DfR Solutions

RELIABILITY DESIGNED & DELIVERED

Introduction to Design for Reliability (DfR) and Design for Manufacturability (DfM)

SMTA North Texas Chapter

November 4, 2016

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

What is Design for Reliability (DfR)?

- Reliability is the measure of a product's ability to
  - …perform the specified function
  - …at the customer (with their use environment)
  - …over the desired lifetime

- Design for Reliability is a process for ensuring the reliability of a product or system during the design stage before physical prototype
  - Often part of an overall Design for Excellence (DfX) strategy

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Why Design for Reliability (DfR)?

- The foundation of a successful product is a robust design
  - Provides margin
  - Mitigates risk from defects
  - Satisfies the customer

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

When Do Mistakes Occur?

- Insufficient exchange of information between electrical design and mechanical design
- Poor understanding of supplier limitations
- Customer expectations (reliability, lifetime, use environment) are not incorporated into the new product development (NPD) process

There can be many things that "you don't know you don't know"

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

List of DfR Tools and Techniques

Many tasks, techniques and analyses are specific to particular industries and applications. Commonly these include:

- Built-in test (BIT) (testability analysis)
- Failure mode and effects analysis (FMEA)
- Reliability hazard analysis
- Reliability block-diagram analysis
- Dynamic Reliability block-diagram analysis[6]
- Fault tree analysis
- Root cause analysis
- Sneak circuit analysis
- Accelerated testing
- Reliability growth analysis
- Weibull analysis
- Thermal analysis by finite element analysis (FEA) and / or measurement
- Thermal induced, shock and vibration fatigue analysis by FEA and / or measurement
- Electromagnetic analysis
- Statistical interference
- Avoidance of single point of failure
- Functional analysis and functional failure analysis (e.g., function FMEA, FHA or FFA)
- Predictive and preventive maintenance: reliability centered maintenance (RCM) analysis
- Testability analysis
- Failure diagnostics analysis (normally also incorporated in FMEA)
- Human error analysis
- Operational hazard analysis /
- Manual screening
- Integrated logistics support

List of DfR Tools and Techniques

- Failure Mode Analysis
  - Failure Mode Effect Analysis (FMEA), Fault Tree/Tolerance Analysis (FTA), Design Review by Failure Mode (DRBFM), Sneak Circuit Analysis (SCA)
- Reliability Prediction - Empirical
- Design Rules
- Design for Excellence
  - Design for Manufacturability (DfM), Design for Testability (DfT)
- Tolerancing (Mechanical, Electrical)
- Simulation and Modeling (Stress)
  - Thermal, Mechanical, Electrical/Circuit
- Simulation and Modeling (Damage)
  - EMI/EMC, EOS/ESD, Physics of Failure, Derating

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Failure Mode Analysis

- A process of identifying potential failure modes and appropriate mitigations early in the design process
  - Likely the most common DfR tool for reliability engineers

- These are generic DfR tools
  - A Strength and Weakness

- Strength: Can provide amazing insight
- Weakness: Can be a boring, monotonous, no-value, check-the-box activity

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Concept / Block Diagram

- Can DfR mistakes occur at this stage?
  - No……..and Yes
- Failure to capture and understand product specifications at this stage lays the groundwork for mistakes at schematic and layout
- Important specifications to capture at concept stage
  - Reliability goals
  - Use environment
  - Dimensional constraints

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Limitations of MTTF/MTBF

- MTBF/MTTF calculations tend to assume that failures are random in nature
  - Provides no motivation for failure avoidance
- Easy to manipulate numbers
  - Tweaks are made to reach desired MTBF
  - E.g., quality factors for each component are modified
- Often misinterpreted
  - 50K hour MTBF does not mean no failures in 50K hours
- Better fit towards logistics and procurement, not failure avoidance

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Field Environment (Best Practice)

- Use standards when…
  - Certain aspects of your environment are common
  - No access to use environment
- Measure when…
  - Certain aspects of your environment are unique
  - Strong relationship with customer
- Do not mistake test specifications for the actual use environment
  - Common mistake with vibration loads

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Electrical Environments

- Often very well defined in developed countries
- Introduction into developing countries can sometimes cause surprises
- Rules of thumb
  - China: Can have issues with grounding (connected to rebar?)
  - India: Numerous brownouts (several a day)
  - Mexico: Voltage surges

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Know Your Environment (Case Study)

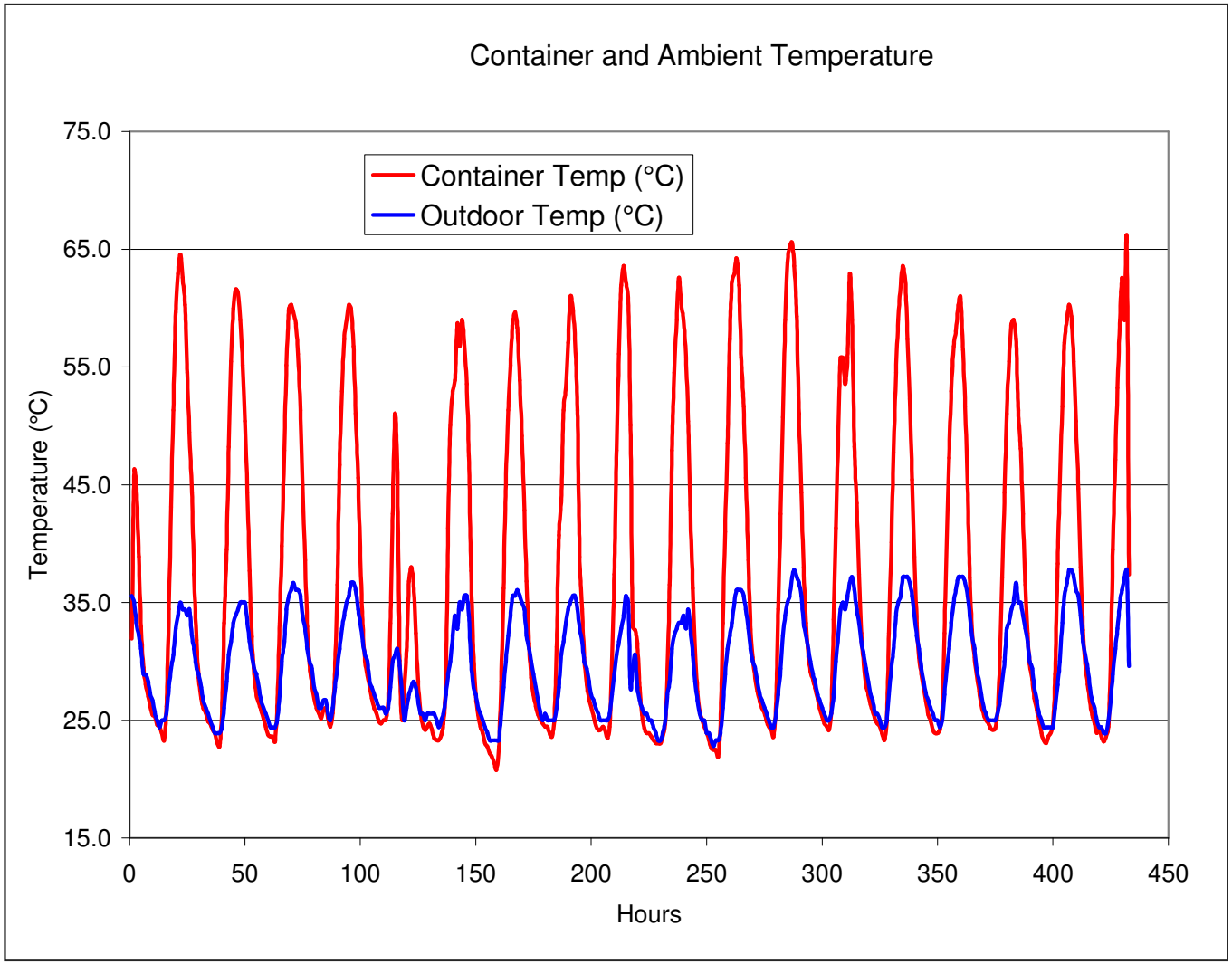
- Leader in surgical systems for eyecare
  - Released latest system with foot pedal for ease of use
- Failed to realize how customers would use foot pedal
  - Moving system across carpet without lifting up foot pedal created large static charges
  - Using foot pedal to pull system caused cable/connector failures

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Thermal Environments (Case Study): Closed Containers

Temp. Variation

Trucking Container



9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

Dimensions

- Keep dimensions loose at this stage
  - Large number of hardware mistakes driven by arbitrary size constraints
  - Examples include poor interconnect strategies and poor choices in component selection

- Case study: Use of 0201 chip components
  - Tight dimensional requirements push designer towards wholesale placement of 0201 components
  - 0201 is not yet an appropriate technology for systems requiring reliability
  - Result: Major issues at customers

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Part Selection

- The process of creating the bill of materials (BOM) during the 'virtual' design process
  - Before physical layout
- For some companies, this is during the creation of the approved vendor list (AVL)
  - Design-independent

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Part Selection (cont.)

