

MICRO-CASTELLATED INTERPOSER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on U.S. Provisional Application Serial No. 60/584025 entitled "Micro Castellated Interposer", filed on June 30, 2004, the teachings of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field):

The present invention relates to packaging of highly reliable, high-speed complex electronics, and more particularly to a method and apparatus for reworking circuits using a micro-castellated interconnect board with its related electrical parts and affixing it to the circuitry.

Background Art:

As electronic devices get smaller and smaller the prior art methods of part substitution and repair of circuitry create errors on existing hardware and become very problematic, if not entirely troublesome. Repair of circuitry and rewiring of devices on high-speed circuitry needs to be manufacturable and to a great extent electrically identical and meet environmental requirements of the product's end use. The present invention addresses a method for incorporating these changes to surface mounted electronics.

An existing prior art device or method uses a custom hybrid part, which internally incorporates the electrical wiring changes with mount die(s) containing the affected parts and provides environmental protection for the electronics. Such a custom part is very expensive, requires extensive lead-

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2 time and is not compliant to the volume allocated to the existing
electronics. This method is not adequate for an individual revision as it is
4 cost prohibitive. It can only be utilized for multiple or similar revisions to a
large quantity of printed wiring boards (PWB's).

6

Another prior art method is to scrap existing product circuit cards, re-
8 layout the electronics, and procure new printed wiring boards and
components. Other methods include reworking the circuit card assembly,
10 usually called "dead bugging" of components and "cut and jumpering" of
circuitry relying on highly skilled operators and requiring the visual aid of a
12 microscope to complete. Presently, the accepted practice for military
electronics is defined by standards for "cut and jumpering" of traces.

14

Scrapping product and re-layout of circuitry is costly and often causes
16 delays in build schedules. Manual rework is not exact, is prone to human
error and adds additional expense due to the use of highly skilled labor.
18 Additionally, some product still gets scrapped due to damage during repair
and the rework is not precise and may introduce variability in electrical
20 integrity.

22

State of the art approaches have been relatively successful until the
current generation of smaller geometry, high-speed electronic parts. Smaller
24 parts require higher skill and use of magnification aids. As parts get smaller,
the manual repair and replacement of parts becomes harder and at some
26 point impossible due to human limitations. Higher speeds require more
exact electrical wiring lengths and electrical trace separation. Depending
28 upon the extent of the change, current approaches utilize additional
adhesive to adhere part and wires to the circuit card assembly.

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A re-layout of the base circuit board can accomplish the same
32 function, that of rewiring, accommodating part changes and providing high
reliability, however this approach would be extremely expensive.

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2 Additionally, this method may introduce additional errors in re-layout of
complex very high-density circuitry by rerouting of critical signals. Other
4 devices, such as individual parts can accomplish one of the desired
outcomes but not all three, wiring changes, part changes, and high reliability.

6
 There are several prior art documents that disclose castellations
8 and/or outer land grid pads however, they do not address any context of
providing a durable interconnect containing the combination of substrate
10 design/materials, pad geometries, and castellation matched to the parent
printed wiring board. Additionally, the intent of utilizing existing parent
12 printed wiring board circuitry and providing changed electrical functionality
that is both manufacturable and low cost is not addressed in any of the prior
14 art.

16 These prior art documents include US Patent No. 6,609,915 B2 which
discloses a piece that only forms the interconnect between a multichip
18 module and the parent printed wiring board. The present invention performs
that function as well as providing new circuitry and mounting of parts and
20 addresses the durability of the interconnect.

22 US Patent No. 6,377,464 B1 is a device which may have castellations
for termination, but does not address durability of the interconnect. In fact,
24 the method described for constellating a part lacks features, which could
provide the necessary durability, namely bottom pads.

26
 US Patent No. 5,247,423 has 1/2 vias which form periphery
28 castellations allowing leads, wires or solder filled springs, to be attached and
provide the interconnect to the parent printed wiring board. The present
30 invention is a durable leadless interconnect.

32 US Patent No. 5,069,626 is a molded plastic device, which is molded
to allow plating of castellations, which have additional geometry attachment

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2 to the parent printed wiring board. While it mentions that the individual
"castellations area able to flex (on a microscopic level)" and it allows that the
4 molded material may be matched to the "second component" it does not
address how the castellations really flex and if this would be of any benefit to
6 the level of stresses induced due to thermal coefficient of expansion
mismatch, not to mention differential heating and cooling. Unless there is
8 major accommodation in the mounting structure, aka flexibility, the solder
joint geometry is critical to sustaining the thermally induced strains to meet
10 the necessary durability.

