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Impact of Pad Design and Spacing on AC Breakdown Performance

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High voltage capacitors are used for isolation and transient protection in electronics that are connected to either phone lines using modems or Ethernet connections. Portable electronics that use those components are driving to smaller case sizes to increase product functionality while shrinking both size and weight. As the users of high voltage capacitors continue driving to smaller high voltage (HV) components, understanding arcing failures becomes critical in designing and manufacturing those assemblies. There are interactions between the PWB (Printed Wiring Board) flux residues, humidity absorption of the board solder mask and flux residue, solder paste used, pad or land shape and spacing. These end product changes require optimum board layout to achieve both functionality and size/weight reductions.

The influence of solder mask beneath parts and slots between component pads have already evaluated¹ for 1206 and 1808 case sizes and that work was used as the spring board for this study. Observations of both bare boards used in high voltage arcing tests showed that the arcs were originating at component pad corners in the previous study. This was the driving force behind evaluating SMT pad shape and spacing impact on high voltage breakdown performance.

Experiment

This study uses two case sizes, 1206 and 1808 sized capacitors with radius vs. square corner pads using slightly different pad spacing to determine improved assembly performance when these capacitors are used. Bare boards and capacitors are tested to failure under AC breakdown conditions to establish a performance baseline. Capacitors were reflow soldered using no-clean lead free solder paste (SAC305) on those boards. Additionally assemblies are split with half exposed to 72 hours of 85°C/85% RH and half tested as soldered. Complete results and breakdown distributions are included in the appendix.

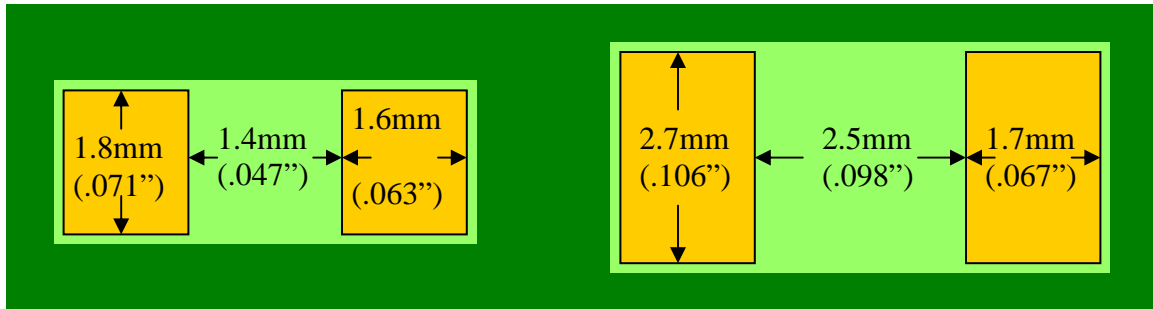
Pad or Land Designs

Pad designs from IPC 7351 (replacement for IPC-SM-782) “Surface Mount Design and Land Pattern Standard” were not used due to reduced spacing or creepage between pads or lands. IPC-7351 1206 and 1808 land sets are shown for reference in Figure 1. Pad designs more suited for both improved high voltage breakdown performance and low manufacturing defects were used instead.



