Reliability Challenges for Solar Electronics

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Solar Panel “Scams” in the News…

http://www.bbb.org/blog/2012/06/dont-fall-for-a-solar-paneling-scam-this-summer/

Don’t Fall for a Solar Paneling Scam this Summer
BY KELSEY OWEN - JUNE 25, 2012
POSTED IN: CONSUMER/BUSINESS SERVICES, HOME IMPROVEMENT, HOME INTERIOR - DESIGN & PRODUCTS, NATIONAL

Do you feel like a Popsicle melting in this summer heat? If you’re looking to stick to a budget when trying to “coolify” your home and are considering turning to green solar energy as a solution, there are some things you should consider when making the switch.

Solar energy scams are no exception when it comes to the typical contracting scam. Fraudulent contractors prey on those who are unfamiliar with their product. Make sure you know how solar energy works and how the benefits will affect you before investing the $5,000 to $60,000 chunk of change on any solar energy products. You might even qualify for the state and federal rebates that offer a reduction in the initial costs.

Before hiring a solar paneling contractor, take the following into consideration:

Determine if solar energy is right for you. Due to the high...
Leading Causes of “Hard” Photovoltaic (PV) System Failures

- Central Inverter: 37% from 2009 Sandia Study
  - IGBT most common component
- 3 basic fail categories
  - Manufacturing Quality
  - Inadequate Design
  - Defective Electronic Components

IGBT = insulated gate bipolar transistor

J. Granata, Sandia; 2009 PV Reliability Conference
Leading Causes of “Hard” PV System Failures

- Central Inverter: 51% from Sun Edison 2008-2010 study
- Communications: 11%
- Weather Station: 7%

Leading Causes of Calls for PV Inverter Failures

- "Other" is largest
- Control software: 16%
- Printed Circuit Board: 11%
Leading Root Causes of “Hard” PV Inverter Failures

- Parts & Materials: 57%
- Software: 16%
Reliability by Inverter Type

Failure Rate & Inverter-Years
for 4 utility-scale inverter vendors and 2 micro/string inverter vendors
based on tickets with definitive affected area (no 'Other'/'Unknown')
and root cause identified as 'Parts/Materials' or 'Vendor S/W'

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Failure Rate</th>
<th>Inverter-Years</th>
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<td>A</td>
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<td>D</td>
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<td>Micro &amp; String</td>
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</table>

SunEdison® EPA
solar electric power association
PV System Reliability & Availability

- Every alert must be handled
- Most software & communication issues can be handled quickly
- Hardware takes longer to resolve

- Potentially easier to improve availability by focusing on software & communication!
- Tend to be hardware biased!
PV System Failures: Utility Perspective

• Leading failure causes in US:
  – Poor Design
  – Poor Installation
    • Code Infraction
    • Ambiguous Instructions
    • Lack of information and documentation

• Leading failure causes in developing countries:
  – Selling PV systems to users and financing them privately or by soft loans
    • Encouraged purchase of cheap, poor quality components and minimal maintenance
    • Led to early failures and poor long term sustainability

DESIGN REVIEW AND APPROVAL OF GRID-TIED PHOTOVOLTAIC SYSTEMS

Evaluation of the PREP Component: PV Systems for Rural Electrification in Kiribati & Tuvalu (7 ACP RPR 175)

presented by:
Inverter Overview

• Inverters perform two key functions
  – Converts the direct current (DC) coming from the panels to the alternating current (AC) used by the electric grid
  – Perform algorithms to maximize the power produced by the system.
Types of PV Inverters

I. Classic
   SMA, KACO, XANTREX, ABB, Siemens ...

II. Classic + per panel MPPT
    Tigo, SolarEdge, National ...

III. Per Panel Micro Inverter
     Enphase, DirectGrid, OKI ...
     Panel level MPPT, scalability, low cost AC wiring

Graph courtesy of Doron Shmilovitz, Tel Aviv University, Israel

presented by: SEIA Solar Energy Industries Association®  SEPA solar electric power association
Central Inverters

• PV modules feed into a central dc-dc converter stage that has:
  – Maximum power point tracking (MPPT)
  – DC-AC inverter to connect to the utility grid.
  – Can’t maximize energy extraction from all modules
Micro-Inverters vs Central Inverters

• Better Reliability & Availability
  – Lack of single failure point
  – Longer warranty: 15-25 years versus 5-10 years

