Lead Free Component Qualification

TURI Lead Free Meeting
Taunton, MA
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EU Directive Comparison

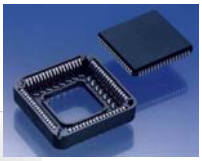
- End of Life Vehicles: ELV (2000/53/EC)
- Essentially bans:
  - Cadmium (Cd)
  - Mercury (Hg)
- Restricts
  - Hexavalent chromium (Cr^{+6})
    - Corrosion applications allowed until 2007
  - Lead – allowed in solder up to 60 grams per vehicle
  - Lead allowed for copper alloys
- Limits – 1000 ppm
- Effective date – 1JUL03

- Restriction on Hazardous Substances: RoHS (2002/95/EC)
- Bans:
  - Cadmium (Cd)
  - Mercury (Hg)
  - Hexavalent Chromium (Cr+6)
  - PBB
  - PBDE
  - Lead
- Exemption
  - Lead *in solder* for network/serve applications (2010)
  - Lead in copper alloys
- Limits – undefined
- Effective Date – 1JUL06

Implications of ELV/RoHS for Components

Lead is biggest issue
Lead is found in:

- Terminal finishes as tin/lead
  - Separable interfaces
  - Crimps
  - IDC connectors
  - Solderable interfaces (not required to be lead free)
- Plastics
  - Heat stabilizer in PVC
    - tribasic lead sulfate
  - Colorants
    - Lead chromate
    - Lead oxide



Lead Free Implementation - Compliance

- Technology Development
  - Plating, molding materials, cable materials
- Customer interaction – ELV/RoHS education
  - 12 months to implement and deplete inventory for ELV
- Customer interaction - reliability and qualification data
- Customer interaction - logistics
- Convert all plating lines (both internal and supplier) to lead free plating
  - Replace tin/lead plating with pure tin
  - No price impact to customer
  - Full PPAP not required
- Convert resin colorants with non-hazardous materials
- Convert PVC heat stabilizers to lead free

Conversion Logistics

Part Change Notification (PCN) used to alert customers
Part numbers remain the same for terminal finish changes

- Required by customers
  - Estimated cost to our customer to change P/N was €50,000
- Implement as running change
  - Use old inventory first

Tracking the conversion using labels on packaging

- Labels reflect the directive to which the products are compliant
- Labeling method adopted by other connector manufacturers
  - Molex, FCI, Amphenol
- Labels applied as stickers or integrated on existing label
- Labels also used to quarantine lead containing stock

ELV	RoHS
Directive 2000/53/EC Compliant	Directive 2002/95/EC Compliant

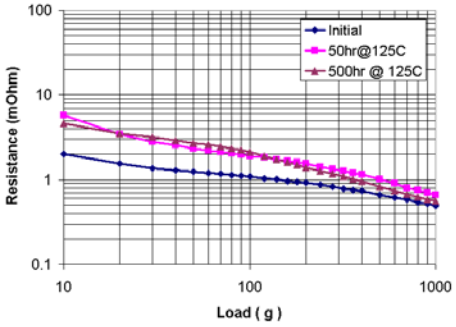
Performance Assessments of Lead Free Components

- Contact Resistance
- Friction/Insertion Force
- Crimp
- Whiskering
- Solderability
- Solder Joint Reliability
- Press-Fit
- Resistance to Soldering Heat

Performance Assessment: Contact Resistance

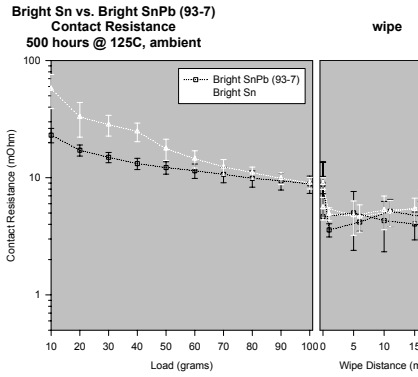
ure matte tin coating
3 µm thick) plated over
uSn4
lo wipe, thus worst
ase condition
Median results for:
- Virgin
- 50 hours at 125 C
- 500 hours at 125 C

light increase in
esistance with aging
Resistance is low and
table



Performance Assessment: Contact Resistance

- Bright finishes occasionally used in automotive
- After 500 hours of heat aging at 125 C
- Good performance above 100 g normal force
- 200 g is the minimum recommended normal force for any tin or tin/lead interconnect
- Wipe improves performance in both tin and tin/lead
- Pure tin meets performance requirements