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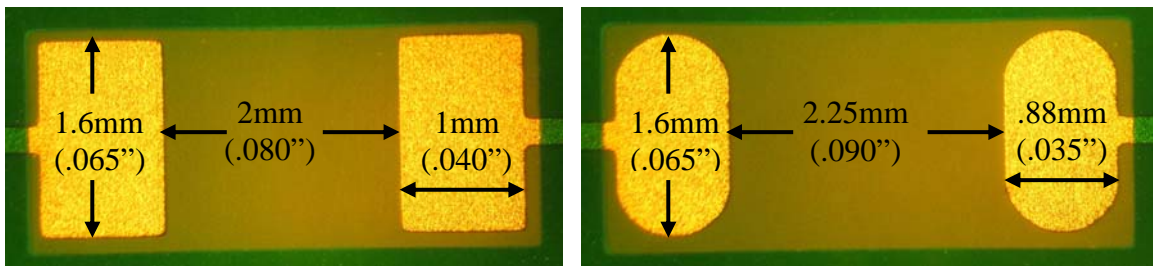
Solder mask degrades HV AC breakdown performance¹ so no solder mask was used between the pads. Figures 2 and 3 show typical rectangular pads and HV pads using a corner radius of 0.019" (0.5mm) for 1206 and 1808 chips. Spacing for the HV pads were increased .010" (.25mm) for additional creepage distance while maintaining assembly manufacturability. Chip capacitors used for high voltage applications typically have shorter and tighter end ban specifications than do standard chip capacitors to increase surface creepage distance reducing necessary pad overlap (the distance the capacitor overlaps the pad) and maintaining high manufacturing yields.



a) 1206 Chips

b) 1808 Chips

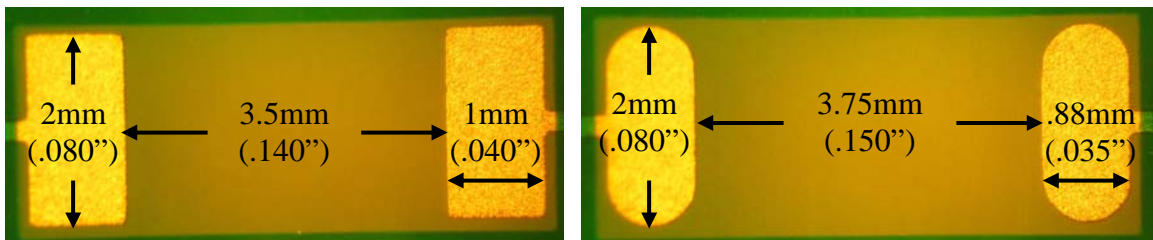
Figure 1. IPC-7351 1206 and 1808 Land Patterns



a) Typical HV Rectangular Pads

b) High Voltage Oval Pads

Figure 2. 1206 Pads



a) Typical HV Rectangular Pads

b) High Voltage Oval Pads

Figure 3. 1808 Pads

Table 1 is a summary of pad or land separation (creepage) for IPC 7351 designs, commonly encountered HV rectangular pads and oval pads with maximum separation.



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Table 1. Pad or Land Design Pad Separation

Case Size	IPC 7351	HV Rectangular Pads	HV Oval Pads
1206	1.4mm (0.047")	2mm (0.080")	2.25mm (0.090")
1808	2.5mm (0.098")	3.5mm (0.140")	3.75mm (0.150")

Test Capacitors

Production 150pF X7R 1808 parts and 120pF 1206 parts were pulled from inventory for use in these experiments. 2.5kV DC rated 1206 capacitors were used for the small case size and a 3kV rated 1808 safety capacitors were mounted on those pads. Eighty piece AC breakdown distributions for both parts are shown in Figure 4. The lower set limit or LSL is a 10% guard band above the 1500VAC test voltage used in product testing to insure parts mounted to assemblies pass using different test equipment in various customer facilities around the world.

