Soldering and Handling of High Brightness Through Holes LED Lamps

Application Note 5334

Introduction

LED is well known of its long useful life compare to conventional incandescent bulb. If LED is not being properly handled, it will significantly shorten its useful life and might even cause catastrophic failure. This application note provide detail information about the soldering process and handling precautions of high brightness through hole (TH) LED in minimizing the risk of LED failure.

Abstract

1) TH LED may be wave soldered, solder dipped or hand soldered in the same manner as other semiconductor components. During wave soldering, TH LED are exposed to high temperature when PCB traveling through solder pot, therefore it is imperative to have proper soldering process control and handling procedure throughout the whole assembly process to avoid of premature failure of the LED lamps.

2) Through hole LED components have their die attached directly to the lead frame or substrate. Therefore, care must be taken to keep thermal and mechanical stresses applied to LED component leads during the soldering process to minimum.

3) For wave soldering, set up the wave soldering profile as follow:

   Preheat temperature = 100 ± 5°C

   Solder = Sn63 (leaded solder) or SAC305 (lead free solder)

   Solder wave temperature = 245 ± 5 °C (maximum Peak temperature =250°C)

   Dwell time in the solder wave = 1.5 to 3 seconds (maximum = 3 sec)

   Rosin flux = ROL0 or ROL1

   Allow the soldered pc board to cool to room temperature (25°C) before handling.

4) Precaution on soldering TH LED including design and handling of fixture that meant to align the LED during wave soldering process.

5) For hand soldering, soldering iron tip should be maintained at 315°C maximum temperature. The maximum allowable time for soldering iron tip to touch the LED lead is 2 sec maximum. The LED must be allowed to cool to room temperature prior to 2nd application on the same LED.

6) Common soldering defects and remedy for each soldering defect.

Soldering Through Hole LED

Soldering process is very important to establish electrical connection between the LED components and PCB traces by forming solder joints. As the process exposes the LED to high temperature environment, care needs to be taken to ensure excessive thermal and mechanical stress is not being induced on LED component that may lead to premature failure.

The most commonly used conventional solder alloy is Sn63. As for lead free soldering, solder alloy recommended by IPC is SAC305. Table 1 lists the some of the commonly used solder alloy in the semiconductor industry.

Flux is used to promote wetting of the molten solder on the component leads which ensure good solder joint, refer Figure 1. This is achieved by:

- Removing oxides from metal surface to provide proper wetting surface to form solder joint
- Preventing re-oxidation during heating;
- Lowering surface tension on the device leads and PC board metallization.

Flux used in soldering should have the following properties:

- Can be easily displaced by molten solder;
- Can be non-injurious to personnel, LED components and PC boards;
- Can be easily removed by a cleaning process that is compatible with LED components, other components and the PC board.

IPC-J-STD-004A addresses all types of flux used in PC board assembly process, this including liquid, paste/ cream or solid. Fluxes shall be classified as either rosin, resin, organic or inorganic based on the largest weight percent constituent of its nonvolatile portion.

Copper mirror testing, corrosion testing, electrochemical migration, surface insulation resistance and halide content will determine flux activity levels. The three main flux/ flux residue activity levels are:

L: Low or no flux/ no flux residue activity

M: Moderate flux/ flux residue activity

H: High flux/ flux residue activity

The "0" and "1" indicate absence (<0.05% by weight in flux solids) and presence of halides in the flux respectively. Refer to Table 2 for detail.

Table 1: Solder type per ANSI/J-STD-006 used in the electronics industry to solder PCB assemblies

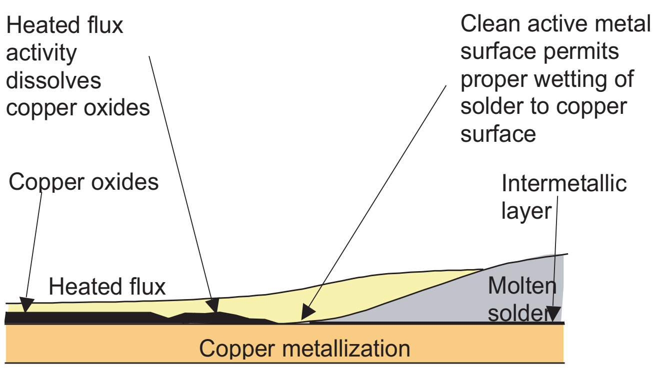
Alloy Name (Former Name)	Primary Metallic Composition	Temperature -°C Solidus (SOL)	Liquidus (LIQ)
Sn60Pb40 (Sn60)	60%Sn 40%Pb	183	191
Sn62Pb32Ag2 (Sn62)	62%Sn 36%Pb 2%Ag	179	e
Sn63 Pb37 (Sn63)	63%Sn 37%Pb	183	e
SnAg3.5	96.5%Sn 3.5%Ag	e	221
SnAg3.0Cu0.5 (SAC305)	96.5%Sn 3%Ag 0.5%Cu	e	217
SnAg4.0Cu0.5 (SAC405)	95.5%Sn 4%Ag 0.5%Cu	217	219

