Excellence in Performance

Proven strategies for producing the world's best RF MMIC's

Mini-Circuits

Table of Contents

Introduction

Mini-Circuits is committed to building products which meet or exceed customers' expectations. As we are ISO 9001:2000 and ISO 14001:2004 certified, we produce products using the highest quality and reliability standards.

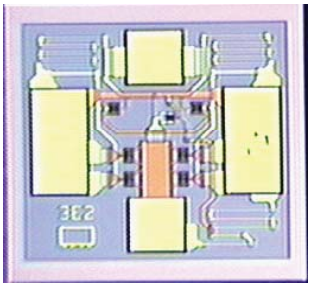
This paper will highlight key differences in the approach between Mini-Circuits' and typical market products. To be the world leader in RF and microwave products, we always insist on consistent performance, world-class quality and outstanding reliability in our products. As one of the few suppliers who own and manage their design and manufacturing facilities, Mini-Circuits is able to provide the most consistent, highest quality products to our customers.

Quality Designed-in:

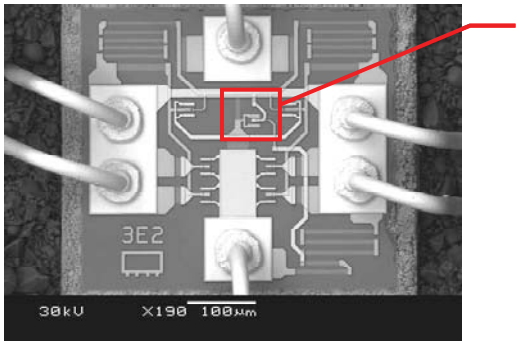
Transient Current Protection Circuit

The EXTRA-RELIABLE Amplifiers (ERA) Series amplifiers are based on InGaP HBT (Heterojunction-bipolar-transistor) technology and achieve wideband high gain performance via a Darlington configuration. HBT technology provides many benefits that are not available in commonly used MESFET devices, namely single supply voltage operation and unconditional stability through the entire amplifier frequency range.

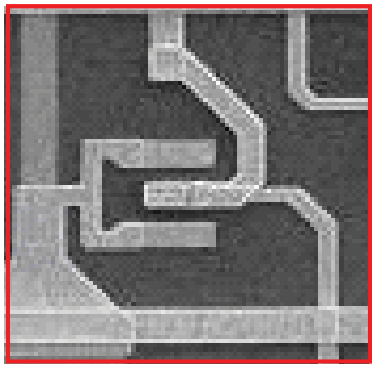
However, current transients that occur during power-up can cause damage in any high gain amplifier that uses a Darlington configuration. To address this issue, we design amplifiers with transient current protection circuits, which prevent damaging of the circuits by unforeseen electrical spikes, while still providing state-of-the-art performance.



ERA-2 die



ERA-2 die close-up view



Transient protection circuits

Quality Designed-in:

Die Layout

Features:

(a) Heat sources are separated to minimize heat coupling.

(b) Metal structures provide better heat sinks

(c) Double bonds on ground provides better grounding and heat dissipation.

Quality Designed-in:

Material Selection

Materials used for assembly have been carefully chosen to meet moisture sensitivity standards and improve thermal conductivity performance. Mini-Circuits' stringent material selection improves GaAs thermal conductivity to prevent performance degradation and catastrophic failures.

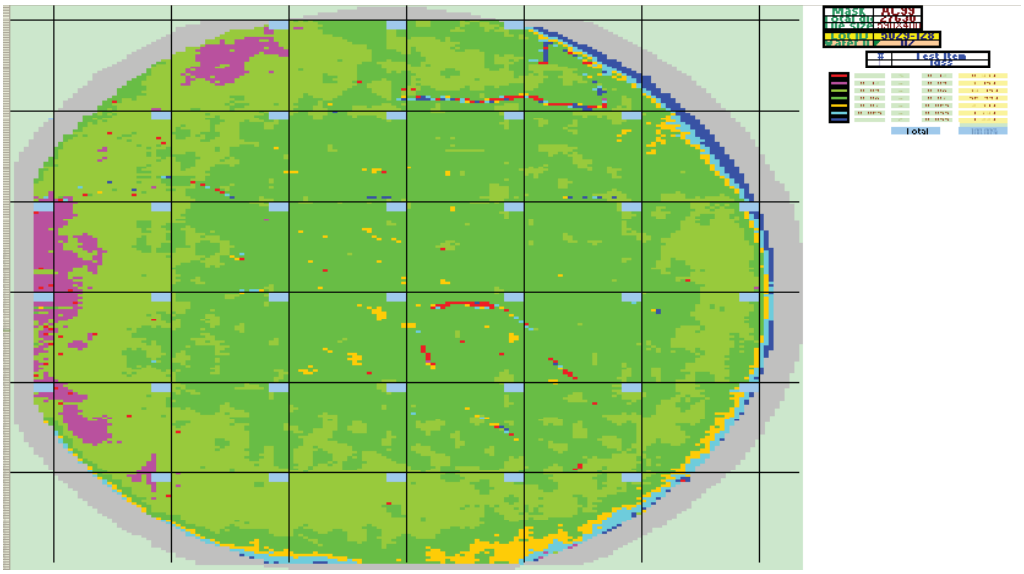
Material	Mini-Circuits	Typical market products
Mold compound Thermal conductivity	**150 x 10^{-2} W/m° K**	**88 x 10^{-2} W/m° K**
Silver Epoxy Thermal conductivity	**45 W/m° K**	**2.5 W/m° K**
Leadframe Thermal conductivity	**(Copper Alloy) 259.0 W/m° K**	**(Alloy42) 14.7 W/m° K**

