Making Selective Soldering Work for You

Gerjan Diepstraten

Dip or drag? Which process to choose depends entirely on your product.

Are you planning to implement a selective soldering process in your manufacturing facility? If so, two major misperceptions must be avoided. The first misperception is that implementing selective soldering is mostly a matter of choosing the right machine, with the most "bells and whistles." Not so; the process is more important than the machine.

All selective soldering processes are unique and require their own specific handling and soldering tools. To meet these requirements, the user must fully understand the process, have a good relationship with the supplier built on prompt communication, and have a worldwide logistical support system that can quickly respond to any needs and problems.

The second misperception is that selective soldering is merely wave soldering with some different wrinkles. Selective soldering is very different from wave soldering. Perhaps the most significant difference is that, in wave soldering, the underside of a PCB is completely bathed in flowing solder. In selective soldering, only specific areas are contacted by solder. Because the board material itself is not an efficient heat transfer medium, this property benefits adjacent components and PCB areas that should not be heated to liquidous.

One disadvantage of this selective heating is that the outer pins of a connector, for example, will transfer more heat to the board than the inner pins; the colder outer area is larger, so a temperature difference (ΔT) occurs over the pin connector. Accordingly, the process must be optimized to achieve good soldering on the outer pins as well.

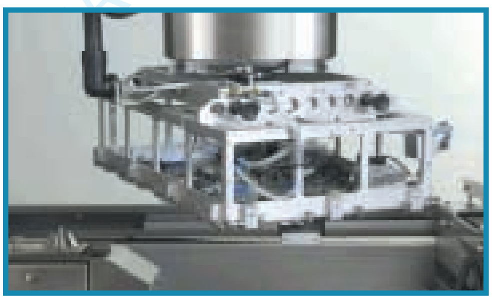

FIGURE 1: Robotic arm for holding PCB.

Successful selective soldering requires a completely new approach. A thorough understanding of the process and how the equipment fulfills the need is a key part of the synergy that must develop between the user and the equipment supplier.

What is Selective Soldering?

In selective soldering, specific through-hole devices on a PCB are "selectively" soldered from below. Unlike wave soldering where PCBs are conveyed in a straight line through a stationary wave, selective soldering uses robotics to individually move each board over stationary soldering nozzles and tooling.

Selective soldering also uses two different techniques—drag or dip soldering—to solder individual sites or components. The robotic arm that moves the PCB can move literally in all directions (Figure 1). The solder fountains are fixed in position, and the board is moved over them.

The tooling is custom to the PCB and the components and can vary widely. While the great variety of tooling needed may seem to be a disadvantage in terms of cost, tooling inventory and variability, it provides great flexibility to meet board configuration challenges. However, tooling is not everything. Certain PCB design rules must also be observed to accommodate the process, so manufacturers and board designers must work together.

Another advantage of selective soldering is the ability to program specific recipes for each board and even for each component. Also, all combined recipes for a board, series of boards or production shift can be automated, for absolute repeatability and consistency.

Process Configuration

In selective soldering, only the through-hole components are soldered. A key goal is to minimally affect the surface-mount components and other adjacent materials on the board. Because every PCB has its own specific layout and materials, the selective soldering machine is designed for different configurations, using software.

The two different selective soldering processes are drag and dip soldering. Briefly, drag soldering is accomplished on a small single nozzle wave. Drag soldering can reach very tight areas, individual spots or leads; for example, an individual row of leads can be drag soldered. The PCB can be handled at different speeds and angles to optimize the soldering results (Figure 2).

In contrast, dip soldering involves dipping the entire PCB onto a custom tooled nozzle plate (Figure 3), soldering all joints in one operation. Although multiple connections are soldered at once, individual tooling plates for each type of PCB are required. This requirement is a major departure from the wave soldering process.

Naturally, components to be soldered must have flux applied to their leads. Again, flux is not applied to any part of the PCB underside that is not going to be soldered. Thus, point-to-point fluxing is used depending on the type of soldering process. When using a select point fluxer, the single or dual head fluxer is fixed, while the PCB travels over it. With multipoint fluxing, the PCB's position is fixed, while the fluxer moves under the board and drop-jets pre-programmed locations.

The process sequence in selective soldering can be user-defined. A typical process sequence is fluxing, preheating, dip soldering and drag soldering. However, in some cases, preheating can be eliminated or a board may be only drag soldered. Another possible combination is preheat, fluxing, preheating and soldering.

