
Mounting instructions for THD (through-hole device) packages

Introduction

The mounting instructions herein provide the main recommendations to appropriately handle, assemble and rework through-hole device packages. It is necessary to follow some basic assembly rules to limit thermal and mechanical stresses or ensure optimal thermal conduction and electrical insulation.



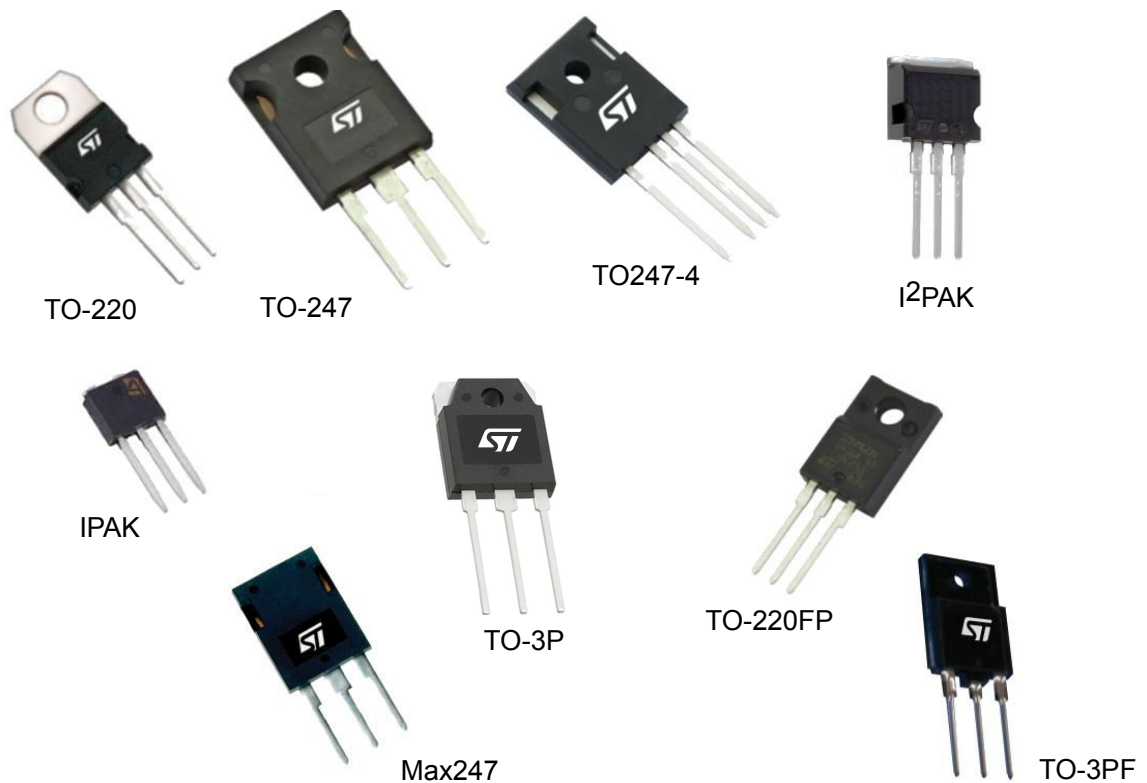
1 Package description

In the through-hole device packages the leads of these type of devices (THD packages) are longer and straight at the end, so that they can be inserted into drilled holes in PCBs and attached by wave soldering. An extra heat sink can be either mounted on the heat slug or exposed die pad.

Depending on the process and technology, this requires an extra process before or after soldering the leads.

The figure below shows examples of THD packages.

Figure 1. Example of THD packages



1.1 Thermal performance

The thermal resistance of semiconductor assembly is the parameter which characterizes its resistance to the heat flow generated by the junction during operation. A temperature exceeding the maximum junction temperature curtails the electrical performance and may damage the device.

The maximum dissipated power capability is:

$$P_{\max} = \frac{T_{J(\max.)} - T_A}{R_{thJA}}$$

where:

- $T_{J(\max.)}$ is the maximum junction temperature of the semiconductor in degrees (°C)
- T_A is the ambient air temperature in degrees (°C)
- R_{thJA} is the thermal resistance between junction and ambient air (°C/W)

R_{thJA} takes into account all materials between the junction and ambient air.

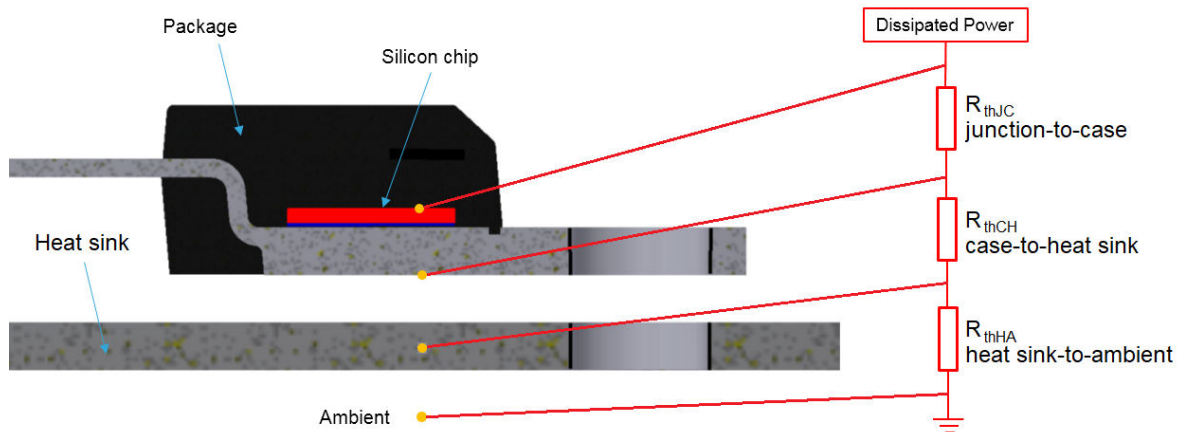
An analogy between Ohm's law and the thermal equivalent circuit can be made:

- Electrical resistance corresponds to thermal resistance
- Current corresponds to dissipated power
- Voltage corresponds to temperature

Thus: $V = R \cdot I$ corresponds to $\Delta T = R_{th} \cdot P$

The overall thermal performance of a package with a heat sink is characterized by a junction-to-ambient thermal resistance R_{thJA} . R_{thJA} can be calculated with following equation (see figure below).