- KIS: Keep it Simple
  - New component technology can be very attractive
  - Not always appropriate for high reliability embedded systems
  - Be conservative

- Reality: Marketing hype FAR exceeds actual implementation
  - Component manufacturers typically use portable sales to boost numbers
  - Claim: We have built 100's of millions of these components without a single return!
  - Actuality: All sales were to two cell phone customers with lifetimes of 18 months

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Part Selection (cont.)

- Even when used by hi-rel companies, some modifications may have been made
  - Example: State-of-the-art crystal oscillator required specialized assembly to avoid failures one to three years later in the field

- Prior examples of where care should have been taken
  - New technologies: X5R dielectric, SiC diodes, etc.
  - New packaging: Quad flat pack no lead (QFN), 0201, etc.

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Part Selection (cont.)

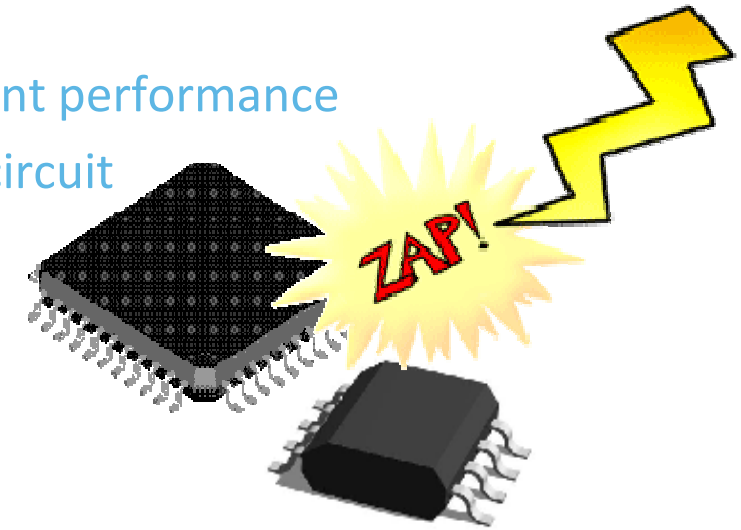
- As technology progresses, functional performance has become a limited aspect of the part selection process
- Other concerns are increasingly taking center stage
  - Moisture sensitivity level (MSL)
  - Temperature sensitivity level (PSL)
  - Electrostatic discharge (ESD) classification
  - Manufacturability (Design for Assembly)
  - Plating material
  - Lifetime / Long-term reliability
    - Sometimes Physics of Failure is required

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Critical Components

- Most small to mid-size organizations do not have the resources to perform a thorough part selection assessment on every part
  - Does not excuse performing this activity
  - Requires focusing on components critical to the design

- Critical Components: A narrowed list of components of most concern to the OEM
  - Sensitivity of the circuit to component performance
  - Number of components within the circuit
  - Output from FMEA / FTA
  - Past experiences
  - Complexity of the component
  - Industry-wide experiences



9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

When to do Simulation and Modeling?

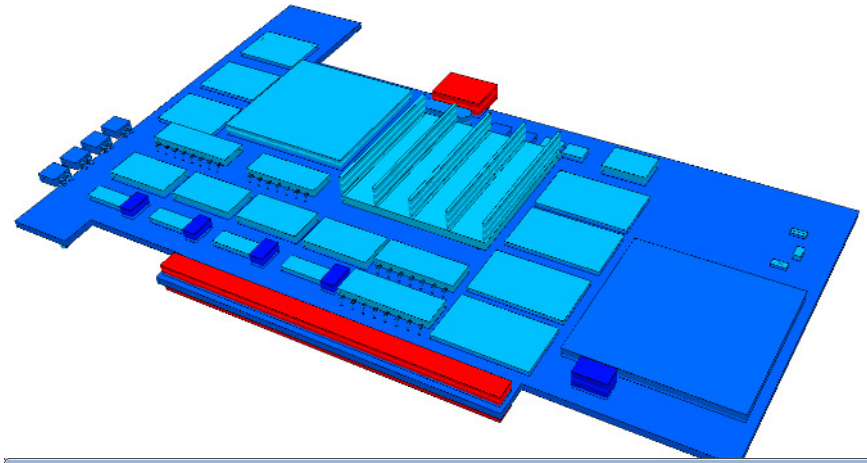
- With recent improvements in model development (typically biggest time sink), there are few limitations to rapid and robust electrical/thermal/mechanical/reliability simulations of electronic products

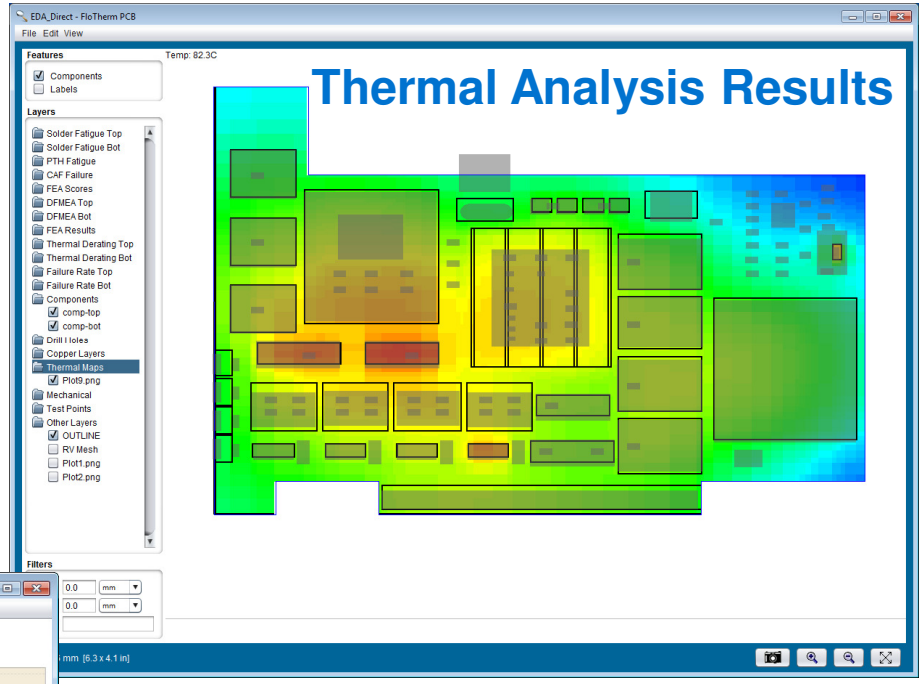
- Simulation and modeling allows organizations to
  - Obtain deeper insight earlier in the design process
  - Quantify price vs. performance for supplier and material selection
  - Iteration and optimization at minimal cost
  - Avoid 'opinioneering'
  - Substitute or replace test requirement
  - Accurately predict field performance
  - Faster time to market

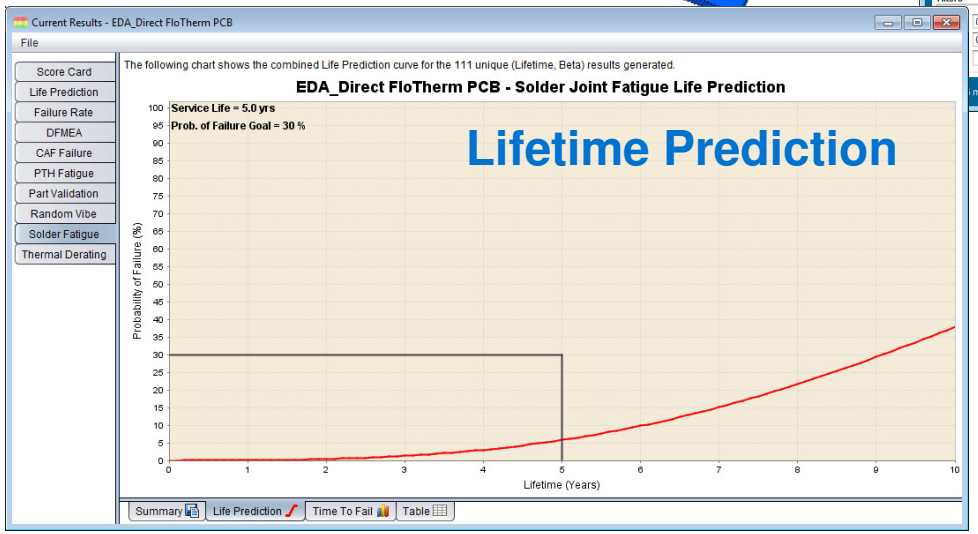
9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Simulation & Modeling Case Study – Virtual Power Cycling

3D Sherlock Model







- EDA → Sherlock → Flotherm → Sherlock → Prediction: <u>8 hours</u>

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

DfR Conclusions

- To avoid design mistakes, be aware that functionality is only the beginning
  - Mechanical and thermal are just as important as electrical
- Maximize knowledge of your design as early in the product development process as possible
- Be aware of industry best practices
- Do not overly rely on supplier statements
  - Their view: Reliability is application dependent
- Design rules are a good start, but not the way to win!

