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Eldridge et al.

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(54) **SPECIAL CONTACT POINTS FOR
ACCESSING INTERNAL CIRCUITRY OF AN
INTEGRATED CIRCUIT**

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patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

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1998.

(51) **Int. Cl.⁷** **G01R 31/02**

(52) **U.S. Cl.** **324/754; 324/158.1**

(58) **Field of Search** 324/754, 761,
324/763, 158.1, 757, 758, 762, 755, 765

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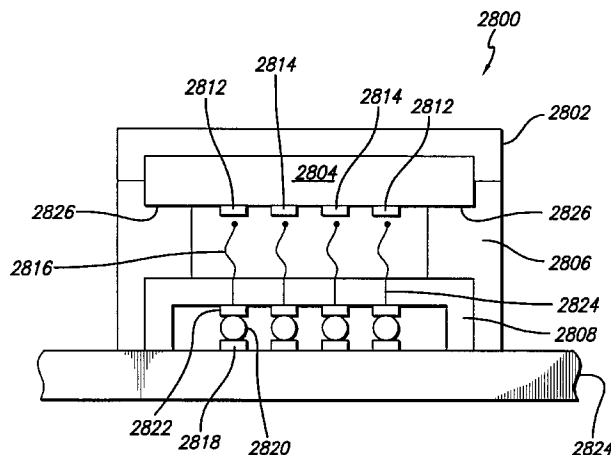
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(57) **ABSTRACT**

An integrated circuit that includes bond pads and special
contact pads or points. The bond pads are for interfacing the
integrated circuit as a whole with an external circuit, and are
to be bonded to a package or circuit board. The bond pads
are disposed on the die in a predetermined alignment such as
a peripheral, grid, or lead-on-center alignment. The special
contact pads are used to provide external test patterns to
internal circuits and/or to externally monitor results from
testing the internal circuits. The special contact pads may be
advantageously located on the integrated circuit with a high
degree of positional freedom. For one embodiment, the
special contact pads may be disposed on the die at a location
that is not in the same alignment as the bond pads. The
special contact pads may be smaller than the bond pads so
as not to increase the die size due to the special contact pads.
The special contact points may also be used to externally
program internal circuits (e.g., nonvolatile circuits) at the die
or package level. The special contact points may also be
used to select redundant circuits for faulty circuits.

23 Claims, 16 Drawing Sheets



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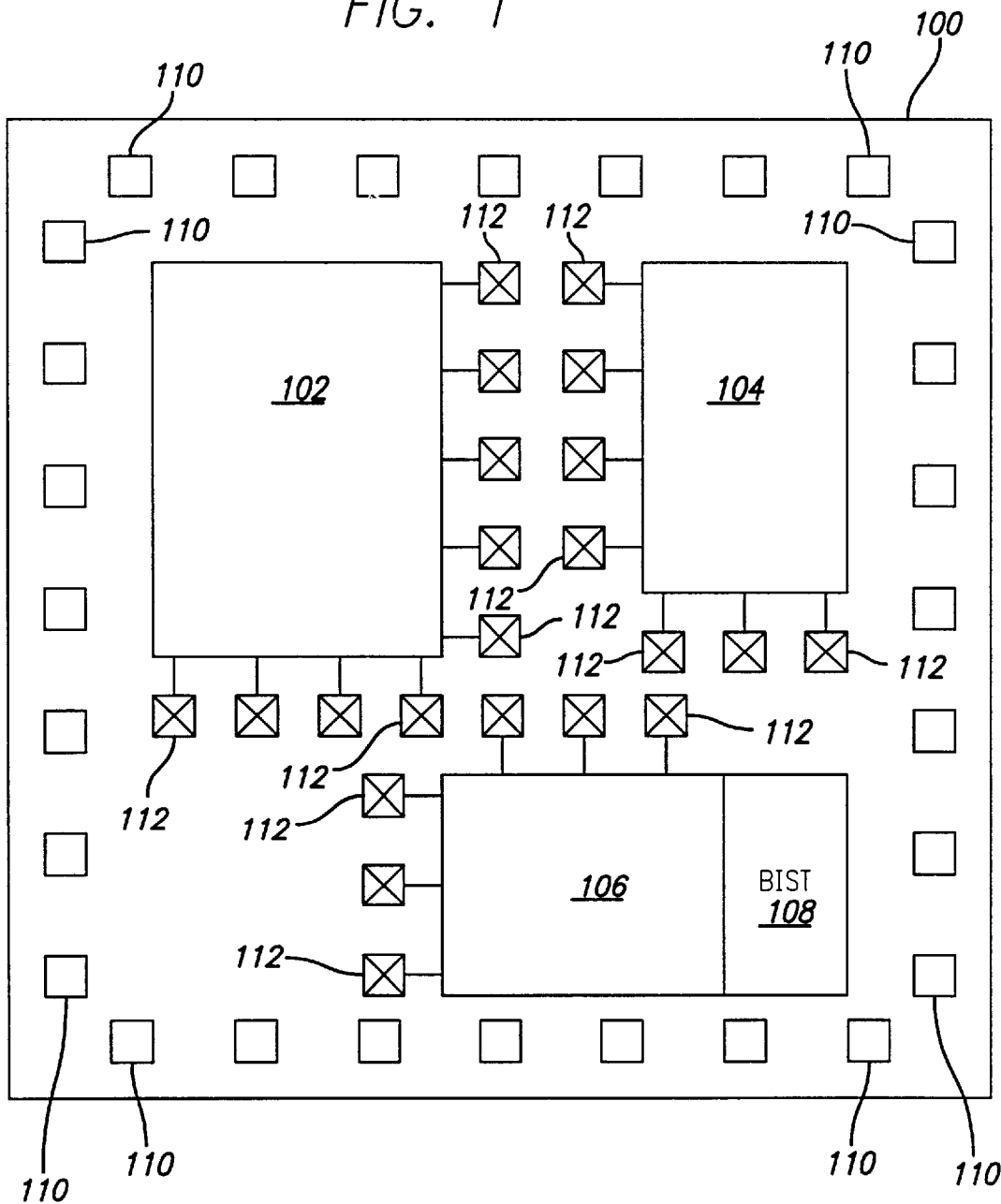
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FIG. 1



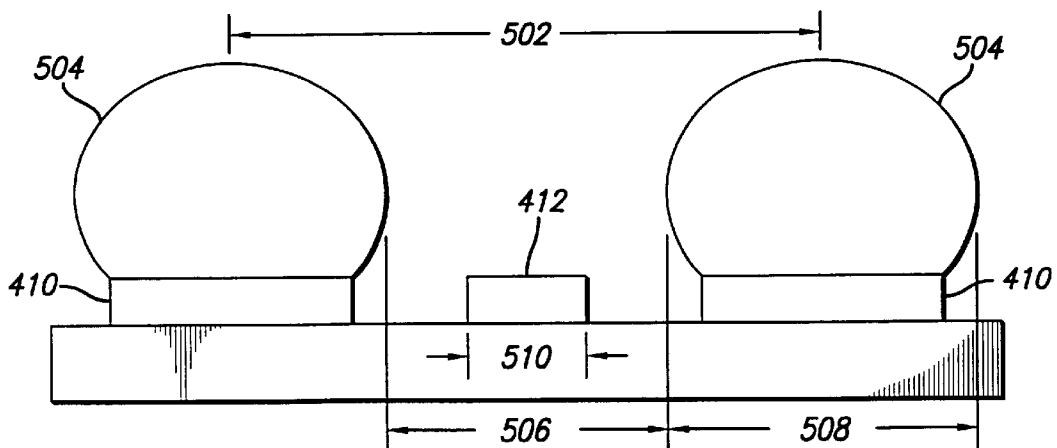
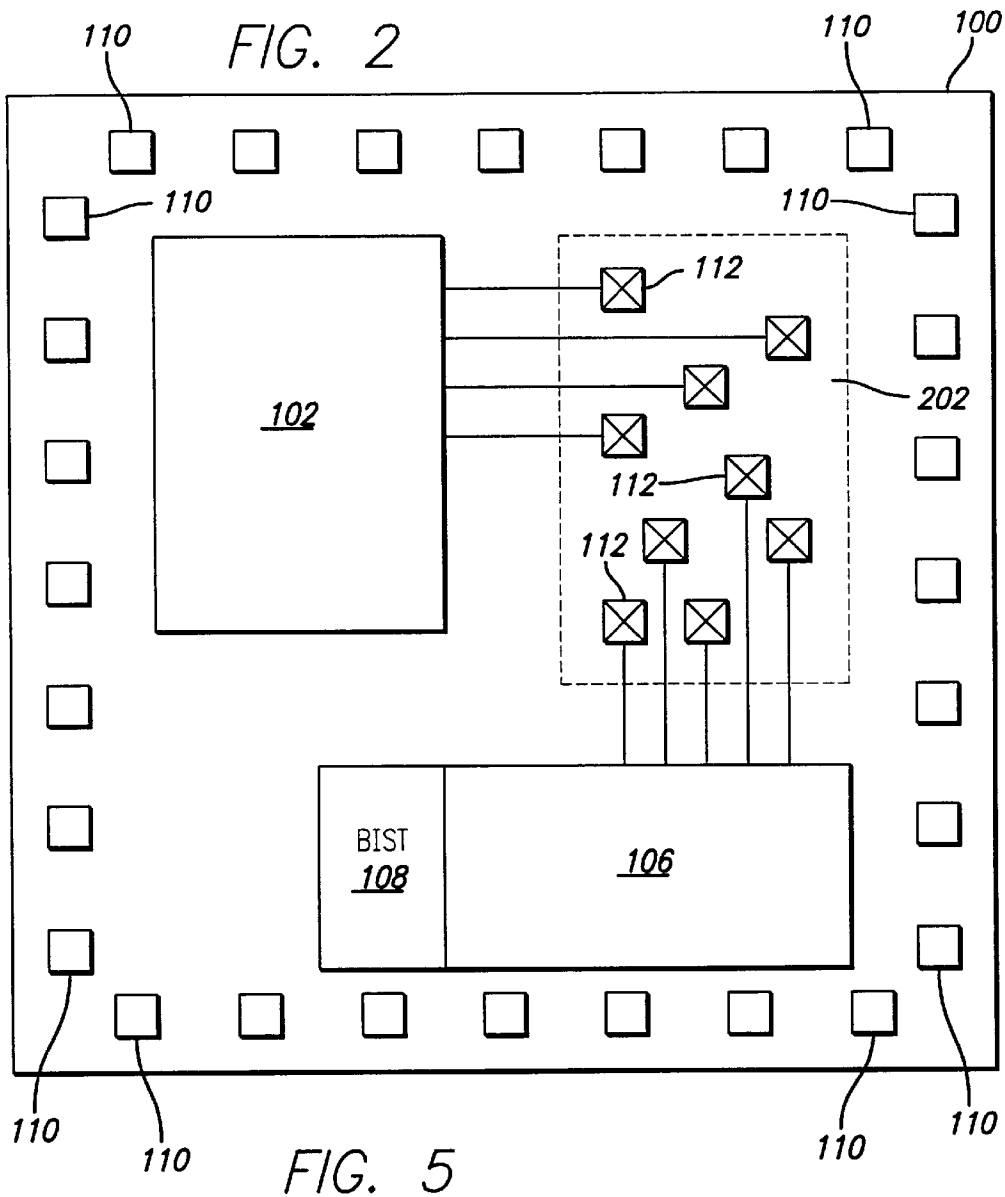