Figure 2. Thermal model



When the package is mounted on a heat sink, it is important to consider the interface resistance R_{thCH} . In an ideal case, R_{thCH} is zero. In real applications, there is a small air gap because of these three factors:

- Package and heat sink are never perfectly smoothed
- Package and heat sink are never perfectly flattened
- Misalignment of package due to imperfect mounting

and thus R_{thCH} always exceeds zero.

For insulated packages like TO-220FP, thermal grease should be used to fill the air gap between the package and the heat sink. Measurements show that using thermal grease reduces the interface resistance by 1.0 °C/W minimum.

In many applications, the package must be electrically insulated from its mounting surface.

The insulation has a comparatively high thermal resistance, which raises junction operating temperatures.

1.1.1 Insulating material

Mica and silicone pads are well-known insulating materials that can be laid between the package and the heat sink. Mica is usually assembled with thermal grease on both sides.

Mica is an effective thermal insulator and its cost is low. However, it is apt to be messy, and it can contaminate adjacent circuitry and dry out overtime. Clean installation is possible with silicone pads. Reworking it is easy and inexpensive.

1.1.2 Thermal grease

To determine the correct amount of grease to apply, several semiconductor samples and heat sinks should be assembled with different amounts of grease applied evenly to one side of each mating surface. When the amount is correct, a very small amount of grease should appear around the perimeter of each mating surface as the assembly is slowly torqued to the recommended value. Examination of a disassembled part should reveal even wetting across each mating surface.

1.1.3 Mounting torque

Increasing the contact pressure between package and heat sink maximizes the contact area between the two surfaces. Increasing the mounting torque in the fastening screw, or using a clip with a high spring constant, increases the contact areas and provides solid conduction heat-flow paths, which are more effective than conduction across an air gap. Applying the proper mounting torque is the key factor to obtain adequate pressure along the contact surfaces of the package and the heat sink, in order to minimize the contact thermal resistance. If mounting torque is too low, the contact thermal resistance increases due to bad thermal contact under insufficient contact pressure. If mounting torque is too high, the package head and mounting tab deform so that the package may be lifted away from the heat sink, as shown in the figure below. This also increases the contact thermal resistance. Hence, appropriate mounting torque must be applied to produce minimal thermal resistance and avoid damaging the package or changing the device characteristics.

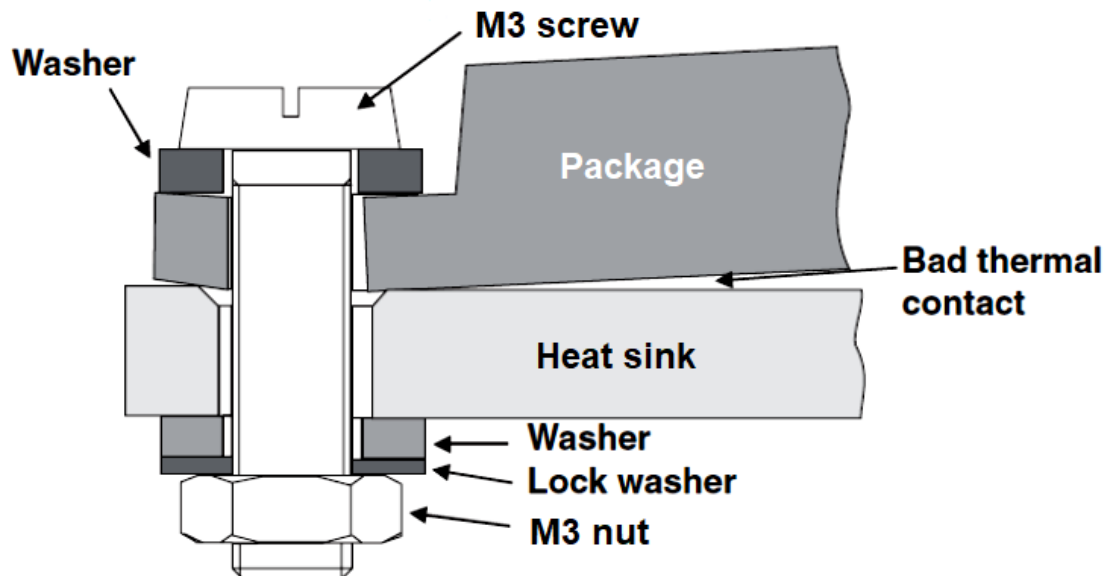
The thermal contact resistance depends on the force generated by the applied torque on the screw:

$$F = \frac{2 \cdot T \cdot \pi}{P + r \cdot D \cdot \pi}$$

Where:

- T is applied torque on the screw in N*m
- P is pitch in m
- D is the screw diameter in m
- r is the rubbing factor: # 0.12 for steel-steel with grease and # 0.2 for steel-aluminum

Figure 3. Example of wrong assembly due to over torque



2 Pre-mounting processes and mounting material

2.1 Lead cutting

The leads of THD packages can be cut before mounting or after mounting and soldering.

When cutting after soldering, the leads are attached by the solder joint. Severe mechanical mishandling during the cutting process could cause solder joint failure, but generally does not harm the component body. When cutting prior to mounting, the leads have to be fixed by a clamp that should be similar to a clamp used for lead bending (refer to the next section).

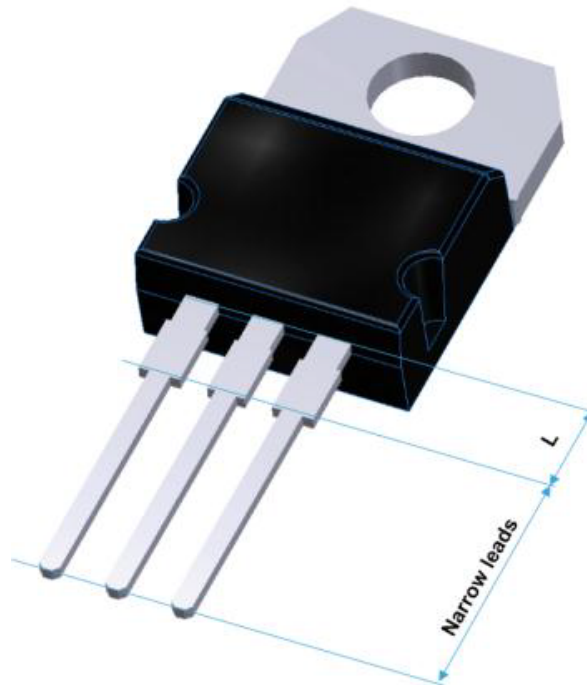
2.2 Lead bending

To insert the terminals of THD package in the holes of the PCB, the terminals may have to be bent to a certain pitch of the solder pads.

