

## Application Note 1027

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### Introduction

The modern printed circuit (PC) board is assembled with a wide variety of semiconductor components. These components may include leaded light emitting diode (LED) lamps and displays in combination with other leaded and surface mounted components. The configuration of a PC board assembly can be single sided, double sided or multilayer with circuit elements as small as 6 mil traces on 8 mil centers and a component count ranging as high as 2000. A typical configuration may have leaded LEDs and other leaded components inserted into holes from the top side of the board and surface mounted components soldered to the backside of the board. The quantity of solder connections will be many times the component count. In some cases it is no longer cost effective or physically possible to repair faulty solder connections on PC board assemblies, as in very high volume production or when multilayer boards are used. Therefore, the solder connections must be good on the first pass through the soldering process. The soldering process is a prime factor in determining assembly yields, manufacturing costs, and long term reliability of a PC board assembly.

The effectiveness of the soldering process is a function of the care and attention paid to the details of the process.

It is important for display system designers and PC board assembly engineers to understand the aspects of the soldering process and how they relate to LED components to assure high yields. A carefully controlled soldering process that is tuned to the requirements of LED devices will also successfully solder other semiconductor components. Post solder assembly yields will be maximized and long term reliability will be enhanced.

This application note provides an in-depth discussion of the soldering process and how it relates to leaded LED lamps and display components, with the objective of serving as a guide to achieving high yields for solder connections.

## An Abstract of Key Points

LED components may be either wave or hand soldered in the same manner as other semiconductor components. High yields are achieved by taking into account certain characteristics of LED components and factoring into the soldering process the following key points:

1. The leads for most plastic LED components are a copper alloy with tin plating. A few have solder dipped leads. Non-plastic LED components typically have solder dipped leads.
2. Plastic LED components have their LED chips die attached directly to the cathode leads.

Therefore, care must be taken to keep thermal and mechanical stresses applied to LED component leads during the soldering process to a minimum.

3. Certain other precautions need to be taken into account with some LED components. See the section on "Precautions on Soldering LED Components."
4. For wave soldering, it is important to set up the soldering machine following the profiles below (refer to each component's technical datasheet for which profile to use).

Preheat temperature = 100°C

Solder = SN63 (leaded solder)  
or SAC305 (lead-free solder)

Profile A: Solder wave temperature = 245°C ± 5°C (maximum peak temperature 250°C). Dwell time in the solder wave = 1.5 to 3 seconds (maximum 3 seconds)

Profile B: Solder wave temperature = 255°C ± 5°C (maximum peak temperature 260°C). Dwell time in the solder wave = 3 to 5 seconds (maximum 5 seconds)

Rosin flux = ROL0 or ROL1

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

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 seconds maximum. The LED must be allowed to cool to room temperature prior to second application on the same LED.
6. Most LED components will withstand an aqueous post solder cleaning process with a 15 minute exposure to water heated to 60°C
7. A process control program paying careful attention to the details of the soldering process yields a low defect rate in the solder connections.

## Leads on LED Components

The lead base metal and plating for LED components is given in Table 1. Plastic LED have leads made mild steel.

Segment displays and Smart Displays will have either copper alloy or phosphor bronze leads with tin plating or solder dipped with lead-free solder.

The purpose of this lead plating is to assure component solderability by inhibiting the buildup of oxides on the lead base metal. LED components should be stored in a manner to protect the lead plating from being exposed to sulfur, dirt, grease and other contaminants. The easiest method is to store LED components wrapped in ESD protective packaging.

Never store LED components in paper bags or cardboard containers. The sulfur in the paper will react with the lead plating forming a sulfide that may inhibit solderability.

## Solder and Flux

### Solder

The most commonly used conventional solder alloy is Sn63. For lead-free soldering, solder alloy recommended by IPC is SAC305. Table 2 lists some of the commonly used solder alloy in semiconductor industry.

**Table 1. Lead Base Metal and Plating for Through Hole LED Component**

LED Component Family	Lead Base Metal	Lead Plating
<b>Plastic LED Lamps</b> T-1, T-1¾, Rectangular Flat Top	Mild Steel	Sn
Subminiature Family	Copper Alloy	Sn
<b>Segment Displays</b> .3/.43/.56/.8 Leadframe Seven Segment Displays .3/.43/.56/.8 PCB Seven Segment Displays Light Bars, Bar Graph Arrays	Copper Alloy	Sn
<b>Smart Dot Matrix Displays</b> Ceramic Package 4x7 Numeric/Hexadecimal Display Plastic 5x7 Smart Alphanumeric Displays	Alloy 42 Phosphor Bronze	Solder Dipped (SnAgCu) Sn
Hermetic 5x7 Smart Alphanumeric Displays	Copper Alloy	Solder Dipped (SnAgCu)

**Table 2. Solder Types 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
Sn63Pb37 (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 temperature for each alloy, users are advised to verify these temperature values before use.

## Flux

The purpose of flux is to remove the oxides from the surfaces to be soldered to permit proper wetting by the solder, see Figure 1a. Proper wetting by the solder to the surfaces of both the component leads and the PC board metallization assures good connections. A flux performs the following functions in the soldering process:

- Removes oxides and penetrates surface films.
- Prevents oxidation during heating.
- Lowers surface tension on the device leads and PC board metallization.

A flux must also have the following properties:

- Be easily displaced by molten solder.
- Be non-injurious to personnel, LED components and PC boards.
- 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.

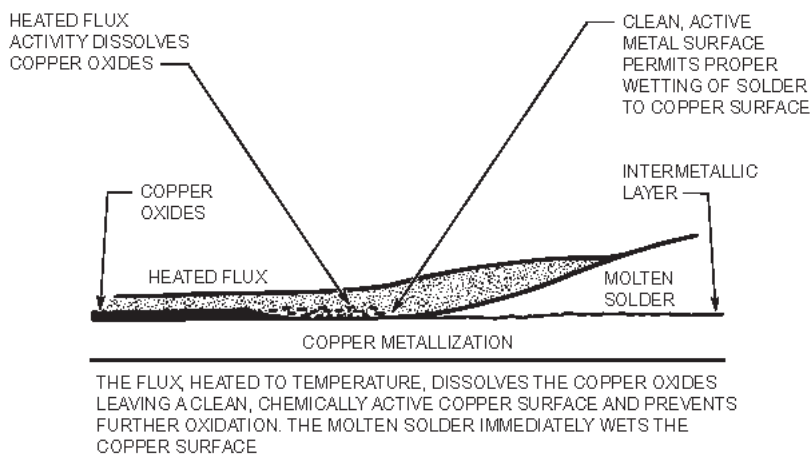
Copper mirror testing, corrosion testing, electrochemical migration, surface insulation resistance and halide content will determine flux activity levels. The three main flux/flux residue activity levels are:

L : Low or no flux/no flux residue activity

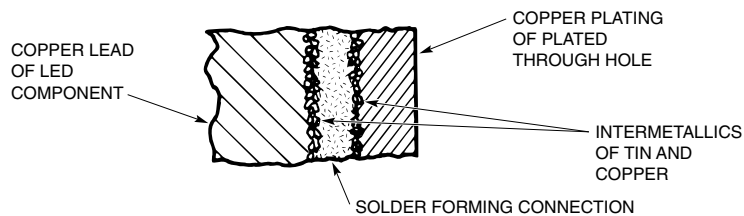
M: Moderate flux/flux residue activity

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 3 for details.



**Figure 1a. Flux Activity on Copper Metallization**



**Figure 1b. Intermetallics Within a Solder Connection**

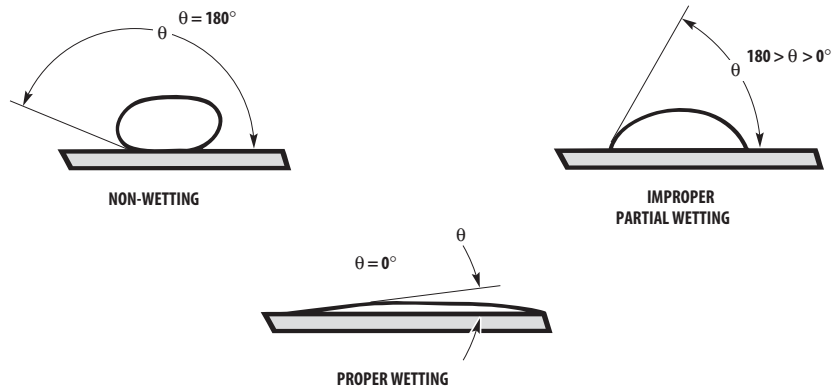


Figure 1c. Solder Wetting on a Copper Surface as Defined by Solder/Copper Interface Dihedral Angle  $\theta$

Table 3. 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	OHM0
		>2.0%	H1	OHM1
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

## Proper Wetting

Solder must form a thin intermetallic compound with each metal surface to be soldered, as shown in Figure 1b. To do so, the solder must wet each surface. Without flux action to remove surface oxides and other contaminants, the solder cannot wet a surface and will ball up like water on wax.

See Figure 1c. On a clean active metal surface, solder will overcome cohesive forces and flow out over the surface. The extent that solder spreads over a metal surface in a given period of time is called "spread rate". The better the wetting action the faster the spread rate.

## The Solderability Test

The purpose of the solderability test is to determine if the leads on an LED component are solderable. The test examines the lead base metal for an active surface under the plating to permit wetting, as determined by the amount of solder coverage on the leads.

Please refer to JESP 22-B102E for details of solderability test.

Avago Technologies specifies a 90% solder coverage for commercial LED components. The solder coverage should be smooth across the surfaces of the leads below the seating plane without evidence of nonwetting, as illustrated in Figure 2. Areas where nonwetting may be evident are at the two tie bar shear locations. The tie bars are lead frame support elements that are sheared away during the component assembly process. The upper tie bar shear is typically above the seating plane and the lower tie bar shear is at the ends of the leads.

Both locations may have exposed lead base metal and some flux is not active enough to clean off the oxides.

This condition is normal and should not interfere with a soldering process.

## Precautions On Soldering

### LED Components

When properly soldered into a PC board, LED components exhibit excellent reliability. Also, it is more cost effective to solder LED displays into a PC board than to use sockets. Therefore, soldering is preferred. However, care must be taken during the PC board assembly and soldering processes to prevent damage to an LED component, especially a plastic component.

### Plastic Encapsulated LED

#### Components

The construction of a plastic encapsulated LED component is conceptually diagrammed in Figure 4. This type of construction is similar for plastic LED segment bar graph arrays, light bars, 7-segment displays, and lamps. In a plastic encapsulated component, the LED chip is die attached directly to the cathode lead and wire bonded to the anode lead. In this kind of construction, the encapsulating epoxy is the only supporting structure for the component leads. The cathode lead is the primary thermal and mechanical stress path to the LED chip. It is imperative that the process of inserting the component leads into a PC board and soldering does not place excessive mechanical and thermal stresses on the part that could result in component failure. The following precautions are recommended:

1. Insure there are no mechanical stresses on the leads after the LED component has been inserted into the PC board.
2. If necessary, use fixturing to hold the LED component in proper orientation with respect to the PC board during the soldering process.
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. Immediately exiting from wave soldering machine, the PC board and LEDs are still hot after exposed 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. After the assembly cools down, the alignment fixture should 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.
5. Set and maintain the soldering process to conform to recommended temperature and dwell time in the solder wave. User is advised to perform daily check on the soldering profile to ensure that it is always conforming to the recommended condition.