FIG. 3A

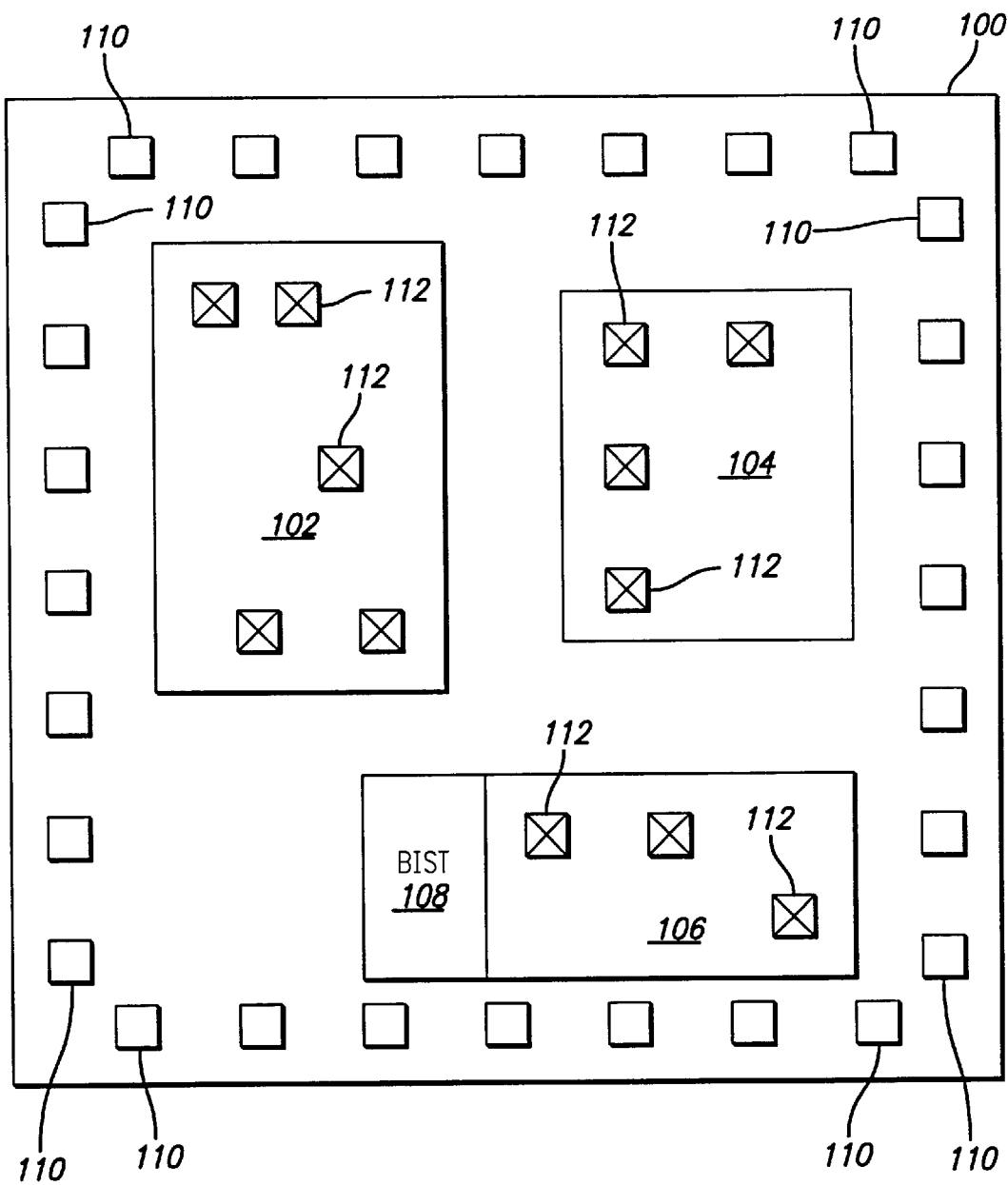


FIG. 3B

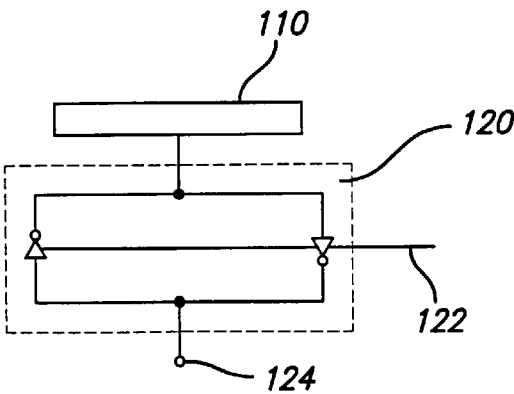


FIG. 4

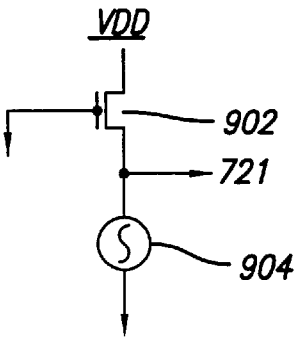
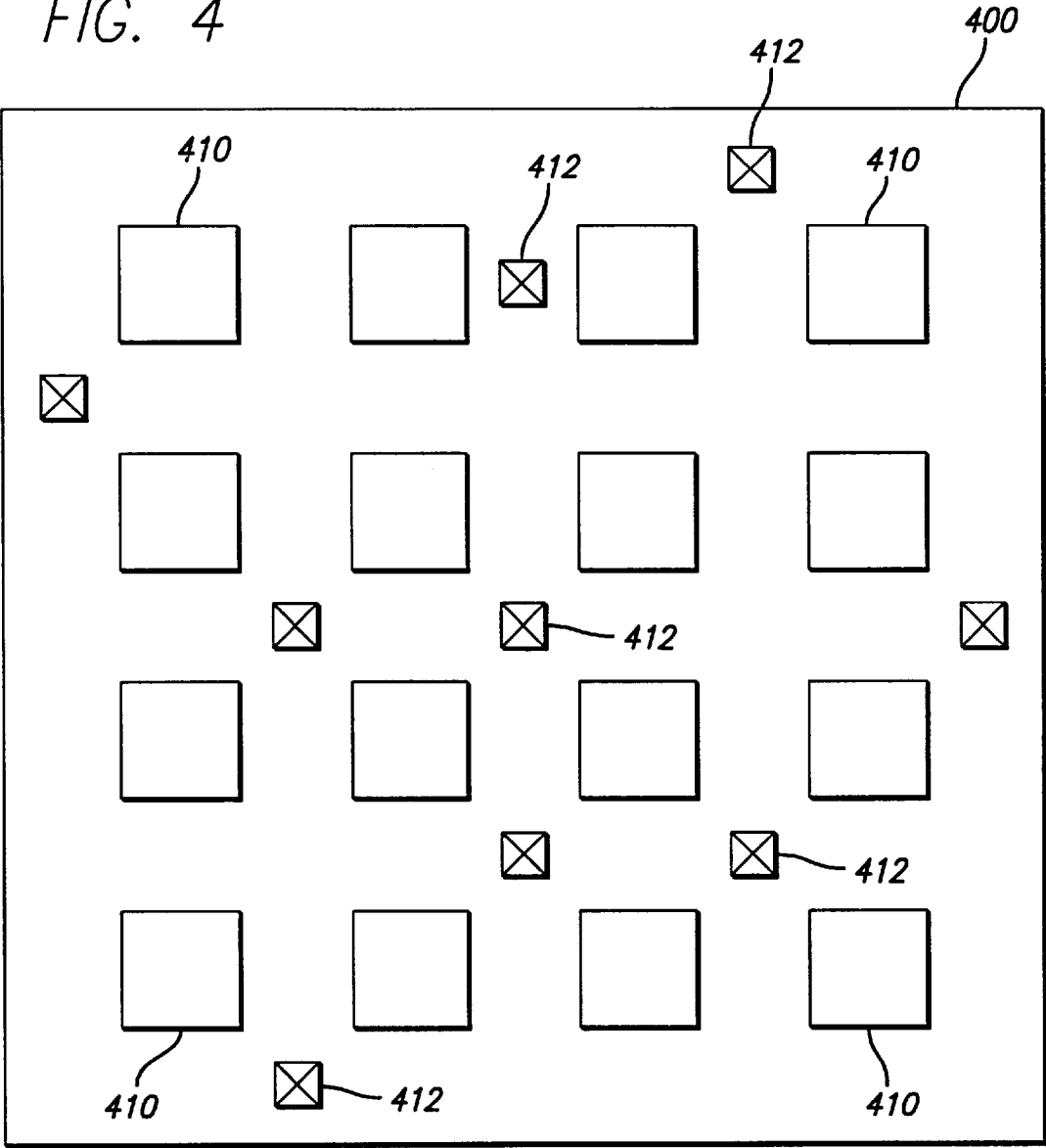


FIG. 9

FIG. 6

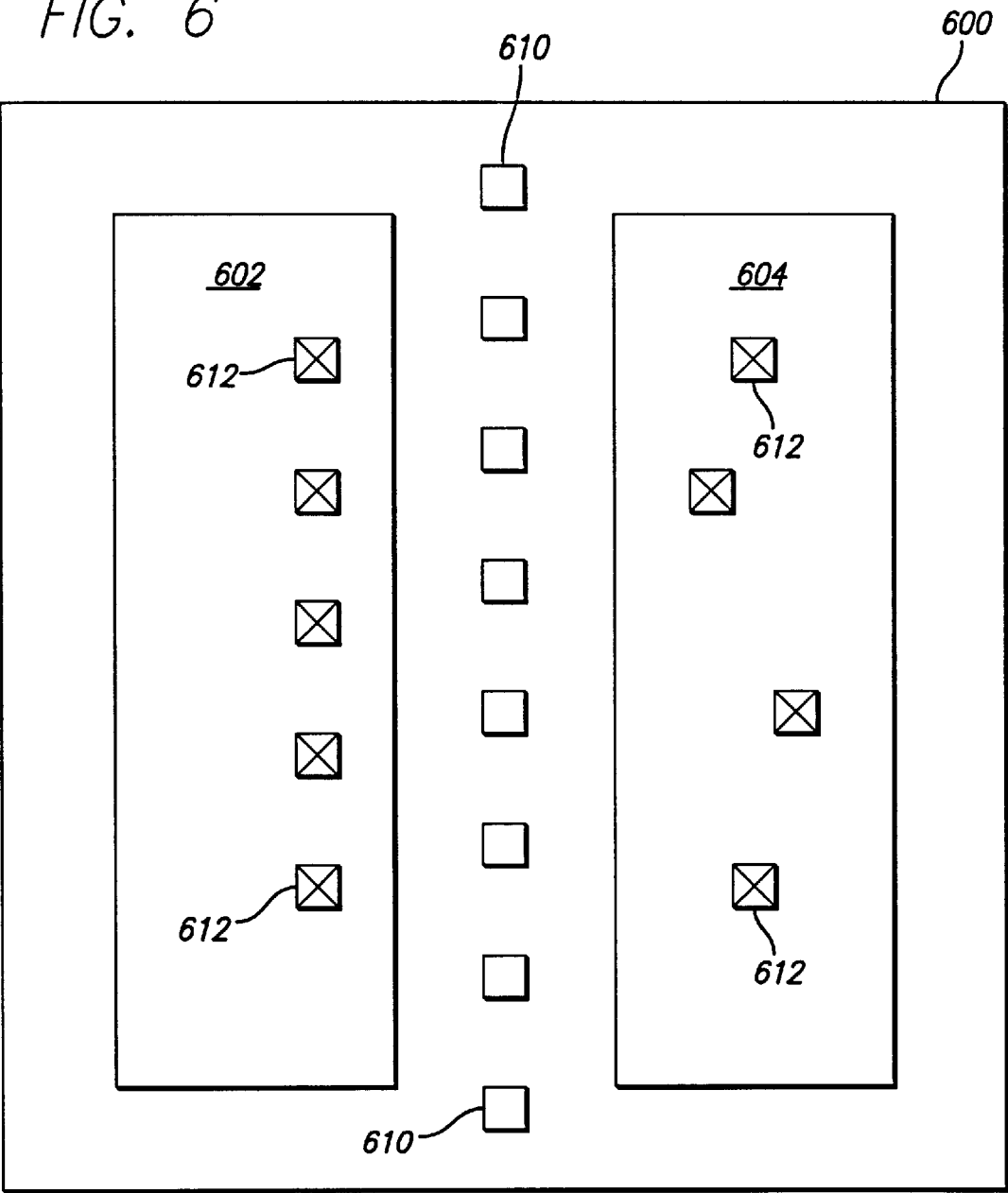
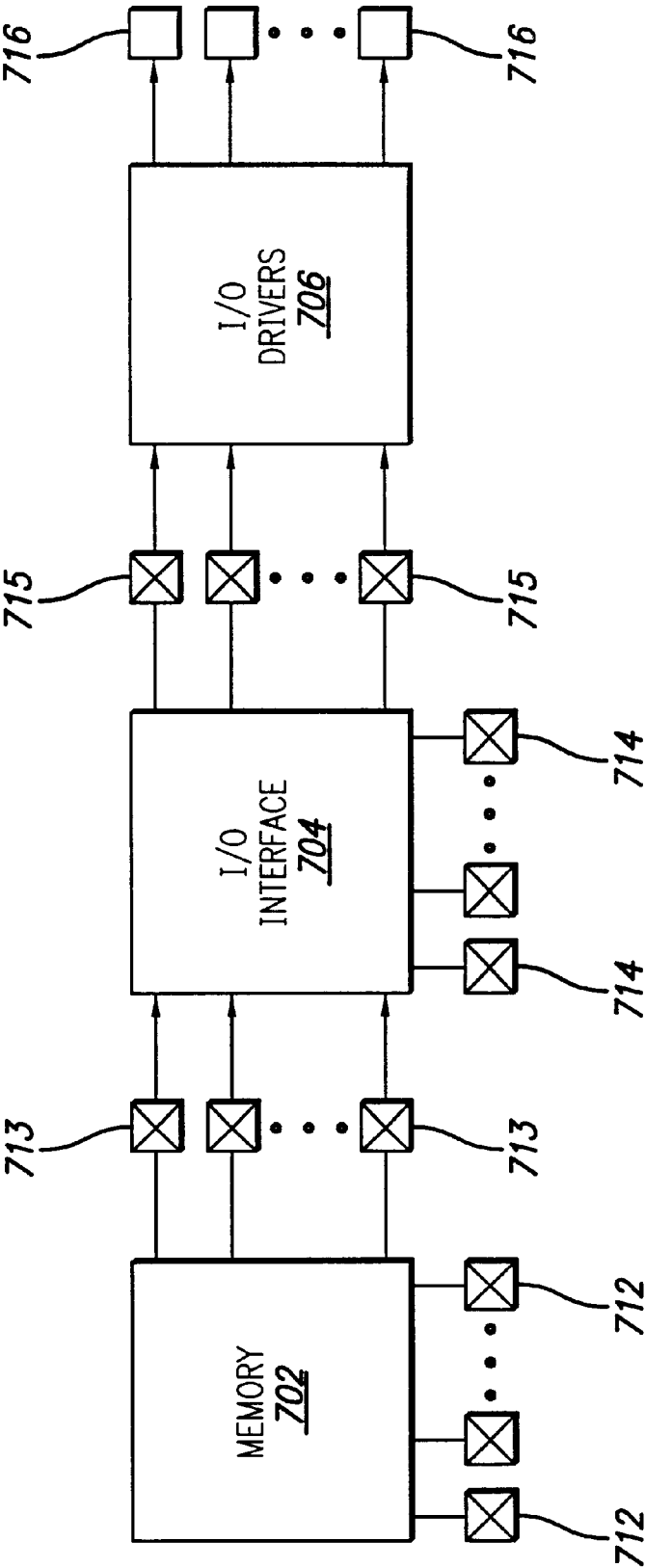


