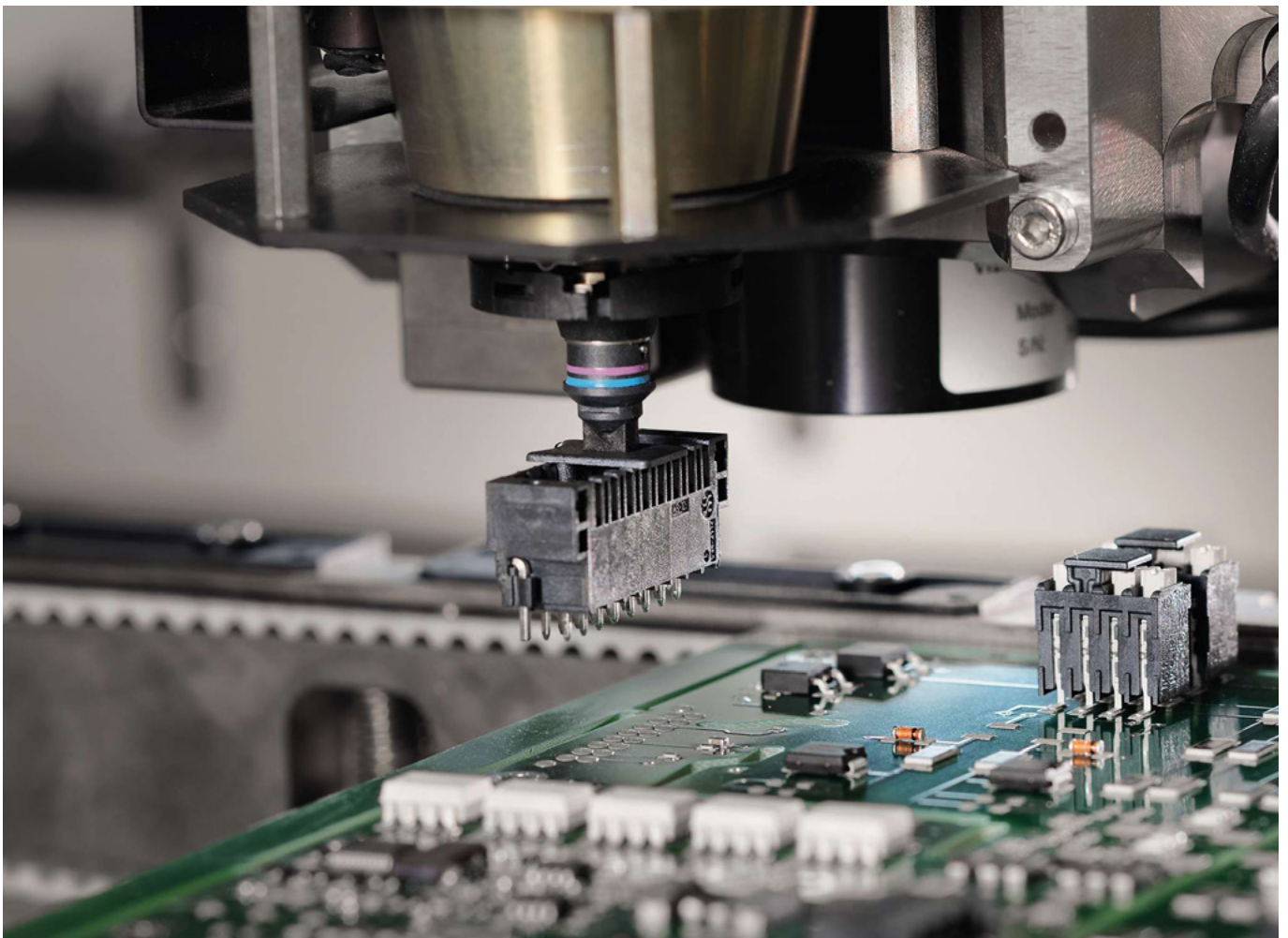


Surface Mount Technology

Integration of device connection technology in the SMT process

White Paper

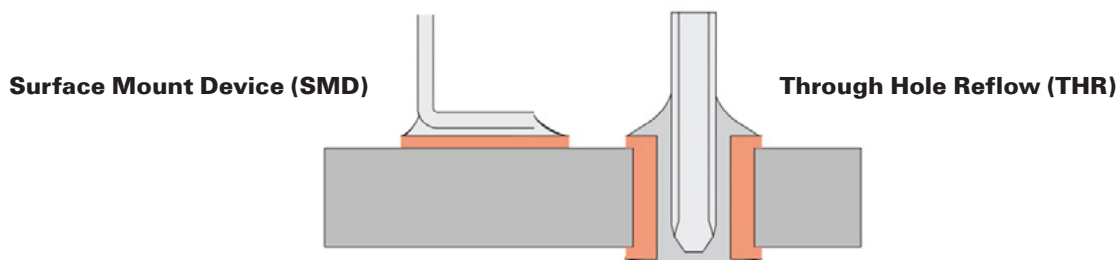


Surface Mount Technology

Integration of device connectivity in the SMT process

Today's PCB is a platform for electronic components, creating circuits whose complexity may vary from simple to highly sophisticated. Increasing requirements such as the miniaturisation of components, greater functional densities and lower production costs have resulted in the successive replacement of classic through hole technology (THT) by surface mount technology (SMT) in previous years. Today SMT is the method of choice – it has been widely adopted as the standard production technique for the surface mounting of electronic components.