6. Solder wave contact time can be measured by using a heat resistant glass with grid line on top as shown in Figure 3.
7. If PC board contains both through-hole LED components and other surface mount components, it is recommended to solder the surface mount components 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 through-hole LED components. 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 through-hole LED and surface mount components together during wave soldering.
8. 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 boards. Figure 15 and 16 show the Avago recommended temperature profiles for through hole LED components. Please follow individual product datasheet for respective recommended profile.
9. If possible, cut the leads of LED lamps to length after soldering process. The solder connection forms a mechanical ground which prevents the mechanical stresses due to lead cutting from travelling to the LED chip die attach and wire bonds. This is highly recommended for hand solder operations, as the excess lead length also acts as a small heat sink.
10. 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

## Auto-insertion of LED Lamps

LED lamps may be obtained packaged on tape and reel for auto-insertion. A properly adjusted auto-insertion process does not subject LED lamps to any excessive mechanical stress and is recommended for high volume production. For details of this process refer to Application Note 1021, *Utilizing LED Lamps Packaged on Tape and Reel*.

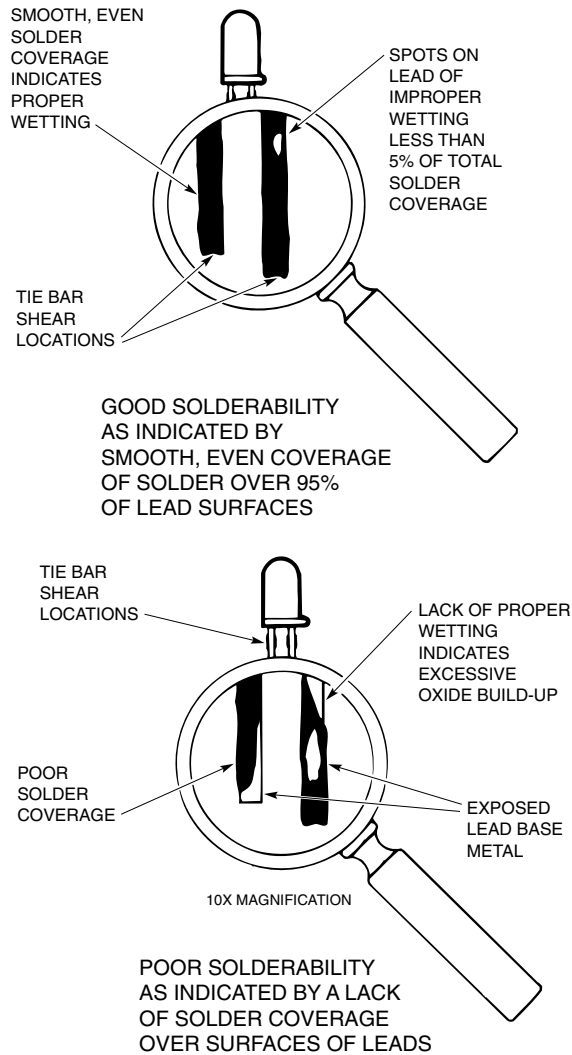


Figure 2. Solderability Test for LED Components

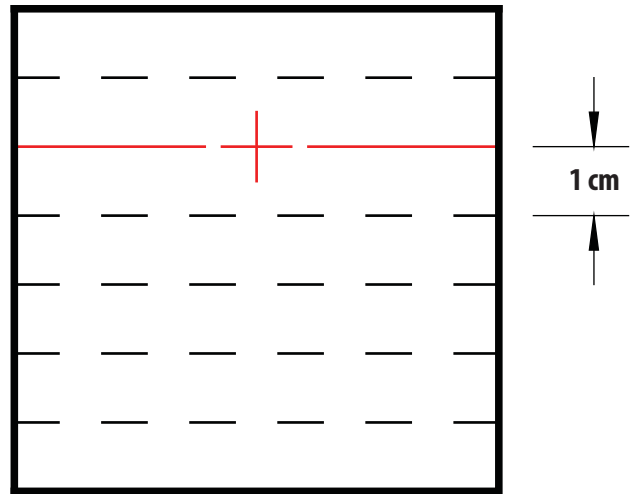


Figure 3. Heat resistant glass for measuring the solder wave contact time

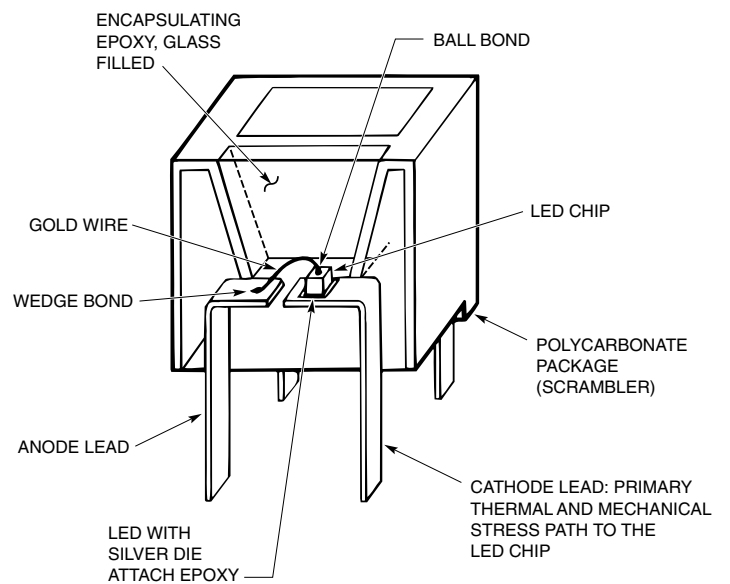


Figure 4. A Conceptual Drawing, Cut Away View, Showing the Construction of a Plastic Encapsulated LED Component. Based on the Construction for a Stretched Segment Ten Element Array



### Preforming and Cutting Leads to Length Prior to Soldering

The leads of an LED lamp may be preformed and/or cut to length prior to insertion and soldering into a PC board. Figure 5 illustrates the necessary precautions to prevent damage to the component:

1. Support the LED lamp by the leads during the lead forming and cutting operations.
2. The support should form a mechanical ground at the base of the LED lamp package to prevent the mechanical stresses placed on the leads from reaching the LED chip die attach and wire bonds.
3. For ongoing production, it is recommended that tooling be made to precisely form and cut the leads to length rather than rely upon a hand operation.

### Caution—Preheating Plastic Encapsulated LED Devices

In a wave soldering process, preheating a plastic LED component with a polycarbonate package above 120°C, as measured on the top side of the PC board, is not recommended. The polycarbonate cannot withstand temperatures above this level. This caution holds for encapsulated segment displays, light bars and bar graph arrays, 101 element arrays, and plastic alphanumeric displays

### Caution—Vapor Phase Reflow Soldering and Plastic LED Components

Plastic LED components that have polycarbonate packages, such as segment displays, light bars and ten element arrays, and those components with polycarbonate lenses such as 101 element arrays, and plastic alphanumeric smart displays are not recommended for use in vapor phase reflow soldering processes. The reason is that the polycarbonate package or lens will deform at the elevated temperature of fluorocarbon vapor.

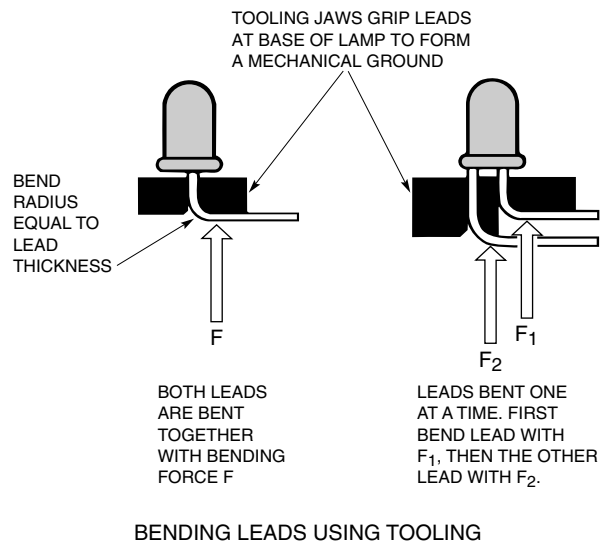
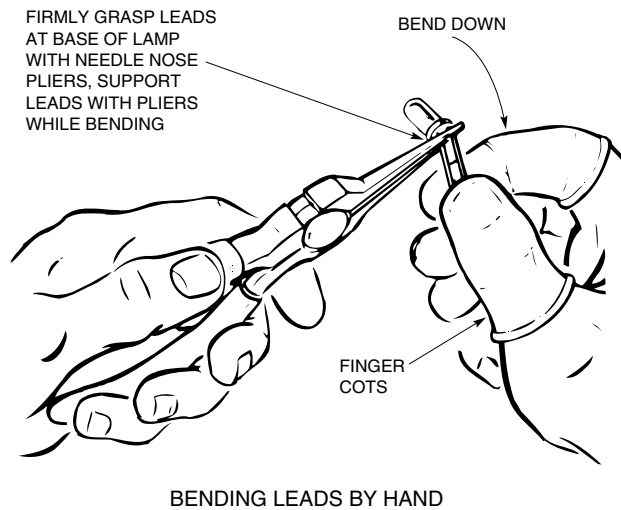


Figure 5. Proper Methods of Bending the Leads of a Plastic LED Lamp Prior to Soldering Into a PC Board. Support LED Lamp Only by the Leads During the Bending Operation

## PC Board Design for Effective Soldering

It is necessary to design and construct the PC board to assure proper lead insertion, solderability, and long term reliability. The base material for the board should be selected to meet performance and cost objectives, but special attention must also be given to board fabrication, solder masking and surface plating, lead hole sizes, and component orientation to assure solderability.

### Plated Through Holes In the PC Boards

Two critical operations in the fabrication of a PC board are the drilling and plating of the lead holes. As shown in Figure 6, the lead holes must be drilled and plated as smooth, round cylinders. The objectives are:

1. To obtain within each hole copper metallization and plating that forms a smooth wall surface of constant thickness, without voids, that permits good wetting to assure solder flowing up the hole by capillary action.
2. Prevent the formation of cavities in the board base material within the wall surface area, due to poor drilling, and pin holes in the copper metallization and plating that cause blow holes in the solder connection.

## Copper Metallization and Solder Masking

Pure ½ or 1 ounce copper metallization is sufficient for the electrical traces on PC boards for most applications involving LED components. Any polymer solder masking should be placed directly over the copper metallization. When solder masking is placed over the clean active surface of copper metallization it will not blister or peel off during the soldering process. Placing solder masking over solder coated metallization is not recommended, as it may blister and peel off when exposed to hot solder. The difference is shown in Figure 6. This is caused by the heat of the soldering process melting the solder coating underneath the masking material.

