INSPECTION STRATEGIES FOR 0201 COMPONENTS

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ABSTRACT

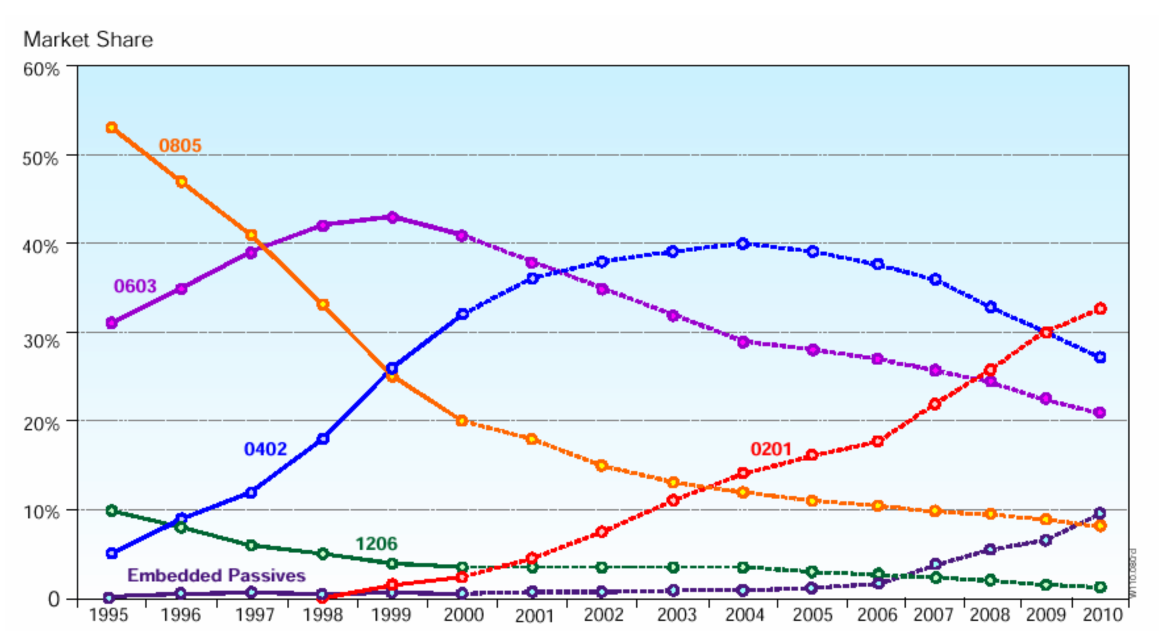
Deploying inspection technologies within a manufacturing process that utilizes miniature passive devices such as 0201s is essential. Specifically, inspection of solder paste and component placement can greatly reduce systematic and random defects and inspection of soldered components can be a manageable alternative to increasingly difficult ICT coverage.

Monitoring and acting upon the information that inspection systems produce can not only eliminate defects but also warn of potential future defects. Vital to the analysis of SPC data is a scalable database and appropriate tools.

INTRODUCTION

The introduction of 0201 passive devices in consumer electronics presents a great challenge to the stability of the surface mount assembly process, as we know it today. The advent of the 0201 significantly decreases the process tolerance in all stages of the assembly process, making the deployment of some form of inspection into their assembly process a critical must. What's more, the minute size of 0201s (0.5mm x 0.25mm) means that inspection by human eye is impossible and that Automated Optical Inspection (AOI) is now becoming mandatory. Numerous studies have started with

Figure 1: Passive device trends (Source: Prismark)



the aim of thoroughly characterizing and understanding the 0201 process and many more will be performed before the many variables involved are understood. This paper aims to discuss the types of defect that can occur when assembling with 0201s and to highlight sensible inspection strategies that will reduce defect levels and maintain high first-pass yields.

