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AUTOMATED DESIGN ANALYSIS™

2019 DESIGN FOR RELIABILITY CONFERENCE

Design for Reliability for Connectors: A Review of Failure Modes and Mitigations

Your Partner Throughout
the Product Life Cycle

March 25, 2019 | Michael Blattau

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Introduction

- Connectors are perhaps the most critical component of a design and are often the first item that fails in a device

- Internal connections and external (separable) connectors typical fail due to wear-out of the contact surfaces
  - Internal connection fail from micro motion (fretting)
  - External connectors due to macro motion (user insertions)

- There are also a number of other issues that may cause connector failures
  - Plating mis-match
  - Red phosphorus
  - Connector Alignment
  - Corrosion (electromigration)

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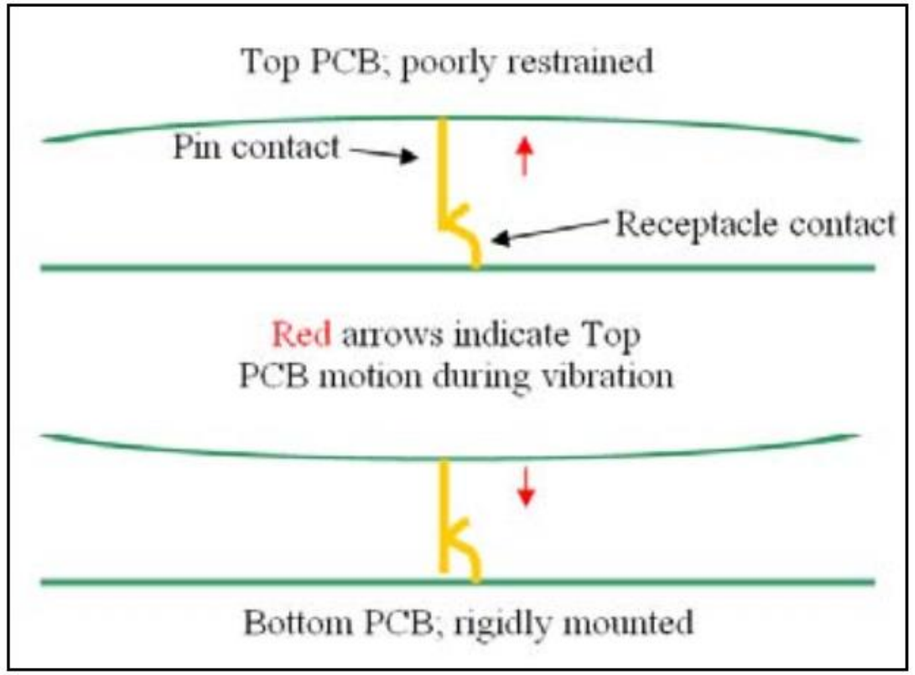
Fretting

- Caused by micro-motion (less than 127 microns) between contact surfaces

- Sources of motion
  - Thermal expansion and contraction
  - Vibrations
    - Examples
      - Flexing of a large PCB
      - Housing motion



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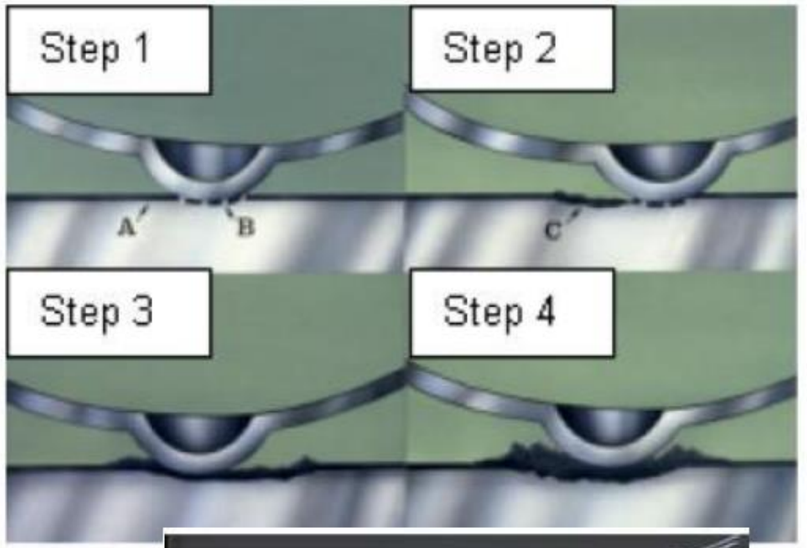
Fretting Failure Mechanism