Note:

1) The Solidus (SOL) and Liquidus (LIQ) temperature values are provided for information only and are not intended to be a requirement formulation of the alloy. In the LIQ column, an "e" indicates eutectic alloys. Although efforts have been made to document the correct solidus and liquidus temperatures for each alloy, users are advised to verify these temperature values before use.

Table 2: Flux identification system per IPC-J-STD-004

Materials of Composition	Flux/Flux Residue Activity Levels	% Halide (by weight)	Flux Type	Flux Designator
Rosin (RO)	Low	0.0%	L0	ROL0
		<0.5%	L1	ROL1
	Moderate	0.0%	M0	ROM0
		0.5-2.0%	M1	ROM1
	High	0.0%	H0	ROH0
		>2.0%	H1	ROH1
Resin (RE)	Low	0.0%	L0	REL0
		<0.5%	L1	REL1
	Moderate	0.0%	M0	REM0
		0.5-2.0%	M1	REM1
	High	0.0%	H0	REH0
		>2.0%	H1	REH1
Organic (OR)	Low	0.0%	L0	ORL0
		<0.5%	L1	ORL1
	Moderate	0.0%	M0	ORM0
		0.5-2.0%	M1	ORM1
	High	0.0%	H0	ORH0
		>2.0%	H1	ORH1
Inorganic (IN)	Low	0.0%	L0	INL0
		<0.5%	L1	INL1
	Moderate	0.0%	M0	INM0
		0.5-2.0%	M1	INM1
	High	0.0%	H0	INH0
		>2.0%	H1	INH1



The flux heated to temperature, dissolves the copper oxides leaving a clean, chemically active copper surface and prevents further oxidation. The molten solder immediately wets the copper surface.

Figure 1. Flux activity on copper metalization

Wave Soldering Process

Wave soldering is the most cost effective method of soldering TH LED into a PC board assembly. The parameters for soldering TH LED in a wave soldering process are compatible with the processing requirements for other semiconductor components.

After flux application, the PC board will be subjected to preheat prior to having contact with the solder wave. The purposes for preheat are:

- To activate the fluxing action.
- To evaporate the flux solvents.
- To reduce thermal shock to the LED and the PC board.
- To reduce the heat transfer needed from the solder wave to bring the connections up to soldering temperature.

The optimum preheat temperature for effective soldering TH LED is 100°C ± 5°C as measured on the bottom side of PCB. It is recommended to have only bottom preheater in order to reduce the thermal stress experienced by the body of the TH LED.

Common wave solder machines utilize a single wave solder flow if only through hole components are present on the assembly. To solder through hole components together with surface mount devices (SMD) at the bottom side of the board, a dual wave configuration is normally used, which the first wave is a narrow turbulent flow and the second wave is a laminar flow.

The turbulent flow helps to deposit a continuous coating of solder on the underside of the PC board and the benefits are:

- virtual elimination of missed solder connections
- positive solder delivery for soldering through the wave surface mount components.

The purpose of laminar flow is to smooth out the solder deposited by turbulent wave to ensure proper flow of solder into plated through hole.

The optimum solder contact time for two solder wave is 1.5 second to 3.0 second. Some of the wave soldering machines are equipped with hot air knife which help to eliminate solder bridging before solder solidified.

Hand Soldering

LED components may be effectively hand soldered to a PC board or to a wiring harness. However, it is only recommended under unavoidable circumstances such as rework. It is very important to follow these simple rules to achieve effective hand soldering:

1. The maximum soldering iron tip temperature is 315°C. The temperature should be the actual temperature measure at the tip by thermocouple and it is not the equipment setting temperature. The soldering iron is allowed to touch the lead of LED for 2 seconds maximum. The LED must be allowed to cool to room temperature prior to 2nd application on the same LED.
2. ESD precaution must be properly applied on the soldering station and personnel to prevent ESD damage to the LED components. Do refer to Avago Application Note AN1142 for details. The soldering iron used should have grounded tip to ensure electrostatic charge is properly grounded.

