DfR Solutions
reliability designed, reliability delivered

HALT and Sherlock Automated Design Analysis™ Software

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March 20, 2014

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HALT Test Plan Development

- ## The HALT test process:

  Helps product designers create a more robust and reliable product, thus improving field reliability and reducing warranty costs. When successfully applied, HALT testing rapidly exposes product weaknesses and gives the designer the opportunity to provide a more mature product at new product launch.

- ## Sherlock:

  Sherlock is an Automated Design Analysis Tool that allows you to predict product failure earlier in the circuit board design process, allowing you to design reliability right into the product. And with results in hours instead of weeks, you'll be able to deliver these products faster and more efficiently, contributing to your customer's success.

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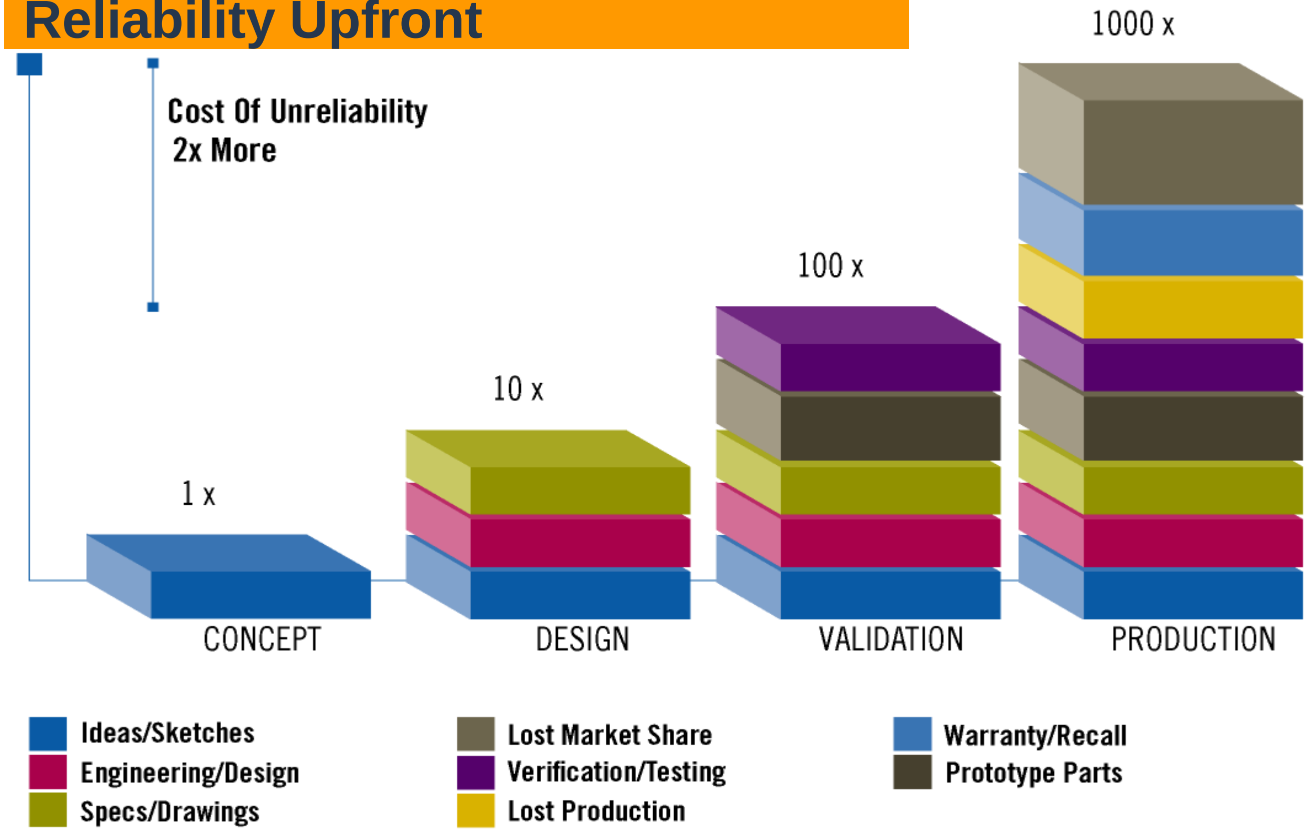
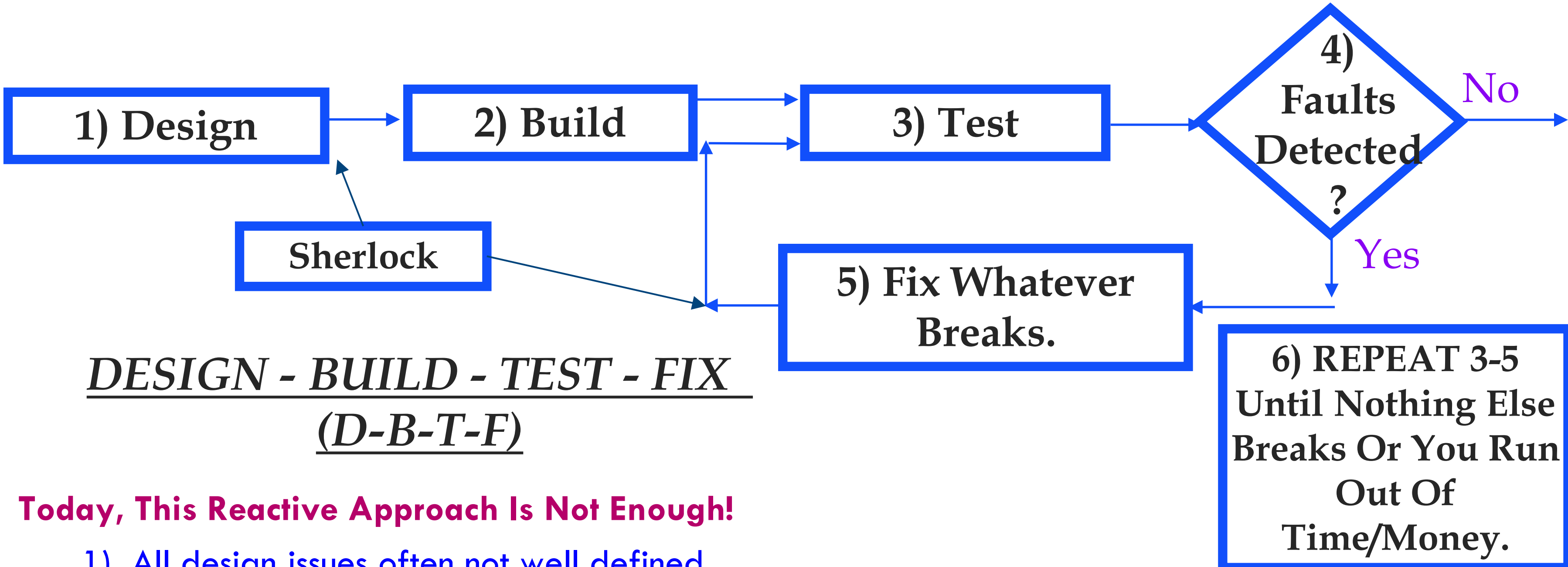
Designing in Reliability, Earlier is Cheaper

Reduce Costs by Improving Reliability Upfront



Traditional Reliability Growth in Product Development

Empirical "TRIAL & ERROR" Method to Demonstrate *Statistical Confidence*



DESIGN - BUILD - TEST - FIX
(D-B-T-F)

Today, This Reactive Approach Is Not Enough!

1) All design issues often not well defined.
2) Early build methods do not match final processes.
3) Testing doesn't equal actual customer's usage.
4) Improving fault detection catches more problems, but causes more rework.
5) Problems found too late for effective corrective action, fixes often used.
6) **Testing more parts & more/longer tests "seen as only way" to increase reliability**.
7) Can not afford the time or money to test to high reliability.
8) Incremental improvements from faster more, capable tests still not enough.

HALT Test Plan Development

- Define HALT specifications (thermal and vibration)
  - Thermal - margin above and below specified operating temperature range
  - HALT Grms vibration level requirements
- Define functional test requirements
  - Electrical functionality
- Determine methods of fixturing/mounting
- Identify components for monitoring
  - Thermocouple locations
  - Accelerometer locations

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Sherlock During Test Plan Development

- Sherlock
  - Identify critical components prior during plan development
  - Identify critical frequencies or board responses
    - Identify locations for accelerometer placement
  - Mounting consideration
    - Boundary conditions
    - Mounting configurations
  - Thermal derating analysis

HALT Specifications - Thermal

- The main purpose of temperature exposure in HALT
  - Determine operating limits
    - Soft failure (recoverable with a decrease/increase in temperature)
    - Hard failures (unrecoverable with a decrease/increase in temperature)
  - Identifying solder defects (thermal transitions)
  - Should not to induce thermal mechanical Fatigue
    - The limited number of thermal cycles during the HALT test will not induce low cycle fatigue in solder joints
    - Even the most fatigue sensitive electronic components take 100's of thermal cycles to failure

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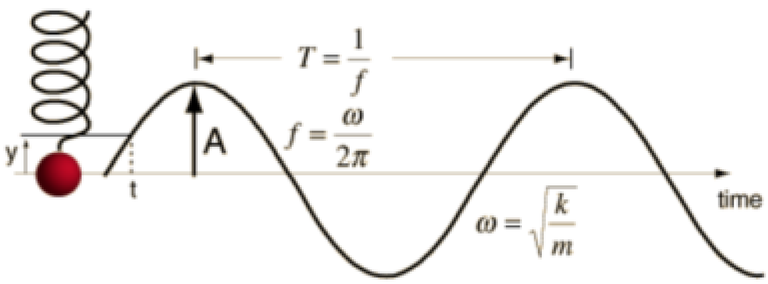
HALT Specifications - Vibration

- HALT chambers utilize repetitive shock (RS) to generate vibration input
  - Type of random vibration
  - Pneumatic hammers strike the chamber table a generate the vibration
  - HALT vibration is not designed to replicate field environments
    - Designed to expose weak links
    - Rapid assessment
  - Input/Output is typically displayed as a Grms value
    - What does this mean?
    - Is it suitable for simulation, can it be used in Sherlock?

