

Apparatus And Method For Detecting Alignment Of Contacts
In A Multi-substrate Electronic Assembly

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Field of the Invention

The present invention relates generally to multi-substrate electronic assemblies, and more particularly to an apparatus and method for detecting alignment of corresponding contacts of a multi-substrate assembly.

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Background of the Invention

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Multi-substrate electronic assemblies are well known in the electronic assembly prior art field. Multi-substrate electronic assemblies typically provide a path for electrically coupling corresponding contacts on the multiple substrates to permit thereby coupling of information therebetween.

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Multi-substrate electronic assemblies are readily used, for example, in the display, printed circuit, connector and integrated circuit prior art fields to name a few. In the display prior art field, a liquid crystal display assembly, for example, includes a display substrate and a printed circuit substrate. In the printed circuit prior art field, a multi-board assembly, for example, includes two printed circuit substrates. In the connector prior art field, a zero insertion force connector, for example, includes a female substrate connector portion and a male flex circuit substrate connector portion. In the integrated circuit prior art field, flip chip bonding, for example, includes an integrated circuit substrate and a printed circuit substrate. Also in the integrated circuit prior art field, tab bonding, for example, includes an integrated circuit substrate and a connector substrate. In each

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of these examples, the multi-substrate electronic assemblies typically provide a path, using techniques well known in the art, for electrically coupling corresponding contacts on the multiple substrates to permit thereby coupling of information therebetween.

A particular problem characteristic of the multi-substrate assemblies is alignment of corresponding contacts on the multiple substrates. Perfect alignment of the corresponding contacts permits good electrical coupling and is most desirable. Misalignment of the corresponding contacts within a predetermined criterion permits good electrical coupling and is acceptable. Misalignment of the corresponding contacts outside the predetermined criterion permits marginal electrical coupling and is unacceptable. Misalignment of the corresponding contacts outside the predetermined criterion permitting electrical decoupling is, of course, unacceptable.

Generally, electrically coupled corresponding contacts produce a functional multi-substrate electronic assembly and electrically decoupled corresponding contacts produce a nonfunctional multi-substrate electronic assembly. Hopefully, electrical decoupling between corresponding contacts is detected during a manufacturing process of the multi-substrate electronic assembly when the detected misalignment can be corrected. Unfortunately, marginal electrical coupling between corresponding contacts is commonly undetectable in the manufacturing process of the multi-substrate assembly and may result in later electrical decoupling due to environmental conditions or conditions of use or abuse.

Further, as the size of the corresponding contacts or the gap between adjacent contacts on the same substrate decreases, alignment of the corresponding contacts becomes increasingly difficult. These size and gap restrictions therefore limit an increase in the density of contacts on the

substrates thereby limiting a reduction in the size of the substrates or an increase in the number of contacts on the substrates.

5 Alignment of corresponding contacts on substrates of a multi-substrate assembly has been achieved in prior art using mechanical and optical alignment techniques.

Generally, the mechanical alignment techniques are subject to a functional test either performed manually which is labor intensive or automatically which is complex and costly.
10 Further mechanical alignment techniques typically involves time consuming trial and error alignment, do not detect marginal misalignment of corresponding contacts, do not detect faulty electrical coupling between presumeably aligned corresponding contacts and do not detect process control
15 parameters related to the alignment of corresponding contacts.

Optical alignment techniques, obviously, are generally limited to multi-substrate electronic assemblies having at least one translucent substrate permitting alignment of an
20 image of the corresponding contacts.

Therefore, there is a need for an improved apparatus and method for detecting alignment of corresponding contacts of a multi-substrate electronic assembly.

Brief Description of the Drawings

The present invention will be better understood when read with reference to the accompanying drawings in which:

5 FIG. 1 illustrates, in a perspective view, an electronic device, such as a radiotelephone as shown, in accordance with the present invention;

10 FIG. 2 illustrates a novel display assembly, including first, second, third and fourth contacts, for use in the electronic device of FIG. 1 in accordance with the present invention;

FIG. 3 illustrates complete misalignment between the first and second contacts of FIG. 2 according to a first criterion in accordance with the present invention;

15 FIG. 4 illustrates marginal misalignment between the first and second contacts of FIG. 2 according to a first criterion in accordance with the present invention;

20 FIG. 5 illustrates substantial alignment between the first and second contacts of FIG. 2 according to a first criterion in accordance with the present invention;

FIG. 6 illustrates perfect alignment between the first and second contacts of FIG. 2 according to a first criterion in accordance with the present invention;

25 FIG. 7 illustrates the first and third contacts coupled to a display substrate of FIG. 2, and the second and fourth contacts coupled to a printed circuit substrate of FIG. 2 in accordance with the present invention;

30 FIG. 8 illustrates alignment of the first and second contacts of FIG. 7 according to a first criterion responsive to alignment of the third and fourth contacts of FIG. 7 according to a second criterion in accordance with the present invention;