FIG. 7



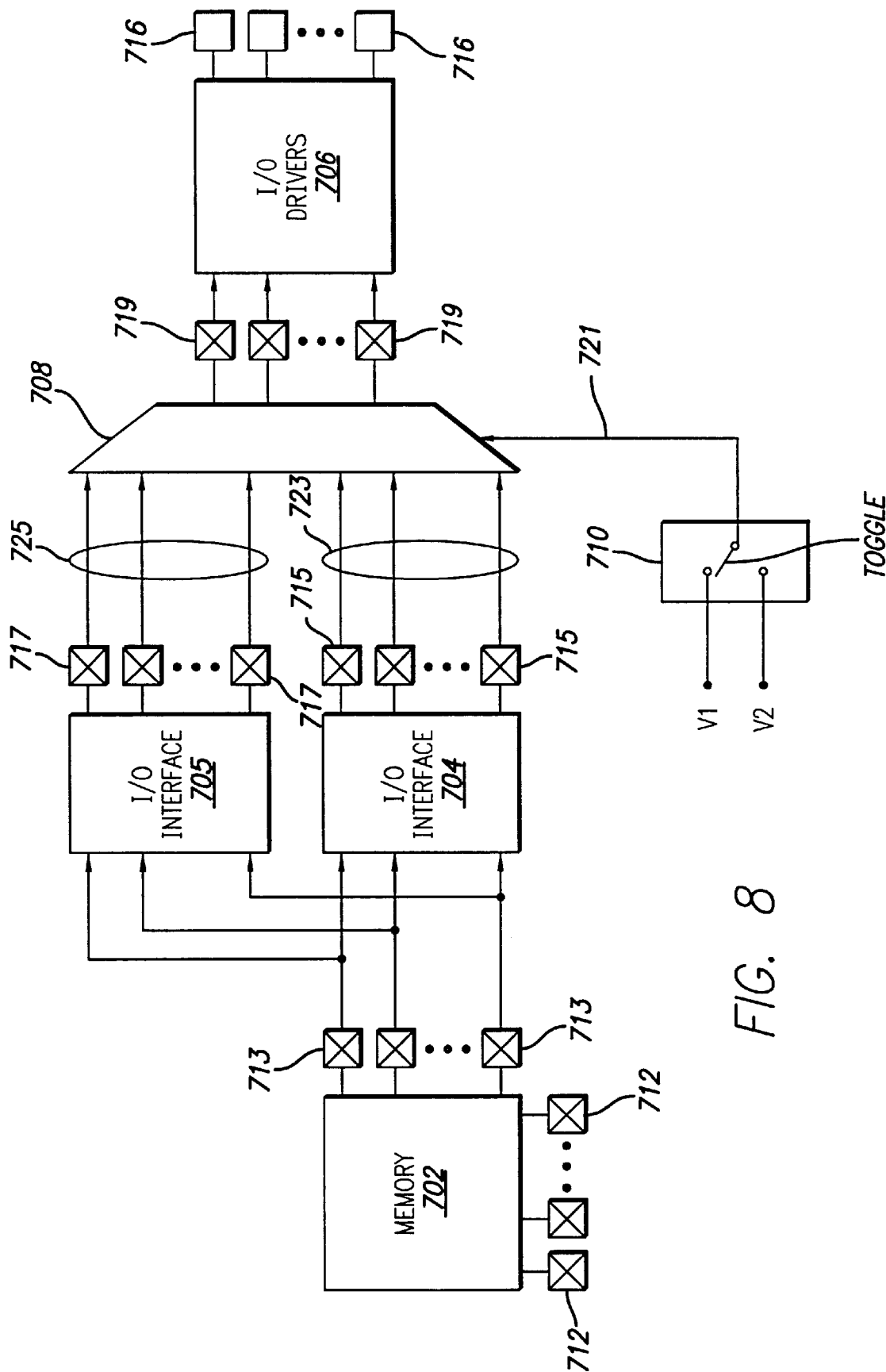


FIG. 8

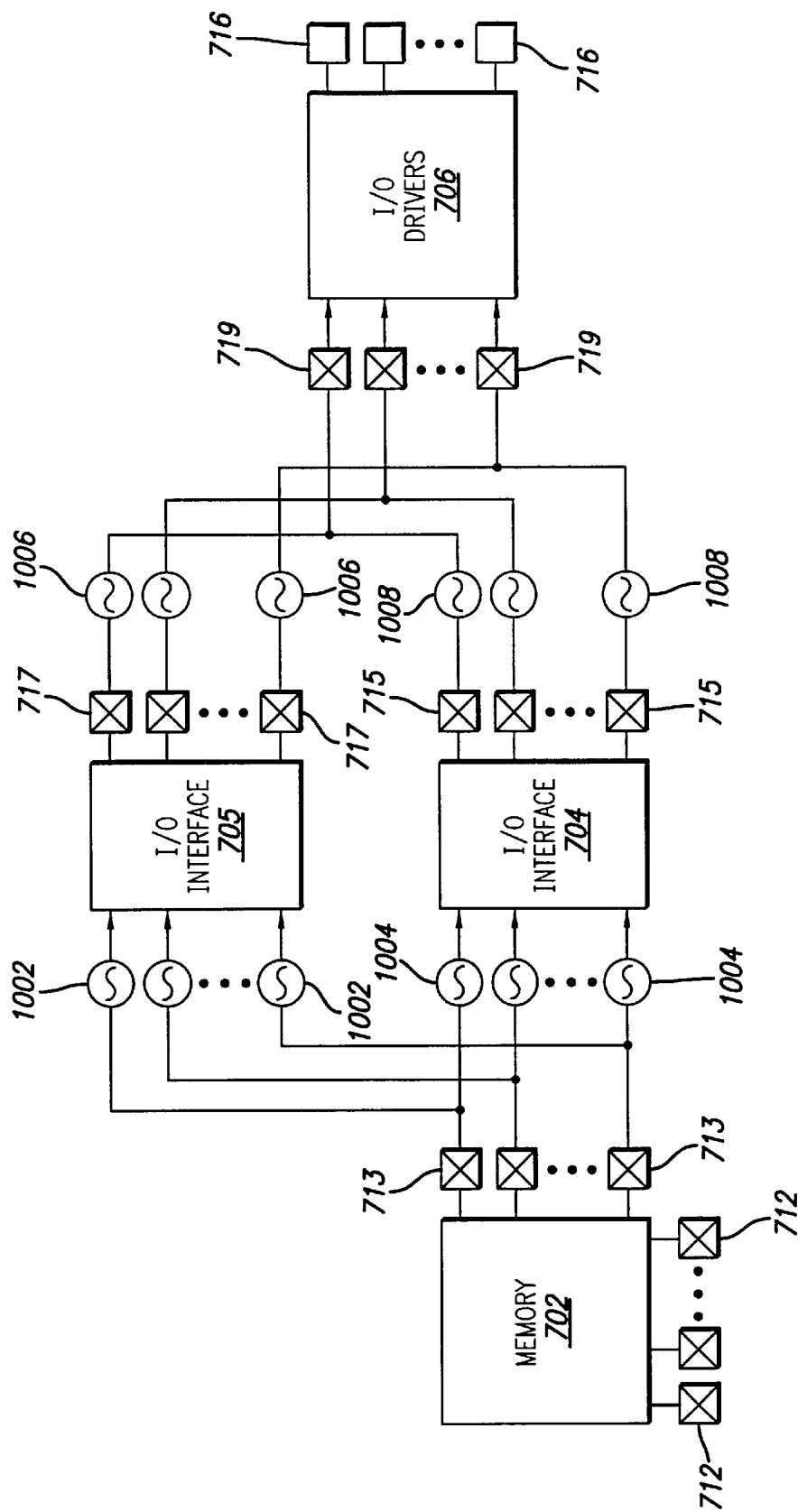


FIG. 10

FIG. 11

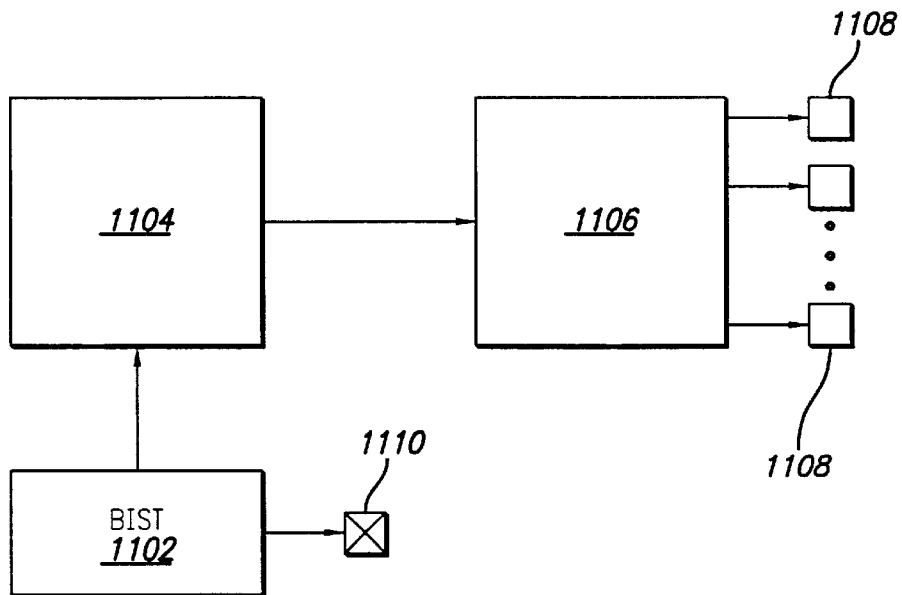


FIG. 12

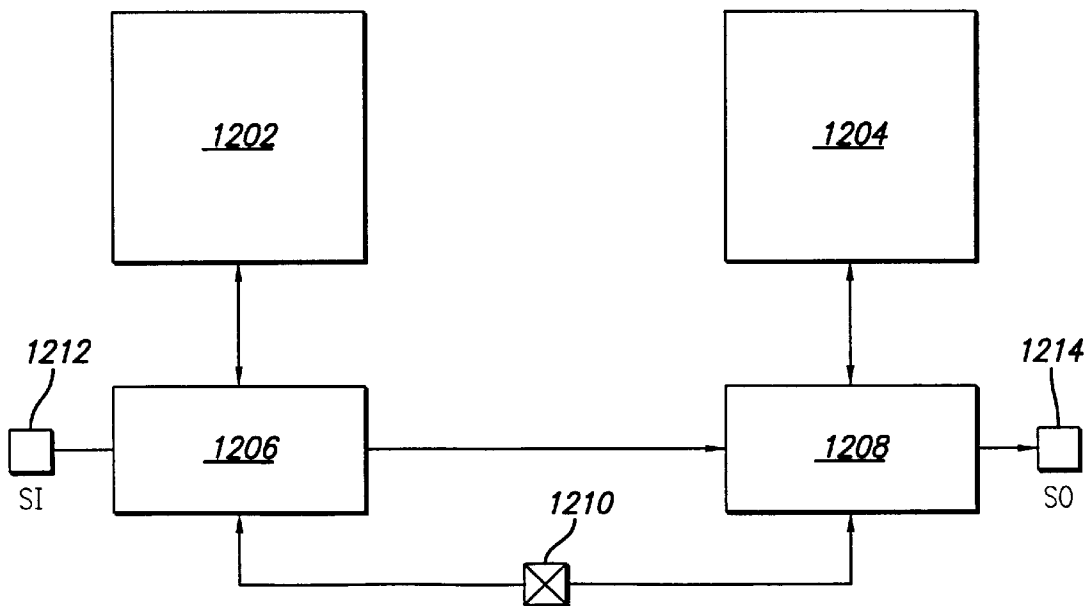


FIG. 13

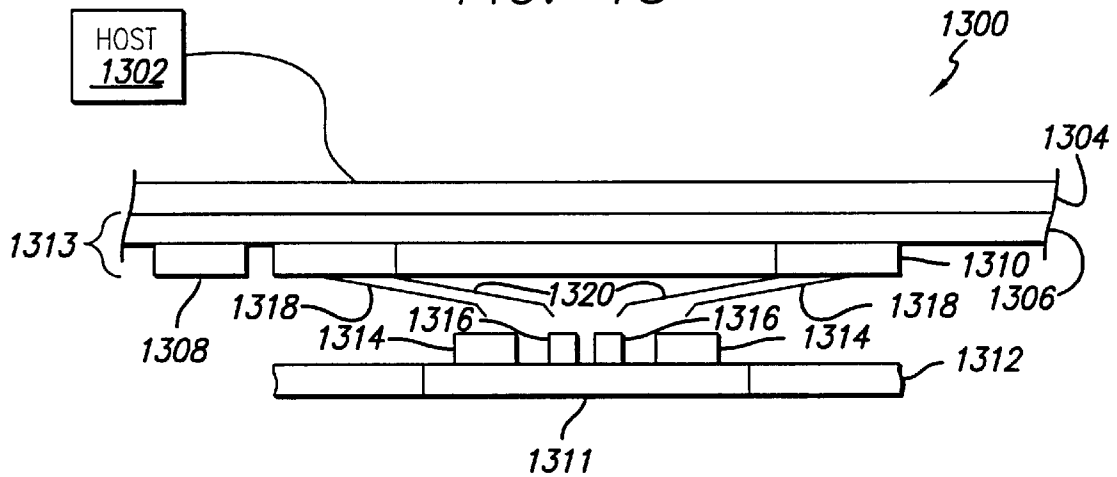


FIG. 14

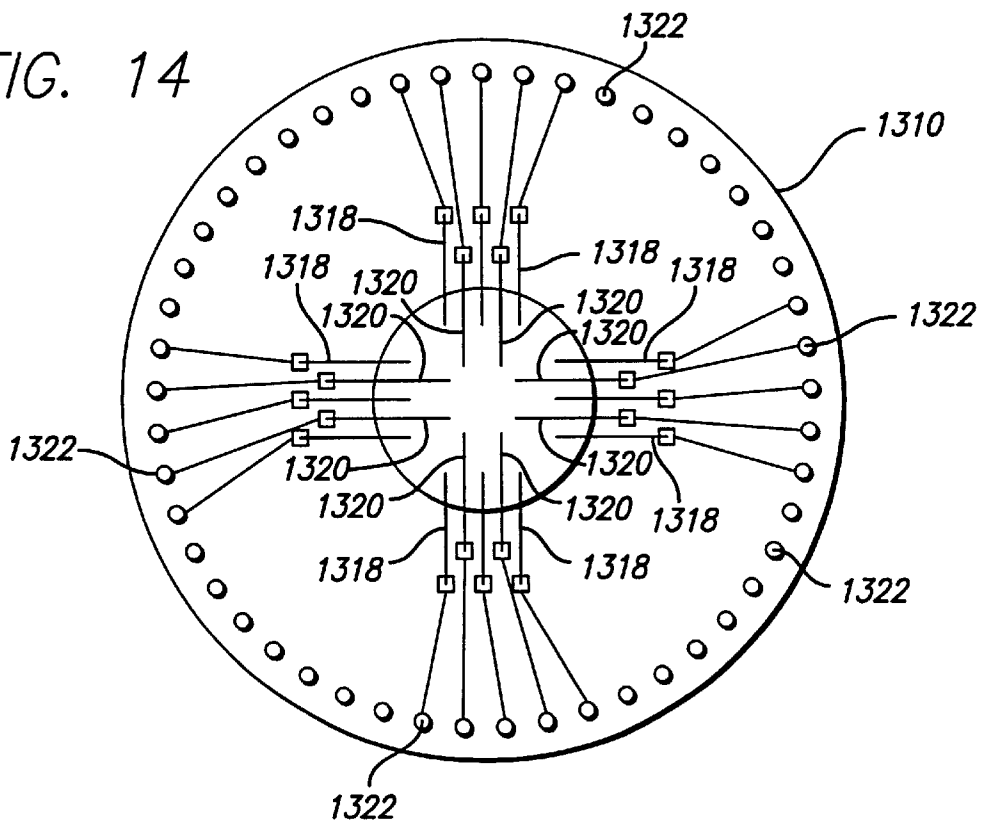


FIG. 18

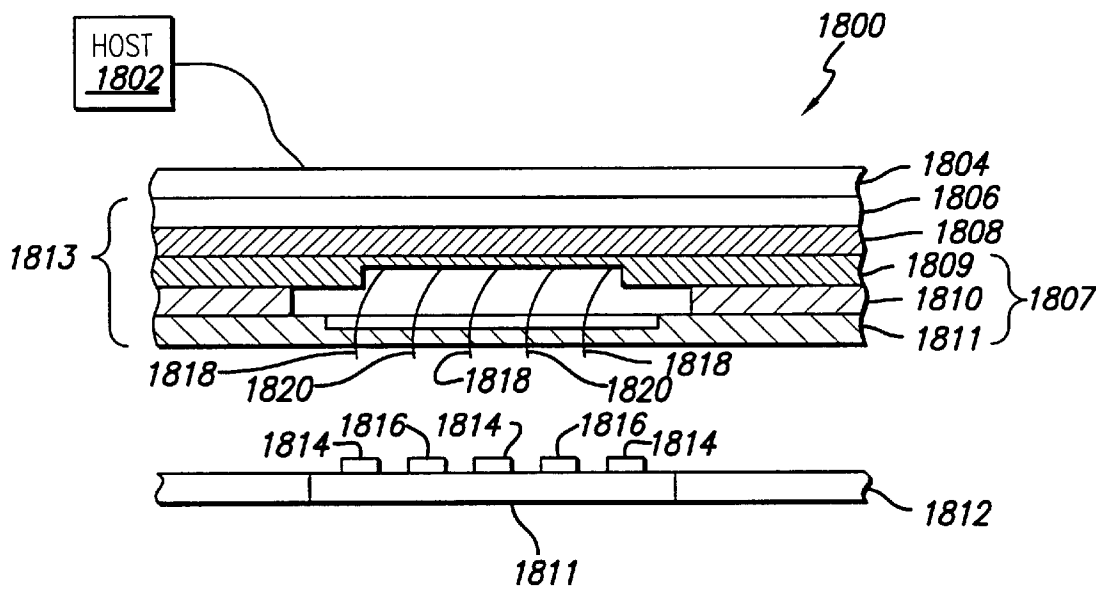


