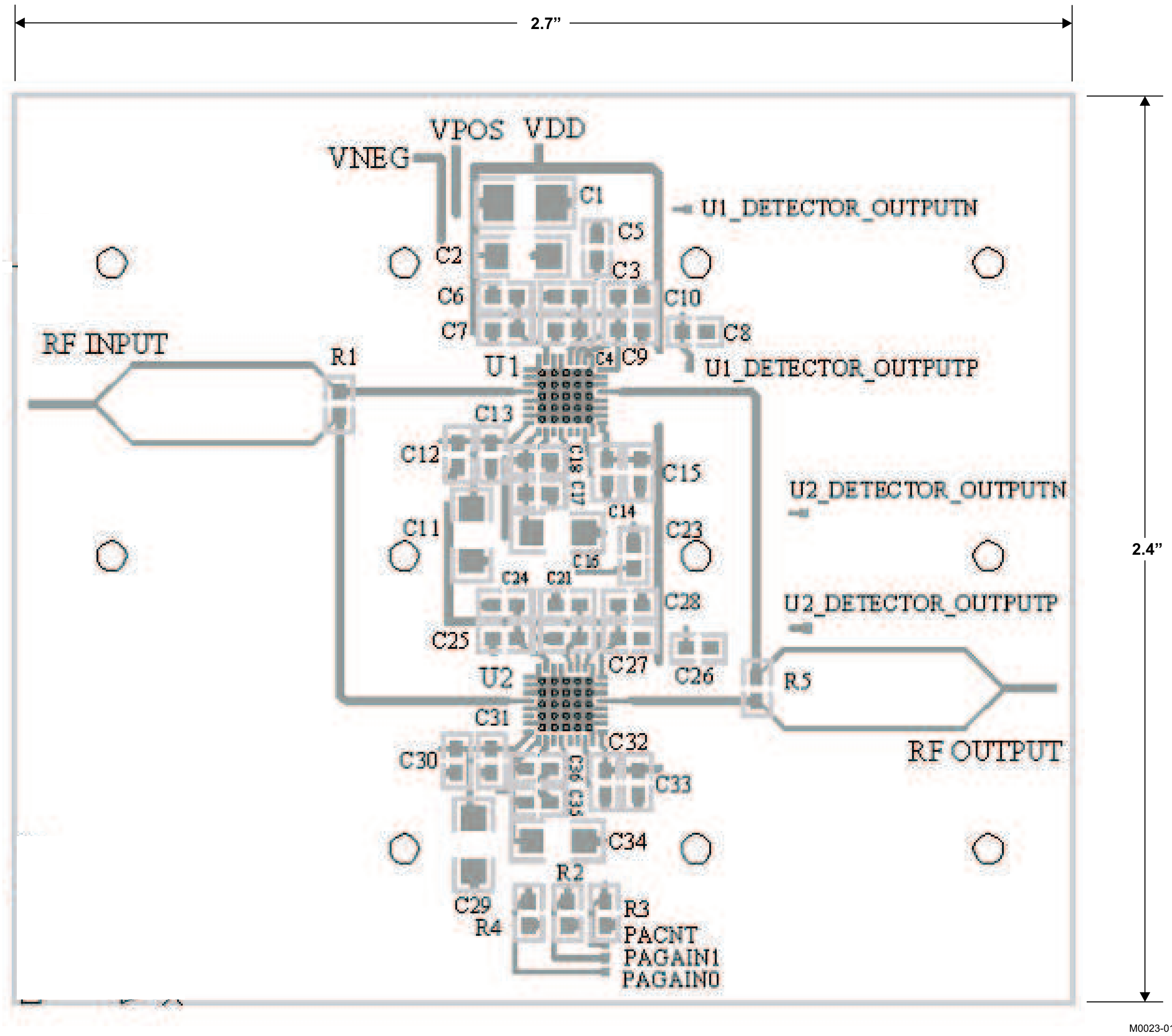

Figure 2. TRF1123 Balanced Stage Layout on Park-Nelco N4000-13

3 Measured Performance

The measured output power (P-1dB) of the balanced TRF1123 is shown in Figure 3 and the measured two-tone IP3 is shown in Figure 4. The figures show data for 5-V and 7-V operation. The performance of the balanced stage is 2.5 dB to 2.8 dB better than performance of a single-ended unit under the same conditions. The measured gain for the balanced stage is similar to single-ended performance and is shown in Figure 5.

