

-1-

PRINTED CIRCUIT BOARD WITH SELECTABLE ROUTING CONFIGURATION

FIELD OF THE INVENTION

The present invention pertains to the field of printed circuit boards. More particularly, the present invention relates to reconfiguring the electrical routing configuration of a printed circuit board after completion of the manufacturing process.

BACKGROUND OF THE INVENTION

Printed circuit boards are commonly used in the computer industry and in numerous other areas of technology to implement electronic circuitry. A printed circuit board typically consists of one or more substrate layers made of a dielectric material, on which electronic components are mounted. One or more layers of conductive material, such as copper, are mounted on and between the substrate layers to form the wiring, or "traces", that interconnect the electronic components. The traces may be formed by fixing a solid metal plane onto the surface of a substrate layer and then etching the metal plane according to a pattern. The traces are typically covered by an insulative protective coating, with the exception of certain portions which are left exposed for the purpose of providing bonding contacts.

Because there are so many potential uses for printed circuit boards, it has become desirable to provide the capability to mass produce a printed circuit board which has a single generic routing configuration, but which later can be tailored to have one of multiple specific configurations. Various solutions have been developed to accomplish this goal. For example, a "zero-ohm" resistor, or jumper, can be used to electrically connect two traces on a printed circuit board to modify the routing configuration. This solution is disadvantageous, however, because it is not cost effective to purchase and maintain an inventory of separate components for this purpose. One way to overcome this disadvantage is to use solder instead of a zero-ohm resistor to connect two traces and thereby modify the routing configuration. There are many situations, however, in which it may be desirable to adjust the routing configuration of a printed

-2-

circuit board during the post-manufacturing test phase. Yet both of the above-mentioned solutions may be impractical to implement once the manufacturing process has been completed.

One situation in which the post-manufacture configuration of a printed circuit board may be desirable is the production of personal computer (PC) motherboards. A PC motherboard, which contains the central processing unit (CPU) of the computer, may also contain a dedicated power supply for the CPU. The CPU requires a regulated power supply which will provide a very precise voltage; often a tolerance of less than 1% is required. However, power supply voltages tend to vary depending upon load, temperature, noise, and manufacturing tolerances. Consequently, the "set point" of the regulated power supply must be carefully adjusted. The "set point" is the regulated output voltage at a steady load and temperature. Typically, the output voltage of a power supply is measured during testing. Power is then removed, and the set point is adjusted according to the measured output voltage.

One way to permit the adjustment of the set point is to provide a feedback circuit comprising a resistor divider network, as illustrated in Figure 1. Figure 1 is a block diagram of a regulated power supply 1 having a feedback circuit 20 comprising a simple resistor divider network which is well-known in the prior art. The resistor divider network consists of a resistor RX having a fixed value and a variable resistor RY. The value of resistor RY is varied manually to adjust the output VFB of the divider network to adjust the set point of the power supply. This solution is disadvantageous, however, because the resistor RY requires mechanical adjustment, and because its value may tend to drift once the motherboard is installed and operating in a PC.

Therefore, it is desirable to provide for the mass production of a printed circuit board having a single routing configuration which can be easily reconfigured to have one of multiple different routing configurations. It is also desirable to make reconfiguration practical and convenient even if performed after the manufacturing process

-3-

has been completed. It is further desirable to provide a means for configuring the trace routing on a printed circuit board such that a separate inventory of parts need not be maintained for that purpose. In addition, it is desirable to provide a regulated power supply which has a set point that is adjustable during post-manufacture testing and which incorporates the aforementioned features.

SUMMARY OF THE INVENTION

A printed circuit board having a selectable circuit routing configuration is described. The printed circuit board comprises a substrate, a plurality of electrical traces mounted to the substrate for interconnecting electrical components, and at least one fusible connector mounted to the substrate. Each of the fusible connectors comprises a fuse line formed from a conductive layer of the printed circuit board and forms a fusible connection between at least two of the electrical traces. The circuit routing configuration is selectable by application of a predetermined current through at least one of the fusible connectors to break the fusible connection formed by the fusible connector.

The fusible signal connector comprises a first contact pad located at an end of a first signal trace on a printed circuit board, a second contact pad located at an end of a second signal trace on the printed circuit board, and a fuse line. The fuse line is formed from the conductive layer of the printed circuit board and is fusibly coupled between the first contact pad and the second contact pad. The predetermined current driven through the fuse line causes the fuse line to fuse open.

