Soldering and Rework of the HDSM-40xx Series, HDSM-50xx Series Patented Surface Mount Seven-Segment Displays

AVAGO TECHNOLOGIES

Application Note 1240

Contents

Introduction to the Surface Mount Seven-Segment Display

The Avago Technologies' HDSM-40xx series and HDSM-50xx series surface mount single-digit *strobable seven stretchable segments* (S4) LED displays are suitable for indoor and outdoor display applications. The SMT S4 is suitable for applications requiring complete SMT board assemblies (type II) or attachment onto flexible circuits.

There are currently two configurations of circuitry and two digit sizes of SMT S4:

- HDSM-401x
  0.4" common anode
- HDSM-403x
  0.4" common cathode
- HDSM-501x
  0.56" common anode
- HDSM-503x
  0.56" common cathode

The SMT S4 is a leadless terminal package with a printed circuit (PC) board as the LED chip carrier. The PC board is plated with 0.5 oz copper (18 μm thickness) and cladded with gold plating. The carrier is FR-4 woven E-glass reinforcement with Tg of 140°C for enhanced thermal properties.

These devices are packaged in tape and reel, and are readily mounted on a PC board using automatic pick-and-place equipment and attached using a reflow solder process.

Tape and Reel Packing

Tape and reel packing serves to provide a delivery medium for automatic placement machines during equipment manufacture. The SMT S4 components are packaged tape and reel in compliance to the EIA Standard 481-2: 16 mm, 24 mm, 32 mm, 44 mm, and 56 mm Embossed Carrier Taping of Surface Mount Components for Automatic Handling. Figures 1a through 1d show the two EIA standard dimensions for the reel and embossed tapes used to package the SMT S4.

The HDSM-50xx components are packaged in 32 mm embossed tape, while the HDSM-40xx components are packaged in 24 mm embossed tape.

Moisture Barrier Bag

The materials used in the SMT S4 components absorb moisture directly out of the air. Absorbed moisture causes the most damage during reflow soldering. However, absorbed moisture in the SMT S4 which has been reflow soldered onto a printed circuit board is typically harmless.

Moisture absorbed by SMT S4 components prior to soldering turns to superheated steam during reflow. The pressure of this superheated steam creates stresses throughout the package (a phenomenon called popcorning) causing fractures and cracks, and eventually leads to catastrophic failures when the cracks reach the wire bond and die attach.