12 None of the prior art documents teach or disclose the combination of
substrate design/materials, pad and castellation geometries, which allow the
14 formation of a robust solder joint. Additionally, the prior art fails to disclose
the utilization of existing parent printed wiring board circuitry and providing
16 changed electrical functionality that is both manufacturable and low cost.

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SUMMARY OF THE INVENTION (DISCLOSURE OF THE INVENTION)

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The present invention forms a robust methodology for
22 accommodating part and/or circuitry changes to an existing printed wiring
board while allowing for automated assembly. It provides these capabilities
24 without incorporation of additional hardware, namely leads or flexible
circuitry. It also allows a method for accommodating parts, materials and
26 geometries that are disparate with the parent's materials and geometries.

28 A primary object of the present invention is to provide a micro
castellated interposer, which has the ability to accommodate different wiring
30 paths, part changes and/or new parts and maintain the original high level of
reliability of the circuit board assembly.

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2 A primary advantage of the present invention is that it provides a
means for circuitry and part changes at the lowest cost with the highest
4 reliability without compromising performance.

6 Other objects, advantages and novel features, and further scope of
applicability of the present invention will be set forth in part in the detailed
8 description to follow, taken in conjunction with the accompanying drawings,
and in part will become apparent to those skilled in the art upon examination
10 of the following, or may be learned by practice of the invention. The objects
and advantages of the invention may be realized and attained by means of
12 the instrumentalities and combinations particularly pointed out in the
appended claims.

16 BRIEF DESCRIPTION OF THE DRAWINGS

18 The accompanying drawings, which are incorporated into and form a
part of the specification, illustrate several embodiments of the present
20 invention and, together with the description, serve to explain the principles of
the invention. The drawings are only for the purpose of illustrating a
22 preferred embodiment of the invention and are not to be construed as
limiting the invention. In the drawings:

Fig. 1 shows the preferred embodiment of the micro-castellated printed wiring board.

Fig. 2 shows the embodiment of Fig. 1 populated with components.

28 Fig. 3 shows the embodiment of Fig. 2 mounted on a parent board.

Fig. 4 shows an alternative embodiment of the present invention using
30 partially occluded micro-castellations.

DESCRIPTION OF THE PREFERRED EMBODIMENTS
(BEST MODES FOR CARRYING OUT THE INVENTION)

The present invention comprises a small but common printed circuit board, which can be manufactured with conventional high precision techniques. The layout of this printed circuit board, which can be done in-house to accommodate interface data from the parent circuit card assembly, uses standard trace routing and interconnect (through-holes) found in printed circuit applications. Exact shape, layering and interconnect are determined at the time of laying out the circuitry. Replacement parts and additional parts are incorporated into the circuitry. The micro-castellations which will subsequently interconnect the micro-castellated interconnect board to its parent are placed to optimize circuitry issues while ensuring a robust solder joint which provides the interconnect. Manufacturing methods for the micro-castellated features may vary depending upon the design intent. This design once completed is panelized to provide fabrication efficiency for the circuit board house and enable a multiple up build of micro-castellated circuits on the manufacturing floor. Once fabricated the panelized micro-castellated circuits are built up with parts using standard high precision surface mount assembly methods and machines to form micro-castellated assemblies. These individual assemblies are then separated and are available for stocking or use on the parent assembly. The design of these castellated "leadless" solder joints comprises two distinct stress areas. One area is the pad to pad region commonly called the foot of the solder joint, which is relatively thin and is stressed predominately by sheering forces. The other area known as the toe is the solder that forms a fillet between the castellated solder joint and the remaining pad area. This region serves as a pseudo column and significantly adds to the life of the solder joint. The second assembly operation with the parent assembly is also an automated process again using standard high precision surface mount assembly methods and machines.