3. Most of the industrial soldering iron tips are pre-tinned by the manufacturer. Example of copper plated soldering iron tips, short length with a conical taper tip as shown in Figure 2.
4. Keep the tip of the iron clean and tinned throughout the soldering operation. It is the tinning (solder coat) on the tip that enhances the heat transfer from the tip to the connection. A tip that is not well tinned will quickly oxidize, thus reducing heat transfer to the connection. The oxides on the tip will contaminate the surfaces within the connection inhibiting solder wetting.
5. Wipe the iron tip on a clean, sulfur-free, damp sponge to remove solder intermetallic build up and immediately re-tin between each series of consecutive connections. Keeping the tip clean ensured maximum heat at the tip surface.
6. Use the iron to heat the LED component lead and solder pad, apply solder at the tip until sufficient flow occurs, remove the solder from the tip, keep the tip in place until the connection is full of solder and remove the iron. This should take 1 to 2 seconds.
7. If necessary, the PC board pads and/or leads of an LED component may be pre-tinned prior to forming the solder connections. When soldering the leads of an LED component to wires of a wiring harness, pre-tin both the wires and the ends of the leads. This will allow the solder connection to be accomplished within minimal time and least stress to the LED component.

Precautions on Soldering TH LED

Figure 3 shows the general construction of TH LEDs. LED chip is electrically connected to the reflector cup lead via conductive die attach material and wire bonded to the stitch post to complete the electrical connection. In this construction, the encapsulation epoxy is the only supporting structure for the component leads. Alignment fixture is normally used in wave soldering process to align the LED position or tilt the LED to a desired angle, whereas soldering pallet is used to prevent warping of PCB. It is critical that assembly processes do not exert excessive mechanical and thermal stress on the LED that could result in component failure.

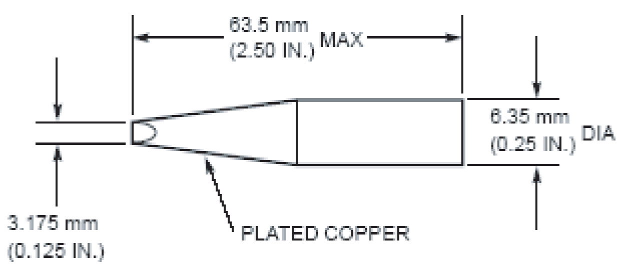


Figure 2. Example of soldering iron tip for hand soldering TH LED components

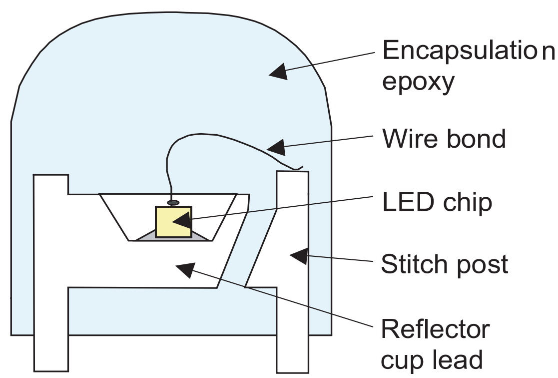


Figure 3. Common TH LED construction

Following are the recommended precautions.