FIG. 19

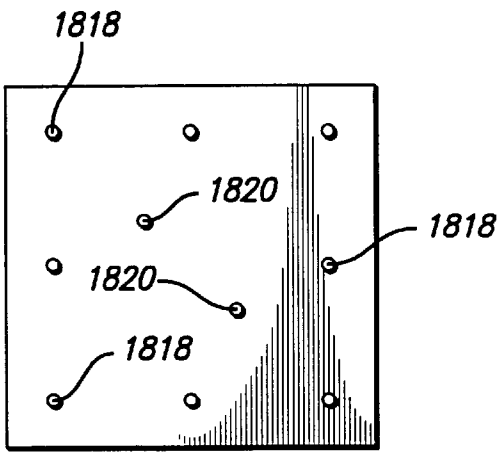
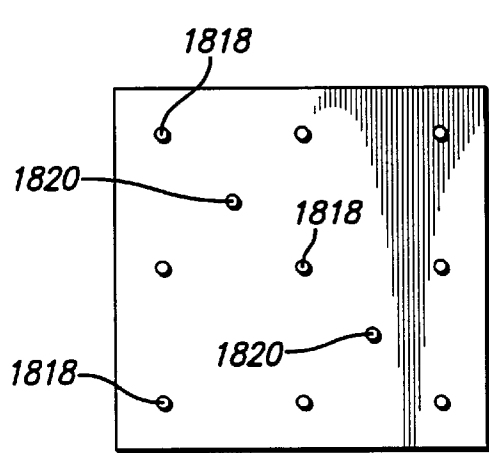
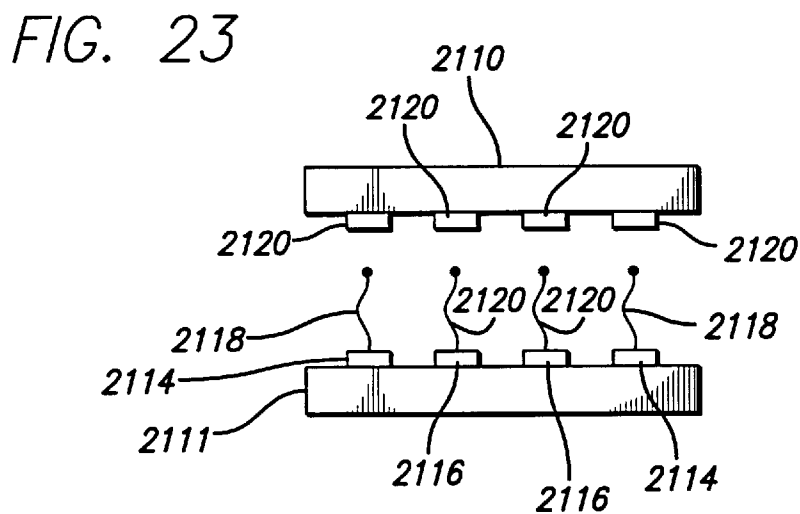
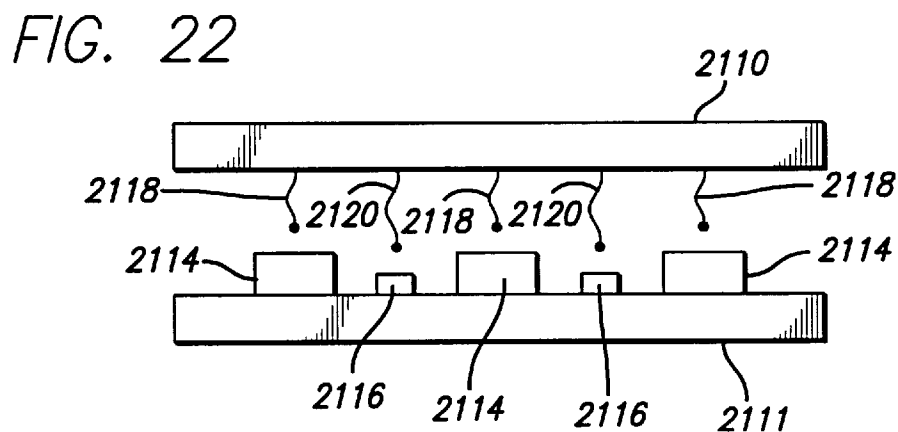
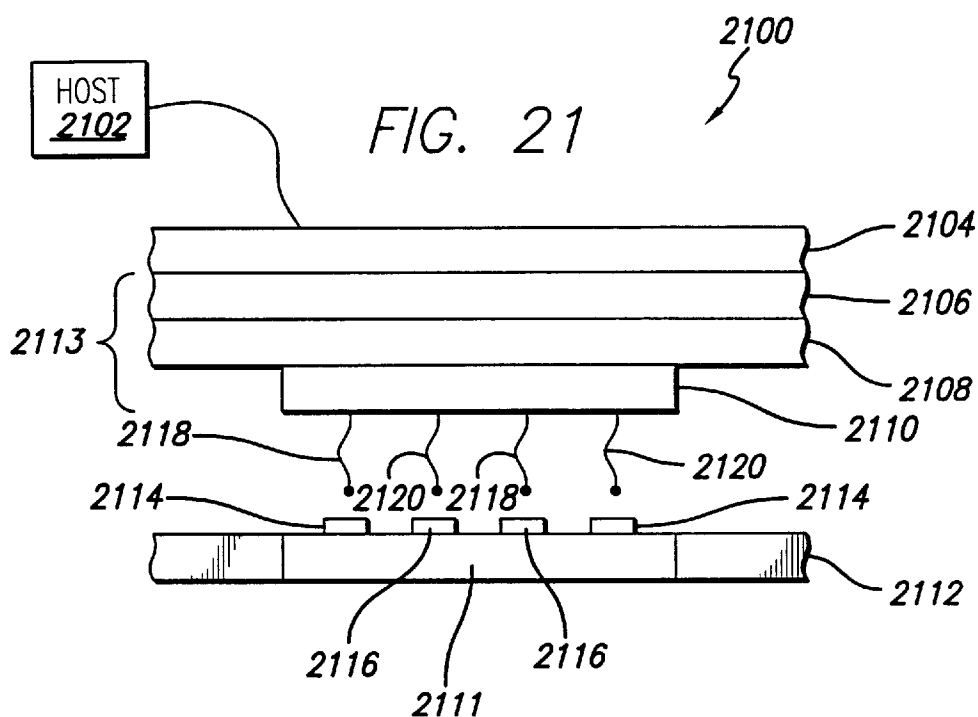


FIG. 20



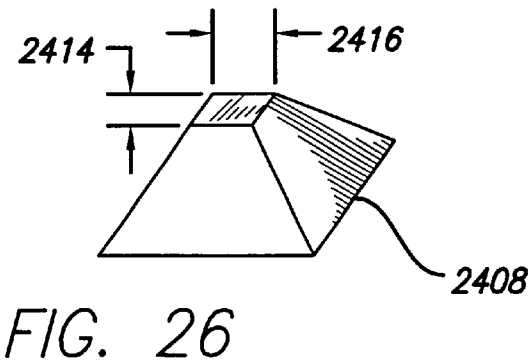
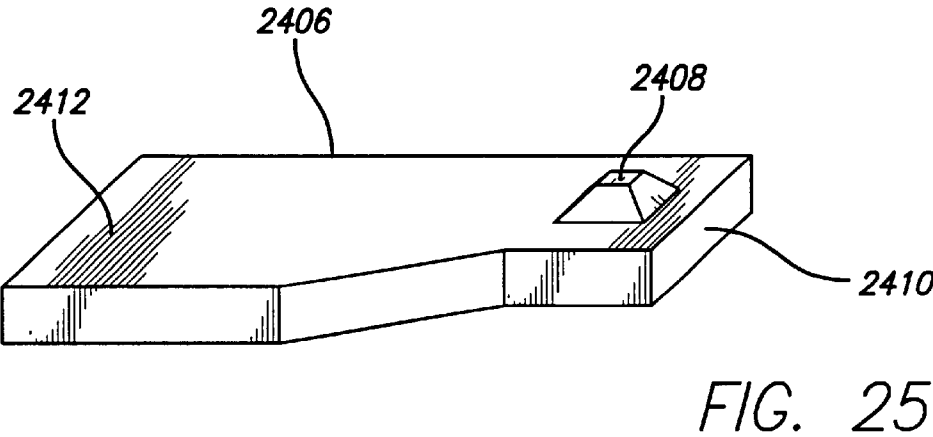
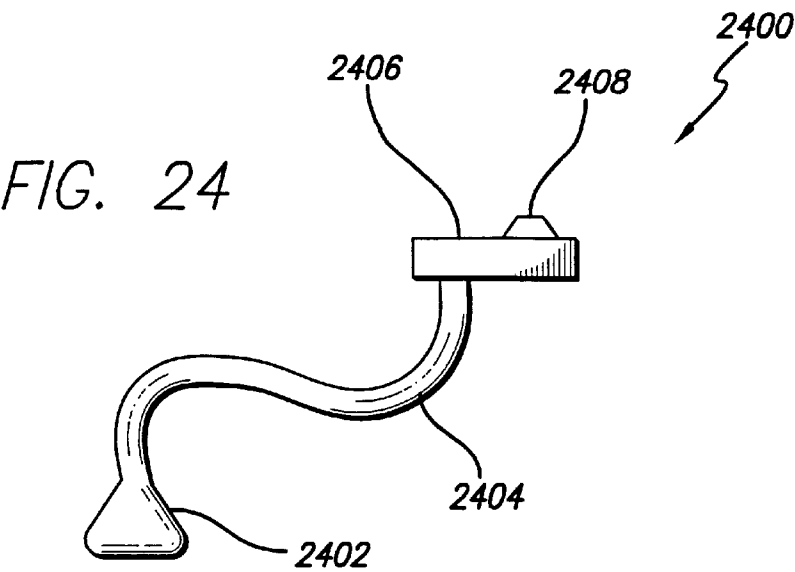


