

# Printed Circuit Board SPLIT-PAD Test Method & Design

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## INTRODUCTION

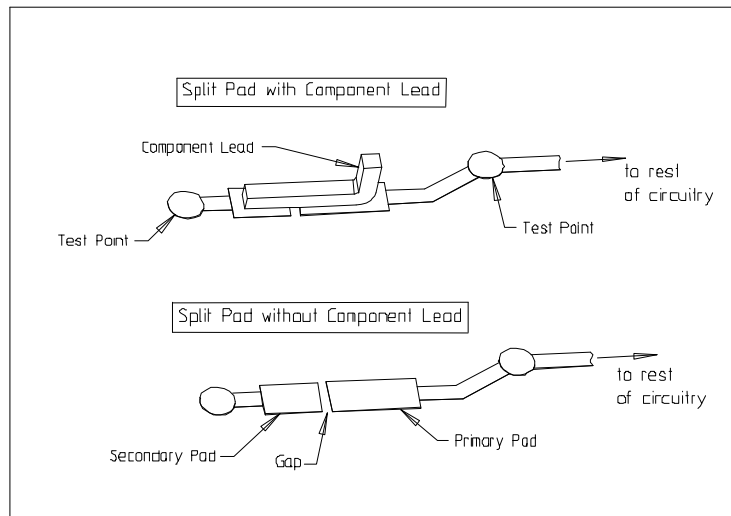
Various designs of surface mount connectors elude adequate test coverage when primarily connected to power and ground circuits. Furthermore, surface mount connectors are a significant source of PCA defects. Realizing that the lead and an altered pad could provide test information, an effort was undertaken to provide adequate test coverage. This application note describes the split-pad concept for use with a bed of nails style test fixture.

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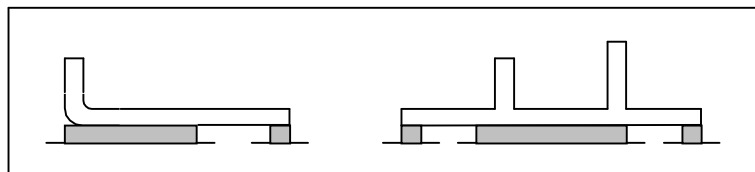
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## CONCEPT & ASSUMPTIONS

The split-pad design provides the capability to test for the presence and electrical continuity of surface mounted component leads correctly placed and soldered onto the split-pad on the PCB (printed circuit board). The split pad design is a slight modification to the current design of pads for surface mounted components. The pad is split and left with a small gap between the two pieces so that there is no electrical continuity from one pad to the other. The primary pad has a trace that runs to a test point and to the rest of the circuitry. The secondary pad has a trace that only runs to a test point. The component lead will bridge the gap when placed and soldered correctly. A shorts test is performed by probing the test points of both pads. When no component lead is present, the gap remains open and there is no electrical continuity across the split pad. By virtue of the design of the split-pad, other additional defects, such as bent leads and misplaced components, can be caught during the test. The split-pad design is optimized for testing of surface mounted connectors, but can be used for test of other surface mounted components. The design allows an electrical test of a connector without the need for the mating connector, or other hardware customization.



The two types of connector leads with which the split-pad design is known to work are similar to those shown in the following graphic. It is possible that there are other lead styles that are