1) Ensure minimal mechanical stress on the LED after auto inserted into PC board by controlling the clinching angle to typical 30°. Refer detail information on auto-insert section.
2) Immediately exiting from the wave soldering machine, the PC board and LEDs are still hot after exposing to the high temperature solder wave. At elevated temperature, the epoxy of LED is softer and is more sensitive to mechanical stress. As such, the alignment fixture and soldering pallet should remain intact on the PC board until the assembly **cools down to room temperature**. When removing the alignment fixture after cooling down, it needs to be removed **vertically** to avoid inducing mechanical stress on LED. Rough handling when LED is still hot will cause potential failure such as shifted lead frame, epoxy crack, broken stitch bond and delamination.
3) The alignment fixture should be loosely fitted and should not apply weight or force on LED package. Non metal material is recommended as it will absorb less heat during the wave soldering process.
4) The alignment fixture should be thin at the area embracing the LED and mounted as high as possible relative to the LED body. This will allow the fixture to be easily removed with minimal mechanical stress to the LED. A step design of the holes and spacers can be used to achieve this objective as illustrated in Figure 4.
5) The alignment fixture can only be used to align or tilt the LED in the y-direction perpendicular to the leads of the LED as shown in Figure 5. Tilting the LED in the x-direction might induce failure to the wire bond of the LED. As such, the alignment holes should be looser along the x-direction and can be tighter in the y-direction.
6) Wave soldering parameter must be set and maintain according to recommended temperature and dwell time. User is advised to perform daily check on the soldering profile to ensure that it is always conforming to the recommended condition.
7) Solder wave contact time can be measured by using a heat resistant glass with grid line on top as shown in Figure 6.
8) If PC board contains both TH LED & other surface mount components, it is recommended that the surface mount components be soldered on the top side of the PC board. If the surface mount components need to be on the bottom side, these components should be soldered using reflow soldering prior to inserting the TH LED. The soldered components can then be covered with the pallet during wave soldering. This can help to eliminate the requirement for higher wave soldering temperature that is needed to properly solder both TH LED and surface mount components together during wave soldering.
9) PCB with different size and design (component density) will have different heat mass (heat capacity). This might cause a change in temperature experienced by the PC board if the same wave soldering setting is used. So, it is recommended to re-calibrate the temperature profile again before loading a new type of PC board by mounting thermocouples at the bottom of the board. An example of temperature profile is as shown in Figure 7. Do refer to individual product datasheet for respective recommended profile.
10) If lead cutting is necessary, cut the leads after the soldering process. The solder connection forms a mechanical ground which prevents mechanical stress due to lead cutting from traveling into the LED package. This is highly recommended for hand solder operation, as the excess lead length also acts as small heat sink.
11) Below are the recommended items/parameters to be checked daily to ensure good process control:
    a. Flux application (spraying or foaming) evenness
    b. Preheat temperature setting
    c. Actual preheat temperature on board
    d. Wave temperature setting
    e. Actual peak wave temperature
    f. Conveyor speed setting
    g. Wave contact duration
    h. Wave contact length

