DfR Solutions

reliability designed, reliability delivered

Enhanced Reliability through Automated Design Analysis™ for the Electronics Industry

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Focus on Quality/Reliability/Durability of Electronics

Reliability Physics

+

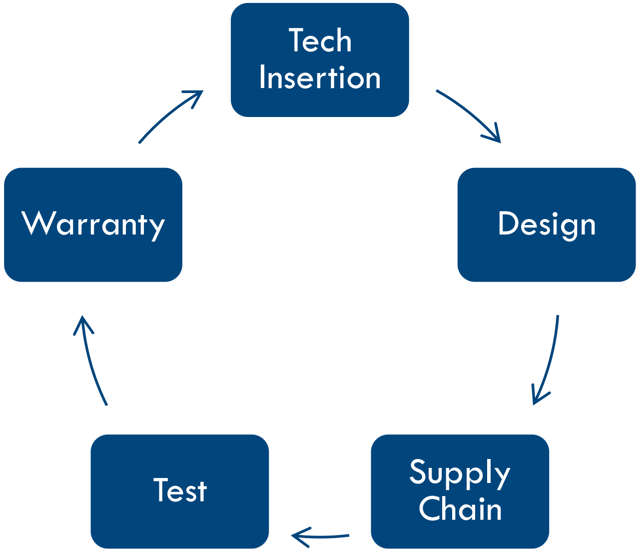
Commercial Experience

+

Onsite Laboratory

=

Unparalleled Results



All levels
of the supply chain

DfR Solutions – Senior Experts

- **Dr. Craig Hillman, CEO and Managing Partner**
- Expertise: Design for Reliability (DfR), Pb-free Transition, Supplier Benchmarking, Passive Components, Printed Circuit Board
- PhD, Material Science (UCSB)

- **Dr. Nathan Blattau, Senior Vice President**
- Expertise: Power Devices, DfR, Nonlinear Finite Element Analysis (FEA), Solder Joint Reliability, Fracture, Fatigue Mechanics.
- PhD, Mechanical Eng. (University of Maryland)

- **Walt Tomczykowski, Vice President, CRE**
- Expertise: Systems Eng., Life Cycle Management (including obsolescence), Spares Analysis, Counterfeit Mitigation, Failure Analysis
- M.S., Reliability Eng. (University of Maryland)

- **Cheryl Tulkoff, CRE**
- Expertise: Pb-Free Transition, PCB and PCBA Fabrication, IC Fabrication, RCA (8D and Red X)
- B.S., Mechanical Engineering (Georgia Tech)

- **Dr. Ron Wunderlich**
- Expertise: Design for EMI/EMC, Power Supply Design, Analog Circuit Design, Spice Model Development, Monte Carlo Circuit Simulation
- PhD, Electrical Engineering (SUNY – Binghamton)

- **Greg Caswell**
- Expertise: Nanotechnology CMOS, CMOS/SOS, Input Protection Networks / ESD, SMT, Pb-free
- B.S., Electrical Engineering (Rutgers)

- **Dr. Randy Schueller**
- Expertise: IC Fabrication, IC Packaging, Pb-Free Transition Activities, Supplier Benchmarking, Corrosion Mechanisms
- PhD, Material Science (University of Virginia)

- **Dr. Gregg Kittlesen**
- Expertise: Semiconductor Lasers and Integrated Modules, Photonic and RF Technologies, IC Process Development and Qualification, Supply Chain Management
- PhD, Inorganic Chemistry (MIT)

- **James McLeish, CRE**
- Expertise: FMEA, Root-Cause Analysis, Warranty Analysis, Automotive Electronics, Physics of Failure, Battery Technology
- M.S., Electrical Eng. (Wayne State University)

- **Norm Anderson**
- Expertise: Avionics, Product Qualification, Safety Criticality Assessment, FTA, FMEA, Component Uprating, Obsolescence
- B.S., Electrical Engineering (Iowa State University)

- **Anne Marie Neufelder**
- Expertise: Software Reliability Prediction, Best Practices in Software Risk Management
- B.S., Systems Engineering (Georgia Tech)

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Purpose

- Early assessment of assembly level reliability
- Uniform design for reliability process
- Design trade-off analysis
  - Include reliability assessment

Presentation Outline

- Analyses
- Methodology
- Design Assessment
- Hardware Capability Assessment

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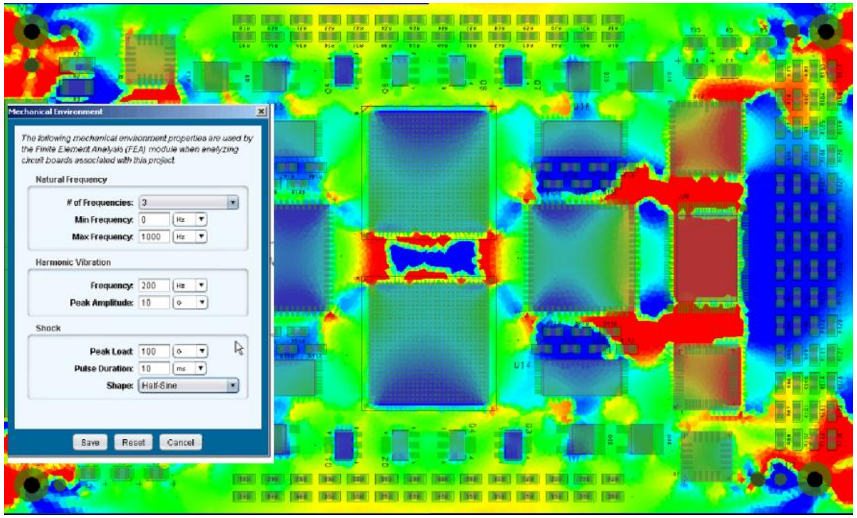
Analyses

Capabilities

- Virtual Shock Testing
- Virtual Vibration Testing
- Virtual Thermal Cycling
- Virtual CAF Testing
  - Conductive Anodic Filament

Shock Strain Example



The following mechanical environment properties are used by the Finite Element Analysis (FEA) module when analyzing circuit boards associated with this project.

