Flat Gain, Wideband and High Linearity Driver Amplifier for WiMAX MGA-30x89 (0.04 GHz to 6 GHz) with Optimized OIP3

Application Note 5467

Introduction

The Avago MGA-30x89 is an innovative wideband, flat gain, low noise, high linearity amplifier for the 0.04 GHz to 6 GHz frequency band. It features low power consumption, only 500 mW (100 mA at 5 V). Wide bandwidth without additional RF matching components keeps designs compact and reliable. DC blocking capacitors and a power supply RF choke are all that a complete design needs. A built-in temperature compensated internal bias circuit also provides stable operation over temperature and normal process variations. The MGA-30x89 amplifier series not only covers low and high frequency bands, but also offers a choice of OIP3 performance as shown in Table 1.

Table 1. MGA-30x89 Amplifier Series

	Low Band (0.04 ~ 2.6 GHz)	High Band (2 ~ 6 GHz)
High OIP3 (40 dBm)	MGA-30689	MGA-30789
Low OIP3 (37 dBm)	MGA-30889	MGA-30989

The Avago proprietary 0.25 µm GaAs Enhancement mode pHEMT (E-pHEMT) process technology gives superior linearity performance. In addition, only a single polarity power supply is needed since the internal amplifier transistor source can be directly DC grounded. The MGA-30x89 amplifier series is available in an industry standard SOT-89 package measuring just 4.5 mm by 4.1 mm by 1.5 mm. The package has two source leads with a large surface area for efficient heat dissipation and low inductance RF grounding. This application note will emphasize the **high band** amplifier series.

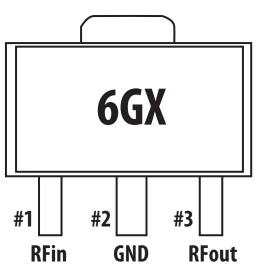

Figure 1a. MGA-30x89 Package Top View

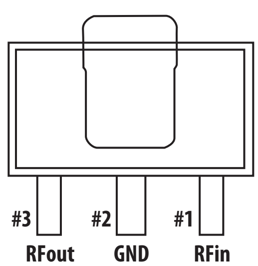

Figure 1b. MGA-30x89 Package Bottom View

Pin Configuration and Biasing

Top and bottom views of the SOT-89 package are shown in Figure 1a and 1b. A generic MGA-30x89 application circuit is show in Figure 1c. The temperature compensated internal bias circuit greatly reduces the total number of external components. The MGA-30x89 amplifiers can be biased from either the top or bottom sides of the board depending on the RF choke package used. A design with a 0402 or 0603 size RF choke should use the top side connection and with a 0805 size RF choke the bottom side should be used. The RF choke and bypass capacitor reference designators of L1, C1, C2 and C3 will refer to the top side of the demonstration board while L2, C4, C5 and C6 represent the bottom side. As shown in Figure 1c, C7 and C8 serve as DC blocks or RF coupling capacitors for the intended frequency band. Decoupling capacitors C1 to C6 suppress low frequency RF signals appearing across the DC bias lines and the L1/L2 inductor serve as an RF choke or DC feed. Self-resonant frequency (SRF) and impedance in the band of operation (F_O) determine the RF choke type and value. The inductor's SRF should be greater than F_O and its impedance should be approximately ten times greater than Z_O (50 Ω). Vdd is the only supply needed to turn on the amplifiers.

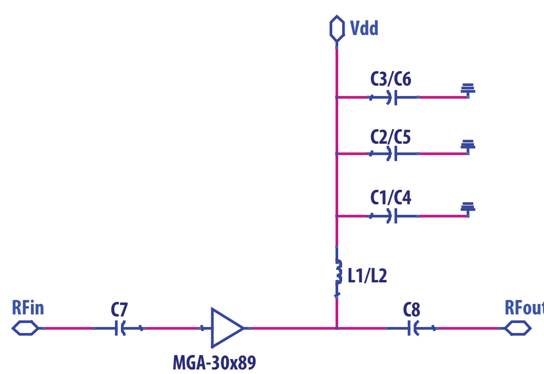

Figure 1c. MGA-30x89 Generic Application Circuit

Demonstration Board and CPWG Design

Common packaging allows the MGA-30x89 amplifier series to use a common demonstration board. Figure 2 shows the demonstration board's cross section. The demonstration board is a three layer PCB with 0.5 ounce (oz.) of copper (Cu) on each layer and a 10 mil dielectric layer of Rogers RO4350. For mechanical strength, FR-4 material (50 mils) is added to the PCB structure. The FR-4 layer also contributes to the overall demonstration board thickness (62 mils), which suits most of the standard PCB edge-mounted SMA connector.