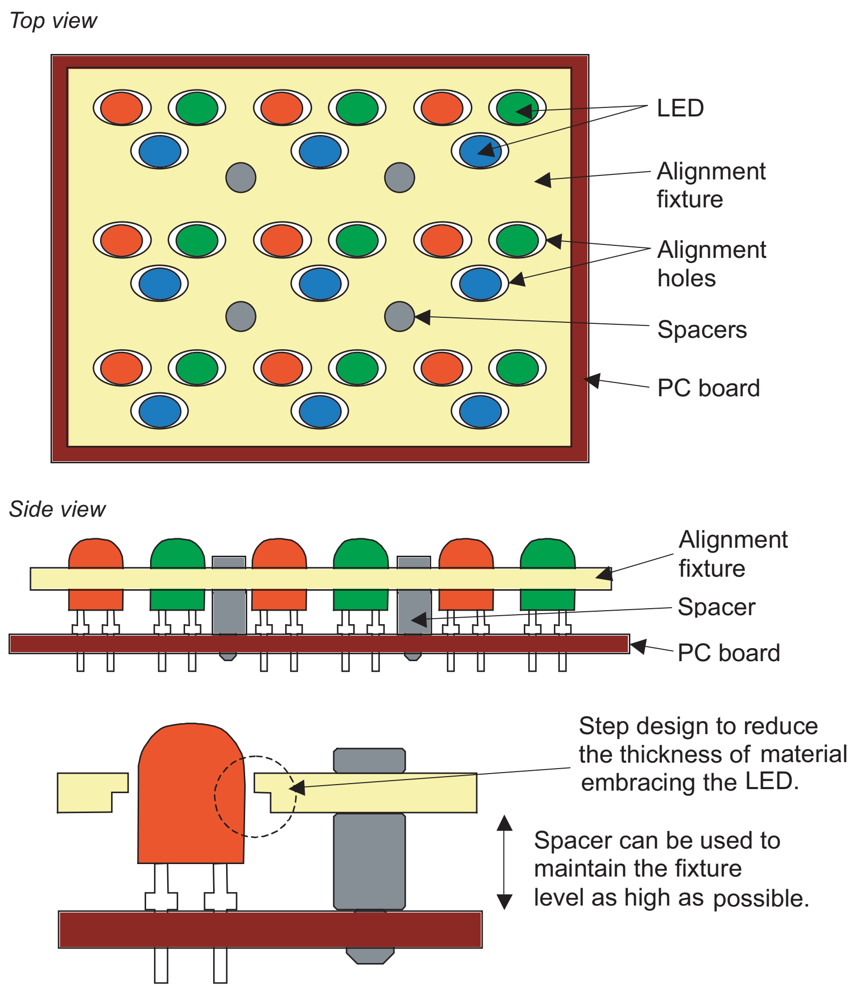


Figure 4. Illustration of the alignment fixture and spacers

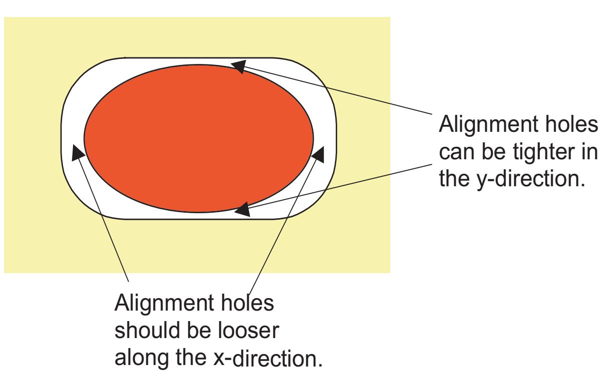


Figure 5. Alignment holes recommendation

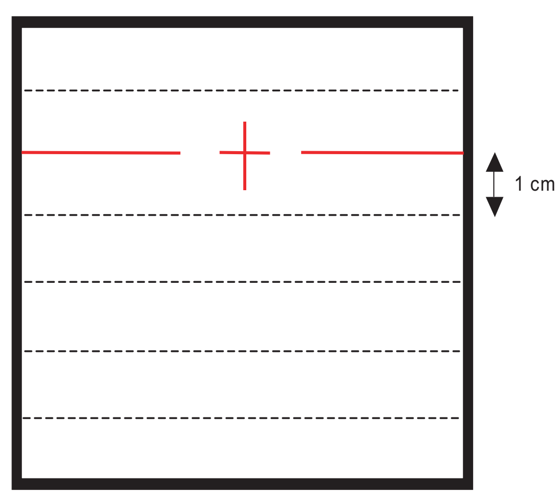
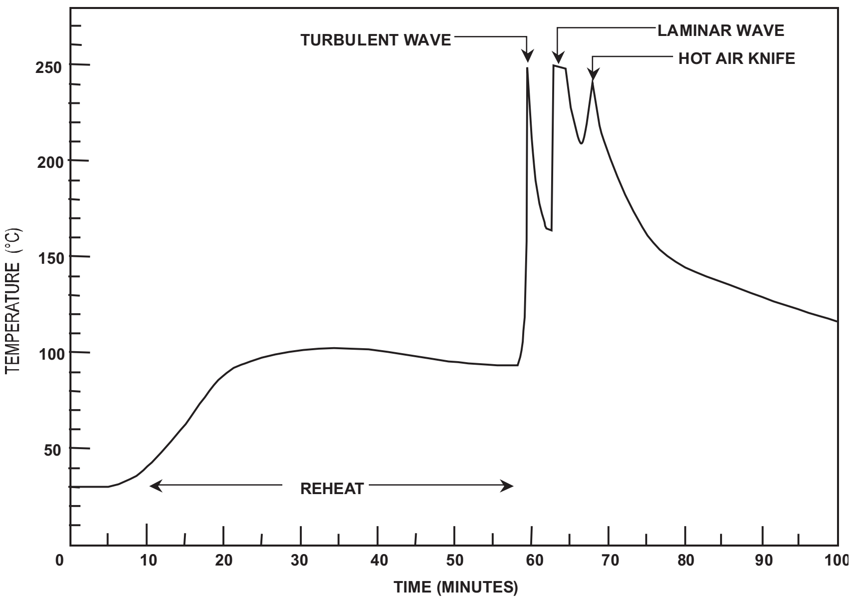


Figure 6. Heat resistant glass for measurement of solder wave contact time



Solder:
Sn63 (Leaded solder alloy)
SAC305 (Lead free solder alloy)

Flux: Rosin flux

Solder bath temperature: 245°C± 5°C

Dwell time: 1.5 sec – 3.0 sec

Note: Allow for board to be sufficiently cooled to room temperature before exerting mechanical force.

