Effects of an Appropriate PCB Layout and Soldering Nozzle Design on Quality and Cost Structure in Selective Soldering Processes

Reiner Zoch, Product Manager
Christian Ott, Sales and Project Manager
SEHO Systems GmbH
Kreuzwertheim, Germany

Abstact
The globalization of markets results in stronger competition with clearly noticeably cost pressure. For companies producing electronic equipment it is therefore of existential importance to reduce production costs whilst maintaining a consistently high quality level of the manufactured products. Manual repair soldering that is expensive, time-consuming and cost intensive is already unacceptable due to the required quality and the reproducibility of the whole manufacturing process.
In addition, densely populated multilayer boards and miniaturised, high-pin-count, fine-pitch devices cannot be efficiently repaired with high quality. "Hidden costs", such as productivity rates, operator training and damaged assembly costs have to be taken into consideration as well.
Special focus has to be set to lead-free applications as manual repair soldering processes can cause enormous thermal problems.

The target, therefore, has to be a zero-fault selective soldering process.

An appropriate printed circuit board design is of the utmost importance here. For example, the shape of the pads and their distance in relation to each other can benefit – or with the corresponding design – exclude the formation of bridges. The distance between a pad to be soldered and an adjoining one that is not to be wetted, also plays a role.
The distance between the individual pins, as well as the length of the pins, are likewise to be taken into account.

Moreover, by choosing the correct soldering nozzle, one can avoid the formation of soldering faults in the automatic selective soldering process.
The design of the soldering nozzle, as for example the shape or diameter, and the soldering nozzle technology used, such as wettable and non-wettable soldering nozzles, play a role here. Additional innovative features, such as debridging knives for example, can effectively avoid the formation of solder bridges, especially in the dip soldering process.

With many practical examples, this paper gives a detailed explanation of the individual points which should be found in the selective soldering process, with regard to the assembly design and solder nozzle technology.

Initial situation
Most frequently a selective soldering process cannot be realized because of missing clearance between the solder joint and neighbouring components, such as

- SMDs which might be washed off during the process or
- Housings of other leaded components which could be touched and damaged by the solder nozzle.

In many other cases, solder bridges and poor hole fill are the main reasons for faults. In addition, solder balls can cause difficulties. The solder's pull-off behaviour, which is influenced by several factors, is what is mainly responsible for reliable soldering results in the selective soldering process.

In general, one has to distinguish between the different selective wave soldering processes.
Selective soldering as a single miniwave process (Fig. 1) can be performed in either a drag or a dip soldering mode and allows soldering with an angle. This offers a high flexibility and fewer restrictions with regard to board design, however, depending on the number of joints to be soldered, single miniwave processes show a longer cycle time. Typical cycle times range between 1 minute and 10 minutes.
Multi-nozzle dip soldering processes (Fig. 2), on the other hand, use product-specific solder nozzle tools which results in a certain inflexibility. As all solder joints of an assembly, however, are processed simultaneously, multi-nozzle dip soldering processes are featured with a short cycle time which ranges between 20 seconds and 30 seconds. Most machine systems do not feature soldering with an angle.

Both processes, at least partially, demand different design rules.

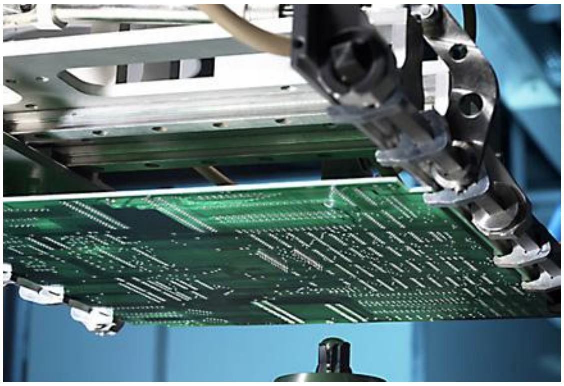


Figure 1 – Single nozzle miniwave process

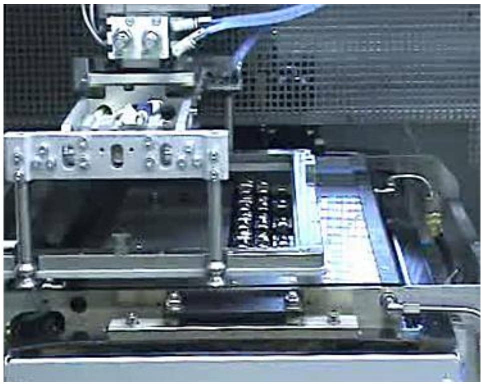


Figure 2 – Multi-mozzle dip process

PCB design rules

To avoid problems during selective soldering processes, PCB design rules are mainly related to clearance areas around the solder joints. Measures also can be taken to improve hole fill, such as a correct component lead length, a proper ratio between the pin diameter and the via, thermal decoupling etc.