Benefits:
Mold compound - 2 times more thermal conductivity compared to the typical market product.
Silver Epoxy - 18 times more thermal conductivity compared to the typical market product.
Leadframe – 18 times more thermal conductivity compared to the typical market product.

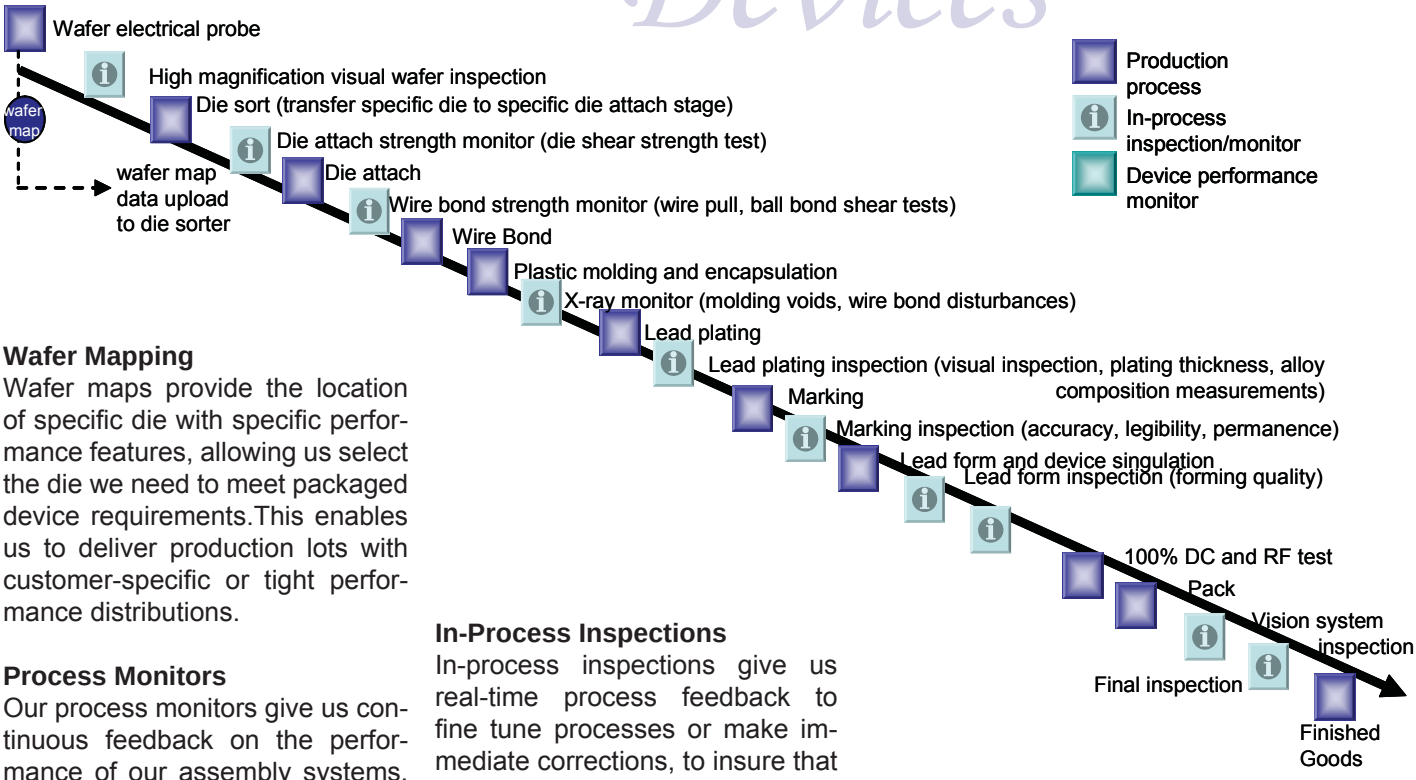
Quality Manufacturing:

Electronic Wafer Mapping

Every die on our wafers is individually tested and electronically mapped according to key performance parameters, enabling us to select specific die for specific production requirements. This results in products with very consistent and tightly distributed performance.



Quality Manufacturing:
In-Process Controls



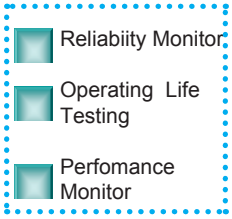
Wafer Mapping
Wafer maps provide the location of specific die with specific performance features, allowing us select the die we need to meet packaged device requirements.This enables us to deliver production lots with customer-specific or tight performance distributions.