Other features of the present invention will be apparent from the accompanying drawings and from the detailed description which follows below.

-4-

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

Figure 1 is a block diagram of a regulated power supply having a resistor divider network according to the prior art.

Figure 2 is a block diagram of a regulated power supply having a resistor divider network with fusible connectors.

Figure 3 illustrates a fusible connector according to one embodiment of the present invention.

Figure 4 illustrates a fusible connector implemented on multiple layers of a printed circuit board.

DETAILED DESCRIPTION

A printed circuit board having a selectable circuit routing configuration is described. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be evident, however, to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

Figure 2 shows a regulated power supply 2. The regulated power supply 2 consists of a regulator 10 which receives an input voltage V_{IN} and which generates an output voltage V_{OUT} . The output voltage is input to a feedback circuit consisting of a resistor divider network 25. The resistor divider network 25 outputs a feedback voltage V_{FB} to a comparator 30. The comparator receives the feedback voltage V_{FB} and a reference voltage V_{REF} and outputs to the

-5-

regulator 10 an error voltage ERROR which is proportional to the difference between the feedback voltage VFB and the reference voltage VREF. The functions performed by the combination of the comparator 30 and the reference voltage VREF may be implemented using well-known integrated circuits, such as the TL1431 or the TL431.

The resistor divider network 25 consists of six resistors R1 through R6. Set Point resistor R1 is coupled between the output VOUT of the regulator 10 and the VFB input of the comparator 30. Set Point resistor R2 is coupled between the VFB input of the comparator 30 and ground. Resistors R3 and R5 are coupled in parallel with Set Point resistor R1, while resistors R4 and R6 are coupled in parallel with Set Point resistor R2. Each of resistors R3 through R6 is coupled to the VFB input of the comparator 30 through a separate one of four fusible resistors 40.

The regulated power supply 2 has a set point which represents the output voltage VOUT at a constant load and temperature. The set point may be adjusted by adjusting the feedback voltage VFB input to the comparator 30 for a given output voltage VOUT. In other words, the set point may be adjusted by changing the transfer function V_{FB}/V_{OUT} of the resistor divider network. This is accomplished by breaking the current path through one or more of resistors R3 through R6. Consequently, the set point of the regulated power supply 2 may be adjusted by selectively fusing open one or more of the fusible connectors 40.

Referring now to Figure 3, a section 60 of a printed circuit board is shown. The printed circuit board consists of a substrate 62 and multiple copper traces, including traces 42 and 44. Traces 42 and 44 are terminated in copper contact pads 46 and 48, respectively. Coupled between contact pads 46 and 48 is a fuse line 50. A fusible connector 40 comprises the contact pads 46 and 48 and the fuse line 50. In the preferred embodiment, the contact pads 46 and 48, the fuse line 50, and the traces 42 and 44 are all formed simultaneously from a single copper layer by the same etching process. Although the traces on the printed circuit board 60 are generally covered by a protective layer of

-6-

insulating material, the contact pads 46 and 48 are exposed to allow electrical contact with a test probe or other similar instrument.

The fuse line 50 may be fused open by applying a predetermined voltage between contact pads 46 and 48 to cause a fusing current to flow through the fuse line 50. The width and shape of the fuse line 50 are calculated such that the fuse line 50 will fuse open at the lowest possible fusing current and provide the cleanest break upon fusing, subject to current manufacturing capabilities. A fuse line 50 having a kinked shape as shown in Figure 3 may be suitable for this purpose. In addition, the length of the fuse line 50 is as short as possible according to current manufacturing capabilities. The contact paths 46 and 48 and fuse line 50 are sized and shaped in order to provide negligible resistance.

The present invention may also be embodied on a multiple layer printed circuit board, as shown in Figure 4. The fuse line 50 is formed on one substrate layer 63 of the printed circuit board while the traces 42 and 44 and the contact pads 46 and 48 are formed on a different substrate layer 64. Connection between the fuse line 50 and contact pads 46 and 48 is made through vias 52 and 54.