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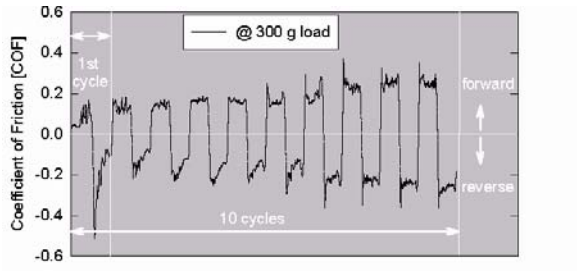
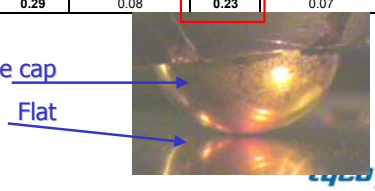
Performance Assessment: Insertion Force

- Pure matte tin coating (1.5 - 3µm thick) plated over CuSn4
- Thinner plating has lower coefficient of friction (COF)
- 10 cycles per condition, 5 mm displacement, three loads
- Lubricated to prevent fretting corrosion – typical in separable interface applications



Performance Assessment: Insertion Force

te cap on Matte flat						
	100 g load		300g load		500g load	
	average	standard deviation	average	standard deviation	average	standard deviation
dfree	**0.29**	0.13	**0.15**	0.06	**0.16**	0.10
Pb	**0.33**	0.05	**0.27**	0.05	**0.17**	0.06
ht cap on Matte flat						
	100 g load		300g load		500g load	
	average	standard deviation	average	standard deviation	average	standard deviation
dfree	**0.33**	0.11	**0.23**	0.06	**0.25**	0.05
Pb	**0.30**	0.08	**0.29**	0.07	**0.17**	0.06
ht cap on Bright flat						
	100 g load		300g load		500g load	
	average	standard deviation	average	standard deviation	average	standard deviation
dfree	**0.24**	0.05	**0.21**	0.05	**0.26**	0.08
Pb	**0.29**	0.08	**0.23**	0.07	**0.24**	0.08



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Performance Assessments: Crimp

Tin plated crimp contacts in use for 50 years

Verify performance to auto standards

- USCAR 20 and 21

Noise factors

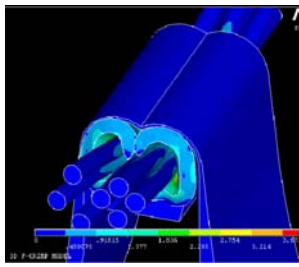
- Geometry, wire size, base metal, thickness

Tin to tin/lead comparison

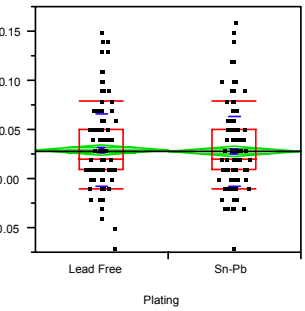
Part Description	Wire Gauge	Base Metal	Method
mm Female	12 AWG	Cu-Ni-Si	USCAR 20 & 21
SF size 16 pin (2 sizes)	18 AWG	Brass	USCAR 21
mm Male	12 AWG	Copper-iron	USCAR 20 & 21
egory 1, Male	1.0 mm^2	Phosphor bronze	USCAR 21
MP Seal, Female	18 AWG	Cu-Ni-Si	USCAR 21

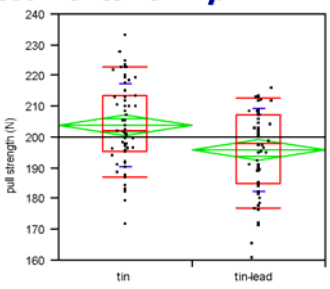
Performance Assessments: Crimp

- Heat Age: 125 C for 72 or 144 hours
- Vibration:
  - 4 or 8 hours/random plane
  - 3.2 g's, RMS, 10 to 2000 Hz
- Thermal Shock:
  - -40 C to 125 C for 72 or 144 cycles
  - 30 min. soak, 30 sec. transition time
- Temperature/Humidity cycling
  - 16 hours at 65 C, 95-98% RH
  - 2 hours at –40 C
  - 2 hours at 85 C
  - 4 hours at 25 C
- Cross-sections at variable crimp heights
- Pull tests at variable crimp heights (CH)
  - 20 minimum CH, 20 nominal CH, 20 maximum CH