FIG. 27

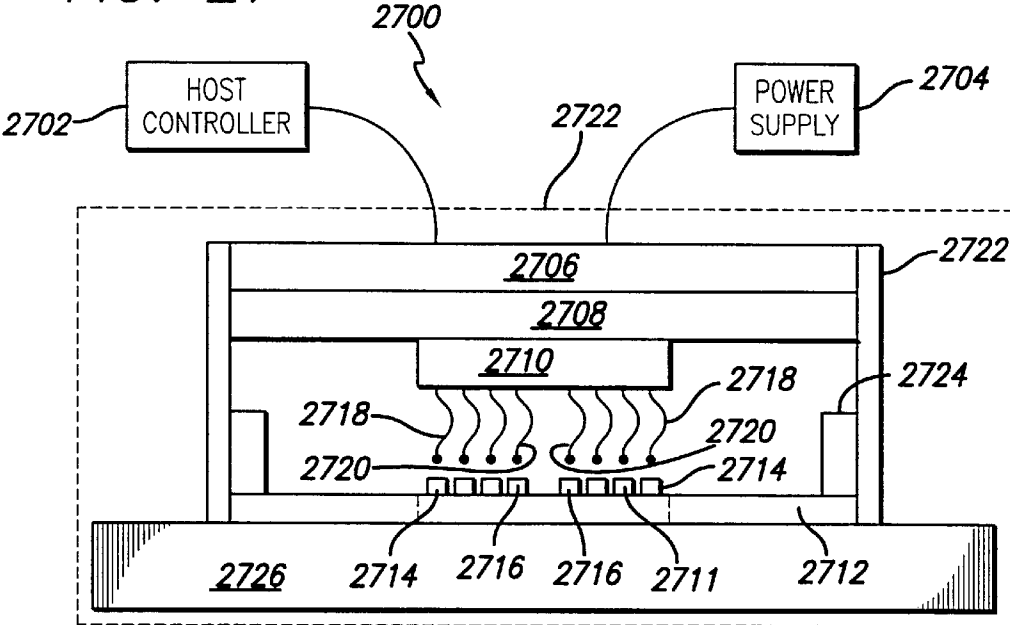


FIG. 28

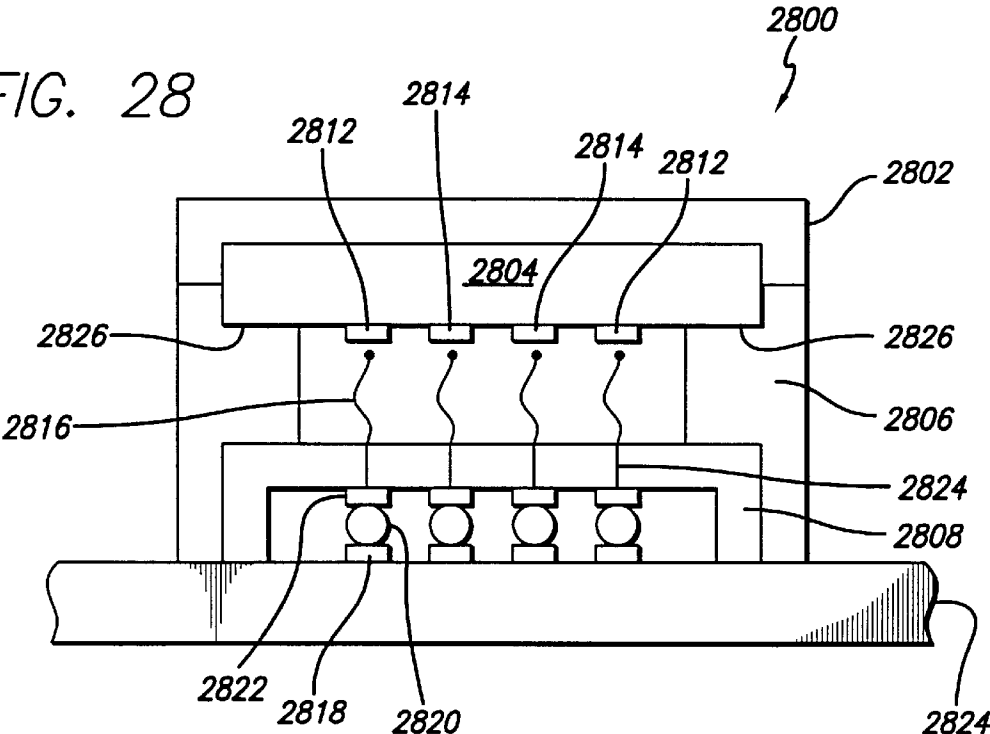


FIG. 29A

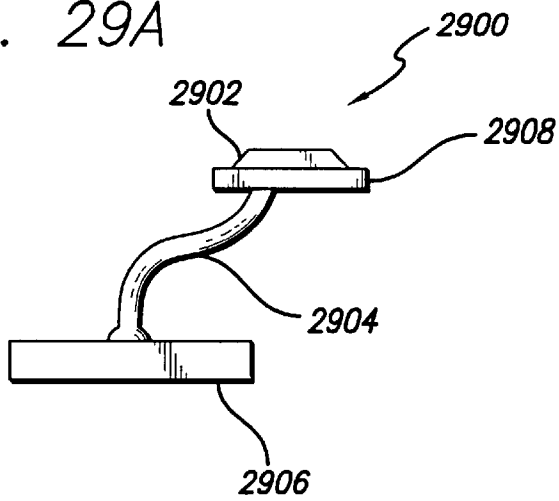


FIG. 29B

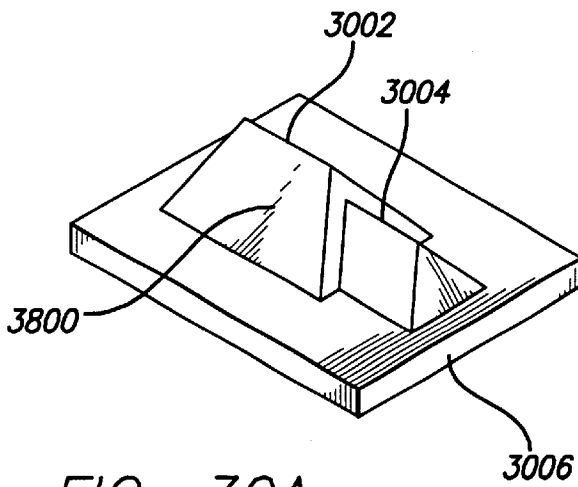
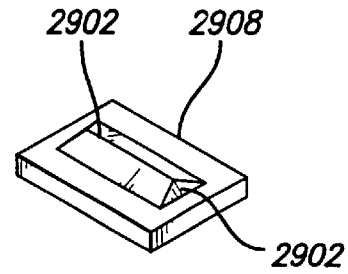


FIG. 30A

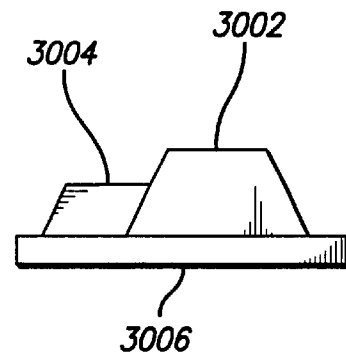
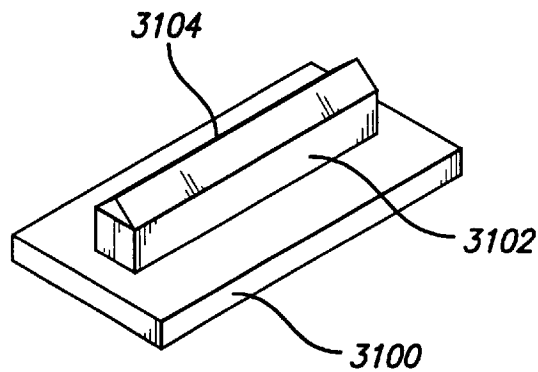


FIG. 30B

FIG. 31



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SPECIAL CONTACT POINTS FOR ACCESSING INTERNAL CIRCUITRY OF AN INTEGRATED CIRCUIT

This is a divisional application of Ser. No. 09/224,169, 5
filed Dec. 31, 1998.

FIELD OF THE INVENTION

The present invention relates to integrated circuit (IC) 10
semiconductor devices and, more particularly, to testing the
devices.

BACKGROUND

Large numbers of identical integrated circuits such as 15
microprocessors, memory devices, and digital signal pro-
cessing devices are generally fabricated on a silicon wafer.
Due to defects that may occur during fabrication, each IC
(die) on the wafer is typically tested or sorted by test
equipment such as automatic test equipment (ATE) 20
machines and probe cards. The test signals are provided to
each die through input or input/output (I/O) bond pads on
each die, and the test results are monitored on output or I/O
bond pads. The good die that pass the wafer-level test are
then singulated and packaged typically by electrically con- 25
necting the bond pads to the package by means of bond
wires, solder balls, or other contact structures. To accom-
modate the bonding wires or solder balls, the bond pads are
generally very large relative to the circuit elements of the
integrated circuit. Typical bond pad sizes are on the order of
100 μm (microns) \times 100 μm (4 mils \times 4 mils). The bond pads
are also typically aligned in regular patterns such as periph-
erally along the outside perimeter of the die, in a grid
pattern, or in a column or row generally through the center
of the die (lead-on-center).

The bond pads allow each die as a whole to be function- 30
ally tested for specified timing parameters (AC parameters),
DC parameters, and overall operation. The bonding pads
may also be used to load test patterns and monitor test result
from on-chip test circuits such as SCAN circuitry and
Built-In Self-Test (BIST) circuitry. The on-chip test circuits
enhance the overall testing of a die by enabling individual
testing of internal circuits or nodes. However, this comes at
the expense of increasing the size of the die to accommodate
the added test circuitry and additional bond pads needed to
support the on-chip test circuitry.

If a die already has all of its peripheral, grid, or lead-on-
center bond pad locations dedicated to a device function,
then adding additional bond pads in the predetermined bond
pad alignment to support the on-chip testing circuitry can
result in a substantial increase in the size of the die. 50
Generally, larger die are more prone to defects and conse-
quently more expensive to manufacture. Additionally,
on-chip testing circuitry can result in a significant increase
in test time as many clock cycles may be required to load test
input data and subsequently output test results from a few
available bond pads. On-chip testing circuitry also does not
allow for direct external access to internal circuit nodes. Test
input data and test results must pass through the SCAN
circuitry or BIST circuitry before it can be monitored. This
introduces additional circuits that can mask failures in the
circuit intended to be tested, or can introduce new failures
caused by SCAN or BIST circuitry.

Additionally, many designs are I/O limited since only a
limited number of leads (e.g., bond wires) may be accom- 65
modated in a given packaging scheme. Moreover, to test I/O
functionality of a chip, these same lead locations must be

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used. It would be advantageous to access more points in a
circuit, especially for testing. It would also be advantageous
if the access points could be located with a high degree of
positional freedom. Small size, large number, arbitrary or
selected positioning of the access points would also be
advantageous.

SUMMARY OF THE INVENTION

One embodiment of the present invention concerns an 10
integrated circuit that includes bond pads and special contact
pads or points. The bond pads are for interfacing the
integrated circuit as a whole with an external circuit, and are
to be bonded to a package or circuit board. The bond pads
are disposed on the die in a predetermined alignment such as
a peripheral, grid, or lead-on-center alignment. The special
contact pads are used to provide external test patterns to
internal circuits and/or to externally monitor results from
testing the internal circuits. The special contact pads may be
advantageously located on the integrated circuit with a high 20
degree of positional freedom. For one embodiment, the
special contact pads may be disposed on the die at a location
that is not in the same alignment as the bond pads. The
special contact pads may be smaller than the bond pads so
as not to increase the die size due to the special contact pads.
25 The special contact points may also be used to externally
program internal circuits (e.g., nonvolatile circuits) at the die
or package level. The special contact points may also be
used to select redundant circuits for faulty circuits.

Other objects, features, and advantages of the present 30
invention will be apparent from the accompanying drawings
and from the detailed description which follows below.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention are 35
illustrated by way of example and are by no means intended
to limit the scope of the present invention to the particular
embodiments shown, and in which:

FIG. 1 is a plan view of one embodiment of an integrated
circuit having peripheral bond pads, internal circuitry, and
special contact pads disposed about internal circuitry and for
testing the internal circuitry;

FIG. 2 is a plan view of one embodiment of an integrated
circuit having peripheral bond pads, internal circuitry, and
special contact pads collectively disposed in a separate 45
region of the integrated circuit;

FIG. 3A is a plan view of one embodiment of an inte-
grated circuit, internal circuitry, and special contact pads
disposed over the internal circuitry;

FIG. 3B is a logic diagram of one embodiment of a special
contact pad coupled to an internal circuit node via a bidi-
rectional buffer;

FIG. 4 is a plan view of one embodiment of an integrated
circuit having bond pads aligned in a grid pattern, special
contact pads not aligned in the grid pattern, and special
contact pads aligned in the grid pattern;

FIG. 5 is a side cross-sectional view of a special contact
pads disposed between two bond pads;

FIG. 6 is a plan view of one embodiment of an integrated
circuit having lead-on-center bond pads, internal circuitry,
and special contact pads for testing the internal circuitry;

FIG. 7 is a block diagram of one embodiment of sequen-
tial circuit blocks and special contact pads for testing the
sequential circuits;

FIG. 8 is a block diagram one embodiment of using
special contact pads to isolate a faulty circuit block and
enable a redundant circuit block;

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FIG. 9 is a circuit diagram of one embodiment of the switch of FIG. 8;

FIG. 10 is a block diagram of another embodiment of using special contact pads to isolate a faulty circuit block and enable a redundant circuit block;

FIG. 11 is a block diagram of one embodiment of using a special contact pad to enable or stimulate a circuit under test;

FIG. 12 is a block diagram of one embodiment of using a special contact pad to provide a control signal to scan circuitry;

FIG. 13 is a side cross-sectional view of one embodiment of a probe card assembly having a probe card with cantilevered probes for probing bond pads and special contact pads of an integrated circuit;

FIG. 14 is a plan view of the probe card of FIG. 13;

FIG. 15 is a side cross-sectional view of one embodiment of a probe card assembly having a membrane probe card with contacts for probing bond pads and special contact pads of an integrated circuit;

FIG. 16 is a plan view of the membrane probe card of FIG. 15 having contact balls aligned in a grid pattern for contacting bond pads, and having contact balls not aligned in the grid pattern for contacting special contact pads;

FIG. 17 is a plan view of the membrane probe card of FIG. 15 having contact balls aligned in a peripheral pattern for contacting bond pads, and having contact balls not aligned in the peripheral pattern for contacting special contact pads;

FIG. 18 is a side cross-sectional view of another embodiment of a probe card assembly having a COBRA-style probe card assembly with probes for probing bond pads and special contact pads of an integrated-circuit;

FIG. 19 is a plan view of the COBRA-style probe tips of FIG. 18 having some tips aligned in a grid pattern to contact bond pads, and having other tips not aligned in the grid pattern to contact special contact pads;

FIG. 20 is a plan view of the COBRA-style probe tips of FIG. 18 having some tips aligned in a peripheral pattern to contact bond pads, and having other tips not aligned in the peripheral pattern to contact special contact pads;

FIG. 21 is a side cross-sectional view of one embodiment of a probe card assembly having spring contact elements for probing bond pads and special contact pads of an integrated circuit;

FIG. 22 is another embodiment of the probe card assembly of FIG. 21 in which the spring contact elements, the bond pads, and the special contact pads have varying heights;

FIG. 23 is another embodiment of the probe card assembly of FIG. 21 in which the spring contact elements are disposed on the integrated circuit;

FIG. 24 is a side cross-sectional view of one embodiment of a spring contact element of FIG. 21;

FIG. 25 is a perspective view of one embodiment of the contact tip structure and pyramid-shaped contact feature of the spring contact element of FIG. 21;

FIG. 26 is a perspective view of one embodiment of the pyramid shaped contact tip structure of FIG. 25;

FIG. 27 is a side cross-sectional view of another embodiment for performing wafer-level test of an integrated circuit having bond pads and special contact pads;

FIG. 28 is a side cross-sectional view of one embodiment of a socket for retaining a package having special contact points and conventional input, output, and input/output pins;

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FIG. 29A is a side cross-sectional view of another embodiment of a spring contact element;

FIG. 29B is a perspective view of the spring contact element of FIG. 29A;

FIG. 30A is a perspective view of another embodiment of a spring contact element;

FIG. 30B is a side cross-sectional view of the spring contact element of FIG. 30A; and

FIG. 31 is a perspective view of another embodiment of a tip structure for a spring contact element.

DETAILED DESCRIPTION

FIG. 1 shows an integrated circuit or die 100 that includes bond pads 110, special contact pads 112, and internal circuits 102, 104, 106 and 108. Internal circuits 102–106 may be any circuit blocks such as memory, control logic, programmable logic, and the like. Bond pads 110 are conventional input, output, or I/O pads for electrically interfacing internal circuits 102–108 with circuits external to integrated circuit 100. Bond pads 110 are peripherally disposed about the perimeter of integrated circuit 100, and are typically large enough to accommodate a probe tip of a probe of wafer sort probe card, a bond wire, or a solder ball.

