White Paper: 2002/07/08 - 0201 placement – Only with the Right Team and Tools

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It appears very logical that the successor of the 0402 size SMD would be the 0201. Curves showing the life-cycle of a body size, from introduction to most used to only for special cases, are very similar for the 1206, 0805, 0603 and 0402. So there is reason to expect that the same will happen with the 0201. Until now there is only little evidence for this, but most technologies come later than expected but faster than expected!

The ever-increasing demand for more functionality in less space, with lower weight, less power consumption, and at higher frequencies, will sooner or later mean that the extra cost of using 0201s can be recovered in the price of the final product. The use of 0201 will pay off on many fronts.

The weight of the 0201 is 160mg per 1000 pieces, so replacing typically 200 0402 components in a mobile phone, PDA or digital camera saves about 30mg.

Space savings are more dramatic. About 2.5 times as many 0201s as 0402s fit on the same area of a PCB. In other words, next to the 200 Rs and Cs, the replacement of the 0402s leaves space for another 300 passives. Of course it is more likely that the saved 100mm2 will be used to place one or more flip-chips and µBGAs.

It looks like a good idea to prepare now for the next generation of components to enter electronics manufacturing sites. The next generation mobile phones will require a lot more functionality. It might be the long-awaited 3G phone or an interim version, but the Internet connectivity, added wireless connectivity, and extended display functionality will all require complex components to be added, with the inevitable Rs and Cs, to control the options. The same goes for PDAs and digital cameras, and in all these cases the customer does not want to pay for these gimmicks with extra weight or size!

As long as seven years ago, manufacturing engineers asked for demonstration of the placement of 0201 components during the selection procedure for SMD placement equipment. Not that they had to produce any product using this kind of component, but they wanted to be sure that the equipment was capable placing 0402s in any circumstances, so why not ask for 0201 capability? It is like asking for a car that has power to run well over 200mph uphill, to guarantee 80mph on the flat road. The only problem was that there were hardly any 0201 components, let alone that they were available in tape! But the availability of 0201s is no longer a problem, and there is also a de facto standard for the packaging of these components in tape.

The way to go

The implementation of 0201 in a manufacturing environment can be accomplished successfully only if it is handled in the same way as the introduction of a completely new process. To imagine that 0201 is just 0402 but a little bit better will lead to intensive involvement of specialists in all aspects of electronics manufacturing, with frustrating results. The fine tuning of each aspect without an in-depth knowledge of the overall process will not lead to optimisation of the process, since the complex parameters within a very narrow process window will strongly interact. Only with a very good insight into the root causes of every anomaly in the production can the yield be maximised and controlled.

The limits of the process window are determined by board layout, solder paste

deposition, component placement and the soldering process. Each of these steps in the process has its own sub processes, some of which are handled in depth in this article.

Board layout
The parameters of importance have been identified and quantified at the Philips Center for Industrial Technology, which supports Philips Electronics' manufacturing with in-depth research. Table 1 shows the most important values.

Minimum copper width	0.075mm
Minimum spacing width	0.100mm
Tolerance solder lands	0.030mm
Eccentricity of solder resist–copper	0.040mm
Minimum distance solder resist–copper	0.050mm
Minimum solder resist dam	0.100mm
Solder resist tolerance	0.015mm
Dimensional stability of board	0.040 percent

Table 1

A very critical value is the inter-pad distance. The solder paste deposition process limits the minimum value. For each lead the deposits have to be separated sufficiently to ensure that two separate solder joints are formed in the reflow oven, allowing some bulging of the deposit due to the placement of the component. The capabilities of the applied stencil also have to be taken into account.

The maximum distance between the pads is limited, as both leads of the component need sufficient overlap with the copper to guarantee a solid electrical connection. Also, the leads have to be placed in the solder paste, preferably with some extra overlap to allow self-alignment during reflow. These values are also referred to as 'occupied area', or the area needed for components to achieve their functionality without disturbing other components or the process. A typical value for the distance between the pads of an 0201 component is 0.230mm. The required occupied area, which varies according to component type, is typically 0.575 x 0.950mm. If any of the listed parameters are not taken into consideration during the design of the board, the impact in production will be enormous. Fig. 1 shows examples of correct and incorrect board layout.

