Low Temperature SMT Process Implementation
Drivers for Low Temperature Soldering

I. Lower Cost Components
II. Lower Cost Laminates
III. Lower Energy Consumption
IV. Eliminate Wave Soldering
V. Reduced Thermal Stress During Assembly Process
Low Temperature Conversion

Components

Alloy

Parameters

Laminates

Process

?
Lower Cost Component Example

• Molex Shrouded Header (105°C)
  – Catalogue Price $.84
• Molex Shrouded Header (130°C)
  – Catalogue Price $1.23
• 46% Savings

Source: Online component catalogs (like RS, DigiKey, Farnell)
## MAJOR EMC PRODUCT ASP

<table>
<thead>
<tr>
<th>Package Categories</th>
<th>Discretes</th>
<th>Integrated Circuits</th>
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<tr>
<td></td>
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<td>Through Hole</td>
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<td>Base Epoxy Resins</td>
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<tr>
<td></td>
<td>• ECN/ OCN</td>
<td>• ECN/OCN, DCPD</td>
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<tr>
<td></td>
<td>• Hybrid</td>
<td>• Hybrid</td>
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<td></td>
<td>• DCPD, Biphenyl, Multi-Aromatic</td>
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<td>$4.6/kg</td>
<td>$5.5/kg</td>
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</table>

**Epoxy Cresole Novolac**

**Ortho-Cresole Novolac**

**Dicyclopentadiene**
Component Warpage Concerns

Only 0.05mm Permissible warpage in 0.15mm pitch FBGA – JEITA roadmap

FBGA – Fine Pitch Ball Grid Array
Low Temperature Conversion

Components

Alloy

Parameters

Process

Laminates
PCB ..... Cheap ⇒ Cheaper

Remote Control Manufacturer case study – potentially save >$108,000 / year through the use of low temperature processing.

Since this was a feasibility study of PCB materials only, the potential savings are estimated below. PCB cost difference was estimated at 10% between materials based on various PCB suppliers.

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<td>1,080,000</td>
<td>US$ 108,000</td>
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</tr>
</tbody>
</table>

FR-4 to Phenolic Paper Laminate Conversion yields even greater savings if possible to implement.
Higher $T_g$ = Higher Cost Laminates
# FR-1 vs XPC – Stiffness Under Heat

<table>
<thead>
<tr>
<th>Grade: RL FR1, ANSI/NEMA Type FR1</th>
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</thead>
<tbody>
<tr>
<td>Bow and Twist (304mm x 304mm)</td>
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</table>

XPC twists > double FR-1

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Warpage Example

FR-1, 1.2mm Thick, 245°C Peak

XPC, 1.2mm Thick, 240°C Peak
Low Temperature Conversion

Components

Alloy

Parameters

Laminates

Process

?
Wave Solder Replacement

Single or Double Sided SMT + Wave Solder

Single or Double Sided SMT (PITH)

Best opportunity with only few Through-Hole components cases
Wave Soldering Elimination

• Savings In:
  – **Factory Footprint** – Wave, Touch Up, Inspection
  – **Equipment** – W/S, Soldering Stations
  – **Working Capital** – 800kg alloy @ $40/kg
  – **Manpower** – Operator, Tech, Engr, Touch Up
  – **Maintenance** – Labor, Spares, Tools, Supplies, Pallets, Dross Management
  – **Processes** – One less thermal excursion
  – **Materials** – Flux and Bar Solder
Eliminating Wave with PITH

**Conventional**

**Paste-In-Hole (PIH)**

**Over Print**

**PITH+ (w Preform)**
Printing Parameters - “Drop In”

<table>
<thead>
<tr>
<th></th>
<th>Present</th>
<th>Previous</th>
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</thead>
<tbody>
<tr>
<td>Print Gap (mm)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Print Speed (mm/s)</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Print Pressure (x 0.1MPa)</td>
<td>1.8</td>
<td>Semi Auto</td>
</tr>
<tr>
<td>Separation Distance (mm)</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Separation Delay (s)</td>
<td>0.1</td>
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<tr>
<td>Separation Speed (mm/s)</td>
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<td>Max</td>
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<td>Printer Model</td>
<td>Hitachi NP-04M</td>
<td>Stencil</td>
</tr>
<tr>
<td>Relative Humidity (%)</td>
<td>55%</td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td>Squeegee Material &amp; Width</td>
<td>Stainless Steel, 10&quot; (254mm)</td>
<td>Underwipe Solvent -NA-</td>
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Paste-In-Hole (PITH) & PITH+ - How It’s Done