• Lower DC Voltages, less vulnerable to arcing

• Optimized Maximum Power Point Tracking (MPPT) per module

• PV Module level real-time monitoring

Images courtesy of Paul Parker, SolarBridge
Micro-Inverters

• The electronic components used in a micro-inverter are commercial off-the-shelf (COTS)
  – Parts designed for consumer electronics but need to survive 25 years in solar installations
  – Outdoor/Partially Protected & Temp Not Controlled
Distributed Inverters

- Similar advantages as Micro
- Designed to work with power optimizers
- Standard 10-12 year warranty, some extended to 20-25 years
- Built-in module-level monitoring receiver with communication to internet via broadband or wireless
- Because MPPT & voltage management are handled separately for each module by the power optimizer, the inverter is only responsible for DC to AC inversion. So potentially less complicated, expensive & more reliable
Micro vs Distributed Inverters

• From a system reliability and maintainability perspective, both offer advantages over Central inverters.
• All inverter types face the same environmental and electronics failure modes.
• Both regarded as more cost effective for commercial applications vs utilities
• Both add significant software complexity for optimizing and monitoring functions
Micro vs Distributed Distinctions

- **Component Selection**
  - Life limits of Electrolytic Caps versus Ceramic Caps
  - Use of ASICs to reduce discreet parts count
- **Derating**
  - Power optimizers are low voltage devices and more easily highly derated
- **Efficiency & Heat Dissipation Differences**
- **Distributed/string benefits are true only if designed for the specific optimizer**
  - One company doing this as a complete system
  - No current standard for DC Optimizers, so other string inverter companies may be hesitant to design a product around a specific vendors’ optimizer.
Inverter Field Failure Mechanisms

- Solder joint fatigue failure
- Plated through hole fatigue failure
- Conductive anodic filament formation (CAF)
- Shock or Vibration (shipping and in use)
- Component wear out
- Potting Induced Failure
Solder Fatigue

- Solder joints “wear out” or fatigue and fail under the long term influence of temperature cycling and mechanical stresses.
Plated Through Hole Fatigue

- When a printed circuit board experiences temperature cycling, expansion/contraction in the z-direction is much higher than that in the x-y plane.
- High stress can build up in the copper via barrels resulting in cracking near the center of the barrel as shown in the cross section photos below.
Conductive Anodic Filament Formation (CAF)

- CAF formation is a risk when Plated Through Hole (PTH) vias are so close together that damage from drilling can open up a pathway between vias.
- Copper from the via can migrate along the pathway and eventually cause shorting.
Failure after Exposure to Vibration

- Mechanical shock and vibration also leads to solder joint failures
- Can occur during transportation, installation or use
Potting Electronic Assemblies

- Potting is the process of filling an electronic assembly with a resin compound
- Provides resistance to shock and vibration, and excludes moisture and corrosives.
Printed Circuit Board Warpage due to Potting Shrinkage

Step: Step-1, Thermal Cycle 1
Increment: 80; Step Time = 3230.
Primary Var: U, Magnitude (RT:CSYS-1)
Deformed Var: U (RT:CSYS-1) Deformation Scale Factor: x = +1.000e+000  y = +1.000e+000  z = +3.000e+01
Potting Rules of Thumb

- The use of underfills, potting compounds and thick conformal coatings greatly influences the failure behavior under temperature cycling
  - Any time a material goes through its glass transition (Tg) temperature problems tend to occur
  - Underfills designed for enhancing shock robustness do not enhance thermal cycling robustness
  - Potting materials can cause PCB warpage and tensile stresses on electronic packages that greatly reduce time to failure
Some Questions You Should Ask Your Inverter Supplier

- How have you evaluated reliability?
  - Not MTBF, certifications or specifications but evaluation under stress conditions to failure
- What is your field failure history & repair rate?
  - What fails & why?
- How long and how many units in the field?
- Who installs them?
- What software monitoring options are available?
Supplementary Material

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Micro vs Distributed Distinctions

- Ceramic versus electrolytic capacitors
- DC/DC converters rely on ceramic capacitors which have a low, fixed rate of aging.
  - Possible due to the relatively high switching frequency used in converters.
- Micro inverters require large input capacitance due to the grid low frequency.
  - In some cases, this is implemented with electrolytic capacitors which have a significantly shorter lifetime.

