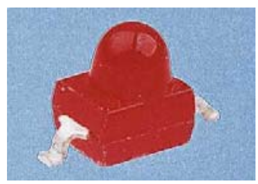
Ensuring Quality with Lead Free Processes

Component Specification

Component functionality

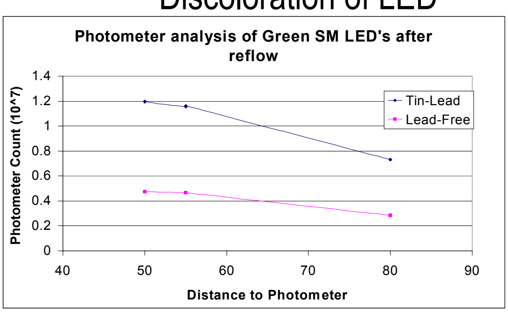
- Investigating components vulnerable to lead-free processing temperatures
  - Dimensional stability
  - Electrical functionality

Surface Mount LED's



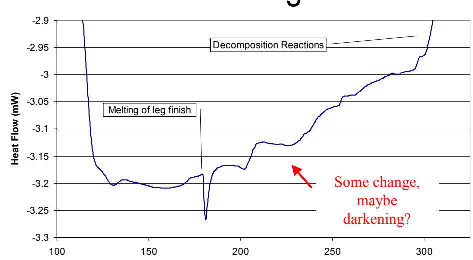
- Concerns about softening of polymer mouldings
- Green, red and yellow, gull wing and chip packages

Discoloration of LED



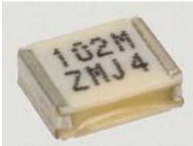
- Darkening of polymer
- No change in threshold voltage

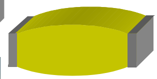
Gull Wing LED



- 2-4% change in dimensions
- DSC shows melting of leg plating
- Possible change in polymer at 210°C

SM Polyester Capacitors





- Coiled metal coated PET foil
- Wound construction could be problematic
- 215°C manufacturers recommended peak temp

Aluminium Electrolytic Capacitors

- High capacitance values
- Aluminium foil wound with paper
- Filled with liquid electrolyte
- Expansion of liquid in sealed system
- Significant expansion in top and bottom of casing
- Plastic mount forced down component legs

ALUMINIUM CAPACITOR FOR LEAD-FREE MANUFACTURING

Electronics Weekly 15 Jan 2003

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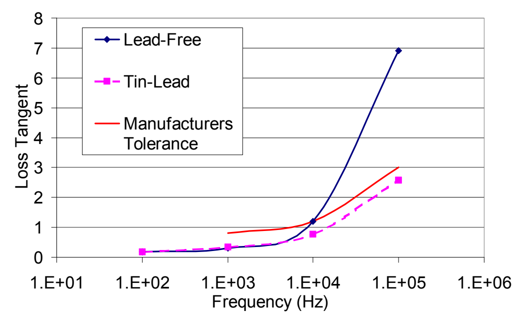
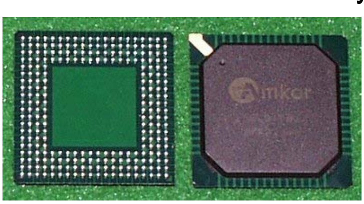
Lead-Free compatible Aluminium Caps using high temperature electrolyte

Loss Tangent, Polyester Cap



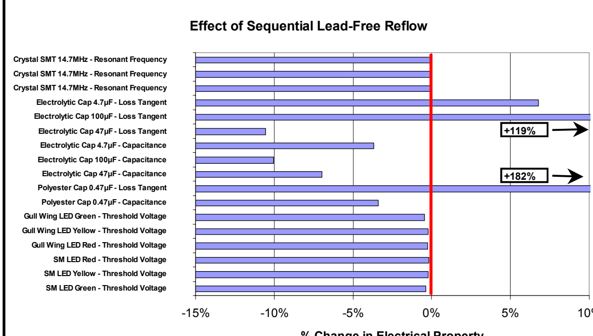
Unacceptable performance at high frequency

BGA - Ball Grid Array



- Silicon die wire bonded on BT laminate
- Encapsulated with moulding compound
- Can be prone to moisture ingression and 'popcorning'
- Can drop a MSL level

Functional Measurements



No change for any SnPb profiled components

Conclusions

- No significant changes for tin-lead profiled components, but for lead-free:
- LEDs
  - Dimensionally stable
  - Polymer darkening could be an issue
- Polyester capacitors
  - Vulnerable due to wound construction
  - Loss tangent at high frequencies effected
  - Cracking and physical deformation possible

Conclusions (2)

Electrolytic Capacitors

- Bulging at top and base
- Planarity of legs may change
- Loss tangent effected

BGA

- No popcorning - laminate structure? Batch issues?