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2 The novel micro-castellated printed wiring board is shown in Fig. 1,
where printed wiring board **101** is designed and fabricated by common but
4 high precision printed wiring board tools and methods producing fine
features **103**. These fine features **103** can include pads for mounting
6 components **105**, traces for top and bottom interconnect **109**, and through-
hole vias **107** for interconnecting layers. Artwork may include intermediate
8 layers for shielding and interconnect depending upon the complexity of the
electrical circuitry (not shown). Printed wiring board **101** includes micro-
10 castellated through-hole vias **111** that form the micro-castellated solder joints
123 (Fig. 3) and interconnect to bottom surface pads **121** (Fig. 3). These
12 micro-castellated vias **111** are designed to align with surface features on the
parent printed wiring board **125** (Fig.3).

14 In Fig. 2, the micro-castellated printed wiring board **101** is populated
16 with changed circuitry devices, such as a microcircuits **113**, resistors **115**,
and/or capacitors **117**. These devices are soldered to the micro-castellated
18 printed wiring board **101** making the micro-castellated circuit card assembly
119. This micro-castellated circuit assembly **119** embodies the replacement
20 circuitry for parent printed wiring board **125**.

22 In Fig. 3 the micro-castellated circuit card assembly **119** is
mounted on the parent printed wiring board **125**. The micro-castellations
24 **111** are soldered directly to the surface pads **121** forming robust leadless
surface mount solder joints **123**. The robustness of the solder joints results
26 from choosing the correct material properties for the micro-castellated
interposer, designing the castellations/pad geometry in relation to the current
28 parent pad geometry to form adequate solder joints/fillets and designing pad
geometry to accommodate part geometries. The materials include the
30 selection of printed wiring board materials whose properties account for a
coefficient of expansion differences between the mounted parts and the
32 parent printed wiring board. Solder durability analysis of the geometries and
materials is performed in the design stage to ensure that the micro-

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2 castellated interposer provides robust solder joints for the parts as well as
the interconnect to the parent printed wiring board. These include a pad to
4 castellation geometry ratio, which ensures that the resultant solder geometry
is capable of accommodating thermal induced stresses between parts, the
6 micro-castellated printed wiring board and the parent printed wiring board.
In addition, the manufacturing method includes supplying the correct solder
8 volume to produce the correct geometry solder joint.

For example if the parent printed wiring board is made of commercial
10 woven E-glass/epoxy with a coefficient of expansion (CTE) of 15 (parts per
million / degree Celsius) and the new parts to be added to the circuitry are
12 ceramic parts with CTE of 7 (ppm/°C), then the Micro-castellated Interposer
board would preferably be designed out of woven aramid/multi-functional
14 epoxy with a CTE in between the parts and the parent printed wiring board.
In this way the necessary interconnect strength could be accommodated
16 from the as designed pad/castellation geometry and the resultant solder joint
morphology.

18
Optional design and construction methods **127** shown in Fig. 4 allow
20 use of partially occluded micro-castellations **133**. This design methodology
permits use of additional area for routing circuitry **131** and use of additional
22 devices **129**. The partially occluded castellations **133** are soldered to the
parent printed wiring board **125** surface pads **121**, forming robust leadless
24 surface mount solder joints **123**.

26 To utilize maximum surface area on the daughter printed wiring board
fully occluded micro-castellations **137** may be utilized as in Fig 5. The fully
28 occluded micro-castellated printed wiring board **135** offers maximum board
area for a slight reduction in solder joint reliability.

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Any of these designs and construction methods can be utilized where
32 the micro-castellations are located anywhere on the micro-castellated printed

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2 wiring board, including underneath device bodies and permitting their
integration into the device land patterns.

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Although the invention has been described in detail with particular
6 reference to these preferred embodiments, other embodiments can achieve
the same results. Variations and modifications of the present invention will
8 be obvious to those skilled in the art and it is intended to cover in the
appended claims all such modifications and equivalents. The entire
10 disclosures of all references, applications, patents, and publications cited
above, are hereby incorporated by reference.

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CLAIMS

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What is claimed is:

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1. An apparatus for accommodating circuitry device (113, 115, 117) and interconnect changes externally to a parent printed wiring assembly (125), the apparatus comprising:

8 a micro-castellated printed wiring board (101), said micro-castellated printed wiring board (101) comprising fine features (103);

10 a first interconnection between said fine features (103) and the changed circuitry devices (113, 115, 117), said first interconnect comprising automated assembly and reflow; and

12 a second interconnection between landed castellations (111) of said micro-castellated printed wiring board (101) and the parent printed wiring assembly (125).