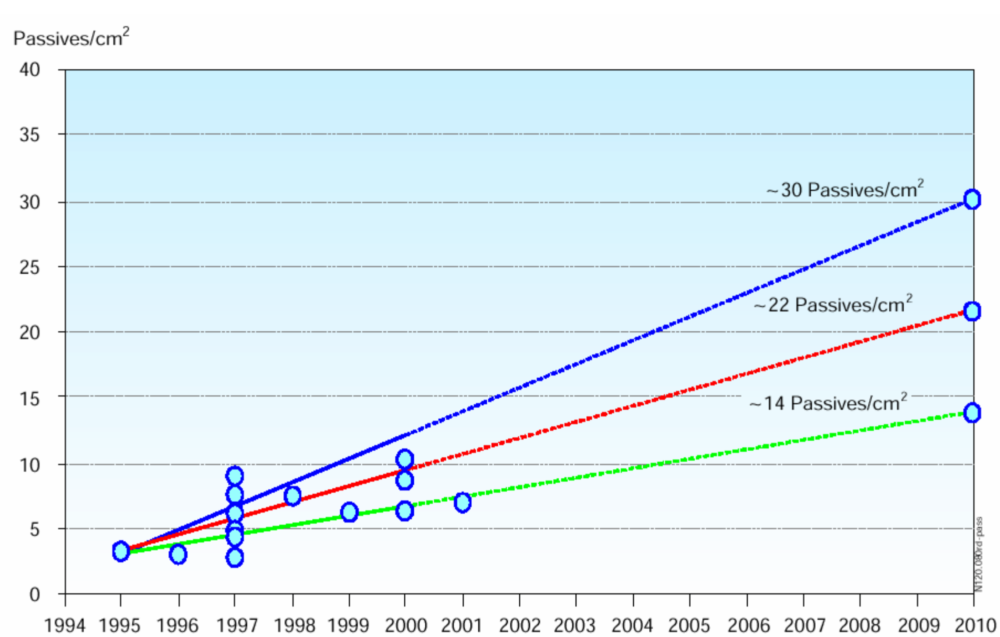
DESIGN FOR MANUFACTURABILITY

It is becoming increasingly important for PCB designers to understand all aspects of the assembly process as the manufacturing engineer has enough scope for producing scrap without contending with bad design practice. Some of the considerations which the designer has to contend with :

- Pad shape
- Pad size
- Distance between pads for same device
- Proximity of pads to adjacent devices
- Orientation of component
- Thermal balancing
- Solder mask layer design (pad defined vs. mask defined edges)

Unfortunately, there is no foolproof guide to this, but a working knowledge of the assembly process makes a significant difference when laying out a circuit board.

Figure 2: The effects of decreased footprint passive devices on interconnection desnity



In the case of board design to incorporate 0201's, the important features are to maximize the pad size to enable reliable printing, whilst not overshadowing the design goals of product miniaturization.

THE PRINTING PROCESS

Printing 0201 sized pads starts to create a fundamental problem to the process engineer in that the rules governing paste release from apertures are close to being broken. The rules can be bent by careful tuning of the print process, by: paste selection (flux performance), stencil design, operating environment, board-stencil separation action etc. The difficulty is that the working range for these process attributes is extremely tight.

In the past the simple act of using a thinner stencil has enabled the stencil designer to maintain the Surface Area ratio, even in the face of decreasing pad sizes. This thickness reduction has reached practical limits for most assembly houses as any further reduction beyond 0.125mm (5 mils) , from which the above are calculated, would leave insufficient paste for many other components.

The tightening of the printing process window is driving many users towards 100% 3D paste inspection for the simple reason that errors at this stage of the process will translate into defects further down the line. What's more, investment in the assembly is low at this stage so boards can be washed and reused with minimal effect. 2D paste inspection only shows the area covered which is in no way an indication as to the quality of all the critical aspects of the deposit, which is critical in 0201 applications.

Figure 3: Circles and squares are more difficult to print

Shape	Size (mm)	SA Ratio
Circle/Square	0.15	0.30
Circle/Square	0.175	0.35
Circle/Square	0.2	0.40
Circle/Square	0.225	0.45
Circle/Square	0.25	0.50
Circle/Square	0.275	0.55
Circle/Square	0.3	0.60
Circle/Square	0.35	0.70
Circle/Square	0.45	0.90
Circle/Square	0.5	1.00
Circle/Square	0.65	1.25
Circle/Square	0.4	0.80
Rectangle	0.1	0.37
Rectangle	0.125	0.45
Rectangle	0.15	0.54
Rectangle	0.175	0.61
Rectangle	0.2	0.69
Rectangle	0.225	0.76
Rectangle	0.25	0.83
Rectangle	0.275	0.90
Rectangle	0.3	0.97
Rectangle	0.35	1.09
Rectangle	0.4	1.21
Rectangle	0.45	1.32