Graphic courtesy of SolarEdge
Component Failures

Infant Mortality:
A. Weak Solder Joints
B. Cracked Ceramic Capacitor

Steady State:
C. FET Single Event Burnout
D. Corrosion

Wearout:
E. Electrolytic Capacitor Degradation
F. Non Compliant Solder Joints (BGA, etc.)

Image Courtesy of SolarBridge
Micro vs Distributed Distinctions

- ASICs allow embedding many electronics into the chip, thereby
  - Reduces number of discreet components and potential points of failure.
  - Reduced component count on the circuit board also allows manufacturers of power optimizers to decrease the overall size of the product and raise MTBF
Micro vs Distributed Distinctions

• Derating
  – Power optimizers are low voltage devices and more easily highly derated
  – A lower derating factor may shorten the lifetime of the product due to increased stress under operating conditions.
Micro vs Distributed Distinctions

• Efficiency & Heat Dissipation Differences
• Micro-inverters have lower efficiencies than power optimizers. The highest known efficiency of micro-inverter brands is 96%, meaning 4% heat dissipation to the module.
Micro vs Distributed Distinctions

• Distributed/string benefits are true only if designed for the specific optimizer
  – One company doing this as a complete system
  – No current standard for DC Optimizers, so other string inverter companies may be hesitant to design a product around a specific vendors’ optimizer.
Reliability Challenges in CPV Interconnects

- Current material selection for CPV (Concentrated PhotoVoltaics) interconnects are insufficient
  - Filled epoxy is cheap ‘temporary’ solution
  - Poor thermal conductivity prevents migration to higher concentration levels, greater efficiencies
  - Insufficient reliability to meet 25-year lifetime

- Extensive life requirements, short product development cycle demands ‘proof-of-concept’ before hardware build
  - Waiting till test to validate reliability requirements is high risk proposition
  - Requires reliability prediction of interconnect structures in the concept and design stages

- New materials and new reliability algorithms provide direct solutions to these industry-limiting issues
Superhydrophilic Coatings

• Provide protection and mechanical support
• Increases optical transmittance by >5% – Anti-reflective Effect
• Provides self-cleaning and antifogging behavior

Images courtesy of Corey Thompson, U of Arkansas

Examples of Anti-reflective & anti-fogging properties
Superhydrophobic Coatings

• Prevent or reduce adhesion (wetting) of water, heavy oils, strong acids, bases, salt solutions
  – Plant & animal matter

• Potential for less cleaning required
  – Contaminants more easily removed

Image courtesy of Tera Barrier
New Coating Technologies

- Explosion in new superhydrophobic coating technologies over the past 24 months
- Reached a frenzy at Consumer Electronics Show in Jan. 2012
- Drivers
  - Tin whiskers
  - Moisture proofing
  - Oxygen barrier
Who are the Players?

- Tera Barrier
  - Vitex Systems / Samsung
- P2I
- HZO
- Liquipel
- GVD
- Lotus Leaf
- Semblant
- Sundew
Market Focus: Flexible Technology
- Displays/Lighting (OLEDs) and Solar (thin film)

A Multi-Layer Barrier Stack to retard water vapor and oxygen diffusion
- Patent history includes Osram, filed in 2001
- Similar patents filed by Battelle Labs and commercialized by Vitex Systems in 1999 (Barix) (now Samsung America)

Flexibility and transparency key attributes of the technology
- Index matching of materials
Tera-Barrier & Multi-Layer Barriers

- Tera-Barrier’s twist is to use nanotechnology to eliminate defects
  - Nanoparticles seal defects and react/retain oxygen and moisture
  - Requires fewer layers to be effective
  - Claims up to 2300 hours at 60C/90%RH
Reliability Modeling of Electronics for Solar Inverters

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Abstract

A critical component in all photovoltaic systems is the DC to AC inverter (micro-inverter, micro-converter and standalone ‘central’ inverters). The long term reliability and stability of this system and is crucial to the cost effectiveness (LCOE) of the system. Inverters are subjected to extreme electrical, thermal and, in some cases, mechanical stresses, in the operating environment of thermal cycling and moisture for very long periods of time i.e. >25 years. Fabricators of these systems need to be comfortable knowing that their designs will meet these aggressive environments. A new reliability modeling tool has been developed that is being used to predict the failure rate of the electronics in these systems. This tool provides the designer with the ability to find and correct design flaws before release of the product, thus avoiding costly failures in the field. The failure rate is predicted for thermal cycle fatigue of solder joints and plated through hole vias as well as shorting from conductive anodic filament (CAF) formation. The tool will also produce a finite element analysis of the circuit boards showing regions susceptible to excessive board strain during vibration or shock events. The most value comes from the ability of the engineers to perform various “what if” scenarios to determine the impact of any number of design choices.