FIG. 9 illustrates an expansion of FIG. 7 by adding fifth and sixth contacts on the printed circuit substrate to further indicate direction and degree of alignment of the first and

second contacts in one dimension of space in accordance with the present invention;

FIG. 10 illustrates alignment of the first and second contacts of FIG. 9 according to a first criterion responsive to alignment of the third contact relative to the fourth, fifth and sixth contacts of FIG. 9 according to a second criterion in accordance with the present invention;

FIG. 11 illustrates an expansion of FIG. 9 by adding seventh and eighth contacts on the printed circuit substrate to further indicate direction and degree of alignment of the first and second contacts in two dimensions of space in accordance with the present invention;

FIG. 12 illustrates an expansion of FIG. 7 by providing third and fourth contacts at multiple locations on the display and printed circuit substrates in accordance with the present invention;

FIG. 13 illustrates the first and third contacts coupled to a display substrate of FIG. 2, and the second and fourth contacts in addition to a fifth contact coupled to a printed circuit substrate of FIG. 2 in accordance with an alternate embodiment of the present invention;

FIG. 14 illustrates alignment of the first and second contacts of FIG. 13 according to a first criterion responsive to alignment of the third contact relative to the fourth and fifth contacts of FIG. 13 according to a second criterion in accordance with the present invention;

FIG. 15 illustrates an expansion of FIG. 13 by adding a sixth contact on the printed circuit substrate to further indicate direction and degree of alignment of the first and second contacts in one dimension of space in accordance with the present invention; and

FIG. 16 illustrates an expansion of FIG. 15 by adding seventh and eighth contacts to further indicate direction and degree of alignment of the first and second contacts in two dimensions of space in accordance with the present invention.

Detailed Description of the Preferred Embodiments

The foregoing need is substantially met by an apparatus and method for detecting alignment of
5 corresponding contacts in a multi-substrate electronic assembly, such as for example, a liquid crystal display (LCD) assembly.

In a preferred embodiment of the present invention, the LCD assembly represents a multi-substrate electronic
10 assembly including a display substrate having first and third contacts and a printed circuit substrate having second and fourth contacts. The first and second contacts are subject to alignment according to a first criterion. The third and fourth contacts are subject to alignment according to a second
15 criterion more restrictive than the first criterion. A path permits electrical coupling between the third contact and the fourth contact. A measure of the electrical coupling through the path is indicative of alignment between the third contact and the fourth contact according to the second criterion, such
20 that alignment of the third contact and the fourth contact according to the second criterion is indicative of alignment of the first and second contacts according to the first criterion.

The present invention further provides an apparatus and method for detecting at least one of direction and degree
25 of alignment of the first and second contacts in at least one dimension of space.

The present invention still further provides an apparatus and method for indicating the quality of the electrical coupling between the third contact and the fourth
30 contact responsive to the measure of electrical coupling.

The multi-substrate electronic assembly of the present invention is applicable not only to display assemblies, but also to printed circuit assemblies, connector assemblies and integrated circuit assemblies of the prior art to name a few.

Thus, as the size of the corresponding contacts or the gap between adjacent contacts on the same substrate decreases, alignment of the corresponding contacts is readily achieved in applications where the mechanical or optical alignment techniques fall short. Relaxation of size and gap restrictions thereby advantageously permit an increase in the density of contacts on the substrates thereby allowing for a reduction in the size of the substrates or an increase in the number of contacts on the substrates.

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The present invention can be better understood when read in light of the accompanying drawings in FIGs. 1-16 in which FIG. 1 illustrates, in a perspective view, an electronic device 100 in accordance with the present invention. In the preferred embodiment of the present invention, the electronic device 100 of FIG. 1 is a particular type of communication unit known as a radiotelephone. Radiotelephones are characterized by their ability to provide a user with wireless communication. Types of radiotelephones include cellular telephones, patio telephones, and cordless telephones in their many different forms, personal communication devices, and the like. Radiotelephones, in general, are well known in the art, for example, a cellular radiotelephone manufactured and available from Motorola Inc. under model number F09SQD8925. Other examples of electronic devices 100 which may advantageously use the present invention include among others: personal organizers, notebook computers and personal digital assistants.

The radiotelephone 100 in FIG. 1 generally comprises a housing including a body portion 101 and a flip element 102, an earpiece transducer 103, a microphone transducer 104, an antenna 105, a keypad 106 and a novel display assembly 107. The body portion 101 contains therein, among other things, a transmitter and a receiver (not shown). Individually, the body portion 101, the flip element 102, the earpiece transducer

103, a microphone transducer 104, an antenna 105, a keypad 106 as well as the transmitter and the receiver are well known in the art, thus no further discussion will be presented except to facilitate the understanding of the present invention. The
5 novel display assembly 107, however, will be described and illustrated in more detail below, in accordance with the present invention.

The receiver receives information to produce received information, for example, an alpha or numeric message.
10 The display assembly is capable of displaying at least a portion of the received information. The transmitter transmits information to produce transmitted information, for example, an alpha or numeric message. The display assembly is capable of displaying at least a portion of the
15 transmitted information.

