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Solderability in relation to PCB design

Introduction

To make a soldering process successful it is necessary that the components to be joined by the solder can withstand the soldering treatment without to be damaged.

To realise a good solder quality it is necessary that the components to be joined have a good wettability with solder. This is called the surface solderability.

Furthermore the design of the joint must be such that the solder can and will stay liquid during the soldering process and will not cool down below its melting point during the joint formation. This is called the thermal solderability.

Only when the demands for surface solderability and thermal solderability are met, we are able to create joints where the solder is able to fill the holes completely.

Surface solderability

Reference: Soldering in Electronics Second Edition, Chapter 7

There are several industrial standards that give directives for the measurement of (surface) solderability. In these documents the test conditions, such as test time, test temperature and the flux to be used are prescribed. Also the test criteria must be given.

Example

The part to be tested should be fluxed with a mildly activated flux. The flux should be allowed to dry. Then the part should be emerged in the solder with a dipping speed of 10 - 25 mm/s. After a 2 seconds dwell time in the solder, the part should be withdrawn with a speed of 10 - 25 mm/s. The solderbath temperature for a SnPb40 alloy should be set at 235° $\pm$ 2°C. After the test the part should be visually investigated with 10 times magnification. The requirement is that the dipped area should be completely covered with a fresh layer of solder.

Often a 'wetting balance' is used for these kind of tests on components. In that case the demands are that within 2 seconds the so called 'buoyancy force line' or '90° level', representing a net wetting force equal to zero, must be crossed and after 3 seconds the wetting force must be > 50% of the theoretical maximum force. Note: This theoretical maximum force can also practically be obtained by testing a perfect wettable component under the same conditions.

It is important to do the solderability test on that part of the component that will be actually soldered. When a electrolytic capacitor is mounted on a PCB, often the last part of the lead which is connected to the component body will be part of the joint. It has no sense to measure the solderability of that lead at a longer distance from the body. The reason why we mention this is that here already the thermal solderability aspect will be involved in the solderability measurement.

Thermal solderability

Reference: Soldering in Electronics Second Edition, Chapter 3.3 - 5 and Chapter 7

In each solderability test we have to deal with both the surface- and the thermal aspects, but for a clear understanding it is useful to separate the solderability aspects into these two categories. The thermal aspect in soldering becomes important if the heatsink effect during the joint formation becomes so strong that good wetting within the allowed process settings is obstructed by solidifying solder.

Example

The electrolytic capacitor lead may have a perfect solderability at a lead part far from the component body. If we measure that same lead at a position close to the body we will find often a very poor wetting behaviour although it is the same lead we are testing. The reason for this is that wetting can only commence when the surfaces are cleaned by flux and when the solder is liquid. The latest is only the case if the solder is above its melting temperature. During soldering the liquid solder will drop in temperature due to the effect that the parts that come in contact with the solder have in our case normally a lower temperature than the melting temperature of the solder. So the solder initially cools down during the formation of the solderjoint. If we could use longer soldertimes or higher solder temperatures, the solder will eventually rise in temperature due to the contact with the solderbath, but the flux at that time will in most cases be exhausted, so that finally the wetting result will not be improved by longer contact times or higher temperatures.

Prevention of thermal damage to components during soldering

Reference: Soldering in Electronics Second Edition, Chapter 3.3.2

During the solderprocess we must apply sufficient heat to the joint area for the creation of a sound solderjoint. On the other hand part of that heat will be transported towards the component body. Most components can not withstand too high temperatures. Therefore it is important to know what measurements should be taken to prevent thermal damage during soldering. The most effective method for wave- or dipsoldering and in selective soldering is to use a stand-off or spacer between the component body and the joint area. This extra leadlength acts as a heat resistance and so diminish the temperature rise in the component body.

Specific soldering distance

Reference: Soldering in Electronics Second Edition, Chapter 7.3.2

A method to determine the minimal space needed between a component body and the solderjoint to reduce the heatsink effect of the component body during soldering and to guarantee a good solderability for a specific component, is the determination of the 'specific soldering distance'. This is the minimal distance from the component body where good wetting can be achieved within 2 seconds dwell time. The specific soldering distance is measured as termination length minus immersion depth. The test is done on a wetting balance. Before this test the lead should be dipsoldered over its entire length, to ensure that the surface solderability is excellent. Since this test is not so well known it will be described next.