The following guidelines should be observed:

- Some of THD packages show a wider leads near the package body. In this case, the bending distance has to be no less than the distance between the narrow lead part to the package body (see [Figure 4. Minimum bending and cutting distance given by the distance between the package and narrow lead area](#)).
- In other cases, the minimum distance between package body and bending should be 2.5 mm (see [Figure 5. Minimum bending distance is 2.50 mm](#)). The leads must not be bent directly at the edge of the package, see [Figure 6. The leads must not be bent directly at the edge of the package](#).
- The minimum bend radius must be equal or higher than lead thickness "T".
- For bending, a clamping tool should be used to ensure that mechanical forces such as pulling and shearing do not occur between the leads and the package body. The part of the lead between the point of bending and the package must be relieved of tensile stress during the bending process (see [Figure 7. Lead clamping element must have a clearance with plastic body](#)). Therefore, it is necessary to avoid slippage due to weak clamping, or weakening of the lead due to overly strong clamping.
- A properly designed clamping tool helps to ensure that the shape of the bends are consistently reproducible.
- The tensile strength of the leads from the clamping to the point where the bending force is applied should not be exceeded by using too much force. This maximum force is mainly dependent on the cross-sectional area of the lead. A typical maximum force is 20 N.
- Bending the leads parallel to the lead plane is not allowed.
- Bending the leads manually is acceptable when the guidelines above are followed as well as (see [Figure 8. Manual lead bending](#)).

Figure 4. Minimum bending and cutting distance given by the distance between the package and narrow lead area



The distance L depends upon the specific package and can be found in relevant package drawing (in datasheet).