Vibration – Harmonic and Random

- Single frequency

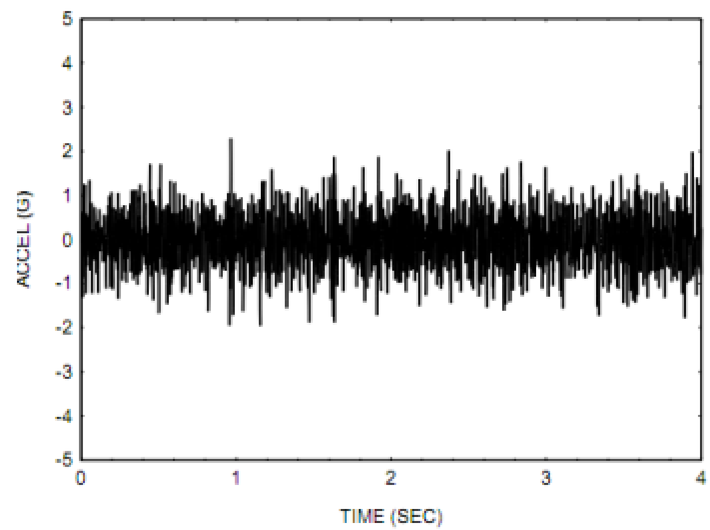


<u>General equivalence</u>. Sine and random characterizations of vibration are based on distinctly different sets of mathematics. In order to compare the effects of given random and sine vibration on materiel, it is necessary to know the details of materiel dynamic response. A general definition of equivalence is not feasible.

<u>Grms</u>. Often, attempts are made to compare the peak acceleration of sine to the rms acceleration of random. The only similarity between these measures is the dimensional units that are typically acceleration in standard gravity units (g). Peak sine acceleration is the maximum acceleration at one frequency (see paragraph 2.3.2). Random rms is the square root of the area under a spectral density curve (see paragraph 2.3.1). **These are not equivalent!**

MIL-STD-810G

- Random vibration is a continuous spectrum of frequencies



AN INTRODUCTION TO RANDOM VIBRATION – Tom Irvine

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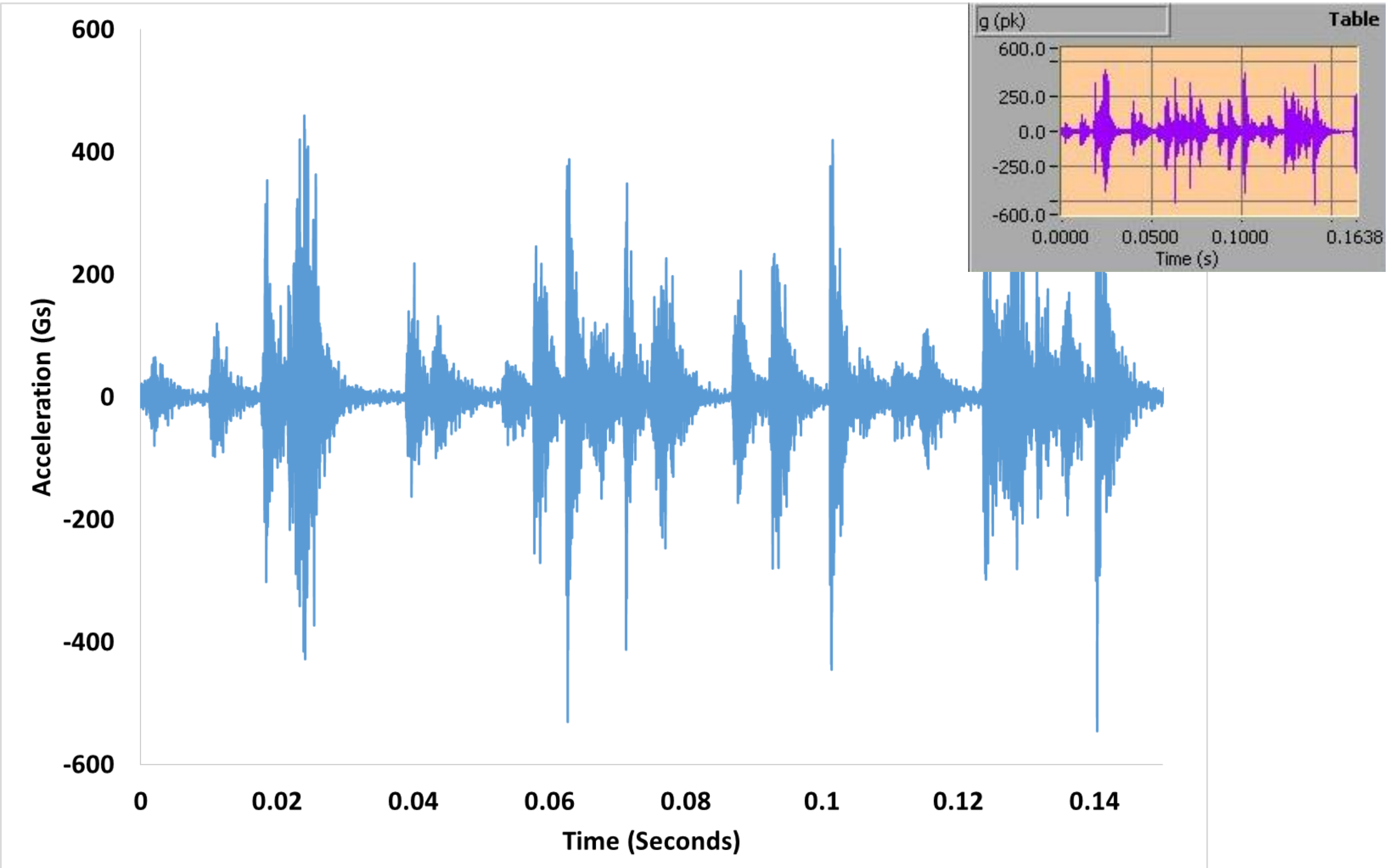
HALT Chamber Settings

- HALT vibration is specified by a Grms level
  - What does this represent
    - The root mean square acceleration (Grms) is the square root of the area under the ASD (acceleration spectral density) curve in the frequency domain
    - The Grms value is typically used to express the overall energy of a particular random vibration event
  - Can it be used for simulation?
    - No
    - A straight Grms value can represent an infinite number of acceleration and frequency combinations
- The time history of the table excitation must be captured and processed into a usable format for the simulation

HALT - Repetitive Shock Induced Vibration



Input HALT level set to 33 Grms

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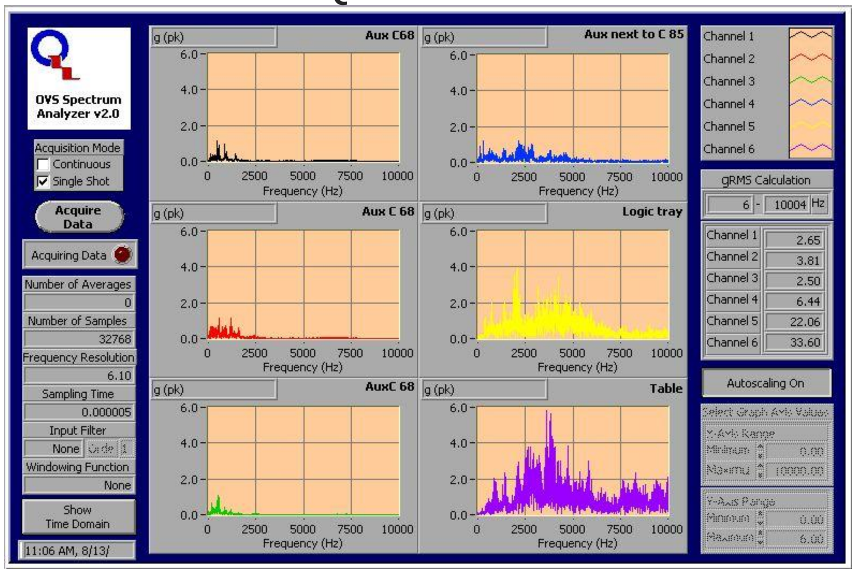
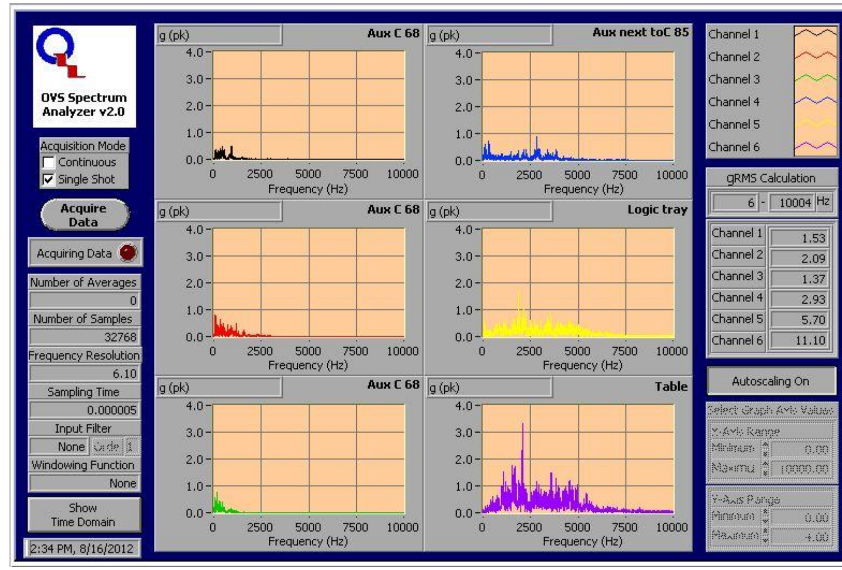
Vibration Data – 16 Grms

Qualmark



Other Chamber



Even though both chambers are programmed to output 16 Grms there is a noticeable difference in the frequency content and magnitudes