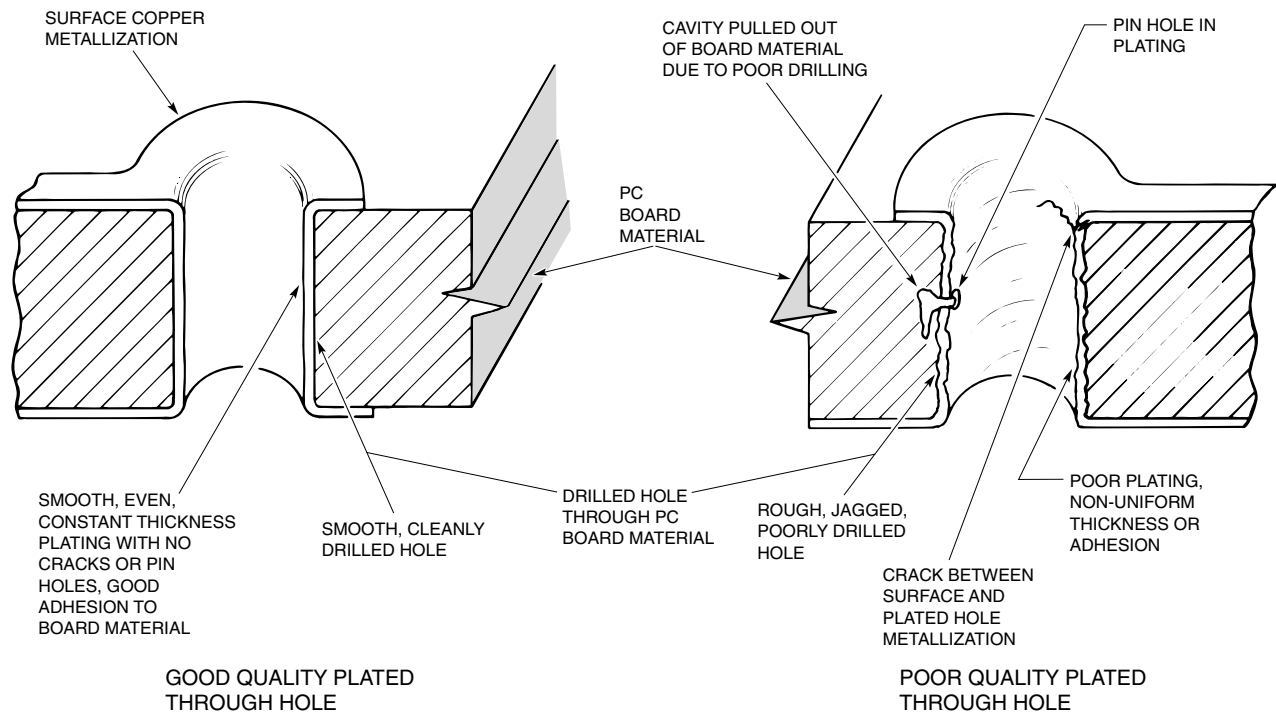
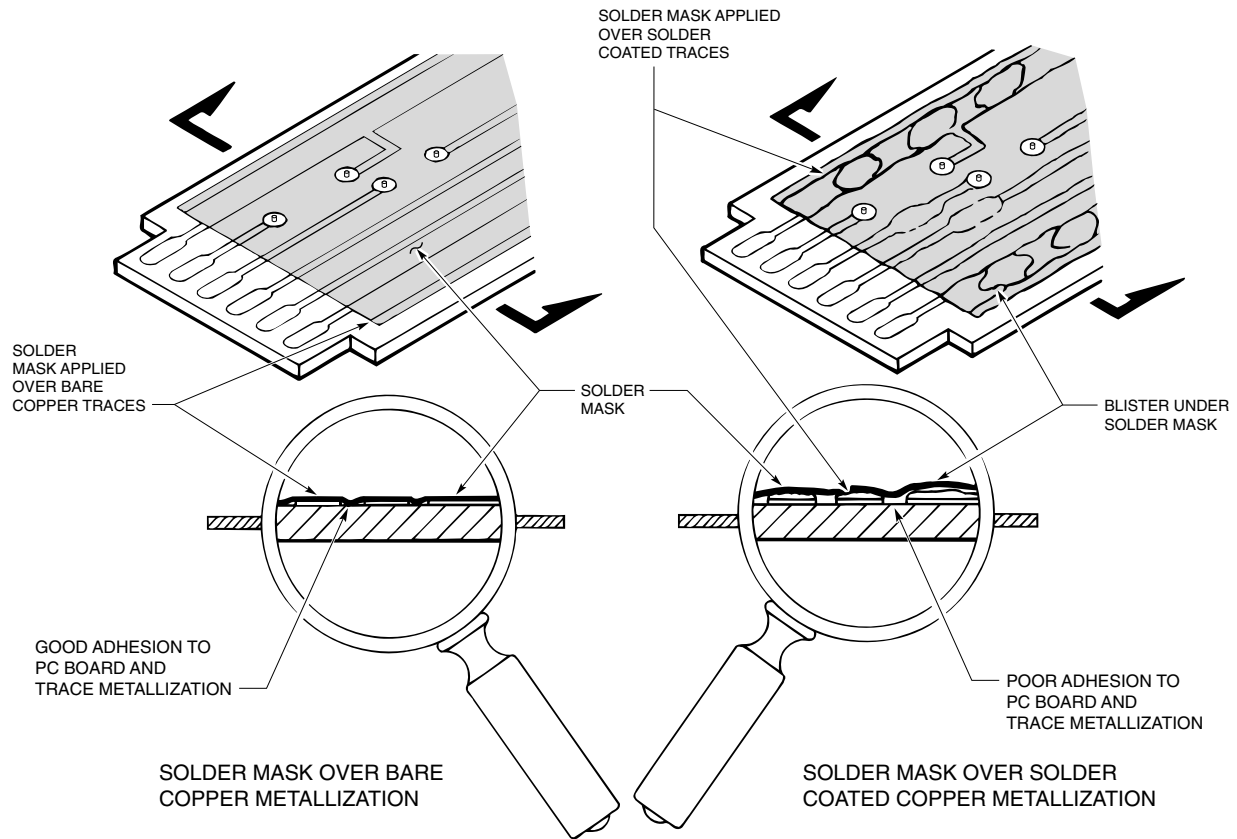


Figure 6. Attributes of Good and Poor Quality Drilled and Plated Through Holes in a Printed Circuit Board



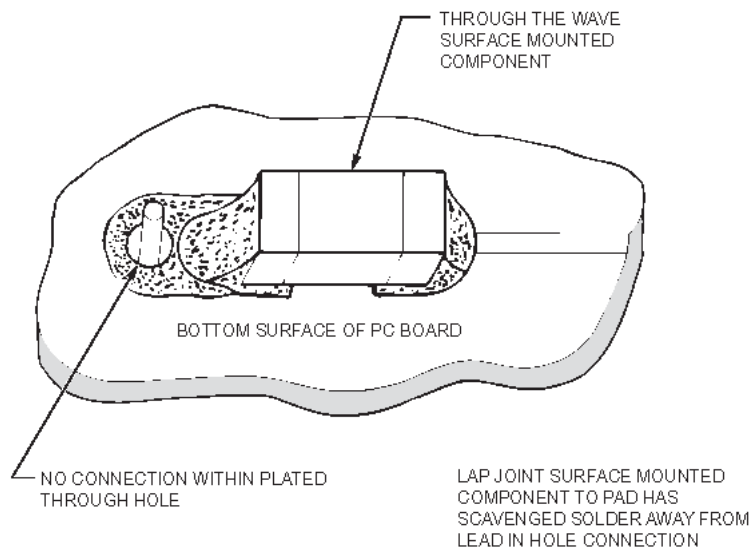
**Figure 7. The Difference Between Solder Masking Over Bare Copper and Solder Masking Over Solder Coated Copper After a PC Board has Passed Through a Wave Soldering Process**

### PC Board Layout Considerations

Three important PC board design guidelines that will assure proper soldering in a wave soldering process are as follows:

1. Orient LED display DIP (dual in-line package) components on the PC board so their lead rows are perpendicular to the solder wave, as shown in Figure 8. This orientation has the leads within a row passing through the solder wave one at a time, reducing the probability of solder bridging.
2. Do not have the backside surface mounted component share the same solder pad with a leaded LED component. When a backside surface mounted component and a leaded component share the same solder pad, the surface mounted component will scavenge solder away from the plated through hole, leaving the through hole connection improperly soldered, as shown in Figure 9.
3. The shape of the PC board should be rectangular. The PC board should be placed into the fingers of a wave solder machine conveyor so that the long dimension is perpendicular to the solder waves, as shown in Figure 10. Small size and odd shaped PC board designs are extremely difficult to solder in wave solder machines. These kinds of boards should be made as post solder "break apart" sections of a larger rectangular board. The outlines of the small or odd shaped PC boards should be scribed for post solder break apart for separation, rather than having pre-routed slots with break away tabs outlining the individual boards.

Pre-routed slots can permit solder to flow up onto the topside surface of individual boards with potentially disastrous results. Pre-routed slots can be used if slot inserts are used to prevent the possibility of solder flowing up onto the topside surface.



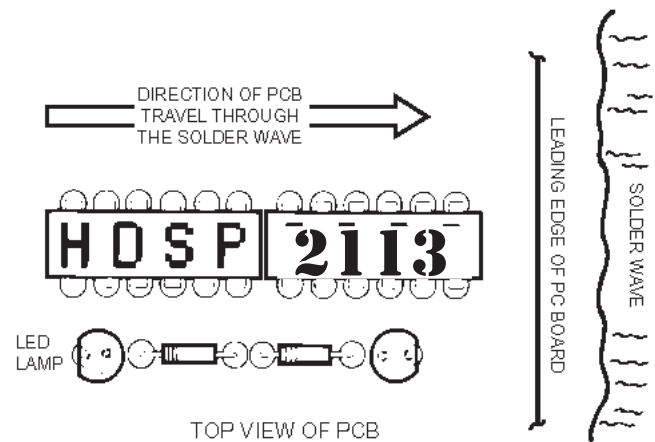
**Figure 9. The Effect of Having the Lead of a Leaded LED Component Share the Same Pad as a Through the Wave Surface Mounted Component**

### PC Board Plated Through Holes and Solder Pad Sizes for LED Leaded Components

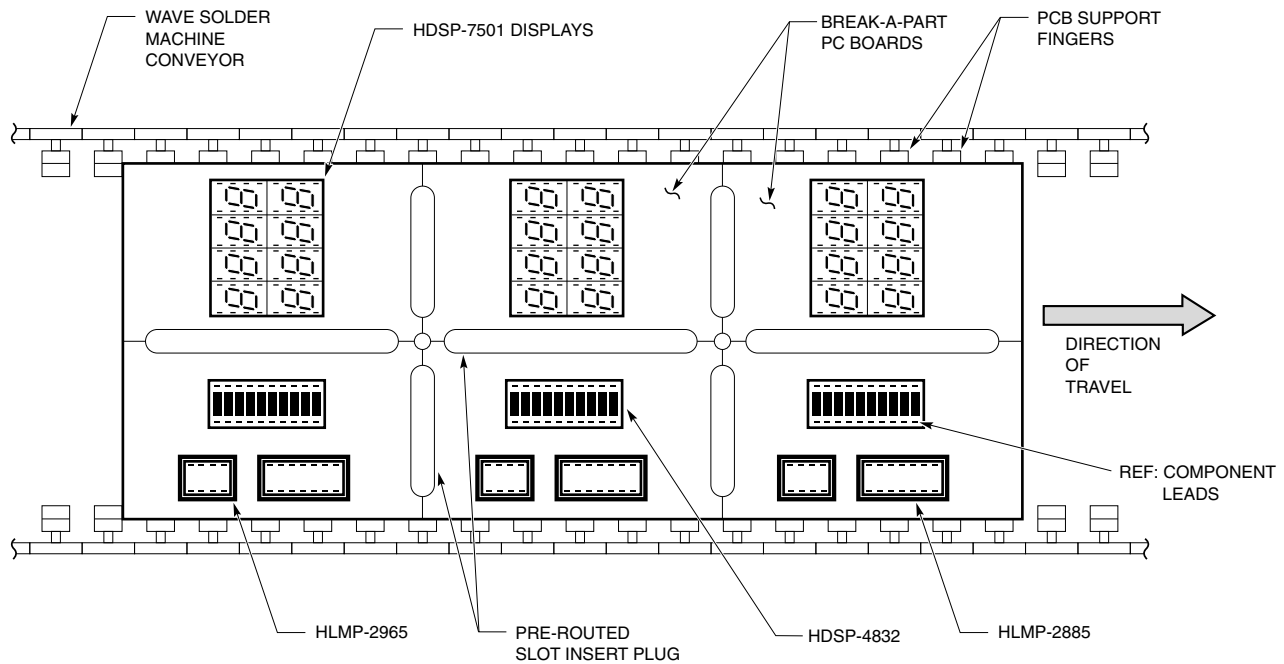
As shown in Figure 11a, the plated through holes in the PC board must be sized to coordinate with the size of the leads on an LED component to assure easy insertion and proper wicking of molten solder up the hole by capillary action.

