

Application Note 1021

Introduction

With the need to assure product quality and consistency at low cost in high volume production, many manufacturers are automatically inserting components into printed circuit boards. Since equipment is now available to automatically insert radial lead components, Avago Technologies offers many of its plastic LED lamp products packaged in the tape and reel configuration.

This application note is a guide to the use of tape and reel LED lamps in the automatic insertion process. Included are sections on the LED lamp tape and reel configuration, an explanation of the radial lead auto-insertion process, PC board design considerations, a method of maintaining vertical alignment of LED lamps during soldering, lamp stand-off heights and other pertinent information.

LED lamps packaged in the tape and reel configuration offer advantages over bulk packaging. The LED lamps are positioned precisely on a carrier tape with anode/cathode orientation consistent part-to-part and reel-to-reel. Bending and tangling of the leads are eliminated. Tape and reel LED lamps are compatible with radial lead auto-insertion equipment designed to handle components conforming to ANSI/EIA Standard RS-468 and IEC Publication 286.

For the user not utilizing auto-insertion equipment, the uniformity of tape and reel packaging offers easier handling of LED lamps than bulk packaging.

Two lead spacings are available: formed leads with 5 mm (0.197 inch) spacing and straight leads with the standard 2.54 mm (0.100 inch) spacing.

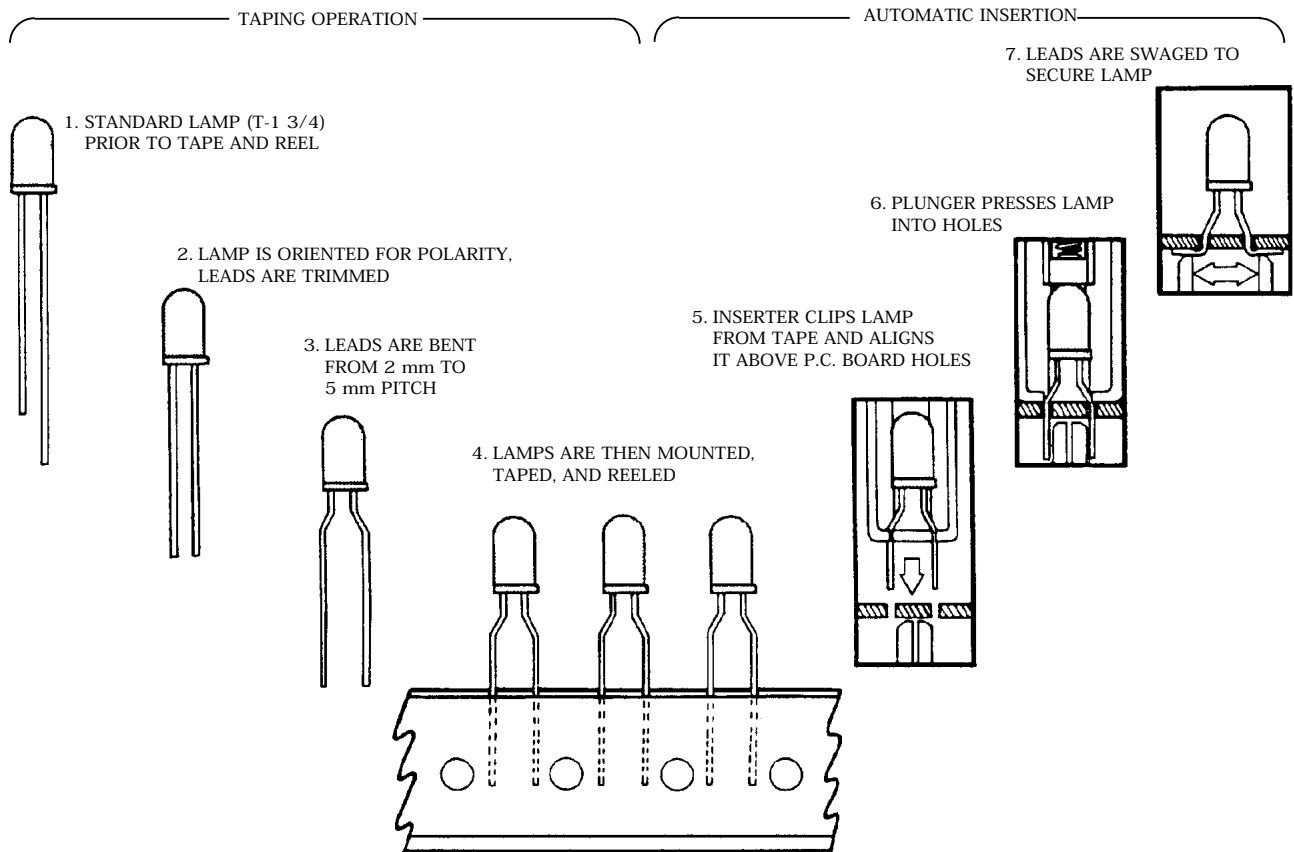


Figure 1. Tape and Reel Lamps.

The Basic Process

The lamp taping and automatic insertion processes are briefly illustrated in Figure 1. Avago Technologies orients the LED lamps for correct polarity, forms the leads to the desired spacing, mounts the lamps on tape, and electrically tests each lamp as the tape is rolled onto a reel. Any reject devices are clipped from the tape. At the user's facility, the auto-insertion machine clips a lamp from the tape and uses an insertion guide to position the lamp above the holes in the PC board. A plunger inserts the lamp into the PC board and an anvil clinches the leads to secure the lamp. The following paragraphs examine these steps in detail.

The Taping Process

The LED lamps are mounted onto the tape by an automatic taping machine. Each lamp is electrically oriented so the anode lead is the first device pin as the tape unwinds off the reel. The leads are either formed to a 5 mm (0.197 inch) spacing or left at the standard 2.54 mm (0.100 inch) spacing. A thermal setting adhesive tape is used to secure the lamps to a paper base carrier tape. All lamps are electrically tested during the reeling process and any reject units are clipped from the tape, with no more than three consecutive blank spaces permitted at any given location along the tape. The carrier tape is made of a 0.50 mm (0.020 inch) thick x 18 mm (0.709 inch) wide kraft paper and the thermal activated adhesive tape is 0.16 mm (0.006 inch) thick x 15 mm (0.591 inch) wide. The maximum thickness of the tape is 0.90 mm (0.035 inch).

The reels are assembled as shown in Figure 2 with the tape wound onto a reel in a counter clockwise rotation. Maximum reel hub thickness is 49 mm (1.93 inch) and the hub inside diameter is 30 mm (1.19 inch) to accommodate most auto-insertion machines. An interlayer paper is used to prevent individual lamps from touching each other. For lamps with silver plated leads, a tarnish inhibiting paper is used as the interlayer.

A quantity of 1300 T-1 3/4 lamps or 1800 T-1 lamps are supplied on a 370 mm (14.57 inch) diameter reel.

