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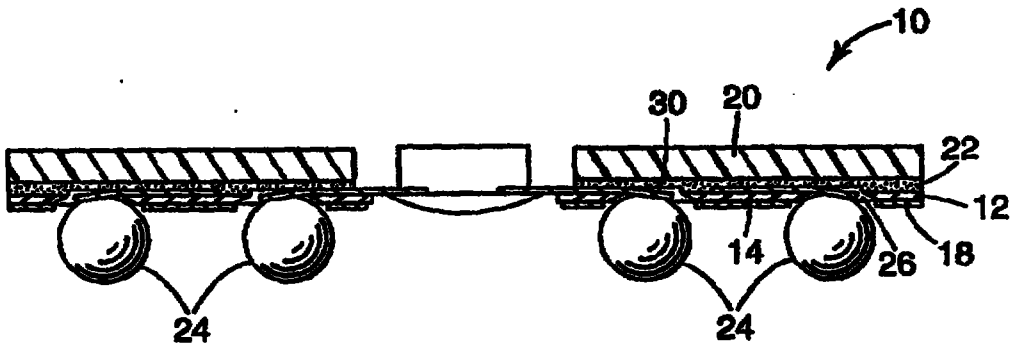
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(54) Title: FLEXIBLE LEADS FOR TAPE BALL GRID ARRAY CIRCUIT



(57) Abstract

A flexible circuit construction includes a polymeric sheet, via holes in the sheet and metal circuitry disposed on the sheet. The circuitry terminates at a cantilever end partially spanning the via hole to which a solder ball is subsequently attached. The cantilever end allows the solder ball to move relative to the flexible circuit and thus compensate for misalignment and differential thermal expansion effects.

Flexible Leads For Tape Ball Grid Array Circuit

Field of the Invention

The present invention relates generally to flexible circuit constructions, particularly to tape ball grid array (TBGA) flexible circuit constructions, and more particularly to the contacts formed on such circuit constructions.

Background of the Invention

A common packaging construction for an electronic device is the so-called quad flat pack wherein an integrated circuit is encapsulated with a polymer for protection. The structure is square with a number of flexible leads exiting the encapsulate for connection to another electronic component such as a circuit board. The flexibility of the leads compensates for differential thermal expansion between the polymer comprising the quad flat pack and the circuit board and thus largely prevents cracking or breakage of the solder joints which connect the leads to the circuit board.

Tape ball grid array (TBGA) devices have been proposed as a substitute for the quad flat pack structure in order to accommodate integrated circuits with higher numbers of inputs and outputs and to reduce production costs. These TBGA devices include a flexible polymeric base sheet on which is disposed a metal layer on at least one side. The base is typically adhesively attached to a metal stiffener and an array of solder balls are attached to the circuitry defined by the metal layer to allow for connection to a circuit board. Unfortunately, such an arrangement does not allow much flexibility of the solder balls relative to the base and so cracking or breakage of the solder connection between the solder balls and the metal layer of the polymeric base is a problem.

Improvement of the construction of the TBGA package is required to match the performance of the quad flat pack.

Summary of the Invention

The TBGA package according to the present invention is resistant to fatigue stresses which occur in ball grid array solder joints during thermal cycling due to differences in the coefficient of thermal expansion between the package and the board. According to the invention, a flexible circuit board is constructed to include a cantilever beam which spans a via hole at the end of the flexible circuitry. A solder ball is attached to the cantilever beam by conventional methods. The cantilever beam is preferably bent downwardly which provides the ball with some mobility relative to the flexible circuit. This added mobility reduces the level of stress built up during thermal cycling thereby increasing the durability of the package, and also improves coplanarity between the package and the board which ensures that each ball contacts the solder paste during surface mounting.

In particular, the invention is a flexible circuit construction for attachment to solder balls comprising a flexible polymeric sheet having two major surfaces, at least one via hole extending through the polymeric sheet, metal disposed on at least one major surface of the polymeric layer and defining electrical circuitry terminating at a lead at the via hole, the lead extending only part way across the via hole to define a cantilever end free to move in directions normal to the major surfaces of the polymeric sheet. The via hole may be extended along the lead or the polymeric sheet may be cut adjacent the lead to increase the effective length of the cantilever end and thus increase the flexibility and range of motion of the cantilever end.