Figure 5. Minimum bending distance is 2.50 mm

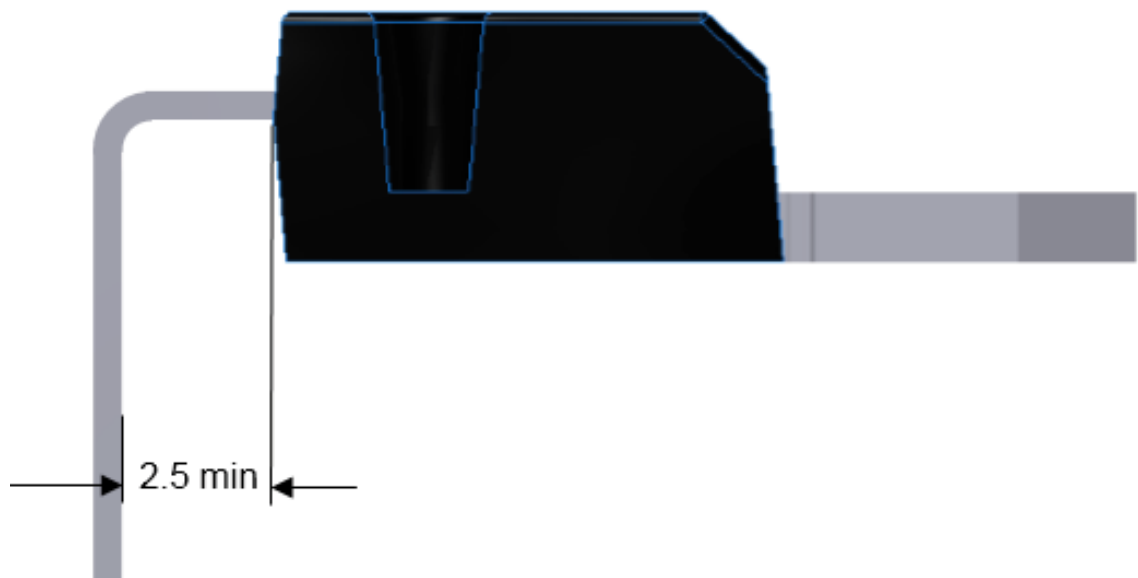


Figure 6. The leads must not be bent directly at the edge of the package

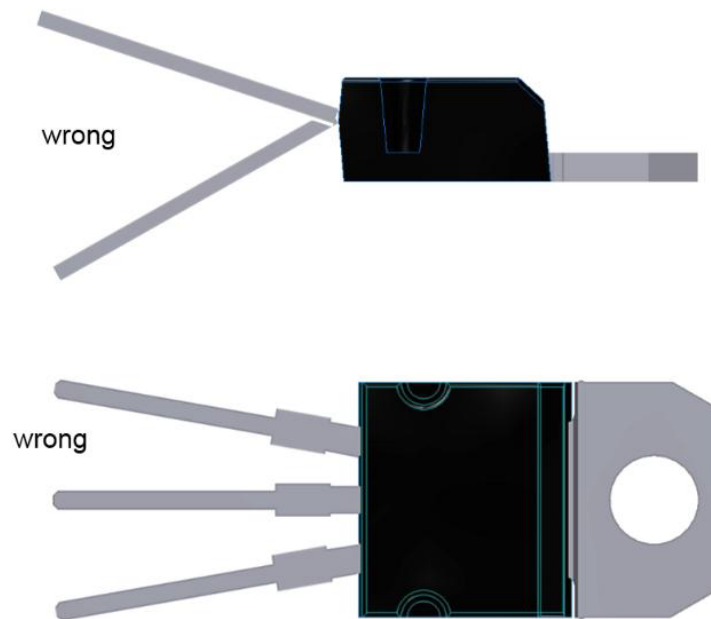


Figure 7. Lead clamping element must have a clearance with plastic body

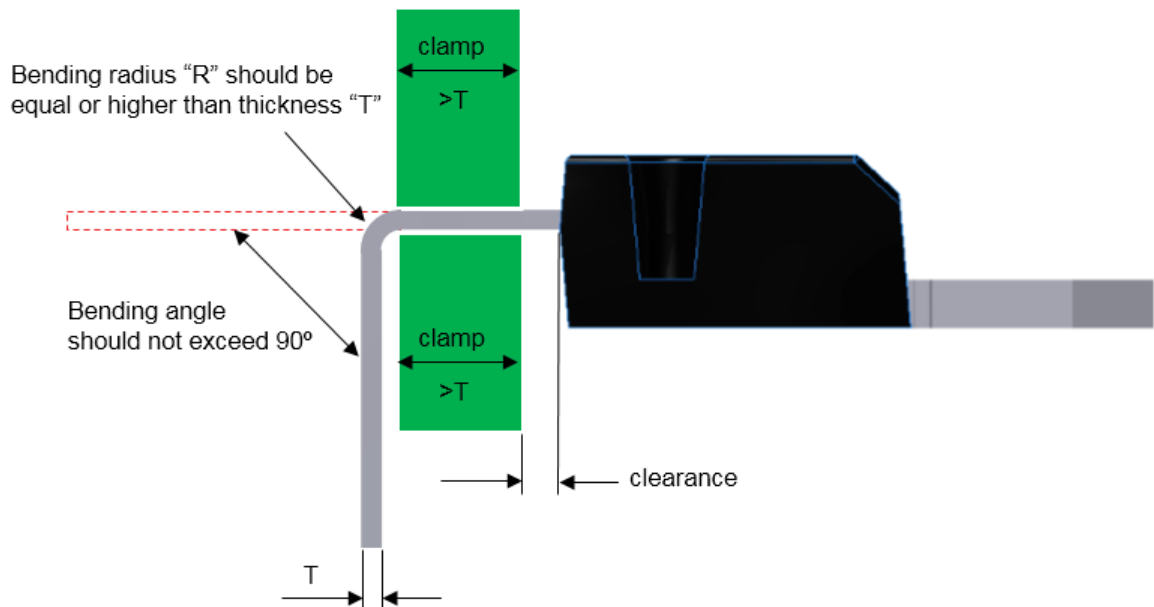
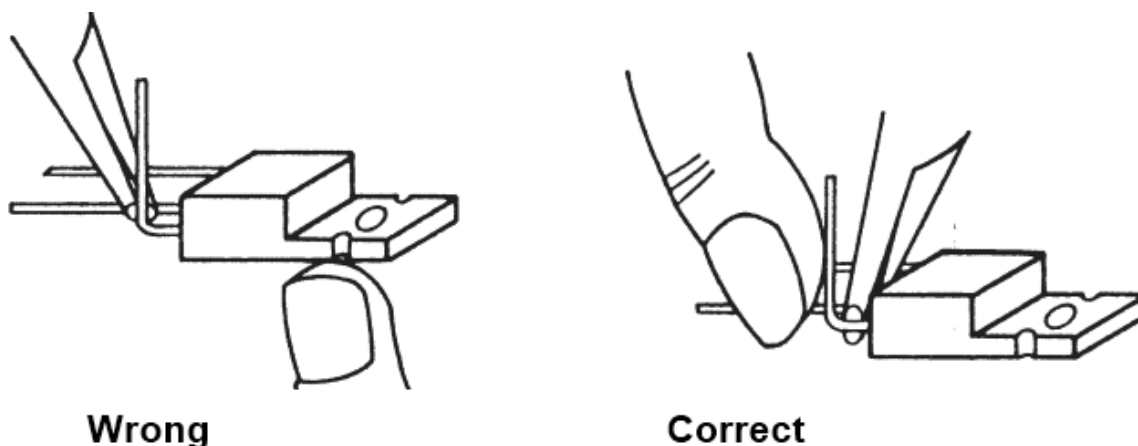


Figure 8. Manual lead bending



2.3 Heat sink requirements

The contact area of the package and the heat sink (separate or PCB) must be free of any particles and damage as well as any other contamination.

The following surface conditions are recommended:

- Heat sink roughness: $R_z \leq 10 \mu\text{m}$
- Heat sink flatness: $\leq 10 \mu\text{m}$ (reference length 15 mm)

2.4 Attachment holes for heat sink screw mounting

Drill holes should be as small as possible. Using oversized drill holes reduces the effectiveness of the heat sink.

The flatness and effectiveness of the heat sink (separate or PCB) is also reduced by intrusions and/or burrs around the hole. These are caused by the punching or drilling process and should be less than the specified heat sink roughness and flatness. If intrusions or large drill holes are unavoidable, a properly sized square washer should be used to get a good and flat contact between heat sink and package.

3 Mounting a THD package

3.1 Main influences on THD package assembly quality

The following factors have to be taken into account to achieve the best assembly quality for a given application:

- Insulating material (for example, washer or spacer)
- Screws
- Thermal grease
- Mounting torque
- PCB and heat sink
- Attachment holes for heat sink screw mounting
- Soldering method / soldering profile
- Solderability of package

3.2 THD package placement

The insertion of the THD package is either done with special automatic equipment or manually.

Special care has to be taken during this insertion to avoid deformation or violent bending. The diameter of the drill holes in the PCB must be taken into account the tolerances of component leads, drill-hole positions, and placement accuracy.

Normally after insertion, the leads are slightly bent to fasten the component to the PCB until soldering. Take care that this does not cause defects in the interconnection between leads and package body.

3.3 Heat sink mounting

For special packages with high power dissipation, the heat sink can be mounted before or after soldering of the leads.

3.3.1 Heat sink screw mounting

Screw mounting is a traditional assembly method accomplished by fastening a screw, nut and washer together.

- Self-tapping screws should not be used.
- Pop rivets should never be used for the following reasons:
 - A too rigorous expansion of the metal can lead to a distortion of the heat sink hole and induce mechanical stresses on the die
 - High crimping shock can damage the die
- Press rivets can be used with caution provided they are of a soft metal like aluminum or plastic. In this case, crimping force must be applied slowly and carefully in order to avoid shock and deformation of the heat sink.
- A washer should be inserted between the screw head and the mounting tab. Care must be taken to ensure that the washer does not damage the plastic body of the package during the mounting process. A lock washer as well as a nut is suggested to be used for optimal mounting. The figure below shows the suggested general fitting kits.