Special contact pads 112 provide a means for providing test input data to, and monitor signals from, internal circuits 102–106 without having to test the function of the entire integrated circuit. Special contact pads 112 also provide a means for testing internal circuits 102–106 when these circuits are not otherwise individually testable and/or accessible through bond pads 110. For one example, internal circuit 102 may be an embedded memory that is not directly accessible through bond pads 110. Address and input data signals may be provided over several of the special contact pads 112 to provide test patterns to the embedded memory, and another group of special contact pads 112 may receive data read from the memory. The external circuitry providing the test patterns for the embedded memory may provide any number of patterns to increase the fault coverage.

For another embodiment, internal circuit 102 may be a programmable circuit such as nonvolatile memory or programmable logic. Data can be programmed into the internal circuit through the special contact pads 112. For example, BIOS information, program code, and system software may be programmed or updated in programmable circuit 102 after fabrication of integrated circuit 100.

On-chip test circuitry such as SCAN and BIST circuitry may not be required in integrated circuit 100 as test stimuli for integrated circuits 102–106 may be provided directly to special contact pads 112. Additionally, test results may be output to special contact pads 112 rather than bond pads 110. The external test circuitry supplying the test stimuli may provide an increased number of tests without impacting the size of integrated circuit 100. Without SCAN or BIST circuitry included in a test input or output signal path, the likelihood of more accurately determining the location of a failure increases as there is no on-chip test circuitry to mask the failure or to introduce further failures. Additionally, speed parameters or the timing of signals into and out of a circuit block or a circuit node may be more accurately measured and monitored without introducing delays caused by intermediary on-chip test circuitry.

As shown in integrated circuit 100, special contact pads 112 may also work with BIST circuitry 108 (or other on-chip test circuitry) to monitor the response of internal circuit 106 to test stimuli provided by BIST 108. This can be accom-

plished without having to add additional bond pads **110**, or to use existing bond pads **110** to communicate with BIST **108**.

As shown in FIG. 1, special contact pads **112** are disposed within a region surrounded by peripheral bond pads **110**. As special contact pads **112** are not disposed in the predetermined peripheral alignment of bond pads **110**, the size of integrated circuit **100** may not be increased by adding special contact pads **112**. For other embodiments, the number and placement of special contact pads **112** may increase the size of integrated circuit **100**.

Special contact pads **112** may also be interspersed between bond pads **110** (e.g., see FIG. 5), or be located outside the region surrounded by bond pads **110**. For one embodiment in which special contact pads **112** are interspersed between bond pads **110**, it may be advantageous for special contact pads **112** to be smaller than bond pads **110** so as not to increase the size of integrated circuit **100**.

Special contact pads **112** may be any size including sizes smaller than bond pads **110**. When special contacts **112** are smaller than bond pads **110**, more special test pads may be disposed on integrated circuit **100** without increasing the size of the die over that defined by the peripheral bond pads **110**. A larger number of special contact pads may increase the number and/or complexity of tests that can be provided to the internal circuit, and thus may increase the fault coverage and robustness of tests. For one embodiment, a bond pad **110** may be approximately $100\ \mu\text{m} \times 100\ \mu\text{m}$, and a special contact pad may be approximately 5 to 10 μm per side. In other embodiments, the special contact pad may be less than 5 μm per side. For still other embodiments, the special contact pads may be manufactured to have different sizes to accommodate their different spatial locations on the die (e.g., between bond pads **110** vs. within the area surrounded by bond pads **110**), to accommodate different dimensions of various probe tips, bond wires, or solder balls, or to accommodate different functions of the circuits under test (i.e., nodes driving output signals may require larger pads than pads for providing input signals, or vice versa). The lower limit for the size of the special contact pads may be limited by the accuracy of the probe-to-pad alignment and the size of the probe.

Special contact pads **112** may be formed into an approximately square shape, rectangular shape, or any other geometric shape. Special contact pad **112** may also have different heights than bond pads **110**. Special contacts pads **112** may be fabricated using conventional photolithography processes that are typically used to create bond pads or other, relatively flat, conductive landings. For one embodiment, the special contact pads may be fabricated from one or more metal layers including aluminum, copper, gold, or other metals or conductive materials.

Integrated circuit **100** shows that special contact pads **112** are logically disposed about the circuit block which they test. In alternative embodiments, special contact pads **112** may be physically located at any other location in integrated circuit **100**. FIG. 2 shows that special contact pads **112** need not be logically disposed about internal circuits **102** and **106**, but may be physically located in region **202**. For alternative embodiments, the special contact pads **112** may be located in any area of integrated circuit **100**.

FIGS. 1 and 2 show that special contact pads **112** may be used to test or monitor signals from an internal circuit block. FIG. 3A shows that the special contact pads may also be disposed directly over internal circuits **102–106** to monitor or excite a particular circuit node within an internal circuit

block. For example, a speed critical path within an embedded memory block or other circuit may be monitored. Alternatively, the voltage level on an internal circuit node or of an internally generated reference voltage source may be monitored.

Special contact pads **112** may not be permanently bonded out to a integrated circuit package (e.g., typical plastic and ceramic chip packages), rather, the special contact pads may be used for receiving test input information (e.g., address, control, or data) or monitoring internal test nodes or signals. The special contact pads are large enough, however, to receive an electrical contact element (as will be described in more detail below). Given that special contact pads **112** are generally not bonded out to a package, special contacts pads **112** may require significantly less supporting circuitry than is typically required by bond pads **110**. Typical bond pads generally include supporting circuitry that requires significant amounts of silicon die area. Examples of supporting circuitry include electrostatic-discharge (ESD) protection structures such as resistors, capacitors, and/or diodes, latch-up prevention circuits such as guard rings, buffers for driving circuits and signal lines external to the integrated device or for buffering internal signals received from external signal lines, logic or voltage translation circuits, and noise reduction circuitry. Special contact pads **112** may reduce the amount of supporting circuitry required. Little or no ESD protection may be needed and little or no buffering may be required for an external probe to electrically contact a special contact pad and monitor a signal thereon. For one example, an I/O buffer **120** may be used between an internal test point **124** and a special contact pad **110** as shown in FIG. 3B. The I/O buffer may be controlled by a control signal **122**. The I/O buffer **120** may be approximately 10 to 100 times weaker than that required for a bond pad having to drive heavy loads in a PCB environment. Additionally, little or no latch-up supporting circuitry or noise reduction circuitry may be required. For example, a weak pull-up resistor may be all that is required for each special contact pad for noise reduction circuitry. Generally, a special contact pad may require only 1 to 50 percent of the supporting circuitry typically required for a bond pad.

FIG. 4 shows an integrated circuit **400** that includes bond pads **410** aligned in a Land Grid Array (LGA) pattern for bonding to contact balls (e.g., solder or other metal interconnect) in a control collapse chip connection (C4) or flip-chip arrangement. Selectively dispersed within and outside of the grid pattern are special contact pads **412** that, as in FIGS. 1–3, may be used to provide test signals to or monitor signals from internal circuits of integrated circuit **400**. In this embodiment, special contact pads **412** may be smaller than the bond pads or contact balls so as not to increase the size of integrated circuit **400** over the minimum size required for a given number of bond pads **410**. In alternative embodiments, the special contact pads **412** may be the same size as bond pads **410**.

FIG. 5 shows a side cross-sectional view of a special contact pad **412** disposed between two bond pads **410**. Bond pads **410** have contact balls **504** formed thereon, and are typically spaced with a minimum pitch **502** between their centers of approximately 10 mils (0.010") or 250 μm . The minimum diameter **508** of the contact balls **504** is typically on the order of the 1 to 3 mils, and the minimum distance **506** between the edges of contact balls **504** is typically on the order of 7 to 9 mils. Special contact pad **412** can be sized to fit between bond pads **410**, and may have a width **510** of less than 9 mils. For other embodiments, special contact pad **412** may have a width of approximately 1 to 5 mils. For still

other embodiments, special contact pad **412** may have a width of less than 1 mil. Special contact pad **412** may be formed into an approximately square shape, rectangular shape, or any other geometric shape. Special contact pad **412** may also have a height different than that of bond pads **410**.

For an alternative embodiment, contact balls **504** need not be formed on bond pads **410**.

The embodiments shown in FIGS. **4** and **5** may also be a LGA package such as Ball Grid Array (BGA) package, Pin Grid Array (PGA) package, C4 package, or flip chip package that has pins or contact balls **410** for interfacing with a socket or printed circuit board (PCB). Special contact pads **412** may be additional pins or pads that can receive test signals or provide test output signals or other signals to probes, a socket, or PCB.

FIG. **5** also illustrates a special contact pad **412** disposed between two bond pads **410** arranged in a peripheral alignment (as shown in FIG. **1**).

FIG. **6** shows an integrated circuit **600** that includes bond pads **610** arranged as a column (or row) in a lead-on-center pattern. Selectively dispersed within and outside of the lead-on-center pattern are special contact pads **612** that, as in FIGS. **1-5**, may be used to provide test signals to or monitor signals from internal circuits **602** and **604** of integrated circuit **600**.

FIGS. **1-6** show that internal circuit blocks or circuit nodes can be tested or monitored by special contact pads. FIG. **7** shows that sequential internal circuit blocks **702**, **704**, and **706** can also be tested by special contact pads with or without the use of bond pads. In this embodiment, test input data is provided on special contact pads **712** to an embedded memory **702**. For an alternative embodiment, the input data can be provided from bond pads. The test data may include an address, control signals (e.g., read, write, etc.), and/or a test pattern. Assuming that the test data is an address of a location within memory **702**, data stored at the accessed address may be provided to I/O interface **704** and monitored by special contact pads **713**. The access time (i.e., address to data out) of memory **702** may be more accurately measured by special contact pads **712** and **713** as no additional time is introduced due to circuit blocks such as I/O interface **704** and I/O drivers **706**. Conventional approaches of using BIST circuitry would typically include additional on-chip circuitry to provide address signals, for example, to memory **702**, and then external circuitry could monitor the results at one or more of bond pads **716**. This conventional approach, however, would be unable to monitor the outputs of memory **702** directly (as with special contact pads **713**) and thus would not be able to directly measure the actual access time of memory **702**.

In response to the data read from memory **702**, I/O interface **704** may format the data prior to providing it to I/O drivers **706**. I/O interface **704** may receive control signals on special contact pads **714**, or internal circuit nodes within I/O interface **704** may be monitored by special contact pads **714**. The data output by I/O interface **704** to I/O drivers **706** may be monitored via special contact pads **715**. I/O drivers **706** may then drive the data to bond pads **716**.

Since special contact pads **713** and **715** and bond pads **716** may be used to monitor the output of each of memory **702**, I/O interface **704**, and I/O drivers **706**, respectively, such that incorrect data received at bond pads **716** can be isolated to the circuit which caused the failure. In conventional BIST techniques in which an address, for example, is provided to memory **702**, the source of incorrect data received at bond pads **716** would be unknown.

While the embodiment shown in FIG. **7** includes a specific example of accessing data in an embedded memory **702**, the example also applies to introducing and monitoring signals from a series of any other circuit blocks.

Special contact pads may also be used to not only isolate failures, but to also enable redundant circuits to be used to replace faulty circuits. FIG. **8** shows one embodiment of using special contact pads to identify faulty circuit blocks and enable a redundant circuit to replace the faulty circuit block. This embodiment again uses the example of accessing data in an embedded memory, but can be extended to a series of circuits in which one of the circuits has a redundant circuit.

FIG. **8** includes a redundant I/O interface **705** that can replace a defective I/O interface **704**. The outputs of memory **702** are provided to both of I/O interfaces **704** and **705**. The outputs of I/O interface **704** can be monitored through special contact pads **715**, and the outputs of redundant I/O interface **705** can be monitored through special contact pads **717**. If the outputs of I/O interface **704** are as expected indicating that I/O interface **704** is operating correctly, multiplexer **708** is configured by the control signal on line **721** to allow the signals on lines **723** to be provided to I/O drivers **706**. If, however, the outputs of I/O interface **704** are not as expected indicating that I/O interface **704** is malfunctioning, and the outputs of redundant I/O interface **705** are as expected, then multiplexer **708** is configured by the control signal on line **721** to allow the signals on lines **725** to be provided to I/O drivers **706**. The signals output by multiplexer **708** may be monitored via special contact pads **719**.

The control signal on line **721** can be driven to the appropriate voltage level or logic state by switch **710**. In response to a TOGGLE signal, either voltage **V1** or **V2** will be selected in response to monitoring the signals at the special contact pads **717** and **715**. The TOGGLE signal can be controlled by another special contact pad (not shown).

FIG. **9** shows switch **910** that is one embodiment of switch **710** of FIG. **7**. Other embodiments of switch **710** may also be used. Switch **910** includes a PMOS transistor biased into an on-state by having its gate coupled to ground, its source coupled to a power supply **VDD**, and its drain coupled to signal line **721**. Switch **910** also includes a fuse element **904** that is coupled between signal line **721** and ground. The fuse element may be a metal fuse, resistive fuse, or memory element. When fuse **904** is blown in response to the TOGGLE signal, signal line **721** is pulled towards **VDD** and the signals on lines **725**, for example, are output by multiplexer **708**. When fuse **904** is not blown, signal line **721** is pulled towards ground by fuse **904** and the signals on lines **723**, for example, are output by multiplexer **708**. Fuse **904** may be blown using several well-known techniques including using a laser pulse or electrical currents. For one embodiment, a special test pad may be used to provide an electrical current that blows fuse **904**.

FIG. **10** shows an alternative embodiment of the redundancy scheme of FIG. **8**. In FIG. **10**, groups of fuses **1002**, **1004**, **1006**, and **1008** may be included before and after the I/O interfaces. When one of the I/O interface is identified as defective it may be isolated by an appropriate fuse group. For example, if I/O interface **704** is defective and I/O interface **705** is functioning correctly, then fuse groups **1004** and **1008** may be blown so as to isolate I/O interface **704**. The fuse groups **1004** and **1008** may be blown via special contact pads (not shown) that provide one or more signals that cause a large amount of current to flow through fuse

groups **1004** and **1008**. Alternative means to blow the fuses may also be used.