New PCB Design Rules

A key goal in selective soldering is to avoid affecting the surface-mount components and other adjacent materials on the board. With wave soldering, many years were needed to optimize the process and apply relevant design rules. Similarly, new design rules must be created for selective soldering due to the different constraints of the drag and dip soldering processes.

Single drag wave soldering

With drag soldering, the following parameter settings may be used:

- solder temperature of 275°C to 300°C
- drag speed of 10 to 25 mm/s
- tilting angle, typically 10°
- pump frequency, depends on selected nozzle.

FIGURE 2: Drag soldering with a single nozzle beneath the PCB.

FIGURE 3: Dip soldering using custom nozzle plate.

A single drag wave can be used for drag-and-dip soldering. For robust processing, the nozzle must have an inside diameter of at least 6 mm, when formed of stainless steel. The flow direction of the solder is defined, but the nozzle can be mounted in different directions and optimized for every application. The robot arm can also approach the wave from different directions and different angles between 0° and 12°. Thus, the user can solder many different components on an assembly. A soldering angle of 10° is recommended for most components.

As compared to dip soldering, the heat transfer in drag soldering is inherently better due to the motion of the solder and the board. However, the heat energy required to form the solder joints must be delivered by the solder wave. Because of the wave's small mass, the wave's temperature must be relatively high to achieve acceptable process settings for the drag speed. For example, with a setting of 275° to 300°C, drag speeds of 10 to 25 mm/s can generally be achieved. Nitrogen is supplied to the soldering area to prevent oxide buildup on the wave.

Drag soldering the PCB also eliminates bridges because oxides are washed off the wave. This advantage also contributes to the robustness and reliability of drag soldering.

Wave height must be controlled, so the level of solder in the pot must be measured periodically. An automatic solder addition unit will help keep the solder level consistent. Also, pump speed must be controlled to keep the wave height constant.

The wave's flow configuration is defined by the nozzle design. Production runs have proven that solder will flow in the proper direction if the first pins are wetted by a dip motion, before the dragging begins. Non-wetted pins might cause solder overflow at the backside of the nozzle.

Overflow at the nozzle backside can also be caused if the board's immersion depth is too great. Over-immersion can be caused, for example, by sagging of the board due to high temperature. To prevent this sagging, supports can be used.

Despite the benefits of drag soldering, its key drawback is its extended cycle time. For this reason, dip soldering is used in tandem with drag soldering for specific applications. Dip soldering has certain capabilities that drag soldering does not. Used together, they can build a robust process with minimal cycle times.

With drag soldering, lead lengths are limited due to the wave height. In general, lead lengths smaller than 2 mm are preferred, but solder leads up to 4 mm are possible. The minimum allowable lead protruding length depends on the board; for single sided boards, the lead length should be at least 1 mm. For other boards, the recommended length should be at least 0.7 mm to make joint inspection possible.

A straight protruding lead length of more than 1 mm will generally not accumulate more solder at the joint in machine soldering and will, therefore, not add any more strength to the solder joint. For a robust process, the distance between the edges of the joints to be soldered to surrounding components or joints that should not be soldered must be greater than or equal to 3 mm. In the downstream direction from the drag wave, this distance must be greater than 4 mm.

Multidip wave soldering

With dip soldering, the following parameter settings may be used:

- solder temperature of 275°C to 300°C

- dip speed of 20 to 25 mm/s
- pump frequency, depends on number of nozzles
- dip time, typically 1 to 3 sec
- speed after dip, typically 2 mm/s.

The soldering technique employed with multi-wave nozzles is dip soldering. Although the process appears to be simply dip the board into the solder and remove it, different concepts can be applied with their own characteristics. During fluxing and preheating, the solder nozzles are covered with a glass plate, beneath which an inert atmosphere blanket is maintained. The solder is rinsed to remove all oxides and to keep the solder in the nozzles at the correct temperature.

Wave height and solder temperature are critical in this process. All nozzles should be at the same temperature and have the same solder bubble height. Standoff supporting pins may also be used to prevent board material warpage.

The simplest dip process is to dip the assembly in the solder. The solder should not overflow the nozzle rim during soldering; otherwise surrounding components may come in contact with the solder.