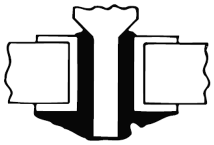
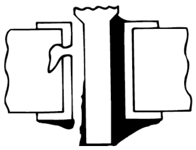
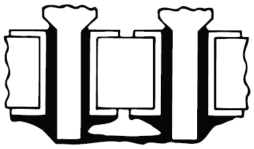
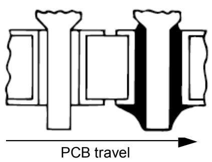
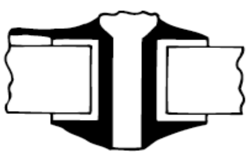
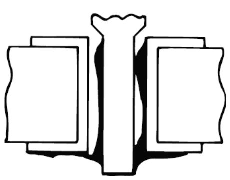
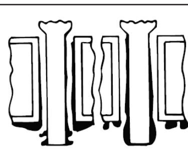
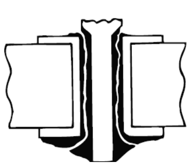
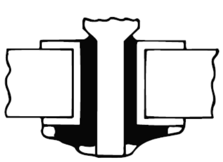
Figure 7. Example of wave soldering temperature profile for TH LED

Wave Soldering Profile Calibration

Wave soldering profile needs to be closely monitored to ensure that it will not induce excessive thermal stress to the LED and to ensure consistent solder joint quality. Wave soldering profile should be calibrated daily. For every product that uses different PC board, parameter fine tuning is needed to cater for the difference of heat mass between designs. One set of settings should not be applied directly on different types of product without proper assessment.

During profile calibration, actual PC board for the product should be fully loaded with components to simulate the actual heat mass. For the 1st calibration, a few thermocouples can be mounted at various locations to determine the highest and lowest temperature spots on the board. For subsequent measurement or daily calibration, these 2 spots need to be monitored by soldering thermocouples on the lead of the LED at the bottom of the board. The thermocouple wires should not be twisted. The 1st contact between the 2 wires of a thermocouple must be at the solder joint on the LED lead.

Common Soldering Defects for TH LED

Solder Connection Defect	Diagram	Possible Causes	Touch Up necessary	Corrective Action
Pin hole in fillet		Small particle of dross trapped in solder	No	Keep solder wave free of dross.
Blow hole in solder connection		Refer section below on blow hole	Cannot be touched up	Stop soldering process. Determine exact cause for blow hole.
Solder bridge between connection		Component lead too closely spaced. Part orientation in PCB. Excess solder. PCB immersed too deep in the wave. Leads picking up dross in the wave.	Yes	Ensure component lead is not closely spaced. Adjust the distance which PCB immersed in the wave. Clean solder dross. Increase solder temperature.
Solder drop out		Solder too hot. Conveyor speed too slow.	Optional	T_{solder} = 245°C±5°C Conveyor speed T_{dwell} = 1.5 to 3 seconds
Missed solder connection		Lead placed in shadow of other component. Poor wave height or dynamics.	Yes	Relocate component on PCB. Adjust wave height and flow rate for proper wave dynamics
Excess solder on top surface of PCB		Flux overflow onto top surface of PCB.	Optional	Adjust fluxer until flux just fills the plated through holes
Poor wetting on lead and PCB solder pad		Poor fluxing. Poor flux mixture. Improper preheat. Contamination on pre-soldered surface. Surface too heavily oxidized. Bleeding solder mask.	Yes	Adjust fluxer to insure through hole fill with flux; specific gravity of flux mixture. Preheat temperature 100°C ±5°C
Dewetting on component lead or PCB solder pad		Oxide or other contaminant build up. Poor surface plating. Lack of Solderability.	Yes. May not be effective	Prevent oxide build up prior to soldering. Inspect plating surface. Do a solderability check.
Cracks in solder connection		Excessive growth of Intermetallics. Too long a dwell time on solder wave.	Possible to remove solder and re-solder by hand.	Shorten dwell time to 1.5 to 3 seconds.
Rosin build up		Rosin rich flux, low on solvent and activator. Poor preheating.	Yes	Maintain flux mixture at proper specific gravity. Preheat bottom side PCB = +100˚C

Blow Hole

Blow hole is caused by out-gassing when the solder is in molten stage that blown up a hole in the solder joint. It may have only a minor effect on a solder connection on a single sided PC board without plated through holes (PTH), as the gas escapes from the top of the hole without weakening the solder fillet. In a PTH, out-gassing will displace the solder from the connection, leaving a void between the component lead and the walls of the PTH, as shown in Figure 8, which can have a catastrophic effect. LED without standoff is more susceptible to this issue compared to LED with standoff as the LED body will physically block the top of the PTH.

Below are possible causes for blow hole:

a. Irregular PTH wall trapping vapor when solder wetting occurs.

b. Out-gassing of residue from plating bath (organic or salt).

c. Physical blockage due to foreign material.

d. In adequate preheat to evaporate flux solvent

e. Component body blocking the escape path of evaporated gasses/moisture. Common for TH LED without standoff.