As discussed above with respect to FIG. 1, special contact pads can be used together with on-chip test circuitry to test an integrated circuit. FIG. 11 shows one embodiment in which one (or more) special contact pad **1110** is used to provide a dock signal, reset signal, enable signal, or other control signal to BIST **1102**. In response, BIST **1102** provides one or more test signals to internal circuit **1104** and/or internal circuit **1106**. The results of the internal test may then be monitored at bond pads **1108** (or alternatively at other special contact pads). For other embodiments, a special contact pad may also be used to provide an enable signal or a clock signal to any other internal circuit.

Similarly, as shown in FIG. 12, one (or more) special contact pad **1210** may be used to provide a dock signal, reset signal, enable signal, or other control signal to shift register elements **1206** and **1208** of a SCAN circuit. The SCAN circuit may be coupled between bond pads **1212** and **1214** (or, alternatively, one or more special contact pads) that may receive SCAN input data (SI), and provide SCAN output data (SO), respectively.

For an alternative embodiment, one or both of pads **1212** may be special contact pads. This may provide for increased design flexibility in the location and use of SCAN circuitry. For example, this may enable multiple SCAN regions or circuits of varying size and complexity to test various different internal circuits or blocks of circuits.

When the special contact pads are available on a die of a wafer, test signals may be supplied to special contact pads, or signals may be monitored at the special contact pads by means of test or probe card assemblies. Probe card assemblies typically include a probe card that has a number of probe elements or contact structures to contact the special contact pads and bond pads. A host controller or other logic device typically communicates with the integrated circuit under test through the probe card.

FIG. 13 illustrates one embodiment of an test system **1300** for performing a wafer-level sort test of a die **1311** that includes bond pads **1314** and special contact pads **1316**. Die **1311** is formed on wafer **1312** that may be disposed on a suitable support structure such as a vacuum chuck (not shown). Die **1311** may embody an integrated circuit such as integrated circuit **100** of FIG. 1.

System **1300** includes a test head **1304** and a probe card assembly **1313**. Probe card assembly **1313** includes a load board or interconnection substrate **1306** and cantilevered or needle probe card **1310**. Host **1302** communicates test signals with test head **1304**. Any type of host may be used including a personal computer, or specialized machines such as Automatic Test Equipment (ATE) provided by LTX, Credence, Teradyne, and others. Test head **1304** typically includes drivers, receivers, and parametric measuring units (PMUs) that communicate signals with load board **1306** and probe card **1310**. Load board **1306** is typically a PCB that provides the appropriate mechanical interconnection and load circuits for probe card **1310**. In alternative embodiments, load board **1310** may be omitted. Load board **1310** may also include control logic such as logic **1308**. Control logic **1308** may be an application-specific IC (ASIC) used to provide tests to die **1311** under the control of host **1302**.

Probe card **1310** is a cantilevered or needle probe card that includes cantilevered probes **1318** and **1320** that provide signals to and receive signals from die **1311**. Probes **1318** and **1320** may comprise any suitable conductive material

including tungsten. As shown in the plan view of probe card **1310** in FIG. 14, probes **1318** and **1320** are connected to contact pins or points **1322** that contact load board **1306** or test head **1304**.

Probes **1318** are provided in a predetermined alignment to contact bond pads **1314**. As shown in FIG. 14, probes **1318** make a relatively rectangular shape. Probes **1320** are provided to contact special contact pads **1316** of die **1311**. Probes **1320** are generally not disposed in the same predetermined alignment of the probes **1318**; rather, they extend into the region surrounded by probes **1318** (and bond pads **1314**). In alternative embodiments, probes **1320** may exist outside of the region surrounded by probes **1318**, or they may be disposed in the same predetermined alignment with probes **1318** and bond pads **1314**.

In another embodiment, probes **1318** may be arranged in a lead-on center arrangement to align with lead-on-center bond pads on a die, and probes **1320** may be arranged outside the lead-on-center arrangement to align with corresponding special contact pads.

While FIGS. 13 and 14 show that a single probe card and probe card assembly may be used to communicate with special contact pads **1316** and bond pads **1314**, in alternative embodiments, separate probe cards may be used for probing special contact pads **1316** and bond pads **1314**. That is, one or more probe cards may be used to contact only bond pads **1314** with one or more of probes **1318** and one or more additional probe cards may be used to contact special contact pads **1316** with one or more probes **1320**. In still other embodiments multiple probe cards may be used that have a mixture of probes **1318** and **1320**.

For an alternative embodiment, bond pads **1316** and special contact pads **1316** may be of different heights. For example, bond pads **1314** may be taller than special contact pads **1316** (or vice versa). For this embodiment, probes **1318** and **1320** may extend to different depths. That is, probes **1320** may extend lower than probes **1318** to make contact with special contact pads **1316**.

FIG. 15 illustrates test system **1500** that is another embodiment for performing a wafer-level sort test of a die **1511** that includes bond pads **1514** and special contact pads **1516**. Die **1511** is formed on wafer **1512** that may be disposed on a suitable support structure such as a vacuum chuck (not shown). Die **1511** may embody an integrated circuit such as those described with respect to FIGS. 1-6.

System **1500** includes a test head **1504** and a probe card assembly **1513**. Probe card assembly **1513** includes a load board or interconnection substrate **1506** and membrane probe card **1510**. Like host **1302** of FIG. 13, host **1502** communicates test signals with test head **1504**. Test head **1504** typically includes drivers, receivers, and parametric measuring units (PMUs) that communicate signals with load board **1506** and probe card **1510**. Load board **1506** is a PCB that typically provides the appropriate mechanical interconnection and load circuits for probe card **1510**. In alternative embodiments, load board **1510** may be omitted. Load board **1510** may also include control logic such as logic **1508**. Control logic **1508** may be an ASIC used to provide tests to die **1511** under the control of host **1502**.

Probe card **1510** is a membrane probe card that includes contact balls **1518** and **1520** that provide signals to and receive signals from die **1511**. Contact balls or probes **1518** and **1520** may comprise any suitable conductive material including solder.

Probes **1518** are provided in a predetermined alignment to contact bond pads **1514**. As shown in FIG. 16, probes **1518**

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may be arranged in a grid array to contact bond pads **1514** arranged in a corresponding grid array pattern. Probes **1520** may be aligned in the predetermined grid array, outside of the grid array pattern, or interspersed within the grid array pattern as shown in FIG. **16** to align with corresponding special contact pads **1516** on die **1511**. Alternatively, as shown in FIG. **17**, probes **1518** may be arranged in a peripheral pattern to contact bond pads **1514** arranged on die **1511** in a corresponding peripheral pattern. Probes **1520** may be aligned in the predetermined peripheral pattern, outside of the peripheral pattern, or within the peripheral pattern as shown in FIG. **17** to align with corresponding special contact pads **1516** on die **1511**. In yet another embodiment, probes **1518** may be arranged in a lead-on-center arrangement to align with lead-on-center bond pads on a die, and probes **1520** may be arranged within or outside of the lead-on-center arrangement to align with corresponding special contact pads.

While FIGS. **15–17** show that a single probe card and probe card assembly may be used to communicate with special contact pads **1516** and bond pads **1514**, in alternative embodiments, separate probe cards may be used for probing special contact pads **1516** and bond pads **1514**. That is, one or more probe cards may be used to contact only bond pads **1514** with one or more of probes **1518**, and one or more additional probe cards may be used to contact special contact pads **1516** with one or more probes **1520**. In still other embodiments, multiple probe cards may be used that have a mixture of probes **1518** and **1520**.

For an alternative embodiment, bond pads **1516** and special contact pads **1516** may be of different heights. For example, bond pads **1514** may be taller than special contact pads **1516** (or vice versa). For this embodiment, probes **1518** and **1520** may have different heights. That is, probes **1520** may extend lower than probes **1518** to make contact with special contact pads **1516**.

FIG. **18** illustrates test system **1800** that is another embodiment for performing a wafer-level sort test of a die **1811** that includes bond pads **1814** and special contact pads **1816**. Die **1811** is formed on wafer **1812** that may be disposed on a suitable support structure such as a vacuum chuck (not shown). Die **1811** may embody an integrated circuit such as those described with respect to FIG. **1–6**.

System **1800** includes a test head **1804** and a COBRA-style probe card assembly **1813**. The COBRA-style probe card assembly is available from Wentworth Laboratories of Brookfield CT. The COBRA-style probe card assembly includes a load board or interconnection substrate **1806**, space transformer (either wired or ceramic) **1808**, and head assembly **1807**. Head assembly **1807** includes upper plate **1809**, spacer **1810**, lower plate **1811**, and COBRA-style probes **1818** and **1820**. Like host **1302** of FIG. **13**, host **1802** communicates test signals with test head **1804**. Test head **1804** typically includes drivers, receivers, and parametric measuring units (PMUs) that communicate signals with load board **1806** and probe card assembly **1813**. Load board **1806** is a PCB that typically provides the appropriate mechanical interconnection and load circuits for probe card assembly **1813**. In alternative embodiments, load board **1810** may be omitted. Load board **1810** may also include control logic to provide tests to die **1811** under the control of host **1802**.

Probes **1818** are provided in a predetermined alignment to contact bond pads **1814**. As shown in FIG. **19**, probes **1818** may be arranged in a grid array to contact bond pads **1814** aligned in a corresponding grid array pattern. Probes **1820** may be arranged with the predetermined grid array, outside

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of the grid array pattern, or interspersed within the grid array pattern as shown in FIG. **19** to align with corresponding special contact pads **1816** on die **1811**. Alternatively, as shown in FIG. **20**, probes **1818** may be arranged in a peripheral pattern to contact bond pads **1814** arranged on die **1811** in a corresponding peripheral pattern. Probes **1820** may be aligned in the predetermined peripheral pattern, outside of the peripheral pattern, or within the peripheral pattern as shown in FIG. **20** to align with corresponding special contact pads **1816** on die **1811**. In yet another embodiment, probes **1818** may be arranged in a lead-on-center arrangement to align with lead-on-center bond pads on a die, and probes **1820** may be arranged within or outside of the lead-on-center arrangement to align with corresponding special contact pads.

While FIGS. **18–20** show that a single probe card assembly may be used to communicate with special contact pads **1816** and bond pads **1814**, in alternative embodiments, separate probe card assemblies may be used for probing special contact pads **1816** and bond pads **1814**. That is, one or more probe card assemblies may be used to contact only bond pads **1814** with one or more of probes **1818**, and one or more additional probe card assemblies may be used to contact special contact pads **1816** with one or more probes **1820**. In still other embodiments, multiple probe card assemblies may be used that have a mixture of probes **1818** and **1820**.

For an alternative embodiment, bond pads **1816** and special contact pads **1816** may be of different heights. For example, bond pads **1814** may be taller than special contact pads **1816** (or vice versa). For this embodiment, probes **1818** and **1820** may extend to different depths (or have different heights). That is, probes **1820** may extend lower than probes **1818** to make contact with special contact pads **1816**.

FIG. **21** illustrates test system **2100** that is another embodiment for performing a wafer-level sort test of a die **2111** that includes bond pads **2114** and special contact pads **2116**. Die **2111** is formed on wafer **2112** that may be disposed on a suitable support structure such as a vacuum chuck (not shown). Die **2111** may embody an integrated circuit such as those described with respect to FIGS. **1–6**.

Apparatus **2100** includes a test head **2104** and a probe card assembly **2113** such as that provided by FormFactor, Inc. of Livermore, Calif. One embodiment of probe card assembly **2113** is disclosed in U.S. patent application Ser. No. 08/789,147 filed on Jan. 24, 1997, which is incorporated by reference herein. Probe card assembly **2113** generally includes probe card **2106**, interposer **2108**, space transformer **2108**, and spring contact elements **1218** and **1220**. Like host **1302** of FIG. **13**, host **2102** communicate test signals with test head **2104**. Test head **2104** typically includes drivers, receivers, and parametric measuring units (PMUs) that communicate signals with probe card assembly **2113**. Probe card assembly **2113** may also include control logic to provide tests to die **2111** under the control of host **2102**.

Spring contact elements **2118** are formed in a predetermined alignment to contact bond pads **2114**. Probes **2118** may be arranged in a grid array to contact bond pads **2114** aligned in a corresponding grid array pattern. Spring contact elements **2120** may be arranged with the predetermined grid array, outside of the grid array pattern, or interspersed within the grid array pattern to align with corresponding special contact pads **2116** on die **2111**. Alternatively, spring contact elements **2118** may be arranged in a peripheral pattern to contact bond pads **2114** arranged on die **2111** in a corre-

sponding peripheral pattern. Spring contact elements **2120** may be aligned in the predetermined peripheral pattern, outside of the peripheral pattern, or within the peripheral pattern to align with corresponding special contact pads **2116** on die **2111**. In yet another embodiment, spring contact elements **2118** may be arranged in a lead-on-center arrangement to align with lead-on-center bond pads on a die, and spring contact elements **2120** may be arranged within or outside of the lead-on-center arrangement to align with corresponding special contact pads.

While FIG. **21** shows that a single probe card assembly may be used to communicate with special contact pads **2116** and bond pads **2114**, in alternative embodiments, separate probe card assemblies may be used for probing special contact pads **2116** and bond pads **2114**. That is, one or more probe card assemblies may be used to contact only bond pads **2114** with one or more of spring contact elements **2118**, and one or more additional probe card assemblies may be used to contact special contact pads **2116** with one or more spring contact elements **2120**. In still other embodiments, multiple probe card assemblies may be used that have a mixture of spring contact elements **2118** and **2120**.

For an alternative embodiment, bond pads **2116** and special contact pads **2116** may be of different heights. For example, as shown in FIG. **22**, bond pads **2114** may be taller than special contact pads **2116** (or vice versa). For this embodiment, probes **2118** and **2120** are extended to different depths (or have different heights). That is, probes **2120** may extend lower than probes **2118** to make contact with special contact pads **2116**.

For an alternative embodiment, as shown in FIG. **23**, spring contact elements **2118** and **2120** may be attached to bond pads **2114** and special contact pads **2116** on die **2111**. For this embodiment, space transformer **2110** may include pads **2120** to make contact with the spring contact elements **2118** and **2120**. For yet another embodiment, some of the spring contact elements **2118** or **2120** may be attached to space transformer **2110** and some may be attached to die **2111**.