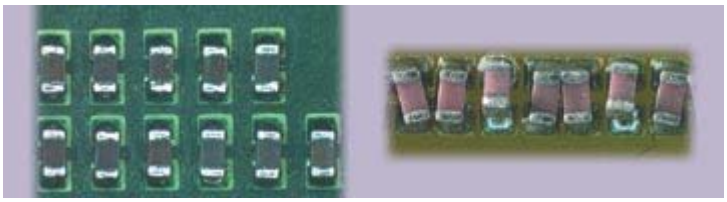


Fig 1

Solder paste application

The solder paste process is the single most significant source of failures in electronics manufacturing. This will become very evident in the case of 0201 application. Just fulfilling the basic requirements for a paste deposit – trapezoidal shape, correct height and width – can be a challenge. Table 2 gives the important parameters for solder paste deposition.

Placement of solder paste with respect to solder land	0.023mm
Tolerances on apertures	0.012mm
Line widening paste deposit	0.020mm
Stencil thickness Class 7	0.150mm
Stencil thickness Class 8	0.100mm
Dimensional stability of stencil	0.004 percent
Metal content by volume	45 percent

Table 2

Modern technology, in both stencil production and screen printing equipment, allows a controlled application of the solder paste. In the event that components on the board have a wide range of sizes, and thus require differing amounts of solder paste on the pads, things get far more complicated. The designer must also ensure that the pads for larger components receive a sufficient supply of solder paste with the use of the 0.100mm thick stencil preferred for 0201 applications.

Penalties for failing to control the solder paste application process are

- solder joints with too little or no electrical connection
- component leads connected to multiple pads
- bridging between pads
- tomb-stoning due to unbalanced application of paste on pads.

A well-controlled solder paste application process is rewarded by the self-alignment of the component during the reflow process. Due to the surface tension, the component will ‘swim’ to the centre of the pad as soon as the solder is melted. The very light 0201 component will more probably benefit from this effect than larger components (Fig. 2).