Remedy for blow hole:

a. Improve PTH quality to eliminate irregular PTH wall, refer Figure 9.

b. Investigate on the PCB PTH quality and cleanliness.

c. Bake the PCB to remove moisture or plating solution residue

d. Increase preheat temperature to effectively evaporate the flux solvent.

e. Redesign PCB to add in additional holes close to PTH for better out-gassing.

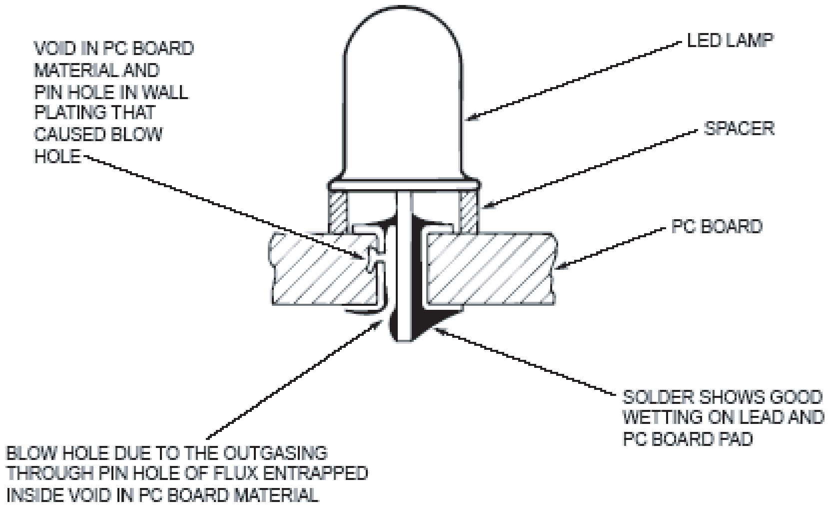


Figure 8. Typical characteristics of a blow hole defect in a through hole solder connection

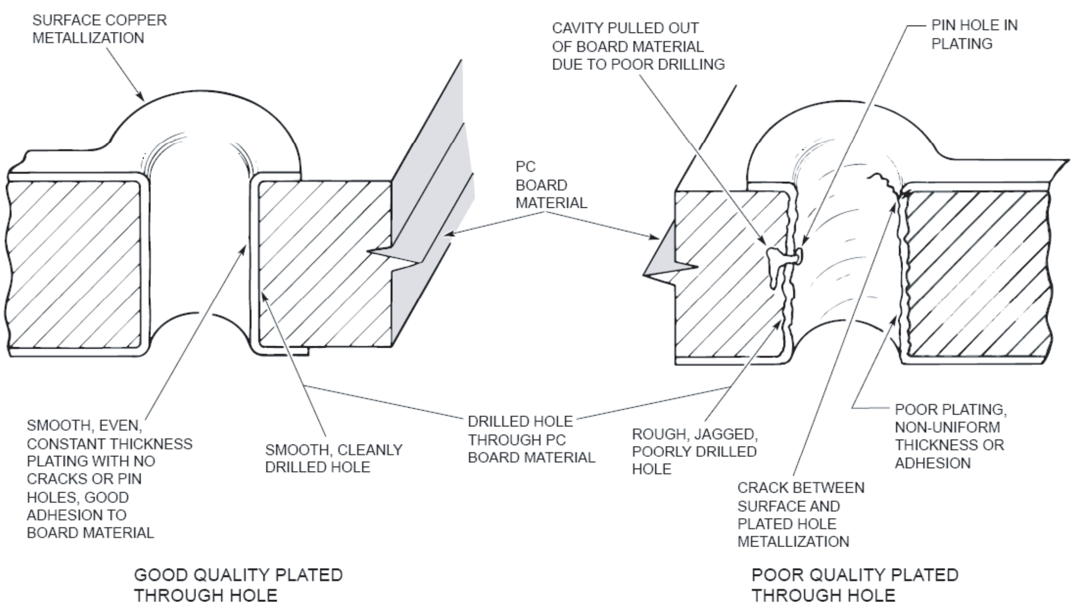


Figure 9. Attributes of good and poor quality plated through hole

Auto-insertion

TH LED is available in ammo pack form for auto-insertion. A properly adjusted auto-insertion process does not subject TH LED to excessive mechanical stress and is recommended for high volume production. During auto-insertion, TH LED lamps are inserted into PC board using insertion guide and plunger (Figure 10). At the same time it will be clinched by the clinch anvil to prevent LED from falling out. Usually, the clinching angle cannot be tuned by adjusting machine parameter but is depending on the type of clinch anvil used. Most commonly used clinching type for TH LED is N-type with 30° clinching angle as defined in Figure 11.