Natural Frequency

\# of Frequencies: 3
Min Frequency: 0 Hz
Max Frequency: 1000 Hz

Harmonic Vibration

Frequency: 200 Hz
Peak Amplitude: 10 G

Shock

Peak Load: 100 G
Pulse Duration: 10 ms
Shape: Half-Sine

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Methodology - Inputs

Input Data Sources

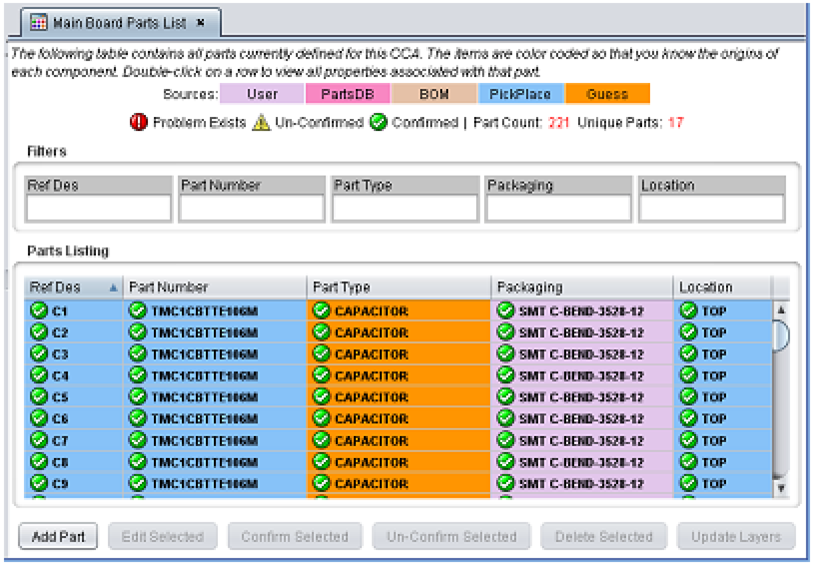
- ODB++ archive
- ODB XML archive
- Files
  - Layers
  - Drill holes
  - BOM
  - Pick and place
  - Thermal map

Environmental Stresses

- Mechanical Shock
- Random Vibration
- Harmonic Vibration
- Thermal Cycle

Methodology – Input Review

Parts List



The following table contains all parts currently defined for this CCA. The items are color coded so that you know the origins of each component. Double-click on a row to view all properties associated with that part.

Sources: User PartsDB BOM PickPlace Guess

❗ Problem Exists ⚠ Un-Confirmed ✓ Confirmed | Part Count: 231 Unique Parts: 17

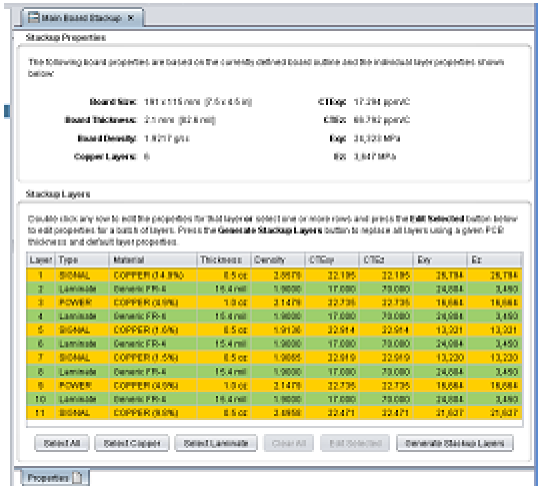
Filters

Ref Des	Part Number	Part Type	Packaging	Location

Parts Listing

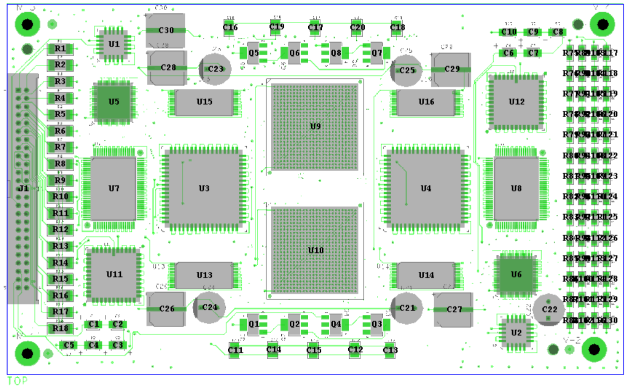
Ref Des ▲	Part Number	Part Type	Packaging	Location
✓ C1	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP
✓ C2	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP
✓ C3	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP
✓ C4	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP
✓ C5	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP
✓ C6	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP
✓ C7	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP
✓ C8	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP
✓ C9	✓ TMC1CBTTE106M	✓ CAPACITOR	✓ SMT C-BEND-3528-12	✓ TOP

Stack-up

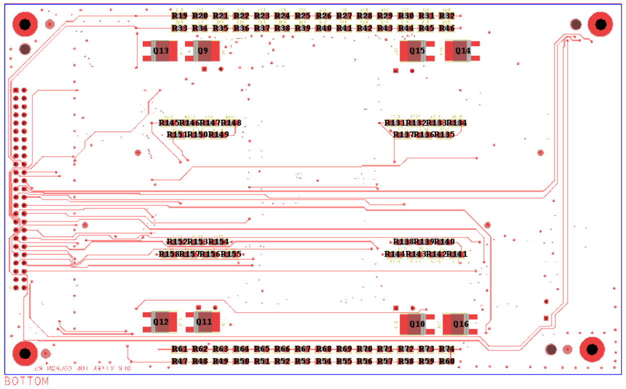


Methodology – Input Review

Top Components

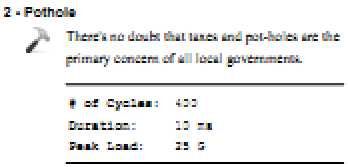


Bottom Components



Virtual Shock Testing - Maximum Stress

Parameters

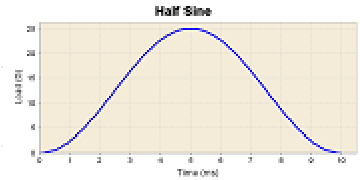


2 - Pothole

There's no doubt that taxes and pot-holes are the primary concern of all local governments.

```
# of Cycles:   400
Duration:      10 ms
Peak Load:     25 G
```

Shock Profile



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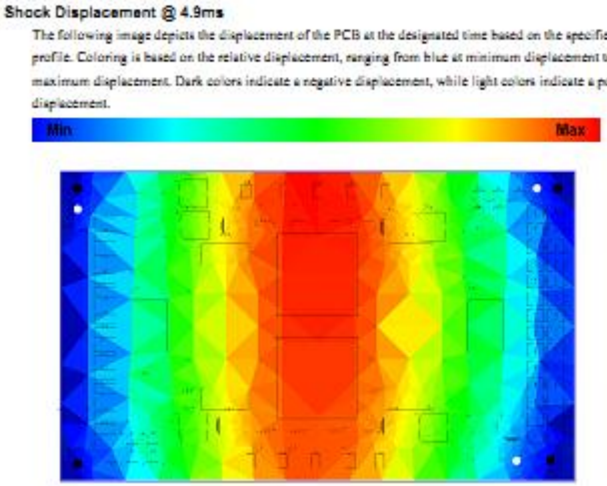
Virtual Shock Testing - FEA Results

