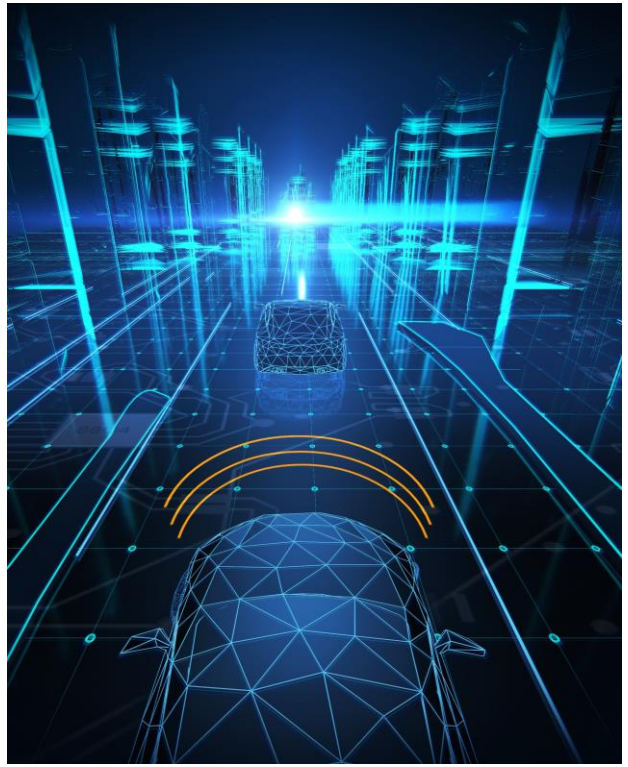
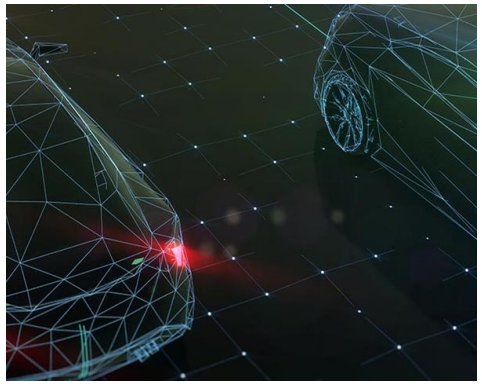
Flash Memory Summit

Ensuring Robust Embedded Memory Solutions in Automotive Applications

Presenter: Nicolas Leng, ATP Electronics Inc.

Agenda





- Automotive Systems & Form Factors
- Automotive Quality Standards for SSD Form Factors (non-package type)
- Qualification Challenges
- Engineering Validation/Design Challenges & Suggestions
- Conclusions

Automotive Systems & Form Factor

- Form Factors
  - eMMC:
    - ADAS, LiDAR, Sensors, IVI, Telematics…

  - SD & µSD
    - Map/navigation system, dashboard cam

  - BGA SSD
    - ADAS, LiDAR, IVI, Telematics…with better performance and larger capacity

  - Other SSD Form Factors, such as NVMe M.2 2280, M.2 22110, U.2
    - IVI, Data logger →high performance

- **Vehicle Controls**
- **Telematics**
- **IVI (In-Vehicle Infotainment)**
- **Navigation**

Automotive Quality Standards for SSD

- Automotive Electronics Council: AEC-Q100/104/…
- IATF 16949
- Automotive SPICE (ASPICE)
- ISO 26262/14001/9000/9001...
- VDA 6.3
- JEDEC312
- …