Both RF input and output traces use a Coplanar Waveguide with Ground (CPWG) with Z_O = 50 Ω. Non-50 Ω traces will degrade board performance, especially the return loss. With a 10 mil thick dielectric and 0.7 mil (0.5 oz.) thick traces, the CPWG line width is designed to be 22 mils to achieve a Z_O of 50 Ω, suitable for the PCB edge-mounted SMA connector center pin.

The CPWG design and calculation were done using AppCAD, a free and versatile software package available from Avago Technologies (http://www.avagotech.com/docs/6001). Figure 3 is a screen shot of the CPWG design using AppCAD.

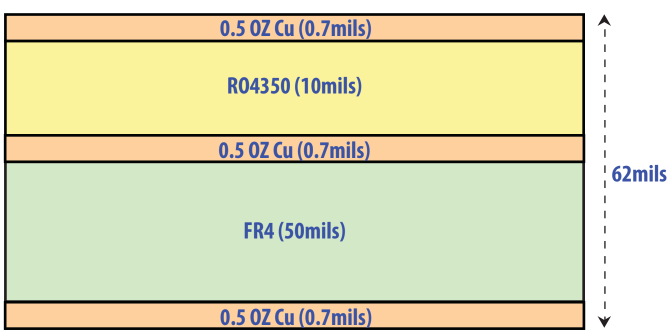

Figure 2. Demonstration Board Stacking Structure

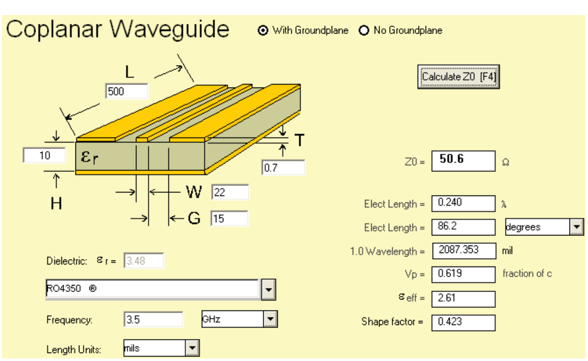

Figure 3. CPWG Design Using AppCAD Software

Demonstration Board Performance

The demonstration board performance was measured under the following test conditions:

Table 2. MGA-30x89 Test Condition

	Vdd	Idd	Fc
MGA-30789	5 V	100 mA	2.3 ~ 2.7 GHz
MGA-30989		51 mA	

Small Signal Performance

Figures 4 to 9 show MGA-30789 and MGA-30989 amplifier performance with a small signal excitation. Both amplifiers have better than 0.5 dB of gain uniformity across the WiMAX operating band. Gain ripple in the pass-band is insignificant relative to the overall gain due to exceptional gain flatness. The MGA-30789's Input and Output return loss (IRL and ORL) is better than 10 dB across the band. IRL and ORL MGA-30989 performance is better than 15 dB across the operating band. For driver or gain block applications, reverse isolation of -23 dB for the MGA-30789 and -28 dB for the MGA-30989 are considered sufficient to prevent any reflected signal due to a load VSWR change caused, for example, by an antenna mismatch. To eliminate the possibility of out-of-band instability, each amplifier's frequency response was measured up to 20 GHz and as an internally matched amplifier. The MGA-30789 and MGA-30989 amplifiers had a Rollet Stability Factor, K, above unity (K > 1) across the operating WiMAX band.