The electronic device 100 of the present invention is not limited to coupling only display information for a display assembly. The present invention is also applicable to other multi-substrate electronic assemblies including printed
20 circuit assemblies, connector assemblies and integrated circuit assemblies of the prior art to name a few. More generally, the electronic device 100 may include a signal generator (not shown) for producing electrical signals. The signal generator may include, for example, a microcomputer
25 or a digital signal processor. The multi-substrate electronic assembly is capable of coupling the electrical signals between multiple substrates.

FIG. 2 illustrates the novel display assembly 107 for use
30 in the electronic device 100 of FIG. 1 in accordance with the preferred embodiment of the present invention. The novel display assembly 107 of the radiotelephone 100 generally represents the multi-substrate electronic assembly. In the preferred embodiment of the present invention, the display
35 assembly 107 is a liquid crystal display (LCD) assembly. The

novel (LCD) assembly 107 generally comprises a bezel 200, a display substrate 201, elastomeric connectors 202 and 203, a light pipe 209 and a printed circuit substrate 204. The display substrate 201 has a plurality of contacts including a first contact 205, a contact 207 and a novel third contact 701. The printed circuit substrate 204 has a plurality of contacts including a second contact 205, a contact 208 and a novel fourth contact 702. The elastomeric connector 203 has a plurality of conductive segments extending therethrough permitting electrical coupling between the display contacts including the first 205 and second 206 contacts. Individually, the bezel 200, the display substrate 201, the elastomeric connectors 202 and 203, the light pipe 209, the printed circuit substrate 204 and the first 205 and second 206 contacts are well known in the art, thus no further discussion will be presented except to facilitate the understanding of the present invention. The novel third 701 and fourth 702 contacts, however, will be described and illustrated in more detail below, in accordance with the present invention.

In the preferred embodiment of the present invention, the novel third 701 and fourth 702 contacts may be advantageously implemented in a conventional LCD assembly, such as LCD assembly 7209901C02, used by Motorola Inc. in the radiotelephone having model number F09SQD8925 mentioned above with FIG. 1.

The present invention provides an apparatus and method for detecting the alignment of the first 205 and second 206 contacts according to the first criterion. According to the present invention, the third 701 and fourth 702 contacts are subject to alignment according to a second criterion more restrictive than the first criterion. A path 709 (see FIG. 7) permits electrical coupling between the third 701 and fourth 702 contacts. A measure of the electrical coupling through the path is indicative of alignment between the third 701 and fourth 702 contacts according to the second criterion. The

alignment of the third 701 and fourth 702 contacts, according to the second criterion, is indicative of alignment of the first 205 and second 206 contacts according to the first criterion. The first and second criterion as well as the path 709 will be described and illustrated in more detail below, in accordance with the present invention.

In the preferred embodiment of the present invention, the first 205 and second 206 contacts and contacts 207 and 208 are functional contacts to couple information signals within the display assembly 107. The third 701 and fourth 702 contacts are test contacts used for providing an indication of alignment of the first 205 and second 206 contacts. The contacts 207 and 208 will be used to present a practical example of the benefits of the present invention in conjunction with FIGs. 7 and 8. Typically, all the contacts on one substrate are formed with common artwork for that substrate.

The present invention provides an indication of alignment of the contacts. Indication of good alignment provides for a relaxation of size and gap restrictions of the contacts advantageously permitting an increase in the density of contacts on the substrates thereby allowing for a reduction in the size of the substrates or an increase in the number of contacts on the substrates.

FIGs. 3-6 illustrate degrees of alignment of the first 205 and second 206 contacts, according to the first criterion, in the novel LCD assembly 107 in accordance with a preferred embodiment of the present invention.

FIG. 3 illustrates complete misalignment between the first contact 205 on the display substrate 201 and the second contact 206 on the printed circuit substrate 204 of FIG. 2 according to the first criterion in accordance with the present invention. Misalignment of the first 205 and the second 206

contacts resulting in no electrical coupling is, of course, unacceptable according to the first criterion.

5 FIG. 4 illustrates the case of marginal misalignment between the first 205 and the second 206 contacts of FIG. 2 according to the first criterion in accordance with the present invention. Misalignment of the first 205 and second 206 contacts permitting electrical coupling at a marginally overlapping area 401 is unacceptable according to the first
10 criterion.

 FIG. 5 illustrates the case of substantial alignment between the first 205 and the second 206 contacts of FIG. 2 according to the first criterion in accordance with the present
15 invention. Alignment of the first 205 and second 206 contacts permitting electrical coupling at a substantially overlapping area 401 is acceptable according to the first criterion.

 FIG. 6 illustrates the case of perfect alignment between
20 the first 205 and the second 206 contacts of FIG. 2 according to the first criterion in accordance with the present invention. Perfect alignment of the first 205 and second 206 contacts permitting electrical coupling at a completely overlapping area 401 is most desirable according to the first criterion.

