01005 Assembly Process, Materials and Tooling

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defining the future
Introduction to the 01005

- History and market information
- Availability

Assembly Issues

Design

PCB

Tools

Printing

Aperture design

Paste

Placement

nozzles

Feeders

Tape

Reflow

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A Challenge Based on Necessity

Chip caps and resistors are among the smallest, simplest and perhaps the least expensive parts in a printed circuit assembly.

However, they require the most attention by perhaps the most expensive investment of the assembly process: the placement machine. Printing and reflow also exert significant influences on the end result.

Developing a process that includes capability for the assembly of 0201 and 01005 components does not have to be a complicated exercise.

Using specific design rules for substrates and stencils, consistent materials, and the proper tools, an acceptable process can be developed.
01005 Component

How small is it?

Size Comparison

01005s mixed with black pepper.

01005 Chip Capacitor, inches (mm)

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Market Information

Drivers

- Continued miniaturization of cell phones, pagers, PDA’s, MP3 players etc. have driven component sizes down from 0603 and 0402 to 0201 and 01005.

- Increased functionality of portable digital electronics such as cell phones and notebook computers that continue to push the envelope of form and functionality.

- Smaller capacitors and integration of components help to achieve the desired performance levels and customer expectations

- Hi Frequency manufacturers are the main users

- Higher performance in smaller packages at the lowest cost.
  - This is not always achievable

Mobile Phone Evolution

SOURCE: Prismark Partners LLC

Bottom View
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Capacitor Footprint</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1206) 3216</td>
<td>3.2 mm x 1.6 mm in 1970</td>
<td></td>
</tr>
<tr>
<td>(0603) 1608</td>
<td>1.6 mm x 0.8 mm in 1983</td>
<td></td>
</tr>
<tr>
<td>(0402) 1005</td>
<td>1.0 mm x 0.5 mm in 1990</td>
<td></td>
</tr>
<tr>
<td>(0201) 0603</td>
<td>0.6 mm x 0.3 mm in 1997</td>
<td></td>
</tr>
<tr>
<td>(01005) 0402</td>
<td>0.4 mm x 0.2 mm in 2004</td>
<td></td>
</tr>
</tbody>
</table>

In spite of having equal capacitance the footprint in 1997 is approximately 1/6 of the size in 1990.

And the 01005 has a footprint of 0.08 mm² vs. 5.12 mm² of a 1206 capacitor. That is a reduction of 98.5%

The 01005 has a footprint of 44% of that of an 0201.
Part Availability

- Availability and price go hand in hand.
- Limited values: cap or resistor
- A simple search on supplier website for 01005, 0201 and 0402 with interesting results
- Placement yields are not as high as larger size parts which only serve to drive the cost of using this part even higher.
- In certain applications increased functionality of the device outweighs the increased cost of the part.

<table>
<thead>
<tr>
<th>Part</th>
<th>Availability</th>
<th>Price</th>
<th>Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>01005</td>
<td>641</td>
<td>$0.0387</td>
<td>185</td>
</tr>
<tr>
<td>0201</td>
<td>6000+</td>
<td>$0.003</td>
<td>3000+</td>
</tr>
<tr>
<td>0402</td>
<td>6000+</td>
<td>$0.002</td>
<td>3000+</td>
</tr>
</tbody>
</table>

Vendors:
- Murata
- HDK
- Rohm
- Panasonic
- Kamya
- Tayio
0201 / 01005 Assembly Issues

Printing: Small apertures
  • Stencil clogging, insufficient deposits, deposit size variation, alignment

Placement: Small passives
  • Component size variation
  • Packaging; tapes, feeders, ESD
  • Nozzles, nozzle contamination
  • Speed, placement accuracy, pick issues, placement order

Reflow: Tolerance to above imperfections?
Component Size/Shapes Vary Greatly

Capacitor (Murata)

Resistor (KOA)

Resistor (Matsushita)

Resistor (Hokuriku)

Outline and electrode vary by each maker. They can influence recognition, placement accuracy and pick-up rate.
In general:

- Paper carriers work well for passive components up to approximately 0.9 mm in thickness.