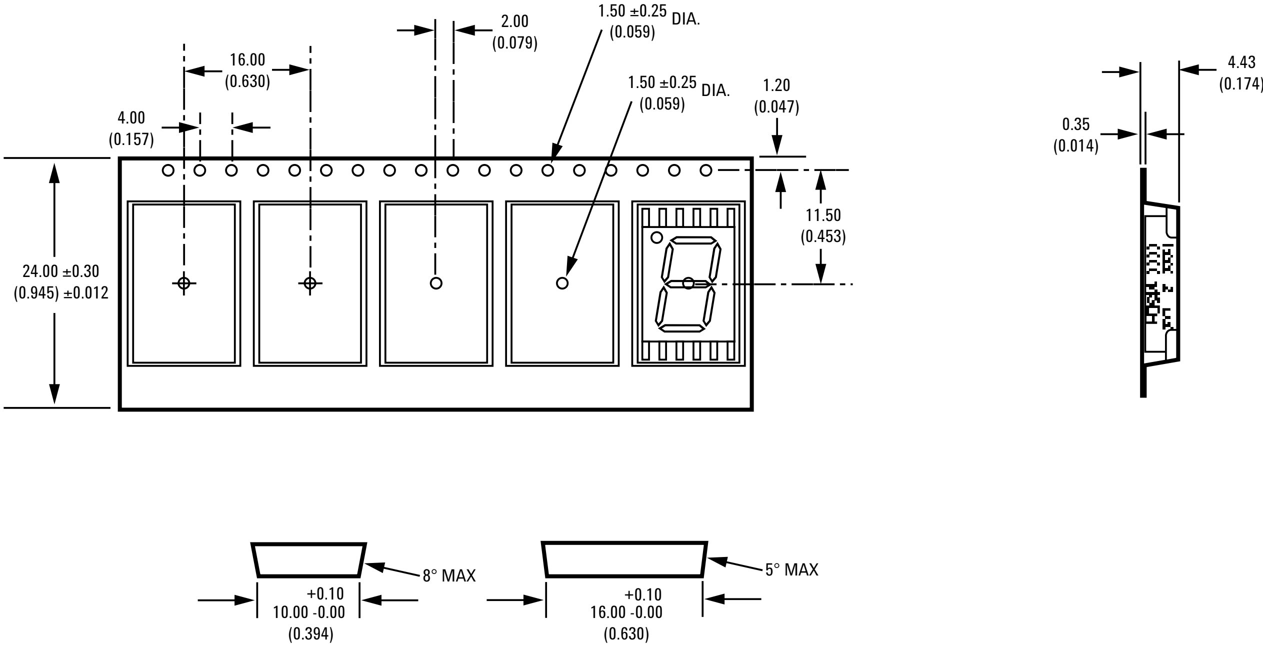


Figure 1a. 24 mm embossed cavity carrier tape details for HDSM-40xx series. The carrier tape will only have a row of sprocket holes.

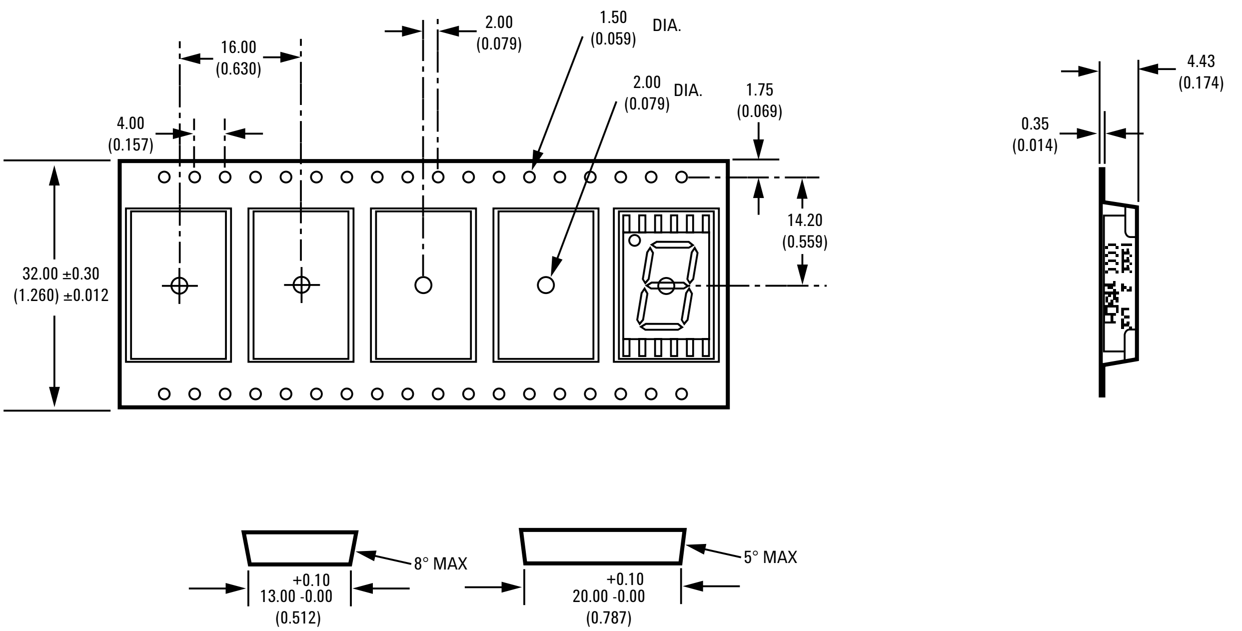
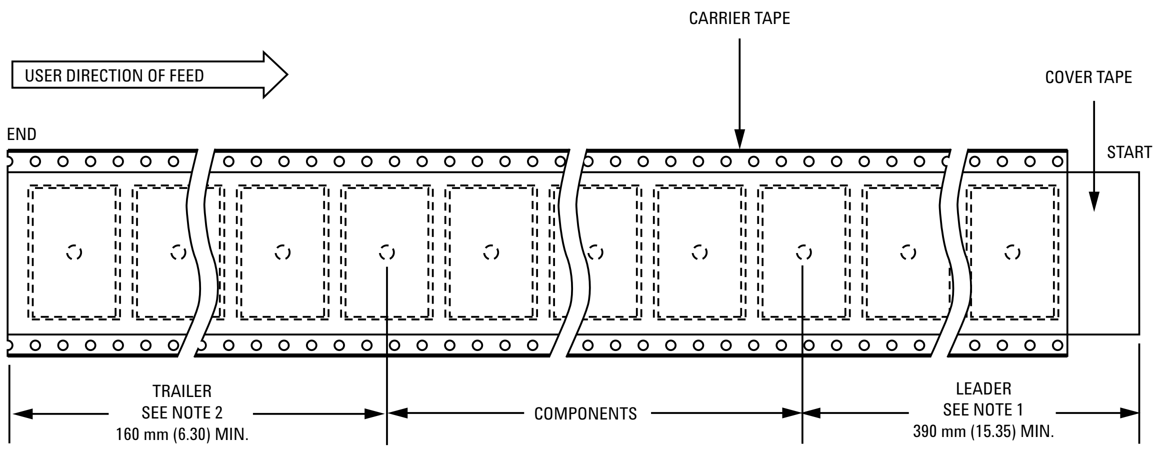