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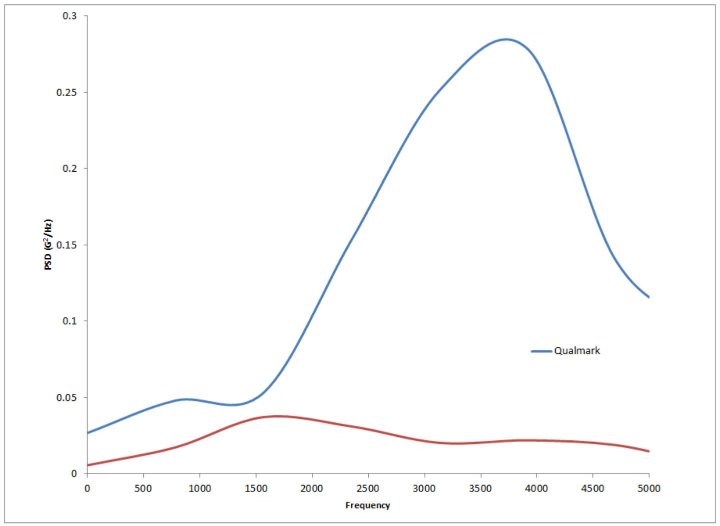
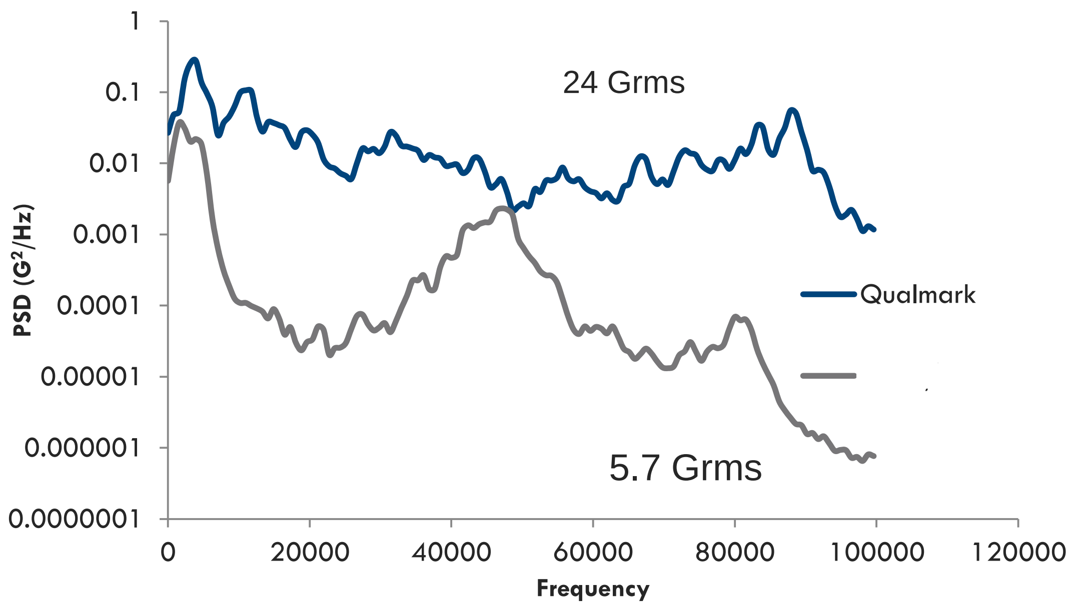
Vibration Data – Post Processing

FFT performed on the time history data to generate a PSD (power spectral density)



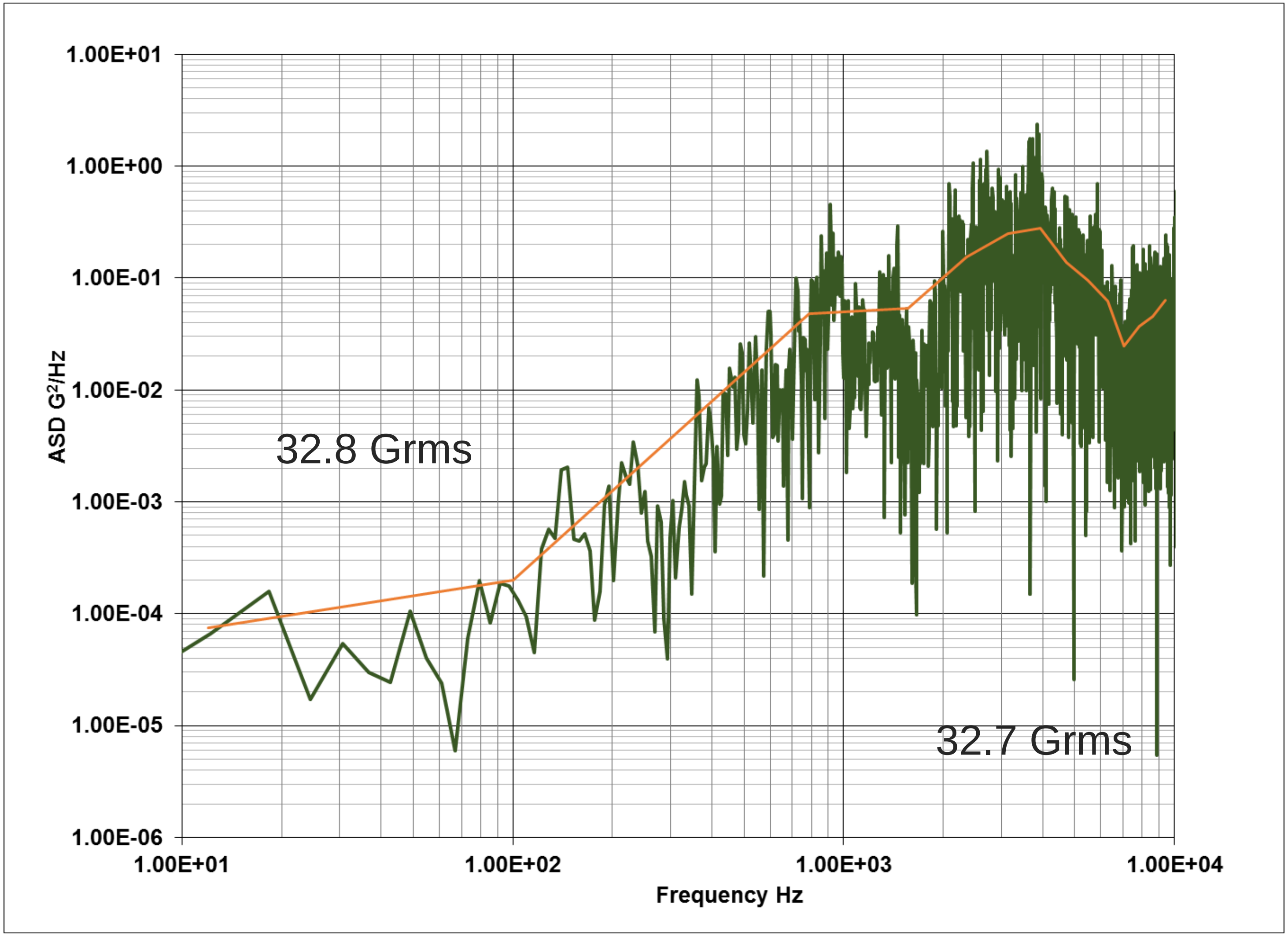
Response below 5KHz



Even though both chambers are programmed to output 16 Grms the PSD profile is higher across the full frequency range for the Qualmark, the content below 5KHz used as Sherlock inputs

Know your chamber! HASS or HALT profiles can be very different

FFT of the Time History



Different FFT parameters

Frequency	PSD
1.20E+01	7.50E-05
1.00E+02	2.00E-04
7.84E+02	4.81E-02
1.57E+03	5.33E-02
2.35E+03	1.54E-01
3.14E+03	2.52E-01
3.92E+03	2.78E-01
4.71E+03	1.39E-01
5.49E+03	9.59E-02
6.27E+03	6.18E-02
7.06E+03	2.48E-02
7.84E+03	3.70E-02
8.63E+03	4.55E-02
9.41E+03	6.39E-02
1.02E+04	9.85E-02
1.10E+04	1.06E-01

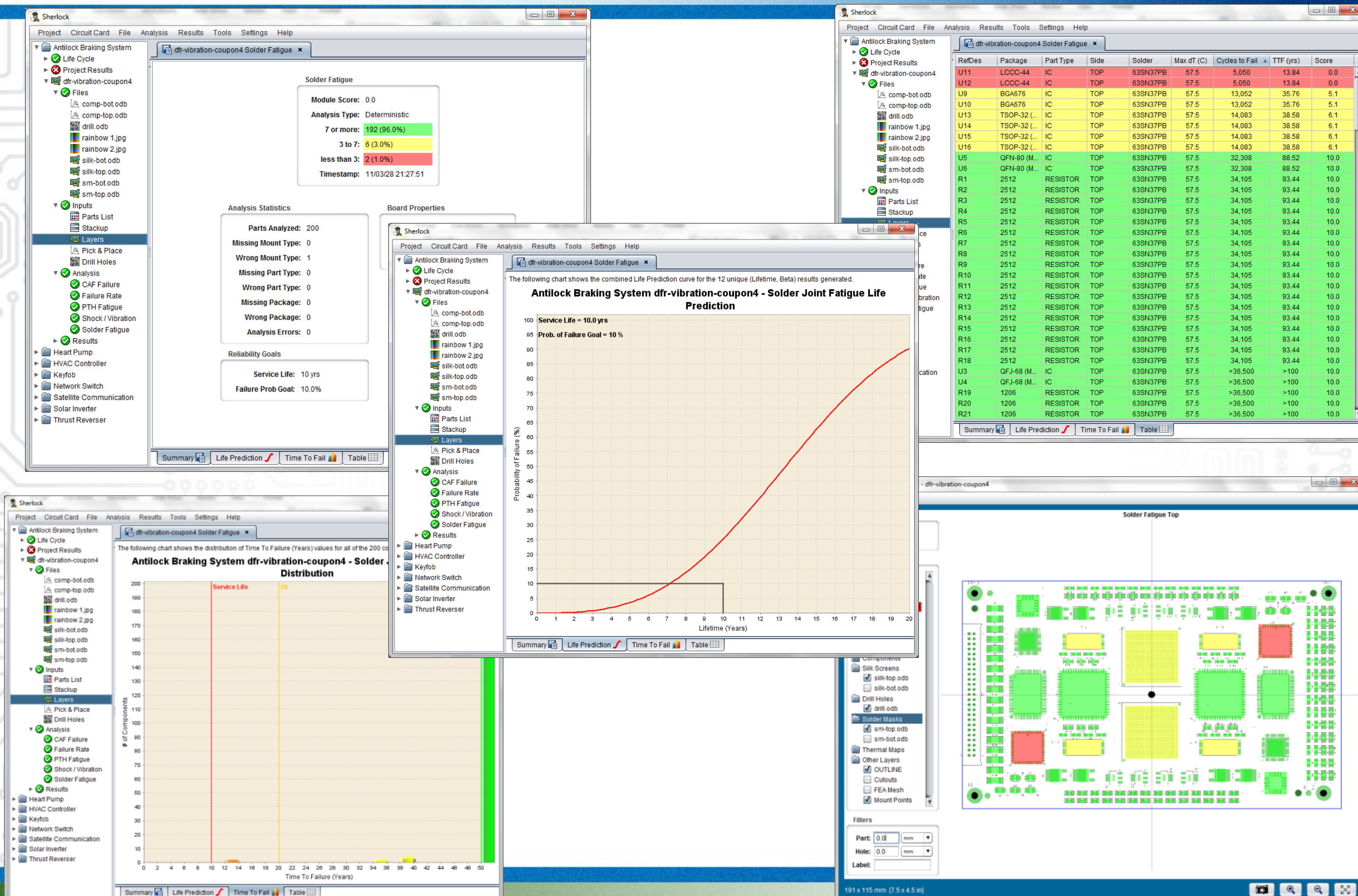
HALT Vibration

- HALT vibration can cause high cycle fatigue of components
- Sherlock can identify critical locations for accelerometer placement
- Sherlock can also identify critical components before HALT testing
- Simulation prior to HALT requires the development of a suitable vibration profile
  - Leverage prior HALT vibration data
    - Product should have similar mass and mounting
    - Need the time history data (time verses acceleration)
  - Data should include table outputs for multiple Grms levels