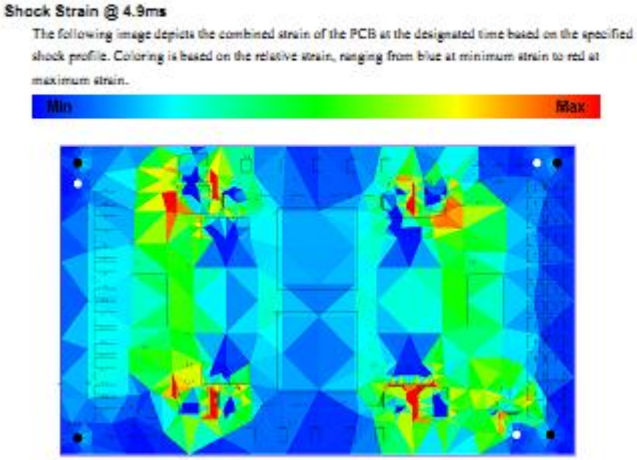
PCB Displacement
25G, 4.9ms, half sine pulse



Shock Displacement @ 4.9ms

The following image depicts the displacement of the PCB at the designated time based on the specified shock profile. Coloring is based on the relative displacement, ranging from blue at minimum displacement to red at maximum displacement. Dark colors indicate a negative displacement, while light colors indicate a positive displacement.

PCB Strain
25G, 4.9ms, half sine pulse



Shock Strain @ 4.9ms

The following image depicts the combined strain of the PCB at the designated time based on the specified shock profile. Coloring is based on the relative strain, ranging from blue at minimum strain to red at maximum strain.

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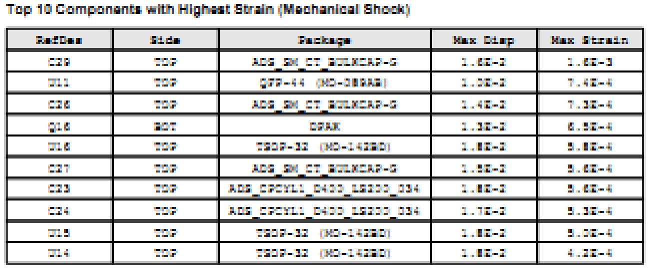
Virtual Shock Testing - Component Assessments

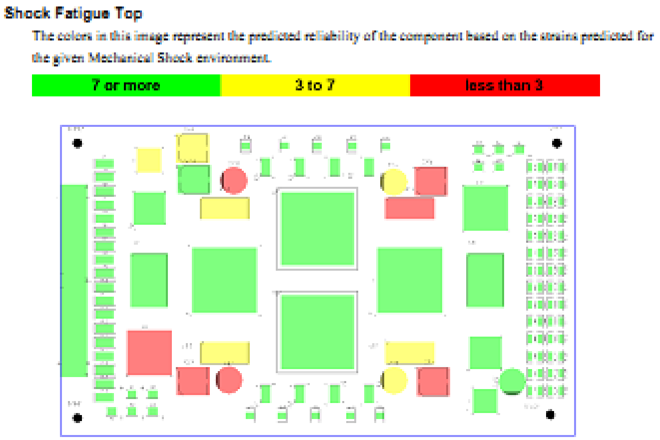
Components with Highest Strain



Top 10 Components with Highest Strain (Mechanical Shock)

RefDes	Side	Package	Max Disp	Max Strain
C29	TOP	ADS_SM_CT_BULKCAP-G	1.6E-2	1.6E-3
U11	TOP	QFP-44 (MO-089AB)	1.3E-2	7.4E-4
C26	TOP	ADS_SM_CT_BULKCAP-G	1.4E-2	7.3E-4
Q16	BOT	DPAK	1.3E-2	6.5E-4
U16	TOP	TSOP-32 (MO-142BD)	1.8E-2	5.8E-4
C27	TOP	ADS_SM_CT_BULKCAP-G	1.5E-2	5.6E-4
C23	TOP	ADS_CPCYL1_D400_LS200_034	1.8E-2	5.6E-4
C24	TOP	ADS_CPCYL1_D400_LS200_034	1.7E-2	5.3E-4
U15	TOP	TSOP-32 (MO-142BD)	1.8E-2	5.0E-4
U14	TOP	TSOP-32 (MO-142BD)	1.8E-2	4.2E-4

Shock Fatigue Scores



Shock Fatigue Top

The colors in this image represent the predicted reliability of the component based on the strains predicted for the given Mechanical Shock environment.

🟩 7 or more | 🟨 3 to 7 | 🟥 less than 3

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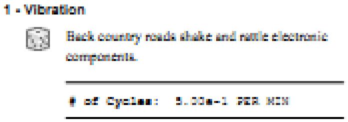
Virtual Vibration Testing - Stress

Parameters

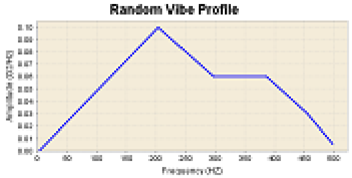


1 - Vibration

Back country roads shake and rattle electronic components.

# of Cycles: 5.00e-1 PER MIN

Random Vibration Profile (Harmonic Vibration also available)



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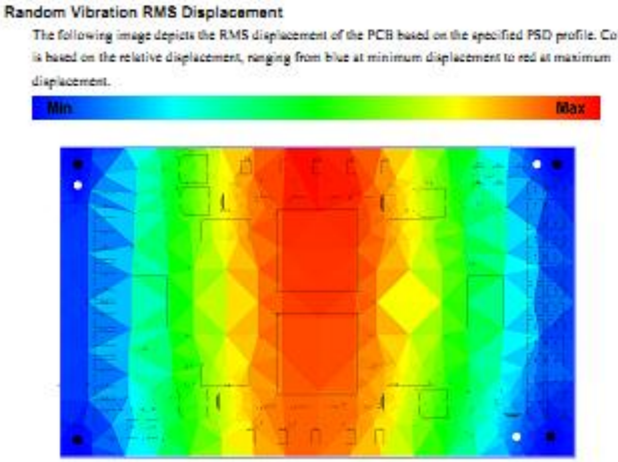
Virtual Vibration Testing - FEA Results

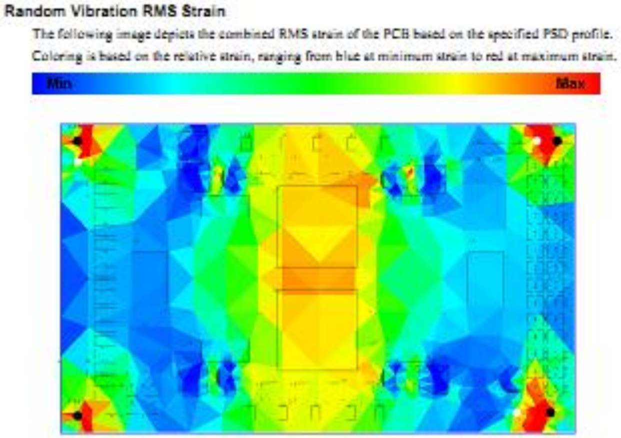
PCB Displacement



Random Vibration RMS Displacement

The following image depicts the RMS displacement of the PCB based on the specified PSD profile. Coloring is based on the relative displacement, ranging from blue at minimum displacement to red at maximum displacement.

