

Surface Mounting

Application Note

Introduction

What is Surface Mounting?

In conventional board assembly technology the component leads are inserted into holes through the PC board and connected to the solder pads by wave soldering on the reverse side (through-hole assembly). In hybrid circuits (thick and thin film circuits) “chips”, i.e. leadless components, are reflow soldered (see paragraph 7.2) onto the ceramic or glass substrate in addition to the components already integrated on the substrate. Surface mounting evolved from these two techniques (Figure 1).

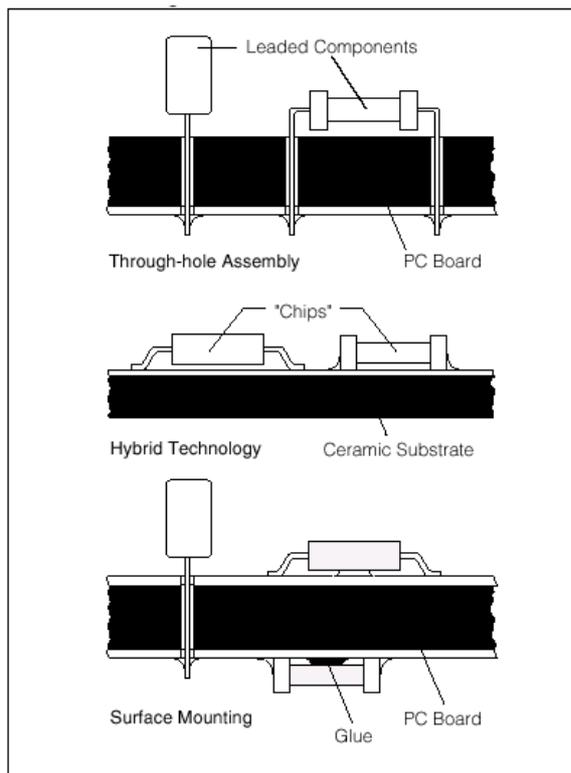


Figure 1. Through-hole assembly - hybrid technology - surface mounting

In through-hole technology the components are placed on one PCB side (component side) and soldered on the other (solder side) (Figure 1, top), whereas in surface mount technology the components can be assembled on both sides of the board (Figure 1, bottom). The components are attached to the PCB by solder paste or non-conductive glue and then soldered.

In the near future mixed assemblies, i.e. a combination of leaded and surface mounted components, will prevail, since not yet all component types are available as surface mount version.

Automatic assembly machines are a must for an expedient production; there are systems for simultaneous and for sequential assembly.

The following explanations point out what is new in surface mounting:

- Up to now connecting materials with large differences in the thermal coefficient of expansion, such as plastic boards and ceramic components, by rigid soldering has been regarded as a serious problem. Practice has shown, however, that this is feasible owing to the elasticity of board and solder; of course, component size and thermal stress are subject to certain restrictions (see section “Restriction and special features of SMD”).
- Components for surface mounting have to withstand high thermal stress during the soldering procedure. Not all component types meet these requirements; therefore new components suitable for surface mounting are constantly developed (see section “Restriction and special features of SMD”).
- In some cases the components are non-conductively glued to the PCB before soldering.

- As compared to through-hole technology there is a closer interrelation between the individual steps in design and production.
- Automatic assembly gains prior importance.

What are SMDs ?

The abbreviation SMD* for Surface Mounted Device is the most common designation for those components. SMDs are designed with soldering leads or short leads and are much smaller than comparable leaded components. In contrast to conventional components, the leads of which must be inserted into holes, SMDs are directly attached to the surface of the PCB and then soldered. In Figure 2 and the section below the various SMD types are summarized. Surface mountable components include "chips"*** with cubic dimensions, cylindrical SMDs, plastic packages with solder pins (SOT, SO, VSO package), chip carrier packages, miniature IC packages (Quad Flat Pack, Flat Pack), TAB components and special SMDs such as inductors, trimmers, quartz crystals, switches, plugs, relays, etc.

* Other terms used: SMC (Surface Mounted Component), SMT (Surface Mount Technology), SMA (Surface Mount Assembly).

