

# Solder Attachment Reliability - A Physics of Failure Approach

#### James McLeish, CRE West Penn SMTA, July 19, 2013

# Introduction

• Jim McLeish >35 Yrs of Vehicular, Military & Industrial E/E Enrg. & QRD Experience

- ESA/EFC Digital Task Force (1st Microprocessor Based Engine Controller) Chrysler Corp.
- o 3 Patents Automotive Electronic Control Systems GM Adv. Product Engineer
- System Engineering and Architecture Planning GM Saturn Project
- E/E EGM GM Military Vehicle
- $_{\odot}$  EE Reliability Manager GM CPC & Mid Lux.
- Manager Reliability Physics (Advance Reliability Method Development) GM NAO
  - o 3 GM EE Test Standards GM9123, GMW3172 GMW8288
  - 2006 GM People Make Quality Happen award
- EE QRD Tech Expert/EE QRD Strategists GM VEC
- SAE EE Reliability & ISO 26262 Functional Safety Workgroups
- Michigan Office Manager & Partner DfR Solutions





# Introduction DfR Solutions

DfR Solutions is an Failure Analysis, Engineering Consulting & CAE Software firm.
 Evolved out of a DoD/NSF consortium that developed the Physics-of-Failure approach developing Ultra Reliable Electronics for defense application & industrial competitiveness
 DfR's Physics of Failure research experience & our multi-disciplined team from "Hi-Rel" & related industries provides knowledge & science based QRD solutions
 (Specializing in the Physics of Failure (PoF) /Reliability Physics (RP) tools & methods.
 Forensic engineering knowledge and science based solutions for:
 Maximizing product integrity

- While accelerating product development
- Electrical/Electronic Robustness, Failure Prevention
   & Total Product Integrity >400 projects/year
   Quality, Reliability and Durability (QRD),
  - Advanced accelerated testing methods
  - Selection & Validation of Robust EE parts appropriate for High Reliability and Harsh Environment Applications



reliability designed, reliability delivered

#### **DfR Solutions HQ - Beltsville, Maryland**



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# **DfR Solutions Locations**



# **Physics of Failure / Reliability Physics Definitions**

- Physics of Failure A Formalized and Structured approach to Root Cause Failure Analysis that focuses on total learning and not only fixing a current problem.
  - To achieve an understanding of "CAUSE & EFFECT" Failure Mechanisms AND the variable factors that makes them "APPEAR" to be Irregular Events.
  - Combines Material Science, Physics & Chemistry with Statistics, Variation Theory & Probabilistic Mechanics.
    - A Marriage of Deterministic Science with Probabilistic Variation Theory for achieving comprehensive Product Integrity and Reliability by Design Capabilities.
  - Failure of a physical device or structure (i.e. hardware) can be attributed to the gradual or rapid degradation of the material(s) in the device in response to the stress or combination of stresses the device is exposed to, such as:
     Thermal, Electrical, Chemical, Moisture, Vibration, Shock, Mechanical Loads . . .

#### • Failures May Occur:

- Prematurely because device is weaken by a variable fabrication or assemble defect.
- Gradually due to a wear out issue.
- Erratically based on a chance encounter with an Excessive stress that exceeds the capabilities/strength of a device,





# **Physics of Failure / Reliability Physics Definitions**

- **Reliability Physics** (a.k.a. the PoF Engineering Approach)
  - A Proactive, Science Based Engineering Philosophy for applying PoF knowledge for the Development and Applied Science of *Product Assurance Technology* based on:
  - Knowing how & why things fail is equally important to understand how & why things work.
  - Knowledge of how thing fail and the root causes of failures enables engineers to identify and avoid unknowingly creating inherent potential failure mechanisms in new product designs and solve problems faster.



- Provides scientific basis for evaluating usage life and hazard risks of new materials, structures, and technologies, under actual operating conditions.
- Provides Tools for achieving Reliability by Design
- Applicable to the entire product life cycle
  - Design, Development, Validation, Manufacturing, Usage, Service.



# **Key PoF Terms and Definitions**

#### • Failure Mode:

• The <u>EFFECT</u> by which a failure is OBSERVED, PERCEIVED or SENSED.







#### • Failure Mechanism :

• The <u>PROCESS</u> (elect., mech., phy., chem. ... etc.) that causes failures.



• FAILURE MODE & MECHANISM are <u>NOT</u> Interchangeable Terms in PoF.

# **Key PoF Terms and Definitions**

- Failure Site :
  - The location of potential failures, typically the site of a designed in:
    - o stress concentrator,

design weakness or

- material variation or defect.
- Knowledge Used to Identify and Prioritized Potential Failure Sites and Risks in New 0 **Designs During PoF Design Reviews.**





# **Generic Failure Categories**

**Overstress - When Loading Stress Exceed Material Strength** 



#### **Overview of How Things Age & Wear Out**

- Stress Driven Damage Accumulation in Materials



3. Strain :

Instantaneous changes (materials\structural) due to loading, different loads interact to contribute to a single type of strain.

Knowledge of how/ which "Key Loads" act & interact is essential for "*efficiently*" developing good products, processes & evaluations.

> 4. Damage Accumulation (or Stress Aging): Permanent change degradation retained after loads are removed. From small incremental damage, accumulated during periods/cycles of stress exposure.



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#### Generic Failure Categories - Wearout (Damage Accumulation) - Over Time of Stress Exposure



# **Errors and Excessive Variation**

- Errors Broadest Category
  - Errors in Design, Manufacturing, Usage & Service.
  - Missing knowledge
  - Human factor Issues



Variation

Fine line between excessive

variation & out right errors.

Both related to quality issues.

#### **Thermal Cycling Fatigue**

- The majority of electronic failures are thermomechanically related\*
  - By thermally induced stresses and strains
  - Root cause: excessive differences in coefficient of thermal expansion

\*Wunderle, B. and B. Michel, "Progress in Reliability Research in Micro and Nano Region", Microelectronics and Reliability, V46, Issue 9-11, 2006.



A. MacDiarmid, "Thermal Cycling Failures", RIAC Journal, Jan., 2011.

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#### **Temperature Cycles in the Field**

- Field conditions are based on usage and application
- The same electronics assembly can have several field conditions depending on the industry

	Temp range	Cycles/year	Service time	Failure rate
Consumer	0 to 60 °C	365	1 year	1 %
Computer	15 to 60 °C	1460	5 years	0.1 %
Telecom	-40 to 85 °C	365	7 to 20 years	0.01 %
Aircraft	-55 to 95 °C	365	20 years	0.001 %
Automotive	-55 to 95 °C	100	10 years	0.1 %

- Examples: LCD touchpanels, voltage regulators, networking modules and many more.
- Special field conditions may exist
  - Long period of storage followed by short period of usage (Munitions, launch platforms, AED, airbags)

#### PoF Example Solder Thermo-Mechanical Fatigue Driven by: hermal Expansion/Contraction (CTE) Mismatch During Thermal Cycling

 As a circuit board and its components expand and contract at different rates the differential strain between them is absorbed by the attachment system leads and solder ioints which drives metal fatiaue.



#### The Component Package Now Influences QRD more than the IC Die **EE Component Solder Fatigue Life is Directly Related to Component Packaging & Solder Attachment Scheme**



Life Varies w/Size & Conf.

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~8 - 480 I/O, .75 in SQ, Gigi Hz Speeds Can have significantly reduces life R Solutions

# Impact of E/E Component Packaging & Attachment Configuration - Through Hole Dip Chip ICs



- Since Electrical Engineers Design Most Printed Circuit Boards (PCB)
  - Their only motivation to accepted the added costs of Plated Through Hole (PTHs) was when increasing component density required placing component and traces on both sides of the circuits board.
  - THE RELIABILITY OF MORE COMPLEX EE MODULES SKY ROCKETED with the use of Double Sides PCB.

Thus More Complexity DOES NOT ALWAYS HAVE TO RESULT IN LESS RELIABILITY.
 A More Capable or Smarter Design Approach
 Can Overcome the Inherent QRD Risks of Increased Complexity
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# Impact of E/E Component Packaging & Attachment Configuration - Leaded Surface Mount ICs



1st Generation Surface Mount Devices J lead - Thermal Expansion/Contraction Cause Rapid Fatigue Due To Lead Rocking 2 Generation Surface Mount Devices Have Gull Wing Fine Pitch Leads Are Designed as an Articulated Spring, Their Leads Flex at Two Bend Points Instead of Transmitting Stress to the Weaker Solder Similar Sized GWFP Devices Avg. 10x the Durability Life of Similar Sized J Leaded Parts under the Same Thermal Cycling Conditions.

> GW FP Devices Take Up More Board Areas So a Larger Boards May Be Require to Hold the Same Number of Components



#### 4) Comparing Thermal Cycling Durability of Flat No Lead (FNL) IC Package Reliability: Thermal Cycling

- Without a flexible terminal lead to absorb thermal Expansion/Contract motions, a high amount of thermal expansion stress is applied to the low profile under body solder joints, which accelerate solder fatigue failure.
- Solder Attachment Cycles to Failure
  - Order of magnitude (10X) reduction from QFPs
  - 3X reduction from BGAs



#### Flat No Lead (FNL) Chip Scale IC Packages?

- FNL ICs help make ultra thin and light portable consumer electronic products possible.
  - Products with a short service life (2-5 years)
  - In a relative benign environment
- The vastly large size of the consumer electronics market provides significance power to influence IC suppliers to develop IC packages & products that meet their needs and priorities.
- With significantly less market influence the high reliability, harsh environment, long life market like the auto and defense industries must increasing learn to use and adapt to the components produced by the predominate market trends.

Q3 2007	ρ.27 million
Q4 2007	1.19 million
Q1 2008	2.315 million
Q2 2008	1.703 million
Q3 2008	0.717 million
Q4 2008	6.89 million
Q1 2009	4.363 million
Q2 2009	3.793 million
Q3 2009	5.208 million
Q4 2009	7.367 million
Q1 2010	8.737 million
Q2 2010	8.752 million
Q3 2010	8.398 million
Q4 2010	14.102 million
Q1 2011	16.240 million
Q2 2011	18.65 million
Q3 2011	20.34 million
Q4 2011	17.07 million
Q1 2012	37.04 million
(	0 25

Worldwide iPhone sales by Apple's fiscal quarters (Q12012 = Oct-Dec 2011).