Automotive SSD Qualification Challenges

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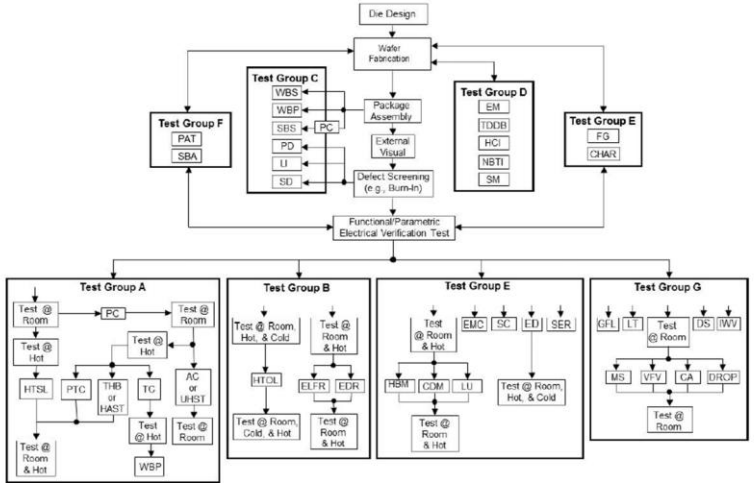
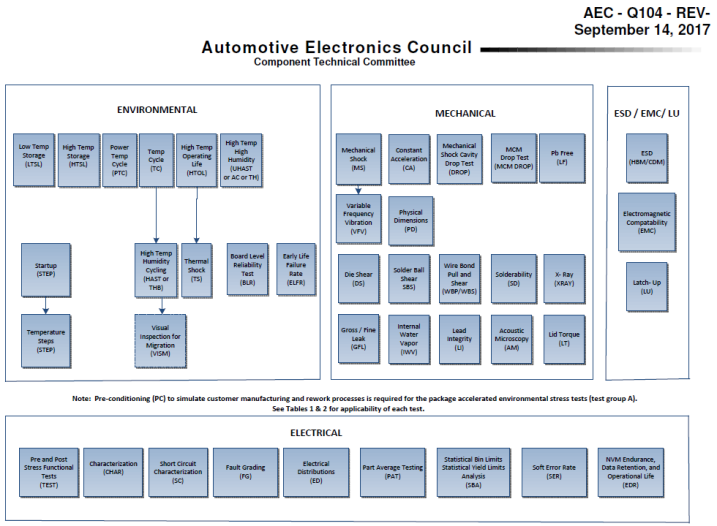
AEC-Q100 Qualification/ Testing Flow



AEC-Q104 Qualification/ Testing Flow



Challenge 1: Multiple Testing Categories

- Accelerated environment stress tests
- Accelerated lifetime simulation tests
- Package assembly integrity tests
- Electrical verification tests

Challenge 2: Large Sample Size

- Each test items contains multiple lots/multiple samples
- Total number could be over 1000pcs

Challenge 3: BOM Control

- What constitutes a qualification family? NAND/controller/DRAM/…
- The complexity of Sub-supplier management

Major Design Challenges for SSD

- **Challenge 1: Environment Dependent Adversity**
  - Temperature extremes/Heat generated by SSDs
  - Humidity/air pollution/altitude…
  - Mechanical shock & vibration
- **Challenge 2: High Sustained Read/Write Performance**
  - Drive performance may be influenced by extreme temperature; heat dissipation is an issue
- **Challenge 3: Endurance/Reliability Assessments**
  - User and market models may influence endurance requirements
  - Endurance is operating temperature dependent

Engineering Design Challenges and Suggestions

Challenge 1: Environment Dependent Adversity

- Conditions: Temperature extremes/humidity/altitude/mechanical shock & vibration
- Qualification Tests to Validate Product Robustness (AEC-Q100/104)
  - Accelerated environment stress test
    -THB Temperature humidity bias/TC temperature cycle/HTSL high temp storage life
  - Accelerated lifetime simulation tests
    -HTOL high temp operating life/ELFR Early life Failure Rate/EDR Endurance data retention…
  - Mechanical tests
    -Shock & Vibration
    -Solderability: a thorough solderability check for automotive applications should incorporate both temperature cycle and shock & vibration (sequentially, not parallelly), followed by dye & pry. Inter-Circuit testing, function check and X-Ray check should be done at various level of temperature cycles
- Other point of consideration: adoption of anti-sulfur resistors, conformal coating for humidity and pollutants