- Beyond the 0.9 mm threshold, paper carrier tapes may be too thick and stiff, resulting in tough handling and errors when feeding into the SMT assembly equipment.
• The smaller the device the more important Dimensional tolerances become in ensuring proper feeding and pick-and-place.
• Standard dimensional tolerances for carrier tape pocket dimensions are 100 µm deviation from target.
  • However, as component sizes drop, the dimensional tolerance of the pocket can become more important.
  • Larger tolerances for a small component could lead to excessive part rotation or tilt within the pocket.
  • Smaller, more complex components may require tighter tolerances down to the 50 µm level.
• Unique tooling and precision processing technology enables smaller form sizes using high-precision tapes.
• Tape pocket-hole-forming down to 0.20 mm will restrict movement and tilting to allow component placement into pocket cavities accurately during component insertion applications.
• Tape and feeder interaction is critical to make sure that they deliver the best accuracy
0402 0201 01005 feeders

• Designed specifically for 01005 and 0201’s

• Reliable feeding mechanisms at maximum machine speeds

• Special shutter/peeler for 01005 and 0201

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Feeders

- Auto Teaching of Tape Pocket and Pick height to assure accurate Pick while machine maps feeder index profile to optimize pick performance
- .66 mil per pixel resolution camera
01005 Pick and Place

Optimized Z placement force

- Optimized Placement Force
- Previous Placement Force

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01005 Pick and Place

- Caps and Resistors are different thicknesses
- Resistors are thinner more opportunity for nozzle contact with paste
Solder Paste:
  Powder size: type 3 $, 4 $$ or 5 $$$

Stencil:
  Thickness: 3, 4 or 5 mil thick
  Material: SS, Nickel, Invar
  Type: Laser cut, Efab
  Squeegees: Metal or Enclosed Print Head
Area Ratio: comparing areas of paste contact inside the aperture = $A \div B$

IPC–7525: Complete solder transfer achieved at Area Ratios > 0.66
## Area Ratio
### Typical 0201 Aperture

<table>
<thead>
<tr>
<th>Aperture Width</th>
<th>Aperture Length</th>
<th>Area of Aperture walls</th>
<th>Area of Printed area</th>
<th>Stencil Thickness</th>
<th>Area Ratio Printed area/wall area</th>
<th>Aspect Ratio width/thickness</th>
<th>Paste volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>11</td>
<td>312</td>
<td>180</td>
<td>6</td>
<td>0.58</td>
<td>1.8</td>
<td>990</td>
</tr>
<tr>
<td>15</td>
<td>11</td>
<td>260</td>
<td>165</td>
<td>5</td>
<td>0.63</td>
<td>2.2</td>
<td>825</td>
</tr>
<tr>
<td>15</td>
<td>11</td>
<td>208</td>
<td>165</td>
<td>4</td>
<td>0.79</td>
<td>2.75</td>
<td>660</td>
</tr>
<tr>
<td>15</td>
<td>11</td>
<td>156</td>
<td>165</td>
<td>3</td>
<td>1.06</td>
<td>3.7</td>
<td>495</td>
</tr>
</tbody>
</table>

- **Area Ratio** = \( \frac{\text{Area of Aperture Opening Area}}{\text{Area of Aperture Wall Surface Area}} \)
Area Ratio 0201

- Recommended Area Ratio: 0.66
- Using 5-mil stencil

Transfer Efficiency vs. Area Ratio graph shows the relationship between these two variables with recommended area ratio marked.
### Area Ratio
**Typical 01005 Aperture**

<table>
<thead>
<tr>
<th>Aperture length (mils)</th>
<th>Aperture length (mils)</th>
<th>Area of aperture walls</th>
<th>Area of pad (mils)</th>
<th>Stencil Thickness</th>
<th>Area Ratio pad area/wall area</th>
<th>Aspect Ratio width/thickness</th>
<th>Paste Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>8</td>
<td>96</td>
<td>64</td>
<td>3</td>
<td>0.67</td>
<td>2.7</td>
<td>192</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>108</td>
<td>81</td>
<td>3</td>
<td>0.75</td>
<td>3</td>
<td>243</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>128</td>
<td>64</td>
<td>4</td>
<td>0.50</td>
<td>2.0</td>
<td>256</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>144</td>
<td>81</td>
<td>4</td>
<td>0.56</td>
<td>2.3</td>
<td>324</td>
</tr>
</tbody>
</table>
Recommended using 4-mil stencil
Solder Paste Printing

