Surface Mount: From Design to Delivery

National Semiconductor
Application Note 467
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Many of us have probably seen, read, or heard a vast amount of information on surface mounting. Some have enough awareness with the technology to decide if surface mount meets their requirements. Yet why are the vast majority of companies (especially U.S. based) still not employing this new, inexpensive assembly technique?

Perhaps the following questions are of concern with respect to surface mount technology.

1) As a systems house, what are the costs of getting into a surface mount program?
2) What are the device outline standards? Why do some support JEDEC while others have diverged?
3) Which equipment vendors are supporting surface mount applications?
4) How quickly are users really converting to surface mount technology?
5) How does one begin to design using surface mount devices?

These are just a few of the many questions associated with the emerging processing. Before examining any of these in greater detail, let us review the basics behind the surface mount assembly process.

S.M.D. BACKGROUND

The benefits of surface mounting need little laboring: assembly speed; lower weight, smaller size; lower equipment cost; improvements in reliability, vibration performance and frequency response. But one underlying reason remains for manufacturers to gain experience in surface mounting: They may have no choice in a few years.

High volume growth areas like portable computers, consumer, and communications equipment will demand the cost savings and performance advantages of surface mounting. As large manufacturers convert to this new technology, these components (which presently cost slightly more than others) will drop below today's price for conventional components. In fact, conventional components will be at a premium.

As surface mount I.C.'s become more readily available over the next few years, they will overcome the DIP in actual usage. By this time the newest semiconductor technologies will be made only for using surface mount. In fact, some integrated circuits developed today are already available only in surface mount packages. A change to surface mounting is inevitable.

SURFACE MOUNT MEANS CHANGE

The changeover to surface mounting cannot be approached as an extension or a straight replacement for conventional assembly. The design and manufacturing processes are basically different. The surface mount solder joint functions as both a mechanical and electrical connection to the circuit board. Placement during manufacturing can be relative. By comparison, the insertion method is absolute: either the leads fit in the hole or they don't.

Surface mount pushes for cooperation between the designer and the production engineers. Testing is more difficult with surface mounting. The position of test pads must be carefully selected during system design. If that is not done, then it may be impossible to test and find faults in the circuit. The real challenge for design engineers is to accept the variety of surface mount methods and packages.

CHANGE IN TECHNOLOGY

Among the changes that surface mount brings is soldering technology *(Figure 1).* The traditional process uses the old wave solder machine with its various improvements throughout the many years.

Switch From Solder to Solder Paste
Change in Shape and Formation of Solder Joints
Must Become Familiar With Reo Metallization Technology

FIGURE 1. Surface Mount Technology Changes

Boards are moved over a flowing wave of hot, molten solder with the bottom side the recipient of transferred solder. Using this method with surface mount components can cause many problems, specifically with I.C. packages. Shadowing

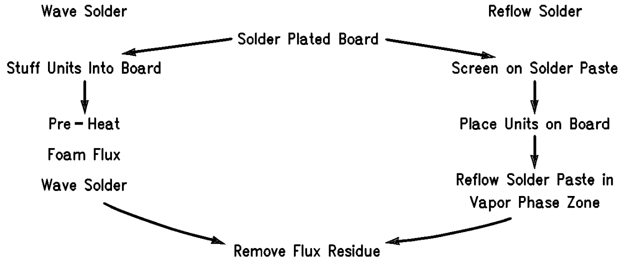

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FIGURE 2. Assembly Processes

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can occur behind chip carriers and other large components, or when one component is placed too close to another. Long term reliability has been found to be compromised with the small outline package when subjected to excessive wave solder immersion time. (See Application Notes #468, 470.)

Reflow soldering is basically more suited for surface mounting. Reflow involves the use of a solder paste (tiny balls of actual solder suspended in an organic medium—much similar to paint). The paste is applied by silk screening onto metal pads on the circuit board. The device is then placed onto the solder-coated pads. The board is heated until the paste ''reflows'' around the leads of the device, and is subsequently cooled. Since the devices and solder use the surface of the circuit board, the board may be inverted and the same procedure used on the opposite side. In this manner, components are mounted on both sides, utilizing yet another advantage of surface mount assembly. *Figure 2* compares insertion versus surface mount process flow.