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

- Design for Manufacturability

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Design for Manufacturing (DfM)

- Definition
  - The process of ensuring a design can be consistently manufactured by the designated supply chain with a minimum number of defects
- Requirements
  - An understanding of best practices (what fails during manufacturing?)
  - An understanding of the limitations of the supply chain

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Introduction to Design for Manufacturing (DfM)

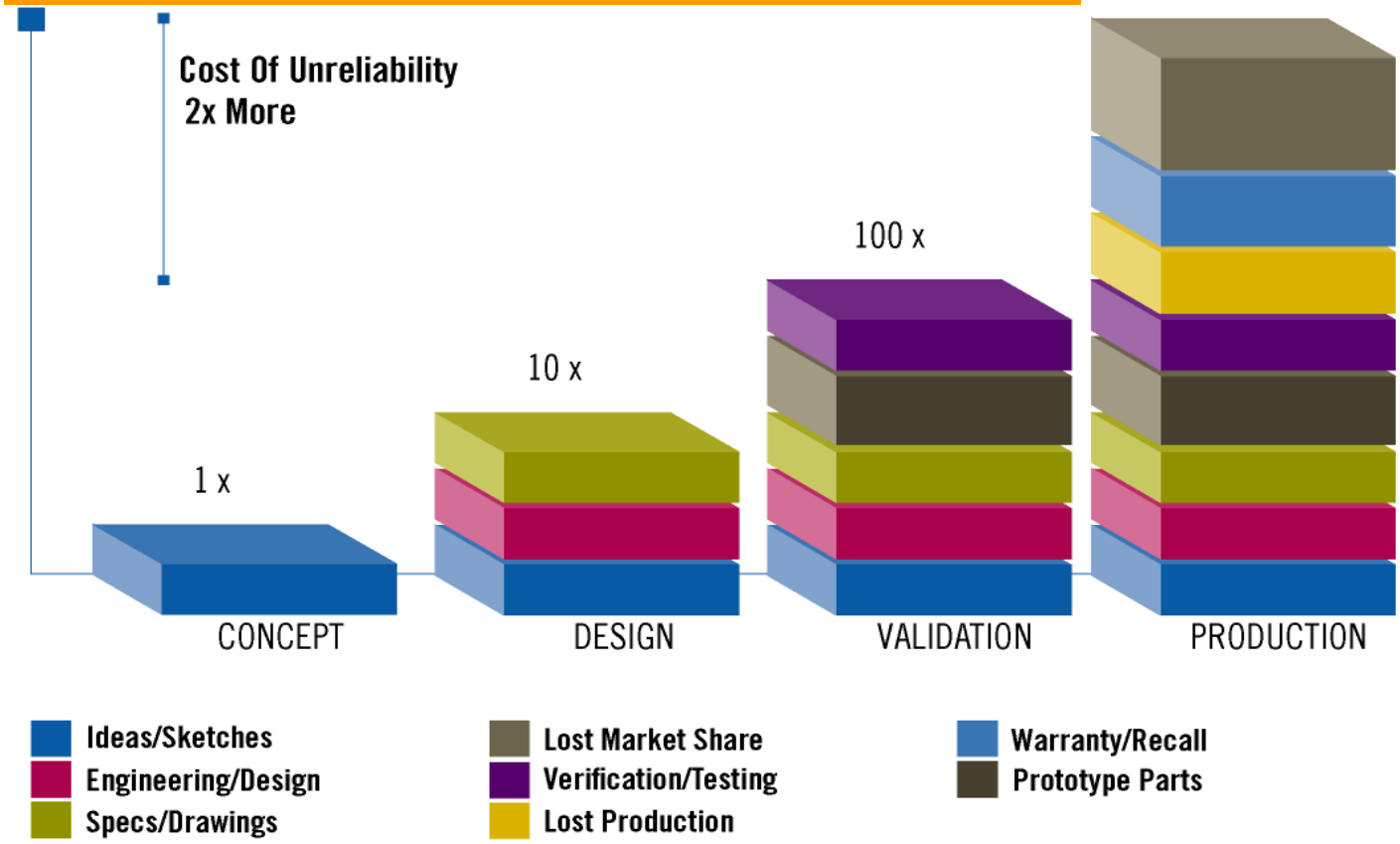
- DfM is the process of proactively designing products to:
  - Optimize all of the manufacturing functions: supplier selection and management, procurement, receiving, fabrication, assembly, quality control, operator training, shipping, delivery, service, and repair.
  - Assure that critical objectives of cost, quality, reliability, regulatory compliance, safety, time-to-market, and customer satisfaction are known, balanced, monitored, and achieved.

Introduction to Design for Manufacturing (DfM)

- Successful DFM efforts require the integration of product design and process planning
  - If existing processes are used, new products must be designed to the parameters and limitations of these processes regardless of whether the product is build internally or externally.
  - If new processes are used, then the product and process need to be developed carefully considering the risks associated with “new”

Why DfM? (cont.)

Reduce Costs by Improving Manufacturability Upfront



9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

Industry Standards – IPC, JEDEC, ISO…

- Start with industry standards where possible
  - Tried and true
  - But, represent only *minimum* acceptable requirements or concerns
    - Modify and extend as needed to customize for your product and environments!
  - Forums provide opportunities for free advice and feedback

IPC Design Requirement/Guideline References

- **IPC-2221- Generic Standard on Printed Board Design**
  - IPC-2221A is the foundation design standard for all documents in the IPC-2220 series. It establishes the generic requirements for the design of printed boards and other forms of component mounting or interconnecting structures, whether single-sided, double-sided or multilayer.

  - 3 Performance Classes
    - *Class 1 General Electronic Products* - consumer products,
    - *Class 2 Dedicated Service Electronic Products*
      - Communications equipment, sophisticated business machine, instruments and military equipment where high performance, extended life and uninterrupted service is desired but is not critical.
    - *Class 3 High Reliability Electronic Products*
      - Commercial, industrial and military products where continued performance or performance on demand is critical and where high levels of assurance are required...

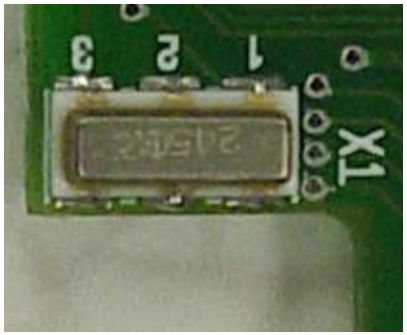
A Word on Quality, Reliability & IPC Class 2 versus Class 3

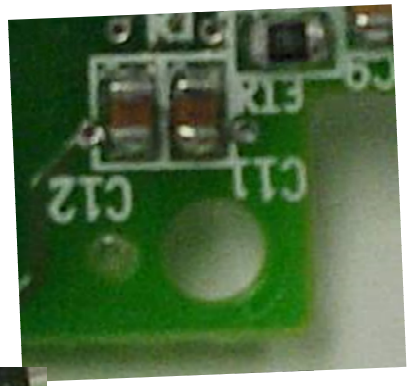
- Good quality is necessary but not SUFFICIENT to guarantee high reliability.
- IPC Class 3 by itself does not guarantee high reliability
  - A PCB or PCBA can be perfectly built to IPC Class 3 standards and still be totally unreliable in its final application.
  - Consider two different PCB laminates both built to IPC Class 3 standards.
    - Both laminates are identical in all properties EXCEPT one laminate has a CTEz of 40 and the other has a CTEz of 60.
    - The vias in the laminate with the lower CTEz will be MORE reliable in a long term, aggressive thermal cycling environment than the CTEz 60 laminate.
    - A CTEz 40 laminate built to IPC class 2 could be MORE reliable than the CTEz 60 laminate built to Class 3.
    - Appropriate materials selection for the environment is key!

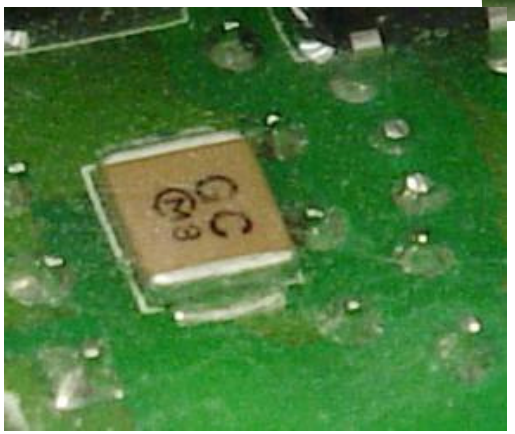
9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Common Types of DfM Review Processes

- Informal "Gut Check" Review
  - Performed by highly experienced engineers.
  - Difficult with transition to original design manufacturers (ODM) in developing countries.
  - "Tribal knowledge"
- Formal Design reviews
  - Internal team
  - External experts
- Automated (electronic) design automation (ADA) software
  - Modules automate DfM rule checking.
- Electronic manufacturing service (EMS) providers
  - Perform DfM as a service







Design for Manufacturing (DfM)

- Formal DfM Reviews and Tools Sometimes Overlooked
  - Organization may lack specialized expertise.
  - More design organizations completely removed from manufacturing.