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 FIGs. 7-12 illustrate alignment of the contacts in the display assembly 107 according to the size of at least the novel third 701 and fourth 702 contacts.

30 Referring now to FIGs. 7 and 8 together, FIG. 7 illustrates the first 205 and third 701 contacts coupled to a display substrate 201 of FIG. 2, and the second 206 and fourth 702 contacts coupled to a printed circuit substrate 204 of FIG. 2 in accordance with the present invention.

According to the present invention, the third contact 701 and the fourth contact 702 are subject to alignment according to a second criterion which is more restrictive than the first criterion. The path, designated by arrow 709, permits
5 electrical coupling between the third contact 701 and at least the fourth contact 702. A measure of the electrical coupling through the path 709 is indicative of alignment of the third contact 701 and the fourth contact 702 according to the second
10 criterion. Alignment of the third 701 and fourth 702 contacts according to the second criterion is indicative of alignment of the first 205 and second 206 contacts according to the first criterion.

In the preferred embodiment of the present invention, the second criterion is related to a dimension 703 of the third
15 701 and fourth 702 contacts. Further, the second criterion is a function of a summation of the dimension 703 of the third contact 701 and the dimension 703 of the fourth contact 702 in the direction of alignment 710. The summation is related to an acceptable overlap 401 in alignment of the first 205 and the
20 second 206 contacts in the direction of alignment 710.

In the preferred embodiment of the present invention, the path 709, electrically coupling the third 701 and fourth 702 contacts, is formed by the elastomeric connector 203 of FIG. 2. A signal is applied to terminal 706 at the second contact 206.
25 The signal is coupled to the first contact 205 by the elastomeric connector 203. The signal is coupled to the third contact 701 by jumper 708. The signal is then permitted to be coupled to the fourth contact 702 via the path 709 and sensed at terminal 705. An advantage to coupling the signal in this manner is that no
30 terminal is needed on the display substrate 201.

Alternatively, the signal may be applied to terminal 707 at the third contact 701. In the alternative embodiment, the jumper 708 is not present. The signal is then permitted to be coupled to the fourth contact 702 via the path 709 and sensed at
35 terminal 705. The advantage of coupling the signal in this

manner over the preferred embodiment discussed above is that no reliance is made on the quality of the electrical coupling between the first 205 and second 206 contacts.

5 FIG. 8 illustrates alignment of the first 205 and second 206 contacts of FIG. 7 according to a first criterion responsive to alignment of the third 701 and fourth 702 contacts of FIG. 7 according to a second criterion in accordance with the present invention. In the preferred embodiment of the present
10 invention, the third 701 and fourth 702 contacts are of equal size and smaller than the first 205 and second 206 contacts in the alignment direction 710.

 When the signal is detected at terminal 705 electrical coupling is present between third 701 and fourth 702 contacts.
15 This indicates that the second criterion is met and the first 205 and second 206 contacts and are considered aligned according to the first criterion. Alignment of the first 205 and second 206 contacts is illustrated by the overlapping area 401 and is representative of the acceptable alignment case as
20 presented above with reference to FIG. 5.

 When the signal is not detected at terminal 705, electrical coupling is not present between between third 701 and fourth 702 contacts. This indicates that second criterion is not met and the first 205 and the second 206 contacts are
25 considered misaligned according to the first criterion. Misalignment of the first 205 and second 206 contacts is not illustrated in FIG. 8 but is representative of the not aligned and misaligned cases presented above with reference to FIGs 3 and 4, respectively.

30 The present invention advantageously provides an indication of alignment of the first 205 and second 206 contacts. This permits relaxation of size and gap restrictions of contacts on the two substrates therefore permitting an increase in the density of contacts on the substrates thereby

allowing for a reduction in the size of the substrates or an increase in the number of contacts on the substrates.

Even with perfect alignment between the first 205 and the second 206 contacts, the electrical connection could be poor due to contamination, high resistance and contact pressure, etc. The present invention may also be used to provide an indication of a measure of the quality of the electrical coupling between the first 205 and the second 206 contacts. Optical and mechanical alignment methods cannot determine the quality of the electrical connection. In the preferred embodiment of the present invention, the measure of quality of the electrical coupling is provided by a resistance measurement between the input terminal 706 of the signal and the output terminal 705 of the signal. Although the measure of quality of the electrical coupling is local, it provides an indication of the quality of the electrical coupling between all other corresponding contacts.

The following discussion provides a practical example for the preferred embodiment of the present invention in accordance with the present invention as illustrated in FIG. 7. FIG. 7 illustrates a first pair 205 and 206 and a second pair 207 and 208 of adjacent corresponding contacts. In the prior art, the first criterion for acceptable alignment of corresponding contacts is a 0.25mm overlap as represented in FIG. 5. For a width 704 of 0.5mm for the each contact 205-208 and a gap 713 of 0.5mm between adjacent contacts 206 and 208, a 0.25mm overlap yields a pitch 712 of 1.0mm between adjacent contacts. To meet the first criterion of the 0.25mm overlap using prior art mechanical alignment techniques, the total mechanical parts tolerance of the display assembly in the alignment direction must be less than $\pm 0.25\text{mm}$. This can be quite difficult to meet since the total tolerance includes the registration of the contacts on each substrate 201 and 204 and the alignment of the substrates 201 and 204 to each other.