SOLDER PASTE

Solder paste must be suitable for application by silkscreen or stencil, be resistent to solder balling, and reflow at the correct temperature. The flux residue must be easily removable. Most solder paste are tin-lead or tin-lead-silver in composition.

The shape of the solder particles is an important factor. Spherical particles are preferred. For soldering of fine-lined surface mount devices (such as 0.020 or 0.025 inch lead spacing), pastes with a mixture of spherical and non-spherical solder particles may work better.

NEW EQUIPMENT NECESSARY

To use surface mount assembly, to its optimum extent, new equipment is required. *Figure 3* illustrates the equipment used for surface mounting in comparison to the traditional insertion method. Surface mounting utilizes silk screen, pick-and-place, and solder reflow equipment, all which are not part of the insertion or DIP process.

Wave Solder	Reflow Solder
Dip Inserter	Screen Printer
Wave Solder	Placement M/C
Cleaning Station	Vapor Phase Reflow System
	Cleaning Station

FIGURE 3. Equipment for Assembly

Solder reflow equipment allows for a variety of techniques. Vapor phase, the most popular form of reflow soldering, is pushing the manufacturers to develop machines capable of soldering both surface mounted and through-hole components. That would eliminate the bridging problems associated with wave soldering and at the same time the need for gluing the surface mounted parts to the printed circuit board (a must for wave soldering).

In vapor phase reflow soldering, the p.c. board assembly is immersed in the vapor of the boiling liquid. The vapor condenses on the board and transfers its heat in doing so. This raises the temperature of the board and causes the solder paste to reflow.

Vapor phase soldering offers precise temperature control through chemical thermodynamics which guarantees that the soldered assembly never reaches a temperature above that of the boiling, reflow liquid. The liquid used must have a boiling point minimum of 20°C above the reflow temperature of the solder, be non-flammable, non-toxic, have high vapor density, and must not decompose or leave a residue. Liquids which meet these criteria generally have boiling temperatures in the 210–230°C range, are based upon carbon-fluorine chemistry, and are very expensive ($500 to $800 per gallon).

Laser reflow soldering is particularly suitable for high-density boards or heat-sensitive components. The heat is localized onto each solder joint individually, and does not contact the main body of the component. This method can apply heat to an area as small as 5 mils in diameter for 200 ms, soldering up to 4 joints per second. Presently, laser soldering is not designed for high volume production use.

In infrared reflow soldering, absorption of radiant energy heats up the materials. The air in the heating path is not directly heated and there is no heat transfer by direct physical contact. In the process, the board first passes into a preheat zone which gently heats the solder paste to drive off volatile solvents and to avoid thermal shocking the p.c. board. After preheating, the assembly enters the main heating area where it is raised to reflow temperature and then cooled.

CHANGES FOR THE PRINTED CIRCUIT BOARD

A major change is occurring in the printed circuit industry now that surface mounting has emerged. More area is available for trace routing and component placement due to the absence of the large diameter component lead mounting holes which were required for through-hole insertion. Required now are only small diameter via holes (0.013–0.020 inch) between circuit layers which are plated to provide electrical path connection. Various CAD/CAE programs are becoming available to assist in the design and layout of surface mount printed circuit boards.

In the design of the board an important factor to consider is that it should be process oriented. It must reflect the handling and material requirements of the proposed manufacturing processes, sequences, and test methods (see *Figure 4*).

	Wave Solder	Reflow Solder
Plated Thru Holes	Many	Few
Number of Layers	6	4
Line/Space Widths	12 mil/12 mil	8 mil/8 mil
Device Mounting	Single	Double

FIGURE 4. Printed Circuit Board Changes

Additional factors which must be considered for surface mount assembly include:

1) Substrate material must be selected corresponding to the type of environment the assembly will see and also the types of devices being assembled. It should also depend on the extent of reliability that is required for the assembly.
2) Special consideration should be given to the design of the board to minimize board warpage during the soldering operation. Any tendency for the mounting surface to warp away from the component leads can result in open solder joints.
3) Test probe access areas should be provided at key functional locations.
4) A solder mask is necessary due to more closely spaced circuit traces and component mounting pads.
5) Thermal dissipation is a key to good surface mounting. With surface area diminishing and density increasing, heat dissipation increases substantially. Using a material with good heat conduction properties can increase the

reliability of the assembly and reduce the number of components that need heat sinks or fans.

