Application Note 5303

Introduction

The MGA-631P8 is a GaAs EPHEMT with an integrated active bias. The target applications are Tower Mounted Amplifier / Main LNA for cellular infrastructure including Personal Cellular System and UMTS bands. This paper provides application information for 900 MHz operation.

The MGA-631P8 is packaged in a miniature 2 by 2 mm leadless package. The package's bottom side has a ground contact in the centre with a large surface area for efficient heat dissipation and low inductance RF grounding.

This application note describes the use of the MGA-631P8 in an extremely high dynamic range low noise amplifier (LNA). The demo-board's nominal performances at 900 MHz are: - Gain (G) = 17.9 dB, Noise Figure (F) = 0.7 dB and output 1 dB gain compression (P1dB) = 18 dBm. Without any deliberate attempt to optimize the output match for best linearity, an output intercept point (OIP3) of 34.6 dBm can be easily achieved. The input and output return losses are better than 15 dB.

Biasing Requirement

The enhancement mode technology provides superior performance while allowing a dc grounded source amplifier with a single polarity power supply to be easily designed and built. The built-in active bias circuit takes care of the V_{GS} spread required to cope with the batch-to-batch variation in forward transconductance, g_m.

Circuit Description

The input network consisting of C1 & L1 provides a match to Q1's input and also impart a high pass characteristic to roll off an undesirable gain increase below the operating frequency. To reduce circuit loss at microwave frequencies, L1 should have the following characteristics: - high unloaded Q, (Q_{ul}) and, operated below its Self Resonant Frequency (SRF). High-Q wire-wound chip inductors are preferred to multilayer chip inductors to minimize potential degradation of noise figure and gain. Assuming that the matching network's loaded Q (Q_l) is known, the loss in the inductor can be estimated from: -

$$loss = 20\log\frac{Q_{ul}-Q_l}{Q_{ul}}$$

On the output side, L2 and C2 form the matching network. L2 also serves at the bias decoupling network in conjunction with C5 and C6. Resistor R1 provides a simple mean to tailor the gain to suit the application requirement. R1 nominal value is 100Ω; however, increasing R1 from 56Ω to 560Ω will increase the gain correspondingly from 16.5 to 19 dB.

This application note describes the use of the MGA-631P8 in an extremely high dynamic range low noise amplifier (LNA). The demo-board's nominal performances at 0.9 GHz are: - G = 17.5 dB and output P1dB = 18.9 dBm. Without any deliberate attempt to optimize the output match for best linearity, an output intercept point (OIP_3) of 35 dBm can be easily achieved. The input and output return losses are better than 20 dB.

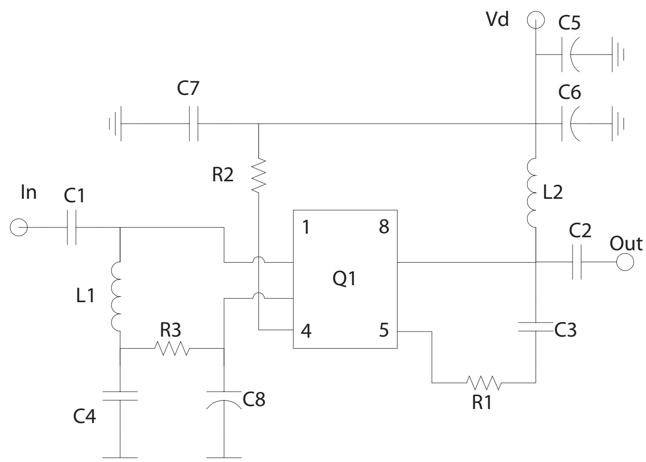

Figure 1. Demoboard circuit

Demoboard

A generic demonstration board is available for quick prototyping and evaluation of the MGA-631P8 in the VHF through 3 GHz range. The demoboard is made from 10 mil Rogers RO4350 substrate. An FR4 substrate is used as backing material to provide mechanical rigidity and to increase the overall thickness to 0.8 mm to suit standard edge launched coax transitions. RF connections to the demoboard are made via edge-mounted microstrip to SMA coax transitions, J1 and J2. The demoboard requires a single 4.0 V power supply.