*** "Chip" should only be used when confusion with semiconductor chip as used in semiconductor technology can be excluded.

SMD Types:

- Cubic components ("chips") - Preference types 0805, 1206, 1210, 1812, 2220, etc.
- Cylindrical components - MELF¹, MINIMELF, MIKROMELF, TUBULAR (e.g. tubular capacitors), SOD 80 (MELF-similar diodes)
- SOT 23, 143, 89, 192
- SO² 4 to 28 pins (SOIC)
- VSO³ 40 pins

- CHIP CARRIER - Plastic case (PLCC⁴), Ceramic case (LCCC⁵)
- ICs with gullwing leads - Flat Pack, Quad Flat Pack
- Ball Grid Array, Chip size package
- Special packages for: Inductors, SAWs⁶, trimmers, quartz crystals, switches, plugs, relays, etc.

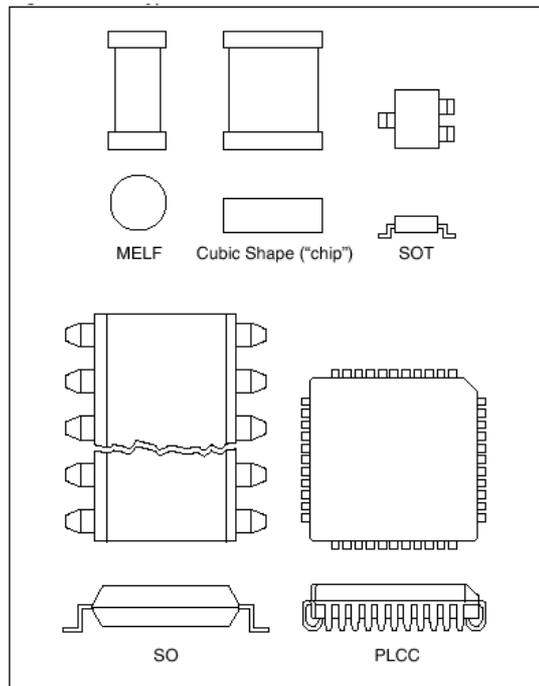


Figure 2. SMD types

Most of these components are suitable for dip soldering; chip carriers, TAB (MIKRO-PACK) and some special versions require other soldering methods.

¹ Metal Electrode Face Bonding

² Small Outline

³ Very Small Outline

⁴ Plastic Leaded Chip Carrier

⁵ Leadless Ceramic Chip Carrier

⁶ Surface Acoustic Wave Filter

Resistors, ceramic capacitors and discrete semiconductors represent at 80% the largest part of the SMD spectrum. In the range of SMDs the cubic shape prevails over cylindrical versions, as the latter can only have two pins thus being exclusively suitable for resistors, capacitors and diodes.

If development of a special SMD package is not advisable for electric or economic reasons, the DIP package can be converted into a surface mountable version by bending the leads.

An important factor for automatic assembly is the components' adequate and uniform geometry. Some packages are already standardized (IEC) or are proposed for standardization (JEDEC Recommendation).

The spectrum of active and passive components available covers ICs, transistors, diodes, ceramic multilayer capacitors, NTC thermistors, as well as SIFERRIT miniature ferrites, and the product menu is growing larger almost daily.

For more than ten years OSRAM Opto Semiconductors has offered its customers optoelectronic SMDs and thus has gained considerable experience in the field of SMD production through continual modernization and development.

Advantages of Surface Mounting

The three major benefits of surface mounting

- rationalization
- miniaturization
- reliability

are discussed in the following.

A consistent concept as regards components, board layout, assembly machines, processing and testing is essential for an efficient application of surface mount technology; in other words, the aim should be an optimized overall concept. The component price, for example, should not be seen isolated, but with regard to the total cost in-

cluding placement, soldering and testing which may already be considerably lower than with conventional board assembly technology. In the following the advantages of surface mounting are analyzed as to component, PC board, automatic assembly, reliability and rework.

