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IMPACT OF 0201 COMPONENTS ON CURRENT MANUFACTURING SYSTEMS

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ABSTRACT

The use of 0201 components in consumer products offers a major competitive advantage over other products since they allow significant design miniaturization. This leads to either smaller products or allows more features integrated into the same package size. One of the critical aspects of having the capability of placing 0201 components in any product is the ability of the manufacturing equipment to handle such small components. Many process studies have been completed by manufacturers and equipment suppliers and have shown that tight process windows are required. The current process control for 0402 components is CpK > 1.5 with a 150µm specification window. For 0201 components, the minimum requirement is CpK > 2.0 with a 100µm specification window. The spec window may need to be reduced down to 75µm if the controls for high volume manufacturing are insufficient. Also directly impacting the placement quality is the ability to apply sufficient solder consistently to the board. The goal is to maintain current printing practices, but the effect of powder size will be examined. This paper will evaluate the impact of placement accuracy and solder powder size on 0201 manufacturing quality.

Another critical aspect of manufacturing with 0201 components is the total cost impact. This not only includes the cost of the components but costs associated with defects, such as rework and scrap, higher density PC board costs, and factory modifications, such as new equipment purchases, equipment modifications/upgrades, inline inspection strategies, factory consumables, preventative maintenance, factory utilization effects, and on-going process changes through gained technology experience.

Key Words: 0201 Components, chipshooters, electronic manufacturing, CpK

INTRODUCTION

The use of 0201 components is an enabling technology to further the miniaturization process of electronic products. While there have been products that have shipped with these components inside, most have been in the form of modules such as Voltage Controlled Oscillators and Power Amplifiers. However, some main board applications are starting to show up, especially in digital cameras as the one shown in Figure 1.

Figure 1. Digital Camera with widespread use of 0201 components.

Many development teams of consumer products have been interested in using 0201 components but have not yet implemented them on a large scale. The main reasons for this include issues in the supply chain, factory equipment capability, the soldering process and high volume production robustness. There are substitute technologies available such as embedded passives in printed circuit board and networked passives. However, process and material issue still hinder the implementation of embedded passives and networked passives provide a limited functionality in the electrical design.

The supply chain issues for 0201 components include component cost, component availability, and supplier production capacity. The current supply of 0201 components is somewhat limited since there is not widespread industry use. As a result, component manufacturers have been reluctant ramp up their volumes. The volume capability is there but there is no demand. This results in higher component prices and longer lead times, especially for samples or small quantities, which is vital to the developing stages of a consumer product. This paper will look at each aspect, breakdown the key component issues and provide industry trends and commitments by the suppliers.

Another key area in 0201 technology is the board design. This is made up of the metal (soldering pads), solder mask, and the solder paste layers of the CAD design for the printed circuit board. 0201 components will push the limits of conventional printed circuit board processes. Some technologies, such as stricter solder mask alignment tolerances, are available but usually at an increase in PC board costs. PC board fabrication processes will be discussed as they relate to 0201 components.

One of the main issues for use of 0201 technology is the capability of placement equipment to place 0201 components compared to that for larger components. Most factories currently use a process window of ±0.15mm for their machine capability studies. However, prior process research on 0201 components[i] has shown that this window needs to be reduced to ±0.10mm to avoid excessive defect rates. As a result, all the major equipment suppliers need to improve their placement control systems compared to those used for 0402 components. This paper will discuss some of the challenges required for placing 0201 components.

This paper will also give an update on the process characterization. In addition to padstack design, process conditions such as stencil thickness, solder paste, and HDI via-in-pad technology (High Density Interconnect) are also being considered to optimize the soldering process.

SUPPLY CHAIN

The major suppliers of 0201 components are the same as those for 0402 components. Their expertise will enable a smooth transition from 0402 component to 0201s from the supply chain side. This section of the study will focus on the main issues in the supply of 0201 components: demand, cost, availability, lead-time for procurement, and supplier production capacity.

Demand: Drivers for Using 0201 Components

The various 0201 manufacturers of capacitor, resistors and inductors each have similar expectations on the 0201 usage over the next 3-4 years. Generally, the expectations are around 10% to 15% of the total passive market will be 0201 components. However, widespread rollout of these components into electronic designs has been delayed and may decrease the forecasts. The delay in the rollout of 0201 components is mainly due to four reasons.

First, higher I/O Integrated Circuits require fewer passive devices to support them.[ii] As many as two and three ICs are integrated into one. Much of the functions provided by the passives are also integrated into the IC.

