G16 High Power Device Qualification Report For FAB 3

Abstract

This report summarizes qualification test results obtained on a product manufactured with the G16 process (TQTRx) from the Dawson Creek Facility (FAB 3). The test vehicle used in this G16 process assessment is TriQuint's TQ9147 standard product encapsulated in a SOIC16 plastic package with thermal tab. Two batches of this product were assembled and encapsulated by Lingsen in Taiwan.

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Introduction:

The TQ9147 is a standard product that is manufactured on the G16 process from FAB 3 (Hillsboro, Oregon). The TQ9147 was chosen to qualify the G16 process for high power applications. This device is a power amplifier that outputs +32 dBm at 60% efficiency with a 4.8 Volt power supply.

Table 1 lists the various tests that were performed on the TQ9147. Two "batches" of devices were run through the battery of tests. These batches came from 2 different wafer runs. Table 2 lists the batches used for this qualification.

Table 1. Qualification Test Plan.

Item #	Test Name	Specification/Duration	Test Points	Sample Size/ Max. Accept #
1	Temperature Cycles	-40°C to +125°C, for 1000 cycles 10 minute minimum dwell time, < 1 minutes transfer time.	500 and 1000 cycles	77 / 1
2	Lifetest	VDD biased at 4.8 Volts. Gates biased by an external circuitry. +7 dBm RF input @ 810 MHz. Case Temperature, 110°C	250, 500 and 1000 hours	49 / 0
3	Bake *For Information only*	Unbiased 150°C Ambient	500 and 1000 hours	N/A
4	Thermal Shock	-40°C to +125°C, for 100 cycles 2 minute min. dwell time, < 10 seconds transfer time.	100 cycle and 500 cycle *500 cycle results used for information only*	77 / 1
5	Autoclave	121°C at 100 % Humidity 96 hours.	96 hours	77 / 1
6	HAST	130°C at 85% Humidity 50 hours under a low power biased condition.	50 hours	77 / 1
7	Precondition	24 hrs of 125°C Bake 168 hrs of 85/85 Humidity 3 IR Cycle (220°C Max.)	Performed before Temperature Cycle, Autoclave and HAST testing.	0 Failures

Table 2. Batch Information.

Lot #	Batch #	Wafer Run #	Assembly Subcontractor	Package Date Code
1	3264	015373-A02	Lingsen	9742
2	3329	015374-A02	Lingsen	9742

Device Description:

The TQ9147 is a highly efficient power amplifier developed to operate in the AMPS cellular band of 824 MHz to 849 MHz. The amplifier is designed to output +32 dBm of power with +7 dBm input power at 60% efficiency. For biasing, the amplifier uses +4.8 Volts to drive VDD and the RF Output (through an RF choke). The TQ9147 is a two stage amplifier where the gain of each stage is controlled externally. There is a recommended gain control circuitry that sets the gain for maximum efficiency. This external circuitry uses 4.8 Volts and -3.5 Volts to set VG1 at -1.5 Volts and VG2 at -2.2 Volts. The TQ9147 is manufactured on the G16 (TQTRx) process with a die size of 63 mils by 51 mils and 7 mils thick. The die is assembled into a SOIC16 Batwing plastic package. Conductive epoxy is used as the die-attach and 1.3 mil gold bond wires are used to bond the circuit to the package lead frame. The two batches used were assembled by Lingsen.

The TQ9147 circuit uses some of the elements and interconnects that are available in the G16 process. There are 8 capacitors that cover approximately 116 K-um^2 of area. In addition to the capacitors, this circuit contains 7 NiCr resistors, and 48 D-FETs. Two spiral inductors are used which are equivalent to 16.4 nH of inductance. Around the die there are 23 bond pads of which 22 are bonded out to the lead frame.

Test Descriptions and Test Results:

Table 3 summarizes the test results for the various lots. Parts were tested on standard production test systems using the QA specification limits. The failure criteria for reliability assessment is a significant change in device performance. Table 4 lists the measured parameters and the QA limits. Parts that failed the QA limit specifications during a test point were retested several times on the same production test system. If the failure occurred at an interim test point due to a parameter shift, then the part was placed back into test for measurement at the next test point. Parts that failed the end point test were retested, if the results were similar, then tests were repeated on the bench with a hand test fixture and/or soldered down on an evaluation board.

