Application Notes Guidelines for Surface Mounting of Tantalum Chip Capacitors

INTRODUCTION

The increased use of surface mount components has led many users to revise their assembly procedures and specifications for printed circuit boards. This section will review basic principles and recommendations for mounting surface mount capacitors.

Capacitors can be attached by conventional soldering techniques such as vapor phase, infrared reflow, wave soldering and hot plate methods. Attachment with a soldering iron is not recommended due to the difficulty of controlling temperature and time at temperature.

RECOMMENDED MOUNTING PAD GEOMETRIES

Proper mounting pad geometries are essential for successful solder connections. The dimensions are highly process sensitive and should be designed to minimize component rework due to unacceptable solder joints.

Recommended pad geometries are shown for both wave and reflow soldering techniques. These dimensions are intended to be a starting point for circuit board designers and may be fine tuned if necessary based upon the peculiarities of the soldering process and/or circuit board design.

The ideal soldering pad should produce an ideal soldering fillet, a satisfactory electrical connection for the component on the board and a mechanically sound structure to handle the stresses which appear during mounting and subsequent use of the board.

It should be remembered that each assembly operation depends on manufacturing tolerances (tolerance of substrate itself and tolerance of placement of the substrate on the mounting equipment, tolerance of the pick-and-place machine itself, etc.). We estimate the total absolute value of this tolerance "e" is 0.010" [0.25].

PAD LAYOUT FOR REFLOW SOLDERING

The "A" width of the pad is equal to the maximum width of the component connection plus the total tolerance of the entire system (e = ± 0.010" [0.25]): manufacturing of substrates and pads, holding systems of the substrate on the equipment, alignment, repeatability of the chip placement, etc...

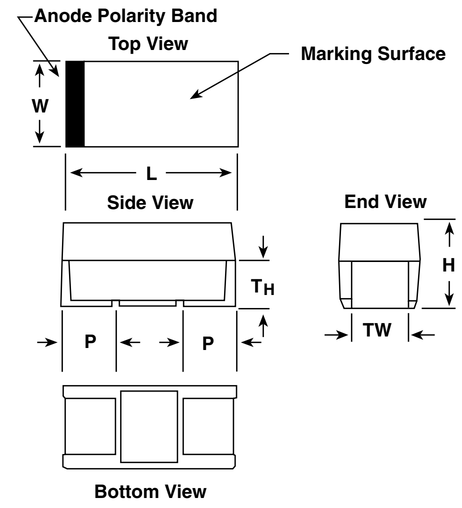
The "D" overall length of the pads is equal to the maximum length of the component plus the "E" zone, necessary to the formation of the soldering fillet. Here we may take into account the tolerance "e" of the system. During reflow, the component tends to center itself on the pads, so, some users don't take into account the tolerance of the system. "D (minimum)" represents this dimension without the tolerance "e" factor and "D (nominal)" takes this factor into account.

The "C" length between the pads is a very critical dimension which has to be maintained; if not, "tombstoning" might occur. We may have to change the dimensions of the pads, however, the "C" dimension should be kept the same.

In the applicable EIA standards, there are recommendations concerning the "E" zone, the outside part of the pads used to form the soldering fillet (0.197" [0.5] ≤ E ≤ 0.039" [1.0]). For the calculation of the "D (minimum)" value, we have chosen "E1" = 0.197" [0.5] and "E2" = 0.039" [1.0] for the "D (nominal)" value.

PAD LAYOUT FOR REFLOW SOLDERING

For a 293D Tantalum Chip Capacitor

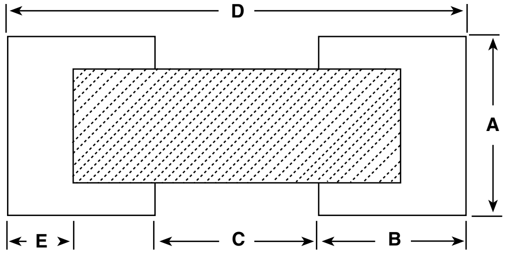


in inches [millimeters]