#### The art of thin

Introducing ThinkPad X300 The no-compromise, ultraportable, 13.3" widescreen notebook with an optional integrated DVD drive and 3 USB ports, starting at just 2.9 lb. Everything else is DfR Solutions

just hot air

#### The Reliability Challenge of Keeping Up With Constantly Evolving E/E Technology

 <u>Every time</u> electronic component packages, attachment schemes & materials change or application usage and environmental conditions change, QRD performance also change and design rules updates are needed.



 This is why PoF CAE based microstructural stress analysis and failure mechanism modeling is becoming essential for accurate reliability assessments of new products.

#### **Thermal Cycling Solder Fatigue Model**

(Modified Engelmaier – Leadless Device)

- Modified Engelmaier 0
  - Semi-empirical analytical approach  $\Delta \gamma = C \frac{L_D}{h_s} \Delta \alpha \Delta T$ Energy based fatigue
  - 0
- Determine the strain range ( $\Delta\gamma$ ) Ο
- Where: C is a function of activation energy, temperature and dwell time, 0  $L_{D}$  is diagonal distance,  $\alpha$  is CTE,  $\Delta T$  of temperature cycle & h is solder joint height
- Determine the shear 0 force applied at the solder joint

$$\left(\alpha_2 - \alpha_1\right) \cdot \Delta T \cdot L_D = F \cdot \left(\frac{L_D}{E_1 A_1} + \frac{L_D}{E_2 A_2} + \frac{h_s}{A_s G_s} + \frac{h_c}{A_c G_c} + \left(\frac{2 - \nu}{9 \cdot G_b a}\right)\right)$$

- Where: F is shear force, LD is length, E is elastic modulus, A is the area, h is thickness, G is shear modulus, and a is edge length of bond pad.
- Subscripts: 1 is component, 2 is board, s is solder joint, c is bond pad, and b is board 0
- Takes into consideration foundation stiffness and both shear and axial loads  $\bigcirc$ (Models of Leaded Components factor in lead stiffness / compliancy)
- Determine the strain energy 0 dissipated in the solder joint
- Calculate N50 cycles-to-failure using: 0
  - An Energy Based model for SnPb 0
  - The Syed-Amkor model for SAC 0

$$\Delta W = 0.5 \cdot \Delta \gamma \cdot \frac{F}{A_s}$$
$$N_f = (0.0019 \cdot \Delta W)^{-1}$$
$$N_f = (0.0006061 \cdot \Delta W)^{-1}$$



#### Electronic Reliability: Risk Mitigation - Physics of Failure – CAE Durability Simulations



- PoF Models for Stress-Stain
   Structural Analysis of Electronics are well proved.
- But creating custom FEA models of EE modules is not easy:
  - Time Consuming & Expensive
  - $_{\circ}$  Shortage of PoF CAE modelers.
  - Structural analysis CAE resources are not deployed to EE Enrg. Depts.

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#### Also Two Types of Circuit Board Related Vibration Durability Issues



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#### PCB Vibration - 1<sup>st</sup>, 2<sup>nd</sup> & 3<sup>rd</sup> Harmonic Modals



Step: Step-1 Mode 1: Value = 4.44353E+06 Freq = 335.49 (cycles/time) Primary Var: U, Magnitude Deformed Var: U Deformation Scale Factor: +2.000e+01



Step: Step-1 Mode 2: Value = 7.38296E+06 Freq = 432.45 (cycles/time) Primary Var: U, Magnitude Deformed Var: U Deformation Scale Factor: +2.000e+01

#### 1<sup>st</sup> Harmonic



#### 2<sup>nd</sup> Harmonic

#### 3<sup>rd</sup> Harmonic

#### Physics of Failure Example - Shock

- Animated Simulation Visualizes Transition of the Shock Wave Through the Structure of the Module.
- Peak Stresses, Material Strain, Motions & Displacements Can be Identified.
- Potential Failure Sites Where Local Stresses Exceed Material Strength Can Be Identified & Prioritized.
- Zoom In On Surface Such as Potential for Snap Lock Fastener Release
- Wire Frame View Allows Xray Vision of Internal Features.







ANSYS 6.0 JAN 22 2002 12:25:22 NODAL SOLUTION STEP=1 SUB =1 UZ (AVG) RSYS=0 POWErGraphics EFACET=1 AVRES=Mat

#### **Drop Module From Drop/Shock Simulation CAE Programs** ANSYS LS-DYNA **Developed By Telecom in the Mid 1990's** September, 1996 Minneapolis, Minnesota, U.S.A. Fourth International LS-DYNA3D Users Conference Commercial Drop/Shock CAE SW Available Since 1996 Drop/Impact Simulation of Electronic Products Jason Wu Chao-pin Yeh Karl Wyatt Applied Simulation and Modeling Research **Motorola** Motorola Inc. 1303 E. Algonquin Road (IL01), Room AN2 Schaumburg, IL, 60196-1079, USA Many Product Engineers are Unaware of Physical CAE Capabilities and How to Use Them to Design QRD in as part of a Product Development Program. - Many E/E Devices Have Drop/Shock Requirement s. - Most Use Test & Fix "Free Fall Drop Validation Test" of Physical Parts. - A "Design for Reliability" Approach Would Integrate CAE Virtual Validation Evaluations into the Design Creation Process. structural design. To obtain the detailed understanding of impact behavior and damage mechanism of

structural design. To obtain the detailed understanding of impact behavior and damage mechanism of electronic products, there are two approaches - test and computer simulation. One can detect failure mechanisms by collecting the impact acceleration, contact force and strain/stress data in both package and component level tests. The disadvantages of this test-based analysis are high cost and after-design determination, and it is quite difficult to mount the sensors on small components.

# The Auto Industry Has Reaped Significant Product development Efficiencies & QRD Benefits Through Math Based, Virtual CAE Tools and Methods

Safety **Vehicle Structure** Energy A Result of Initiatives to: Migrate **Evaluations Performance Integration** Thermal Vehicle Dynamics from Road to Lab to Computer, at the Vehicle, Aerodynamics Noise & Vibration Subsystem & **Durability** Component Level **DfR Solutions** 

#### Reduced Dependence on Costly D-B-T-F (Design – Build – Test – Fix)



As the use of CAE based modeling & simulation methods increase, dependence on physical testing can be reduced and refocused.



By 2004 GM was able to reduce vehicle road testing to the point that the southern portion of their Mesa Az. Proving Grounds was sold. In 2006 the remaining northern 5 square miles, that formerly operated with 1,200 people, was sold for Real Estate Development. GM now operates with a much smaller DPG in Yuma Az. and realized a significant reduction in structural costs.

#### PoF Durability/Reliability Simulations for Virtual Reliability Growth of Electronics



#### Thermal Modeling Identifies the Thermal Stress Conditions

SR	TJ	T <sub>Case</sub>	T <sub>HSink</sub>	Ρ	Rth <sub>J-C</sub>	Rth <sub>J-HS</sub>	
(HSink@85°C)	(°C)	(°C)	(°C)	(W)	(°C/W)	(°C/W)	
Q6 <sub>IGBT</sub>	96.29	89.23	85.0	6.50	1.09	1.74	
D6 <sub>Diode</sub>	103.40	89.52	85.0	13.80	1.01	1.33	
Q3 <sub>IGBT</sub>	98.35	90.20	85.0	6.50	1.25	2.05	
D9 <sub>Diode</sub>	104.98	90.99	85.0	13.80	1.01	1.45	
Q5 <sub>IGBT</sub>	97.95	90.56	75.0	6.50	1.14	3.53	
D4 <sub>Diode</sub>	104.07	90.74	85.0	13.80	0.97	1.38	
Q2 <sub>IGBT</sub>	96.89	89.59					
D8 <sub>Diode</sub>	104.08	90.42					
Shunt R8	103.98	87.14					
Shunt R9	103.68	87.17					
Q4 <sub>IGBT</sub>	96.61	89.40	Temperature				
D2 <sub>Diode</sub>	103.40	89.89	109.027				
Q1 <sub>IGBT</sub>	96.98	89.13	101.637				
D7 <sub>Diode</sub>	103.29	89.94	86,8552				
Shunt R6	108.75	86.50	79,4644				
Shunt R7	104.64	87.95	64.6829				
			57,2921				
			49.9014				
			Emerson_SR				



#### Predicting & Confirming Thermal Stress & Thermal-Mech. Reliability

- Detection of the Module's Durability Weak Link,
  - Two Large 1020 Resistors, Located in the High Temperature Zone



Thermal-Mechanic Durability Modeling to Identify Potential Intermittent Circuits Due to Themo-Mechanical Fatigue



Durability Simulations Identifies Most Likely Parts to Fail Due To Thermo-Mechanical Fatigue Identified (Large Body 1020-S.M. Resistors)

Days to Failure
1.581139E+10 - 5.000000E+10
5.000000E+09 - 1.581139E+10
1.581139E+09 - 5.000000E+09
5.000000E+08 - 1.581139E+09
1.581139E+08 - 5.000000E+08
5.000000E+07 - 1.581139E+08
1.581139E+07 - 5.000000E+07
5.000000E+06 - 1.581139E+07
1.581139E+06 - 5.000000E+06
5.000000E+05 - 1.581139E+06
1.581139E+05 - 5.000000E+05
5.000000E+04 - 1.581139E+05
1.581139E+04 - 5.000000E+04
5.000000E+03 - 1.581139E+04
1.581139E+03 - 5.000000E+03
5.000000E+02 - 1.581139E+03

Infrared Thermal Imaging Of Thermal Stress & Overstress "Hot Spots"





1020 Resistor Fatigue Confirmed In Accelerated Life Test





#### 1020 Resistor Reliability vs AST Cycles as Demonstrated During DV Testing



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#### AUTOMATED DESIGN ANALYSIS

# Predicting the Future

A Award Winning CAE App for Physics of Failure Durability Simulations & Reliability Assessments



#### **SAE Aerospace Engineering – Cover Story April 2012**

#### - Putting CAE to Work for Non-Experts



Making CAE easy enough to use for non-experts is a prime goal for both providers and users of CAE software. New innovations such as product templates and overset meshing, shown here, will help. (CD-adapco)

SAE International

- Application Specific Customized CAE Solutions.
- An emerging trend where auto guided, specific function, CAE Apps or analysis templates are created
  - Provides a common, reusable semi-automated interface
    - Perform regularly needed product optimization modeling
    - Solving frequently encountered problems.
    - Allows product teams to perform expert level CAE analysis without a rare, high cost PoF CAE expert
    - To see full article: <u>http://www.sae.org/mags/SVE/10767</u>



# **CAE** Apps

- The shortage of time and modeling experts has limited the expansion of CAE tools in many industries.
  - More upfront CAE analysis work would be performed if engineering organizations could find and afford enough high priced CAE experts.
  - A growing trend to resolve this bottleneck is the development of CAE Apps and Templates.
  - This new generation of CAE solutions provide common, application specific, reusable, semi-automated interface for solving frequently encountered problems and performing regularly needed product optimization tasks that allow non-CAE experts to rapidly perform expert level evaluations.
  - Knowledge based, application specific, CAE Apps are now available for PoF analysis of electronic products that allow non-CAE experts to perform expert level PoF evaluations. This course will introduce and provide examples of PoF CAEs Apps for electronic equipment.