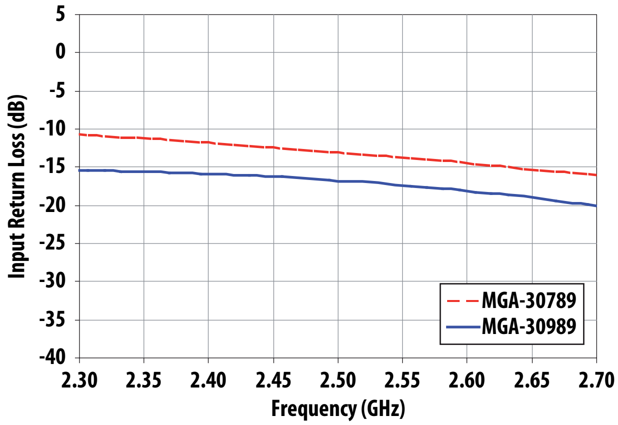

Figure 4. Input Return Loss

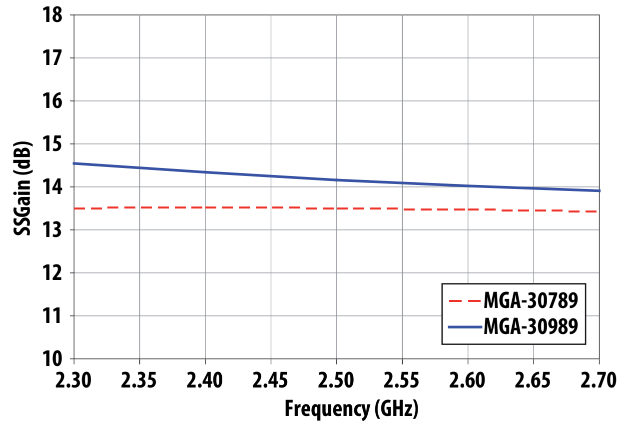

Figure 5. Small Signal Gain

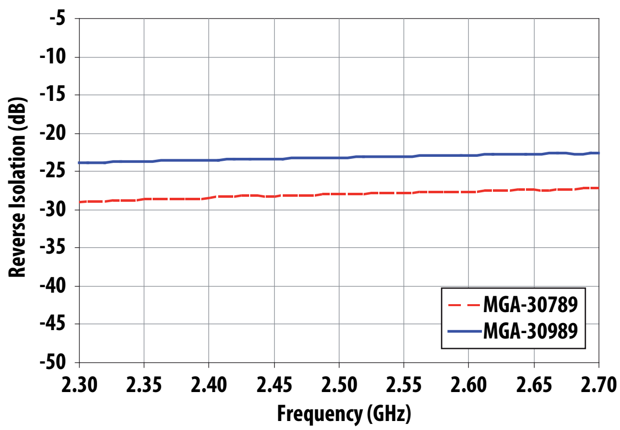

Figure 6. Reverse Isolation

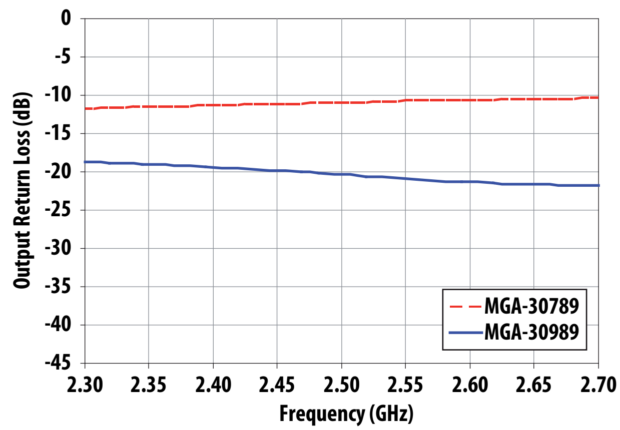

Figure 7. Output Return Loss

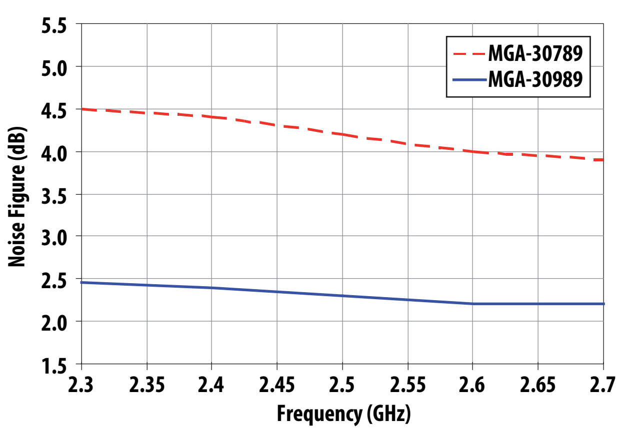

Figure 8. Noise Figure

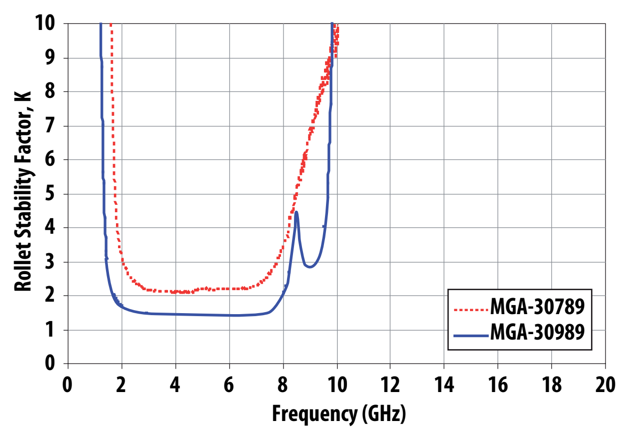

Figure 9. Rollet Stability Factor, K

Non-Linear Performance

As shown in Figure 10, the Output 1 dB Gain Compression Point (OP1dB) is approximately 24.8 dBm and 22.7 dBm for the MGA-30789 and MGA-30989 respectively. Based on the 7 to 10 dB power back-off required for WiMAX, both amplifiers are highly recommended for pre-driver and linear operation at 12 dBm output power or less. As shown in Figure 11, OIP3 is approximately 40 dBm for the MGA-30789 and 37 dBm for the MGA-30989 with -10 dBm input tones and with 10 MHz frequency spacing.

