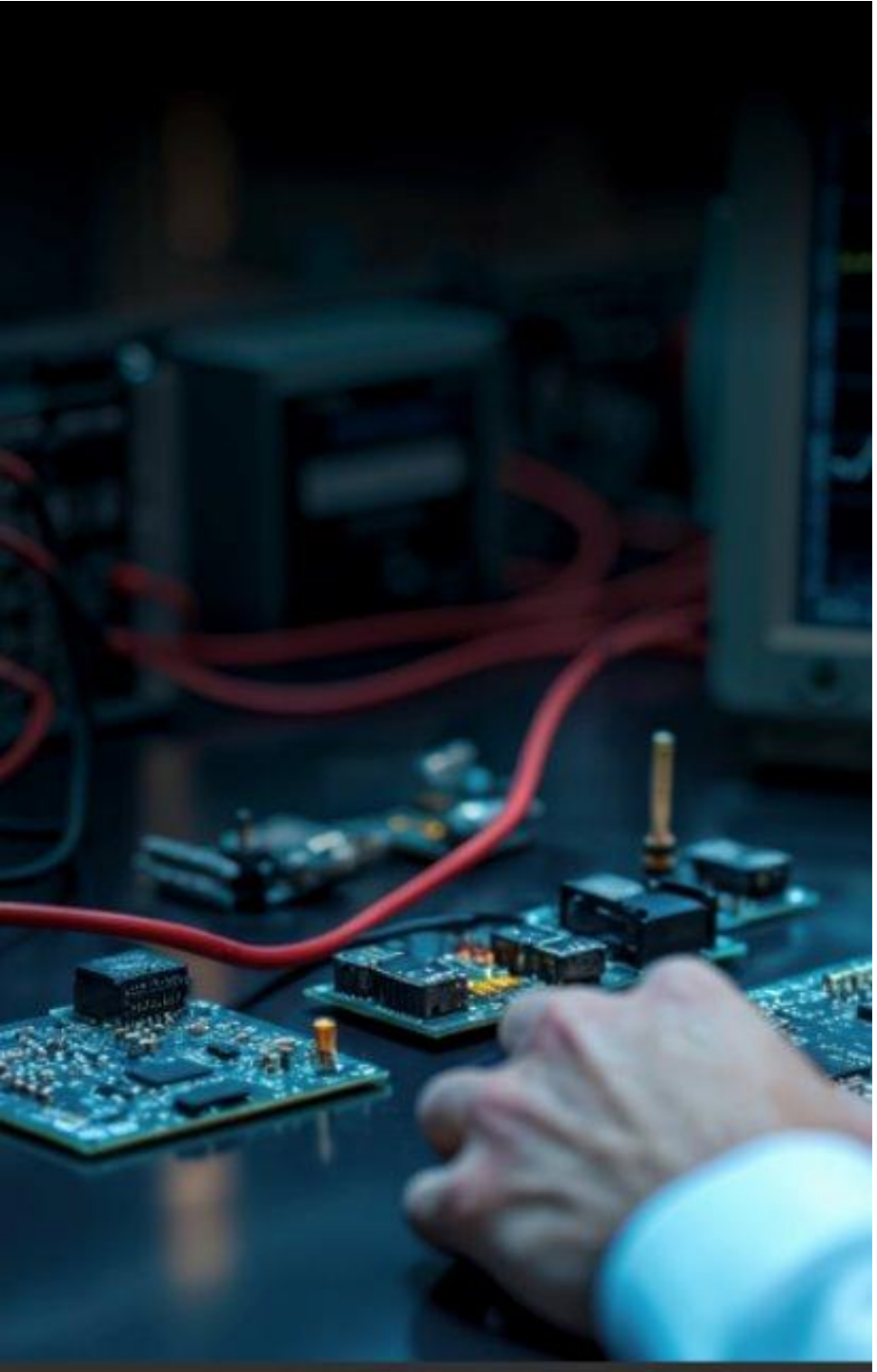
Designer’s Guide to Silicon Carbide Power

SESSION 4 : GOING BEYOND A QUALIFICATION REPORT

ROBERT SHAW





AGENDA

I. AQG 324 vs AEC-Q101

II. T Platform Overview

III. Reliability Test Vehicle

IV. Reliability Assessment

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AQG 324 vs AEC-Q101

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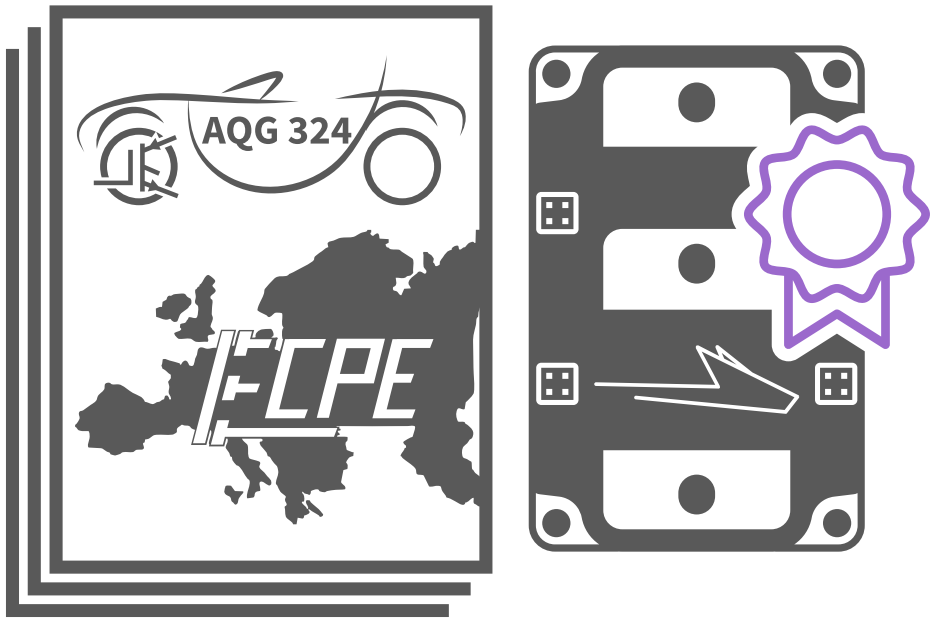
AQG 324 vs AEC-Q101