Hence, the routing configuration of the printed circuit board 60 can be easily altered after the manufacturing process has been completed (e.g., during the testing phase) by selectively fusing open any of the fusible connectors 40. By applying a predetermined voltage between contact pad 46 and contact pad 48 to cause a predetermined current to pass through and to fuse open the fuse line 50. Furthermore, if this process is performed during the testing phase, the open/short condition of the fusible connector 40 can be easily tested, since the printed circuit board is already connected to the test equipment. Therefore, the printed circuit board 60 can be mass produced to have a single routing configuration that can be easily reconfigured into one of multiple different routing configurations. It is not necessary to maintain a separate inventory of parts for the purpose of performing such reconfiguration. Furthermore, the fusible connector 40 can be implemented in a regulated power supply such



-7-

that the set point of the power supply can be easily adjusted during testing without the need for mechanical adjustment of a variable resistor, and such that the set point has minimal variance during operation.

Although the present invention has been described with reference to specific exemplary embodiments, it will be evident that various modifications and changes may be made to these embodiments without departing from the broader spirit and scope of the invention as set forth in the claims. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

**CLAIMS**

What is claimed is:

1. A printed circuit board having a selectable circuit routing configuration, the printed circuit board comprising:
 - a substrate;
 - a plurality of electrical traces mounted to the substrate for interconnecting a plurality of electrical components; and
 - at least one fusible connector mounted to the substrate, each of the fusible connectors comprising a fuse line formed from a conductive layer of the printed circuit board and forming a fusible connection between at least two of the electrical traces, such that the circuit routing configuration can be selected by applying a predetermined current through at least one of the fusible connectors to break the fusible connection formed by the fusible connector.
2. The printed circuit board of claim 1, wherein each of the fusible connectors further comprises:
 - a first contact pad located at an end of a first signal trace on a printed circuit board; and
 - a second contact pad located at an end of a second signal trace on the printed circuit board;
 - wherein the fuse line is fusibly coupled on the printed circuit board between the first contact pad and the second contact pad, such that a predetermined current driven through the fuse line causes the fuse line to fuse open to decouple the first signal trace from the second signal trace.
3. The printed circuit board of claim 2, wherein the first signal trace, the second signal trace, the first contact pad, and the second contact pad are formed from the conductive layer of the printed circuit board.
4. The printed circuit board of claim 3, wherein the first signal trace, the second signal trace, the first contact pad, the second contact pad,



-9-

and the fuse line are formed simultaneously by etching the conductive layer of the printed circuit board.

5. The printed circuit board of claim 1, wherein the fuse line has a predetermined shape selected to cause the fuse line to fuse open cleanly.
6. The printed circuit board of claim 5, wherein the fuse line has a kinked shape.
7. A fusible signal connector, comprising:
 - a first contact pad located at an end of a first signal trace on a printed circuit board;
 - a second contact pad located at an end of a second signal trace on the printed circuit board; and
 - a fuse line formed from a conductive layer of the printed circuit board, the fuse line fusibly coupled between the first contact pad and the second contact pad, wherein a predetermined current driven through the fuse line causes the fuse line to fuse open.
8. The fusible signal connector of claim 7, wherein the first signal trace, the second signal trace, the first contact pad, and the second contact pad are formed from the conductive layer of the printed circuit board.
9. The fusible signal connector of claim 8, wherein the first signal trace, the second signal trace, the first contact pad, the second contact pad, and the fuse line are formed simultaneously by etching the conductive layer of the printed circuit board.
10. The fusible signal connector of claim 9, wherein the fuse line has a predetermined shape selected to cause the fuse line to fuse open cleanly.



-10-

11. The fusible signal connector of claim 8, wherein the fuse line has a kinked shape.

12. A regulated power supply having an adjustable set point, comprising:

a voltage source;

a voltage regulator coupled to receive an input voltage generated by the voltage source for outputting a regulated voltage;

a comparator coupled to receive as input a feedback voltage and a reference voltage, the comparator circuit for outputting an error voltage to the regulator, the error voltage indicative of a difference between the reference voltage and the feedback voltage; and

a feedback circuit having a transfer function, the feedback circuit coupled to receive the regulated voltage as input for outputting the feedback voltage, the feedback circuit including at least one fusible connector, such that the transfer function of the feedback circuit can be adjusted to control the set point of the power supply by selectively fusing open at least one of the fusible connectors.

13. The regulated power supply of claim 12, wherein each of the fusible connectors comprises a fuse line formed from a conductive layer of a printed circuit board

14. The regulated power supply of claim 13, wherein the first signal trace, the second signal trace, the first contact pad, and the second contact pad are formed from the conductive layer of the printed circuit board.

