ABSTRACT
The MSP430™ ultra-low-power (ULP) FRAM platform combines uniquely embedded FRAM and a holistic ultra-low-power system architecture, allowing innovators to increase performance at lowered energy budgets. FRAM technology combines the speed, flexibility, and endurance of SRAM with the stability and reliability of flash at much lower power. The ultra low-power architecture of the MSP430FR5969-SP showcases seven low-power modes, optimized to achieve power efficient distributed telemetry/housekeeping systems. The integrated mixed-signal features of the MSP430FR5969-SP make it ideally suited for distributed telemetry applications in next-generation spacecraft. The strong immunity to single-event latch-up (SEL) and total ionizing dose (TID), enable the device to be used in a variety of space and radiation environments.

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1 Device Introduction
MSP430FR5969-SP is a Radiation Hardness Assured (RHA) device in plastic package which allow this device to be use in a space application. The device was verified immune to 72 Mev·cm²/mg at 125°C for single event latchup. Each Fab lot was tested according to MIL-STD-883 for Radiation Lot Acceptance Tested (RLAT) up to 50 krad(Si) and each Assembly and Test lot will go thru MLS flow as shown in Section 2. To ensure the quality of MSP430FR5969-SP, it is qualified with MLS qualification requirement, which will be explained in Section 3.
2 MSP430FR5969-SP Production Flow

This section discusses the MLS production flow for assembly and test.

- Die Mount Roughened NiPd/Au Leadframe
- Wire Bond - Gold Wire
- Mold Compound
- X-Ray Sample AQL = 0.005% one mold per shot
- Symbol Traceability from one Fab lot/Assembly/Test lot
- Temperature Cycle - 100% 20 Cycles -55°C to +125°C
- Pre Burn-in +25°C Electrical Test – 100%
- 100% Dynamic monitored Burn-in 125°C – 240 hours
- Post Burn-in 1+25°C Electrical Test – 100%
- +25°C Electrical Lot Accept
- Post Burn-in 2+105°C Electrical Test – 100%
- +105°C Electrical Lot Accept
- Split 22 units for RLAT per Fab lot
- RLAT for High Dose Rate 20-kRad
- Radiation Lot Acceptance Testing (RLAT)
- Dry Bake = 150°C / 8 hours
- Visual Inspection – 100%
- Lead/Ball Automated Visual Inspection Lot Accept
- Dry Pack – MSL 3 / 260°C
- Ship out with QCI Documentation
- Split 50 units for Assemble Lot level Qual
- 22 units each for Temp cycle – 500 cycles
  And Unbiased Heat 150 hours
  Post Stress CSAM
- Quality Lot Accept
3 Device Qualification

This section discusses the initial and lot level qualification.

Texas Instruments MLS Products Reliability Report

Device Type/Device Family: MSP430FR5969-SP
Package Type: 48/QFN/QFP
Wafer Fabrication Facility: DMOS5
Assembly/Test Facility: CLARK/AT/PHI/TAI

Biased Life Test

Test Method: JESD22-A108
Test Condition: 125°C / 1000 hours or equivalent
Sample Size: 77
Rejects: 0
Activation Energy (eV):
Equivalent Device Hours: 1000 hours or equivalent
Failure Rate (FIT)*:

*Derated to +55°C with a 60% Confidence Level

Note: Data for MLS products is specific to device technology and foundry. For this reason the FIT rate above may differ from TI's external web page. This does not reflect a difference in quality but only a difference in sample size.

Package Related Tests

<table>
<thead>
<tr>
<th>Description</th>
<th>Condition</th>
<th>Referenced Method</th>
<th>Sample Size</th>
<th>Rejects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biased HAST</td>
<td>130°C / 85% / 96 hours</td>
<td>JESD22-A110</td>
<td>77</td>
<td>0</td>
</tr>
<tr>
<td>Unbiased HAST</td>
<td>130°C / 85% / 96 hours</td>
<td>JESD22-A102</td>
<td>77</td>
<td>0</td>
</tr>
<tr>
<td>Temperature Cycle</td>
<td>-55°C to +125°C (200, 700, 1000°C)</td>
<td>JESD22-A104</td>
<td>77</td>
<td>0</td>
</tr>
</tbody>
</table>

* Preconditioning per JEDEC Std. 22, Method A112/A113
### Initial Product Qualification