Surface area ratio is calculated as follows:

$$\frac{\text{Area of Aperture Opening}}{\text{Wall Area of Stencil Aperture}}$$

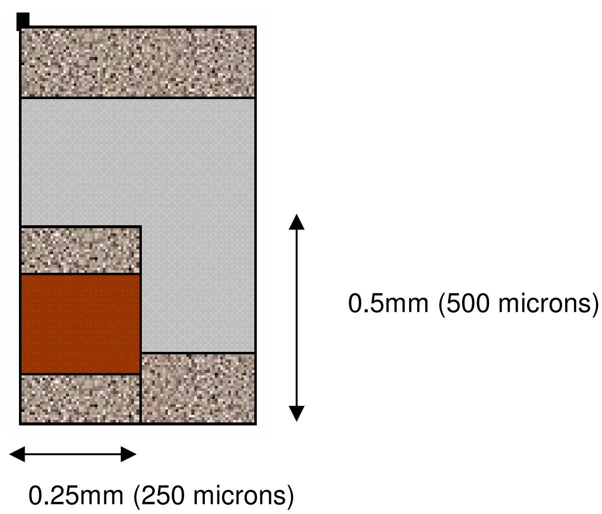
This ratio should be greater than 0.6 for a successful print.

THE PLACEMENT PROCESS

All placement machine manufacturers have spent a great deal of time improving their capabilities to the point which placing 0201s becomes a practical alternative. Even so, picking, carrying and placing a part so small is no mean feat and with millions of placements defects do occur.

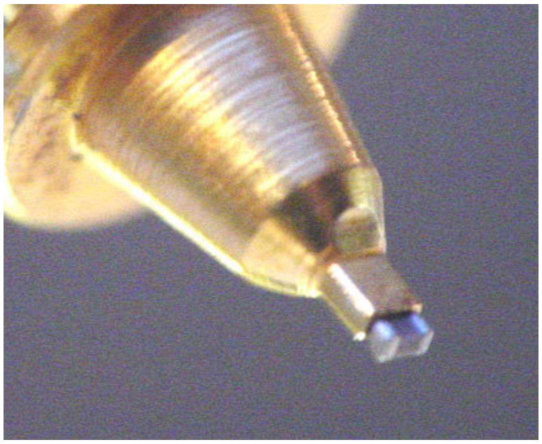
The potential for component mis-picks, loss of component between vision and placement, and misplacement is many times greater. The effect of misplacement is greater than for bigger devices, and in particular, the opportunity for tomb-stoning increases greatly. Misplacement of greater than 100 microns presents a significant hazard.

Figure 4: A 0402 is four times the area of a 0201



The increased opportunity for missing and misplaced parts is justifiably creating significant anxiety within the assembly process engineering community. For this reason, post placement AOI is increasing in popularity, and the preferred application is not for gross defect screening, but for process measurement capability also. Positional measurement capability enables the process engineer defect prevention, from the monitoring of process drift in addition to gross defect detection. Any positional drift and trends will often drive the process engineer towards reviewing equipment maintenance procedures and schedules.

Figure 5: Placement head with 0201 device

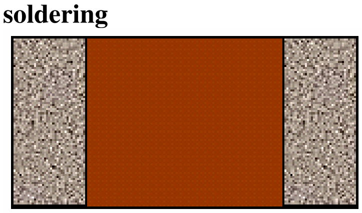


THE REFLOW PROCESS

In general, if the paste is in the right place and the volume is correct and consistent, and the component is placed evenly on the paste then the assembler is in good shape to achieve successful, defect free reflow results. However, when placing 0201s, the opportunity for defects is not completely eliminated as component quality and board design could still create problems.

The first potential failing was previously observed on 0402 devices. This problem is tomb-stoning caused by gross variation in the dimensions of the metalized terminals at either end of the device. This will cause differential wetting forces at each end of the device and pull the component up during reflow.

