Fundamentals of AEC-Q100: What “Automotive Qualified” Really Means

Richard Oshiro,
Director, QMS-Automotive

November 2018
MPS Automotive Background

- **Flip-Chip Packaging Qualified**
- **First Q100 Flip-Chip Part, MPQ4470**
- **AEC Participation**
- **First Q100 Part, MPQ2451**
- **Automotive Hits $12M Annual Revenue**
- **World’s Most Compact LED Driver Module, MPM6010**
- **80 AEC Orderables**
- **Automotive Spiked Out in Company Earnings, $53M**
- **240+ AEC Products**
- **200M Units Shipped**
- **First Functional Safety PMIC, MPQ7901**
- **77GHz Radar for ADAS**
- **$120M+**
• Nearly 20 years experience in Automotive Quality

• Currently responsible for MPS Automotive Quality as well as our Quality Management System. Representative for MPS on Automotive Electronics Council

• 11+ years as Director of Quality at Cypress Semiconductor with first task getting 2 internal fabs and 1 assembly test facility ISO/TS 16949 certified

• 5 ½ years as Director of Quality at a U.S. based assembly subcon where we assembled a Ford microelectronics component
Agenda

The Who/What/Why’s of AEC
The Many AEC-Qxxx Standards
AEC-Q100: Temperature Grades
AEC-Q100: Key Reliability Tests
Spotlight on HTOL, ELFR, PTC, TC, HAST
Beyond AEC: STRM, Road Test, EVB BI
MPS Consumer / Industrial / Automotive Grades Compared
Background: Automotive Ecosystem

- PCN guidelines
- ISO-9001:2015
- IATF-16949 IATF
- IATF Rules 5th edition
- Customer Requirements
- ISO-19011 (audit)
- ISO-17025 (calibration)
- AEC Q100 (IC Reliability)
- VDA 6.3 (audit)
- APQP & Control Plan
- AIAG reference manuals
- FMEA
- MSA
- SPC
- PPAP
Who is AEC?

Automotive Tier-1 Suppliers

- Aptiv
- Harman
- Kostal
- Continental
- Visteon
- Valeo
- John Deere
- Lear
- Magna
- Magna Electronics
- ZF
- TRW
- Denso

Automotive Electronics Council
Component Technical Committee

Semiconductor Suppliers

- Analog Devices
- MPS
- Infineon
- Texas Instruments
- ON Semiconductor
- Maxim Integrated
- Xilinx
- Qualcomm
# Automotive vs. Consumer

<table>
<thead>
<tr>
<th></th>
<th>Consumer</th>
<th>Automotive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Temperature Range</td>
<td>0° to 85°C</td>
<td>-40°C to 150°C</td>
</tr>
<tr>
<td>Expected Operating Life</td>
<td>2-3 years</td>
<td>10 years+</td>
</tr>
<tr>
<td>Acceptable Failure Rates</td>
<td>300 parts per million</td>
<td>Zero</td>
</tr>
<tr>
<td>Supply Lifetime</td>
<td>2-3 years</td>
<td>15-20 years</td>
</tr>
</tbody>
</table>
Automotive companies sell millions of very expensive vehicles – to some people this means they think they can sue them for a lot of money.

Automotive buyers have increased their quality requirements, partly due to automotive company’s own advertisements.

Example

1000 defective cars

Single 1 ppm per part defect rate

1000 parts per ECU (IC, res, cap, etc)