CASE	A	B	C	D
T_W Max.	0.091 [2.3]	0.091 [2.3]	0.091 [2.3]	0.098 [2.5]
L Max.	0.134 [3.4]	0.146 [3.7]	0.248 [6.3]	0.299 [7.6]
L Nom.	0.126 [3.2]	0.138 [3.5]	0.236 [6.0]	0.287 [7.3]
P Max.	0.043 [1.1]	0.043 [1.1]	0.063 [1.6]	0.063 [1.6]
P Nom.	0.031 [0.8]	0.031 [0.8]	0.051 [1.3]	0.051 [1.3]
T_H Min.	0.028 [0.7]	0.028 [0.7]	0.039 [1.0]	0.039 [1.0]

PAD DIMENSIONS

For a 293D Tantalum Chip Capacitor



[Numbers in brackets indicate millimeters]

CASE	A	B	C	D
A (Min.)	0.071 [1.8]	0.110 [2.8]	0.110 [2.8]	0.118 [3.0]
B (Min.)	0.059 [1.5]	0.059 [1.5]	0.083 [2.1]	0.083 [2.1]
B (Nom.)	0.083 [2.1]	0.083 [2.1]	0.106 [2.7]	0.106 [2.7]
C	0.051 [1.3]	0.063 [1.6]	0.122 [3.1]	0.173 [4.4]
D (Min.)	0.173 [4.4]	0.185 [4.7]	0.287 [7.3]	0.339 [8.6]
D (Nom.)	0.220 [5.6]	0.232 [5.9]	0.335 [8.5]	0.386 [9.8]
E (Min.)	0.020 [0.5]	0.020 [0.5]	0.020 [0.5]	0.020 [0.5]
E (Nom.)	0.047 [1.2]	0.047 [1.2]	0.051 [1.3]	0.051 [1.3]

The calculation formula for the pad layout:

A (Min.) = Tw (Max.) + 2e
B (Min.) = [D (Min.) - C]/2
B (Nom.) = [D (Nom.) - C]/2
C = L (Nom.) - 2P (Nom.) - e
D (Min.) = L (Max.) + 2 E1
D (Nom.) = L (Max.) + 2 E2 + e
E (Min.) = [D (Min.) - L (Max.)]/2
E (Nom.) = [D (Nom.) - L (Nom.)]/2

REFLOW SOLDER PROCESS

Two reflow processes are commonly used, vapor phase and infrared reflow. Both reflow solder processes require the application of solder paste prior to component placement.

The thickness of the soldering paste deposited or applied by screen printing is generally equal to 0.008" [0.2]. This thickness, related to the surface of the pad, determines the quantity of solder which will form the joint during the reflow. This reflow has to be sufficient to obtain an ideal solder fillet at a 45° angle.

Care should be exercised in selecting the solder paste. The metal purity should be as high as practical. The flux (in the paste) must be active enough to remove the oxides formed on the metallization prior to the exposure to soldering heat. In practice this can be aided by extending the solder preheat time at temperatures below the liquidous state of the solder.

The Vapor Phase Reflow Solder Process uses fluorocarbon liquids, boiled to produce a vapor saturated atmosphere, at a temperature slightly higher than the boiling point of the liquid and high enough to reflow the solder.

The Infrared Reflow Solder Process uses heat energy produced by an infrared radiation source and by convection (natural or forced). In such a system, the heat time is dependent of the absorption coefficient of the material surfaces and of the thermal mass of all the components in relation to the surface available to the infrared radiation.

The temperature of the components in an infrared oven is not precisely defined and temperature measurements should be taken on the capacitors themselves when they are going through the oven. The temperature of small components may reach + 280 °C when they are soldered at the same time as larger ones. The parameters which act on the temperature of the components are:

- Time and power
- Mass of the component
- Size of the component
- Dimensions of the substrate
- Absorption coefficient of the surfaces
- Density of the components
- Wave length of the radiation source
- Ratio between radiated energy and convection energy

A standard profile of this process is given in the graph shown:

A preheat period is necessary for the evaporation of all the volatile solvents contained in the solder paste before the action of the flux. It initializes the action of the flux on the solder and also on the metallic surfaces of the component terminations and substrate.