The soldering technique used in the SMT process is reflow soldering, specifically infrared, convection or vapour phase soldering. In contrast to the wave soldering process, a solder deposit applied to the PCB is melted. The device connection technology can be integrated in the SMT process by the through hole reflow (THR) or the surface mount device (SMD) processes. These two processes can also be combined.

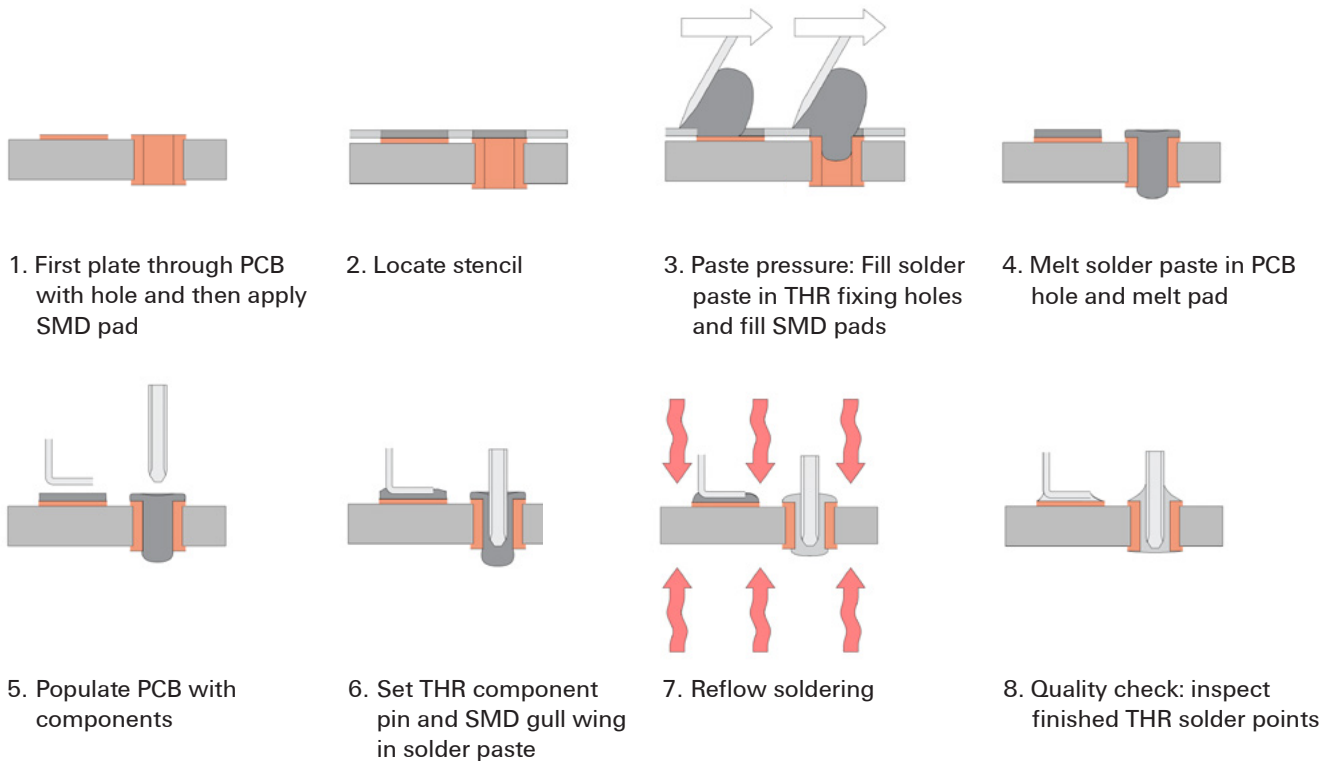


Process steps in surface mount technology

In surface mount technology (SMT), contacts are established via connections to the housing side or via the connection surfaces directly under the housing. Unhoused components can also be used which are then directly mounted on the PCB and contacts are established wire links or via the flip chip technique.