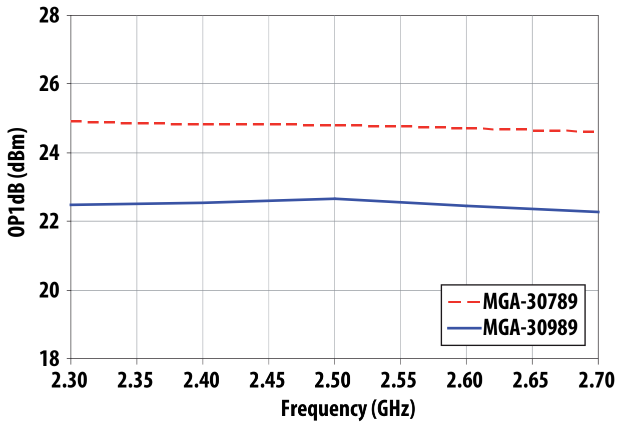

Figure 10. OP1 dB across the band

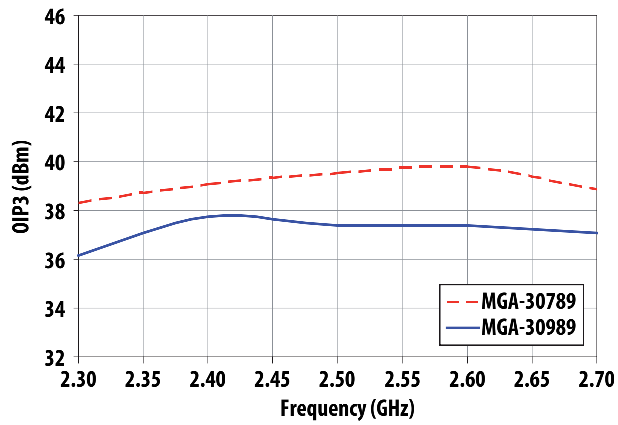

Figure 11. OIP3[1] across the band

Notes:
1. Fspacing = 10 MHz, Pin = -10 dBm

Factors Affecting OIP3 Performance

The following section discusses how the output matching network affects OIP3 performance. The data presented is based on MGA-30789 performance and will serve as a general guideline to OIP3 performance improvement and tradeoffs.

Wirewound Inductor vs. Multilayer Ceramic Chip Inductor

Although there is no direct relationship between the quality factor of an inductor (Q) and OIP3 performance, a higher Q inductor will definitely minimize circuit losses.

Using the MGA-30789 as an example, a high-Q RF choke in the output matching network will minimize circuit loss.

As shown in Figure 12, OIP3 decreases by about 1 dB after replacing the high-Q wirewound RF choke that has a Q of 67 at 1.7 GHz (Coilcraft - 0402CS-19NX_L), by an MLC choke with a lower Q of 27 at 1.8 GHz (TOKO - LL1005-FHL18NJ). Other critical parameters, shown in Figures 13 to 16, were only slightly changed by inductor Q and can therefore be ignored.

