The BGA/QFN Repair Process

D Ball Size	T Stencil Thickness	H Height of Ball in Aper.	H/T Ratio	A Aperture Dia. of circle	Area Ratio	Stencil Type Recommended	Paste Vol. as % of ball Volume
12	4	3	0.75	10.4	0.65	E-FAB	21.9%
12	5	4.5	0.90	11.6	0.58	E-FAB	26.9%
16	4	3.5	0.88	13.2	0.83	Laser	13.4%
16	5	3.5	0.70	13.2	0.66	E-FAB	19.8%
20	5	4	0.80	13.0	0.80	Laser	13.6%
20	6	4.5	0.75	16.7	0.70	Laser	18.5%
24	6	4.5	0.75	18.7	0.78	Laser	13.6%
24	7	5	0.71	19.5	0.70	Laser	17.6%
30	7	5.5	0.79	23.2	0.69	Laser	12.1%
30	8	6	0.75	24.0	0.64	Laser	15.2%

Dimensions are in mils (1 mil = .001" = 25.4 microns = .0254 mm).

Table 1. BGA Repair Stencil Design Guidelines

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Repairing a PCB with a defective BGA, micro-BGA, or QFN often is a challenging and tedious task. The conventional method is to remove the defective device, clean the pads on the PCB, then print solder paste on the pads with a mini-stencil. The stencil footprint must be small enough to fit into the area of the removed part, which typically is surrounded by other devices in close proximity. An alternative repair method is to print solder paste directly onto the QFN pads or the BGA solder balls using a specialized tool.

Specialized repair tools are straightforward and easy to operate. In a typical reballing situation, a package can be manually inserted into the tool, printed, and placed on the PCB in less than a minute. One such reballing device consists of two components: a master tool, which can be reused for a number of different packages; and a device-specific tool, which is designed for a

particular package. The device-specific tooling consists of a stencil and a device-holding fixture. Both are free-standing metal foils with laser-cut or electroformed apertures.

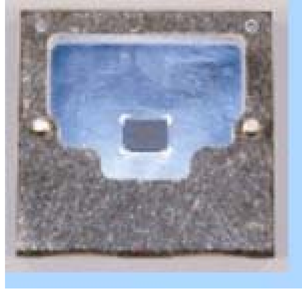

Figure 1. A QFN package in the repair tool.

QFN/BGA Repair Tool

First, the QFN/BGA fixture retains the package-holding fixture as well as the stencil. The package-hold-down fixture is mounted on this assembly. Two puller pins and two fixed pins are used. The stencil then is mounted on the tooling pins. The frame can then have a QFN package placed in the package holder (Figure 1), and the fixture is prepared to print. After printing, the package is lifted out of the holding fixture, pulling paste from the stencil apertures. A manual vacuum pick can be used, but a vision-assisted vacuum pick is recommended for the repair process.

QFN Stencil Design

A QFN package-holding tool is laser-cut and designed according to the package dimensional tolerances, typically 0.127 mm (5 mils) larger than the maximum package dimension. The thickness of this tool is selected to bring the package in contact with the stencil when the hold-down tool is placed in position. It may be convenient to have more than one package-holding tool to achieve the correct thickness. For a 0.76-mm (30-mil) -thick QFN, two holding tools, with dimensions of 0.51 mm (20 mils) and 0.25 mm (10 mils), would provide the correct thickness. The stencil apertures are typically small, therefore the area ratio[1] must be taken into account. Stencil designs are shown in Table 1 for 3-, 4-, and 10-mm QFNs with 0.5-mm pitch.

BGA Stencil Design

In the case of BGAs, it is desirable to have the stencil gasket to the BGA ball at a point that is less than the diameter of the ball. Secondly, the ball cannot extend beyond the topside of the stencil. Otherwise, the ball would interfere with the squeegee during printing. A third condition is to have an acceptable area ratio. Given these conditions, the goal is to optimize the solder volume printed on top of the BGA ball while having an acceptable area ratio.

T = Thickness of stencil
R = Radius of BGA ball
H = Height that ball protrudes into stencil aperture
D = Radius of stencil aperture

Volume of the stencil aperture: $V_1 = \pi D^2 T/4$
Volume of the solder ball sphere in the stencil aperture: $V_2 = 1/3 \pi H^2(3R-H)$
Useful relationship between D and R: $R^2 = (D/2)^2 + (R-H)^2$

Volume of solder paste printed on the ball: $V_3 = V_1 - V_2$
Or: $V_3 = \pi T(R^2-(R-H)^2) - 1/3\pi H^2(3R-H)$

Using these conditions for various BGA ball sizes, a stencil design guide to deliver optimum solder volume is developed and shown in Table 2.

The BGA package-holding tool must be the correct thickness to allow the BGA ball to gasket securely in the stencil aperture when the hold-down tool pushes the package up against the stencil. As with the QFN package-holding tool, multiple BGA package-holding tools may be stacked up to achieve the required thickness. Positional accuracy of the package-holding tool is not as critical for BGAs as it is for QFNs, since the balls self-center into the apertures when pushed against the stencil.

Conclusion

Increased layout densities have made repair by printing solder paste directly on the board's component pads with mini repair stencils difficult. This article describes an alternate approach, in which solder paste is printed directly on the package, either QFN or BGA. The component, with paste-on-pad or paste-on-ball, is placed on the PCB prior to reflow. With proper stencil and component-holding tool design, successful solder paste printing for QFNs — for example a 10-mm QFN with dual-row pad layout having 124 I/Os on 0.5-mm pitch — and BGAs — for example a 35-mm BGA with 1-mm pitch and 1156 I/Os — can be achieved.

REFERENCES:

[1.] W. Coleman and M. Burgess: "Using the Area Ratio Calculator for Stencil Design," *PCB007*, May 15, 2006.

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[1.] BGA and QFN packages for the research were provided by Top Line.
[2.] E-FAB is a Photo Stencil trademark for its AMTX electroform stencil.

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Package Size	Pitch	Aperture Width	Aperture Length	Stencil Thickness	Area Ratio	Recommended
10mm	.5mm	9.5	16	5	0.60	E-FAB
4mm	.5mm	10	16	5	0.62	E-FAB
3mm	.5mm	9.5	14.5	5	0.57	E-FAB

Dimensions are in mils (1 mil = .001" = 25.4 microns).
Package and pitch are in mm.

Table 2. QFN Repair Stencil Design Guidelines