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(54) **SAMPLE AND LOAD SCHEME FOR OBSERVABILITY INTERNAL NODES IN A PLD**

(56) **References Cited**

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Reissue of:

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U.S. Applications:

(62) Division of application No. 09/012,667, filed on Jan. 23, 1998, now Pat. No. 6,014,334, and a division of application No. 08/615,342, filed on Mar. 11, 1996, now Pat. No. 5,764,079.

(51) **Int. Cl.**
G1C 7/00 (2006.01)

(52) **U.S. Cl.** **365/189.08; 326/40**

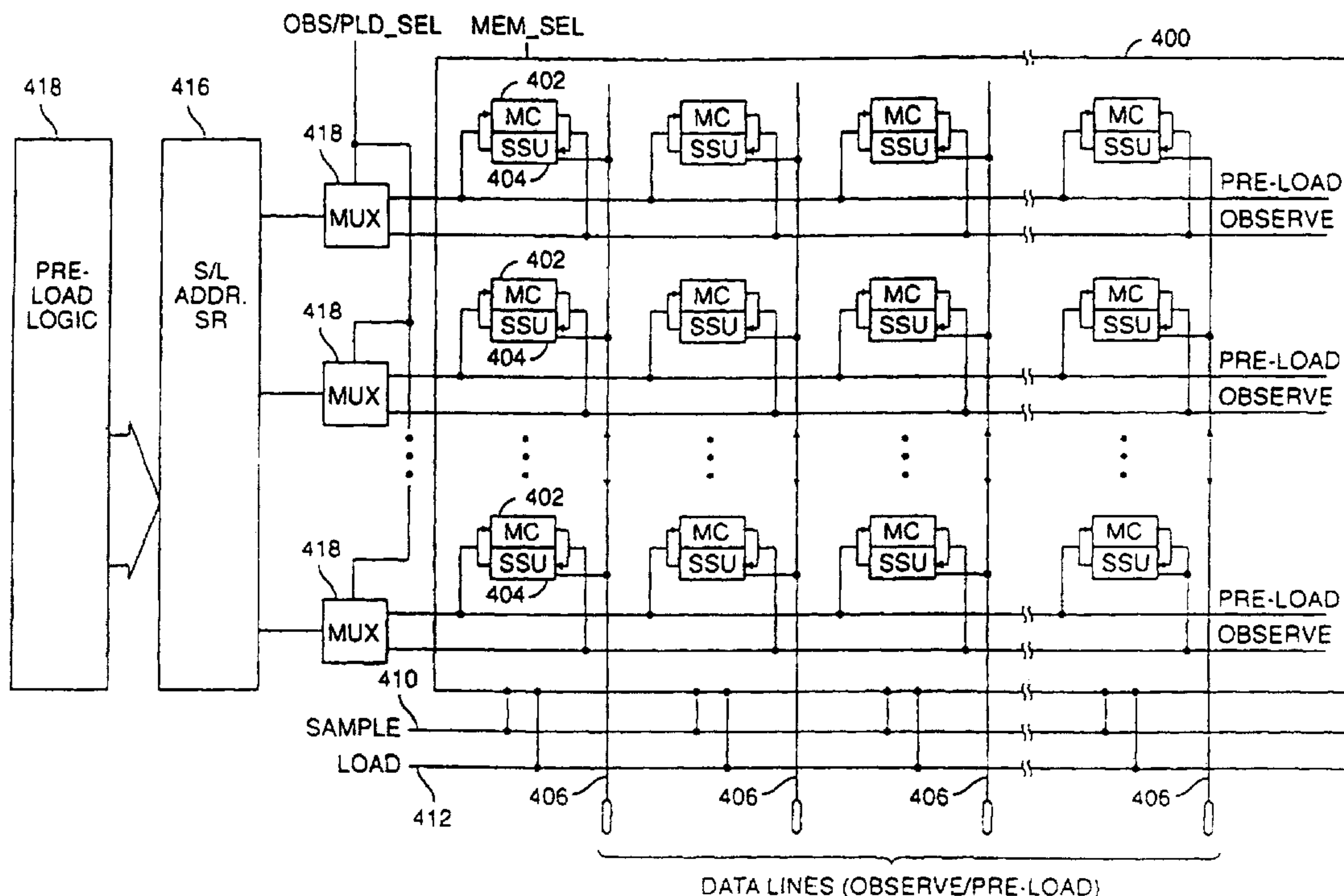
(58) **Field of Classification Search** **365/189.08; 326/40**

See application file for complete search history.

(57) **ABSTRACT**

A programmable logic device (PLD) that provides the capability to observe and control the logic state of buried internal nodes is disclosed. The PLD provides shadow storage units for internal nodes such as logic element registers, memory cells, and I/O registers. A sample/load data path includes bidirectional data buses and shift register that facilitate the sampling of internal nodes for observing their logic states, and loading of internal nodes for controlling their logic states.