Background



- Based on the former LV324 guideline
- Established in 2017 by the European Center for Power Electronics (ECPE)
- Guideline for power modules for use in power electronics converter units in motor vehicles

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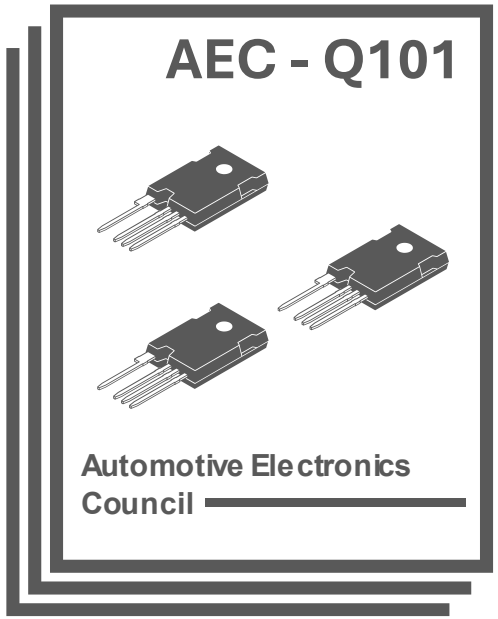
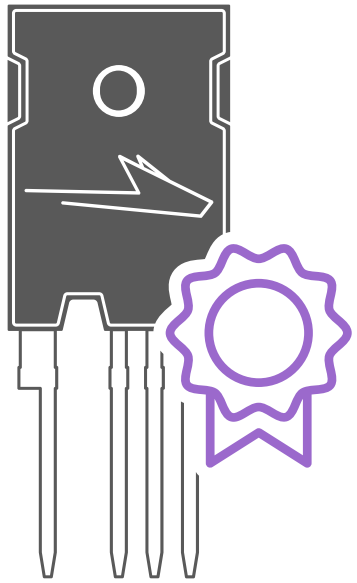
AQG 324 vs AEC-Q101

Background





- Established in mid-1990s by the Automotive Electronics Council
- Influenced by well established MIL-STDs from the 1960s
- Qualification standard for discrete semiconductors in automotive applications

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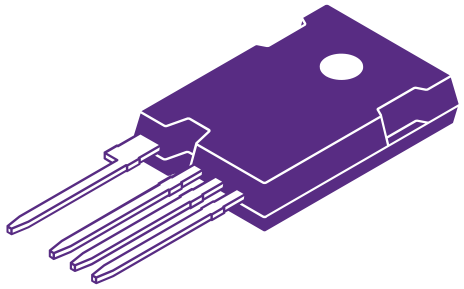
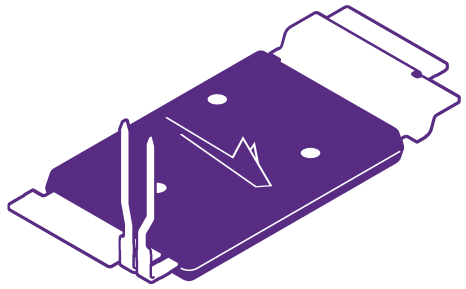
AQG 324 vs AEC-Q101

Package Types

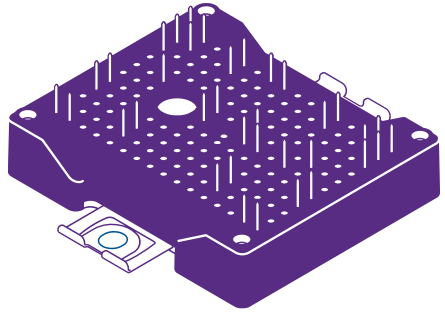
Discretes

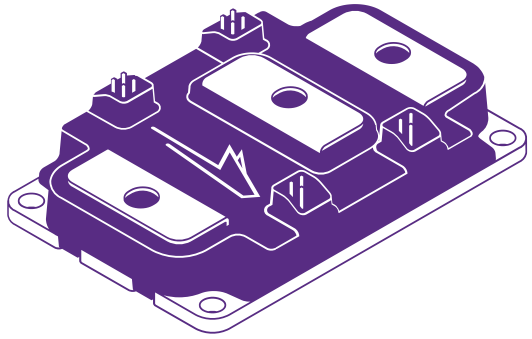


Overmolded Modules



Case/Frame Modules





AEC-Q101

AQG 324

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AQG 324 vs AEC-Q101

Scope Comparison

AQG 324	AEC-Q101
Applicable to automotive components	Applicable to automotive components
Targets modules and power electronic converter units (PCUs) based on discrete devices	Targets discrete semiconductors
Stress tests are designed to mimic end use application, including mounting	No consideration for stresses that occur once the device is mounted
Includes Power Cycling to failure	Does not include testing to failure

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AQG 324 vs AEC-Q101

Test Comparison

AQG 324	Reliability Test	AEC-Q101
1,000 cycles between rated storage temperatures **mounted similar to application**	Thermal Shock/Cycle	1,000 cycles from -55 °C to +150 °C, **unmounted**
Selection of vibration profiles based on vehicle mounting location	Vibration	Required for hermetic package only
Simulates mechanical load in a vehicle, e.g., driving over a curb or during an accident	Mechanical Shock	Required for hermetic package only
Provides lifetime data that can be mapped to a specific mission profile	Power Cycling	Not performed

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AQG 324 vs AEC-Q101

Test Comparison

AQG 324	Reliability Test	AEC-Q101
1,000 hours at maximum storage temperature	High Temperature Storage	Not performed
1,000 hours at minimum storage temperature	Low Temperature Storage	Not performed
1,000 hours at ≥ 80% of maximum drain voltage	High Temperature Reverse Bias	1,000 hours at maximum rated drain voltage (or less if specified)
1,000 hours at maximum gate voltage	High Temperature Gate Bias	1,000 hours at maximum gate voltage
1,000 hours at **80% of maximum drain voltage**	High Humidity, High Temperature Reverse Bias	1,000 hours at up to **100V**