- Tin plated contacts
  - A thin layer of tin oxide fractures allowing for metal-metal contact
  - Micromotion breaks the contact and forms new contact points
  - Old location re-oxidizes
  - Cycle repeats with each contact movement
  - Tin-oxide debris builds up eventually making contact impossible resulting in high resistance and intermittent contact



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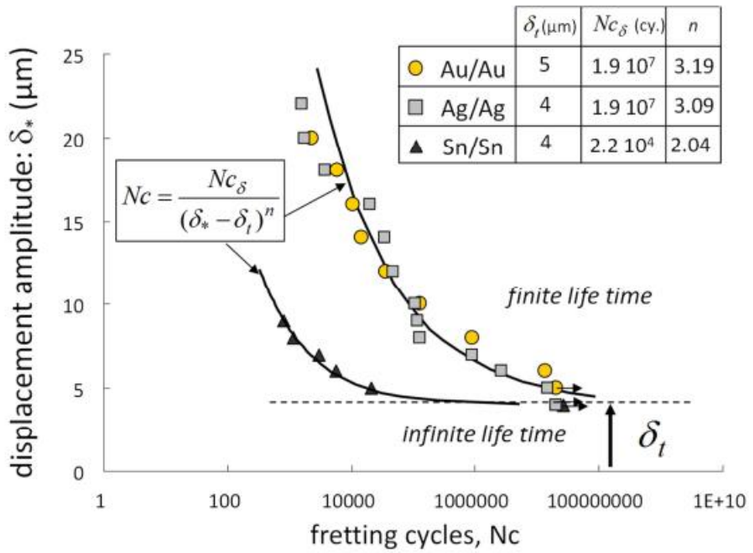
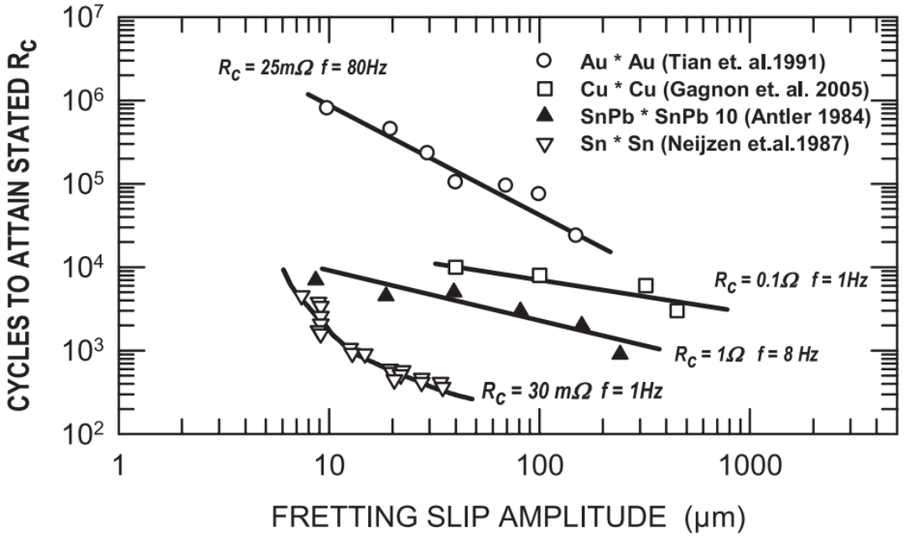
Fretting Failure Mechanism

- Predicting fretting failure (various platings)
  - Noble metal contacts wear from friction (don't corrosion)
  - Micromotion eventually exposes the base metal or underplate allowing corrosion products to accumulate



"Fretting wear of low current electrical contacts: quantification of electrical endurance" by S. Fouvry, O. Perrinet, P. Jedrzejczyk, O. Graton, O. Alquier, J. Sautel, and Radiall, Voreppe



"Fretting in Electrical/Electronic Connections: A Review", IEICE TRANS. ELECTRON., VOL.E92-C, NO.8 AUGUST 2009 by Milenko Braunovic predicts cycles to an increase in resistance based on micro-motion of leads