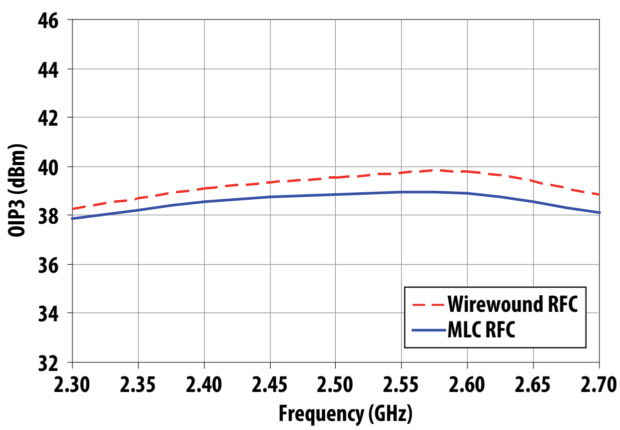

Figure 12. Effect on OIP3

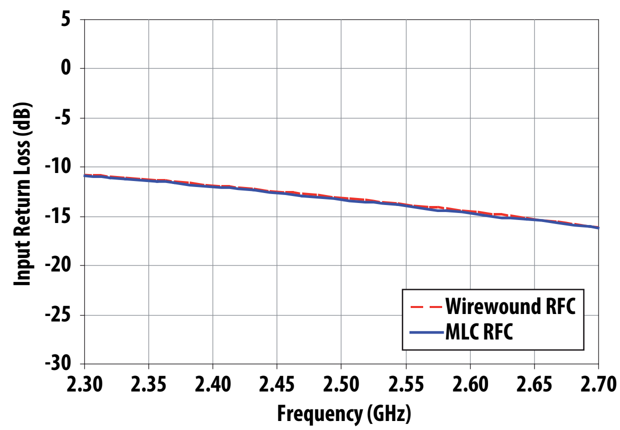

Figure 13. Effect on IRL

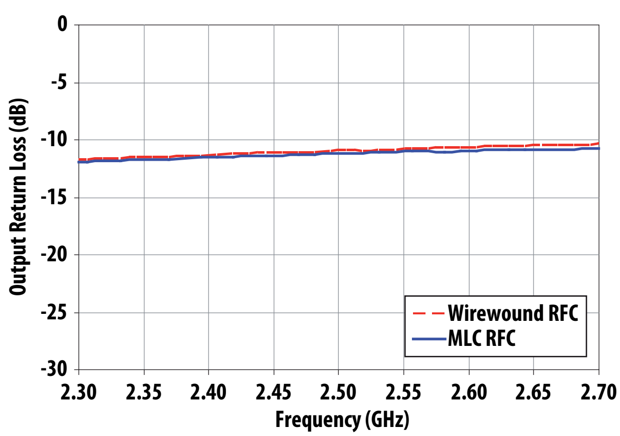

Figure 14. Effect on ORL

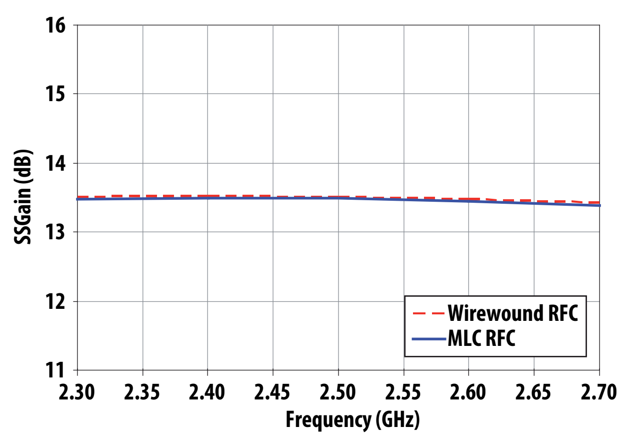

Figure 15. Effect on SSGain

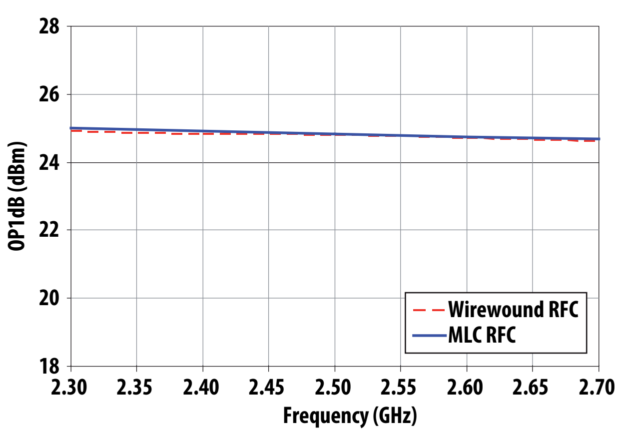

Figure 16. Effect on OP1dB

Output re-matching

The MGA-30789 matching network was designed to provide an excellent OIP3, adequate gain and good return loss (> 10 dB) across the operating band. However, for the application that requires higher linearity, WiMAX and LTE for instance, the OIP3 can be improved by changing the location of the Load Reflection Coefficient (Γ_{load}) for the intended frequency operation. This can be accomplished by re-matching the output impedance of the MGA-30789. Figure 17 demonstrates an exceptional OIP3 of 42 dBm at 2.5 GHz and an average of 2 dB OIP3 improvement across the band. However, the higher OIP3 was obtained at the expense of ORL and SSGain. As shown in Figures 19 to 21, the ORL dropped to 7 dB, and both SSGain and OP1 dB decreased by about 1 dB from the typical performance.