52 Claims, 6 Drawing Sheets



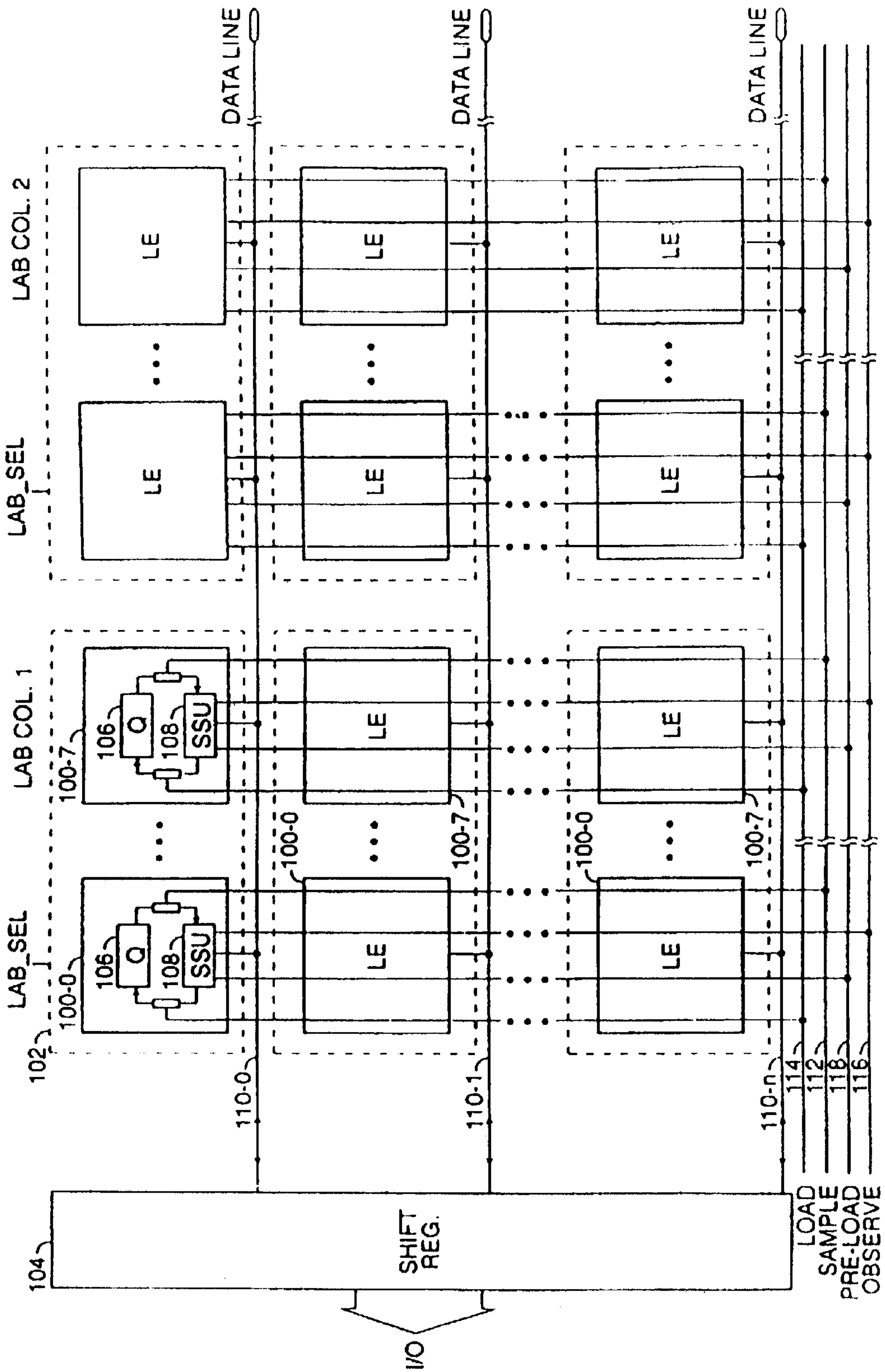


FIG. 1

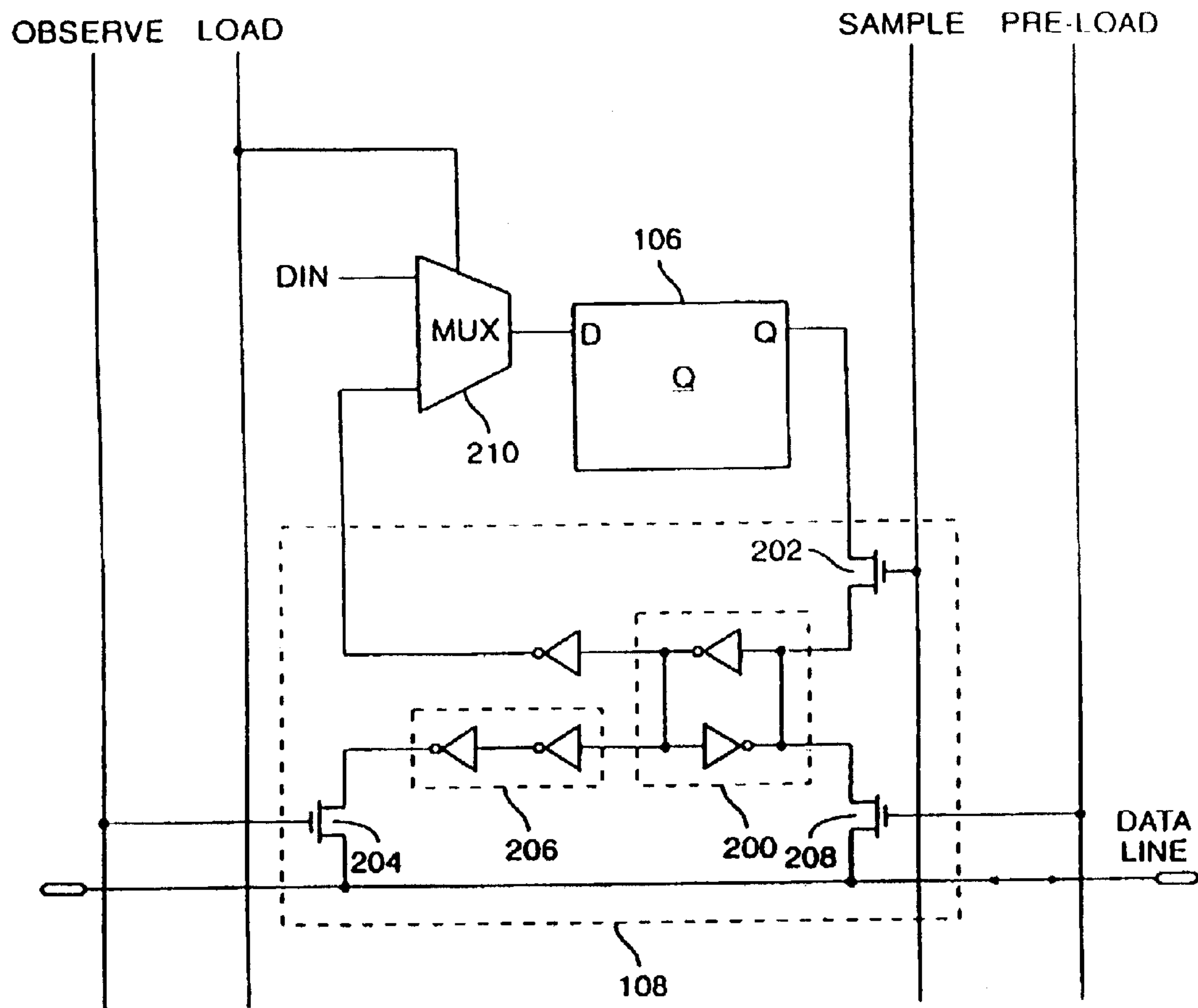


FIG. 2

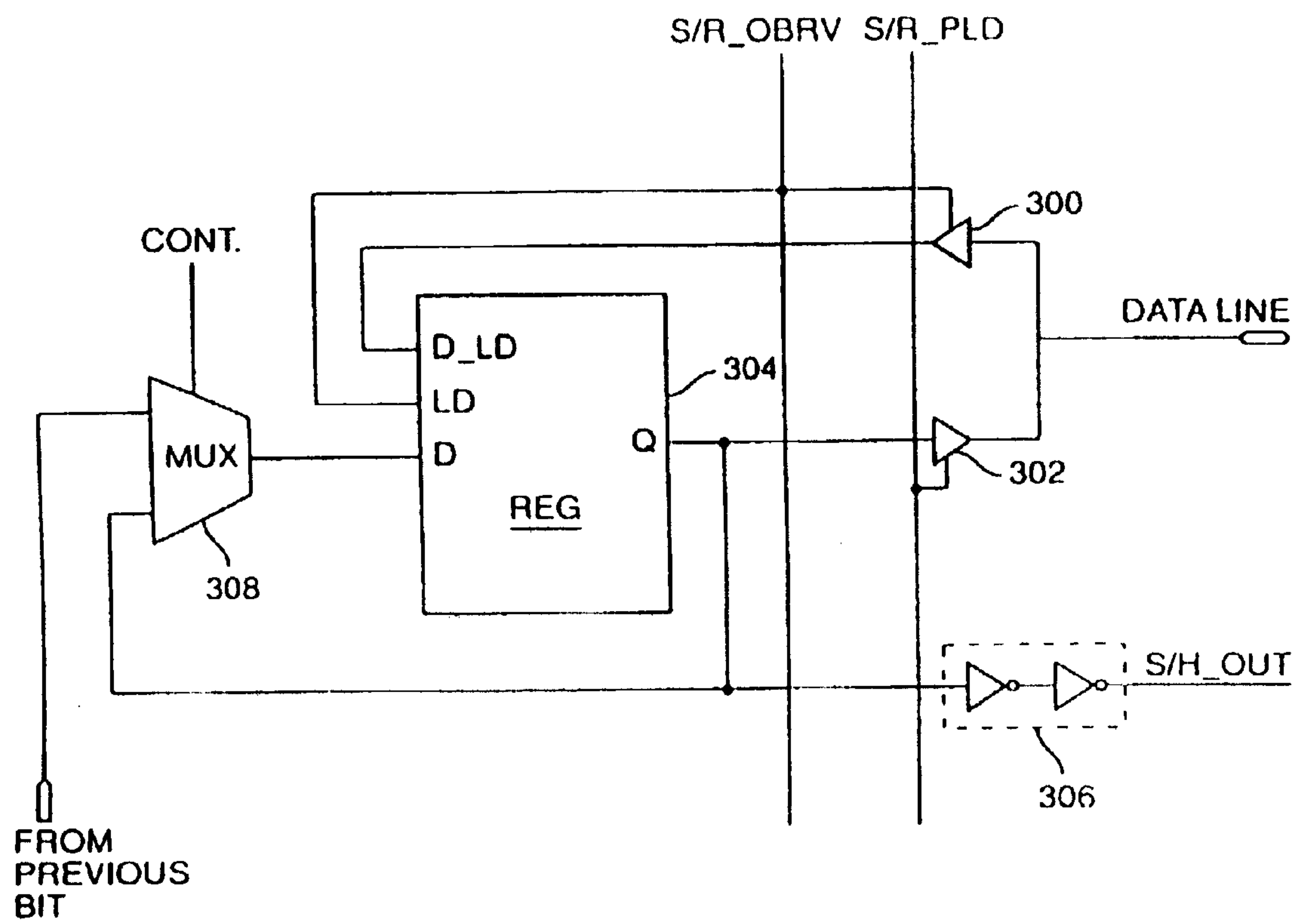


FIG. 3

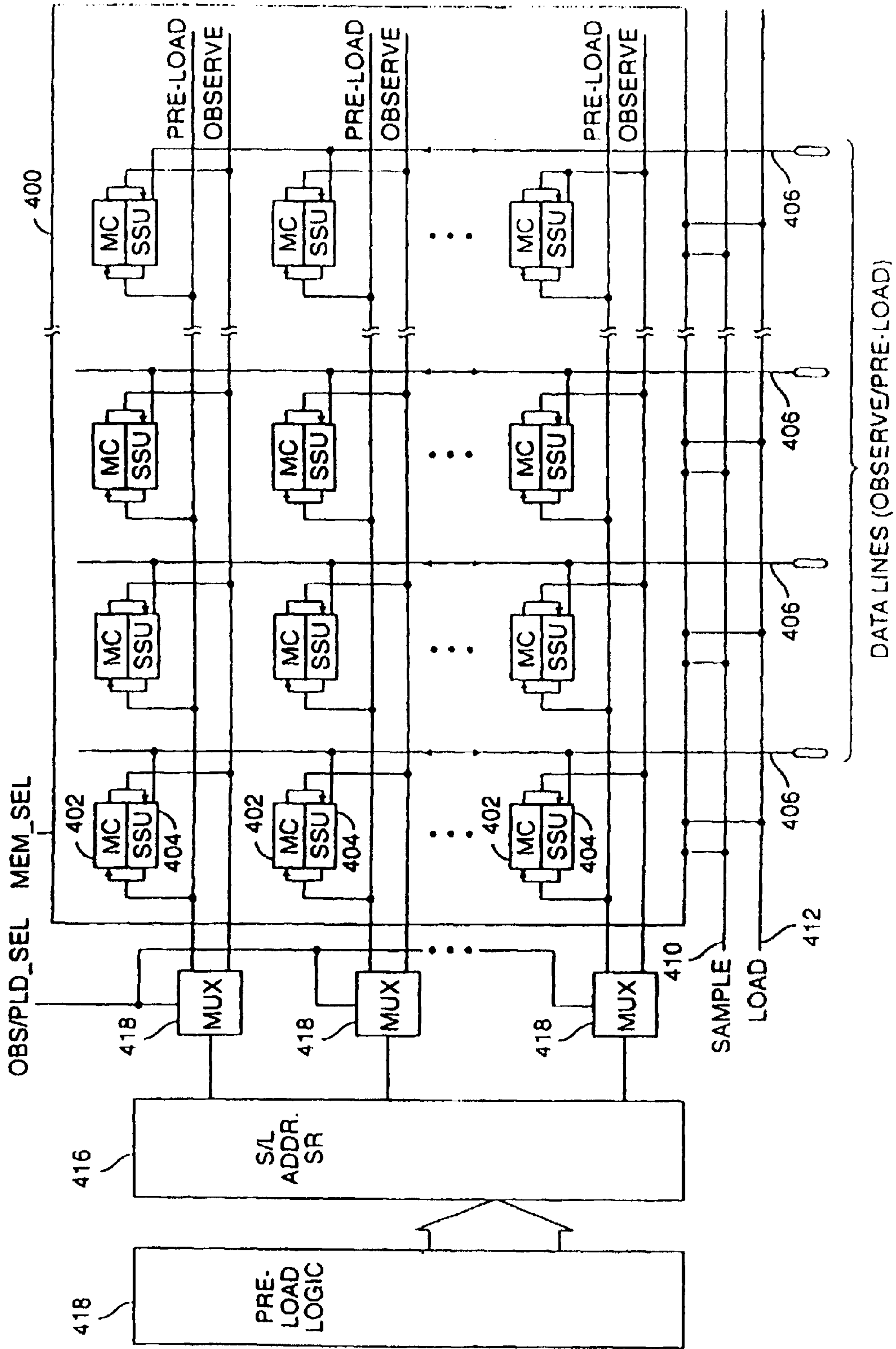


FIG. 4

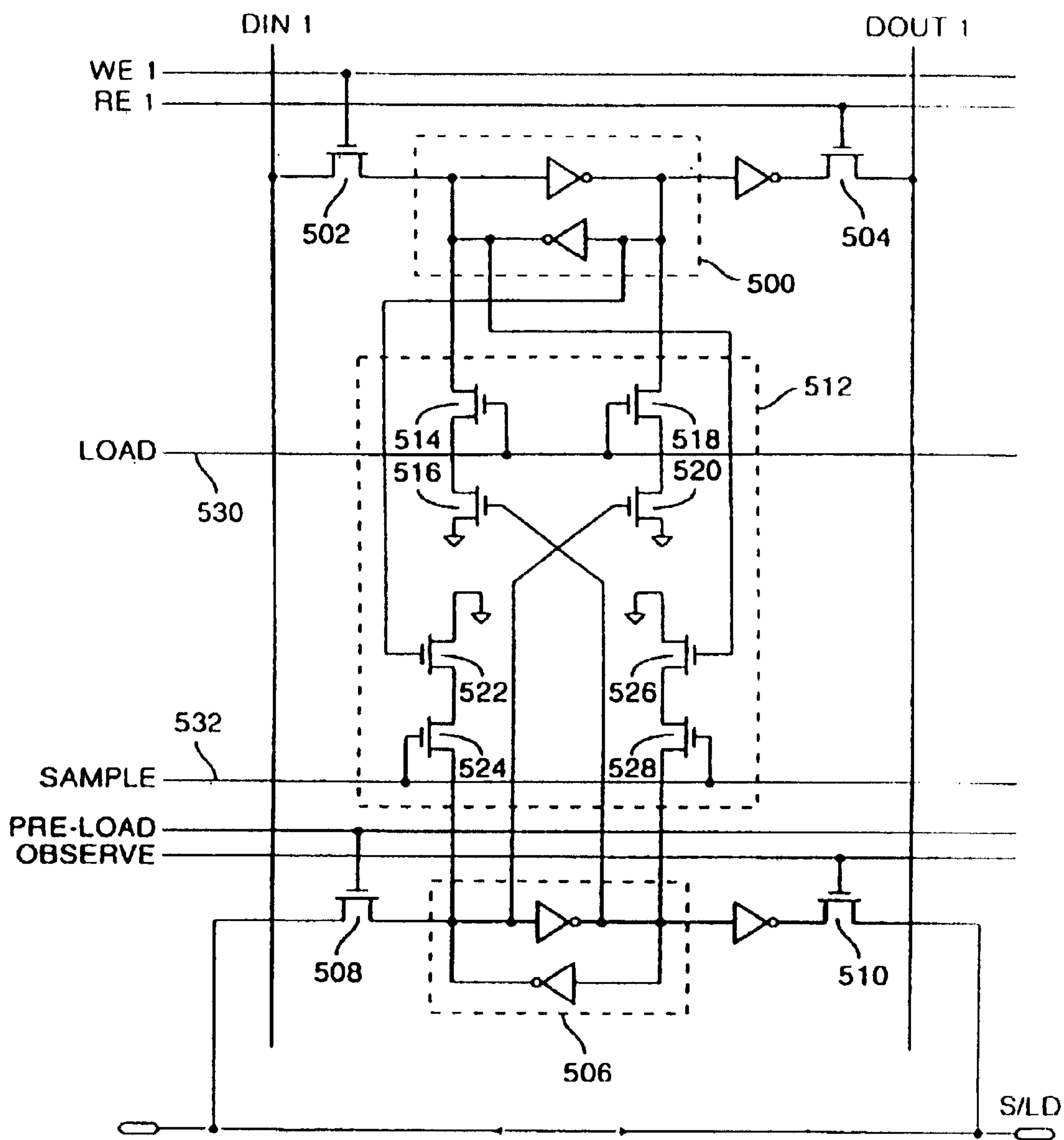


FIG. 5

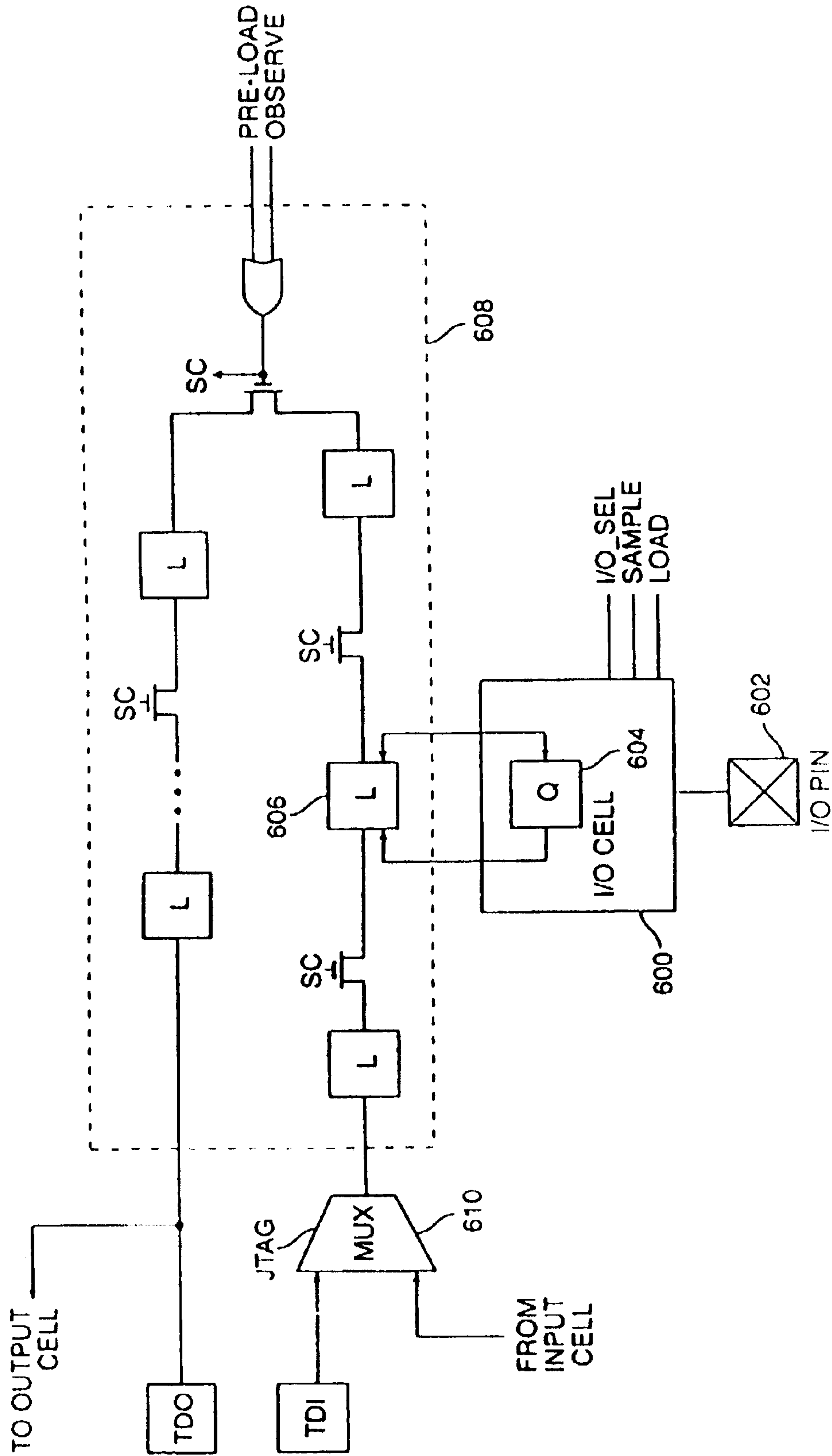


FIG. 6

SAMPLE AND LOAD SCHEME FOR OBSERVABILITY INTERNAL NODES IN A PLD

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This application is a *Reissue of Ser. No. 09/441,143 filed Nov. 12, 1999, U.S. Pat. No. 6,243,304 B1, which was a Div of Ser. No. 09/012,667 filed Jan. 23, 1998, U.S. Pat. No. 6,014,334, and a div of application Ser. No. 08/615,342 filed Mar. 11, 1996, U.S. Pat. No. 5,764,079.*

RELATED APPLICATIONS