Process Monitors
Our process monitors give us continuous feedback on the performance of our assembly systems, to make sure they are operating as designed to produce high quality products. Critical machine performance parameters are monitored using control charts, which are reviewed frequently to keep our processes in control.

In-Process Inspections
In-process inspections give us real-time process feedback to fine tune processes or make immediate corrections, to insure that products meet our quality standards, before they are allowed to be processed further.

Material Selection
We use mold compounds, lead frame materials, and package designs with excellent heat dissipation properties, that improve product performance and long-term reliability, and that also meet regulatory requirements.
All Mini-Circuits semiconductor products are offered in RoHS compliant models.

Performance monitors
Environmental testing such as temp cycling, helps us monitor our products' reliability. HTOL, HAST, and other operating life tests give us the information needed to improve our production processes and future product designs. Performance monitors such as junction temperature measurements assure us that the product continues to meet data sheet requirements as originally designed. Tin whisker growth, solderablility, and other tests, help us monitor the integrity of our products.



Quality Manufacturing:

In-Process Controls details

No	Process	Characteristics	Sample size	Frequency	Acceptance Criteria
1	Die Attach	Die tilt	1 unit/machine	1x/day/machine set up	≤ 5 mils
		Die bond line thickness	1 unit/machine		Min 0.3 mils
		Die shear strength	4 units/machine		≥ 0.25 kgF
2	Wire bond	Ball size	2 units; 2 balls/unit/machine	1x/day/machine set up	2.50 to 3.50 mils
		Wire loop height	5 units; 1 wire/unit for each ground & lead bond		5.0 +/-1.0 mils (Lower loop) 6.0 +/-1.0 mils (higher loop)
		Wire pull strength	2 wires/unit;4 units/machine		≥ 4 gF
		Ball shear strength	2 balls/unit; 4 units/machine		≥ 25 gF
3	Molding	Wire sweep	1 wire/unit;5 units/ machine	1x/day/machine set up	< 12%
4	Plating	Plating thickness	2 strips; 5 readings/ strip	Every lot	≥ 300 micro inch
		Scratch test	8 leads		No peeling plating
		Adhesion test	8 leads		No peeling plating
		Bend test	5 leads		No peeling plating
		Solderability	8 leads		> 95% solder coverage
5	Ink marking	Resistance to solvent	20 units/solvent	Every shift	No smearing of marking
6	Trim/ Form/ Singulate	Package outline	5 units	Every lot	Per Package Outline Specification
		Lead Coplanarity	5 units		≤ 0.1 mm
7	Test	At Mini-Circuits, we do not consider it good enough to ship products that just meet specifications. To pursue our goal of *exceeding* our customers' expectations, we test our products to ***4.5 sigma*** limits instead of the specification limits.			

Benefits: Our extensive in-process controls provide early detection of process variation and potential quality issues, providing crucial information for real-time process corrections.

Quality Manufacturing:

Dynamic Test Specifications

In pursuit of our goal to exceed our customers' expectations, we test our products to statistically generated 4.5 sigma limits instead of the specification limits. As a result, the products that are shipped to our customers are very consistent in performance with tight distributions.

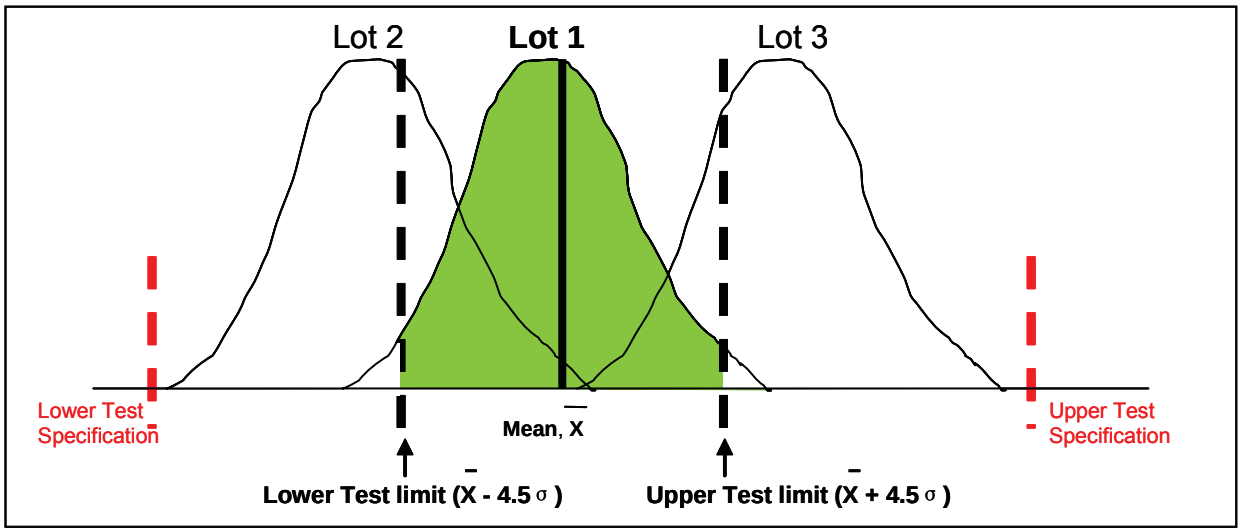


Diagram illustrates 4.5 sigma limits used instead of specification limits.
Only products from the shaded area for lot 1 will be tested good and shipped to customers.

