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INFRARED
REFLOW
SOLDERING

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BENDIX AEROSPACE-ELECTRONICS COMPANY

KANSAS CITY, MISSOURI

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ABSTRACT

Infrared Reflow Soldering is a method of simultaneously connecting all leads of flatpacks to circuit boards by means of focused radiant heat. Ease of solder control, rework capabilities, and speed are the major benefits of this technique. These advantages prompted the investigation of infrared reflow soldering to determine the feasibility of soldering integrated circuits and hybrids to two-sided circuit boards by this method, and to determine the plating and printed circuit board requirements for optimal application of the process. Research indicates that such a process is impractical for placement of component leads on the circuit pad because of the difficulty in simultaneously positioning all leads on the pad for soldering. Bonding leads of the "through hole" placement design is also deemed impractical since not enough solder was present at the hole to form an adequate bond.

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Section 1

INTRODUCTION

Infrared reflow soldering, which employs the applique technique for mounting flatpacks on printed circuit boards, is a method of simultaneously joining and connecting all leads to circuit boards by means of focused radiant heat. Ease of solder control, rework capabilities and speed are the major benefits of this technique. These advantages prompted the investigation of infrared reflow soldering to determine: (1) the feasibility of soldering integrated circuits and hybrids to two-sided circuit boards by this method; (2) the plating and printed circuit board requirements for optimal application of the process; (3) the feasibility of reworking soldered assemblies using the process; and (4) the acceptance criteria for solder joints made by this technique.

Section 2

SUMMARY

The infrared reflow soldering process designed for applique lead placement (placement of the component leads flat on the circuit pad) proved impractical because of the extreme difficulty in simultaneously positioning all leads on the pad for the soldering process. The reflow process also proved impractical for bonding leads of the "through-hole" and cordwood placement design because not enough solder was present at the hole to form an adequate solder bond.

Section 3

DISCUSSION

The infrared reflow soldering process employs a controlled, reflected beam of infrared light to heat the surface of the printed circuit board and the pretinned lead. The heat melts the solder, causing the lead to become bonded to the printed circuit pad. The amount of energy emitted by the beam can be controlled by varying the voltage applied to the lamp and by varying the length of time the lamp is activated. The two graphs in Appendix C represent heat ranges for the various time and voltage settings. Optimum time and voltage settings for soldering 14-lead integrated circuits are 2 seconds and 60 volts which yield a temperature at the lead-pad interface of approximately 370°F. Potential and time settings of 115 volts and 11 seconds yield the best results when soldering 30-lead hybrid packages (Appendix B). These settings produce a temperature of approximately 375°F. Peel strength tests per lead show that an average of 14 to 15 ounces can be produced by the infrared reflow soldering method for integrated circuits. Previous studies have indicated that Sn-Pb (tin-lead) plating of 0.0015 inch is optimal and that, in general, the wider the pad, the greater the strength of the joint. The exact effect of different fluxes, Sn-Pb plating on the pads and on the component leads, pad spacing, infrared radiation on pad bonding, exact heat range and rework, however, are still unknown.

EQUIPMENT

Two model SR-10 infrared reflow soldering machines were leased from Federal Tool Engineering Company for this study. Each was equipped with a quartz-iodine lamp which provided the infrared heat source. The amount of voltage and its duration when applied to the lamp can be varied for temperature control. The first SR-10 (Figure A-1) was designed for integrated circuit placement. The second model (Figure A-2) was modified for hybrid placement and employed an individual infrared beam for each side of the component package in contrast to the standard SR-10 which employed a single beam. The twin beam effect of the modified model was accomplished by using a special parabolic reflector and a single lamp. The component bodies on both types of components were protected from the beam by the placement chuck which also acted as a heat sink for the component. In each machine, vacuum held the component in the chuck during placement.

A Honeywell R7161B temperature recorder and iron Constantan thermocouples were used to measure temperature. An Electrovert flow WD-4

solder pot was used for tinning of the component leads with eutectic 63 percent Sn and 37 percent Pb solder. For the 90-degree pull test a Unitek Micropull (Model 6-092-02) was used.

COMPONENT PARAMETERS

The printed circuit boards used in this project consisted of: (1) 0.063-inch G-10 printed circuit material, which has a maximum continuous operating temperature of 265°F; (2) 2- and 3-ounce copper-clad, single-sided, glass cloth epoxy resin; and (3) FR-5 printed circuit material, which is flame retardant, temperature resistant, and has a continuous operating temperature of 300°F. Test pad widths for all boards were 0.040, 0.035, 0.030, and 0.025 inch with 0.050-inch centers for both integrated circuits and hybrids. Sn-Pb plating was 63 percent Sn and 37 percent Pb with plating thicknesses of 0.0015 and 0.003 inch on integrated circuit pads and 0.001, 0.015, 0.002 or 0.003 inch on hybrid pads. The leads of the hybrids were plated at various solder pot temperatures in order to vary the Sn-Pb plating thickness.