To reduce the risk of solder bridging, mainly the pitch between the component leads and length of the leads need to be considered. But also a special soldering nozzle design can help to minimize solder bridges.

Another issue is solder balling which also can be reduced by a proper board design or special soldering nozzle design.

Clearance around the solder joints

To perform a reliable soldering process, the minimum allowed inner diameter of a single miniwave soldering nozzle is 3 mm which corresponds to an outer diameter of 4 mm.

Minimum external dimensions for a soldering nozzle in multi-nozzle dip soldering processes are 5 x 8 mm.

To avoid difficulties caused by edge clearance, multi-nozzle dip soldering processes require a distance of at least 3 mm between the edges of the joints to be soldered to surrounding components or joints which should not be soldered. With a minimum nozzle size of 5 x 8 mm this results in a "clear area" of 11 x 14 mm at least (Fig. 3).

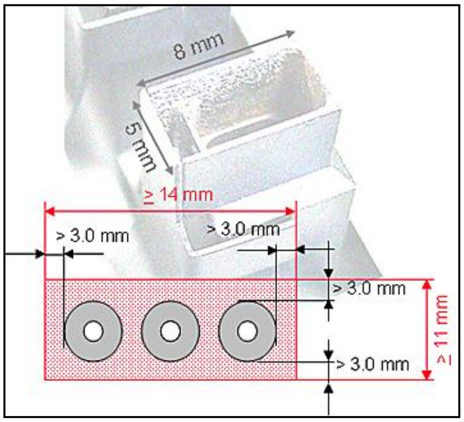


Figure 3 – Minimum required clearance for multi-nozzle dip processes

Depending on the specific process conditions, smaller clearances can be realized as well. This, however, needs to be checked thoroughly. It mainly depends on the type of neighbouring components and may require special measures, such as e.g. grippers with centering pins or the use of wettable solder nozzles.

For miniwave soldering processes, board designers should consider 2 mm on three sides around a pin or a pin row and 5 mm on the side where the component leaves the wave, to allow a proper peel-off (Fig. 4). If a clearance of 5 mm should not be possible at all, leaving the wave with an angle or the use of wetted solder nozzles can be helpful (Fig. 5).

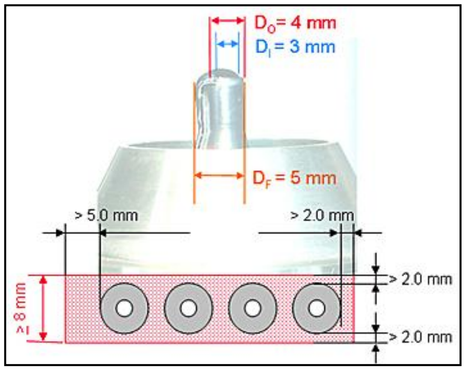


Figure 4 – Minimum required clearance for single miniwave processes

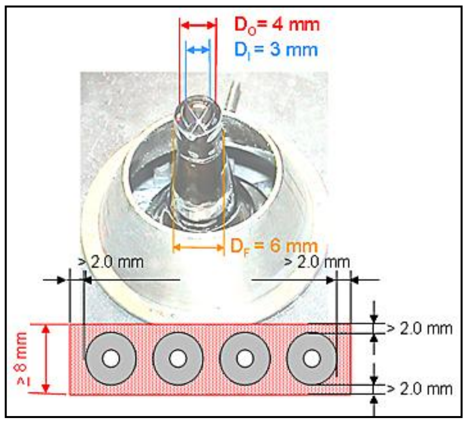


Figure 5 – Minimum required clearance for single miniwave process, wettable nozzle

If board designers should not be able to keep the required 2 mm distance on at least three sides, neighbouring SMD components should be aligned inline (Fig. 6). The advantage of an inline alignment is that if the neighbouring reflow soldered component should be wetted during the selective soldering process, it will not immediately be washed away.

Figure 6 – Alignment of neighbouring SMD components

Single miniwave soldering in a drag process moreover requires consideration of the distance between the solder joint and a neighbouring component higher than 10 mm on the soldering side. When soldering with an angle, components higher than 10 mm could touch the soldering nozzle or gassing hood. The rule of a thumb that applies to these specific components is that the height of the component should be equal or less than the distance to the solder joint.