Paste-In-Hole

Large Overprint Apertures

Paste-In-Hole + Preform

DIP Socket

RJ45 Connector

RJxx Connector

RJxxx Connector
PIH+ Worked Example

**U105 PIH Calculation**

**Lead count = 12**

<table>
<thead>
<tr>
<th>Component</th>
<th>Cu pad area</th>
<th>PTH volume</th>
<th>Solder paste vol</th>
<th>Preform volume</th>
<th>Preforms needed</th>
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</thead>
<tbody>
<tr>
<td>Rectangle</td>
<td>4550.00</td>
<td>22437.92</td>
<td>4883.63</td>
<td>306016.88</td>
<td>T&amp;R 0805</td>
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<tr>
<td>Outer circle</td>
<td>3846.50</td>
<td>230495.69</td>
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<td>Hole size</td>
<td>1589.83</td>
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<tr>
<td>Annular ring</td>
<td>2256.88</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Final area</td>
<td>4883.63</td>
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<tr>
<td>PTH volume</td>
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<td>PTH volume</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Total joint volume</td>
<td></td>
<td></td>
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<tr>
<td>Solder paste vol</td>
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<td>Component lead volume</td>
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<tr>
<td>Solder vol shortfall</td>
<td>222667.19</td>
<td>0.00022267</td>
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<td></td>
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</tr>
<tr>
<td>Nearest preform sizes</td>
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<tr>
<td></td>
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<td></td>
<td>Conversion to in³</td>
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<td></td>
</tr>
</tbody>
</table>

1" cube = 0.000000001 mil cube

**Conversion to in³**

- 1" cube = 0.000000001 mil cube

**Preform Vol**: 0.000113

**Preform Dimensions**: 79x51x28 mils
PITH+ Stencil Aperture Design

U105 PIH Stencil Aperture Design
Lead count = 12

Cu pad area
- Rectangle: 4550.00
- Outer circle: 3846.50
- Hole size: 1589.63
- Annular ring: 2256.88
- Final area: 4833.63

Stencil Aperture
- Rectangle: 4550.00
- Notch: 506.25
- Pad circle: 1923.25
- Notch: 506.25
- Final Area: 5460.75

Extra paste helps initiate lead wetting
Common PITH Defects - Hole Fill, Chicken Drumstick!
Parameters At A Glance

• **Printing**
  – Can be drop-in
  – Stencil design changes minimal with PITH & PITH+ preform

• **Placement**
  – Standard SMT
  – Preforns placed as if passives (0402, 0201…)

• **Reflow Soldering**
  – Peak 170-190° C
  – If soak required, 110-120° C
Typical Reflow Profile

Avoid high peak, TAL compensation

CVP-520 Suggested Profile
42Sn / 57.6Bi / 0.4Ag

Peak Temp
155°C – 175°C

Liquidus – 138°C

100°C – 138°C
(75 – 120 secs)

125°C – 138°C
(30 – 90 secs)

TAL (>138°C)
30 – 90 secs

≤ 3°C/sec

Time (seconds)
Low Temperature Conversion

Components

Alloy

Parameters

PCB

Process
Commonly Used Alloys

- **BiSnAg**
  - 138°C
- **SnPb**
  - 183°C
  - 50°C
- **PbSnAg**
  - 296°C
  - 287°C
- **SAC305**
  - 227°C
  - 225°C
- **SACX+**
  - 217°C
  - 206°C
- **Innolot**
  - 206°C

**Note:** Not just BiSn! Not Pb-free.
Shiny, Strong Fillets

QFN
Bluetooth Module
Connector

SOIC
SOT
Button Cell Battery Holder
Void Performance? Soak Profile Helpful

QFN Thermal Pad - Bare
QFN Thermal Pad - Actual
QFN Terminations - Bare

Chip Resistor & Cap - Bare
QFN Terminations - Actual
Conclusion – Low Temp Alloy Use

• Substantial cost savings over regular processes
  – Materials
  – Energy
  – Eliminate Wave/Selective Soldering
• Printing is normally a Drop In
• Major process for high volume consumer electronics for 5 years

Thank You!
Agenda - Low Temperature Conversion

1) Introduction & Agenda
2) Value Created
3) Converting Components
4) Laminate Conversion
5) Processes Involved in Conversion
6) Hands-On Exercise - Rework
7) Specifically Reflow Parameters
8) Alloy Data – Strength & Voids
## Low Temperature – Alpha Value Propositions