However, there are still some components, mainly electro-mechanical components like connectors or relays, which are not available in a SMD version; they are therefore mounted on the PCB after the actual SMT process itself by applying the classic THT process. Weidmüller has therefore developed a product range for the THR process that also makes wired device connection technique applicable in the SMT process, therefore supporting complete continuity in SMT production.

Surface mount technology includes the following process steps:



Through Hole Reflow (THR)

Through hole reflow (THR) refers to processing components, which are inserted through a hole in the PCB and then soldered with other SMT components. It should be noted that the components themselves must be able to withstand the higher temperatures of the SMT process.

THR is a milestone in PCB assembly – with the following characteristics: A mechanically stable solder connection is established to the PCB; all that is required a soldering process; manual / wave soldering can be dispensed with; the PCB is automatically populated - at low production costs.

Requirements on components for the THR soldering process

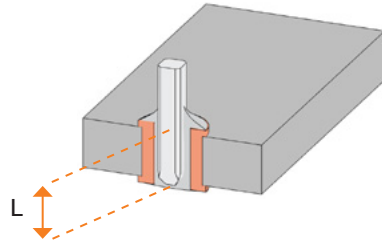
In the case of automatic assembly, mounting is via a vacuum pipette on the placement head: for this reason, the components must have a smooth suction surface. This may be a component surface or a separate pick-and-place pad, which that the components are securely fixed from pick-up to set-down. Finally, the component should have a low intrinsic weight.

With automatic sequential assembly or feed of the components, pick-and-place systems are used. The prerequisite is that the components are packed in a manner suitable for product-specific handling by robots, whereby a distinction is made between tape-on-reel, tray und tube.

The soldering process requires high temperature resistant materials, an optimised heat supply and enough space in the soldering area. As the insulating body of the wired component may not come into contact with the solder paste, a sufficiently large stand-off should exist, depending on part size.

Solder pin length for the THR process

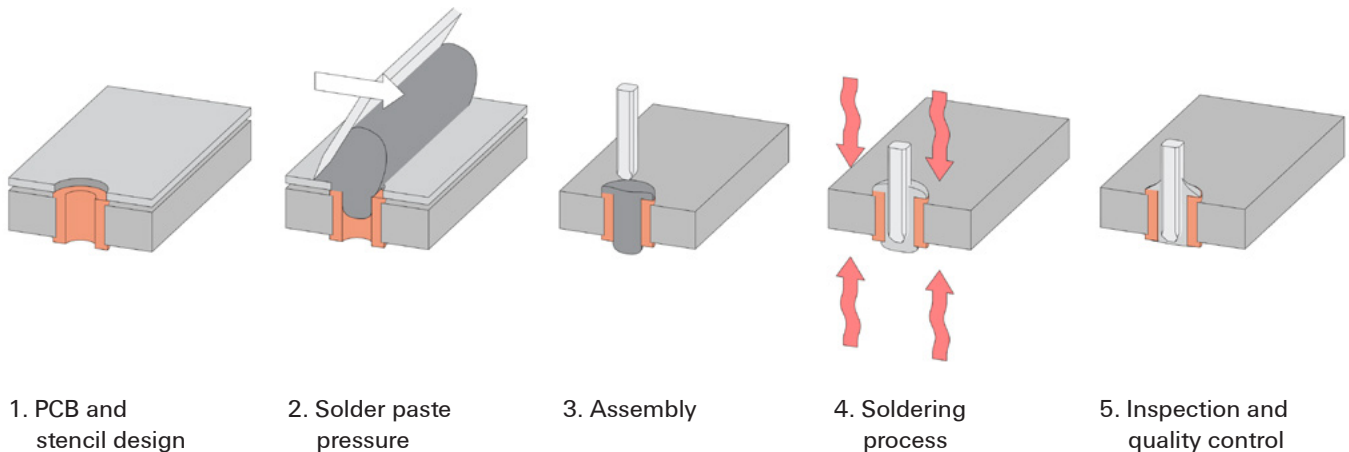
The pin length L (more precisely, the pin protrusion on the PCB bottom side facing the component) depends on the chosen soldering process.



Pin geometries of 3.2 mm and 3.5 mm length are suitable for wave soldering. Customised variable intermediate lengths of about 2.1 mm or 2.6 mm mean that parameters such as paste pressure can be flexibly adjusted.

A pin length that is shorter than the PCB thickness has proven an ideal for reflow soldering. For PCB thicknesses greater than 1.6 mm, Weidmüller therefore recommends a pin length of 1.5 mm - with optimum hole fill and optimal paste consumption (>> see also section "IPC-A-610-compliant: pin length 1.50 mm and 1.60 mm PCB thickness").

