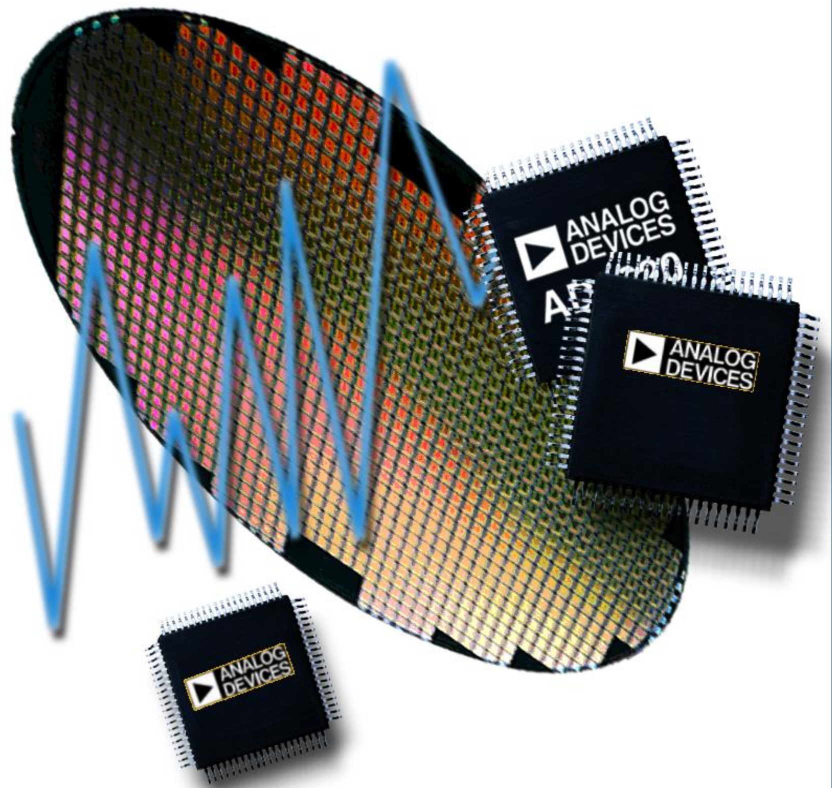


Reliability Report

Report Title: AD5941/AD5943 Automotive Grade 2 Qualification

Report Number: 14989

Revision: B

Date: 11 October 2021

Summary

This report documents the successful completion of the reliability qualification requirements for the Release to Automotive of the AD5941 product in a 48-LFCSP package. The AD5941 is a high precision, low power analog front ends (AFEs) which is designed for portable applications that require high precision, electrochemical-based measurement techniques, such as amperometric, voltammetric, or impedance measurements. This report also covers the AD5943 which is also an AFE designed for carrying high precision impedance measurement. The AD5943 is also in 48-LFCSP package.

Table 1: AD5941/AD5943 Product Characteristics

Die/Fab

Die Id	TMIS57/C-T1
Die Size (mm)	4.20 x 3.60
Wafer Fabrication Site	TSMC Fab 4
Wafer Fabrication Process	0.18µm CMOS
Approximate Transistor Count	1.35 million
Passivation Layer	undoped-oxide/SiN
Bond Pad Metal Composition	AlCu
Polyimide	Yes

Package/Assembly

Package	48-LFCSP
Body Size (mm)	7.00 x 7.00 x 0.75
Operating Temperature Range	-40°C < TA < 105°C
Assembly Location	ASE (AEK)
Molding Compound	Sumitomo G700LYT
Die Attach Material	Hitachi EN-4900GC
Lead Frame Material	Copper Alloy 194
Lead Finish	Matte Sn
Wire Type	MKE PC Pd/Cu
Wire Diameter (mils)	0.80
Moisture Sensitivity Level	3
Maximum Peak Reflow Temperature (°C)	260

Description / Results of Tests Performed

Tables 2 through 4 provide a description of the qualification tests conducted and the associated test results for products manufactured on the same technologies as described in Table 1. All devices were electrically tested before and after each stress. Any device that did not meet all electrical data sheet limits following stressing would be considered a valid (stress-attributable) failure unless there was conclusive evidence to indicate otherwise.

Table 2: LFCSP at ASE (AEK) Package Qualification Test Results

<table>
<tr><th>Test Name</th><th>Specification</th><th>Conditions</th><th>Device</th><th>Lot #</th><th>Sample Size</th><th>Qty. Failures</th></tr>
<tr><td rowspan="4">High Temperature Storage Life (HTSL) [1]</td><td rowspan="4">JESD22-A103</td><td rowspan="4">150°C, 1,000 Hours</td><td>AD5941</td><td>Q14989.HS1</td><td>77</td><td>0</td></tr>
<tr><td>ADDR9501</td><td>Q12421.HS1</td><td>77</td><td>0</td></tr>
<tr><td>ADV7380</td><td>Q13235.HS1</td><td>45</td><td>0</td></tr>
<tr><td>ADW15002</td><td>Q12257.11</td><td>45</td><td>0</td></tr>
<tr><td rowspan="6">Highly Accelerated Temperature and Humidity Stress Test (HAST) [2,1]</td><td rowspan="6">JESD22-A110</td><td rowspan="6">130C 85%RH 33.3 psia, Biased, 96 Hours</td><td rowspan="3">ADV7380</td><td>Q13235.HA1</td><td>45</td><td>0</td></tr>
<tr><td>Q13235.HA2</td><td>45</td><td>0</td></tr>
<tr><td>Q13235.HA3</td><td>45</td><td>0</td></tr>
<tr><td rowspan="3">ADW15002</td><td>Q11955.HA1</td><td>77</td><td>0</td></tr>
<tr><td>Q11955.HA2</td><td>77</td><td>0</td></tr>
<tr><td>Q11955.HA3</td><td>77</td><td>0</td></tr>
<tr><td rowspan="3">Solder Heat Resistance (SHR) [2,3]</td><td rowspan="3">J-STD-020</td><td rowspan="3">MSL-3</td><td rowspan="3">AD5941</td><td>Q14989.SH1</td><td>16</td><td>0</td></tr>
<tr><td>Q14989.SH2</td><td>16</td><td>0</td></tr>
<tr><td>Q14989.SH3</td><td>16</td><td>0</td></tr>
<tr><td rowspan="9">Temperature Cycling (TC) [2,4]</td><td rowspan="9">JESD22-A104</td><td rowspan="3">-65°C/+150°C, 1,000 Cycles</td><td rowspan="3">AD5941</td><td>Q14989.TC1</td><td>77</td><td>0</td></tr>
<tr><td>Q14989.TC2</td><td>77</td><td>0</td></tr>
<tr><td>Q14989.TC3</td><td>77</td><td>0</td></tr>
<tr><td rowspan="6">-65°C/+150°C, 500 Cycles</td><td rowspan="3">ADDR9501</td><td>Q12421.TC1</td><td>77</td><td>0</td></tr>
<tr><td>Q12421.TC2</td><td>77</td><td>0</td></tr>
<tr><td>Q12421.TC3</td><td>77</td><td>0</td></tr>
<tr><td rowspan="3">ADW15002</td><td>Q11955.TC1</td><td>77</td><td>0</td></tr>
<tr><td>Q11955.TC2</td><td>77</td><td>0</td></tr>
<tr><td>Q11955.TC3</td><td>77</td><td>0</td></tr>
<tr><td rowspan="6">Temperature Cycling (TC) [2,1]</td><td rowspan="6">JESD22-A104</td><td rowspan="3">-65°C/+150°C, 1,000 Cycles</td><td rowspan="6">ADV7380</td><td>Q13235.TC1</td><td>45</td><td>0</td></tr>
<tr><td>Q13235.TC2</td><td>45</td><td>0</td></tr>
<tr><td>Q13235.TC3</td><td>45</td><td>0</td></tr>
<tr><td rowspan="3">-65°C/+150°C, 500 Cycles</td><td>Q13235.TC1a</td><td>32</td><td>0</td></tr>
<tr><td>Q13235.TC2a</td><td>32</td><td>0</td></tr>
<tr><td>Q13235.TC3a</td><td>32</td><td>0</td></tr>
<tr><td rowspan="3">Temperature Humidity Bias (THB) [2,1]</td><td rowspan="3">JESD22-A101</td><td rowspan="3">85°C, 85%RH, Biased, 1,000 Hours</td><td rowspan="3">AD5941</td><td>Q14989.TH1A/B</td><td>77</td><td>0</td></tr>
<tr><td>Q14989.TH2</td><td>77</td><td>0</td></tr>
<tr><td>Q14989.TH3</td><td>77</td><td>0</td></tr>
<tr><td rowspan="7">Unbiased HAST (UHST) [2,3]</td><td rowspan="7">JESD22-A118</td><td rowspan="7">130C 85%RH 33.3 psia, 96 Hours</td><td rowspan="3">AD5941</td><td>Q14989.UH1</td><td>77</td><td>0</td></tr>
<tr><td>Q14989.UH2</td><td>77</td><td>0</td></tr>
<tr><td>Q14989.UH3</td><td>77</td><td>0</td></tr>
<tr><td rowspan="3">ADDR9501</td><td>Q12421.UH1</td><td>77</td><td>0</td></tr>
<tr><td>Q12421.UH2</td><td>77</td><td>0</td></tr>
<tr><td>Q12421.UH3</td><td>77</td><td>0</td></tr>
<tr><td>ADW15002</td><td>Q11955.UH1</td><td>77</td><td>0</td></tr>
</table>

Test Name	Specification	Conditions	Device	Lot #	Sample Size	Qty. Failures
				Q11955.UH2	77	0
				Q11955.UH3	77	0

[1] Pre- and post-stress electrical test was performed at room and hot temperatures.