15. The regulated power supply of claim 14, wherein the first signal trace, the second signal trace, the first contact pad, the second contact pad, and the fuse line are formed simultaneously by etching the conductive layer of the printed circuit board.



-11-

16. The regulated power supply of claim 15, wherein the feedback circuit comprises a voltage divider circuit having a plurality of electrical components, wherein fusing open one of the fusible connectors breaks an electrical connection between at least two of the electrical components.

17. The regulated power supply of claim 16, wherein the plurality of electrical components comprises a plurality of resistors.

18. The regulated power supply of claim 13, wherein each of the fusible connectors further comprises:

- a first contact pad located at an end of a first signal trace on a printed circuit board;

- a second contact pad located at an end of a second signal trace on the printed circuit board;

- wherein the fuse line is fusibly coupled on the printed circuit board between the first contact pad and the second contact pad, such that a predetermined current driven through the fuse line causes at least a portion of the fuse line to fuse open to decouple the first signal trace from the second signal trace.

19. A printed circuit board having an adjustable circuit routing configuration, the printed circuit board comprising:

- substrate means;

- means for providing a plurality of electrical traces mounted to the substrate means for interconnecting a plurality of electrical components; and

- fusible connector means mounted to the substrate means, the fusible connector means formed from a conductive layer of the printed circuit board and forming a fusible connection between at least two of the electrical traces, wherein the circuit routing configuration can be selected by applying a predetermined current through the fusible connector means to break the fusible connection formed thereby.



-12-

20. The printed circuit board of claim 19, wherein the first signal trace, the second signal trace, the first contact means, and the second contact means are formed from the conductive layer of the printed circuit board.

21. The printed circuit board of claim 20, wherein the first signal trace, the second signal trace, the first contact means, the second contact means, and the fuse line are formed simultaneously by etching the conductive layer of the printed circuit board.

22. A fusible signal connector, comprising:

first contact means located at an end of a first signal trace on a printed circuit board;

second contact means located at an end of a second signal trace on the printed circuit board; and

fuse line means formed from a conductive layer of the printed circuit board fusibly coupled on the printed circuit board between the first contact means and the second contact means, such that a predetermined current driven through the fuse line means causes at least a portion of the fuse line means to fuse open to decouple the first signal trace means from the second signal trace means.

23. The fusible signal connector of claim 22, wherein the first signal trace, the second signal trace, the first contact means, and the second contact means are formed from the conductive layer of the printed circuit board.

24. The fusible signal connector of claim 23, wherein the first signal trace, the second signal trace, the first contact means, the second contact means, and the fuse line are formed simultaneously by etching the conductive layer of the printed circuit board.



-13-

25. A regulated power supply having an adjustable set point, comprising:

voltage source means;

regulator means coupled to receive an input voltage generated by the voltage source means for outputting a regulated voltage;

a comparator means coupled to receive as input a feedback voltage and a reference voltage, the comparator means for outputting an error voltage to the regulator means, the error voltage indicative of a difference between the reference voltage and the feedback voltage; and

feedback means having a transfer function, the feedback means coupled to receive the regulated voltage as input for outputting the feedback voltage, the feedback means including fusible connector means, such that the transfer function of the feedback means can be adjusted to control the set point of the power supply by selectively fusing open the fusible connector means.

26. The regulated power supply of claim 25, wherein the fusible connector means is formed from a conductive layer of a printed circuit board.

27. The regulated power supply of claim 26, wherein the first signal trace, the second signal trace, the first contact means, and the second contact means are formed from the conductive layer of the printed circuit board.

28. The regulated power supply of claim 27, wherein the first signal trace, the second signal trace, the first contact means, the second contact means, and the fuse line are formed simultaneously by etching the conductive layer of the printed circuit board.

29. A method of providing a printed circuit board having a selectable circuit routing configuration, the method comprising the steps of:
providing a substrate;



providing a plurality of electrical traces mounted to the substrate for interconnecting a plurality of electrical components; and
providing at least one fusible connector at least partially formed from a conductive layer mounted to the substrate, such that each of the fusible connectors forms a fusible connection between at least two of the electrical traces, wherein the circuit routing configuration can be selected by applying a predetermined current through at least one of the fusible connectors to break the fusible connection formed thereby.