Design steps in the THR process



1. PCB and stencil design

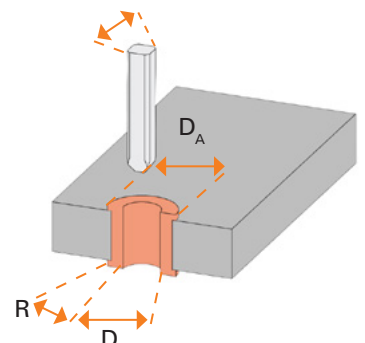
The first step in the SMT production process is design of the PCB. This first step is decisive for the future smooth running of the production process and thus the quality of PCB assembly. Compared to the classic SMD or through-hole technology, some special considerations should be taken into account in relation to THR components in PCB design:

For THR solder points - in comparison to the wave soldering - a slightly larger mounting hole diameter is recommended because the fusion of the paste requires sufficient space in the drilled hole.

The rule of thumb for placement hole diameters (D) is:

- a. for round or orthogonal soldering pins: $D = d + \min. 0.3 \text{ mm}$
- b. for rectangular solder pins: $D = d + \min. 0.25 \text{ mm}$

D = Inner diameter of solder eyelet
 D_A = Outer diameter of solder eyelet
 d = Solder pin diameter
 R = Residual ring width



So that the smallest possible volume of solder can be achieved, it is important to optimise the volume of the solder meniscus: the solder eyelet diameter is therefore minimised in comparison to what is the case with classic through-hole technology.

The recommended solder diameter for hole through solder points is calculated as follows:

$$D_A = D + 2 \cdot R$$

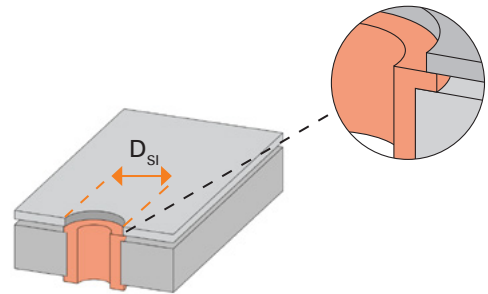
The residual ring width is normally $R = 0.3 \text{ mm}$. For THR components, such as plug-in connectors, a slight increase in the residual ring width to about 0.4 mm is recommended due to the resulting higher solder point stability and reparability.

After determining the solder eyelet diameter, the standard stencil layout is used for the hole design. The stencils usually have a thickness of $120 \mu\text{m}$ to $180 \mu\text{m}$. The stencil hole diameter in this case is about ten percent less than the solder eyelet diameter.

The rule of thumb for calculation is:

$$D_{SI} = D_A - 0.1 \text{ mm}$$

D_{SI} = Diameter of stencil hole
 D_A = Outer diameter of solder eyelet



2. Solder paste pressure

An essential step in the SMT manufacturing process is the preparation of the PCB, i.e. the application of solder paste to the holes and the solder pads. The quality achieved here largely determines that of all subsequent process steps. The solder quality depends on the paste volume and fill level of solder paste during paste application (paste pressure).

3. Assembly

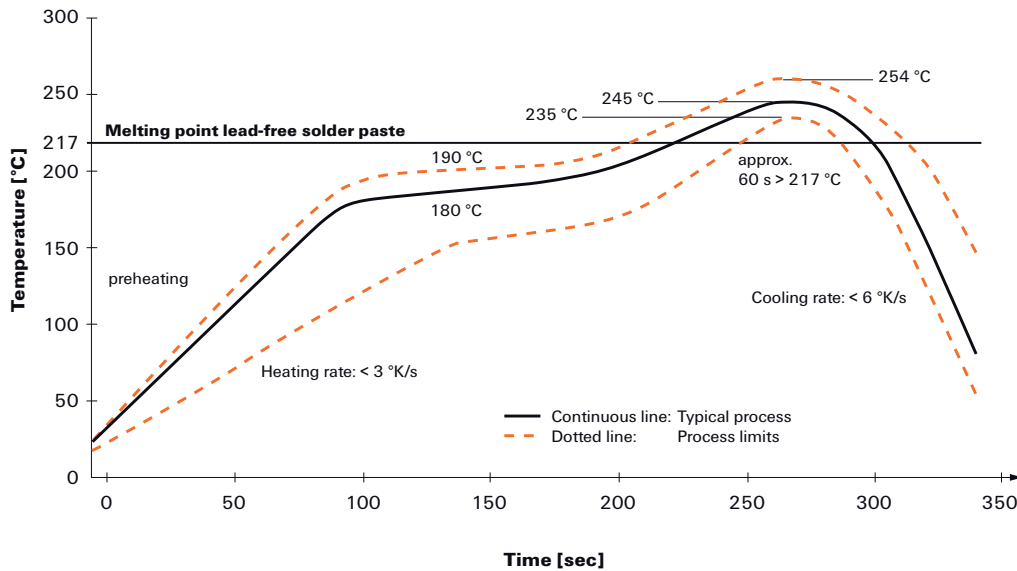
In the SMT process, automatic sequential assembly is preferably used. A component is picked up by a vacuum pipette from the component feeder and placed on the PCB in the pick-and-place station. In wired connection elements, such as connectors, the pick-and-place method with tape on reel or tray packaging has become the accepted standard.