Brief Description of the Drawings

The present invention will be described with respect to the accompanying drawings, wherein like numbers refer to like parts in the several views, and wherein:

Figure 1 is a cross-sectional view of a flexible circuit construction according to the invention with solder balls attached thereto;

Figure 2 is a top plan view of a portion of the flexible circuit of Figure 1 showing the end of one circuit trace;

Figure 3 is a cross-sectional view of a portion of the flexible circuit of Figure 1 with a solder ball attached and a cross-sectional view of a device for manipulating the solder ball after attachment to the flexible circuit;

Figure 4 is a cross-sectional view of the flexible circuit of Figure 1 with a solder ball attached showing the result of manipulating the solder ball by the device of Figure 3;

Figure 5 illustrates an alternate embodiment of a flexible circuit according to the invention; and

Figure 6 illustrates a second alternate embodiment of a flexible circuit according to the invention.

Description of the Preferred Embodiment

Figure 1 illustrates a flexible circuit, generally indicated as 10, and an environment in which it is typically used. The flexible circuit 10 includes a polymeric sheet 12, usually of polyimide, and metal, usually copper, disposed on at least one of the major surfaces of the sheet 12 to define electrical circuitry 14. In the illustration of Figure 1, the upper layer of metal 14 defines signal traces 16 and the lower layer defines a ground plane 18. In some instances, the ground plane 18 is not present and so the polymeric sheet 12 includes only one layer of metal.

The flexible circuit 10 is typically attached to a stiffener 20 by means of an adhesive 22. The stiffener 20 lends dimensional stability to the flexible circuit 10. The integrated circuit is typically connected to the signal traces 16 and ground plane 18, by any conventional means such as wire bonding, thermal compression bonding or flip chip techniques.

The assembly of the flexible circuit 10, its stiffener 20 and the other components are typically attached to a conventional printed circuit board. This attachment is by means of solder balls 24 soldered to the flexible circuit 10, and in turn mass reflow soldered to the printed circuit board. Attachment of the solder balls 24 to the flexible circuit 10 is accomplished by soldering each ball 24 to the proper circuit trace 16 through a via hole 26 formed in the polymeric sheet 12. In conventional flexible circuit constructions the circuit trace 16 spans the via hole 26 and thus is maintained rigidly in place relative to the flexible circuit 10. This rigidity results in stresses being built up in the assembly, particularly at the solder ball 24 solder joints, as the various components change dimensions as a result of temperature changes. In time, these stresses result in breakage of the components or their areas of attachment and may result in failure of the device.

The present invention is designed to eliminate these stresses and does so by providing circuit traces 16 which terminate at the via hole 26 short of completely spanning the hole 26. As best seen in Figure 2, the circuit trace 16 terminates in an enlarged lead 28 which includes a cantilever end 30 which extends only part way across the via hole 26.

The solder ball 24 is attached to the cantilever end 30 by conventional means and is free to move relative to the polymeric sheet 12 by virtue of the fact that the cantilever end 30 can move relative to the sheet 12 unlike circuit traces in the past. The flexibility and

spring constant of the free end 30 can be adjusted by choice of the width and thickness of the cantilever end 30.

Figure 3 illustrates a method of increasing this mobility of the solder ball 24 by bending the cantilever end 30 into the via hole 26. A fixture 32 includes a channel 34 sized to accept the solder ball 24. Once positioned, the fixture 32 is moved relative to the flexible circuit 10 (to the left as viewed in Figure 3) to cause the cantilever end 30 to bend to the position shown in Figure 4. It should be understood that Figure 3 illustrates only one of many solder balls 24 which are engaged simultaneously. The solder balls 24 are typically arranged in a number of rows and columns, hence the "array" portion of tape and ball grid array. The fixture will be built with a series of channels 34 to accommodate the number of rows of solder balls 24 which are present in the array. Of course, Figure 3 illustrates only one method of deflecting the solder balls 24 and others are possible. For example, it would be possible to deflect the cantilever ends 30 from above with projections which contact the cantilever ends 30.

The final configuration of the cantilever end 30 and the solder ball 24 shown in Figure 4 allows the solder ball 24 to move in the vertical and horizontal directions to accommodate movement of the components to which it connects due to thermal effects and to cure any misalignment of solder balls 24 due to such things as manufacturing tolerances, differences in size of solder balls 24 or warpage of the components.