30. A method of adjusting the routing configuration of a printed circuit board, the method comprising the steps of:

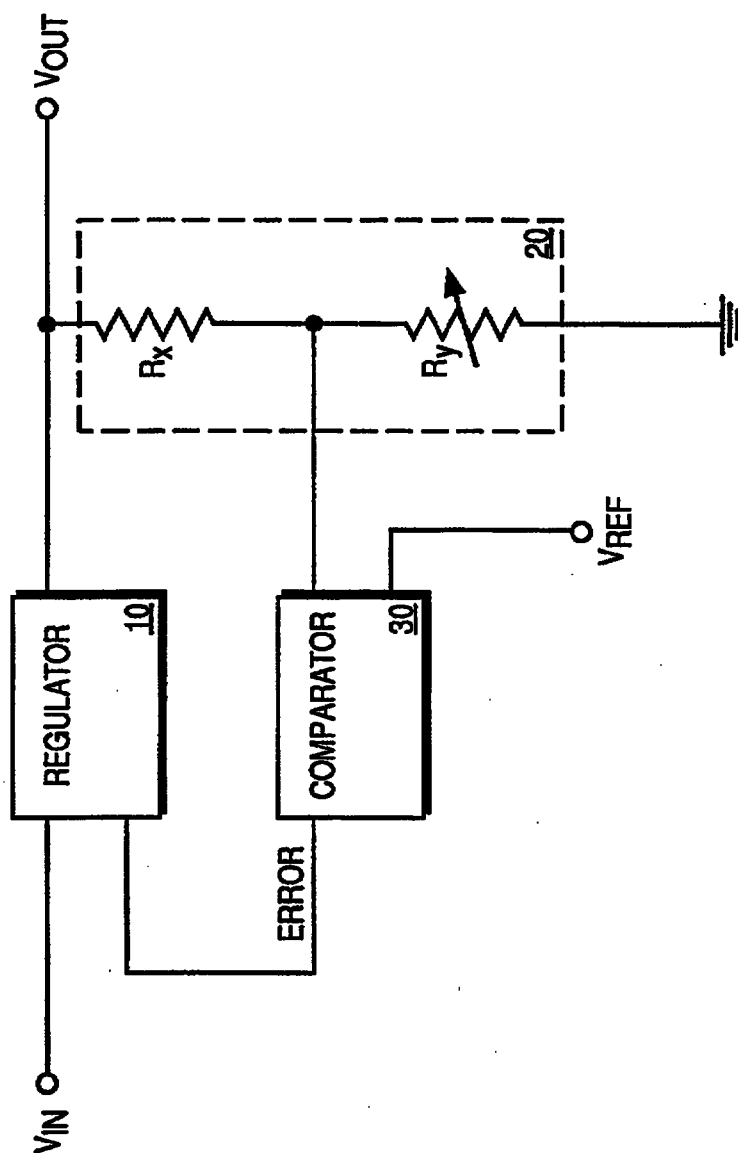
providing a substrate;
providing a plurality of electrical traces mounted to the substrate for interconnecting a plurality of electrical components;
providing at least one fusible connector at least partially formed from a conductive layer mounted to the substrate, such that each of the fusible connectors forms a fusible connection between at least two of the electrical traces; and
applying a predetermined current through at least one of the fusible connectors to break the fusible connection formed thereby.

31. A method of adjusting a set point of a regulated power supply, the power supply having a voltage regulator coupled to a comparator and a feedback circuit for controlling the set point, the comparator separately coupled to the feedback circuit, the feedback circuit having a transfer function, the method comprising the steps of:

providing within the feedback circuit at least one fusible connector at least partially formed from a conductive layer mounted to a printed circuit board, each of the fusible connectors forming a fusible connection between at least two of a plurality of electrical traces on the printed circuit board; and
applying a predetermined current through at least one of the fusible connectors to break the fusible connection formed thereby to change the transfer function of the feedback circuit.

