ITW EAE

Conquering The Miniature Component Challenge

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Overview: Miniature Component Printing

- Component size overview
- Key factors for successful printing
- Materials
- Machine
- Process
- Design Of Experiment
Moore’s law continues……

• Development of miniaturization continues for electronic manufactures
• Demands for high functionality of mobile devices, smart watches, wearables, military, medical and audio technology continue to drive the need for miniaturization
• Metric 1005 (0402 in) is seen today in mass production with metric 0603 (0201 in) becoming more common – Metric 0402 (01005 in) is now entering mainstream production
• The shock and awe has been realized by the introduction of the Metric 0201 (008004 in) component with a 6% area and 1.6% volume reduction when compared to a metric 1005 (0402 in) component
• The challenges to presented by these small components will need to be addressed by both equipment and material developers as well as adopted by the end users.
• As the equipment providers are making changes to the machine to accommodate metric 0201 components so does the process engineer in how he introduces this into their manufacturing process
• Changes to the materials used as well as the process being tightly controlled where a clean room environment may be needed to be considered
• Regardless of what the smallest component you are presently using – the benefits of what has been learned with Metric 0201 components can be applied
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### Component sizes

<table>
<thead>
<tr>
<th>Millimeter (mm)</th>
<th>Inch (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Component</strong></td>
<td><strong>Length (mm)</strong></td>
</tr>
<tr>
<td>3216</td>
<td>3.2</td>
</tr>
<tr>
<td>2012</td>
<td>2.0</td>
</tr>
<tr>
<td>1608</td>
<td>1.6</td>
</tr>
<tr>
<td>1005</td>
<td>1.0</td>
</tr>
<tr>
<td>0603</td>
<td>0.6</td>
</tr>
<tr>
<td>0402</td>
<td>0.4</td>
</tr>
<tr>
<td>03015</td>
<td>0.3</td>
</tr>
<tr>
<td>0201</td>
<td>0.25</td>
</tr>
</tbody>
</table>

* : 03015 only offered in resistive package—no Capacitors
Key points to printing miniature components

• Each element of the print process must be addressed to make sure that every advantage is taken into consideration
• The solution to micro-component printing is in the aggregate – not one element but all the elements combined equals success
• Presented here are the best practices – deviation or elimination of an element will most likely result in a less than repeatable process
• For this discussion we will touch on each of these elements where individually they can be discussion on to themselves
• Key Points:
  • PCB
  • Stencil
  • Paste
  • Blades
  • Support
  • Machine Calibration
  • Process Parameters
PCB

• Most often the PCB design is out of our hands – we are left to make adjustments and compromises based on what we receive

• Most applications so far have been dedicated modules where there has been little to no mixed technology on multi-up panels

• Thin PCB’s < 0.020 should be expected

• The ability to form a good gasket between the PCB and the stencil is critical – the PCB plays a big part

• Key Issues to avoid in the design of the PCB:
  • Varied board thickness
  • Variation of mask thickness
  • Encroachment of mask on pads
  • Pads recessed below mask
  • Nomenclature /silk screens
  • Barcode labels
  • Board stretch or step/repeat errors

• Invest in the PCBs to avoid issues that can some cases become impossible to overcome
Blades

- Recommend using a specific set of blades for printing small apertures
- Recommended blade angle of 55 degrees should be used – standard blades are 60 degrees
- Spring steel with a sharp edge is all that is required
- Make sure you are getting a clean sweep across the stencil with no residue left behind
- Check (site) Squeegee regularly for damage
- The Enclosed Flow has been applied for micro component applications
- The pump’s ability to extrude paste into the aperture delivers a consistent aperture fill
- The material cost savings on Type 6 paste gives it a short ROI
- Applications using a dedicated family of products in mass production has seen great success
Stencil

- For our experiments we used a laser cut 0.002” thick stencil with Nano coating

- Recommendation for stencils:

  - Fine-grain Laser cut over E-Form
    - Issues with alignment / image stretch due to process
    - Inconsistencies of stencil thickness point to point
    - Variability in aperture size