Figure 1b. 32 mm embossed cavity carrier tape details for HDSM-50xx series. There will be two rows of round sprocket holes, one on each end of the carrier tape.



NOTES

1. THERE SHALL BE A LEADER OF 230 mm (9.05 IN.) MINIMUM WHICH MAY CONSIST OF CARRIER AND/OR COVER TAPE FOLLOWED BY A MINIMUM OF 160 mm (6.30 IN.) OF EMPTY CARRIER TAPE SEALED WITH COVER TAPE.
2. THERE SHALL BE A TRAILER OF 160 mm (6.30 IN.) MINIMUM OF EMPTY CARRIER TAPE SEALED WITH COVER TAPE.

Figure 1c. Tape Leader and Trailer Dimensions.

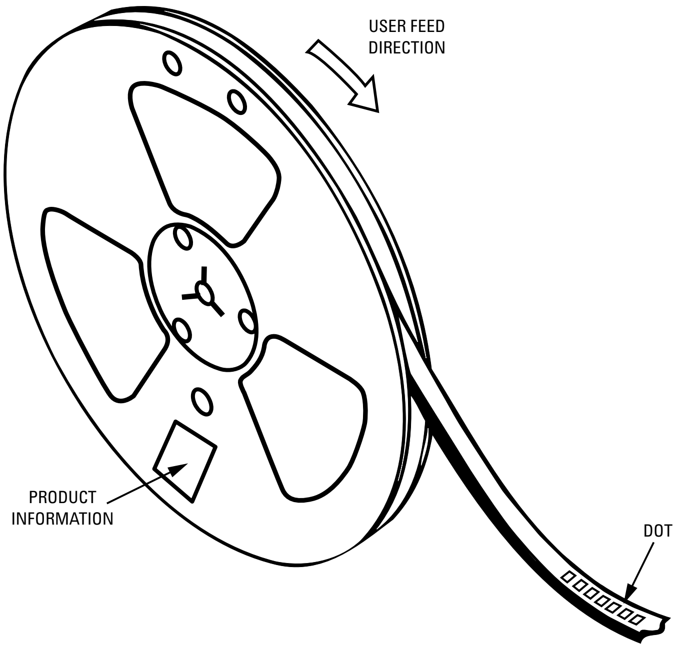


Figure 1d. User feed direction with sprocket holes location and product information label on the reel.