sherlock

AUTOMATED DESIGN ANALYSIS

Sherlock - Reliability Prediction



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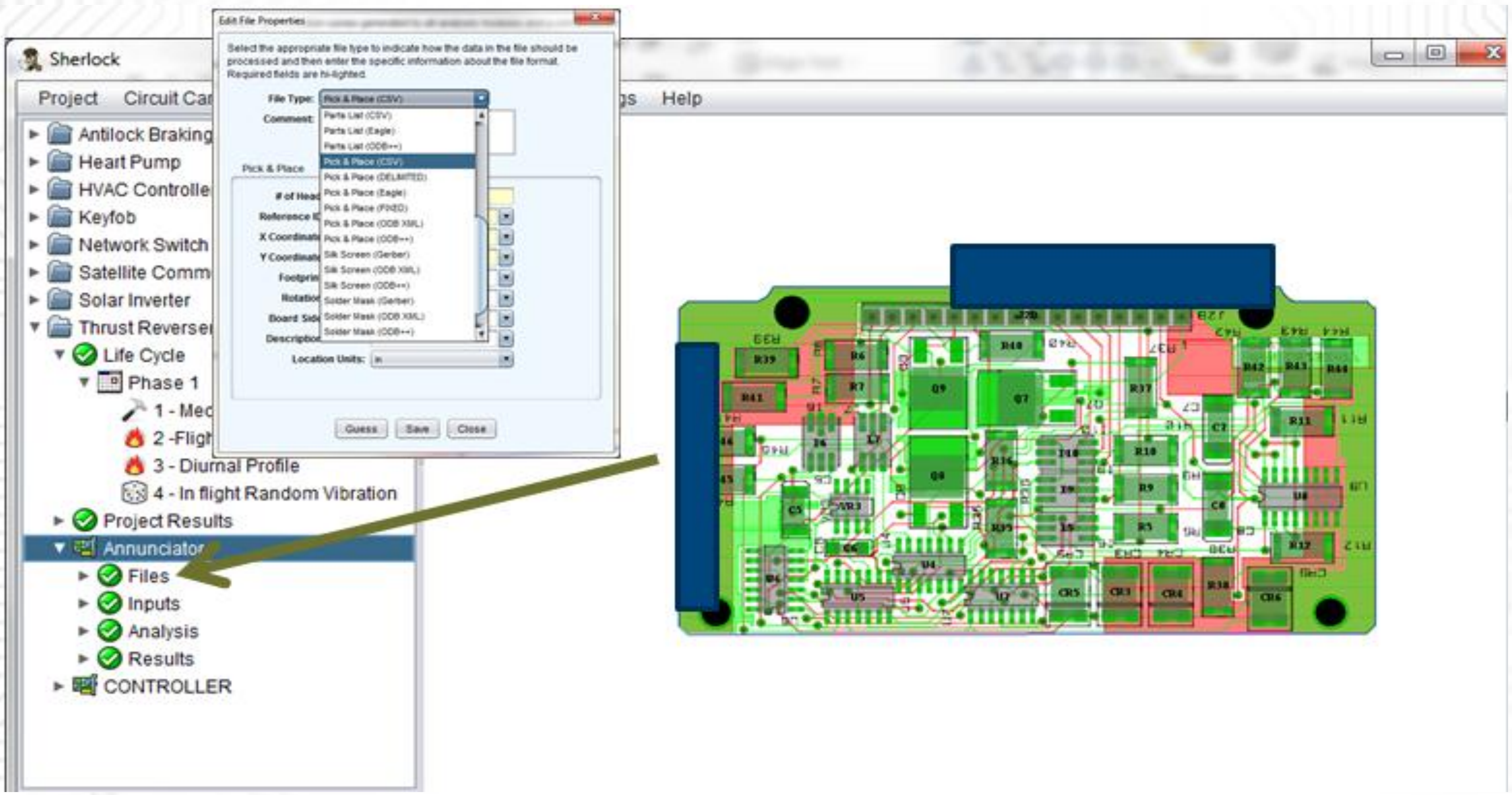
Import the PWBA



Timely feedback to the design layout - daily

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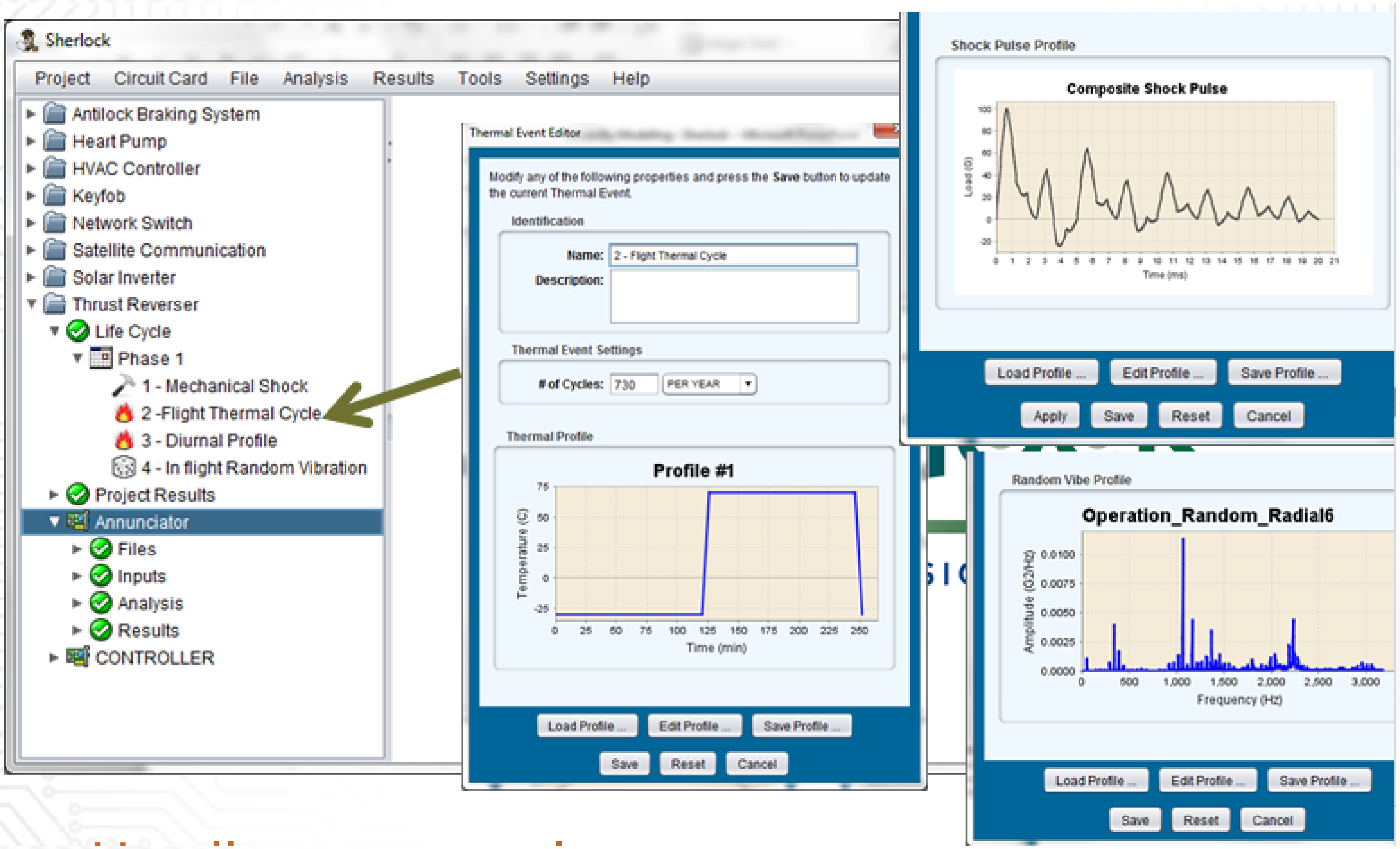
AUTOMATED DESIGN ANALYSIS™