This large-scale integration leads to the second reason-space savings. The integration has led to dramatic part count reductions, especially in cell phones, thus freeing up space in the board designs. In some cell phones, part count reductions are as much as 50%-75% compared to phones from just a few years ago, with component counts in the 150 range. The use of 0201 components is simply yet not needed.

The third reason is cost. 0201 components have a 5x – 10x cost increase associated with them. As a result, with pricing pressures on most consumer electronic devices, most companies are reluctant to use them due to their increase in cost, especially when the smaller components are not required in the design.

The last reason is lack of manufacturing experience. Many companies have spent much time and money determining the optimum process conditions for using 0201 components. However, since the process is not a drop in replacement for 0402 components, both board design and manufacturing process changes will be required in the factory for successful implementation. Many companies are not ready for the initial factory resources in equipment, manpower and other capital expenditures necessary for 0201 implementation.

Still, given the continuing trends in miniaturization and integration of more features, i.e. GPS, Bluetooth, 802.11 modules, E911, FM radios, 3G, etc., into cellphones and other consumer electronics, the use of 0201s seems inevitable. The miniaturization of the actual size of the device may level out, but each device will have more features. The human interface features for the electronic devices, such as the display and keyboard, limit how small the industrial design can actually go. Therefore, the driver for the use of 0201s will point to feature integration, not package size miniaturization.

0201 Component Volume Forecasts & Costs

Component costs historically have been directly linked to volumes produced and the 0201 component is no different. A capacitor manufacturer projects the total 0201 surface mount capacitor market will reach up to 17% by the year 2005 and a resistor manufacturer projects an 8% surface mount 0201 resistor market by year 2004.

These volumes may be overstated given the slow ramp up of 0201 utilization. However, this may rapidly change if the demand for smaller products packed with more features takes off. This may be the case with the 3G phones, which the initial handsets are due to hit the market later this year. Even though the initial handsets do not utilize 0201 components, subsequent handsets that require more features will likely have to use them.

Current 0201 component costs from various suppliers are approximately 5x to 10x of 0402 components. It is expected that the cost maturity curve will be similar to cost curves of 0603 and 0402 components. Current 0201 component costs are shown in Figure 2. It should be noted that the costs of 0201 components have widely varied over the past couple of years, ranging from $0.048 a couple of years ago to approximately $0.006 per part recently. However, the pricing should stabilize with increased industry usage.

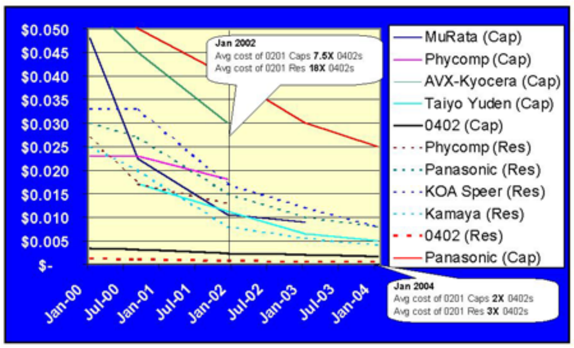

Figure 2. Current 0201 pricing trends

0201 Component Availability and Lead Time

Short lead times for 0201 component procurement are critical to the success of implementing this technology into consumer products. Unstable designs, which are indicative of new products in the development stage, tend to use many different values early in the prototyping stage. If the lead-time for component procurement is too long, then the project development cycle time is adversely affected. Successful implementation of this technology will require lead times of 4 weeks or less.

Available resistor values from most suppliers range from 1Ω to 10 MΩ. Some suppliers are keeping a supply of certain values in the United States to help combat long lead times. If a required value is in stock, lead times are usually overnight. If the component must be manufactured, the lead-time is usually 4-6 weeks.

Capacitor values generally range from 0.1pF to 47,000pF with different ranges for different voltages and dielectrics. Lead times for these components are similar to those for resistors.

0201 Supplier Production Capacity

The 0201 component is still in its infancy since not many manufacturers are using them. As a result, supplier production ramp-up rates vary due to each one's perception of how fast this technology will take off. Still, the manufacturers of 0201 components offer reassurance that volume capacity of 0201 components is not an issue.

Even though the ramp-up rate is slow, the manufacturers of 0201 components are optimizing their processes. New methods of dicing have been developed in order to improve and ensure dimension tolerances. A new type of pocket tape has been developed that allows easier pickup from the placement equipment. Finally, new manufacturing process controls allow higher capacitance ranges than compared with just a couple of years ago.