Critical Dimensions and Lead Tensile Strength

LED lamps are spaced along the tape at an interval of 12.7 mm (0.500 inch). The height of all tape mounted lamp types is between 23 mm (0.906 inch) and 32 mm (1.260 inch), as measured from the centerline of the tape sprocket feed holes to the top of the dome, to comply with insertion guide plunger height requirements. The 5 mm lead spacing bend is located at 16 mm (0.630 inch) above the centerline of the tape sprocket feed holes to insure proper insertion travel distance. LED lamps packaged tape and reel have 0.46 mm (0.018 inch) square leads which are compatible with the size limitations of insertion guide assemblies. Lead frame tensile strength does not exceed 60K psi, allowing the auto-insertion machine knives and anvils to easily cut and clinch the leads. The dimensions and tolerances for a taped T-1 3/4 lamp are shown in Figure 3. Note, the taping machine uses the base of a lamp as a reference base line to establish dimensions H at 20.5 mm (0.807 inch) and Ho at 16 mm (0.630 inch) for all lamp types.

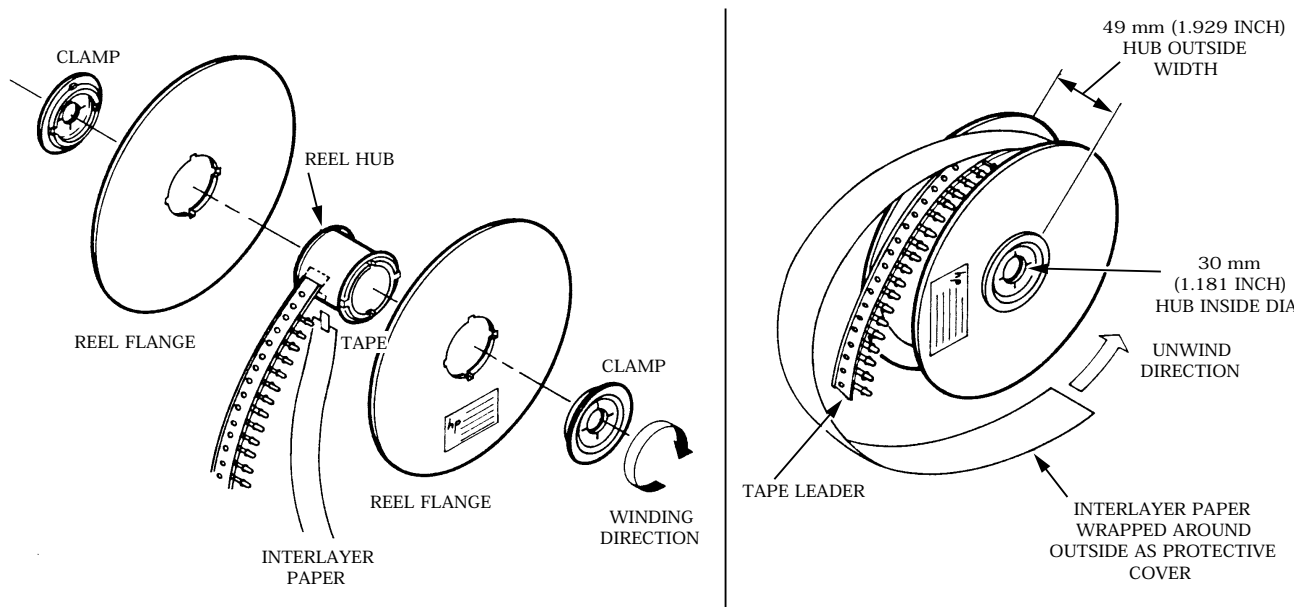
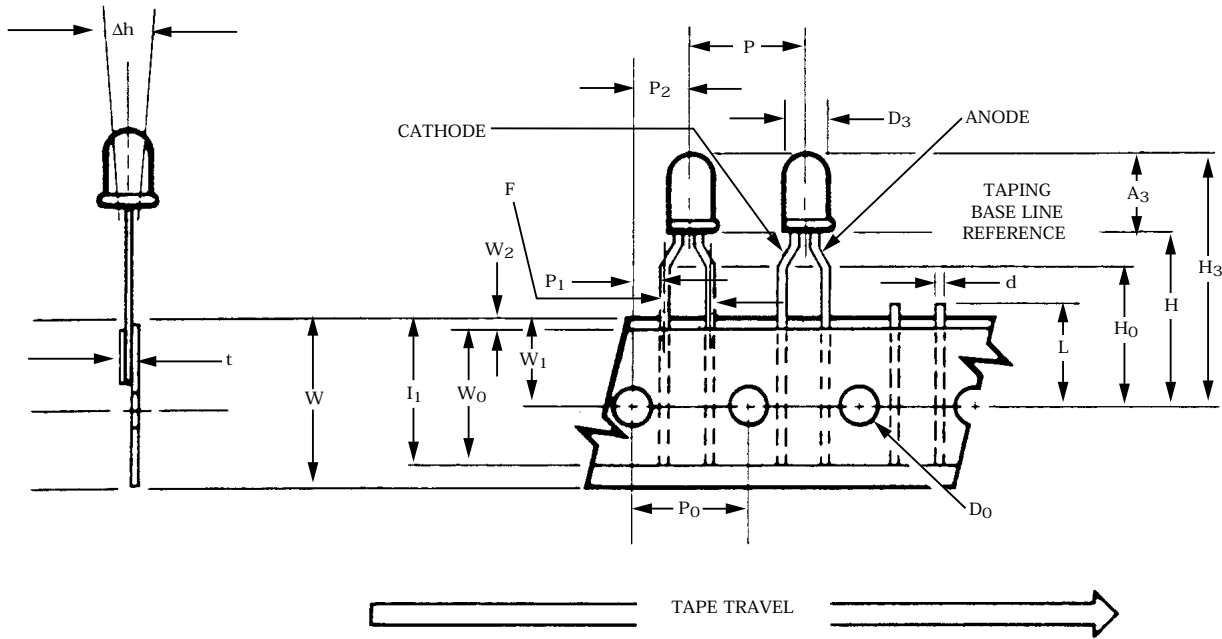


Figure 2. Reel Configuration. Flange Diameter is 370 mm (14.57 inches).

Tape Device Retention Parameters

Retention of the LED lamps by the tape meets certain minimum criteria as specified by the three pull tests shown in Figure 4. A lamp will be retained by the tape when a 100 gram lateral load, a 70 gram longitudinal load or a 500 gram vertical load is applied for 3 seconds (one load per test, no two loads applied at the same time). The force required to unwind a reel does not exceed 500



