Vitronics Soltec

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Useful information for wave soldering tests

Introduction

During wave soldering tests one often has a limited amount of boards and a customer demanded type of flux available for a machine soldering evaluation test.

In some cases special test boards with a layout that is designed with a big risk of soldering defects must be soldered, while at the same time there is a demand that no visual flux residues should be present after the soldering process.

Both situations create a test platform that includes a big risk for ending up with a test result that is not optimal, or at least will not fulfil all the demands.

This information will elucidate the effects of the parameters involved in the wave soldering process that will affect the test results besides Murphy's law. ("Anything that can go wrong, will go wrong.")

Note: As a result of Murphy's law it is possible that a demonstration may end up in a 'demonstruction'.
Nevertheless one should keep the good spirit.

General demands after soldering

- The soldered boards should be clean
- There should be no unwanted solder bridges in-between joints
- There should be no skipped joints
- There should be no solderballs present on the board
- The thermal load on components should be within specification
- The desired soldering quality should be obtained in one process operation

Aspects that have an effect on the soldering quality

The two most important aspects in the wave soldering process are the board-layout and the flux that is used in the process, under the prerequisite that the solderability of the board and the components fulfil the demands for wave soldering.
This has been proved in many production tests e.g. within Philips, which were done in the seventies of the last century.
These are in fact the aspects that we do not have under our control during tests on our equipment.

What are further of importance is that the flux should be well distributed and that the preheating setting is sufficient to evaporate the flux solvent and to prepare the flux activator. Next the contact time in the wave(s) should be sufficient to give good wetting and hole filling.
Finally the departure of the board from the wave should be such that all unwanted solderbridging will be removed and that no flux residues should be present.

To fulfil these last demands it is necessary that the board must be kept sufficiently flat and that too much bending of the board is compensated for. Knowing that most boards have a thickness of only 1.6 mm and that the wave width in some cases can go up to 500 mm, it is clear that one needs a stable conveyor system. This conveyor should also be able to keep its speed fixed under different loads. The nozzle-sprayfluxer setting should match with the conveyor speed, so that the correct amount of flux is applied with a full coverage of the solderside of the board and a sufficient gap penetration.
Also the preheater setting should match with the conveyor speed and the thermal demands given by the flux supplier.

That is exactly what our machines repeatedly can do with great accuracy when properly set and well maintained.

The solderdrainage conditions are to a great part layout dependent. The setting of the backplate can be adjusted, so that the oxide skin on the wave surface will be removed when the board enters the wave.
An additional nitrogen supply can be used to assist the drainage conditions.

Finally the use of the SelectX® can under certain conditions be recommended to remove specific solderbridges.

Defects and their possible causes

The fact that most defects are related to the layout can simply be proved. Just compare the majority of sound joints to those joints that give a defect. One should thereby keep in mind that all these joints are soldered with the same machine settings.
Another important aspect to keep in mind is that some joints may give a bi-stable behaviour. This means that with the same setting one board may give a perfect result without a specific defect, while at the next board that specific defect appears, but always in the same area.
One may easily draw the conclusion that the process is unstable. This is however seldom the case. It is the bi-stable character of such joints that gives the operator a false impression. Again, compare these joints with the majority of sound joints, which soldered under the same conditions will always be sound.

The best advise one can give in such situations is to optimise the layout. This will give a final solution, which is far more robust than one can get from a wave soldering process.
The main reason for the process instability is the 'random' drainage condition at the point where the board separates from the solderwave when there is a concentration of joints.

By optimising the process settings one often has the possibility to bring the balance in the right direction, so that the process becomes more robust. This is however in most cases only possible when a series of boards are soldered under defined test conditions. (Taguchi test set-up).
If only a small amount of boards are available for a first setting, such a process optimisation is often a too difficult target.

Solderbridging

The separation conditions must be such that the remaining flux on the board surface is able to reduce the oxide formation on the liquid solder that separates from the individual joints. Only in that case the solder can withdraw to its own joint. If in that process an oxide film is formed over the separating solder, an envelope of oxidised solder will be present between adjacent joints, resulting in solder bridging.

In the case of a concentration of joints and/or long protruding leads, the remaining flux that is present on the board during the departure from the wave might not be sufficient to get this job done well.

Note: One should notice that this remaining flux is only present in the space in-between the joints, because at the position where is solder there can be no flux. This small amount of flux can only be active in the direct area of solder separation from the board. If the joints are not directly separated, e.g. due to long leads, this flux can no longer be effective, resulting in solder defects, like solderbridging, spikes, flags, etc.

In that case the use of nitrogen, which prevents oxidation, can be of assistance.

A 'drawback' of nitrogen however is that it will increase the surface tension of the solder, so that more solder will be left on each joint. When joints are close together this might then also give solderbridging.

Increasing the space between joints, by reducing the solderpad size will mostly give the best solution.

Increasing the flux amount might also help, but this can have a negative effect on the formation of skipped joints and on the cleanliness requirements.