Figure 5 illustrates one method of increasing the flexibility and range of the cantilever end 30. Here two cuts 36 are made in the polymeric sheet 12 adjacent and in the direction of the circuit trace 16. This allows the sheet 12 to bend in the vicinity of the cantilever end 30 and add to the motion which is available to the solder ball 24.

Figure 6 illustrates another method of increasing the flexibility and range of the cantilever end 30. Here, the shape of the via hole 26 is modified in shape to extend further down the length of the circuit lead 28 and thus increase the free length of the cantilever end 30.

Thus there has been described an improved flexible circuit construction which provides for movement of solder balls in tape ball grid array devices and so reduces the effects of thermal expansion and increases the ability of the assembly to accommodate misalignment. Although the invention has been described with respect to only a limited number of embodiments, it will be apparent to those skilled in the art that many modifications are possible. For example, the shape of the cantilever end 30 can vary widely. Also, one cut 36 or differently shaped cuts 36 can be utilized to increase flexibility of the cantilever end 30 rather than the cuts shown in Figure 5. As a further example, although the cantilever end is shown located on the opposite side of the polymeric sheet relative to the solder ball, the lead and its cantilever end could be located on the same side of the sheet as the solder ball if a solder mask were used to define the cantilever ends upon which the solder balls are subsequently attached. These cantilever ends are then deflected in a similar manner to that described above. Also, the cantilever end arrangement is not limited to flexible circuit construction. The principle is equally applicable to rigid printed circuit boards.

The invention claimed is:

1. A circuit construction for attachment to solder balls comprising:

a base having two major surfaces;

metal disposed on at least one major surface of said base and defining electrical circuitry terminating at a cantilever end free to move in directions normal to the major surfaces of said base.

2. A circuit construction according to claim 1 wherein said base is a flexible polymeric sheet including a via hole, and wherein said cantilever end spans only a portion of said via hole.

3. A circuit construction according to claim 2 wherein said cantilever end is bent to extend into said via hole toward the major surface of said polymeric sheet opposite the major surface on which said metal is disposed.

4. A circuit construction according to claim 2 wherein said flexible sheet is cut adjacent said via hole to allow greater movement of said cantilever end relative to the plane of said polymeric sheet.

5. A circuit construction according to claim 4 wherein said polymeric sheet includes two cuts extending from said via hole adjacent said lead.

6. A flexible circuit construction according to claim 2 further including a second hole through said polymeric sheet adjacent and in contact with said via hole, said second hole being disposed over said lead to increase the extent of said via hole and thus increase the length, flexibility and range of motion of said cantilever end.