The PTH hole size should be determine based on the LED lead thickness to ensure easy insertion and proper wicking of molten solder up the hole by capillary action. Over-sizing the PTH can lead to twisted LED after clinching. On the other hand, under-sizing the PTH can cause difficulty inserting the components. The diameter of a PTH should be 0.34 mm to 0.44 mm larger than the diagonal dimension of the lead. Figure 12 shows the recommended hole size for Avago TH LED lamps. The solder pad diameter should be about two times of the diameter of the plated through hole.

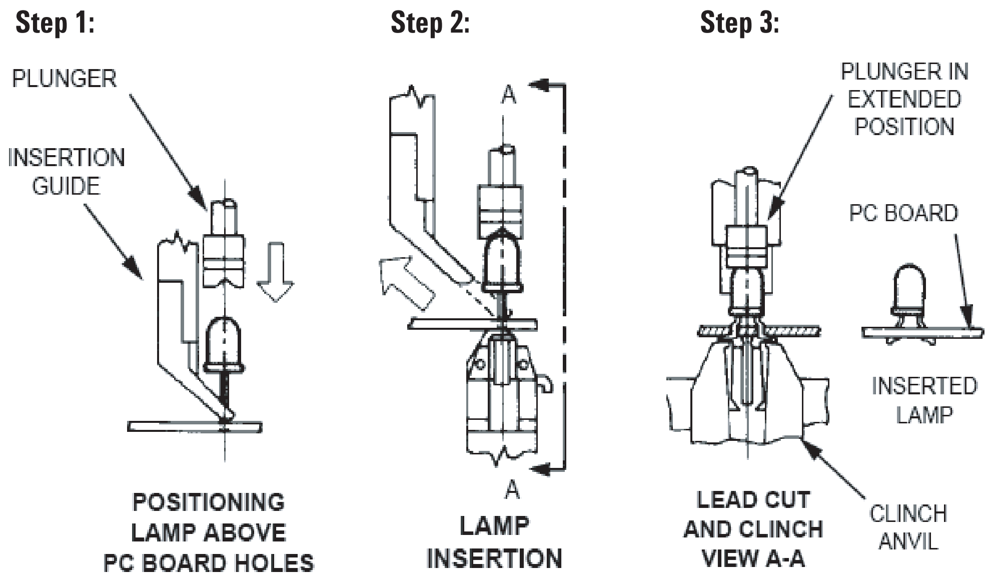


Figure 10. Example of auto-insertion of LED components

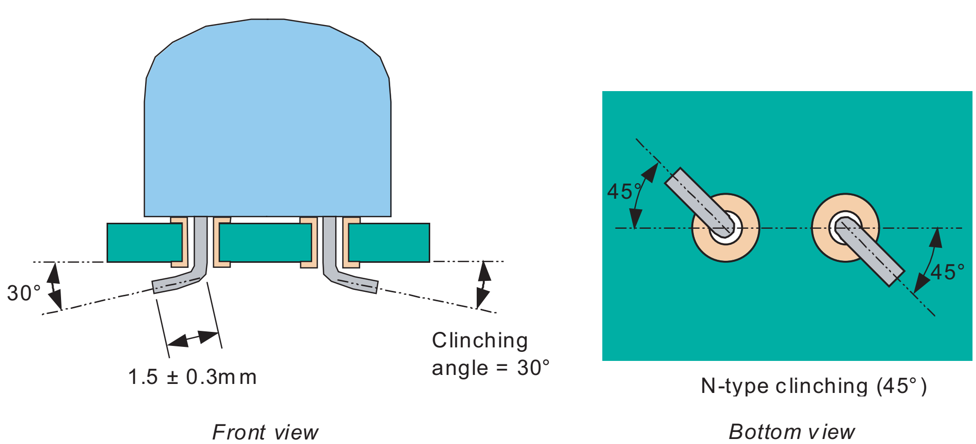
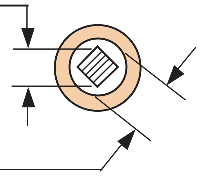


Figure 11. Clinching angle and N-type clinching



LED Component Lead Size	Diagonal	Plated Through Hole Diameter
0.45 x 0.45 mm (0.018 x 0.018 in)	0.636 mm (0.025 in)	0.98 to 1.08 mm (0.039 to 0.043 in)
0.50 x 0.50 mm (0.020 x 0.020 in)	0.707 mm (0.028 in)	1.05 to 1.15 mm (0.041 to 0.045 in)

Figure 12. Recommended PTH size for TH LED

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

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