DIMENSION	SYM	VALUE	DIMENSION	SYM	VALUE
BODY HEIGHT	A ₃	9.19 (0.362) 8.43 (0.332)	TAPE WIDTH	W	18.5 (0.728) 17.5 (0.689)
BODY DIAMETER	D ₃	5.08 (0.200) 4.32 (0.170)	HOLD DOWN TAPE WIDTH	W ₀	15.3 (0.602) 14.7 (0.579)
COMPONENT HEIGHT	H ₃	30.2 (1.189) MAX.	FEED HOLE LOCATION	W ₁	9.75 (0.384) 8.50 (0.335)
SQUARE LEAD THICKNESS	d	0.45 (0.018)	HOLD DOWN TAPE POSITION	W ₂	0.50 (0.020) MAX.
PITCH OF COMPONENT	p	13.7 (0.539) 11.7 (0.461)	HEIGHT OF COMPONENT FROM HOLE CENTER	H	21.0 (0.827) 20.0 (0.787)
FEED HOLE PITCH	P ₀	12.9 (0.508) 12.5 (0.492)	LEAD CLINCH HEIGHT	H ₀	16.5 (0.650) 15.5 (0.610)
FEED HOLE TO LEAD CENTER	P ₁	4.55 (0.179) 3.15 (0.124)	FEED HOLE DIAMETER	D ₀	4.20 (0.165) 3.80 (0.150)
FEED HOLE TO COMPONENT CENTER	P ₂	7.35 (0.289) 5.35 (0.211)	TOTAL TAPE THICKNESS	t	0.90 (0.035) 0.50 (0.020)
LEAD TO LEAD DISTANCE	F	5.40 (0.213) 4.90 (0.193)	LENGTH OF SNIPPED LEAD	L	11.0 (0.433) MAX.
COMPONENT ALIGNMENT, F/R	Δh	±1.0 (0.039)	LEAD LENGTH UNDER HOLD DOWN TAPE	I ₁	14.5 (0.571) MAX.

DIMENSIONS IN MILLIMETERS (INCHES)

Figure 3. Dimensions for Taped T-1 3/4 LED Lamps.

Tape Splicing

The tape may be spliced by using a prepunched splicing tape and a splicing jig similar to that shown in Figure 5. The tape sprocket feed hole spacing of 12.7 mm (0.500 inch) must be maintained and the misalignment must not be more than 1 mm (0.039 inch) over a pitch of twenty holes.

Universal Instruments offers a tape splicing tool (part number C24639) and an adhesive splicing tape (part number C24782). The splicing operation is pictured in Figure 6. The splicing tape is 3M #256 and is prepunched on 12.7 mm (0.500 inch) centers and precut to a length of 63.5 mm (2.50 inches) per strip, width is 18 mm (0.709 inch). The tape comes in a dispensing roll 54.9 m (120 feet) in length, sufficient for 425 splices. Contact:

Universal Instruments Corporation P. O. Box 825
Binghamton, New York 13902 Telephone: (607) 772-7522

Prepunched splicing tape, FORMSTANZTEILE PSL 769, 17 mm (0.669 inch) wide, may be obtained from the 3M Company representative in Germany:

Ernst Rockelein GmbH
Blumenstrasse 9
Postfach 3815
8500 Nurnberg 1
Telephone: 0911/22 25 00

Caution: The use of staples for splicing is not recommended, as they may damage auto-insertion machine tab cutters.

The Insertion Sequence

Two basic types of automatic insertion machines are the horizontal conveyor, such as the Universal 6346A, TDK AVI-SERT VC-5, and the vertical shuttle such as the TDK AVI-SERT VC-4H. Eighty part stations are available on the horizontal conveyor machines and 40 part stations are available on the vertical shuttle machines. Yielded insertion rates on the order of 5000 units per hour are achievable.

A typical insertion sequence for the horizontal conveyor machine is pictured in Figure 7. The component hole locations on the printed circuit board are sequentially programmed into the machine computer memory. The insertion operation follows the insertion sequence automatically under control of the machine software.

Step 1: The tape sequencer dispenses the tape by use of a sprocket drive and cuts a tab containing the lamp to be inserted from the tape. A part sensor checks to insure that the tab does contain a lamp. If a lamp is missing from the tab, the tape is dispensed one more position and another tab is cut. If more than three consecutive lamps are missing from the tape, the sensor stops the machine, signaling the operator to take corrective action.

Step 2: The lamp is captured by a conveyor clip which holds the lamp by its leads. The tab is cut from the lamp and discarded. The conveyor transports the clip containing the lamp to the insertion guide transfer station. A part sensor at the insertion guide transfer station checks to see that the conveyor clip does contain a lamp. If a lamp is missing, the machine stops, allowing the operator to manually insert a lamp into the conveyor clip.

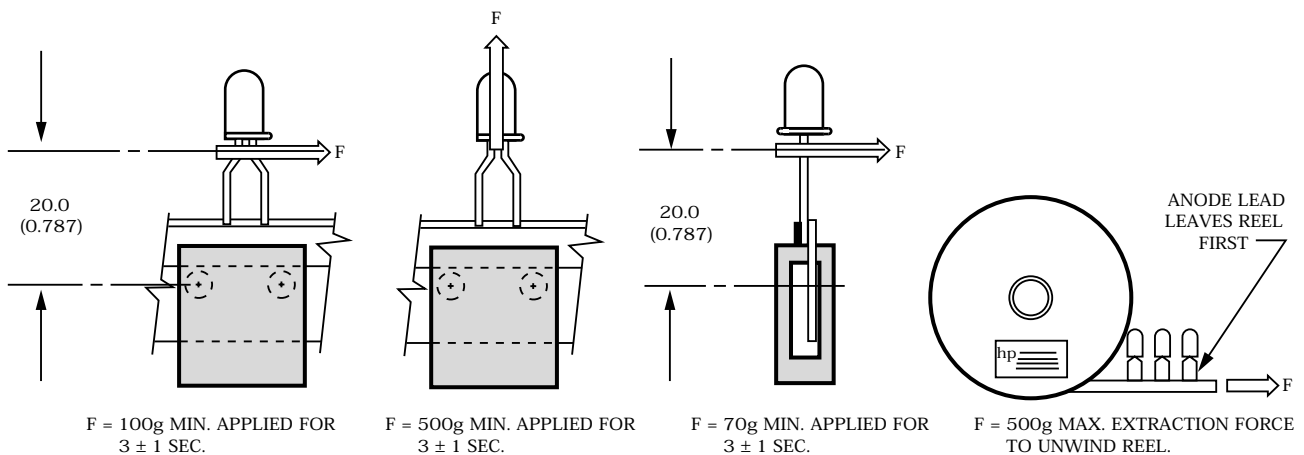


Figure 4. Device Retention Pull Tests.

Step 3: Just prior to the transfer of the lamp from the conveyor clip to the insertion guide assembly, the X-Y support table positions the PC board holes for component insertion directly under the insertion guide assembly.

Step 4: The lamp is transferred from the conveyor clip to the insertion guide assembly which uses moveable fingers to grip the leads.

Step 5: The insertion guide assembly orients the lamp for correct polarity and X-Y axis alignment, lowers and positions the lamp directly over the holes in the PC board.

