

COMPLIANT ELECTRICAL CONTACT
BACKGROUND OF THE INVENTION

Field of the Invention

he present invention relates to electrical contacts, more
5 particularly, to very small compliant electrical contacts
with very low inductance at high frequencies.

The Prior Art

The purpose of an electrical contact is to provide a
separable electrical interconnection between two electrical
10 conductors. The characteristic of separability means that
the conductors are not interconnected by permanent mechanical
means, such as soldering or bonding, but by temporary
mechanical means. Consequently, in order to maintain a good
mechanical contact in an attempt to minimize detrimental
15 electrical effects of the contact, some form of spring force
is used to press the two conductors together. These
electrical contacts are called compliant (as in "flexible")
contacts.

Small compliant contacts are necessary for separably
20 interconnecting integrated circuit (IC) devices to whatever
electrical device the user desires. A prime example is
connecting the IC to a test fixture or sorting equipment used
for testing and sorting IC's during manufacture. The
compliant contact should be as close to electrically
25 transparent as possible in order to minimize parasitic
effects, such as inductance, that alter the signals to and
from the IC which could lead to erroneous results.

Compliant contacts provide another advantage in that
they can compensate for noncoplanarities of the electronic
30 unit under test (UUT) being connected. The conduction points
on the UUT are not exactly coplanar, that is, they are not
within the same plane, even between the same conduction point
on different UUT's. The compliant contacts deflect by
different amounts depending upon the actual position of the
35 conduction point.

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Conventional compliant contacts for connecting to UUT's include spring probes, conductive rubber, compliant beam contacts, and bunched up wire called fuzz buttons. Each technology provides the necessary means to overcome the noncoplanarities between the contact points and provides uniform electrical contact throughout a plurality of contacts. Each technology has shortcomings in one characteristic or another and all have high electrical parasitic characteristics. In addition, they are relatively expensive to manufacture.

A typical spring probe consists of at least three or four parts, a hollow barrel with a spring and one or two plungers. The spring is housed in the barrel with the end of the plungers crimped in opposed open ends of the barrel at the ends of the spring. The spring biases the plungers outwardly, thereby providing a spring force to the tip of the plungers. Spring probes can have highly varying degrees of compliance and contact force, and are generally very reliable for making contact many times or for many cycles. Spring probes can accommodate many different conduction interfaces, such as pads, columns, balls, etc. Spring probes, however, have a size problem in that the spring itself cannot be made very small, otherwise consistent spring force from contact to contact cannot be maintained. Thus, spring probes are relatively large, leading to an unacceptably large inductance when used for electrical signals at higher frequencies. Additionally, spring probes are relatively costly since the three components must be manufactured separately and then assembled.

Conductive rubber contacts are made of rubber and silicones of varying types with embedded conductive metal elements. These contact solutions usually are less inductive than spring probes, but have less compliance and are capable of fewer duty cycles than spring probes. The conductive rubber works when the conduction point is elevated off the

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UUT thus requiring a protruding feature from the UUT or the addition of a third conductive element to the system to act as a protruding member. This third member lessens the contact area for a given contact force and thus increases the force per unit area so that consistent contact can be made. The third element may be a screw machined button which rests on the rubber between the conduction point. This third element can only add inductance to the contact system.

Compliant beam contacts are made of a conductive material formed such that deflection and contact force is attained at one end to the UUT conduction point while the other end remains fixed to the other conductor. In other words, the force is provided by one or more electrically conductive leaf springs. These contacts vary greatly in shape and application. Some compliant beam contacts are small enough to be used effectively with IC's. Some compliant beam contacts use another compliant material, such as rubber, to add to the compliance or contact force to the beam contact point. These later types tend to be smaller than traditional compliant beam contacts and thus have less inductance and are better suited for sorting higher frequency devices. However, these contacts still tend to be somewhat too large to be useful in some radio frequency (RF) applications.

