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ANTIFUSE REROUTE OF DIES

The present invention relates generally to integrated circuits, and more particularly to integrated circuits with programmable contacts.

Known semiconductor chips incorporate packaged dies that contain a plurality
5 of contact pads. The contact pads are electrically coupled to discrete external
contact pins that extend from the die packaging for interfacing the semiconductor to
external components. While this configuration is acceptable in some applications, it
has been recognized by the present inventors that certain applications benefit where
a signal path within the chip can be rerouted to different physical locations on the
10 packaging.

Known techniques for rerouting the physical termination point on a
semiconductor chip sometimes require external components such as frames and
packages, such as those used for chip stacking. Further, some techniques are
expensive to implement, require a number of components, and take considerable
15 time to fabricate, often resulting in additional testing requirements. Depending upon
the sophistication of the process deployed, as many as eight additional steps are
required to form a complete chip with a rerouted pin. Further, the additional parts
required, the additional testing required and the production speed lost due to the
added steps all affect the cost of fabricating chips with rerouted contact pins.

20 The present invention overcomes the disadvantages of previously known
rerouting and chip stacking techniques. According to the present invention,
semiconductor chips are provided with an internally programmable routing circuit to
assign signal paths to select connection points. This allows a user to utilize the same
chip fabricating apparatus and testing devices for a number of chips that have
25 different final configurations. This technique is useful in any number of applications
including enabling and disabling select features of a chip, rerouting the contact pins to
accommodate various sockets, and relocating select contact pins such as chip
enable, or input/output lines for forming chip stacks. In a chip stack according to the
present invention, once the chips are tested, they can be programmed such that

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select signal paths line up in parallel, while other signal paths are routed to unused pin locations. The chips are then stacked piggyback, or one on top of the other, and the contact pins are electrically coupled together, thus avoiding the need for external frames and pin rerouting schemes.

5 In accordance with one embodiment of the present invention, a signal routing circuit is provided. A first signal path includes a first segment and a second segment. A logic circuit is coupled to the first segment of the first signal path, while a first connector pad is coupled to the second segment of the first signal path. A routing matrix circuit is in-line with the first signal path disposed between the first and second
10 segments. The routing matrix circuit is programmable between a first state wherein the first segment is coupled to the second segment, and a second state wherein the first segment is decoupled from the second segment. A programming circuit is coupled to the routing matrix circuit for programming the routing circuit between the first and second states. Where there is concern that the programming circuit will
15 introduce signals that may damage circuits or connectors connected to the routing matrix, it is preferable that the programming circuit be capable of isolating the routing matrix circuit from the first and second segments of the first signal path during programming.

In addition to allowing a single signal path to be programably coupled or
20 decoupled from the circuit logic, the routing matrix circuit may further include a plurality of second segments, each of the plurality of second segments independent from one another and routed to a discrete connection point. Under this arrangement, the first and second states of the routing matrix circuit are programmable between the first segment and each of the plurality of second segments so that the first segment
25 can be isolated from every one of the connectors on the second segment side of the routing matrix. Alternatively, the first segment can be programmed to be routed to one or more of the plurality of second segments to route the first segment between any number of possible physical connection positions. As an alternative to routing one internal signal to any possible combinations of physical external connections, a
30 single physical connection can be routed to any number of internal signal paths.

Under this arrangement, the first segment further comprises a plurality of first segments, each of the plurality of first segments independent from one another, and wherein the first and second states of the routing matrix circuit are programmable between each of the plurality of first segments and the second segment. Depending upon the complexity and routing options required, the first segment may further comprise a plurality of first segments, and the second segment may further comprise a plurality of second segments, wherein the routing matrix is programmable to selectively couple and decouple any of the plurality of first segments to any of the plurality of second segments.

10 The determination of routing configuration for the routing matrix may be stored using at least one antifuse. In one circuit according to the present invention, the antifuse may be disposed serially between the first and second segments of the first signal path. Under this approach, where there is a concern that the programming voltage will damage additional circuitry coupled to the antifuse, the routing matrix circuit further comprises a first programming switch positioned serially between the
15 antifuse and the first segment, the first programming switch is operatively coupled to the programming circuit and is capable of isolating the antifuse from the first segment. A second programming switch is optionally positioned serially between the antifuse and the second segment, the second programming switch operatively
20 coupled to the programming circuit and capable of isolating the second segment from the antifuse.