Now, in the present invention, the novel test contacts 701 and 702 are disposed on the substrates 201 and 204 to establish the second criterion for alignment that is more restrictive than the first criterion for alignment. A width 703 of 0.1mm is chosen for each novel test contact 701 and 702. Assuming that the lack of electrical coupling between the novel test contacts 701 and 702 violates the second criterion, the second criterion becomes 0.1mm in the alignment direction. Using the second criterion of 0.1mm to achieve the 0.25mm overlap according to the first criterion, the width 704 of the contacts 205-208 can be beneficially reduced to 0.35mm. Therefore, the pitch 712 between adjacent contacts can be reduced to 0.70mm. Thus, the present invention allows for a 30% reduction in the pitch between the adjacent contacts in the prior art. Reducing the pitch between the adjacent contacts by 30% corresponds to an increase in the density of the contacts on the substrates by 30% which in turn corresponds to a reduction in the size of the substrates by 30% or an increase in the number of contacts on the substrates by 30% in the alignment direction 710. These benefits are gained while maintaining confidence in the quality of the electrical coupling between corresponding contacts.

Referring now to FIG's 9 and 10 together, FIG. 9 illustrates an expansion of FIG 7 by adding fifth 901 and sixth 902 contacts on the printed circuit substrate 204 to further indicate direction and degree of alignment of the first 205 and second 206 contacts in one dimension of space in accordance with a the preferred embodiment of the present invention.

In the preferred embodiment of the present invention, the fifth 901 and sixth 902 contacts are placed on opposite sides of the fourth contact 702 at a distance 903 in the alignment direction 710. The distance 903 is less than a dimension of the third contact 701 in the alignment direction 710. Terminal 904 is coupled to the fifth contact 901 and terminal 905 is coupled

to the sixth contact 902. Terminals 904 and 905 in addition to terminal 705 permit detection of the signal applied to terminal 706 or alternatively applied to terminal 707. Application of the signal to either terminal 706 or terminal 707 has already
5 been discussed with FIG. 7.

FIG. 10 illustrates alignment of the first 205 and second 206 contacts of FIG. 9 according to a first criterion responsive to alignment of the third 701 contact relative to the fourth 702 ,
10 fifth 901 and sixth 902 contacts of FIG. 9 according to a second criterion in accordance with the preferred embodiment of the present invention. The third contact 701 may be perceived as sliding across the fourth 702, fifth 901 and sixth 902 contacts in the alignment direction to produce varying degrees of
15 alignment conditions of the first 205 and second 206 contacts.

When the signal is only detected at the terminal 905, electrical coupling is present between third 701 and sixth 902 contacts. This indicates that the second criterion is not met and thus the first 205 and the second 206 contacts are
20 considered misaligned to the right according to the first criterion. Misalignment of the first 205 and second 206 contacts according to the first criterion is represented above with reference to FIGs. 3 and 4.

When the signal is only detected at terminals 705 and
25 905, electrical coupling is present between the third 701, fourth 702 and sixth 902 contacts. This indicates that the second criterion is met and the first 205 and the second 206 contacts are considered aligned and shifted by a small degree to the right according to the first criterion. This example is
30 specifically shown in FIG. 10. Alignment of the first 205 and second 206 contacts according to the first criterion is represented above with reference to FIG. 5.

When the signal is only detected at terminal 705, electrical coupling is present between the third 701 and fourth
35 702 contacts. This indicates that the second criterion is met

and the first 205 and the second 206 contacts are considered substantially aligned according to the first criterion. Substantial alignment of the first 205 and second 206 contacts according to the first criterion is represented above with
5 reference to FIG. 6.

When the signal is only detected at terminals 705 and 904, electrical coupling is present between the third 701, fourth 702 and fifth 901 contacts. This indicates that the second criterion is met and the first 205 and the second 206
10 contacts are considered aligned and shifted by a small degree to the left according to the first criterion. Alignment of the first 205 and second 206 contacts according to the first criterion is represented above with reference to FIG. 5.

When the signal is only detected at terminal 904,
15 electrical coupling is present between third 701 and fifth 901 contacts. This indicates that the second criterion is not met and the first 205 and the second 206 contacts are considered misaligned to the left according to the first criterion. Misalignment of the first 205 and second 206 contacts
20 according to the first criterion is represented above with reference to FIGs. 3 and 4.

FIG. 11 illustrates an expansion of FIG. 9 by adding seventh 1101 and eighth 1102 contacts on the printed circuit
25 substrate 204 to further indicate direction and degree of alignment of the first 205 and second 206 contacts in two dimensions of space in accordance with the preferred embodiment of the present invention.