#### Yes - There's a App For THAT!!!!



#### Sherlock ADA – A Durability Simulation Reliability Assurance CAE Tool Suite - the Physics of Failure App.

Sherlock is a Semi-Automated CAE App program for Physics of Failure durability simulations & reliability assessment of electronic equipment

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AUTOMATED DESIGN ANALYSIS

Sherlock is the backbone to one of the most powerful reliability tools to be released for use not just by the reliability group, but by the entire engineering design and management team. Sherlock is the future of Automated Design Analysis (ADA), the integration of design rules, best practices and a return to a physics based understanding of product reliability.



It is not at the Iphone or Droid App store. But yes there is now a Physics of Failure Durability Simulation App

![](_page_37_Picture_9.jpeg)

#### **A New Revolutionary CAE Tool Suite for Electronic Design Analysis**

![](_page_38_Picture_1.jpeg)

![](_page_38_Picture_2.jpeg)

![](_page_38_Picture_3.jpeg)

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女女女女女

**Editor's Choice** 

![](_page_39_Picture_0.jpeg)

# A Semi-Automated CAE knowledge based tool suite for: Performing Physics of Failure durability simulation and reliability assessments on electronic equipment. Semi-Automated features simplifies model creation and analysis Eliminates the long, complicated, model creation process and the need for a PhD level expert in PoF, FEA and CFD numerical modeling. Designed to be used by non-CAE experts to quickly create and perform PoF

#### durability & reliability analysis.

- The "Knowledge Based" features customized for E/E component and materials includes customizable, preloaded libraries of:
  - Component models
  - Material properties
  - Design templates
  - Analysis wizards
  - Environmental profiles for various applications.

![](_page_39_Picture_10.jpeg)

 Design Capture - provides the detailed inputs to the modeling software and calculation tools

sherlock

AUTOMATED DESIGN ANALYSIS

- 2) Life-Cycle Characterization define the reliability/durability objectives and expected environmental & usage conditions (Field or Test) under which the device is required to operate
- 3) Load Transformation automated calculations that translates and distributes the environmental and operational loads across a circuit board to the individual parts
- 4) PoF Durability Simulation/Reliability Analysis
   & Risk Assessment Performs a design and application specific durability simulation to calculates life expectations, reliability distributions & prioritizes risks by applying PoF algorithms to the virtual PCBA model created in steps 1, 2 & 3

![](_page_40_Picture_5.jpeg)

![](_page_40_Figure_6.jpeg)

![](_page_40_Figure_7.jpeg)

![](_page_40_Picture_8.jpeg)

![](_page_41_Picture_0.jpeg)

#### 1) Files Imported/Exported Via Intuitive Drop Down & Side Menus

![](_page_41_Figure_2.jpeg)

Project Circuit Card File Analysis Add Project Import Project Import ODB Archive Import ODB XML Archive Import Eagle Archive Project Properties Delete Project Open Project Close Project Export Project Add Circuit Card Run All Project Tasks Clear Project Results Exit Sherlock Demo 🐼 Reliability Goals Environments 🕝 Thermal Vibration Mechanical Shock Project Results dfr-vibration-coupon3 🔻 🕝 Files A comp-bot.odb A comp-top.odb drill.odb 🖼 silk-bot.odb 🖼 silk-top.odb 🖼 sm-bot odb 🖷 sm-top.odb 🔻 📀 Inputs 📰 Parts List

Stackup Stackup

Import PCBA Layout,

- Gerber, ODB++, Eagle & Valor CAD formats.
- Import BOM Parts List
  - Correlated supplier component part # and industry/JEDEC package styles to auto link component to Sherlock's libraries of component geometry and material property to the individual parts locations mounted on the PCB to create the computer models for the life assessment.

 Define PCB Laminate & Layers to Calculate Substrate Performance

• Automated FEA Mesh generation.

![](_page_41_Picture_10.jpeg)

![](_page_42_Figure_0.jpeg)

 Creates CAE virtual model from standard circuit board CAD/CAM design files (Gerber / ODB Format)

![](_page_42_Picture_2.jpeg)

#### Step 1 - Design Capture - Graphic Verification

![](_page_43_Picture_1.jpeg)

![](_page_43_Figure_2.jpeg)

![](_page_44_Picture_0.jpeg)

#### 1) Design Capture - Define PCB **Laminate & Layers to Calculate**

![](_page_44_Figure_2.jpeg)

![](_page_45_Picture_0.jpeg)