Fuzz buttons are a relatively old yet simple technology in which a wire is crumpled into a cylindrical shape. The resulting shape looks very much like tiny cylinder made of steel wool. When the cylinder is placed within a hole in a sheet of nonconductive material, it acts like a spring that is continuously electrically shorted. It provides a less inductive electrical path than other contact technologies. Like rubber contacts, the fuzz button is most commonly used with a third element needed to reach inside the hole of the nonconductive sheet to make contact with the fuzz button.

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This third element increases parasitic inductance, degrading the signals to and from the UUT.

IC packaging technology is evolving toward being smaller, higher frequency (faster), and cheaper, resulting in new requirements for these types of electrical contacts. They need to perform adequately at the lowest cost.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a compliant contact with a lower self-inductance at higher frequencies than existing technologies.

Another object is to provide a low-self-inductance contact that provides sufficient compliance to test various UUT's.

Yet another object is to provide a low-self-inductance contact that can be made extremely small for testing UUT's with close conduction points

A further object is to provide a low-self-inductance contact that is relatively inexpensive to manufacture.

The present invention is a very low self-inductance, compliant contact in two embodiments. The skewed coil embodiment includes a coil of wire with a pair of oppositely extending leads. The leads extend in a direction angled from the coil axis, the magnitude of the angle being dependent on the particular application. The greater the angle, the greater the force necessary to compress the contact. During compression, the coil loops are electrically shorted while they slide along each other. The coil only needs to have enough of a loop to cause a short circuit between the leads when compressed, a minimum of just over 360°.

The cross-sectional shape of the wire can be any shape, including round, square, triangular, elliptical, rectangular, or star, nor does the cross-sectional dimension have to be uniform over the length of the wire. Cross-section with flat sides provide a greater contact surface than wire with a round or oval cross-section, but are not necessarily

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preferred. The wire is made of any electrically conductive material which has inherent elastic properties.

The leads ends can be configured in shapes that aid in the contact integrity, for example a hemisphere or ring for
5 receiving a ball contact, or a spear for piercing oxides.

In one application, the contact is placed within a through aperture in a dielectric panel. The aperture has openings at both ends of a larger center section. In one embodiment, the dielectric panel has a base sheet with one of
10 the openings and the center section and a top sheet with the other opening. The contact is placed in the center section and the sheets are sandwiched together, capturing the contact within the aperture. In another embodiment, the dielectric panel has two mirror image sheets where each sheet has one
15 opening and a half of the center section. The contact is placed in one side and the sheets are sandwiched together to capture the contact. Optionally, the remaining space of the aperture is filled with a compliant, electrically conductive elastomer that adds resiliency and aids in electrically
20 shorting the coil loops.

The raveled wire embodiment of the contact of the present invention is created by forcing a length of wire into a cylindrical cavity that has a diameter larger than the cross-sectional dimension of the wire, resulting in randomly
25 entangled convolutions formed within the confines of a cylindrical shape. The lead ends protruding paraxially from the convolutions. The characteristics of the wire are the same as those of the skewed coil contact. All other characteristics of the raveled wire contact are the same as
30 or similar to those of the skewed coil contact.

Other objects of the present invention will become apparent in light of the following drawings and detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and object of the present invention, reference is made to the accompanying drawings, wherein:

5 Fig. 1 is a perspective view of the basic contact of the skewed coil embodiment of the present invention;

 Fig. 2 is a side view of the skewed coil contact with oval loops;

10 Fig. 3 is a side view of the skewed coil contact made from a wire with rectangular cross-section;

 Fig. 4 is a perspective view of the skewed coil contact with a lead formed into a ring;

 Fig. 5 is a perspective view of the skewed coil contact with a lead formed into a prong;

15 Fig. 6 is a partial cross-sectional side view of one embodiment of an assembly employing the skewed coil contact;

 Fig. 7 is a partial cross-sectional top view of the assembly of Fig. 6;

20 Fig. 8 is a partial cross-sectional side view of another embodiment of an assembly employing the skewed coil contact and filled with a conductive elastomer;

 Fig. 9 is a partial cross-sectional side view of a pair of skewed coil contacts mounted in a dielectric sheet in very close proximity;

25 Fig. 10 is a partial cross-sectional view of several configurations of the raveled wire contact mounted in a dielectric sheet; and

30 Fig. 11 is a partial cross-sectional side view of a configuration of the raveled wire contact mounted in a dielectric sheet and filled with a conductive elastomer.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a compliant electrical contact with a very low self-inductance. It has two embodiments.