As an alternative to using the antifuse serially with the first signal path, the antifuse can be used as a control signal to trigger a switching matrix. Under this arrangement, the routing matrix circuit further comprises a switching matrix disposed
25 between the first and second segments of the first signal path, at least one antifuse coupled to a programming circuit, and a sensing circuit coupling the antifuse to the switching matrix. The switching matrix comprises at least one switch and can include additional logic including demultiplexors and decoders depending upon the sophistication of the rerouting required. The sensing circuit outputs at least one

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switch control signal coding the programmed state of the antifuse. This signal is used to operatively control at least one switch.

The switching matrix coupled to the antifuse sensing circuit can have a first side contact pad, a second side contact pad, and at least one switch disposed
5 between the first side contact pad and the second side contact pad, wherein the switch acts as an open circuit when the antifuse is in a first state, and the switch acts as a closed circuit when the antifuse is in a second state. The first and second states represent blown or programmed, and unblown or unprogramed states of the antifuse. Further, the contact pads can be implemented merely as connection points to either
10 side of the switching element. Further, the switching matrix may include a plurality of first side contact pads, such that the switch is programmable to selectively couple and decouple the second side contact pad to any of the plurality of first side contact pads. Alternatively, the switching matrix may include a plurality of first side contact pads and a plurality of second side contact pads. Under this arrangement, the switch is
15 programmable to selectively couple and decouple any of the plurality of first side contact pads to any of the second side contact pads.

In a second embodiment, a bare semiconductor die is formed with internally assignable contact pads. The semiconductor die comprises a logic circuit, a programmable routing matrix, a signal path coupling the logic circuit to the routing
20 matrix, and a contact pad coupled to the routing matrix. The routing matrix comprises a switching circuit programmable between a first state wherein the signal path is coupled to the contact pad, and a second state wherein the signal path is decoupled from the contact pad. The semiconductor die may optionally include a plurality of signal paths coupling the logic circuit to the routing matrix. Under this arrangement,
25 the switching circuit is programmable between the first and second states to selectively route any of the plurality of signal paths to the contact pad. Alternatively, the contact pad may further comprise a plurality of contact pads coupled to the routing matrix, and the switching circuit is programmable between the first and second states to selectively route any of the plurality of contact pads to the signal
30 path. Preferably, the contact pad further comprises a plurality of contact pads

coupled to the routing matrix, and the signal path further comprises a plurality of signal paths coupling the logic circuit to the routing matrix. Where the routing matrix receives multiple contact pads and multiple signals, the switching circuit is programmable between the first and second states selectively coupling and
5 decoupling any of the plurality of contact pads to any of the plurality of signal paths. The switching circuit may be realized using at least one antifuse. To use the antifuse in a switching capacity, the antifuse is positioned serially between the contact pad and the signal path, and a programming circuit coupled to the antifuse. As an alternative to using the antifuse as a switch, the antifuse can be used to control a
10 switch, including transistor based switches. This is realized where the routing matrix circuit further comprises a switching controller including at least one antifuse, an antifuse programming circuit coupled to the antifuse, an antifuse sensing circuit coupled to the antifuse, and at least one switch controlled by the switching controller. Further, demultiplexing, decoding and other logic circuits coupling the antifuse
15 sensing circuit to the at least one switch.

With reroutable semiconductor dies, a stacking scheme can be easily realized. A second semiconductor die can be stacked with a first semiconductor die having programable contacts. Preferably, the second semiconductor die includes at least one unused contact, not coupled to a logic circuit. The first and second
20 semiconductor dies are piggybacked and the contact pads of the dies are coupled together in parallel. Optionally, both semiconductor dies may include rerouting circuits, and unused contacts.