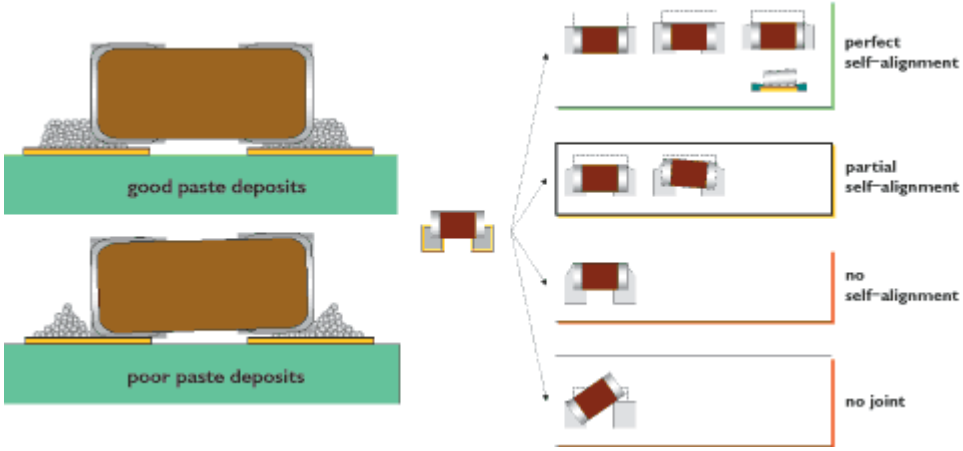


Fig 2

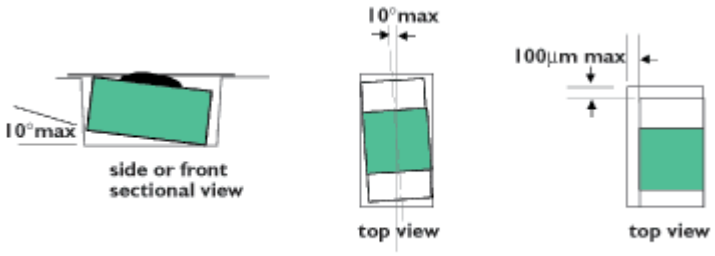


Fig 3

Starting the placement
The placement of the 0201 component is not seen as the most critical part in product manufacturing (Fig. 3), but 'doing it a little better' is not good enough. The feeding, picking and placement of the component need special attention (Table 3).

Placement accuracy of components	0.100mm
Placement accuracy of fine pitch components	0.050mm
Minimum distance between solderable parts	0.025mm

Table 3

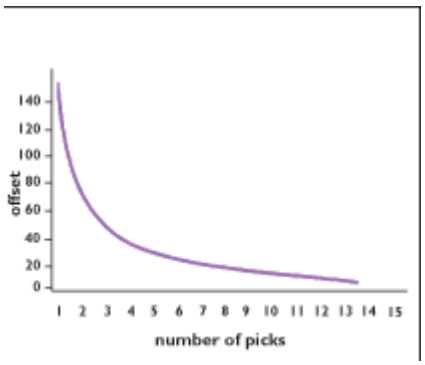
The 0201 can be bulk or tape fed. The known advantages of bulk feeding are valid for 0201s. The disadvantages of the application of paper-tape packaging are even more striking (for 0201 components IEC 60283-3 is not yet applicable).

The strict tolerances for pocket dimensions are very demanding for a material such as paper tape, as the paper fibres are relatively large compared to the component size. Applying the right feeding concept can compensate for tolerances on specified parameters such as hole diameter, pitch, burrs etcetera. For 0201 processes it is therefore recommended that the feeders are positioned with high stability, and do not move between pick operations.

Even when using the far superior concept of bulk feeding for better component pick performance, high feeder stability is preferable. The reason for this is that within known surface mount placement equipment concepts no solution has yet been found for easily and quickly stabilising moving feeder banks to guarantee a stable pick position.

The index movement of the tape, and also the peel-off of the top tape, have to be well controlled. The use of two separate motors to accomplish these tasks with the required accuracy cannot be avoided. Again, this makes bulk feeding the preferred method. However, strict component dimensional tolerances and minimum contamination in the cassettes are a must for the component supplier.

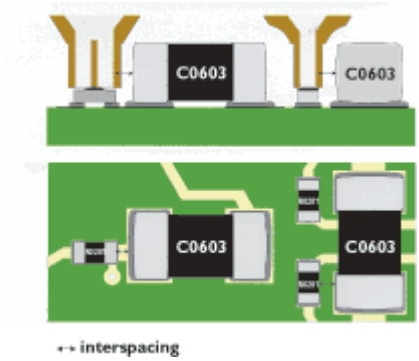
The tolerances at the pick position can be compensated for by feeding back the alignment data of each pick and calculating the expected position of the next component. At every pick, the offset under the nozzle is measured. Using this offset the next expected pick position is calculated. After several pick and measure cycles this procedure will result in a more stable pick and place action, reducing the ppm levels. This adaptive pick (Fig. 4)



compensates for structural deviation from
the packaging standard, and proactively compensates for drift of the position of sprocket holes and component pockets. Without this adaptive pick the quality levels will rapidly go down.

Transferring to placement

The lifting of the component from the tape is accomplished by the vacuum created at the tip of the nozzle designed for the task. One of the aspects of nozzle design is the inter-spacing requirement (Fig. 5). The necessary inter-spacing limits the size of the nozzle to avoid damaging or shifting surrounding components during placement.