Step 6: The insertion guide fingers release the leads as the insertion guide plunger pushes the lamp to its seated position in the printed circuit board. As the plunger extends downward, the insertion guide retracts backwards

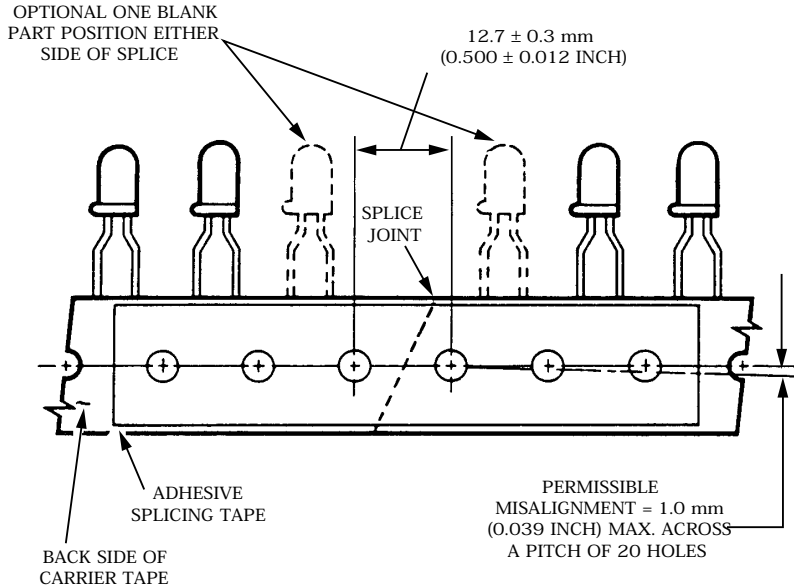
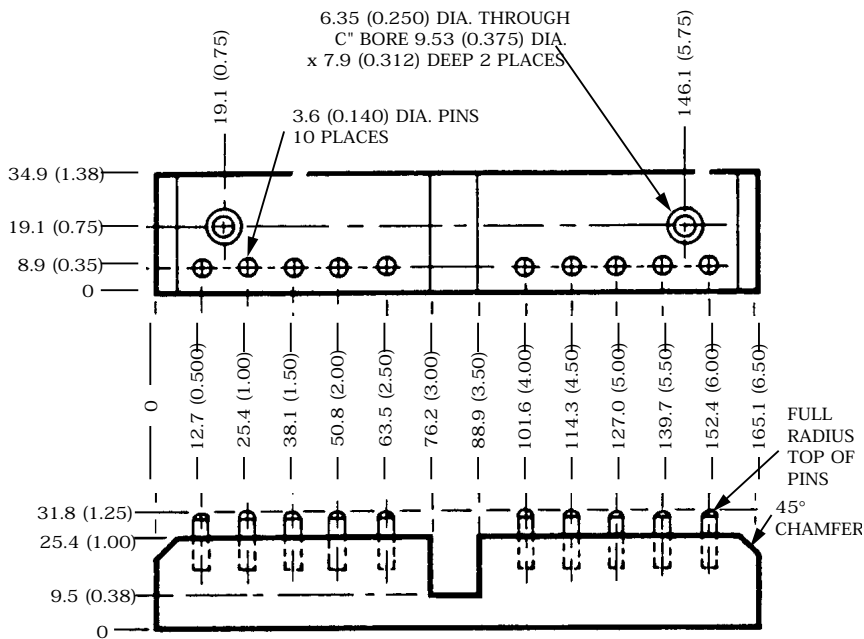


Figure 5a. Tape Splicing.



NOTE: DIMENSIONS ARE MILLIMETERS (INCHES)

Figure 5b. Tape Splicing Fixture.

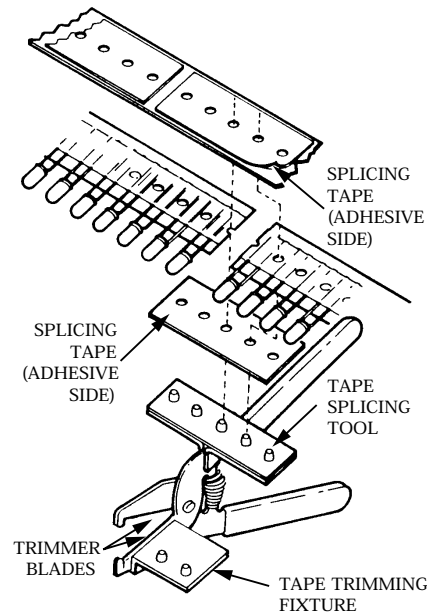


Figure 6. Universal Instrument Tape Splicing Technique, C24639 Splicing Tool and C24782 Splicing Tape.

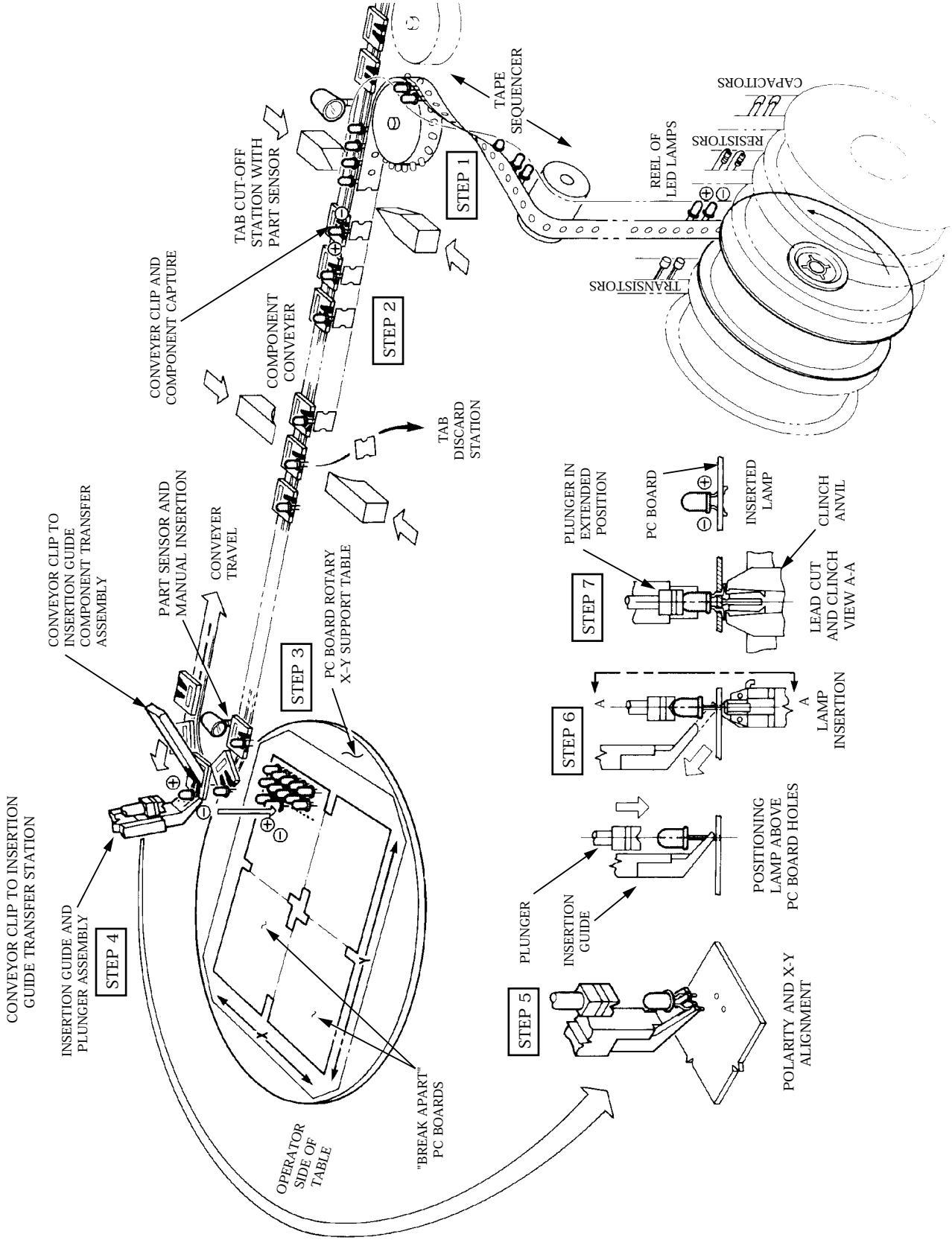


Figure 7. LED Lamp Insertion Sequence for a Radial Lead Horizontal Conveyor Machine.

and upwards to give clearance to the plunger.