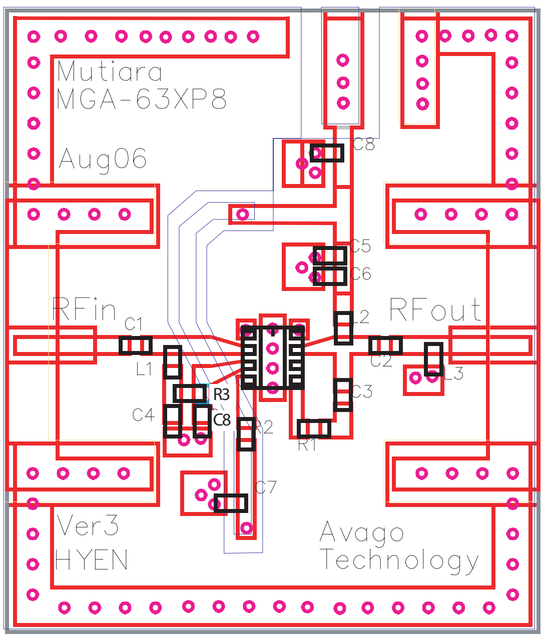

Figure 2. Component placement diagram

Measured performance

The demoboard performance was measured under the following test conditions: - V_d = 4.0 V, I_d = 60 mA and f_c = 900 MHz.

The MGA-631P8 is intended for either first or second stage LNA in cellular infrastructures. Both a low noise figure (NF) and a good return loss over a broad bandwidth are the critical requirements. Although a ceramic chip wire-wound inductor is suggested for the input matching network, it can be replaced with a higher Q air-core spring wound inductor for an even lower NF.