A second aspect in nozzle design is a trade-off between holding power of the vacuum, requiring a narrow air channel, and the surface touching the component, which should be maximised to ensure stable positioning of the component on the flight to the placement position. Finally, due to the very small size of the 0201, an important aspect in nozzle design is measurement of the vacuum to detect if a component is present. Even with modern technology, detecting 0201 components is a difficult task. However, by adapting the design of the nozzle this technology can be supported in an unexpected way. By applying the vacuum force through two channels, instead of one, all the above mentioned objectives can be achieved (Fig. 6). The two channels ensure enough vacuum to hold the component and, at the same time, provide the detection capability for flipped, on edge or missing components. Another welcome aspect of the dual-channel approach prevents the tilting of the component before placement. Components placed on edge or not balanced on the pads can lead to bad or no electrical contact.

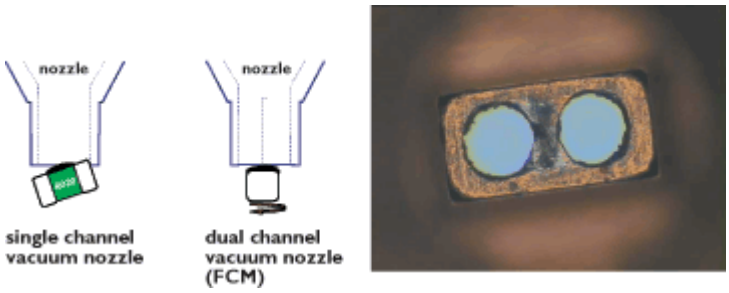


Fig 6

Finalising the placement

Picking and placement of the 0201 should be gentle. An uncontrolled pick can lead to damaged components, therefore during pick the goal is not to ‘hit’ the component with great force. Because of the material used for the nozzles, the impact force during pick can easily crack the 0201s. Therefore machines should be designed with the possibility of so-called ‘floating’ pick, meaning the nozzle does not ‘hit’ the component during pick but gently lets it flow through the air, via vacuum suction, until it is held by the nozzle.

Not only are the components themselves vulnerable to brute force but damage to the solder paste fillet applied carefully by the screen printer must also be avoided (Fig. 7). An uncontrolled placement can lead to disturbance of the solder paste fillet in such a way that during the reflow process the bulging paste connects with the opposite pads, adjacent pads, or component parts and forms bridges. Another consequence of the mistreatment of the solder paste is that particles are scattered over the PCB to be formed into tiny solderballs. These solderballs are a

potential time bomb built into the end product, causing all kind of problems when they come loose during use. In high-volume production the controlled force of placement has to be pre-programmed, since complicated landing control, as used with fine pitch components, does not fit into the required timing settings of high-speed production.

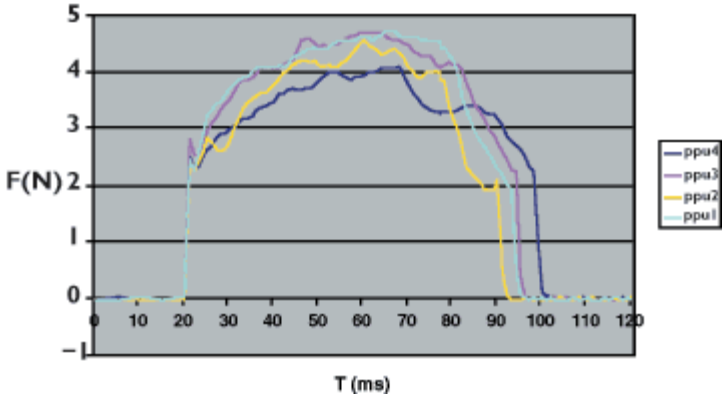


Fig 7

Alignment of the component is especially critical in situations where tight-packed placement is required. In modern high-speed placement equipment the alignment measurement does not take extra time since it is carried out during the flight from pick to placement. Limitations in vision systems, however, can be a disturbing factor. The resolution of most known analogue vision systems is far too low to achieve reliable detection and aligning of components as small as 0201s. Digital vision, on the other hand, is capable of detecting these components more reliably, but has the disadvantage of high cost. Therefore laser alignment is preferable for aligning such small components. Together with the dual-channel nozzle this guarantees a stable pick, detect (after pick), place and detect (after placement) cycle.