The present invention is related to commonly assigned, U.S. Pat. No. 6,020,758, entitled "Partially Reconfigurable Programmable Logic Device," by Patel et al., which is hereby incorporated by reference in its entirety for all purposes.

BACKGROUND OF THE INVENTION

The present invention relates in general to programmable logic circuits, and in particular to a circuit and methodology that allow the user to observe the state of internal nodes within the programmable logic circuit.

A growing trend in the field of electronic circuits and systems design is the use of prototyping or emulation systems that are built with programmable logic devices (PLDs). Such emulation systems help in debugging complex designs with quick turn-around which ensure successful time-to-market for the final product. Programmable logic devices, including programmable logic arrays (PLAs) and field programmable gate arrays (FPGAs) are particularly suited for such debug systems since they provide the flexibility required by design adjustments resulting from design errors or enhancements. Furthermore, such hardware prototyping solutions are often fast enough to operate in the context of the rest of the system. This gives the system designers a high degree of confidence.

A drawback of existing PLD-based emulation or prototyping systems, however, is that the internal state of the programmable logic devices are inaccessible and buried inside the device. This limits the troubleshooting and debugging capabilities of the system. Software based emulation systems provide for complete observability of all nodes within the system, but at the cost of running from 100 to 1 million times slower than the rest of the system.

There is therefore a need for programmable logic devices that can operate at full system speed while simultaneously providing access to observe the state of internal nodes of the device.

SUMMARY OF THE INVENTION

The present invention provides various embodiments for a programmable logic device (PLD) that allows complete observability of the states of internal nodes. Among the various internal nodes, the PLD of this invention provides observability and controllability of, for example, the state of a flip-flop inside each logic element, the state of memory bits, as well as the state of input/output (I/O) pins.

Accordingly, in one embodiment, the present invention provides a programmable logic device including a plurality of logic array blocks each having a plurality of logic

elements, and a network of interconnect lines interconnecting the plurality of logic array blocks. Each logic element includes a primary register coupled to a shadow storage unit. Data buses couple a shift register to the plurality of logic array blocks. The shift register also couples to an I/O pin. In a sample mode of operation, the contents of selected primary registers are sampled into the corresponding shadow storage units, and made available on the I/O pin via the shift register. In a load mode of operation, the contents of selected shadow storage units are loaded into the corresponding primary registers.