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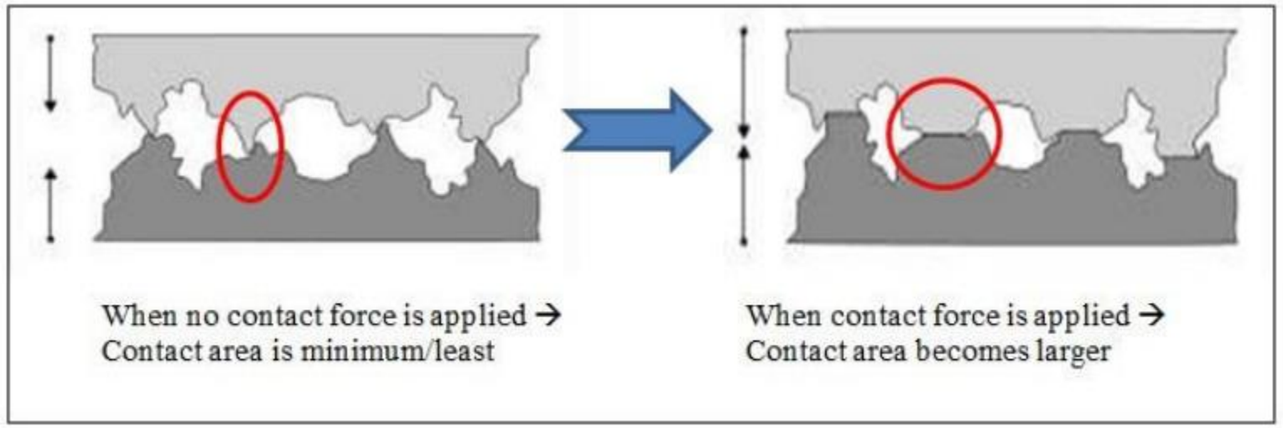
Fretting Mitigation

- Keep PCB natural frequencies high > 200 Hz
- Have mounting stand-offs nearby to prevent independent motion of the mated PCBs
- Increase plating thickness
  - Doesn't prevent but prolongs life
- Use a contact lubricant
- Higher contact forces reduces fretting motion and reduces contact resistance



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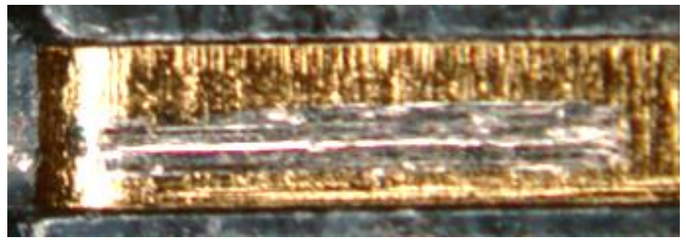
Plating Wear-Out

- For user interface connections the thickness of the plating determines the cycles
- Rules for gold plating
  - 50u" for high reliability, high cycle situations
  - 30u" for high reliability, moderate cycles
  - 10u" for moderate reliability, moderate cycles (or high reliability, few cycles)
  - Flash gold (3-5u") for use with single mate situations or those with low reliability requirements



The Tin Commandments (AMP. Inc.)

1. Tin coated contacts should be mechanically stable in the mated condition.
2. Tin coated contacts need at least 100 grams contact normal force.
3. Tin coated contacts need lubrication.
4. Tin coating is not recommended for continuous service at high temperatures.
5. The choice of plated, reflowed, hot air leveled, or hot tin dipped coating does not strongly affect the electrical performance of tin or tin alloy coated contacts.
6. Electroplated tin coatings should be at least 100 micro inches
7. Mating tin coated contacts to gold-coated contacts is not recommended.
8. Sliding or wiping action during contact engagement is recommended with tin coated contacts.
9. Tin coated contacts should not be used to make or break current.
10. Tin coated contacts can be used under dry circuit or low-level conditions.