[2] These samples were subjected to preconditioning (per J-STD-020 Level 3) prior to the start of the stress test. Level 3 preconditioning consists of the following: Bake: 24 hrs @ 125°C, Unbiased Soak: 192 hrs @ 30°C, 60%RH, Reflow: 3 passes through an oven with a peak temperature of 260°C.

[3] Electrical test was performed at room temperature.

[4] Electrical test was performed at hot temperature.

Table 3: 0.18μm CMOS at TSMC Fab-4 Fab Qualification Test Results

Test Name	Specification	Conditions	Device	Lot #	Sample Size	Qty. Failures
Early Life Failure Rate (ELFR) [1]	AEC-Q100-008	Ta=105°C, 48 Hours	AD5941	Q14989.EL1BB	20	0
				Q14989.EL1CC	20	0
				Q14989.EL2BB	20	0
				Q14989.EL2CC	20	0
				Q14989.EL3CC	20	0
		Ta=125°C, 48 Hours		Q14989.EL1A	250	0
				Q14989.EL1B	250	0
				Q14989.EL1C	250	0
				Q14989.EL2A	270	0
				Q14989.EL2AREP	250	0
				Q14989.EL2B	250	0
				Q14989.EL3A	249	1[4]
				Q14989.EL3B/B+	270	0
				Q14989.EL3C	250	0[5]
High Temperature Operating Life (HTOL) [2]	JESD22-A108	Ta=125°C, Biased, 1,000 Hours	AD5941	Q14989.HO1REP	77	1[6,7]
				Q14989.HO2REP	77	0
				Q14989.HO3REP	77	0
High Temperature Storage Life (HTSL) [1]	JESD22-A103	150°C, 1,000 Hours	AD5941	Q14989.HS1	77	0
Temperature Humidity Bias (THB) [3,1]	JESD22-A101	85°C, 85%RH, Biased, 1,000 Hours	AD5941	Q14989.TH1A/B	77	0
				Q14989.TH2	77	0
				Q14989.TH3	77	0

[1] Pre- and post-stress electrical test was performed at room and hot temperatures.

[2] Electrical tests were performed at Room/Cold/Hot.

[3] These samples were subjected to preconditioning (per J-STD-020 Level 3) prior to the start of the stress test. Level 3 preconditioning consists of the following: Bake: 24 hrs @ 125°C, Unbiased Soak: 192 hrs @ 30°C, 60%RH, Reflow: 3 passes through an oven with a peak temperature of 260°C.

[4] FA#220584: Post-ELF failure. One unit failed at the Hibernate DVDD_AD Sensor Bias Gross IDD test at both Ambient and Hot temperature. Complete physical analysis confirmed abnormal emission site in the circuit block near the Xtal pins. Cross-section using the Focused Ion Beam (FIB) confirmed the defect on a poly capacitor connected to 1.8V DVDD and GND. Feedback is that this was a fab defect and likely caused by an anomaly during the OD (operation domain) etch process at TSMC. A tool particle dropped on the wafer during the etch process caused a residue that would make extra OD pattern and caused poor isolation. The TSMC improvement plan of enhancing the process by improving the etch chamber condition and cleanliness of the OD etcher tool can help reduce or eliminate the OD flat type defects.

[5] FA#221487: Post-ELF failure. One unit failed at Leakage test at both Ambient and Hot temperature. Lot processing history review verified that the unit was an outlier on AIN0IleakStat2v0 test parameter at time-zero test. The test program limit set used for the automotive qual was based on the initial test program used for the commercial part. The limits set for the SW Leakage parameters are too wide that the failure was not captured. Test program optimization was done as corrective action. This includes proper guardbanding and implementation of IPAT. This is an invalid failure.

[6] FA#220586: One unit failed ADC_Vchannel_Endpoint_Error (Offset) Test at post-500 hours of HTOL. Complete physical analysis confirmed no anomaly on the ADC Core block. The ADC core design used for the AD5941 is widely used for other related products. Failure history check shows that there was no customer issue on ADC of these products. Thus, this supports that the ADC is robust enough and does not pose any reliability risk.

[7] FA#220587: One unit failed Continuity test at post-1000 hours of HTOL. Failure analysis showed that device was exposed to Electrical Over-Stress (EOS), the cause of which are the presence of metal extrusions shorting the Met1 layers on the Vref circuit. These metal extrusions are suspected to be metallic polymers that are formed during the Metal Etch process at the TSMC fabrication site. The TSMC improvement plan dealt with improving the polymer disposition condition by the addition of heater in the upper chamber of the etch machine. This would control and improve the chamber temperature uniformity and would avoid polymer peeling and improve polymer density.

Table 4: 0.18µm CMOS at TSMC Fab-8B Fab Qualification Test Results

Test Name	Specification	Conditions	Device	Lot #	Sample Size	Qty. Failures
High Temperature Operating Life (HTOL) [1]	JESD22-A108	150°C<Tj<175°C, Biased, 500 Hours	ADAU1442	Q7010.18	77	0
				Q7010.19	77	0
				Q7010.20	77	0
High Temperature Operating Life (HTOL) [2]	JESD22-A108	Ta=70°C, Biased, 1,000 Hours	ADV7682	Q12351.1	77	0
				Q12351.10	77	0
				Q12351.11	77	0
High Temperature Storage Life (HTSL) [3]	JESD22-A103	150°C, 1,000 Hours	AD8284W	Q10514.HS1	77	0
			ADAR7251W	Q12279.HS1	77	0
				Q9759.14	77	0
Highly Accelerated Temperature and Humidity Stress Test (HAST) [4,3]	JESD22-A110	130C 85%RH 33.3 psia, Biased, 96 Hours	ADAR7251W	Q9759.13	77	0
				Q9759.17	77	0
				Q9759.9	77	0
			ADAU1442	Q11427.HA1	77	0
				Q11427.HA2	77	0
				Q11427.HA3	77	0
			ADV7680	Q12351.2	77	0
				Q12351.4	77	0
				Q12351.7	77	0

[1] Electrical test was performed at room temperature.
[2] Pre- and post-stress electrical test was performed at hot, room and cold temperatures.
[3] Pre- and post-stress electrical test was performed at room and hot temperatures.
[4] These samples were subjected to preconditioning (per J-STD-020 Level 3) prior to the start of the stress test. Level 3 preconditioning consists of the following: Bake: 24 hrs @ 125°C, Unbiased Soak: 192 hrs @ 30°C, 60%RH, Reflow: 3 passes through an oven with a peak temperature of 260°C.

Samples of the many devices manufactured with these package and process technologies are continuously undergoing reliability evaluation as part of the ADI Reliability Monitor Program. Additional qualification data is available on Analog Devices' web site.

ESD Test Results

The results of Human Body Model (HBM) and Field-Induced Charged Device Model (FICDM) ESD testing are summarized in Table 5. All parts were electrically tested at room and hot temperatures pre- and post-stress. ADI measures ESD results using stringent test procedures based on the specifications listed. Any comparison with another supplier's results should ensure that the same ESD test procedures have been used. For further details, please see the EOS/ESD chapter of the ADI Reliability Handbook (available via the 'Quality and Reliability' link on Analog Devices' web site).

Table 5: AD5941 ESD Test Results

ESD Model	Package	ESD Test Spec	RC Network	Highest Pass Level	First Fail Level	Class
FICDM	48-LFCSP	JS-002	1Ω, Cpkg	±750V	±1000V	C2b
HBM	48-LFCSP	ESDA/JEDEC JS-001	1.5kΩ, 100pF	±2000V	±2500V	2

Latch-Up Test Results

Three samples of the AD5941 were latch-up tested at T_A=125°C per JEDEC Standard JESD78, Class II. Pre- and post-stress electrical test was performed at room and hot temperatures. All pins passed.

Passing Positive Current	Passing Negative Current	Passing Over-Voltage
+200mA	-200mA	+4.9V

Approvals

Reliability Engineer: Ryan Quintin

Additional Information

Data sheets and other additional information are available on Analog Devices' web site.