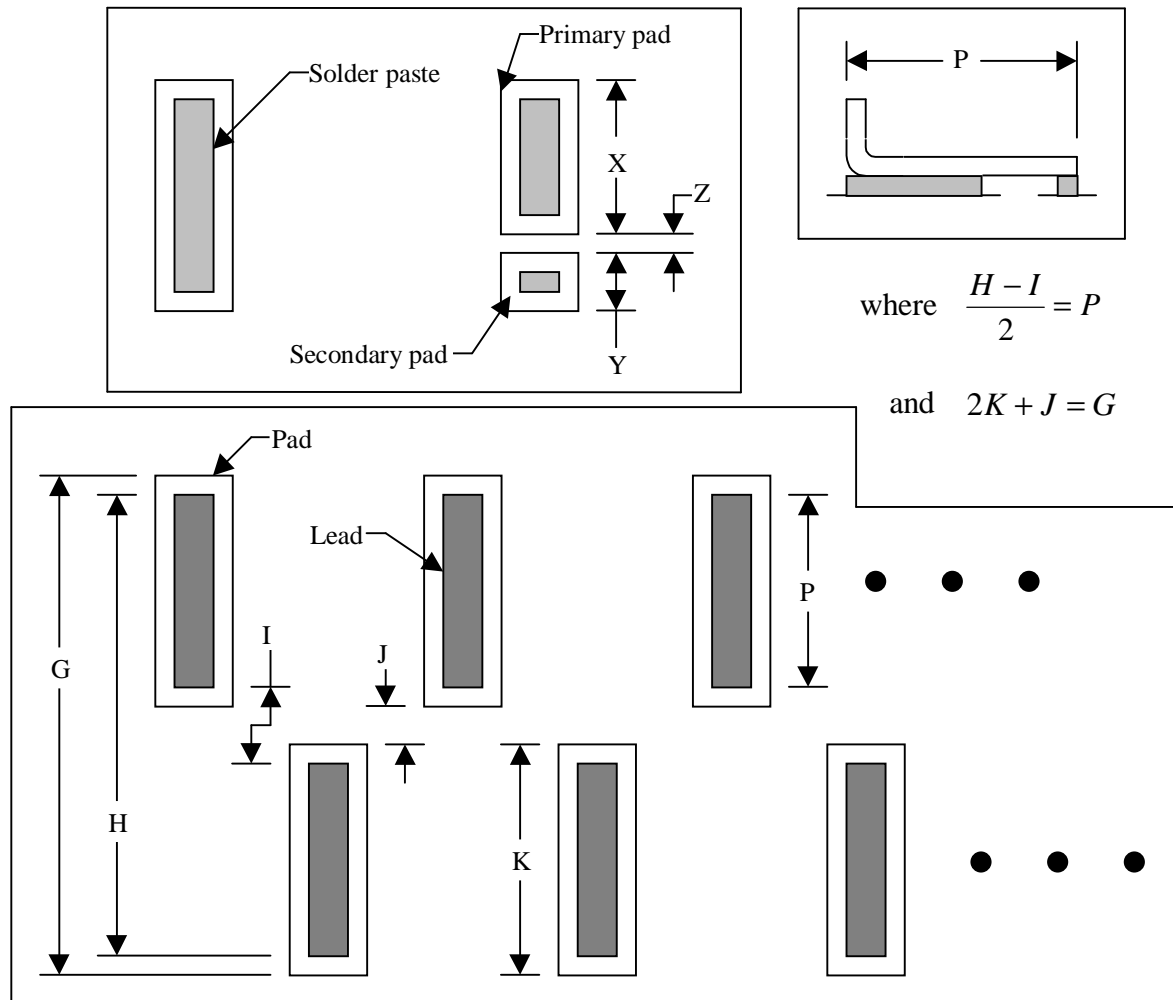
suitable also, but the lead styles that are relatively long and flat at the point of contact on the PCB tend to work the best. Split-pad test modification may be used at the ends/corners of the component, but may also be included on any other non-verifiable leads with critical functions.

To enable testability, an assumption is made that in the design of the split-pad of the gull wing style lead there are two test points per split joint, as shown in the above illustrations. The design of the second style of connector lead assumes that there are three test points per split joint. One test point is associated with each section of the split-pad, i.e. primary pad, secondary pad, etc. It is also assumed that testing is done on a “bed-of-nails” tester, or a “flying probe” tester, or a similar testing device.

## SPLIT-PAD DESIGN

The design of the split-pad is determined by the existing pad and lead geometries and the toe or heel solder fillet specifications or comparable positioning tolerances. Two common lead styles with the methods and examples for determining the split-pad dimensions are shown below.

### 2-Row Gull Wing-Leaded Device



R = Toe fillet spec. (or tighter tolerance, if any) i.e. “toe fillet dimension must be at least 0.005 in.”