Step 7: From underneath the PC board, a clinching anvil with lead cutters aligns itself with the insertion guide. When the lamp is seated, the anvil rises to trim the leads to length and clinch them against the underside of the PC board to secure the part. The plunger maintains its extended position to keep the part seated during the clinching operation. After clinching, the plunger and anvil retract to their home positions and the process is repeated for the next part to be inserted.

PC Board Design Considerations

The design of a printed circuit board that will use automatically inserted components must take into account the various size, dead space and component location restrictions as specified by the insertion machine manufacturer. These restrictions include such items as:

1. PC board size and design to match the X-Y support table.
2. Restricted areas where components may not be located.
3. Hole locations, size and spacing tolerances.

4. Dead space requirements to allow space for the insertion guide and anvil foot print, defining achievable device packing density.
5. Component insertion sequence planning to insure unhindered operation of the insertion guide assembly and the clinch anvil.

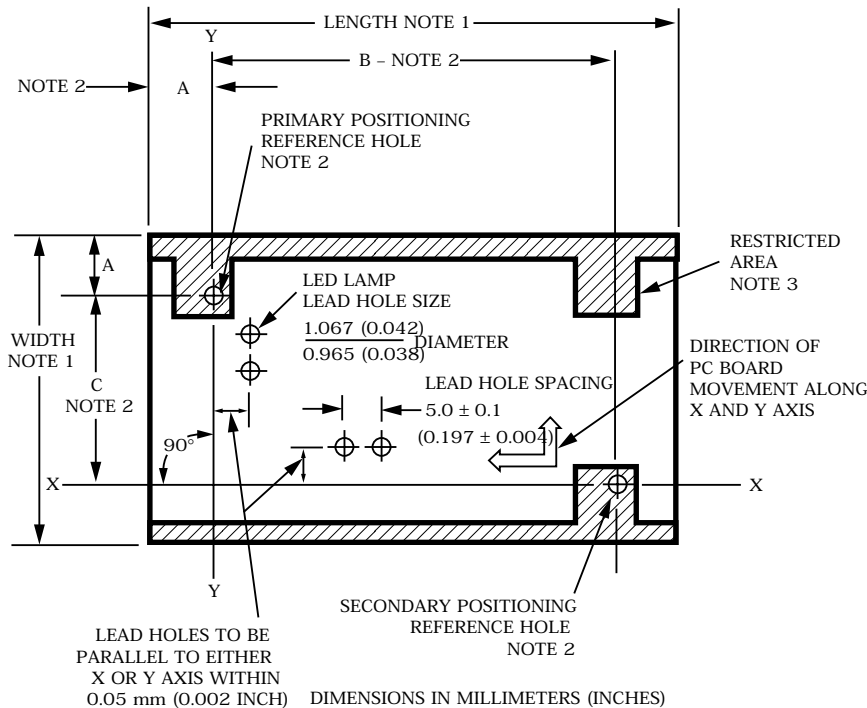
PC Board Size Limitation and Restricted Areas

An auto-insertion machine has an X-Y table that supports the printed circuit board during the insertion process and is capable of handling PC boards up to a maximum size. Certain areas of the PC board must be component free to allow space for X-Y table alignment pins and PC board-to-table mounting hardware. For specific information, refer to the PC board layout requirements specified by the insertion machine manufacturer.

Proper insertion requires that the deviation from flatness of a printed circuit board due to warpage must not exceed one unit of board thickness.

Hole Size, Locations, Spacing and Tolerances

Since the positioning accuracy of an auto-insertion machine is typically ± 0.05 mm (0.002 inch) with a repeatability of ± 0.02 mm (0.001 inch), it is necessary to maintain



NOTES:

1. PC BOARD LENGTH AND WIDTH SIZED TO FIT AUTO-INSERTION MACHINE PC BOARD SUPPORT TABLE.
2. POSITIONING REFERENCE HOLE LOCATION PER AUTO-INSERTION MACHINE REQUIREMENTS.
3. RESTRICTED AREAS FREE OF COMPONENTS TO PROVIDE SPACE FOR SUPPORT TABLE CLAMPS.
4. LEAD HOLE LOCATIONS DIMENSIONED FROM PRIMARY REFERENCE HOLE WITHIN A TOLERANCE OF ± 0.10 (± 0.004) NON-CUMULATIVE.

Figure 8. Representative PC Board Design Considerations.

the PC board hole size, locations, spacing and tolerances as shown in Figure 8. The size of the holes in the PC board for LED lamps with 0.45 mm (0.018 inch) square leads should be between 0.965 mm (0.038 inch) diameter and 1.067 mm (0.042 inch) diameter. When dimensioning the printed circuit board to prevent tolerance accumulation, it is good practice to dimension all holes from a single reference point, typically the center of the support table indexing hole. The polarity and mechanical orientation of a component is typically set by either a 0°, a right 90° or a left 90° rotation of the insertion guide assembly with respect to the PC board support table X-Y axes, as shown in Figure 9. A 180° rotation option is available on some machines.

Dead Space Requirements and Achievable Packing Density

When determining component positioning on the PC board layout, it is necessary to allow for sufficient “dead space” around each component. “Dead space” is defined as the required space around each component to allow for unobstructed insertion. This “dead space” includes the area needed to accommodate the size and motion of the insertion guide and the clinch anvil foot print. This is necessary to insert an LED lamp without interfering with previously inserted adjacent components, such as the LED current limiting resistor. Insertion machine manufacturers define the “dead space” requirements for each type of insertion guide and anvil assembly. It is the “dead space” requirements that determine the achievable packing density. Figure 10 illustrates representative requirements.

Insertion Sequence Planning

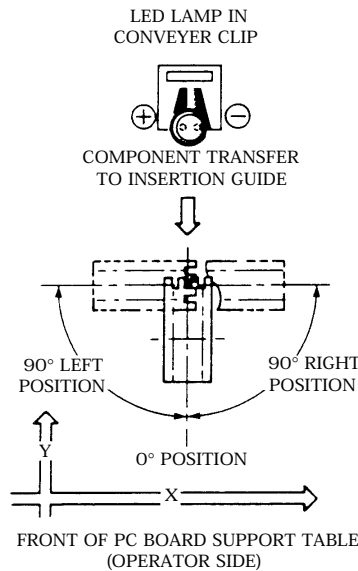


Figure 9a. Rotational Orientation of Insertion Guide Assembly with Respect to PC Board Support Table X-Y Axis.