Figure 6: Effect of cap symmetry while soldering



Asymmetry such as this will lead to tomb-stoning:

Another potential failing is when thermal barriers are not employed by PCB designers to the extent that one pad goes into reflow significantly before the other, again producing a tombstone.

IN-CIRCUIT TEST

The very nature of 0201s is such that the main uptake will be on products that require miniaturization, weight loss and increases in functionality simultaneously. These products were the first to suffer in terms of In-Circuit Test coverage because of the impracticality of nodal testing on such small parts. So the reality is that only functional testing is practical, which presents the problem of identifying defective products, whilst not identifying which components are to blame! For that reason, end-of-line AOI serves to complement the test strategy, filling in holes by "testing" components and solder joints for presence/absence, position and other gross defects. AOI at the end of the line typically serves as a defect catcher, and rarely as a process improvement tool.

DATA CORRELATION AND SPC

The immense amount of data that can be generated from inspection systems is a large concern. For example, for each solder pad on a PCB, more than 6 parameters are stored and the number of parameters actually increases as the board progresses down the line. What this means is that a typical manufacturing line making cell-phones creates about 2Gigabytes of information in around 8 hours.

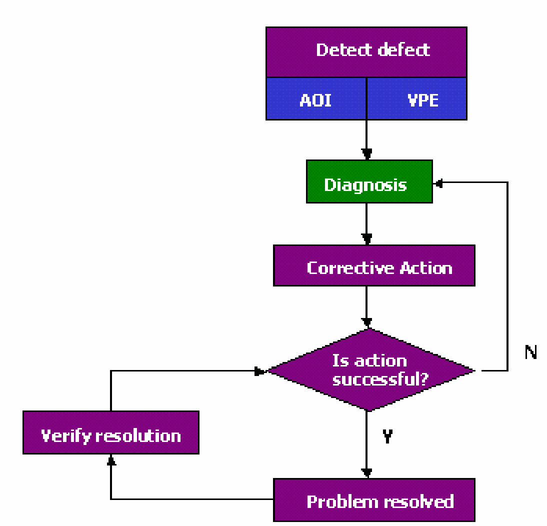
A common mistake is to assume that a desktop database will be sufficient for the manipulation and analysis of such large amounts of data. Desktop databases usually have a limit as to their capacity so an enterprise level database is inevitably required.

The medium in which reports can be viewed is important too. Limiting access to SPC data to a particular machine is sub-optimal. SPC data should be freely available in the form of web accessible charts and graphs.

Using SPC effectively can be useful in maintaining yields, enabling knowledge transfer and predicting and helping to diagnose potential future problems. Historic data (pareto charts etc) from a previous production run can remind operators what problems may be specific to a particular board or component. Current data can be utilized to alarm on certain conditions preventing a process from going out of control.

The next generation of inspection systems will be capable of feeding information real-time to powerful application software that can process it, looking for trends and using its knowledge of the process to provide corrective actions. This software will act as a virtual engineer, suggesting remedial operations, verifying and confirming their success and will have the ability to escalate through many different media (email, pager etc). The virtual engineer will be invaluable to contract manufacturers where engineer time is a premium.

Figure 7: Workflow chart for advanced diagnostic software



For such software to exist, the reliability and quality of the data the inspection systems produce must be excellent, particularly if there is to be any communication back to upstream devices in order for corrective action to take place.

With placement being a major concern in using 0201s, the accuracy of the measurements an AOI system provides will be fundamental to the success of diagnostic software. No longer will it be sufficient to be just repeatable; repeatability and accuracy will be mandatory. An 0201 has a process tolerance of ±80µm and an AOI system must be ten times better than the process it is measuring. With the advent of digital color cameras, breakthrough vision technologies and full color image processing, this is now achievable.

MEASUREMENT STUDIES

Measurement System Analysis (MSA) takes into account many different characteristics of a measurement process. These characteristics include such things as:

- Bias (accuracy)
- Repeatability
- Reproducibility
- Stability
- Linearity
- Discrimination Ratio

Two major areas of interest to AOI end users are accuracy and repeatability. Accuracy can be interpreted from the AOI machine perspective as being the difference between where the component is reportedly found and where it actually is. Repeatability can also be interpreted from an AOI machine perspective as being the variations of the measured locations of a component when measured multiple times.