1 Million cars sold
Reliability “Bathtub Curve”

The "Bathtub" Covered with “Safe Launch” Protocols

Covered with AEC-Q100 Qualification

Early Infant Mortality Failures

Wear-Out Failures

Constant / Random Failures

Time

Failure Rate
The Many AEC-Q Standards

Additional Standards

AEC - Q100-007 - Rev-B: Fault Simulation and Test Grading
AEC - Q100-008 - Rev-A: Early Life Failure Rate (ELFR)
AEC - Q100-009 - Rev-B: Electrical Distribution Assessment
AEC - Q100-010 - Rev-A: Solder Ball Shear Test
AEC - Q100-011 - Rev-C1: Charged Device Model (CDM) Electrostatic Discharge Test
AEC - Q100-001 - Rev-C: Wire Bond Shear Test
AEC - Q100-002 - Rev-E: Human Body Model (HBM) Electrostatic Discharge Test
AEC - Q100-004 - Rev-D: IC Latch-Up Test
AEC - Q100-005 - Rev-D1: Non-Volatile Memory Program/Erase Endurance, Data Retention, and Operational Life Test
AEC - Q100-012 - Rev-: Short Circuit Reliability Characterization of Smart Power Devices for 12V Systems

AEC - Q101 Rev - D1: Failure Mechanism Based Stress Test Qualification For Discrete Semiconductors (base document)
AEC - Q101-003 - Rev-A: Wire Bond Shear Test
AEC - Q101-004 - Rev-: Miscellaneous Test Methods
AEC - Q101-005 - Rev-: Charged Device Model (CDM) Electrostatic Discharge Test
AEC - Q200 Rev - D base: Stress Test Qualification For Passive Components (base document)
AEC - Q200-001 - Rev-B: Flame Retardance Test
AEC - Q200-002 - Rev-B: Human Body Model (HBM) Electrostatic Discharge Test
AEC - Q200-003 - Rev-B: Beam Load (Break Strength) Test
AEC-Q100 Key Figures & Grades

| Number of unique lots tested | 3 |
| Sample size per lot | 77 |
| Accelerated tests duration | 1000h |
| Minimum CPK for distribution related parameters | 1.67 |
| Number of fails allowed | 0 |

Ambient Temperature Range

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 3</td>
<td>-40° to 85°C</td>
</tr>
<tr>
<td>Grade 2</td>
<td>-40° to 105°C</td>
</tr>
<tr>
<td>Grade 1</td>
<td>-40° to 125°C</td>
</tr>
<tr>
<td>Grade 0</td>
<td>-40° to 150°C</td>
</tr>
</tbody>
</table>
AEC-Q100 Key Test Categories

- Accelerated Environment Stress
- Accelerate Lifetime Simulation
- Packaging/Assembly
- Die Fabrication
- Electrical Verification
- Defect Screening
- Cavity Package Integrity
AEC-Q100: Key Reliability Tests

Accelerated Environment Stress Tests

- Preconditioning
- Temperature-Humidity-Bias (THB) / Biased Highly Accelerated Stress Test (HAST)
- Autoclave (AC) / Unbiased (HAST)
- Temperature Cycling (TC)
- Powered Temperature Cycling (PTC)
- High Temperature Storage Life (HTSL)

Accelerate Lifetime Simulation Tests

- High Temperature Operating Life (HTOL)
- Early Life Failure Rate (ELFR)
- NVM Endurance, Data Retention, and Operational Life (EDR)

Packaging/Assembly

- Wire Bond Shear (WBS)
- Wire Bond Pull (WPL)
- Solderability (SD)
- Physical Dimensions (PD)
- Solder Ball Shear (SBS)
- Lead Integrity (LI)

Die Fabrication

- Electromigration (EM)
- Time Dependent Dielectric Breakdown (TDDDB)
- Hot Carrier Injection (HCI)
- Negative Bias Temperature Instability (NBTI)
- Stress Migration (SM)

Electrical Verification

- Pre- and Post-Stress Function Parameter
- ESD – HBM/CDM
-Latch-Up
- Electrical Distributions
- Fault Grading
- Characterization
- Electromagnetic Compatibility (EMC)
- Short Circuit (SC)
- Soft Error Rate (SER)
- Lead (Pb) Free

Defect Screening

- Part Average Testing
- Statistical Bin/Yield Analysis

Package Integrity
### Table 2: Qualification Test Methods (continued)

