PRODUCT RELIABILITY TESTING:
Environmental, Mechanical and Packaging
Case study: 19” Rackmount Switch
Overview

• **Background**
  – Why Test?, DOE, Product Classifications
• **Environmental tests**
  – Temperature, Humidity, Altitude
• **Mechanical tests**
  – Mechanical Shock, Vibration, Handling
• **Shipping / Packaging Tests**
  – Drop, Compression, Vibration
• **Conclusions and Questions**
Why Test?

• Products **will** be subjected to hazards
  – Shipment
  – Storage extremes
  – Operating environment
  – Rough handling, installation

• Regulatory / Certification Requirements
  – Safety (Optical, Acoustic, Electrical, Fire)
  – EMI/EMC
  – Product Functionality

• Customer Satisfaction, Warranty, Liability
Establishing the Test Plan

• Design of Experiments (DoE)
  – Characterize environments DUT will see
    • Define test inputs to cover all hazards
      – Environmental, Mechanical, Shipping
    • Consider unique / combined environments
  – Determine acceptance criteria / inspections
  – Start small (EVT, DVT, Final Production)
    • Test temperature and mechanical handling
  – Test to level vs. testing to failure
### Product Classifications

- **Example: Rackmount network switch**

<table>
<thead>
<tr>
<th>Handheld Product</th>
<th>Small Product</th>
<th>Large Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smaller units a user will carry by hand or their person</td>
<td>A single user can install / move without assistance. (usually &lt;100 pounds)</td>
<td>Requires two or more people or mechanical lift to install / move. (usually &gt;100 lbs)</td>
</tr>
<tr>
<td>Ships single parcel and freight (unitized load)</td>
<td>Ships single parcel and freight (unitized load)</td>
<td>Ships as freight only</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Moderate Environment</strong></th>
<th><strong>Severe Environment</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>General office or server farm environment. Moderate operating environment.</td>
<td>Consumer product, could be used anywhere, could be in used in extreme temperature conditions.</td>
</tr>
</tbody>
</table>
Non-Operational Temperature

• Define temperature range
  – Storage temperatures
    • -40°C to +85°C (Severe)
    • -30°C to +60°C (Moderate)
  – Shipping conditions
    • Cold, Tropical, Desert
    • -40°C, 40°C/90%RH, 60°C/30%RH
  – Static extremes, cyclic and shock tests
  – Standards: IEC 60068-2-1 (Cold), IEC 60068-2-2 (Hot),
    IEC 60068-2-14 (Thermal Cycle), IEC 60068-2-78 (Humidity),
    ASTM D4332 (Shipping)

• Common issues / results
  – Thermal expansion / contraction
  – Oxidation / Corrosion
  – Exceeding material limits, mechanical failures
Operating Temperature Setup

- Instrument components of interest
  - Internal temp sensors or externally mounted
  - Define maximum allowable operating temperatures
Operating Temperature / Humidity

• Test conditions
  – Cold: 0°C
  – Hot/Wet: 40°C / 90%RH
    • Dew point and condensation
  – Hot/Dry: 40°C / 20%RH

• Test plan
  – Operate at each condition for 12 – 24 hours
  – Power cycle unit on / off

• Common Issues / Results
  – Electrical problems (often caused by condensation)
  – Component overheating
Operating Temperature / Humidity

Operating Temperature Rise

<table>
<thead>
<tr>
<th>Ambient (°C)</th>
<th>Temperature Rise (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>3.04</td>
</tr>
<tr>
<td>25.00</td>
<td>3.19</td>
</tr>
<tr>
<td>40.00</td>
<td>3.17</td>
</tr>
</tbody>
</table>
Non-Operating Altitude

• Define environment (shipment, storage)
  – Usually tested to 14,000, 16,000 or 40,000-ft equivalent
  – Only applicable for sealed volumes, potted parts, etc.