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AQG 324 vs AEC-Q101

Test Comparison

AQG 324	Reliability Test	AEC-Q101
PC and Thermal Shock: device mounted representative of application	Intermittent Operating Lifetime	1,000 hours of temperature cycling, typically unmounted
HV-H3TRB provides conditions more similar to application	Highly Accelerated Stress Test	96 hours at 130 °C / 85% RH, typically limited to 42V bias
1,000 hours switching near maximum rated drain voltage	Dynamic H3TRB	Not performed
≥ 10^{11} cycles between minimum and maximum rated gate voltage	Dynamic Gate Stress	Not performed
≥ 10^{11} cycles to near maximum rated drain voltage	Dynamic Reverse Bias	Not performed

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T Platform Overview

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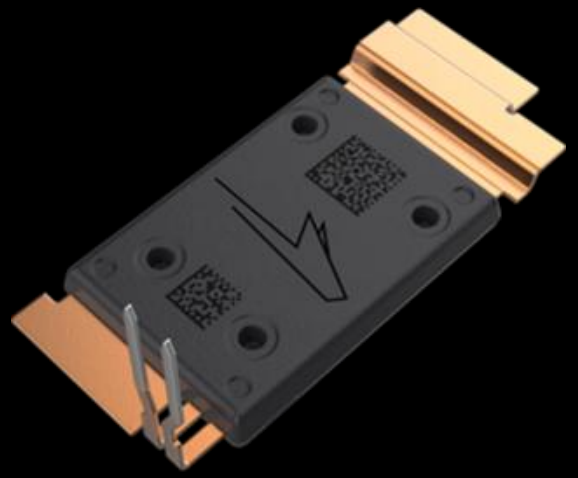
TM POWER MODULE FAMILY



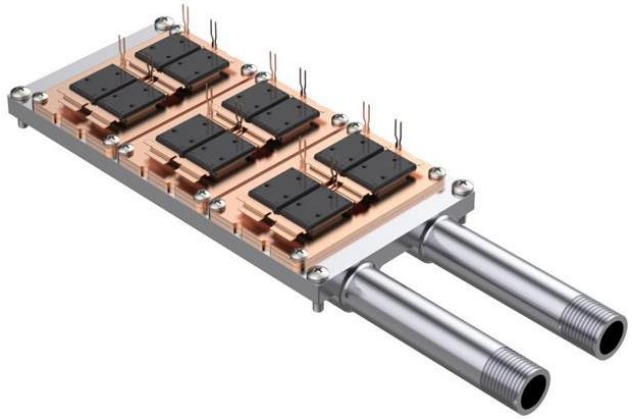
Technical Highlights

- Automotive single-switch overmolded power module
- Industry standard “TPAK” footprint
- Easily parallel for broad inverter system scalability
- Ultra-reliable interconnect technologies
- Sinterable or solderable backside
- Laser-weldable power terminals
- AQG 324 qualification

VALUE PROPOSITION

Most scalable power module platform to address a broad range of inverter power levels for new designs or as a drop-in replacement for performance improvement in existing designs

Faster time to market with power core solution that lowers the burden of entry with pre-attached sintered/soldered modules



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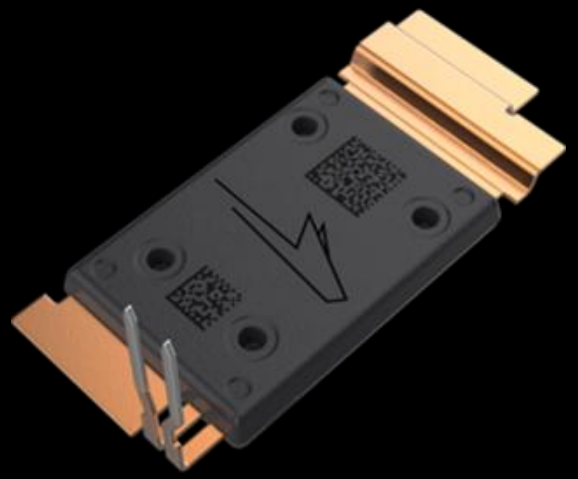
TM POWER MODULE FAMILY



Technical Highlights

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PRODUCT OVERVIEW

1200 V	650 V
EDB005M12TM4(L): 5.3 mΩ, 300 A	EDB003M06TM3(L): 3.4 mΩ, 410 A
EDB007M12TM4(L): 7.0 mΩ, 240 A	EDB005M06TM3(L): 4.5 mΩ, 330 A
EDB010M12TM4(L): 10.4 mΩ, 180 A	EDB007M06TM3(L): 6.7 mΩ, 260 A

$I_{D,continuous}$ for T_F = 65 °C, R_{thJF} based on WS cooler, $R_{DS(on,typ)}$, and $T_{J(max)}$

KEY FEATURES

- Low inductance design (<7 nH)
- Fast & clean switching for high efficiency
- True Kelvin source connection
- Isolated, baseplateless module
- Standard signal pin length of 18.5mm, L option for 19.0mm