- DfM Reviews Needs to be Performed for:
  - Bare Board
  - Circuit Board Assemblies
  - Chassis/Housing Integration Packaging
  - System Assembly

- DfM Needs to be conducted in conjunction with the actual electronic assembly source.
  - What is good DfM for one supplier and one set of assembly equipment may not be good for another.

Failure Analysis Techniques

- Returned parts failure analysis always starts with Non-Destructive Evaluation (NDE)
- Designed to obtain maximum information with minimal risk of damaging or destroying physical evidence
- *Emphasize the use of simple tools first!*
- (Generally) non-destructive techniques:
  - Visual Inspection
  - Electrical Characterization
  - Time Domain Reflectometry (TDR)
  - Acoustic Microscopy (SAM)
  - X-ray Microscopy
  - Thermal Imaging (Infra-red camera)
  - Superconducting Quantum Interfering Device (SQUID) Microscopy

Failure Analysis Techniques

- Destructive evaluation techniques
  - Decapsulation
  - Plasma etching
  - Cross-sectioning
  - Thermal imaging (liquid crystal; SQUID and IR also good after decap)
  - SEM/EDX – Scanning Electron Microscope / Energy dispersive X-ray Spectroscopy
  - Surface/depth profiling techniques: SIMS-Secondary Ion Mass Spectroscopy, Auger
  - OBIC/EBIC
  - FIB - Focused Ion Beam
  - Mechanical testing: wire pull, wire shear, solder ball s
- Other characterization methods
  - FTIR- Fourier Transform Infra-Red Spectroscopy
  - Ion chromatography
  - DSC – Differential Scanning Calorimetry
  - DMA/TMA – Thermo-mechanical analysis

Electrical Characterization

- Most critical step in the failure analysis process
  - Can the reported failure mode be replicated?
    - Persistent or intermittent?
    - Intermittent failures often incorrectly diagnosed as no trouble found (NTF)
  - Least utilized to its fullest extent
- Approach dependent upon the product
  - Component
  - Bare substrate
  - PCB assembly
- Sometimes performed in combination with environmental exposure
  - Characterization over specified/expected temperature range
  - Characterization over specified / expected radiation range
  - Humidity environment (re-introduction of moisture)
  - Not intended to induce damage!

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

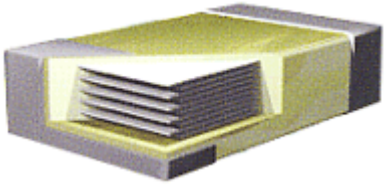
Robustness - Components

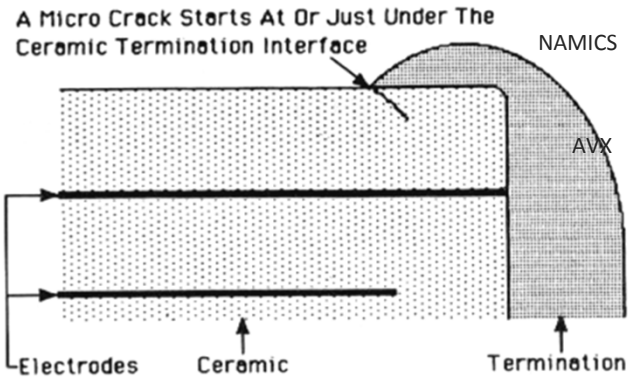
- Concerns
  - Potential for latent defects after exposure to Pb-free reflow temperatures
  - 215°C - 220°C peak → 240°C - 260°C peak
- Drivers
  - Initial observations of deformed or damaged components
  - Failure of component manufacturers to update specifications
- Components of particular interest
  - Aluminum electrolytic capacitors
  - Ceramic chip capacitors
  - Surface mount connectors
  - Specialty components (RF, optoelectronic, etc.)

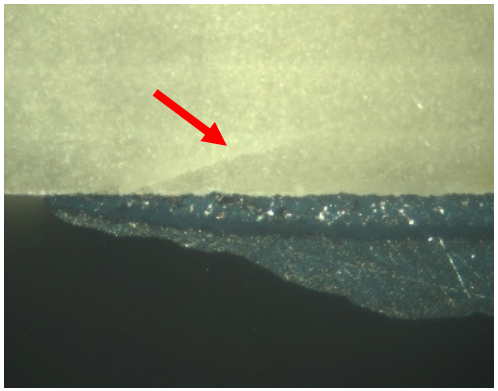
9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

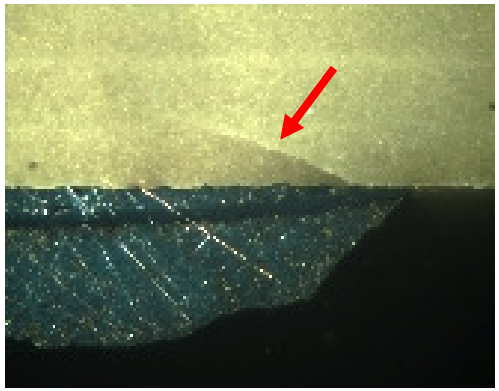
Ceramic Capacitors (Thermal Shock Cracks)

- Due to excessive change in temperature
  - Reflow, cleaning, wave solder, rework
  - Inability of capacitor to relieve stresses during transient conditions.
- Maximum tensile stress occurs near end of termination
  - Determined through transient thermal analyses
  - Model results validated through sectioning of ceramic capacitors exposed to thermal shock conditions
- Three manifestations
  - Visually detectable (rare)
  - Electrically detectable
  - Microcrack (worst-case)





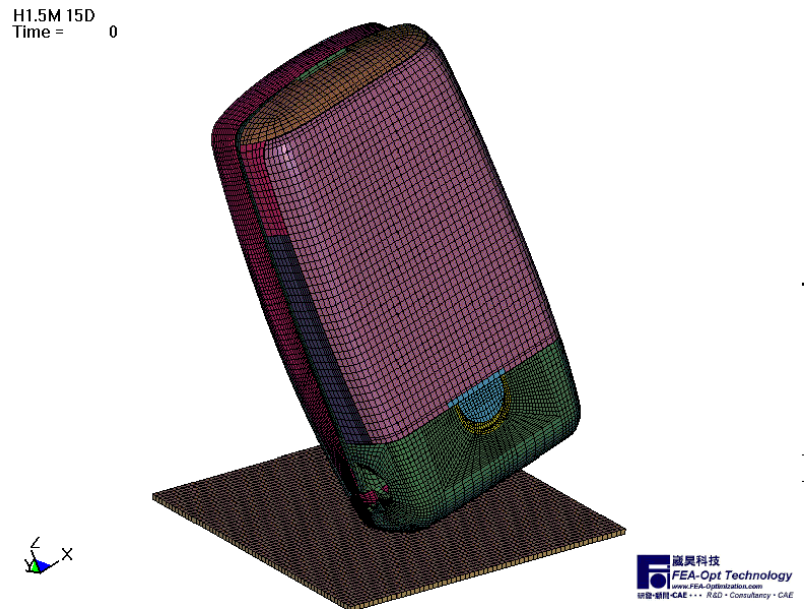


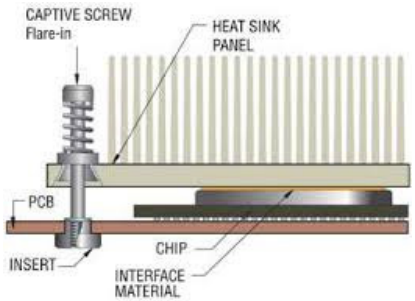


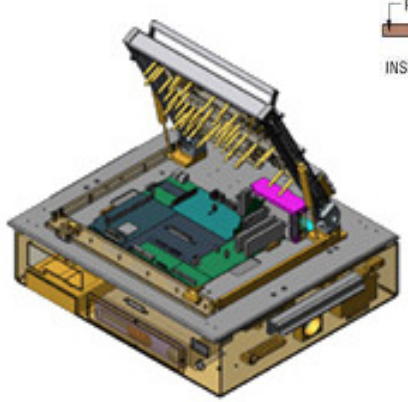
9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