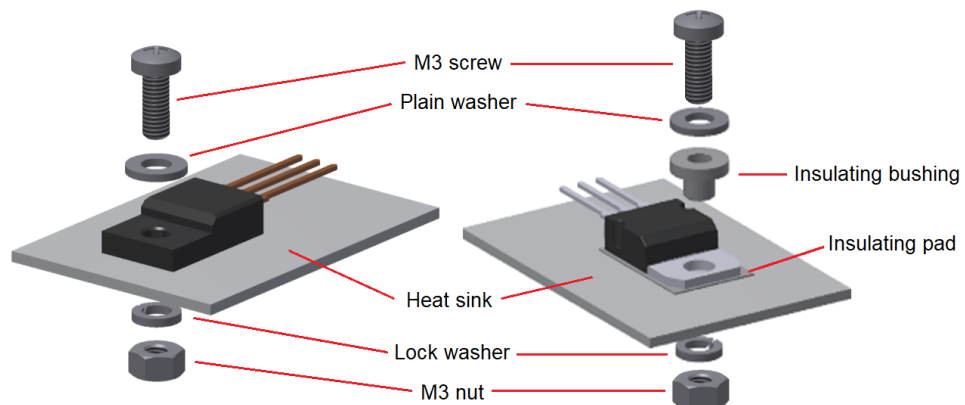
Figure 9. Screw, nut, plain washer and lock washer kit



- In case of pneumatic or electric screwdriver use, the number of revolution needs to be well-considered and should not exceed 200 rpm.

The screw should be tightened properly to ensure that the package makes good contact with the heat sink. The figure below illustrates proper mounting methods for a TO-220FP and a TO-220.

Figure 10. Suggested mounting method for TO-220FP (left side) and TO-220 (right side)



Typical and maximum mounting torque values are shown in the table below:

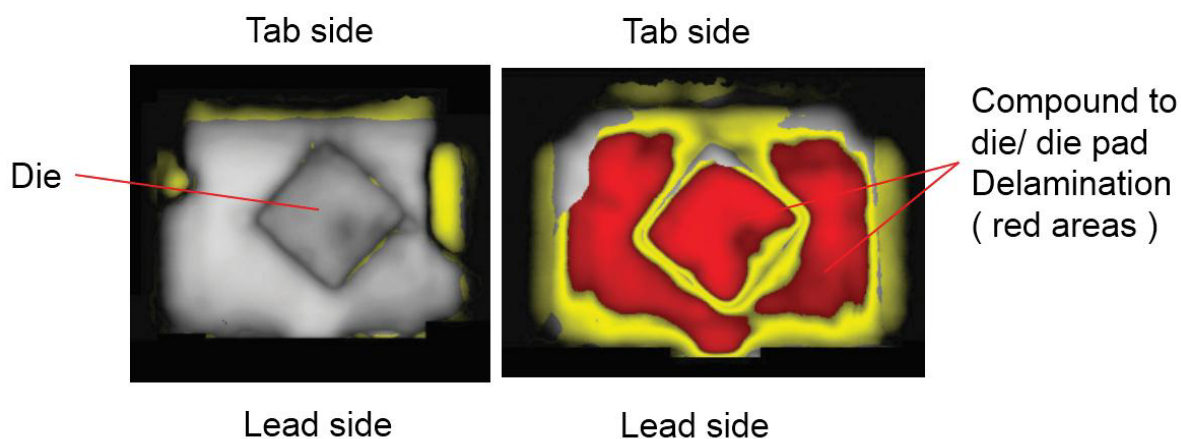
Table 1. Mounting torque values (M3 screw)

| Package | Mounting torque | | Unit |
|----------|-----------------|---------|------|
| | Typical | Maximum | |
| TO-220 | 0.55 | 0.70 | N*m |
| TO-220FP | 0.55 | 0.70 | N*m |
| TO-247 | 0.55 | 1.00 | N*m |
| TO247-4 | 0.55 | 1.00 | N*m |
| TO-3P | 0.55 | 1.00 | N*m |
| TO-3PF | 0.55 | 1.00 | N*m |

Examples of improper mounting:

SAM (scanning acoustic microscopy) delamination of molding compound to die paddle at package head caused by external mechanical stress for improper mounting.

Figure 11. TO-220 component not assembled yet on left side. On right side, component that underwent heavy mechanical stress due to improper mounting



3.3.2 Heat sink clip mounting

The clip-mounting method has become popular because it is simple and reliable. The process is fast and appropriate for mass-production assembly. The screw mounting is applied to one end of the package during fastening. This causes uneven contact pressure and a bad thermal contact. By comparison, the clip is mounted on the package center over the die and this results in more uniform contact pressure and good thermal contact. Using clip mounting ensures that the force is applied above the silicon.

For heat sinks less than 5 mm in thickness, saddle clips should be used, see [Figure 12. Example of clip mounting \(saddle type\)](#). These produce contact forces between 15 N and 50 N.

For heat sinks greater than 5 mm in thickness, U clips are used. These produce contact forces between 15 N and 50 N.

There are a number of proprietary clip solutions where the clip is anchored in a feature in an extruded heat sink. Contact forces between 25 N and 50 N can be achieved.

If clips are used, the contact area between the plastic case and the clip must be treated carefully. The maximum pressure allowed on plastic is 150 N/mm². Above this value, cracks in the molded body may appear. Therefore, clips have to be round or smooth in the contact area to avoid concentrated loads on the plastic body of the package. For some applications, it is necessary to have the package electrically isolated from the heat sink or PCB. The differences can be seen in [Figure 13. Example of clip mounting with and without insulated assembly](#)

Figure 12. Example of clip mounting (saddle type)