No work done on field reliability of electronic devices after lead-free processing

Component Finishes

Termination Options

- Plated Finishes
  – Pd/Ni/Au(?) (available from TI)
  – Sn (component suppliers favourite, many passives already Sn)
  – SnAg (difficult to plate)
  – SnCu (difficult to plate)
  – SnBi (problems with SnPb solder)
- Hot Dipped Finishes
  – Lead-free solders
  – Avoid Bi-containing alloys

NPL Component Finishes Project

- This project intends to investigate the options available and benchmark them with a series of tests which will assess the processibility of the alternative Pb-free termination finishes.
  – Wirebondability
  – Moisture ingression
  – Plating ductility (SEM)
  – Tin whisker evaluation
  – Solderability testing
  – Process yield

Component Finishes

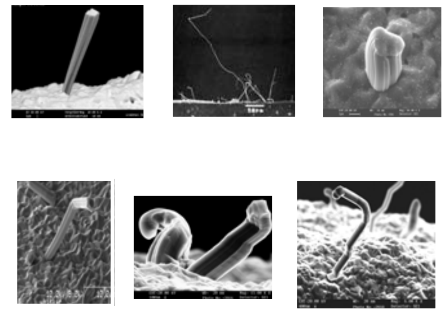
- 5 off pure Sn
- 3 off SnAg
- 3 off SnBi
- 3 off SnCu
- 1 off Ni/Pd/Au
- 1 off SnPb
- 1 off offshore Sn

Sn **SnAg**

SnBi **SnCu**

Tin Whiskers

- Tin whiskers are single crystal, commonly 1-3 microns in diameter and several millimeters in length.
- Usually straight but can change direction
- Can be solid, perforated or hollow.
- External surfaces often have striations.
  - Deep striations believed to be the boundaries of two whiskers growing together

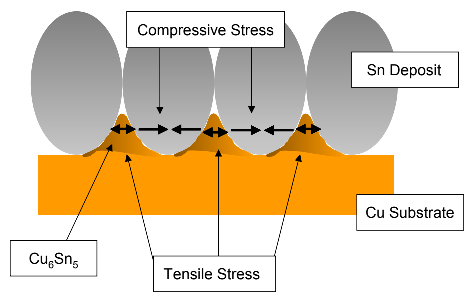


Whisker Properties

- Growth rates are highly variable. Grows more quickly at first, slows over time, and eventually stops completely.
- Electrical resistance of 3 mm long whisker ~ 50 ohms.
- Current carrying capacity ~ 10 - 30 mA.
- Yield strength approx. 100 times that of bulk tin.

Source: Shipley

Origin of Compressive Stress
Role of Intermetallic Formation



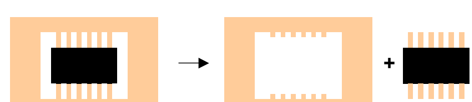
Adapted from Lee B.Z, and Lee, D.N.1998 Acta Metallurgica

Design of a Whisker-Free Pure Tin

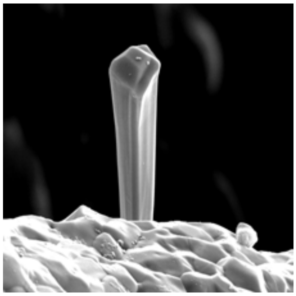
- Large grain
- Low stress
- Low stress substrate
- Anneal to relieve stress
- High thickness
- Nickel underplate to prevent diffusion

Tin Whisker Propensity Tests

- Accelerated ageing of all finishes
  - 85C/85%RH
  - 40C/90%RH
  - 50C/85%RH
  - 50C/lowRH
- 50C/85%RH found to generate most whiskering with old plating chemistries
- Both scrap frames and components tested