The lead feet of the flatpacks were preformed at 0, 8 or 12 degrees from horizontal so that adequate pressure could be applied. The length of the lead foot was varied (trials made at 1/4, 1/8 and 1/16 inch). Both RMA (Resin Mildly Activated) and RA (Resin Activated) fluxes were used.

TEST RESULTS

Tests such as the application of the flatpack to the pad, and the removal and reapplication of flatpacks to simulate rework, showed that bonds made at one heat setting might not delaminate the first time, but that removal and reapplication at the same heat setting would produce lamination. Optimum machine settings for integrated circuits on G-10 and FR-5 printed circuit boards were approximately 2 seconds at 60 volts, which produced an average peel strength per lead of 19.6 ounces with RA flux and 1/8-inch foot-contact length. Removal and reapplication of the flatpack for rework reduced the peel strength to approximately 13.5 ounces. This reduction was primarily due to the fusing of the solder and a resulting round surface; thus the leads were more prone to misalign on the pad.

The foot length of the integrated circuit leads proved optimal at 1/8 inch and produced an average peel strength of 19.6 ounces compared to 17.7 ounces for 1/4 inch lengths under the same conditions. One-sixteenth-inch lead lengths were tried but difficulties in preforming the lead at an angle necessary to allow the feet to lie flat on the pad resulted in failure of many of the leads to bond.

RA fluxed circuits produced an average peel test of 16.8 ounces compared to 11.8 ounces for RMA flux application. Visual inspection of the solder bonds was made using Bendix Corporation Process Standard 9913008 modified to apply to infrared reflow soldering. RMA fluxed bonds were more apt to be visually accepted than RA fluxed bonds. RA fluxed circuits were often rejected for excess surface porosity and excess solder, whereas the RMA fluxed circuits were apt to be rejected for insufficient solder and insufficient solder fillets.

Circuit pad widths proved optimal on a peel test basis at the widest widths tested which were 0.040 inch and 0.035 inch, producing a peel test of 16.8 and 11.9 ounces respectively (3 sec., 60 v). Widths of 0.030 and 0.025 inch produced a peel test of 15.8 and 12.0 ounces respectively. The dispersion of the rejects for misalignment of leads reflected the problem of aligning all fourteen leads simultaneously.

Hybrid circuit bonds produced results similar to those of integrated circuit bonding. Widths of 0.040, 0.035, 0.030, and 0.025 inch produced average peel strengths of 22.0, 17.2, 17.5, and 17.5 ounces respectively. Because of stiffer leads on the hybrids the type of flux did not significantly alter this peel test.

Section 4

CONCLUSIONS AND RECOMMENDATIONS

The ability to keep all 14 integrated circuit leads and 30 hybrid circuit leads on the pads simultaneously is the primary problem of the infrared reflow soldering method. The time saved by soldering all the leads simultaneously is consumed by aligning the leads so that they all lie on the pads at once with adequate uniform pressure. The infrared method relies on the force produced by the spring of the leads which are bent at an angle to the pad. Adequate pressure to force the leads to the pad, however, cannot be achieved by this method. Attempts to design a chuck that is transparent to the infrared beam and to apply uniform pressure to each lead so that little operator time is consumed in loading the chuck have failed.

Inability of the operator to view the flatpacks as they are placed under the beam and during the bonding cycle increases the lead alignment problem. The method requires an overhead light source which, in turn, hampers the operator in viewing the flatpack during the placement of the circuit under the beam and during the actual bonding process. This factor does not allow the operator to correct any misalignments that might occur after placing the circuit on the pad, thus contributing further to the lead alignment problem. Because of the lead alignment problem and difficulties in assuring an adequate bond by visual inspection, this process is not recommended for the production attachments of integrated circuits and hybrid circuits to printed circuit boards.

Appendix A

Infrared Reflow Soldering Equipment and Integrated Circuit Attachments for Printed Circuit Boards

Figure A-1. SR-10 Infrared Reflow Soldering Machine for Integrated Circuit Placement.

Figure A-2. SR-10 Infrared Reflow Soldering Machine Modified for Hybrid Circuit Placement.

Figure A-3. Work Station and Equipment.

Figure A-4. Printed Circuit Board for Testing Integrated Circuits.

Figure A-5. Integrated Circuit Attachment to Printed Circuit Board.

Figure A-6. Integrated Circuit Lead Attachment to Printed Circuit Board.