The supply chain aspect of 0201 technology is critical to successful implementation. Many improvements have been made during the past 3 years and show that the component manufacturers are ready for volume deployment.

DESIGN ISSUES FOR 0201 COMPONENTS

The use of 0201 components will have a big impact on the printed circuit board fabrication processes. Tighter tolerances, finer line and space capability, and better alignment between the solder pads, solder mask and the stencil will all be required. Many of these improvements are available, however, most increase the board cost. This section will review the requirements for 0201 technology and explain the impact on the printed circuit board.

Printed Circuit Board Space Savings

The main reason to use 0201 components is for the PC board space and/or area savings, so that more components can be added to the design to increase functionality or that products may be reduced in total size. In addition to the component size reduction, component-to-component spacing can also be realized with the implementation of 0201 chip components. Many studies have been completed by various organizations from equipment suppliers to manufacturers and most have shown 0201 board designs with a board real estate savings of around 60% compared to 0402 components. In addition, the studies have shown component-to-component spacing as low as 6 mils.

Board Fabrication

One of the benefits from using 0201 components is reduction in component spacing. The current manufacturing guideline required by many Contract Manufacturers is 15 mils. However, previous 0201 studies have shown good manufacturing results down to 8 mils.[iii] In order to successfully achieve component spacing on this order, some PC Board processes will need to be improved. Such processes include fine line and spaces (denoted as x/x). Currently the minimum standard is 5/5. Some PC Board shops will allow localized 4/4 without a cost adder as is sometimes required when routing a Ball Grid Array. If localized 3/3 design rules are used, then the cost adder is typically 5% - 10%. Any widespread use of 4/4 or 3/3 designs will result in a significant cost increase. If the metal solder pads for 0201 components are spaced at 8 mils, even the 3/3 design cannot be used for placing a trace between the components due to inadequate space (9 mils is required). This means that all of the routing of the trace runners to the solder pad must be routed on the inner layers. This can be achieved most effectively by using High Density Interconnect, or HDI, technology by placing the via in the solder pad.

Using HDI has its advantages since it minimizes the size of the via capture pads, however, this too can provide a limitation on the soldering pads. Typical design rules that avoid additional board costs are 5 mil laser drill and a 12 mil capture pad (5/12). Designs can be made with 4/10 but with additional cost in the 10% to 15% range. Therefore, the minimum size for an 0201 solder pad is 10 mils x 10 mils.

One process study utilized 6 mil component spacing from one component to another. This design was denoted as fillet-less since there was no room for solder fillets along the ends of the components. All of the solder pads were completely underneath the components and were less than 10 mils in diameter. However, since 2/2 trace lines and spacing would be required to route the traces to the pads and since the solder pads were not receptive for an HDI via for routing on the inner layer, this spacing component spacing scheme is somewhat impractical. Conventional printed circuit board fabrication processes are unable to support such tight spacing requirements without a tremendous cost increase to the board. Figures 3 and 4 respectively show 12 mil and 8 mil component spacing.

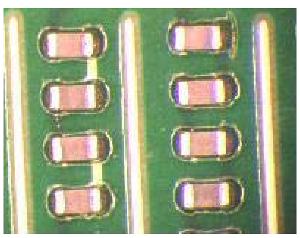

Figure 3: 12 mil spacing

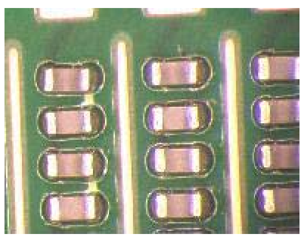

Figure 4: 8 mil spacing

Solder Mask Alignment

Another critical aspect of printed circuit board fabrications that affects the use of 0201 components is solder mask alignment. This is the alignment tolerance for the solder mask to the metal solder pads on the board. The alignment is difficult to maintain on large fabrication panels that measure up to 18”x24”. Temperature and humidity affect the board materials and the artwork used to define the metalization patterns at different rates. This leads to misalignment and “stretch” in the metalization from one end of the board to the other. This affects the placement equipment ability to accurately place components on the solder pads and why boards should have at least three fiducials in the design to compensate for the error.[iv]

Typical tolerance for solder mask alignment to the metal solder pads is ±2.5 mils. Since many solder pad designs are mask defined, this means that the metal pads must be 5 mils larger than the mask opening. This is unacceptable for soldering 0201 components since it increases minimum achievable component-to-component spacing. Board shops have the ability to hold a ±2 mil tolerance, but at a cost premium. However, even this tolerance is inadequate. To improve this problem, some board shops are developing a laser defining imaging system for the solder mask. This will allow the solder mask to be defined with reference to the metalization by using localized fiducials on the board fabrication panel. However, this technology is still being developed and will not be ready at least until 2003. Figure 5 illustrates the solder mask shift issue.