- Multiple testing categories, large sample size, and strict BOM control make automotive SSD qualification resource & time consuming
  - Feasible Sample size/lots to make sure the application environment scenarios are covered: tests and its acceptance criteria are per agreement between supplier and user

Engineering Design Challenges and Suggestions

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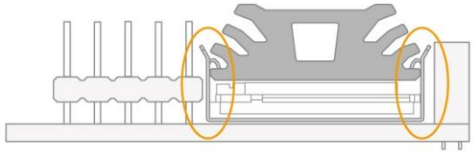
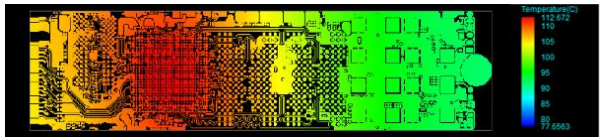
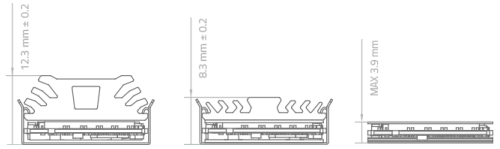
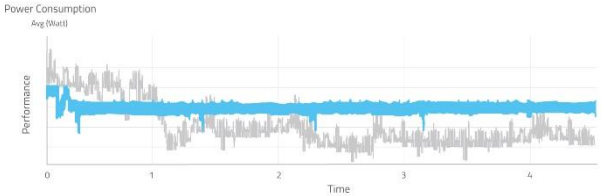
Challenge 2: High Sustained Read/Write Performance

- Drive performance may be influenced by extreme temperature; heat dissipation of SSD (heat sink adoption/design) and active cooling are needed for better performance and better product reliability
- Joint validation should be conducted and therefore, customization and performance optimization can be achieved









STEP 1: ASSESSMENT

- System/mechanical criteria
- User applications
- System specifications including, but not limited to:
  - Temperature
  - Airflow
  - Mechanical design
  - Workload and performance requirement

STEP 2: SIMULATION

Combining hardware and software simulation in a three-pronged simulation testing strategy for thermal solutions:

- **Component-Level Simulation**.
  Pure hardware simulation based on full-speed operation, which is the worst-case scenario, to determine heat distribution in each PCB layer.

- **System-Level Simulation.**
  Contrasting results for scenarios with or without thermal solution.

- **Proprietary ATP-built mini chamber**
  Simulates and adjusts thermal environments based on customer's profile.

STEP 3: CUSTOMIZATION

- **Adaptive Thermal Control**
  through the ATP Dynamic Thermal Throttling mechanism, which provides a delicate balance between performance and temperature instead of dramatic performance reduction. Temperature sensors continuously detect the device temperature. After sophisticated FW transactions, the performance gradually declines, and the temperature is adjusted.

- **H/W Heatsink Solution**
  A variety of HW heatsink options (materials, dimensions, types) are available to match the mechanical constraints of each system design.

- **Garbage Collection F/W Tuning**
  A periodic background refresh offsets the significant performance drop caused by the long garbage collection process.

STEP 4: OPTIMIZATION

An optimized solution combines both HW and FW to meet customer's needs. As the graph above shows, performance can drop sharply when standard thermal throttling is used. ATP NVMe SSDs with the customized thermal management solution, on the other hand, deliver higher sustained write performance.

Engineering Design Challenges and Suggestions

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Challenge 3: Endurance/Reliability Assessment

- life span of automotive SSD assessment is difficult
- TBW rating decreases in the higher temperature range
- TBW/DWPD requirements during the life span of a drive highly depends on temperature rating and personal or professional auto scenario

JESD312 Endurance Requirements

Characteristic	Personal Auto	Professional Auto
Years of Operation	15	8
Days per year of use	344	365
Average Hours per Day of Use	3	12
Nominal temperature, power on, active use	55 °C	55 °C
Nominal temperature, power off	30 °C	30 °C

Design point of view/Suggestions

- Adopt SLC NAND or pSLC mode for TLC-based NAND (with large OP) to guarantee sufficient endurance→ Intrinsically better reliability and better sustained performance, as compared to TLC NAND
- Adopt heat sink adoption/design for SSD heat dissipation and system active cooling design may be required. Close collaboration with SSD supplier on heat sink design to tailor-fit the system active cooling design.