DELIVERY SYSTEMS FOR AUTOMATION

Perhaps the major overriding benefit to surface mount assembly is factory automation. Components can be bulk loaded, magazine fed, or tape-and-reel fed. In terms of speed of the assembly process, a tape-and-reel system, such as National Semiconductor's STAR™ (Semiconductor Tape-and-Reel) system offers certain advantages (*Figure 5*). The magazine fed approach requires more frequent operator intervention during the assembly process. Labor savings of 50 to 1 or more can be realized (Table I).

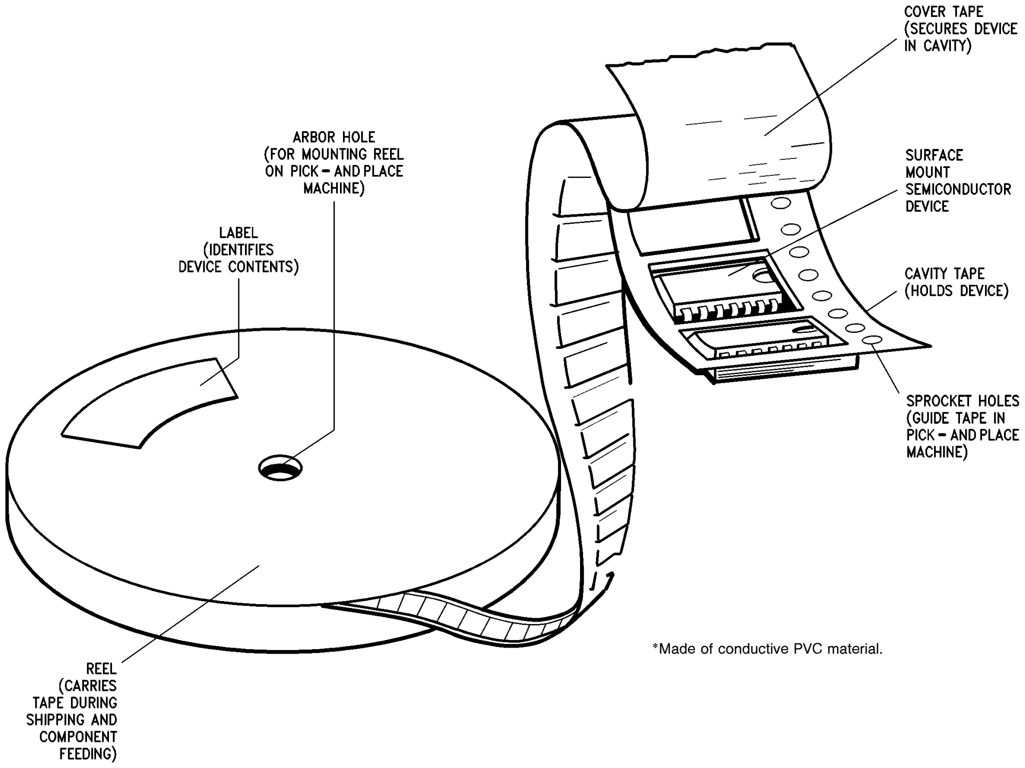
FUTURE NEEDS

Surface mount is projected to be the dominant assembly technique by 1990, as over half of all components will be using the format. As more functions are squeezed onto a semiconductor chip, the need for higher leadcount devices in yet smaller packages will be demanded.

Integrated circuit packages utilizing 0.010 to 0.020 inch lead centers will be commonplace. These next generation of surface mount packages will solve some of the present surface mount package problems by having built-in lead protection and testability.

TABLE I. Delivery System Comparison

Device	Units/Rail	Units/Reel
SO-8	100	2500
SO-14	50	2500
SO-14 W	50	1000
SO-16	50	2500
SO-16 W	50	1000
SO-20 W	40	1000
SO-24 W	30	1000
PCC-20	50	1000
PCC-28	40	750
PCC-44	25	500
PCC-68	20	250
PCC-84	15	250
PCC-124	10	100



*Made of conductive PVC material.

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FIGURE 5. Tape-and-Reel Diagram

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