Sn Whisker on Cu Scrap Frame



Sn2 (redundant chemistry) (x4000)

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Summary of Results

- For components
  - No whiskers were seen to grow on all types of coatings after 56 days at 50ºC/ 85%RH
- For scrap frames
  - Whiskers were seen to grow with Sn2 finish (redundant chemistry) & one SnAg finish
  - No whiskers/ nodules were seen to grow on all new Sn, SnBi and SnAg plated scrap frames and two out of three SnCu plated scrap frames.
  - Current project looking at XRD

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Solderability Degradation

- Two types of degradation effect the solderability of surface finish:
- Oxidation
  - Grows comparatively quickly, and can be considered to be non-consequential
- Intermetallic
  - Growth typically over periods of years. Big issue when the intermetallic converts all of the surface layer

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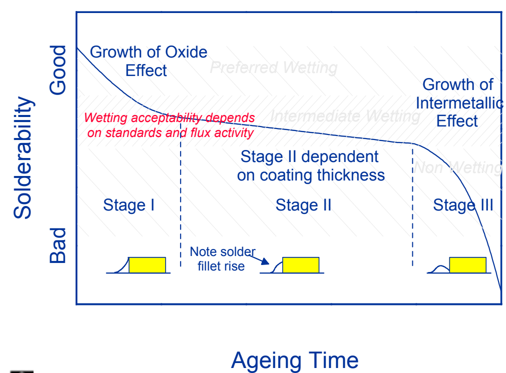

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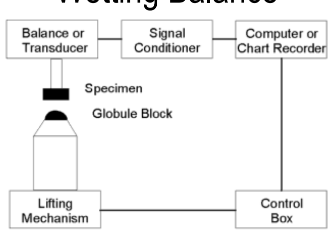
Wetting Balance



- Molten globule of solder
- Specimen (component leg) is brought down into contact
- Once contact is detected movement stops
- Force is measured as solder wets the lead

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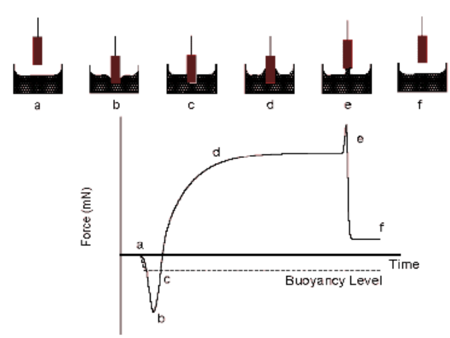
Wetting Force Curve



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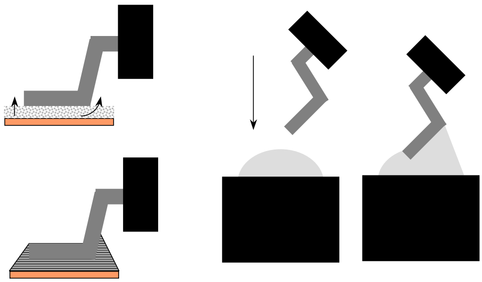
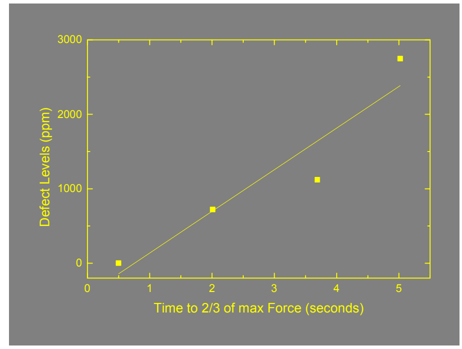
Differences between reflow and solderability testing

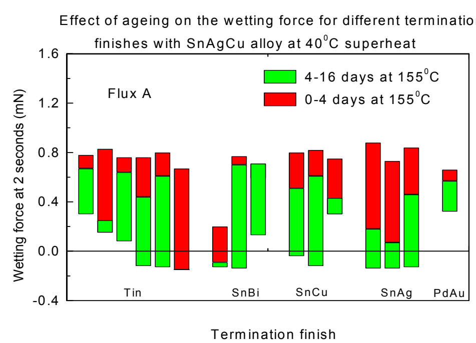


Correlation Between Solderability and PPM



Solderability Test Conditions

- 16 termination finishes:
  - Tin x 5
  - Tin x 1 offshore
  - SnBi x 3
  - SnCu x 3
  - SnAg x 3
  - PdAu x 1
- 40^0 C superheat
- As received, artificially aged 4 days and 16 days
- 2 fluxes:
  - 'A' 0.5% halide activated pure rosin
  - 'B' VOC free, water soluble no-clean
- 3 alloys:
  - SAC
  - SnCu
  - SnAgBi