The diameter of a plated through hole should be 0.33 mm (0.013 inch) to 0.432 mm (0.17 inch) larger than the diagonal dimension of the lead. The solder pad diameter should be about two times larger than the diameter of the plated through hole.

The maximum pad size for soldering an HLMP-6000 series subminiature LED lamp to the topside surface of a PC board is shown in Figure 11b. A larger pad size may require excessive heating to form the solder connection that could damage the subminiature LED lamp.



**Figure 8. Recommended Orientation of DIP Packaged LED Display Components on a PC Board to Reduce Solder Bridging**



**Figure 10. Break-Apart PC Boards Loaded Into the Conveyor of a Wave Soldering Machine as a Single Larger PC Board Assembly**

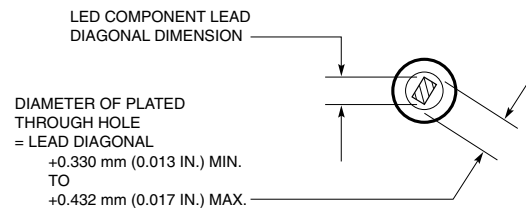
When using “lands” as current carrying elements, the through holes should be thermally relieved as shown in Figure 11c. Thermal relieving prevents the heat of soldering from flowing out into the “lands” causing cold solder connections.

### The Attributes of a Good Solder Connection

#### Plated Through Hole Solder Connection for a Leaded LED Component

An ideal plated through hole solder connection for a leaded LED component is shown in Figure 12a. The solder connection exhibits well contoured fillets on the top and bottom of the board, indicating the solder has flowed up through the hole. The radius of the fillets is approximately one to two times the thickness of a lead. The connection is free of voids and cracks and the solder has properly covered the exposed lead, indicating proper wetting. The amount of solder is sufficient to make the connection mechanically strong.

The surface of the solder fillet should appear dull (low in reflectance), not bright or shiny. A bright or shiny surface indicates the presence of a brightener in either the component lead plating or in the PC board metallization. Brightening agents weaken a solder connection and can cause failure.



LED Component Lead Size	Diagonal	Plated Through Hole Diameter
0.457 x 0.457 mm (0.018 x 0.018 IN)	0.646 mm (0.025 IN)	0.976 to 1.078 mm (0.038 to 0.042 IN)
0.508 x 0.254 mm (0.020 x 0.010 IN)	0.568 mm (0.022 IN)	0.898 to 1.000 mm (0.035 to 0.039 IN)
0.508 x 0.508 mm (0.020 x 0.020 IN)	0.718 mm (0.028 IN)	1.049 to 1.150 mm (0.041 to 0.045 IN)
0.508 x 0.381 mm (0.020 x 0.015 IN)	0.635 mm (0.025 IN)	0.965 to 1.067 mm (0.038 to 0.042 IN)
0.508 x 0.305 mm (0.020 x 0.012 IN)	0.592 mm (0.023 IN)	0.923 to 1.024 mm (0.036 to 0.040 IN)
0.635 x 0.635 mm (0.025 x 0.025 IN)	0.898 mm (0.035 IN)	1.258 to 1.330 mm (0.048 to 0.052 IN)
0.540 x 0.254 mm (0.021 x 0.010 IN)	0.597 mm (0.023 IN)	0.927 to 1.029 mm (0.036 x 0.040 IN)
0.508 x 0.203 mm (0.020 x 0.008 IN)	0.547 mm (0.022 IN)	0.877 to 0.979 mm (0.036 to 0.039 IN)
0.584 x 0.508 mm (0.023 x 0.020 IN)	0.774 mm (0.030 IN)	1.104 to 1.206 mm (0.043 to 0.047 IN)
0.506 mm DIA (0.020 IN DIA)	-	0.838 to 0.940 mm DIA (0.033 to 0.037 IN DIA)

**Figure 11a. Recommended PC board Plated Through Hole Size for LED Component Leads. Please follow respective datasheet if it is otherwise stated.**

### The Lap Connection for a Subminiature LED Lamp

The HLMP-6000 series subminiature LED lamps may be mounted to the surface of a PC board with a lap connection, as shown in Figure 12b. A good lap connection has the gap between the lead and the pad filled with solder and minimal solder on top of the leads. The radius of the fillet should be equal to the thickness of the lead, a nominal 0.20 mm (.008 inch). The accurate placement of the lead on the pad should be so the lead covers ½ the length of the pad, and the lead to pad mismatch should be no more than 25% of the lead width. The solder connections may be made by hand using a 315°C temperature controlled iron, with a time period of 1 to 2 seconds required to solder each lead.

These subminiature lamps will not survive a through the wave soldering process.

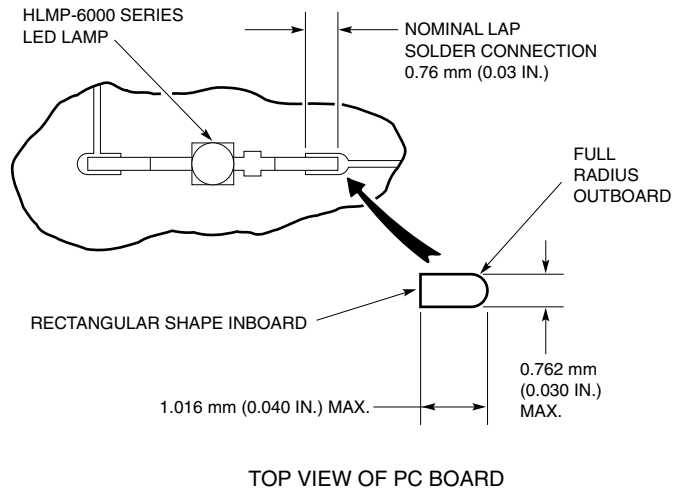
It is recommended that an off-set bend be formed in both leads of the subminiature lamp to act as strain relief.

### Solder Connection Defects and Touch-Up

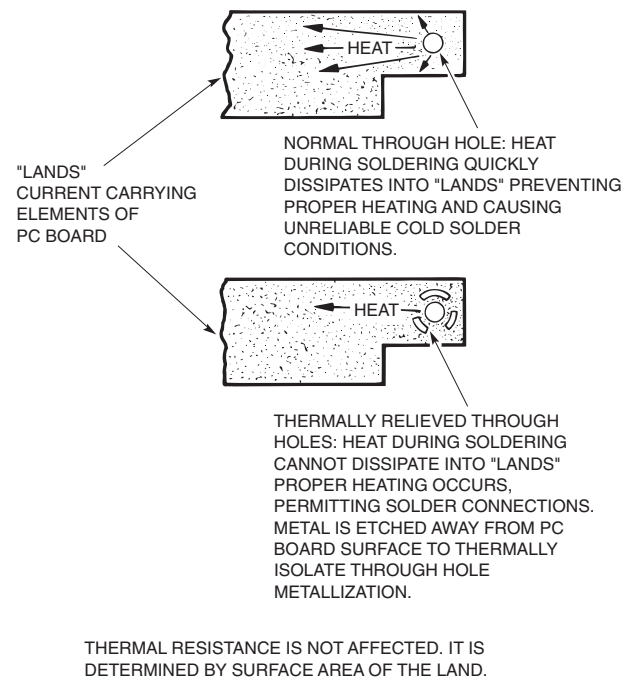
The important part of a through hole solder connection is formed by the solder that flows between the lead and the plated through hole, as illustrated in Figure 12. It is this thin film of solder that provides the electrical connection and all of the mechanical strength. The fillet actually does not add to the integrity of the connection, but is usually inspected as an indicator of the quality of the connection, a carry over from single sided PC boards. For a single sided PC board without plated through holes, the integrity of the fillet is most important, as it is the fillet that forms the electrical connection and provides the mechanical strength.

Touch-up is a hand soldering operation that is placed immediately after a wave solder operation. The purpose is to correct soldering defects which are observed by visual inspection. Some defects are cosmetic while others affect functionality.

Table 5 lists defects that may occur in a through hole solder connection formed with a wave soldering process. Cosmetic defects such as pits and dropouts do not need to be touched up since they do not reduce the integrity of a connection. Solder bridges and missed connections affect electrical operation and must be corrected. Defects such as nonwetting and blow holes require special attention.



**Figure 11b. The Maximum Solder Pad Size for a Plastic Subminiature LED Lamp**



**Figure 11c. Thermally Relieved Through Holes to Allow Good Solder Connections**

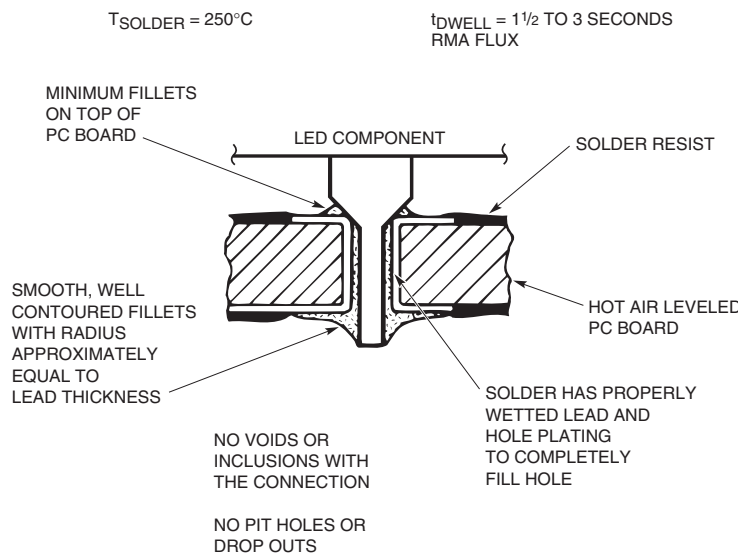
## Nonwetting

Nonwetting is evident when the solder does not flow up through a plated through hole and/or does not evenly cover the LED component leads or the PC board solder pads.

