G16 Low 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 TQ9203B product encapsulated in a SOIC14 plastic package. Two batches of this product were assembled and encapsulated by Mitsui in Japan. Another batch was assembled and encapsulated by Lingsen in Taiwan.

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Introduction:

The TQ9203 design is a standard product that is manufactured on G2 process. The design and layout were adjusted so it could be manufactured on the G16 process from FAB 3 (Hillsboro, Oregon). The product name was changed to TQ9203B to reflect the process change. The TQ9203B was chosen to qualify the G16 process for low power applications. This device typically draws about 53 mW at 5 Volts.

Table 1 lists the various tests that were performed on the TQ9203B. Three "batches" of devices were run through the battery of tests. These batches came from 3 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	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	77 / 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 #	Assembly Subcontractor	Package Date Code
1	4667	014878	Lingsen	9732
2	3233	015035-A03	Mitsui	9746
3	3262	014760-A01	Mitsui	9742

Device Description:

The TQ9203B 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 TQ9203B is composed of a Mixer and two selectable RF inputs that each contain a Low Noise Amplifier. This circuit is manufactured on the G16 (TQTRx) process with a die size of 44 mils by 44 mils. The die is assembled into a SOIC14 plastic package. 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. Two batches were assembled at Mitsui. Mitsui used die coat on the die surface during encapsulation. One batch was assembled by Lingsen. No die coat was used by Lingsen.

The circuit uses all the elements and interconnects that are available in the G16 process. There are 12 capacitors that cover approximately 178 K-um^2 of area. In addition to the capacitors, this circuit contains 21 NiCr resistors, 40 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 19 bond pads of which 17 are bonded out to the lead frame. This device 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 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 TQ9203B (Results listed by: Sample Size / Test Rejects)

Test	Test Points	Batch # 4667	Batch # 3233	Batch # 3262
Temperature Cycle	Precondition	77 / 0	77 / 1	77 / 0
	500 Cycles	77 / 0	77 / 1	77 / 0
	1000 Cycles	77 / 2	77 / 1	77 / 1
Lifetest	250 Hours	77 / 1	77 / 0	77 / 0
	500 Hours	76 / 0	77 / 0	77 / 0
	1000 Hours	76 / 0	77 / 0	77 / 1
Bake	500 Hours	77 / 0	NA	35 / 0
	1000 Hours	77 / 1	NA	35 / 4
Thermal Shock	100 Cycles	77 / 0	77 / 0	77 / 0
	500 Cycles	77 / 1	77 / 0	77 / 0
Autoclave	Precondition	77 / 0	77 / 0	100 / 0
	96 Hours	77 / 0	77 / 1	100 / 1
HAST	Precondition	77 / 0	77 / 0	77 / 0
	50 Hours	77 / 5	77 / 0	77 / 1

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: Batches 4667 and 3262 completed the Precondition test without failures. Part Number 191 failed for low gain and high Noise Figure for both channels from Batch 3233. LNA 1 Gain measured 16.7 dB and LNA 0 Gain measured 16.2 dB.

Batch 4667 completed 500 cycles with no failures. Two failures occurred at the 1000 cycle readout. Part Number 434 measured LNA 1 Gain at -2.38 dB with a Noise Figure of 19.9 dB. Part Number 442 measured 5.44 dB for LNA 1 Gain, with a Noise Figure of 11.1 dB and 4.61 dB for LNA 0 Gain, with a Noise Figure of 11.7 dB. Curve tracer testing found that the DC blocking capacitors on pin 9 (LNA Out) and pin 11 (Mixer RF IN) were shorted on both parts. Both parts were decapsulated for visual inspection. The surface of the die was damaged by the decapsulation process, so visual inspection was difficult.

Batch 3233 had 1 failure after Preconditioning, Part Number 191. Part Number 191 continue to failed after the 500 and 1000 cycle read point. Part Number 191 showed very little change during the test. At the 1000 cycle read point, LNA 1 Gain measured 16.1 dB

and LNA 0 Gain measured 15.7 dB. Curve trace testing found that the DC blocking capacitor on the LNA Out (pin 9) was shorted. No other failures occurred during the test.

Batch 3262 had 1 failure at the end of 1000 cycles. Part Number 12 failed marginally for low gain in both channels. LNA 1 Gain measured 0.6 dB outside the failure criteria and LNA 0 Gain measured 0.4 dB outside the failure criteria. No failure analysis was performed. Temperature Cycle is an unbiased test, so degradation of performance may have been caused by an ESD event during the handling of the parts.