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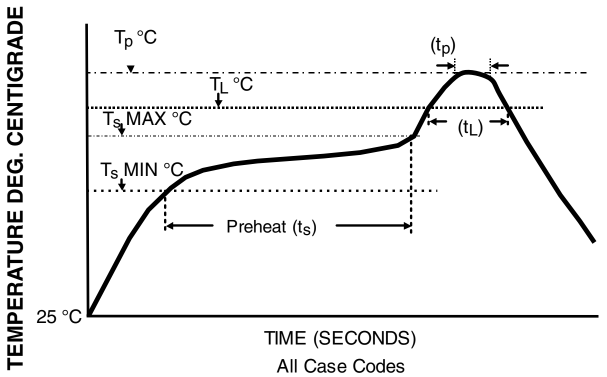
REFLOW SOLDER STANDARD TEMPERATURE PROFILE



All Case Codes

RECOMMENDED REFLOW PROFILES

TYPE	CASE CODE	T_p Pb FREE	T_p Sn/Pb	t_p	T_L Pb FREE	T_L Sn/Pb	T_s MIN Pb FREE	T_s MIN Sn/Pb	T_s MAX Pb FREE	T_s MAX Sn/Pb	t_s Pb FREE	t_s Sn/Pb	t_L
552D	ALL CASES	225 °C	225 °C	10	217 °C	183 °C	130 °C	130 °C	200 °C	160 °C	60 - 150	60 - 90	60
293D 593D 893D CWR11 TR3	ALL CASES	260 °C	240 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
292D		260 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	200 °C	60 - 150	60 - 90	60
298D		260 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 150	60
T83 T86 TH3	A,B,C,D,E	260 °C	240 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
T96	R	245 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 150	60
T88	M,R	260 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
592D 591D T92	ALL	260 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
595D 594D	D R	245 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
	A,B,C,T, G,H,M,S	260 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
597D T97	F,E,R,V	245 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
572D	P,Q,S,A,B,T	260 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
695D	ALL	245 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
CWR06/ CC/EC	ALL	245 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
194D	ALL	245 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
195D	ALL	245 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 90	60
T95	B,C,S, V,X,Y	260 °C	225 °C	10	217 °C	183 °C	150 °C	100 °C	200 °C	150 °C	60 - 150	60 - 150	60
	D,R,Z	245 °C											

RECOMMENDATIONS:

1. Preheat the substrate (to eliminate all traces of humidity on the substrate) before applying the solder paste - 4 hours at + 65 °C minimum.
2. In case of a double side mounting, do not clean the substrate after the first pass. This may induce a high humidity level which will affect the quality of the solder during the second pass through.
3. Minimal solder fillets are always preferable. Solder paste should not creep very high on the terminations.
4. Good fillets are produced by a good wetting of the terminations (verify the angles resulting from wetting).
5. The mechanical adhesion of the part on the substrate is primarily produced by the solder of the terminations directly in contact with the substrate.

PAD LAYOUT FOR WAVE SOLDERING

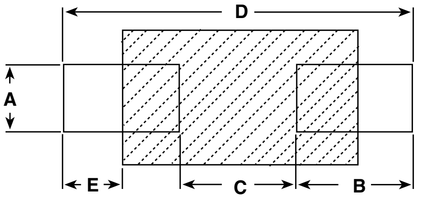
The pad layout is similar to that for reflow soldering except for the "A" dimension, which is reduced by two-thirds because the components are completely dipped into the solder bath, providing enough material to achieve the solder fillet.

Processing should avoid too much solder in the termination zone in order to limit the mechanical stresses during the assembly and use of the component. Hot air flow wave soldering may help reduce the dimensions of the solder fillet.

The components are glued before soldering which prohibits movement during processing. The "D" dimension must include the tolerance of the system.

PAD DIMENSIONS

For a Molded Tantalum Chip Capacitor



[Numbers in brackets indicate millimeters]

CASE	A	B	C	D
A (Min.)	0.047 [1.2]	0.075 [1.9]	0.075 [1.9]	0.079 [2.0]
B (Min.)	0.063 [1.6]	0.063 [1.6]	0.087 [2.2]	0.087 [2.2]
B (Nom.)	0.083 [2.1]	0.083 [2.1]	0.106 [2.7]	0.106 [2.7]
C	0.051 [1.3]	0.063 [1.6]	0.122 [3.1]	0.173 [4.4]
D (Min.)	0.181 [4.6]	0.193 [4.9]	0.295 [7.5]	0.346 [8.8]
D (Nom.)	0.220 [5.6]	0.232 [5.9]	0.335 [8.5]	0.386 [9.8]
E (Min.)	0.024 [0.6]	0.020 [0.5]	0.024 [0.6]	0.024 [0.6]
E (Nom.)	0.047 [1.2]	0.047 [1.2]	0.051 [1.3]	0.051 [1.3]