Appendix

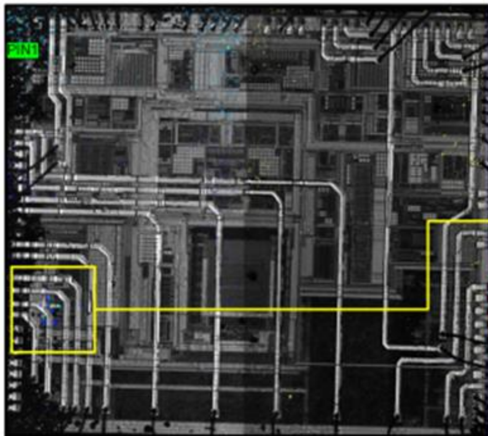
Failure Analysis Report 220584

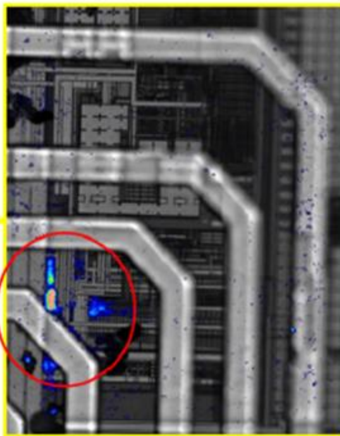
Summary:

Bench testing confirmed the abnormal DVDD leakage during hibernate mode. Die inspection post chemical decapsulation showed no obvious die surface anomalies. Light Emission Microscopy (LEM) while the failure mode is active showed an abnormal emission site in the circuit block near the Xtal pins. Optical inspection post mechanical delayering revealed a defect on the location where the abnormal emission was observed. Cross-section using the Focused Ion Beam (FIC) confirmed the defect on a poly capacitor connected to DVDD.

LEM

Emission Microscopy enables the location of sublayer defects through detection of faint light levels emitted from silicon device structures. These faint light levels arise from recombinant radiation emitted from p-n junctions and from oxides. Photon emission analysis was performed on the failing unit to further isolate the location of the suspected defect, while biasing the unit in the failing state. Abnormal emission site was observed on the internal circuitry near the xtal pins. This block is supplied by DVDD pin.

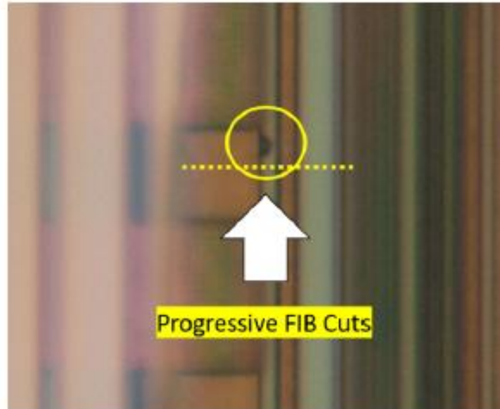




LEM result of the failing unit comparable with the results from a known good unit

FIB CROSS-SECTION

The unit was subjected to a series of milling using Focused Ion Beam (FIB) to expose a cross-sectional view of the defect site. Anomalous profile of the substrate was observed connected to the adjacent poly capacitor; see Figure 4 Note: capacitor is directly connected to DVDD.



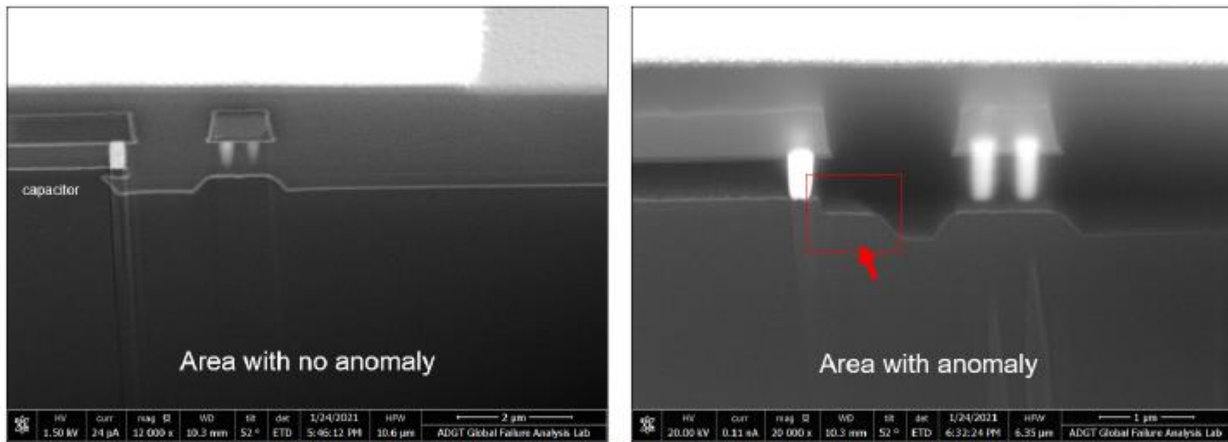


Image of the defect observed on the poly capacitor connected to DVDD

Failure Analysis Report 220586

Summary:

Curve trace analysis found no I-V curve anomalies on all the pinouts of the reject. Bench testing confirmed the abnormal ADC offset error of the reject at zero scale, positive full-scale and negative full-scale. Die inspection post chemical decapsulation showed no obvious die surface anomalies. Light Emission Microscopy (LEM) while the failure mode is active did not show any abnormal emission sites and the results were comparable with a known good unit.

Conclusion:

The extensive bench testing isolated the ADC offset failure to the ADC core block. LEM analysis using another setup to activate the failure mode still found no obvious anomalies on the ADC core block. High power optical inspection post parallel lapping to remove all the top metal layers found no obvious defect or anomalies on the ADC core block.

LEM

Photon emission analysis was performed again on the failing unit while biasing the unit in the failing state and focused on the ADC core block. Still no abnormal emission sites were observed and were comparable with a known good unit; see Figure 3.

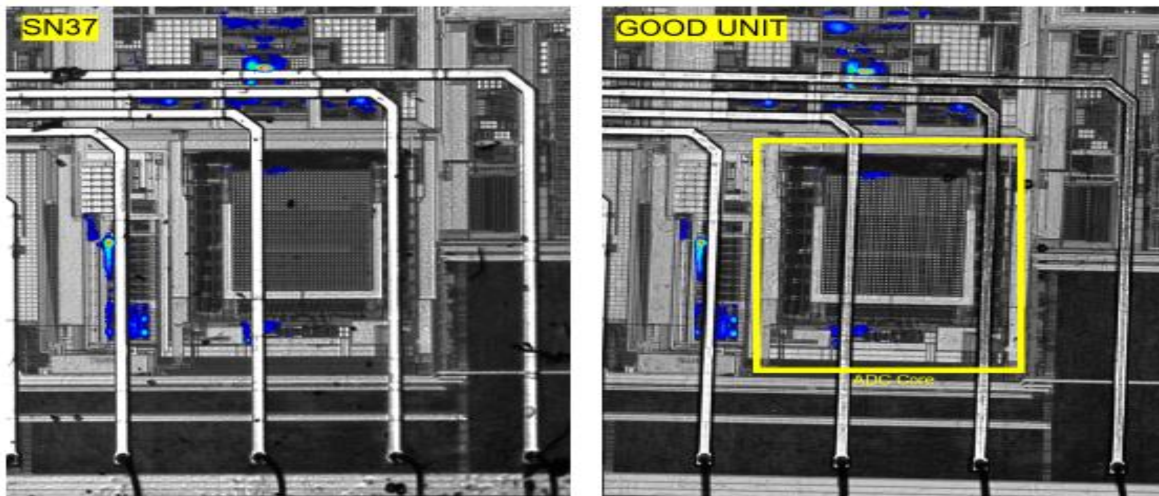


Figure 3. LEM results focused on the ADC core block of the failing unit showing no obvious anomalies

Failure Analysis Report 220587

Summary:

Curve trace analysis confirmed an abnormal I-V curve on Pin 43 (VREF) with respect to pin 44 (REF_AGND). Optical Beam Induced Resistance Change (OBIRCH) analysis revealed an abnormal hotspot on the circuitry near the shorted pins. Infrared (IR) imaging from the die backside confirmed an electrical damage on the exact location where the hotspot was observed.

Conclusion:

Electrical overstress (EOS) damage on VREF circuitry caused by metal intrusions causing metal-to-metal shorting within the same Metal 1 layer.

OBIRCH

Optical Beam Induced Resistance Change (OBIRCH) identifies the failure location by scanning the surface of the die using an infrared laser and then detecting any changes in resistance value caused by the laser. Extremely small changes in resistance can be observed due to localized heating caused by the laser. The unit was analyzed using OBIRCH, using the abnormal leakage on Pin43 (VREF) to activate the failure mode. Abnormal resistance-changing site or hotspot was detected on the circuitry connected to the shorted pins; see Figure 2.