Reroutable contacts find numerous applications in the fabrication of memory devices wherein the memory device includes a logic circuit having an array of storage
25 cells, an address decoder coupled to the array of storage cells, and a memory controller coupled to the array of storage cells. A plurality of conductive paths are coupled to the logic circuit, wherein the plurality of conductive paths further comprise a plurality of input/output conductive paths coupled to the memory controller, and at least one chip select conductive path coupled to the memory controller. Additionally,
30 a plurality of contacts are coupled to the plurality of conductive paths, and a

programmable rerouting circuit is serially positioned between at least one of the plurality of contacts and at least one of the plurality of conductive paths. In one application, the rerouting circuit is programmable to route and insulate the chip select conductive path between at least two of the plurality of contacts. The non-selected
5 contact is accordingly isolated from the logic and memory circuits. Alternatively, the rerouting circuit is programmable to route and insulate the input/output conductive paths between the plurality of contacts. Under either of these arrangements, a second memory device may be provided, either identical to the first memory device or otherwise. Preferably, both memory devices will have at least one unused contact.

10 The memory devices are piggybacked and the contacts of the devices coupled in parallel. Where the goal is to increase the total storage capacity of the chip stack, the chip select of the reroutable memory chip is reassigned such that it aligns with the unused contact of the second memory device. The chip select of the second memory device should align with the unused contact of the first memory device. The power,
15 input/output, address, or other lines are positioned to align in parallel configuration. Thus the two devices can share the same data, address, and power connections, and still be individually selectable because the chip select for each memory device includes a discrete connection.

Alternatively, where the first, reroutable memory device includes multiple
20 input/output lines, and a like number of unused contacts, and the second memory device includes the same number of unused contacts, the two memory devices can be programmed and stacked piggyback such that the input/output lines of the first memory device align with unused contacts of the second memory device, and the input/output of the second memory device align with the unused contacts of the first
25 memory device. All other contacts are positioned to align in parallel with like connections. Accordingly the power, chip select, and other reference contacts align. Under this arrangement, an enable signal enables both chips simultaneously, and each memory device input/outputs contacts are discretely routed. Thus a single address can now provide an increased word length on the total input/output lines
30 available, over each memory device individually.

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It will be appreciated that the present invention can be used to reprogram bare dies, or finished packaged chips. Further, the rerouting of contacts can be used to implement stacked die as well as stacked chip arrangements. While described as stacking of two devices, any number of stacked devices can be realized, depending upon the number of unused pins available, and the sophistication of the routing and switching circuitry implemented. Further, the present invention can be utilized to increase capacity of stacked combinations, used to reconfigure a single chip to accommodate a number of different socket configurations, or to change the features or function of a single or multiple devices.

The following detailed description of the preferred embodiments of the present invention can be best understood when read in conjunction with the following drawings, where like structure is indicated with like reference numerals, and in which:

Fig. 1 illustrates in block diagram fashion, a logic line switchable between two external pin connections on a packaged semiconductor chip;

Fig. 2 is a block diagram of a system for routing one or more logic lines to any of several external pin connections on a packaged semiconductor chip using an array of antifuses;

Fig. 3 is a simplified schematic of a circuit for routing one logic line between two external pin connections on a packaged semiconductor chip;

Fig. 4 is a simplified schematic diagram of a circuit for rerouting a signal path in a semiconductor using an antifuse, wherein the antifuse is in-line with the signal path; and,

Fig. 5 is an illustration of a stacked semiconductor chip where one of the chips has had a logic line reroutable to a different pin location on the semiconductor package.

The following detailed description references drawings which show by way of illustration, and not by way of limitation, specific embodiments in which the present invention may be practiced. It is to be understood that based upon the functional description herein, other embodiments may be realized, and structural as well as

logical changes may be incorporated without departing from the scope of the present invention.

Referring to Fig. 1, the present invention is illustrated in a simplified block diagram. The packaged semiconductor 100 includes a plurality of external pin
5 connectors 102, 104, 106, 108. Connector pin 102 is unused and is therefore isolated electrically from the logic circuit 120. An external signal applied to contact pin 102 will be isolated from the logic circuit 120. Connector pin 108 is coupled to the logic circuit 120 via a dedicated circuit path 114. A circuit path 118, couples the logic circuit 120 to a routing matrix 116. Depending upon the state of the routing matrix
10 116, the logic circuit 120 is coupled to either connector pin 104 via circuit paths 118 and 110, to connector pin 106 via circuit paths 118 and 112, or alternatively, the signal path 118 may terminate, for example at node 122, wherein the signal path 118 is not coupled to any connection pin. Notably, where the signal path 118 is coupled to pin 104, the connector pin 106 is uncoupled from the logic circuit 120, and thus a
15 signal applied to connection pin 106 is isolated from the logic circuit 120. It is to be understood that the logic circuit can be any circuit including memory devices, microprocessors, gates, convertors and the like. Further, any number of pins, including electrically isolated and electrically conductive pins may be used. Further, the electrically conductive pins, including those coupled through the routing matrix,
20 may carry power connections including ground and supply voltages, may include input/output data information, chip selection or enabling information, clock signals, reference signals, address information, or any other type of signal to be applied to a logic circuit. Additionally, depending upon the application and the sophistication of the signal rerouting required, any known technique for constructing the routing matrix
25 116 may be implemented. The routing matrix can be a single switch, fuse, antifuse, or as sophisticated as necessary, including demultiplexors, decoders, switching matrices, switching arrays and the like.