• What if mounting point locations are modified?
• What if via diameters, spacing, or copper thickness on the circuit board is modified?
• What effect does the laminate thickness or material selected have on reliability?
• What component is at highest risk of failure and how does the packaging format of that component affect failure rate?
• What quantifiable impact exists on the long term reliability when changing from SnPb to SAC305 solder?
Inverters

- An inverter converts the DC voltage created by solar cells to AC voltage that can be used with our power grid.
- Micro-inverters are designed to invert the voltage from a single solar panel – thus allowing solar panels to be used in areas where shading occurs.
- Micro-inverter electronics are expected to survive for the life of the panel and must survive the environmental elements in which it is placed.
Micro-Inverters

- The electronic components used in a micro-inverter are commercial off-the-shelf (COTS)
  - Designed for consumer electronics, but need to survive 25 years in solar installations
# Micro-Inverter Requirements

How will these electronic assemblies survive the demands of the solar industry?

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<th>Consumer Electronics</th>
<th>Micro-Inverter Electronics</th>
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<tbody>
<tr>
<td><strong>Expected Life</strong></td>
<td>5-7 years</td>
<td>20-25 years</td>
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<tr>
<td><strong>User Environment</strong></td>
<td>Indoor/Protected</td>
<td>Outdoor/Partially Protected</td>
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<tr>
<td></td>
<td>Temp Controlled</td>
<td>Temp Not Controlled</td>
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</table>
What can be done?

• How can a micro-inverter supplier design the product to meet the requirements & convince the customer of this?
• This talk will discuss a novel new method to model the reliability of an electronic assembly in a variety of conditions based on the design (before building anything).
• Design for Reliability (DfR) concepts and Physics of Failure (PoF) are used.
• A comprehensive software package was developed to simplify this modeling, thus making it available to design engineers.
Design for Reliability (DfR)

• **DfR**: A process for ensuring the reliability of a product or system during the design stage *before* physical prototype

• **Reliability**: The measure of a product’s ability to
  – …perform the specified function
  – …at the customer (with their use environment)
  – …over the desired lifetime
Due to some of the limitations of classic DfR, there has been an increasing interest in PoF (aka, Reliability Physics) – to improve on DfR techniques.

PoF Definition: The use of science (physics, chemistry, etc.) to capture an understanding of failure mechanisms and evaluate useful life under actual operating conditions.
Micro-Inverter Environment

• Extreme hot and cold locations (AZ to AK)
• Possible exposure to moisture/humidity
• Large diurnal thermal cycle events (daily)
• Largest temp swings occur in desert locations where it can reach 64°C in the direct sun down to 23°C at night (Δ41°C)
NREL – Solar Panel Data

• Diurnal Cycles for Each Month

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**Phoenix, AZ**

**WBAN NO. 23183**

**LATITUDE:** 33.43° N  
**LONGITUDE:** 112.02° W  
**ELEVATION:** 339 meters  
**MEAN PRESSURE:** 974 millibars

**STATION TYPE:** Primary

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![Chart showing variability of latitude fixed-tilt radiation](chart)

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</tbody>
</table>

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**Presented by:** SEIA Solar Energy Industries Association®
Inverter Failure Mechanisms

- Solder joint fatigue failure
- Plated through hole fatigue failure
- Conductive anodic filament formation (CAF)
- Shock or Vibration (during shipping)
- Component wear out.
Is There a Method to Model these Failure Mechanisms?

• Yes!
• Algorithms exist to estimate the failure rate from solder joint fatigue for different types of components.
• IPC TR-579 models PTH reliability
• Risk for CAF can be determined
• Finite Element Analysis can be used for Shock & Vibration risk.
• MTBF calculations can be performed to estimate component failure rates.
Leverage in Product Design

http://www.ami.ac.uk/courses/topics/0248_dfx/index.html

70% of a Product’s Total Cost is Committed by Design
Why is modeling reliability early important?