1. The Skewed Coil Embodiment of Figs. 1 to 9.

In the skewed coil embodiment, shown in Figs. 1-9, the contact 10 is created by winding a length of electrically conductive wire into a cylindrical coil 12. The gap 44
5 between loops 14 of the coil 12, shown in Fig. 6, ranges from essentially no gap (a closed coil) to a distance of up to about 100% of the largest wire cross-sectional dimension. The greater the wire cross-sectional dimension, the greater the gap 44 can be as a percentage of the cross-sectional
10 dimension. For example, with a wire cross-sectional dimension of 0.0031 inch, a gap of 0.0001 inch (3%) is acceptable, whereas with a wire cross-sectional dimension of 0.020 inch, a gap of 0.010 inch (50%) is acceptable.

The coil 12 can be round, as in Fig. 1, or oval, as in
15 Fig. 2. The two wire extremities extend as leads 16, 18 away from the coil 12 in opposite directions generally parallel to each other and at an angle from the coil axis 38. The magnitude of this skew angle will depend on the particular application and the compliance forces required for that
20 application. The greater the angle, the greater the force necessary to compress the contact 10, which means that the contact 10 will provide a greater force against the conduction point of the UUT. When the contact 10 is mounted such that the leads 16, 18 can be compressed axially, the
25 coil 12 provides compliance as the loops 14 slide along each other. When the compression force is removed, the loops 14 return to their quiescent state. While compressed, the coil 12 pushes the leads 16, 18 against the conduction points of the UUT being connected, providing an acceptable electrical
30 connection. In addition, the coil 14 provides the necessary feature of adjusting for the noncoplanarities of the conduction points.

Once the gap 44 is closed, the loops 14 are electrically shorted throughout the compression of the contact 10 while
35 they slide along each other. The coil 12 only needs to have

enough of a loop to cause a short circuit between the leads 16, 18 when compressed, and thus can be extremely short with very low electrical parasitics. The smallest coil has slightly more than one loop. The wire is coiled a minimum of
5 just over 360° so that the ends of the coil 12 make contact during compression.

In addition to the skew angle, the force versus deflection curve of the skewed coil contact 10 is also determined by the volume of the wire used in manufacturing
10 the contact, e.g. the wire cross-sectional dimension, coil diameter, and wire length, as well as the cross-sectional shape and wire material. The cross-sectional shape of the wire can be round, as shown in Fig. 1, or any other shape including square, triangular, elliptical, rectangular, or
15 star. The present invention also contemplates that the cross-sectional dimension does not have to be uniform over the length of the wire. When using wire with a cross-section having flat sides, such as rectangular or star-shaped, adjacent loops are in contact along a greater surface area
20 than when using wire with a round or oval cross-section. Consequently, the shortest electrical path possible is created, resulting in a lower inductance connection. However, for cost and other reasons, wire with flat sides is not necessarily preferred over round and oval wire.

25 The wire can be made of any electrically conductive material which has inherent elastic properties, for example, stainless steel, beryllium copper, copper, brass, and nickel chromium alloy. All of these materials can be used in varying degrees of temper from annealed to fully hardened.

30 The ends of the leads 16, 18 can be configured in shapes that aid in the contact integrity of the contact point. One example of a lead formation is a hemisphere or ring 20, shown in Fig. 4, for receiving a ball contact as in the testing of a ball grid array (BGA) device. Another example is a spear,

shown in Fig. 5, with one or more prongs 22 for piercing oxides at the conduction point.