Improved hole fill

The phenomenon of poor hole fill is mostly based on an insufficient heat transfer rate which also can be improved with an appropriate PCB layout.

The length of the component leads plays an important role in this regard, particularly in multi-nozzle dip soldering processes. Multi-nozzle dip soldering processes require a lead length greater than 2.5 mm. This is related with the energy transfer rate which directly affects hole penetration. Longer component leads are dipped deeper into the liquid solder which improves the heat transfer which finally results in an improved hole fill.

Another issue which should be considered in respect to hole fill is an ideal ratio between the pin diameter and the via. If this ratio should be too large, no capillary action will emerge. Should this ratio be too small, flux cannot soar through the via and therefore solder joints cannot be formed properly. As a rule of a thumb, the diameter of the via should be equal to the diameter of the pin plus 0.2 up to 0.4 mm. Lead Free processes even can require a plus of 0.5 mm.

Thermal energy also will be transferred better when the pad size is enlarged to a certain extent or if oval pads are used.
If possible, solder resist close to the solder joint should be avoided. This helps to keep the heat at the solder pad and in addition also helps to avoid solder balling.

Attention should be given also to thermal decoupling. With an appropriate thermal decoupling of the PCB, the heat will not be completely withdrawn to the strip conductor, but will be hold for a longer time at the pad (Fig. 7).

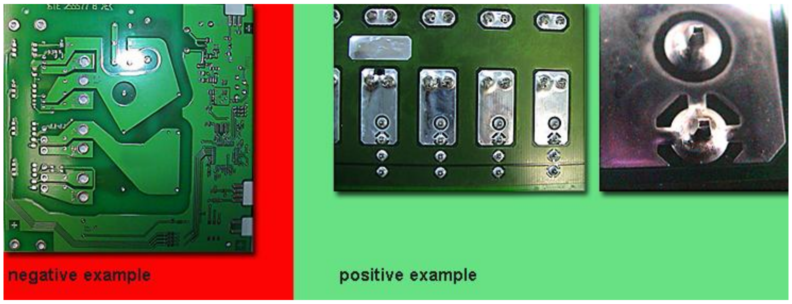


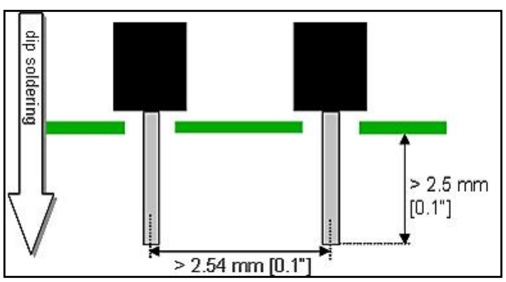
Figure 7 – Thermal decoupling

Flowing solder waves, also in dip soldering processes, should generally be preferred. This ensures that oxide-free and correctly heated solder alloy is continuously supplied to the solder joints. Even during the contact phase, the solder alloy does not cool down. This improves hole fill remarkably, even in case of high-mass pins, at pins with connection to inner layers or pins which are located at the outer edges of an assembly.

Reduced solder bridging
Solder bridges are a major reason for defects in selective soldering processes and mainly are caused through small distances between the component leads.

Whereas multi-nozzle dip soldering processes require a pitch greater than 2.54 mm, single miniwave soldering processes allow remarkably smaller pitches of 1.27 mm. This applies for machine systems that facilitate setting of a soldering angle, which has an impact on the solder's peel strength to reduce the risk of bridging, or for systems featuring wettable soldering nozzles.
Although pin rows with a lead distance smaller than 2.54 mm bear an increased risk of solder bridging in a dip soldering process, they still can be processed if some basic layout rules are considered. A smaller pad diameter, for example, can be helpful, or, if possible, an oval pad form which helps to spread the liquid solder into a different direction, off the component leads. With specific modifications at the multi-nozzle soldering tool, a pitch to 2.0 mm can be realized as well.

The length of the component leads plays an important role in regard to solder bridging as well.
Multi-nozzle dip soldering processes require a lead length greater than 2.5 mm (Fig. 8). The peel strength of the solder is enhanced with longer component leads which pulls the solder away from the solder joint to reduce the risk of bridging.