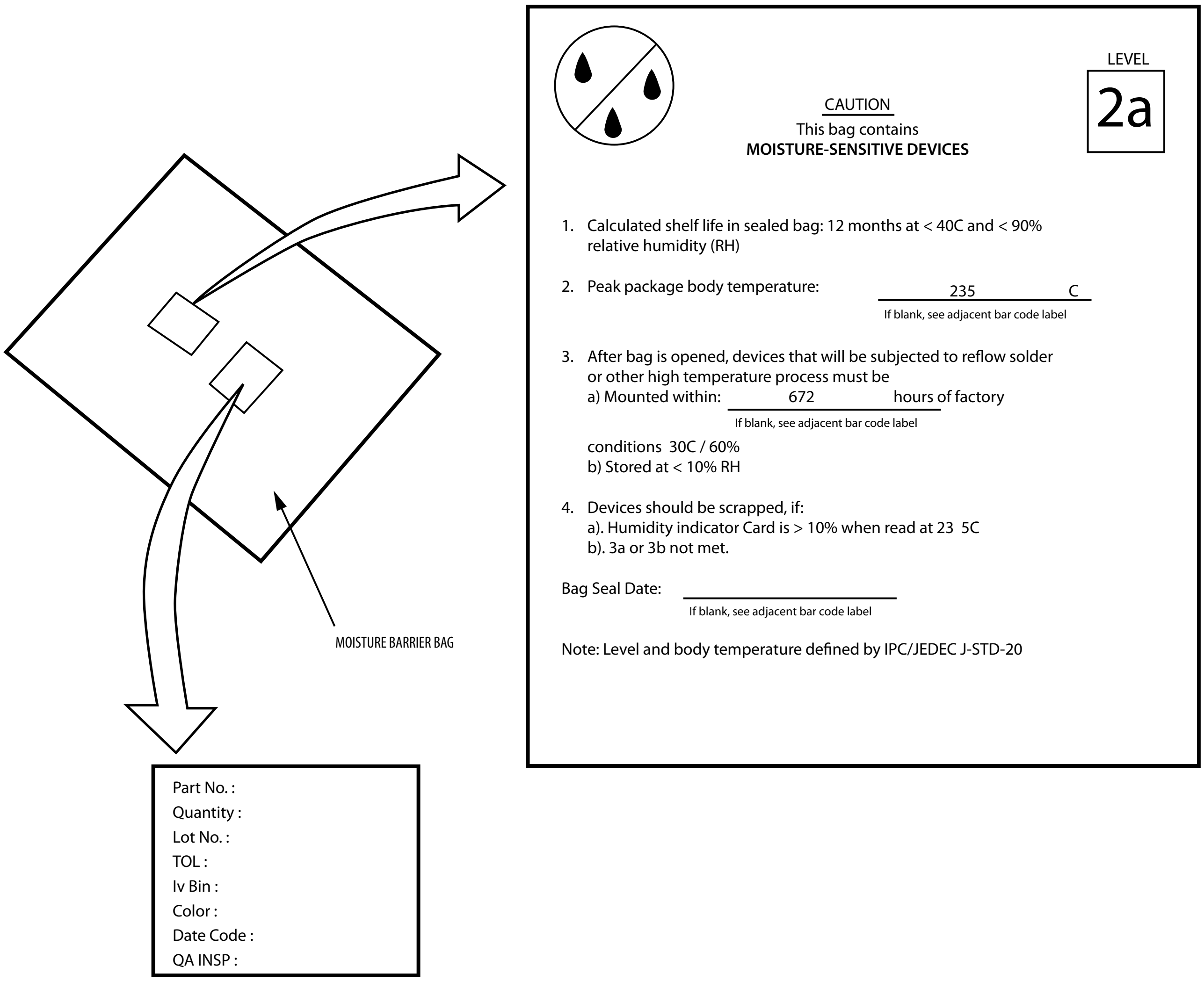


Figure 2. The label for the surface-mountable seven-segment display is in accordance to JEP113-B standard, *Symbol and Labels for Moisture-Sensitive Devices.*

To protect the SMT S4 from excess moisture absorption during shipping and handling, the reels are packaged in moisture barrier bags, as illustrated in Figure 2. Each bag contains a minimum of 10 packs of 10g silica gel desiccant. Once the bag is opened, the SMT S4 should be handled in accordance with the recommendations based on the appropriate moisture sensitivity classification.

JEDEC Moisture Level Characterization

The classification of the SMT S4 currently stands at level 2a of the IPC/JEDEC J-STD-020A standard.

Table 1a. JEDEC Level 2 test performed on the SMT S4.