One method of controlling the routing matrix is through the use of antifuses. An antifuse is a circuit element useful for providing selective one time programmable
30 permanent electrical connections between circuit nodes. An antifuse can be

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implemented with a structure similar to that of a capacitor. In its default state, two conductive terminals are separated by a dielectric layer. This provides a high resistance between the antifuse terminals, resulting in an "off" state without programming. The antifuse can be programmed to an "on" state by applying a large programming voltage across the antifuse terminals. Upon the application of a large voltage, the dielectric breaks down forming conductive pathways between the terminals. The conductive pathways effectively lower the antifuse resistance. Once programmed however, the antifuse cannot be programmed back to an off state.

Referring to Fig. 2, a block diagram is presented illustrating one method for using an antifuse to reroute signals from one connection pin to another. Any number of signal paths 128 couple the logic circuit 120 to the routing matrix 116. The number of circuit paths 128 will depend upon the number of paths desired to be switched, rerouted or terminated. The signal paths 128 feed into a switching matrix 130. The switching matrix 130 assigns each individual signal path 128 to any of the possible connector paths 126. Any one of the signal paths 128 can be routed to one or more of the possible connector paths 126, or alternatively, any one of the signal paths 128 can be isolated from the connector paths 126. To determine the switching pattern, an antifuse array 134 is programmed by selectively blowing one or more antifuses in the array using programming circuit 136. Latch circuit 132 is a sensing circuit that reads the state of the antifuses in the antifuse array 134 and presents a control signal 138 to the switching matrix 130. Depending upon the number of antifuses implemented, the latch circuit 132 may encode the states of the antifuses into a smaller number of control lines. Where the latch circuit encodes the states of the antifuses in the antifuse array 134, the switching matrix 130 includes additional decoder logic.

Referring to Fig. 3, an example of an implementation of a pin programming and routing circuit 200 is illustrated. In this example, a signal 248 is routed to one of two possible connections 272, 274. This can be used for example, to program a chip select signal to one of two possible connectors, leaving the unused connector isolated from the logic circuit (not shown). Firstly, it should be appreciated that the flexibility and structure of the typical antifuse results in a broad degree of latitude to

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the designer to vary the design of the rerouting circuit. Further, any routing scheme can be developed based upon the application to which the chip is to be used, and the requirements of the intended applications for the chip. Accordingly, Fig. 3 is intended to be for illustration and not considered a limitation. Briefly, the rerouting circuit 200

5 comprises an antifuse array 134 coupled to a latching or sensing circuit 132, and to a programming circuit 136. The output of the sensing circuit 132 is coupled to the switching matrix 130. Specifically, switching action of the switching matrix 130 is controlled by the state of the antifuse array 134. While shown herein with only one antifuse 202, it is to be understood that any number of antifuses 202 may be

10 implemented, depending upon the number of signals to be programably rerouted and other like considerations. Typically, control signal Vcont1 208 is biased such that the gate 210 of transistor 212 is closed, and the program voltage Vprog 214 is isolated from the antifuse 202. Control signal Vcont2 216 is biased such that the gate 218 of transistor 220 is open, and the second plate 206 of antifuse 202 is effectively coupled

15 to ground 222 through transistor 220. The state of control signal Vcont3 224 is biased such that the gate 226 of transistor 228 is closed, effectively isolating the first plate 204 of antifuse 202 from a path to ground 230, through transistor 228.