#### 1) Design Capture PCB Material Property Database

10         December 2         Cert Restrict Dery Preschaldigen F, Field? IPC Starb Sheet (400), Tg. Tg. tech. Td. 1280 (and Denemy (short, 2 (port, 2 (		A B	C	D	F G H	I JKLMNOPQ	R S T U 🔺
No.       N	1	ID Company	Material	Product Name	sta Dicy / Phenc Halogen Fi Filled? IPC Slash	Sheet (4101) Tg Tg tech Td T260 (m T288 (m Density (g/: CTE, Z (p CTE, Z (	(po CTE, XY (¢ CTE, XY CTE, XY CTE, XY 2 💌
101       1104       11	109	4 ITEQ	FR-4	IT180	Dicy No N/A 24	175 DSC 350 60 20 ^1.9 50 250	^16 ^16 ^16 <b>^</b> 16 <b>▲</b>
111       11104       11540       11560       1	110	4 ITEQ	FR-4	IT180CAF	Diau Na NJA *126	175 DSC 350 80 20 *1.9 50 250	A16 A16 A16 A16
11/2       11/2	111	4 ITEQ	FR-4	IT588			
10       First       Pr-4       Pr-22050       C       C       Laminate Library         10       First       Pr-22050       C       C       Laminate Library         10       First       Pr-22050       C       C       Laminate Library         10       First       Pr-22050       C       Defines 48 Categories Of PCB Material         10       First       Pr-22050       Pr-22050       C       Defines 48 Categories Of PCB Material         10       First       Pr-32050       Properties and Characteristics       C       Currently 319 Circuit Board Laminates Materials         10       First       Pr-4       Pr-4       Fr-4       Pr-4       Fr-4	112	4 ITEQ	FB-4	IT600	1 4 . 141		
<ul> <li>Contribution of the Material (SMC) FR-4</li> <li>EN-280</li> <li>End Material (SMC) FR-4</li> <li>EN-283</li> <li>End Material (SMC) FR-4</li> <li>EN-283</li> <li>End Material (SMC) FR-4</li> <li>EN-285</li> <li>End Material (SMC) FR-4</li> <li>EN</li></ul>	113	5 Elite Materials (EMC)	FB-4	EM-220(5), EM-22B (5)	Laminato Libi		
15       Size Material (MC)       FR-4       ER-285         15       Size FR-4       VI-42       VI-42         15       Vertee       FR-4       VI-42         15       Vertee       FR-4       VI-42         15       Vertee       FR-4       VI-42         16       Gase FR-4       GA-50       GA-50         17       Vertee       FR-4       GA-10-10P         18       Gase FR-4       GA-10-10P         18       Gase FR-4       GA-10-10P      <	114	5 Elite Materials (EMC)	FR-4	EM-280			
<ul> <li>18 5 Rice Matchald (EMC) FR-4 EM-320 5 Rice Matchald (EMC) FR-4 EM-825 18 6 Ringboard FR-4 KB-650(650) 19 7 Varces FR-4 VT-42 19 7 Varces FR-4 GA-170-07 19 8 Gases FR-4 GA-16-18-7 10 8 Gases FR-</li></ul>	115	5 Elite Materials (EMC)	FB-4	EM-285			
117       5 New Matrials (EMU)       FR-4       EH-827         118       5 New Matrials (EMU)       FR-4       EH-827         128       6 Kingboard       FR-4       K8-5500 fb00         126       6 Kingboard       FR-4       K8-5500 fb00         127       6 Kingboard       FR-4       K8-5500 fb00         128       7 Wentee       FR-4       K8-5600 fb00         127       Ventee       FR-4       VT-42         128       7 Wentee       FR-4       VT-45         127       Ventee       FR-4       VT-47         128       Finese       GLA-100         129       Ventee       FR-4       GA-100         129       Ventee       FR-4       GA-100         128       Giace       FR-4       GA-100         129       Giace       FR-4       GA-100         128       Giace       FR-4       GA-100 <t< td=""><td>116</td><td>5 Elite Materials (EMC)</td><td>FR-4</td><td>EM-320</td><td></td><td></td><td></td></t<>	116	5 Elite Materials (EMC)	FR-4	EM-320			
<ul> <li>         To Materials (FR-1)         FR-4         (FR-578)         Frequence         (FR-4)         (FR-578)         Frequence         (FR-4)         (FR-588)         (Frequence)         (FR-4)         (FR-588)         (Frequence)         (FR-4)         (FR-588)         (Frequence)         (FR-4)         (FR-4)</li></ul>	117	5 Elite Materials (EMC)	FB-4	EM-825	Defines 10 C	ateration Of DCP Materia	
110       6 Kingboard       CEM-1       KB-750         120       6 Kingboard       CFM-1       KB-750         120       6 Kingboard       CFM-1       KB-750         120       6 Kingboard       CFM-1       KB-750         120       6 Kingboard       FR-4       KB-6800 (BOC         120       6 Kingboard       FR-4       KB-6862         120       6 Kingboard       FR-4       KB-6862         120       7 Wintee       FR-4       KB-6862         121       7 Wintee       FR-4       VI-42         121       7 Wintee       FR-4       VI-42         121       7 Wintee       FR-4       VI-42         121       Vintee       FR-4       VI-42         122       Vintee       FR-4       VI-42         123       Vintee       FR-4       GA-50-LDP         128       Grace       FR-4       GA-400-LDP         128       Grace	118	5 Elite Materials (EMC)	FR-4	EM-827	O Defines 40 C	aleaones Of FCD Maleria	
Display         Composed         CH-3         KB-750           Display         Kingboard         FR-4         KB-750           Display         FR-4         KB-750         Frequency	119	6 Kingboard	CEM-1	KB-5150			
10       6 Kingboard       FR-4       KB-61500160C         20       7 Wintec       FR-4       KB-6150         21       7 Wintec       FR-4       VI-42         21       7 Wintec       FR-4       VI-42         21       7 Wintec       FR-4       VI-42         22       7 Wintec       FR-4       VI-42         23       Vintec       FR-4       VI-42         24       Vintec       FR-4       VI-42         25       Vintec       FR-4       VI-41         26       Vintec       FR-4       VI-41         27       Vintec       FR-4       VI-41         28       Giace       FR-4       Off-100         27       Vintec       FR-4       GA-170         28       Giace       FR-4       GA-170-L0P         28       Giace       FR-4       GA-170-L0P         28       Giace       FR-4       GA-170-L0P         28       Giace       FR	120	6 Kingboard	CEM-3	KB-7150	_		
12       6 Kingboard       FR-4       K0-65001600         13       6 Kingboard       FR-4       K0-6502         14       6 Kingboard       FR-4       K0-6502         15       6 Kingboard       FR-4       K0-6502         16       Kingboard       FR-4       K0-6502         17       Ventee       FR-4       VT-42         18       7 Ventee       FR-4       VT-42         17       Ventee       FR-4       VT-42         18       7 Ventee       FR-4       VT-43         18       7 Ventee       FR-4       VT-43         18       7 Kentee       FR-4       GA-150         18       6 Grace       FR-4       GA-150         18       8 Grace       FR-4       GA-160         18       8 Grace       FR-4       GA-167         18       8 Grace       FR-4       GA-167         18       8 Grace       FR-4       GA-167         18       8 Grace       FR-4	121	6 Kingboard	FR-4	KB-6150/6150C	Droportion an	d Characteristics	
12       6       Kngboard       FR-4       K8-5600560C         12       6       Kngboard       FR-4       K8-5600         12       6       Kngboard       FR-4       K8-5600         12       7       Ventec       FR-4       VI-42         12       7       Ventec       FR-4       VI-42         12       7       Ventec       FR-4       VI-44         13       7       Ventec       FR-4       VI-44         13       7       Ventec       FR-4       VI-44         13       7       Ventec       FR-4       VI-47         13       7       Ventec       FR-4       VI-47         13       7       Ventec       FR-4       VI-47         13       7       Ventec       FR-4       OFA-107         13       8       Grace       FR-4       GA-170-07         13       8       Grace       FR-4       GA-170-07         14       8       Grace       FR-4       GA-170-07         14       8       Grace       FR-4       GA-170-107         15       8       Grace       FR-4       GA-170-107	122	6 Kingboard	FB-4	KB-6150/6160	riopernes an	a Characteristics	
121       6 Knopbard       FR-4       KK0-5162         126       6 Knopbard       FR-4       KK0-5162         126       6 Knopbard       FR-4       KK0-5162         127       10       FR-4       KK0-5162         127       Ventee       FR-4       VT-42 (Ani-CAF)         128       6 Grace       FR-4       GA-170         126       6 Grace       FR-4       GA-170         128       6 Grace       FR-4       GA-187-07         128       8 Grace       FR-4       GA-187-07         128       8 Grace       FR-4       GA-187-14         128       8 Grace       FR-4       GA-187-14         128       8 Grace       FR-4       GA-187-1710	123	6 Kingboard	FR-4	KB-6160/6160C			
120       6 Kingboard       FR-4       KR-6167         121       6 Kingboard       FR-4       KR-6167         121       6 Kingboard       FR-4       KR-6167         121       7 Wintee       FR-4       KR-6167         121       7 Wintee       FR-4       VT-42         121       Vintee       FR-4       GA-170         126       6 Grace       FR-4       GA-170-107         126       8 Grace       FR-4       GA-170-107         126       8 Grace       FR-4       GA-100         126       6 Grace	124	6 Kingboard	FR-4	KB-6162			
100       6 Kingboard       FR-4       KR-685         101       7 Ventec       FR-4       VT-42         101       7 Ventec       FR-4       VT-46         101       7 Ventec       FR-4       VT-46         101       7 Ventec       FR-4       VT-46         101       7 Ventec       FR-4       FR-4         101       7 Ventec       FR-4       FR-4         101       8 Grace       FR-4       GA-170         101       8 Grace       FR-4       GA-160         101       8 Grace       FR-4       GA-167         101       8 Grace       FR-4	125	6 Kingboard	FR-4	KB-6164	Currontly 210	Circuit Roard Laminator	Matariala
T2       6 Kngboard       FR-4       KB-6167         TV       Ventec       FR-4       VT-42         TV       Ventec       FR-4       GA-150         ST       Scace       FR-4       GA-170-07         No       Scace       FR-4       GA-160         M1       Scace       FR-4       GA-160         M2       Scace       FR-4       GA-160         M3       Scace       FR-4       GA-160         M3 <td>126</td> <td>6 Kingboard</td> <td>FR-4</td> <td>KB-6165</td> <td></td> <td>7 CITCUIT DOUTH LUMINATES I</td> <td></td>	126	6 Kingboard	FR-4	KB-6165		7 CITCUIT DOUTH LUMINATES I	
128       7       Ventee       FR-4       VT-42       VT-42         17       Ventee       FR-4       VT-42       FR-4       VT-42         17       Ventee       FR-4       VT-42       FR-4       VT-42         18       7       Ventee       FR-4       VT-42       FR-4       VT-42         18       7       Ventee       FR-4       VT-42       Ventee       FR-4       VT-42         18       7       Ventee       FR-4       VT-42       Ventee       FR-4       VT-42         18       7       Ventee       FR-4       VT-42       Ventee       FR-4       VEntee       FR-4       VEntee       FR-4       VEntee       KE       VEntee       FR-4       GA-170       VEntee       FR-4       GA-170-07       KE       Gentee       FR-4       GA-176-10       KE       Gentee       FR-4       GA-176-10       KE       Gentee       FR-4       GA-176-10       KE       Gentee       FR-4       GA-16       Gentee       FR-	127	6 Kingboard	FR-4	KB-6167	· · · · ·		
12       7       Ventee       FR-4       VT-42         17       Ventee       FR-4       VT-44         18       7       Ventee       FR-4       VT-46         17       Ventee       FR-4       VT-46       Ventee       FR-4         17       Ventee       FR-4       Ventee       FR-4       Ventee       Ventee       FR-4       Ventee       Ventee       FR-4       Ventee       Ventee       FR-4       Ventee       Ventee       Ventee       FR-4       Ventee	128	7 Ventec	FR-4	VT-42			
130       7       Ventee       FR-4       VT-44         17       Ventee       FR-4       VT-45         181       7       Ventee       FR-4       VT-46         181       7       Ventee       FR-4       VT-47         17       Ventee       FR-4       VT-47       Ventee         181       7       Ventee       FR-4       VT-48         181       7       Ventee       FR-4       VT-47         181       6       Gace       FR-4       GA-150         181       8       Gace       FR-4       GA-170-07         181       8       Gace       FR-4       GA-10-170         182       8       Gace       FR-4       GA-14F-14         185       8       Gace       FR-4       GA-10-18         183       8       Gace       FR-4       GA-10-19         183       8       Gace       FR-4       GA-10-19         183	129	7 Ventec	FR-4	VT-42 (Anti-CAF)	Erom 20 Glak	ad Producors	
131       7       Ventee       FR-4       VT-45         132       7       Ventee       FR-4       VT-46         133       7       Ventee       FR-4       VT-47         134       7       Ventee       FR-4       VT-47         135       7       Ventee       FR-4       VT-47         135       7       Ventee       FR-4       VT-47         135       7       Ventee       FR-4       VT-47         136       7       Ventee       FR-4       VT-47         136       7       Ventee       FR-4       VT-47         136       7       Ventee       FR-4       FR-4-97         137       8       Grace       FR-4       GA-170-D7         138       8       Grace       FR-4       GA-170-LDP         138       8       Grace       FR-4       GA-HF-14         148       8       Grace       FR-4       GA-HF-14         148       8       Grace       FR-4       GA-HF-37         151       8       Grace       FR-4       GA-HF-37         152       8       Grace       FR-4       GA-HF-37	130	7 Ventec	FR-4	VT-44			
132       7       Ventec       FR-4       VT-46         137       7       Ventec       FR-4       VT-47         138       7       Ventec       FR-4       VT-47         138       7       Ventec       FR-4       VT-481         138       7       Ventec       FR-4       VT-481         138       7       Ventec       FR-4       VT-481         138       8       Grace       FR-4       FR-4       FR-4         138       8       Grace       FR-4       GA-170-07         138       8       Grace       FR-4       GA-170-107         138       8       Grace       FR-4       GA-167-10         141       8       Grace       FR-4       GA-HF-14         141       8       Grace       FR-4       GA-HF-14         141       8       Grace       FR-4       GA-10-18         142       8       Grace       FR-4       GA-10-18         143       8       Grace       FR-4       GA-10-18         143       8       Grace       FR-4       GA-10-18         143       8       Grace       FR-4       GA-10-1	131	7 Ventec	FR-4	VT-45			
133       7       Ventec       FR-4       VT-47         135       7       Ventec       GIPolymide       VT-47         135       7       Ventec       GIPolymide       VT-47         135       7       Ventec       GIPolymide       VT-40         135       7       Ventec       GIPolymide       VT-30         136       Grace       FR-4       GA-150       Gaze       Gaze       FR-4       GA-170-07         137       8       Grace       FR-4       GA-170-107       Gaze       FR-4       GA-170-107         138       8       Grace       FR-4       GA-170-107       Gaze       FR-4       GA-160-108         138       8       Grace       FR-4       GA-HF-14       Gaze       FR-4       GA-HF-14         148       8       Grace       FR-4       GA-HF-14       GA       Gaze       FR-4       GA-LD         151       8       Grace       FR-4       GA-LD-18       ZBIS       TO       ZBIS       TO         152       8       Grace       FR-4       GA-LD-18       ZBIS       ZBIS       TO         153       8       Grace       GIPolymide <td< td=""><td>132</td><td>7 Ventec</td><td>FR-4</td><td>VT-46</td><td></td><td></td><td></td></td<>	132	7 Ventec	FR-4	VT-46			
