Experiences/Issues with Plastic Parts At Cold Temperatures

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AGENDA

Introduction

Cold Temperature Issues

Cold Temperature Flight Applications

Test Results

Summary
INTRODUCTION

- Missions to MARS/planets/asteroids require electronic parts to operate and survive at extreme cold conditions.

- At extreme cold temperatures many types of cold related failures can occur.

- Office 514 is currently evaluating plastic parts under various cold temperature conditions and applications.

- Evaluations, screens, and qualifications are conducted on flight parts.

<table>
<thead>
<tr>
<th>°C</th>
<th>°K</th>
<th>°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>273.2</td>
<td>32</td>
</tr>
<tr>
<td>-55</td>
<td>218.2</td>
<td>-67</td>
</tr>
<tr>
<td>-105</td>
<td>168.2</td>
<td>-157</td>
</tr>
<tr>
<td>-125</td>
<td>148.2</td>
<td>-193</td>
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<tr>
<td>-175</td>
<td>98.15</td>
<td>-283</td>
</tr>
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</table>
COLD TEMPERATURE RELIABILITY ISSUES

Reported Failure mechanisms as a result of Low Temperature Operation:

• Hot carrier electron injection
• Bipolar current gain degradation

Reported Failure mechanisms as a result of Temp Cycling / Thermal Shock:

• Package / die cracking
• Lifted / fatigued bond wires
COLD TEMPERATURE PERFORMANCE ISSUES

Reported Failure mechanisms as a result of Cold Temperature Startup:

• Non Functionality
• False initialization or setup
• Timing Problems (Bus Contention)
SCREENING/QUALIFICATION METHODS USED AT COLD TEMPERATURES

<table>
<thead>
<tr>
<th>GRADE EVALUATED</th>
<th>EXPECTED YIELD</th>
<th>EXPECTED OUTCOME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial 0 to +70C</td>
<td>Low</td>
<td>High No. of Outliers, Large Degradations</td>
</tr>
<tr>
<td>Industrial -40C to +85C</td>
<td>Medium</td>
<td>Medium No. of Outliers, Some Degradations</td>
</tr>
<tr>
<td>Military -55C to +125C</td>
<td>High</td>
<td>Few Outliers, Few Degradations</td>
</tr>
</tbody>
</table>

Acceptable parts must be within 10-20% of lot parametric distributions at temperature, while accepted lots must yield at least 50% upon completed screening. Qual lots must pass 100%.
# TEMPERATURE REQUIREMENTS

(OL/NOP Example)

<table>
<thead>
<tr>
<th>Part Test/Eval</th>
<th>Qualification</th>
<th>Flight Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable Flight</td>
<td>-105°C minimum</td>
<td>-110°C minimum</td>
</tr>
<tr>
<td>Qualification</td>
<td>-125°C minimum</td>
<td>-110°C minimum</td>
</tr>
<tr>
<td>Flight Acceptance</td>
<td>-110°C minimum</td>
<td>-110°C minimum</td>
</tr>
<tr>
<td>Part Test/Eval</td>
<td>-115°C minimum</td>
<td>-120°C minimum</td>
</tr>
<tr>
<td>Part Test/Eval</td>
<td>-135°C minimum</td>
<td>-120°C minimum</td>
</tr>
<tr>
<td>Part Accept</td>
<td>-130°C minimum</td>
<td>-120°C minimum</td>
</tr>
<tr>
<td>Part Accept</td>
<td>-130°C minimum</td>
<td>-120°C minimum</td>
</tr>
<tr>
<td>Part Accept</td>
<td>-115°C minimum</td>
<td>-130°C minimum</td>
</tr>
</tbody>
</table>
A WORD OF CAUTION ON THE USE OF PARTS BEYOND MFR SPEC

• The manufacturers are not going to guarantee the operation of their parts outside the specified temperature ranges, nor will they encourage the use of their parts outside the stated application conditions. Most manufacturers are not even set up to test production parts at extreme cold temperatures.