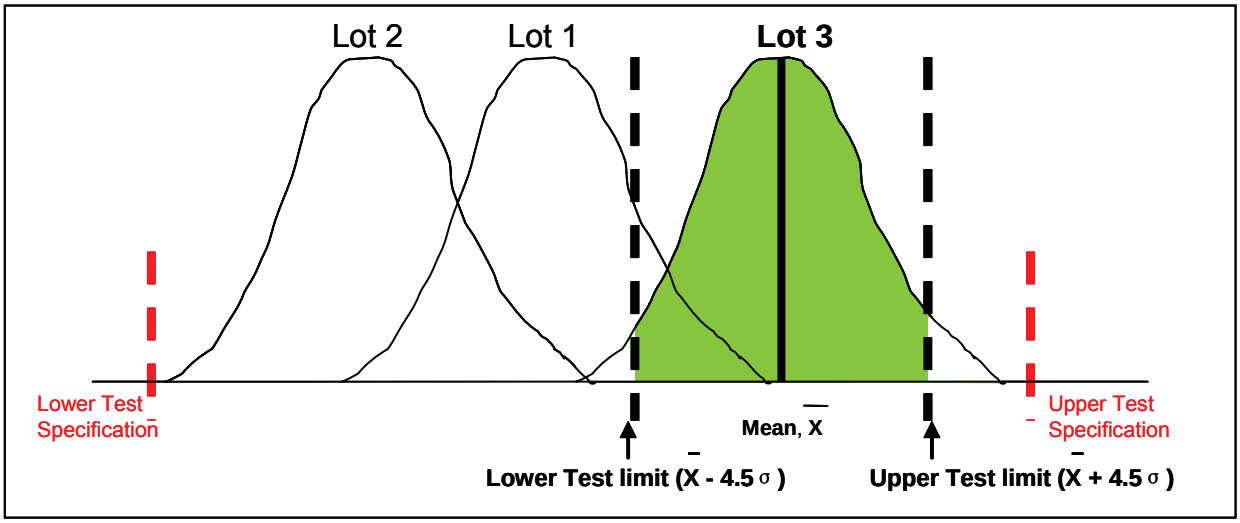


Diagram illustrates 4.5 sigma limits used instead of specification limits.
Only products from the shaded area for lot 3 will be tested good and shipped to customers.

Reliability Testing:

New Product Introduction/Qualification

Extensive qualification processes for new products. Every new product goes through stringent JEDEC and MIL-STD stress and accelerated-life tests. Every product is subjected to destructive stress tests to add to our understanding of each product's capabilities and operating limitations.

Required Test	Conditions	Reference	Quantity
Bond Pull	4 gr. minimum for 1.0 mil diameter Au wire	MIL-STD-883E method 2011	30 readings
Ball Shear	30 gr. average: 20 gr. for 1.0 mil diameter Au wire with 3X ball size	JESD22-B116	30 readings
Die Shear	.04 kg per 10^{-4} in^2 die area	MIL-STD-883E method 2019	10 readings
Visual Inspection	Low Power Microscope Magnification 40X	Mini-Crcuits specification	172 units
Electrical Test	Room Temperature	Data Sheet	92 units
Moisture Sensitivity Level 1	Bake at 125C for 24 hours. Soak at 85C and 85% RH for 168 hours Solder Reflow 3 cycles at 260C peak	JESD-020C	92 units
Temperature Cycle	-65C to 150C 500 cycles, 15 minute dwell time	MIL-STD-883E Method 1010.7 condition C	77 units
Autoclave	121C, 100% RH 15 psig for 96 hours	JESD22-A102C condition C	15 units
Solderability Test *SnPb solder paste*	8 hours steam ageing Reflow 3 cycles at 225C +/- 5C	JESD22-B102D	10 units
Solderability Test *SnAgCu solder paste*	8 hours steam ageing Reflow 3 cycles at 245C +/- 5C	JESD22-B102D	10 units
Method 2004.5 Tension A	Apply a tension of 227 gr. on a package lead for 30 seconds	MIL-STD-883E Method 2004.5 condition A	30 units
Method 2004.5 Bending Stress B	Apply a tension of 227 gr. on a package lead and swing at a 15 degree angle	MIL-STD-883E Method 2004.5 condition B	30 units
Package Dimension	Per package outline specifications	Datasheet	10 units
Resistance to Solvents	Solution A,C,D and reflow 3 cycles	MIL-STD-202F Method 215J	10 units