The diagram illustrates the percentage of lifetime costs locked in at each phase of the life cycle. By modeling reliability early, costs are locked in at a lower percentage level, which is beneficial. The graph shows:

- **Concept/Feasibility**: 3% of lifetime costs
- **Design/Development**: 12% of lifetime costs
- **Critical Design Review**: 95% of lifetime costs
- **Operation/Support**: 50% of lifetime costs

The diagram clearly demonstrates the importance of early modeling in reducing the overall costs locked in at later stages of the life cycle.
Earlier is Cheaper

Reduce Costs by Improving Reliability Upfront

Cost Of Unreliability

2x More

1 x

CONCEPT

10 x

DESIGN

100 x

VALIDATION

1000 x

PRODUCTION

- Ideas/Sketches
- Engineering/Design
- Specs/Drawings
- Lost Market Share
- Verification/Testing
- Lost Production
- Warranty/Recall
- Prototype Parts
What is the cost impact of poor reliability?

- Assessing and ensuring reliability during the design phase maximizes return on investment (ROI)
  - Caught during design: 1x;
  - Caught during engineering: 10x;
  - Caught during production: 100x
  - Caught at the customer: 1000x
- Electronic OEMs that use design analysis tools
  - Hit development costs 82% more frequently
  - Average 66% fewer re-spins
  - Save up to $26,000 in re-spins
Solder Joint (SJ) Wearout

- Elimination of leaded devices
  - Provides lower RC & higher package densities
  - Reduces compliance

Cycles to failure
-40 to 125C

QFP: >10,000
BGA: 3,000 to 8,000
CSP / Flip Chip: <1,000
QFN: 1,000 to 3,000
The Newest DfR Tool - Sherlock

• Sherlock – a new tool that models all the circuit card assemblies and provides predicted life curves from many common failure mechanisms.

• It is a Semi-Automated CAE knowledge based program

• The Semi-Automated Features simplify 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.
Software Coverage

- This software modeling tool predicts failures from:
  - Solder joint wear-out from thermal cycling (SAC305 or eutectic SnPb)
  - Plated through hole fatigue
  - Conductive anodic filament formation
  - 217 MTBF calculations are also generated
- In addition the software uses FEA to determine:
  - Board deflection and SJ failure from mechanical vibration
  - The natural frequencies for the board based on the mount points.
  - Board deflection due to shock events
Data Import

- ODB files are preferred since they contain all the data necessary for modeling
  - Component details and placement
  - PCB outline & stack-up
  - Drill hole file with mount points
  - Metal layers, silkscreen, solder mask layers

Gerber Data can also be imported
PCB Details Required for Modeling

- Calculates
  - Thickness
  - Density
  - CTE x-y
  - CTE z
  - Modulus x-y
  - Modulus z
  - From the material properties of each layer
  - Using the built in Laminate Data Library
Establish Part Parameters

- Components identified along with packaging properties.
- Minimizes data entry through intelligent parsing and embedded package and material databases.
Defining Durability & Reliability

Objectives

• Define the Expected Service Life
  – Sets The Analysis Range And The Scale For Reliability Over Time Plots

• Life Cycle Phases
  – Shows relative time spent at each phase
Identify Field Environment

• Approach 1: Use of industry/military specifications
  – MIL-STD-810,
  – MIL-HDBK-310,
  – SAE J1211,
  – IPC-SM-785,
  – Telcordia GR3108,
  – IEC 60721-3, etc.

• Advantages
  – Sometimes very comprehensive
  – Agreement throughout the industry

• Disadvantages
  – Most more than 20 years old
  – Always less or greater than actual (by how much, unknown)
Field Environment (cont.)

• Approach 2: Based on actual measurements of similar products in similar environments
  – Determine average and realistic worst-case
  – Identify all failure-inducing loads
  – Include all environments
    • Manufacturing
    • Transportation
    • Storage
    • Field
Input Field (or Test) Environment

Thermal Cycle Profile

Vibration Profile

Shock Profile

Handles very complex environments
Thermal Cycle Modeling

• The thermal cycle conditions the product will experience can be modeled (Minor’s rule applied for multiple temperatures).

• Powered components can be assigned an added value above ambient temperature.

Example of Diurnal TC Conditions in a hot climate

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<table>
<thead>
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SnPb, SAC305, or SN100C alloys can be selected.