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Reliability Test Vehicle



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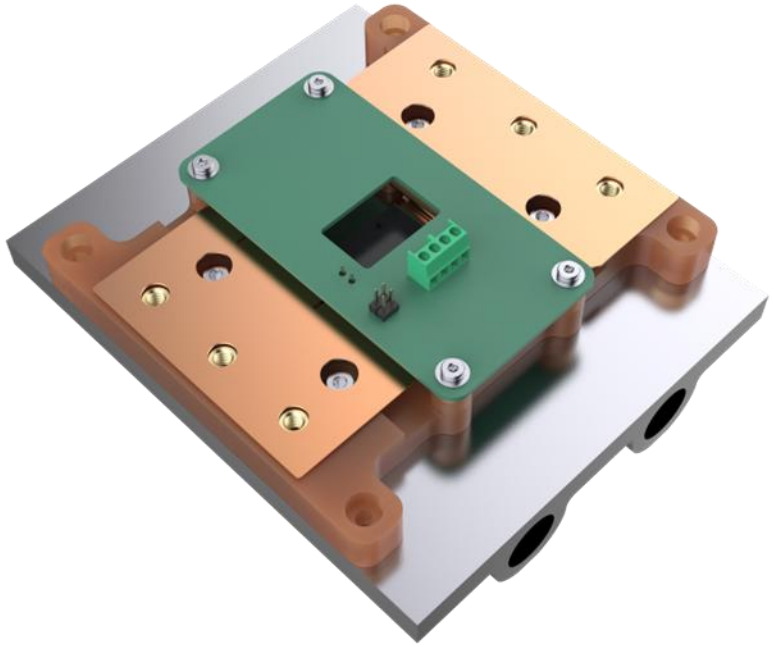
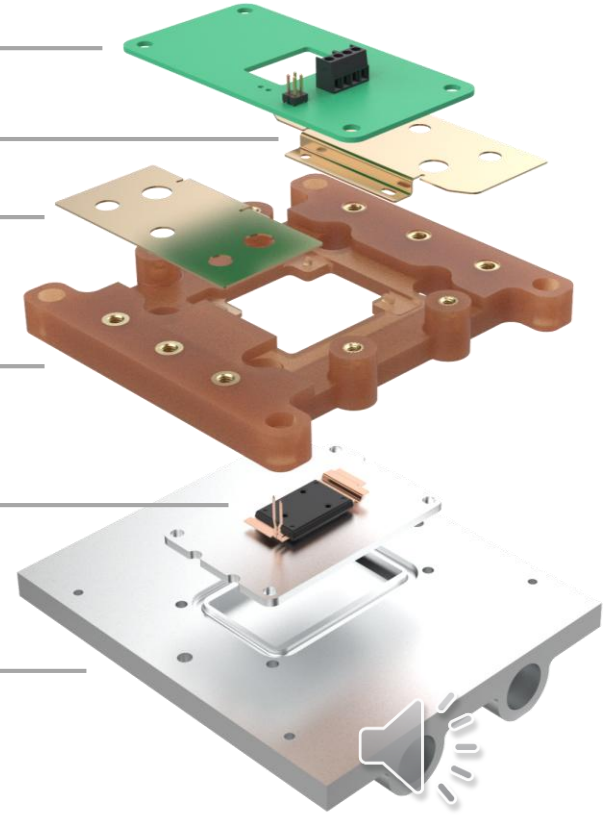
Reliability Test Vehicle

Exploded and Assembled View





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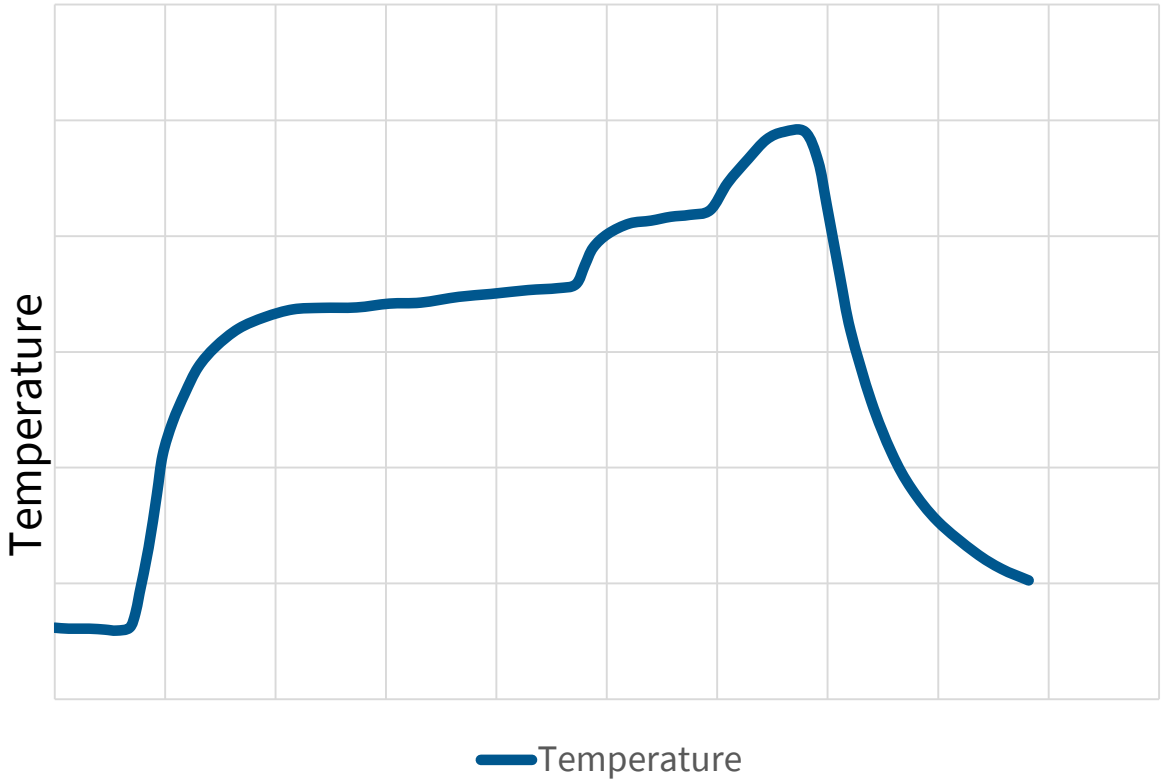
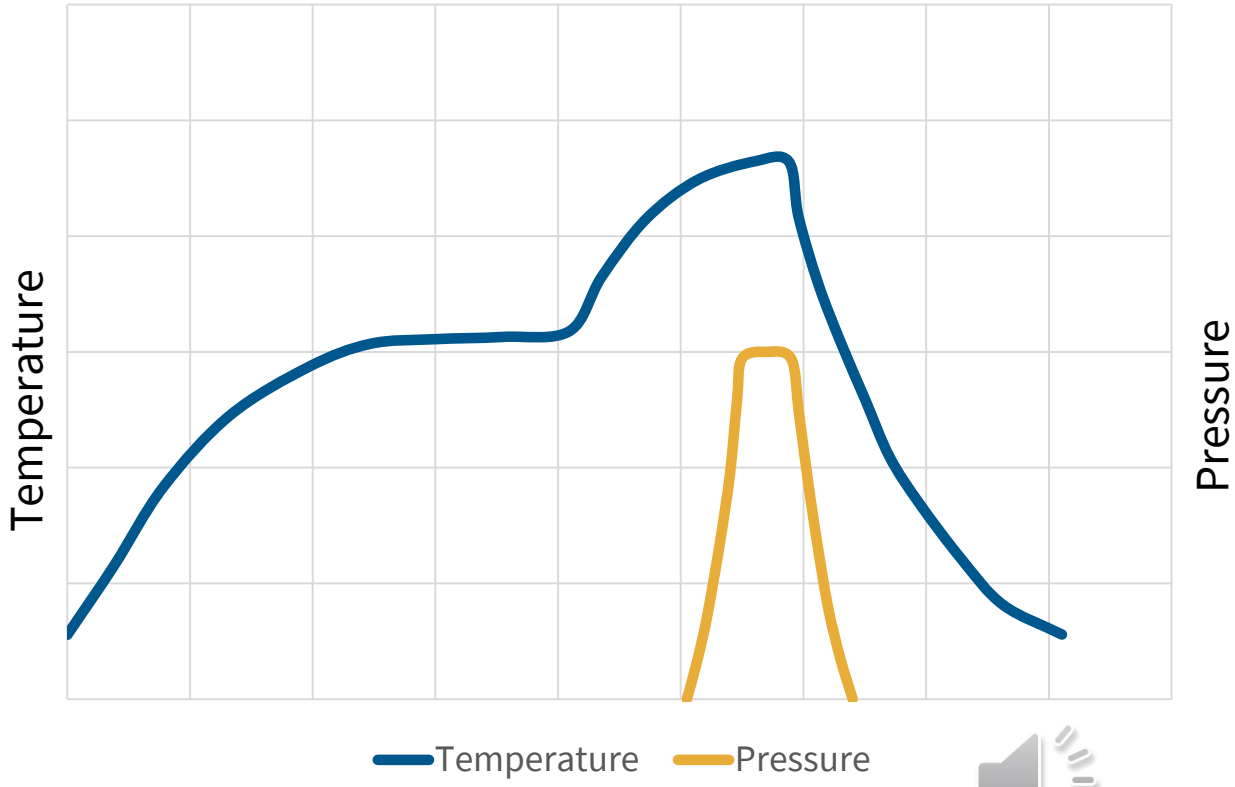
Package Attach Profile

