TQ9203
G2 Device Qualification Report
For FAB 3

Abstract

This report summarizes qualification test results obtained on a standard product manufactured with the G2 process (QED/A) from the Dawson Creek Facility (FAB 3). The test vehicle used in this G2 process assessment is TriQuint's TQ9203 standard product encapsulated in a SOIC14 plastic package. This product is assembled and encapsulated by Mitsui in Japan.

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Introduction:

The TQ9203 has been previously qualified with devices manufactured on the G2 process from FAB 2 (Beaverton, Oregon). Since the performance of this device was previously established, and it is one of the highest volume products, the TQ9203 was chosen to qualify the G2 process from FAB 3 (Hillsboro, Oregon).

Table 1 lists the various tests that were performed on the TQ9203. Five "batches" of devices were run through the battery of tests. These batches came from 5 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 5 Volts. Ambient Temperature, 125°C Junction Temperature, 135°C	250, 500 and 1000 hours	77 / 1
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 minimum 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	100 / 1
6	HAST	130°C at 85% Humidity 50 hours	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 #	Package Date Code
1	3023	015278	9738
2	3024	015307	9738
3	3436	015400	9745
4	3576	015452	9746
5	3580	015501	9746

Device Description:

The TQ9203 is an RFIC Downconverter used in front-end designs for cellular communications. This device operates at an RF frequency range of 800 MHz to 1000 MHz with a single +5 Volt power supply. The TQ9203 is composed of a Mixer and two selectable RF inputs that each contain a Low Noise Amplifier. This circuit is manufactured on the G2 (QEDA) process with a die size of 63 mils square and is 10 mils thick. The die is assembled into a SOIC14 plastic package by Mutsui in Japan. Conductive epoxy is used as the die attach and 1.25 mil gold bond wires are used to bond the circuit to the package lead frame. A die coat is used to protect the die surface during encapsulation and provide a uniform electrical environment for the device.

The circuit uses all the elements and interconnects that are available in the G2 process. There are 13 capacitors that cover approximately 645 K-um^2 of area. In addition to the capacitors, this circuit contains 47 NiCr resistors, 36 N+ implanted resistors, 3 M-FETs, 18 D-FETs, 21 E-FETs and 8 Overlap Schottky Diodes. Three spiral inductors are used which are equivalent to 17.5 nH of inductance. Around the die there are 32 bond pads, of which 24 are bonded. This devices is an excellent assessment vehicle because it employs all these various elements.

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. For the qualification testing, the test specifications were widened to take into account the variability between test systems and test boards. The failure criteria for reliability assessment is a significant change in device performance. Table 4 lists the measured parameters, the QA limits and the qualification test limits. For gain, the QA specification limits were widened by 1 dB, the noise figure increased by 0.5 dB and the current limit widened by 1 mA. Parts that failed the QA limits specification 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 TQ9203J (Results listed by: Sample Size / Test Rejects)

Test	Test Points	Batch # 3023		Batch # 3024	Batch # 3436	Batch # 3576	Batch # 3580
Temperature Cycle	Precondition	77/0	100/0	77 / 0	77 / 0	77 / 0	77 / 0
	500 Cycles	77/2	100/0	77 / 0	77 / 0	77 / 0	77 / 0
	1000 Cycles	77/4	100/0	77 / 0	77 / 1	77 / 1	77 / 0
Lifetest	250 Hours	77 / 0		77 / 0	77 / 0	77 / 0	77 / 0
	500 Hours	77 / 0		77 / 1	77 / 0	77 / 0	77 / 0
	1000 Hours	77 / 0		77 / 1	77 / 0	77 / 0	77 / 0
Bake	500 Hours	26 / 0		77 / 0	50 / 0	49 / 0	59 / 0
	1000 Hours	26 / 1		77 / 1	50 / 0	49 / 0	59 / 0
Thermal Shock	100 Cycles	77 / 0		77 / 0	75 / 0	77 / 0	77 / 1
	500 Cycles	NA		NA	75 / 0	77 / 0	77 / 1
Autoclave	Precondition	77 / 0		77 / 0	100 / 0	100 / 0	100 / 0
	96 Hours	77 / 24		77 / 16	100 / 1	100 / 2	100 / 1
HAST	Precondition	77 / 0		77 / 0	77 / 0	77 / 0	77 / 0
	50 Hours	77 / 0		77 / 0	77 / 0	77 / 0	77 / 0

Table 4. Test and Test Limits.