Insertion sequence planning should be incorporated into the programming of an auto-insertion machine. The objectives are 1.) to have as little movement of the PC board X-Y support table as possible between successive component locations and 2.) to prevent previously inserted components from interfering with the operation of the insertion guide assembly and the clinch anvil. Keeping movement of the X-Y table to a minimum between component insertions increases the insertion rate, and careful sequencing increases yield by preventing damage to previously inserted components caused by insertion guide/component collision. One method of achieving a high yield insertion rate is to use the technique of row insertion. Component insertions are programmed to occur along one axis in a row, followed by stepping along the other axis to pick up the next row after the previous row is filled. The empty row behind the insertion guide gives clearance for the unhindered operation of both the insertion guide and the clinch anvil. This is an effective technique for inserting an array of LED lamps; see Figure 10C.

Insertion Guide Plunger

The shape of the face of the insertion guide plunger is important to 1.) prevent missed insertions of LED lamps and 2.) to provide compatibility between LED lamps and other types of components to be inserted. The use of a compound shaped tip for the insertion guide plunger is recommended over the use of a flat surfaced tip. One possible compound shaped tip design is shown in Figure 11. This plunger tip has been designed to accept the round cylindrical dome of an LED lamp as well as other components, such as resistors, disc capacitors and tran-

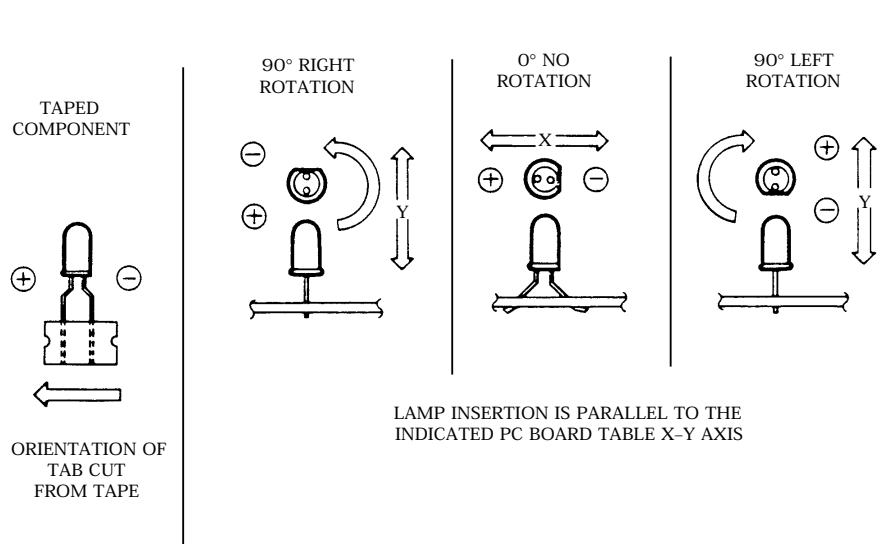


Figure 9b. Insertion Orientation Achieved by Rotation of Insertion Guide Assembly.

sistors. This tip provides the plunger with positive vertical control of each device type, reducing the possibility of a missed insertion.

Lamp Vertical Alignment Considerations During Soldering

The clinching action of auto-insertion does not insure precise vertical alignment of an LED lamp with respect to the PC board. In some applications this may not be a concern. In applications where vertical alignment is important, it will be necessary to build a fixture to hold the LED lamps perpendicular to the PC board during the soldering process. Figure 12 illustrates the concept. The reusable fixture slips over the top of the LED lamps and is keyed to the PC board. The fixture rides on the PC board through the soldering operation and should be removed prior to post solder cleaning.

CAUTION: Bending the leads to obtain vertical alignment with respect to the PC board after soldering may damage an LED lamp, resulting in catastrophic failure of the device.

LED Lamp Stand-Off Height, Lead Neck Length and Seating Plane.

In the design of a front panel assembly, the stand-off

height of the auto-inserted LED lamps determines the distance between the front panel and the PC board. Figure 13 gives nominal values of the lamp stand-off height and lead neck length for T-1 and T-1 3/4 lamps. The stand-off height is the overall height of an auto-inserted LED lamp when soldered into a PC board, the sum of the lead neck length and the height of the lamp dome. The lead neck length is the difference between the height of the base of a lamp mounted on tape and the crimp height. The crimp height is the location of the 5 mm lead bend, and establishes the seating plane for lamps with 5 mm lead spacing.

$$\text{LEAD NECK LENGTH} = H - H_0$$

$$\text{STAND-OFF HEIGHT} = (H - H_0) + A$$

Where:

H = Height of base of lamp from the tape feed hole centerline; 20.5 mm (0.807 inch) nominal.

H₀ = 5 mm lead crimp height from the tape feed hole centerline; 16 mm (0.630 inch) nominal.

A = Height of lamp dome, base of lamp to top of dome.

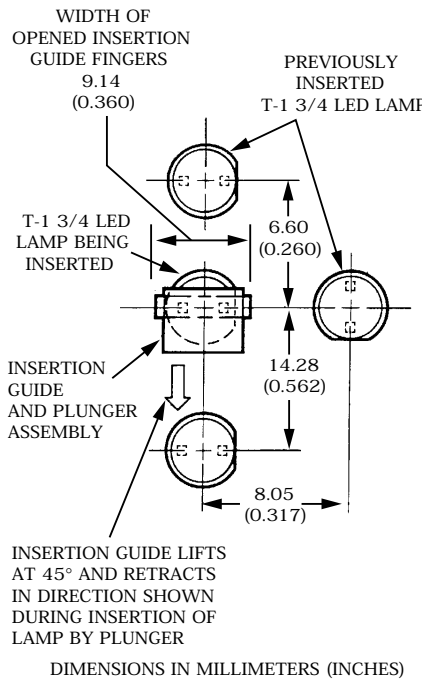


Figure 10a. An Example of Clearances on a PC Board Between Adjacent T-1 3/4 Lamps Required for Proper Insertion.

