TriQuint SEMICONDUCTOR®

Product Application Note **May 16, 2003**

Improvements in Linearity Performance of Millimeter Wave HPAs

Introduction: During the last several years, linearity requirements for millimeter wave High Power Amplifiers (HPA) have increased significantly, primarily due to the move toward higher order modulation schemes for digital radio transmitters. In the past, many point-to-point radios used in cellular back-haul applications, operated in constant envelope, saturated power modes or other low order modulation schemes. Today it is more common to see requirements for digital modulation schemes from QPSK up to 128 QAM. This change in requirements demands that MMIC suppliers have a method for delivery of high linearity amplifier components with consistent performance.

Method: Over the last two years, TriQuint has implemented a project to systematically improve our capability to deliver high linearity millimeter wave HPA MMICs. This project, comprised of a cross-functional team of design, product, process and test engineers, has made significant progress toward our goals. Improvements were achieved by implementing tighter controls of critical wafer fabrication processes which have a direct effect on linearity, coupled with improvements in the measurement and screening operations. It is important to note that this approach did not require a change in the existing standard power pHEMT process or a new process to be developed, but rather a tightening of a process variable while staying within the standard process. This narrowing of the process variable “window” has a first-order effect on reducing the variation in linearity performance across a wafer. This will be referred to as the “enhanced process” in this article. The enhanced process produces improvements in both TOI mean performance and overall TOI variability. Additionally, improvements in the test and screening operations allow delivery of 100% tested, known-good-die (KGD) for customer applications.

Results: As stated above, the primary result from the enhanced process is a narrowing of the measured TOI distribution toward the top end of the existing distribution. While, for a given MMIC design, the best case linearity may not be improved, the average of the distribution over multiple wafers and lots will be higher and the distribution sigma will be reduced. This result, coupled with 100% on-wafer testing of TOI, allows reliable and consistent-performance delivery of KGD for customer applications. Figure 1 below illustrates on-wafer, 23GHz TOI distributions for the TGA1135 (EG1157), 1W standard product HPA. The three distributions show results for:

1) two wafer lots using the standard process, (i.e. without additional control of the process parameter), and

2) one typical lot using the enhanced process.

Results clearly indicate that the enhanced process lot exhibits a higher mean TOI value and a very tight distribution. It is important to note that all lots shown in Figure 1 exhibited similar small signal and power performance. If HPAs are screened using only small signal and power data, delivery of some devices that are poor TOI performers is possible. TriQuint is able to implement 100% on-wafer TOI screening on all high linearity devices to eliminate that possibility.

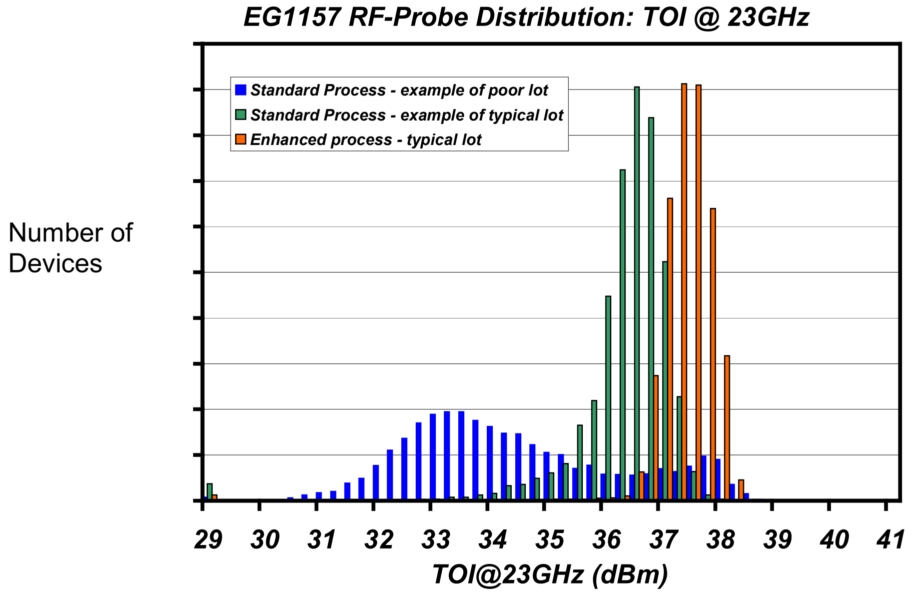

Figure 1 – TOI Distributions for TGA1135

Enhanced Process Effect on RF Small Signal and DC Parameters

This information is included to inform and advise foundry customers who may plan to utilize the enhanced process, of the effect on device model parameters

RF small signal parameters: Most small signal parameters remain unchanged. However, TriQuint has observed a consistent increase of 7.4% in Cgd over 7 lots measured. This represents about 0.80 sigma of the total standard Cgd distribution. Table 1 below summarizes the data.