Reliability Testing:

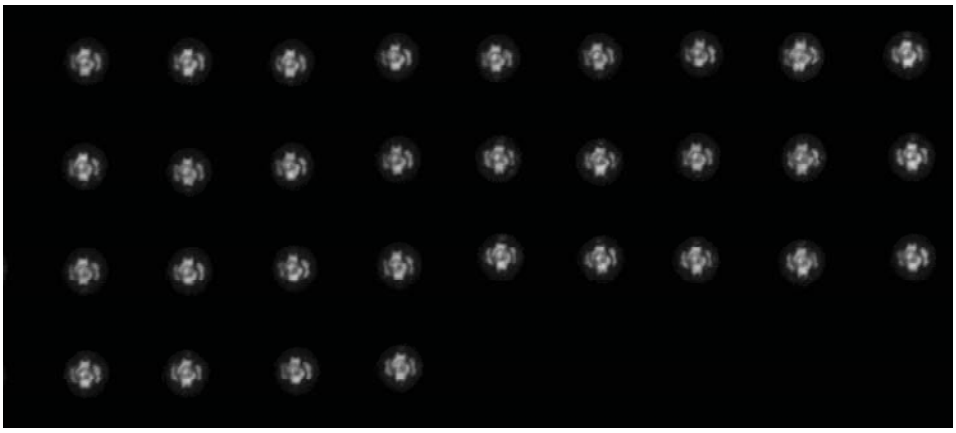
Ongoing Monitoring

In addition to product qualifications, Mini-Circuits commits to regular monitors of our products to ensure that our high standards in quality and reliability are maintained and achieved over the product lifetime.

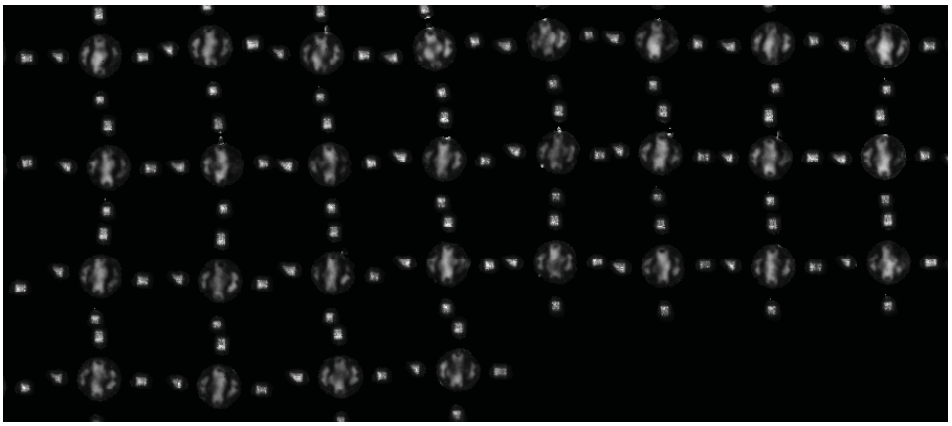
Our Reliability Database captures and tracks the reliability performance of our manufacturing lots over time. This database provides a complete record of each product's reliability history.

Example: Moisture Sensitivity Level 1 (MSL 1) rating in accordance with IPC/ JEDECSTD-020C.

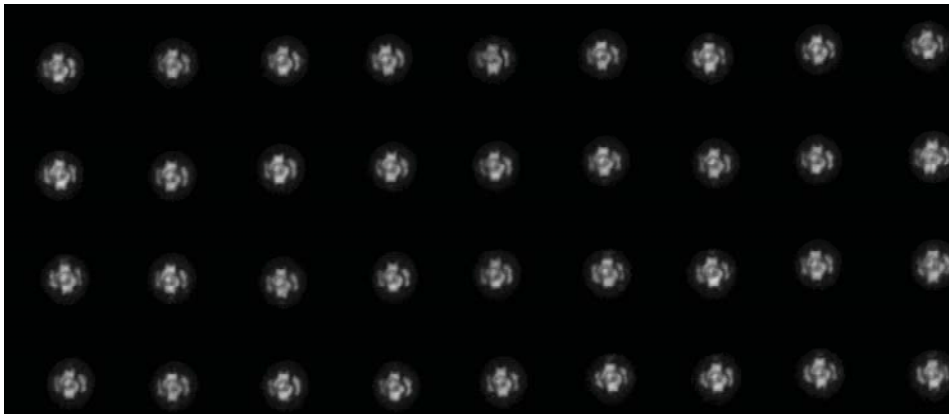
The following shows C-Mode Scanning Acoustic Microscope (C-SAM) photos of a device before and after moisture sensitivity level 1 (MSL 1) tests.