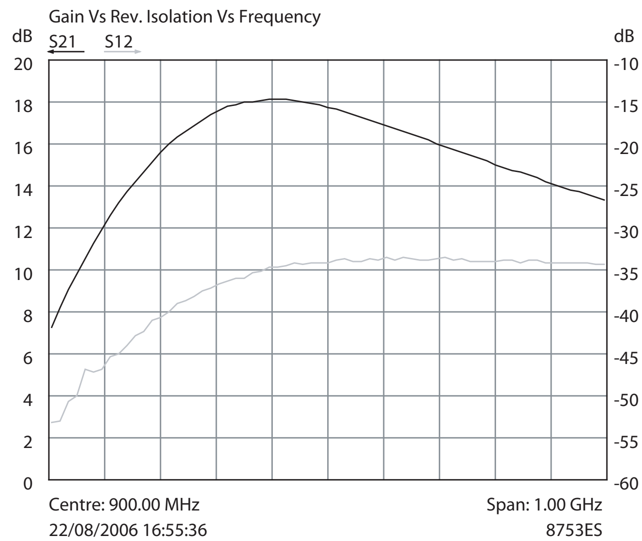

Figure 3. Gain and Reverse Isolation Vs. Frequency

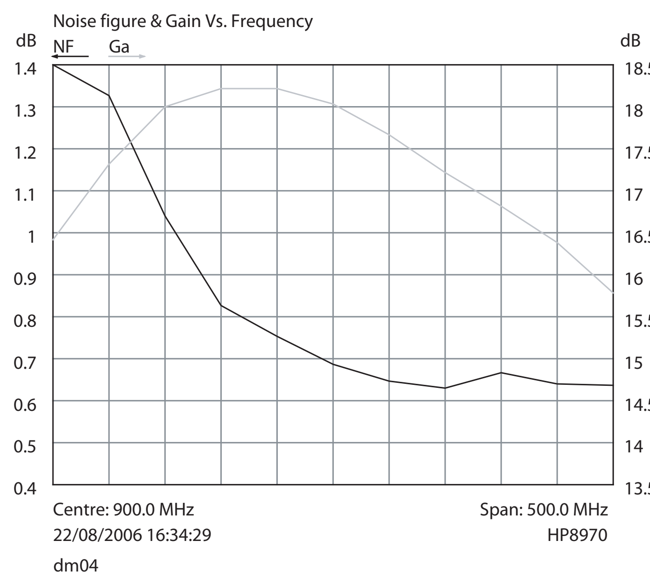

Figure 4. Gain & Noise Figure Vs. Frequency

The demoboard amplifier exhibits good input and output return losses over a wide bandwidth. This minimizes detuning effects when the LNA is cascaded with other stages in the RF chain. For example, filters and aerials are especially susceptible to the adverse effects of reflective terminations. Designing the amplifier's input and output for a close match to 50Ω over the operating bandwidth, prevents unpredictable shift in the cascaded frequency response.

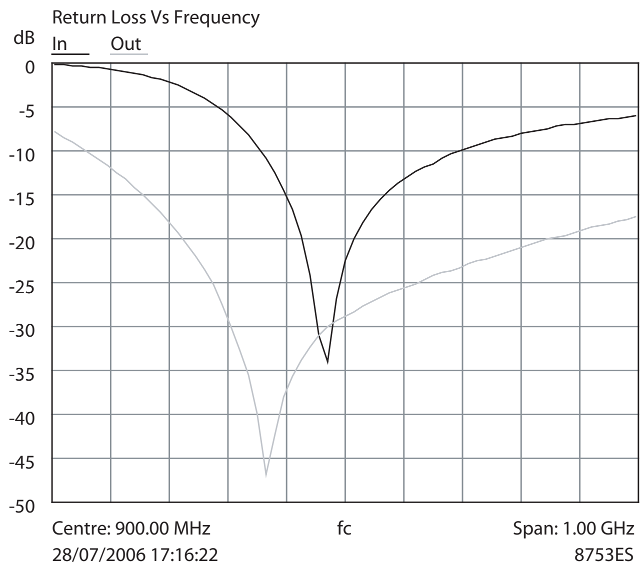

Figure 5. Input & output return loss vs. Frequency

Like all microwave transistors, the MGA-631P8's gain increase with decreasing frequency. If the low frequency gain increase is not rolled-off with the appropriate high-pass matching networks, the amplifier can break into self-oscillation below its operating frequency; in the tens of MHz range. To assess the effectiveness of the low frequency circuit stabilization described previously, the Rollett stability criterion was calculated from the measurement of the demoboard's s-parameters. The MGA-631P8 demoboard is designed to be unconditionally stable (k >1) over the range of frequencies that an 8753 network analyzer is capable of operating. This reduces the design effort required to adapt the MGA-631P8 into the final product.

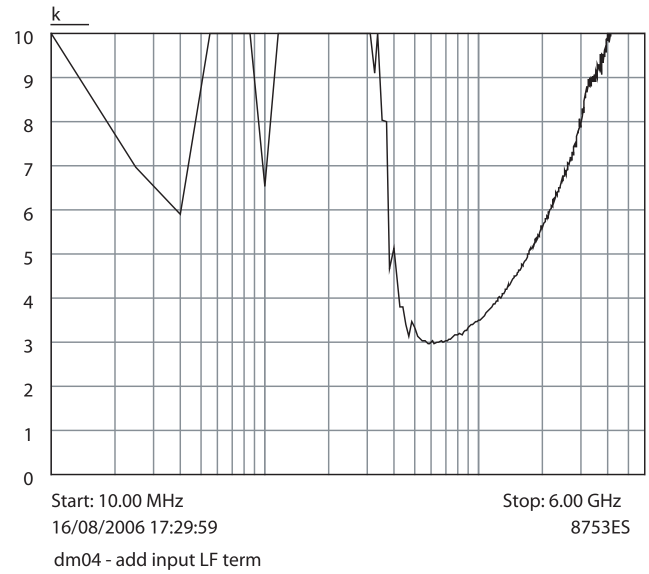

Figure 6. Stability factor vs. frequency (calculated from measured s-par)

Inadvertent coupling between the amplifier's input and output sides and other component parasitics can lead to instability in the upper microwave region. If there are pronounced gain peaks above its operating frequency, the amplifier may oscillate under certain operating conditions. In a wideband sweep test of the MGA-631P8 demoboard up to 20 GHz, no abnormal peak was observed in the frequency response.