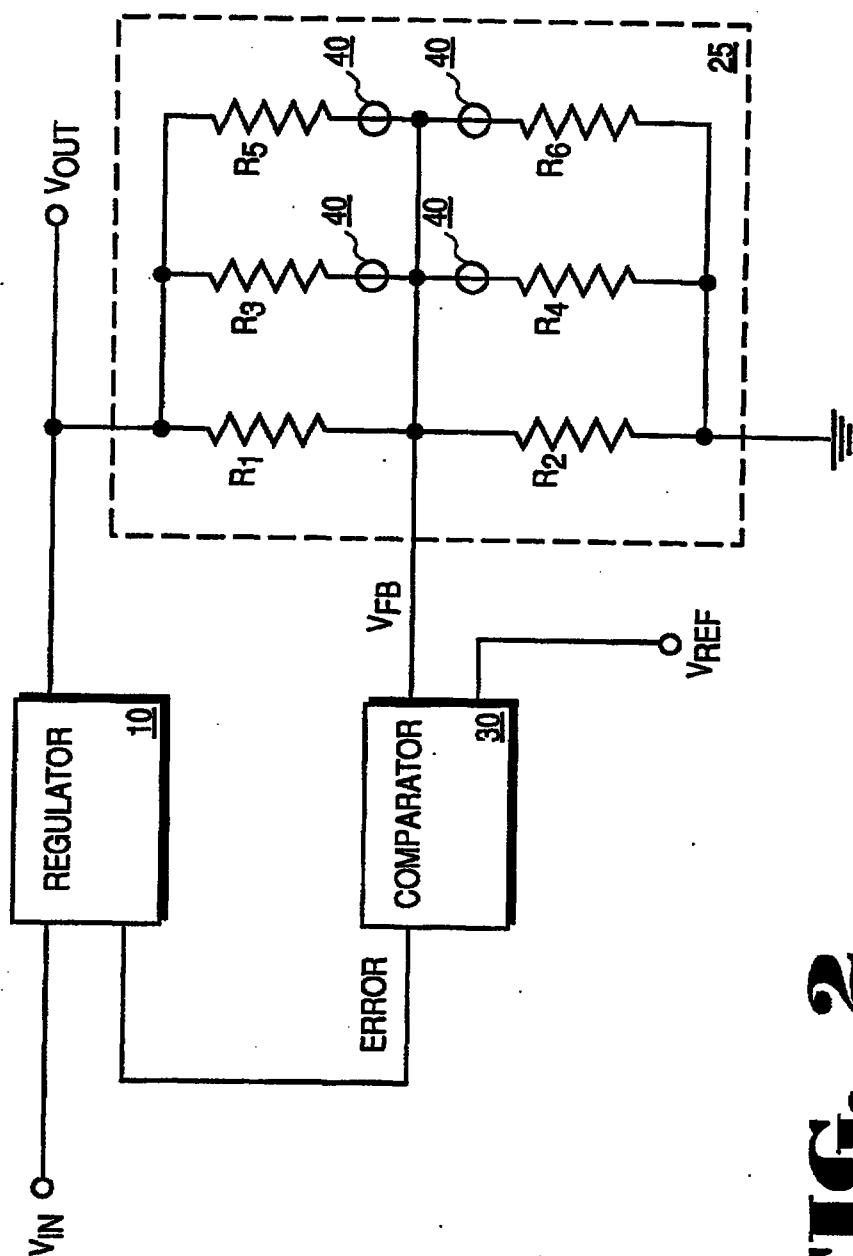
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1