The calculation formula for the pad layout:

A (Min.) = (Tw (Max.) + 2e x 0.67
B (Min.) = [D (Min.) - C]/2
B (Nom.) = [D (Nom.) - C]/2
C = L (Nom.) - 2P (Nom.) - e
D (Min.) = L (Max.) + 2 E1 + e
D (Nom.) = L (Max.) + 2 E2 + e
E (Min.) = [D (Min.) - L (Max.)]/2
E (Nom.) = [D (Nom.) - L (Nom.)]/2

WAVE SOLDERING PROCESS

Wave soldering includes the five steps shown:
- Drying
- Fluxing
- Preheating
- Soldering

1. Drying:

The goal of drying is to eliminate water from the substrate. This is dependent on prior steps, particularly on the storage conditions. It may be optional.

2. Fluxing:

The goal of the fluxing operation is to improve the wetting by:
- Deoxidation of metallic parts,
- Decreasing the surface tension produced in contact with the solder wave,
- Preservation of the board from oxidation between the flux and the wave soldering operation.

The choice of the flux (resin, organic or inorganic) will determine cleaning solvents employed.

3. Preheat:

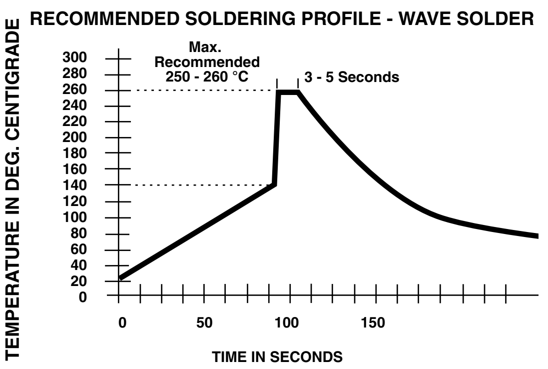
This step is intended:
- To evaporate the volatile products contained in the flux.
- To take the flux to its activation temperature,
- To limit the thermal shock, which acts on the boards and the components.

The preheating may be accomplished by hot air or infrared processes.

4. Soldering:

The soldering of surface mounted components requires the use of a wave which insures sufficient flow of the solder between the components and which, however, minimize solder fillet and bridging. The graph indicates a standard temperature profile used in this process:

WAVE SOLDER STD. TEMPERATURE PROFILE



RECOMMENDATIONS:

1. Preheat both substrate and components.
2. Do not use a standard wave normally used for boards with leaded components. These waves are not optimized for solder boards with surface mount components.
3. The temperature gradient between preheat and wave soldering must be smaller than + 100 °C.
4. Terminations must go through the wave simultaneously.
5. Optimal conditions: Travel through the wave from + 240 °C to + 250 °C for 3 to 5 seconds.
6. Verify that the upper side temperature of the board does not exceed + 150 °C.
7. Do not increase the wave temperature to improve solderability.
8. Do not increase the time to improve solderability.
9. Do not increase the temperature to reduce solder balls or bridges.
10. Check wave profiles frequently.
11. Use hot air at + 275 °C blowing on the solder joints immediately after the wave, in order to minimize bridging and to reduce the solder fillet size. Hot air should be applied to the substrate when the temperature is approx. + 230 °C.
12. Control cooling speed between 2 °C and 5 °C per second.

REWORK AND REPAIR TECHNIQUES:

Occasionally rework or repair will be required. For example:

1. Repair to correct too much or not enough solder.
2. Realignment of the component when it has been misplaced in wet solder paste or in wet adhesive or even during the solder operation itself.
3. Replacement of the component because of placement error or failure.

   The standards for visual inspection have to be defined very precisely for points 1 and 2. The following must be kept in mind:

A) Are the risks of repair larger than the risks involved in not repairing?
B) The repair process must yield products which will meet the standard specifications on a regular basis.
C) Do not include repair in your process specification. Any repair must be an exception.

ADDING SOLDER

If there is not enough solder, inspect for the cause:

1. Not enough solder or improper paste screening (reflow solder).
2. Shadowing of terminations in wave soldering due to the carrier tray, other components, a too close termination or a ripple in the solder wave.
3. Non-wetting of pads or terminations.