In the preferred embodiment of the present invention,
30 the seventh 1101 and eighth 1102 contacts are placed on opposite sides of the fourth contact 702 at a distance 1106 in a second alignment direction, designated by arrow 1103. The distance 1106 is less than a dimension 703 of the third contact 701 in the alignment direction 710 or 1103. The size of the
35 third 701, fourth 702, fifth 901, sixth 902, seventh 1101 and

eighth 1102 contacts are the same. Terminal 1104 is coupled to the seventh contact 1101 and terminal 1105 is coupled to the eight contact 1102. Terminals 1104 and 1105 in addition to terminals 705, 904 and 905 permit detection of the signal applied to terminal 706 or alternatively to terminal 707. Application of the signal to either terminal 706 or terminal 707 has already been discussed with FIG. 7. The third contact 701 may be perceived as sliding across the fourth 702, fifth 901, sixth 902, seventh 1101 and eighth 1105 contacts, and in both alignment directions 710 and 1103 to produce varying degrees of alignment conditions of the first 205 and second 206 contacts. The detection of degree and direction of alignment in the second direction 1103, essentially orthogonal to the first direction 710, is analogous to detection of degree and direction of alignment in the first direction 710 as previously described in FIG. 10, therefore no further explanation will be given here.

FIG. 12 illustrates an expansion of FIG. 7 by providing third 701 and fourth 702 contacts at multiple locations on the display 201 and printed circuit 204 substrates in accordance with the preferred embodiment of the present invention. By locating the novel contacts 701 and 702 as far apart from one another as possible on each substrate, rotational alignment may be detected in both a clockwise 1201 and counterclockwise 1202 direction. This arrangement advantageously provides an indication of the "skew" of the display substrate 201 relative to the printed circuit substrate 204.

FIGs. 13-16 illustrate alignment of the contacts of the display assembly 107 according to the size of at least the novel contacts 701 and 702 and according to a gap between at least one novel contact and another contact.

Referring now to FIG's 13 and 14 together wherein FIG. 13 illustrates the first 205 and third 701 contacts coupled to a display substrate 201 of FIG. 2, and the second 206 and fourth 702 contacts in addition to a fifth 901 contact coupled to
5 a printed circuit substrate 204 of FIG. 2 in accordance with an alternate embodiment of the present invention.

According to the alternate embodiment of the present invention, the third contact 701 and the fourth contact 702 are subject to alignment according to a second criterion which is
10 more restrictive than the first criterion. The path, designated by arrow 709, permits electrical coupling between the third contact 701 and one of the fourth 702 and fifth 901 contacts. A measure of the electrical coupling through the path 709 is indicative of alignment of the third contact 701 relative to the
15 fourth 702 and fifth 901 contacts according to the second criterion. Alignment of the third relative to the fourth 702 and fifth 901 contacts according to the second criterion is indicative of alignment of the first 204 and second 205 contacts according to the first criterion.

20 In the alternate embodiment of the present invention, the second criterion is related to a dimension 1300 of the third contact 701 in a direction of alignment 710 and a gap 1301 in the direction of alignment 710 between the fourth contact 702 and at least one other contact on the printed circuit substrate
25 204, for example the fifth contact 901. The dimension 1300 of the third contact 701 is preferable less than, but may be greater than, the gap 1301 in the direction of alignment 710.

In the alternate embodiment of the present invention, terminal 705 is coupled to the fourth contact 702 and terminal
30 904 is coupled to the fifth contact 901 to permit detection of the signal applied to either terminal 706 or 707. The third contact 701 may be perceived as sliding between the fourth 702 and fifth 901 contacts in the alignment direction 710 to produce varying degrees of alignment conditions of the first 205 and
35 second 206 contacts as previously presented in FIGs. 3-6.

In the case mentioned above that the dimension 1300 of the third contact 701 is greater than, the gap 1301 in the direction of alignment 707, two conditions may exist. The first condition is where no signal is coupled to the third contact 701 wherein only alignment can be detected. The second condition is where a signal is coupled to the third contact 701 wherein both alignment and direction can be detected.

FIG. 14 illustrates alignment of the first 205 and second 206 contacts of FIG. 13 according to a first criterion responsive to alignment of the third 701 contact relative to the fourth 702 and fifth 901 contacts of FIG. 13 according to a second criterion in accordance with the alternate embodiment of the present invention. The third contact 701 may be perceived as sliding across the fourth 702 and fifth 901 contacts in the alignment direction 710 to produce varying degrees of alignment conditions of the first and second contacts 205 and 206.

When the signal is only detected at terminal 705 as shown in FIG. 14, electrical coupling is present between third 701 and fourth 702 contacts. This indicates that the second criterion is not met and the first 205 and the second 206 contacts are considered misaligned to the right according to the first criterion. Misalignment of the first 205 and second 206 contacts according to the first criterion is represented above with reference to FIGs. 3 or 4.