Solder Attach



Sinter Attach



Differences in package attach methodology will result in unique stress conditions!

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Reliability Assessment



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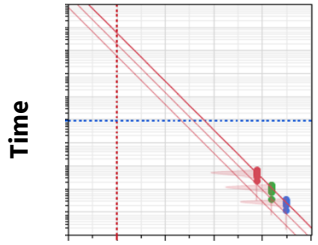
Mission Profile Reliability

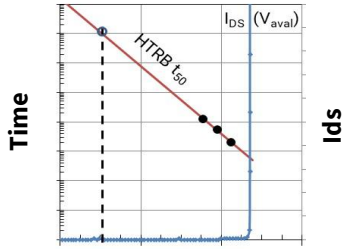
Electrical Reliability

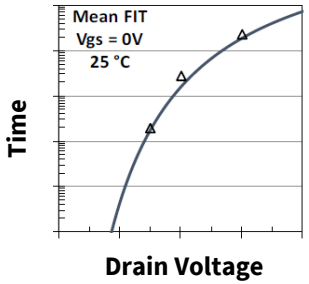
Driven by electrical bias, junction temperature, altitude, and time

Reliability tests to failures:

- TDDB
- ALT-HTRB
- Random Events (Single Event Burnout/Terrestrial Neutrons)



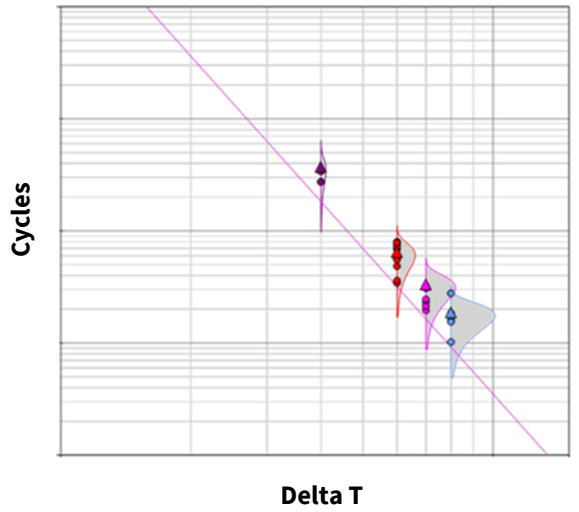




Thermomechanical Reliability

Driven by junction temperature, temperature delta, cycle time, and number of cycles

Power cycling to failure is the primary reliability test



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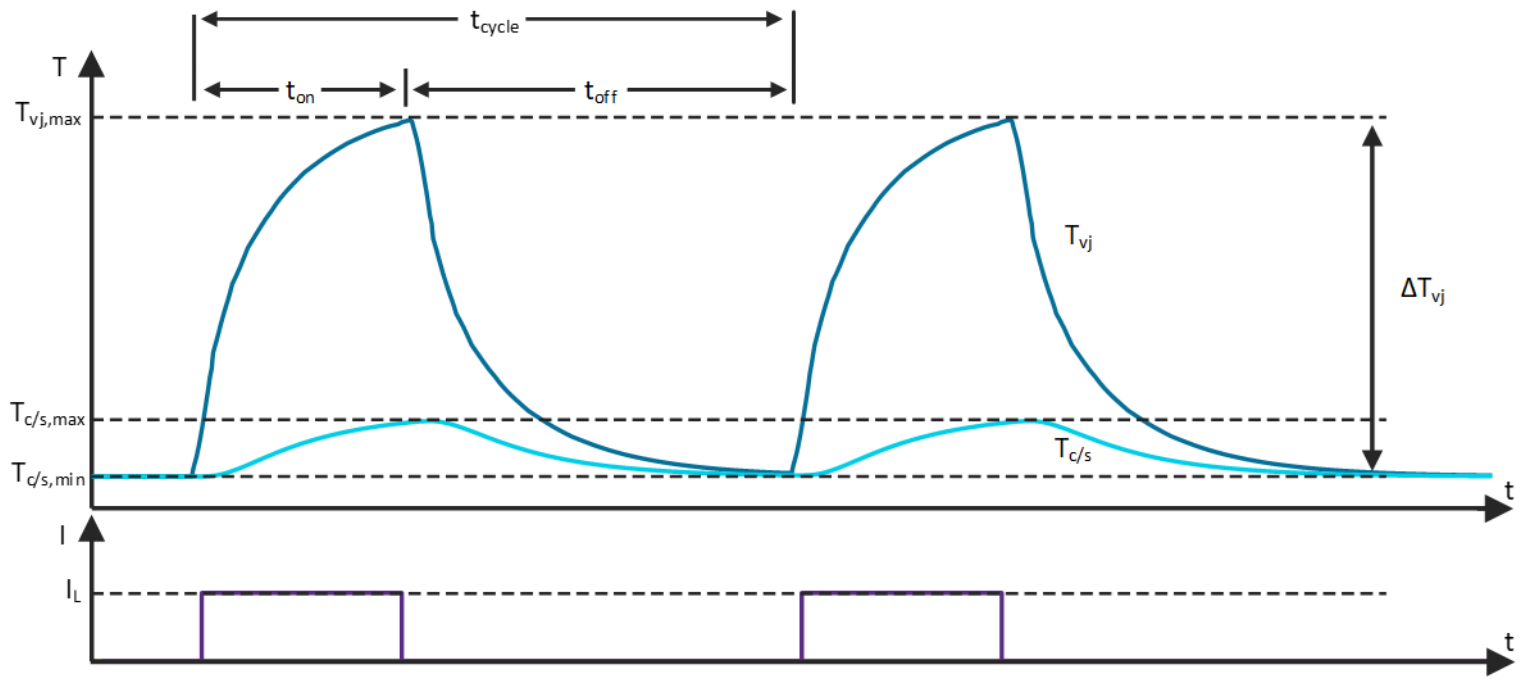
Power Cycling