Engineering Design Challenges- Endurance/Reliability Assessments

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Other Reliability Considerations

- What constitutes a qualification family?
- Apart from Controller, NAND, and DRAM, there are also tons of other ICs and passive components on an SSD
- How to guarantee reliability as a whole??

Design point of view/Suggestions

- Component derating for all components used on an SSD should be assessed to ensure enough design guard band
- Reliability demonstration test with decent sample size should be conducted to obtain MTBF, and should not just rely on reliability prediction software (such as Telcordia)

  -Temperature accelerated (ex. assess using testing script with actual application workload)

Ea	0.6eV
T_{STRESS} High	72°C
T_{STRESS} Low	

Sample Size	T_{STRESS} (hours)	AF	T_{USE} (hours)
432	1555	2.84	1,910,181
T_{STRESS} Hours:	671,760		
T_{USE} Hours:			1,910,181

Choose Confidence Level>> 60%

Fallures	X^2	MTBF @ 55°C
0	1.83	2,084,689
1	4.04	944,553
2	6.21	615,120
3	8.35	457,500
4	10.47	364,774
5	12.58	303,593

Engineering Design Challenges- Endurance/Reliability Assessments

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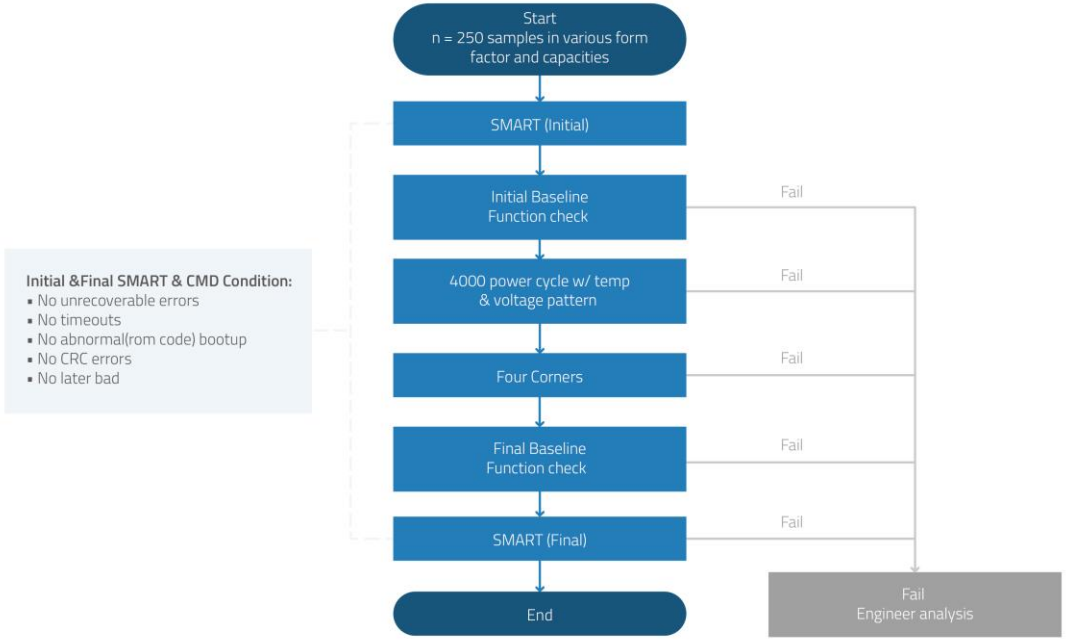
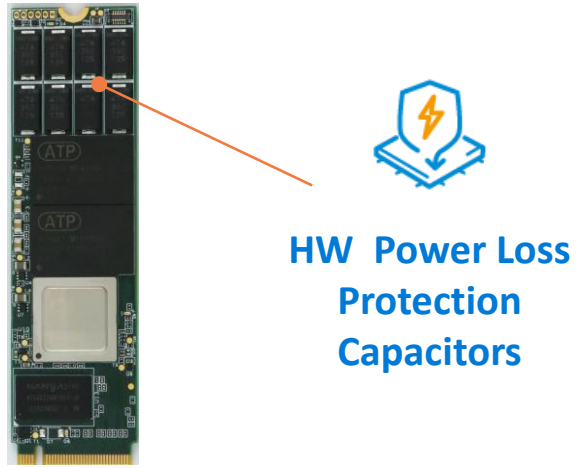
Other Reliability Considerations