Figure 2. Image of the abnormal resistance-change or hotspot observed on the unit

IR MICROSCOPY

The unit was inspected using an IR microscope to determine the presence of any anomaly as seen through the back of the die. Electrical damage was observed on the exact location where the hotspot was observed; see Figure 3.

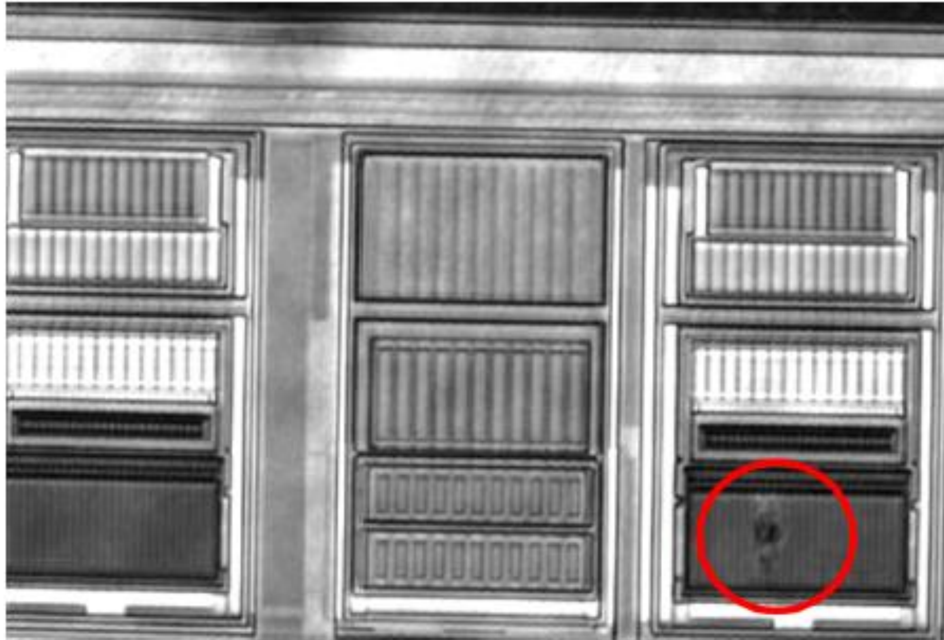


Figure 3. IR image from the die backside showing the electrical damage observed on the VREF circuitry

PARALLEL LAPPING

The unit was mechanically lapped using a parallel lapping tool to remove the top metal layers covering the fail site. No obvious anomalies were observed after removal of Metal 2, Metal 3 and Metal 4 layers; see Figure 4.

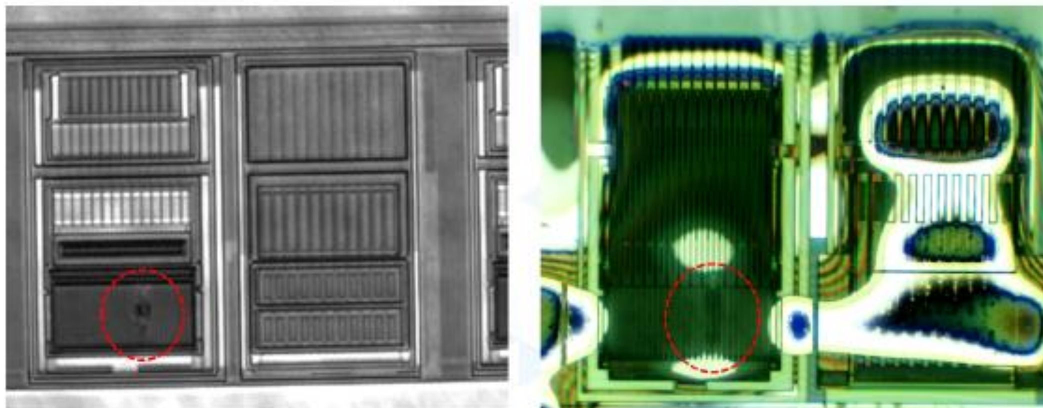
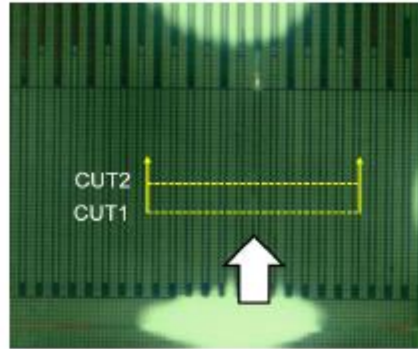


Figure 4. Photo (right) showing no obvious anomalies on the Metal 1 layer around the damaged site

CROSS-SECTION

The damaged site was cross sectioned using a Focused Ion Beam (FIB) to examine the site at higher magnifications. Anomalies were observed on the Metal 1 layer causing metal-to-metal shorting within the same layer; see Figures 5 and 6.



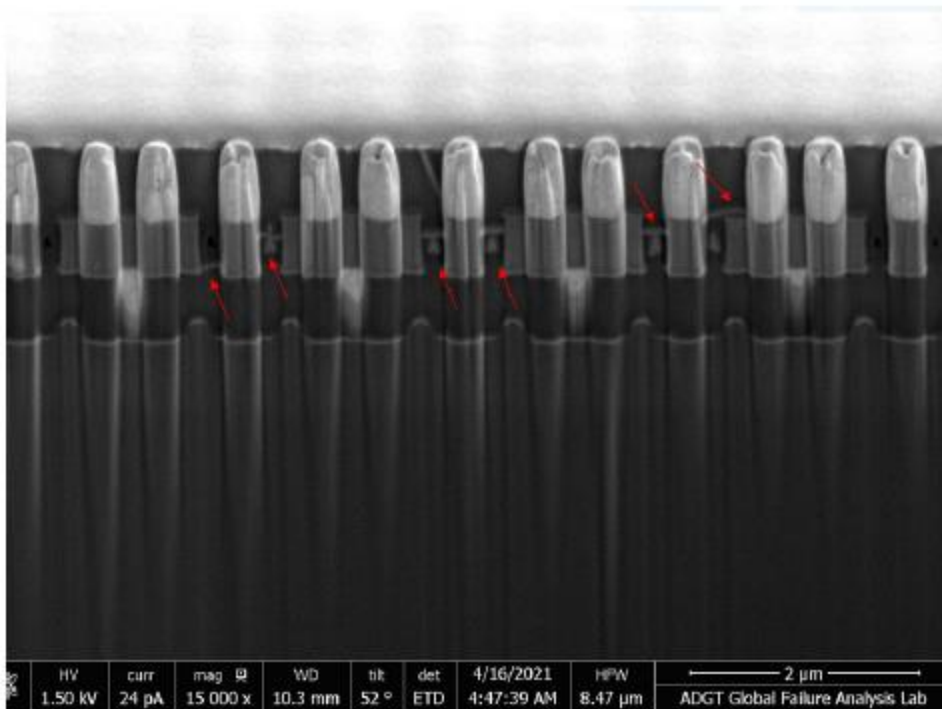


Figure 5. Cross-section result for CUT1 showing the anomalies on Metal 1 layer

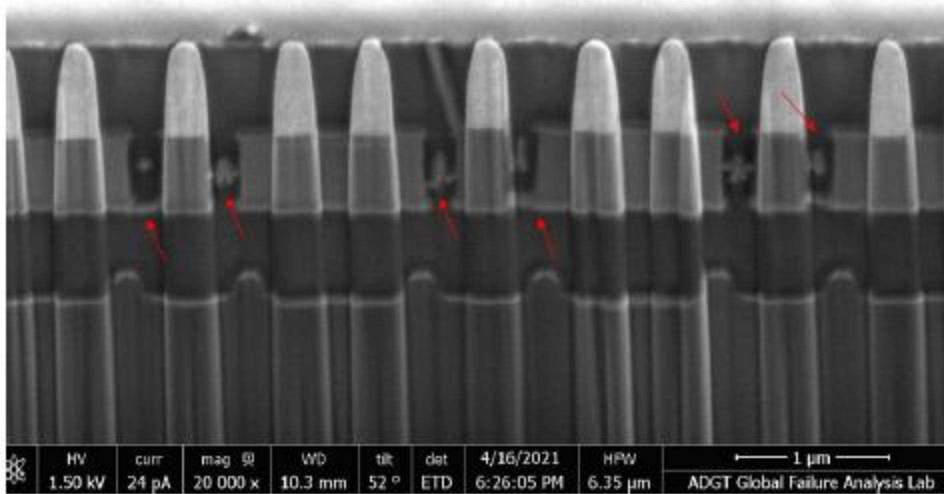


Figure 6. Cross-section result for CUT2 showing the anomalies on Metal 1 layer

12. Elemental Analysis

The fail site was analyzed using an Energy Dispersive X-Ray (EDX). Mapping results showed the anomalies are mostly Aluminum (Al); see Figure 7.