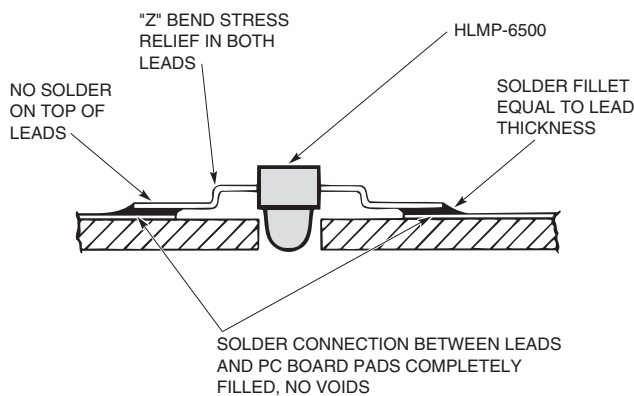
A probable cause is some form of contamination or oxide buildup on either the component leads or the metallization on the PC board, or both. Cleaning the leads and the PC board to remove the contamination will typically remedy this condition.

The leads on an LED component may be cleaned by dipping them into one of the commercially available lead conditioners. Usually an immersion time of one to two seconds is sufficient to remove any oxide and contaminant build up. The leads must be thoroughly washed to completely remove the conditioner.

**CAUTION:** Do not immerse the package of an LED component in the conditioner fluid. A lead surface conditioner may contain dilute hydrofluoric acid, or other strong active agents, that will have a damaging effect on the package of the LED component.

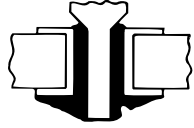

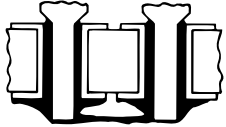
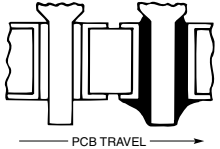
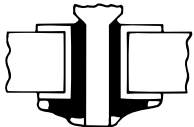

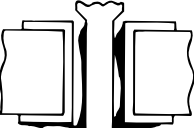
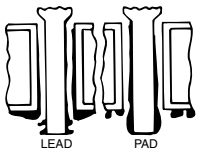
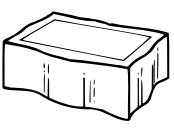
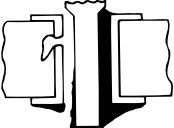



**Figure 12a. The Attributes of an Ideal Through Hole Solder Connection**



**Figure 12b. The Attributes of Ideal Hand Soldered Lap Connections for a Subminiature LED Lamp (Shown mounted Inverted to Illuminate a Membrane Switch Panel)**

**Table 4. Through Hole Solder Connection Defects**

Solder Connection Defect	Diagram	Possible Causes	Touch Up Necessary	Corrective Action
Pit hole in fillet		Small particle of dross trapped in solder.	No	Keep solder wave free of dross.
Solder drop out		Solder too hot. Conveyor speed too slow.	Optional	$T_{\text{SOLDER}} = 245^{\circ}\text{C} \pm 5^{\circ}\text{C}$ Conveyor speed $t_{\text{DWELL}} = 1\frac{1}{2}$ -3 seconds
Solder bridge between connections		Component leads too closely spaced. Part Orientation in PCB. Excess solder. PCB immersed too deep in the wave. Leads picking up dross in the wave.	Yes	Layout PCB per Figure 8. Ensure component leads are not too closely spaced. Clean solder dross. Increase solder temperature. Adjust PCB immersion level.
Missed solder connections		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.
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.
Excessive 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 holes fill with flux; specific gravity of flux mixture; preheat temperature 100°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; preclean; inspect plating surface; do a solderability check.
Deformed polycarbonate package of plastic LED display/light bar		Top surface PCB preheat temperature exceeded 120°C; Duration in solder wave too long.	Replace LED unit.	Top surface PCB preheat not to exceed 120°C max. $t_{\text{SOLDER}} = 1\frac{1}{2}$ -3 seconds
Blow hole in solder connection		See section on blow holes, Figure 13.	Can not be touched up.	Stop soldering process. Determine exact cause for blow hole.
Cracks in solder connection		Excessive growth of intermetallics; too long a dwell time on solder wave.	Possible to remove solder and resolder by hand.	Shorten dwell time to 1½ to 3 seconds.



## Blow Hole Defects

A blow hole is caused by outgassing from a void in the wall of a through hole. It may have only a minor effect on a solder connection on a single sided PC board without plated through holes, as the gas escapes out the top of the hole without weakening the solder fillet. But in plated holes, a blow hole can have a catastrophic effect.

In a plated through hole, blow hole outgassing will displace the solder from the connection, leaving a void between the component lead and the walls of the plated through hole, as shown in Figure 13a. It is the result of the entrapment of water, flux or other liquid within a void in the PC board base material under the surface of the wall metallization. A pin hole in the wall metallization provides the access from the void to the open environment. The void is caused by imperfections in the drilling and/or plating operations.

When the PC board hits the solder wave, or when a soldering iron is applied, the heat from the solder causes the entrapped liquid to vaporize and escape from the void into the connection displacing the solder.

Below are possible causes for blow hole:

- Irregular plated through hole wall trapping vapor when solder wetting occurs.
- Out-gassing of residue from plating bath (organic or salt).
- Physical blockage due to foreign material.
- Inadequate preheat to evaporate flux solvent
- Component body blocking the escape path of evaporated gasses/moisture. Common for through hole LED without standoff. Typically, a blow hole is visible as a loss of solder from the connection, even though good wetting may be indicated. However, good fillets on the top and bottom can hide a blow hole condition within a connection, as shown in Figure 13b.

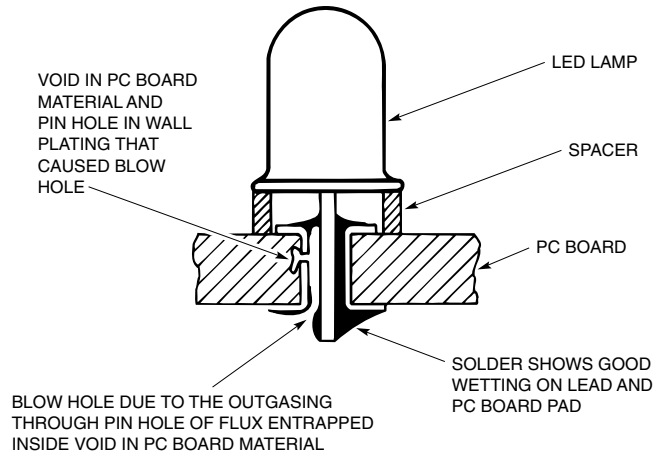
Thus, visual inspection of fillets may not indicate the integrity of a through hole connection.

Blow holes are usually not repairable. If a blow hole condition is detected the PC boards should be examined for imperfections in the surfaces of the plated through holes.

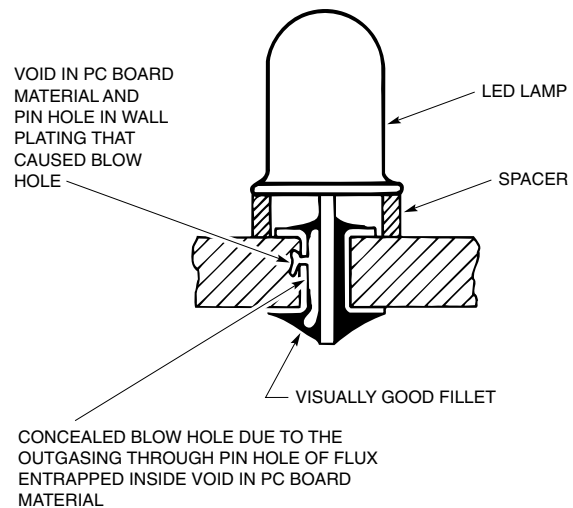
Remedy for blow hole:

- Improve plated through hole quality to eliminate irregular plated through hole wall. Refer to Figure 6.
- Investigate the quality and cleanliness of the PCB plated through hole
- Bake the PCB to remove moisture or plating solution residue.

- Increase preheat temperature to effectively evaporate the flux solvent.
- Additional legend marking and/or solder mask and/or addition copper on top side of PCB to create a gap between LED body and PCB for out-gassing. For better effect, legend mark or solder mask can be specially made thicker.
- Redesign PCB to add in additional holes close to plated through hole for better out-gassing.



**Figure 13a. Typical Characteristics of a Blow Hole Defect in a Through Hole Solder Connection**



**Figure 13b. Characteristics of a Concealed Blow Hole Defect in a Through Hole Solder Connection. Visual Inspection of Fillet Will Pass This Condition as a Good Solder Connection**

## Wave Soldering LED Components

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

The wave soldering process must be set up to properly solder each individual PC board configuration in order to achieve high solder connection yields. With this in mind, the following guidelines may be used for setting up a wave soldering process for LED components.

### The Solder Wave

Modern day solder machines utilize a dual wave configuration, as pictured in Figure 14a. The first wave is a narrow turbulent wave and the second is a laminar flow wave. The purpose of the turbulent wave is to deposit a continuous coating of solder onto the underside of the PC board. The benefits of the turbulent wave are 1) virtual elimination of missed solder connections (solder skips), and 2) positive solder delivery for soldering through the wave surface mounted components on the underside of a PC board.

The purpose of the laminar flow wave is to smooth out the solder deposited by the turbulent wave and to assure proper flow of solder into the plated through hole and lap joint connections.

For most LED components, the optimum solder temperature is  $245^{\circ}\text{C} \pm 5^{\circ}\text{C}$ . The optimum combined dwell time in the two waves is 1 1/2 to 3 seconds (Figure 15).

Certain LED components are qualified to withstand solder wave temperature up to  $260^{\circ}\text{C}$ , with an optimum combined dwell time of 3-5 seconds, as specified in each components' technical datasheet (Figure 16).

Establishing the dwell time in the solder waves sets the speed of the solder machine conveyor.

Some modern technology machines are equipped with a hot air knife located just beyond the laminar flow wave, as shown in Figures 14a and b. The purpose of the hot air knife is to hot air level the solder on the backside of the PC board to eliminate solder bridging before the solder solidifies.