Performance Assessments: Crimp





Change in contact resistance of crimps after environmental exposure

Statistically equivalent

- Crimp pull strength of tin versus tin/lead
- Not statistically equivalent, but functionally equivalent (2% difference in means)

Performance Assessments of Lead Free Components

- Contact Resistance
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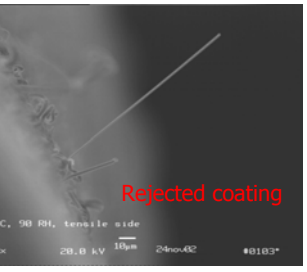
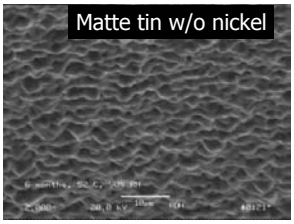
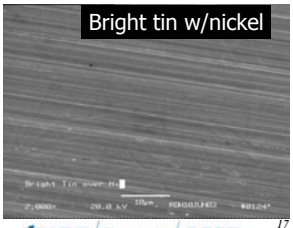
Performance Assessment: Tin Whiskers





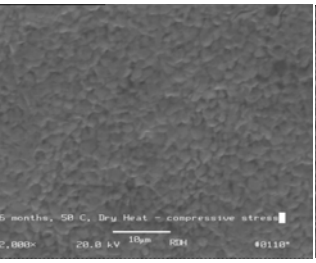


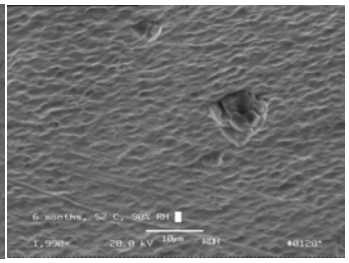
Two acceptable coatings

Performance Assessment: Tin Whiskers

- Tin whiskers are a known risk in tin plated components
- No universally accepted test method exists for tin whiskers
- The following test method is used to test for whiskers and has been adopted by the major connector companies:
  - Plated parts are bent then exposed to aging conditions
    - Room Temp, 6 months
    - 50 C, 6 months
    - 52 C, 90% RH, 6 months
    - Thermal cycling (-40 to 85 C, 1000 cycles)
  - Parts are examined by SEM for evidence of whiskers
  - Failure criteria
    - No whiskers greater than 50 um in length
- Due to the length of the test, the test qualifies the plating, not individual products

Performance Assessment: Tin Whiskers



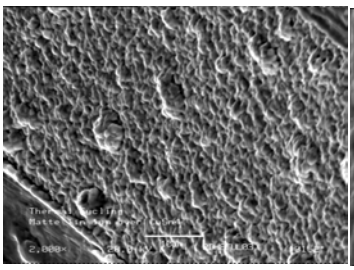


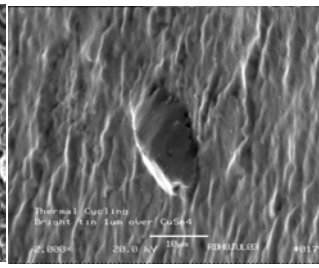
Left – matte tin coating, 1 µm thick over CuSn4 exposed to 50C dry heat.

Right – matte tin coating, 1 µm thick over CuSn4 exposed to 52 C 90%RH.

Acceptable tin coatings after environmental exposure. Small hillocks form, but no long whiskers

Performance Assessment: Tin Whiskers





Left – matte tin coating, 1 µm thick over CuSn4.

Right – bright tin coating, 1 µm thick over CuSn4.