Skipped joints

Skipped solderjoints are not touched by the solderwave for a sufficient long time. The reason for this is often that the pads in relation to the SMD-component dimension are too small. Another reason can be that small SMD-components are positioned too close to larger SMD-components, where the latter is shadowing the smaller one, so that the wave is unable to get in contact with the solderpads. Last but not least there is the possibility that too much flux is collected underneath or in-between the SMD-components. This flux will then evaporate fast as the wave touches the component. This will cool the wave surface and may 'press' the wave away from the joint area.

A limitation of the Chipwave height and/or the Smartwave setting due to the risk of solder overflow in gaps or holes in the board, will limit the wetting capacity of these waves and therefore increase the risk of skipped joints.

A lower conveyor speed setting might be a solution for some of these SMD's, but in general the best solution lies in the improvement of the layout.

One should always keep in mind that the general layout rules given by the designer of the SMD's are normally only valid when only these types of components are used. As soon as SMD's with different dimensions are mixed, the general validity is questionable or even false.
In the case that SMD-components with different dimensions are placed next to each other, one should always use the space rules in-between SMD-components that are valid for the biggest components.

Solder not wicked up to the topside

Provided the joints were fluxed well and the wave did contact the joint for the set dwell time, then the common reason for this behaviour is the poor thermal solderability. If the 'heatsink effect' of the joint is such that the solder will solidify during the penetration of the joint gap, wetting stops. This effect is often intensified by lack of surface solderability as well.

The filling of the gap between component lead and hole wall with solder is based on capillary action on clean metal surfaces.

The laws for wetting and capillaries are however only valid for liquids. If solder is solidifying it is no liquid anymore and the wicking process stops.

Only a proper joint design in combination with a good surface solderability can exclude this behaviour. In the soldering process there is not much that can be done to prevent this.

Solderballs

The formation of solderballs in a wave soldering process is unavoidable, because it is part of the physical behaviour of a separating liquid flow.

If a liquid flow becomes thin, the flow will form separate droplets. A running water tap that is gently closed can easily demonstrate this. One then will see the flow changing from massive to a thin flow consisting of a row of single droplets.

When the solder between the joints and the wave is separating the same behaviour will take place, both in vertical and horizontal separations. Normally these solderdroplets will fall back to the solderwave, unless there is a strong 'adhesive' bond between the solderresist and the solder. In the latter case the solderdroplets may remain partly on the board surface, often in a reproducible systematic pattern between individual adjacent joints.

If solderballs will adhere to the board surface is depending of the interaction between the solderresist, the flux and the solder.
It has been proved that the 'bond strength' of such tiny solderballs exceeds often an acceleration force of 40 g. ($g = 9.8\ m/s^2$)

Solderballs on the topside of the board are most probably solderparticles blown out from a solderjoint as a result of 'barrel cracking'. This barrel cracking phenomenon often also causes 'blowholes'

Flux residues

Flux must adhere to the board during the soldering process. It is necessary that part of the flux is still active at the point where the board leaves the last solderwave. Therefore it is unavoidable that some flux residues are still present on the board after the process is finished.

The flux has two main tasks. At the board entrance in the wave, the flux must be able to reduce the oxides of the jointparts and from the solderwave surface. The second stage where the flux activity is needed is at the wave departure. Here the oxides covering the separating solderparts should be reduced to avoid solderbridging. The use of nitrogen at this stage can be of help to prevent the oxide formation on the solder surfaces and will so assist in better drainage conditions.

If the flux does not well adhere to the board surface soldering problems will be the result.
If the solderresist that is applied on the board is not properly cured, then the curing process may proceed in the solderwave. As a result of that a vapour film in-between the solderresist and the flux will be formed.

This will cause a serious problem because the flux can adhere to the solderresist, but is not able to adhere to a vapour blanket. As a result of the friction between the solderwave and the board the flux will be whipped off almost completely so that it is unable to employ its full activity for the process.

Thermal load to components

During the soldering process components will become heated. The maximum temperature that is allowed and the time it would resist this temperature can be found in the supplier's data sheet. Reduction of the thermal load during wave soldering can often be accomplished by increasing the distance between solderjoint and component body. This is a matter of the design of the board.

The use of temporary heatsink jigs during the soldering process may also give a solution, but is in general not recommended due to the extra handling and logistics (cooling after use before using again).

Desired soldering quality

The desired soldering quality level is often depending on the product specification. In general one can say that a good joint is a joint that is soldered in one operation and that will fulfil both its electrical and its mechanical requirements within the specified lifetime conditions without failures.

The solderquality is mostly controlled by visual inspection according to common specifications like IPC ANSI/J-STD-001. However one should also use its common sense. For example one should not touch up a 'fat' joint so that it will fit to the 'hollow shaped ideal solderjoint profile'. Such fat joint is in machine soldering a perfect joint as it is. The reason that it is fat, is that the 'excess' solder that remains on the joint, after separation from the wave, has no way to drain off e.g. to a track, since these tracks are covered by solderresist. The wetting of such a joint is perfect, otherwise no or insufficient solder should be found on that joint.