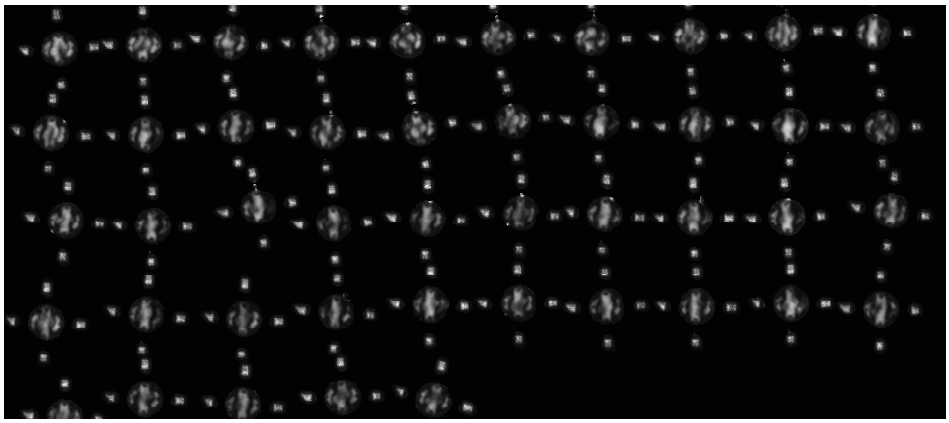
Before MSL-1 level testing : top view



Before MSL-1 level testing : bottom view



After MSL-1 level testing : top view



After MSL-1 level testing : bottom view

The table below shows delamination determination after MSL 1 pre-conditioning tests. Monitoring results have shown no delamination detected over the past 3 years.

Quarter/Year	Delamination Study	
	Quantity Tested	Quantity Failed
Q1/05	1671	0
Q2/05	2416	0
Q3/05	1040	0
Q4/05	1281	0
Q1/06	1280	0
Q2/06	560	0
Q3/06	1651	0
Q4/06	1969	0
Q1/07	2089	0
Q2/07	2088	0
Q3/07	1819	0
Q4/07	1520	0

Reliability Testing: *Additional tests and evaluations conducted by Mini-Circuits*

No	Test Type	Reference Document	Application
1	Visual Inspection	Mini-Circuits Specification	External Package Inspection
2	Room Temperature Electrical Test	Mini-Circuits Specification	Electrical Test to data sheet specifications
3	Scanning Acoustic Microscope (SAM) Analysis	Jedec Standard, J-Std-020C	To detect Delamination or gap between materials
4	Resistance to Soldering Heat	Jedec Standard, J-Std-020C	To simulate Surface Mount Assembly Processes
5	Moisture Sensitivity Level	Jedec Standard, J-Std-020C	To determine the Moisture Sensitivity Level of a package
6	Temperature Cycle	Military Standard, Mil-Std-883E, method 1010.7	Test the ability to withstand Alternating Temperatures
7	Autoclave	Jedec Standard, JESD22-A102-C	To evaluate the ability to withstand Moisture Resistance
8	High Temperature Storage	Jedec Standard, JESD22-A103C (Extended to 5000 hours)	To evaluate the effect of device storage at Elevated Temperatures
9	Humidity Steady-State	Military Standard, Mil-Std-202F, method 103B condition C	To evaluate at High Humidity and at an Elevated Temperature
10	Temperature and Humidity Test without Bias	Jedec Standard, JESD22-A101-B	To evaluate storage in a Humid Environment
11	Whisker Growth Test	Jedec Standard, JESD22A121	To study Tin Whisker Growth on finishes containing Tin
12	Thermal Diode	Mini-Circuits specification	MMIC Junction Temperature Measurement
13	Solderability Test, Solder Dip Method	Military Standard, Mil-Std-883E, method 2003.7	To determine the Solderability of a device
14	Solderability Test, Surface Mount Method	Jedec Standard, JESD22-B102D	To determine the Solderability of a device
15	Lead Integrity Test	Military Standard, Mil-Std-883E, method 2004.5	To evaluate the Integrity of Device Leads
16	Tape Peel Test	Mini-Circuits specification	To evaluate Plating Adhesion
17	Scratch Test	Mini-Circuits specification	To evaluate Plating Adhesion
18	Resistance to Solvents	Military Standard, Mil-Std-202F, method 215J	To evaluate the Ink Marking and encapsulant materials.
19	Welding Test	Mini-Circuits specification	To determine Weld-ability and Weld Peel Strength
20	Plating Thickness	Mini-Circuits specification	Thickness Measurement
21	Plating Composition	Mini-Circuits specification	Composition Measurement
22	X-Ray Analysis	Mini-Circuits specification	Internal Package Inspection

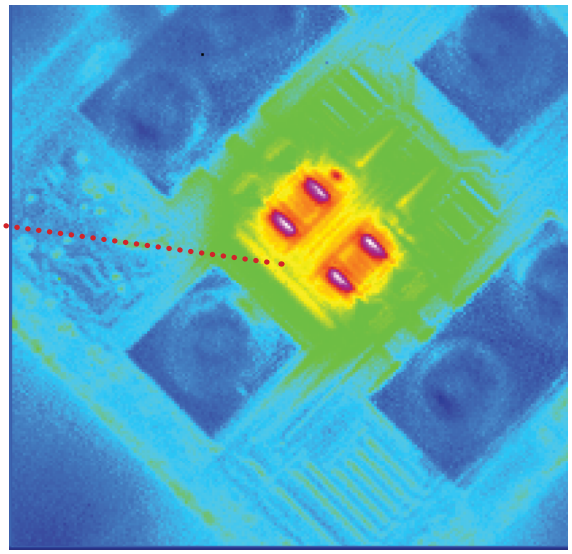
Reliability Testing: *MMIC Amplifier Junction Temperature*