Figure A-7. Heel Fillet of Integrated Circuit Leads.

Appendix B

Flatpack Lead Peel Tests for Integrated and Hybrid Circuits

Table B-1. Flatpack Lead Peel Tests: Integrated Circuits

Setting: 3 seconds, 60 volts Pad Width: 0.040 inch		Flux: RMA Lead: 1/4 inch
Lead No.	Peel Test (oz)	Results (Visual Inspection)
1	12.6	Insufficient Solder
2	15.1	Cold Solder
3	24.6	
4	10.6	
5	10.5	
6	14.5	
7	17.0	Cold Solder
8	19.5	Insufficient Solder
9	21.1	
10	20.6	
11	15.1	
12	18.0	
13	16.0	
14	20.1	
	Avg. 16.81	Insufficient Solder

Table B-1 Continued. Flatpack Lead Peel Tests: Integrated Circuits

Setting: 3 seconds, 60 volts Pad Width: 0.040 inch		Flux: RMA Lead: 1/4 inch
Lead No.	Peel Test: 90% (oz)	Results (Visual Inspection)
1	9.3	Excessive Solder
2	13.5	Acceptable
3	21.0	Incomplete Fillet
4	5.8	Acceptable
5	17.2	Insufficient Solder
6	15.5	Incomplete Fillet
7	10.6	Insufficient Solder
8	9.5	Acceptable
9	9.2	
10	7.6	
11	8.5	
12	10.7	
13	17.2	
14	9.5	Acceptable
		Insufficient Solder, Misaligned Lead
	Avg. 11.80	

Table B-1 Continued. Flatpack Lead Peel Tests: Integrated Circuits

Setting: 3 seconds, 60 volts Pad Width: 0.035 inch		Flux: RMA Lead: 1/4 inch
Lead No.	Peel Test: 90% (oz)	Results (Visual Inspection)
1	11.6	Incomplete Fillet
2	11.0	Incomplete Fillet
3	11.5	Insufficient Solder
4	7.9	Lead not parallel to conductor at heel
5	10.8	
6	11.4	Incomplete Fillet
7	6.8	
8	9.5	
9	21.3	Incomplete Fillet
10	15.4	Insufficient Solder
11	12.8	Insufficient Solder
12	13.4	Acceptable
13	13.4	Acceptable
14	10.2	Acceptable
	Avg. 11.93	

Table B-1 Continued. Flatpack Lead Peel Tests: Integrated Circuits

Setting: 3 seconds, 60 volts Pad Width: 0.030 inch		Flux: RMA Lead: 1/4 inch
Lead No.	Peel Test (oz)	Results (Visual Inspection)
1	18.2	Incomplete Fillet
2	14.8	Lead not Parallel to the Conductor
3	13.4	Lead not Parallel to the Conductor
4	18.8 (delaminated)	Misaligned Lead
5	16.1 (delaminated)	Incomplete Fillet
6	error	<div></div>
7	10.9	
8	11.2	
9	19.6	
10	18.4	
11	17.1	
12	19.4	
13	12.4	
14	15.4	
	Avg. 15.82	Incomplete Fillet

Table B-1 Continued. Flatpack Lead Peel Tests: Integrated Circuits

Setting: 3 seconds, 60 volts Pad Width: 0.025 inch		Flux: RMA Lead: 1/4 inch
Lead No.	Peel Test (oz)	Results (Visual Inspection)
1	20.4	Incomplete Fillet
2	11.8 (pad off)	
3	error	
4	10.4 (pad off)	
5	8.8 (pad off)	
6	9.8 (pad off)	
7	15.3	
8	14.3	
9	10.9 (pad off)	
10	11.1 (pad off)	Incomplete Fillet
11	10.8 (pad off)	Incomplete Fillet, Misaligned Lead
12	11.0 (pad off)	Incomplete Fillet
13	10.7 (pad off)	Incomplete Fillet
14	10.8 (pad off)	Incomplete Fillet, Misaligned Lead
	Avg. 12.01	

Table B-1 Continued. Flatpack Lead Peel Tests: Integrated Circuits

Setting: 2 seconds, 60 volts Pad Width: 0.040 inch		Flux: RA Lead: 1/4 inch
Lead No.	Peel Test: 90% (oz)	Results (Visual Inspection)
1	22.6	Excessive Surface Porosity
2	22.5	Acceptable
3	20.0	Discontinuous Solder Fillets
4	20.7	Insufficient Solder
5	18.0	Insufficient Solder
6	22.4	Insufficient Solder
7	23.0	Incomplete Fillet
8	15.7	Insufficient Solder
9	16.7	Acceptable
10	14.4	Acceptable
11	13.4	No Fillet at Heel
12	12.4	Discontinuous Solder Fillets
13	13.7	Insufficient Solder
14	12.8	Insufficient Solder
	Avg. 17.74	