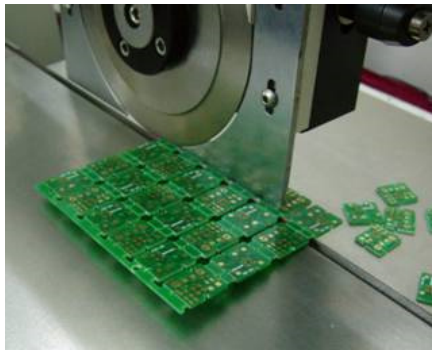
Mechanical Shock Events

- Tend to be overly focused on drop, but excessive flexure can occur at multiple points post-assembly





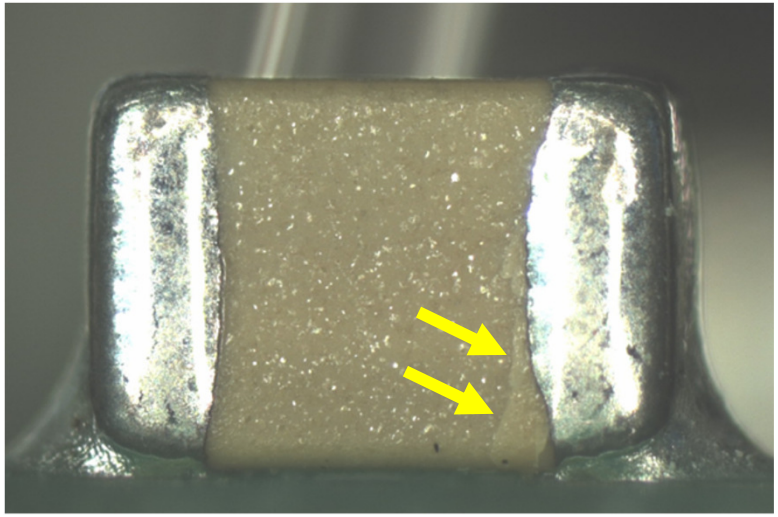




9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

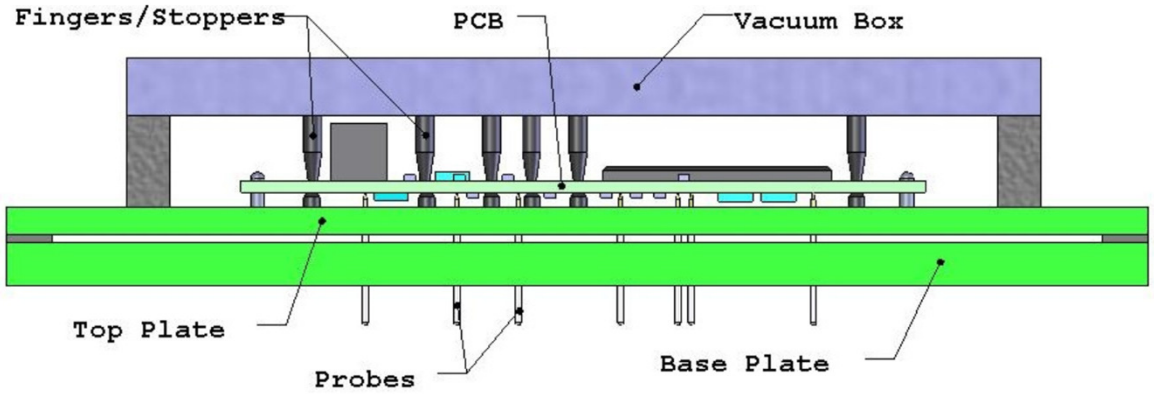
Flex Cracking



9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

ICT Strain: Fixture & Process Analysis

- Review/perform ICT strain evaluation at fixture mfg and in process: 500 us, IPC 9701 and 9704 specs, critical for QFN, CSP, and BGA
- http://www.rematek.com/download_center/board_stress_analysis.pdf

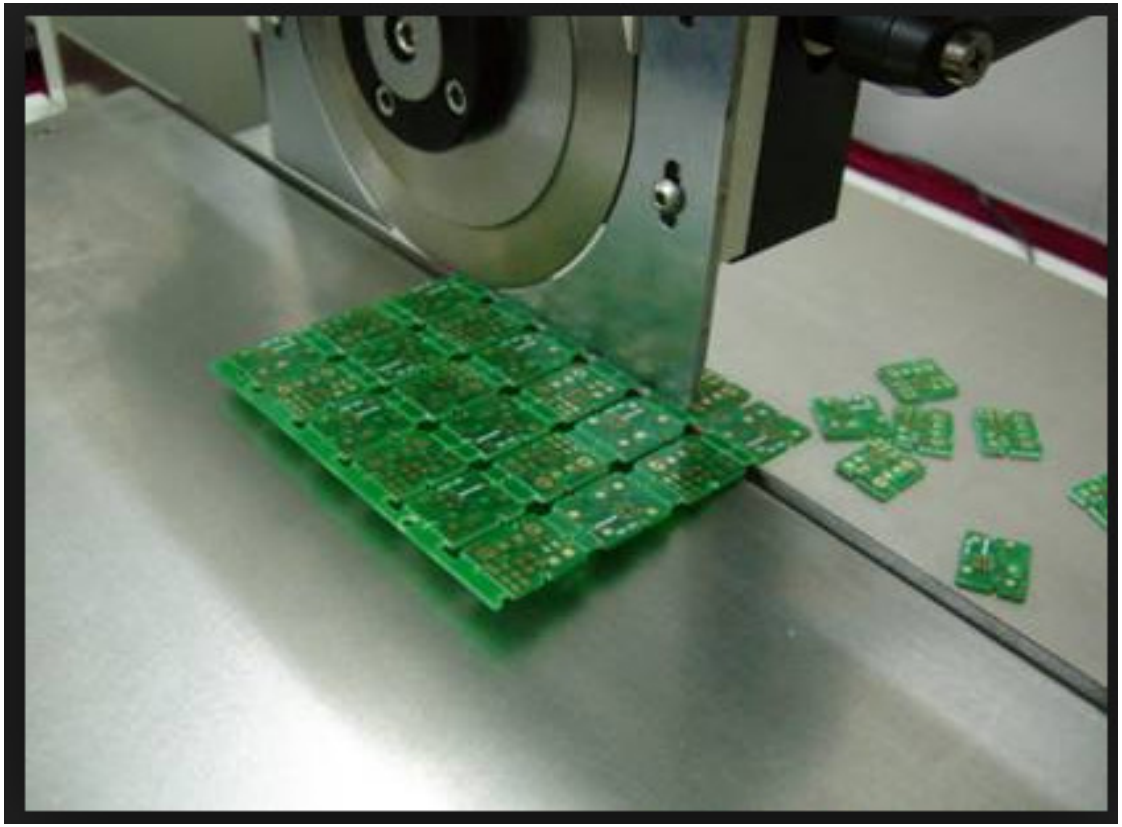


- To reduce the pressures exerted on a PCB, the first and simplest solution is to reduce the probes forces, when this is possible.
- Secondly, the positioning of the fingers/stoppers must be optimized to control the probe forces. But this is often very difficult to achieve. Mechanically, the stoppers must be located exactly under the pressure fingers to avoid the creation of shear points

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

What Can Cause Cracked Capacitors-Mechanical Stress?

- The most common method for PCB Panel Singulation is to use V-grooved boards and a system as shown below to slice though the boards at the grooves.
- If the PCBs in the panel are not properly supported, then mechanical stress cracks can occur in MLCC capacitors.