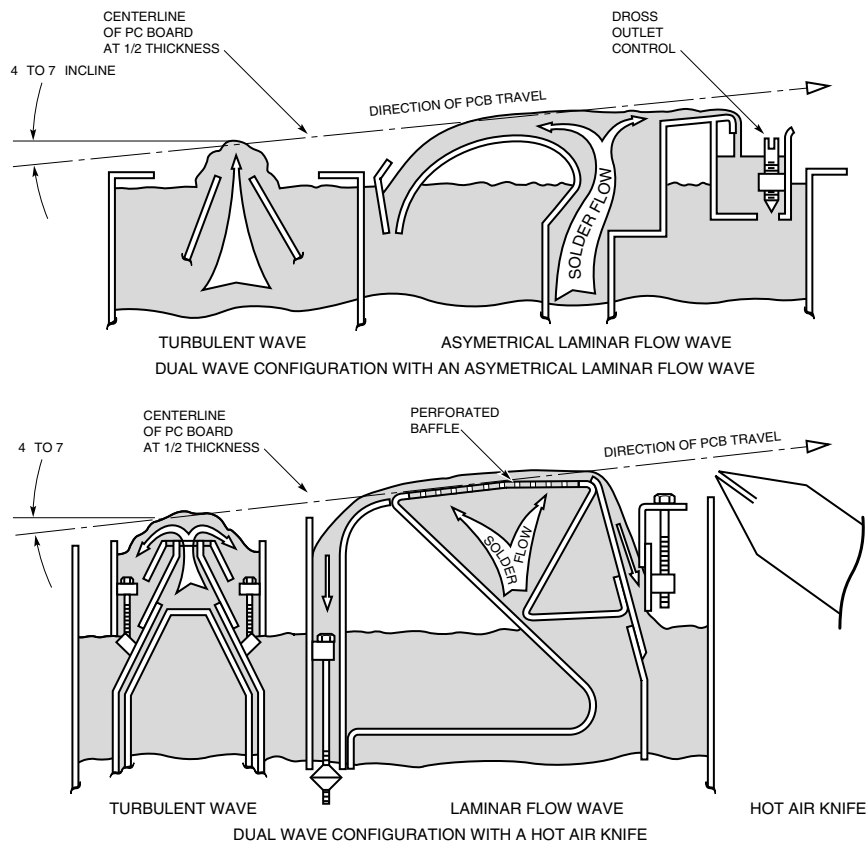
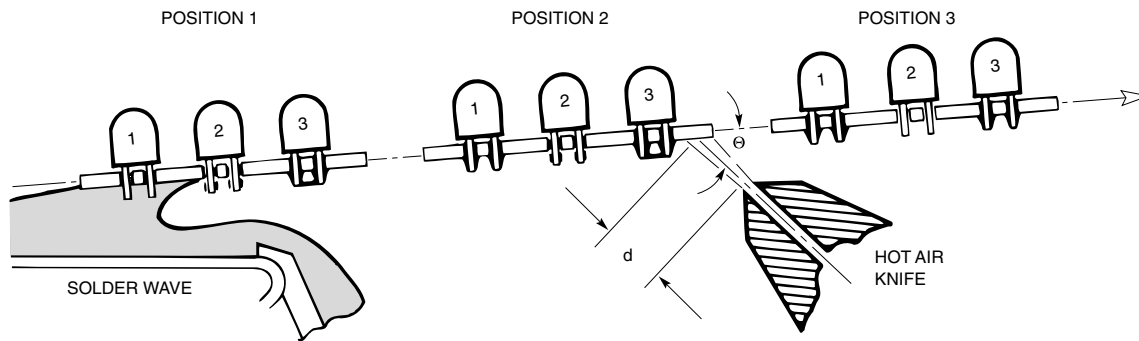


Figure 14a. Dual Solder Wave Configurations



Solder Connections	PC Board Location			Hot Air Knife Settings	
	Position 1. Exiting the solder wave	Position 2. Passing over the air knife	Position 3. Leaving the wave solder machine	Nozzle Orifice	Air Temperature
LED Lamp 1	Good wetting	Solder will remain in connections	Good connection with good fillets	0.51 to 0.76 mm (0.02 to 0.03 IN)	+350°C to +390°C
LED Lamp 2	Poor wetting	Solder in connections will be removed	Exposed faulty connections, no solder in holes	Air Flow	50-60 SCFM
LED Lamp 3	Good wetting solder bridge	Solder bridge will be removed	Good connections, no solder bridge	d	5.08 to 12.70 mm (0.20 to 0.50 IN)
				θ	40° TO 45°

Figure 14b. Operation of a Hot Air Knife on a Wave Soldering Machine

It also provides the unique benefit of stress testing the solder connections while the solder is still molten. If improper wetting or a blow hole condition is present, the air knife will blow the solder out of the connection. The faulty connection is now visible to the unaided eye. If proper wetting is present and the solder connection is good, the adhesive forces will prevent the air knife from removing solder from the connection.

### Preheat

The purposes for preheat are:

1. To activate the fluxing action.
2. To evaporate the flux solvents.
3. To reduce the heat transfer from the wave needed to bring the connections up to solder temperature.
4. To reduce the thermal shock to the components and the PC board.

An optimum preheat temperature for effective soldering of LED components is  $100^{\circ}\text{C} \pm 5^{\circ}\text{C}$ , as measured on the bottom side of the PC board just as the board assembly exits the preheat chamber. It is recommended to have only bottom preheater in order to reduce thermal stress experienced by the body of LED component. A higher preheat temperature is not desirable, as it may cause degradation of the flux by separating the halide activator from the flux mixture in the form of an acid that will initiate corrosion.

### Application of Flux

Most modern wave solder machines use a foam fluxer to apply flux to the bottom surface of a PC board. The foam height should be set to assure flux reaching the top of the plated through holes without having any flux overflow onto the top side of the PC board.

### Profiling the Operation of a Wave Solder Machine

PC Board Travel Through the Solder Wave: As shown in Figure 14, the PC board should contact the two solder waves at an incline of 4 to 7 degrees with foot prints that are even across the bottom surface of the board. The sizes of the foot prints are a function of wave geometry and the PC board configuration. As a guide, the immersion depth into the two waves should be equal to half the thickness of the PC board. An easy way to visually check the foot prints is to take a plate of heat resistant glass, cut to the same geometry as the PC board, and run it through the waves. The correct foot prints can be set accurately by observing the solder contact of each wave through the top side of glass plate.

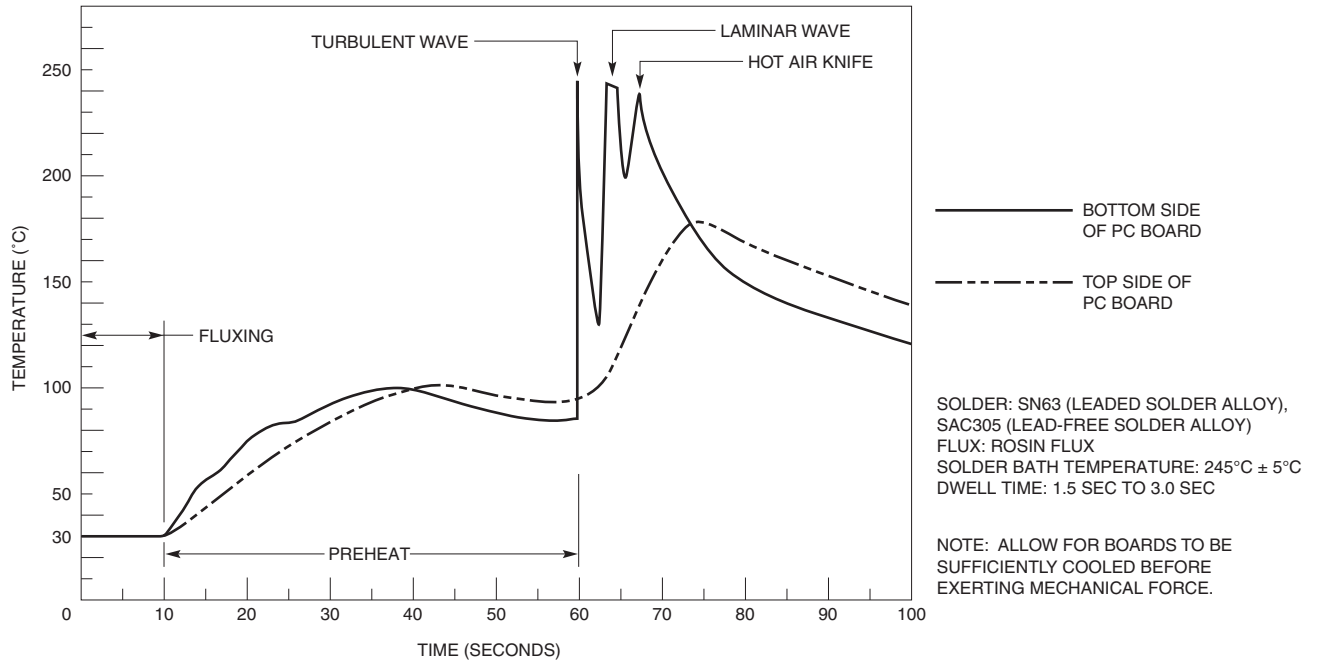


Figure 15. Sample Temperature Profile of a Wave solder Process ( Max 250°C)

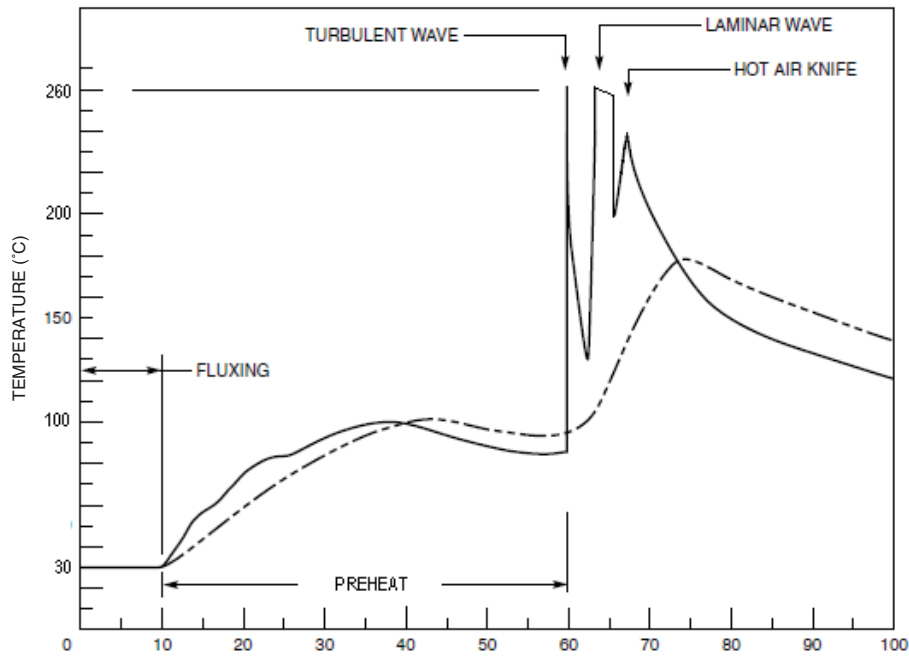


Figure 16. Sample Temperature Profile of a Wave solder Process ( Max 260°C)

**Temperature Profile:** It is good practice to run a temperature profile check on the wave soldering process for each PC board configuration to assure proper preheating and to assure the LED components are not being overheated. Figure 15 and 16 are the sample temperature profiles using the recommended wave soldering conditions. Common methods of obtaining temperature profile data are: 1) to place temperature sensitive adhesive strips on the top side surface of the PC board, 2) install thermocouples on the top and bottom sides of the PC board, and 3) to insert a thermocouple directly into the package of an LED component near the center, leading edge of the PC board. The use of temperature sensitive adhesive strips is the easier method, but does not give the temperature profile as seen by the LED components.

Placing thermocouples on both sides of the PC board provides a comparison of the top and bottom temperatures experienced by the board as it passes through the wave soldering machine. Inserting a thermocouple directly into an LED component is the best method as it gives the temperature profile as experienced by the LED component. The use of thermocouples is somewhat difficult as the signal wiring must travel through the wave soldering machine along with the PC board. Placing infrared sensors at various locations along the conveyor path is a good way to monitor the temperature profile as it is experienced by the PC board assembly during the wave soldering process.