The subject Enhanced Plastic device, device family, and/or package family have passed Texas Instruments product qualification as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Condition</th>
<th>Referenced Method</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Characterization</td>
<td>TI Data Sheet</td>
<td>N/A</td>
<td>3 lot(s)/30 Units</td>
</tr>
<tr>
<td>Electrostatic Discharge Sensitivity</td>
<td>CDM</td>
<td>JESD22-C101</td>
<td>3 Units/voltage</td>
</tr>
<tr>
<td>Physical Dimensions</td>
<td>TI Data Sheet</td>
<td>EIAJESD22- B100</td>
<td>N/A</td>
</tr>
<tr>
<td>Thermal Impedance</td>
<td>Theta-JA on board</td>
<td>EIAJESD51</td>
<td>Per Pin-Package</td>
</tr>
<tr>
<td>Bias Life Test</td>
<td>125°C / 1000 hours or equivalent</td>
<td>JESD22-A108</td>
<td>77 units</td>
</tr>
<tr>
<td>Bias Life Test with precycling</td>
<td>125°C / 1000 hours or equivalent</td>
<td>JESD22-A108</td>
<td>77 units</td>
</tr>
<tr>
<td>Biased HAST</td>
<td>130°C / 85% / 96 hours</td>
<td>JESD22-A110</td>
<td>77 units</td>
</tr>
<tr>
<td>Unbiased HAST</td>
<td>130°C / 85% / 96 hours</td>
<td>JESD22-A110</td>
<td>77 units</td>
</tr>
<tr>
<td>Temperature Cycle</td>
<td>-55°C to +125°C (200, 700, 1000°C Cyc)</td>
<td>JESD22-A104</td>
<td>77 units</td>
</tr>
<tr>
<td>Moisture Sensitivity</td>
<td>Surface Mount Only</td>
<td>J-STD-020-A</td>
<td>12 units</td>
</tr>
<tr>
<td>FRAM Low Voltage-Low Temperature Characterization</td>
<td>-55°C, Vmin Write / 105°C drop / -55°C, Vmin Read</td>
<td>N/A</td>
<td>10 units</td>
</tr>
<tr>
<td>Electromigration</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrinsic FRAM endurance</td>
<td>25°C, 2 bytes 1e13 cycles</td>
<td>N/A</td>
<td>12 units</td>
</tr>
<tr>
<td>Intrinsic FRAM endurance</td>
<td>125°C, 2 bytes 1e13 cycles</td>
<td>N/A</td>
<td>12 units</td>
</tr>
<tr>
<td>Intrinsic FRAM endurance</td>
<td>105°C, 2 bytes 1e13 cycles</td>
<td>N/A</td>
<td>12 units</td>
</tr>
<tr>
<td>No-Read FRAM Retention</td>
<td>175°C / 750°, 1000° hours</td>
<td>N/A</td>
<td>120 units</td>
</tr>
<tr>
<td>FRAM Retention/Imprint with 105°C pre-cycling</td>
<td>150°C SS Bake (168, 500, 1000 Hrs) With DS Depolanzation @105°C (30min)</td>
<td>N/A</td>
<td>77 units</td>
</tr>
<tr>
<td>Visual Quality Reliability Inspection</td>
<td>Post -700TC</td>
<td>N/A</td>
<td>14 units</td>
</tr>
<tr>
<td>Visual Quality Reliability Inspection</td>
<td>Post -96hr uHAST</td>
<td>N/A</td>
<td>14 units</td>
</tr>
<tr>
<td>X-ray</td>
<td>Post Temp Cycle</td>
<td>N/A</td>
<td>5 units</td>
</tr>
</tbody>
</table>

* Preconditioning per JEDEC Std. 22, Method A112/A113
4 Outgas Report

Outgasing was performed on 5 units of MSP430FR5969-SP. A total mass loss (TML) of 1.00% and collected volatile condensable material (CVCM) of 0.10% were used as screening levels for rejection of spacecraft materials. The outgas test was performed in a vacuum environment of less than $5 \times 10^{-5}$ torr according to ASTM E 595, for a duration of 24 hours, at 125°C. The TML, CVCM, and the amount of Water Vapor Recovered (WVR) were measured after the test.

### RESULTS

The following tables list the results of the testing:

<table>
<thead>
<tr>
<th>Sample</th>
<th>TML (%)</th>
<th>CVCM (%)</th>
<th>WVR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/N MSP430 FR5969-MLS</td>
<td>0.06</td>
<td>&lt;0.01</td>
<td>0.05</td>
</tr>
</tbody>
</table>
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