Table 3. Test Results For TQ9147 (Results listed by: Sample Size / Test Rejects)

Test	Test Points	Batch # 3264	Batch # 3329
Temperature Cycle	**Precondition**	77 / 0	77 / 0
	500 Cycles	77 / 0	77 / 0
	1000 Cycles	77 / 0	77 / 0
Lifetest	**250 Hours**	49 / 0	49 / 0
	500 Hours	49 / 0	49 / 0
	1000 Hours	49 / 0	49 / 0
Bake	**500 Hours**	75 / 0	77 / 0
	1000 Hours	75 / 0	77 / 0
Thermal Shock	**100 Cycles**	77 / 0	75 / 0
	500 Cycles	77 / 0	75 / 1
Autoclave	**Precondition**	100 / 0	100 / 0
	96 Hours	100 / 1	100 / 0
HAST	**Precondition**	77 / 0	77 / 0
	50 Hours	77 / 0	77 / 0

Table 4. Test and Test Limits.

PARAMETER	UNITS	QA MIN	QA MAX
IDD_Q	mA	0	300
IDD1	mA	0	150
IDD2	mA	0	690
AMP_EFF @ 824 MHz		0.55	-
AMP_EFF @ 849 MHz		0.55	-
AMP_POWER OUT @ 824 MHz	dBm	31.5	-
AMP_POWER OUT @ 849 MHz	dBm	31.5	-

Temperature Cycling (Air to Air)

Procedure: Precondition all the parts at Level 1 (JESD22-A113-A). After Preconditioning, subject parts to 1000 Cycles from -40°C to +125°C with a dwell time of no less than 10 minutes, transfer time of less than 1 minute, 48 cycles per day. Test points are at time 0, Post-Precondition, 500, and 1000 cycles.

Purpose: This test checks the mechanical integrity of the packaged device including the die attach, wire bonds, and leads.

Failure: Any device that does not meet the electrical end point parameters, and/or has visual defects on the case or the leads.

Results: Batches 3264 and 3329 completed the Precondition test without failures.

Both batches continued to have no failure at end of 500 and 1000 cycles.

HTOL (High Temperature Operating Lifetest)

Background: The worst operating condition for the TQ9147 is under RF bias. To perform a lifetest at the maximum case temperature of 110°C and under RF bias an EJ Burn-in system was used. The EJ Burn-in system is designed to only heat the part, this allows the biasing circuitry and RF stimulus to be maintained at room temperature. Because or the limited space on the EJ Burn-in system, and the complexity of using RF stimulus, the quantity of parts was limited to a sample size of 49 pieces.

Procedure: HTOL is a biased test, operated at 110°C case temperature for 1000 hours, with interim test points at 0, 250, 500, and 1000 hours. VDD biased at 4.8 Volts, gain control circuitry sets VG1 at -1.5 Volts and VG2 at -2.2 Volts. The RF Input is driven with an RF stimulus operating at 810 MHz at +7 dBm. The +7 dBm input power is the power level used for production testing and during the characterization of the TQ9147.

Purpose: To determine the long term effects of bias conditions and temperature.

Failure: A device is considered a failure if it exceeds the specified parameter limits or cannot demonstrate functionality under the normal and/or worst case conditions.

Results: Batches 3264 and 3329 had no failures through 1000 hours. One part from Batch 3264 was damaged during the 250 hour read point, Part Number 216. This part had normal RF performance at test, but the IDD2 was just out of specification. When the test was reconfigured to measure IDD_Q, the power supply reached current limit when the part was turned “on”. The device was retested on a bench setup, the IDD2 current exceeded the power supply current limit of 1 A. The second stage amplifier was still drawing maximum current. Curve tracer testing found that the VG2 control pin was shorted to ground, measuring 30 ohms. Visual inspection found excessive electrical damage to the RF Output FET due to the high current generated when the gate is shorted to ground. It is assumed that Part Number 216 was damaged by an EOS event during the testing of the part at the 250 hour test point.