PARAMETER	UNITS	QA MIN	QA MAX	Failure Criteria MIN	Failure Criteria MAX
IDD	mA	8.7	12.0	7.7	13
LNA 1 CON_GAIN	dB	18.9		17.9	
LNA 0 CON_GAIN	dB	18.0		17	
SYSTEM NF_RF1	dB		3.0		3.5
SYSTEM NF_RF0	dB		3.3		3.8

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^{o}C to +125^{o}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: All 6 batches completed the Precondition test without failures.

Batches 3024 and 3580 had no failures during cycling.

Batch 3023; the first group of parts (77 pcs) had 2 failures at 500 cycles and 2 additional parts at 1000 cycles. Failure analysis found that the tail bond to the ground down bonds for the two LNA current FETs were broken. A corrective action request was issued to the subcontractor regarding this assembly anomaly. A second group from the same batch (100 pcs) was run through Preconditioning and Temperature Cycle testing with no failures.

Batch 3436 had 1 failure at the end of 1000 cycles. Failure analysis found a shorted DC blocking capacitor at the LO Input pin (# 1). It is likely that Pin 1 was electrically overstressed during testing or while handling the device.

Batch 3576 had 1 failure at the end of 1000 cycles. Failure analysis found that the tail bond to the ground down bonds for the two LNA current FETs were broken. The resistance of these bonds measured > 2 K-ohms to ground. (Same root cause as Batch 3023).

HTOL (High Temperature Operating Lifetest)

Procedure: Biased test at 125°C ambient temperature for 1000 hours, with interim test points at 0, 250, 500, and 1000 hours. For this test, the TQ9203 was biased at 5 Volts. At an ambient temperature of 125°C, the channel temperature was estimated to be 135.5°C.

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 3023, 3436, 3576 and 3580 had no failures.

Batch 3024 had 1 failure at 500 hours, Part Number 9. Part Number 9 continued to fail at the end of 1000 hours. At 1000 hours, LNA 1 Gain measured -9.62 dB and LNA 0 measured -25.5 dB. Curve Tracer testing of the pins found that that Select pin (# 5) had been electrically damaged. Visual inspection found anomalies across the channel of the Select pin series diode causing the diode to be shorted. Other diodes in the logic circuit also had visual anomalies across the channel. Probing the circuit also found that the VDD voltage was not reaching the mixer section. The Mixer VDD input 15.5 ohm NiCr resistor was measuring 200 ohms. This degradation may have been caused by an overstress or an ESD event.

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: Batch 3436, 3576 and 3580 completed the Bake Lifetest without failures.

One parametric anomaly out of a sample size of 26 pieces was noted on Batch 3023. Part Number 8 exceeded the LNA 1 NF specification. The Noise Figure measured 3.53 dB, the qualification limit is 3.5 dB. No additional analysis was performed because this anomaly was very marginal.

Batch 3024 had 1 failure out of a sample size of 77 pieces. Part Number 45 measured 15.3 dB for LNA1 Gain and 14.4 dB for LNA 0 Gain. Failure analysis found that the tail bond to the ground down bonds for the two LNA current FETs were broken. The ground resistance of the LNA 1 current FET is 6.1 K-ohms and for LNA 0 current FET is 1.2 K-ohms to ground; these bonds normally measure 0 ohms to ground. This was another instance of an assembly issue not related to the design or process.

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 3023, 3024, 3436, and 3576 completed 100 cycles without failure.

Batch 3580 had 1 failure for a sample size of 77 pieces. Part Number 380 failed for low current and low gain in both channels. Failure analysis found that the tail bond of the wire bond that connects the Mixer IF_Out pin (# 14) to the die had broken loose, causing a high resistance connection. This connection supplies the 5 Volts to the drain of the output FET. This was another instance of an assembly issue not related to the design or process.

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: All 5 batches completed the Precondition test without failures.

Batch 3023 and 3024 were tested at 48 hours and at 96 hours. Both batches had a large number of Autoclave failures at both test points. Batch 3023 had 24 total failures out of a sample size of 77. Batch 3024 had 16 total failures out of a sample size of 77. All the failures failed for low gain. Some for one channel and others had both channels failing. Failure analysis found that two parts from Batch 3023, Part Numbers 33 and 44 had bonding problems. Part Number 33 had broken tail bonds of the down ground bonds for the LNA 0 current FET. Part Number 44 had broken tail bonds of the down ground bonds for both the LNA 1 and LNA 0 current FETs. Devices with the worse gain shifts were microprobed. It was found that the Threshold Voltage for E-FETs in the logic circuit had shifted negative. Some of the devices that had the most significant

negative Threshold shifts were bake 150°C ambient temperature for 36 hours, then remeasured. The Threshold shifted back to a nominal range. Placing these same samples back in Autoclave for 48 hours shifted the Threshold negative once again.