HTOL (High Temperature Operating Lifetest)

Procedure: HTOL is a biased test, operated at 125^{o}C ambient temperature for 1000 hours, with interim test points at 0, 250, 500, and 1000 hours. For this test, the TQ9203B was biased at 5 Volts.

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: Batch 4667 had Part Number 315 fail catastrophically at the 250 hour read point. No other failures occurred during the lifetest. Failure Analysis found a burnt NiCr resistor due to an electrical overstress condition. This resistor is in series with the VDD input pin. Visual inspection could not find any other damage. Not all the die could be inspected because large areas on the surface of the die had been damaged by decapsulation. It is assumed that the DC bypass capacitor (C7) which is after the resistor, shorted during the test which then caused high current to flow and damage the resistor.

Batch 3233 had no failures.

Batch 3262 had 1 failure at the 1000 hour read point for low gain and high Noise Figure on both channels; Part Number 423. Part Number 423 measured 11.2 dB for LNA 1 Gain with a 5.1 dB Noise Figure and LNA 0 measured 10.8 dB with a Noise Figure of 5.19 dB. Curve tracer testing found that the Tune pin (pin 13) measured 15 ohms to ground. Visual inspection, after decapsulation found a small spot caused by EOS on a 0.4 pF capacitor (C13).

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 4667 had 1 failure at the 1000 hour read point; Part Number 373. Part Number 373 failed for low gain and high Noise Figure on both channels. LNA 1 Gain measured -21.4 dB with a Noise Figure of 31.3 dB and LNA 0 Gain measured -21.9 dB with a Noise Figure of 31.3 dB. Curve tracer testing found that the DC blocking capacitor on LNA 1 Input (pin 6) was shorted and the Tune pin (pin 13) was measured as a 5 ohm short to ground. Visual inspection was difficult because large areas of the die surface was damaged by the decapsulation process.

No parts were run through unbiased bake for Batch 3233.

Batch 3262 had 4 failures at the 1000 hour read point; Part Numbers 467, 469, 485 and 492. Part Numbers 469, 485 and 492 had both channels fail for low gain and high Noise Figure. Part Number 469 measured LNA 1 Gain at -1.59 dB with a 11.6 dB Noise Figure, LNA 0 Gain measured -1.97 dB with a 11.8 dB Noise Figure. Part Number 485 measured -19.3 dB for LNA 1 Gain with a 28.7 dB Noise Figure, LNA 0 measured -19.7 dB with a 29.2 dB Noise Figure. Part Number 492 measured 7.43 dB for LNA 1 with a 5.24 dB Noise Figure, LNA 0 measured 6.9 dB with a 5.55 dB Noise Figure. Part Number 467 failed only for low gain on LNA 1, the gain measured -34.5 dB with a 50.9 dB Noise Figure. Curve tracer testing found a shorted DC blocking capacitor on LNA 1 Input (pin 6) on Part Number 467; visual inspection found a small spot on C1 caused by EOS. The Tune pin (pin 13) on Part Number 469 measured as a 5 ohm short to ground; a small spot was noted on C13. Part Numbers 485 and 492 also had the Tune pin shorted to ground; visual inspection found a small dot at the edge of C13 on Part Number 485 and a small dot on top of C13 was noted on Part Number 492. All these anomalies appear to be caused by EOS/ESD phenomenon occurring during handling or electrical measurement.

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: All three batches completed 100 cycles with no failures.

At the completion of 500 cycles, Batches 3233 and 3262 had no failures. Batch 4667 had Part Number 17 fail for low gain and high Noise Figure for both channels. LNA 1 measured 15.7 dB with a 3.63 Noise Figure, LNA 0 measured 15.4 dB with a 3.59 dB Noise Figure. The LNA Out (pin 9) DC blocking capacitor was found to be shorted. The Mixer IF Output was found to be drawing 40% more current than a normal. A small spot was noted on top of LNA Out DC blocking capacitor, C6.

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 3 batches completed the Precondition test without failures.

Batch 4667 had no failures at the completion of 96 hours.

Batch 3233 had 1 failure at the 96 hour read point. Part 39 failed marginally. LNA 1 was out by 0.6 dB and the Noise Figure was out by 0.26 dB. LNA 0 was out by 0.3 dB and the Noise Figure was out by 0.07 dB. No failure analysis was performed on this device.