PCB Strain



Random Vibration RMS Strain

The following image depicts the combined RMS strain of the PCB based on the specified PSD profile. Coloring is based on the relative strain, ranging from blue at minimum strain to red at maximum strain.

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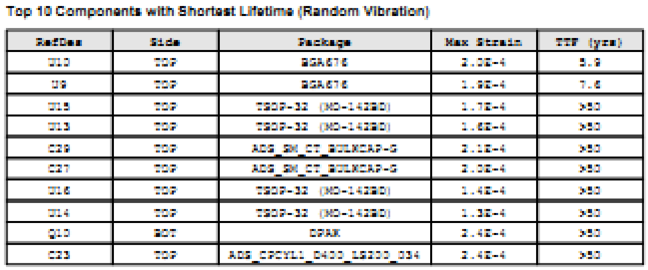
Virtual Vibration Testing - Component Assessments

Components with Highest Strain



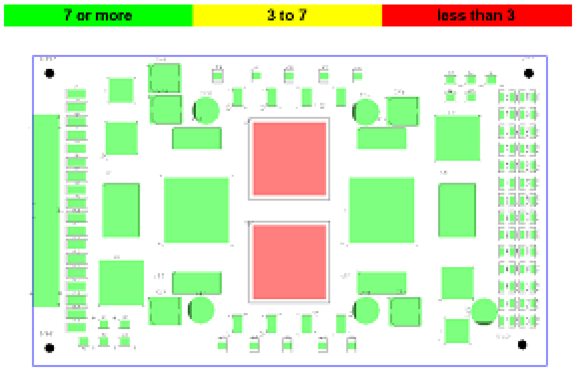
Top 10 Components with Shortest Lifetime (Random Vibration)

RefDes	Side	Package	Max Strain	TTF (yrs)
U10	TOP	BGA676	2.0E-4	5.9
U9	TOP	BGA676	1.9E-4	7.6
U15	TOP	TSOP-32 (MO-142BD)	1.7E-4	>50
U13	TOP	TSOP-32 (MO-142BD)	1.6E-4	>50
C29	TOP	ADS_SM_CT_BULKCAP-G	2.1E-4	>50
C27	TOP	ADS_SM_CT_BULKCAP-G	2.0E-4	>50
U16	TOP	TSOP-32 (MO-142BD)	1.4E-4	>50
U14	TOP	TSOP-32 (MO-142BD)	1.3E-4	>50
Q10	BOT	DPAK	2.4E-4	>50
C23	TOP	ADS_CPCYL1_D400_LS200_D34	2.4E-4	>50

Shock Fatigue Scores

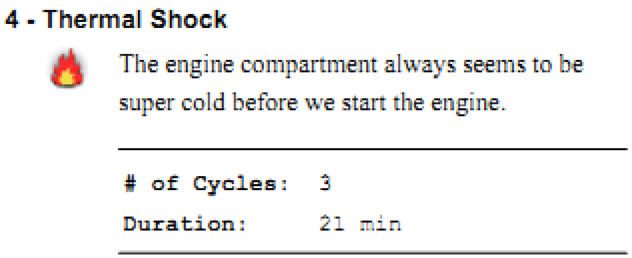
Random Fatigue Top

The colors in this image represent the predicted reliability of the component based on the strains predicted for the given Random Vibration environment.



Virtual Thermal Cycle Testing - Stress

Parameters



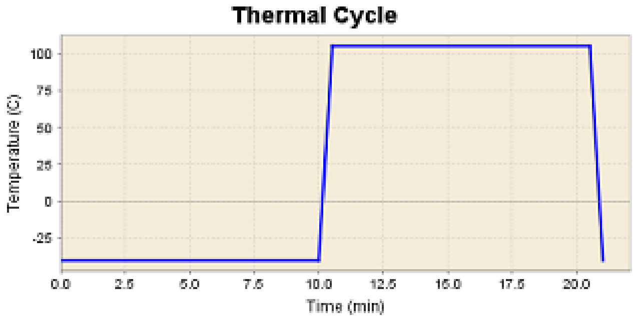
4 - Thermal Shock

🔥 The engine compartment always seems to be super cold before we start the engine.

`# of Cycles:  3`

`Duration:     21 min`

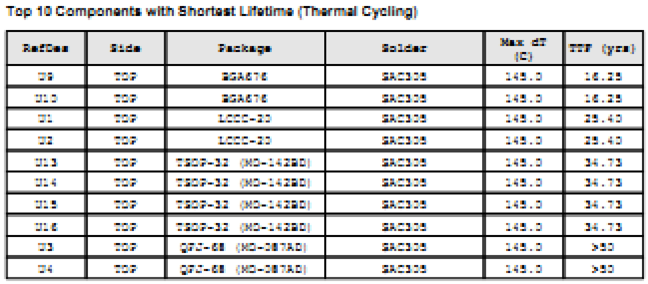
Temperature Cycle Profile



Virtual Thermal Cycle Testing - Component Assessments

Components with Shortest Lifetime

Solder Fatigue Scores



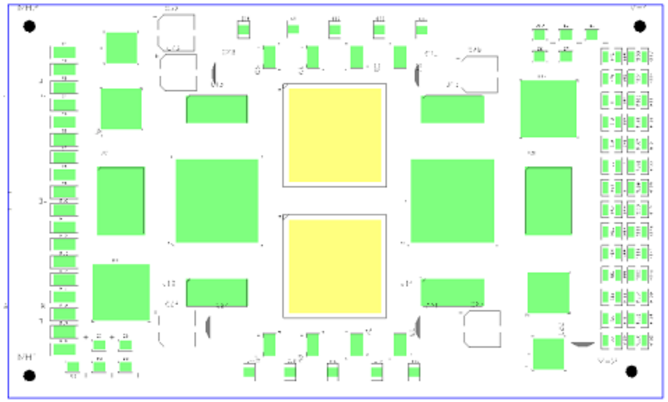
Top 10 Components with Shortest Lifetime (Thermal Cycling)