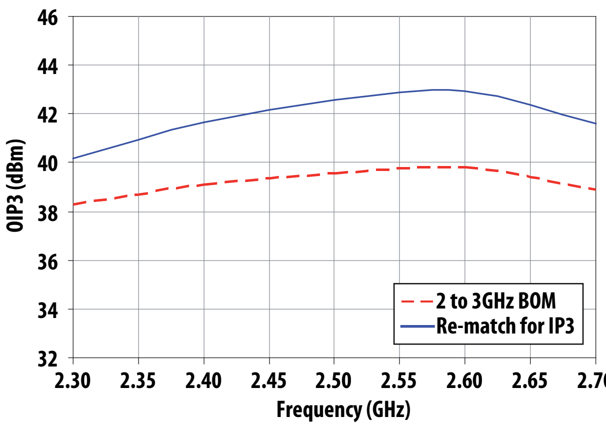

Figure 17. Effect on OIP3

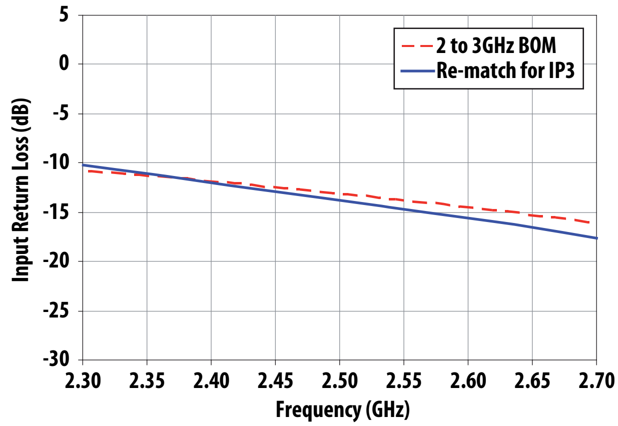

Figure 18. Effect on IRL

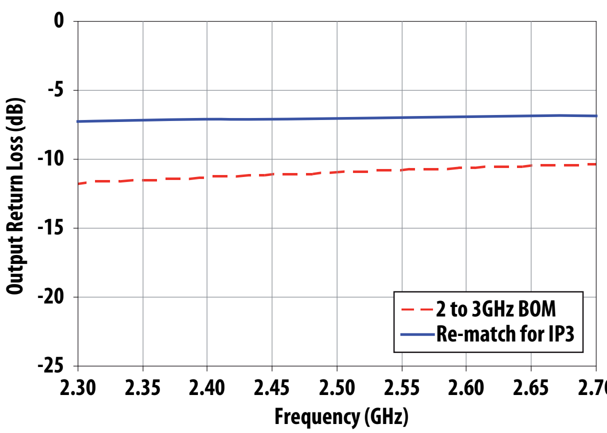

Figure 19. Effect on ORL

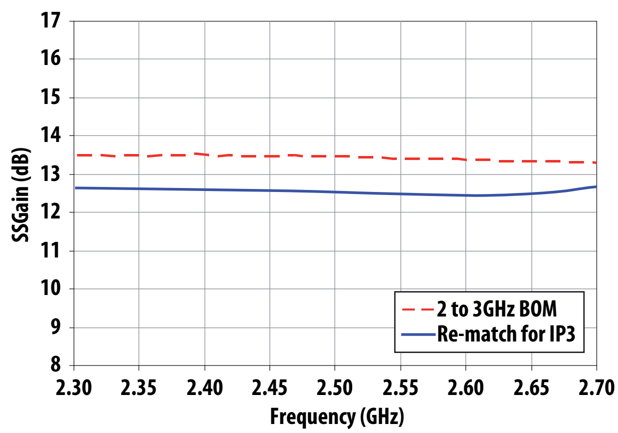

Figure 20. Effect on SSGain

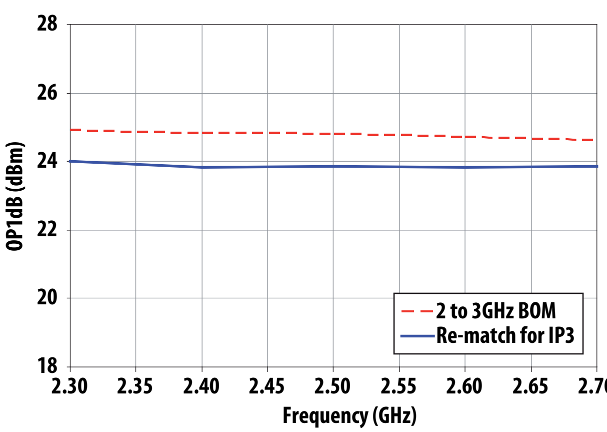

Figure 21. Effect on OP1dB

Schematic, Component Placement and Bill of Materials

Demonstration board component placement is shown in Figures 22 and 23. Schematics for the 2-3 GHz MGA-30789 and 2-4 GHz MGA-30989 amplifiers are shown in Figures 23 and 24.

Figure 26 shows the MGA-30789 amplifier schematic with the output match circuit optimized for OIP3 performance.