<table>
<thead>
<tr>
<th>STRESS</th>
<th>ABV</th>
<th>#</th>
<th>NOTES</th>
<th>SAMPLE SIZE / LOT</th>
<th>NUMBER OF LOTS</th>
<th>ACCEPT CRITERIA</th>
<th>TEST METHOD</th>
<th>ADDITIONAL REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Temperature Operating Life</strong></td>
<td>HTOL</td>
<td>B1</td>
<td>H, P, B, D, G, K</td>
<td>77</td>
<td>3</td>
<td>0 Fails</td>
<td>JEDEC JESD22-A108</td>
<td>For devices containing NVM, endurance preconditioning must be performed before HTOL per Q100-005. Grade 0: +150°C Tₐ for 1000 hours. Grade 1: +125°C Tₐ for 1000 hours. Grade 2: +105°C Tₐ for 1000 hours. Grade 3: +85°C Tₐ for 1000 hours.</td>
</tr>
<tr>
<td><strong>Early Life Failure Rate</strong></td>
<td>ELFR</td>
<td>B2</td>
<td>H, P, B, N, G</td>
<td>800</td>
<td>3</td>
<td>0 Fails</td>
<td>AEC Q100-008</td>
<td>Devices that pass this stress can be used to populate other stress tests. Generic data is applicable. TEST before and after ELFR at room, cold, and hot temperature.</td>
</tr>
</tbody>
</table>

- EVB based
### Table 2: Qualification Test Methods (continued)

**TEST GROUP A – ACCELERATED ENVIRONMENT STRESS TESTS (CONTINUED)**

<table>
<thead>
<tr>
<th>STRESS</th>
<th>ABV</th>
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<th>NOTES</th>
<th>SAMPLE SIZE / LOT</th>
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<th>ACCEPT CRITERIA</th>
<th>TEST METHOD</th>
<th>ADDITIONAL REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Temperature Cycling</td>
<td>PTC</td>
<td>A5</td>
<td>H, P, B, D, G</td>
<td>45</td>
<td>1</td>
<td>0 fails</td>
<td>JEDEC</td>
<td>PC before PTC for surface mount devices. Test required only on devices with maximum rated power ≥ 1 watt or ΔT ≥ 40°C or devices designed to drive inductive loads. Grade 0: T&lt;sub&gt;e&lt;/sub&gt; of -40°C to +150°C for 1000 cycles. Grade 1: T&lt;sub&gt;e&lt;/sub&gt; of -40°C to +125°C for 1000 cycles. Grades 2 and 3: T&lt;sub&gt;e&lt;/sub&gt; -40°C to +105°C for 1000 cycles. Thermal shut-down shall not occur during this test. <strong>TEST before and after PTC at room and hot temperature.</strong></td>
</tr>
</tbody>
</table>

- EVB
### Table 2: Qualification Test Methods (continued)