134       7 Ventec       FR-4       VT-481         135       7 Ventec       Gi(Polyimide)       VT-30         136       8 Grace       FR-4       FR-4/37         137       8 Grace       FR-4       GA-150         138       8 Grace       FR-4       GA-150-UDP         138       8 Grace       FR-4       GA-170-UDP         140       8 Grace       FR-4       GA-170-UDP         141       8 Grace       FR-4       GA-170-UDP         142       8 Grace       FR-4       GA-170-UDP         142       8 Grace       FR-4       GA-170-UDP         142       8 Grace       FR-4       GA-HF-14         148       8 Grace       FR-4       GA-HF-14         148       8 Grace       FR-4       GA-LD-18         151       8 Grace       FR-4       UV Block FR4-37 (CM)         152       8 Grace       FR-4       UV Block FR4-37 (CM)         153       8 Grace       FR-4       UV Block FR4-37 (CM)         153       9 Dossan       CCM-1       DS-706 (HC)         155       9 Dossan       CCM-1       DS-706 (HC)         157       9 Dossan       CCM-1	133	7 Ventec	FR-4	VT-47	- Now Entries (	an Addad as Naw Laming	
135       7       Ventec       GI (Polymide)       V1-90         136       8       Grace       FR-4       FR4-37         137       8       Grace       FR-4       GA-150         138       8       Grace       FR-4       GA-170-10         138       8       Grace       FR-4       GA-170-10P         138       8       Grace       FR-4       GA-170-10P         141       8       Grace       FR-4       GA-170-10P         142       8       Grace       FR-4       GA-170-10P         142       8       Grace       FR-4       GA-14F-14         143       8       Grace       FR-4       GA-14F-14         144       8       Grace       FR-4       GA-14F-14         145       8       Grace       FR-4       GA-1D-18         150       8       Grace       FR-4       GA-LD-18         151       8       Grace       FR-4       UV Block FR4-37 (CF)         152       8       Grace       GI (Polymide)       2BIS-1DP         153       9       Dosan       CEM-1       DS-7106 (HC)         153       9       Dosan	134	7 Ventec	FR-4	VT-481	0 INCW LIIIICS (		
<ul> <li>136 8 Grace FR-4 GA-150-LDP</li> <li>137 8 Grace FR-4 GA-170-LDP</li> <li>140 8 Grace FR-4 GA-170-LDP</li> <li>141 8 Grace FR-4 GA-170-LDP</li> <li>142 8 Grace FR-4 GA-170-LDP</li> <li>143 8 Grace FR-4 GA-180-LDP</li> <li>144 8 Grace FR-4 GA-161-LDP</li> <li>145 8 Grace FR-4 GA-161-LDP</li> <li>146 8 Grace FR-4 GA-161-LDP</li> <li>147 8 Grace FR-4 GA-161-LDP</li> <li>148 8 Grace FR-4 GA-161-LDP</li> <li>149 8 Grace FR-4 GA-161-LDP</li> <li>149 8 Grace FR-4 GA-161-LDP</li> <li>149 8 Grace FR-4 GA-161-LDP</li> <li>140 8 Grace FR-4 GA-161-LDP</li> <li>150 8 Grace FR-4 GA-161-LDP</li> <li>151 8 Grace FR-4 GA-17-LDP</li> <li>151 8 Grace FR-4 GA-161-LDP</li> <li>151 8 Grace FR-4 GA-161-LDP</li> <li>151 9 Docsan CEM-1 D5-7106 (hC)</li> <li>153 9 Docsan CEM-1 D5-7106 (hC)</li> <li>153 9 Docsan CEM-1 D5-7106 (hC)</li> <li>153 9 Docsan CEM-1 D5-7106 (hC)</li> <li>154 9 Docsan CEM-1 D5-7106 (hC)</li> <li>155 9 Docsan CEM-1 D5-7106 (hC)</li> </ul>	135	7 Ventec	GI (Polyimide)	VT-90			
137       8       Grace       FR-4       GA-150-DP         138       8       Grace       FR-4       GA-170-07         139       8       Grace       FR-4       GA-170-07         141       8       Grace       FR-4       GA-170-10P         142       8       Grace       FR-4       GA-180         143       8       Grace       FR-4       GA-18-10         143       8       Grace       FR-4       GA-16-10         148       8       Grace       FR-4       GA-10         150       8       Grace       FR-4       GA-10         151       8       Grace       FR-4       UV Block FR4-37 (CF)         152       8       Grace       FR-4       UV Block FR4-37 (CF)         153       9       Grace       61 (Polyimide)       2BIS-LDP         154       9       Grace       61 (Polyimide)       2BIS-LDP         155       9       Docsan	136	8 Grace	FR-4	FR4-97			
188       8       Grace       FR-4       GA-170         190       8       Grace       FR-4       GA-170-D7         141       8       Grace       FR-4       GA-170-D7         142       8       Grace       FR-4       GA-180         143       8       Grace       FR-4       GA-180         143       8       Grace       FR-4       GA-1F-14-DP         145       8       Grace       FR-4       GA-HF-14-DP         147       8       Grace       FR-4       GA-HF-14-DP         147       8       Grace       FR-4       GA-HF-14-DP         148       8       Grace       FR-4       GA-HF-14-DP         149       8       Grace       FR-4       GA-HF-37         151       8       Grace       FR-4       GA-LD-18         153       8       Grace       FR-4       UV Block FR4-37 (CF)         153       8       Grace       FR-4       UV Block FR4-37 (CF)         153       8       Grace       FR-4       UV Block FR4-37 (CF)         155       9       Docsan       CEM-1       DS-7106 (HC)         155       9       Docsan	137	8 Grace	FR-4	GA-150	Materials are	Introduced to the Market	
139       8       139       8       139       8       139       8       139	138	8 Grace	FR-4	GA-150-LDP			•
Null 8       Grace       FR-4       GA-170-07         142       8       Grace       FR-4       GA-170-00         142       8       Grace       FR-4       GA-180-00P         143       8       Grace       FR-4       GA-170-01P         144       8       Grace       FR-4       GA-180-00P         144       8       Grace       FR-4       GA-HF         145       8       Grace       FR-4       GA-HF         147       8       Grace       FR-4       GA-HF         148       8       Grace       FR-4       GA-180-0P         147       8       Grace       FR-4       GA-HF         148       8       Grace       FR-4       GA-18-0P         148       8       Grace       FR-4       GA-10-18         158       8       Grace       FR-4       UV Block FR4-97 (CF)         152       8       Grace       FR-4       UV Block FR4-97 (CF)         153       8       Grace       GI (Polyimide)       2815-10P         154       8       Grace       GI (Polyimide)       2815-10P         155       9       Doosan       CEM-1	139	8 Grace	FR-4	GA-170			
N1       0       Drace       FH-4       GA-170-LUP         143       8       Grace       FR-4       GA-180-LOP         143       8       Grace       FR-4       GA-1HF-14         144       8       Grace       FR-4       GA-HF-14         146       8       Grace       FR-4       GA-HF-14-LOP         147       8       Grace       FR-4       GA-HF-14-LOP         148       8       Grace       FR-4       GA-LD-18         150       8       Grace       FR-4       GA-LD-18         151       8       Grace       FR-4       UV Block FR4-37 (CF)         152       8       Grace       FR-4       UV Block FR4-37 (CF)         153       8       Grace       GI (Polyimide)       2BIS-LDP         154       8       Grace       GI (Polyimide)       2BIS-LDP         155       9       Doosan       CEM-1       DS-7106 (HC)         157       9       Doosan       CEM-1       DS-7106 (HC)         158       9       Doosan       CEM-1       DS-7106	140	8 Grace	FH-4	GA-170-07			
N2       0 Grade       FN-4       GA-100         144       8 Grace       FR-4       GA-HF         145       8 Grace       FR-4       GA-HF-14         146       8 Grace       FR-4       GA-HF-14         147       8 Grace       FR-4       GA-HF-14-LDP         147       8 Grace       FR-4       GA-HF-14-LDP         148       8 Grace       FR-4       GA-HF-14-LDP         148       8 Grace       FR-4       GA-HF-14         149       8 Grace       FR-4       GA-HF-14         150       8 Grace       FR-4       GA-HF-10P         151       8 Grace       FR-4       GA-HF-10P         151       8 Grace       FR-4       UV Block FR4-97         152       8 Grace       FR-4       UV Block FR4-97         153       8 Grace       FR-4       UV Block FR4-97         153       8 Grace       GI (Polyimide)       2BIS-LDP         153       8 Grace       GI (Polyimide)       2BIS-LDP         156       9 Doosan       CEM-1       DS-7106 (HC)         157       9 Doosan       CEM-3       OS-7203         158       9 Doosan       CEM-3       OS-72	141	o Grace	FD 4	GA-ITO-LDP			
NS 0       Orace       FR-4       GA-HF         145       8       Grace       FR-4       GA-HF-14         147       8       Grace       FR-4       GA-HF-10P         148       8       Grace       FR-4       GA-LD-18         151       8       Grace       FR-4       GA-LD-18         151       8       Grace       FR-4       UV Block FR4-97 (CF)         151       8       Grace       FR-4       UV Block FR4-97 (CF)         152       8       Grace       GI (Polyimide)       2BIS         153       8       Grace       GI (Polyimide)       2BIS         154       8       Grace       GI (Polyimide)       2BIS-LDP         155       9       Doosan       CEM-1       DS-7106 (HC)         157       9       Doosan <t< td=""><td>142</td><td>o Grace</td><td>FD-4</td><td>GA-100</td><td></td><td></td><td></td></t<>	142	o Grace	FD-4	GA-100			
NMA       NVA       N	143	9 Grace	FD-4	GA-HE			
No. 0       Orace       FR-4       Orach1-14-LDP         147       8       Grace       FR-4       GA-HF-14-LDP         148       8       Grace       FR-4       GA-LD         148       8       Grace       FR-4       GA-LD         148       8       Grace       FR-4       GA-LD         150       8       Grace       FR-4       UV Block FR4-97         150       8       Grace       FR-4       UV Block FR4-97         151       8       Grace       FR-4       UV Block FR4-97         151       8       Grace       GI (Polyimide)       2BIS         153       8       Grace       GI (Polyimide)       2BIS         154       8       Grace       GI (Polyimide)       2BIS         155       9       Docsan       CEM-1       DS-7106 (HC)         157       9       Docsan       CEM-3       DS-7106 A         158       9       Docsan       CEM-3       DS-7106 A	145	8 Grace	FD-4	GA-HE-14			
No. 0       No. 0       No. 0       No. 0       No. 0       No. 12, 81       135       USC       310       55       350       24       28       78 <th78< th="">       78        78       78</th78<>	146	8 Grace	FR-4	GA-HE-14-L DP			
International       International         143       8       Grace       FR-4       GA-LD         149       8       Grace       FR-4       GA-LD-18         150       8       Grace       FR-4       UV Block FR4-97 (CF)         151       8       Grace       FR-4       UV Block FR4-97 (CF)         152       8       Grace       FR-4       UV Block FR4-97 (CF)         153       8       Grace       GI (Polyimide)       2BIS         154       8       Grace       GI (Polyimide)       2BIS         155       9       Doosan       CEM-1       DS-7106 (HC)         155       9       Doosan       CEM-1       DS-7106A         157       9       Doosan       CEM-3       DS-7203	147	8 Grace	FB-4	GA-HE-LDP			
111       1111       111       111 <th1< td=""><td>148</td><td>8 Grace</td><td>FB-4</td><td>GA-LD</td><td></td><td></td><td></td></th1<>	148	8 Grace	FB-4	GA-LD			
100       8       Grace       FR-4       UV Block FR4-97 (CF)         151       8       Grace       FR-4       UV Block FR4-97 (CF)         152       8       Grace       FR-4       UV Block FR4-97 (CF)         153       8       Grace       GI (Polyimide)       2BIS         153       8       Grace       GI (Polyimide)       2BIS         154       8       Grace       GI (Polyimide)       2BIS         155       9       Doosan       CEM-1       DS-7106 (HC)         157       9       Doosan       CEM-1       DS-7106A         158       9       Doosan       CEM-3       DS-7209       No       N/A       TZ, 81       T35       USC       T310       T5       U       T.5       55       T350       Z4       Z8       T18       T18	149	8 Grace	FB-4	GA-LD-18			
No.       No.       NA       No.       NA       T2, 81       T35       USC       T31       USC       USC       T31       USC       T31 <thu< td=""><td>150</td><td>8 Grace</td><td>FB-4</td><td>LIV Block FB4-97</td><td></td><td></td><td></td></thu<>	150	8 Grace	FB-4	LIV Block FB4-97			
12       8       Grace       FR-4       UV Block FR4-97 (CV)         153       8       Grace       GI (Polyimide)       2BIS         153       8       Grace       GI (Polyimide)       2BIS         155       9       Doosan       CEM-1       DS-7106         156       9       Doosan       CEM-1       DS-7106A         157       9       Doosan       CEM-1       DS-7209         158       9       Doosan       CEM-3       DS-7209	151	8 Grace	FB-4	LIV Block FB4-97 (CF)			
Single Strace       Gl (Polyimide)       2BIS         154       8       Grace       Gl (Polyimide)       2BIS-LDP         155       9       Doosan       CEM-1       DS-7106         156       9       Doosan       CEM-1       DS-7106(HC)         1757       9       Doosan       CEM-1       DS-7106(HC)         1788       9       Doosan       CEM-3       DS-7209	152	8 Grace	FB-4	UV Block FB4-97 (CV)			
154       8       Grace       GI (Polyimide)       2BIS-LDP         155       9       Doosan       CEM-1       DS-7106         156       9       Doosan       CEM-1       DS-7106 (HC)         157       9       Doosan       CEM-1       DS-7106 (HC)         158       9       Doosan       CEM-1       DS-7106 (HC)         158       9       Doosan       CEM-1       DS-7106 (HC)         158       9       Doosan       CEM-3       DS-7209         No       N/A       N/A       TZ, 81       T35       USC       T310       T5       U       T1.5       55       T350       Z4       Z8       T18       T18	153	8 Grace	GI (Polvimide)	2BIS			
155       9       Doosan       CEM-1       DS-7106         156       9       Doosan       CEM-1       DS-7106 (HC)         157       9       Doosan       CEM-1       DS-7106A         157       9       Doosan       CEM-1       DS-7106A         158       9       Doosan       CEM-3       DS-7209         No       N/A       N/A       12, 81       135       USC       1310       15       US       24       28       18       18	154	8 Grace	GI (Polvimide)	2BIS-LDP			
156       9       Doosan       CEM-1       DS-7106 (HC)         157       9       Doosan       CEM-1       DS-7106 (HC)         158       9       Doosan       CEM-3       DS-7209         No       N/A       No       N/A       135       DSC       1310       15       0       17.5       55       1350       24       28       18       18	155	9 Doosan	CEM-1	DS-7106			
157       9       Doosan       CEM-1       DS-7106A         158       9       Doosan       CEM-3       DS-7209       No       N/A       N/A       T2, 81       T35       DSC       T310       T5       U       T1.5       55       T35U       Z4       Z8       T18       T18	156	9 Doosan	CEM-1	DS-7106 (HC)			-
158 9 Doosan CEM-3 DS-7209 No N/A No N/A 12, 81 135 DSC 310 5 0 71.5 55 350 24 28 718 718	157	9 Doosan	CEM-1	DS-7106A			
	158	9 Doosan	CEM-3	DS-7209	N/A No N/A 112,81	135   DSC   1310   15   0   11.5   55   1350	24 28 18 18
159 9 DoosanCEM-3 DS-7209 (HC) No N/A No N/A *12 81 130 TMA *310 *5 0 *1.5 55 *350 24 28 *18 *19	15.9	9 Doosan	CEM-3	DS-7209 (HC)	N/A No N/A *12 81	130 TMA (310 15 0 11.5 55 1350	24 28 *18 *10 *
I ▲ ► M laminate / Show desktop	1	L ► M \ laminate /					Show desktop