4. Soldering process

No less essential in the SMT production process is reflow soldering: In this step, an existing solder deposit is melted, whereby around 50 percent of the paste volume vaporises. After the PCB is populated, a drop forms on the pin tip: it is melted in the reflow profile, flows by capillary action into the drill hole and forms the solder meniscus.



The soldering profile recommended by Weidmüller presents the typical progression and limitations of the process:

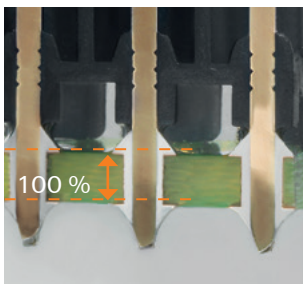


PCB and components are gently heated in the preheating phase. This "activates" the solder paste in parallel. During the period above the fusion temperature (217 °C to 221 °C), the solder is liquefied and connects the components to terminals on the board. The maximum temperature of 245 °C to 254 °C is maintained for approximately ten to 40 seconds. The solder hardens during the cooling phase. The PCB and components should not be allowed to cool too quickly, however, to prevent stress cracks in the solder.

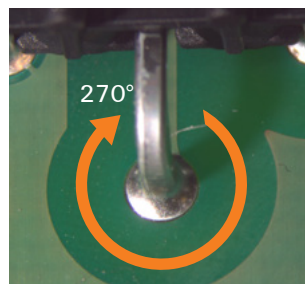
5. Inspection and quality control

The SMT production process is rounded off by inspection and quality control. The goal in this process step is, using appropriate techniques, to check the quality of the solder joints of the THR components with short or long pins quickly and easily. The quality control of THR soldering is based on assessment criteria according to the standard IPC-A-610, which are recognised worldwide. IPC-A-610 divides THR solder quality in three classes. The requirements of Class 3 are usually definitive for high power electronics in industrial applications. The following values apply for the total of five evaluation criteria:

- The vertical solder fillet (fill level) must be at least 75 percent.
- The circumferential wetting of the primary side (populated side of PCB from perspective of components), connection and sleeve may not be less than 270 degrees.
- The secondary side solder wetting coverage (i.e. the underside from viewpoint of the component) should not be less than 330°.
- The solder wetting of the original contact surface (residual ring with THR solder joints) on the primary side is set at 0 percent.
- The solder wetting of the original touchdown surface on the secondary side must be at least 75 percent.



Vertical solder fillet
(fill level)



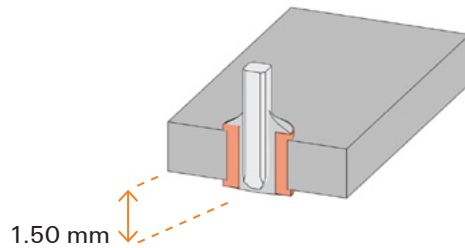
Primary side: Circumferential
wetting and solder wetting



Secondary side: Circumferential
wetting and solder wetting

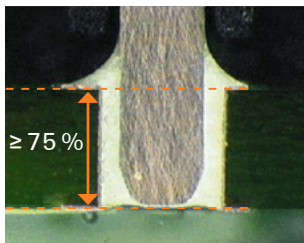
Optimised pin length for the SMT process of 1.50 mm

For the SMT process, pin lengths of 1.50 mm are preferable for several reasons. They meet the requirements of IPC-A-610 E and support double-sided population at PCB thicknesses ≥ 1.50 mm. They also simplify the paste printing process and reduce costs by minimising the paste volume. In addition, there is the advantage of process acceleration due to optimum temperature absorption and easy degassing of flux in the soldering process. Pin lengths of 1.50 mm at a PCB thickness ≥ 1.50 mm are also ideal for vapour phase soldering, because no droplets form on the underside of the circuit board..

