

By G. Schouten

## Calculations on the relation between solderwave pressure and solder penetration in gaps

### Introduction

For the soldering of SMD's mounted on the solderside of a printed circuit board, the wave pressure to the board must in general be higher than for soldering components with protruding leads on the solderside. With higher wave pressures the risk of solder flooding via gaps in the board increases. In this article the relation between solder pressure, gap dimensions and wetting power will be explained, using a calculation model. We make the assumption that the solder pressure works only vertically.

Calculation model:

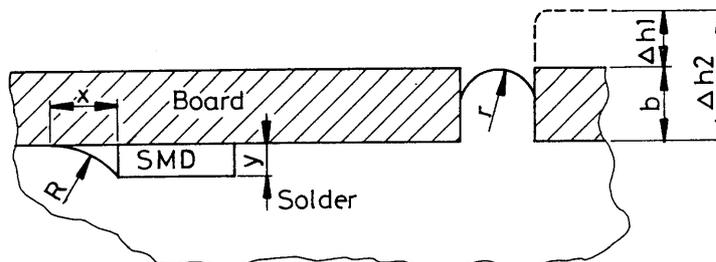


fig. 1 Board with SMD and gap in solder wave (detail)

### Elucidation

- $\Delta h_1$  = relative wave height measured from the topside of the board
- $\Delta h_2$  = relative wave height measured from the underside of the board
- $b$  = board thickness
- $r$  = solder radius in gap
- $R$  = solder radius at SMD component
- $x$  = solder shadow zone
- $y$  = height of non-wettable component body.

From Young and Laplace we know the relation between liquid pressure, surface tension and capillary. This relation can be expressed in the equation:

$$\Delta h = \frac{\gamma}{d \cdot g} \left( \frac{1}{R_1} + \frac{1}{R_2} \right)$$

- where  $\Delta h$  = liquid rise or depression (R can be positive or negative)
- $\gamma$  = the surface tension of the liquid
- $R$  = capillary radius (for small holes  $R_1 = R_2$ , for parallel gaps  $R_2 = \infty$ )
- $d$  = liquid density
- $g$  = specific gravity

If we substitute the known values for the surface tension, the density and the specific gravity we find that:

$$\Delta h = 5 \cdot 10^{-6} \left( \frac{1}{R_1} + \frac{1}{R_2} \right) m \qquad \Delta h = 5 \cdot \left( \frac{1}{R_1} + \frac{1}{R_2} \right) mm$$

EQUATION I

If we assume that the board in fig. 1 contains a routed slot, we can substitute it as a parallel gap. In that case we have the following relation:

$$\Delta h_1 = \frac{5}{r} (r \leq b)$$

EQUATION II

From equation II we can calculate the theoretical allowed wave height pressure  $\Delta h_2 = \Delta h_1 + b$ . For a specific gap "r" we can calculate  $\Delta h_1$  for the case that the solder is just not penetrating to the topside of the board.

### Example I

When the board thickness is 1.6 mm and the board contains a routed gap of 4 mm, we find  $r = 2$  mm.

Since  $r_{max} > b$ , we must calculate with  $r = 1.6$  mm.

This gives  $\Delta h_1 = 3,1$  mm and  $\Delta h_2 = \Delta h_1 + b = 4.7$  mm.

So the maximum allowable wave height pressure in this case is 4.7 mm. Smaller gaps may allow higher pressures.

Keep however in mind that only the vertical solder pressure is taken into account in these examples. A horizontal pressure component enlarges the risk of solder flooding considerably.

**NOTE:** This wave height pressure can only be used if the board is fitted in a pallet of sufficient thickness, otherwise the solder will flood the board as it enters the solderwave. The board must be kept flat during soldering.

## Wetting capacity on SMD's

When we know the maximum allowable wave height pressure we can use that figure to calculate the theoretical wetting possibilities for the SMD's.

