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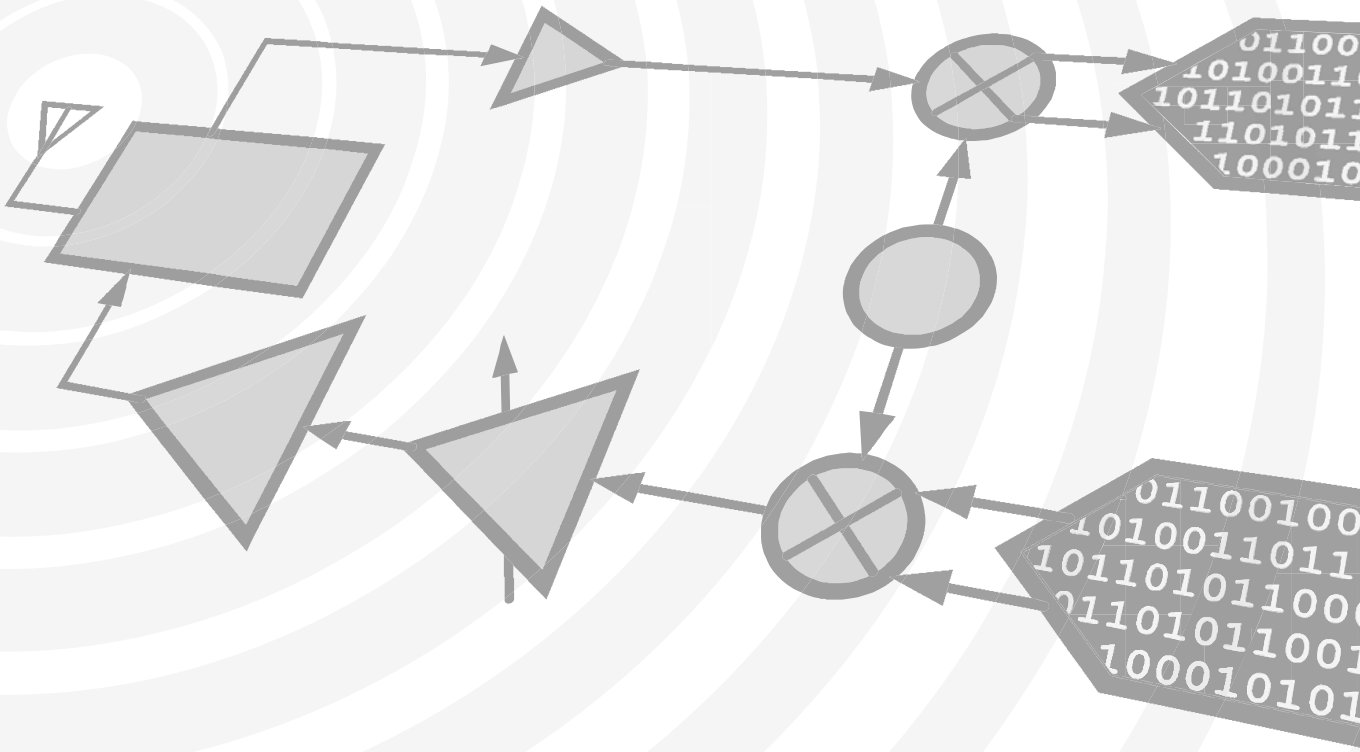

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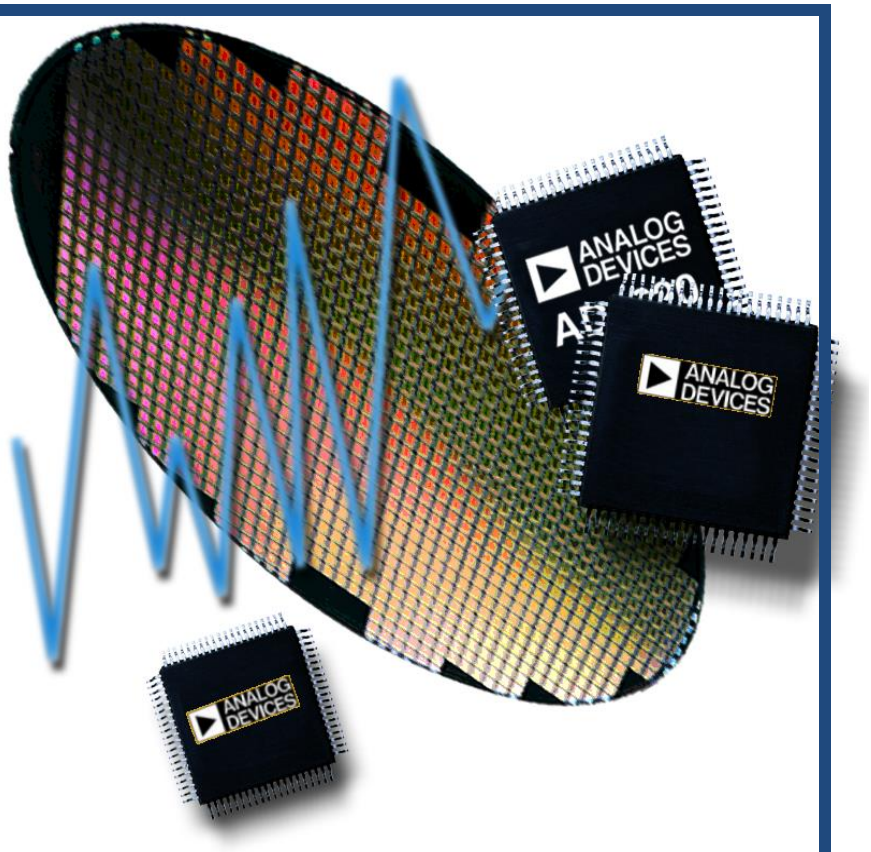