RefDes	Side	Package	Solder	Max dT (C)	TTF (yrs)
U9	TOP	BGA676	SAC305	145.0	16.25
U10	TOP	BGA676	SAC305	145.0	16.25
U1	TOP	LCCC-20	SAC305	145.0	25.40
U2	TOP	LCCC-20	SAC305	145.0	25.40
U13	TOP	TSOP-32 (MO-142BD)	SAC305	145.0	34.73
U14	TOP	TSOP-32 (MO-142BD)	SAC305	145.0	34.73
U15	TOP	TSOP-32 (MO-142BD)	SAC305	145.0	34.73
U16	TOP	TSOP-32 (MO-142BD)	SAC305	145.0	34.73
U3	TOP	QFJ-68 (MO-087AD)	SAC305	145.0	>50
U4	TOP	QFJ-68 (MO-087AD)	SAC305	145.0	>50

Solder Joint Fatigue Scores (Top Components)

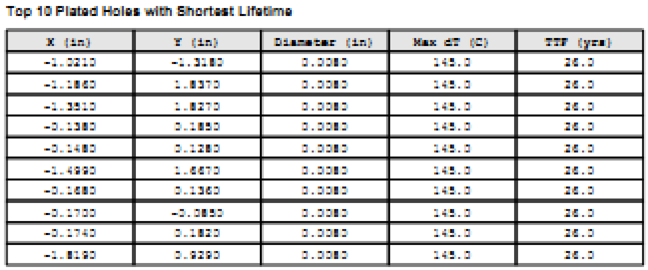
The following image shows the results for all leadless chip components and Ball Grid Array (BGA) components analyzed. The colored symbols represent the predicted reliability of the component relative to the expected service life of the circuit card.

🟩 7 or more	🟨 3 to 7	🟥 less than 3



Virtual Thermal Cycle Testing - PTH Assessments

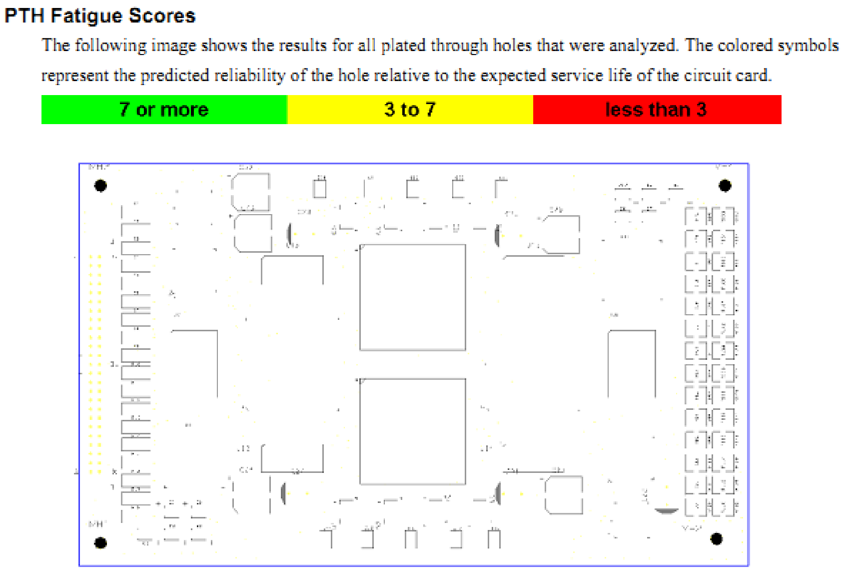
PTH with Shortest Lifetime



Top 10 Plated Holes with Shortest Lifetime

X (in)	Y (in)	Diameter (in)	Max dT (C)	TTF (yrs)
-1.0210	-1.3180	0.0080	145.0	26.0
-1.1860	1.8370	0.0080	145.0	26.0
-1.3510	1.8270	0.0080	145.0	26.0
-0.1380	0.1850	0.0080	145.0	26.0
-0.1480	0.1280	0.0080	145.0	26.0
-1.4990	1.6670	0.0080	145.0	26.0
-0.1680	0.1360	0.0080	145.0	26.0
-0.1700	-0.0850	0.0080	145.0	26.0
-0.1740	0.1820	0.0080	145.0	26.0
-1.8190	0.9290	0.0080	145.0	26.0

PTH Fatigue Scores



PTH Fatigue Scores

The following image shows the results for all plated through holes that were analyzed. The colored symbols represent the predicted reliability of the hole relative to the expected service life of the circuit card.

🟩 7 or more	🟨 3 to 7	🟥 less than 3

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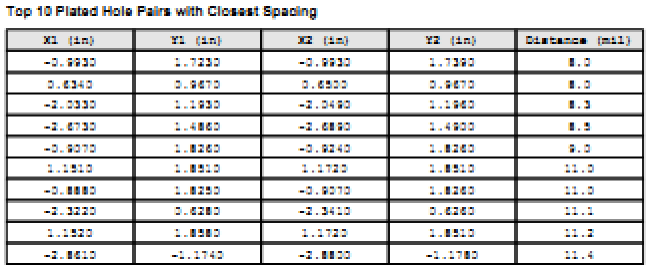
Virtual Conductive Anodic Filament (CAF) Assessments

Hole Pairs with Closest Spacing



Top 10 Plated Hole Pairs with Closest Spacing

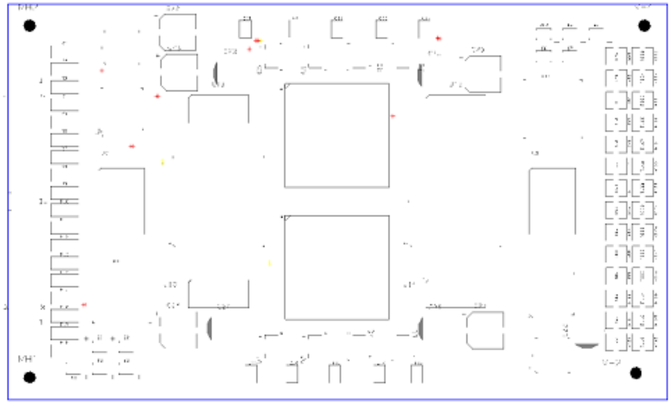
X1 (in)	Y1 (in)	X2 (in)	Y2 (in)	Distance (mil)
-3.9930	1.7230	-3.9930	1.7390	8.0
0.6340	0.9670	0.6500	0.9670	8.0
-2.0330	1.1930	-2.0490	1.1960	8.3
-2.6730	1.4860	-2.6890	1.4900	8.5
-3.9070	1.8260	-3.9240	1.8260	9.0
1.1510	1.8510	1.1720	1.8510	11.0
-3.8880	1.8250	-3.9070	1.8260	11.0
-2.3220	0.6280	-2.3410	0.6260	11.1
1.1520	1.8580	1.1720	1.8510	11.2
-2.8610	-1.1740	-2.8800	-1.1780	11.4

CAF Scores

CAF Formation Scores

The following image shows the results for all hole pairings that were analyzed. The colored symbols represent the predicted reliability of the hole pairings based on the distance between hole centers and the percentage of overlap.