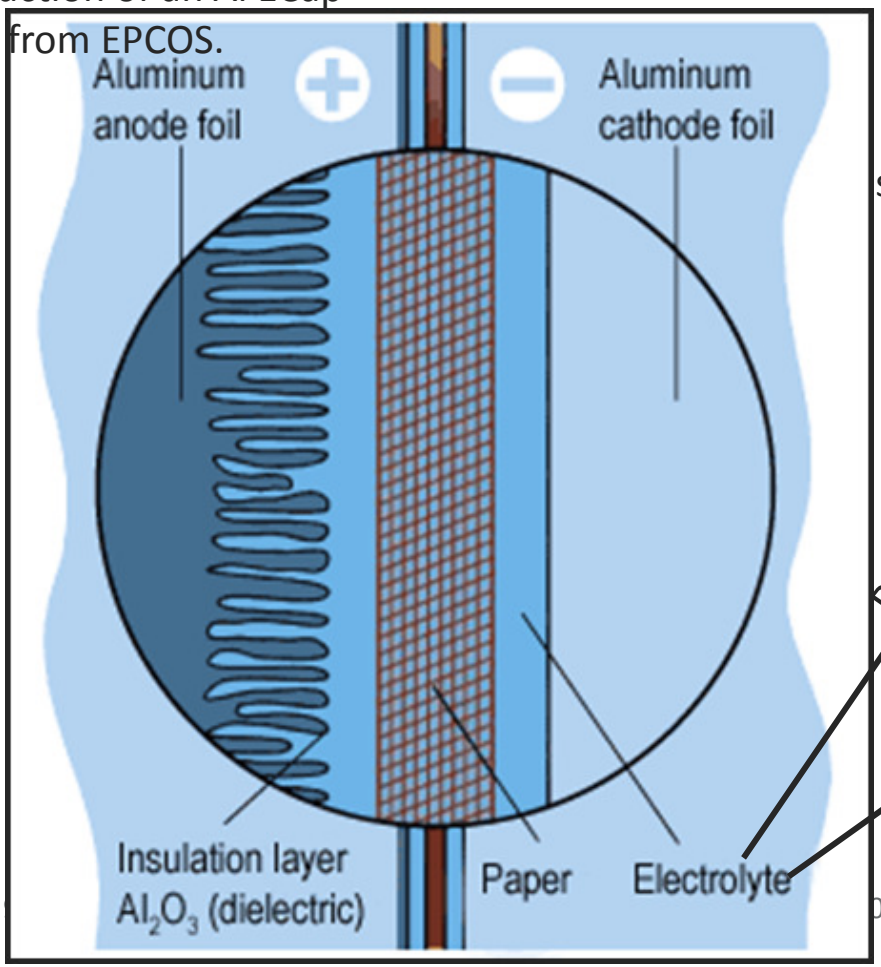


41

Aluminum Electrolytic Capacitors – Failure Criteria

Capacitance Change	Within +/- 20% of initial value
Dissipation Factor	Not more than 200% of the specified value
Leakage Current	Initial specific value or less

Detailed internal construction of an Al ECap from EPCOS.

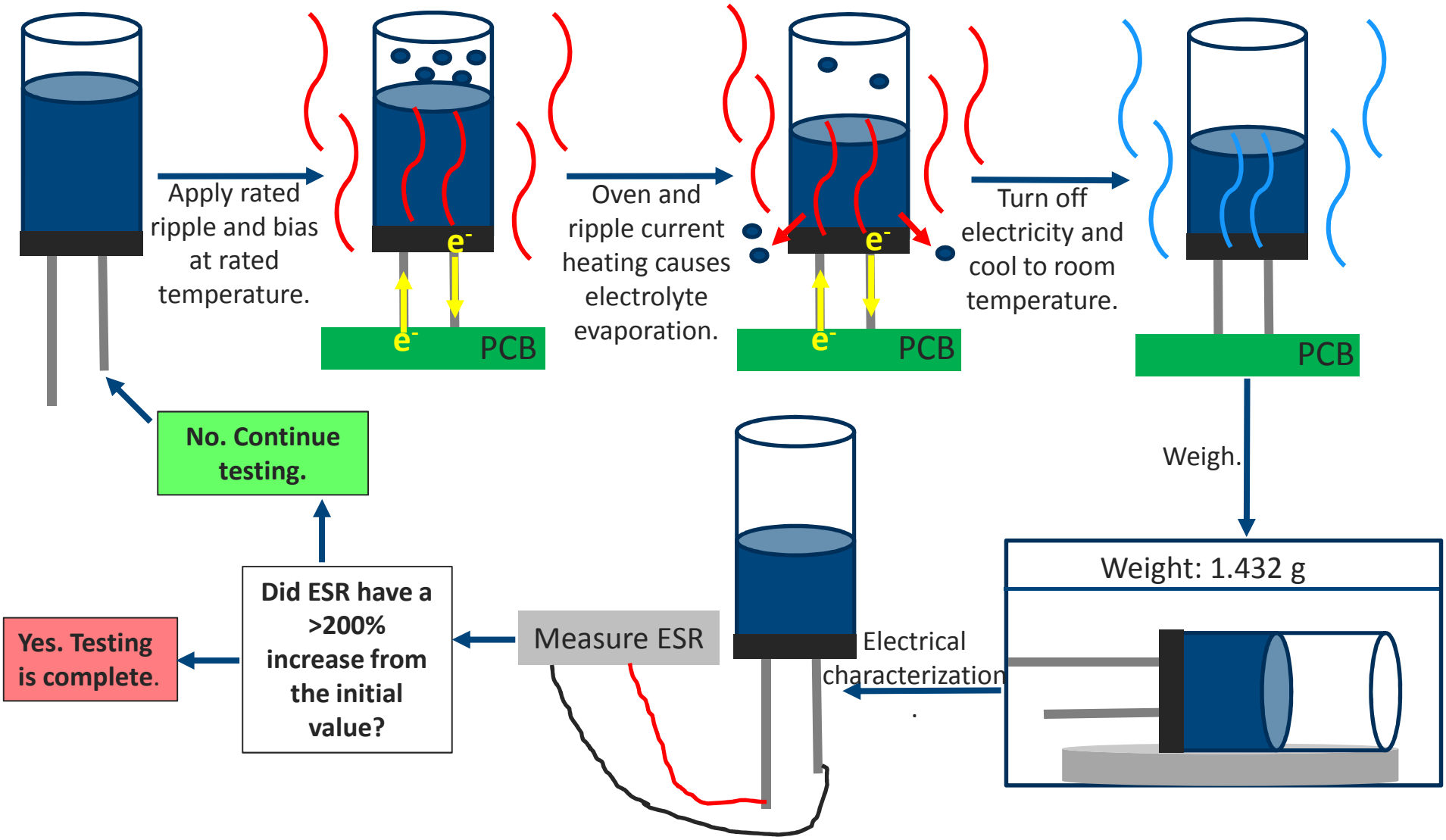


Failure criteria defined in manufacturer datasheets.
Dissipation factor is proportional to equivalent series resistance (ESR), so >200% increase in ESR is classified as failed.

Bad chemistry → Increase in leakage current

Evaporation → Increase in dissipation factor (ESR); Decrease in capacitance

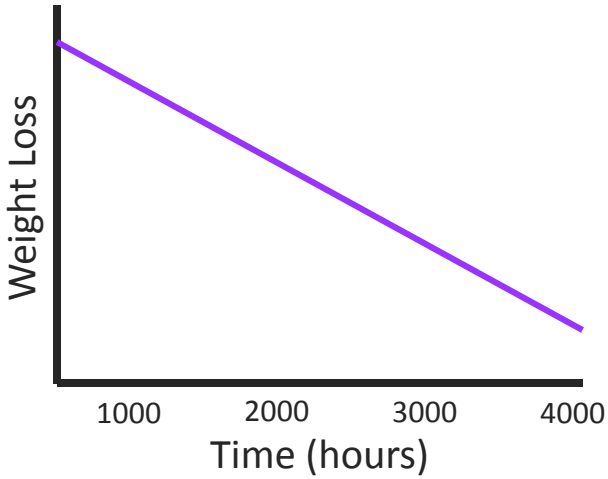
Life Test – Traditional (& Accelerated: Rate of Weight Loss)



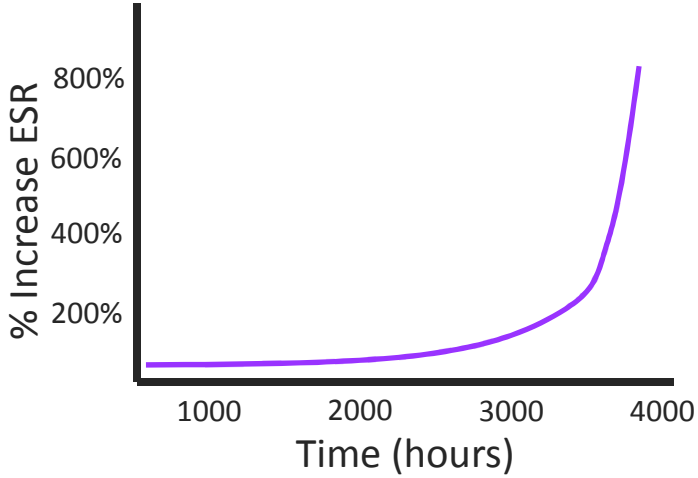
9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

Life Test – Trends in Traditional Data



Linear throughout entire test lifetime of an Al ECap population.



Exponential behavior that is relatively constant until approach time to failure.