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
<th>Status</th>
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<tbody>
<tr>
<td>Halogen Free / Zero Halogen</td>
<td>Reduced cost of entry barrier</td>
<td>✔️</td>
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<tr>
<td>Wave Solder Replacement</td>
<td>Process simplification, cost savings</td>
<td>✔️</td>
</tr>
<tr>
<td>2nd Side Reflow</td>
<td>Product improvement</td>
<td>✔️</td>
</tr>
<tr>
<td>Manual Soldering Elimination</td>
<td>Quality consistency improvement, reliability &amp; repeatability</td>
<td>✔️</td>
</tr>
<tr>
<td>PCB Material Cost Reduction</td>
<td>Improved materials’ thermal compatibility</td>
<td>✔️</td>
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</table>
Areas of Value Creation

1) Cost Savings
   I. Components
   II. PCB
   III. Electricity (Heat)
   IV. Wave Solder Replacement

2) Process Gains
   I. Less Thermally Induced Issues
Low Temperature Conversion

Components

Alloy
Parameters
Process
PCB

?
Connector Price By Temperature

- Molex Shrouded Header (105ºC)
  - USD 0.84
- Molex Shrouded Header (130ºC)
  - USD 1.23
- 46% More Expens

Some components just cannot be converted & needs manual soldering

Exceptions

Source: Online component catalogs (like RS, DigiKey, Farnell)
Component Warpage Concerns

Only 0.05mm Permissible warpage in 0.15mm pitch FBGA – JEITA roadmap

FBGA – Fine Pitch Ball Grid Array
Low Temperature Conversion

Components

Alloy

Parameters

Process

PCB
PCB ….. Cheap ⇔ Cheaper

Philips Home Control case study – potentially save >US$108,000 / annum through the use of low temperature processing (CVP-520)!

Since this was a feasibility study of PCB materials only, the potential savings are estimated below. PCB cost difference was estimated at 10% between materials based on various PCB suppliers.

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Data extracted from technical report TW110511 by TW Mok on the feasibility of using even cheaper PCB laminates

The comparison above is not even between FR-4 & XPC
PCB Warpage Concerns

Halogen Free PCBs Stiff Enough Are $$$
FR-1 vs XPC – Stiffness Under Heat

<table>
<thead>
<tr>
<th>Grade</th>
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<th>Bow and Twist (304mm x 304mm)</th>
<th>As is</th>
<th>mm/M</th>
<th>10 (with Cladding)</th>
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<tr>
<td>FR1</td>
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XPC twists > double FR-1
PCB Tg Revisited – Cost & Material Impact

- **High Performance Epoxy**
- **Multifunctional Epoxy**
- **FR-4**
- **Polyimide (220°C – 280°C)**
- **Cyanate Ester (180°C – 260°C)**
- **Bismaleimide Triazine Epoxy**

PCB Cost vs. PCB Warpage

- PCB Cost: $$$$$
- PCB Warpage: Less to More
Warpage? Really?

FR-1, 1.2mm Thick, 245°C Peak

XPC, 1.2mm Thick, 245°C Peak

XPC, 1.2mm Thick, 240°C Peak
Low Temperature Conversion

Components

Alloy

Parameters

PCB

Process
Stencil Printing – Multiple Applications

Conventional

Paste-In-Hole (PIH)

Over Print

PIH+ (w Exactalloy)
Printing Parameters

Stencil Printing

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Paste-In-Hole (PIH) & PIH+ - How Its Done

Paste-In-Hole

Beware - Aperture Damage!

Paste-In-Hole + Preform

DIP Socket

RJ45 Connector

RJxx Connector
Overprinting vs PIH+ - Flux Residue
### U105 PIH Calculation

**Lead count = 12**

<table>
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<tr>
<th>Cu pad area</th>
<th>Rectangle</th>
<th>4550.00</th>
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<td></td>
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<td>3846.50</td>
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</tr>
<tr>
<td></td>
<td>Annular ring</td>
<td>2256.88</td>
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<th>PTH volume</th>
<th>Top fillet volume</th>
<th>22437.92</th>
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<td></td>
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<td>230495.63</td>
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<td></td>
<td>Total joint volume</td>
<td>306016.88</td>
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<table>
<thead>
<tr>
<th>Solder paste vol</th>
<th>Aperture area</th>
<th>4883.63</th>
</tr>
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<tbody>
<tr>
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<tr>
<td><strong>Nearest preform sizes</strong></td>
<td>0805 x 2 pcs</td>
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</table>

| Preforms needed | T&R 0805 | 24 per | Preform Vol | 0.000113 | Preform Dimensions | 79x51x28 mils |
## PIH+ Stencil Aperture Design