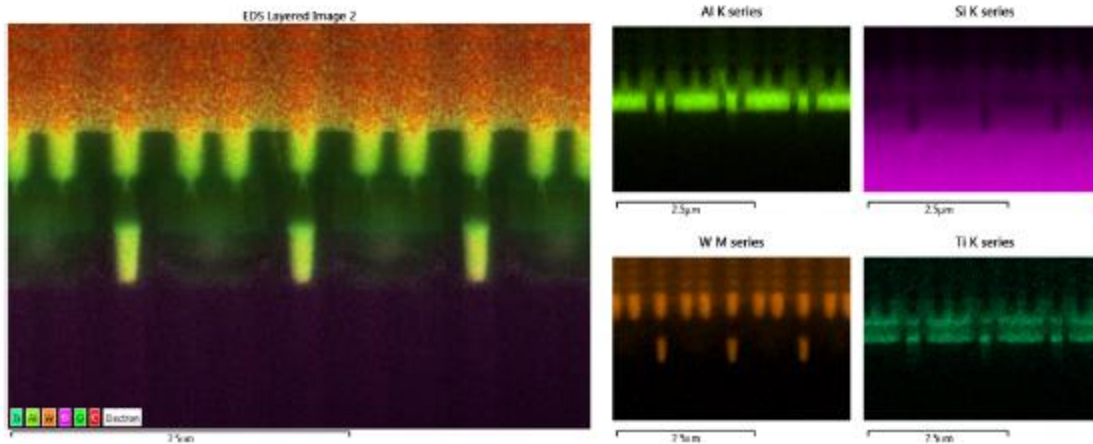
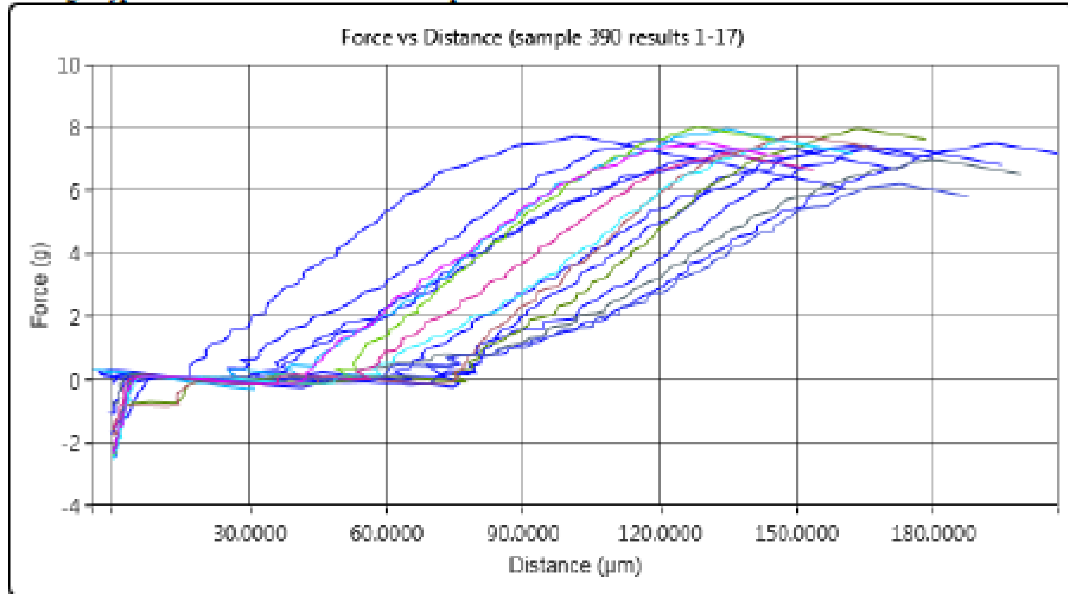
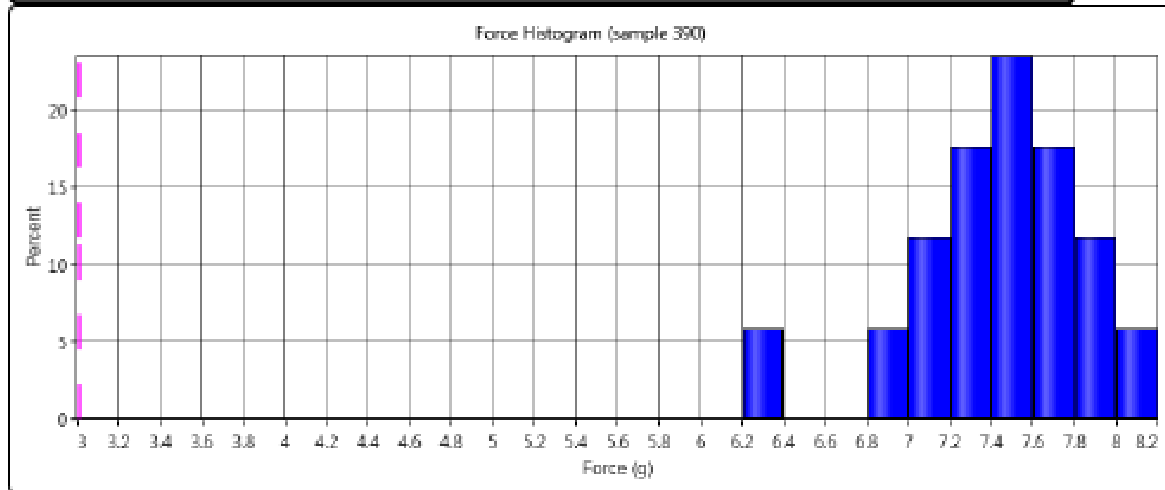


Figure 7. EDX mapping result of the fail site

WIREBOND PULL TEST Result

Test Group:	BOND PULL
Operator:	Default operator
Test Speed:	500.00 µm/s
Test Load:	25.000 g
Machine:	20184717
Cartridge serial number:	20184517
Date saved:	9/1/2021 9:59:45 AM
Total number of tests:	17
Product type:	AD5941 (Q14989.TC1) #1 BOND PULL
Package Type:	48 lfcsp





Test Group:	BOND PULL
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Test Load:	25.000 g
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Cartridge serial number:	20184517
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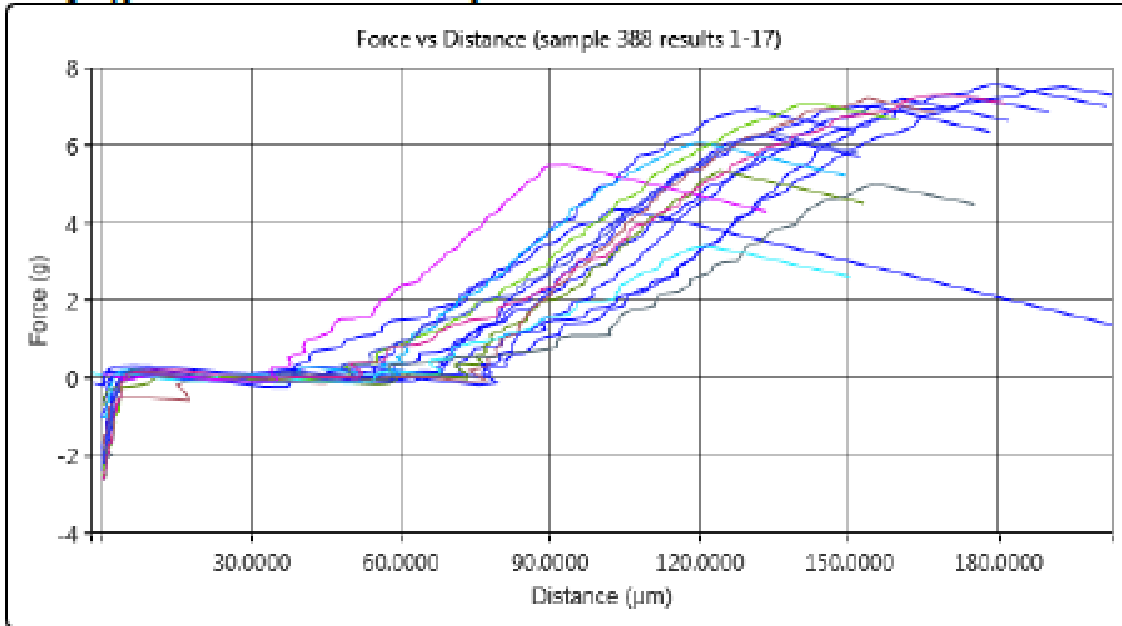
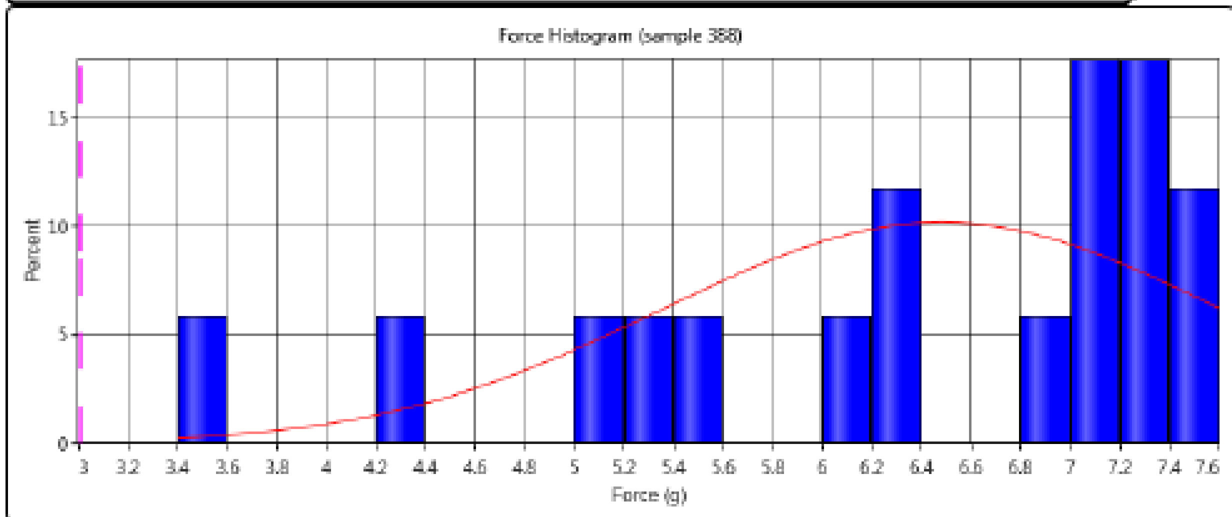
Package Type:	48 lfcsp