Components

- SMDs are much smaller than leaded components, thus enabling smaller board size, higher packing density, reduced storage space and finally smaller equipment to be obtained.
- Light weight makes them ideal for mobile appliances.
- No leads means high resistance to shock and vibration.
- Cutting and bending of leads are eliminated.
- Parasitic inductance and capacitance due to leads are substantially lowered making SMDs particularly suitable for RF applications.
- Automatic assembly machines ensure accurate placement.
- MIKROPACKs, PLCCs and similar packages permit a considerably higher number of pins.
- Closer capacitance tolerances can easily be obtained for capacitors with low capacitance values.
- The growing demand for SMDs results in lower production costs, so that further cost reductions can be anticipated.

Printed Circuit Board

- Surface mount technology makes PC boards smaller. When using SMDs on both sides of the board, size can be reduced by more than 50 per cent. On the other hand, maintaining the PCB size implies reduced packing density and thus higheryields and higher reliability.
- In many cases the printed circuits can be shrunk and reduced in number. Owing to the compact "leadless" construction the electrical characteristics can easily be reproduced,

- thus cutting the cost for adjusting RF circuits.
- Surface mount technology does not require a special PCB material; standard materials such as FR4, FR2, CEM1 are quite suitable, but of course, special materials, e.g. for RF circuits, can be used, too. For normal packing density the printed circuit precision should meet current requirements.
- The elimination of through-holes entails a further cost reduction. This is quite an important factor, as the cost for the drilling of holes can amount up to 10% of the total PCB cost.
- Mixed assembly with leaded components is possible. The reason for using this assembly variation was explained in the beginning.

Assembly

The average cost per component for automatic assembly can be considerably cut by surface mounting, because the smaller number of assembly machines entails less capital investment, maintenance, servicing and factory space.

- A major advantage of surface mounting are the high component placement rates attained by automatic placers. Fast machines can place several ten thousand components on the PCBs per hour.
- Automatic placement systems for SMDs feature high placement reliability. Failure rates of less than or equal to 20 ppm (parts per million) can be obtained by machines capable of identity checking and defective recognition. This means that out of a million placed components only max. 20 are not at all or incorrectly assembled.
- In mixed assembly any ratio of SMDs and leaded components is possible, thus facilitating transition to SMD technology.
- Some automatic placement systems can handle a wide range of different components.

At present three assembly machines are usually required for leaded components:

- Insertion machine for radial-leaded components
- Insertion machine for axial-leaded components
- Insertion machine for DIPs.

Reliability

The demands on quality and reliability of PCB assemblies increase steadily. In this respect SMDs have at least to meet the standard set by conventional through-hole technology.

Following general statements can be made:

- The failure rate of SMDs does not exceed that of leaded components. Omission of leads means one point of contact less. Owing to their small size and light weight SMD assemblies feature a higher resistance to mechanical stress (vibration, shock) than the corresponding assemblies with leaded components.
- A quality approval for SMDs used in hybrid circuits can be usually applied to surface mounting, as well.
- High requirements are placed on the solderability of SMDs. The specifications for wetting, leaching and storage have to be observed (see section "Soldering Techniques").
- In many cases the soldering methods are the same as with other mounting methods. The known advantages and disadvantages apply to surface mount technology as well. One should bear in mind, however, that the criteria for judging solder joints are different for wave soldering and reflow soldering (see section "Soldering Techniques"). For example, the filling of through-holes with solder is only possible with the wave soldering method, with reflow soldering the amount of solder is too small.

- If components have to be replaced because of incorrect assembly, reliability of the board—although correctly assembled then—is diminished. Hence, automatic placement systems with their high degree of placement reliability enhance board reliability.

Rework

Elimination of component preparation, high placement reliability provided by automated systems, and careful planning of each step of the design and production process considerably reduce expensive rework of PCB assemblies with SMDs.

Restrictions and Special Features of Surface Mounting

Maximum packing density—one of the primary goals in surface mount technology—requires the use of miniature components, i.e. certain IC packages (e.g. VSO or MIKRO-PACK). This involves problems, not necessarily resulting from surface mount technology as such, but from miniaturization in general.