It should be noted that TriQuint will not be releasing new models specifically for the enhanced process. Therefore, TriQuint recommends that foundry customers choosing to utilize the enhanced process should investigate the sensitivity of their designs to a slightly higher mean Cgd.

process	waferid	CDS	CGD	CGS	FT2	GMM	RDS	RI	TAU
modified	mean	0.0690	0.0310	0.439	37.37	0.1103	257.73	2.79	2.79
	stdev	0.0031	0.0015	0.022	1.13	0.0034	9.11	0.17	0.19
	%stdev	4.5506	4.8083	4.979	3.03	3.0587	3.53	6.21	6.85
std_stats	mean	0.0706	0.0288	0.447	37.00	0.1104	268.08	2.84	2.90
	stdev	0.0055	0.0027	0.032	1.80	0.0065	24.15	0.36	0.26
	%stdev	7.7652	9.3660	7.263	4.85	5.8414	9.01	12.51	9.06
%Deltas		-2.36	7.44	-1.73	1.01	-0.12	-3.86	-1.94	-3.71

Table 1 – Summary of Small Signal Parameters

DC Breakdown Voltage: A shift in breakdown voltage has been observed as shown in the BVGD comparison shown in Figure 2. Wafers using the "enhanced process" show the measured BVGD distribution shifting towards the lower end of the existing distribution. This shift in breakdown voltage performance introduces no change in the specification for TriQuint standard products and in general is an excellent trade-off for foundry customers requiring higher linearity performance for circuits operated at VDS= 7V or less.

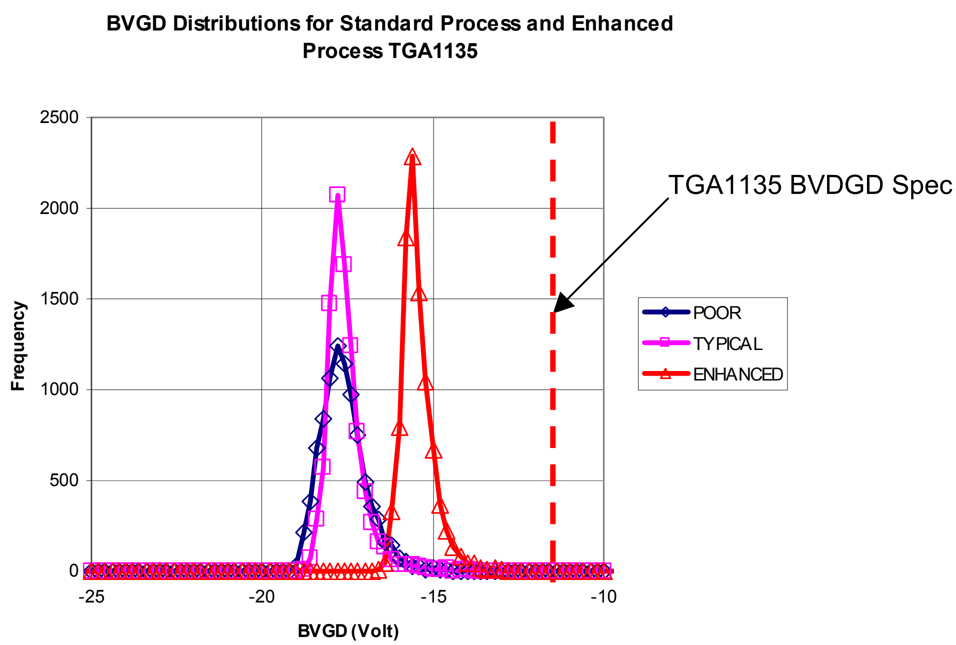

Figure 2 – BVGD Distributions for TGA1135

Reliability: DC life tests have indicated no issues resulting from the use of the enhanced pHEMT process flow.

Conclusions: TriQuint has made the commitment to deliver high performance, high linearity products through a combination of selectively controlling critical wafer fabrication processes, coupled with improvements in our measurement and screening operations. The result is an increased capability to deliver KGD to specified linearity requirements. All TriQuint millimeter wave standard products designed for high linearity applications will be processed and tested utilizing this method. Additionally, we can offer and recommend this as an option to our foundry customers for millimeter wave HPA designs that require linearity vs. saturated power performance.

For additional information, please contact TriQuint Texas Applications Engineering Department at 972-994-5691 or TriQuint Texas Foundry Services at 972-994-4545