The sensing circuit 132 reads the state of antifuse 202 by biasing control signal Vlatch1 238 to open the gate 240 of transistor 242, and further, by biasing

20 control signal Vlatch2 232 to open the gate 234 of transistor 236 effectively coupling the sensing voltage Vsense 246 through transistors 242 and 236 to the antifuse 202. The gate 226 of transistor 228 is off isolating the first plate 204 of antifuse 202 from ground 230 through transistor 228. Likewise, the gate 210 of transistor 212 is closed to isolate the programming voltage Vprog 214 from the antifuse 202. The gate 218

25 on transistor 220 is open effectively connecting the second plate 206 of antifuse 202 to ground 222 through transistor 220. If the antifuse 202 is unprogrammed, or unblown, the dielectric layer between the first and second plates 204, 206 isolates the sensing voltage Vsense 246 from seeing ground through the antifuse 202, thus the voltage at node 244 will be the sensing voltage 246. All paths to ground through the

30 antifuse 202 are essentially floated. If the antifuse 202 is programmed or blown, then

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conductive pathways are developed through the dielectric separating the first plate 204 from the second plate 206, and the sensing voltage 246 finds a path to ground 222 through antifuse 202 and transistor 220. This pulls the voltage at the reference node 244 towards ground. Accordingly, the sensing circuit realizes a voltage

5 approximately equal to sensing voltage V_{sense} 246 when the antifuse 202 is unblown, and a voltage approximating ground when the antifuse 202 is blown. It should be appreciated that in this simple example, only one signal is to be rerouted. Any more complex sensing and coding schemes may be utilized depending upon the application. For example, where numerous signals are to be potentially rerouted, a

10 plurality of antifuses 202 would be utilized, each separably programmable. Further, the sensing of the antifuse states may be coded or otherwise manipulated using any technique including multiplexing, encoding, and the like.

To program the antifuse 202, V_{cont2} 216 is biased to close the gate 218 of transistor 220. The antifuse 202 is now isolated from ground 222 through transistor

15 220. Likewise, control signal V_{latch2} 232 is biased to close the gate 234 of transistor 236, turning off transistor 236 and thus isolating the sensing circuit 132 from the antifuse 202. Next, control signal V_{cont1} 208 is turned on. V_{cont1} 208 is biased to open the gate 210 of transistor 212. Accordingly, the programming voltage V_{prog} 214, is coupled to the second plate 206 of the antifuse 202. The transistor 228 is

20 turned on by biasing the control signal V_{prog3} 224 to open the gate 226 of transistor 228, thus coupling the first plate 204 of the antifuse 202 to ground 230 through transistor 228. When both the programming voltage V_{prog} 214 is applied to the second plate 206 of the antifuse 202, and the first plate 204 of antifuse 202 is tied to ground 230, the voltage differential between the first and second plates 204, 206

25 should be sufficient to break down the dielectric formed between the first and second plates 204, 206 thus forming a reduced resistance circuit path. Turning off transistor 236 isolates the circuit other than the antifuse from the programming voltage V_{prog} 214. The excessive voltage sometimes required to blow the antifuse 202 may damage other portions of the circuit. Where all other circuit elements would be

30 unaffected by the higher programming voltage V_{prog} 214, it may be unnecessary to

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close the gate 234 of transistor 236. Likewise, transistors 212, 220 and 228 should be designed so as to be able to withstand the higher voltages and currents associated with programming the antifuse 202. Further, as the antifuse 202 is a one time programmable device, the programming operation need only be performed once, usually some time after fabrication and testing. It should be appreciated that programming can be accomplished when the device is in the form of a bare semiconductor die, or alternatively, it can be programmed in a finished package. Finally, since the antifuse 202, by design is fabricated in an unblown state, programming may not be required.

10 The reference node 244 provides a signal that reflects the state of the antifuse 202. The voltage at the reference node is applied directly to the gate 268 of transistor 270. A copy of the reference voltage at node 244 passes through an inverter circuit formed by transistors 254 and 260. When the reference voltage is low, the gate 258 at transistor 260 is closed and the inverter node 256 is isolated from
15 ground 276 through transistor 260. Transistor 254 is always on because the inverter reference voltage 250 is tied to the gate 252 of the transistor 254 thus allowing the inverter node 256 to stay high. When the reference node 244 is high, the gate 258 of the transistor 260 opens effectively coupling inverter node 256 to ground. Accordingly, the control signal at the gate 262 will generally be opposite that of gate
20 268, and only one of the transistors 264, 270 will be on at any given time. Signal 248 is accordingly passed to either connection 272 or connection 274. The unused connection is isolated from the circuitry.