- The use of high-pin-count ICs may require new PCB design (fine etching and super-fine etching) and an increased number of layers (multilayer) because the space between the IC pins is too narrow for printed circuits.
- Due regard must be paid to heat dissipation. The high packing density may cause thermal problems. Special PCBs with good thermal conductivity can aid heat removal, if necessary.
- Using ceramic components is restricted. Due to the different thermal expansion coefficient of ceramic and PCB material, ceramic SMDs with edges longer than 6 mm should not be used on phenolic resin laminated paper and epoxy glass fiber boards.

- Not all SMDs are suitable for dip or wave soldering. This has to be considered when designing a PC board.
- Some components are not yet available as SMD version. Not all SMDs available are standardized.
- High voltages naturally require certain minimum spacings.
- Visual inspection of solder joints becomes difficult if the leads are partially beneath the component body. Therefore, soldering methods should be optimized so that visual inspection will become unnecessary.
- Test methods have to be adjusted to SMD assemblies. Development of new adapters may be required.
- Repair of SMD assemblies may be more costly as compared with conventional PCB assemblies.

Fixing SMDs by Glue

New in surface mounting is the gluing procedure required for fixing the components when the PC board is to be turned upside down for soldering. The glue has to meet numerous requirements. It must provide reliable fixing of the components (also of heavy ones) on all kinds of PC boards. Furthermore, it should feature uniform viscosity to ensure easy handling; a pot life of at least several days is advisable. The glue should feature short curing time at low temperature. After curing the glue must not show chemical reactions in order not to impair board or components. On the one hand the adhesive is required to withstand high thermal stress, and on the other hand it must permit removal of SMDs from the assembled board in case of repair. For repairs the component body is heated, so that the adhesive becomes soft and allows the component to be removed without damaging the printed circuit below it. The glue has to be non-toxic, as odorless as possible, and free of sol-

vents. Besides, it should feature good heat conductivity. Development of new adhesives is under way.

The component outline should be such that the adhesive can easily be applied, i.e. the distance between component body and board must be closely tolerated (Figure 3).

There are three methods of dispensing the glue:

- by applicator
- by pin transfer
- by screen printing.

Not all adhesives are equally suitable for all methods.

Component and glue dot have to be shaped such that the component is reliably wetted while the contact area remains free of glue.

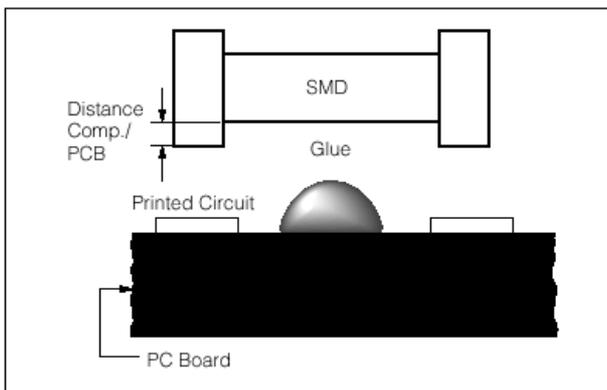


Figure 3: Form of the glue dot and component outline

Soldering Techniques

An appropriate soldering method is particularly important for obtaining good electrical contact and inhibiting short circuits. The choice of the soldering procedure depends on the PCB design (single or double-sided, multilayer, etc.), the components supplied, and the production facilities. While many SMDs are suitable for all soldering methods,

the soldering technique for ICs, for example, has to be chosen very carefully. Besides manual soldering, which should only be used for repair purposes, there are several automated soldering methods such as bath soldering (wave and dip soldering) and reflow soldering.

With bath soldering the solder is applied during the soldering process itself, whereas with reflow soldering the solder is applied before. For this reason the preconditions for bath soldering, e.g. component orientation and configuration are quite different from those for reflow soldering. The reflow method is particularly advisable for soldering certain ICs.

Wave Soldering

With wave soldering, a heated solder bath is used. The solder bath temperature lies between 240 and 260°C and the dwell time is 1 to 3 seconds. Before soldering the flux is applied.

High packing density on the PCB side to be wave soldered involves the problem of solder bridges and shadows (not completely wetted leads and pads). Therefore, PCB layout, i.e. component configuration, should match the soldering method used.

Dual-wave soldering best meets requirements of surface mounting. The first turbulent wave sends up a jet of solder to ensure good wetting of all metallization areas, while the second more laminar wave removes the excess solder (solder accumulations and bridges).