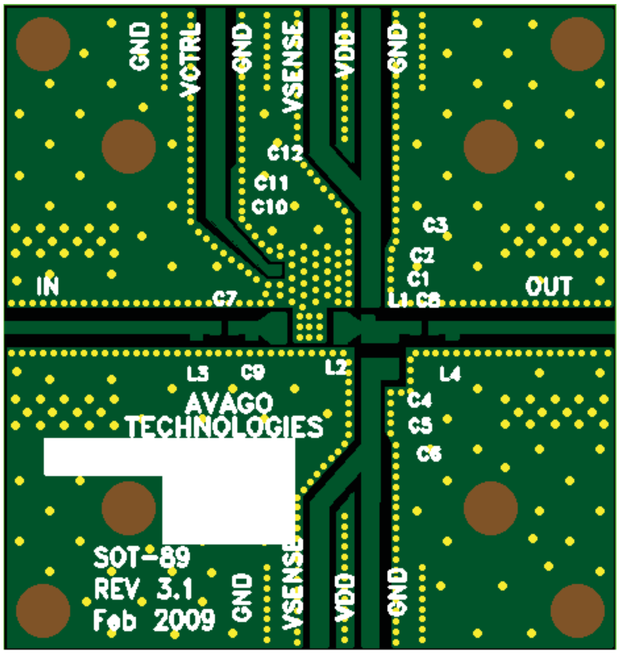

Figure 22. Demonstration Board Top View

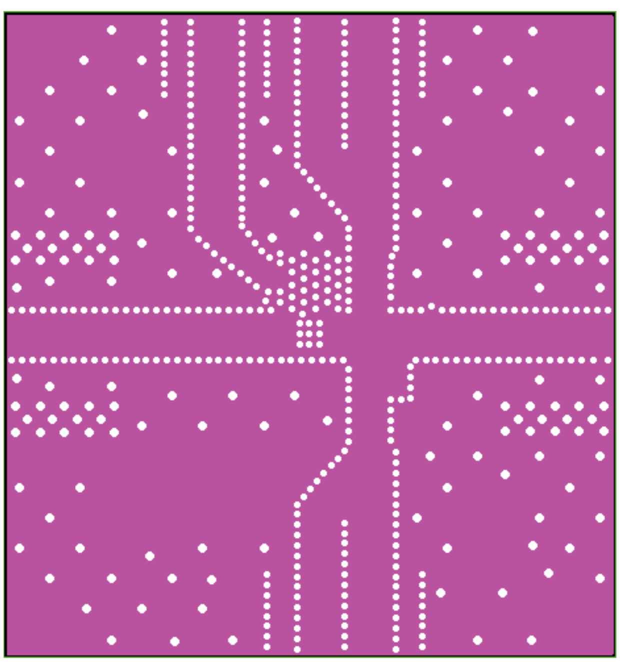

Figure 23. Demonstration Board Bottom View

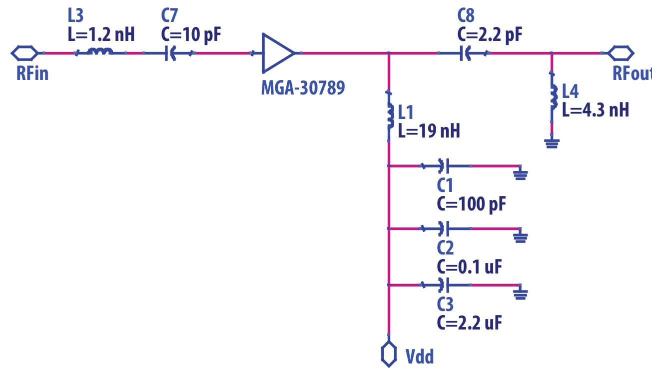

Figure 24. MGA-30789 Schematic for 2 to 3 GHz

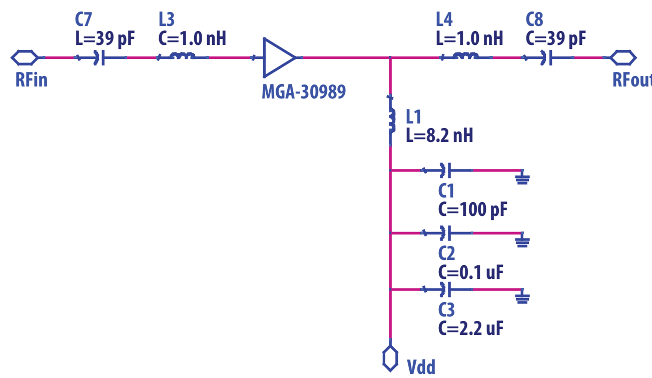

Figure 25. MGA-30989 Schematic for 2 to 4 GHz

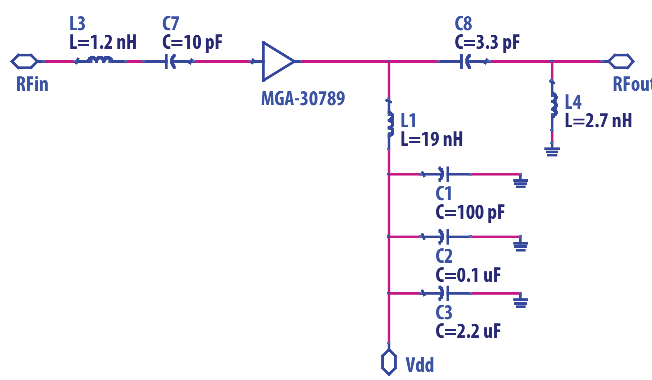

Figure 26. MGA-30789 Output Matching for Optimized OIP3

Table 3. MGA-30789 BOM for 2 to 3 GHz Schematic

Circuit Symbol	Size	Value	Part Number	Description
L1	0402CS	19nH	0402CS-19NX (CoilCraft)	Wire Wound Chip Inductor
L4	0402	4.3nH	0402CS-4N3X (CoilCraft)	Wire Wound Chip Inductor
C1	0402	100pF	GRM1555C1H101JZ01 (Murata)	Ceramic Chip Capacitor
C2	0402	0.1uF	GRM155R71C104KA88D (Murata)	Ceramic Chip Capacitor
C3	0402	2.2uF	GRM21BR61E225KA12L (Murata)	Ceramic Chip Capacitor
C7	0402	10pF	GRM1555C1H100JZ01 (Murata)	Ceramic Chip Capacitor
L3	0402	2.2pF	GRM1555C1H2R2CA01 (Murata)	Ceramic Chip Capacitor
C14	0402	1.2nH	LL1005-FHL1N2 (Toko)	MLC Inductor

Table 4. MGA-30989 BOM for 2 to 4 GHz Schematic

Circuit Symbol	Size	Value	Part Number	Description
L1	0603	8.2nH	LLQ1608-F8N2 (Toko)	Wire Wound Chip Inductor
C1	0402	100pF	GRM1555C1H101JZ01 (Murata)	Ceramic Chip Capacitor
C2	0402	0.1uF	GRM155R71C104KA88D (Murata)	Ceramic Chip Capacitor
L3	0805	2.2uF	GRM21BR61E225KA12L (Murata)	Ceramic Chip Capacitor
L4	0402	1nH	LL1005-FHL1N0 (Toko)	MLC Inductor
C7	0402	1nH	LL1005-FHL1N0 (Toko)	MLC Inductor
C8	0402	39pF	CM05CH390J50AH (Kyocera)	Ceramic Chip Capacitor
C14	0402	39pF	CM05CH390J50AH (Kyocera)	Ceramic Chip Capacitor

Table 5. MGA-30789 BOM after output re-matched for OIP3

Circuit Symbol	Size	Value	Part Number	Description
L1	0402CS	19nH	0402CS-19NX (CoilCraft)	Wire Wound Chip Inductor
L4	0402	2.7nH	0402CS-2N7X (CoilCraft)	Wire Wound Chip Inductor
C1	0402	100pF	GRM1555C1H101JZ01 (Murata)	Ceramic Chip Capacitor
C2	0402	0.1uF	GRM155R71C104KA88D (Murata)	Ceramic Chip Capacitor