Test Group:	BOND PULL
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Test Speed:	500.00 µm/s
Test Load:	25.000 g
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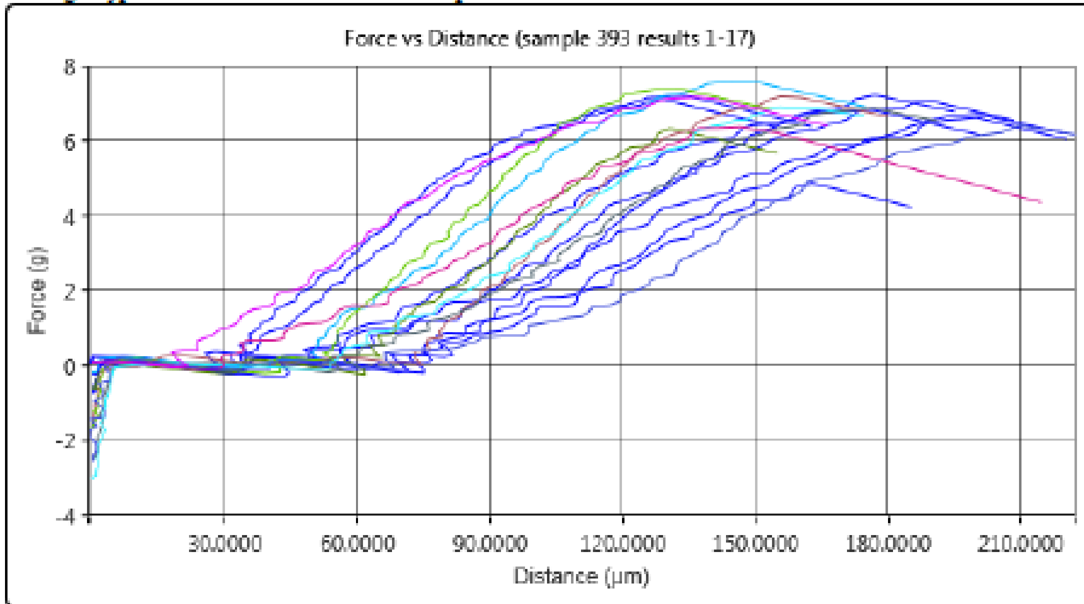
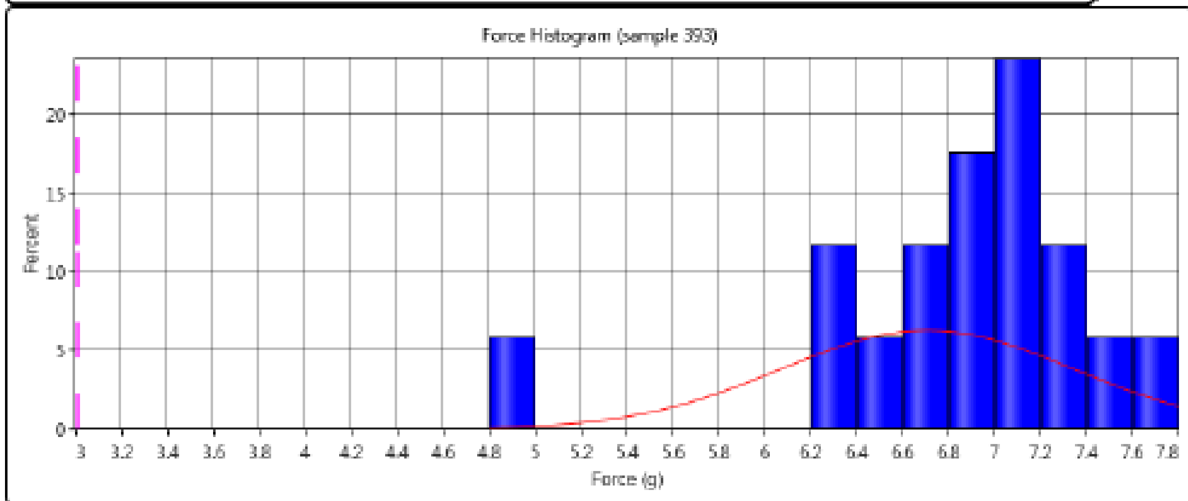
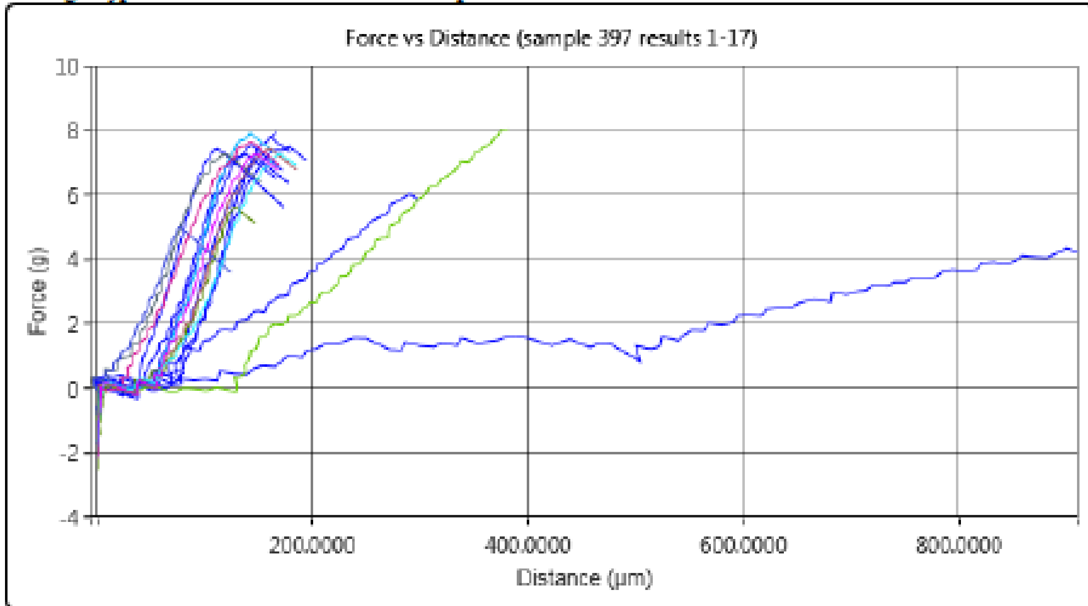
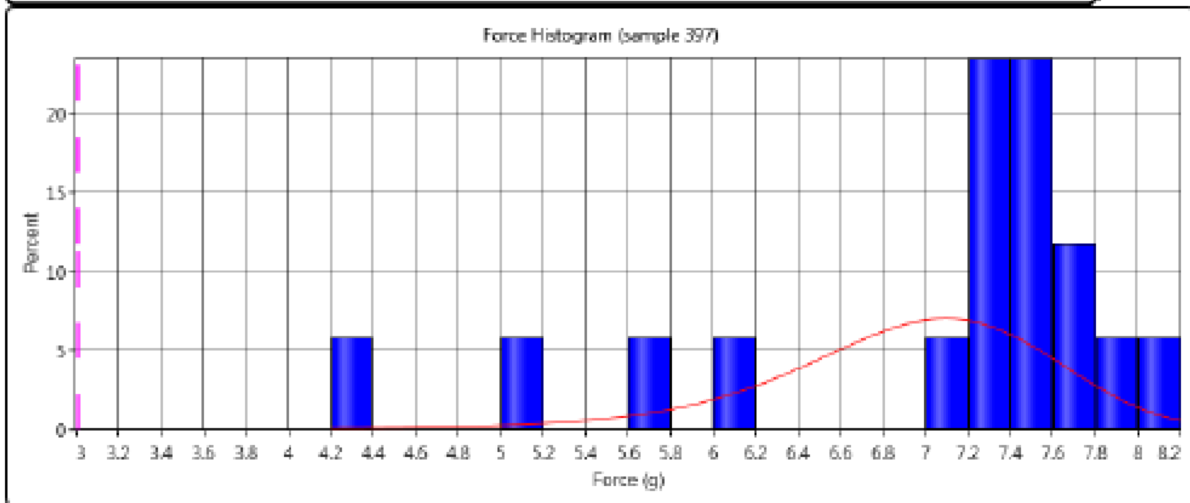
Package Type:	48 lfcsp