  - Nano-Coating
    - Improvements in application techniques have increase production life
    - Improvements in transfer efficiency has been well documented
    - Aggressive fluxes and excessive wiping will limit production life

  - High Tension foils
    - Range of tension = 28 – 40 N/cm² (Newtons/Centimeter)
    - Normal stencils are in the low 30”s
    - High tension has shown to prevent stencil drag during release on thin stencils

- Extra care needs to be used when using thin stencils – household foil is 0.001” thick – think about it
Paste

- Type 6 paste will be required for Metric 0201 components
- Paste costs for Type 5 have been coming down where the average cost is 40% more when compared to Type 4
- Type 6 paste has held steady where average costs are as much as 3-X
- Demand plus yield technology to increase yields will hopefully bring prices down
- Type 5 can be used but yields will be less than Type 6
- Development of a Type 5.5 powder could ease the impact of cost
- Printer requirements remain the same regardless of what type paste used
- Print speed and release will be dictated by the flux used with these powders
- Requirements will include Nitrogen for reflow
- Issues such as paste stencil life, solder balls and “grape-ing” will also need to be addressed

<table>
<thead>
<tr>
<th>Powder size</th>
<th>Mesh</th>
<th>Size Range (um)</th>
<th>Average ball size (um)</th>
<th>Largest Ball size (um)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 3</td>
<td>-325 +500</td>
<td>24 – 45</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>Type 4</td>
<td>-400 +635</td>
<td>20 – 38</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td>Type 4.5</td>
<td>-450 +635</td>
<td>20 – 32</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>Type 5</td>
<td>-500 +635</td>
<td>20 – 25</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Type 5.5</td>
<td>-550 +635</td>
<td>22 - 10</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>Type 6</td>
<td>+635</td>
<td>&lt;20</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>
Support

- Support is key to small feature printing
- Most applications so far have had board thickness 0.002” or less
- Pins, blocks or Grid-tooling will not give the support needed
- Solid Aluminum support plate is recommended
- High precision needs to be applied to insure flatness to the table
- Venturi vacuum over table vacuum is recommended when using thin substrates
- Use a matrix of small vacuum holes to insure the vacuum will not deform the board surface
- Avoid top clamping – use side clamping unless PCB is too thin
Calibration

- When printing small feature apertures, make sure your machine is up to date on manufacturers recommended calibrations
- Vision calibration is key to accurate alignment but it is not the only calibration needed
- Gasketing is key to successful printing
- Board to stencil leveling – that all four corners of the table are parallel to the stencil surfaces
- Standard specifications to date have been to have the four corners of the table within 0.004’ of each other
- Recent studies has shown that this number needs to be 0.001”
- Difficulty with using a feeler gage – repetitive tweaking until specification is met – time = 3-4 hours
- New calibration jig is soon to be released increases accuracy of the calibration to 0.001” in 1 hour
- When using tooling – calibration can use tooling as reference – otherwise the track rails can be used
- Improvements in printing results, regardless of aperture size, can be realized from this calibration
Wiping Parameters

• A design of experiment should be done to determine the correct wipe interval
• Most likely a wipe after each print will need to be applied
• However don’t assume that this will be the case – do the work
• Recommendation is a Vacuum / Vacuum / Dry sequence – this will address the metal residue
• To address the flux, solvent wiping is recommended
• This should be applied every 3rd to 5th wipe cycle – this will address the flux that can build up on the bottom of the stencil effecting release
• Recommendation is to consult the paste manufacturer for solvent compatibility
• Use quality paper – lint Free – FOD can be an issue – False calls / bridging
Design Of Experiment

• Objective
  To demonstrate small component printing capability, focusing on the component 0201m (008004in) (pad size of 5mil x 6mil with a 4.7mil air gap and 12.6mil pitch between the 0201m (008004) components) using the Edison platform.