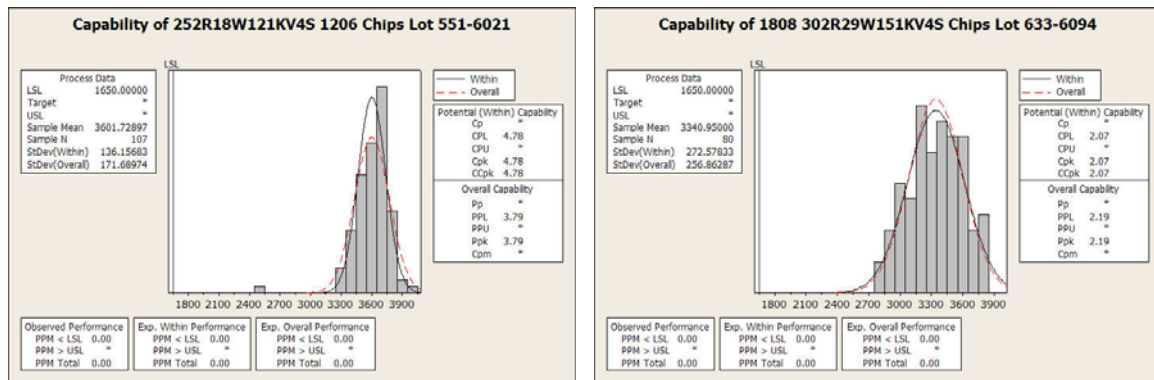


Figure 4. AC Breakdown Distribution for the Chip Capacitors Used

Test Results

Table 2 summarizes 80 piece test results for each pad design variation (4) and test conditions including boards as received, bare chips, boards with parts reflow soldered with no-clean SAC lead free solder paste and exposed to 72 hours of 85%RH @ 85°C. The latter boards were tested for AC breakdown within an hour of removal from the 85/85 chamber.

Table 1. AC Breakdown Mean Value Summaries of Pad Design and Evaluation Boards

Pad Types	Bare Boards	Capacitors	Caps w/SAC	Caps w/SAC 85/85 Not Mounted
1206 Chip Case Size		3601VAC		
Typical Square Pads	2393VAC		2676VAC	2736VAC
HV Rounded Pads	2642VAC		2901VAC	3022VAC



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Pad Types	Bare Boards	Capacitors Not Mounted	Caps w/SAC	Caps w/SAC 85/85
1808 Chip Case Size		3341VAC		
Typical Square Pads	3477VAC		2846VAC	2734VAC
HV Rounded Pads	4050VAC		2863VAC	2767VAC

Conclusions

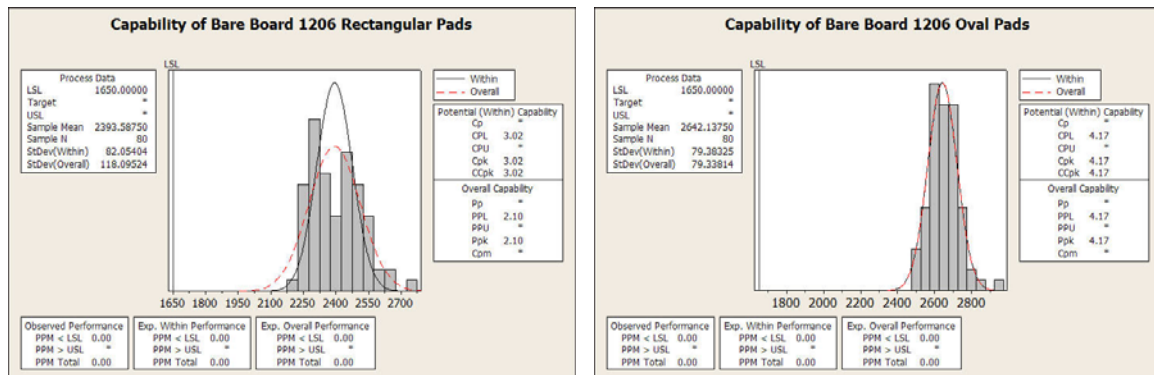
The impact of radius corners and increased creepage distance was most pronounced on the 1206 case sized chips with a 200V + increase in breakdown voltage for bare boards, chips mounted on boards and chips on boards after humidity exposure. An interesting side note was that breakdown voltages increased on 1206 case sized parts after being mounted on the boards with or without humidity exposure. The experiments were repeated with the same results.

The effect on the larger case size was not significantly different enough to take note of. Perhaps there is a threshold creepage distance that is between 1206 and 1808 case sizes where increases beyond that distance yields diminishing returns but that was beyond the scope of this study.

