High linearity Class B Power Amplifiers in GaN HEMT Technology

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A 36dBm, high linearity, single-ended Class B MMIC power amplifier is reported in GaN HEMT technology. The circuit demonstrates high linearity, greater than 35dBc of 3rd order inter-modulation (IM3) suppression and high power added efficiency (PAE) of 34 percent. Class B power amplifiers can achieve IM3 suppression comparable to that of Class A, while providing PAE ~10 percent higher than that of Class A. Single-ended GaN HEMT Class B amplifiers have efficiency and linearity equal to that of the push-pull Class B, but avoid the difficulty in fabricating microwave baluns suitable for push pull operation.

For operation in sub-octave bandwidths, a classical push-pull Class B power amplifier can be replaced by a single-ended class B amplifier with a low pass or band pass output filter. The single-ended Class B amplifier can achieve high PAE and high IM3 suppression simultaneously if the I_d vs. V_{gs} characteristics are linear above threshold [1] and if the V_{gs} bias voltage is set precisely at pinch-off. An output filter provides the even harmonic short-circuit termination required for Class B operation. Theoretical analysis has also been reported in [1].

The amplifier (Fig. 1) uses dual gate (cascode) GaN HEMT to reduce Miller multiplication of C_{gd} and increase breakdown voltage [2]. The input is matched with a broadband lossy network, and C_{ds} is absorbed into the output filter/tuning network. [2]. The amplifier is fabricated on a SiC substrate [3] (Fig. 2). The 0.25 µm L_g, 1.2 mm W_g HEMT has 1A/mm I_{dss}, >55V breakdown, and 55 GHz f_t. The circuit is tested with four different bias conditions: V_{gs}=-3.1V for Class A, -4V for Class AB, -5.1V for Class B and -5.5V for Class C. Single tone and two-tone measurements were performed. The 3rd order distortion output powers, $2f_1$-f_2 and $2f_2$-f_1, are measured with input signals at f_1 = 8GHz and f_2 = 8.001GHz.

The circuit under Class B bias condition exhibits 13dB gain at 8GHz with 7GHz to 10GHz bandwidth (Fig. 6). As expected, the gain under Class B bias is ~6dB less than under Class A. 35.5dBm saturated output power and 34% maximum PAE are obtained under Class B bias for single tone operation (Fig. 3a), and high IM3 suppression is obtained over a wide output power range for two-tone input signals (Fig. 3b). Under Class A bias, (Fig. 4a,b), the IM3 output power increases rapidly with input power, making IM3 suppression very poor at high output power levels.

To compare classes A, AB, B, and C, the PAE and IM3 suppression vs. output power are plotted in Fig. 5 and 7. At low output power levels, Class A is very linear (>50dBc), while IM3 suppression of Class B also maintains a >40dBc level. At high power levels, however, Class B has IM3 suppression similar to Class A, but provides 10% greater PAE (Fig. 7).

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Reference:

[1] Paidi, V., et. al., "Simulations of high linearity and high efficiency of Class B power amplifiers in GaN HEMT technology*", IEEE Lester Eastman Conference on High Performance Devices*, Aug., 2002.
[2] Krishnamurthy, K., et al., "Broadband GaAs MESFET and GaN HEMT Resistive Feedback Power Amplifiers." *IEEE Journal of Solid State Circuits*, Vol. 35, No. 9, pp. 1285-1292, Sept 2000.
[3] Coffie, R. et. al., "Dual-gate AlGaN/GaN modulation-doped field-effect transistors with cut-off frequencies f_τ >60 GHz", *IEEE Electron Device Letters*, vol.21, (no.12), IEEE, Dec. 2000. p.549-51.