**FIG. 1** (PRIOR ART)

2/4

2

**FIG. 2**

3/4

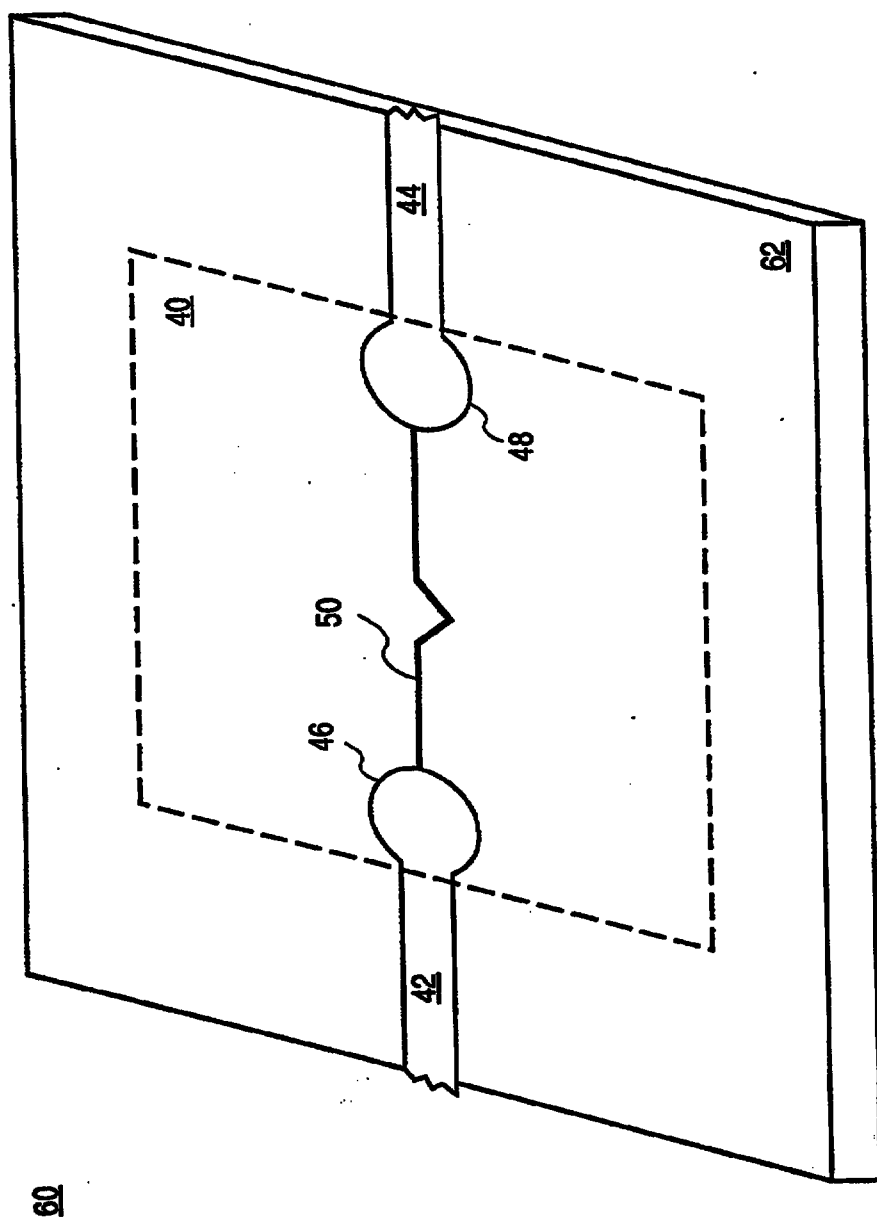


FIG. 3

4/4

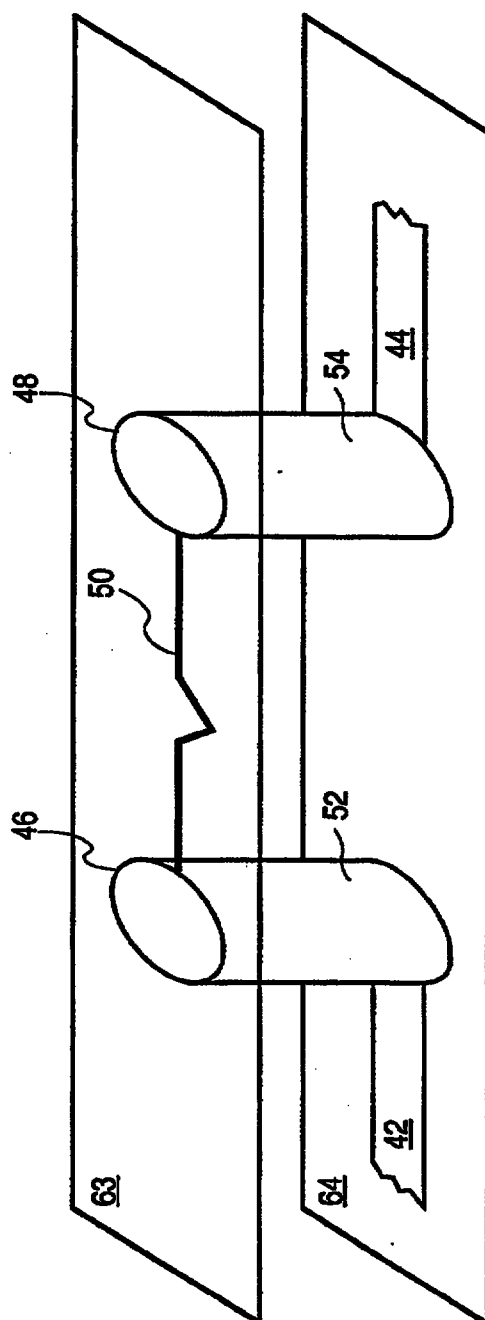


FIG. 4

insulating material, the contact pads 46 and 48 are exposed to allow electrical contact with a test probe or other similar instrument.