When the signal is not detected at either terminal 705 or 904, electrical coupling is not present between third contact 701 and either the fourth contact 702 or the fifth contact 901. This indicates that the second criterion is met and that the first 205 and the second 206 contacts are considered substantially aligned according to the first criterion. Substantial alignment of the first 205 and second 206 contacts according to the first criterion is represented above with reference to FIGs. 5 or 6.

When the signal is only detected at terminal 904, electrical coupling is present between third 701 and fifth 901 contacts. This indicates that the second criterion is not met and the first 205 and the second 206 contacts are considered
5 misaligned to the left according to the first criterion. Misalignment of the first 205 and second 206 contacts according to the first criterion is represented above with reference to FIGs. 3 or 4.

10 FIG. 15 illustrates an expansion of FIG 13 by adding a sixth 902 contact on the printed circuit substrate 204 to further indicate at least one of direction and degree of alignment of the first 205 and second 206 contacts in one dimension of space in accordance with the alternate embodiment of the present
15 invention. In the alternate embodiment of the present invention the dimension 1300 of the third contact 701 is preferably wider than the dimension 703 of the fourth contact 702 in the alignment direction 710 but narrower than the sum of the dimension 703 of the fourth contact 702 plus the gap 1301
20 on each side of the fourth contact 702. When the third 701 and fourth 702 contacts are test contacts, an indication of direction and degree of alignment of the first 205 and second 206 contacts is provided in an analogous manner as described in FIGs. 9 and 10 and thus will not be described in detail. In
25 another alternate embodiment, when the third 701 and fourth 702 contacts are functional contacts, an indication of only direction of alignment of the first 205 and second 206 contacts is provided in an analogous manner as described in FIGs. 9 and 10 and thus will not be described in detail. The second
30 embodiment is advantageous in that the functional contacts permits coupling of additional information signals within the display assembly 107.

In a variation of the design in FIG. 15, wherein the dimension 1300 of the third contact 701 is greater than the
35 dimension 703 of the fourth contact 702 plus the gap 1301 on

each side of the fourth contact 702 in the direction of alignment 707, three conditions may exist. The first condition is where no signal is coupled to the third contact 701 wherein alignment and direction can be detected. The second
5 condition is where a test signal is coupled to the third contact 701 wherein alignment, direction and degree can be detected. The third condition is where a functional display signal is coupled to the third contact 701 wherein alignment and direction can be detected.

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FIG. 16 illustrates an expansion of FIG. 15 by adding seventh 1101 and eighth 1102 contacts to further indicate at least one of direction and degree of alignment of the first 205 and second 206 contacts in two dimensions of space in
15 accordance with the alternate embodiment of the present invention. The operation of FIG. 16 is provided in an analogous manner as described in FIG 11 and thus will not be described in detail.

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Although numerous embodiments have been illustrated and discussed, further modifications can be made by those skilled in the art which fall within the scope of the claimed invention. Such modifications may include without limitation the shape, number and arrangement of the novel
25 and functional contacts.

Thus, it is apparent that there is provided an apparatus and method for detecting alignment of corresponding contacts 205 and 206 of a multi-substrate assembly 107 which fully
30 meets the needs set forth above. First 205 and second 206 corresponding contacts are subject to alignment according to a first criterion. Third 701 and fourth 702 corresponding contacts are subject to alignment according to a second criterion more restrictive than the first criterion. A measure
35 of the electrical coupling through a path 709 permits electrical

coupling between the third 701 and fourth 702 contacts.
Alignment of the third 701 and fourth 702 contacts according
to the second criterion is indicative of alignment of the first
205 and second 206 contacts according to the first criterion.

- 5 The present invention advantageously permits relaxation of
size and gap restrictions of contacts on the substrates
therefore permitting an increase in the density of contacts on
the substrates thereby allowing for a reduction in the size of
the substrates or an increase in the number of contacts on the
10 substrates.

- Further, the present invention offers several more
advantages over the the prior art alignment techniques.
Firstly, the multi-substrate electronic assemblies can be
tested without either manual or automatic functional testing.
15 Secondly, the degree and direction of misalignment of
corresponding contacts can be determined to reduce time
consuming trial and error alignment of corresponding
contacts. Thirdly, marginal misalignment of corresponding
contacts can be detected which reduces field failures of the
20 multi-substrate electronic assemblies. Fourthly, faulty
electrical coupling between presumeably aligned
corresponding contacts can be detected which increases
manufacturing yield and also reduces field failures of the
multi-substrate electronic assemblies. Fifthly, process
25 control parameters related to the alignment of corresponding
contacts can be monitored which in turn can be used to
improve the quality of material used to build the multi-
substrate electronic assemblies.