Reflow Soldering

In reflow soldering a specific amount of solder, in the form of solder paste, is applied to the PCB. Reflow soldering is the preferred process for soldering SMD components. After attaching the SMDs the

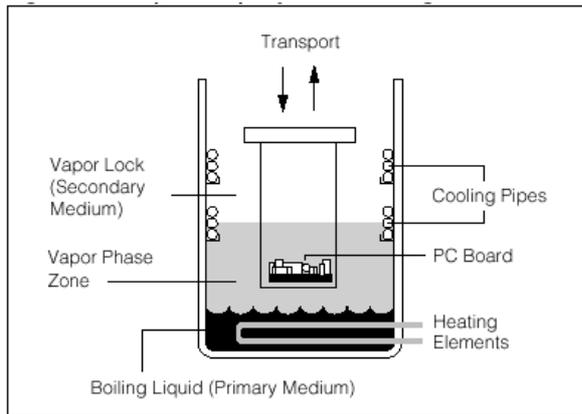


Figure 4. Principle of vapor phase soldering

reflow process is performed by one of the following methods:

- infrared soldering
- hot gas soldering
- heat collet soldering
- vapor phase soldering

The latest reflow technique is vapor phase soldering, where the entire PC board is uniformly heated until a defined temperature is reached; there is no possibility of overheating. The defined temperature (e.g. 210C) in a saturated vapor zone is obtained by heating an inert (neutral) fluid to the boiling point. A vapor lock above this primary vapor zone prevents the expensive primary medium from escaping (Figure 4).

Other methods are hot gas and infrared soldering in continuous- type furnace. Hot gas and infrared soldering have become the most common reflow soldering methods.

For heat collet or pulse soldering a collet or a soldering iron is used to transfer the heat to the component leads. It is important to force the leads into reliable contact with the solder pads before and during the soldering process. This method is preferably used for Flat Pack packages.

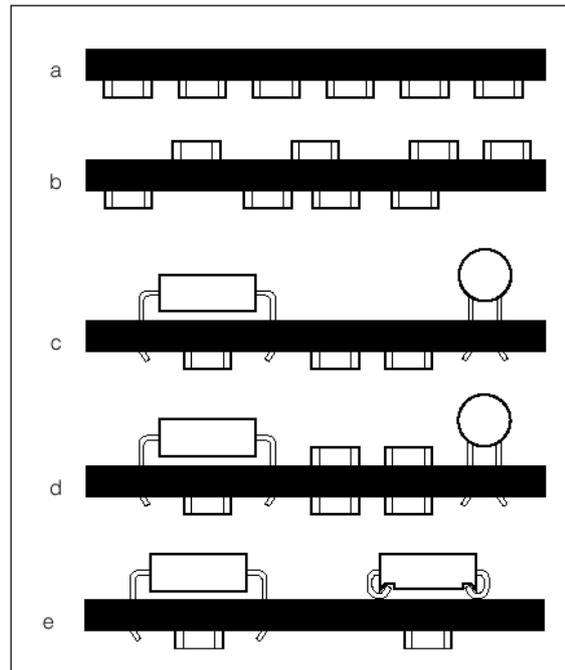


Figure 5 Variations of PCB assemblies

Iron Soldering

Manual soldering with temperature-controlled miniature iron should only be used in exceptional cases (repair, etc.), because this method is not only uneconomic, but can also damage components or PC board.

Fluxes, Cleaning Agents

Wave soldering requires no other fluxes than those used for conventional techniques (e.g. collophony F-SW32 per DIN 8511).

Most of the solder pastes required for reflow soldering, however, contain aggressive fluxes the residues of which must be removed by a cleaning process.

Conductive Adhesion

Conductive adhesion is not a soldering process, but shall be described here for the sake of completeness. It is not very often used since most conventional PC boards with a surface of tin or solder tin are not suitable for gluing. If components or PC board permit gluing, silver filled mixed epoxy

resin adhesives can be recommended. These can be spread by an applicator, screen printing, or by pin transfer.