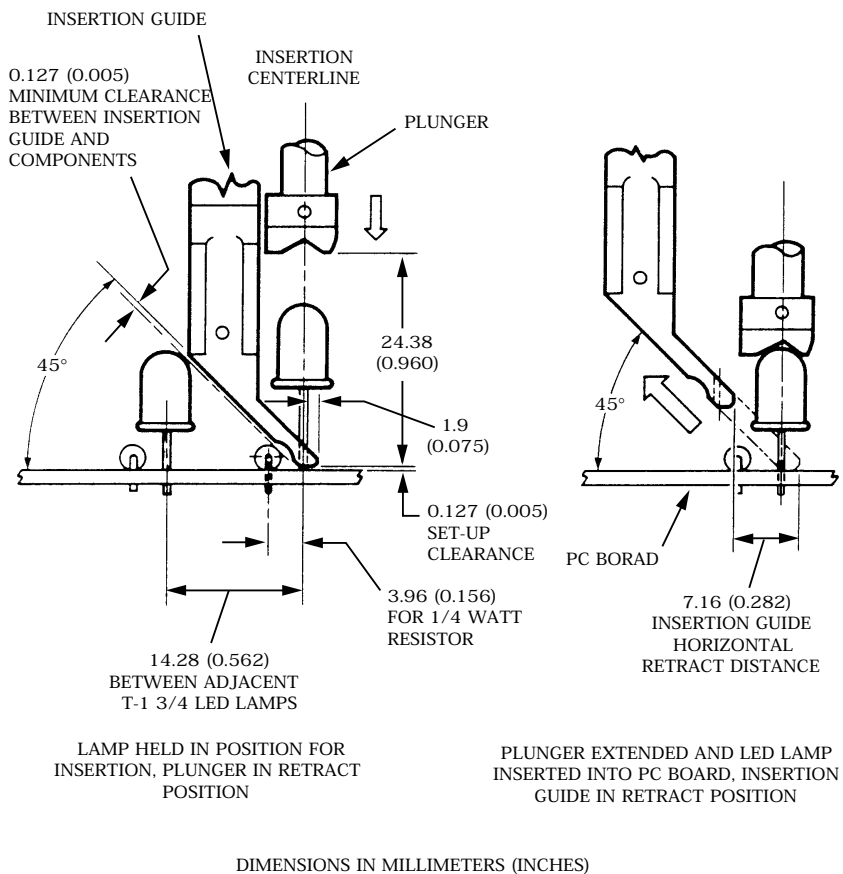


Figure 10b. An Example of Insertion Guide to Component Clearance Requirements, shown for T-1 3/4 LED Lamps and 1/4 Watt Current Limiter Resistors.

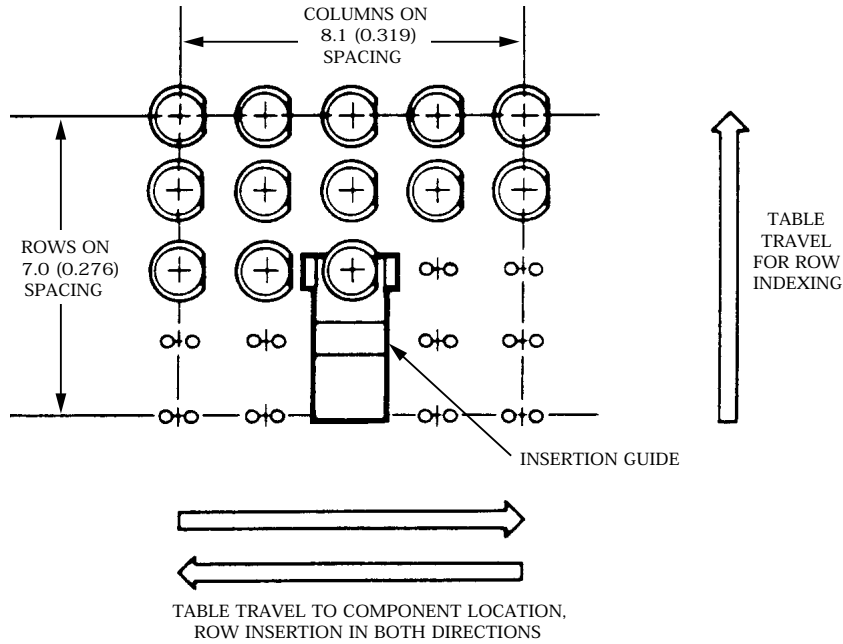


Figure 10c. Representative Packing Density of Auto-Inserted T-1 3/4 LED Lamps.

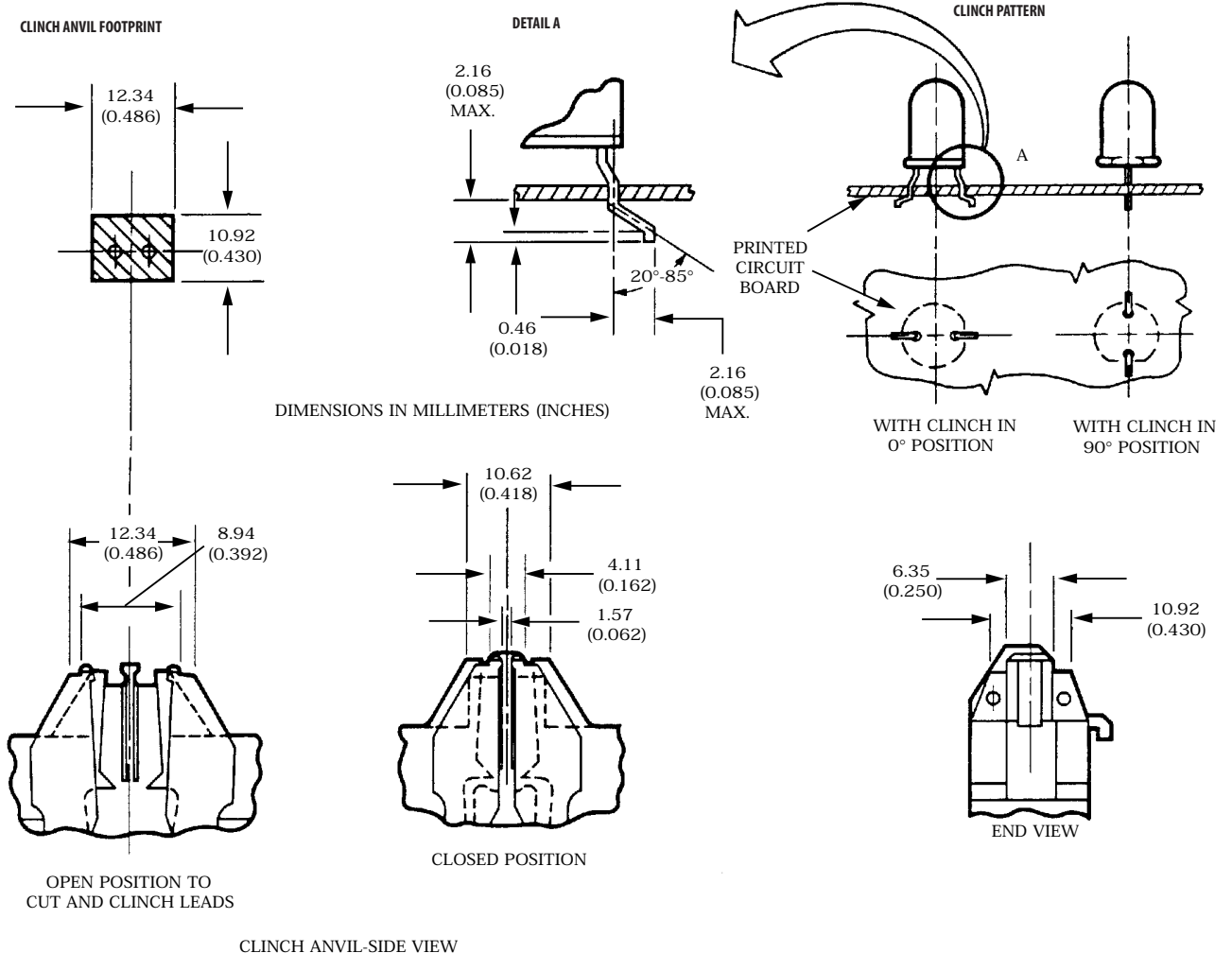


Figure 10d. An Example of Anvil Footprint and Lead Cut and Clinch Detail.