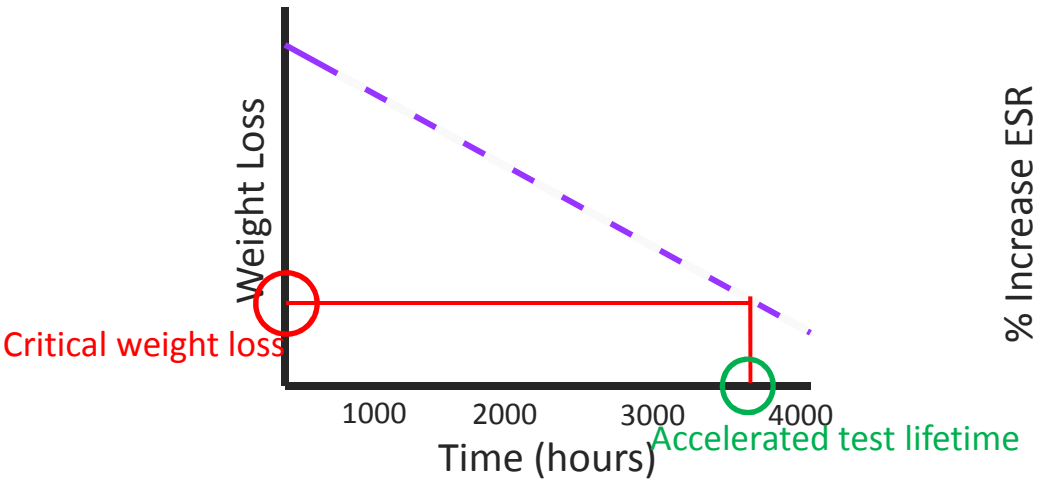
Variable	Impact on Rate of Weight Loss
↑ Ambient temperature	↑
↑ Applied ripple current	↑
↑ Heat dissipation	↓
↑ Space between bung and can	↑

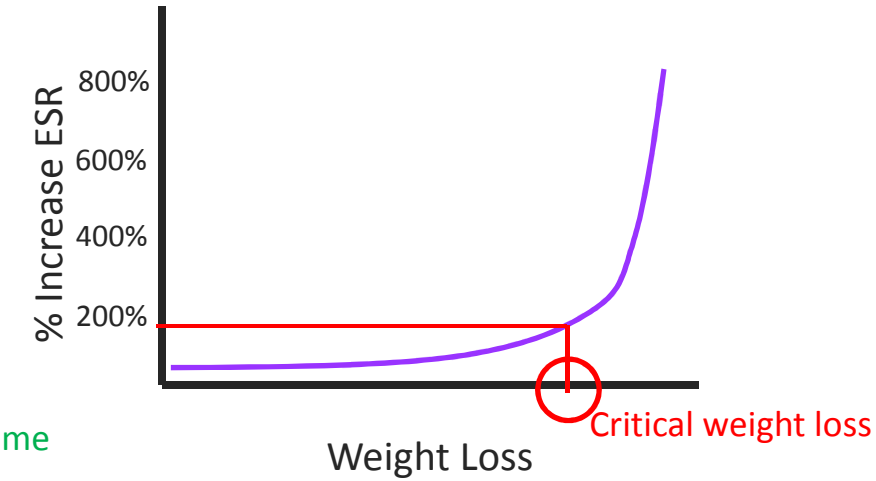
Variable	Impact on Critical Weight Loss
↑ Electrolyte stability	↑
↑ Initial ESR measurement	↓

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

Life Test– Accelerated Calculations



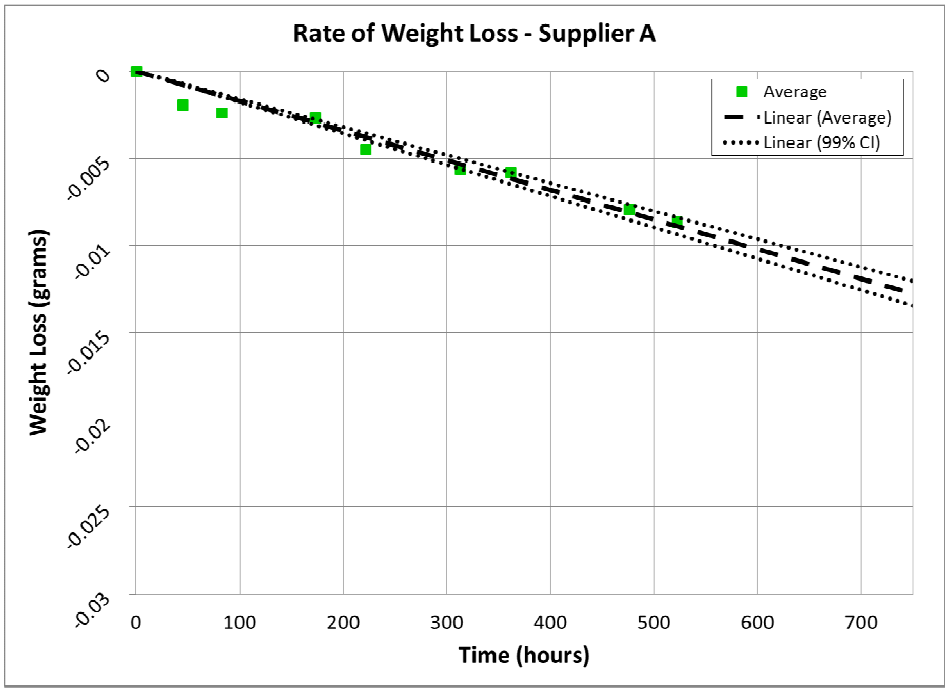


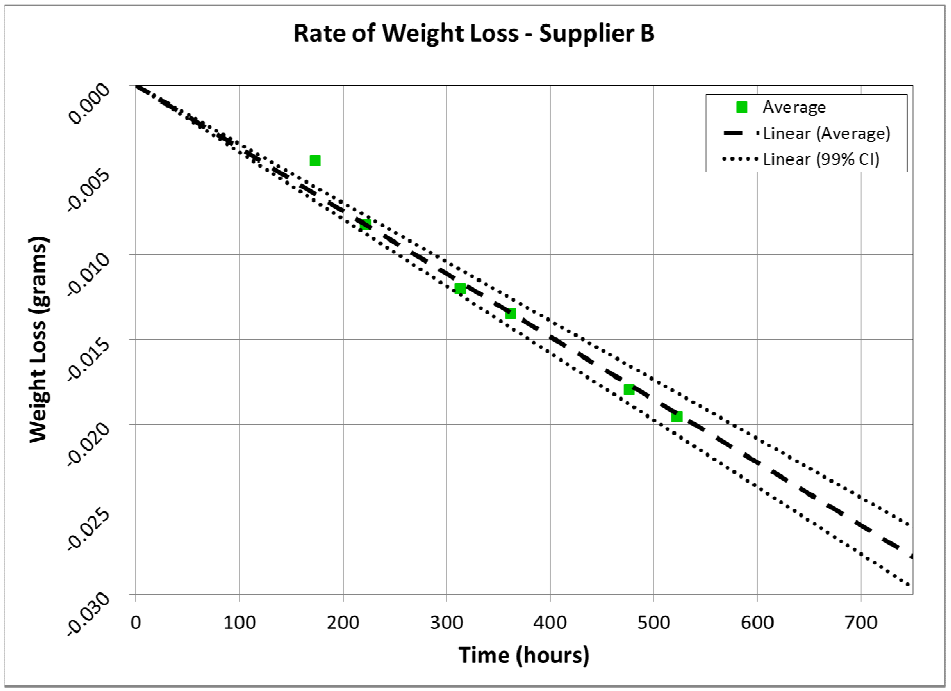
1. Critical weight loss at 200% increase in ESR is calculated using the ESR-Weight Loss curve
2. Rate of weight loss is extrapolated to the critical weight loss and the corresponding time is recorded as the accelerated test lifetime

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Accelerated Life Test – Suppliers A & B Rate of Weight Loss

450 V, 68 µF





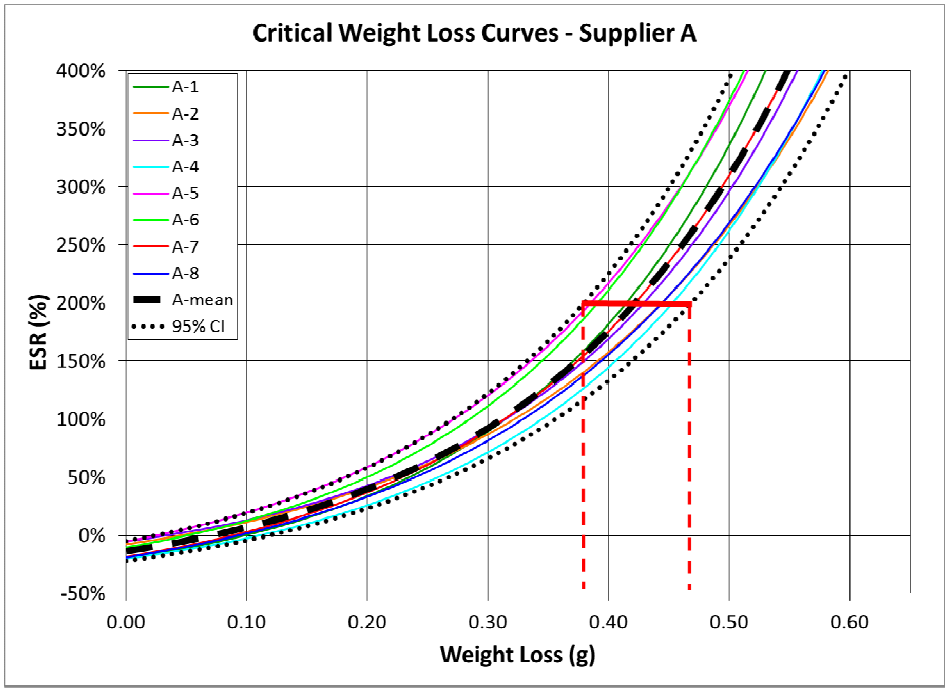
- Supplier $A_{\text{Rate of Weight Loss}} \approx ½$ Supplier $B_{\text{Rate of Weight Loss}}$
  - Supplier A capacitors have a better seal between the can and bung