Measurement and Monitoring Program

Temperature has a direct impact on the operating performance and reliability of semiconductor devices. Devices that operate at high junction temperatures for a long period of time can sustain permanent damage and shorten lifetimes.

At Mini-Circuits, MMIC amplifier junction temperature measurement and monitoring is performed on every production wafer lot to ensure our customers receive products with the highest quality, reliability and performance.

A Temperature-Sensing Diode is embedded next to the operating junction on this new die design



Applying a temperature-sensing diode as a sensor to the device can accurately measure the junction temperature and the thermal resistance over a range of operating and environmental conditions.

Thermal mapping image of an MMIC amplifier die.

Year	Junction Temperature Measurement Study	
	Measured Wafer lots	Quantity Failed
2005	52	0
2006	154	0
2007	132	0

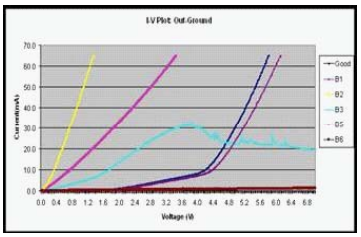
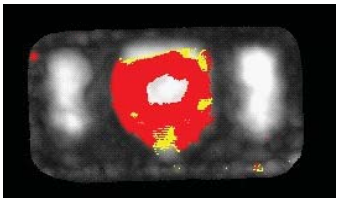
Benefits:
Reliability Monitoring is used to evaluate product reliability performance throughout a product's lifetime. Comprehensive qualifications are performed for process and materials changes during the product's lifetime. A Reliability Database tracks the reliability performance over time and archives all qualification data. This database provides a complete record of each product's reliability history.

Physical Analysis

Our world-class Physical Analysis lab provides unparalleled analysis capabilities. We have the ability to analyze product performance characteristics from packaged devices through individual layers in a die. This ability gives us a powerful tool to help us correlate device construction and physical characteristics with device performance.

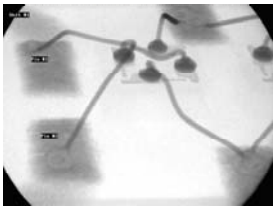
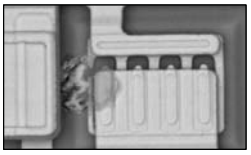
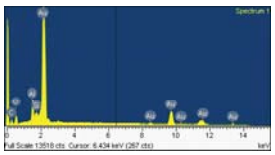
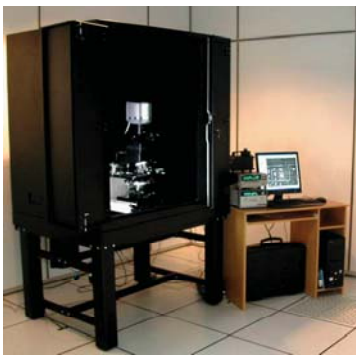
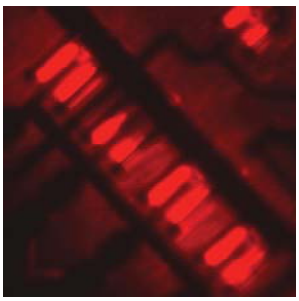
Physical Analysis:

Non-Destructive Analysis Techniques

Equipment	Application
 High Power and Low Power Optical Microscope	Visual surface analysis. Up to 500x magnification.
 Parametric Analyzer	V characteristics Electrical test. 
Scanning Acoustic Microscope 	 Non-destructive internal package characterization

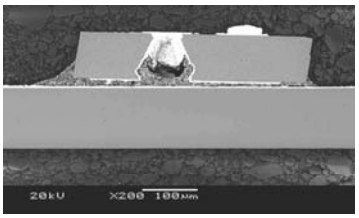
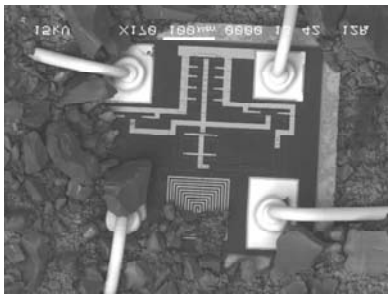
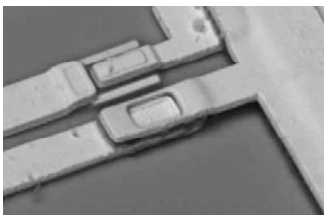
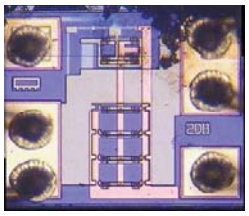
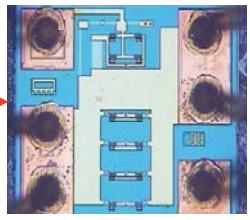
Physical Analysis:

Non-Destructive Analysis Techniques

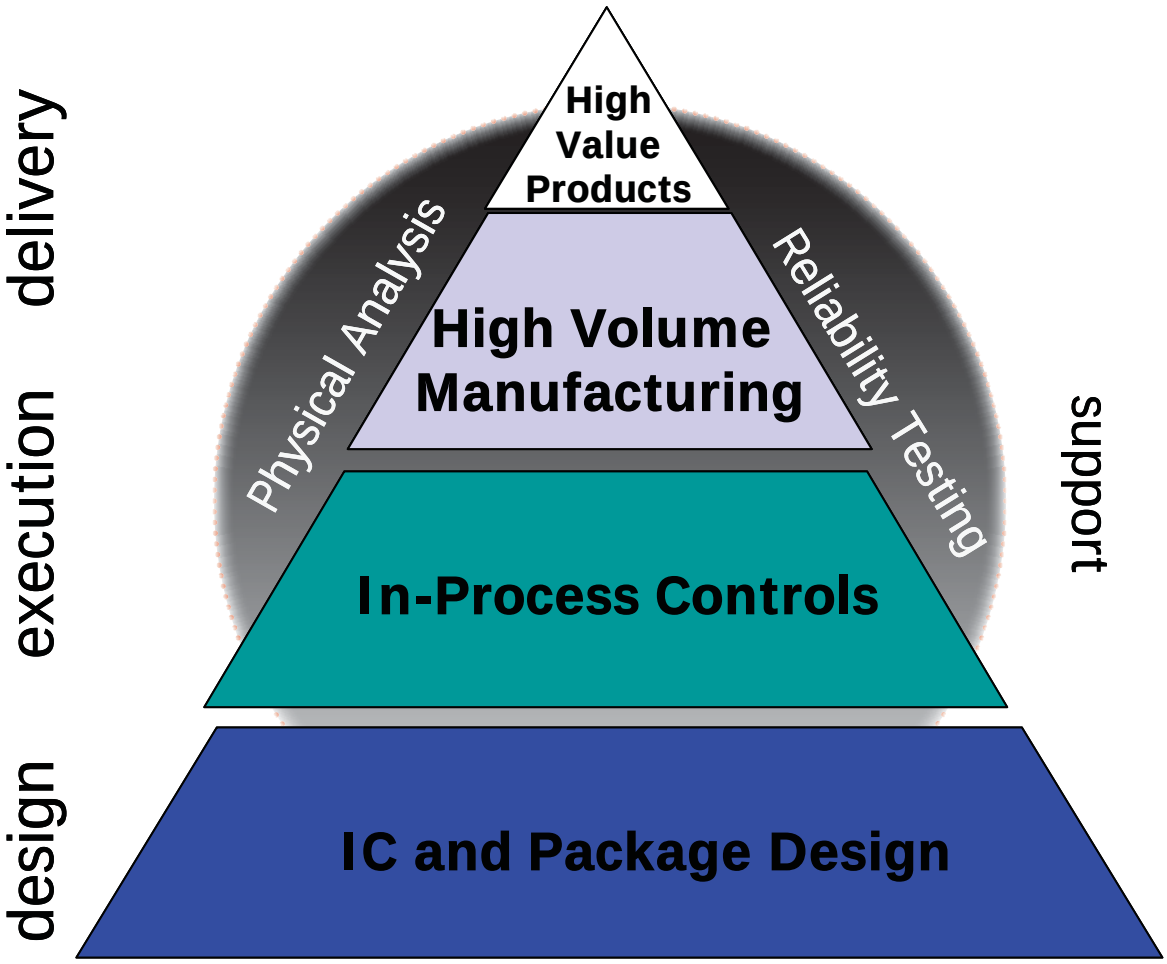
Equipment	Application
X-Ray 	 Internal Package Inspection
Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray (EDX) 	Up to 3000X magnification SEM  Surface topographic analysis and surface qualitative and quantitative analysis EDX 
 Photon Emission Microscope	 Die-level fault isolation technique

Physical Analysis:

Destructive Analysis Techniques

Equipment	Application
Cross section Polisher and Grinder  	 Internal Package Inspection
 Auto Decapsulator	 Removes plastic housing to expose die
 Reactive Ion Etcher	 Die-level delayering through dry etching
 Wet chemical die delayering	 Removal of passivation and metal layers through wet chemical etching

Excellence in Performance *Delivery System*



Our high-volume delivery of high-value products is based on the foundation of innovative product designs, comprehensive in-process controls, rigorous product qualifications and reliability testing, and the most complete physical analysis capabilities in our industry. These work in concert to provide our customers the best RF and Microwave components available on the market, giving them a true competitive advantage.

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