 An alternative arrangement for using antifuses to reroute signals is to place the antifuse in the signal path directly. Referring to Fig. 4, a signal 402 is coupled to
25 external pin connector 436 via transistors 404, 412, and antifuse 414. During normal operation, control signal Vcont1 is biased such that the gate 406 of transistor 404 is open, and likewise the gate 410 of transistor 412 is open. Control signal Vcont2 420 is biased such that the gate 422 of transistor 426 is closed isolating the programming reference signal 424 from the antifuse 414. Likewise, the control signal Vcont3 428 is
30 biased such that the gate 430 of transistor 432 is closed isolating the antifuse 414

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from a path to ground 434 through transistor 432. Accordingly, the programming circuit is isolated from the antifuse 414. If the antifuse 414 is unprogrammed, or not blown, the dielectric between the first plate 416 and second plate 418 of the antifuse insulates the signal 402 from external connector pin 436. To couple signal 402 to
5 external connection pin 436, the antifuse is programmed, or blown.

To program the antifuse 414, the control signal V_{cont1} is biased to isolate the antifuse. Under this arrangement, the gate 406 of transistor 404 is closed isolating the first plate 416 of the antifuse 414 from the signal 402, and the gate 410 of transistor 412 is closed to isolate the second plate 418 of the antifuse 414 from
10 external connection pin 436. This is done to protect the signal path 402 and the external connection pin 436 from the programming voltage. Should the components be able to withstand the program voltage without harm, then their presence is not required. Once isolated, control signal 420 is biased such that the gate 422 of transistor 426 is open, coupling the programming reference voltage V_{prog} 424 to the
15 first plate 416 of antifuse 414. Additionally, the control voltage V_{cont3} 428 is biased to open the gate 430 of transistor 432 effectively tying the second plate 418 of the antifuse 414 to ground 434 through transistor 432. Under this arrangement, current flows through the antifuse 414, breaking down the dielectric between the first plate 416 and the second plate 418 and creating conductive pathways between the first
20 and second plates 416, 418 of the antifuse 414. It should be appreciated that, while illustrated with only one antifuse, and only one external pin connector, any number of antifuses can be utilized to route any number of signal paths to external connection pins. Further, known processing techniques may be used, including demultiplexors, encoders, decoders, antifuse arrays, antifuse matrices and the like may be used.

25 A Stacked Device

Based upon a circuit similar in function to that illustrated in Fig. 3 or 4, a stacked device can be easily realized. For example, memory chips can be stacked together to either increase available word size, or alternatively to increase total memory capacity. Where increased storage capacity is to be realized, two or more
30 chips can be stacked together. The power, address, and input/output lines are all tied

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together in parallel, while each chip retains a unique routing to its chip select or chip enable pin. This is typically accomplished by the use of external, complex stacking frames.

Referring to Fig. 5, a chip stack 300 is illustrated. The chip stack 300 includes
5 a first chip 301, having a plurality of contact pins 304, 308, 312, 316. A second chip 302 includes contact pins 306, 310, 314, 318. The chips 301, 302 are stacked piggyback style such that select contact pins from the first chip 301 align with corresponding contact pins of the second chip 302 to form substantially vertical, conductively coupled columns. At least one of the chips 301 further includes a
10 routing matrix 332 to internally reprogram at least one signal 322 from the logic circuit 330 to select between pins 308 and 312 as shown, however it will be appreciated that any number of routing schemes are possible as more fully explained herein. The routing matrix 332 avoids the necessity of external frames and external rerouting circuitry otherwise required for stacking chips, and further eliminates the need for two
15 distinct chips and duplicative testing apparatus to form the stack. Two identical chips can be stacked together, or alternatively, chips with different configurations may be stacked. Further, both chips 301, 302 may include a routing matrix, 332.