C3	0805	2.2uF	GRM21BR61E225KA12L (Murata)	Ceramic Chip Capacitor
C7	0402	10pF	GRM1555C1H100JZ01 (Murata)	Ceramic Chip Capacitor
L3	0402	3.3pF	GRM1555C1H3R3CA01 (Murata)	Ceramic Chip Capacitor
C14	0402	1.2nH	LL1005-FHL1N2 (Toko)	MLC Inductor

Conclusion

The designed and measured performance of a flat gain, wideband and high linearity 2.5 GHz WiMAX driver amplifier using the Avago MGA-30x89 has been presented. An exceptionally good OIP3 of 40 dBm has been achieved across the WiMAX frequency band. Additionally, a factor that affects OIP3, inductor Q, has been discussed. Overall MGA-30x89 amplifier performance is detailed in Table 6.

The Avago MGA-30x89 is a modern solution offering considerable performance and convenience advantages over previous WiMAX amplifier solutions.

Reference

1. P. MacIntosh, "Addressing The Ultra-Linear Requirements Of WiMAX Radio Systems", White Paper, M/A-COM, 2006.
2. R. S. Pengelly, "Improving the Linearity and Efficiency of RF Power Amplifiers", High Frequency Electronics, September 2002, pp. 26.
3. Chin-Leong Lim, "0.5 W High Linearity Power Amplifier for Broadband Wireless (3.3 ~ 3.9 GHz)", 2007 Korea-Japan MicroWave Conference.
4. "Characteristics of E-pHEMT vs. HBTs for PA Applications", White Paper, Avago Technologies, April 2003.

MGA-30x89 Performance Summary[1]

Table 6. MGA-30x89 Performance Summaries

Parameters	MGA-30789	MGA-30989	Unit
Supply Voltage, Vdd	5.0	5.0	V
Demonstration board Total Current, Idd	100.0	51.0	mA
Input Return Loss, S11	-13.2	-16.6	dB
Output Return Loss, S22	-10.9	-20.4	dB
Small Signal Gain, S21	13.5	14.2	dB
Gain Flatness	0.5	0.5	±dB
Reverse Isolation, S12	-28.0	-23.2	dB
Output 3rd Order Intercept Point, OIP32	39.5	37.4	dBm
Output 1-dB Gain Compression Point, OP1dB	24.8	22.7	dBm
Noise Figure, NF	4.2	2.3	dB

Notes:
1. Data based at 2.5 GHz
2. Fspacing = 10 MHz; Pin = -10 dBm/tone

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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