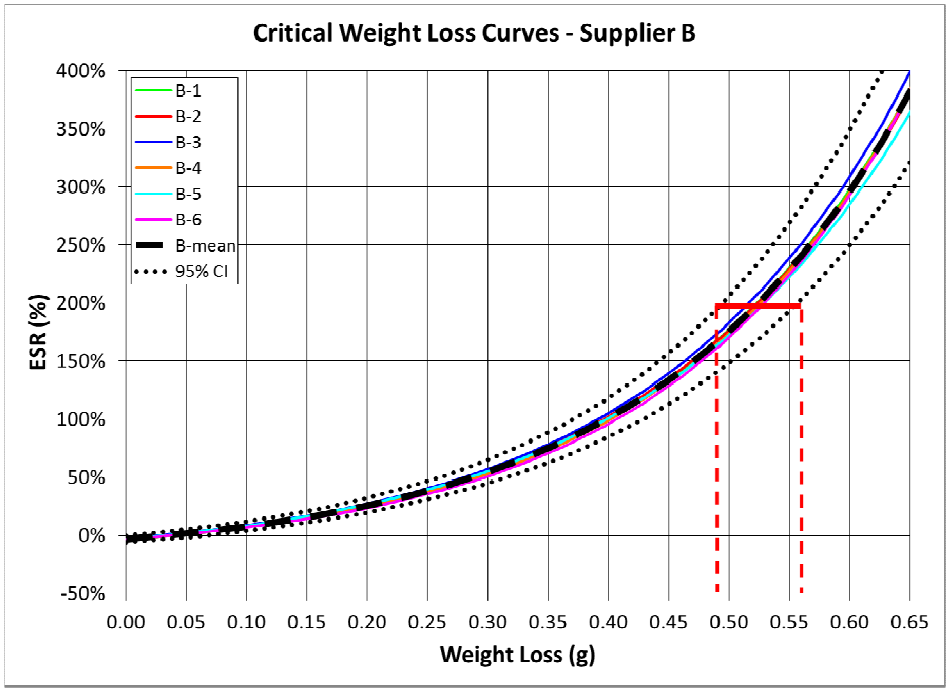
9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

Accelerated Life Test – Suppliers A & B Critical Weight Loss

450 V, 68 µF





- Supplier $A_{\text{Critical Weight Loss}} \approx$ Supplier $B_{\text{Critical Weight Loss}}$
  - Chemical stability of Supplier A and Supplier B electrolyte is comparable

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

DfR Solutions
RELIABILITY DESIGNED & DELIVERED

Accelerated Life Test – Suppliers A & B Comparison

Supplier	Minimum Accelerated Lifetime (hours)	Maximum Accelerated Lifetime (hours)	Datasheet Lifetime (hours)
A	21,130	29,140	10,000
B	12,540	16,030	>15,000

- Accelerated life test results indicate that the Supplier A Al ECap is more reliable than Supplier B
  - This is opposite of what the datasheet lifetimes suggest

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Peak Temperature Ratings

- AKA: 'Temperature Sensitivity Level' (TSL)
- Some component manufacturers are not certifying their components to a peak temperature of 260ºC
  - 260ºC is industry default for 'worst-case' peak Pb-free reflow temperature
- Why lower than 260ºC?
  - Industry specification
  - Technology/Packaging limitation

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Moisture Sensitivity Level (MSL)

- Popcorning controlled through moisture sensitivity levels (MSL)
  - Defined by IPC/JEDEC documents J-STD-020D.1 and J-STD-033B
- Higher profile in the industry due to transition to Pb-free and more aggressive packaging
  - Higher die/package ratios
  - Multiple die (i.e., stacked die)
  - Larger components

LEVEL	FLOOR LIFE	
	TIME	CONDITIONS
1	Unlimited	≤30 °C/85% RH
2	1 year	≤30 °C/60% RH
2a	4 weeks	≤30 °C/60% RH
3	168 hours	≤30 °C/60% RH
4	72 hours	≤30 °C/60% RH
5	48 hours	≤30 °C/60% RH
5a	24 hours	≤30 °C/60% RH
6	Time on Label (TOL)	≤30 °C/60% RH

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

MSL: Typical Issues and Action Items

- Identify your maximum MSL
  - Driven by contract manufacturer (CM) capability and OEM risk aversion
  - Majority limit between MSL3 and MSL4 (survey of the MSD Council of SMTA, 2004)
  - High volume, low mix: tends towards MSL4
    Low volume, high mix: tends towards MSL3
- Not all datasheets list MSL
  - Can be buried in reference or quality documents
- Ensure that listed MSL conforms to latest version of J-STD-020

Highest Level Assembled :

Don't know	26%
None used	4%
MSL 2A	4%
MSL 3	18%
MSL 4	18%
MSL 5	12%
MSL 5A	7%
MSL 6	10%

Cogiscan

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Future of Contamination / Cleanliness

- Continued reductions in pitch between conductors will make future packaging more susceptible
- Increased use of leadless packages (QFN, land grid array, etc.) results in reduction in standoff
  - Will reduce efficiency of cleaning, which may lead to increased concentration of contaminants
- Increased product sales into countries with polluted and tropical environments (East Asia, South Asia, etc.)
  - ECM occurrence very sensitive to ambient humidity conditions
- Pb-Free and smaller bond pads
  - Require more aggressive flux formulations

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Nominal Ionic Levels

- Bare printed circuit boards (PCBs)
  - Chloride: 0.2 to 1 µg/inch^2 (average of 0.5 to 1)
  - Bromide: 1.0 to 5 µg/inch^2 (average of 3 to 4)
- Assembled board (PCBA)
  - Chloride: 0.2 to 1 µg/inch^2 (average of 0.5 to 1)
  - Bromide: 2.5 to 7 µg/inch^2 (average of 5 to 7)
  - Weak organic acids: 50 to 150 µg/inch^2 (average of 120)
- Higher levels
  - Corrosion/ECM issues at levels above 2 (typically 5 to 10)
  - Corrosion/ECM issues at levels above 10 (typically 15 to 25)
  - Corrosion/ECM issues at levels above 200 (typically 400)
- General rule
  - Dependent upon board materials and complexity

9000 Virginia Manor Rd Ste 290, Beltsville MD 20705 | 301-474-0607 | www.dfrsolutions.com

Reflow Profile Optimization

- Start with paste manufacturer's recommendations!
- Preheating Phase - Ramp & Soak vs. Straight Ramp preheating profiles
  - Ramp & Soak (soak period just below liquidus), more common, more forgiving.
    - Allow flux solvents to fully evaporate and activate to deoxidize the surfaces to be soldered.
    - Allows temperature equalization across the entire assembly.
      - Consistent soldering and reduces tomb stoning.
    - If too long, flux may be consumed resulting in excessive oxidation.
      - Flux may become volatile - producing solder balls or voiding defects.
  - Straight Line is faster and causes less thermal damage to materials
    - But more susceptible to defect and quality variation, does not work as well on complex, dense assemblies.

Reflow Profile Optimization

- Peak Temperature and Time at (above) Liquidus (TAL)
  - A balance between being hot enough for long enough to achieve good consistent solder wetting and bonding for proper joint formation, across the entire assembly.
  - Yet as quickly as possible to prevent thermal damage to the components and board and to prevent excessive copper dissolution and excessive intermetallic growth.
- Cooling Rate of SnAgCu effects the Microstructure & Bulk Intermetallics
  - Faster cooling rates produce a finer, stronger microstructure and limits intermetallics.
- Overall Time (Costs & Efficiency)
  - Overall throughput is determined the board size/complexity and the oven's heat transfer capabilities.
  - Rule of Thumb: 2-3 C/second ramp up and down rate

Summary

- *DfM is a* proven, cost-effective strategic methodology.
- Early effective cross functional involvement:
  - Reduces overall product development time (less changes, spins, problem solving)
  - Results in a smoother production launch.
  - Speeds time to market.
  - Reduces overall costs.
    - Designed right the first time.
    - Build right the first time = less rework, scrap, and warranty costs.
  - Improved quality and reliability results in:
    - Higher customer satisfaction.
    - Reduced warranty costs.

Contact Information

- Questions?
  - Contact Greg Caswell, gcaswell@dfrsolutions.com, 301-640-5825- office 443-834-9284 - cell
  - askdfr@dfrsolutions.com
  - www.dfrsolutions.com

- Connect with me in LinkedIn as well!