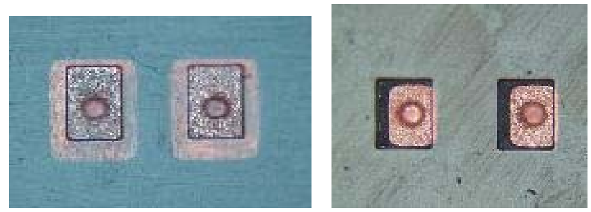

Figure 5. Solder Mask Shift on Two 0201 Pad Designs.

The design on the left has the metal solder pads 6 mils larger than the solder mask to accommodate a ±3 mil solder mask alignment tolerance. This allows the design to maintain its mask-defined characteristic even with a severe shift. The overall shift in this case is 2 mils in the Y direction. The design on the right shows the solder mask opening 3 mils larger than the metal solder pads illustrating a metal defined pad system. In this case the shift in the X-direction is severe enough to loose its metal defined characteristic.

The printed circuit board industry has major technological hurdles to overcome in order for tight component spacing to become a reality, not only from a capability standpoint, but cost as well. The capability will come in time as new processes are being developed to combat the fine lines/spaces and solder mask alignment issues. Given the pricing pressures on consumer electronics, cost adder processes will need to be controlled.

0201 MANUFACTURING EQUIPMENT

Solder Printing

All of the 0201 manufacturers interviewed recommended using a four mil thick solder stencil. This is a change from the standard manufacturing process that utilizes a five-mil thick stencil. A modification of the solder paste stencil from 5 to 4 mil thick is a theoretical reduction of 20% volume of solder paste. For some manufacturing processes, this may be difficult. Components such as shields and leaded devices may not be able to withstand a paste volume reduction of this quantity due to solder joint reliability standards. Therefore, in order to implement the 0201 process, the use of a five mil thick stencil must be evaluated first. The results gathered to date suggest that 0201’s can be used with the five-mil stencil. Also, it may be the introduction of 0201’s that reduces the stencil thickness to 4 mils, as did fine pitch and micro devices reduce the stencil thickness from 6 to 5 mils.

The stencil design appears to be the most critical part of the solder printing process. It appears that if a 0201 component is placed in the solder paste defects are minimal. Therefore the aperture opening should be able to accommodate component offsets, without becoming as large as the current pad stack. The optimal solder geometry probably lies somewhere between the Motorola and the one benchmark pad design.

Another concern in the paste printing process is the component-to-component spacing. The desire is to place components as close together as possible, but the printing process will likely be the gating factor on component spacing. The stencil design must have sufficient metal between openings to be rigid and durable, but also not to allow the paste to bridge or smear together during the print or placement processes.

Placement Equipment

The capability of the chipshooters has steadily improved with exposure to 0201 production experience over the last several years. Placement is still the most critical of the 0201 front-end processes with a multitude of important variables. The variables can be comprised from various subsystems such as; camera (positioning, calibration, resolution and scaling), vision recognition, nozzles, vacuum, X, Y, theta, and Z axes for placement and pickup, feeders and PCB support.

Chipshooter may be specified to place 0201, but not have the subsystem accuracies to support a process window of 100 microns. As one example, it has been found that camera pixel resolution and scaling of a major vendor were not addressed or not sufficient to support the anticipated requirements. The accuracy results with the scaling issue are shown in Table 1. To address this deficiency in the short term, the component library data had to be altered from true data. Table 2 shows the accuracy results after altering the library data to account for the incorrect camera scaling. The long-term approach was resolved by integrating improved placement head/camera systems.

	X	Y
Cp	2.09	1.97
CpK	1.79	1.66
Mean	14.8µm	16.0µm
σ	16.2µm	17.2µm

Table 1. Initial data with inaccurate camera scaling for 0201s.

	X	Y
Cp	3.02	2.47
CpK	2.65	2.01
Mean	12.6µm	18.9µm
σ	11.2µm	13.7µm

Table 2. Altered 0201 library information correcting camera pixel scaling factors.