S = Heel fillet spec. (or tighter tolerance, if any) i.e. “heel fillet dimension must be at least 0.010 in.”

Given: G, H, I, J, K, P, R, and S

Find: X, Y, Z (Split-pad dimensions), and V

**1) Compare specs (possibly IPC specs) to existing design:**

Change design if  $\frac{I-J}{2} < S$  or if  $\frac{G-H}{2} < R$ . (current design is too restrictive and specs can't be met)

**2) Check that the design guidelines for solder paste stencil are not violated for existing design.**

**3) Set V equal to the smallest of  $\frac{I-J}{2} - S$  and  $\frac{G-H}{2} - R$  then determine split pad dimensions:**

$$Y = \frac{G-H}{2} + V \quad Z = 0.008\text{in. or } 0.20\text{mm} \quad X = K - Y - Z$$

**4) Check that the design guidelines for solder paste stencil are not violated for new design.**

Example:

Given: G=0.252in, H=0.210in, I=0.090in, J=0.044in, K=0.104in, P=0.060in, R=0.004in, and S=0.012in.

Find: X, Y, and Z

$$\frac{I-J}{2} = \frac{0.090-0.044}{2} = 0.023 > 0.012 = S$$

$$\frac{G-H}{2} = \frac{0.252-0.210}{2} = 0.021 > 0.004 = R$$

$$\frac{I-J}{2} - S = \frac{0.090-0.044}{2} - 0.012 = 0.011$$

$$\frac{G-H}{2} - R = \frac{0.252-0.210}{2} - 0.004 = 0.017 \quad V = 0.011$$

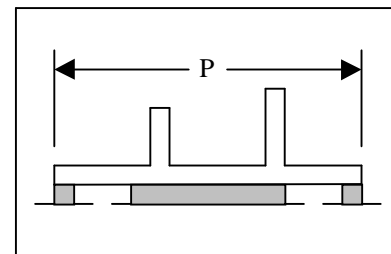
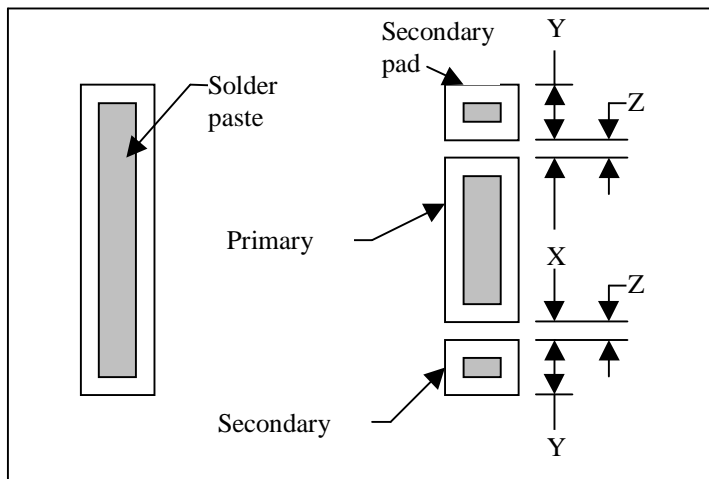
$$Y = \frac{G-H}{2} + V = \frac{0.252-0.210}{2} + 0.011 = 0.032$$