electronic components package and material databases

![](_page_45_Picture_4.jpeg)

#### All IPC 4101 Laminates are not equal

ISOLA 370HR:

NELCO N4000-29:

ISOLA 410:

**ISOLA 415:** 

37.67

44.995

52.35

52.35

2,120

574

266

266

#### ISOLA 410, ISOLA IS415

45

55

65

65

-45 - +85

-45 - +85

-45 - +85

-45 - +85

Nelco N4000-29

#### **ISOLA 370HR**

-	Stackup Propert	ties		Stackup Pro	operties		Г	Stackup Droportion				Stackup	Properties			
ſ		territe transfer at a second way						Stackup Properties	•			Juckup	rioperues			92 - 119 - CC
	Based on the cu	irrently defined board outli	ne and the stack	Based on th	e currently defined boa	rd outline and the stack		Based on the currer	ntly defined boa	ard outline ar	d the stackup lay	Based o	n the current	tly defined	board outline and	he stack
	B	oard Size: 139 x 117 mm	n [5.5 x 4.6 in]		Board Size: 139 x 1	117 mm [5.5 x 4.6 in]		Boar	<b>d Size:</b> 139 x	117 mm [5.5	i x 4.6 in]		Board	Size: 13	x 117 mm [5.5 x	4.6 in]
	Board T	hickness: 62.8 mil		Boa	ard Thickness: 62.8 m	nil		Board Thic	kness: 62.8 r	nil			Board Thick	ness: 62.	8 mil	
		CTExy: 12.227 ppm/0	D I		CTExy: 13.977	7 ppm/C			CTExy: 17.15	6 ppm/C			С	TExy: 13.	977 ppm/C	
		CTEz: 52.320 ppm/0	c		CTE2: 52.320	) ppm/C			CTEz: 44.99	5 ppm/C			Ĩ	CTEz: 37.	670 ppm/C	
		Exy: 48,410 MPa			Exy: 50,417	MPa			Exy: 48.41	0 MPa				Exy: 49.	407 MPa	
		Ez: 4,658 MPa			Ez: 4.658	MPa			E7: 4 658	MPa				Ez: 4.6	58 MPa	
L							-		22. 4,000	in u						
	Stackup Layers			Stackup La	rers			Stackup Layers				Stackup	Layers			
	Double click any	row to adit the properties	for that layer or s	Double clici	any row to add the pro	portion for that lower or a		Daubla aliak any av	. to odit the new		at law and a d	Daubla	atick courses			
	button to replace	e all layers using a given F	CB thickness an	button to rep	place all layers using a	given PCB thickness an		button to replace all	l layers using a	given PCB t	nickness and defa	button to	o replace all I	layers usin	g a given PCB thic	kness an
	Layer # Type	Thickness Mate	rial	Layer # Ty	pe Thickness	Material		Layer# Type	Thickness	Material		Laver #	Туре	Thickne	ss Material	
	1 SIGNA	L 2.0 oz COP	PER (50%)	1 SI	GNAL 2.0 oz	COPPER (50%)		1 SIGNAL	2.0 oz	COPPER	(50%)	1	SIGNAL	2.0 oz	COPPER (5	)%)
	2 Lamina 3 SIGNAI	ate 10.0 mil IS41	0 PER (50%)	2 La	minate 10.0 mil	IS415		2 Laminate	10.0 mil	N4000-29	(50%)	2	Laminate	10.0 mil	370HR	10/1
	4 Lamina	ate 8.0 mil IS41	0	4 La	minate 8.0 mil	IS415		4 Laminate	2.0 02 8.0 mil	N4000-29	(50%)	3	Laminate	2.0 oz 8.0 mil	370HR	J%)
	5 SIGNA	L 2.0 oz COP	PER (50%)	5 SI	GNAL 2.0 oz	COPPER (50%)		5 SIGNAL	2.0 oz	COPPER	(50%)	5	SIGNAL	2.0 oz	COPPER (5	)%)
	6 Lamina	ate 10.0 mil IS41	0	6 La	iminate 10.0 mil	IS415		6 Laminate	10.0 mil	N4000-29	(500()	6	Laminate	10.0 mil	370HR	
	8 Lamina	ate 8.0 mil IS41	0	7 SI	GNAL 2.0 0Z	COPPER (50%)		7 SIGNAL 8 Laminate	2.0 0Z	N4000-20	(50%)	7	SIGNAL	2.0 oz	COPPER (5)	)%)
	9 SIGNA	L 2.0 oz COP	PER (50%)	9 SI	GNAL 2.0 oz	COPPER (50%)		9 SIGNAL	2.0 oz	COPPER	(50%)	9	SIGNAL	2 0 07	COPPER (5)	9%)
	10 Lamina	ate 10.0 mil IS41	0	10 La	minate 10.0 mil	IS415		10 Laminate	10.0 mil	N4000-29		10	Laminate	10.0 mil	370HR	
	11 SIGNA	L 2.0 oz COP	PER (50%)	11 SI	GNAL 2.0 oz	COPPER (50%)	Ļ	11 SIGNAL	2.0 oz	COPPER	(50%)	11	SIGNAL	2.0 oz	COPPER (5)	)%)
					Р	lated Through	Ho	le Fatigue L	ife Proj	ections	)					
						Ca	lcu	lated Resul	ts - Cycl	e to Fa	ilure at Life P	oint				
	CTEz	Delta T	Lamir	nate	CTEz	0.400		401			500		0.001		Test to Fie	ld
	Lamina	te			PCB Stack	0.10%		1%	10	%	50%		63%		Correlatio	n
		Field														
	45	25 - 75	ISOLA 3	70HR	37.67	305 339 412	5/	43 592 804	978 13	3 260	1 566 516 30	7 17	714 362	676	144 021	
	55	25 - 75	NELCO N	4000-29	44 995	522 431		930 079	1 673	571	2 680 286		2 933 2/	19	910	
	65	25 - 75	ISOLA	410-	52 32	27 707		49 327	88.7	59	142 150		155 560	s l	104	
	60	25 - 75	ISOLA	446.	52.52	27,707		40,027	00,7	55	142,150		155,500		104	
	65	25 - 75	ISULA	415:	52.32	21,101		49,327	88,1	59	142,150		155,566	P	104	
		Test														