7 or more	3 to 7	less than 3



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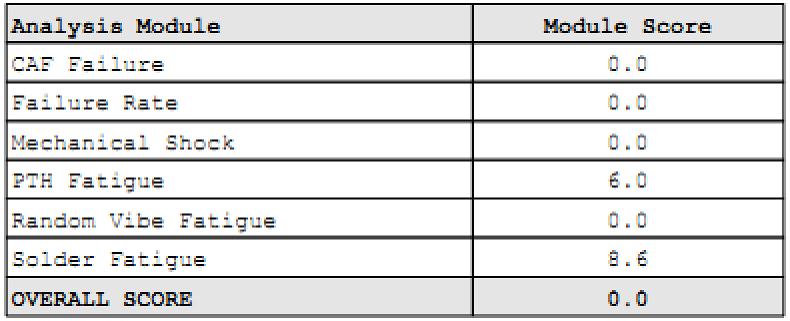
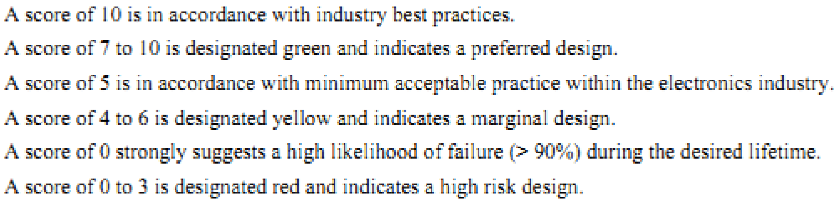
Scorecard

Tutorial Board Scores



Analysis Module	**Module Score**
CAF Failure	0.0
Failure Rate	0.0
Mechanical Shock	0.0
PTH Fatigue	6.0
Random Vibe Fatigue	0.0
Solder Fatigue	8.6
OVERALL SCORE	**0.0**

Score Classifications



A score of 10 is in accordance with industry best practices.

A score of 7 to 10 is designated green and indicates a preferred design.

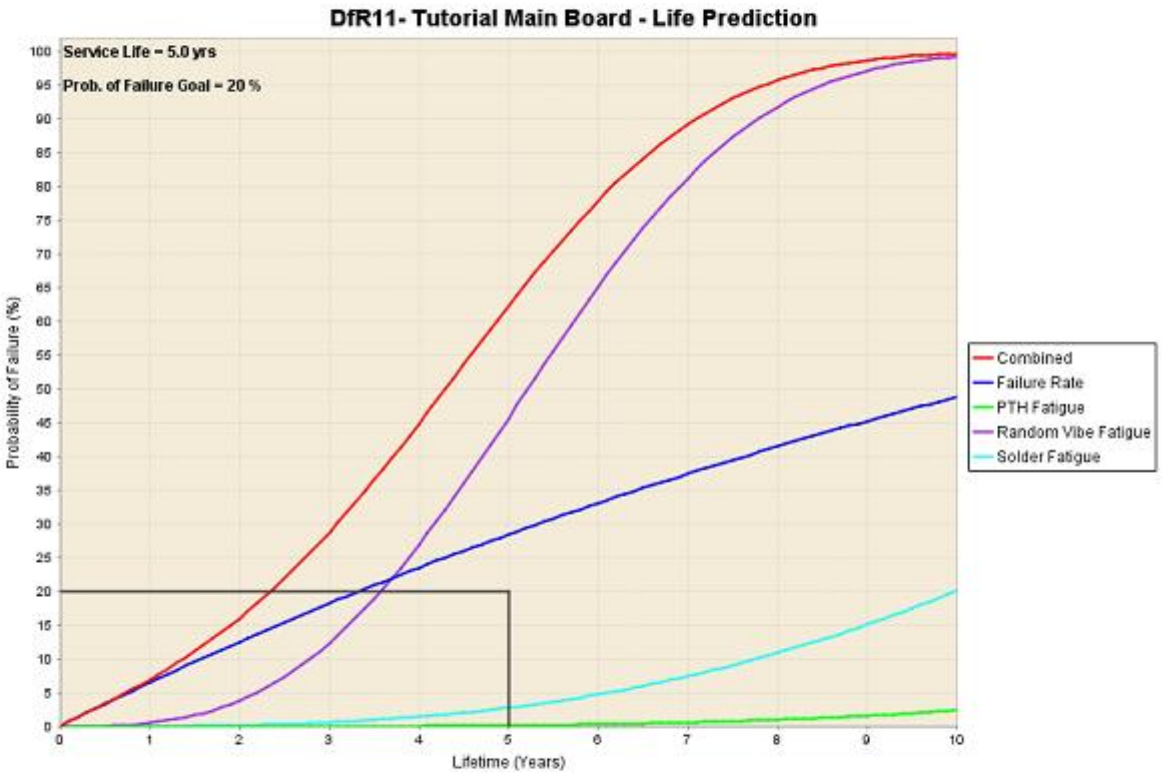
A score of 5 is in accordance with minimum acceptable practice within the electronics industry.

A score of 4 to 6 is designated yellow and indicates a marginal design.

A score of 0 strongly suggests a high likelihood of failure (> 90%) during the desired lifetime.

A score of 0 to 3 is designated red and indicates a high risk design.