Reliability Assessment

- **4 corner testing** based on temperature cycle and high/low voltage to better simulate actual automotive environment





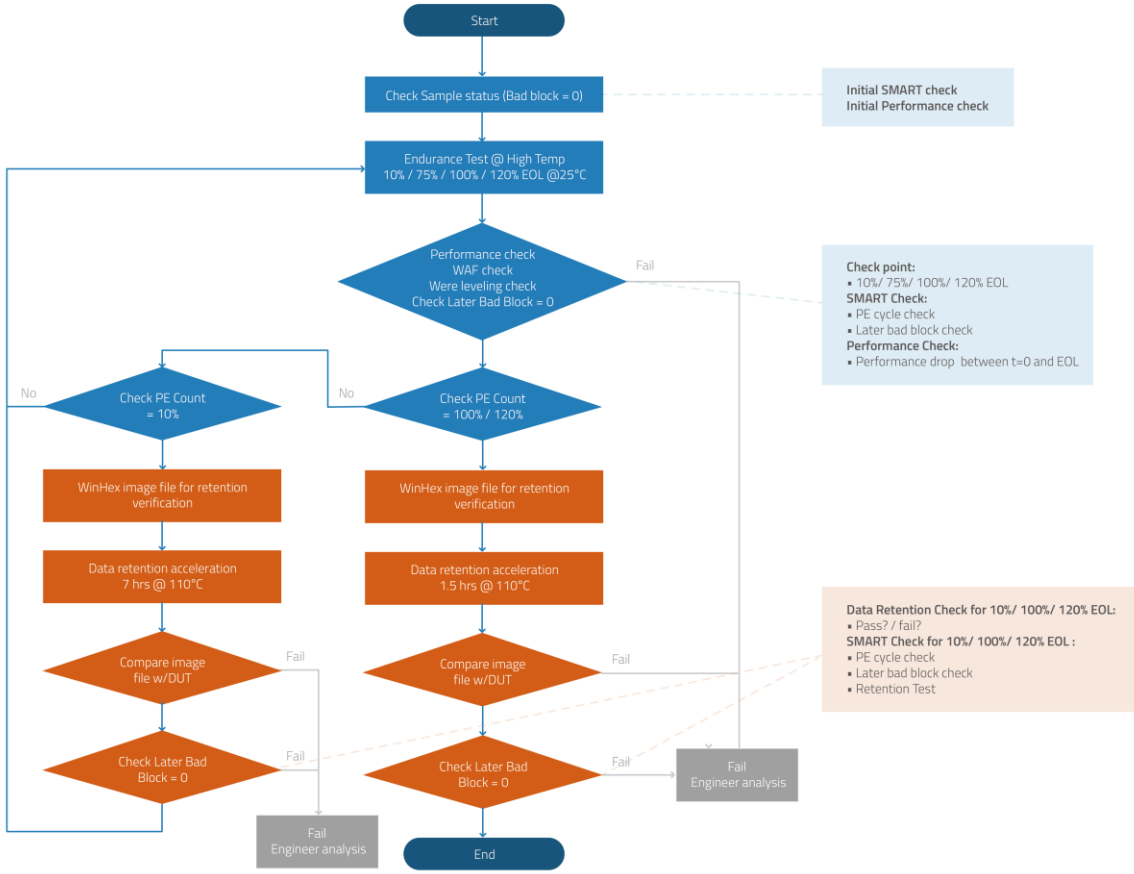
- Power cycling test/sudden power off recovery test should be conducted in temperature extremes.
  - **HW Power loss protection capacitor design** should be adopted on SSD