In one application, shown in Fig. 6, the skewed coil contact 10 is placed within a through aperture 24 in a dielectric panel 26. The aperture 24 has openings 28 at both ends of a larger center section 30. The cross-sectional dimension of the center section 30 is slightly larger than the largest dimension of the contact perpendicular to the leads. In one configuration, shown in Fig. 7, the center section 30 has an oval cross section, where the direction 40 in which the coil 12 expands has the larger dimension. The smaller dimension 42 can be the same as the coil dimension, since the coil 12 does not expand in that dimension 42.

In one embodiment, shown in Fig. 6, the dielectric panel 26 has a base sheet 34 that contains one of the openings 28 and the entire center section 30 and a top sheet 32 that contains only the other opening 28. The contact 10 is placed in the base sheet part of the aperture 24 and the sheets 32, 34 are sandwiched together, capturing the contact 10 within the aperture 24.

In another embodiment, shown in Fig. 8, the dielectric panel 26 has two mirror image sheets 46, 48, where each sheet has one opening 28 and a half of the center section 30. The contact 10 is placed in one side of the aperture 24 and the sheets 46, 48 are sandwiched together, capturing the contact 10 within the aperture 24.

When an axial compression force is applied to the leads 16, 18 protruding through the openings 28 of the dielectric panel 26, the loops 14 of the coil 12 expand. The aperture 24 maintains the position of the contact 10 as it is compressed. The aperture 24 may also maintain the integrity of the contact 10 by preventing the coil loops 14 from separating under the axial compression.

In another application, the skewed coil contact 10 is installed in the aperture 24 and the remaining space of the

aperture 24 is filled with a compliant, electrically conductive elastomer 36, as shown in Fig. 8. The elastomer 36 performs a dual function. It adds to the resiliency of the contact 10, meaning that the contact 10 can tolerate more operational cycles than without the elastomer 34. The elastomer 34 also aids in electrically shorting the coil loops 14, thus potentially minimizing the electrical parasitic values of the contact system.

The skewed coil contact 10 can be made extremely small by employing extremely small wire and forming apertures 24 in the dielectric panel 26 for testing UUT's with pitches smaller than 0.5 mm (0.020"). The contacts 10 are adaptable to silicon wafer probing with pitches in the micrometers.

An alternate arrangement of the contacts 10 within a dielectric panel 26 is shown in Fig. 9. Note that one lead 16 is longer than the other 18 and that the apertures 24 are elongated and staggered. With this arrangement, the contacts 10 can be placed closer together. Particular applications of this arrangement include 4-wire testing where each IC lead requires two contacts, one for a drive current and the other for high-impedance sensing.

The skewed coil contact can be made of an optical fiber so that it may be used to make a temporary connection to UUT's with fiber optic interfaces. The skewed coil leads protrude axially from the coil, thus directing the light signals straight in and out of the contact. The purpose, obviously, is not to minimize parasitic electrical effects, since optical signals do not have such problems. The optical contact permits a mixture of electrical and optical signals on the same test fixture while providing the same compliance as the electrical skewed coil contact.

2. The Raveled Wire Embodiment of Figs. 10 and 11.

The raveled wire embodiment, shown in Figs. 10 and 11, consists of a length of wire that is forced into a cylindrical cavity that has a diameter larger than the cross-

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sectional dimension of the wire, typically two to four times larger. The result, shown variously in Figs. 10 and 11, is a contact 50 that is comprised of randomly entangled convolutions 52 formed within the confines of a cylindrical shape with both extremities of the wire protruding paraxially as leads 54, 56 from either end of the convolutions 52. The leads 54, 56 protruding from the convolutions 52 provide a compliant contact point. The axially protruding leads 54, 56 are the key differentiators from the fuzz button contact of the prior art in that no additional contact elements are required in the contact system. Consequently, the contact has less inductance and can be made smaller than the fuzz button contact system.

The wire can be made of the same materials as the skewed coil contact 10. A contact 50 using a rectangular cross-section wire can induce consistent convolutions 52. When the wire is forced into a cavity at the time of manufacture, the wire tends to bend along its weakest point. With the rectangular cross-section, the weakest point is the shortest line through the wire axis, which is essentially the same throughout the length of the wire. Thus, a unidirectional collapse pattern is induced, causing the contact to compress consistently from contact to contact.