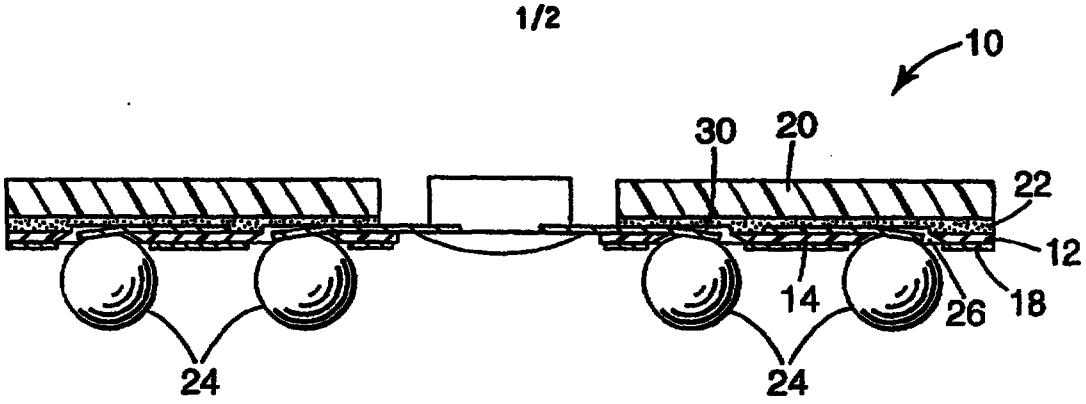


Fig. 1

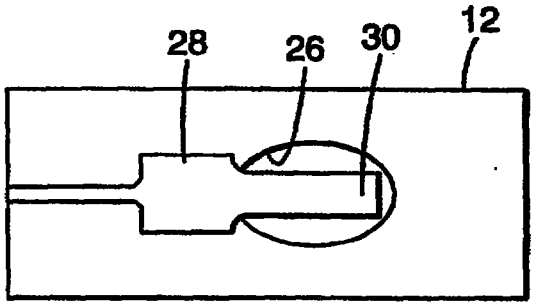


Fig. 2

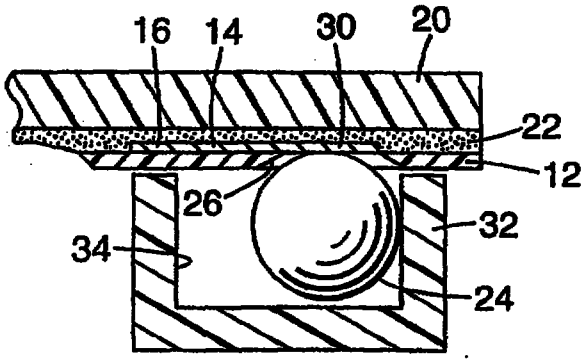


Fig. 3

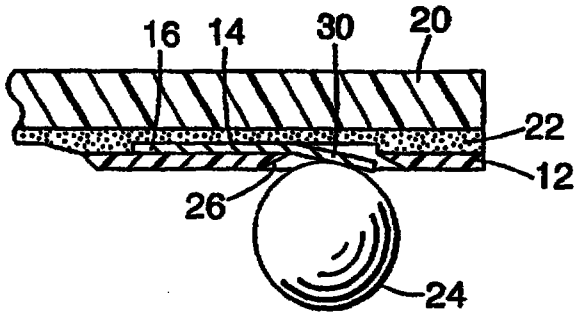


Fig. 4

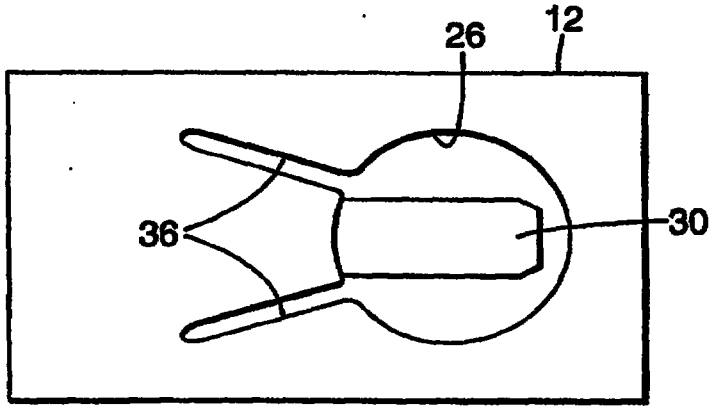


Fig. 5

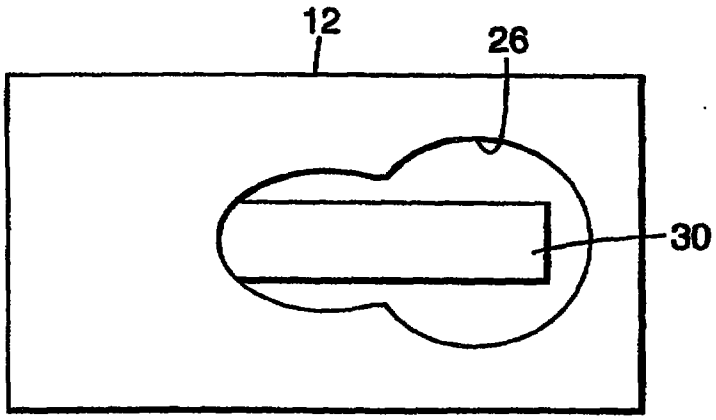


Fig. 6

PATENT COOPERATION TREATY

PCT

REC'D 25 SEP 1997
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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
Hi-bu 962231wo		
International application No.	International filing date (day/month/year)	Priority date (day/month/year)
PCT/US 96/06373	03/05/1996	16/06/1995
International Patent Classification (IPC) or national classification and IPC		
H01L23/498		
Applicant		
MINNESOTA MINING AND MANUFACTURING COMPANY		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   [X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consists of a total of 1 sheets.