The temperature profile should show the following:

1. The temperature increases at a smooth, predictable rate as the PC board passes through the preheat chamber.
2. The maximum preheat temperature is in the desired range and occurs just prior to the PC board exiting the preheat chamber.
3. Minimal temperature is lost between the preheat chamber and the turbulent wave.
4. Passage through the turbulent wave increases the temperature to a value sufficient for solder deposition on the bottom of the PC board.
5. Passage through the laminar flow wave brings the board assembly to the maximum temperature just as the board exits the wave.

## **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 first 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 should be monitored by soldering thermocouples on the lead of the LED at the bottom of the board. The thermocouples wires should be not twisted. The first contact between the two wires of a thermocouple must be at the solder joint on the LED lead.

## **Post Solder Cleaning for LED Components**

### **Reasons for Cleaning**

Some reasons for cleaning a PC board assembly after the soldering operation are:

1. **Esthetics:** Customers like the looks of clean PC board assemblies.
2. **Corrosion:** Polar ionic flux residues can cause corrosion to take place at the solder connections.
3. **Electromigration:** Polar ionic flux residues can permit copper electromigration to occur between adjacent circuit traces in high humidity environments.
4. **Signal leakage paths:** Polar ionic flux residues can provide signal leakage paths on the surface of a PC board in the presence of high humidity.
5. **PC board testing:** Flux residues can coat the tips of the probes on a bed-of-nails tester, in effect inserting an insulator or semiconductive resistor between a probe and a test point on the board.

The need to clean after soldering and how clean a PC board assembly must be is determined by the kind of flux used and the requirements of the end use application. In many cases, the need to assure reliable functional testing of a PC board assembly will necessitate the removal of flux residues (reason 5 listed above).

### The Fundamentals of a Post Solder Cleaning Process

It is important to match the flux used for soldering to the cleaning process. The flux and cleaning process must work in concert in order to obtain effective cleaning, i.e. the cleaning process and solvents or aqueous solutions must be able to remove the flux residues. A post solder cleaning process should have both wash and rinse cycles to achieve efficient removal of the flux residues. The dwell time in each cycle is a function of the amount of flux residues to be removed, configuration of the PC board assembly, and the tolerance limitations of the LED components. Mechanical agitation is necessary to loosen and remove residue solids from underneath LED and other components, and should be part of the cleaning process. In automatic conveyor cleaning equipment, spray nozzles are used to wash the PC board assembly. In manual cleaning processes, agitation may be accomplished by hand spraying the PC board assembly in the cleaning and rinse liquids. The agitation achieved by the boiling action of the cleaning solvent or aqueous solution is not sufficient by itself.

The use of ultrasonic agitation of the cleaning solvents is not recommended for use with plastic LED components. The danger is that the ultrasonic waves in the solvent, although at low energy level, may excite the natural resonance of the cathode and anode leads of a plastic LED component which could cause catastrophic failure of the wire bonds and die attach.

### Cleaning Solvents that are Safe for use with LED Components

The plastics and optical grade encapsulating epoxies used in the packages of LED components have limited resistance to many of the solvents used for post solder cleaning. Many of the cleaning solvents that have been formulated will chemically attack these plastics and epoxy compounds, and the resulting damage to the package of a plastic encapsulated LED component causes degraded optical performance. Also, many of the formulated cleaning solvents will attack the glass to ceramic epoxy seals on LED dot matrix and alphanumeric displays.

Table 6 lists the chemical resistance of Lexan resin used in plastic alphanumeric displays for reference.

### Cleaning Solvents that are Not Safe for use with LED Components

Solvents formulated with trichloroethane FC-111 or FC-112 or trichloroethylene (TCE) can attack optical grade epoxies and are not recommended for use with LED components.

Cleaning solvents that contain acetone or other ketones, methylene chloride, and/ or methanol *must not be used*, as they severely attack the optical grade epoxies of plastic encapsulated LED components.

**Table 5. Chemical Resistance of Lexan Resin for Plastic Alphanumeric Displays.**

Chemicals	Lexan Resin
Hydrocarbons	
Aliphatic	-/*
Aromatic	-
Halogenated – fully	*
Halogenated – partly	-
Alcohols	+
Phenols	-
Ketones	-
Amines	n
Esters	-/*
Ethers	-
Acids	
Inorganic	-/*
Organic	*
Oxidizing	-
Alkalis	-
Environmental UV	*/+

Note:

++ very good	found unaffected in its performance with regard to time, temperature and stress; according to agency requirements
+ good	found acceptable in normal exposure; long term exposure may result in minor loss of properties, higher temperature may result in major loss of properties
* fair	found marginal; only for short exposure at lower temperature or when loss of mechanical properties is not critical
- poor	found unacceptable; will result in failure or severe degradation
n	not tested

Ratings as shown are based on controlled tests and are purely indicative. Finish part performance must always be evaluated on the actual part in the end-use environment.

Acetone and other ketones will dissolve the polycarbonate outer packages of stretched segment displays, light bars, bar graphs, and the lenses of plastic alphanumeric displays.

### Aqueous Cleaning Solvents for use with LED Components

Most of the rosin saponifiers, detergents, and acid neutralizers used in water cleaning processes have no chemical effect on plastic encapsulated and glass-ceramic LED components.

## Hand Soldering LED Components

LED components may be effectively hand soldered to a PC board or to a wiring harness. It is very important to follow these simple rules to achieve effective hand soldering:

1. Use an electronic, temperature controlled soldering iron with a plug in tip. Set the tip temperature to 315°C. An electronically temperature controlled iron has a regulated power supply to operate the temperature sensing circuit and supply current to the 24 volt heating element. It has a grounded continuous electrostatic shield, tip to ground lug on the power plug, to prevent electrical damage to sensitive integrated circuit components. An iron with a thermocouple sensor in the shank can hold the tip temperature within 22°C during the process of making a solder connection. An iron with a thermistor sensor in the tip is best, since it will hold tip temperature within 11°C.

Do not use a mechanically controlled temperature compensated iron that has either a ferromagnetic, bimetallic strip or resistance wire sensor in the iron shank to sense tip temperature.

The shank temperature is typically 315°C, 371°C or 427°C as selected by changing tips. The temperature control is not accurate. This kind of soldering iron uses ac line voltage in both the temperature sensing and heater circuits. An important concern with this kind of soldering iron is that, although it is grounded, an inductive field of many millivolts is generated at the tip. This inductive field can cause a current to be generated in a PC board trace that has the potential of damaging integrated circuit and other sensitive components.

2. Use copper plated tips, short length with a conical taper tip as shown in Figure 17. Note: Tips longer than 63.5 mm (2.50 inch) can exhibit a reduced tip temperature by 56°C per inch for a ¼ inch diameter tip.
3. 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, reducing heat transfer to the connection. The oxides on the tip will contaminate the surfaces within the connection inhibiting solder wetting.
4. 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.
5. 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.

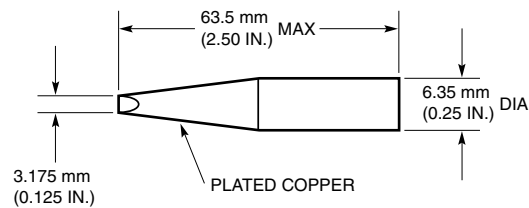


Figure 17. Soldering Iron Tip for Hand Soldering LED Components

6. Use RMA rosin core wire solder, 0.031 or 0.040 inch diameter. If necessary, the PC board pads and/or leads of an LED component may be pre-tinned prior to forming the solder connections. Pre-tinning the pads and the tips of the leads may prove beneficial when surface mounting HLMP-6000 series subminiature LED lamps by hand soldering. 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.

## Post Solder Repair

If it is necessary to remove and replace an inoperative LED component from a PC board assembly, it is done with a hand soldering operation.

The procedure must be performed with extreme care so as not to cause damage to the PC board, such as a fracture between the solder pad and the through hole wall metallization, the lining of the pad from the surface of the board or removing metallization from the wall of the plated through hole, as shown in Figure 18. On a multi-layer board, the lifting of a solder pad or the removal of through hole wall metallization may not be repairable and the PC board becomes scrap.

The following procedure permits the removal and replacement of an inoperative LED component without causing damage to the PC board. Set the soldering iron temperature at 371°C to 427°C.

1. Since the LED component is inoperative, it can be destroyed. With a pair of small diagonal cutters, carefully cut the leads to the component to remove the device package exposing the leads.

2. Next, the solder may be removed from the connection in one of two ways, by using, 1) a soldering iron and a vacuum solder extractor, or 2) using copper braid. See Figure 19. The tip of the soldering iron must be properly tinned while removing the component leads in order to assure heat transfer into the connections and to prevent oxide contamination from entering the connections.

If a vacuum solder extractor is to be used, be sure that it is the metallized kind that will not generate a static charge with the operation of the plunger. Push in the plunger to cock the extractor. Place the soldering iron tip onto the lead and solder pad to melt the solder in the connection. The lead will provide the thermal path for maximum heat transfer into the connection. When the solder melts, place the extractor over the lead and solder pad while moving the soldering iron tip to one side. Immediately press the release button on the extractor to remove molten solder from the connection. This should take about 1 to 2 seconds. Cock the extractor and tap the tip to shake out the extracted solder. Repeat this step until the connection is free of solder. Next, take a pair of small needle nose pliers and gently move the lead back and forth to break any residual adhesion and then gently lift the lead out from the hole.

If copper braid is to be used, use braid that is near the same width as the solder pad. Dip the top of the braid in flux. Place the fluxed tip of the braid over the lead and solder pad. Heat both the top of the braid and the exposed lead until molten solder wicks up into the braid. Remove the braid first and then the tip of the iron to prevent the braid from becoming soldered to the pad. This should take only a few seconds. Cut off the soldered tip of the braid and repeat this step until the connection is free of solder. Then gently remove the lead as described above.

3. Check for correct component polarity and orientation with respect to the placement on the PC board and insert the leads of the new LED component into the holes in the board and hand solder in normal manner. Hand clean with the appropriate solvent.

Remember, the first and most important priority is to perform the removal and replacement of an LED component with extreme care, and without causing any damage to the PC board solder pads or plated through holes. Applying as little heat as possible in as short a time as possible helps to prevent damage to the PC board.