Cost Adders for 0201 Manufacturing

The added placement equipment cost impact related the to support of 0201 components can be divided into capital, consumables, and resources. The resources that are referred to are the access to the equipment for increased critical preventative maintenance, process development, and troubleshooting and the added technical support. The related capital costs are new capital purchases, upgrades, feeders, advanced calibration tools, the related consumable costs would be nozzles, increased and hypersensitive wear components, filters, grease, etc. The hypersensitive components are items that would otherwise function to acceptable levels for non-0201 production. The related capital items would have to be assessed on an older machine for possible replacement or rebuild or monitored on a new machine for degradation verses cycles or production hours.

When upgrading a production chipshooter from the normal non-0201 placement process to be capable of supporting the 0201 process, the machine's subsystem status needed to be assessed. This process was performed on a machine with approximately 230 million placements cycles and 4.75 years old at the time. The machine was originally specified to be 0201 capable. The machine's accuracy was quantified and a review process was setup with the original chipshooter manufacturer to define critical measurable settings that were required to be attained before 0201 placements would begin. The overall original accuracy was quantified to be 1.41 Cp/1.35Cpk for the X-axis and 1.35 Cp/0.97 Cpk for the Y-axis with limits of +/-100 microns. With this result, further measurements were completed to measure head and X-Y table subsystems. It was found that a head had to be replaced and the Y-axis ballscrew also needed replacement.

Advance calibration tools and jigs were used to verify the camera subsystem and dialing in of the total system. The resulting accuracy measurement resulted in a 2.09 Cp/1.95 Cpk for the X-axis and 1.96 Cp/1.58 Cpk for the Y-axis with limits of +/-100 microns. Wear items were replaced in the heads and vacuum solenoids as a precautionary measure due to the hypersensitivity of the process. The total cost to refurbish and outfit the machine to 0201 capability was approximately $25,000 in parts and labor. This amount did cover nozzles but did not cover the purchase of any cameras or 0201 feeders.

Overall, the cost to retrofit an older chipshooter for 0201 capability can vary widely depending on which components need to be replaced or upgraded. Cameras and vision systems alone can run up to $50K. Cost is greatly dependent on what needs to be upgraded and what wear items need to be replaced.

Inline Inspection Equipment

The emphasis for 0201 technology has been on the placement equipment and related capability in the past. With feedback from production facilities and lab testing, the chipshooter suppliers have greatly improved the machines from several years ago. Going forward, the level of sophistication to improve and the opportunities to take the 0201 process to the next level will require more data. That data will come from the metrology capable in-line inspection machines, both solder paste inspection and component placement inspection. With these high-end systems variables data can be obtained verses the low-end system, which only logs pass/fail criteria. This high-end data rich information can be used for more in-depth statistical analysis. These high-end systems typically cost $180,000 for a base machine, excluding repair loops, off-line programming software, etc.

With a solder paste and component placement in-line inspection system in each line, this can represent significant additional capital. For the factory not able to put in-line inspection in every line an offline highly accurate measurement system would be a minimum requirement. For the factory with multiple inspection machines the offline optical measure system is a useful independent tool to insure the proper operation of inspection machines. The cost of the offline system is about $100,000 depending on the table size, advanced accuracy requirements and other options.

The inspection machines will immediately highlight the changes to equipment, materials, and processes with SPC and trend analysis. Insuring a more stable environment will be the basis for improvement. The 0201 production will require inspection and measurements to quantify any and all process improvement work, while insuring a predictable production environment. These inspection machines will give the advanced warning to a hypersensitive 0201 process. The inspection machines (solder paste and placement) will quantify and separate the process indicators for solder paste and placement, allowing a more simplistic troubleshooting of any catastrophic failure that occurs.

Selection of the in-line inspection machines (solder paste and component placement) will be critical to the effectiveness of the data collection. In the past, inspection companies have had difficulties delivering on capabilities for anything but a dedicated line and product. With the 0201 process window anticipated to be between 75 to 100 microns the measurement system should be 10X improved compared to the process requirements. The inspection machines to be metrology capable will have to be accurate to 7 to 10 microns. Pixel resolution will also be an important factory with the decreased component and solder deposit size. Many other system factors are important for the viability of a metrology capable inspection machine. Those factors may not be readily apparent after the machine is installed but may realized after a prolonged exposure to high volume/high mix environment. Programming, robustness, balance of low false accept and low false failures are just a few factors.