Exemplary Power Cycling Profile



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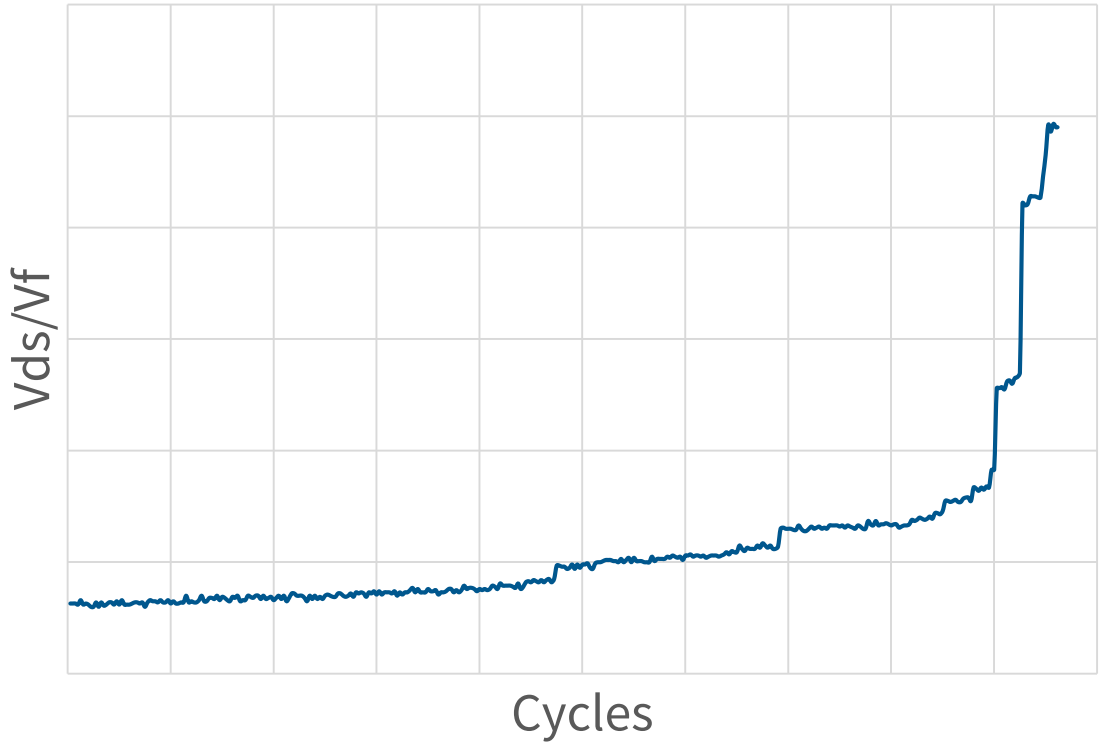
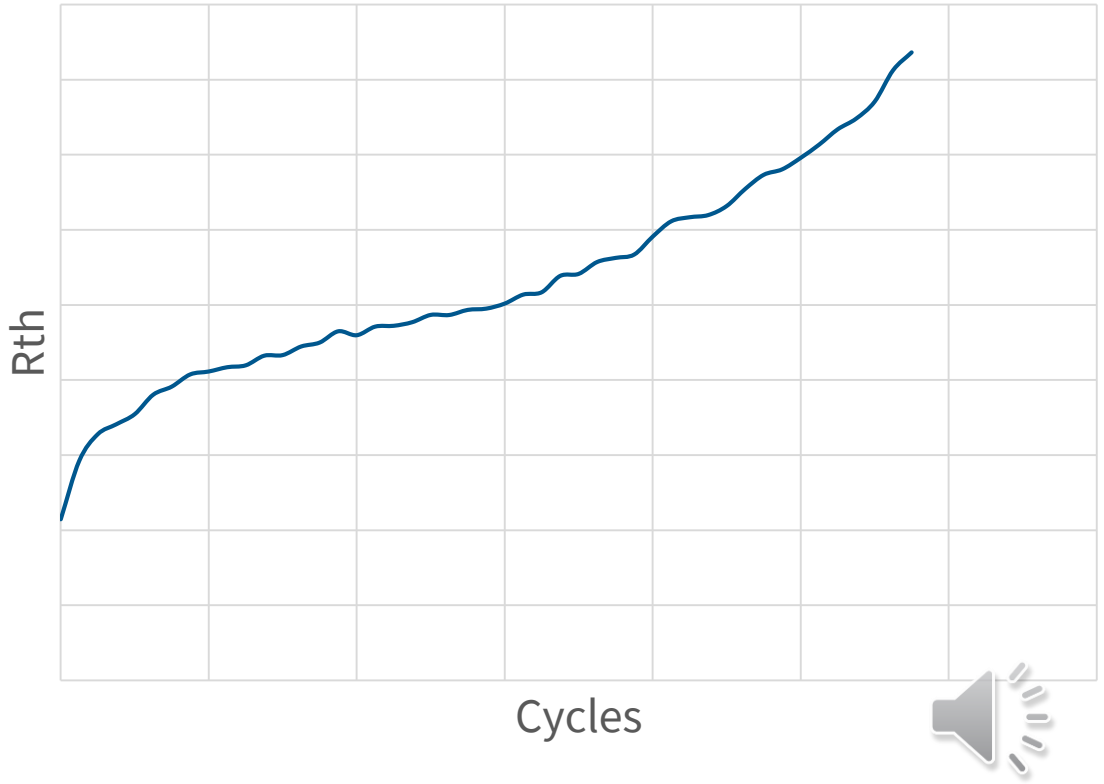
PC Parameters of Interest

