Using Calibration Testing as a method of reducing Product Time-Based Failures Risk

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MISSION STATEMENT

NI equips engineers and scientists with systems that accelerate productivity, innovation, and discovery.
Defects are expensive

<table>
<thead>
<tr>
<th>Industry</th>
<th>Warranty Claims*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>2.50%  $18.8 billion</td>
</tr>
<tr>
<td>Computers</td>
<td>1.70%  $165 million</td>
</tr>
<tr>
<td>Homes</td>
<td>0.80%  $712 million</td>
</tr>
<tr>
<td>Planes</td>
<td>0.40%  $1.6 Billion</td>
</tr>
</tbody>
</table>

https://www.warrantyweek.com/archive/ww20190627.html
* Info derived from [www.statista.com](http://www.statista.com) and [www.ibisworld.com](http://www.ibisworld.com)
Add Health Monitoring to Current Solution

Reliability Prediction

FMEA

Accelerated Life Testing

Supplier Management

RMA Analysis

Customer Complaints

T&M On-going Calibration
How Test & Measurement (T&M) Companies handle Product returns

**Calibration Cycles $$**

- Pass/Fail with Adjust
- Limited Trending
- Adjust Calibrations timing as needed
- Replace/Rework

**Internal BIST/Self Test $**

- Compensates for Environment
- User defined for testing events

**Fix on Failure $$$$**

- Customer Risk
- Extensive Downtime
Benefits of different forms of Health Monitoring: Self-Test, Calibration

Accuracy Matters

- Electronic component naturally drift over time, which can cause uncertainty in your measurements – Loss and/or Corrupted Data

Product Yield are Important

- Two Production issues that can drive down your yields are:
  - False Passes: Cause a bad unit to appear to pass
  - False Failures: Describes the case where a good unit appears to fail a test

Compliance with Standards

- Provides a benchmark for end customers

Downtime is Expensive

- Self-Test, Calibration can help avoid more expensive unplanned downtime.

## List of Typical Devices used by NI with Drift or Changes over time Concerns

### 5-year RMA

<table>
<thead>
<tr>
<th>Type of Components</th>
<th>Application</th>
<th>Failure Rate “Predicted”</th>
<th>Life Data to Failure (CAL)</th>
<th>Life Data to Failure (Non-Cal)</th>
<th>Customer Issue</th>
<th>Typ. Failure Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision Oscillators</td>
<td>Freg. Synthesis Timing</td>
<td>0.0165</td>
<td>1,610 Days</td>
<td>2,184 Days</td>
<td>Cannot Lock</td>
<td>Change in Resonance</td>
</tr>
<tr>
<td>Op. Amps</td>
<td>Drive Circuits</td>
<td>1.140</td>
<td>1,820 Days</td>
<td>2,003 Days</td>
<td>Non-Opp</td>
<td>Voltage Range Out of Limit</td>
</tr>
<tr>
<td>RF Amplifiers</td>
<td>Transmit/Rec.</td>
<td>0.827</td>
<td>1,669 Days</td>
<td>2,245 Days</td>
<td>Rx/Tx Power variation</td>
<td>Gain Degradation</td>
</tr>
<tr>
<td>Ceramic MLCC Capacitors</td>
<td>Filtering/Decoupling</td>
<td>0.7023</td>
<td>1,893 Days</td>
<td>2,240 Days</td>
<td>Random Failure</td>
<td>Delamination microcracks</td>
</tr>
<tr>
<td>Seals/Gaskets</td>
<td>EMI/EMC Mgt.</td>
<td>2.946</td>
<td>1,890 Days</td>
<td>1,850 Days</td>
<td>EMI/RF Leakage.</td>
<td>Relaxation over time</td>
</tr>
<tr>
<td>Fuse</td>
<td>Surge/Transient</td>
<td>2.727</td>
<td>1,820 Days</td>
<td>2,230 Days</td>
<td>Non-Opp. Safety Risk</td>
<td></td>
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Discussion

- Mechanical Device (Gasket) overlay matched
- Ceramic Capacitors and RF Amplifier greatest level of separation from Calibration Returns and Repair Returns
- Fuses are impacted by uncontrolled events and environment.
- Oscillators are typically adjusted or tuned during Calibration.
Case Study #1 - RF Amplifier

- RF Amplifiers
  - Know for “gracefully degradation”
  - Bias Level of Gain Amplifiers critical design aspect
  - Understand Thermal Management and its effects on life and overall health

Shifting a Paradigm...

“...aging has traditionally been the bailiwick of engineers who guarantee the transistor will operate for 10 years or so... But as transistors are scaled down further and operated with thinner voltage margins, it’s becoming harder to make those guarantees... transistor aging is emerging as a circuit designer’s problem.”

Reliability Maintenance and Managing Risk
Conference 2019

**Thermal Issue - RF Amplifier - IR Thermal/Optical Image**
*(70°C Stage Temp.)*

- **Die Size:** 486um x 280um
- **Calculated Junction Temp.** 126°C
- **As Measured** 156°C Peak on the Transistor
- **Vendor Spec. Limit** 150°C

Note: Size of important features within 50mil by 80mil IC Package

*Updated Thermal Solution lowered Junction Temp by 32 degrees C*
Case Study #2 - Ceramic Capacitors

Life Plots

Ceramic Multi-Layer Capacitors

• Wide variation “lack-of Fit” with random failures of non-Calibration related failures.

• Calibrated units detected defects ~427 days earlier than Non-Calibrated units. *Reducing Customer Down-time*
Case Study #2 - Ceramic Capacitors

Ceramic Capacitors Typical Failure Modes:

- Failed open
- Failed shorted
  - *Shorted as shown with de-lamination, microcracks*
- Catastrophic
- Contamination
- Solder Joint Fractures
- Handling Damage

Inherent defects can propagate over time and impact key filtering or parasitic circuit applications

C-Mode Scanning Acoustic Microscope showing cracks and/or delamination's
How can other companies implement this type of program

**Design**

- Incorporate Self-Test Circuit Blocks into the design
- FMEA – ID Failure Risk
- Understand BOM Risk (MTBF, Industry Data, Commercial vs. industrial components)
- Up-Screening of critical components

**Product Launch**

- Physics of Failures on all early failures

**Field Sustaining**

- Heath Monitoring
- RMA/CAPA
Conclusion

Calibration & Hardware monitoring addresses:
- Addresses Component variation
- Thermal detection
- ID’s Defects early

Perform Trade-off Analysis early in the design to understand the risk of not using product monitoring technique vs. Customer Satisfaction

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