Life Prediction



DfR Solutions

Outdoor Deployment Thermal Stresses

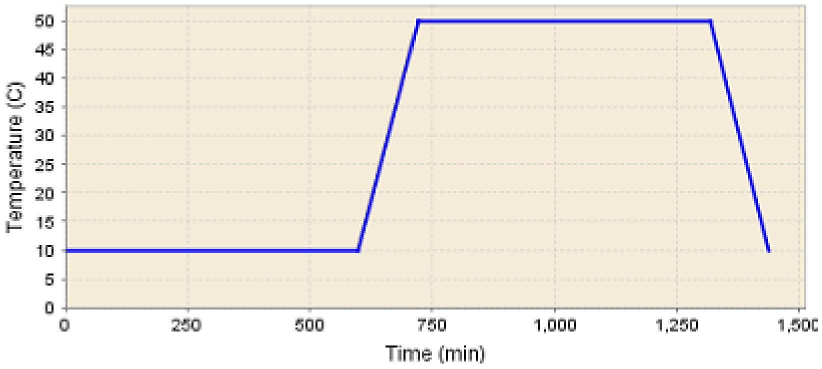
- Daily thermal cycle
  - Modeled daily dT = 40°C
    - Ambient dT + solar load + internal dT
    - Compared 3 temperature ramp durations: 1, 2, 3 hours

- Daily thermal cycle with mini-cycles
  - Modeled daily dT = 20°C, temperature ramp 1 hour
  - Superimposed 25 daily cycles dT = 20°C at low temp
  - Superimposed 25 daily cycles dT = 20°C at high temp

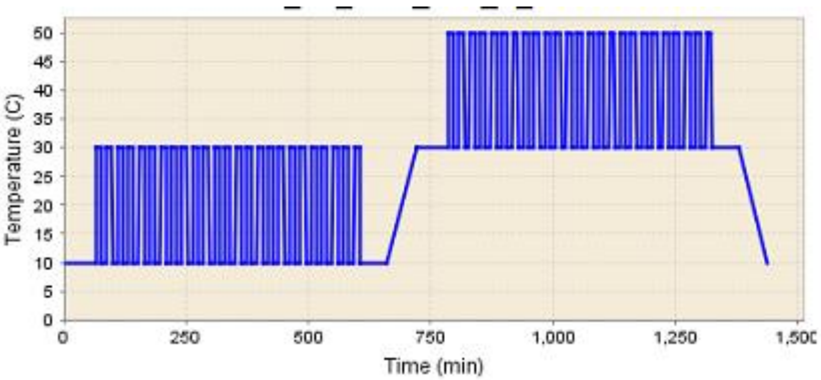
DfR Solutions

Outdoor Deployment Thermal Stresses (cont.)