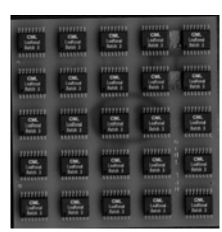


Solderability Conclusions

- All lead-free finishes showed acceptable solderability in as-received condition
- 4 days aged components still had acceptable solderability when tested with no clean flux

Process Yield Test Assembly

- 25 components per assembly, 20 assemblies per finish
- Each assembly has single component finish
- All reflow assembled by same line through same reflow profile
- Tin/Silver/Copper (SAC) no-clean solder paste
- 14 finishes
  - 4Sn, 3SnBi, 3SnAg, 3SnCu, 1AuNi



Visual Inspection

- Binocular zoom microscope
  - X15 magnification
- Single operator
- Four corner leads on each device inspected
  - 2000 solder joints inspected per finish
  - Total of 38,000 solder joints

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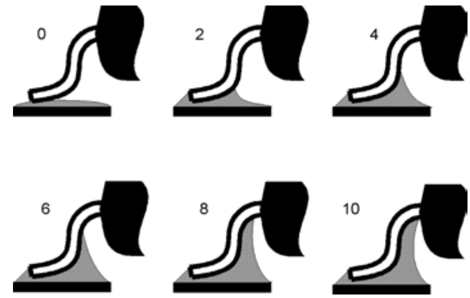
Visual Inspection Scoring



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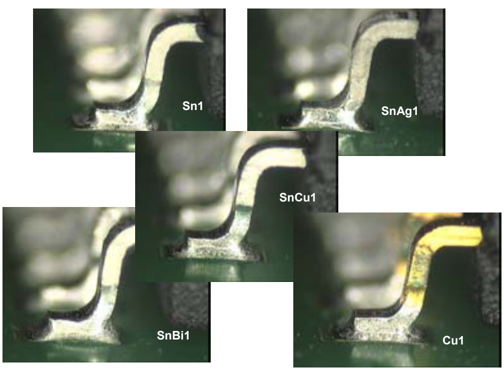
Solder Joints to Sn Finish Components



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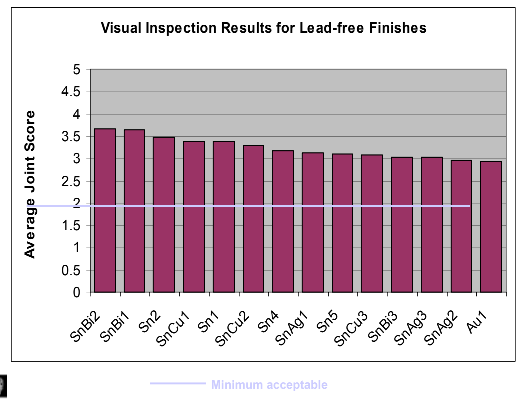

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Process Yield Conclusions

- All finishes gave acceptable process yields
- Very little discernible difference between the finishes using this assembly process
- Only two failed solder joints out of 28,000 solder joints inspected
  - 1 x AuNi & 1 x SnBi
- A limited number of SnAg showed signs of reflow during assembly resulting in higher visual inspection scores

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Conclusions

- Four types of lead-free component finishes studied
- All gave acceptable results in the following areas :
  - Solderability
  - Process yield
  - Moisture ingression
  - Plating ductility
  - Tin whisker (exceptions were a redundant Sn chemistry and one of three SnAg chemistries)
    - In both the above exceptions tin whiskers were only located on scrap frames not on components

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Inspection Requirements

LF Inspection Standards

- IPC-A-610 has been reviewed for lead-free inspection
- Lead-Free Cookbook has examples
- SAC joints
  - Slightly duller surface
  - Copper halo more likely
- Re-education of inspectors

AOI and LF

- NPL Study included the following defects:
  - Missing components.
  - Misaligned components (x and y directions).
  - Wrong components (correct size but different value).
  - Poor quality solder joints (insufficient or excess solder).
  - Wrong polarity components.
  - Solder bridges (shorts).
  - Poor lead or component planarity including tombstones (component on end) and components on edge.