Reliability Report

Report Title: Qualification Test Report

Report Type: See Attached

Date: See Attached

QTR: 2013- 00236 **Rev: 03**

Wafer Process: SiGe HBT-B

HMC697
HMC862
HMC916
HMC917
HMC926
HMC6409

Hittite MICROWAVE CORPORATION
20 Alpha Road, Chelmsford, MA 01824
Ph: 978.250.3343 Fax: 978.250.3373
www.hittite.com

Introduction

The testing performed for this report is designed to accelerate the predominant failure mode, electro-migration (EM), for the devices under test. The devices are stressed at high temperature and DC biased to simulate a lifetime of use at typical operating temperatures. Using the Arrhenius equation, the acceleration factor (AF) is calculated for the stress testing based on the stress temperature and the typical use operating temperature.

This report is intended to summarize all of the High Temperature Operating Life Test (HTOL) data for the SiGe HBT-B process. The FIT/MTTF data contained in this report includes all the stress testing performed on this process to date and will be updated periodically as additional data becomes available.

Glossary of Terms & Definitions:

1. **CDM:** Charged Device Model. A specified ESD testing circuit characterizing an event that occurs when a device acquires charge through some triboelectric (frictional) or electrostatic induction processes and then abruptly touches a grounded object or surface. This test was performed in accordance with JEDEC 22-C101.
2. **ESD:** Electro-Static Discharge. A sudden transfer of electrostatic charge between bodies or surfaces at different electrostatic potentials.
3. **HBM:** Human Body Model. A specified ESD testing circuit characterizing an event that occurs when a device is subjected to an electro-static charge stored in the human body and discharged through handling of the electronic device. This test was performed in accordance with JEDEC 22-A114.
4. **HTOL:** High Temperature Operating Life. This test is used to determine the effects of bias conditions and temperature on semiconductor devices over time. It simulates the devices' operating condition in an accelerated way, through high temperature and/or bias voltage, and is primarily for device qualification and reliability monitoring. This test was performed in accordance with JEDEC JESD22-A108.
5. **HTSL:** High Temperature Storage Life. Devices are subjected to 1000 hours at 150°C per JESD22-A103.
6. **MSL:** Moisture sensitivity level pre-conditioning is performed per JESD22-A113.
7. **Operating Junction Temp (T_{oj}):** Temperature of the die active circuitry during typical operation.
8. **Stress Junction Temp (T_{sj}):** Temperature of the die active circuitry during stress testing.
9. **THB:** Temperature Humidity Bias. Devices are subjected to 1000 hours of 85% relative humidity at a temperature of 85°C while biased. This test is performed in accordance with JESD22-A101.

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10. UHAST: Unbiased Highly Accelerated Stress Test. Devices are subjected to 96 hours of 85% relative humidity at a temperature of 130°C and pressure (18.6 PSIG). This test is performed in accordance with JESD22-A118.

Qualification Sample Selection:

All qualification devices used were manufactured and tested on standard production processes and met pre-stress acceptance test requirements.

Summary of Qualification Tests:

HMC4376 (QTR2012-00275)

TEST	QTY IN	QTY OUT	PASS / FAIL	NOTES
Initial Electrical	359	359	Complete	
HTOL, 1000 hours	80	80	Complete	
Post HTOL Electrical Test	80	80	Pass	
HTSL, 1000 hours	80	80	Complete	
Post HTSL Electrical Test	80	80	Pass	
MSL1 Preconditioning	160	160	Complete	
MSL1 Preconditioning Final Test	160	160	Pass	
UHAST (Preconditioned)	80	80	Complete	
UHAST Final Test	80	80	Pass	
Temperature Cycle (Preconditioned)	80	80	Complete	
Temperature Cycle Final Test	80	80	Pass	
ESD	39	39	Complete	
Post ESD Test	39	39	Complete	HBM Class 1A MM Class <50V CDM Class II

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HMC6409 (QTR2012-00460)