Acceptable tin coatings after thermal cycling exposure. Small hillocks form, but no long whiskers

Whisker Countermeasures

Nickel barriers
- Used whenever possible; typical thickness is 1.25 um, but thicknesses as low as 0.4 um are effective

Low stress plating

Low carbon content plating
- Matte and bright finishes available

Deposit with preferred crystallographic texture (220)

Annealing is under consideration

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- Contact Resistance
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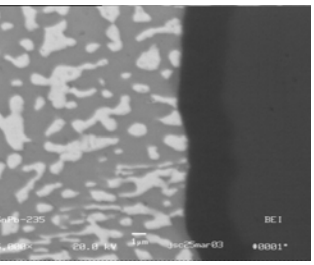
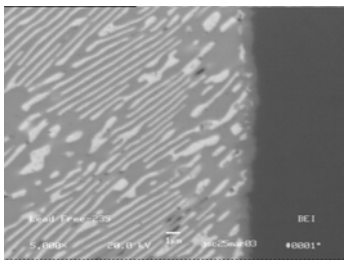
Performance Assessment: Solderability



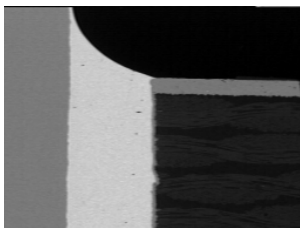


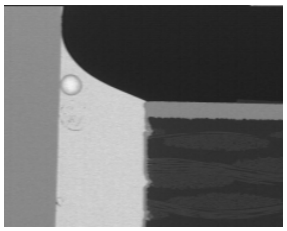
Dip and look solderability of tin/lead finish (left) and tin (right) with a nickel underlayer

Tin and tin/lead finishes are completely dissolved
- Eutectic solder at 235 C

Small tin/nickel intermetallic layer forms during wetting

Performance Assessment: Solderability





1 mm

- Wave solder joint with tin/lead (left) and pure tin (right) finishes
- Good fillets and wetting angles for both joints
- Tin/Lead solder temperature = 235 C
- Tin finishes show good backwards compatibility

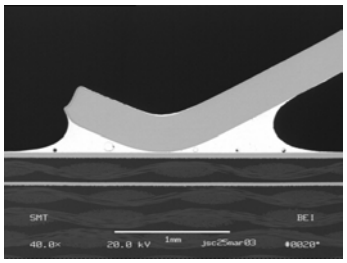
Performance Assessment: Solderability

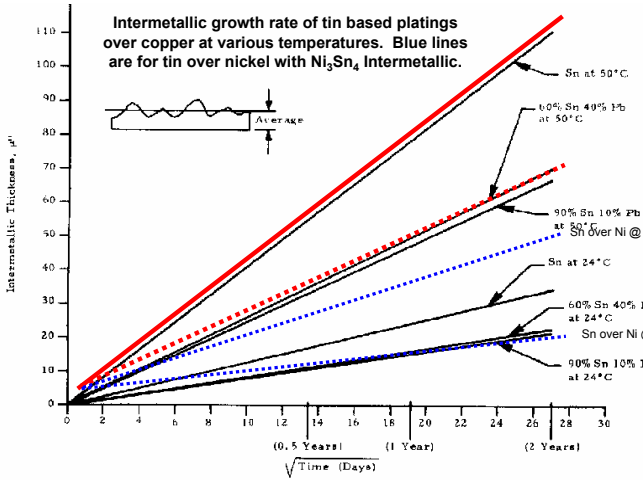
Tin is also forward compatible with lead free solder processes

This joint was made with a tin plated component and SAC405 solder

Good wetting angles

No failures after thermal shock or heat age testing





Performance Assessments of Lead Free Components

- Contact Resistance
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Performance Assessment: Solder Joint Reliability

- Solder joint reliability is strongly dependent on soldering conditions
- For these tests, joints were made with:
  - Two plating finishes (tin and tin/lead)
  - Two eutectic tin/lead solder temps (235, 250 C)
  - One flux (Kester 145)
  - Wave soldered with 3 second wave contact time, 100 C preheat
- Parts were exposed to thermal shock, then tested for electrical performance
  - -40 to 125 C, 1000 cycles
- Parts were tested for solder joint pull strength

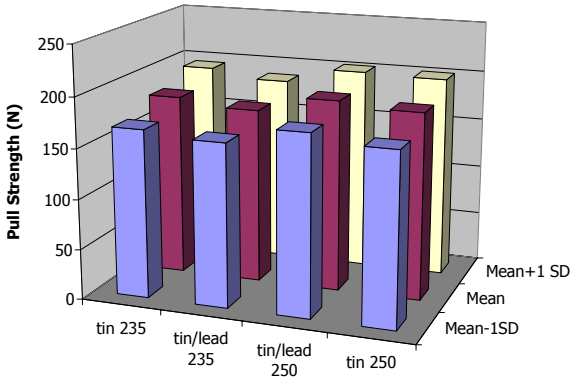
Performance Assessment: Solder Joint Reliability