INTELLIGENCE ACCELERATED

Environmental Stresses



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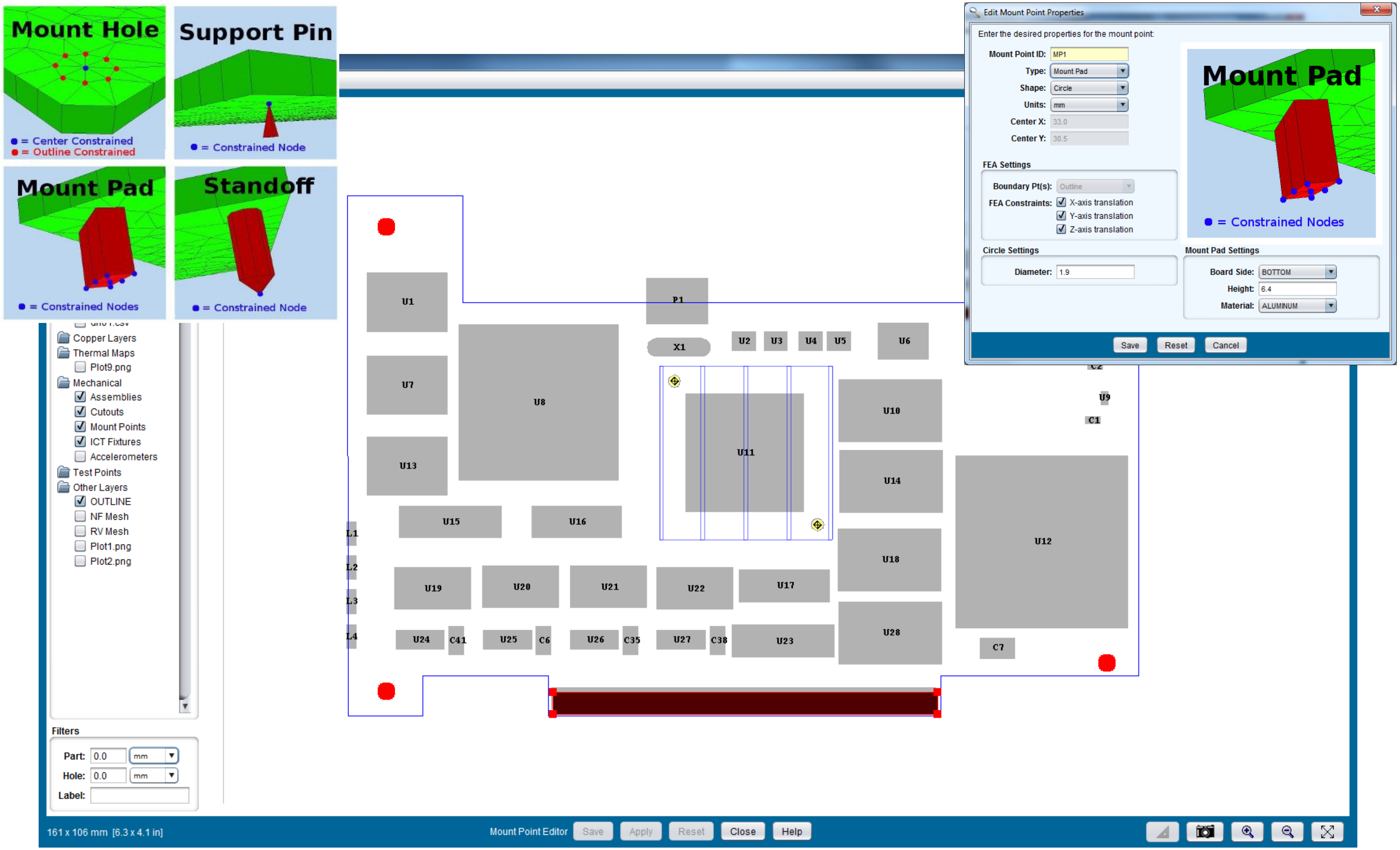
Boundary Conditions (Mounting)



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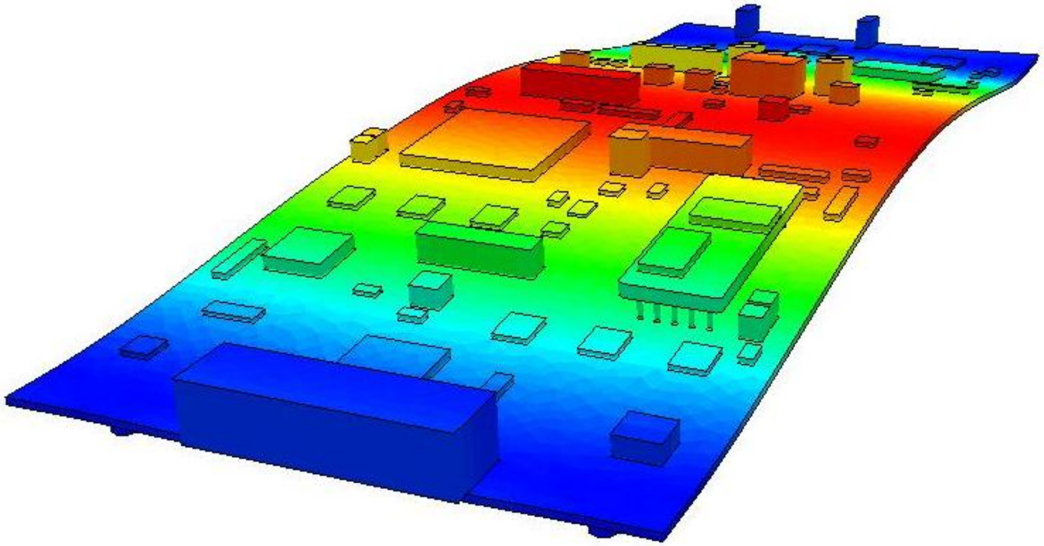
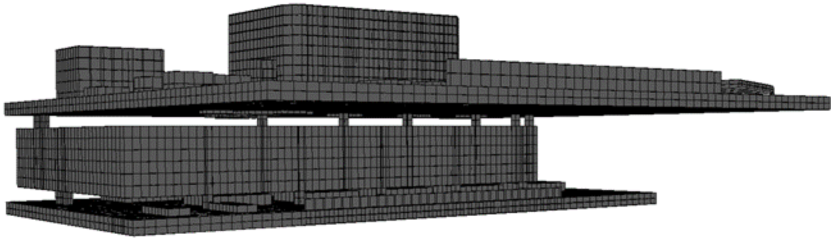
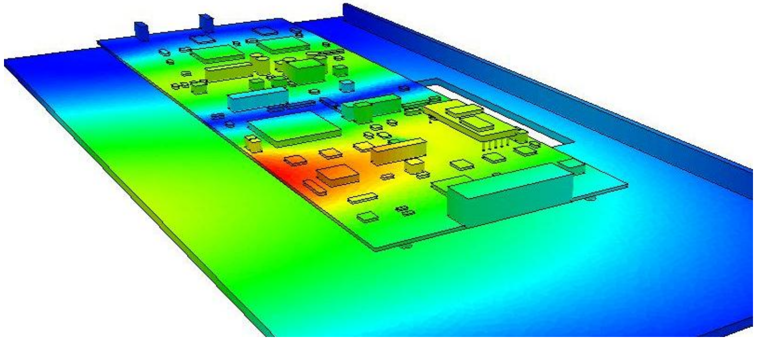
Sherlock - Assemblies







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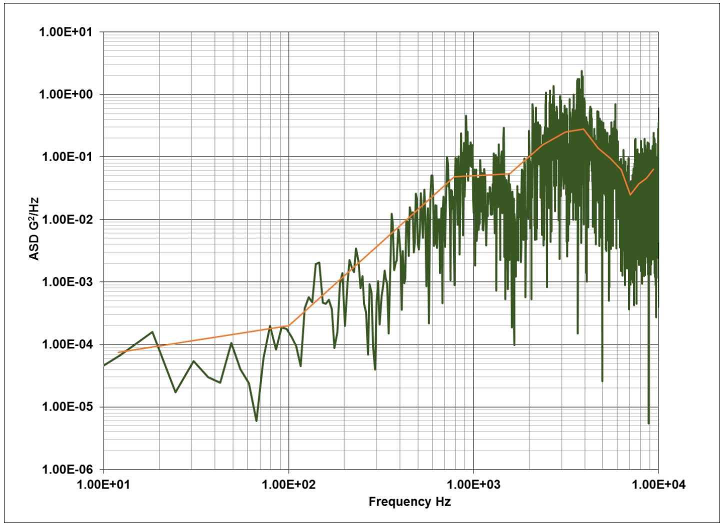
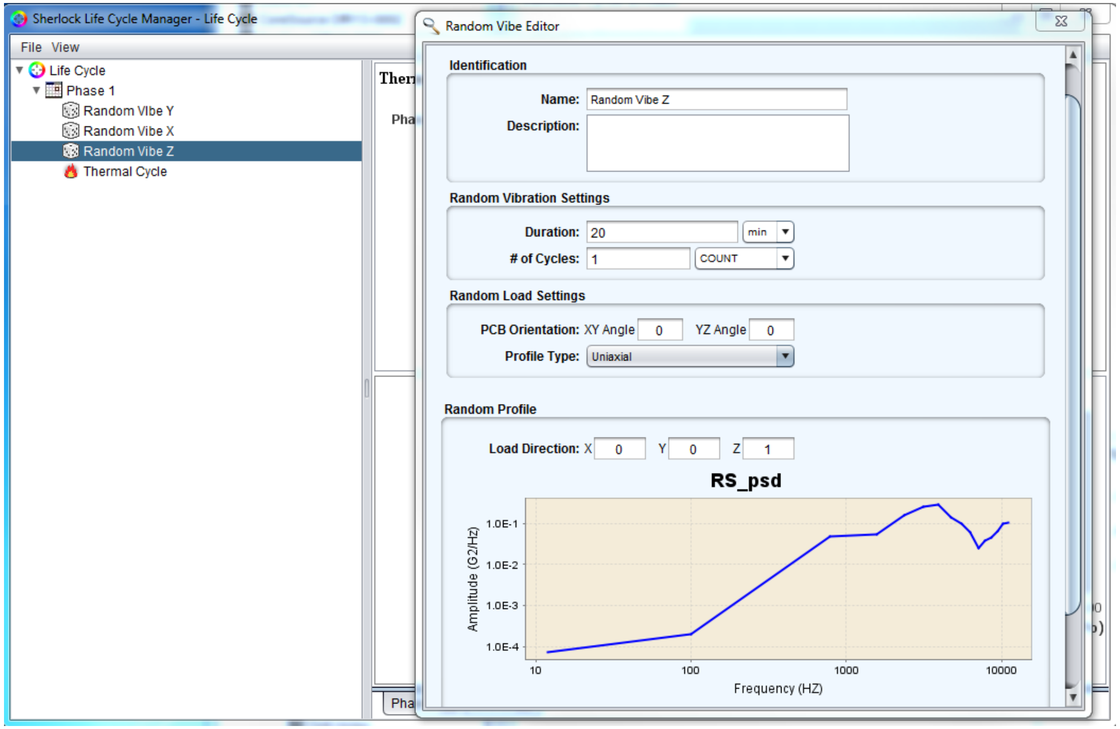
Pre-HALT Example