- 30 While the present invention has been described with
reference to illustrative embodiments thereof, it is not
intended that the invention be limited to these specific
embodiments. Those skilled in the art will recognize that
variations and modifications can be made without departing

from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

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Claims

1. In a multi-substrate electronic assembly including at least a first substrate having at least a first contact and a
5 second substrate having at least a second contact, wherein the first and second contacts are subject to alignment according to a first criterion, an apparatus for detecting alignment of the first and second contacts according to the first criterion comprising:
10 at least a third contact coupled to the first substrate;
at least a fourth contact coupled to the second substrate,
wherein the third contact and at least the fourth contact are subject to alignment according to a second criterion more restrictive than the first criterion; and
15 a path permitting electrical coupling between the third contact and at least the fourth contact, wherein a measure of the electrical coupling through the path is indicative of alignment of the third contact and at least the fourth contact according to the second criterion, such that alignment of the
20 third contact and at least the fourth contact according to the second criterion is indicative of alignment of the first and second contacts according to the first criterion.
2. An apparatus according to claim 1 wherein the second
25 criterion is further indicative of a direction of alignment of the first and second contacts in at least one dimension of space.
3. An apparatus according to claim 1 wherein the second
30 criterion is further indicative of a degree of alignment of the first and second contacts.
4. An apparatus according to claim 1 wherein the second
35 criterion is a function of a summation of a dimension of the third contact in a direction of alignment and a dimension of the fourth contact in the direction of alignment.



5. An apparatus according to claim 1 wherein the second criterion is related to a dimension of the third contact in a direction of alignment and a gap in the direction of alignment
- 5 between the fourth contact and the at least the one other contact on the second substrate.
6. An apparatus according to claim 1 wherein the measure of electrical coupling is further indicative of the
- 10 quality of the electrical coupling between the third contact and at least the fourth contact.



7. In a multi-substrate electronic assembly including at least a first substrate having at least a first contact and a second substrate having at least a second contact, wherein the first and second contacts are subject to alignment according to a first criterion, a method for detecting alignment of the first and second contacts according to the first criterion comprising the steps of:
- 5 providing a path permitting electrical coupling between a third contact coupled to the first substrate and at least a fourth contact coupled to the second substrate, wherein the third contact and at least the fourth contact are subject to alignment according to a second criterion more restrictive than the first criterion; and
- 10 measuring the electrical coupling through the path to produce a measure of electrical coupling indicative of alignment between the third contact and at least the fourth contact according to the second criterion, such that alignment of the third contact and at least the fourth contact according to the second criterion is indicative of alignment of the first and second contacts according to the first criterion.
- 15
- 20



8. A communication unit comprising:
a transmitter for transmitting information to produce transmitted information; and
a display assembly for displaying at least a portion of the transmitted information, wherein the display assembly further comprises:
a display substrate having at least first and third contacts;
a printed circuit substrate having at least second and fourth contacts, wherein the first and second contacts are subject to alignment according to a first criterion, and wherein the third and fourth contacts are subject to alignment according to a second criterion more restrictive than the first criterion; and
a path permitting electrical coupling between the third contact and at least the fourth contact, wherein a measure of the electrical coupling through the path is indicative of alignment between the third contact and at least the fourth contact according to a second criterion, such that alignment of the third contact and at least the fourth contact according to the second criterion is indicative of alignment of the first and second contacts according to the first criterion



9. An electronic device comprising:
a signal generator for producing electrical signals; and
a multi-substrate assembly permitting coupling of the
electrical signals between multiple substrates, comprising:
- 5 a first substrate having at least first and third
contacts;
- a second substrate having at least second and
fourth contacts, wherein the first and second contacts are
subject to alignment according to a first criterion, and wherein
- 10 the third and fourth contact are subject to alignment according
to a second criterion more restrictive than the first criterion;
and
- a path permitting electrical coupling between the
third contact and at least the fourth contact, wherein a
- 15 measure of the electrical coupling through the path is
indicative of alignment between the third contact and at least
the fourth contact according to a second criterion, such that
alignment of the third contact and at least the fourth contact
according to the second criterion is indicative of alignment of
- 20 the first and second contacts according to the first criterion.



10. In an liquid crystal display assembly including at least a display substrate having at least a first contact and a printed circuit substrate having at least a second contact, wherein the first and second contacts are subject to alignment according to a first criterion, and wherein a path, formed by an elastomeric member having a plurality of conductive segments extending therethrough, permits electrical coupling between the first and second contacts, such that when the first and second contacts are aligned according to the first criterion display information is permitted to be coupled between the first contact on the display substrate and the second contact on the printed circuit substrate, an apparatus for detecting alignment of the first and second contacts according to the first criterion, comprising:
- 15 at least a third contact coupled to the display substrate;
 at least a fourth contact coupled to the printed circuit substrate, wherein the third contact and at least the fourth contact are subject to alignment according to a second criterion more restrictive than the first criterion; and
 - 20 a path, formed by the elastomeric member having the plurality of conductive segments extending therethrough, permitting electrical coupling between the third contact and at least the fourth contact, wherein a measure of the electrical coupling through the path is indicative of alignment between
 - 25 the third contact and at least the fourth contact according to the second criterion, such that alignment of the third contact and at least the fourth contact according to the second criterion is indicative of alignment of the first and second contacts according to the first criterion.