Therefore,

• The users must perform a thorough characterization, screening and qualification of the lots intended for use in extreme cold temperature conditions. Any radiation requirements should also be addressed.
USE OF PEMS ON MER CAMERAS
SCREENING STEPS

• Initial electricals over temperature
• Temperature Cycle (10 cycles, down to -125C)
• X-ray
• CSAM
• Pre Burn-in electricals
• Burn-in
• Final electricals over temperature
• Data review
USE OF PEMS ON MER CAMERAS
QCI STEPS

• Destructive Physical Analysis (DPA)
• Radiation Tests
• Life Test
• Temperature cycle (300 cycles, down to -125C)
• Outgassing
Part A Summary: 627 flight parts (PEMs) passed 10 cycles to the above requirement. 20 samples were qualified to 300 cycles using the same T/C profile.
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COLD TEMPERATURE TEST RESULTS - COTS UPCODE

(Examples)

Part A Ios Range @ -65C

Part A Isc Range @ -65C

Note: Some devices exhibit more variations and divergence at cold temperatures. Devices >10% from norm are rejected.
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Cold Temperature Capabilities/Developments

-195°C  Cold Test Evaluation Chamber

-125°C  Cold ATE Digital Tester

-180°C  Liquid Nitrogen Bath
COLD TEMPERATURE TEST RESULTS COTS SRAMS

COTS SRAMS have been evaluated by JPL at military temperature range:

+125C +70C +25C 0C -20C -55C
+5.5V +4.5V +3.6V +3.0V

Vendor A Pass

+125C +70C +25C 0C -20C -55C
+5.5V +4.5V +3.6V +3.0V

Vendor B Pass

+125C +70C +25C 0C -20C -55C
+5.5V +4.5V +3.6V +3.0V

Vendor C Pass

Results:
Three different parts from three different vendors passed.
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COLD TEMPERATURE TEST RESULTS
COTS PROGRAMMABLE OSCILLATORS

Hermetic Package

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Part No</th>
<th>Programmed Frequency (MHz)</th>
<th>-55C</th>
<th>-40C</th>
<th>25C</th>
<th>80C</th>
<th>125C</th>
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<tbody>
<tr>
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<td>1</td>
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<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
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<tr>
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<td>2</td>
<td>66.0000</td>
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<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>5.0</td>
<td>3</td>
<td>99.0000</td>
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<td>40</td>
<td>38</td>
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<td>33</td>
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<tr>
<td>5.0</td>
<td>4</td>
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<td>31</td>
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<tr>
<td>3.3</td>
<td>6</td>
<td>25.0000</td>
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<td>27</td>
<td>24</td>
<td>22</td>
<td>21</td>
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<tr>
<td>3.3</td>
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<tr>
<td>3.3</td>
<td>8</td>
<td>75.0000</td>
<td>18</td>
<td>18</td>
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<td>17</td>
<td>17</td>
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<tr>
<td>3.3</td>
<td>9</td>
<td>100.0000</td>
<td>22</td>
<td>22</td>
<td>20</td>
<td>19</td>
<td>18</td>
</tr>
</tbody>
</table>

Powered and Measured by the HP E3612A DC Power Supply.
All current readings are in mA.

-55C - 125C
0 5 10 15 20 25 30 35 40 45

-55C - 125C
0 5 10 15 20 25 30
TEST RESULTS for COTS PEMS

Test Conditions: 30 cycles from –185° C to +135° C liquid bath

Sample 1  PASSED
Sample 2  FAILED
Sample 3  PASSED
Sample 4  PASSED
Sample 5  PASSED
Sample 6  FAILED
Sample 7  PASSED

Miniature Cracks Found
SUMMARY

- Many COTS PEM devices evaluated beyond their low-end rated temperature ranges have done quite well.

- Plastic packages have held up under low temperature cycling but show signs of cracking under low temperature shock conditions.

- Future work is planned to examine long term cold environmental effects such as cold start and operating life degradation.

- When the parts must be used at extreme low temperatures, the users must collect sufficient data in order to insure that the parts would meet their application/mission requirements.