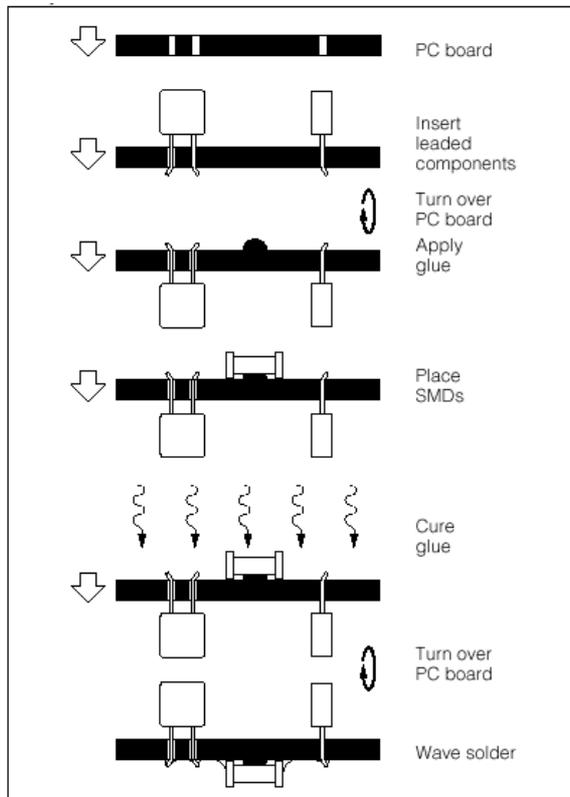


Figure 6. Mixed assembly of SMDs and leaded components (variant 1)

The times required for curing are between 1 min and 12 h depending on the temperature. The thermal stress imposed on the components is less than with soldering, but the adhesion process must be performed separately after soldering the other components.

Assembly Variations

Figure 5 shows the PCB assembly variations possible with SMDs: Assemblies exclusively with SMDs in the top row (Figure 5a and 5b), mixed assemblies, i.e. SMDs combined with leaded components in the middle (Figure 5c and 5d), and mixed assembly consisting of dip solderable components (on solder side) and non-dip-solderable components (on

component side) in the last row (Figure 5e). The versions illustrated in Figures 5b, d, e require double-sided PC boards.

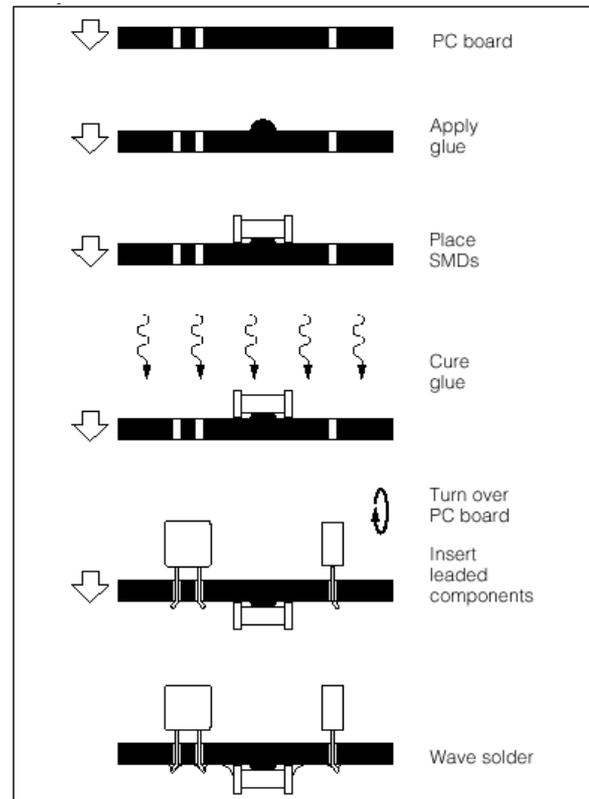


Figure 7. Mixed assembly of SMDs and leaded components (variant 2)

In mixed assemblies with SMDs and leaded components (Figure 5c and 6) the leaded components are usually placed first, then the board is turned over and the glue applied. Subsequently the SMDs are placed, the glue is cured and after a renewed turn over the board is wave soldered.