Before stacking, the first chip 301 is programmed to route the signal 322 to either pins 308 or 312. Assume for example, that the signal path 322 is routed to pin
20 308. The unprogrammed pin, 312 becomes isolated from the logic circuit 330. The contact pin 310 of the second chip 302 may be an unused contact pin, or support for example, a similar function as that provided by the signal path 322 of the first chip 301. The chips 301, 302 are stacked piggyback such that the programmed pin 308 of the first chip 301 aligns vertically with the contact pin 310 on the second chip 302.
25 The unprogrammed contact pin 312 on the first chip 301 aligns vertically with a contact pin 314 assigned to the logic in the second chip 302.

The rerouted signal can be a chip select signal or any other external signal to be applied to the chip stack 300. Further, multiple lines can be rerouted. For example, several lines containing input/output on the first chip 301 can be rerouted to
30 align with unused pins on the second chip 302. Likewise, input/output pins on the

second chip 302 may be rerouted to align with unused pins on the first chip 301. This technique can be used for any signal to the chip stack. Further, it should be appreciated by those skilled in the art that this technique applies equally to bare semiconductor dies as it does to packaged dies. Finally, any number of chips can be
5 stacked together, depending upon the design of the rerouting matrix 332 implemented.

In addition to utility in rerouting pin assignments for stacking chips without the need for external rerouting, the present invention finds utility in providing programmable single chip solutions capable of being adapted to several different pin
10 out assignments. For example, the same microprocessor can be utilized for several different sockets by providing the pins in a default configuration for one socket, but providing a routing matrix on the chip of sufficient sophistication to redirect signal paths to different pin connections, making the chip operable in a different socket configuration.

15 As a third alternative, internally reroutable options are provided. For example, a single logic chip can be utilized in a number of applications where functions and features are selectively disabled or enabled. For example, one chip can be fabricated and tested and sold as two chips, where the lesser model chip disabled features and connections. Alternatively, a user may wish to render a pin unused. In this
20 application, the pin is isolated from the logic, but an internal signal path may need redirected. For example, in a simple application, a three input NAND gate chip can be internally converted to a two input NAND gate by disabling one of the external pin connectors leading to one of the NAND gate inputs, and internally tying the signal path that once led to the now disabled connection to the gate ON position. This
25 allows the exact same chip die to serve multiple purposes.

It should be appreciated by those skilled in the art that programming the present invention can be practiced either before or after final assembly. The antifuse arrangement as described herein can be programmed while the semiconductor is in the form of a bare die, and then packaged in its final form, or alternatively, the bare
30 die can be packaged, then programmed.

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Having described the invention in detail and by reference to preferred embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims.

CLAIMS

1. A signal routing circuit comprising:

- a first signal path having a first segment and a second segment;
- a logic circuit coupled to said first segment of said first signal path;
- a first connector pad coupled to said second segment of said first signal path;
- a routing matrix circuit in-line with said first signal path disposed between said first and second segments, said routing matrix circuit programmable between a first state wherein said first segment is coupled to said second segments and a second state wherein said first segment is decoupled from said second segment; and
- a programming circuit coupled to said routing matrix circuit, said programming circuit arranged to selectively program said routing circuit between said first and second states, and to isolate said routing matrix circuit from said first and second segments of said first signal path during programming.

2. The signal routing circuit according to claim 1, wherein said routing matrix circuit comprises an antifuse disposed serially between said first segment and said second segment, and wherein said programming circuit is arranged to program said antifuse between said first and second states.

3. The signal routing circuit according to claim 2, wherein said routing matrix circuit further comprises a first programming switch positioned serially between said antifuse and said first segment and a second programming switch positioned serially between said antifuse and said second segment, said first and second programming switches operatively coupled to said programming circuit and arranged to isolate said antifuse from said select one of said second segments during programming.

4. A signal routing circuit comprising:

a first signal path having a first segment and a plurality of second segments, each of said plurality of second segments independent from one another;

a routing matrix circuit in-line with said first signal path disposed between said first segment and said plurality of second segments; and

a programming circuit coupled to said routing matrix circuit, wherein

said routing matrix circuit is programmable for each of said plurality of second segments between a first state where contact is made to said first segment and a second state where contact is broken to said first segment,

said first segment is further coupled to a logic circuit,

each of said second segments are further coupled to an associated contact pad,

said routing matrix comprises a switching matrix disposed between said first and second segments of said first signal path,

said switching matrix is programmable between said first and second states;

said programming circuit further comprises at least one antifuse and a sensing circuit coupling said at least one antifuse to said switching matrix;

said programming circuit is arranged to selectively program said antifuse to control said switching matrix between said first and second states,

said sensing circuit outputs at least one switch control signal coding the programmed state of said at least one antifuse, and

said switching matrix further comprises decoding logic to control switching thereof by said at least one control signal.