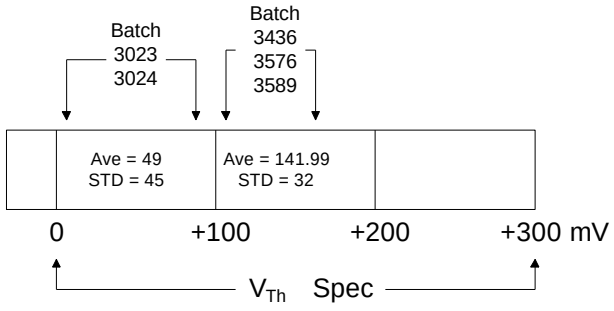
Batch 3436, 3576 and 3580 where picked as qualification vehicles because the PCM E-FET mean Thresholds value were near the center of the specification. See Figure 1.

Batch 3436 and 3580 had 1 failure each out of a sample size of 77 pieces per batch. For Batch 3436 Part Number 164 had gain 1 dB out side the failure criteria on both channels. No visual abnormalities were noted during inspection after decapsulation. Part Number 69 failed from Batch 3580. LNA 1 had gain 0.3 dB below the failure criteria and Noise Figure 0.25 dB outside the failure criteria. No visual abnormalities were noted when the die was inspected after decapsulation.

Batch 3576 had 2 failures from a sample size of 77 pieces. Part Number 37 failed for low current only; IDD measured 0.35 mA below the failure criteria. No visual abnormalities were noted when the die was inspected after decapsulation. Part Number 93 failed for low current and low gain in one channel; IDD measured 0.04 mA below the failure criteria, LNA 1 Gain measured 0.6 dB below the failure criteria. No visual abnormalities were noted when the die was inspected after decapsulation. Because both parts are marginal failures no further failure analysis was performed.

These investigations in Autoclave indicate a sensitivity of the TQ9203 design to the non-operating pressurized moisture environment of Autoclave testing, especially when the material has particularity low E-FET Threshold voltages. This anomaly was similarly noted in tests on FAB 2 material (see TQS Reliability Report #95-02). These anomalies are not expected to manifest in actual operation nor were they indicated in HAST testing.

Figure 1



Additional investigations in Autoclave have been conducted on similar devices utilizing the same process with different designs. The results in the table below provide data that alternate designs successfully complete autoclave testing.

Table 5. Alternate Design Autoclave Results

Part Type	Process	FAB	48 hour results (Pass/Fail)	96 hour results (Pass/Fail)
TQ9121	G2	FAB 2	80/0	80/0
TQ9122	G2	FAB 2	105/1	104/0
ASIC (2072)	G2	FAB 3	105/0	105/0

HAST

Procedure: A biased test at 130^{o}C at 85% Relative Humidity and 33.5 PSI for 50 hours. The TQ9203 was biased at 5 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: No failures were noted at 50 hours.

Summary

Five batches of TQ9203 were run through 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. No failures were noted after precondition testing.

Temperature Cycle found a bonding problem with Batch 3023. It was found that the bonding heater stage was mis-adjusted during the assembly of Bath 3023 and 3024. This mis-adjustment caused the capillary to damage the tailed bonds, so that under stress the tail bond would break way. A second group of parts for the same batch was run through Temperature Cycle, the lot passed. All the other lots passed the criteria for lot acceptance.

Parts in Lifetesting, Thermal Shock and HAST pass the criteria for lot acceptance.

Bake testing was performed information only. After batches were divided into lots for the other qualification tests, left over parts were placed into bake at 150^{o}C. The main function for the bake test was to look for catastrophic failures. One part was found to have a tail bond that became open during the stress.

The first two batches that were run through Autoclave had anomalies. Failure analysis found the E-FET Threshold voltage had shifted negatively causing the device to fail the gain and noise figure specification. The last three batches were chosen for more nominal initial PCM E-FET Threshold voltages. Two of the these nominal batches passed the criteria for lot acceptance, and the other batch had two minor anomalies.

As a side experiment, batches of TQ9203 that were manufactured in FAB 2 on the G2 process were run through Autoclave. Batches behaved similarly as to the batches manufactured in FAB 3, as they have historically. Additional autoclave testing was completed from both FABs on alternate designs, and they each passed the autoclave testing. The anomalies of the TQ9203 in autoclave appear to be design related.

Based on the results from the tests run with TQ9203 samples manufactured in FAB 3 and FAB 2 there is no difference in device reliability performance between the two FABs. Both sets of samples have demonstrated the capability of meeting the standard device reliability qualification test plan. Therefore, the G2 process is qualified in FAB 3.