TEST	QTY IN	QTY OUT	PASS / FAIL	NOTES
Initial Electrical	316	316	Complete	
HTOL, 1000 hours	79	79	Complete	
Post HTOL Electrical Test	79	79	Pass	
HTSL, 1000 hours	80	80	Complete	
Post HTSL Electrical Test	80	80	Pass	
MSL3 Preconditioning	157	157	Complete	
MSL3 Preconditioning Final Test	157	157	Pass	
UHAST (Preconditioned)	78	78	Complete	
UHAST Final Test	78	78	Pass	
Temperature Cycle (Preconditioned)	79	79	Complete	
Temperature Cycle Final Test	79	79	Pass	

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HMC6409 (QTR2013-00562)

TEST	QTY IN	QTY OUT	PASS / FAIL	NOTES
Initial Electrical	75	75	Complete	
HTOL, 1000 hours	25	25	Complete	
Post HTOL Electrical Test	25	25	Pass	
MSL3 Preconditioning	50	50	Complete	
MSL3 Preconditioning Final Test	50	50	Pass	
THB (Preconditioned)	25	25	Complete	
THB Final Test	25	25	Pass	
Temperature Cycle (Preconditioned)	25	25	Complete	
Temperature Cycle Final Test	25	25	Pass	

HMC6409 (Q12405)

TEST	QTY IN	QTY OUT	PASS / FAIL	NOTES
Initial Electrical	75	75	Complete	
HTOL, 1000 hours	25	25	Complete	
Post HTOL Electrical Test	25	25	Pass	
MSL3 Preconditioning	50	50	Complete	
MSL3 Preconditioning Final Test	50	50	Pass	
THB (Preconditioned)	25	25	Complete	
THB Final Test	25	25	Pass	
Temperature Cycle (Preconditioned)	25	25	Complete	
Temperature Cycle Final Test	25	25	Pass	

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SiGe HBT-B Failure Rate Estimate

Based on the HTOL test results, a failure rate estimation was determined using the following parameters:

With device case temp, T_c = 60°C

HMC4376 (QTR2012-00275)
Operating Junction Temp (T_{oj}) = 87.5°C (360.5 °K)
Stress Junction Temp (T_{sj}) = 150°C (423 °K)

HMC6409 (QTR2012-00460)
Operating Junction Temp (T_{oj}) = 68.3°C (341.3 °K)
Stress Junction Temp (T_{sj}) = 150°C (423 °K)

HMC6409 (QTR2013-00562)
Operating Junction Temp (T_{oj}) = 68.3°C (341.3 °K)
Stress Junction Temp (T_{sj}) = 150°C (423 °K)

HMC6409 (Q12405)
Operating Junction Temp (T_{oj}) = 68.3°C (341.3 °K)
Stress Junction Temp (T_{sj}) = 150°C (423 °K)

Device hours:

HMC4376 (QTR2012-00275) = (80 X 1000hrs) = 80,000 hours
HMC6409 (QTR2012-00460) = (79 X 1000hrs) = 79,000 hours
HMC6409 (QTR2013-00562) = (25 X 1000hrs) = 25,000 hours
HMC6409 (Q12405) = (25 X 1000hrs) = 25,000 hours

For SiGe HBT-B MMIC, Activation Energy = 0.8 eV

Acceleration Factor (AF): $$AF = \exp\left[\left(\frac{E_A}{k}\right)\cdot\left(\left(\frac{1}{T_{USE}}\right)-\left(\frac{1}{T_{STRESS}}\right)\right)\right]$$

HMC4376 (QTR2012-00275) Acceleration Factor = exp[0.8/8.6 e^{-5}(1/360.5-1/423)] = 45.3
HMC6409 (QTR2012-00460) Acceleration Factor = exp[0.8/8.6 e^{-5}(1/341.3-1/423)] = 193.3
HMC6409 (QTR2013-00562) Acceleration Factor = exp[0.8/8.6 e^{-5}(1/341.3-1/423)] = 193.3
HMC6409 (Q12405) Acceleration Factor = exp[0.8/8.6 e^{-5}(1/341.3-1/423)] = 193.3

Equivalent hours = Device hours x Acceleration Factor

Equivalent hours = (80,000 x 45.3) + (79,000 x 193.3) + (25,000 x 193.3) + (25,000 x 193.3) = 2.86×10^7 hours

Since there were no failures and we used a time terminated test, F=0, and R = 2F+2 = 2

The failure rate was calculated using Chi Square Statistic:

$$\lambda_{CL} = \frac{\chi^2_{\%CL,2f+2}\cdot 10^9}{2\cdot t\cdot ss\cdot AF}$$ at 60% and 90% Confidence Level (CL), with 0 units out of spec and a 60°C package backside temp;

Failure Rate

$\lambda_{60} = [(\chi^2)_{60,2}]/(2X \quad 2.86\times10^7 \;)] = 1.83/\ 5.71\times10^7 = \ 3.20\times10^{-8}$ failures/hour or 32.0 FIT, MTTF = 3.12×10^7 hours

$\lambda_{90} = [(\chi^2)_{90,2}]/(2X \quad 2.86\times10^7 \;)] = 4.61/\ 5.71\times10^7 = \ 8.07\times10^{-8}$ failures/hour or 80.7 FIT, MTTF = 1.24×10^7 hours

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