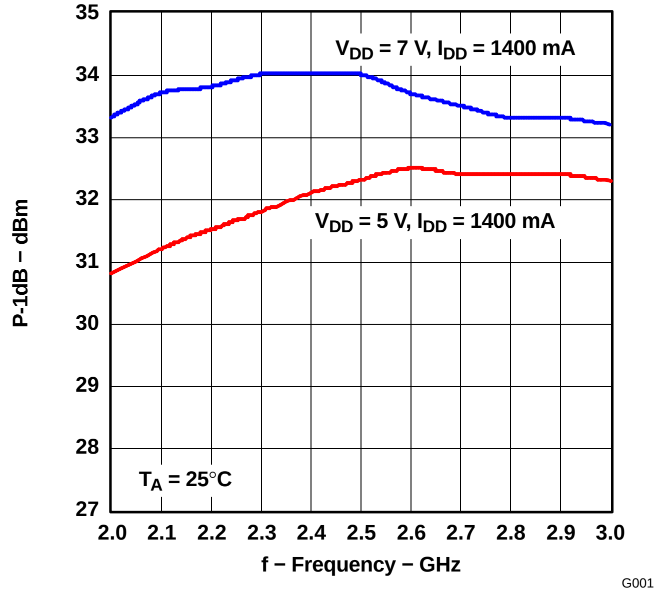

Figure 3. P_{1dB} Performance of a Balanced TRF1123 Stage

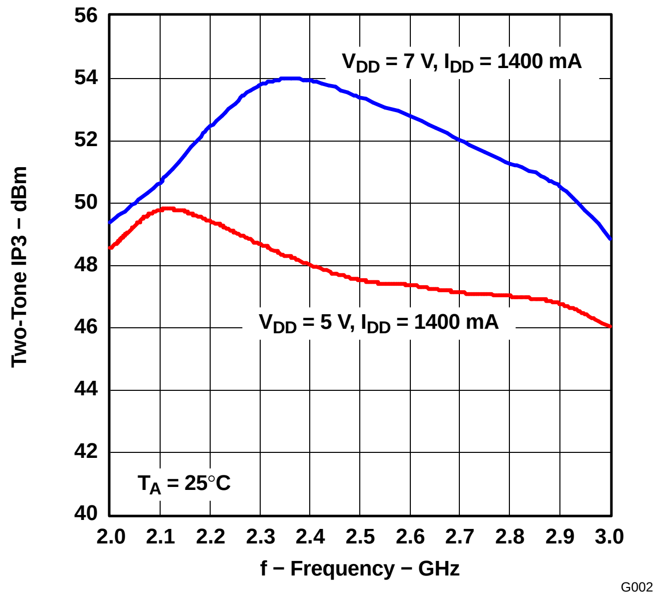

Figure 4. Output IP3 Performance of a Balanced TRF1123 Stage

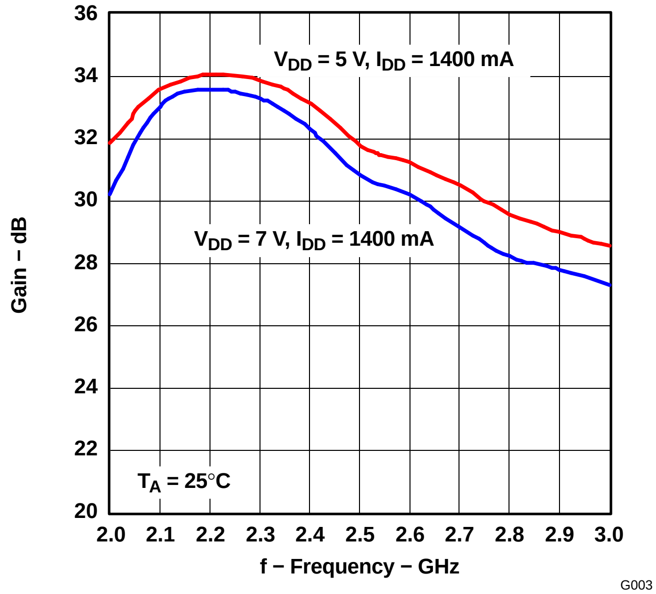

Figure 5. Gain Performance of a Balanced TRF1123 Stage

4 Summary

This novel design approach for combining two power amplifiers offers simple low-cost implementation, wide bandwidth (approximately 40% versus 15% for a branch-line approach), and economical use of PCB space.

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