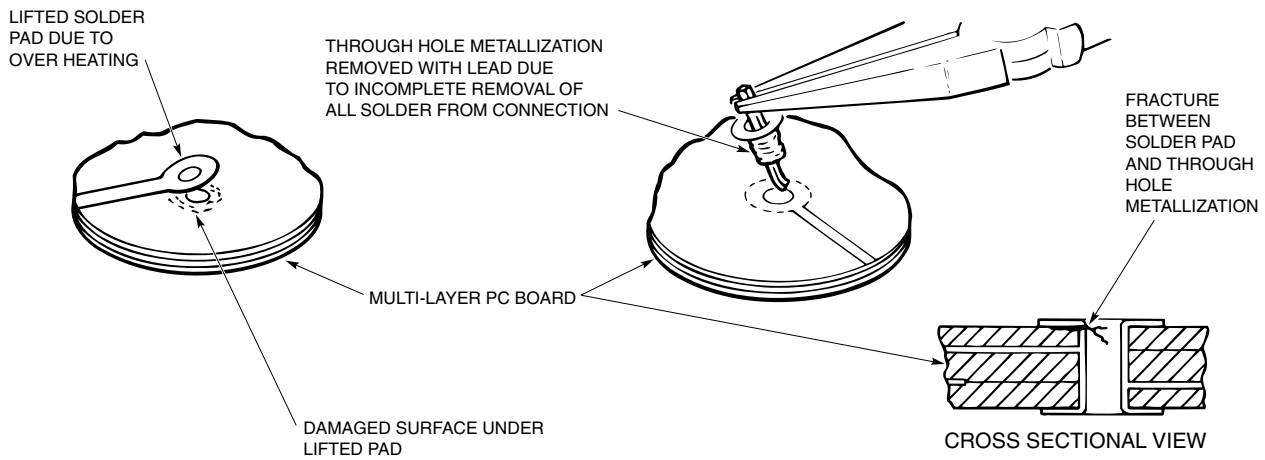
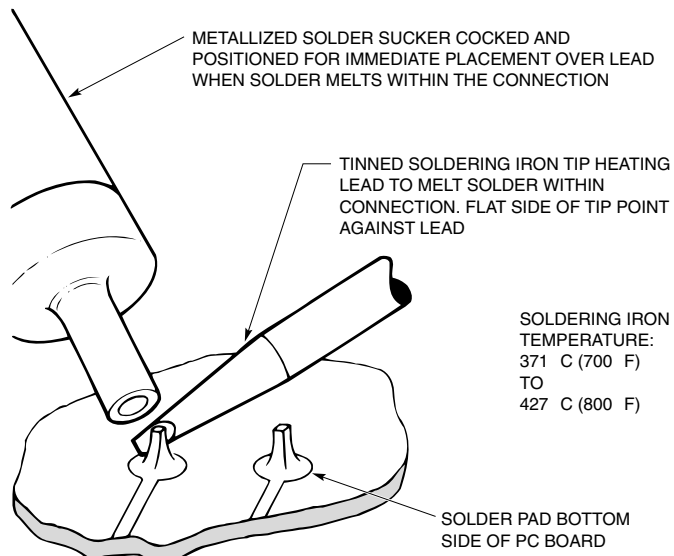
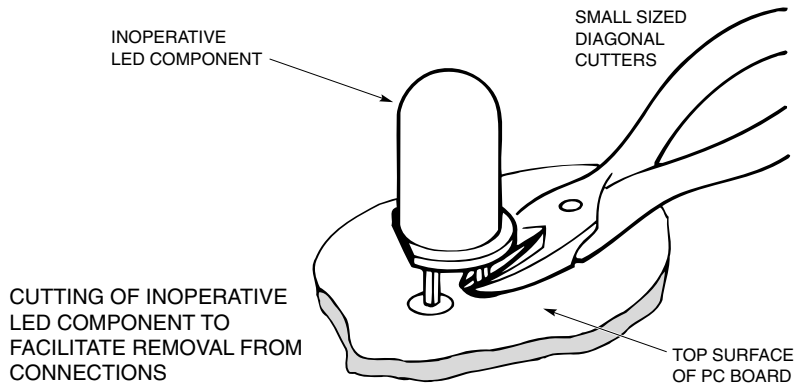
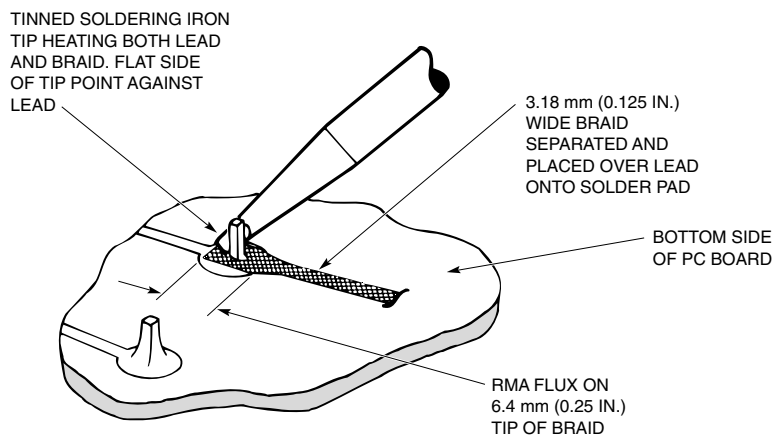


Figure 18. Non-Repairable Damage to a Multi-Layer PC Board Caused During the Process of Removing the Lead of an Inoperative Component





**SOLDER REMOVAL USING A METALLIZED SOLDER SUCKER**



**SOLDER REMOVAL USING BRAID**

**Figure 19. Removing the Leads of an Inoperative LED Component from Through Hole Connections in a PC Board**

## **Saving The Inoperative LED Component for Failure Analysis**

If a failure analysis is to be performed on an inoperative LED component it must be unsoldered and removed from the PC board with sufficient care so as not to damage the component. Do not cut the component leads. The component may be carefully unsoldered and removed by either of the two methods described above. When sending the component to Avago Technologies for failure analysis, please include all pertinent information concerning the use, drive conditions, testing, and PC board assembly processing to which the LED component has been exposed.

## **Electrostatic Discharge (ESD) Considerations**

### **ESD susceptibility of LED Components**

LED chips using GaP, AlInGaP and AlGaAs technologies are not as susceptible to damage from ESD as are CMOS ICs and other MOS devices. They also do not contain the same degree of junction degradation from ESD that causes latent failures in TTL devices, and are considered to be Class 3b devices in the classification listed in ANSI/ESDA/JEDEC JS-001-2010.

For LED components with InGaN LED or On-board Integrated Circuit (OBIC), they are extremely sensitive to ESD damage and require special handling. This includes all InGaN LED, InGaN displays and all Smart Displays such as HCMS family, HDSP-0xxx family, HDSP-2xxx family and HDLx-1414/2416/3416 family. These components are shipped in ESD protective packaging, and should be stored in that packaging until mounted into PC board assembly. ESD precaution must be properly applied on the assembly floor including soldering station and personnel to prevent ESD damage. Refer to respective datasheet for each LED components' classification and Avago Application Note AN 1142 for details on handling ESD sensitive components.

## **The Causes of ESD**

Nonconductive surfaces do not cause electrostatic discharge, but conductive surfaces do cause ESD.

The most common cause of static electricity is triboelectric charging: the build up of electric charge from the separation of two surfaces in contact, one of which must be a nonconductor. It takes an exposed conductive surface to attract a static charge to produce ESD. ESD is the rapid discharge from a nonconductive surface containing a charge of static electricity to a conductive surface as a high energy spark.

Common conductive surfaces that produce ESD are metal, metallic carbon and human skin. These conductive surfaces can easily have electric charges induced upon them. For example, when a piece of charged plastic, a nonconductor, is brought in close proximity to one of these conductors, the static potential difference can cause the instantaneous bleedoff of the electric charge from the plastic to the conductive surface; ESD! If an LED component is in the discharge path, the high energy ESD current will pass through the component causing damage to the on board integrated circuit chips.

## Preventing ESD Damage to ESD Sensitive LED Components

ESD prevention is simply the prevention of a static charge build up and/or the prevention of a rapid bleedoff of a static charge from a nonconducting service.

The two most common causes of ESD damage to LED components is the handling by human hands and the use of common plastic containers and tools. The following procedures will prevent ESD damage to LED components and PC board assemblies.

1. Keep all common plastics such as Styrofoam coffee cups, molded containers, packaging "popcorn balls", vinyl and teflon containers and plastic wrap away from LED components and PC board assemblies.
2. Have all operators that handle LED components wear wrist ground straps, that are in fact touching their skin and securely grounded. Static shielding garment must be worn to protect against ESD discharge. It is recommended that human hair be shielded as well. Avago specifies that static charge shall not exceed 50V for "Class 1x" and 100V for "Class 2".
3. Use only tables and benches that are covered with ESD protective pads. The high surface resistance permits the static charge to bleed off very slowly at an energy level sufficiently low enough to prevent any damage to an LED component.
4. It is recommended to ground all metal work bench frames.
5. Store LED components and PC board assemblies only in ESD protective packaging and use that packaging for transporting from one location to another.  

Plastic ESD protective containers are made from surfactant impregnated resins, such as polyethylene. The impregnated surfactants maintain a microscopic film of moisture on the surface of the plastic which prevents the build up of any static charge.
6. Never apply adhesive tape or an adhesive label to a PC board assembly for temporary identification through the assembly process. The triboelectric charge that is created when it is removed prior to shipment may damage the LED components.
7. Continually train and remind operators and other personnel of the rules and procedures to be followed to protect LED components and PC board assemblies from ESD damage.

## ESD and Soldering

Operators performing a soldering and cleaning process must wear wrist ground straps when handling PC board assemblies. Most cases of ESD damage due to soldering occur when proper handling procedures are not followed. This is especially true during hand solder operations. A grounded electronically temperature controlled soldering iron, as described in the section titled "Hand Soldering" should always be used. Wave soldering does not cause ESD damage to sensitive components. However, the bulk resistivity of the flux solvent should be less than 105 ohms to prevent localized charge build up on the surface of a PC board as it passes through the wave solder process.

### Process Control for Low Defect Soldering

With the ever increasing complexity of PC board assemblies in the form of multilayer boards, the wide variety of leaded and surface mounted components and increased solder connection counts, it is imperative to achieve low solder connection defects with a one time pass through the soldering process. As mentioned in the Introduction, it may no longer be cost effective or even possible to repair PC board assemblies that have faulty solder connections. It is essential to place into effect real time process control of the PC board manufacturing and assembly processes, from design through post solder cleaning to insure low defect levels. The goals are to eliminate the costly labor intensive post solder touch up operations and to reduce to near zero the PC board assembly loss due to faulty solder connections.

The only way to succeed in improving solder connection defect rate is to have real time process control at all levels of the PC board manufacturing process:

1. PC board designers must be familiar with the PC board design parameters that permit effective soldering and implement these parameters in their designs.
2. Work closely with the PC board vendor to insure that the board manufacturing process produces solderable boards that will not delaminate with the thermal shock associated with soldering.
3. Work closely with component suppliers to insure that all components are functional, solderable and have as low a PPM defect level as possible.
4. Make regular inspection of solder, flux and cleaning solvent to insure desired formulations and purity levels.
5. Maintain an ongoing training program for all manufacturing personnel involved in the component placement, soldering and post solder cleaning operations. Utilize an operator certification program to insure operator skill and performance proficiency.
6. Pay continual and careful attention to every detail in the soldering/post solder cleaning process. Utilize lot tracking, control charts and other techniques to continually monitor the PC board assembly processes. Publish the data on a daily basis. Keep all personnel personally involved in the effort to achieve low defect soldering.
7. When a problem arises or the PPM defect level increases, immediately stop the soldering process. Find the problem and implement corrective action before resuming the soldering process. Don't make scrap!
8. Keep informed on the up to date technology and modern PC board assembly and soldering techniques.

Maintaining an ongoing real time process control program towards low defect soldering will help insure product reliability and customer satisfaction, and achieve sales goals and profitability objectives.

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