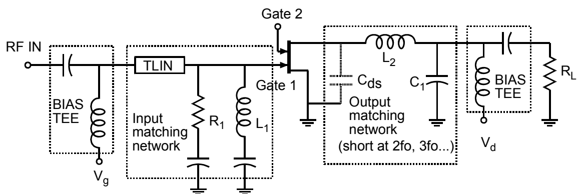


Figure 1: Circuit schematic

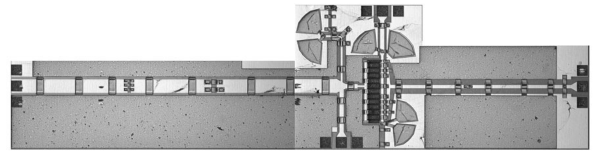
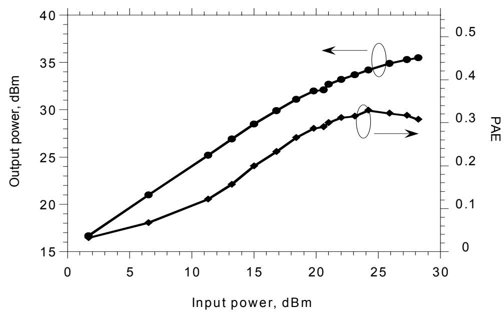
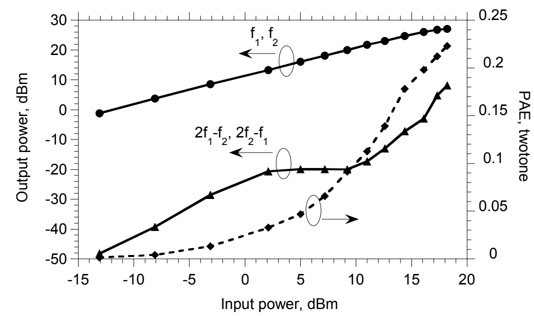


Figure 2: IC photograph (dimensions 6mm x 1.5mm)

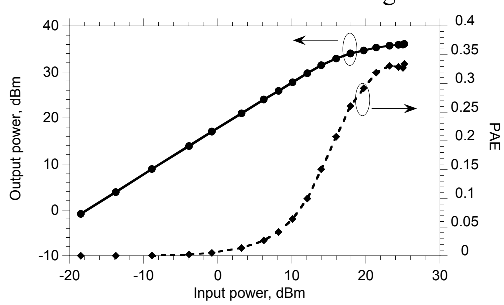


(a) Single tone output power and PAE

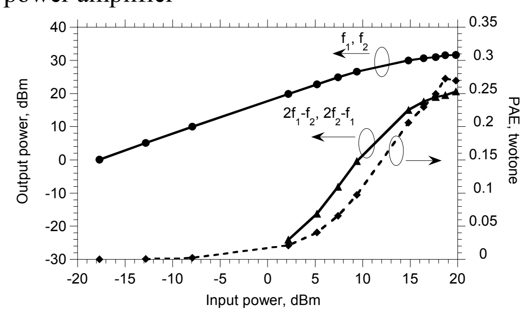


(b) Two-tone output power and IM3 suppression

Figure 3: Class B bias power amplifier

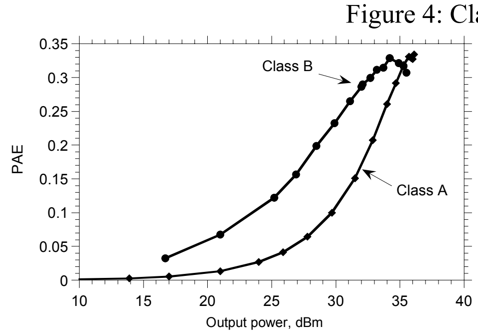


(a) Single tone output power and PAE

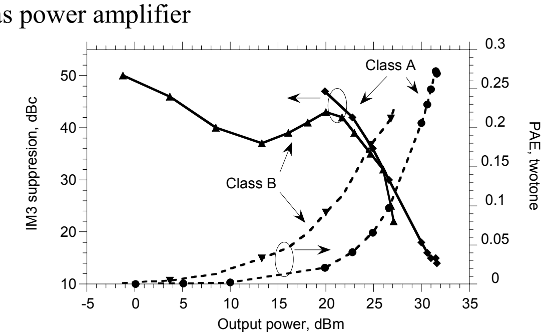


(b) Two-tone output power and IM3 suppression

Figure 4: Class A bias power amplifier



(a) Single tone PAE



(b) Two-tone PAE and IM3 suppression

Figure 5: Summary of comparing of Class B and Class A

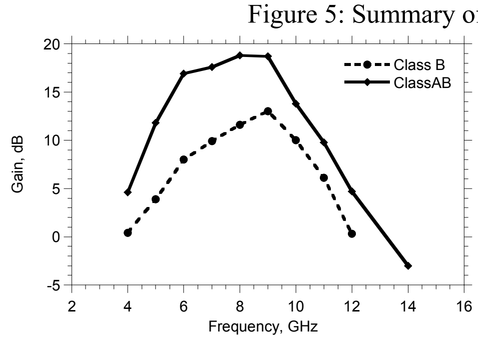


Figure 6: Gain vs. frequency

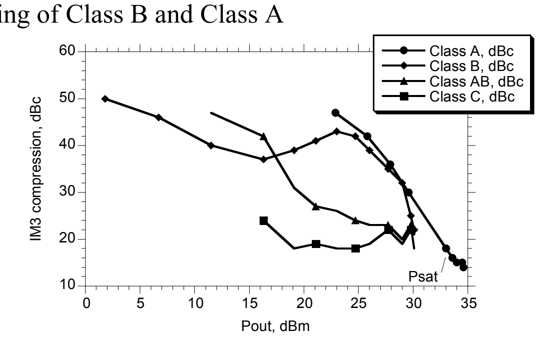


Figure 7: Summary of IM3 suppression