- X,Y,Z RS vibration
- HALT profile converted to PSD profile





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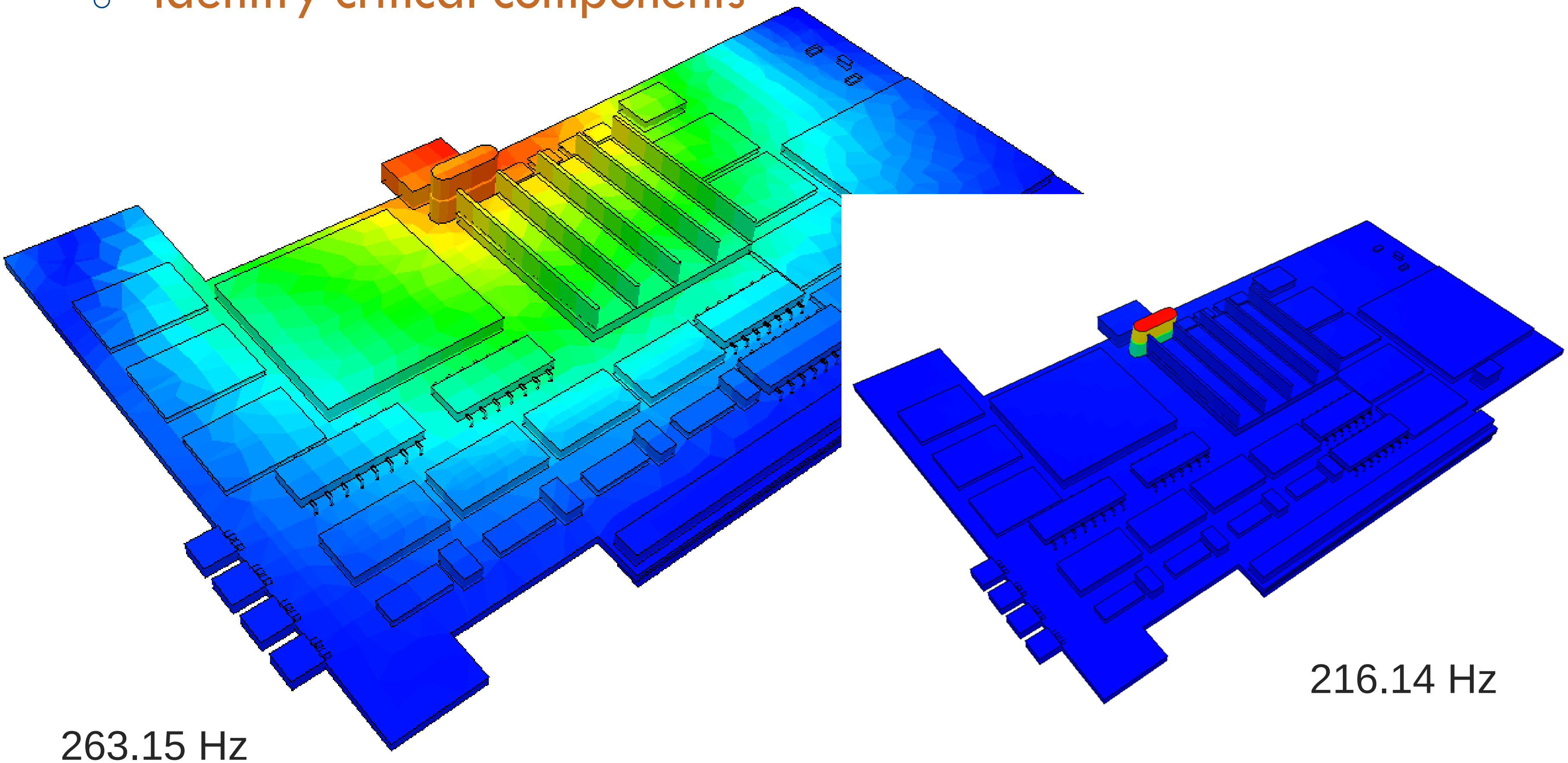
HALT Vibration - Modal Analysis

- Identify locations for accelerometers
- Identify critical components



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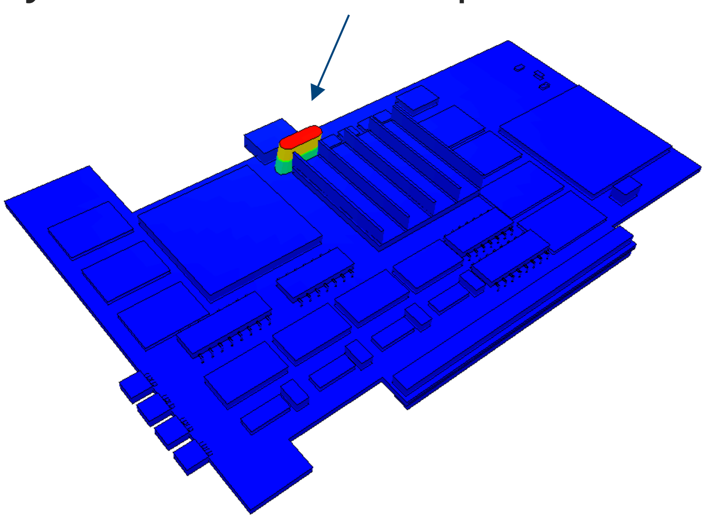
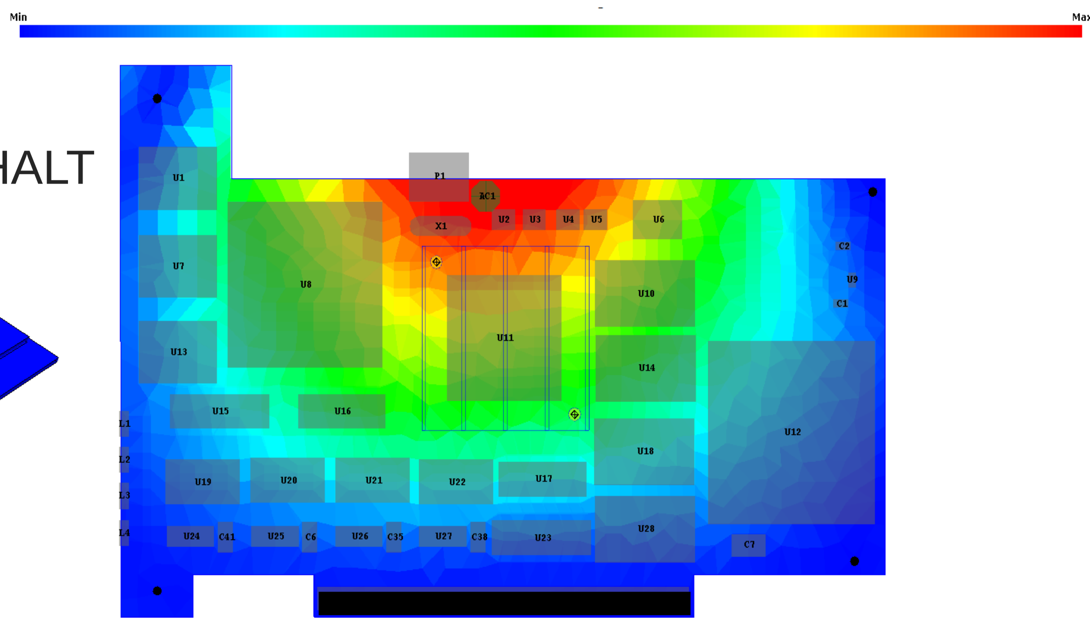
Accelerometer Locations

- Sherlock supports "Virtual Accelerometers"
- The modal analysis identifies the regions of greatest board response which can be used to place the HALT accelerometers

Through hole crystal oscillator may need to be staked prior to HALT





Nf = 263.2 Hz

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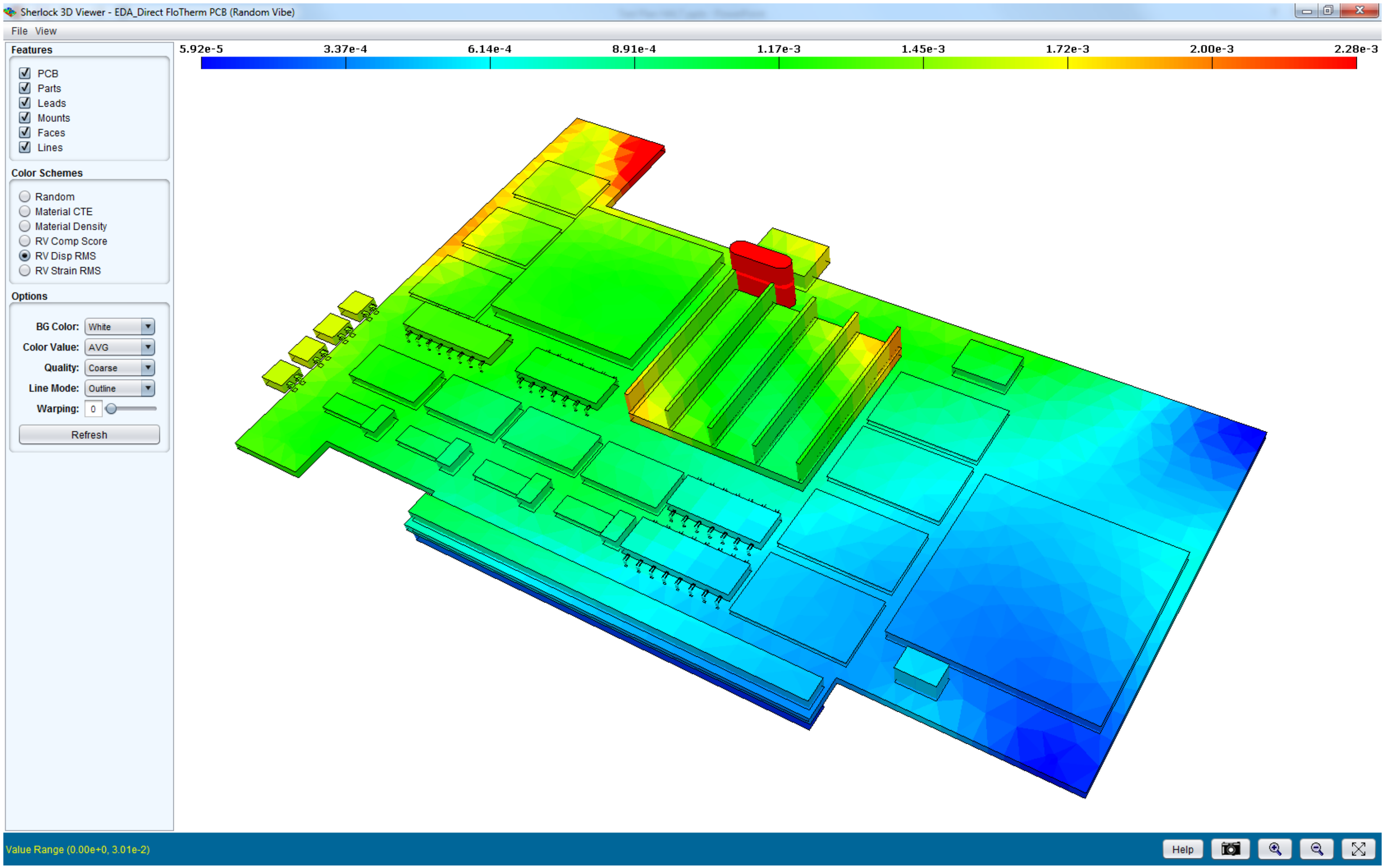
Product Response to Multiply Axis Vibration