Accuracy is a difficult metric to establish on a real PCB with real components. Boards tend to suffer from manufacturing errors, localized warping and stretching and sagging from the weight of placed components. Placement machines use board fiducials to define an origin for a board and may use additional local fiducials to place QFPs and BGAs. In order to accurately measure a real board it is necessary to 'flatten' the board. The act of flattening a board (whether physically or synthetically) introduces errors.

In order to gauge the accuracy of an AOI machine, several tests can be performed. Placement machine manufacturers use certified glass plates to gauge the accuracy of their equipment and all machines are tested thoroughly prior to shipment. The test process involves placement of glass slugs onto glass plates and then the measurement of the slugs using an offline measurement machine (examples of which are the View Précis range and the Mitotoyu QVM range, known as CMMs). An AOI system's accuracy is determined by measurements of a NIST certified artifact (glass line scale, fiducials on glass plate, glass slugs, etc.). This ensures traceability to a national or international standard.

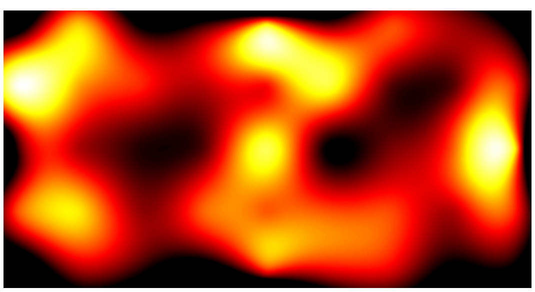
As with any measurement system, the effect of the object being measured on the measurement result and the environment in which it is being measured must be taken into account. FR4 boards are affected by humidity and temperature, giving rise to stretch and warp of the boards. This will give rise to differences when actual boards are measured on AOI systems, CMM's, etc.

Repeatability (GR&R) ❑

GR&R tests are designed to test, amongst other things, how much measurement variation is caused by the measurement system. Appropriate reporting of an AOI system's live component capability mandates that the repeatability be determined from live component testing. Broadly speaking, the industry tends to look to the raw percentage result as an indication of a systems repeatability. However this pre-supposes that the measurement data is normally distributed. Where possible data should be viewed graphically and sanity-checked by eye.

Another test of interest is to attempt to look for linearity in the measurement data. Plotting the standard deviations of components across the board as shown in Figure 8 allows the assessor to look for trends or hotspots on a board which may indicate a potential systematic problem with the measurement system.

Figure 8: Standard deviations mapped back onto PCB area – colors should be randomly dispersed with no regular patterns.



SUMMARY

There are many opportunities to inspect PCBs as they are assembled. Judicious use of appropriate and capable equipment, together with intelligent software can greatly reduce scrap and increase yields.

Measurement fidelity is essential, not only in reducing false calls, but in providing good information for third parties to access and potentially use in a corrective, remedial or diagnostic manner.

The following summary details the philosophy employed at each inspection opportunity.

Post Print

Rationale: Screening defects at the earliest assembly stage to minimize cost of defects and removing defects.

- 0201 printing is at the limits of the printing process as we know it.
- Minor variations in environment, paste rheology, stencil dimension, printer performance, PCB quality will throw the process out of control.
- Full 3D volumetric measurement is required to reliably control an 0201 print process.

Post Placement

Rationale: Placement process measurement and defect detection to take out major defect risk further down the line.

- Placement of 0201's presents the placement machine with a greatly increased risk of placement failure.
- Placement is possibly the greatest process risk in a 0201 process.
- Standard ICT test strategy will not detect defects due to tomb-stoned, missing and misplaced parts as 0201's are often not covered.

Post-Soldering

Rationale: Defect detection as a compliment to decreasing end of line ICT coverage.

- If the solder paste is present in the correct position and has the correct volume, and the component is placed on target then the risk of defects is minimized but not eliminated.
- Ensures that missing parts, wrong parts and soldering defects are not shipped out of the factory.

CONCLUSION

With the advent of 0201s, now, more than ever, the inspection strategies deployed within manufacturing need to move away from generalized screening and towards true process control. 3D inspection of solder paste and accurate measurement of component placement will become an absolute necessity as the industry confronts its latest and greatest challenge.