• Common tests
  – 1 hour duration at low pressure
  – ASTM D6653, IEC 60068-2-13

• Common results
  – Expanded/imploded parts
Operating Altitude

• Define environment (end use)
  – Usually tested to 10,000 or 14,000-ft equivalent
  – Low air pressure greatly reduces effectiveness of convective cooling

• Common tests
  – 12-24 hour duration at low pressure
  – IEC 60068-2-13

• Common results
  – Unit overheating
Operating Altitude - Data

Low Pressure (Altitude)

<table>
<thead>
<tr>
<th>Ambient (°C)</th>
<th>Altitude (feet)</th>
<th>Temperature Rise (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.00</td>
<td>sea level</td>
<td>3.18</td>
</tr>
<tr>
<td>40.00</td>
<td>10,000</td>
<td>3.79</td>
</tr>
<tr>
<td>40.00</td>
<td>14,000</td>
<td>4.11</td>
</tr>
</tbody>
</table>
Other Environmental Tests

- Ultraviolet (UV) Light
  - ASTM G154 (UV only) or G155 (Full Spectrum)
  - Materials selection or comparative testing
  - Fading, legibility, brittle plastics

- Corrosive Atmosphere
  - ASTM B117
  - Corrosion of metals, dissimilar metals uncoated parts

- Water Spray / Ingress Protection
  - IEC 60529
  - Depends on application
Other Environmental Test Considerations

• Typical input vs. worst case scenario
• Operating Inputs
  – High / Low Nominal Voltage
• Safety
  – Do safety cut outs work (thermal)
  – Does the device fail safely?
• Acceptance Criteria
  – Cosmetic, functional, safety
Questions
Mechanical Testing - Setup

• Why use Accelerometers?
  – Resonance search
  – Characterize response to mechanical excitations
  – Characterize response to operating components (fans)

• Typical Test Setup
  – 1 Accelerometer on chassis
  – 1 to 4 Accelerometers on components of interest
Mechanical Testing - Setup

- Choose most rigid practical chassis location
Mechanical Testing - Setup

• Mounting accelerometer
Mechanical Testing - Setup

• Component Accelerometer
  – Sensitive components / spring-mass systems
  – Use appropriate adhesion method!
Mechanical Testing - Setup
Mechanical Testing - Setup
Mechanical Testing - Setup
Mechanical Testing - Orientations
Operating / Non-Operating Sine Vibration

- **Reasons to test**
  - Non-operating: Resonance Search
  - Operating: Unique and Severe Use Environments (Stress Test)

- **Typical Test**
  - All tests: X, Y, Z axis
  - Resonance search: 2 sweeps
  - Stress test: 10 sweeps / resonant dwell
  - 0.1G to 5.0G constant acceleration
  - Frequency Domain: 5-500Hz
  - Test Standards
    - ASTM D3580, ASTM D5112, IEC 60068-2-6

- **Common Issues / Results**
  - Unit shut down or operating errors
  - Unsupported / surface mount component failure
  - Critical component resonance / failure
Sine Vibration Control
**Sine Vibration Response - Chassis**

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Chassis</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.00</td>
<td>100.000</td>
</tr>
<tr>
<td>10.00</td>
<td>10.000</td>
</tr>
<tr>
<td>50.00</td>
<td>1.000</td>
</tr>
<tr>
<td>100.00</td>
<td>0.100</td>
</tr>
<tr>
<td>500.00</td>
<td>0.010</td>
</tr>
</tbody>
</table>

![Graph showing sine vibration response for Chassis](image-url)
Sine Vibration Response - PCB

PCB: 171.2734 Hz, 25.1815 (gn)/(gn)
PCB: 216.4476 Hz, 21.3627 (gn)/(gn)

dx = -45.1742 Hz, dy = 3.8188 (gn)/(gn)
Operating / Non-Operating Random Vibration

• Reasons to test
  – Non operating: Resonance Search / Shipment
  – Operating: End use environment

• Typical Tests
  – All tests: X, Y, Z axes tested / 10-60 minutes per axis
  – Non-operating: 5Hz to 500Hz up to 5 Grms
  – Operating: 5Hz to 500Hz up to 1 Grms