Reflow Oven

The majority of reflow ovens today use forced hot air convection to heat the PCB and components for soldering. Convection rates vary from the different oven suppliers and must be monitored to ensure the 0201 components are not displaced during the reflow process. Additionally, the reflow atmosphere and profile must be carefully characterized to obtain the optimum results for 0201 component soldering. It was determined that ambient air environment was preferred in these experiments for reasons of cost and process flexibility.

Repair Strategies

Repair strategies in the past in non-0201 environments usually consist of a person with tweezers and a soldering iron or heat gun. However, this method will be extremely difficult when repairing 0201 defects. Certainly, any manual repair of 0201 defects will require the use of a microscope given the extreme small size of the components. There are soldering irons available with tweezer-like tips designed specifically for 0201s. Also, there are hot air systems available with a component clamping mechanism that will lift the component off the board. There are two issues with this design. First, the hot air system will reflow adjacent components and could cause further defects if the boards is bumped or moved while the components are in the reflow state. Second, the grabber mechanism requires a keepout area and with tighter component spacings, there may be an interference problem.

Another “repair strategy” is to not repair. With this strategy, all defective boards found during production would be scrapped. Obviously, this will increase scrap costs, requiring the evaluation of the break-even point of scrap verses repair. The scrapping of a VCO module will probably be cost effective whereas scrapping a cellphone board would be cost prohibitive due to the high direct material cost for the design.

There is no easy choice in 0201 repair strategies due to the technological challenges. Careful evaluation of the costs involved- manpower, capital, and time require for repair- must be completed

PADSTACK DEVELOPMENT

The process variables governing the mass production of 0201 component placement do not differ from other components, such as 0402s. However, they become more sensitive to causing defects. The study outlined in this paper concentrates on developing a process to drop in 0201 by developing the correct padstack to yield a 6σ process without altering the stencil thickness or paste type.

Experimental Procedure

Five padstacks were developed using best in class practices, varying from metal defined, mask defined, mask/metal defined all of which had to be able to accommodate an HDI microvia in the metal pad. Figure 6 shows the different padstacks used for this experiment.

Three solder pastes were used:

Paste 1: Flux A type III, type V blend

Paste 2: Flux A type III.

Paste 3: Flux B type III, type V blend

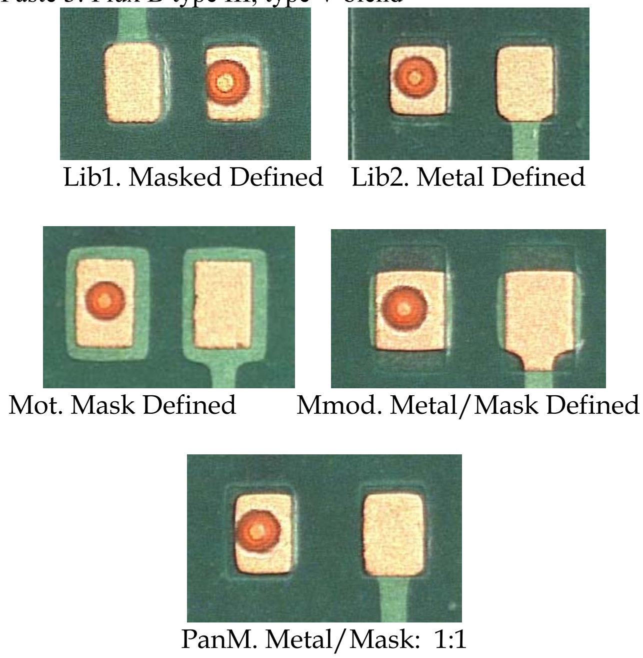

Figure 6. Padstacks Used in Experiments

Test boards were created with several hundred of each pad type with varying spacing options, 15mil, 12mil, 10mil and 8mil. The spacing is not being studied as a factor of the pad stack but as a design/process limitation.

Parts were place with varying offsets on a number boards - (0, 0), (0.5, 0.5), (0.1, 0.1)- in mm. The effect of the offset is to simulate an out of control process. With the increasing offset, more defects are expected thus allowing for statistical analysis of the defect data. The machine placing the components was running at a Cp of 2.75 and CpK of 2.5 to +/-0.1mm window throughout the experiment. The Cp and CpK measurements were taken for every board, the placement machine did not waiver from these values throughout the experiment.