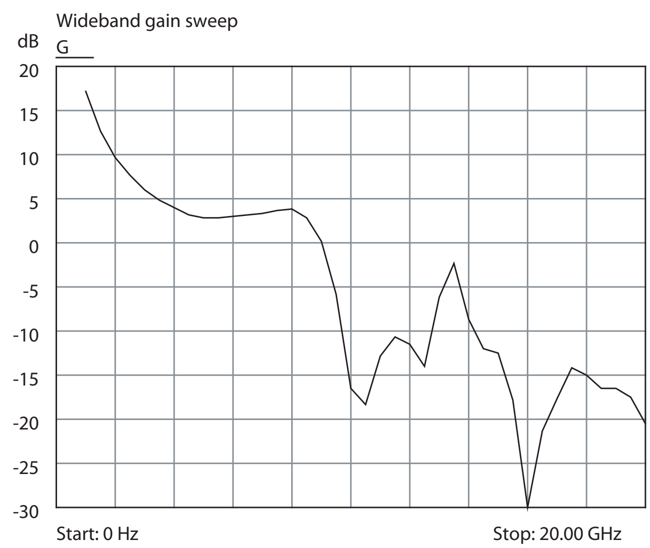

Figure 7. Wideband gain sweep

In third generation (3G) cellular systems such as WCDMA, the combination of high peak-to-average power ratio (PAR) of the hybrid-QPSK modulation and the simultaneous transmission and reception (frequency domain duplexing) impose a stringent linearity demand on the RF front-end. The duplex filters separating the transmit path from receive path have finite isolation. As a result, transmitter leakage may desensitize the LNA stage. The 1 dB gain compression point, P_{1dB}, indicates the upper limit of either the input or the output power level at which saturation has started to occur in the LNA. The GaAs PHEMT's well-recognized linearity advantage over other semiconductor technologies results in the MGA-631P8 having a relatively high P_{1dB} value of 18 dBm.

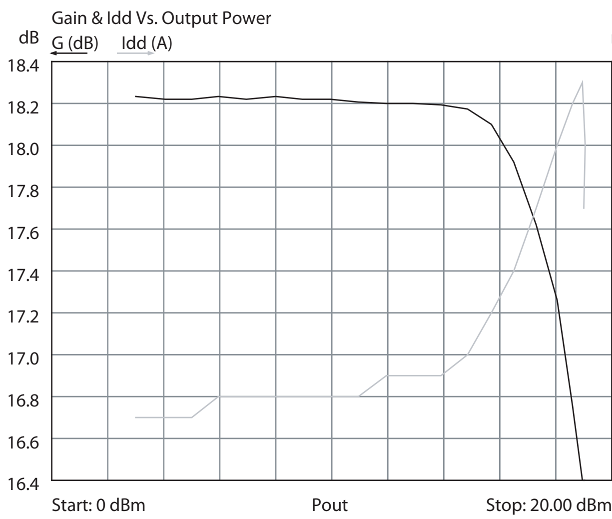

Figure 8. Gain & Current vs. Output Power at 900 MHz

The intercept point is another measure of amplifier linearity. The theoretical point when the fundamental signal and the third order intermodulation distortion are of equal amplitude is the third order intercept point, IP_3. The distortion level at other power levels can be conveniently calculated from the amplifier's IP_3 specification.

Two test signals spaced 5 MHz apart were used for evaluating the MGA-631P8 demoboard. The large dynamic range between the fundamental tones and the intermodulation products meant that the latter is barely above the spectrum analyzer's noise floor. To measure the 3rd order product amplitude accurately, a very narrow sweep span can be used to improve the signal to noise ratio. As a tradeoff from the narrow sweep span, only one fundamental and one 3rd order intermodulation output signals can be practically displayed on the graph. Both the fundamental and intermodulation tones are overlaid over the same frequency axis for amplitude comparison purpose. The IP_3, referenced to the output, can be calculated from: -

$$IP_3 = P_{fund} + \frac{\Delta IM}{2}$$

where is the amplitude of either one of the fundamental outputs, and is the amplitude difference between the fundamental tones and the intermodulation products.