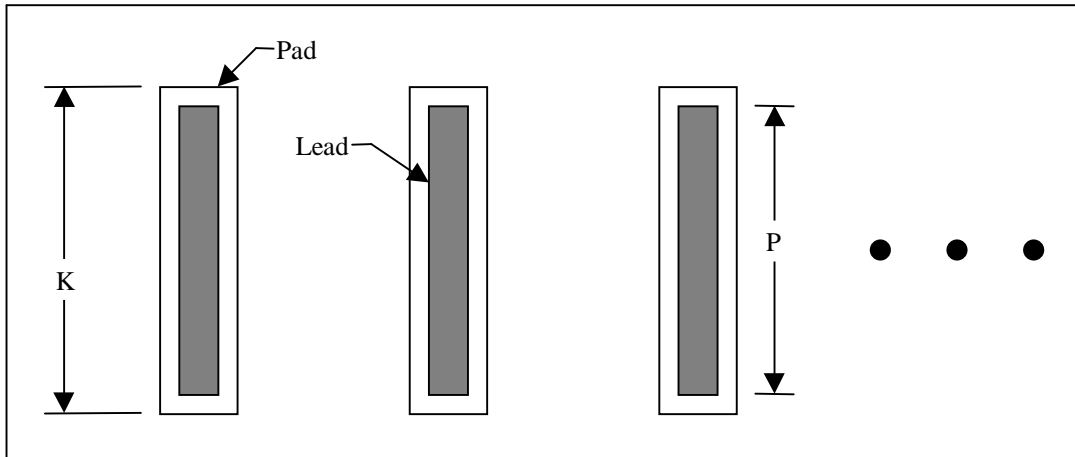
$$Z = 0.008$$

$$X = K - Y - Z = 0.104 - 0.032 - 0.008 = 0.064$$

Therefore, X = 0.064in, Y = 0.032in, and Z = 0.008in.

**1-Row Unique-Leaded Device (similar to the illustration shown below)**





R = Toe fillet spec. (or tighter tolerance, if any) i.e. “toe fillet dimension must be at least 0.005 in.”

Given: K, P, and R

Find: X, Y, and Z (Split-pad dimensions)

**1) Compare specs (possibly IPC specs) to existing design:**

Change design if  $\frac{K-P}{2} < R$  . (current design is too restrictive and spec can't be met)

**2) Check that the design guidelines for solder paste stencil are not violated for existing design.**

**3) Determine split pad dimensions:**

$$Y = K - P - R \quad Z = 0.008\text{in. or } 0.20\text{mm} \quad X = K - 2Y - 2Z$$

**4) Check that the design guidelines for solder paste stencil are not violated for new design.**

Example:

Given: K=0.276in, P=0.240in, and R=0.004in.

Find: X, Y, and Z

$$\frac{K-P}{2} = \frac{0.276-0.240}{2} = 0.018 > 0.004 = R \quad Y = K - P - R = 0.276 - 0.240 - 0.004 = 0.032$$

$$Z = 0.008 \quad X = K - 2Y - 2Z = 0.276 - 2(0.032) - 2(0.008) = 0.196$$

Therefore, X = 0.196in, Y = 0.032in, and Z = 0.008in.

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## 307X CODE

The split-pad test is performed by testing for an expected short between two nodes in the 307X test. An example of typical 307X test code for a device with four secondary split-pad node names of "J2\_1S", "J2\_2S", "J2\_29S", and "J2\_30S" with corresponding primary split-pad node names of "FIRE\_K", "VPEN\_K", "FIRE\_C", and "GND", respectively, would look like the following:

```
short "J2_1S" to "FIRE_K"  
short "J2_2S" to "VPEN_K"  
short "J2_29S" to "FIRE_C"  
short "J2_30S" to "GND"
```