The defect level for each offset is noted and the lower the defect levels at the larger offset, the more robust the padstack. The location of the parts post-reflow was measured using an SVS laser inspection machine and the better the self-centering effect during reflow, the more robust and more effective the padstack. For this particular experiment over 300,000 components were placed. Experiments for both resistor and capacitors were carried out. Only data for capacitors is reported, however, the results were similar for resistors.

Gage Repeatability & Reproducibility
Gage R&R was performed on the measurements for both placement in paste and post reflow. The pasted board was measured immediately after placement three times, removed from the machine, placed back by a different operator and the measurements repeated. The time between solder print and final measurement was three hours. The same procedure was carried out on reflowed boards but the operator variable was time. The boards were measured on day one then after three days. During which time the inspection machine was used for other measurements.

The results were acceptable for both components in paste and post reflow. Figure 7 shows the output for the post-reflow part inspection. The gage R&R is 6.45%.

Gage R&R		
Measurement Unit Analysis		% Tolerance
Repeatability (EV)	0.0058167	5.8167
Reproducibility (AV)	0.0027652	2.7652
Operator * Part Variation (IV)	0.0003561	0.3561
Gage R&R (RR)	0.0064504	6.4504
Part Variation (PV)	0.0748410	74.8410
Total Variation (TV)	0.0751185	
Sigma Multiple	6.0000000	
Tolerance	0.1000000	

Figure 7. Gage R&R as Generated by Jump Software.

Results
The theory behind the post-reflow data is that the better the padstack, the better the post-reflow centering data. The measurement program outputs the distance from the CAD centroid. It should be noted that where components are missing from the board the line item is ignored, potentially skewing the analysis. However, this data becomes insignificant on three of the padstacks due to the vast quantity of data. The three padstacks are shown in the defect charts, Figures 8 and 9.

The data analysis is a simple crossed DOE including the interaction of paste and padstack as the factors and post reflow location of the part as the output. Figure 7 shows the prediction model for the various padstacks and solder pastes.

The self-centering results show paste type to have little effect. However, the pad stack plays a critical role in the self-centering effect. Of the pads shown, PanM_0201 performs self-centering the best. Mmod and Lib2 performed the worst.

Defect Rates
The number of defects were counted and are shown in Figures 9 and 10. The data for two of the pad types was ignored in the chart due to the large number of defects that occurred and obscures the chart.