Voltage



Thermal Resistance



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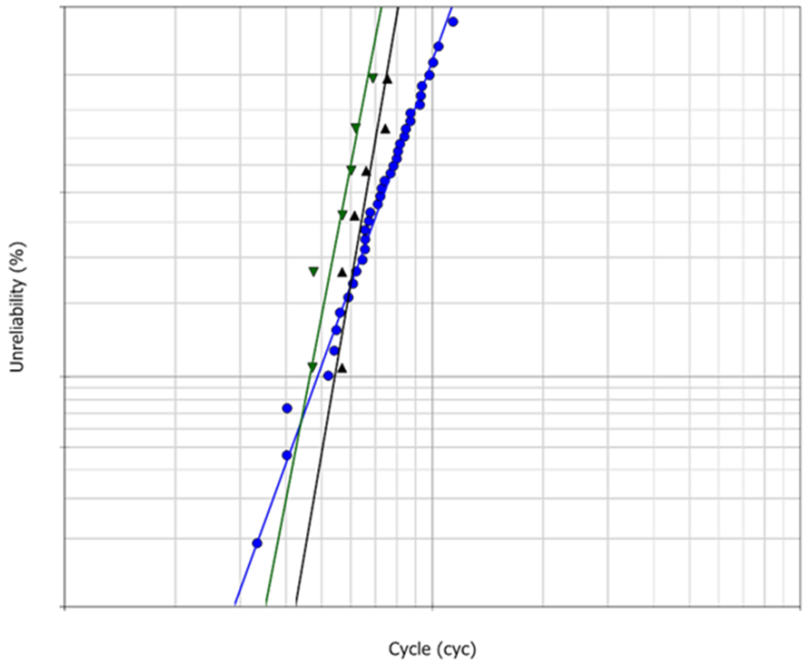
Creating a PC Life Model



$$N_f = K \cdot \Delta T_j^{\beta_1} \cdot e^{\frac{\beta_2}{T_j}} \cdot t_{on}^{\beta_3}$$

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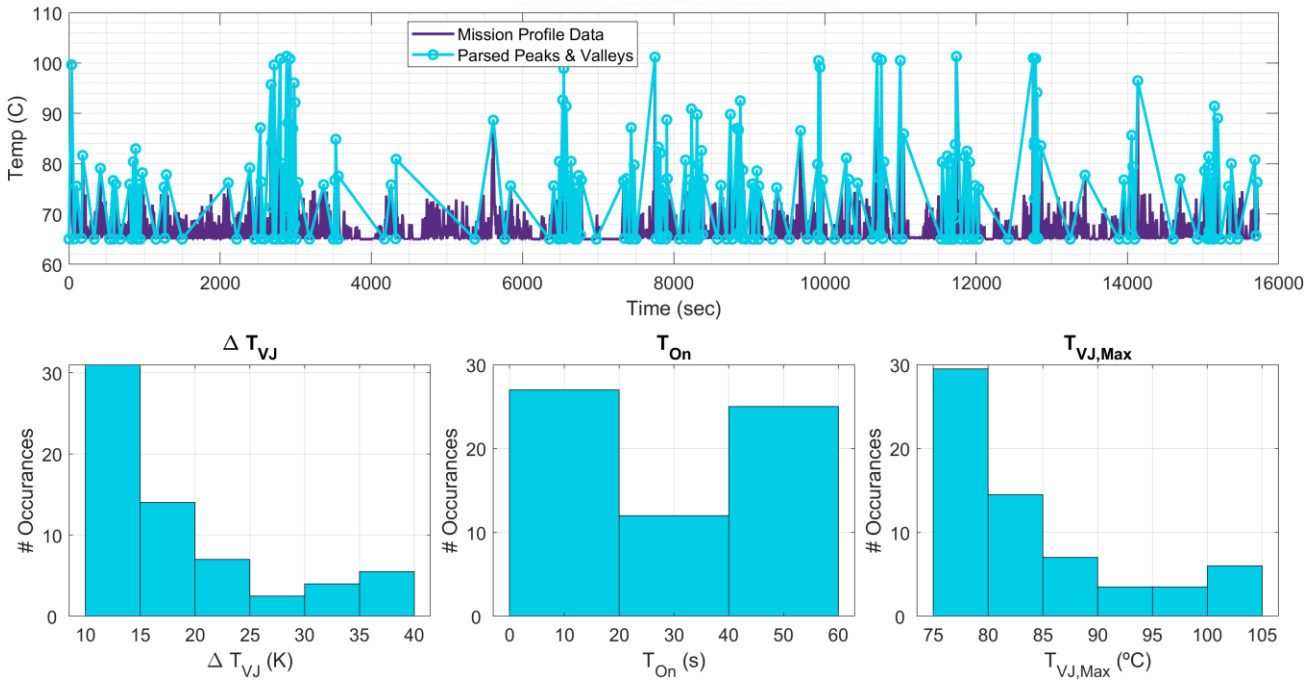
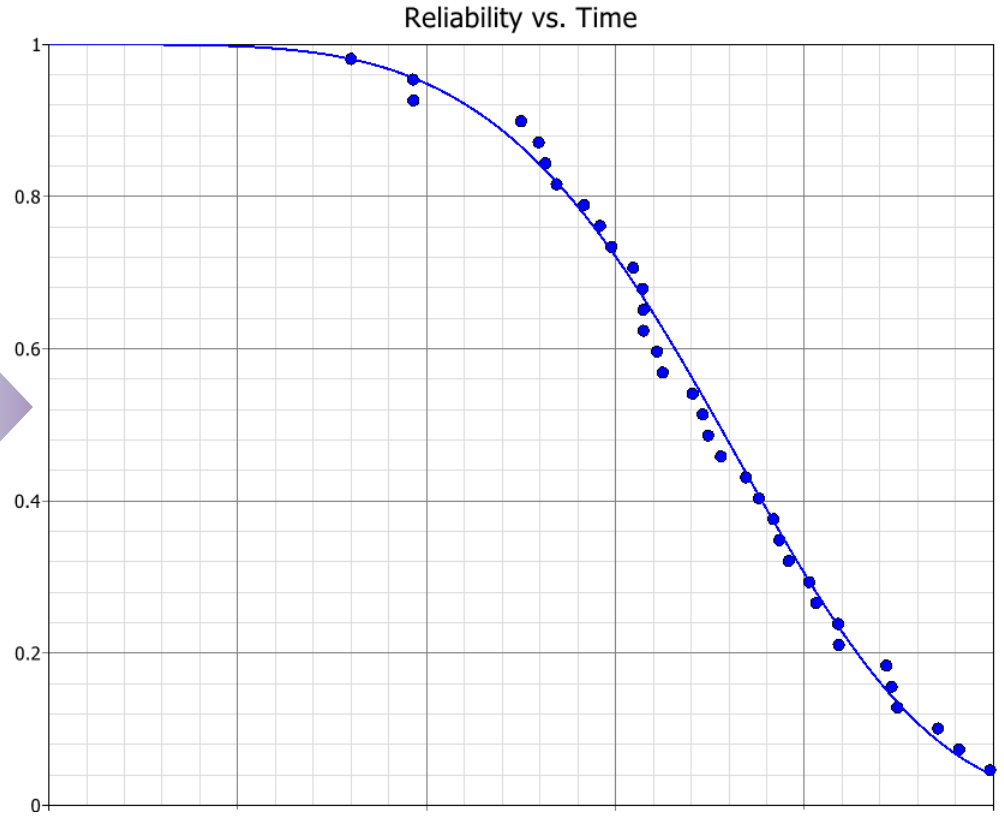
PC Mission Profile Mapping