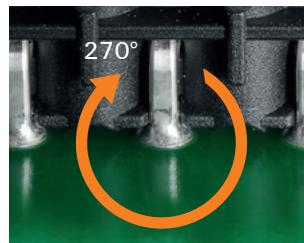


IPC-A-610-compliant: pin length 1.50 mm and PCB thickness 1.60 mm

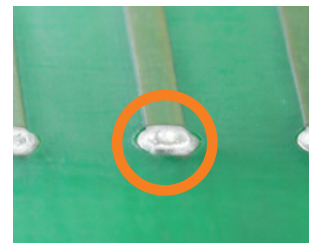
The requirements of IPC-A-610 E ideally realise the requirement of a pin length of 1.50 mm and a PCB thickness of 1.60 mm: The vertical solder fillet (fill level) at 1.60 mm PCB thickness and using Weidmüller components with pin lengths of 1.50 mm is at least 75 percent, provided that the processing recommendations are complied with. The peripheral wetting of the primary side, that is the underside from the perspective of the components is not less than 270 degrees. Weidmüller components with pin lengths of 1.50 mm are always shorter than the board thickness of 1.60 mm. According to IPC-A-610, the wire end may not be visible at the solder point, as the component should be flush with the board surface (see IPC-A-610 E, 7.3.3, Table 7-3, Note 1).



Vertical solder fillet
(fill level)



Primary side:
Circumferential wetting
and solder wetting



Secondary side:
Wire residual length

Surface Mount Device

In surface mount technology (SMT), the surface mounted devices (SMD's) are soldered to the PCB with solder pads. The use of SMD components means that it is possible to dispense with wire connections on the components and mounting holes in the PCB.

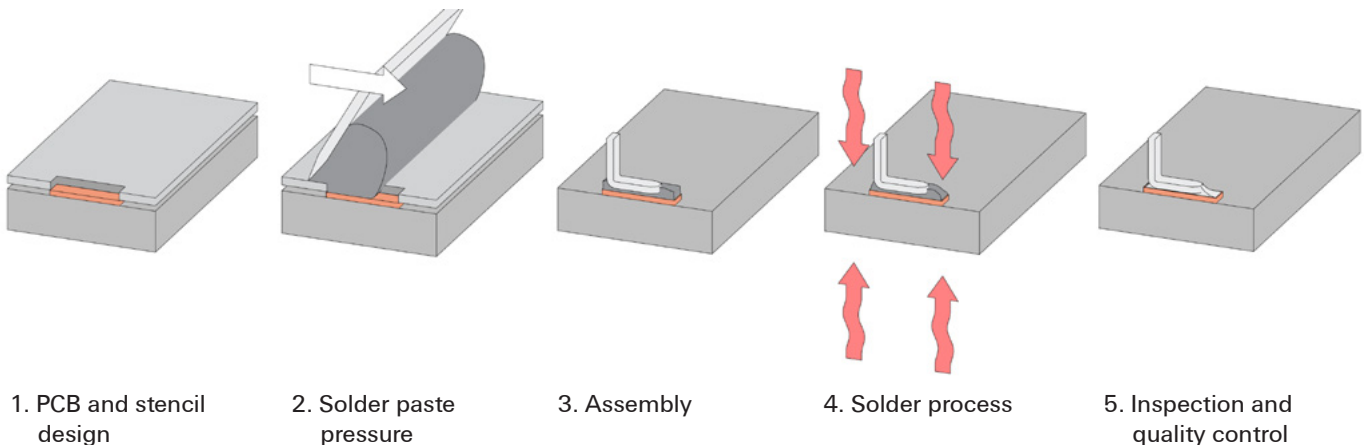
SMD offers with clear advantages: firstly, it enables a high packing density and integration of miniaturised components. Secondly, PCB's can be assembled as desired on one or both sides. Thirdly, quality can be significantly improved by automated population and inspection. Fourthly, full automated handling reduces manufacturing costs. And fifthly, the small components and the absence of holes and connecting wires decreases the weight of components.

Requirements on components for the SMD process

Even in the SMD process, the pick-up of components for automatic assembly of the PCB is performed by the placement head. The components must have a smooth suction surface, be suitable for the application of pads and should have a low intrinsic component weight. In the automatic sequential assembly, pick-and-place systems are also used (in this case tape-on-reel and tube). The soldering process also requires highly temperature resistant materials, an optimised heat supply and enough space in the soldering area.

Coplanarity: to ensure reliable soldering quality in the manufacturing process, the contact surfaces of solder pins must be wetted with the solder paste immediately after assembly. This allows the flux contained within the paste to react with the Sn coating, resulting in a reliable solder quality. As per IEC 61760-1 coplanarity is between 0.10 mm to 0.15 mm.