LF AOI Test Board

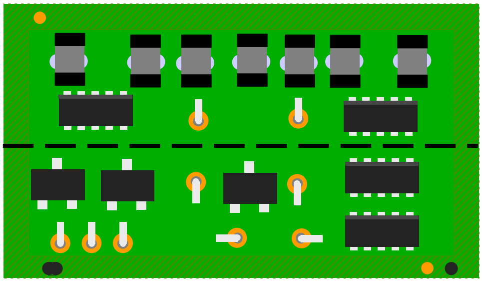
•machine cost
•ability to locate assembly defects
•amount of false detections made
•speed of inspection

AOI Study Conclusions

- Systems proved capable of inspecting lead-free assemblies
- Same algorithms were used in programming the systems that are normally used for the inspection of SnPb.
- Algorithm thresholds may be set differently for SnPb and SAC assemblies.
- False detect rates were also similar for both alloys.
- AOI inspection of lead-free SM assemblies presents no more challenges than would SnPb assemblies

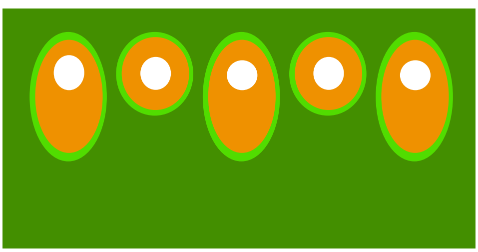
Changes to PCB Layout

Changes to PCB Layout

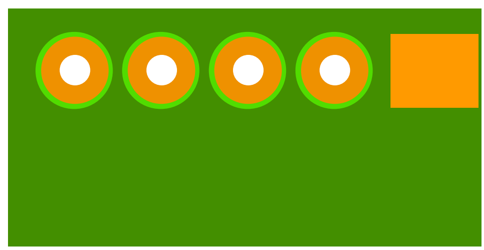


Changes to PCB Layout

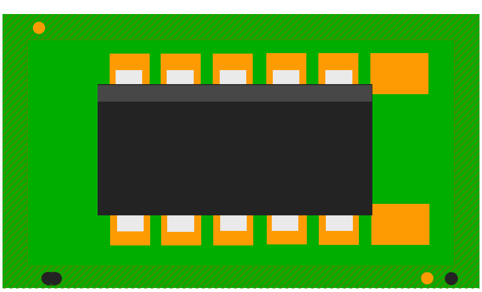
Changes to PCB Layout



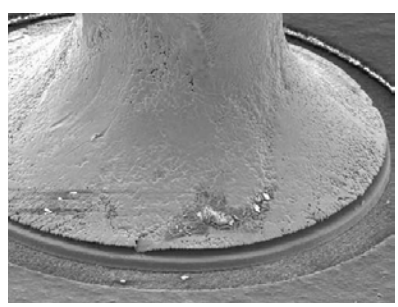
Changes to PCB Layout



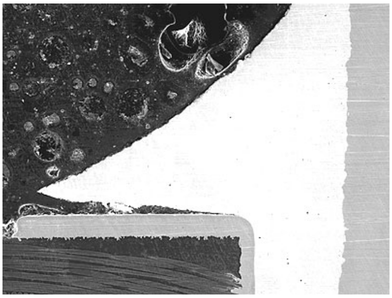
Changes to PCB Layout



Fillet Lifting During Wave Solder



Pad Lifting During Wave Solder



Wave Soldering Issues

Lead-Free Wave Soldering

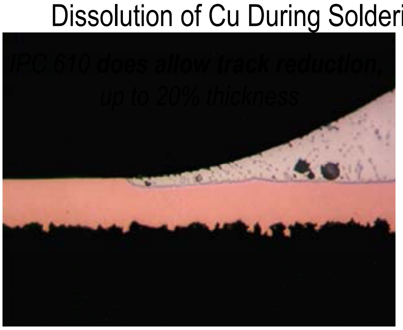
Lead-Free Wave Soldering

Bulk 304L SS

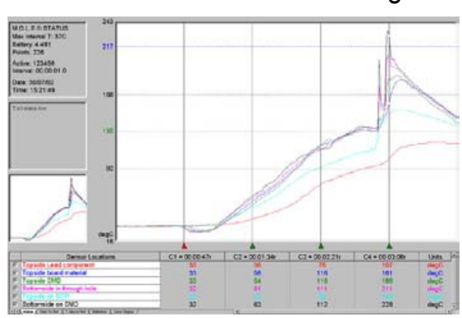
Nickel	8.76%
Iron	71.25%
Manganese	1.69%
Chromium	17.31%
Silicon	1.0%