<table>
<thead>
<tr>
<th>STRESS</th>
<th>ABV</th>
<th>#</th>
<th>NOTES</th>
<th>SAMPLE SIZE / LOT</th>
<th>NUMBER OF LOTS</th>
<th>ACCEPT CRITERIA</th>
<th>TEST METHOD</th>
<th>ADDITIONAL REQUIREMENTS</th>
</tr>
</thead>
</table>
| Temperature Cycling TC  | A4  | H, P, B, D, G | 77  | 3             | 0 Fails        | JEDEC JESD22-A104 and Appendix 3 | PC before TC for surface mount devices.  
Grade 0: -55°C to +150°C for 2000 cycles or equivalent.  
Grade 1: -55°C to +150°C for 1000 cycles or equivalent.  
Note: -65°C to +150°C for 500 cycles is also an allowed test condition due to legacy use with no known lifetime issues.  
Grade 2: -55°C to +125°C for 1000 cycles or equivalent.  
Grade 3: -55°C to +125°C for 500 cycles or equivalent.  
TEST before and after TC at hot temperature. After completion of TC, decap five devices from one lot and perform WBP (test #C2) on corner bonds (2 bonds per corner) and one mid-bond per side on each device. Preferred decap procedure to minimize damage and chance of false data is shown in Appendix 3. |
<table>
<thead>
<tr>
<th>STRESS</th>
<th>ABV</th>
<th>#</th>
<th>NOTES</th>
<th>SAMPLE SIZE / LOT</th>
<th>NUMBER OF LOTS</th>
<th>ACCEPT CRITERIA</th>
<th>TEST METHOD</th>
<th>ADDITIONAL REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoclave or Unbiased HAST or Temperature-Humidity (without Bias)</td>
<td>AC or UHST or TH</td>
<td>A3</td>
<td>P, B, D, G</td>
<td>77</td>
<td>3</td>
<td>0 Fails</td>
<td>JEDEC JESD22-A102, A119, or A101</td>
<td>For surface mount devices, PC before AC (121°C/15psig for 96 hours) or unbiased HAST (130°C/85%RH for 96 hours, or 110°C/85%RH for 264 hours). For packages sensitive to high temperatures and pressure (e.g., BGA), PC followed by TH (85°C/85%RH) for 1000 hours may be substituted. TEST before and after AC, UHST, or TH at room temperature.</td>
</tr>
</tbody>
</table>

- AC
# Process/Design Change Impact on AEC-Q100

## Table 2 Test #


- Active Element Design
- Circuit Rerouting
- Wafers Dimension / Thickness

**WAFF FAB**

- Lithography
- Die Shrink
- Diffusion / Doping
- Polysilicon
- Metalization / Via / Contacts
- Passivation / Oxide / Interlevel Dielectric
- Backside operation
- FAB Site Transfer

**ASSEMBLY**

- Die Overcoat / Underfill
- Leadframe Plating
- Bump Material / Metal System
- Leadframe Material
- Leadframe Dimension
- Wire Bonding
- Die Scribe / Separate
- Die Preparation / Clean
- Package Marking
- Die Attach
- Molding Compound
- Molding Process
- Hermetic Sealing
- New Package
- Substrate / Interposer
- Assembly Site Transfer

- Highly Recommended

- A Only for peripheral routing
- B For symbol rework, new cure time, temp
- C If bond to leadfinger
- D Design rule change
- E Thickness only
- F MEMS element only
- G Only from non-100% burned-in parts
- H Hermetic only
- J EPROM or E’prom
- K Passivation only
- L For Pb-free devices only
- M For devices requiring PTC
- N Passivation and gate oxide
- Q Wire diameter decrease
- T For Solder Ball SMD only

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**MPS**
FAQ About AEC-Q100 Qual

- Do all qualification tests have to be performed for every new device?
- How long is qualification data valid?
End Product: Qual Report in PPAP

1. Device Information

- Product: MPS
- Package: ECQEN2-3-14
- Process Technology: BCD
- Report Date: 09/27/2018