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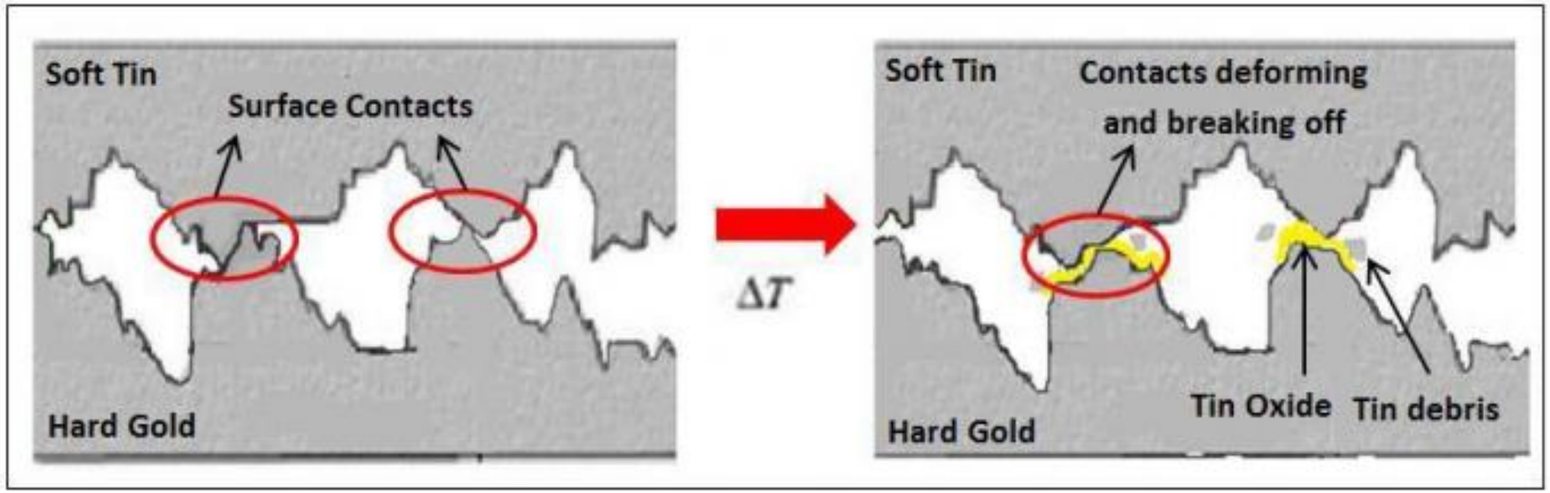
Plating Mis-Match

- Mating contacts should always be the same material
  - Gold on Gold
  - Tin on Tin
- The different CTEs of the plating surfaces can create abrasive tin oxide/debris accelerating the wear of the contact surface



"Effects of Fretting Corrosion on Au-Sn Plated Contacts in Electronic Cable Interconnect"
J. H. Lau, B. Y. Kuu, W. K. Koh, Hui-Hong J. K. Li
JSB Tect Pte, 20 Science Park II, Singapore 117674

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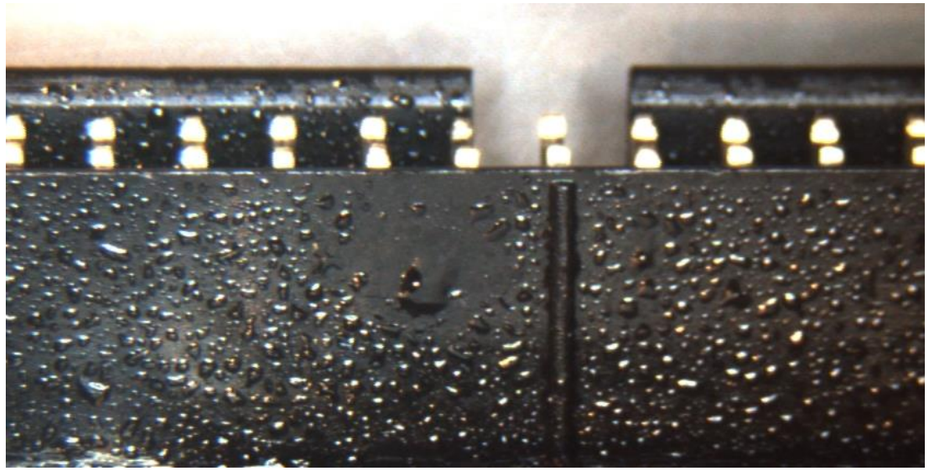
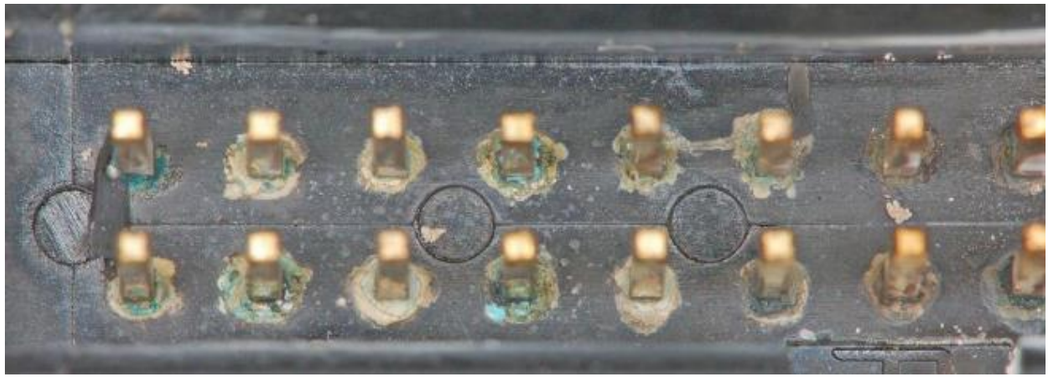
Red Phosphorus