Use an iron with enough wattage. A good method of judgement is to control the time to reflow the solder: Less than 1 to 1.5 seconds, the tip temperature is excessive; more than 3 to 3.5 seconds, either the tip temperature is insufficient or the tip is cooling when applied to the circuit board. An iron which regulates the temperature is required. Apply a small amount of flux to the component termination and the pad layout (the new synthetic no residue fluxes are excellent). After tinning, the iron tip should be placed on the circuit pad at the edge furthest from the component. The operation must be done in 1.5 to 3 seconds. If it is necessary to keep the iron on longer than 3 seconds, the component should be replaced. The solder should be added at the solder iron tip and will flow from the pad to the termination of the component. Be careful not to add too much solder. Direct contact with the component may cause damage and subsequent failure.

REMOVING SOLDER

Bridges, splatter and solder spikes are examples of excess solder conditions.

Our recommendations concerning the soldering iron apply here as well: time on the solder joint not to exceed 3 secs., do not touch the component or its termination. Use a copper braid solder wick or a vacuum solder pump to remove the excess solder. Use of hot gas nozzles or other complex tools should be restricted to removal of component itself.

REALIGNMENT

This should be done rarely because it is usually preferable to replace the component. If misalignment appears after placement in molten solder paste, it is easy to correct by lifting the part with a vacuum nozzle and realigning it. But it is always better to correct the cause of the problem at the placement machine, solder paste screening, etc.

For wave soldering, an alignment defect is even easier to correct before curing of the adhesive. At that time, the part should be removed with most of the adhesive. Add new adhesive and place a new part. Use of too much adhesive will result in definitive solder defects (open circuit). For misalign-ment noted after curing of the adhesive, the only solution is to replace it with a new part.

REPLACEMENT

This operation must be done in less than 6 seconds in order not to damage the pad layout on the boards. Twisting and pulling forces are transmitted to the pads during the removal of a component. Again, strict temperature control is required. For parts glued with adhesive, the solder must first be removed by means of copper braid solder wicks or a vacuum pump. Replacement must be done with a new part, after a careful cleaning of the substrate.

CLEANING

After mounting, components and boards are normally cleaned. Cleaning methods are the same for traditional leaded components but the geometry or the assembly of surface mount components make the cleaning more difficult to achieve. Most of the components (resistor or capacitor chips) have no cleaning stand offs and are applied directly on the board.

Commonly used are solvents such as TES, TMS, Prelete, Chlorethane, Terpene and aqueous cleaning media. However, CFC/ODS products are not used in the production of these devices and are not recommended. Solvents containing methylene chloride or other epoxy solvents should be avoided since these will attack the epoxy encapsulation material.

When using ultrasonic cleaning, the board may resonate if the output power is too high. This vibration can cause cracking or a decrease in the adherence of the termination.

STANDARD TESTS

A number of standards (particularly CECC, IEC, MIL) have used tests which are applicable to surface mount components. The tables summarize common test conditions which are pertinent to soldering.

RESISTANCE TO SOLDER HEAT

CONDITIONS		SIMULATED PROCESS
°C	SECONDS	
260 ± 5	10 ± 1	Double wave infrared
260 ± 5	5 ± 1	Single wave infrared
215 ± 3	40 ± 1	Vapor phase infrared

SOLDERABILITY AND LEACHING RESISTANCE

PARAMETER TESTED	CONDITIONS		SIMULATED PROCESS
	°C	SECONDS	
Wetting	235 ± 5	2 ± 0.2	Wave
	215 ± 3	3 ± 0.3	Infrared Vapor phase Wave
Dewetting	260 ± 5	10 ± 1	
Leaching	260 ± 3	30 ± 1	Wave

CLEANING CONDITIONS

PROCESS	CONDITIONS		CLEANING SOVENTS
Liquid	Boiling	40 - 80 °C/4 min.	• Deionized water • Ethanol • Isopropanol • Halogenated Hydrocarbons
	Ultrasonic	45 °C/2 min.	
	Steam	80 °C/30 sec.	
	Spray	45 °C/16 bar	

Vishay Sprague routinely tests to these and other test specifications. For information or assistance in selecting components for your particular application, consult your Vishay Sprague representative directly.