2. Summary of Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>#</th>
<th>Test Condition</th>
<th>Lot/ or Date Code</th>
<th>Test Results</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>7SIO22-A108</td>
<td>(q=125°C for 1000 hours or equivalent)</td>
<td>HP5451</td>
<td>770</td>
<td></td>
</tr>
<tr>
<td>B2</td>
<td>AEC-Q000-008</td>
<td>(q=125°C for 48 hours or equivalent)</td>
<td>HA9550</td>
<td>880/9</td>
<td>880/9</td>
</tr>
<tr>
<td>E2</td>
<td>AEC-Q000-0002</td>
<td></td>
<td>HP545112</td>
<td>3.0</td>
<td>&gt;2000V</td>
</tr>
<tr>
<td>E3</td>
<td>AEC-Q000-0011</td>
<td></td>
<td>HP545113</td>
<td>3.0</td>
<td>&gt;750V</td>
</tr>
<tr>
<td>E4</td>
<td>AEC-Q000-0004</td>
<td></td>
<td>HP545114</td>
<td>3.0</td>
<td>&gt;150mS &amp; &gt;1.5Vnomax</td>
</tr>
<tr>
<td>A1</td>
<td>STD-020</td>
<td></td>
<td></td>
<td>216/9</td>
<td>216/9</td>
</tr>
<tr>
<td>A2</td>
<td>JESD22-A101</td>
<td>(q=85°C/85%RH static Bias at Vmax for 1000 hours or equivalent)</td>
<td>1808</td>
<td>770</td>
<td>770</td>
</tr>
<tr>
<td>A3</td>
<td>JESD22-A102</td>
<td>(q=125°C/100%RH for 600 hours or equivalent)</td>
<td>1808</td>
<td>770</td>
<td>770</td>
</tr>
<tr>
<td>A4</td>
<td>JESD22-A104</td>
<td>(q=65°C to 135°C for 1000 cycles or equivalent)</td>
<td>1808</td>
<td>770</td>
<td>770</td>
</tr>
</tbody>
</table>
Beyond Q100: EVB Burn-In

- 80 application evaluation boards
- 1000 hours
- 125°C ambient temperature – 150°C junction temperature
- Fully operational (switching)
Beyond Q100: Road Test & EMC

MPQ4572GL R2 Quick Road Test Report
2A, 60V, High-Efficiency SYNC Buck

- 300-point application road test
- Grade 1: 25°C, -55°C, 150°C for margin
- Tests include stability/margin, ripple, fault response, load dump, cold crank
- CISPR25 radiated & conducted emissions testing

<table>
<thead>
<tr>
<th>AE</th>
<th>Luke Wang</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor</td>
<td>Huafei Ding</td>
</tr>
<tr>
<td>Manager</td>
<td>Zheng Luo</td>
</tr>
<tr>
<td>Date</td>
<td>2018-04-27</td>
</tr>
</tbody>
</table>

LOT: HP481815R2W20-C  Date code: 1814  IC Designer: Surely (Li) Xu  Production Engineer: Lux Zhang

MPS EMI Lab
Hangzhou, China
**Beyond Q100: Short Term Reliability Monitoring**

**MPS “AEC1” Grade Production Lot**
- Finished Goods
- Reserved for STRM

**Short Term Reliability Monitoring Criteria**
1. Preconditioning (3x Reflow)
2. 96-Cycle Temperature Cycling (-65° to 150°C)
3. 48h Autoclave
4. Final Test
5. Lot Accepted
<table>
<thead>
<tr>
<th>MPS Product Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Qual</strong></td>
</tr>
<tr>
<td>Qualification Standard</td>
</tr>
<tr>
<td>Tri-Temp Application Road Test</td>
</tr>
<tr>
<td>Dedicated Fab / Assembly</td>
</tr>
<tr>
<td>Specialized Tools / Personnel</td>
</tr>
<tr>
<td>Enhanced Process Controls*</td>
</tr>
<tr>
<td>Ultra-Enhanced Process Controls*</td>
</tr>
<tr>
<td><strong>Supply Chain</strong></td>
</tr>
<tr>
<td><strong>Process</strong></td>
</tr>
<tr>
<td>Test Lot Size Restriction</td>
</tr>
<tr>
<td>ATE Test at Room Temp</td>
</tr>
<tr>
<td>ATE Test at Hot Temp</td>
</tr>
<tr>
<td>STRM &amp; QA Sample Test</td>
</tr>
<tr>
<td>PPAP</td>
</tr>
</tbody>
</table>

*(SPC, Particle, PCM) & SBL/SYL
Thank You – Q&A

Additional resources:
http://www.aecouncil.com

For more information, contact:
automotive@monolithicpower.com

Check out our AEC-Q100 Power Management Solutions at MonolithicPower.com