• Test Standards
  – ASTM D3580, ASTM D5112, IEC 60068-2-64

• Common Issues / Results
  – Operational issues
  – Unsupported / surface mount component failure
  – Critical component resonance / failure
Non-Operating Random Vibration

Example: 1.35 Grms, 2-500 Hz
Random Vibration Control

![Graph showing (gn)^2/Hz vs Frequency (Hz)]

- **control(f)**
- **profile(f)**

Frequency (Hz)

(gn)^2/Hz

- 0.1000
- 0.0100
- 0.0010
- 1.00E-04
- 10.00
- 100.00
- 500.00
Random Vibration Response - Chassis

![Graph showing random vibration response for Chassis]
Random Vibration Response - PCB

PCB: 170.6250 Hz, 20.5499 ((g/n)²/Hz)/((g/n)²/Hz)
PCB: 216.8750 Hz, 19.1423 ((g/n)²/Hz)/((g/n)²/Hz)

dx = -46.2500 Hz, dy = 1.4077 ((g/n)²/Hz)/((g/n)²/Hz)
Operating Mechanical Shock

• Typical Test
  • Half-sine duration (0.5ms – 18ms)
  • Peak G level (6-50G’s)
  • X, Y, Z axes both directions

• Test Standards
  • ASTM D3332, IEC 60068-2-27

• Common Issues / Results
  • Unsupported / surface mount component failure
Non-Operating Mechanical Shock

• Typical Test
  • Half-sine duration (0.5ms – 18ms)
  • Will see ‘shock’ in shipment
  • Peak G level (6-50G’s)
  • X, Y, Z axes both directions

• Consider using trapezoidal pulse shape

• Test Standards
  • ASTM D3332, IEC 60068-2-27

• Common Issues / Results
  • Unsupported / surface mount component failure
Non Operating Mechanical Shock

Example: 40G’s, 11ms, Half-Sine
Mechanical Shock - Control

![Graph showing mechanical shock control profile versus time in milliseconds. The x-axis represents time in milliseconds from -11 to 22, and the y-axis represents the control and profile values from -50.0000 to 50.0000. The control profile is represented by a blue line, and the profile is represented by a green line. There is a peak at around 4 milliseconds with a value of approximately 50.0000.](image-url)
Mechanical Shock Response - Chassis

![Graph showing Mechanical Shock Response - Chassis](image-url)
Mechanical Shock Response - PCB
Manual Handling

• Simulate Installation Drop
Mechanical Cycling

• All moving mechanical components should be evaluated
• For Network Switch
  • AC Cord / LAN Connections
  • ~100 cycles
  • Define cycle force, speed, duration
  • Inspect periodically
  • Test by hand or by machine
• Test Standards
  • Various
• Common Issues / Results
  • Quick wear out
  • Change in actuation or insertion/removal force
Questions
Shipping

• Every product will be shipped!
• Common test inputs
  • Environmental Conditioning
  • Freefall Drop / Side Impact
  • Compression
  • Vehicle Vibration
  • Other hazards
Common Shipment Standards

• Small Parcel (less than 150 pounds)
  • ISTA 2A or 3A
  • ASTM D4169 (DC3 or DC13)
  • ASTM D7386 (TS4)

• Freight (greater than 150 pounds, or on pallet)
  • ISTA 2B, 3B, 3E
  • ASTM D4169 (DC5 or DC6)
Package Orientations
Environmental Conditioning

• Simulate extreme environments in shipping

• ASTM D4332 Standard Conditions
  • Cold (-30°C)
  • Desert (60°C / 15% RH)
  • Tropical (40°C / 90% RH)

• Stresses hygroscopic packaging (CFB)
  • May cause condensation on EUT
  • May cause tape or closures to come open
Small Parcel Packaged Freefall Drop

• ISTA 2A parameters
  • 10 drops: 1 corner, 3 edges, 6 faces
  • Height based on weight (38”)
  • Test equipment per: ASTM D5276

• Common Issues / Results
  • Box denting, box failure, product damage
Packaged Freefall Drop
# Packaged Freefall Drop - Chassis