Summary

Avago Technologies plastic LED lamps, packaged on tape and reel, are available in two lead spacing options. The tape and reel packaging of LED lamps follows industry standards for lead spacing and dimensions. Critical parameters and dimensions are maintained to be compatible with radial lead auto-insertion equipment. Product electrical, optical and reliability performance meet standard catalog specifications.

To assure compatibility for auto-insertion of tape and reel LED lamps, the design and layout of a printed circuit board should include the various PC board design and dead space requirements specified by the auto-insertion machine manufacturer. Insertion sequence planning should be incorporated in the programming of the auto-insertion machine for best insertion rate and yield. Fixturing may be required to assure vertical alignment of

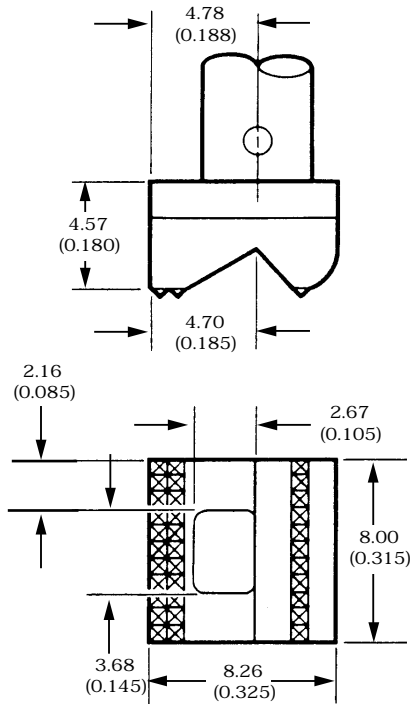
the LED lamps with the PC board during soldering. The design of a front panel application should utilize the LED lamp stand-off height to determine the correct spacing between the front panel and the printed circuit board.

Acknowledgement

Avago expresses its appreciation to the following auto-insertion machine manufacturers for their support in supplying information contained within this application note.

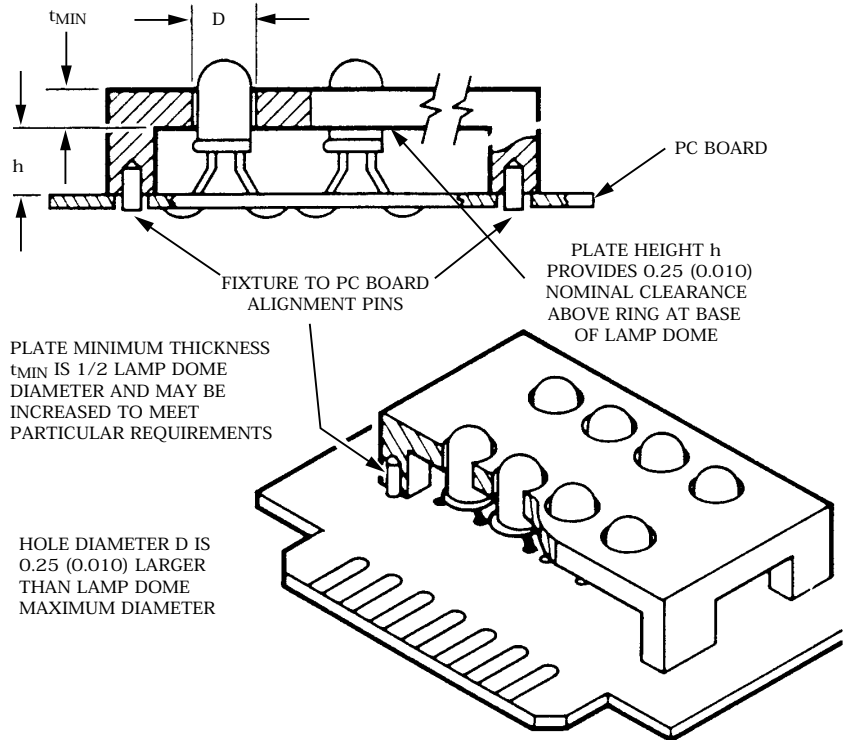
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DIMENSIONS IN MILLIMETERS (INCHES)

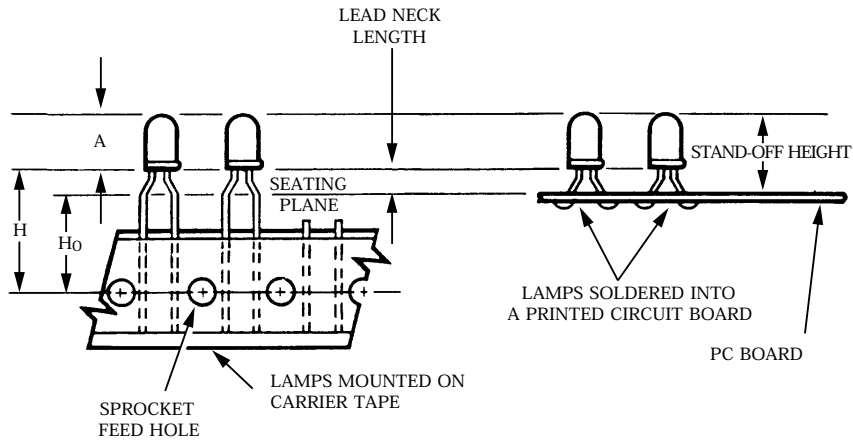
Figure 11. Compound Shaped Tip Design for Insertion Guide Plunger.



LAMP TYPE	D-HOLE DIAMETER	t _{MIN} -PLATE THICKNESS	h-PLATE HEIGHT
T-1 3/4	5.33 (0.210)	2.54 (0.100)	5.64 (0.222)
T-1 3/4 LOW PROFILE	5.33 (0.210)	2.54 (0.100)	6.41 (0.252)
T-1	3.43 (0.135)	1.58 (0.062)	5.77 (0.227)
T-1 LOW PROFILE	3.43 (0.135)	1.58 (0.062)	5.77 (0.227)

DIMENSIONS IN MILLIMETERS (INCHES)

Figure 12. Fixturing Concept to Achieve Vertical Alignment of Auto-Inserted Lamps During the Soldering Process.



LAMP TYPE	T-1	T-1 LOW PROFILE	T-1 3/4	T-1 3/4 LOW PROFILE
LEAD NECK LENGTH	4.5 (0.177)	4.5 (0.177)	4.5 (0.177)	4.5 (0.177)
STAND-OFF HEIGHT	9.2 (0.362)	8.2 (0.324)	13.7 (0.539)	10.8 (0.427)

DIMENSIONS IN MILLIMETERS (INCHES).
DIMENSIONS ARE NOMINAL VALUES.

Figure 13. Lamp Stand-off and Lead Neck Length Dimensions.

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