The second method is to maintain solder height just below the rim of the nozzle as the board is moved downward, until it contacts the nozzle rim. Then, solder pump speed is increased to push the solder up and into contact with the board. Then, pump speed is reduced and the board is moved out of the solder. During this process, the pump speed should not be too high during dwell, to prevent depositing oxides on the board. Also, the exit speed must be optimized to prevent bridging.

Nozzle dimensions should be as large as possible to ensure a stable process, but without affecting adjacent components on the board. This task is important and perhaps difficult for the design engineers, because the stability of the process may depend upon it. Nozzle plates are created with a high accuracy of less than 0.1 mm tolerance. Algorithms are used to compensate for the effects of temperature.

Using this process, joints from 0.7 mm to even 10 mm may be soldered. Shorter leads and smaller pad sizes make the process more stable and less sensitive to bridging. The space between the edges of the surrounding joints or components and the nozzle should be greater than 0.5 mm.

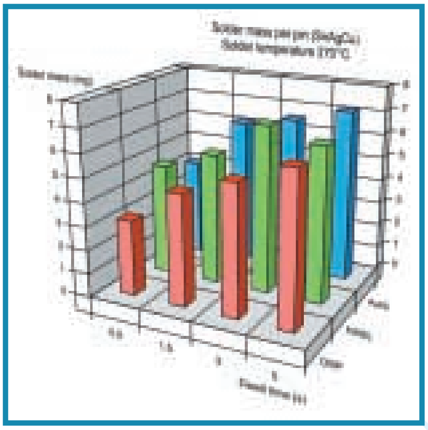

FIGURE 4: Mass of solder joints at 270°C.

Hole fill (solder temperature 270°C)				
Finish:	0.5 sec	1.5 sec	3 sec	5 sec
OSP	24%	65%	89%	100%
NiAu	65%	96%	100%	100%
HASL	81%	100%	100%	100%

TABLE 1: Required hole fill percentages.

Different Process Results

The process results obtained in selective soldering differ from those of wave soldering. The results also differ between drag soldering and dip soldering, due to the heat distribution characteristics of the type of soldering used and the individual thermal transfer characteristics of the different types of boards.

As in wave soldering, preheating is used to prepare the PCB for soldering. In selective soldering, preheating lessens the impact of ΔT on the board because a localized area is in contact with the solder instead of the entire PCB. The overall thermal effect on the PCB is much less, with a consequent reduced probability for thermal stress-induced board problems.

With drag soldering, process experimentation will determine the optimum speed through the tiny wave. In dip soldering, dwell time is defined as the duration of contact between the molten solder and the parts to be soldered. Dwell time and solderpot temperature determine the total heat flow to the soldering area. Good solder penetration in a through hole is influenced by these parameters. Process development for dip soldering involves varying dwell times with different temperatures and materials to determine the optimal dwell time for a specific PCB.

Determining Dwell Time

An experiment was conducted to determine the optimal dwell time for a pin connector in the dip soldering process. The weight of the PCB was measured before and after soldering. The weight difference is the solder applied. The experiment was run at 270° and 300°C for nickel/gold (NiAu), organic solderability preservative (OSP) and hot air solder leveling (HASL) finishes. The 270° results are shown in Figure 4.

In *Soldering in Electronics*, Wassink explained that the upper and lower fillet volumes of a solder joint (for a 1.6 mm board and land radius of 1.5 mm) have a ratio from 1.25 to 0.69, due to differences in liquid pressure. With this information, the required hole fill percentages can be calculated (Table 1).

This data reveals that short dwell times in dip soldering for 1.6-mm boards achieve good solder filling. Another plus for short dwell times is that the flux is still stable, thus preventing bridging.

Conclusion

Today's selective soldering technology is capable of soldering with lead-free solders and tin-lead combinations. The process offers flexibility, advanced control and automation. Its robustness and wide process window make it ideal for lead-free soldering, where solderability and thermal vulnerability of certain components may be issues. Selective soldering delivers quality, repeatability and increased product reliability. ■

The next article in this series will discuss the parameters in the selective soldering process and their specification limits. The article will also provide recommendations for allowable parameter tolerances.

References

1. Wassink, R. 1989. *Soldering in Electronics*. Isle of Man, U.K.: Electrochemical Publications Ltd. p.53.

Gerjan Diepstraten *is an application engineer with Vitronics Soltec BV, Osterhout, The Netherlands; e-mail: gdiepstraten@nl.vitronics-soltec.com.*