Using the figure for  $\Delta h_2$  from the foregoing calculation, it is possible to calculate the smallest radius R in which the solder is able to penetrate, using equation I.

For this case we can transform equation I to:

$$R = \frac{5}{\Delta h} \quad \text{for parallel gaps or} \quad R = \frac{10}{\Delta h} \quad \text{for narrow gaps}$$

In most cases we have to calculate for dense circuits so that in that case it is realistic to calculate with the formula for narrow spaces:

$$\frac{5}{\Delta h_2} < R < \frac{10}{\Delta h_2} \text{ mm} \quad \text{EQUATION III}$$

## Solderpads for SMD's

The relation between x, y and R in figure I can be expressed, using Pythagoras equation, as:

$$x = \sqrt{R^2 - (R - y)^2} \quad \text{EQUATION IV}$$

Now it is possible to calculate the relation between the SMD body height (y) and the shadow zone (x), where the solder is unable to penetrate, in case the SMD body surfaces are not wettable with solder.

This enables us to calculate the necessary solder pad dimensions for specific SMD's, in case the wave height pressure must be limited for whatever reason. The solderpad dimension should at least extend the shadow zone (x in fig. 1) to enable the solder to flow to the joint area.

## Example 2

We want to calculate the shadow zone for a SOT 23 with a body height of 1.2 mm. The maximum allowed wave height pressure must be limited to  $\leq 4.7$  mm.

From equation III we can calculate R knowing that  $\Delta h_2 \leq 4.7$  mm.

This gives  $1.1 < R < 2.1$  mm.

From equation IV we can now calculate x, knowing R and the body height  $y = 1.2$  mm.

This gives  $x = 1.1$  mm in case the solder has free access to the component. In the worst case situation, where there is no free access for the solder  $x = 1.9$  mm.

This example shows us that solderpads for SOT 23 should be 1.9 mm long. The fact that smaller pad dimensions still may give good wetting is due to the fact that the solder pressure has often also a horizontal component and/or higher waves can be used if the boards have no open gaps and are mounted in a pallet.

## Elucidation of the necessary solder pressure

Understanding the mechanism makes it also possible to make a calculation for the necessary wave pressure if the component and the pad design dimensions are given. (See fig. 2).

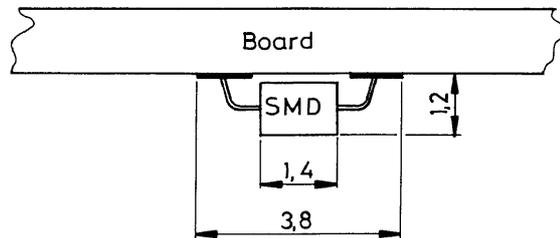


Fig. 2 Calculation model for a typical SMD

For example, if a component with body width 1.1 mm is mounted on a pad pattern with a width area of 3.8 mm, we can make the following calculation:

Referring to figure 2, we find

$$x = \frac{3,8 - 1,4}{2} = 1,2 \text{ mm} \quad , y = 1.1 \text{ mm} \text{ giving} \quad R = \frac{x^2 + y^2}{2y} = 1,1 \text{ mm}$$

In case the solder has a free access to the component area, the wave height pressure can be calculated from equation 1.

For  $R1 = 1.1 \text{ mm}$  and  $R2 = \infty$ , we find  $\Delta h_2 = 4.55 \text{ mm}$ .

In case the solder has no free access to the joint area, the wave height must be set considerably higher. In that case only small gaps, or better no gaps, are allowed in view of the risk of solder flooding.

### DISCLAIMER

All content is subject to periodic review and may be changed without notice.  
Vitronics Soltec BV assumes no obligation for content contained herein.

### COPYRIGHT VITRONICS SOLTEC BV

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of Vitronics Soltec BV. This publication remains the property of Vitronics Soltec BV and may not be passed, loaned or given to any third party.

Vitronics Soltec BV reserves the right to make changes in design and specifications without notice.