16

2. The apparatus of claim 1 wherein said landed castellations (111) interface directly to parent printed wiring assembly (125).

18

20 3. The apparatus of claim 1 wherein said second interconnection comprises a leadless robust solder joint (123).

22

24 4. The apparatus of claim 3 wherein said robust leadless solder joint (123) comprises two distinct soldered zones, a first formed between land patterns (121) comprising a thin structure and a second being formed in the landed castellations (111) which functions as a solder column.

26

28 5. The apparatus of claim 3 wherein said micro-castellated printing wiring board (101) comprises:

30 a printed wiring board material whose properties account for coefficient of expansion differences between the changed circuitry devices

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2 (113, 115, 117) and a parent printed wiring board (125) from the printed wiring assembly (101); and

4 a solder joint (123) with a specific geometry based on a pad to a part lead geometry and thermal induced stresses.

6 6. The apparatus of claim 1 wherein said first interconnection comprises a robust solder joint.

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10 7. The apparatus of claim 6 wherein said first interconnection comprises:

12 a unique pad geometry (105) for said changed circuitry devices (113, 115, 117) which defines a footprint;

14 a printed wiring board (101) material whose properties account for a coefficient of expansion differences between the changed circuitry devices (113, 115, 117) and a parent printed wiring board (125) from the printed wiring assembly (101); and

16 a solder joint (123) with a specific geometry based on a pad to lead geometry and thermal induced stresses.

20 8. The apparatus of claim 1 wherein said landed castellations (111) are formed on an edge of the micro-castellated printed wiring board (101).

24 9. The apparatus of claim 1 wherein said landed castellations (111) are formed internal to the micro-castellated printed wiring board (101) comprising partially occluded castellations (133).

28 10. The apparatus of claim 1 wherein said landed castellations (111) are formed internal to the micro-castellated printed wiring board (135) comprising fully occluded castellations (137).

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2 11. The apparatus of claim 1 wherein said second interconnection comprises a means for automated assembly and reflow.

4 12. A method for revising a portion of a parent board (125), the method comprising the steps of:

6 a) removing the portion of the parent board (125) to be replaced;

8 b) providing a miniature printed wiring board (101) comprising micro-castellations (111) for mounting on the parent board (125) wherein said micro-castellations (111) are electrically connected to component mounting pads (105) and which align with surface features (121) on the parent board (125);

12 c) mounting at least one component (113, 115, 117) to the component mounting pads (105); and

14 d) affixing the miniature printed wiring board (101) to the parent board (125).

16 13. The method of claim 12 further comprising the step of underlaying the miniature printed wiring board (101) comprising providing cutouts in the miniature printed wiring board (101) and placing the at least one component (113, 115, 117) to accommodate the cutouts.

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24 14. The method of claim 12 wherein the step of providing a miniature wiring board (101) comprises interfacing the micro-castellations (111) directly to the surface features (121) of the parent printed wiring board (125).

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28 15. The method of claim 12 wherein the step of affixing comprises affixing with a robust leader less solder joint (123).

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- 2 16. The method of claim 12 wherein the step of providing a
miniature printed wiring board (101) comprises:
 selecting a printed wiring board (101) material whose
4 properties account for coefficient of expansion differences between the at
least one component (113, 115, 117) and the parent board (125); and
6 selecting a solder joint (123) with a specific geometry based on
a pad (121) to castellation (111) geometry ratio and thermal induced
8 stresses.
- 10 17. The method of claim 12 wherein the step of providing a
miniature printed wiring board (101) comprises forming the micro
12 castellations (111) on an edge of the miniature printed wiring board (101).
- 14 18. The method of claim 12 wherein the step of providing a
miniature printed wiring board (101) comprises forming the castellations
16 (123) internal to the miniature printed wiring board (101), forming partially
occluded castellations (133).
- 18 19. The method of claim 12 wherein the step of providing a
miniature printed wiring board (101) comprises forming the castellations
20 (111) internal to the miniature printed wiring board (101), forming fully
occluded castellations (137).
- 22 20. The method of claim 12 wherein the step of affixing the
miniature printed wiring board (101) to the parent board (125) comprises
24 automated assembly and reflow.
- 26