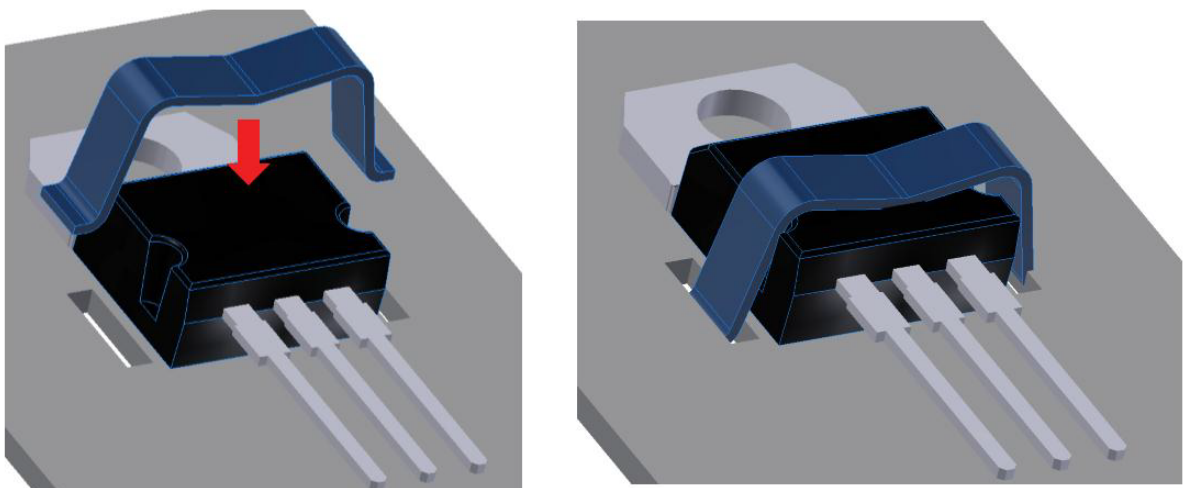
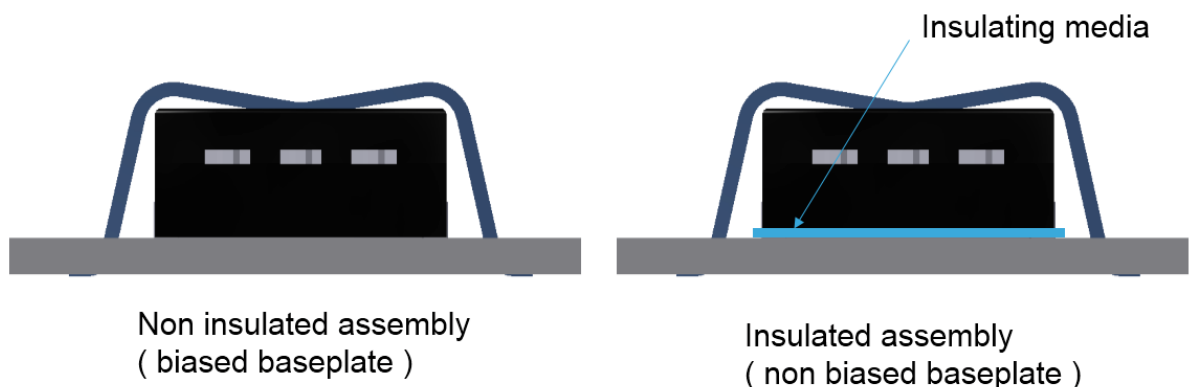


Figure 13. Example of clip mounting with and without insulated assembly



4 Package handling

4.1 ESD protective measures

Semiconductors are normally electrostatic discharge sensitive (ESDS) devices requiring specific precautionary measures regarding handling and processing. Static discharges caused by human touch or by processing tools may cause high-current and/or high-voltage pulses, which may damage or even destroy sensitive semiconductor structures. On the other hand, integrated circuits (ICs) may also be charged by static during processing. Discharging, which occurs too quickly (hard discharge) may also cause peak loads that can lead to damage. ESD protective measures must therefore prevent contact with charged parts as well as charging of the ICs. Protective measures against ESD include procedures for proper ESDS handling, processing and packing. A few handling and processing tips are provided below.

4.1.1 ESD protective measures in the workplace

- Standard marking of ESD-protected areas
- Access controls, with wrist strap and footwear testers
- Air conditioning
- Dissipative and grounded floor
- Dissipative and grounded working and storage areas
- Dissipative chairs
- Ground bonding point for wrist strap
- Trolleys with dissipative surfaces and wheels
- Suitable shipping and storage containers
- No sources of electrostatic fields

4.1.2 Personal equipment

- Dissipative/conductive footwear or heel straps
- Suitable garments made of fabrics that do not generate excessive static electricity
- Wrist strap with safety resistor
- Volume conductive gloves or finger cots

4.1.3 Production installations and processing tools

- Machine and tool parts made of dissipative or metallic materials
- No materials having thin insulating layers for sliding tracks
- All parts properly connected to ground potential
- No potential difference between individual machine and tool parts
- No sources of electrostatic fields

Our recommendations are based on the internationally applicable standards IEC 61340-5-1 and ANSI/ESD S2020.

4.2 Packing of components

Refer to product and package specifications and our sales department for information regarding what packaging is available for a given product. Generally, the following list of standards dealing with packing should be considered if applicable for a given package and packing:

- IEC 60286-4 packaging of components for automatic handling - part 4: stick magazines for dual inline packages
- IEC 60286-5 packaging of components for automatic handling - part 5: matrix trays

4.3 Storage and transportation conditions

Improper transportation and unsuitable storage of components can lead to a number of problems during subsequent processing, such as poor solderability, delamination and package cracking effects. These relevant standards should be taken into account as appropriate:

- IEC 60721-3-0 classification of environmental conditions: Part 3: Classification of groups of environmental parameters and their severities; introduction
- IEC 60721-3-1 classification of environmental conditions: Part 3: Classification of groups of environmental parameters and their severities; Section 1: Storage
- IEC 60721-3-2 classification of environmental conditions: Part 3: Classification of groups of environmental parameters and their severities; Section 2: Transportation
- IEC 61760-2 Surface mounting technology - Part 2: Transportation and storage conditions of surface mounting devices (SMD) - Application guide
- IEC 62258-3 semiconductor die products - Part 3: Recommendations for good practice in handling, packing and storage ISO 14644-1 clean rooms and associated controlled environments part 1: Classification of airborne particulates

Table 2. General storage conditions - overview

| Product | Storage conditions |
|------------------------------------|--|
| Wafer / die | N2 or MBB ⁽¹⁾ (IEC 62258-3) |
| Component - not moisture sensitive | 1K2 (IEC 60721-3-1) |

1. MBB = moisture barrier bag

Maximum storage time

The conditions to be complied with in order to ensure problem-free processing of active and passive components are described in standard IEC 61760-2.