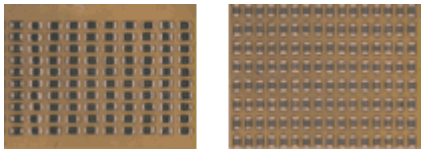
After the measurement, the component should be moved as little as possible to prevent shifting under the nozzle. A disadvantage of vertical or horizontal turret type equipment is that, after the alignment measurement, the component is manipulated with rather high forces before placement, with an inherent risk of shifting.

Possibly worse than a shifted component is the loss of a component after it is picked from the tape. As the component might have fallen on the board it has to be found and removed, since it can cause failure of the final product. Finding a soldered 0201 on a PCB lying on a desk top is a challenge. It is a nightmare to find such a component at the line under production pressure, and impossible to see it during visual inspection. This underlines the importance of nozzle design in combination with laser alignment, and the need to check the presence of the component at all times during the pick and place cycle so that the operator is alerted in the event of a lost component.

Other factors

Accurate placement begins with knowing the position of the pads. This can be measured using an attribute of the artwork, preferably a marker designed for visual alignment. Most likely the PCBs used in production with 0201 are not so big that local fiducials are needed.

The next issue is the ability to control the X-Y system in such a way that the component will land on the pre-determined place on the board. The capability of a placement machine is



expressed as Cpk. The Cpk is influenced
by the accuracy and repeatability of the placement. It is not enough to be able to place components very accurately most of the time. Nor is it good enough to place a component **always** on the same spot if it is not exactly the right one. For these critical applications, components must always be on the right spot. The right spot is within 0.050mm of the co-ordinates of the pad. To guarantee correct placement for 999 950 out of every million components (or 50ppm), a Cpk of well over 1 is required. The parallel principle placement machines with high-speed gantry systems are preferable to high-speed belt driven serial placement machines (Fig. 8).

Accuracy is a more and more demanding factor in 0201 processes, therefore vibrations and stresses in systems can no longer be allowed. They can be eliminated by using gantry systems or by slowing down the machines. Due to the somewhat slower movements of gantry systems, both issues are tackled with remarkable results. There is more time to stabilise the motor movements. Vibration during the stop sequence, and also stresses, are eliminated. With the parallel placement principle, the speed 'loss' is easily re-gained, indeed the speed of parallel placement machines far exceeds that of other types of machine, resulting in a more stable process compared to belt or turret driven technologies. As a result, a Cpk greater than 2 has been easily reached in real production with high-speed gantry-type equipment.

There are no special reflow process requirements with 0201. The component does not attract much heat, so where it is placed near a big component, care should be taken that the solder paste is heated to a sufficiently high temperature for the formation of a solid solder connection.

Conclusion
The introduction of 0201 into high-volume production requires that new technology barriers are broken. Once the process is well in place, a stable production environment can be established. The introduction must be effected by a team which overviews all the processes involved, and initial problems must be tackled at their root cause. Optimisation of the individual processes in the line will not lead to the required stability. The equipment in the line must be capable of supporting 0201 technology. In particular, the screen printer and the placement machine must be of best-in-class quality.

A successful introduction demands close cooperation between the electronics manufacturer and the equipment supplier during configuration, installation, training and ramp-up. Therefore today's suppliers to electronics manufacturers are required to provide the technology together with expertise in the processes. The best utilisation of equipment capabilities, with high yields and uptime, are established by project management to which both parties contribute their best efforts, ensuring that the manufacturer will receive the optimum start-up, ramp-up, training, technology and process support. The fact that equipment suppliers in today's world are capable of providing e-support, through which they can monitor the production processes in real time and take corrective action when required, provides the guarantee the manufacturer needs.

Only a supplier which can deliver both sound process knowledge and top-level equipment can be a partner in such an operation.

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