FIG. **24** shows a side cross-sectional view of spring contact element **2400** that is one embodiment of the spring contact elements **2118** and **2120** of FIGS. **21–23**. Spring contact element **2400** includes a base **2402**, elongated resilient member **2404**, an elongated contact tip structure **2406**, and a pyramid-shaped contact feature **2408**. Many other embodiments of spring contact elements may be used including those disclosed in commonly-owned, co-pending U.S. application Ser. No. 08/526,246 filed on Sep. 21, 1995, commonly-owned, co-pending U.S. application Ser. No. 08/558,332 filed on Nov. 15, 1995, commonly-owned, co-pending U.S. application Ser. No. 08/789,147 filed on Jan. 24, 1997, commonly-owned, co-pending U.S. application Ser. No. 08/819,464 filed on Mar. 17, 1997, commonly-owned, co-pending U.S. application Ser. No. 09/189,761 filed on Nov. 10, 1998, which are all incorporated by reference herein.

Structure **2406** can be any shape. FIG. **25** shows one embodiment of structure **25** which includes a relatively wider end for contacting to member **2404**, and a relatively narrower end for supporting pyramid-shaped contact feature **2408**.

FIG. **26** shows one embodiment of pyramid-shaped contact feature **2408**. Other shapes may be used. Feature **2408** is advantageously be significantly smaller than typical tungsten probe tips of cantilevered probes and contact balls of C4 of flip-chip probe card technologies. The tip of pyramid-shaped contact feature **2408** may have a length **2414** and

width **2416** dimensions of approximately 1 to 5 μm . For alternative embodiments, **2414** and **2416** may be submicron dimensions. The small size of contact **2408** may allow for special contact pads to be smaller than bond pads. As previously discussed, when the special contact pads are smaller than the bond pads, then the special contact pads can be added to an integrated circuit without increasing the die size. Additionally, smaller special contact pads can be placed between bond pads.

FIGS. **29A** and **29B** show side and perspective views, respectively, of another embodiment of a spring contact element disclosed in U.S. application Ser. No. 09/189,761. Spring contact element **2900** is coupled to a substrate **2906** and includes an elongated resilient member **2904**, tip structure **2908**, and blade **2902**. Blade **2902** is used to make electrical contact to bond pads or special contact pads. Blade **2902** may advantageously be used to provide a good electrical connection to contacted bond or special contact pads as blade **2902** may cut, slice, or otherwise penetrate the top surface of the pad. Blade **2902** may be disposed substantially horizontally on tip structure **29A**, or in any other orientation.

FIGS. **30A** and **30B** show perspective and side views, respectively, of another embodiment of using blades on tip structures of spring contact elements. Blade **3000** is a multi-height blade disposed on tip structure **3006**. Blade **3000** has a primary blade **3002** toward the front edge of tip structure **3006**, and a trailing blade **3004** toward the back of tip structure **3006**.

FIG. **31** shows a perspective view of another blade structure formed on a tip structure **3100**. The blade of FIG. **31** is formed having a substantially rectangular base **3102** and a substantially triangular shape **3104**.

FIG. **27** illustrates test system **2700** that is another embodiment for performing a wafer-level sort test of a die **2711**. One embodiment of apparatus **2700** for testing more than one die at a time is described in commonly-owned, co-pending U.S. patent application Ser. No. 08/784,862 filed on Jan. 15, 1997, which is incorporated herein by reference.

Die **2711** includes bond pads **2714** and special contact pads **2716**. Wafer **2712** includes die **2711** and may be disposed on a suitable support structure such as vacuum chuck **2726**. Die **2711** may embody an integrated circuit such as integrated circuit **100** of FIGS. **1–6**.

System **2700** includes a support chuck **2704** and a probe card assembly or test substrate. The probe card assembly includes an interconnection substrate (base plate) **2708**, an active electronic component **2710**, and spring contact elements **2718** and **2720**. Component **2710** includes circuitry for applying test signals to, monitoring the test output from, die **2711**. For one embodiment, component **2710** may be an application-specific integrated circuit (ASIC).

Like host **1302** of FIG. **13**, host **2702** communicates test signals with the probe card assembly. For one embodiment, host **2702** communicates test signals with component **2710** via interconnection substrate **2708**. Power may be provided to component **2710** from power supply **2704**.

System **2700** also includes guide pins **2722** disposed around the periphery of wafer **2712** and the probe card assembly to ensure accurate alignment when spring contact elements **2718** and **2720** are urged into contact with bond pads **2714** and special contact pads **2716**, respectively. A compression stop (block ring) **2724**, which may be suitably disposed on the face of wafer **2712**, limits the amount of travel or distance that the tips of the spring contact elements **2718** and **2720** will deflect when urged against the pads of die **2711**.

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Spring contact elements **2718** are formed in a predetermined alignment to contact bond pads **2714**. Probes **2718** may be arranged in a grid array to contact bond pads **2714** arranged on die **2711** in a corresponding grid array pattern. Spring contact elements **2720** may be aligned in the predetermined grid array, outside of the grid array pattern, or interspersed within the grid array pattern to align with corresponding special contact pads **2716**. Alternatively, spring contact elements **2718** may be arranged in a peripheral pattern to contact bond pads **2714** arranged on die **2711** in a corresponding peripheral pattern. Spring contact elements **2720** may be arranged with the predetermined peripheral pattern, outside of the peripheral pattern, or within the peripheral pattern to align with corresponding special contact pads **2716**. In yet another embodiment, spring contact elements **2718** may be arranged in a lead-on-center arrangement to align with lead-on-center bond pads on a die, and spring contact elements **2720** may be arranged within or outside of the lead-on-center arrangement to align with corresponding special contact pads.

While FIG. **27** shows that a single probe card assembly may be used to communicate with special contact pads **2716** and bond pads **2714**, in alternative embodiments, separate probe card assemblies may be used for probing special contact pads **2716** and bond pads **2714**. That is, one or more probe card assemblies may be used to contact only bond pads **2714** with one or more of spring contact elements **2718**, and one or more additional probe card assemblies may be used to contact special contact pads **2716** with one or more spring contact elements **2720**. In still other embodiments, multiple probe card assemblies may be used that have a mixture of spring contact elements **2718** and **2720**.

For an alternative embodiment, bond pads **2716** and special contact pads **2716** may be of different heights. For example, bond pads **2714** may be taller than special contact pads **2716** (or vice versa). For this embodiment, probes **2718** and **2720** are extended to different depths (or have different heights). That is, probes **2720** may extend lower than probes **2718** to make contact with special contact pads **2716**.

For an alternative embodiment, spring contact elements **2718** and **2720** may be attached to bond pads **2714** and special contact pads **2716** on die **2711**. For this embodiment, component **2710** may include pads to make contact with the spring contact elements. For yet another embodiment, some of the spring contact elements **2718** or **2720** may be attached to component **2710** and some may be attached to die **2711**.

As previously described above, special contact pads can be disposed on a die or on packages such as Land Grid Array (LGA) packages. When special contact pads are disposed on packages or on devices arranged in a C4 or flip-chip can provide a means for supplying test signals or programming signals to the special contact pad of the die. This may be advantageous to allow, for example, field programming of packaged programmable logic device or nonvolatile devices without having to provide dedicated bonded out pins for the programming function. Additionally, embedded nonvolatile memory arrays that store program code, application software, or BIOS may be updated in the field. Special contact pads disposed on a package may also provide an advantageous means for testing a faulty device and programming redundant circuits to replace a faulty circuit as described above with respect to FIGS. **8–10**.

FIG. **28** illustrates one embodiment of solder-down (surface mount) LGA socket **2800** for mounting to a printed circuit board (PCB) substrate **2810** and for making pressure contacts to bond pads **2812** and special contact pads **2814** of

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LGA package **2804**. As used herein, the term “socket” refers to an electronic component having interconnection elements, suitable for making electrical connection to terminals or connection points of another electronic component. The socket shown in FIG. **28** is intended to permit a semiconductor package to be removably connected to a circuit board. Other embodiments of socket **2800** are disclosed in commonly-owned U.S. Pat. No. 5,772,451 which is incorporated herein by reference.

PCB **2810** has a plurality of terminals or pads **2818**, and package **2804** have a plurality of bond pads **2812** and special contact pads **2814**. Socket **2800** provides a means for electrically interconnecting terminals **2818** with pads **2812** and **2814**. Circuitry provided on PCB **2810**, or in communication therewith, may provide signals to or monitor signals from pads **2812** and **2814** through socket **2800**. For example, programmable circuitry within package **2804** may be programmed or monitored through spring contact elements **2816**, special contact pads **2814** and/or pads **2812**.

Socket **2800** includes a support substrate **2808** formed, for example, from a conventional PCB material. Support substrate **2808** includes spring contact elements **2816** formed on a top surface thereof, and pads **2822** formed on a bottom surface thereof. Spring contact elements **2816** are for contacting pads **2812** and **2814** of package **2804** when package **2804** is urged downward by a force applied to the top side of package **2804** by retaining means **2802**. Other contact elements besides spring contact elements may also be used. Support substrate **2808** also includes electrical conduits **2824** that provide an electrical interconnection between spring contact elements **2816** and pads **2822**. For an alternative embodiment, spring contact elements **2816** may be connected directly to terminals **2818**.

Contact balls (such as conventional solder balls) are disposed on the bottom surface of pads **2822**. The contact balls **2822** serve as contact structures disposed on the bottom surface of the support substrate **2808** to contact corresponding pads or terminals **2818** on PCB **2810**. Other electrical contact structures may also be used.

Socket **2800** also includes a frame **2806** that is attached to PCB **2802**. Frame **2806** includes landings **2826** to support package **2804**. Socket **2800** also includes retaining means **2802** that is disposed over frame **2826** and package **2804**. Retaining means **2802** retains package **2804** on landings **2826** such that spring contact elements **2816** remain in electrical contact with pads **2812** and **2814**. Any suitable mechanical means may be used for retaining means **2802** including, for example, a spring clip.

In the foregoing specification the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention. The specification and drawings are, accordingly, to be regarded in an illustrative rather than restrictive sense.

What is claimed is:

1. A method of testing an integrated circuit, said method comprising:

- contacting a plurality of bond pads disposed on said integrated circuit, said bond pads electrically connected to a plurality of input/output drivers on said integrated circuit, said input/output drivers electrically connected to an internal circuit formed on said integrated circuit;
- contacting a special contact pad disposed on said integrated circuit, said special contact pad electrically connected directly to said internal circuit;

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providing test data to said internal circuit through ones of said bond pads and corresponding ones of said input/output drivers, said internal circuit processing said test data and generating response data;
 sensing at ones of said bond pads said response data, said response data provided from said internal circuit to corresponding ones of said input/output drivers to said bond pads; and
 monitoring at said special contact pad said processing of said test data by said internal circuit.

2. The method of claim 1, wherein said monitoring comprises monitoring a state of a node in said internal circuit.

3. The method of claim 1, wherein said internal circuit comprises a plurality of subcircuits.

4. The method of claim 3, wherein said monitoring comprises monitoring signals between said plurality of subcircuits.

5. The method of claim 3, wherein said plurality of subcircuits comprises a memory and an input/output interface, wherein said input/output interface provides an interface between said input/output drivers and said memory.

6. The method of claim 5, wherein said monitoring comprises monitoring a signal between said memory and said input/output interface.

7. The method of claim 5, wherein said monitoring comprises monitoring a signal between said input/output interface and said input output drivers.

8. The method of claim 5, further comprising contacting a plurality of said special contact pads, wherein said monitoring comprises monitoring:

- a state of a plurality of nodes in said internal circuit,
- a plurality of signals between said memory and said input/output interface, and
- a plurality of signals between said input/output interface and said input/output drivers.

9. A method of testing an integrated circuit, said method comprising:

- contacting a plurality of bond pads disposed on said integrated circuit, said bond pads electrically connected to a plurality of input/output drivers on said integrated circuit, said input/output drivers electrically connected to an internal circuit formed on said integrated circuit;
- contacting a special contact pad disposed on said integrated circuit, said special contact pad electrically connected directly to said internal circuit;
- providing test data directly to said internal circuit through said special contact pad, said internal circuit processing said test data and generating response data; and
- sensing at ones of said bond pads said response data, said response data provided from said internal circuit to corresponding ones of said input/output drivers to said bond pads.

10. The method of claim 9, further comprising contacting a plurality of said special contact pads.

11. The method of claim 10 further comprising monitoring at least one of said plurality of special contact pads said processing of said test data by said internal circuit.

12. The method of claim 9, wherein:

- said internal circuit comprises a memory and an input/output interface,
- said test data comprises an address of a location within said memory, and
- said processing comprises providing data stored in said location to ones of said input/output bond pads through said input/output interface and corresponding ones of said input/output drivers.

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13. A method of testing an integrated circuit comprising an internal circuit, a plurality of bond pads providing electrical connections with elements external to said integrated circuit, and a plurality of input/output drivers providing electrical connections between said internal circuit and said plurality of bond pads, said method comprising:

- contacting a special contact pad disposed on said integrated circuit, said special contact pad electrically connected directly to a first subcircuit composing said internal circuit;
- providing test data to said internal circuit, said internal circuit processing said test data and generating response data;
- monitoring at said special contact pad said processing of said test data by said internal circuit;
- based on said monitoring, determining whether said first subcircuit functions as expected, and
- if said first subcircuit does not function as expected, activating a redundant subcircuit, said redundant subcircuit replacing said first subcircuit in said internal circuit.

14. The method of claim 13, wherein said activating said redundant subcircuit comprises switching a multiplexer in said internal circuit.

15. The method of claim 13, wherein said activating said redundant subcircuit comprises disconnecting said first subcircuit from said internal circuit.

16. The method of claim 15, wherein said disconnecting said first subcircuit from said internal circuit comprises severing at least one fuse interconnecting said first subcircuit to at least one other subcircuit composing said internal circuit.

17. The method of claim 13, wherein said activating said redundant subcircuit comprises providing a control signal through a special contact pad on said integrated circuit.

18. The method of claim 13, wherein said step of providing test data to said internal circuit comprises providing said test data through at least one of said bond pads.

19. The method of claim 13, wherein said step of providing test data to said internal circuit comprises providing said test data through a special contact pad electrically connected directly to said internal circuit.

20. The method of claim 19, wherein said step of providing test data to said internal circuit further comprises providing said test data through a plurality of other special contact pads electrically connected directly to said internal circuit.

21. The method of claim 13, wherein:

- said contacting step comprises contacting a plurality of said special contact pads; and
- said monitoring step further comprises monitoring at least two of said plurality of special contact pads.

22. The method of claim 13, wherein:

- said internal circuit further comprises a memory, and
- each of said first subcircuit and said redundant subcircuit comprises an input/output interface providing an interface between said memory and said input/output drivers.

23. The method of claim 22, wherein said monitoring step further comprises:

- monitoring data input into said first subcircuit from said memory; and
- monitoring data output from said first subcircuit to said input/output drivers.

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