The output intercept point, OIP_3, is approximately 35 dBm.

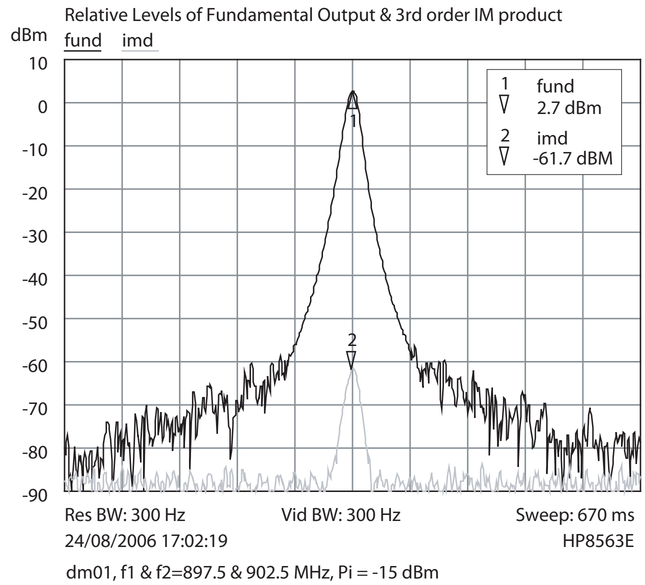

Figure 9. Fundamental output tone overlaid over the 3rd. order intermodulation product

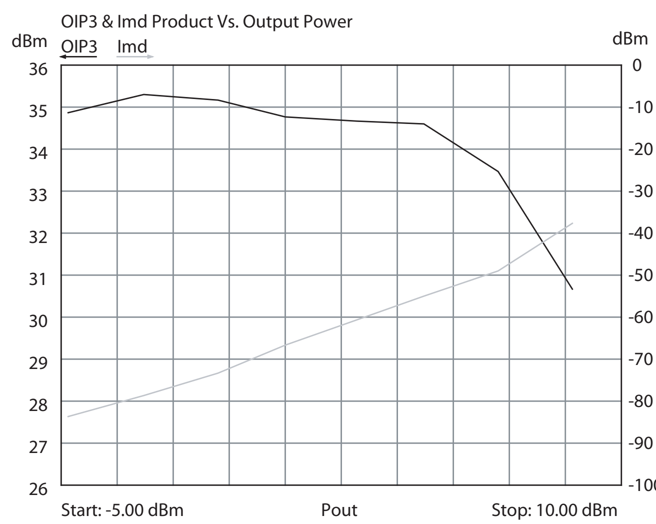

Figure 10. Output Third Order Intercept Point & Intermodulation Product vs. Output Power

The nominal performance of the MGA-631P8 demoboard is summarized below: -

Table 1. Demoboard nominal performance values

Vsupply (V)	4.0
Isupply (mA)	60
Fc (MHz)	900
G (dB)	17.8
F (dB)	0.7
RL in (dB)	< -20
RL in (dB)	< -20
k	> 1
P1dB (dBm)	18
OIP3 (dBm)	34.6

Demoboard part list

The demoboard's table of components is listed below.

Table 2. Part list

Part	Size	Value	Description
L1	0402	12 nH	Coilcraft 0402CS
L2	0402	19 nH	Coilcraft 0402CS
C1	0402	2.2 pF	
C2	0402	100pF	
C3	0402	5.6pF	
C4	0402	27pF	
C5	0402	0.1uF	
C6	0402	9pF	
C7	0402	0.1uF	
C8	0402	10 nF	
Q1		MGA-631P8	Avago Technologies
R1	0402	100 Ω	
R2	0402	510 Ω	
R3	0402	56 Ω	

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