3,774

1,022

473

473

6,792

1,839

852

852

10,877

2,945

1,364

1,364

11,904

3,223

1,493

1,493

# sherlock

#### AUTOMATED DESIGN ANALYSIS

#### 1) Parts ID & Management

Sherlock	Public Rollings	and from the second second	and the second sec				
Project Circuit Card File Analysis	Results Tools Settin	gs Help					
Antilock Braking System	Main Board Sta	ckup 🛪 🔲 Main Board Parts List 🛪					
🔻 🚞 Heart Pump							
🔻 🤣 Life Cycle	<ul> <li>The following table col</li> </ul>	ntains all parts currently defined for this CCA. The	he items are color coded so that you know the origins of	each component. Double-click o	in a row to view all properties associated with	that part.	
🔻 🧰 Phase 1		5	Sources: User PartsDB BOM Pic	kPlace Guess			
✓ Harmonic Vibe		Pro	blem Exists 🛕 Un-Confirmed 🥝 Confirmed   Part Co	Junt: 2394 Unique Parts: 142			
hechanical Shock	Filters						
Random Vibe					1. P		
8 Thermal Cycle	RetDes	Part Number	Part Type	Packaging	Location		
Project Results							
Score Card	Deste Listing						
Cife Prediction	Parts Lisung						
Main Board	Ref Des	Part Number	Part Type	Packaging	Location		
Files	A U110	A 075-1313-5	Aic	A SMT BGA256 1.0MMSP	17MMB .020BALL A TOP	A	
v 🖉 Inputs	A U700	075-0973-5	Aic	A SMT TSSOP16 .65MMS	P .177X.201B .25 A BOT		
Parts List	A U701	075-0973-5	A IC	A SMT TSSOP1665MMS	P177X.201B25 A BOT		
Stackup	🔥 U702	A 075-0700-5			468 449W DO 4 A BOT		
N Layers	<u> U</u> 703	A 075-0700-5	Sector Package Chooser			Part Properties - U13	
A Pick & Place	<u> (</u> U704	<u>A</u> 075-0700-5					
Drill Holes	🛕 U705	A 075-0700-5	Select the desired package:			The following properties are currently defined for the selected	part as derived from the listed source. Press
🔻 😢 Analysis	🔔 U707	A 075-0676-5	Package Type Pin Coun	t Size (mm)	Package Name	the button to see all source values for a given property.	
🛕 CAF Failure	A U708	A 075-0676-5	LCCC ALL	ALL	A QFP-64 (MO-112BD-1)		
🛕 Failure Rate	A U709	A 075-0676-5	LSOP 16	4.0 x 4.0	QFP-64 (MO-112BD-2)	Confirmed A Un-Confirmed	📶 Guess 🕕 Unknown
🛕 PTH Fatigue	A U710	A 075-0676-5	MELF 20	5.0 x 5.0	QFP-64 (MO-112CA-1)	Part Properties - U13	
A Shock / Vibration	A U720	<u>A</u> 075-0686-5	PDIP 24	7.0 x 7.0	QFP-64 (MO-112CA-2)		
A Solder Fatigue	A U721	<u>A</u> 075-0686-5	PDSO 28	73×73	QFP-64 (MO-204AB)	ID Pkg Loc Solder Thermal Ball P	ad Die Flag Lead Qual
Results	<u>A</u> U722	<u>/1</u> 075-0736-5	QFJ 32	88788	QFP-64 (MO-204BC)		
Score Card	A U723	A 075-0099-5	QFN 26	10.0 x 10.0	QFP-64 (MS-022BB)	Package Name: A TSOP-32 (MO-142BD)	Package DB
S Life Prediction	A U724	A 075-1154-5	QFP / LQFP / TQFP 40	10.2 × 10.2	QFP-64 (MS-022BE)	Package Mount: 🋕 SMT	Package DB
HVAC Controller	A 11729	A 075-0560-5	SOD	10.2 × 10.2	QFP-64 (MS-022GA-1)		
Keylob	A 11730	A 075-0667-5	SOIC / SO	11 4 4 11 4	QEP-64 (MS-022GA-2)		Package DB
Satellite Communication	A U731	A 075-0667-5	SOJ/LSOJ/TA/TSOJ 50	11.4X 11.4	QEP-64 (MS-026ABD)	Package Length: 🛕 18.4	Package DB
Solar Inverter	A U732	A 075-1154-5	SON SI	12.0 x 12.0	OFP-64 (MS-026ACD)	Package Width: A 80	Package DB
Thrust Reverser	A U733	075-0667-5	SOT/TSOT	12.2 X 12.2	OEP-64 (MS-026ADC)		
-	A U734	A 075-1386-5	SSOP / TSSOP / VSSO - 70	12.0 X 12.0	OEP-64 (MS-026AEB)	Package Thickness: A 1.0	Package DB
	A U738	A 075-0853-5		14.0 X 14.0	0EP-64 (MS-0268BD)	Corner Shape: (1)	User
	🛕 Y2	A 076-0050-5	80	14 / X 14 /		Corner Padius:	
	🕂 ҮЗ	A 076-0050-5	Package Name: QFP-64 (MS-022GA-1	)		comer Radius.	User
	<u> </u> Y4	A 076-0050-5	Package Type: QFP			Material: 🕂 EPOXYENCAPSULANT	Package DB
			Package Material: EPOXYENCAPSULAN	т		Technology: 2 TTI	Guess
		Add Part Edit Se	lect				
			Package Leads: 64 - Gullwing - Coppe	<u>(</u>	and the second second	Seal Type: 2 NONHERMETIC	Guess
			Dimension (mm): 20.0 x 20.0 x 2.7		all all a lease		
- / / /						Prev Part U13	Next Part
						the second secon	
						Edit Part (	Nose
			Use F	ackage Properties Cancel		EditPalt	

 Minimizes data entry through intelligent parsing and embedded electronic components package and material databases

![](_page_47_Picture_5.jpeg)

![](_page_48_Picture_0.jpeg)

#### 2) Define Environments

![](_page_48_Figure_2.jpeg)

49

![](_page_49_Picture_0.jpeg)

**3) Load Transformation** Automated FEA Mesh Creation for Calculating Stress

**Distribution Across the PCBA & to Each Component** 

![](_page_49_Picture_3.jpeg)

#### Automatic Mesh Heneration

Days of FEA modeling and calculations, executed in minutes
Without a FEA modeling expert.

![](_page_49_Figure_6.jpeg)

![](_page_49_Picture_7.jpeg)

Specify the desired properties for the finite element analysis. The "Analysis -> FEA Properties" main menu option can also be used to specify analysis properties across all projects and CCAs.

![](_page_49_Figure_9.jpeg)

![](_page_50_Picture_0.jpeg)

#### **3) Load Transformation**

- Automated FEA for Dynamic Vibration/Shock Modal Analysis

![](_page_50_Figure_3.jpeg)

Embedded Abacus compatible FEA engine

Can export files and results to either Abacus or Calculix

![](_page_50_Picture_6.jpeg)

![](_page_51_Picture_0.jpeg)

- Finite Element Analysis (FEA) and Computational Fluid Dynamic (CFD)
   CAE program are regularly used to identify the stress conditions that products and systems will experience under various usage conditions.
   A standard practice in mechanical and structural products.
- Combining CAE Stress Analysis Tools with Failure Mechanism Models enables the creation of:
  - "Virtual Durability Simulations" that can Calculate Stress Driven Reliability Perfromance Over Time .
  - PoF Research has enable the migration of this technology to the materials and micro structures of E/E components and circuit board assemblies.

![](_page_51_Picture_6.jpeg)

![](_page_51_Figure_7.jpeg)

![](_page_52_Picture_0.jpeg)

#### 4) PoF Durability/Reliability Risk Assessment Thermal Cycling Solder Fatigue

UTOMA	TED	DESIGN	ANALYSIS	
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RefDes	Package	Part Type	Part Number	Solder	Temp Rise	Cycles to Fail	TTF (yrs)	Score	100	Service Life = 26.7 yrs
R355	2512	RESISTOR	SCD	63Sn37Pb	0.0	90,605	93.89	1.9	95	Failure Goal = 5.0%
R339	2512	RESISTOR	SCD	63Sn37Pb	0.0	90,605	93.89	1.9	90	
R347	2512	RESISTOR	SCD	63Sn37Pb	0.0	90,605	93.89	1.9		
R435	2512	RESISTOR	SCD	63Sn37Pb	0.0	90,605	93.89	1.9	85	
R363	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6	80	
R364	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6	75	
R6	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6	70	Parts With Low Fatigue Endurance
R126	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6	65	
R123	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6		Found In Initial Design
R337	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6	in in in	
R338	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6	ji 55	8/1% Eailure Projection
R464	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6	<u>i</u> ∰ 50	
R461	2010	RESISTOR	SCD	63Sn37Pb	0.0	96,085	99.57	2.6	qe 45	Within Service Life
R19	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	بط 40	
R15	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	25	Starting at ~3.8 years.
R304	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	35	
R305	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	30	
R421	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	25	
R422	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	20	
R424	1210	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	15	
R413	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	10	
R419	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	10	
R262	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	5	
R265	1206	RESISTOR	SCD	63Sn37Pb	0.0	114,710	118.87	4.9	0	

 N50 fatigue life calculated for each of 705 components (68 unique part types), with risk color coding, prioritized risk listing and life distribution plots based on known part type failure distributions (analysis performed in <30 seconds) after model created.</li>

- Red Significant portion of failure distribution within service life or test duration.
- Yellow lesser portion of failure distribution within service life or test duration.
- Green Failure distribution well beyond service life or test duration.