- Selecting the most inexpensive connector since it is only used once (production programming) can have dire consequences.



- Connector housings containing red phosphorus will sweat phosphoric acid when used in a sealed environment



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Pin Corrosion

- Some connectors/cables have a continuous voltage on some pins (even when unplugged)
- In a high moisture environment corrosion can take place
  - Based on pin to pin distance
  - Presence of containments

- Mitigation
  - Maximize distance between pins of differing voltage potentials
  - Avoid use resistance measurement to determine mating with other devices, charging station, or external battery pack

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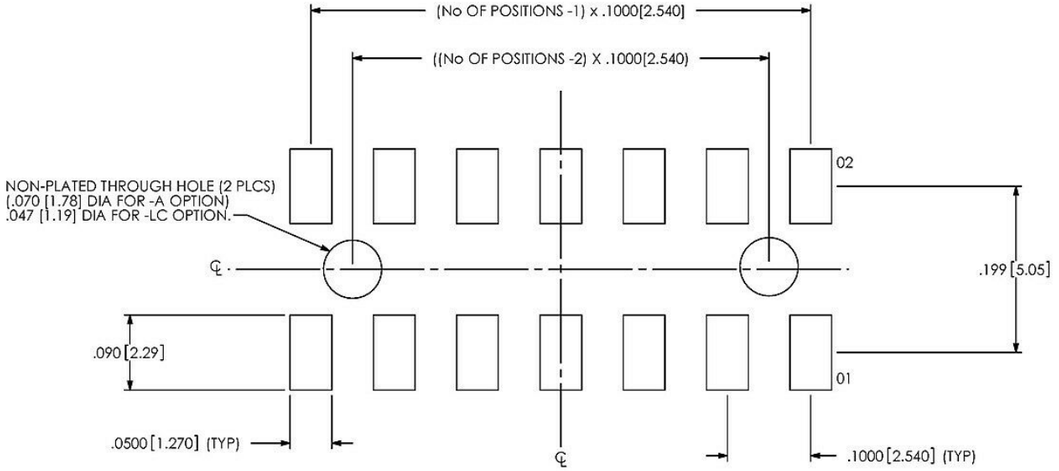
Connector Alignment

- Skewed headers and receptacles can cause alignment issues during assembly
  - Becomes a major issue when multiple connectors are used to mate two boards
- Forcing the mating of the connectors can result in high residual stresses in the joints leading to cracked joints or even broken joints during board mating
  - SMT headers and receptacles should both have alignment features and be the determining feature for board mating alignment (Mezzanine)
  - PCB hole position tolerance +/- 0.10 mm
  - Without alignment pegs the header may float (become skewed)



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Connector Alignment

- Avoid using multiple connector sets (when possible)
- Select connectors that have a defined misalignment tolerance
- Use SMT connectors with locking pins or large solder tabs
  - Especially if multiple insertions are expected over the life of the product

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