The second variant shown in Figure 7 differs from the first in so far as the glue is applied by screen printing at first; the following production steps are executed as illustrated in Figure 7. This procedure has the advantage that the glue can be applied by screen printing, however, it has to be taken into account that because of the already mounted SMDs vacant board space is required for the mounting tools of the insertion

machines, which are needed for cutting and bending the leads of conventional components.

The procedure for double-sided SMD mounting is as follows:

- Screen printing of solder paste
- SMD placement
- Reflow soldering
- Insertion of leaded components
- PCB turn over
- Application of glue
- Placement of SMDs on the reverse side
- Curing of the glue

- PCB turn over
- Mounting of components requiring special handling
- Fluxing, wave soldering

Here both reflow and wave soldering are used. Assemblies including leaded components always require wave soldering.

The aim is a uniform mounting procedure with the exclusive use of SMDs. Figure 8 shows examples for totally surface mounted assemblies with reflow soldering (top) and wave soldering (bottom).

Figure 9 is a flow chart for the various assembly and exclusive use of SMDs.

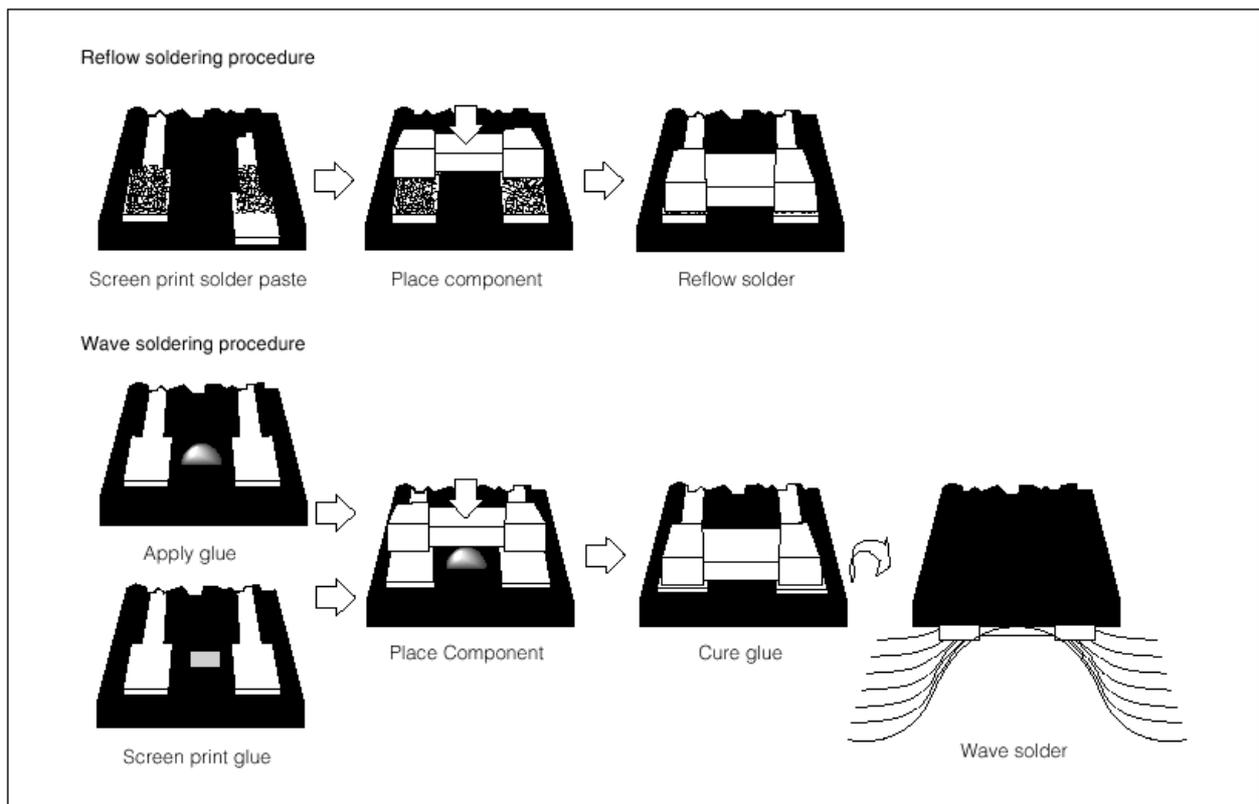


Figure 8. - PC board exclusively with SMDs, reflow soldered or wave soldered

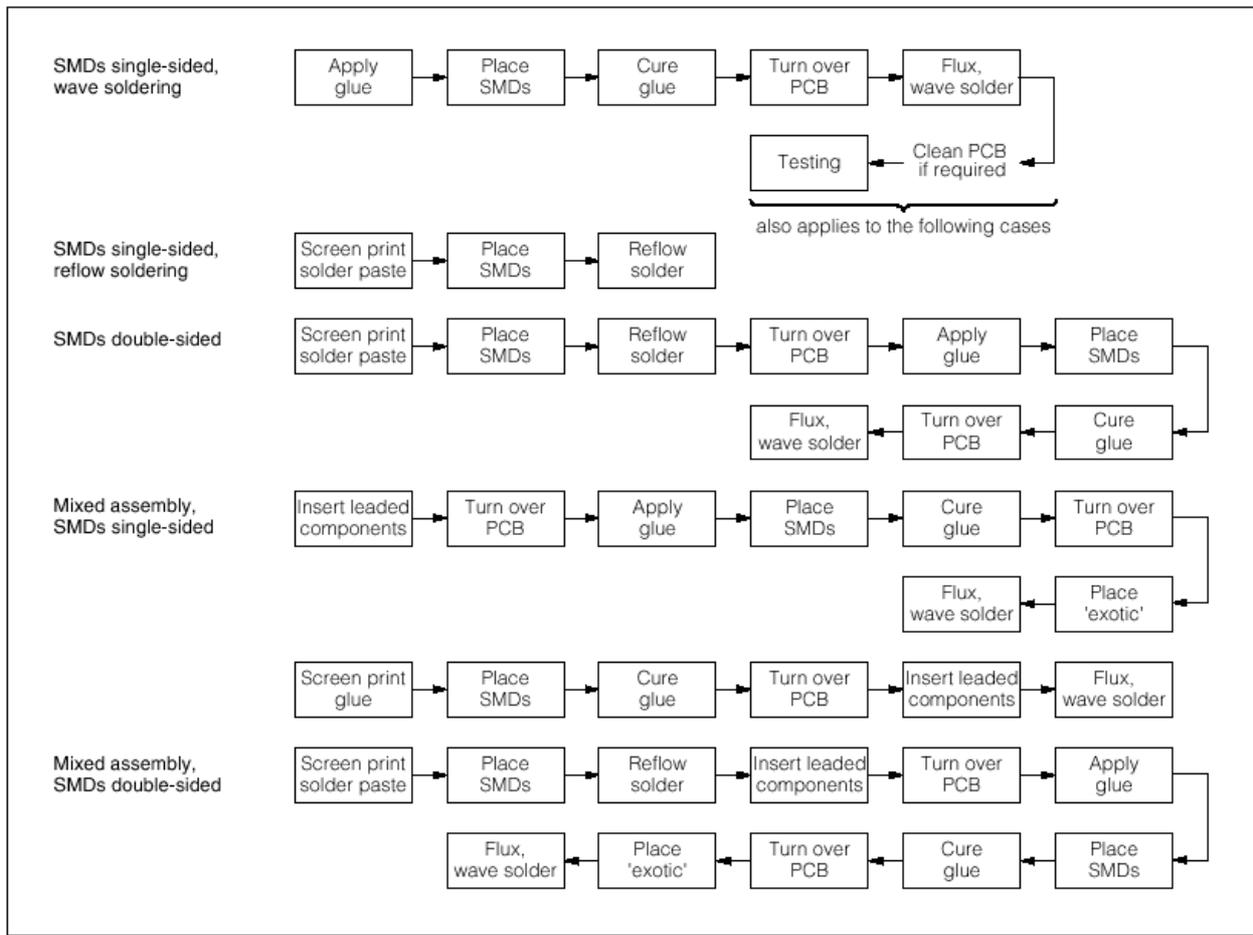


Figure 9. Possible assembly procedures for SMDs and leaded components

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