### U105 PIH Stencil Aperture Design
*Lead count = 12*

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<thead>
<tr>
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<td></td>
<td>Rectangle</td>
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*Extra paste helps initiate lead wetting*
Common PIH Defects - Hole Fill, Chicken Drumstick!
Wave Solder Replacement

Single or Double Sided SMT + Wave Solder

Single or Double Sided SMT (PIH or PIH+)

Best opportunity with only few Through-Hole components cases
W/S Replacement – Alpha Value Proposition

• Savings In:
  – **Space** – Footprint Of M/c, T/u, Inspection
  – **Machines** – W/S, Soldering Stations
  – **Manpower** – Operator, Tech, Engr
  – **Maintenance** – Labor, Spares, Tools, Supplies
  – **Processes** – W/S, T/u, Inspection
  – **Materials** – Direct & Indirect
Manual Soldering Elimination

1. Load PCB Panel
2. Manual Comp Insertion
3. Flip & Solder

Single or Double Sided SMT (PIH or PIH+)
Soldering Tip Temperature – 400°C Best

344°C Tip Temp

Pin 1 Clean Break!

400°C Tip Temp

PTH Clean Break!

No Evidence Of Wetting!

Brute Push Test

There is no BiSnAg wire, only SACX wire
Reworked Joint Strength

Shear Strength Comparison

- Solder Iron Tip Temp (°C): 300°C, 350°C, 400°C, 450°C
- Shear Force (kgf)
- CVP-520 & TLC+
- CVP-520 & TLC XL
- TLC+ Only
- TLC XL Only

Taken from 3 shear readings each
Low Temperature Conversion

Components

Alloy

PCB

Parameters

Process

?
Parameters At A Glance

• **Printing**
  – Can be drop-in
  – Very minimal changes even with PIH & PIH+

• **Placement**
  – Standard SMT – None
  – PIH & PIH+ - As required to accommodate

• **Reflow Soldering**
  – Major temperature drop

• **Rework / Touch-up**
  – 400°C Solder Iron tip temperature
Thermal Profile

CVP-520 Suggested Profile
42Sn / 57.6Bi / 0.4Ag

Avoid high peak, TAL compensation

Liquidus - 138°C

100°C - 138°C (75 - 120 secs)

125°C - 138°C (30 - 90 secs)

Peak Temp 155°C - 175°C

TAL (>138°C) 30 - 90 secs

≤ 3°C/sec

Time (seconds)
Low Temperature Conversion

Components

Alloy

Parameters

PCB

Process

?
Knowing Solder

- **BiSnAg**: 138°C
  - SACX+
    - SAC305
    - SnPb
  - Note: Not Just BiSn!
  - Low Temperature

- **PbSnAg**: 296°C
  - 287°C
  - 227°C
  - 225°C
  - 217°C
  - 206°C
- **SnPb**: 183°C
  - Note: Not Pb-free
Shiny, Strong Fillets

- QFN
- BlueTooth Module
- Connector
- SOIC
- SOT
- Button Cell Battery Holder
57.6Bi42Sn0.4Ag vs SAC-305

**Average Shear Strength**

- **CVP-520 Lo Tg PCB**: 9.95 kgf
- **CVP-520 Hi Tg PCB**: 8.54 kgf
- **OM-338PT Lo Tg PCB**: 6.25 kgf
- **OM-338PT Hi Tg PCB**: 5.63 kgf

*Shear Strength (kgf)*

*Test Groups*

*Taken from 7 shear readings each*
Void Performance?

QFN Thermal Pad - Bare
QFN Thermal Pad - Actual
QFN Terminations - Bare
Chip Resistor & Cap - Bare
QFN Terminations - Actual
Conclusion – Low Temp Conversion

• Substantial cost savings over regular processes
• Savings can outweigh paste cost differences
• Can be mechanically stronger if done right
• Involves more than just changing pastes
• Beware of excessive flux residue
• Pick on plastic components / flex circuits
• Avoid high peak temperature

Thank You!