JEDEC Level 2 (90 units per package)	
External Cracks and Functional Test	Pass
Bake at 125 +5/-0°C at 24 hours	Pass(1)
Moisture soak 85°C/ 85%RH	Pass(1)
3X IR Reflow Soldering	Pass
5X TMCLs	0.56": 3 Open 0.40": 1 Open
20X TMCLs	0.56": 1 Open 0.40" : 1 Open
50X TMCLs	No Open
Conclusion: Fail Level 2	

1. No light-up test performed. Visual check for defects.

Table 1b. JEDEC Level 2a test performed on the SMT S4.

JEDEC Level 2a (90 units per package)	
External Cracks and Functional Test	Pass
Bake at 125 +5/-0°C at 24 hours	Pass(1)
Moisture soak 85°C/ 85%RH	Pass(1)
3X IR Reflow Soldering	Pass
5X TMCLs	Pass
20X TMCLs	Pass
50X TMCLs	Pass
Conclusion: Pass Level 2a	

1. No light-up test performed. Visual check for defects.

At Level 2a, the warranted floor life of the SMT S4 is 4 weeks or 672 hours at ≤30°C/60% RH. Should a unit be exposed beyond this condition, it must be baked to remove absorbed moisture before soldering to ensure no catastrophic failure.

Land Pattern Design

The design of land patterns is very important in determining solder joint strength and thus its reliability. It also impacts solder defects, testability, and reworkability. Consideration for land pattern design is an important facet of the SMT S4's design for manufacturability. Tombstoning, bridging, skewing and solder wicking, poor wetting and other solder defects can be prevented or minimized with a good land pattern design.

Assuming a machine's placement tolerance of ±0.10 mm and a need for a minimum of 0.10 mm heel and toe fillet, the calculated land pattern is as shown in Figures 3a and 3b. These land pattern calculations are based on the popular IPC-SM-782A standard.

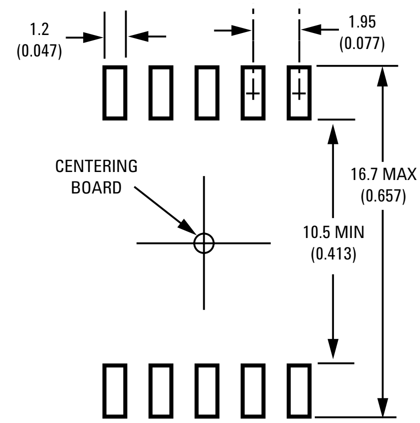


Figure 3a. Recommended land pattern for the 0.4" SMT S4 package with a minimum 0.10 mm heel and toe fillet using a 0.10 mm placement tolerance.

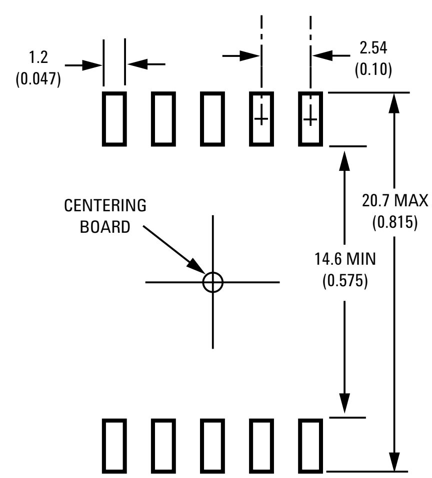


Figure 3b. Recommended land pattern for the 0.56" SMT S4 package with a minimum 0.10 mm heel and toe fillet using a 0.10 mm placement tolerance.

Accurate placement of the SMT components onto the printed circuit board attachment pads enhances the probability of proper alignment after soldering. When the printed circuit board pads are of the correct size in relation to the device's terminals, the SMT S4 self aligns with respect to the pads, assisted by the capillary attraction/wetting forces of the hot liquid solder.

Desoldering and Reworking

The SMT S4 cannot be addressed using conventional soldering irons for reworking as the terminals are directly beneath the package. The SMT S4 can best be reworked using either hot air or IR stations. In general, component spacing of 0.040 in. (1.0 mm) to 0.060 in. (1.5 mm) is the rule of thumb for reworkability. The more spacing that is provided, the easier it is to rework. Often that is the preferred choice versus scrapping the entire board.

For working with boards containing smaller adjacent components and in applications where an extractor is rendered unusable because of the close juxtaposition of other components, a focused IR method is highly recommended. In general cases, the SMT S4 can be desoldered using a hot-air flow system. In particular, the JBC Advanced AM6000 rework station was found to be suitable for reworking the SMT S4.