A 307X failure report of the shorts test on "J2\_2S" to "VPEN\_K" with an open split-pad would look like the following:

```
-----  
Shorts Report for "shorts".  
Tue Dec 02 11:08:54 1997  
BOARD_Z: PART#_0123 REV_A  
-----  
Open #1 Thresh 20, Delay 50us      Ohms  
From: J2_2S                          21507 Open  
To:   VPEN_K                          21649  
Common Devices:  
                                     j2  
Message is: None  
-----End, 1 Problem Reported-----
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## WHAT IS TESTED (THE 5-P'S)

The 5-P's are **p**resence, **p**olarity, **p**osition, **p**in integrity, and **p**ain. The goal is to maximize the ability of the test to detect the presence, polarity, position (alignment), and pin integrity (electrical continuity) of the component while minimizing the pain (maintenance or support issues, ergonomics, cycle time, cost) associated with the specific test method. The split-pad test method attempts to maximize the ability to detect defects while minimizing the pain in the following ways:

- **Presence** – A minimum of one split-pad per component is required to detect the presence of the component. Presence is detected when the lead bridges the gap between the primary and secondary pads.
- **Polarity** – The polarity of the component may or may not be caught by split-pads. In order for the split-pad test to detect a component with the wrong polarity, either of the following two things must exist: 1) the component lead geometry is non-symmetrical, (In other words, if the component were placed with the wrong polarity, the lead geometry would not match the pad geometry.) or 2) the component is designed with a polarity pin allowing it to be placed flat on the

PCB *only* if the polarity is correct. In these cases a pad corresponding to a lead that would not be correctly soldered in a reversed polarity configuration should be designed as a split-pad.

- **Position** – When the end leads (or corner leads) are tested using the split-pad method, the position of the component can be tested. With end leads (or corner leads) tested, a component in the wrong position is detected when a split-pad gap is left open by the shift of the component up or down, or to the left or right, or by an excessive angular rotation.
- **Pin integrity** – Pin integrity, or electrical continuity, is tested on each pad that has been designed as a split-pad. Defects such as insufficient solder, lead toe up, lead toe down, or insufficient heel or toe fillets are examples of pin integrity issues that can be caught by the split-pad test, recognizing that it is still detecting contact (electrical continuity) and not the volume of paste in a given solder joint.
- **Pain** – The pain is minimal with the split-pad design. There are no maintenance or support issues with the test method. Because the split-pad test is automated, there are no ergonomic concerns. The test cycle time is negligible. The cost of test is not affected, but the cost of the board can be affected by the number of additional test points required for the test and the potential increased complexity or difficulty of the PCB design layout.

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## METHOD OF REPAIR

Because of the nature of the split-pad test and the types of defects that are being tested, caution should be used when repairing a component that has failed the split-pad test. One method of repair that is generally not acceptable is touch-up. Although a specific situation may warrant the touch-up method, often the touch-up method only masks the process assembly defects that were detected by the split-pad test. An example would be an occurrence of an insufficient solder heel fillet because of a component that is slightly out of position. If solder is added in a touch-up repair to bridge the open gap in the split-pad at the toe fillet position, the heel fillet will still have an issue with insufficient solder and will still have the extended life reliability loss associated with that defect.

A preferred method of repair is to remove the component completely and clean the pads of leftover solder. The correct amount of solder paste can be placed on the pads and a new component can be correctly placed and positioned. After this the component can be soldered to the pads and retested.

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## SOLDER JOINT STRENGTH & RELIABILITY

Two areas of concern addressed during our study are the resulting solder joint strength and long term solder joint reliability. Below is an outline of the investigation and conclusions, depending on the actual geometry of the solder joint with the split-pad design you may require further investigation.

- **Solder Joint Strength** – With a gap in the pad, the lead does not have as much solder adhering the connector to the pad. But, remember that the majority of the benefit of the design uses only four split-pads for the connector. For the case of a 30-pin connector, there is no discernable difference in connector adhesion to the PCB. The pull strength of the solder joint with or without the split pad

remained stronger than the interface of the pad to the laminate. Therefore, our conclusion is that the resulting solder joint strength is adequate for the application.

- **Solder Joint Reliability** – The failure mode for a surface mount solder joint is often a crack propagating from the heel to the toe through the solder near the lead. The crack initiates and propagates because of the coefficient of thermal expansion (CTE) mismatch between the PCB and the connector system. One method to estimate the life of a solder joint is the FAIR (Fast Assessment of Interconnect Reliability) model. The model incorporates the solder joint geometry, CTE's, and operating temperature range. Using this model the 30-pin connector's expected solder joint life decreased by more than half, from 190 years to 71 years. Also, given that this analysis considers only an isolated solder joint and not the beneficial affects of the system of joints, our conclusion is the resulting solder joint reliability with a split-pad is adequate for the application.

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## CONCLUSION

PCB's with split-pad test capability have been designed into products during their developmental cycles, and are now a part of high volume production in the newest product releases. It has been accepted as a recommended design alternative to allow adequate automated testing of surface mount components (especially connectors) and is being considered for application on other critical devices where verification of position is desired for assurance of product reliability.