In another embodiment, the PLD further includes memory blocks having random access memory cells. The memory cells within the memory block are made observable by a similar arrangement whereby each memory cell is provided with and coupled to a shadow storage unit.

In yet another embodiment, I/O cells around the periphery of the PLD are provided with dedicated shadow storage units as well. In a specific embodiment of the present invention, the JTAG boundary scan chain of latches are used as the shadow storage units to provide observability of the I/O cells.

A better understanding of the nature and advantages of the PLD of the present invention may be gained by reference to the detailed description and diagrams below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified block diagram showing a portion of a PLD with observable logic element registers;

FIG. 2 is an exemplary partial circuit schematic for a logic element according to one embodiment of the present invention;

FIG. 3 is an exemplary schematic of a single bit inside the shift register;

FIG. 4 shows a simplified block diagram of a memory block within the PLD with observable memory cells;

FIG. 5 is an exemplary schematic for a static random access memory cell coupled to a shadow storage unit; and

FIG. 6 shows a simplified diagram of an observable I/O cell in a PLD according to one embodiment of the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

Referring to FIG. 1, there is shown a portion of a PLD having logic elements whose states are observable. A number, for example eight, of logic elements **100** are grouped together to form a logic array block or LAB **102**. LABs **102** are then grouped together in two or more stacks or columns **103** coupled together by an interconnect array. FIG. 1 shows two columns of LABs and a shift register **104**. A column of LABs **102** receives a LAB_SEL line that activates that particular LAB column when asserted.

Each logic element **100** includes a primary register **Q 106** coupled to a shadow storage unit **SSU 108**. Shadow storage units **108** in the logic elements in a row connect to a bidirectional data line **110**. Each row of logic elements **100** thus has a dedicated bidirectional data line **110**. Data lines **110** connect to the shift register **104**. Given *n* data lines per column of LABs, shift register **104** would be an *n*-bit long shift register.

Depending on the PLD programming architecture, data lines **110** either need to be added or can share already existing programming data lines. For example, in those PLDs that provide for address wide access to the LABs, dedicated data

lines are already provided for programming and can thus be utilized in the sample/observe mode as well. In those PLDs whose programming is based on a first-in first-out (FIFO) architecture, however, dedicated data lines are not provided and thus data lines **110** must be added for observability. The two different exemplary programming architectures are described in greater detail in the above-referenced related co-pending, commonly-assigned patent application Ser. No. 08/615,341.

A sample line **112**, load line **114**, observe line **116**, and pre-load line **118** connect to all logic elements **100** in each LAB **102**. When a transition (e.g. rising edge) occurs for the signal on the sample line **112**, the contents of primary registers **Q 106** in the logic elements **100** in the selected LAB **102** are sampled into their respective SSUs **108**. This data is then transferred to the respective bidirectional data line **110** in response to a signal on the observe line **116**, and down loaded into the shift register **104**. The down loaded data is then clocked out of the shift register **104** and supplied to dedicated diagnostics I/O pins (not shown) for user observability.

For diagnostics purposes, at times it may be desirable to initialize portions of the configuration logic or restore sampled data. The PLD of the present invention provides for a diagnostics load operation. The load operation performs essentially the reverse of the sample/observe operation discussed above. The data to be loaded is first shifted into the shift register **104** through the diagnostics I/O ports (not shown). SSUs **108** are then pre-loaded with the desired data via data lines **110** in response to a signal on the pre-load line **118**. Upon a transition (e.g., rising edge) of the signal on the load line **114**, the primary register **106** of a selected LAB **102** is then loaded with the data.

Thus, all logic element state information is sampled simultaneously, and clocked out over the course of several, for example, microseconds. Similarly, all logic element state information is set (or loaded) simultaneously, even though the data which is being injected is loaded into the device over the course of, for example, several microseconds. The use of SSUs **108** allow the sampling of the logic element register states while the system is still running in normal operation. That is, the user can observe the state of the logic element registers at any time during the normal operation of the system without disturbing the design functionality.

FIG. **2** is a partial circuit schematic for an exemplary logic element **100**. SSU **108** includes a pair of cross-coupled inverters to form a static latch **200**. When sampling the contents of the primary register **106**, a signal on the sample line turns on pass transistor **202**. This feeds the output of register **106** to the input of latch **200**. Next, the observe line is asserted causing pass transistor **204** to couple the latched data to the bidirectional data line via a buffer **206**.

When loading data into the logic element, the pre-load line is asserted causing pass transistor **208** to couple the data on the bidirectional data line to the input of latch **200**. A multiplexer (MUX) **210** receives the output of latch **200** and a data-in (Din) line at its inputs. In normal programming mode, MUX **210** connects the Din line to the input of the register **106**. When performing a diagnostic load operation into the logic element, the load signal is asserted causing MUX **210** to couple the output of latch **200** to the input of register **106**. Data is preferably loaded into the slave latch of the master/slave register **106**.