Design steps in the SMD process

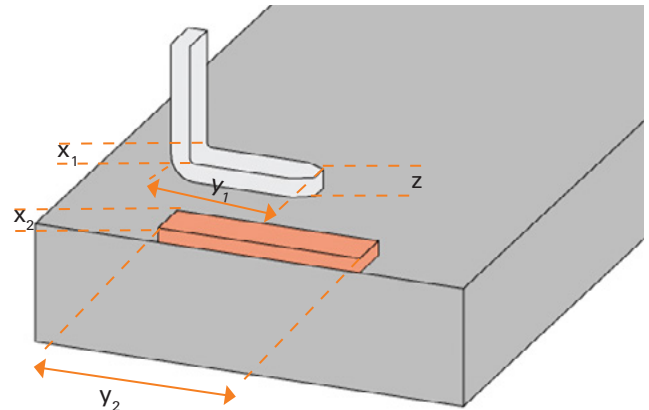


1. PCB and stencil design

The first step in the SMD manufacturing process is the design of the PCB, which represents the fundamental process and quality-determining aspect of PCB assembly process. In SMD soldering, the dimensions of the SMD pads should be determined according to the method used. Optimum results depend on tolerances and process sequences. For components such as (larger) connection elements or plug-in connectors, a slight increase in pad area is recommended as this results in increased solder point stability.

The following rule of thumb applies:

- a. $x_2 = x_1 + (0.2 \text{ mm bis } 0.4 \text{ mm})$ oder $x_2 = x_1 + 2 \cdot z$
- b. $y_2 = y_1 + (0.2 \text{ mm bis } 0.4 \text{ mm})$ oder $y_2 = y_1 + 2 \cdot z$

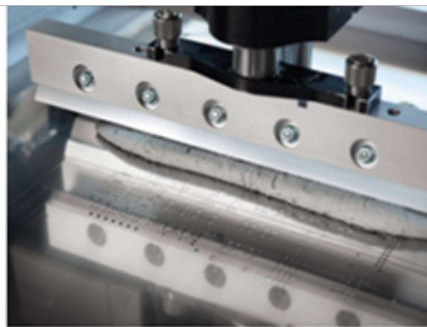


2. Solder paste pressure

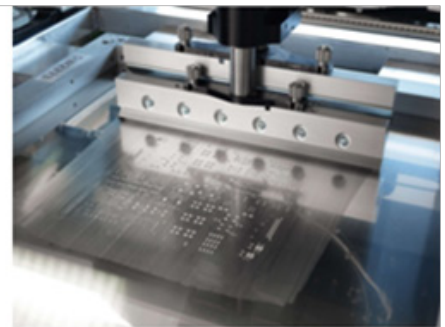
Another critical step in the SMD process is the preparation of the PCB, i.e. the application of solder paste to the drilled holes and solder pads. Their quality determines the quality of all other process steps. The solder result depends on the paste volume and on the fill level of the solder paste during paste application (paste pressure).



The PCB is transported to the paste pressure station and measured



The stencil is applied, the scraper pushes the paste and in the process squeezes it into the stencil drill hole



The completed printed PCB is transported to the optical checking station

3. Assembly

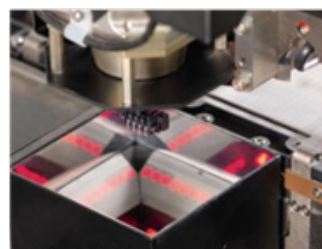
The SMD process is also based on automatic sequential assembly. In relation to connecting elements such as connectors, the pick-and-place method has prevailed with Tape-on-Reel or tray packaging has become the accepted standard.



Component feed with tape-on-reel



Removal of the component by means of vacuum pipette from the belt ("picking")