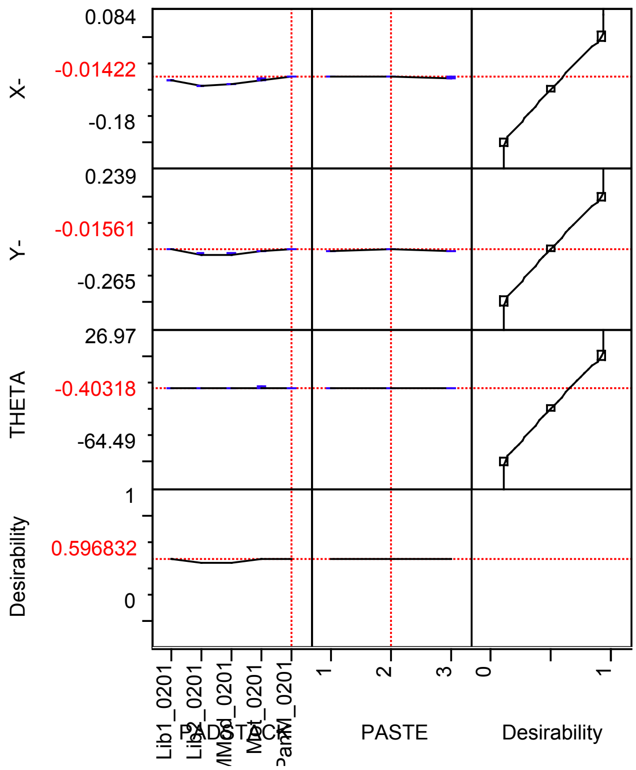

Figure 8. Prediction Model for Padstacks and Solder Pastes

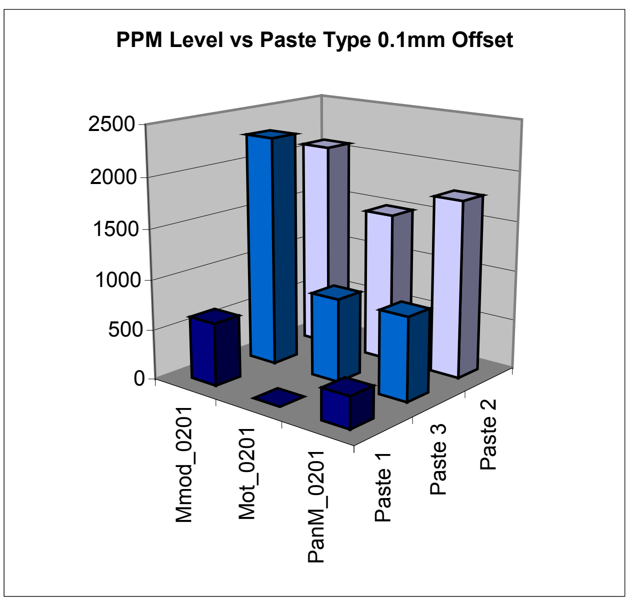

Figure 9. Defect rates- padstacks vs solder paste types with a 0.01mm placement offset.

The defect data only half confirms the prediction model for self-centering. The defects from lib1 and lib2 were so high that the parts were not on the boards after reflow and could not be measured. In many of these cases the parts had "drawbridged" (the part rests on the reflowed solder at one end but has not formed a joint) not allowing the inspection machine to record a location for the part.

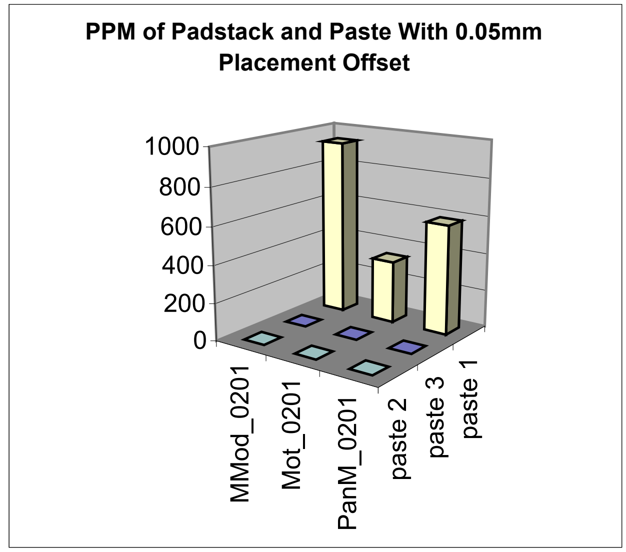

Figure 10. Defect rates- padstacks vs solder paste type with 0.05mm placement offset.

It was also noted that the blended pastes was not a significant variable in producing defects. Both pastes #2 and #3 produced very few defects at the 0.05mm placement offset. Paste #1 was from a solder paste supplier where the flux vehicle was not optimized for the Type III/Type V blended powder.

Conclusion

Mot_0201 is the ideal pad stack and should be used with paste 1, however, the pad design prevented component spacings closer than 0.38mm. The desire to drive spacings closer and realize the full benefits of the 0201 process negates this option. The PanM_0201 padstack and Mmod_0201 resulted in two options for the choice of padstacks. PanM_0201 resulted with zero defects with a 0.05mm offset and is a good choice for implementation. Since the defect rates increased significantly from the 0.05mm placement offset to the 0.1mm placement offset, this highlights the need to use tighter process margins.

The experiment has proven that the process can be developed that allows 0201 placement with acceptable yields. However a true sigma level of the process cannot be determined until run in full production. The data suggests that with a correct machine and feeder maintenance, a stencil wipe every print the defect levels close to 6σ should be possible.

It is also recommended that early on in 0201 placement quality inline inspection will be required to monitor the solder print deposition and the placement accuracy. This will be required until placement machines can truly have a 6σ process with a 0.075μm placement window.

[i] Butterfield, Andrew & Kevin Pieper, "0201 Solder Process Study", Motorola 1999 Hermes Symposium, Austin, TX, July 1999.

[ii] Thome, John, NEMI Presentation on Hand Held Products, APEX 2002, San Diego, CA, January 2002.

[iii] Adriance, Jim and Jeff Schake, "Process Parameter Optimization for Mass Reflow of 0201 Components", Universal Instruments Corporation SMT Lab, February 2000.

[iv] Baldwin, Daniel F. et al, "High-Speed 0201 Processing and Characterization: Placement – Screening", Center for Board Assembly Research, Georgia Institute of Technology, November 6, 2000.