Principle

The termination of the specimen to be tested, after having been provided with a flux, is immersed over a length of 2 mm in a liquid solder under precisely defined conditions.

Apparatus and aids

Wetting balance, using an immersion speed equal to or greater than 15 mm/s with an immersion depth of 2 ± 0.1 mm at a dwell time of at least 2 s. The solderbath temperature for a SnPb40 alloy should be set at 235° ± 2°C. The flux used should be mildly activated.

Procedure

Cut off the termination of the specimen to be tested at the soldering distance to be apprised + 2 mm. Immerse the termination over 2 mm in the solder for at least 5 s using the wetting balance and record the time - wetting force trace.

Test requirement

From the chart recorder trace obtained determine the time at which the net wetting forces are equal to zero. The specific soldering distance to be accepted is that soldering distance, specified to 0.5 mm, at which the thermal soldering time is smaller than 2 seconds for at least 9 of the 10 specimens measured.

Elucidation

1. For components with dissimilar terminations such as electrolytic capacitors, the specific soldering distance must be determined for each termination.
2. In some cases a recorder trace can be obtained showing a stepwise increase of the wetting forces. For such traces the obtained trace itself is not used for the measurement, but its higher enveloping curve at the side of longer wetting times.

Determination of the specific soldering distance

After each test in which the requirement is fulfilled, select a shorter length of the termination and repeat the test.

Note: Some preliminary tests suffice to limit the number of tries sufficiently.

Note: There is no guarantee that this distance will be sufficient to prevent thermal damage during soldering. For this even larger distances may be necessary. See previous chapter.

There is also no guarantee that a good solderjoint can be made, because for that also the solderability of the PCB is involved. As long as the solderability of the PCB involved is not proved, there is no guarantee for making a sound joint within the process limits.

Solderability of PCBs

Reference: Soldering in Electronics Second Edition, Chapter 7.2.3

The measurement of the solderability of a PCB is always a combination of measuring the surface solderability and the thermal solderability. For the PCB there are in fact no separate tests for both solderability aspects. The solderability test of a PCB with plated through holes is in so far a destructive test that after the test the PCB can not be used for mounting components because all the holes are filled with solder after such a test.
Often only small coupons of a PCB are tested. In that case it is important to use those parts for the test that will be the most critical from the thermal point of view. If after the test even the most critical thermal layout will give completely filled holes the solderability fulfils both requirements.

The test conditions for PCBs are:

Make from the most critical pattern part of the PCB test specimens measuring 25 ± 1 mm by 30 ± 1 mm. In most cases the most critical part is that part in which the most holes appear and the holes have the largest surface on conductors connected with the plated hole wall on the component side, or holes with innerlayers connected to the hole barrel.
Flux the PCB test specimen surface and the holes to be soldered with a mildly activated flux. Allow the flux to dry and the PCB to cool down to ambient temperature. Subject the specimens to the rotary dip method, soldering the test specimens for 3 s at 235° ± 2°C with SnPb40 solder.
The requirement after this test is that all holes should be completely filled with fresh solder up to or over the topside of the hole wall barrel.

Optimal gap between lead and hole

For good hole filling the difference between lead and hole diameter should be at least 0.4 mm for component leads up to a diameter of 0.8 mm. The optimal gap is 0.7 mm. For larger lead diameters the hole diameter should be at least 1.5 times the lead diameter.
A hole diameter up to twice the lead diameter will normally give no problems for a good solder quality. In case of PCBs thicker than 1.6 mm, or multilayer PCBs with more than one interlayer connected to the barrel, larger holes may assist in better hole filling.

General note

In case a lead-free solder is used for soldering, the test procedures and requirements should be adopted in relation with this solder. This means that higher test and process temperatures are involved due to the higher melting temperatures and necessary higher soldering process temperatures of such solders in relation to the SnPb40 solder for which these tests originally are developed.
It is good practise to have the test temperature at a 10 - 15°C lower setting than the solder temperature used in the solder process. In this way a good process window is guaranteed.

Literature

Soldering in Electronics Second Edition R.J. Klein Wassink.

Note: The book Soldering in Electronics can be ordered via the web at http://www.elchempub.com