References

- 1) Maxwell, ., Lemus, E. "Arc Season and Board Design Observations" CARTS 2006

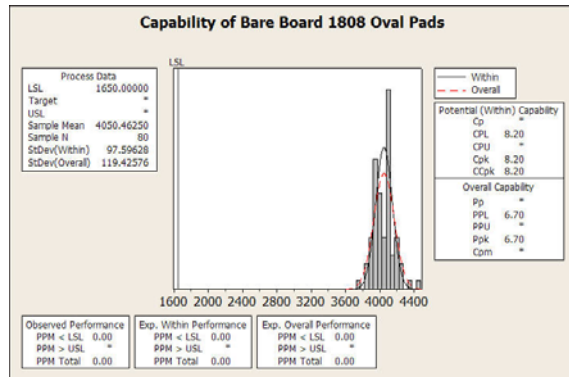
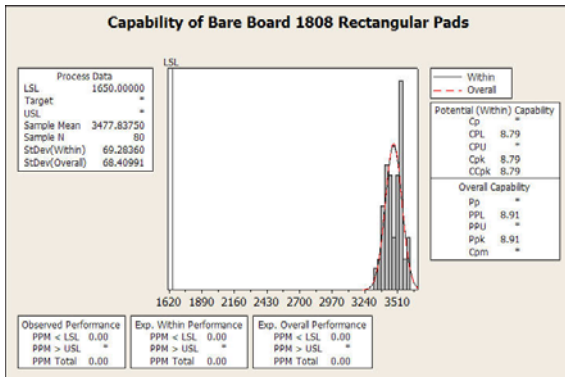
Appendix 1. AC Breakdown Distributions



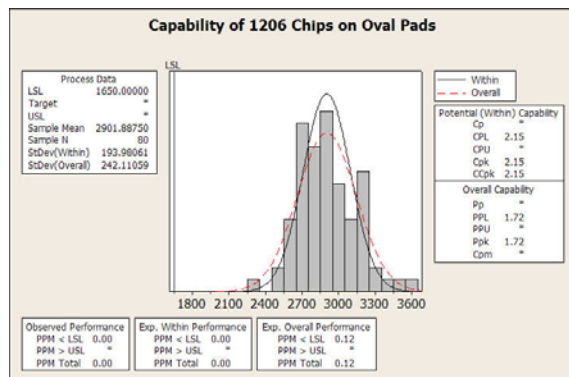
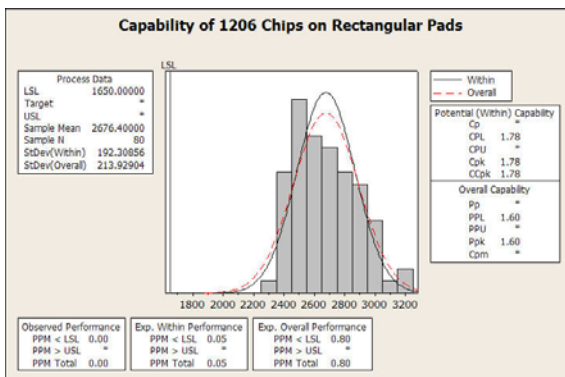
Bare Board Breakdown Capability 1206 Pads



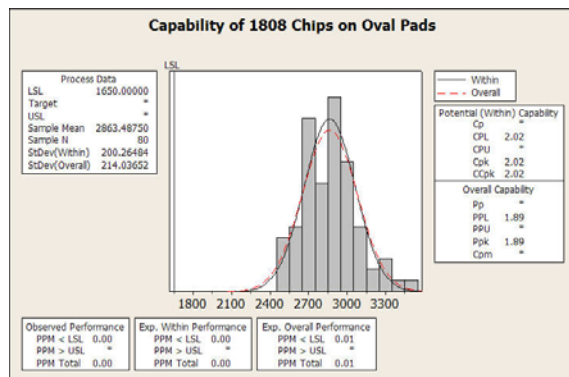
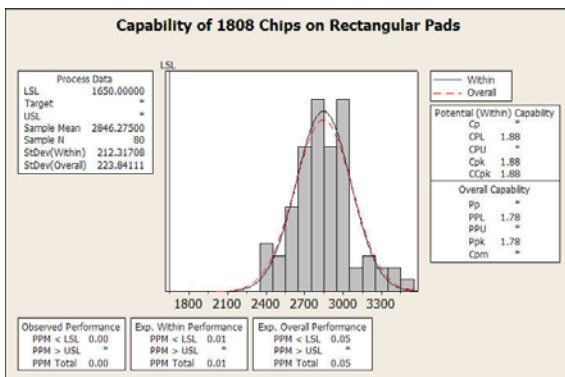
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Bare Board Breakdown Capability 1808 Pads