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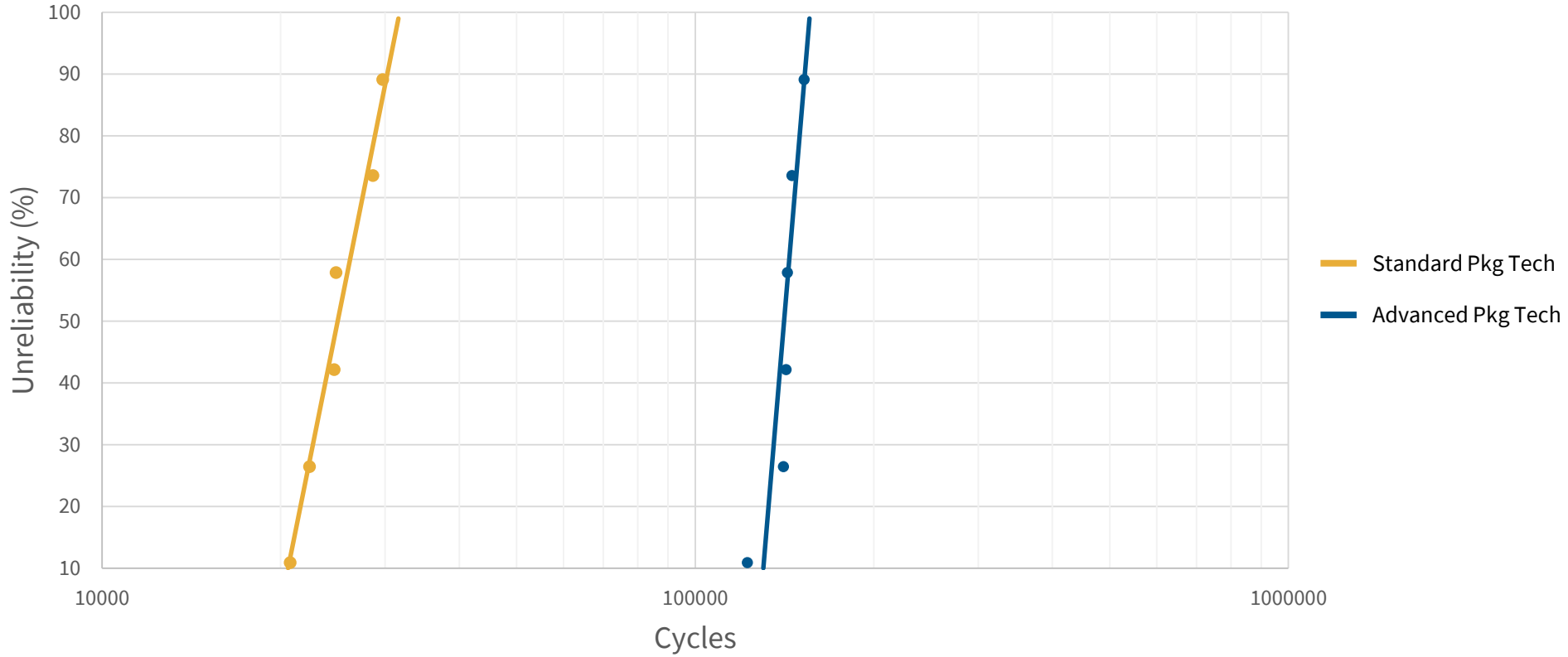
T Platform PC Reliability

Standard vs Advanced Packaging Technology



~10x power cycling improvement!

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Summary

- AQG 324 qualification was chosen due to the importance of system level interactions
- The development of a qualification test vehicle was critical to ensure those interactions were accounted for
- The packaging technology chose for the T platform translates to a significant reliability improvement for customers



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QUESTIONS
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