Plating & solder temp.	Mean ΔR, mΩ
Tin/Lead, 235 C	<0.05
Tin/Lead, 250 C	<0.07
Tin, 235 C	<0.05
Tin, 250 C	<0.05

Change in resistance after 1000 cycles of thermal shock

Pure tin is statistically equivalent or better than tin/lead

Performance Assessment: Solder Joint Reliability



- Pull strength of tin and tin/lead plated finishes
- Wave soldered at two temperatures
- Statistically equivalent

Performance Assessments of Lead Free Components

- Contact Resistance
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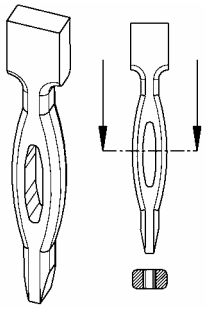
Press-Fit Qualification

- Full Factorial DOE during development
  - Board finish (6)
  - Pin finish (4)
  - Repair cycles (3)
  - Insertion force
  - Withdraw force
  - Hole damage
  - Hole size (7)
  - Three products
  - Single pin testing
    - As per IEC 60352-5
  - ~15,000 tests



Eye of the needle design

0.46 and 0.60 mm nominal hole size

Press-Fit Qualification: Terminal Finish

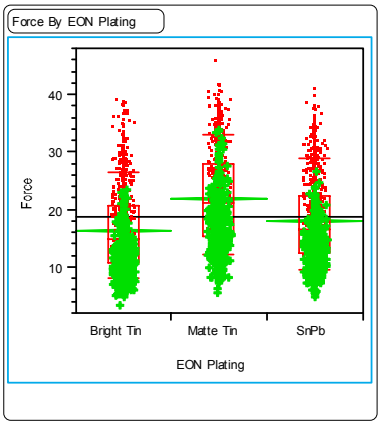
Box plots of withdraw force of two products (red and green data)

Ranges are similar for all three materials.

Mean shift increase for matte tin finish

Bright tin and bright tin/lead are similar

All are well above minimum retention of 4 N.



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Resistance to Soldering Heat: Reflow

Follows IPC/JEDEC 020B (modified to look like rev C, pending)

5 components per qualification

- Qualify families when possible

85 C/85%RH for 168 hours precondition

Reflow conditions

- 3 cycles
- Max temps of 245 or 260 C depending on application
  - Not dependent on package size

Many passive components not previously rated for MSL

Samples must not exhibit any of the following:

- Blisters on the plastic housings
- Gross physical deformation and/or warpage
- Critical to functional properties that are beyond the tolerances specified in the engineering drawings

Resistance to Soldering Heat: Wave Solder

- Follows no specification – none exist
- 5 components per qualification
  - Qualify families when possible
- No preconditioning
- Wave solder simulated by fluxing, then dipping solder tails into molten solder at 265 C.
- Can be performed with or without a PCB
- Samples must not exhibit any of the following:
  - Blisters on the plastic housings
  - Gross physical deformation and/or warpage
  - Critical to functional properties that are beyond the tolerances specifie in the engineering drawings

Conclusions

Automotive industry has implemented lead free components into production

Pure tin has been a connector finish for > 50 years

Tin whisker concerns have been mitigated and test method proposed for evaluating risk

Engineering performance has been assured:

- Contact Resistance, Insertion Force, Crimping, Whisker Resistance, Solderability, Solder Joint Reliability, Press-fit performance and Resistance to Soldering Heat

Parts have been converted without part number changes

- A marking methodology has been proposed and adopted by some component manufacturers