The fuse line 50 may be fused open by applying a predetermined voltage between contact pads 46 and 48 to cause a fusing current to flow through the fuse line 50. The width and shape of the fuse line 50 are calculated such that the fuse line 50 will fuse open at the lowest possible fusing current and provide the cleanest break upon fusing, subject to current manufacturing capabilities. A fuse line 50 having a kinked shape as shown in Figure 3 may be suitable for this purpose. In addition, the length of the fuse line 50 is as short as possible according to current manufacturing capabilities. The contact pads 46 and 48 and fuse line 50 are sized and shaped in order to provide negligible resistance.

The present invention may also be embodied on a multiple layer printed circuit board, as shown in Figure 4. The fuse line 50 is formed on one substrate layer 63 of the printed circuit board while the traces 42 and 44 are formed on a different substrate layer 64. Connection between the fuse line 50 and contact pads 46 and 48 is made through vias 52 and 54.

Hence, the routing configuration of the printed circuit board 60 can be easily altered after the manufacturing process has been completed (e.g., during the testing phase) by selectively fusing open any of the fusible connectors 40. By applying a predetermined voltage between contact pad 46 and contact pad 48 to cause a predetermined current to pass through and to fuse open the fuse line 50.

Furthermore, if this process is performed during the testing phase, the open/short condition of the fusible connector 40 can be easily tested, since the printed circuit board is already connected to the test equipment. Therefore, the printed circuit board 60 can be mass produced to have a single routing configuration that can be easily reconfigured into one of multiple different routing configurations. It is not necessary to maintain a separate inventory of parts for the purpose of performing such reconfiguration. Furthermore, the fusible connector 40 can be implemented in a regulated power supply such



32. A method of providing a circuit board having a selectable circuit routing configuration, the method comprising the steps of:

forming a conductive layer on a substrate;

forming a plurality of electrical traces from the conductive layer; and

forming a fusible connection from the conductive layer between at least two of the electrical traces simultaneously with said step of forming the plurality of electrical traces, such that the circuit routing configuration of the circuit board is configurable by-- application of a predetermined fusing current through the fusible connection to cause the fusible connection to fuse open.

33. A method according to claim 32, further comprising the step of applying the predetermined fusing current through the fusible connection during a test phase to cause the fusible connection to fuse open.

34. A method according to claim 32, wherein the steps of forming the plurality of electrical traces and forming the fusible connection are performed substantially simultaneously by etching the conductive layer.

35. A method of producing a circuit board, the circuit board having a circuit routing configuration, the method comprising the steps of:

forming a plurality of electrical traces and a fusible connection between the electrical traces from a conductive layer of the circuit board; and

verifying the routing configuration of the circuit board as part of a test phase; and

configuring the circuit routing configuration of the circuit board as part of the test phase by applying a predetermined current through the fusible connection to fuse open the fusible connection.



36. A method according to claim 35, wherein the step of forming the plurality of traces and the fusible connection comprises the step of forming the plurality of traces and the fusible connection from the conductive layer concurrently by etching the conductive layer.

37. A method of producing a circuit board, the circuit board having a circuit routing configuration, the method comprising the steps of:

forming a conductive layer on a substrate;

forming a plurality of electrical traces from the conductive layer; and

forming a fusible connection from the conductive layer between at least two of the electrical traces;

testing the routing configuration of the circuit board during a test phase; and

configuring the circuit routing configuration of the circuit board during the test phase by applying a predetermined current through the fusible connection to fuse open the fusible connection.

38. A method according to claim 37, wherein the steps of forming the plurality of electrical traces and forming the fusible connection are performed concurrently by etching the conductive layer.

39. A method of providing a circuit board having a selectable circuit routing configuration, the method comprising the steps of:

forming a conductive layer on a substrate;

forming a plurality of electrical traces from the conductive layer; and

forming a fusible connection from the conductive layer between at least two of the electrical traces;

connecting the circuit board to test equipment; and

using the test equipment to apply a predetermined fusing current through the fusible connection to cause the fusible connection to fuse open; and



using the test equipment to verify the routing configuration of the circuit board without removing the circuit board from the test equipment.

40. A method according to claim 39, wherein the steps of forming the plurality of electrical traces and forming the fusible connection are performed concurrently by etching the conductive layer.