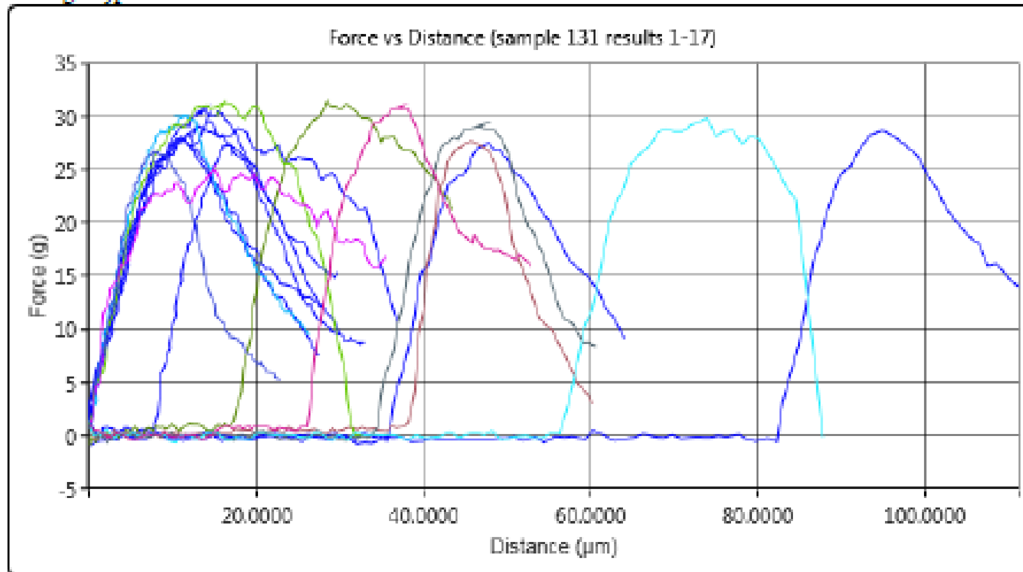
Test Group:	BOND PULL
Operator:	Default operator
Test Speed:	500.00 µm/s
Test Load:	25.000 g
Machine:	20184717
Cartridge serial number:	20184517
Date saved:	9/9/2021 1:04:29 PM
Total number of tests:	17
Product type:	AD5941 (Q14989.TH1A) #2 BOND PULL
Package Type:	48 lfcsp

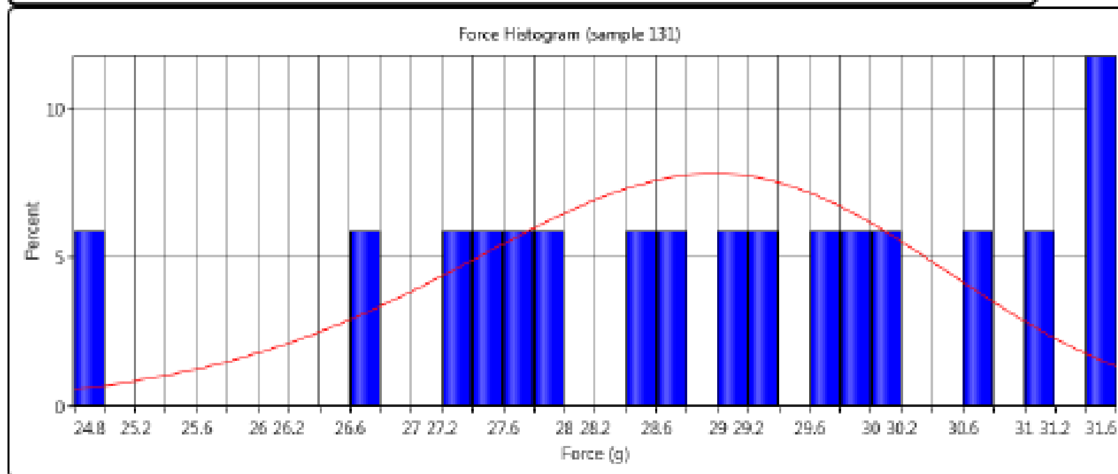




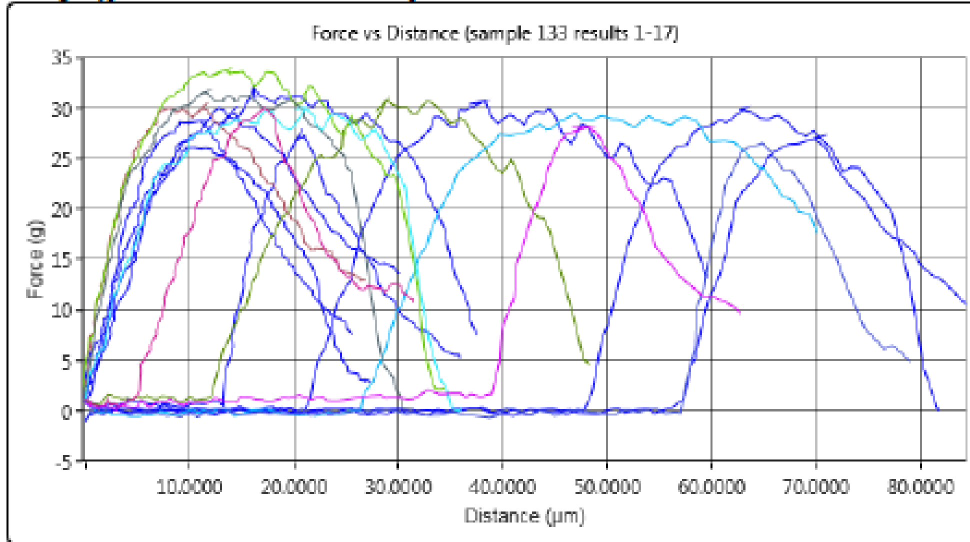
WIREBOND SHEAR TEST Result

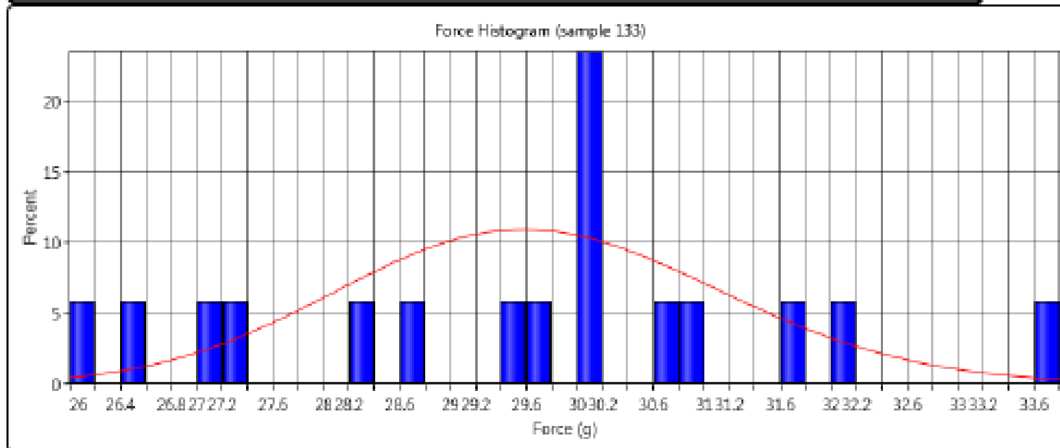
Test Group:	S5KG-BALLBOND_SHEAR
Operator:	Default operator
Test Speed:	500.00 µm/s
Shear height:	3.0000 µm
Test Load:	400.00 g
Machine:	20184717
Cartridge serial number:	20184117
Date saved:	6/15/2021 11:07:57 AM
Sample number:	131
Total number of tests:	17
Product type:	ad5941 (Q14989.TC1) DIE #6
Package Type:	48LFCSP