Daily dT = 40°C



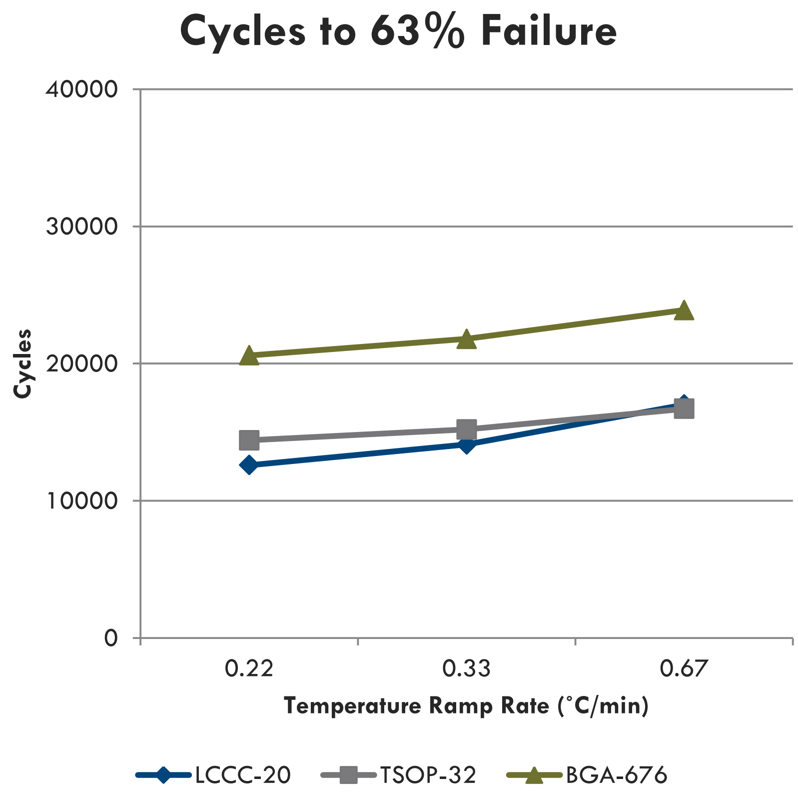
Daily dT = 20°C + mini-cycles



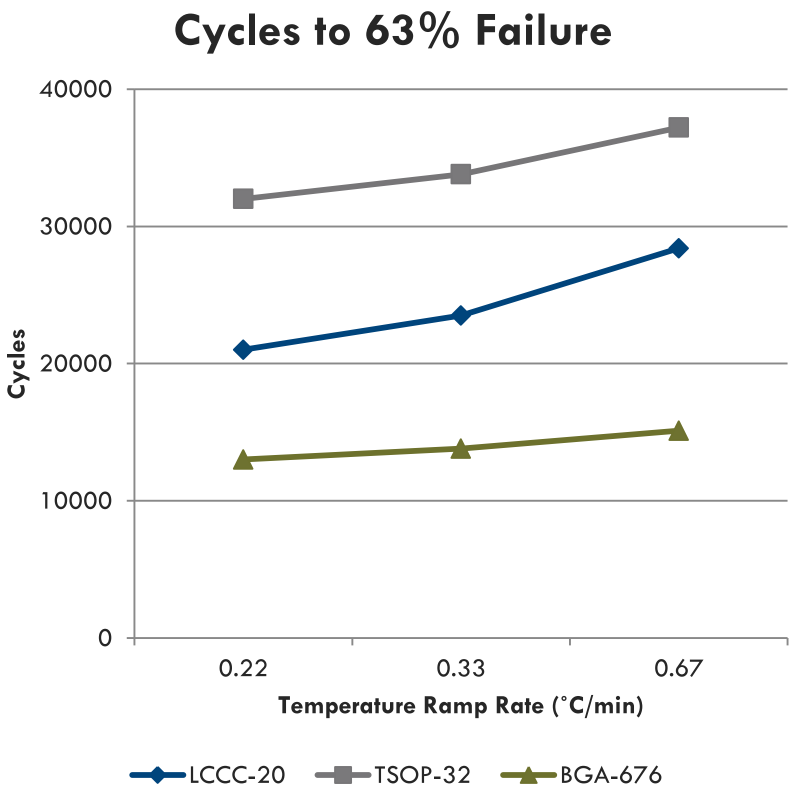
DfR Solutions

Daily 40˚C dT Solder Fatigue by Solder and Component

63Sn37Pb

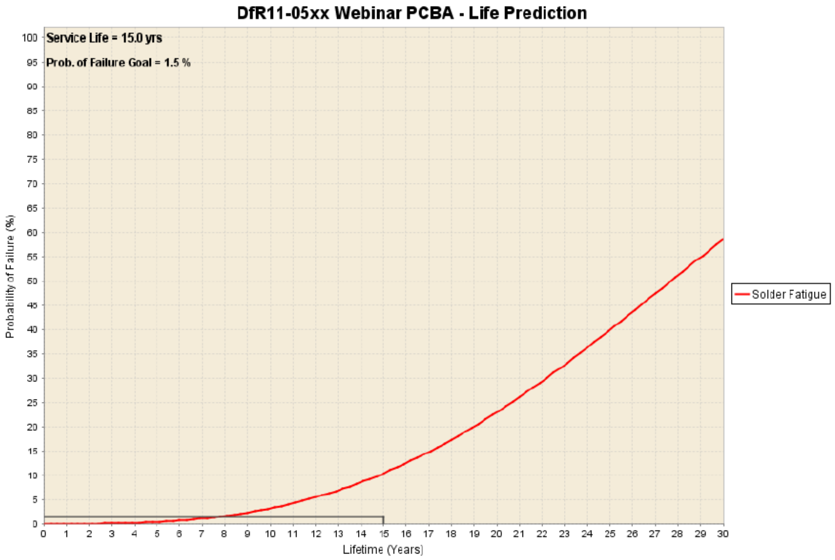


SAC305

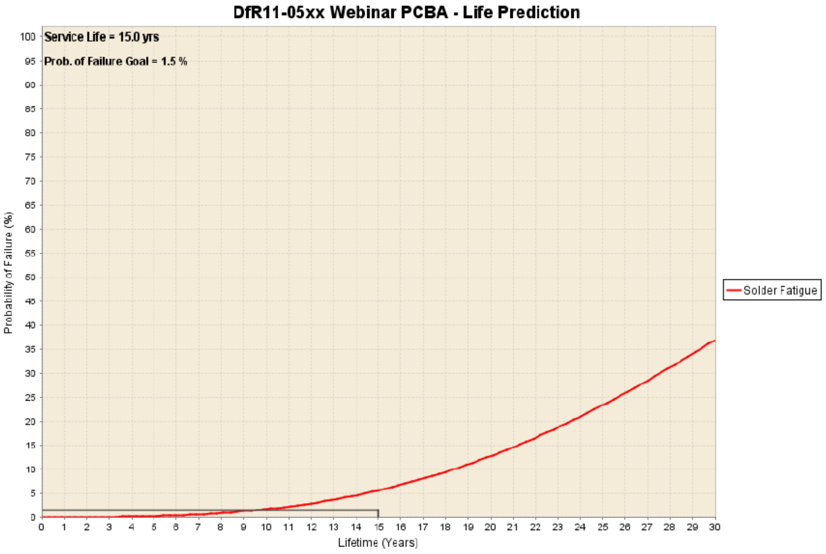


Daily 40°C dT Assembly Solder Fatigue Life Prediction

63Sn37Pb

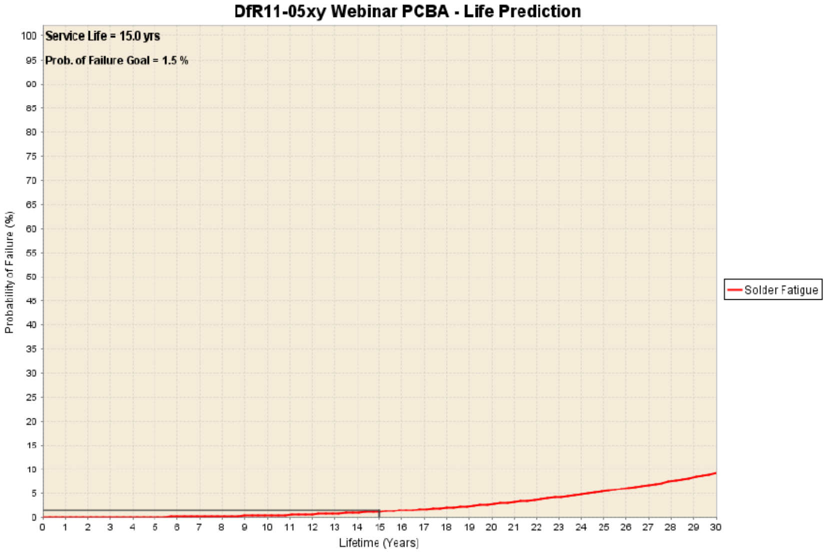


SAC305

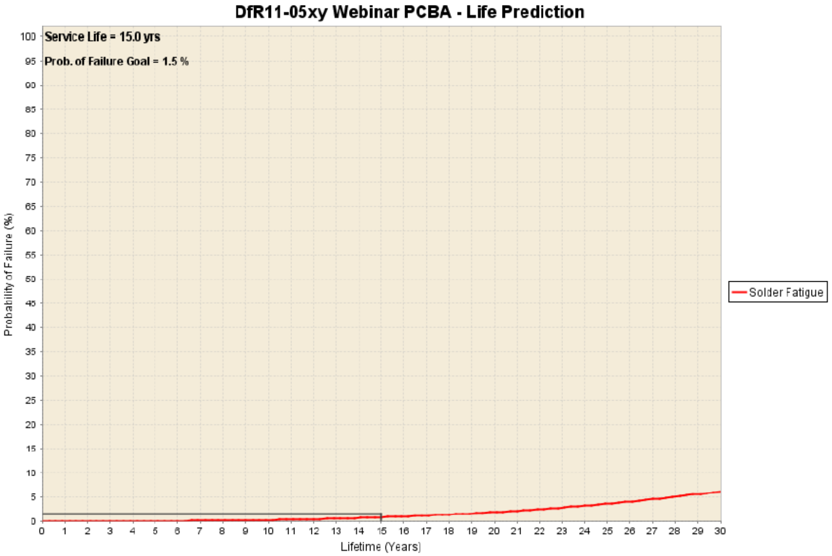


Daily 20°C dT + 20°C Mini-cycles Assembly Solder Fatigue Life Prediction

63Sn37Pb



SAC305



Observations

- Solder fatigue predictions at dT = 40°C
  - ~10% failures at 15 years for this SnPb assembly
  - ~ 6% failures at 15 years for this SAC305 assembly

- Predictions at dT = 20°C + 20°C mini-cycles
  - ~1% failures at 15 years for this SnPb assembly
  - <1 % failures at 15 years for this SAC305 assembly

Observations (cont.)

- All components included in this analysis except BGA components are predicted to have longer solder joint lifetimes with SAC305 compared to SnPb eutectic.

- Solder fatigue is predicted to increase at slower temperature ramp rates

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Further Information

- Recommend stress dependent lifetime modeling for assemblies with sizable BGA and QFN components
- Model validation reports are available from DfR Solutions