Table B-1 Continued. Flatpack Lead Peel Tests: Integrated Circuits

Setting: 2 seconds, 60 volts Pad Width: 0.035 inch		Flux: RA Lead: 1/4 inch
Lead No.	Peel Test: 90% (oz)	Results (Visual Inspection)
1	13.4	Insufficient Solder
2	22.6	Cold Solder
3	19.0	
4	22.5	
5	23.0	
6	23.0	
7	22.3	Cold Solder
8	12.4	Insufficient Solder
9	17.3 (pad off)	
10	13.7	
11	15.0 (pad off)	
12	16.7 (pad off)	
13	17.4 (pad off)	
14	11.8	Insufficient Solder
	Avg. 17.86	

Table B-1 Continued. Flatpack Lead Peel Tests: Integrated Circuits

Setting: 1 second, 60 volts Pad Width: 0.025 inch			Flux: RMA Lead: 1/4 inch
Lead No.	Peel Test (oz)	Results (Visual Inspection)	
1	14.5	[Excessive Heat, Misaligned Leads, Incomplete Fillet, Excessive Surface Porosity, Insufficient Solder.]	
2	10.2		
3	11.4		
4	8.0		
5	9.8		
6	9.9		
7	12.0		
8	5.5		
9	7.0		
10	6.6		
11	6.7		
12	9.6		
13	13.0		
14	10.5		
	Avg. 9.62		

Table A-2. Flatpack Lead Peel Tests: Hybrid Circuits

Setting: 15 seconds, 115 volts Pad Width: 0.025 inch Flux: RA Leads: Selected at random	Setting: 13 seconds, 115 volts Pad Width: 0.030 inch Flux: RA Leads: Selected at random
Peel Test (oz)	Peel Test (oz)
13.6	34.6
16.8	13.6
23.2	15.7
12.6	7.0
27.2	20.8
9.8	14.9
8.0	15.7
24.0	Avg. 17.5
22.4	
Avg. 17.5	
Setting: 11 seconds, 115 volts Pad Width: 0.035 inch Flux: RA Leads: Selected at random	Setting: 9 seconds, 115 volts Pad Width: 0.040 inch Flux: RA Leads: Selected at random
Peel Test (oz)	Peel Test (oz)
9.8	18.1
12.0	31.2
41.8	15.2
18.1	25.1
16.0	20.2
5.6	21.9
Avg. 17.2	Avg. 22.0

Table A-2 Continued. Flatpack Lead Peel Tests: Hybrid Circuits

Setting: 15 seconds, 100 volts Pad Width: 0.025 inch Flux: RA Leads: Selected at random	Setting: 14 seconds, 100 volts Pad Width: 0.030 inch Flux: RA Leads: Selected at random
Peel Test (oz)	Peel Test (oz)
21.9	10.4
12.0	18.4
16.0	17.6
12.0	13.9
28.0	16.8
28.0	35.0
Avg. 19.7	Avg. 18.7
Setting: 13 seconds, 100 volts Pad Width: 0.035 inch Flux: RA Leads: Selected at random	Setting: 12 seconds, 100 volts Pad Width: 0.040 inch Flux: RA Leads: Selected at random
Peel Test (oz)	Peel Test (oz)
39.5	25.6
24.6	24.0
27.4	21.4
37.4	25.6
24.0	15.2
40.0	8.0
Avg. 32.2	Avg. 20.0

Appendix C

Temperature Curves for Standard and Modified Infrared Reflow Soldering Equipment

Figure C-1. Temperature Curves for Standard SR-10 Infrared Reflow Soldering Machine

Figure C-2. Temperature Curves for Modified SR-10 Infrared Reflow Soldering Machine

Appendix D

Safety

SAFETY

Intense infrared radiation may have damaging effects on the eye such as photophobia (abnormal light sensitivity which is characterized by pain associated with reflex movements of the iris). Infrared light can irreversibly bleach the visual pigments of the retina and is a probable source of eye cataracts.

A study conducted by the Bendix Health and Safety Department revealed that the two Conray Tweezer-Weld machines leased from the Federal Tool Engineering Company presented little hazard to the operator's vision if safety glasses with Number 3 green lenses were worn. In production, special protection would probably be unnecessary unless visual checks of the operation were made.

At some future date it may be necessary to fabricate tooling for an Infrared Reflow Solder Machine. This tooling must be covered with a non-reflective coating. It is permissible to use a flat black, flat blue or flat green color. Teflon in these colors makes an excellent heat resistant finish.

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