(Note: N50 life - # of thermal cycles where fatigue of 50% of the parts are expected to fail)

![](_page_52_Picture_9.jpeg)

Lifetime (Years)

![](_page_53_Picture_0.jpeg)

#### 4) PoF Durability/Reliability Risk Assessment Enables Virtual Reliability Growth

- Identification of specific reliability/durability limits or deficiencies,
   of specific parts in, specific applications, enables the design to be revised with more suitable/robust parts that will meet reliability/durability objectives.
- Reliability plot of the same project after fatigue susceptible parts replaced with electrically equivalent parts in component package suitable for the application.

![](_page_53_Figure_4.jpeg)

 $_{\circ}$  Life time failure risks reduced from  $\sim$ 84% to  $\sim$ 1.5%

![](_page_53_Picture_6.jpeg)

#### PoF Durability/Reliability of Various Failure Mechanism

![](_page_54_Figure_1.jpeg)

#### Detailed Design and Application Specific PoF Life Curves are Far More Useful that a simple single point MTBF (Mean Time Between Failure) estimate. DfR Solutions

#### Reliability/Capability Growth with Traditional D-B-T-F Product Development Processes Takes Years to Achieve Maturity

![](_page_55_Figure_1.jpeg)

#### The Efficiency Improvements of a PoF Knowledge & Analysis Based Product Development Process

![](_page_56_Figure_1.jpeg)

#### Accelerating Testing Challenges E/E Modules are Complex Assemblies of Hundred of Parts and Scores of Components Types

![](_page_57_Figure_1.jpeg)

- Combined T&V Overstress Test Profiles that Accelerate Time to Failure Testing For Actual Failure Mechanism Have Been Demonstrated on Test Coupons for Various Component Types.
  - Accelerated Test Profiles that Produce
     "Foolish Failures" Have Also Been Experienced.

#### Developing Practical Application of Accelerated Testing for "VALIDATION" is a Challenge.

- Hard to Develop an "Optimized" Overstress Profile for REAL LIFE COMPLEX E/E Modules with MANY DIFFERENT COMPONENT TYPES
- An Overstress profile appropriated for one component on a circuit board may be excessive for the next part.
- The "Weakest Links" in EACH NEW DESIGN needs to be identified and used as the pace setter in an accelerated test.

![](_page_57_Picture_8.jpeg)

#### **Comparing Thermal Cycling Durability - IC Packages**

![](_page_58_Figure_1.jpeg)

Without a flexible terminal lead to absorb thermal Expansion/Contract Stresses,
 Flat No Lead - Chip Scale IC Packages (FNL-CSP) experience a high amount of thermal expansion stress in their low profile under body solder joints, which accelerate solder fatigue failure.

- Solder Attachment Cycles to Failure
  - Order of magnitude (10X) reduction from QFPs
  - **3X reduction from BGAs**

![](_page_59_Picture_0.jpeg)

#### PoF SAT - Simulation Aided Testing - Accelerated Life Test to Field Correlation

![](_page_59_Figure_2.jpeg)

![](_page_59_Picture_3.jpeg)

#### Motivation for Conversion to an Upfront Analysis Based Product Development Process.

- Use Computer Simulations of "the" Design,
  - Early During the CAD Stage,
  - To Identify and Resolve Application Specific Design & Packaging Circuit, EMC, Thermal & Structural Integrity . . . etc.
- Real, value added activities to create capable designs, faster, at lower costs via:
  - Reducing prototype part build time & costs.
  - Reducing physical testing time & costs (up to 50% reduction).
  - Reducing potential for schedule & costs over runs due to late problem discovery.
  - Reducing effort & costs of test incident investigation, reporting & resolution.

![](_page_60_Figure_9.jpeg)

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![](_page_61_Picture_0.jpeg)

#### PoF Durability/Reliability Capabilities

# o Thermal Cycling Solder Attachment Fatigue Life o Thermal Cycling PCB PTH Via Barrel Cracking Fatigue Life o Vibration Solder Fatigue Life o Shock Solder Fracture Life o Conductive Anodic Filament Risk Assessment Stress load in Fracture Risk Assessments ICT Test Stress Analysis **Compliant Pin Connector Insertion** ISO-26262 Functional Safety FMEA and Metric Generation

Sn-Pb

![](_page_61_Picture_3.jpeg)

#### PCB Plated Through Hole Via Barrel Cracking Fatigue Life Based On IPC TR-579

• Determine applied stress applied (σ)

$$\sigma = \frac{\left(\alpha_{E} - \alpha_{Cu}\right)\Delta TA_{E}E_{E}E_{Cu}}{A_{E}E_{E} + A_{Cu}E_{Cu}}, \text{ for } \sigma \leq S_{y}$$

$$\sigma = \frac{\left[(\alpha_{E} - \alpha_{Cu})\Delta T + S_{y}\frac{E_{Cu} - E_{Cu}^{'}}{E_{Cu}E_{Cu}^{'}}\right]A_{E}E_{E}E_{Cu}^{'}}{A_{E}E_{E} + A_{Cu}E_{Cu}^{'}}, \text{ for } \sigma > S_{y}$$

$$A_{E} = \frac{\pi}{4} \left[ (h+d)^{2} - d^{2} \right]$$
$$A_{Cu} = \frac{\pi}{4} \left[ d^{2} - (d-2t)^{2} \right]$$

![](_page_62_Picture_4.jpeg)

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• Determine strain range ( $\Delta \epsilon$ )

$$\Delta \varepsilon = \frac{\sigma}{E_{Cu}}, \text{ for } \sigma < S_y$$

 $\Delta \varepsilon = \frac{S_y}{E_{Cu}} + \frac{\sigma - S_y}{E_{Cu}}, \text{ for } \sigma > S_y$ 

 $\Delta \varepsilon_{\rm eff} = \Delta \varepsilon \left| K_{\rm d} \frac{10}{K_{\rm o}} \right|$ 

- Apply calibration constants
  - Strain distribution factor, K<sub>d</sub>(2.5 5.0)
  - PTH & Cu quality factor  $K_Q(0-10)$
- Iteratively calculate cycles-to-failure (N<sub>f50</sub>)

$$N_{f}^{-0.6} D_{f}^{0.75} + 0.9 \frac{S_{u}}{E} \left[ \frac{\exp(D_{f})}{0.36} \right]^{0.1785 \log \frac{10^{5}}{N_{f}}} - \Delta \varepsilon = 0$$

#### PoF Durability/Reliability Risk Assessments PCB Plated Through Hole Via Fatigue Analysis

![](_page_63_Figure_1.jpeg)

When a PCB experiences thermal cycling the expansion/ contraction in the z-direction is much higher than that in the x-y plane. The glass fibers constrain the board in the x-y plane but not through the thickness. As a result, a great deal of stress can be built up in the copper via barrels resulting in eventual cracking near the center of the barrel as shown in the cross section photos below.

![](_page_64_Picture_0.jpeg)

#### New Sherlock DFMEA Module ISO-26262 Function Safety

SHOT			Ŭ		Circuit	Card De	tails		, , , , , , , , , , , , , , , , , , ,
AUTOMATED DESI	GN ANALYSIS				onoun	ouru bo	canto		
Project:	DFMEA Exam	ple		Desc	ription:	This project w	as crea	ated to	show how Sherlock can be
Circuit Card:	Mother Board					used to maint	ain and	genera	ate DFMEA spreadsheets.
Prepared By:				Revi	sion:				
0.1.0; ;;	4.5V.D		<b>F</b> :14			1			4
SubCircuit:	1.5V Requiator	and	Filters		Min SEV: Max SEV:	8	Max	RPN:	32
Component: C1.	C3.C5-C6 (Filters	)							
Failure Mode	Potential Effect	SEV	Potential Cause	000	Prevention	Detection	DET	RPN	Actions Taken
DC Leakage, EPR < 50K	Minimal effect	1	Cracked dielectric layers	2	Note 1	Note 2	2	4	
Open	Minimal effect	2	Open trace or solder joint	2	Note 1	Note 2	2	8	
Short to circuit ground	Controller INOP	8	Crack propagation through part	2	Note 1	Note 2	2	32	
	Min Value:	1		2			2	4	
	Max Value:	8		2			2	32	

![](_page_64_Picture_3.jpeg)

![](_page_65_Figure_0.jpeg)

#### Limits of PoF Modeling - Errors & Excessive Variation Can Not Model Probability of Manufacturing Defects, But Can Model the Outcome

- PoF/RP can Provide Knowledge for Optimizing or Error Proofing Manufacturing Processes or Determining if Parts are built right.
- 5 Most Common E/E Device Manufacturing Issues:

![](_page_66_Picture_3.jpeg)

**ASSEMBLY & SOLDERING PROCESS** (Related to up to 60% of E/E Assembly Issues)

![](_page_66_Picture_5.jpeg)

In Process Board Flexure Cracked & Missing Components. (Related to up to 15% Of E/E Assembly Issues).

![](_page_66_Picture_7.jpeg)

Ionic Contaminate (Circuit Board Cleanliness to Prevent Humidity Related Short Circuit Growths) (Up to 20% Of E/E Assembly Issues).

![](_page_66_Picture_9.jpeg)

Electro Static Discharge (ESD) (Component Damage)

(% Varies Often Related To Spills)

![](_page_66_Picture_12.jpeg)

**Rework & Repair** Latent Rework & Handling Damage (% *Varies*)

#### Summary - Physics of Failure/Reliability Physics is Reliability Science for the Next Generation

- PoF Science based Virtual Validation Durability Simulation/ Reliability Assessments Tools Enable Virtual Reliability Growth that is:
  - Faster and Cheaper than Traditional Physical Design, Build, Test and Fix Testing.
- Determines if a Specific Design is Theoretically Capable of Enduring Intended Environmental and Usage Conditions.
  - "Stress Analysis" Followed by "Material Degradation/Damage Modeling"
- Compatible with the way modern products are designed and engineered (i.e CAD/CAE/CAM).
- Sherlock the PoF CAE Apps Tools Enables Rapid, Low Cost Analysis
   Without a Highly Trained CAE/PoF expert.

O Produces Significant Improvement In Accelerated Fielding of High QRD Products

![](_page_67_Picture_8.jpeg)

![](_page_67_Picture_9.jpeg)

#### Want to Know More – Suggested Reading

![](_page_68_Figure_1.jpeg)

# **Questions & Discussion**

# DfR Solutions

reliability designed, reliability delivered

Thank you for your attention.

![](_page_69_Picture_4.jpeg)

#### For More Information Contact

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