The use of a 6 mm diameter nozzle is recommended for both packages of the SMT S4. A smaller nozzle (4 mm diameter) works as well, but the concentration of heat is much greater and care must be taken to avoid damage to the SMT S4, adjacent components, and the printed circuit board. Especially vulnerable to the heat is the top surface of the SMT S4. It has been shown that hot air set at 350°C causes the gray ink on the surface of the SMT S4 to melt when the nozzle is closely directed for more than 2 sec. Keeping the temperature below 350°C and an air setting 7 (approx. 32 liter/min) in the AM6000 system is recommended for desoldering the SMT S4 with a minimum risk of damage.

It is helpful to preheat the board assembly to 100–120°C for 10 to 15 minutes before rework to prevent thermal damage such as measling or white spots of the boards and to avoid pressure on the pads during rework operation. Two methods can be carried out on the AM6000 to desolder the units depending on the placement and the density of the board. Figures 4a through 4c show the use of an extractor to desolder the SMT S4. The extractor helps trap the hot air and prevent the heat from affecting nearby components.

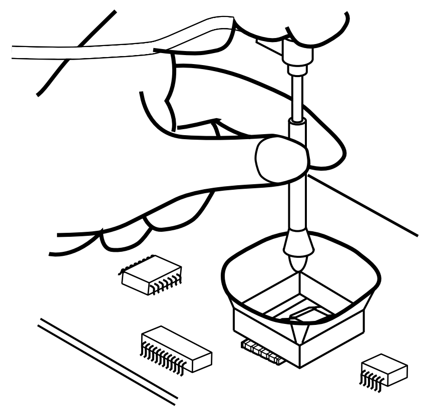


Figure 4a. Select an appropriate extractor size and start the vacuum button to activate the suction pump.

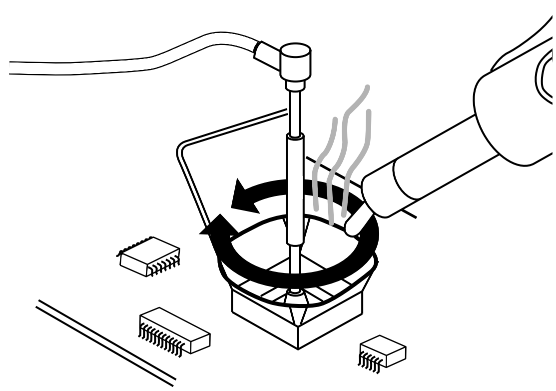


Figure 4b. Start the hot air generator and direct the nozzle in a circular movement at the component terminals. Take care to distribute the heat evenly.

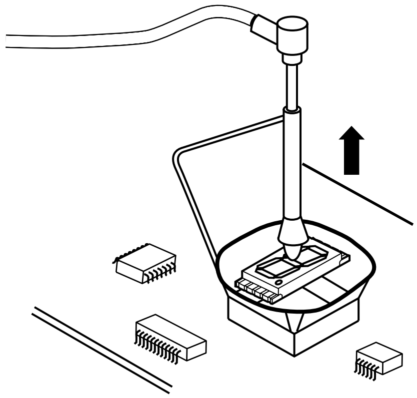


Figure 4c. When the solder turns to liquid the extractor will automatically lift the component.

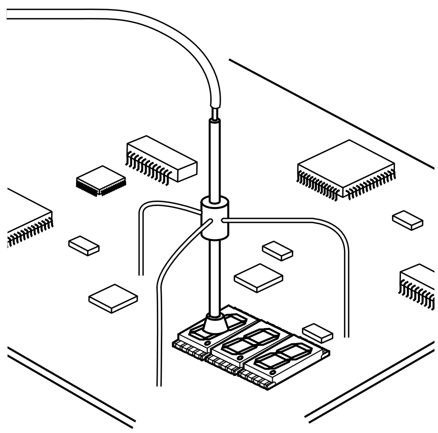


Figure 4d. In cases whereby an extractor cannot be used, Avago Technologies recommends the use of a tripod.

When the use of an extractor is not practical, the tripod is recommended. Care should be taken to direct the nozzle at the terminals with a circulatory movement to prevent overheating when using either method. While the extractor normally removes the SMT S4 in 60 seconds, the tripod method takes slightly longer.