The leads 54, 56 can be formed into shapes in the same manner as the leads 16, 18 of the skewed coil contact 10. The raveled wire contact 50 can be made very small, like the skewed coil contact 10. As with the skewed coil contact 10, the raveled wire contact can be installed in a through aperture 58 in a dielectric panel 62. Also, as with the skewed coil contact 10, the remaining space of the aperture 58 can be filled with a compliant, conductive elastomer 60, as shown Fig. 12.

The cavity in which the contact 50 is formed can be round, square, or any other desired cross sectional shape. If the contact 50 is formed inside a rectangular, rather than

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circular, cavity, the apexes of the formed contact 50 may be used to hold the contact within the aperture 58.

Thus it has been shown and described a compliant electrical contact which satisfies the objects set forth
5 above.

Since certain changes may be made in the present disclosure without departing from the scope of the present invention, it is intended that all matter described in the foregoing specification and shown in the accompanying
10 drawings be interpreted as illustrative and not in a limiting sense.

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What is claimed is:

- 1 1. A compliant electrical contact comprising:
 - 2 (a) a length of wire having extremities and being
 - 3 composed of an electrically conductive, inherently elastic
 - 4 material;
 - 5 (b) said wire being formed into a coil having at least
 - 6 slightly more than one loop and an axis;
 - 7 (c) each of said extremities forming a lead separated
 - 8 from said coil by a bend in said wire, said leads extending
 - 9 in approximately opposite directions; and
 - 10 (d) said coil axis being angled from said leads.
- 1 2. The compliant electrical contact of claim 1 wherein
- 2 said wire has a round cross-section.
- 1 3. The compliant electrical contact of claim 1 wherein
- 2 said wire has a cross-section with at least one flat side.
- 1 4. The compliant electrical contact of claim 1 wherein
- 2 at least one of said leads is configured with a shaped end.
- 1 5. The compliant electrical contact of claim 1 wherein
- 2 one of said leads is longer than the other of said leads.
- 1 6. The compliant electrical contact of claim 1 wherein
- 2 said wire is metallic.
- 1 7. The compliant electrical contact of claim 1 wherein
- 2 said wire has a cross-sectional dimension and the gap between
- 3 said loops is no more than 100% of said cross-sectional
- 4 dimension.
- 1 8. A compliant electrical contact assembly comprising:
 - 2 (a) at least one compliant electrical contact, said
 - 3 contact including a length of wire having extremities and
 - 4 being composed of an electrically conductive, inherently
 - 5 elastic material, said wire being formed into a coil having
 - 6 at least slightly more than one loop and an axis, said
 - 7 extremities extending from said coil as leads in
 - 8 approximately opposite directions, and said coil axis being
 - 9 angled from said leads; and
 - 10 (b) a dielectric panel having a through aperture for each
 - 11 of said at least one electrical contact, said through

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12 aperture having a center section in which said coil is
13 captured and opposed openings through which said leads
14 extend, said center section being sized to permit said coil
15 to compress and expand as axially pressure is applied to and
16 removed from said leads.

1 9. The compliant electrical contact assembly of claim 8
2 wherein said aperture is filled with a compliant, conductive
3 elastomer after said contact is installed in said aperture.

1 10. The compliant electrical contact assembly of claim 8
2 wherein said wire has a round cross-section.

1 11. The compliant electrical contact assembly of claim 8
2 wherein said wire has a cross-section with at least one flat
3 side.

1 12. The compliant electrical contact assembly of claim 8
2 wherein at least one of said leads is configured with a
3 shaped end.

1 13. The compliant electrical contact assembly of claim 8
2 wherein one of said leads is longer than the other of said
3 leads.

1 14. The compliant electrical contact assembly of claim 8
2 wherein said wire is metallic.

1 15. The compliant electrical contact assembly of claim 8
2 wherein said wire has a cross-sectional dimension and the gap
3 between said loops is no more than 100% of said cross-
4 sectional dimension.