Bake Lifetest

Procedure: Unbiased Lifetest at 150°C ambient for 1000 hours with an interim test point at 500 hours.

Purpose: For information only. Looking for catastrophic failures caused by long term effects of high temperature.

Failure: Catastrophic failure.

Results: Batches 3264 and 3329 had no failures through 1000 hours. Batch 3264 had two parts that were mechanically damaged by the handler at the 500 hour read point. No measurements could be taken for these damaged parts at the 500 hour read point.

Thermal Shock (Liquid to Liquid)

Procedure: Unbiased test. Perform 100 cycles from -40°C to +125°C with a 2 minute minimum dwell time and less than 10 second transfer time. For information only, some groups completed up to 500 total cycles.

Purpose: To check the mechanical integrity of the packaged device, including the die attach, wire bonds, and leads.

Failure: Any device that does not meet the electrical end point parameters, and/or has visual defects on the case or the leads.

Results: Batch 3264 completed 100 and 500 cycles with no failures.

Batch 3329 completed 100 cycles with no failure. Two parts were mechanically damaged by the handler at the 100 cycle read point. One failure occurred at the completion of 500 cycles. Part Number 278 failed for high current and low power output. I_{DDQ} measured 1 Amp, I_{DD1s} measured around 113 mA, I_{DD2s} measured around 800 mA and the Power Output measurements were at -12 dBm. Curve tracer testing found that VG2 was shorted to ground, (normally this pin is seen as a normal diode curve). Visual inspection found excessive electrical damage to the RF Output FET due to the high current generated when the gate is shorted to ground. The short may have been caused by ESD or by poor connection to the gain control pin during test.

Autoclave

Procedure: Unbiased test at 2 Atm of Saturated Steam, +121°C for 96 hours. Precondition testing at Level 1 (JESD22-A113-A) before Autoclave.

Purpose: To evaluate the moisture resistance of non-hermetically sealed, plastic packaged integrated circuits.

Failure: Any device that does not meet the electrical end point parameters, and/or has visual defects on the case or the leads.

Results: Both batches completed the Precondition test without any failures.

Batch 3329 had no failures at the completion of 96 hours.

Batch 3264 had 1 failure at the 96 hour read point. Part 41 failed high current and low power output. IDD_Q measured 1.1 Amps, IDD1s measured 230 mA, IDD2s measured 800 mA, and the power outputs measured -15 dBm. Curve tracer testing found that VG2 was shorted to ground, (measured 6 ohms to ground). Visual inspection found excessive electrical damage to several FET structures on the RF Output FET. Damage was caused by excessive current generated because the gate was shorted to ground. The short may have been caused by ESD or by poor connection to the gain control pin during test.

HAST

Procedure: A biased test at 130°C at 85% Relative Humidity and 33.5 PSI for 50 hours. The TQ9147 was biased with VDD set at 0 Volts and with VG1 and VG2 set at -3 Volts.

Purpose: To evaluate the reliability of the device in a humid environment. This test employs severe conditions of temperature, humidity and bias that accelerate the penetration of moisture through the external protective material or along the interface between the external protective material and the metallic conductors that pass through it.

Failure: Any device that does not meet the electrical end point parameters, and/or has visual defects on the case or the leads.

Results: Both batches completed the Precondition testing without failures.

Both batches completed 50 hours without failures.

Summary

Two batches of TQ9147 were subjected to a series of tests to stress the die and package and qualify FAB 3. The tests performed were Temperature Cycle, Biased Lifetest, Bake, Thermal Shock, Autoclave, and HAST.

Level 1 Preconditioning testing (as per JESD22-A113) was performed on parts prior to Temperature Cycle, Autoclave, and HAST stresses. 508 parts ran through Precondition without any failures.

Temperature Cycle, Lifetesting, Bake, Thermal Shock and HAST completed the minimum test requirement without any failures.

Batch 3329 completed Autoclave testing without any failures. Batch 3264 had one failure at the end of the stress. The failure was cause by an EOS event. With only one failure, this batch passes the criteria for lot acceptance.

Results of the qualification stress testing show that the G16 process is reliable for high power application.