Usually, the bigger 0.56" package requires a longer time to desolder compared to the 0.4" package. The recommended size of the extractor is 64 (20 mm x 26 mm) or 68 (27 mm x 27 mm). The size 68 extractor was found to be more suitable for the 0.56" package.

The top surface of the SMT S4 is flat with some unevenness from the meniscus of the optical epoxy. However, a typical suction cup can effectively function to suck the SMT S4. Should there be a suction problem, verify if the suction cup is well placed and in perfect condition. Check the incoming air filter in the interior of the station and replace it if it is dirty. Always clean dust or dirt from the contacts and the printed circuit board being desoldered.

After the units have been removed, there is some solder left over on the bond pads and the terminals of the SMT S4. It must be removed using a desoldering braid or a solder-wick®. A fast wicking action protects the components from harmful heat damage.

Desoldering using IR normally requires the PC board to be heated to about 150°C and the SMT S4 up to 210°C. For lead free soldering, the temperature needs to be even higher (up to about 245°C), depending on the solder alloy. The advantage of IR is that it is a radiation and does not involve any moving currents of air. Therefore, adjacent components are not disturbed during the desoldering process.

The Rintronics EC-001 IR rework station was effective in desoldering the SMT S4. The EC-001 station comes with independent controllers for top and bottom IR quartz heaters. It has a dual display temperature setting for set point temperature and actual temperature monitoring. Maintaining the board temperature at 150°C while setting the top temperature to 210°C is recommended for desoldering the SMT S4 soldered with $Sn_{63}Pb_{37}$.

The method for desoldering is to brush liquid flux onto the terminations. Next, place the board on the heating platform, making sure that the heating platform covers almost the whole board in order to prevent warpage. Attach the thermocouples, making sure the left thermocouple is placed beneath the PCB, and the right thermocouple on the topside of the PCB. Set the ramp-up dials to position 6, making sure the rate is not greater than 4°C/s to avoid delamination from thermal shock.

The top quartz heater is rectangular in shape, but modifications can be made to have various apertures to localize the heating. If the SMT S4 to be desoldered is close to other components, the localization of the heating through these aperture settings may not be that well controlled. In that case, use aluminum foil to protect the adjacent units. If left exposed to the radiation, the metallurgical properties of these adjacent joints are bound to deteriorate by being melted twice. (Rudolf Strauss)

Once the temperature rises above 183°C, the solder turns liquid. Wait about 10 seconds before removing the component with either a tweezers or a vacuum pick-up syringe.

The type of flux used should be the same as used during soldering. If a focused IR rework station is used, the IR lens must be positioned above the SMT S4, and its beam size adjusted to cover the component and its terminals.

Soldering

Reflow soldering is the primary method for forming solder joints during SMT PC board assembly. When properly carried out, the reflow process provides the advantages of high yield, high reliability, and low cost. Ironically, the high temperature requirement for soldering is also the biggest concern for component makers. A carefully optimized reflow profile is crucial to ensure good soldering and minimal component defects.

The types of defects affected by the reflow profile include component cracking, component delamination, tombstoning, wicking, solder balling, bridging, solder beading, cold joints, excessive intermetallic formation, poor wetting, voiding, skewing, charring, leaching, dewetting, and solder or pad detachment.

In essence, a reflow profile can be divided into three major regions: the peak temperature, the heating stage, and the cooling stage. Each region has its impact on the reflow results and must be engineered to minimize defects and maximize reliability.

The peak temperature is typically determined by the (eutectic) melting temperature of the solder. The minimum peak temperature should be about 30°C above the solder melting temperature. In the case of eutectic Sn63Pb37 solder, the minimum peak temperature is approximately 210°C.

Reflow with a peak temperature below the recommended value yields cold joints and undesirable wetting. On the other hand, a high peak temperature invites an excess amount of intermetallic compound and results in a brittle solder joint. Although the peak temperature desired is about 230°C, care must be taken to prevent the charring and delamination of the optical grade epoxy and plastic parts if this dwell time is too long.