Type 3
Pad size: 11x11, 5 mil space between pads
Aperture size 11x11
Stencil thickness: 4 mil
Area ratio .69

Type 4
Pad size 8.8 round, .4mm pitch
Aperture size 9.5 square
Stencil thickness 3 mil
Area ratio .79

What if... Stencil 4 mil = .59 ratio

Type 5

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Paste Positioning on Attachment Pads

Recommend best pad / stencil design combination. Report assembly yield trends for:

• Grab (balanced / imbalanced)
• Print mis-registration tolerance
• Reflow atmosphere (N₂ vs. air)
• 0201 vs. 01005

Typical grab solutions for 0603 and smaller parts
Typical solder joint defects

- Insufficient solder volume
- Excessive solder volume
- Component misalignment
- Mis-placed component
Typical defects

Open solder joints (tombstone)

Solder beads (solder balls)

Solder bridges
Typical Defects
Tombstoning 0201 vs 01005

$N_2$ reflow comparison. Resistors only. Caps may act differently.
Solder Mask Related Defects, 01005

Source: 01005 assembly process—from the board design to reflow

Global SMT & Packaging – September 2008

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Solder Mask Related Defects, 01005

- Solder mask is omitted from beneath the components,
- The height of the solder mask can prevent proper collapse of the solder joints.
Solder Paste Reflow

- Forced Convection oven
- Air or Nitrogen. Process window tighter for Air.
- Orientation has little effect on defect rates
“Standard” apertures centered on pad. (1 mil cutback)

Minimum trace to trace and pad to pad spacing for most PCB manufacturers is .005” for outer layers.

When posing the question ‘how tight can I get these little suckers’, you must do a reality check and think about what you are asking for and why.

Pad size tolerances are often +/- .001” and starting copper weights are often in the ¼ oz. range when requesting features .010” or less.
Pad Design, 0201

Attachment Pad

Component

Attachment Pad

0.009"

0.015"

0.018"

0.012"
Stencil design

- 5 mil (125 mm) thick stencil maximum
- 11*15 mil aperture (275*380 mm),
- 3 mil grab minimum (75 mm), application specific

Paste deposit
Pad on PCB
Component
Assembly Defects by Attachment Pad Width and Assembly Process Type

Number of Solder Joint Defects vs. Pad Width (mils)

- No-Clean, Air Reflow
- Water-Soluble, Air Reflow
- No-Clean, Nitrogen Reflow

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0201 Experiment data

Assembly Defects by Attachment Pad Length and Assembly Process Type

- No-Clean, Air Reflow
- Water-Soluble, Air Reflow
- No-Clean, Nitrogen Reflow

Number of Solder Joint Defects vs. Pad Length (mils)
Assembly Defects by Attachment Pad Spacing and Assembly Process Type

- No-Clean, Air Reflow
- Water-Soluble, Air Reflow
- No-Clean, Nitrogen Reflow

Number of Solder Joint Failures vs. Attachment Pad Spacing (mils)
Screen Printer Process 0201

- DEK 265GSX
- Print speed 1.0”/sec.
- Metal squeegee blades
- Squeegee angle 60 degree
- Squeegee pressure 2.3 lb/inch
- Print gap 0 (on contact)
- Separation speed 0.02”/sec.
0201 Pad Spacing

Pad spacing

- Component distance > 7 mil (175 µm)

- 4 mil pad distance minimum, 6 to 8 mils preferred
Conclusions

Nitrogen reflow (under 50 PPM oxygen tested) can increase assembly defects under certain conditions.

Attachment pad design sensitivity is reduced when using lower activity fluxes and air reflow.

Solder beads can be reduced or eliminated by reducing the amount of solder paste that is printed under the component.

The number of tombstones increases as the distance between solder paste deposits increase.

Component orientation is significantly dependent upon the use of Nitrogen and/or solder paste flux type.
Thank You for Attending

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