Figures 8 – Multi-nozzle dip soldering: pitch and lead length

In single miniwave soldering processes the board is moved and usually a soldering angle is used to improve the solder's peel-off. The typical lead length here should be around 1 mm (Fig. 9). Shorter pins could cause poor meniscus formation and ball-shaped solder joints.

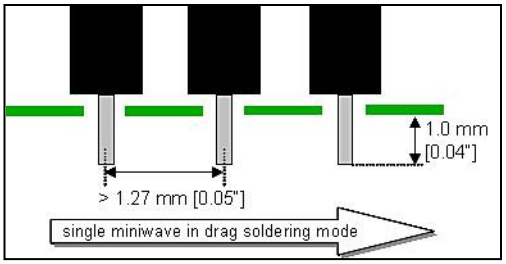


Figure 9 – Single nozzle miniwave soldering: pitch and lead length

Particularly in the dip soldering process, an appropriate soldering nozzle design can remarkably reduce the risk of solder bridging as well. So-called debridging knives, for example, which are wettable plates installed inside the solder nozzle and drain the liquid solder after dwell time (Fig. 10). Debridging knives are suited for special applications where the design rules mentioned earlier could not be followed, this means the pin length is smaller than 2.5 mm and / or pitch is between 2.54 mm and 2.0 mm.

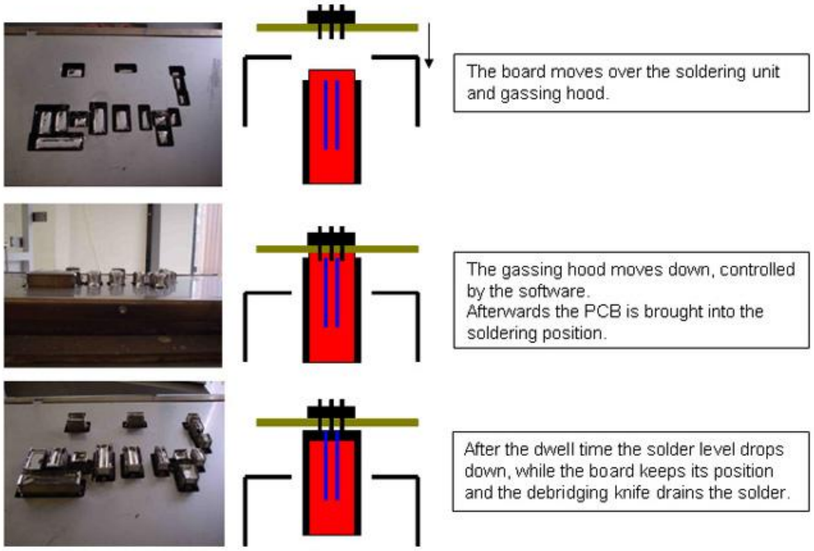


Figure 10 – Debridging kives

Minimum solder balling

Solder balling is a phenomenon in all wave soldering processes which always occurred in the past and which will occur in future as well. It, however, appears more frequently in lead-free soldering processes as process temperatures are remarkably higher than in traditional soldering processes. The higher process temperatures can have a negative effect on the solder resist. Depending on the quality, the solder resist might soften during preheating which abets arising solder balls to stick at the solder resist. In traditional lead bearing processes or applications featuring high quality lead-free solder resists, arising solder balls just would bounce off.

Therefore, if possible, solder resist close to the solder joint should be avoided (Fig. 11).

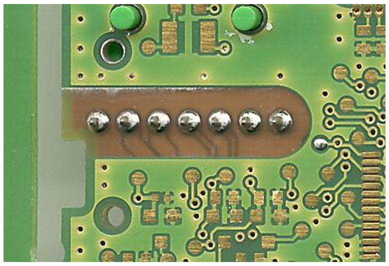


Figure 11 – Avoid solder resist close to the solder joint

Particularly in multi-nozzle dip soldering processes, special nozzle designs can help to avoid solder balling as well. These nozzle tools are featured with a defined solder flow which is directed by means of a flow plate. In addition, the complete nozzle tool is covered with a second top plate. Any splashes, which might occur while the liquid solder is flowing back to the reservoir, therefore will not get a chance to touch the printed circuit board.

Conclusion

Among all automated soldering processes, selective soldering is probably the most demanding process, requiring some experience and basic knowledge about the process itself and involved materials.

Up-to-date selective soldering systems, however, already take out most of the difficulties which could arise during the process.

With some basic board design rules being considered, time-consuming and cost intensive repair soldering are a thing of the past with simultaneously increasing quality level of the manufactured products.