5. A method of routing a signal in a semiconductor device comprising:

providing a first signal path having a first segment and a second segment;

coupling a logic circuit to said first segment of said first signal path;

coupling a first connector pad to said second segment of said first signal path;

positioning a routing matrix circuit in-line with said first signal path disposed between said first and second segments;
isolating said routing matrix from said first and second segments;
programming said routing circuit to a select one of a first state wherein said first segment is coupled to said second segment, and a second state wherein said first segment is decoupled from said second segment; and
re-coupling said first and second segments to said routing matrix.

6. The method of routing a signal according to claim 1, wherein the routing matrix comprises at least one antifuse.

7. The method of routing a signal according to claim 6, further comprising:

applying a programming voltage to at least one antifuse after the routing matrix is isolated from the first and second segments, wherein the first and second segments are re-coupled to the routing matrix after said programming voltage has been removed from said at least one antifuse.

8. The method of routing a signal according to claim 5, wherein said routing matrix is selectively isolated and coupled to the first and second segments by:

positioning serially, a first transistor between said routing matrix and said first segment;
positioning serially, a second transistor between said routing matrix and said second segment; and
controlling the gates of said first and second transistors to isolate the first and second segments.

9. A method of routing a signal in a semiconductor device comprising:

providing a routing matrix circuit by coupling a switching matrix between a first signal path and a plurality of second signal paths, providing at least one antifuse, and coupling a sensing circuit between said at least one antifuse and said switching matrix, wherein
each of said second signal paths is independent from one another,

said routing matrix circuit is programmable to selectively connect said first signal path to one or more of said plurality of second signal paths, and
said first signal path is isolated from remaining ones of said plurality of second signal paths;

providing a programming circuit coupled to said at least one antifuse, said programming circuit being arranged to selectively program said routing matrix circuit;

coupling said first signal path to a logic circuit;

coupling each of said plurality of second signal paths to contact pads; and

using decoding logic to control said switching matrix using a switch control signal.

10. A signal routing circuit comprising:

a first signal path having a first segment and a plurality of second segments, each of said plurality of second segments independent from one another;

a routing matrix circuit in-line with said first signal path disposed between said first segment and said plurality of second segments, said routing matrix circuit programmable for each of said plurality of second segments between a first state wherein contact is made to said first segment, and a second state wherein contact is broken to said first segment, wherein

said routing matrix comprises a switching matrix disposed between said first and second segments of said first signal path,

said switching matrix is programmable between said first and second states,

said programming circuit further comprises at least one antifuse and a sensing circuit coupling said at least one antifuse to said switching matrix, wherein said sensing circuit outputs at least one switch control signal coding the programmed state of said at least one antifuse, and said switching matrix is operatively controlled by said at least one control signal, and said switching matrix further comprises decoding logic to control switching thereof by said at least one control signal, and

said programming circuit is arranged to selectively program said antifuse to control said switching matrix between said first and second states; and

a programming circuit coupled to said routing matrix circuit, said programming circuit arranged to selectively program said routing matrix circuit between said first and second states for each of said plurality of second segments.

11. A method of routing a signal in a semiconductor device comprising:
 - providing a routing matrix circuit by coupling a switching matrix between said first signal path and said plurality of second signal paths, providing at least one antifuse, and coupling a sensing circuit between said at least one antifuse and said switching matrix;
 - coupling a first signal path to said routing matrix circuit;
 - coupling a plurality of second signal paths to said routing matrix, wherein each of said second signal paths is independent from one another, said routing matrix circuit programmable to selectively connect said first signal path to one or more of said plurality of second signal paths, and said first signal path is isolated from the remainder ones of said plurality of second signal paths;
 - providing a programming circuit coupled to said at least one antifuse arranged to selectively program said routing matrix circuit; and
 - using decoding logic to control said switching matrix using said switch control signal.