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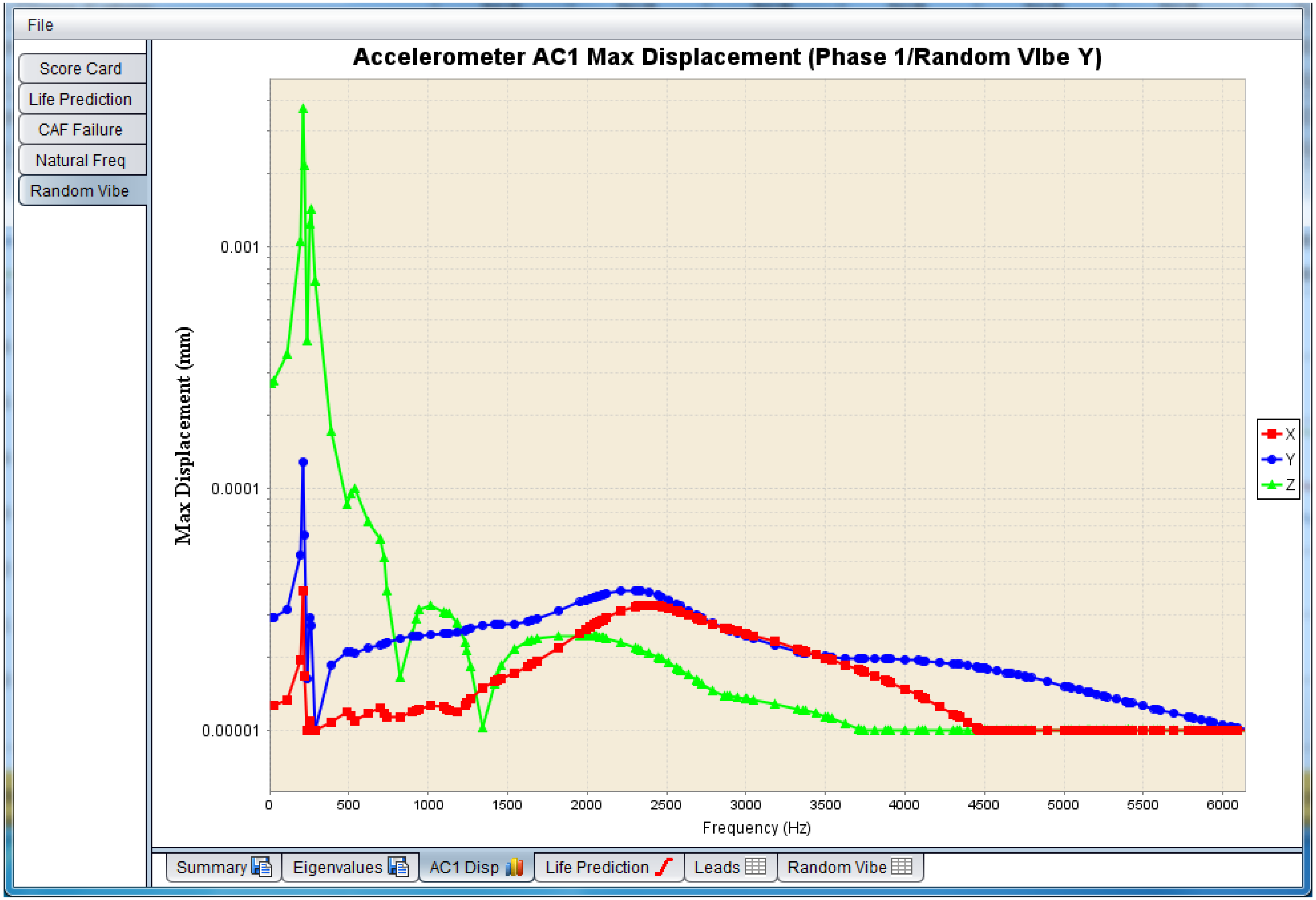
Accelerometer Response



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Critical Components

Current Results - EDA_Direct FloTherm PCB

File

Score Card | Life Prediction | CAF Failure | Natural Freq | Random Vibe

RefDes	Lead ID	Max PCB Strain	Max Part Strain	Max Lead Str...	Score
X1	0	6.3E-3	1.3E-2	1.4E-2	0.0
X1	1	6.2E-3	1.2E-2	1.4E-2	0.0

Current Results - EDA_Direct FloTherm PCB

File

Score Card | Life Prediction | CAF Failure | Natural Freq | Random Vibe

RefDes	Package	Part Type	Side	Solder	Max Disp	Max Strain	Damage	TTF (yrs)	Score
P1	CONN POL	PLUG CO...	TOP	SAC305	2.5E-2	9.7E-5	1.0E-6	>50	10.0
U2	SOIC-8 (MS-012AA)	IC	TOP	SAC305	2.2E-2	2.3E-5	1.0E-6	>50	10.0
C10	1206	CAPACITOR	BOT	SAC305	2.2E-2	2.1E-5	1.0E-6	>50	10.0
X1	CRYSTAL	TRANSDU...	TOP	SAC305	2.2E-2	6.3E-3	7.2E5	0.0	0.0
U3	SOIC-8 (MS-012AA)	IC	TOP	SAC305	2.2E-2	2.0E-5	1.0E-6	>50	10.0
U4	SOIC-8 (MS-012AA)	IC	TOP	SAC305	2.1E-2	2.1E-5	1.0E-6	>50	10.0
U5	SOIC-8 (MS-012AA)	IC	TOP	SAC305	2.0E-2	2.0E-5	1.0E-6	>50	10.0
U8	QFP-132 (MO-086...	IC	TOP	SAC305	2.0E-2	7.1E-5	1.0E-6	>50	10.0
C11	1206	CAPACITOR	BOT	SAC305	2.0E-2	2.0E-5	1.0E-6	>50	10.0
U11	BGA-264	IC	TOP	SAC305	1.9E-2	3.2E-5	1.0E-6	>50	10.0
R8	1206	RESISTOR	BOT	SAC305	1.9E-2	3.8E-5	1.0E-6	>50	10.0
U6	SOIC-20 (MO-271...	IC	TOP	SAC305	1.8E-2	2.2E-5	1.0E-6	>50	10.0
C16	1206	CAPACITOR	BOT	SAC305	1.8E-2	1.1E-5	1.0E-6	>50	10.0
C17	1206	CAPACITOR	BOT	SAC305	1.8E-2	1.6E-5	1.0E-6	>50	10.0
C15	1206	CAPACITOR	BOT	SAC305	1.7E-2	3.8E-5	1.0E-6	>50	10.0
C18	1206	CAPACITOR	BOT	SAC305	1.7E-2	1.2E-5	1.0E-6	>50	10.0
U10	TSOP-32 (MO-135...	IC	TOP	SAC305	1.7E-2	2.2E-5	1.0E-6	>50	10.0
R15	0805	RESISTOR	BOT	SAC305	1.7E-2	5.5E-6	1.0E-6	>50	10.0
X3	SOIC-36 (MO-230...	TRANSDU...	BOT	SAC305	1.6E-2	1.3E-5	1.0E-6	>50	10.0
R16	0805	RESISTOR	BOT	SAC305	1.6E-2	9.1E-6	1.0E-6	>50	10.0
C24	1206	CAPACITOR	BOT	SAC305	1.6E-2	3.9E-5	1.0E-6	>50	10.0
R19	0805	RESISTOR	BOT	SAC305	1.5E-2	5.2E-6	1.0E-6	>50	10.0
C19	1206	CAPACITOR	BOT	SAC305	1.5E-2	8.1E-6	1.0E-6	>50	10.0
C25	1206	CAPACITOR	BOT	SAC305	1.4E-2	5.8E-6	1.0E-6	>50	10.0
C27	1206	CAPACITOR	BOT	SAC305	1.4E-2	5.2E-6	1.0E-6	>50	10.0

Summary | Eigenvalues | AC1 Disp | Life Prediction | Leads | Random Vibe

Excessive lead stains (1.4%) will lead to a rapid HALT failure

X1 needs to be staked

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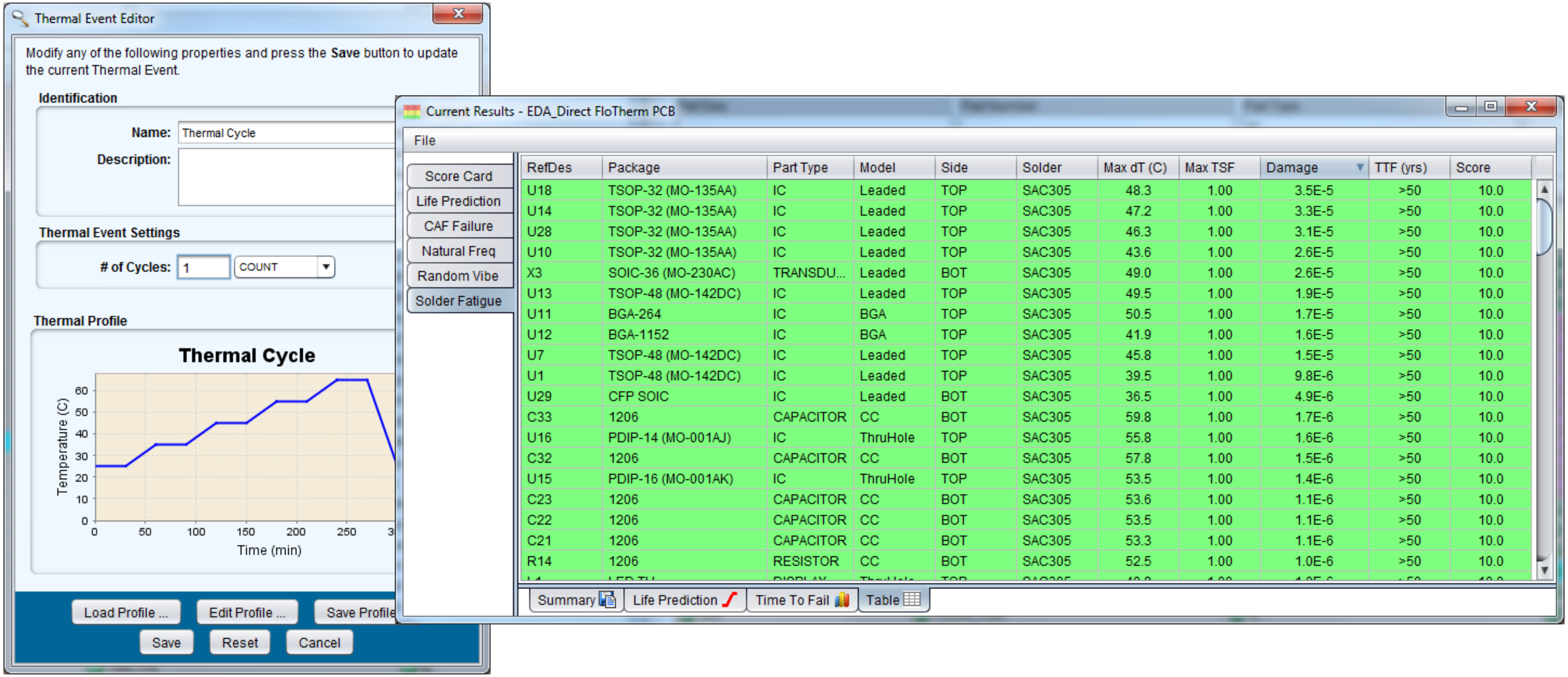
Thermal Cycling Conditions