Engineering Design Challenges- Endurance/Reliability Assessments

Other Reliability Considerations

Reliability Assessment

- JEDEC Enterprise workload
- NAND endurance (DWPD/TBW) and retention should be tested based on design environment and temperature
- To check the rated life span of NAND flash and beyond



Conclusions

- No current automotive quality standards are fully applicable to all form factors of SSDs
- Multiple testing categories, large sample size, and strict BOM control make automotive SSD qualification resource & time consuming; how to strike a balance between qualification feasibility and reliability coverage is important.
- life span of automotive SSD assessment is difficult: drive life is temperature dependent/ user dependent. Apart from HW design perspective to address endurance and reliability concerns, the following tests should be conducted to prove rated endurance & reliability:
  - Accelerated environment stress tests
  - reliability demonstration test should be conducted to prove actual MTBF
  - Solderability assessment via temperature cycle and shock & vibration.
  - 4 corner testing based on temperature cycle and voltage to better simulate automotive environment
  - Power cycling testing (sudden power off recovery testing) should be conducted in temperature extremes
  - NAND endurance (DWPD/TBW) and retention should be tested based on design environment and temperature; check the rated life span of NAND flash and beyond

For More Information on ATP Electronics

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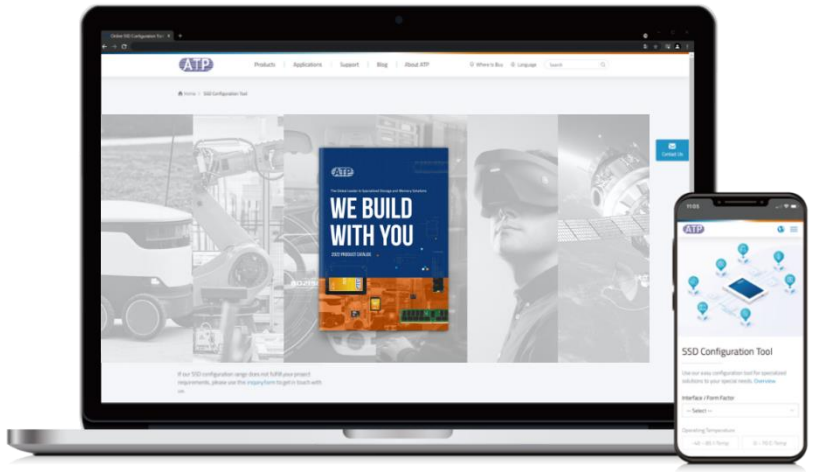
Visit our website: www.atpinc.com



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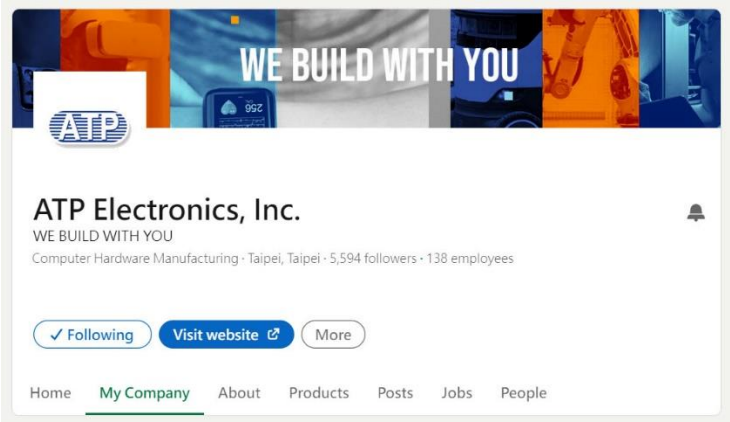

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