## Acceleration vs Time

<table>
<thead>
<tr>
<th>Channel Description</th>
<th>G's</th>
<th>msec</th>
<th>In/S</th>
<th>Filter Hz</th>
<th>Max G's</th>
<th>Min G's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch1 Chassis X Axis</td>
<td>37.05</td>
<td>2.60</td>
<td>34.89</td>
<td>500.00</td>
<td>37.05</td>
<td>-17.93</td>
</tr>
<tr>
<td>Ch2 Chassis Y Axis</td>
<td>66.82</td>
<td>7.20</td>
<td>108.73</td>
<td>500.00</td>
<td>66.82</td>
<td>-8.63</td>
</tr>
<tr>
<td>Ch3 Chassis Z Axis</td>
<td>253.32</td>
<td>6.20</td>
<td>302.92</td>
<td>500.00</td>
<td>253.32</td>
<td>-92.87</td>
</tr>
</tbody>
</table>

![Graph showing acceleration vs time for different channels](image-url)
Packaged Freefall Drop - PCB

<table>
<thead>
<tr>
<th>Channel Description</th>
<th>G's</th>
<th>msec</th>
<th>In/G</th>
<th>Filter Hz</th>
<th>Max G's</th>
<th>Min G's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch1 PCB X Axis</td>
<td>106.77</td>
<td>1.20</td>
<td>22.36</td>
<td>500.00</td>
<td>106.77</td>
<td>-28.28</td>
</tr>
<tr>
<td>Ch2 PCB Y Axis</td>
<td>72.73</td>
<td>1.20</td>
<td>17.38</td>
<td>500.00</td>
<td>72.73</td>
<td>-35.27</td>
</tr>
<tr>
<td>Ch3 PCB Z Axis</td>
<td>419.69</td>
<td>3.60</td>
<td>277.72</td>
<td>500.00</td>
<td>419.69</td>
<td>-176.94</td>
</tr>
</tbody>
</table>
Package Compression

• Top load to simulate stacking in shipment
  • Top load based upon cubic volume above box in a tractor trailer
• Sample compression formula (ISTA 2A)
  • Top load = Wt x (S – 1) x F x 1.4
  • 415 lbs = 3.7 x (21 – 1) x 4 x 1.4
  • Test equipment per ASTM D642

• Common issues / results
  • Box failure
  • Damage to internal components
Vehicle Vibration

• Simulates truck/aircraft shipment
• ISTA 2A
  • 30 minutes base, 10 minutes top, side, end
  • Test Equipment per: ASTM D4728

Common Issues / Results
• Components coming loose (SMT, large mass)
• Resonance
• Scuffing
Vehicle Vibration
Vehicle Vibration – ISTA 2A Profile

![Graph showing Vehicle Vibration – ISTA 2A Profile](image-url)
Vehicle Vibration – Chassis Response

Chassis (Z axis): 15.6250, 2.3483
Vehicle Vibration – PCB response

PCB (Z axis): 18.1250, 3.0485
dx = -155.6250, dy = -1.1496
RMS = 14.5191, Power = 210.8054
Parting Thoughts

• Start by defining environment and regulatory requirements.
  – Establish acceptance criteria

• Think about design and material choices first
  – Reference existing solutions!

• Start with small portions of the test plan
  – Test as early as possible, expect to have findings
  – Take corrective action before finalizing tooling

• Don’t forget you have to ship it!
Next Webinar: Packaging Dynamics Series

#1: Overview and Definition of Terms – Jan 2015  DONE!

#2: Defining & Quantifying the Distribution Environment Through Which All Products Must Travel – March 2015  DONE!

#3: Determining the Vibration Sensitivity & Shock Fragility of Products; Test Methods, End Results, and Significant Insights – DONE!


#5: Design and Testing of the Protective Package System; How We Know When the Job Was Done Correctly – Oct 2015
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THANK YOU!

Please feel free to Contact Us with any questions or assistance with your testing needs.

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