Replace with 316 Stainless Steel

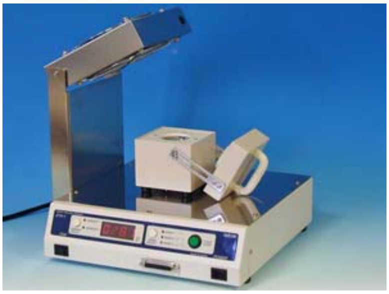
Dissolution of Cu During Soldering



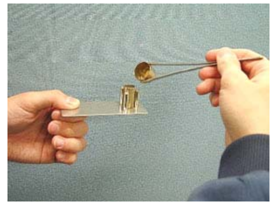
Wave Solder Profile Sn/Ag/Cu



Wave Solder Bath Analysis

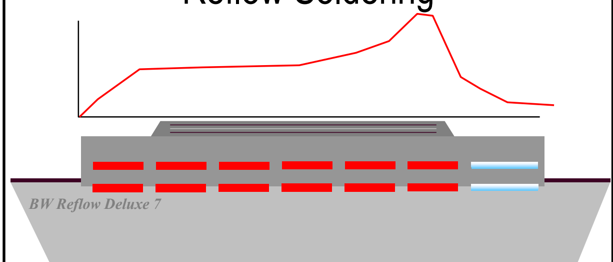


Wave Solder Bath Analysis

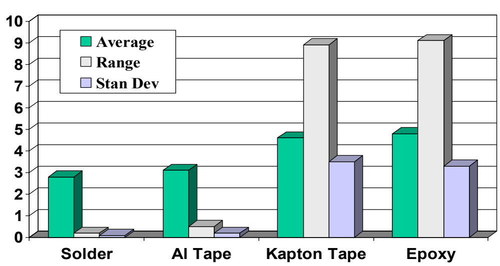


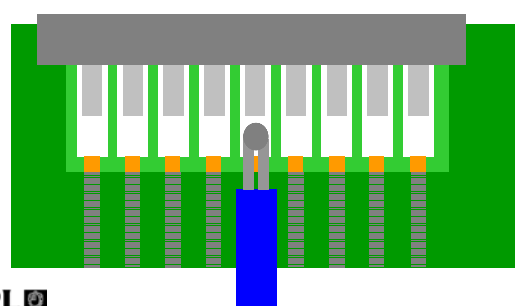
Reflow Soldering Issues

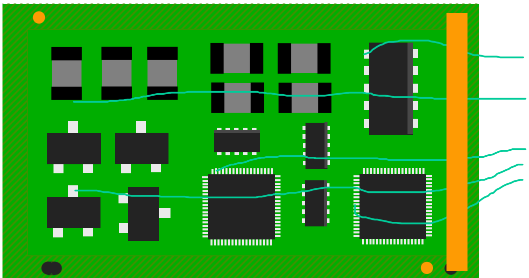
Reflow Soldering

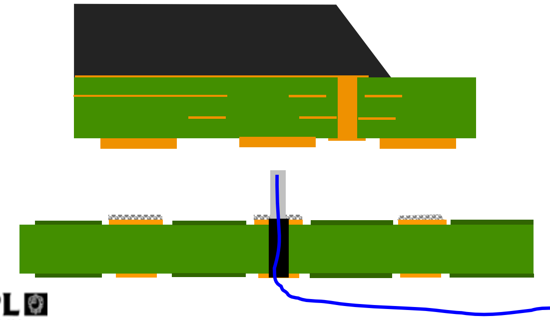


Temperature Profiling









NEC Lead-Free Assembly

Thank you for your attention

www.npl.co.uk/npl/ei