3. This report contains indications and corresponding pages relating to the following items:

   - I [X] Basis of the report
   - II [ ] Priority
   - III [ ] Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV [ ] Lack of unity of invention
   - V [X] Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI [ ] Certain documents cited
   - VII [ ] Certain defects in the international application
   - VIII [X] Certain observations on the international application

Date of submission of the demand	Date of completion of this report
29/11/1996	23.09.97
Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. (+49-89) 2399-0, Tx: 523656 epmu d Fax: (+49-89) 2399-4465	H. Wolfrum Telephone No. 2498

Intern. application No.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT PCT/US96/06373

I. Basis of the report

1. This report has been drawn up on the basis of (Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.):

[ ] the international application as originally filed.

[x] the description, pages 1-6, as originally filed,
pages _____, filed with the demand,
pages _____, filed with the letter of _____,
pages _____, filed with the letter of _____,

[x] the claims, Nos. _____, as originally filed,
Nos. _____, as amended under Article 19,
Nos. _____, filed with the demand,
Nos. 1,2, filed with the letter of 18.6.97,
Nos. _____, filed with the letter of _____,

[x] the drawings, sheets/fig 1/2-2/2, as originally filed,
sheets/fig _____, filed with the demand,
sheets/fig _____, filed with the letter of _____,
sheets/fig _____, filed with the letter of _____.

2. The amendments have resulted in the cancellation of:
[ ] the description, pages _____.
[ ] the claims, Nos. _____.
[ ] the drawings, sheets/fig _____.

3. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

The amendments filed with the letter dated 18.6.97 introduce subject-matter which extends beyond the content of the application as filed, contrary to Article

34(2)(b) PCT.

The amendments concerned are the following:

The term "cut" used in original claims 4 and 5 as well as the description has been replaced in present claim 1 by the term "elongate slit".
If at all, an elongate slit is disclosed only in the context of figure 5 and the corresponding description in combination with the information given on page 6, lines 16-19. This disclosure refers exclusively to a cut extending from the via hole "adjacent and in the direction of the circuit trace" (cf. page 5, lines 33-34). Without the definition of these features in claim 1, the term "elongate slit" introduces added subject-matter.

None of the original claims specifies a solder ball forming part of the circuit. The disclosure given by the original description refers to a circuit comprising a solder ball only in the context of a tape ball grid array circuit having a plurality of via holes and corresponding cantilever ends with solder balls arranged in an array of rows and columns. The claims presently on file do however not define a TBGA circuit.
In this context it is also noted that the original claims do not refer to a flexible circuit "for attachment to a printed circuit board" and that such a circuit is disclosed only as a TBGA circuit.

There is also no disclosure for the definition "on an opposite side of said conductive trace", as comprised in present claim 2.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

1. STATEMENT

Novelty (N)	Claims 1,2	YES
	Claims	NO
Inventive Step (IS)	Claims	YES
	Claims 1,2	NO
Industrial Applicability (IA)	Claims 1,2	YES
	Claims	NO

2. CITATIONS AND EXPLANATIONS

1. Reference is made to the following documents :

D1 : DE-A-44 17 679,
D2 : PATENT ABSTRACTS OF JAPAN, vol. 11, no. 209 (E-521), 5 July 1987 & JP-A-62 030 342,
D3 : EP-A-0 532 898, and
D4 : US-A-5 203 075.

2. The application does not satisfy the criterion set forth in Article 33(3) PCT because the subject-matter of claims 1 and 2, as far as it is understood and based on the original disclosure, does not involve an inventive step (Rule 65(1)(2) PCT).

2.1 A "flexible circuit" (in the form of a TAB tape) being suitable for attachment to a printed circuit board and comprising a base of a flexible polymeric sheet having two major surfaces, a via hole through the base, and a conductive trace disposed on a first major surface of the base and terminating at a cantilever end spanning

only a portion of the via hole and being bent ("angularly displaced") to extend into the via hole is known from D2 (see in particular the abstract and figures 1a,b).

The subject-matter of claim 1 (even if properly clarified and based on the original disclosure) differs from the known circuit only in that
a) an elongate slit is provided in the base, terminating at the via hole (adjacent and in the direction of the trace); and
b) a solder ball is attached to the cantilever end from the second major surface.

It is noted that no difference can be seen in the intended attachment of the claimed circuit to a printed circuit board because such a use does not define any structural difference compared to the attachment to any other circuit element (as for instance a semiconductor wafer or chip). A circuit element suitable for attachment to a printed circuit board is also suitable for attachment for instance to a semiconductor chip and vice versa.
Apart from that it is noted that a TAB circuit having cantilever ends of conductive traces above via holes intended for bonding to circuit boards is known from D3 (see in particular figure 8 with the corresponding description showing "outer lead" 65 with cantilever ends).