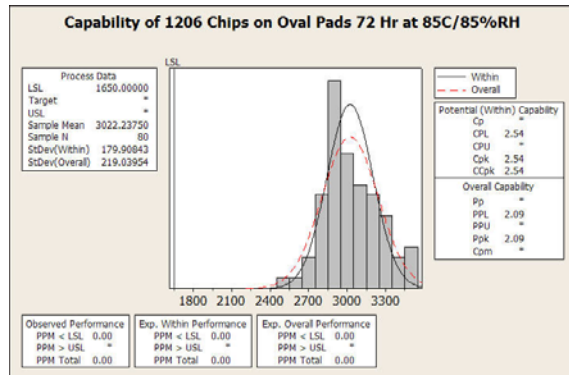
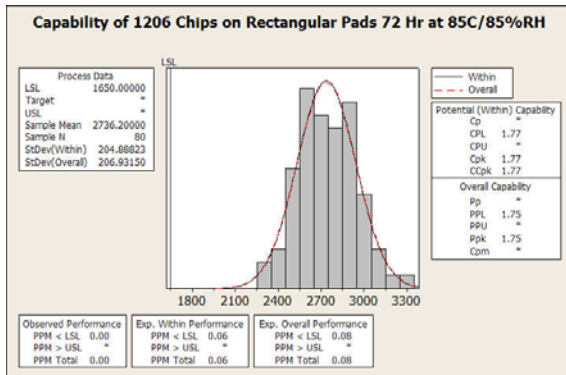
1206 Chip Capacitors Mounted on Boards as Soldered Breakdown Capability



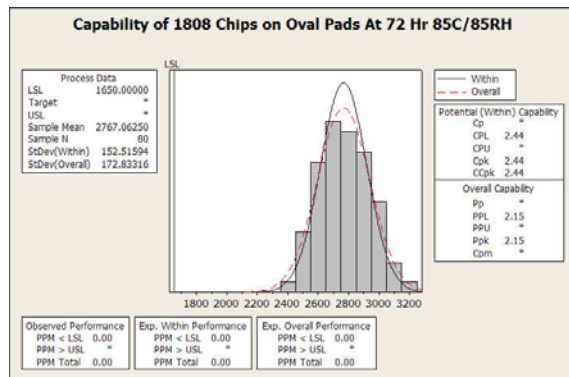
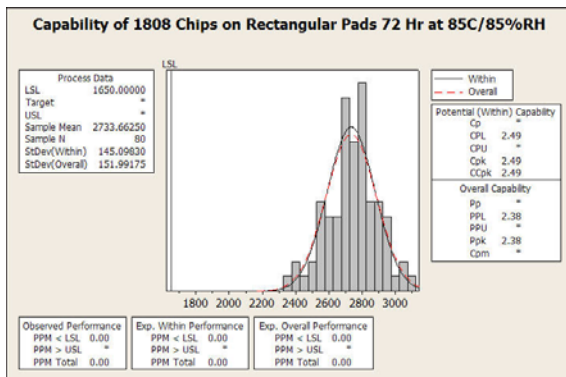
1808 Chip Capacitors Mounted on Boards as Soldered Breakdown Capability



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1206 Chip Capacitors Mounted on Boards Breakdown Capability after 72 Hours of 85°C/85%RH Exposure



1808 Chip Capacitors Mounted on Boards Breakdown Capability after 72 Hours of 85°C/85%RH Exposure

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