A slow ramp-down rate at temperatures above the melting temperature of the solder also results in excess intermetallic growth. Aside from that, solder joints with a large grain structure having a poor fatigue resistance are formed. However, a fast cooling rate may also induce thermal shock and solder joint deformation. In general, a cooling rate of 4°C/s to 4.5°C/s is the optimum to achieve a desirable solder joint.

The heating stage of the reflow soldering is known to be the most complicated part where time and temperature parameters are critical to achieve a reliable solder joint.

A high ramp-up rate from room temperature lowers the viscosity of the solder paste, and likely leads to slumping and bridging. Similarly, a high ramp-up rate results in the outgassing of the flux through vigorous vaporization, promoting solder beading. In general, a slower ramp-up rate of about 0.5 to 1.0°C/s prevents slumping and solder beading.

Tombstoning and skewing are caused by uneven wetting that occurs at the two ends of the component. The temperature plateau seen in the conventional soldering profile is to even out the temperature gradient of different parts of the board. In conventional reflow soldering, the plateau's duration is typically 30–120 seconds depending on the heating efficiency of the reflow system.

Solder balling is a consequence of spattering or excess oxidation which happens when the ramp-up rate is set greater than 2°C/s prior to solder coalescence. Poor wetting and voiding are also consequences of excess oxidation. Therefore, a slower ramp-up rate must be maintained to eliminate these phenomena.

Modern air-forced convection reflow technology allows a controllable heating rate and overcomes sensitivity in the difference in color, material type, and density distribution of the components. The temperature gradient across the board becomes less significant and the justification for the equilibrating zone is no longer valid. Consequently, the plateau structure of the reflow profile can be minimized, and the rapid initial ramp-up rate can be slowed down to allow the realization of an optimized profile.

The unfavorable attributes of the conventional profiles can be categorized as:

a. rapid initial ramp-up
b. long soaking time at about 150–160°C, resulting in excessive heat exposure and oxidation
c. rapid ramp-up when passing through the melting point
d. slow cooling, therefore excessive heat exposure, as noted in Figure 5.

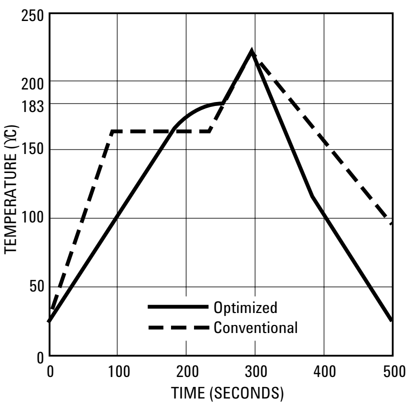


Figure 5. Conventional profile in an IR reflow oven versus an optimized profile that can be achieved using a modern forced-air convection oven (Ning-Cheng Lee).

A forced-air convection system is recommended, but the IR reflow system is still suitable if the desirable solder profile can be effectively implemented. The SMT S4 has been verified to withstand 3 times IR reflow soldering without failure. Reliability testing up to 5 times IR reflow has been conducted with encouraging results.

Table 2a. Temperature profile for a nominal convective IR reflow solder process.

Recommended Convective IR Reflow Profile		
Process Zone	**ΔT**	**ΔT/Δtime**
Heat Up	25°C to 125°C	3°C/s max.
Solder Paste Dry	125°C to 170°C	0.5°C/s max.
Solder Reflow	170°C to 230°C (235°C max.)	4.5°C/s typ.
	230°C to 170°C	-4.5°C/s typ.
Cool down	170°C to 25°C	-3°C/s max.

Table 2b. Reliability test results of the SMT S4 during multiple IR reflow operations.

Reliability Testing 25 pieces per package	
Visual Test	
1x IR	Pass
2x IR	Pass
3x IR	Pass
4x IR	Pass
5x IR	Pass
Hot/Functional Test	
1x IR	Pass
2x IR	Pass
3x IR	Pass
4x IR	1 Open Segment
5x IR	1 Open Segment

For a more in-depth discussion into SMT soldering, please refer to Application Note 1060.

References

Rudolf Strauss (1998), *"SMT Soldering Handbook,"* Newness, Woburn, Massachussets, p.155

Ning-Cheng Lee (1998), *"Optimizing the reflow profile via defect mechanism analysis,"* Indium Corporation of America, Utica, NY, USA

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

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