• Test Process
  • Test consisted of printing 20 PC boards/test vehicles with (200) 0201m (008004in) pads at zero degrees and (200) 0201m (008004in) pads at 90 degrees with optimized print parameters.
  • All printed PC boards were then inspected by the Parmi SPI machine.
  • Inspection data of 0201m (008004in) component analyzed through a SPC package
  • Process capability of Volume and Height results for 0201m (008004in) component displayed to validate the fine pitch capability of the process

All equipment involved in testing was recertified before testing
**Equipment**

**Printer:**
- Machine Model: Edison 300
- Printer was recertified through Cetaq before any testing

**SPI:**
- Machine Model: Parmi Sigma X
- SPI was recertified with a Gage R &R verification test before any testing

**Cleaner:**
- Machine Model: Electrovert Aquastorm 50
- All PC boards were cleaned prior and after testing to eliminate any false data
MPM Edison was designed with Micro components in mind

- 8 micron alignment, 15 micron wet print repeatability.
- 25% improvement in wet print accuracy over current best-in-class
- Minimized movement in table Z-Axis. Reduced camera size (POE) minimizes distance between vision and stencil height
- Axis alignment done using stencil rather than table
- Rails ascend with the substrate to print height – eliminating stack-up intolerance between table and substrate
Material

• Solder Paste
  Type 6 Paste SAC 305

• Stencil:
  Laser Cut 2mil Stencil with Nano Coat

• Squeegee Blades:
  55 degree Metal Squeegee blades (220mm)

• Work holder:
  Dedicated Work holder with Vacuum
PC Board Test Vehicle

Board Size:
- X axis: 8 in
- Y axis: 5.5 in
- Thickness: 0.062 in

0201m (008004in) Pad size:
- 5mil x 6mil (with a 4.7mil space between the pads)

Components that will be inspected:
- 0201m (008004in) located at 0 degree (Qty 100)
- 0201m (008004) located at 90 degree (Qty 100)

The pitch of the component is 12.6mil.
## Print Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squeegee Print Force</td>
<td>14lbs</td>
</tr>
<tr>
<td>Squeegee Print Speed</td>
<td>1.5in/sec</td>
</tr>
<tr>
<td>Snap-off distance</td>
<td>0.1in</td>
</tr>
<tr>
<td>Snap-off speed</td>
<td>3in/sec</td>
</tr>
<tr>
<td>Wipe Cycle Profile</td>
<td>Vacuum, Vacuum, &amp; Dry</td>
</tr>
<tr>
<td>Wipe Frequency</td>
<td>Every board</td>
</tr>
<tr>
<td>Tooling</td>
<td>Dedicated tooling with vacuum</td>
</tr>
<tr>
<td>Board Clamping</td>
<td>Side Snugger</td>
</tr>
</tbody>
</table>
Measured 0201M (008004) Solder Paste Deposits (Scanned Images from SPI)
Paste Volume Results for 0201M (008004) Pads Zero Degree
Paste Height Results for 0201M (008004) Pads Zero Degree
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Measured 0201M (008004) Solder Paste Deposits (Scanned Images from SPI)
Measured 0201M (008004) Solder Paste Deposits (Scanned Images from SPI)
Paste Volume Results for 0201M (008004) Pads
90 Degree
Paste Height Results for 0201M (008004) Pads
90 Degree
Process Capability Results for 0201M (008004) Pads

0201m (008004in) pads (Zero Degrees)

- Volume
  - $C_p$ 2.370210
  - $C_{pK}$ 2.210097
- Height
  - $C_p$ 3.279691
  - $C_{pK}$ 2.322249

0201m (008004in) pads (90 Degree)

- Volume
  - $C_p$ 2.272988
  - $C_{pK}$ 2.224115
- Height
  - $C_p$ 4.322438
  - $C_{pK}$ 3.817346
Questions?

This project was support by:

Chrys Shea
Senior Application Engineer
Shea Engineering Services

John Morini
Senior Application Engineer
Parmi

Greg Smith
Manager ofStencil Technology
Blue-Ring Stencils

Thank You!