Cumulative failure curve is plotted (2x target life is shown).
### Highest Risk Components

- Large Resistors provide the weakest solder joints in this example.

<table>
<thead>
<tr>
<th>RefDes</th>
<th>Package</th>
<th>Part Type</th>
<th>Part Number</th>
<th>Solder</th>
<th>Temp Rise</th>
<th>Cycles to Fail</th>
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<td>SAC305</td>
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Plated Through-Hole Reliability Modeling

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.
PTH Fatigue Results - Example

The plated through hole failure plot (-40/80C ATC)

Takes into account:
- via diameter
- Cu thickness
- Plating quality
- PCB thickness
- Z-axis CTE
Combined (SJ & PTH) Lifetime Prediction

- Combines analysis results into overall failure prediction curve
CAF Analysis

• The primary variables that effect the probability of CAF formation are:
  – Distance between vias
  – Damage during drilling process
  – Temperature and humidity conditions
  – Voltage differential between vias
• The analysis takes into account the first two variables only (measures distance between all PTH pairs).
• Vias identified as being too close are flagged.
CAF Analysis

- Software will flag vias at high risk for CAF formation
Finite Element Analysis
• PCBA Example with Mesh Outlined

Shock / Vibration Analysis Properties

Specify the desired properties for shock / vibration analysis. The Analysis >> FEA Settings main menu option can also be used to specify FEA analysis properties across all projects and CCAs.

- Max Mesh Size: 3 mm
- Min Part Size: 5.0 mm
- Min Hole Diam: 2.0 mm
- Min Mesh Angle: 15
- Analysis Types: Natural Freq, Shock, Harmonic Vibe

Save & Run  Save  Reset  Cancel
Natural Frequencies are Calculated

Select the number of natural frequencies to look for within the desired frequency range.

Components in high strain regions are at risk.
- Move the components
- Move/add mounting points.

Figure 19: 1st natural frequency 299.6 Hz, red denotes areas of highest deflection

Figure 20: 2nd and 3rd natural frequencies 478.6 and 511.6 Hz
Vibration Environment

Complex vibration profiles can be modeled.

- Qualification test parameters
- Shipping/Transportation
- Field conditions
Random Vibration Strain

Vibration set to simulate shipping

Board strain from random vibration is shown (calculated for x, y, and z directions)
Components most at risk for vibration fatigue damage are listed first.

<table>
<thead>
<tr>
<th>RefDes</th>
<th>Package</th>
<th>Part Type</th>
<th>Material</th>
<th>Solder</th>
<th>Max Disp</th>
<th>Max Strain</th>
<th>TTF (yrs)</th>
<th>Score</th>
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<td>1.4E-4</td>
<td>34.9</td>
<td>1.4</td>
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</table>