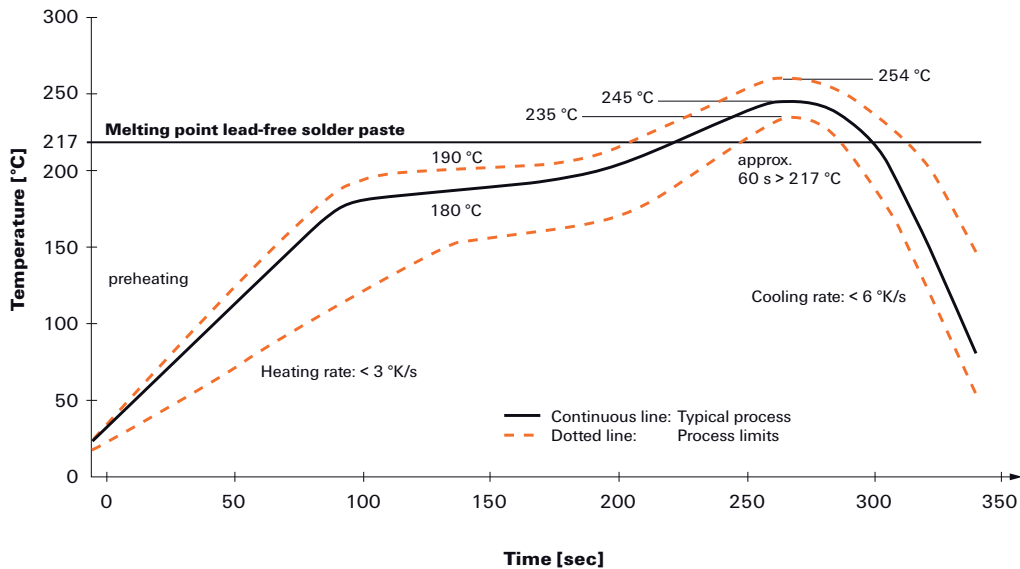
The component is measured



Place the component on the PCB

4. Soldering process

The soldering profile recommended by Weidmüller describes the characteristic curve and the limits in process:



Circuit board and components are pre-heated gently in the preheating phase. The solder paste is "activated" in parallel to the above. Above the melting temperature of 217 °C to 221 °C, the solder liquefies and joins the components to the connectors on the board. The maximum temperature of 245 °C to 254 °C is maintained for approximately ten to 40 seconds. The solder hardens during the cooling phase. To avoid stress cracking, PCB and components should not be allowed to cool too quickly.

5. Inspection and quality control

The SMD process is rounded off by inspection and quality control. Here, too, the quality control assessment criteria according to standard IPC-A-610 apply. The following applies for the total of five evaluation criteria:

1. The max. projection (A) is not greater than 25 percent of the terminal width (W).
2. If the foot length (L) is greater than three connection widths (W), then the min. length of the solder joint on the side (D) is equal to or greater than three connection widths (W).
3. The min. width at the end of the solder joint (C) is 50 percent of the terminal width (W).
4. Maximum height of the solder joint at the heel (E): The solder touches the body of a plastic component (except SOIC and SOTs).
5. The min. height of the solder joint at the heel (F) is equal to the solder gap thickness (G) plus the terminal thickness (T) in solder point area.

OMNIMATE® PCB components

As a leading supplier and pioneer of device connectivity, Weidmüller offers the widest existing range of products for the SMT process. Connection components in THR and SMD versions support high efficiency in device manufacturing in the electronics sector. As Weidmüller terminal elements can be processed fully automatically and in a single manufacturing process with the component assembly, this effectively reduces the manufacturing cost. In addition, Weidmüller offers assistance throughout the design-in process. The offer thus ranges from products through in-depth application expertise to proven solutions expertise.

For secure board mounting by means of THR technology, Weidmüller offers rigid pin strips of glass fibre-reinforced LCP (Liquid Crystal Polymer):

Optimum pin length

The pin length of 1.50 mm enables space-saving, double-sided population of the PCB. At the same time, Weidmüller components meet all requirements of IPC-A-610 E.

Robust insulating body

Thanks to MSL 1 (moisture sensitivity level 1), users can mount Weidmüller THR components directly onto the PCB without pre-drying. The durable material ensures dimensional stability and perfect grid alignment.

High precision pin connectors

With a position tolerance of less than 0.1 mm +/- around the zero position, Weidmüller solder pins fulfil the standard IEC 61760-3 and thanks to the latest production techniques, they always remain dimensionally stable.

Stable position with solder flange pin

Weidmüller solder flanges make additional fixation with screws redundant. Users can fix the THR components securely to the circuit board in only one operation.

Sophisticated technology

Weidmüller SL-SMaRT units have a modular design and can thus be flexibly combined. This reduces the number of components, the effort spent on data administration and the storage requirements.

With OMNIMATE components for fully automated SMD assembly, populating PCB's with components becomes extremely efficient and quality assured:

Stable solder connection

Featuring two soldering pads per pole, LSF-SMD PCB terminals satisfy the most stringent mechanical fixing requirements without the need for additional mounting flanges.

Reliable processing

By using the LCP assembly, the SMD process can be executed without pre-drying. The low expansion coefficient prevents bending of assemblies.

Efficient assembly

High component precision and low weight support the assembly process. In addition, a high number of components per roll increases efficiency.

Further information on OMNIMATE product range, on the relevant services (such as. creation of patterns within 72 hours) and an application-oriented product selection guide is available online at:

www.weidmueller.com/OMNIMATE

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