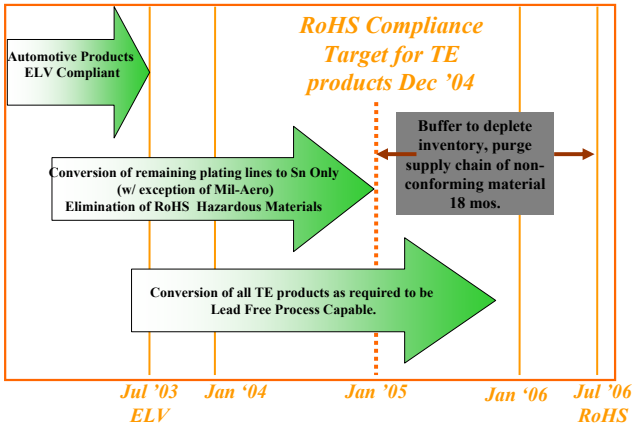
Other markets are developing lead free soldering capability

- Implementation in those markets in 2004

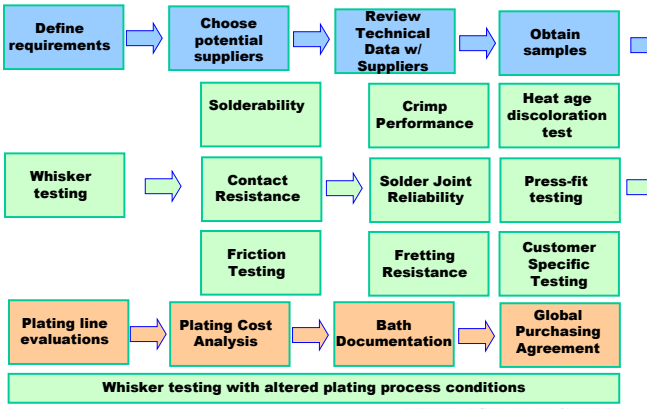
Supporting information

Robert Hilty, Tyco Electronics

Tyco Electronics Target Timeline



Plating Bath Qualification



Press-Fit Qualification: Board Finish

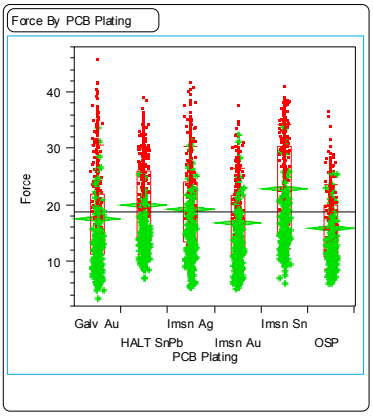
Box plots of withdraw force of two products (red and green data)

Ranges are similar for six board finishes

Immersion Sn appears to provide highest retention

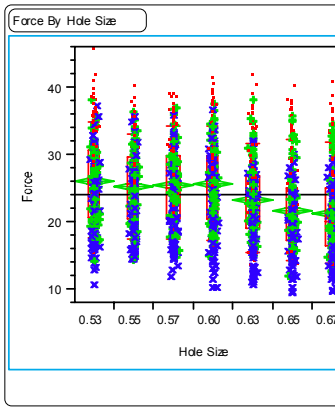
Gold and OSP finishes are slightly lower than Sn/Pb

Aligns with expectations from friction measurements *(Corman & Myers)*

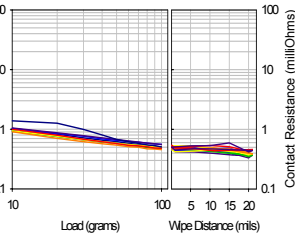


Press-Fit Qualification: Hole Size

- Box plots of withdraw force of for one product, three cycles (red=1st, green = 2nd, blue = 3rd)
- Mean trends down with increasing hole size
- Extreme hole sizes are beyond specification limits
- Plots include data from all pin and PCB finishes

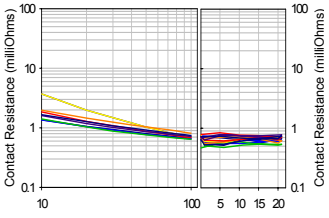


Performance Assessment: Contact Resistance



- 93/7 tin/lead loaded to 100 g (1N) then wiped to 20 mils (0.5mm)
- Plating has been heat aged at 125 C for 500 hours
- Slight increase in resistance

- 93/7 tin/lead loaded to 100 g (1N) then wiped to 20 mils (0.5mm)
- Plating is fresh



Tyco Electronics Web Resources

- Catalog of lead free products
  - Catalog.tycoelectronics.com
- Lead free program and technical data
  - www.tycoelectronics.com/leadfree