References to standard institutes

- American national standards institute (ANSI)
- Electronics industries alliance (EIA)
- Association connecting electronics industries (IPC)

4.4 Handling damage and contamination

Any mechanical damage during automatic or manual handling of components (in or out of the component packing) that may harm the package leads and/or body must be avoided. In particular, unintentional bending of the leads may cause a loosening in the package body which can result in electrical malfunction. Along with other factors, contamination of a component or packing may cause:

- Solderability problems
- Corrosion
- Electrical short-circuit (due to conductive particles)

4.5 Component solderability

The final plating of most semiconductor packages is sufficiently thick and wettable to assure good solderability, even after an extended storage time. Note that the cut edges of the pins should be ignored in any assessment of solderability. Suitable methods for the assessment of solderability can be derived from JESD22B 102 or IEC6068-2-58.

Components are plated with pure Sn, or preplated with noble metals on a Ni carrier (for example, NiAu, NiPdAu). Tin-plated and preplated components are compatible with both SnPb and Pb-free soldering.

5 Soldering

5.1 Selective wave soldering

Wave soldering is a large-scale soldering process by which electronic components are soldered to a PCB to form an electronic assembly. The name derives from the fact that the process uses a tank to hold a quantity of molten solder; the components are inserted into or placed on the PCB and the loaded PCB is passed across a pumped wave or cascade of solder. The solder wets the exposed metallic areas of the board (those not protected with a solder mask), creating a reliable mechanical and electrical connection.

For THD, only the leads that extend through the drill holes in the PCB contact the hot solder. The body of the package is heated by the hot leads. This has two consequences:

1. The package body is cooler than in the case of reflow soldering
2. The temperature gradient between leads and body and inside the package is greater than in the case of reflow soldering

Therefore, for wave-solderable THD packages, the heat resistance is tested according to JESD22-B106 and IEC668 2-20 (typically 260 °C, 10 s).

Immersion of the whole package body into the molten solder is not recommended since THD packages are not designed for such a harsh temperature shock.

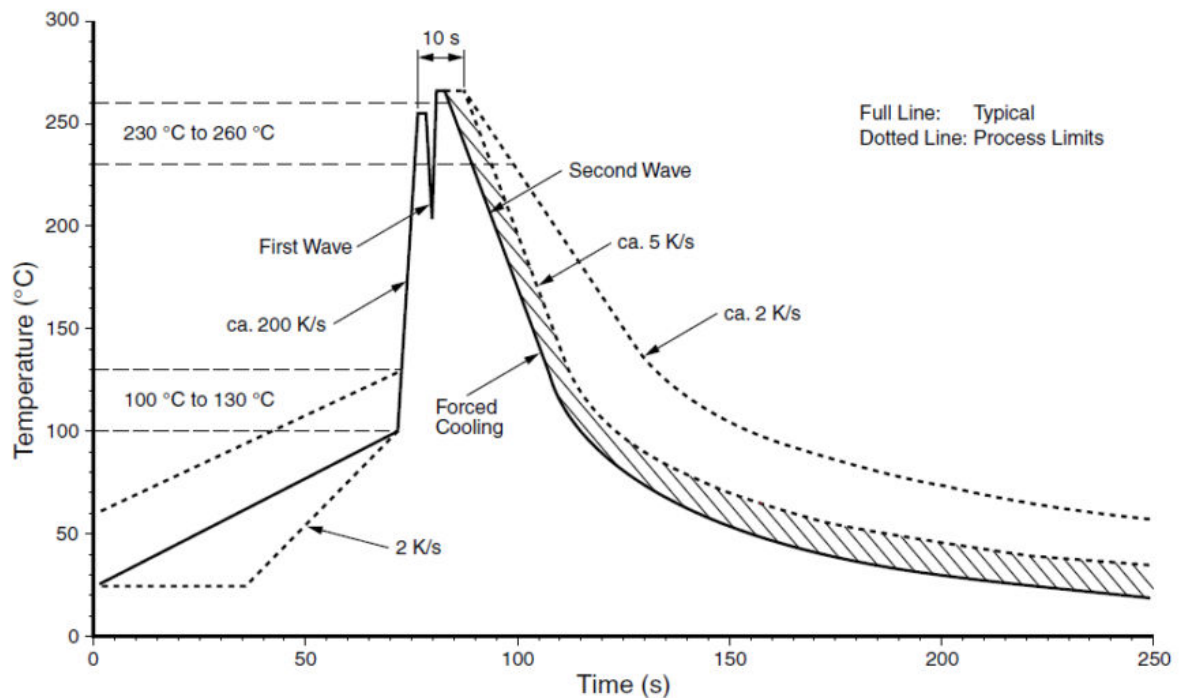
There are many types of wave-soldering machines, but their basic components and principles are the same. A standard wave-soldering machine consists of three zones: the fluxing zone, the preheating zone, and the soldering zone. A fourth zone, the cleaning zone, may be used depending on the type of flux applied.

Dual-wave soldering is the most commonly used wave-soldering method (see figure below). The peak temperatures, ramp rates, and times that are used depend on the materials and the wave-soldering equipment. The first wave has a turbulent flow and therefore guarantees a wetting of nearly all shapes of leads and board pads, but also creates an increased number of unwanted solder bridges. These solder bridges have to be removed by the second, laminar wave.

When using lead-free solder alloys, a nitrogen atmosphere is recommended.

Selective wave soldering is used when only a few THD packages need to be soldered onto the board. Generally this is done after the other components are already soldered by reflow soldering. This requires effective protection of the components undergoing the selective wave soldering. This protection can be achieved either by using special fixtures and deflectors for the PCB and/or a small wave shape achieved by using special wave-guiding tubes or covers.

Figure 14. Typical dual-wave soldering profile



5.2 Other soldering techniques

Besides wave and reflow soldering, other techniques are used in special applications. Examples include selective wave soldering, laser welding and soldering, hot bar soldering, and manual soldering with soldering irons and hot air guns.

For this broad group of soldering techniques, which cannot be tested for every component, some general guidelines should be observed:

- The maximum temperature of the package body and leads must not exceed the maximum allowed temperature for reflow or wave soldering.
- The maximum allowed time at high temperatures must not exceed the maximum allowed time for reflow or wave soldering.
- If heat is applied to the leads, the maximum temperatures in the package and of the package body must not exceed the maximum allowed temperatures during reflow or wave soldering.
- For details and special arrangements, refer to the product datasheet and/or qualification report.

If long contact and heating times are unavoidable, the resulting temperatures on different leads near the package body should be measured and compared to the temperatures and durations achieved during wave or reflow soldering, which must not be exceeded.