Feature a) serves for the purpose of further increasing the flexibility of the free cantilever end in order to avoid mechanical stresses to the solder connection upon bonding of the solder ball, whereas feature b) eliminates the need to form the solder ball on the contact area to which the cantilever end will eventually be bonded.

Feature a) is known in the same narrow technical field of TAB circuits for the same purpose of reducing bonding stresses from D1 (see figures 4-6 with the corresponding description and in particular "elongate slits" 8 in figure 6).
Feature b) concerns a widely practised alternative for the placement of the solder ball in solder connections between TAB tape circuits and contact areas (on chips or printed circuit boards).

Therefore, a skilled person, being faced before the priority date of the present application with the desire to further reduce stresses in a solder connection between the cantilever end of the trace of the circuit known from D2 and a contact area and having to prepare the circuit so that the trace can be solder bonded to a contact area which is not equipped with a solder ball, would have found a solution in document D1 so that he would not have had to exercise any inventive skill in order to arrive at the subject-matter of claim 1.

2.2 Even if claim 1 were amended so as to define a tape ball grid array circuit device as disclosed in the description on file, it would still not define inventive subject-matter.

A tape ball grid array circuit device with circuit leads (traces) spanning or traversing via holes extending through the flexible tape base is known from D4 (see in particular the abstract; figures 1, 2, 7 and 8 with the corresponding description; and column 3, lines 10-16). No exercise of inventive skill would have been required to modify the TAB circuit in the device according to D4 in a manner as rendered obvious for TAB circuits from documents D1 and D2, i.e. of using a TAB circuit in which the cantilever parts of the traces extending over the via holes span only a portion of the hole, once the

skilled person had observed intolerable stresses in the solder bonds of the known TBGA circuit device. This is all the more true as D4 (cf. column 6, lines 22-50) informs the skilled reader about the possibility that the traces, onto which solder balls are attached in the area of the via holes, do not have to completely traverse the via hole.

2.3 In view of the teaching given by D1 from which it is known to increase the flexibility and range of motion of a cantilever end of a conductive trace by additional holes in the supporting base, the additional feature recognizable from claim 2 is regarded as constituting a simple and straightforward design option to which the skilled person had resorted without exercising inventive skill.

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The application does not meet the requirements of Article 6 PCT in various respects.

The claims do not refer to a tape ball grid array device or package and thus do not address the problem indicated on page 1, line 24 - page 2, line 2 of the description. In this respect the subject-matter of the claims is also not supported by the description (see in addition page 2, lines 6-14).

Moreover the definition referring in claim 1 to the "elongate slit" defines a result to be achieved without specifying in a clear and unambiguous manner the location, orientation and extension of the slit which allow to achieve the desired result.

The phrase "on an opposite side of said conductive trace" given in claim 2 is unclear.

The description is not in accordance with the subject-matter of the claims. This applies in particular to the introductory part on pages 1 and 2, to figures 2 and 6 with their corresponding description, and to the statements given on page 6, lines 19-29.

REPLACEMENT SHEET
18 JUN 1997

* C L M S *

C L A I M S

1. A flexible circuit for attachment to a printed circuit board, said flexible circuit comprising:
   - a base comprising a flexible polymeric sheet, said base having two major surfaces,
   - a via hole through said base,
   - a conductive trace disposed on a first major surface of said base and defining electrical circuitry terminating at a cantilever end spanning a portion of said via hole and being free to move in directions normal to the major surfaces of said base, said cantilever end being angularly displaced from said conductive trace to extend into said via hole,
   - an elongate slit terminating at one end thereof at said via hole to permit greater movement of said cantilever end relative to the plane of said flexible polymeric sheet, and
   - a solder ball attached to said cantilever end from a second major surface of said base such that a subsequent attachment of a printed circuit board to said flexible circuit from said second major surface will accommodate physical displacement of said flexible circuit and said printed circuit board.

2. The flexible circuit according to claim 1, wherein said flexible polymeric sheet includes two elongate slits each terminating at one end thereof at said via hole and each extending from said via hole on an opposite side of said conductive trace to allow greater movement of said cantilever end relative to the plane of said flexible polymeric sheet.

AMENDED SHEET