RefDes	Package	Part Type	Model	Side	Solder	Max dT (C)	Max TSF	Damage	TTF (yrs)	Score
U18	TSOP-32 (MO-135AA)	IC	Leaded	TOP	SAC305	48.3	1.00	3.5E-5	>50	10.0
U14	TSOP-32 (MO-135AA)	IC	Leaded	TOP	SAC305	47.2	1.00	3.3E-5	>50	10.0
U28	TSOP-32 (MO-135AA)	IC	Leaded	TOP	SAC305	46.3	1.00	3.1E-5	>50	10.0
U10	TSOP-32 (MO-135AA)	IC	Leaded	TOP	SAC305	43.6	1.00	2.6E-5	>50	10.0
X3	SOIC-36 (MO-230AC)	TRANSDU...	Leaded	BOT	SAC305	49.0	1.00	2.6E-5	>50	10.0
U13	TSOP-48 (MO-142DC)	IC	Leaded	TOP	SAC305	49.5	1.00	1.9E-5	>50	10.0
U11	BGA-264	IC	BGA	TOP	SAC305	50.5	1.00	1.7E-5	>50	10.0
U12	BGA-1152	IC	BGA	TOP	SAC305	41.9	1.00	1.6E-5	>50	10.0
U7	TSOP-48 (MO-142DC)	IC	Leaded	TOP	SAC305	45.8	1.00	1.5E-5	>50	10.0
U1	TSOP-48 (MO-142DC)	IC	Leaded	TOP	SAC305	39.5	1.00	9.8E-6	>50	10.0
U29	CFP SOIC	IC	Leaded	BOT	SAC305	36.5	1.00	4.9E-6	>50	10.0
C33	1206	CAPACITOR	CC	BOT	SAC305	59.8	1.00	1.7E-6	>50	10.0
U16	PDIP-14 (MO-001AJ)	IC	ThruHole	TOP	SAC305	55.8	1.00	1.6E-6	>50	10.0
C32	1206	CAPACITOR	CC	BOT	SAC305	57.8	1.00	1.5E-6	>50	10.0
U15	PDIP-16 (MO-001AK)	IC	ThruHole	TOP	SAC305	53.5	1.00	1.4E-6	>50	10.0
C23	1206	CAPACITOR	CC	BOT	SAC305	53.6	1.00	1.1E-6	>50	10.0
C22	1206	CAPACITOR	CC	BOT	SAC305	53.5	1.00	1.1E-6	>50	10.0
C21	1206	CAPACITOR	CC	BOT	SAC305	53.3	1.00	1.1E-6	>50	10.0
R14	1206	RESISTOR	CC	BOT	SAC305	52.5	1.00	1.0E-6	>50	10.0

As expected the thermal cycling damage during halt does not cause fatigue, if a solder joint failure occurs during HALT thermal cycling then it is due to a soldering defect

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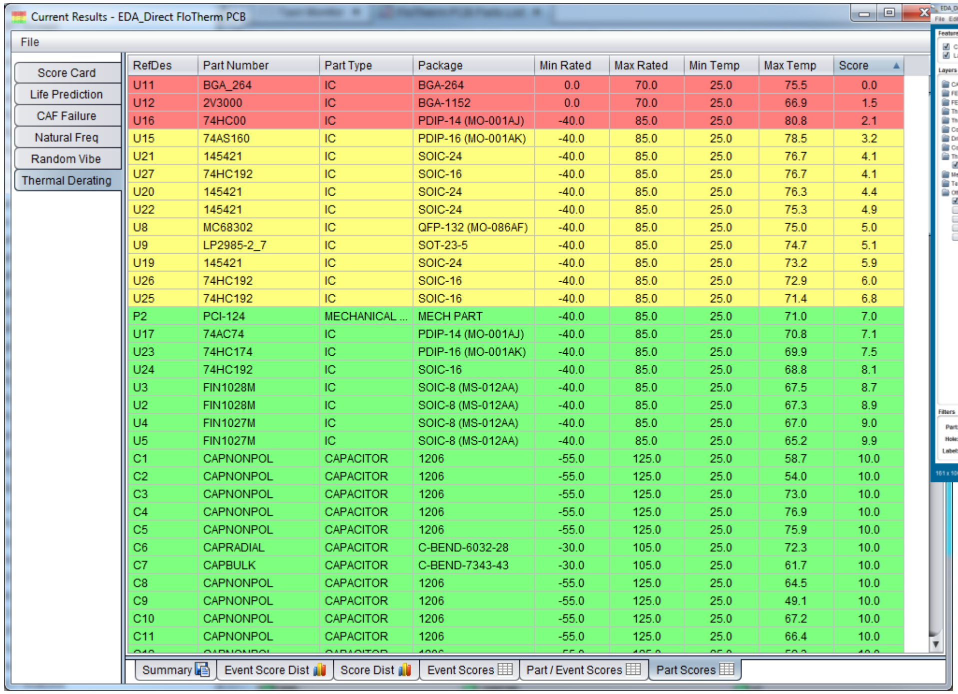
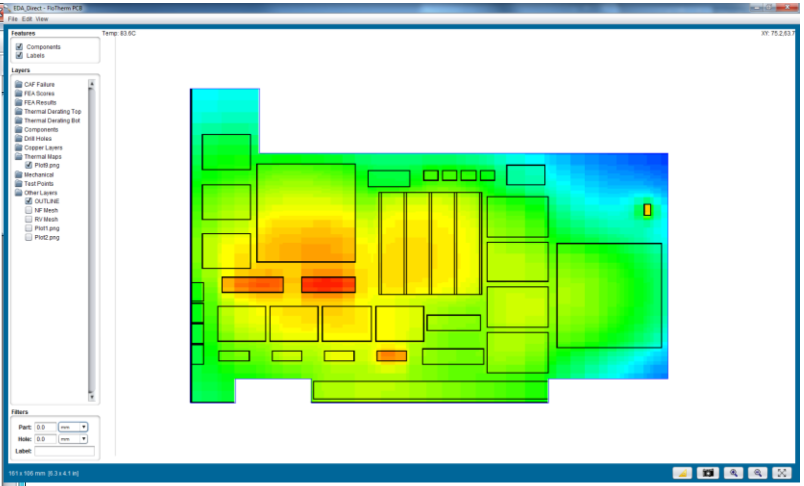
Thermal Derating

- Sherlock can compare the temperature profile to the component ratings
- The actual temperature limits before the part stops operating (either soft or hard) will be determined by HALT

Import thermal analysis results



RefDes	Part Number	Part Type	Package	Min Rated	Max Rated	Min Temp	Max Temp	Score
U11	BGA_264	IC	BGA-264	0.0	70.0	25.0	75.5	0.0
U12	2V3000	IC	BGA-1152	0.0	70.0	25.0	66.9	1.5
U16	74HC00	IC	PDIP-14 (MO-001AJ)	-40.0	85.0	25.0	80.8	2.1
U15	74AS160	IC	PDIP-16 (MO-001AK)	-40.0	85.0	25.0	78.5	3.2
U21	145421	IC	SOIC-24	-40.0	85.0	25.0	76.7	4.1
U27	74HC192	IC	SOIC-16	-40.0	85.0	25.0	76.7	4.1
U20	145421	IC	SOIC-24	-40.0	85.0	25.0	76.3	4.4
U22	145421	IC	SOIC-24	-40.0	85.0	25.0	75.3	4.9
U8	MC68302	IC	QFP-132 (MO-086AF)	-40.0	85.0	25.0	75.0	5.0
U9	LP2985-2_7	IC	SOT-23-5	-40.0	85.0	25.0	74.7	5.1
U19	145421	IC	SOIC-24	-40.0	85.0	25.0	73.2	5.9
U26	74HC192	IC	SOIC-16	-40.0	85.0	25.0	72.9	6.0
U25	74HC192	IC	SOIC-16	-40.0	85.0	25.0	71.4	6.8
P2	PCI-124	MECHANICAL ...	MECH PART	-40.0	85.0	25.0	71.0	7.0
U17	74AC74	IC	PDIP-14 (MO-001AJ)	-40.0	85.0	25.0	70.8	7.1
U23	74HC174	IC	PDIP-16 (MO-001AK)	-40.0	85.0	25.0	69.9	7.5
U24	74HC192	IC	SOIC-16	-40.0	85.0	25.0	68.8	8.1
U3	FIN1028M	IC	SOIC-8 (MS-012AA)	-40.0	85.0	25.0	67.5	8.7
U2	FIN1028M	IC	SOIC-8 (MS-012AA)	-40.0	85.0	25.0	67.3	8.9
U4	FIN1027M	IC	SOIC-8 (MS-012AA)	-40.0	85.0	25.0	67.0	9.0
U5	FIN1027M	IC	SOIC-8 (MS-012AA)	-40.0	85.0	25.0	65.2	9.9
C1	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	58.7	10.0
C2	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	54.0	10.0
C3	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	73.0	10.0
C4	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	76.9	10.0
C5	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	75.9	10.0
C6	CAPRADIAL	CAPACITOR	C-BEND-6032-28	-30.0	105.0	25.0	72.3	10.0
C7	CAPBULK	CAPACITOR	C-BEND-7343-43	-30.0	105.0	25.0	61.7	10.0
C8	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	64.5	10.0
C9	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	49.1	10.0
C10	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	67.2	10.0
C11	CAPNONPOL	CAPACITOR	1206	-55.0	125.0	25.0	66.4	10.0



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During the HALT Planning Stage

- Sherlock identifies critical components and they are mitigated before HALT is performed
- Different mounting configurations are investigated in Sherlock and modified to prevent unrealistic movement during the HALT test
- Thermal ratings and the thermal cycle are compared and possible weak components are identified
  - The actual limits need to be determined
- The hard questions
  - How much of a margin do I need on temperature (20 to 30C)
  - What is a good vibration level, depends on the product and use

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