| R2     | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 7.0E-2   | 1.9E-4     | >150      | 10.0  |
| R17    | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 7.2E-2   | 1.9E-4     | >150      | 10.0  |
| U11    | LCCC-44 | IC        | ALUMINA                      | SAC305 | 2.4E-1   | 1.0E-4     | >150      | 10.0  |
| R1     | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 6.7E-2   | 1.8E-4     | >150      | 10.0  |
| R18    | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 6.6E-2   | 1.8E-4     | >150      | 10.0  |
| R102   | 1206    | RESISTOR  | ALUMINA                      | SAC305 | 2.3E-2   | 2.5E-4     | >150      | 10.0  |
| Q7     | SOT-223 | TRANSIST...| OVERMOLD-LEADED | SAC305 | 4.5E-1   | 1.7E-4     | >150      | 10.0  |
| U12    | LCCC-44 | IC        | ALUMINA                      | SAC305 | 2.7E-1   | 9.6E-5     | >150      | 10.0  |
| Q3     | SOT-223 | TRANSIST...| OVERMOLD-LEADED | SAC305 | 4.4E-1   | 1.7E-4     | >150      | 10.0  |
| R103   | 1206    | RESISTOR  | ALUMINA                      | SAC305 | 2.0E-2   | 2.4E-4     | >150      | 10.0  |
| Q5     | SOT-223 | TRANSIST...| OVERMOLD-LEADED | SAC305 | 4.5E-1   | 1.7E-4     | >150      | 10.0  |
| Q1     | SOT-223 | TRANSIST...| OVERMOLD-LEADED | SAC305 | 4.4E-1   | 1.7E-4     | >150      | 10.0  |
| R88    | 1206    | RESISTOR  | ALUMINA                      | SAC305 | 4.5E-2   | 2.4E-4     | >150      | 10.0  |
| U8     | QFP-100 (MS-026... | IC  | OVERMOLD-LEADED             | SAC305 | 2.6E-1   | 8.6E-5     | >150      | 10.0  |
| R3     | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 8.0E-2   | 1.5E-4     | >150      | 10.0  |
| R11    | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 8.5E-2   | 1.4E-4     | >150      | 10.0  |
| R116   | 1206    | RESISTOR  | ALUMINA                      | SAC305 | 1.3E-2   | 2.0E-4     | >150      | 10.0  |
| R9     | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 9.3E-2   | 1.4E-4     | >150      | 10.0  |
| C5     | C-BEND-3528-21 | CAPACITOR | TANTALUM | SAC305 | 6.4E-2   | 1.8E-4     | >150      | 10.0  |
| R75    | 1206    | RESISTOR  | ALUMINA                      | SAC305 | 5.4E-2   | 2.0E-4     | >150      | 10.0  |
| Q2     | SOT-223 | TRANSIST...| OVERMOLD-LEADED | SAC305 | 4.6E-1   | 1.4E-4     | >150      | 10.0  |
| Q6     | SOT-223 | TRANSIST...| OVERMOLD-LEADED | SAC305 | 4.8E-1   | 1.4E-4     | >150      | 10.0  |
| R16    | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 7.7E-2   | 1.4E-4     | >150      | 10.0  |
| R8     | 2512    | RESISTOR  | ALUMINA                      | SAC305 | 8.3E-2   | 1.4E-4     | >150      | 10.0  |
Software Shock

• Implements Shock based upon a critical board level strain
• Will not predict how many drops to failure
• Either the design is robust with regards to the expected shock environment or it is not
• Additional work being initiated to investigate corner staking patterns and material influences
Shock Results - Example

Modify any of the following properties and press the Save button to update the current Shock Event.

Identification
- Name: Mechanical Shock
- Description: Half Sine

Shock Event Settings
- Peak Load: 30 G
- Duration: 11 ms
- # of Cycles: 18

Shock Pulse Profile
- Half Sine

Disp Rang (-2.1e-2, 6.0e-4) mm
Shock Results – Component Breakdown

Components listed in order of maximum strain experienced.

<table>
<thead>
<tr>
<th>RefDes</th>
<th>Package</th>
<th>Part Type</th>
<th>Material</th>
<th>Solder</th>
<th>Max Disp</th>
<th>Max Strain</th>
<th>TTF (yrs)</th>
<th>Score</th>
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Constant Failure Rate Module – Components (Mil-HNBK-217F)

This takes into account the failure rate of the components themselves.
Combined Failure Rate is Provided
Additional Uses for Modeling

• Use Sherlock to determine thermal cycle test requirements.
• Use to modify mount point locations
• Use to determine ESS conditions
• Component Replacement
• Determine impact of changing to Pb-free solder
• Determine expected warranty costs
Warranty Cost Estimate: Example

- Solder joint fatigue was the dominant wearout mechanism, where the failure rate is predicted ~2% after 20 yrs.
- Warranty from SJ failure = failure rate * motherboard replacement cost * units sold.
Summary

• It is important to eliminate design flaws early in development.
• Micro-Inverters must survive a challenging environment for long periods of time.
• A software tool is now available to model the primary failure mechanisms so that inverter electronics can be made more reliable.
• Sherlock modeling will enable a number of “what if” scenarios.
  – Changing package types
  – Changing location of components
  – Changing the mount point locations
  – Changing laminate type, etc.
• The software can also be used to determine the TC test conditions that best simulate the field use conditions.
• Micro-Inverter designs can be built with more confidence that they will survive the challenging environments where they are placed.
Summary

A software tool is now available to model the primary failure mechanisms so that inverter electronics can be built with more confidence that they will survive the challenging environments where they are placed.
Contact Information

Any Questions?

Contact Cheryl Tulkoff, ctulkoff@dfrsolutions.com, 512-913-8624

Connect with me on Linked In!

www.dfrsolutions.com
Questions

Thank you for your attention.

culkoff@dfrsolutions.com