Batch 3262 had 1 failure at the 96 hour read point. Part Number 213 failed for low gain in both channels. LNA 1 Gain measured 16.3 dB with a 3.58 dB Noise Figure. LNA 0 Gain measured 15.7 dB, Noise Figure was within specification. Curve tracer testing found that the LNA Out (pin 9) DC blocking capacitor was shorted. A small spot on C6 (LNA Out DC blocking capacitor) was noted.

HAST

Procedure: A biased test at 130°C at 85% Relative Humidity and 33.5 PSI for 50 hours. The TQ9203B 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: All three batches completed the Precondition testing without failures.

Batch 4667 had 5 failures at the completion of 50 hours. Part Number 179 measured -23.5 dB for LNA 1 with a 32.5 dB Noise Figure, LNA 0 measured -24 with a 32.2 dB Noise Figure. Part Number 216 failed the LNA 0 measurement, gain measured -2.02 dB with a 19.4 dB Noise Figure. Part Number 225 measured -14.8 dB for LNA 1 Gain with a 34.7 dB Noise Figure, LNA 0 measured -44.6 dB with a 61.8 dB Noise Figure. Part Number 235 was a catastrophic failure. Part Number 240 measured 11.2 dB for LNA 1 gain with a 6.66 dB Noise Figure, LNA 0 gain measured 10.6 dB with a 6.93 dB Noise Figure. After testing, the failures were placed into an oven at 150°C for several days to bake out the moisture then re-tested. After bake the package leads were re-dressed before re-testing on the bench with a hand test fixture. All five parts passed the bench test. No failure analysis was performed.

Batch 3233 had no failures.

Batch 3262 had one failure at the end of 50 hours. Part Number 359 failed marginally for low gain in LNA1. LNA 1 measured 0.1 dB below failure criteria. No failure analysis was performed.

Human Body ESD Testing

Procedure: Mil-Std-883, Method 3015. Start Voltage at 50 Volts and step 25 Volts. Use a new part for each voltage polarity.

Purpose: During the failure analysis, pins 6 (LNA 1 In), 9 (LNA Out), and 13 (Tune) were in most cases found to be shorted. ESD testing was performed to determine the threshold of these pins.

Failure: Any change to the curve tracer characteristics.

Results:

Pin #	Pin Name	ESD Threshold Pin to GND		ESD Threshold Pin to VDD (pin 3)		ESD Threshold Pin to Mixer IF Out (pin 14)	
		Negative	Positive	Negative	Positive	Negative	Positive
6	LNA 1 In	-2100	425	-900	1600	N/A	N/A
9	LNA Out	-525	275	-400	350	N/A	N/A
13	Tune	-450	275	-600	300	-300	1500

Summary

Three batches of TQ9203B 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. Out of 716 parts run through Precondition, only one failure was noted. The one failure (Batch 3233) was found to have EOS damage.

Temperature Cycle was performed, Batches 3233 and 3262 pass the criteria for lot acceptance. Batch 3233 had a precondition failure, this failure was placed in the stress and the measured parameters did not change through out the test. Batch 4667 had two failures at the end of 1000 cycles. The two failures most likely damaged by an EOS event.

Parts in Lifetesting, Thermal Shock and Autoclave 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 purpose for the bake test, was to look for catastrophic failures. Parts from Batches 4667 and 3262 were stressed in bake. At the end of 1000 hours Batch 4667 had one failure and Batch 3262 had four failures. All the 5 failures were damaged by an EOS event.

Batches 3233 and 3262 pass the criteria for lot acceptance for HAST. Batch 4667 had 5 failures at the end of 50 hours of stress. These five parts were baked at 150^{o}C. After the bake, the parts passed when re-tested.

During the analysis of the failures, it was found that pins 6 (LNA 1 In), 9 (LNA Out) and 13 (Tune) were damaged by an EOS event. Visual inspection found physical evidence of EOS damage to some of the DC blocking capacitors and RF bypass capacitors. A Human Body Model ESD test was performed on the 3 pins. The lowest threshold for pin 6 was 435 Volts and 275 Volts for pins 9 and 13. Due to the amount of handling the parts see during the qualification testing, it is suspected that parts were electrically overstressed by and ESD event.

Results of the qualification stress testing show that the G16 process is reliable for low power application. Circuits designed in the G16 process should consider the sensitivity to an EOS event and take added counter-measures to protect the device.