Ask your local sales, quality, or application engineer to provide an evaluation report for further information if needed.

5.3 Heat sink mounting by reflow soldering

In special applications, the heat sink of high-power THD packages can be mounted on the board by solder paste printing, pick&place, and reflow soldering. In this case, the packages undergo a reflow profile.

THD packages are qualified for wave soldering and not for reflow soldering. Therefore, reflow soldering should not be used for heat sink mounting of THD packages.

6 **Cleaning**

After the soldering process, flux residues may be found around the solder joints. However, if the solder joints have to be cleaned, the cleaning method (for example, ultrasonic, spray, or vapor cleaning) and solution must be selected with consideration of the packages to be cleaned, the flux used (rosin-based, water-soluble, etc.), and environmental and safety aspects. Removing/drying even of small residues of the cleaning solution should also be done very thoroughly.

7 Inspection

After component placement:

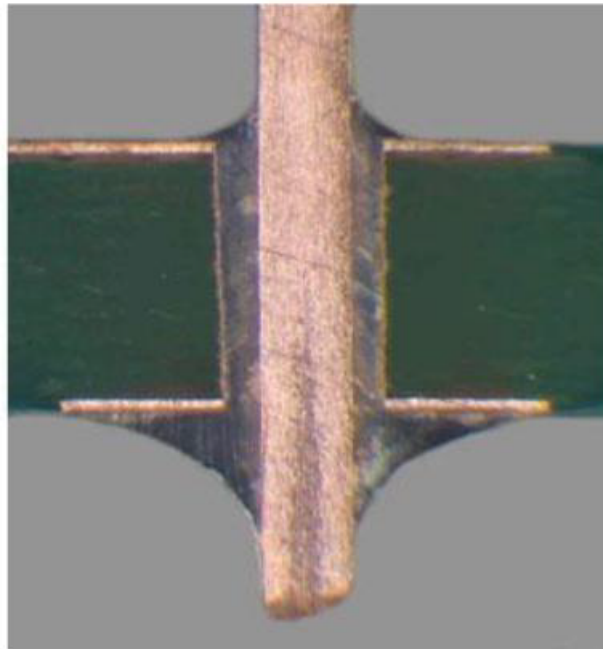
A visual inspection after component placement can be done by AOI. It is used to check if the mounting is done completely and if severe misplacements have occurred. The correct orientation of the component can also be checked.

After soldering:

The solder joint meniscus of the leads of THD packages can be inspected by an optical microscope or AOI. Acceptable solder joints are described in international standards such as IPC-A-610.

The figure below shows a THD lead with optimal wetting. Metallized vias must be filled properly. This cannot be detected by visual inspection, but can be done by x-ray and/or cross-sectioning.

Figure 15. THD package pin soldered into the hole is well-wetted and free of defects



Automatic x-ray inspection (AXI) is the only reasonable method for efficient inline control. AXI systems are available as 2D and 3D solutions. They usually consist of an x-ray camera and the hardware and software needed for inspection, control, analysis, and data transfer routines. These systems enable the user to reliably detect soldering defects such as poor soldering, bridging, voiding, and missing parts. For the acceptability of electronic assemblies, refer also to the IPC-A-610C standard.

Cross sectioning of a soldered package as well as dye penetrant analysis can serve as tools for sample monitoring only, because of their destructive character. Nonetheless, these analysis methods must be used during engineering of new products at customer production sites to obtain detailed information about the solder joint quality.

Lead-free (SnAgCu) solder joints typically do not have a bright surface. Lead-free solder joints are often dull and grainy. These surface properties are caused by the irregular solidification of the solder as the solder alloys are not exactly eutectic. This means that SnAgCu solders do not have a melting point but rather a melting range of several degrees. Although lead-free solder joints have a dull surface, this does not mean that lead-free joints are of lower quality or weaker. It is therefore necessary to teach the inspection staff what these lead-free joints look like, and/or to adjust optical inspection systems to handle leadfree solder joints.

8 Rework

If a defective component is observed after board assembly, the device can be removed and replaced with a new one. Repair of single solder joints is generally possible, but requires proper tools. For example, repairing the solder joint of an exposed die pad cannot be done with a soldering iron.

Whichever rework process is applied, it is important to recognize that heating a board and its components above 200 °C may result in damage. As a precaution, every board with its components should be baked prior to rework. For details, refer to the international standard J-STD-033.

In any case, mechanical, thermal or thermomechanical overstress must be avoided, and rework must be performed according to JEDEC J-STD-033A, IPC-7711 and IPC-7721.

8.1 Device removal

If a defective component is going to be sent back to the supplier, no further defects must be caused during the removal of this component, as this may hinder the failure analysis by the supplier. The following recommendations should be considered:

- Temperature profile: during the desoldering process, ensure that the package peak temperature is not higher and temperature ramps are not steeper than for the standard assembly wave process.
- Mechanics: be careful not to apply high mechanical forces during removal. Otherwise, failure analysis of the package may become impossible, or the PCB may be damaged. For large packages, pipettes can be used (implemented on most rework systems); for small packages, tweezers may be more practical.

8.2 Site redressing

After removing the defective component, the pads on the PCB must be cleaned to remove solder residues. This may be done by vacuum desoldering or using a wick.

Do not use steel brushes because steel residues can lead to bad solder joints. Before placing a new component, it may be necessary to apply solder paste on the PCB pads by printing (special microstencil) or dispensing.

8.3 Reassembly and reflow

After preparing the site, the new package can be placed onto the PCB and the leads inserted into the holes. Regarding placement accuracy and placement force, the process should be comparable to the (automatic) pick&place process.

During the soldering process, ensure that the package peak temperature is not higher and temperature ramps are not steeper than for the standard assembly process. Soldering wire can be used to re-solder the leads. Only use no-clean solder paste, solder wire, and flux for repair.

Revision history

Table 3. Document revision history

| Date | Revision | Changes |
|-------------|----------|---|
| 27-Oct-2015 | 1 | Initial release. |
| 20-Nov-2023 | 2 | <p>Updated title.</p> <p>Updated Figure 1. Example of THD packages, Figure 2. Thermal model, Figure 10. Suggested mounting method for TO-220FP (left side) and TO-220 (right side), Table 1. Mounting torque values (M3 screw) and Figure 14. Typical dual-wave soldering profile.</p> <p>Minor text changes.</p> |

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