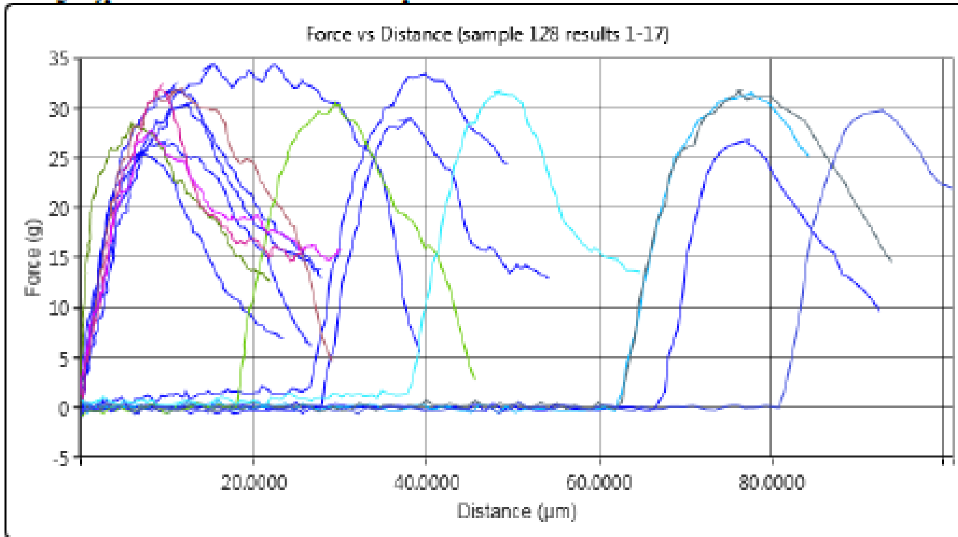


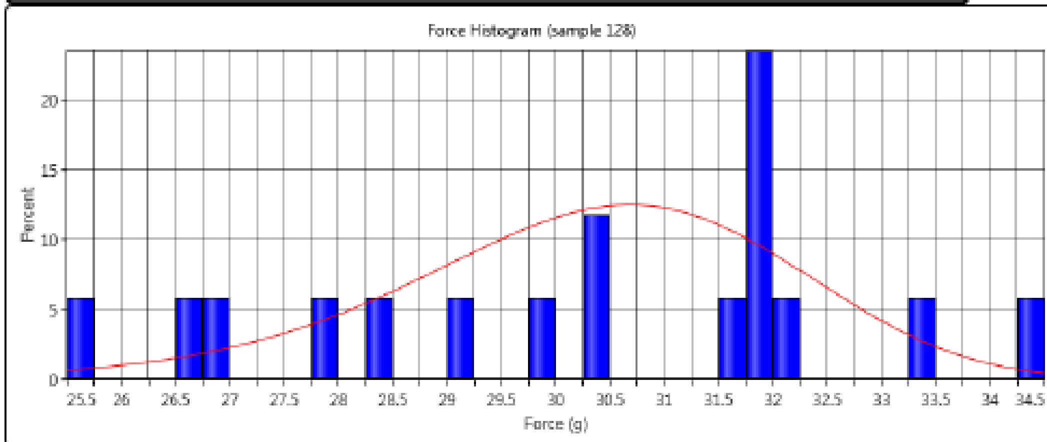
Test Group:	S5KG-BALLBOND_SHEAR
Operator:	Default operator
Test Speed:	500.00 µm/s
Shear height:	3.0000 µm
Test Load:	400.00 g
Machine:	20184717
Cartridge serial number:	20184117
Date saved:	6/15/2021 11:30:32 AM
Sample number:	133
Total number of tests:	17
Product type:	AD5941 (Q14989.TC1) DIE #8
Package Type:	48 lfcsp



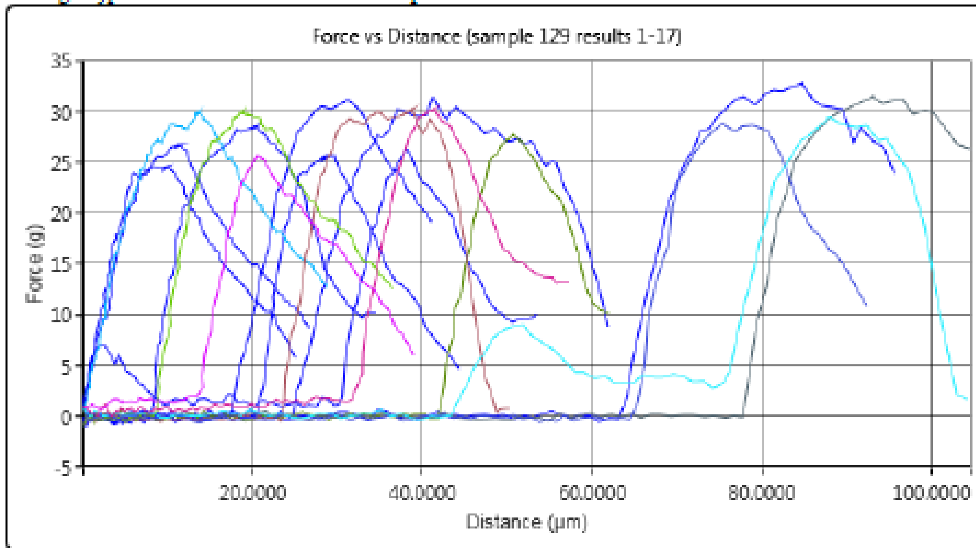


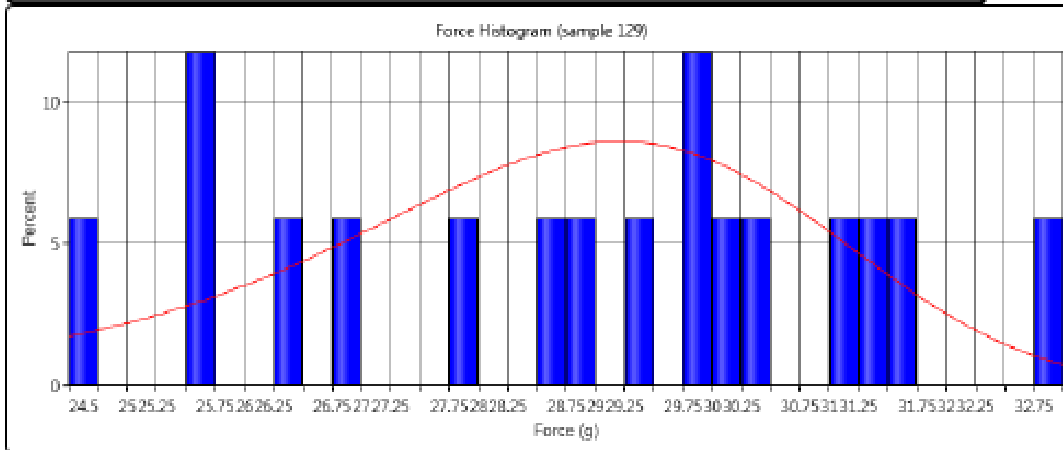
Test Group:	S5KG-BALLBOND_SHEAR
Operator:	Default operator
Test Speed:	500.00 µm/s
Shear height:	3.0000 µm
Test Load:	400.00 g
Machine:	20184717
Cartridge serial number:	20184117
Date saved:	6/15/2021 10:23:03 AM
Sample number:	128
Total number of tests:	17
Product type:	ad5941 (q14989.th2) die #6
Package Type:	48 lfcsp





Test Group:	S5KG-BALLBOND_SHEAR
Operator:	Default operator
Test Speed:	500.00 µm/s
Shear height:	3.0000 µm
Test Load:	400.00 g
Machine:	20184717
Cartridge serial number:	20184117
Date saved:	6/15/2021 10:34:18 AM
Sample number:	129
Total number of tests:	17
Product type:	ad5941 (q14989.th2) die #7
Package Type:	48 lfcsp





Test Group:	S5KG-BALLBOND_SHEAR
Operator:	Default operator
Test Speed:	500.00 µm/s
Shear height:	3.0000 µm
Test Load:	400.00 g
Machine:	20184717
Cartridge serial number:	20184117
Date saved:	6/15/2021 9:19:56 AM
Sample number:	125
Total number of tests:	17
Product type:	ad5941 (q14989.th3) die #6
Package Type:	48 lfcsp