FIG. **3** is a circuit schematic of an exemplary bit of the shift register **104**. The bidirectional data line couples to an input and an output of tri-state drivers **300** and **302**, respec-

tively. Tri-state driver **300** drives the data load **D_LD** input of a register **304**, and is enabled by a shift register observe **S/R_OBSRV** signal. The **S/R_OBSRV** signal also connects to register **304**. Tri-state driver **302** connects to the output of register **304**, drives the bidirectional data line, and is enabled by a shift register pre-load **S/R_PLD** signal. The output of register **304** is provided on a separate output line **S/R_OUT** via a buffer **306**. A MUX **308** connects either the output of register **304** or the output from the preceding bit in the shift register to the **D** input of register **304**. The feedback path through MUX **308** allows the register to hold the data.

Certain types of PLDs may include blocks of memory for specialized applications. Such a PLD with an array of LABs may typically include separate blocks of memory, one for each row of LABs. For diagnostics purposes, it would also be desirable to be able to observe the contents of the memory blocks. FIG. **4** is a simplified block diagram for a PLD memory block with observable memory cell contents. The general approach is similar to the logic element observability scheme. Memory block **400** includes an array of memory cells (MCs), for example, static random access memory (SRAM) cells **402**. Each MC **402** is provided with, and coupled to, a shadow storage unit (SSU) **404**. Bidirectional data lines **406** carry the data that is being observed or being loaded into the memory cells **402**. Memory block **400** shares the same data shift register **104** (FIG. **1**, not shown here) that is provided for the given row of LABs. A separate sample line **410** and load line **412** provide the signals that activate the sampling and the loading operations for the memory block.

A separate address shift register **416** performs address decoding for row-wide sample and load operations. A logic "1" is shifted through shift register **416** to select the various rows of the memory block **400**. A pre-load logic block **418** connects to shift register **416** to facilitate random selection of a row of memory. A multiplexer MUX **418** is provided for each row of memory to connect an output of shift register **416** to one of either the pre-load or the observe lines for each row of memory. MUX **418** is controlled by an **OBS/PLD_SEL** signal. In this example, therefore, the contents of the memory cells are observable and controllable on a row-wide basis. A memory select line **408** selects each memory block **400**.

FIG. **5** is one example of a circuit schematic for a memory cell that provides for observability and controllability according to this invention. A primary memory cell **500** includes a pair of cross-coupled inverters to form a static memory cell. Pass transistors **502** and **504** connect primary memory cell **500** to internal data lines **DIN1** and **DOUT1**, respectively. Transistors **502** and **504** provide access to the cell for writing and reading the cell contents, respectively. A shadow latch **506** with access transistors **508** and **510** couples to a bidirectional sample/load global data line **S/LD**. In this example, a global data line **S/LD** separate from internal memory data lines **DIN1** and **DOUT1** are provided for the observe/control mode. Also, an alternative embodiment may provide separate input (control) and output (observe) data lines instead of a single bidirectional data line.

Shadow latch **506** couples to primary memory cell **500** by a data transfer circuit **512**. Data transfer circuit is made up of transistors **514**, **516**, **518**, **520**, and **522**, **524**, **526**, **528**, that couple the storage nodes inside shadow latch **506** to the storage nodes inside primary memory cell **500**. Transistors **514** and **518** receive the load signal on a load line **530** at their gate terminals, and transistors **524** and **528** receive the sample signal in a sample line **532** at their gate terminals. When the load signal is asserted, data transfer circuit **512**

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causes the contents of shadow latch **506** to be loaded into primary memory cell **500**. When the sample signal is asserted, data transfer circuit **512** causes the contents of primary memory cell **500** to be transferred to shadow latch **506**.

Registers inside I/O cells are another group of internal nodes in a PLD that are typically inaccessible to the user for diagnostics purposes. The present invention provides for a similar observability and controllability technique for the state of registers inside I/O cells. FIG. 6 is a simplified diagram showing an I/O cell with an internal register whose state is observable and controllable by the user. An I/O cell **600** is shown including a register Q **604**. I/O cell **600** connects to an I/O pin **602**. A shadow latch L **606** is coupled to register Q **604**. I/O cell **600** receives signal lines I/O_SEL, sample, and load that operate in a similar fashion as described in connection with the logic elements and memory blocks.

FIG. 6 shows shadow latch L **606** outside the boundaries of I/O cell **600** and as part of a chain of latches **608**. Many PLDs support the JTAG standard and are thus already equipped with a chain of boundary scan latches. One embodiment of this invention uses the JTAG boundary scan latches to act as shadow latches for observability and controllability of I/O registers. A multiplexer **610** is provided to connect one of the TDI (test data in) or an input cell to the chain of latches depending on the mode of operation. Observe line **116** and pre-load line **118** are logically ORed together to generate a single serial chain control signal. The serial chain control signal turns on pass transistors **612** that link the chain of latches **606** together. Thus, the assertion of either one of the two signals (observe or pre-load) connects the chain of latches **606** together to facilitate the sample or load operations. This arrangement also allows the JTAG shift register to be used in the diagnostics mode.

Thus, the present invention offers the circuitry and methodology to provide the user with access to internal nodes buried inside a PLD. When the PLDs according to the present invention are used in prototyping or emulation systems, the observability and controllability allow the user to more effectively debug and troubleshoot the emulated design. While the above provides a complete description of various embodiments of the present invention, it is possible to use various alternatives, modifications and equivalents. For example, complete observability can be made available by type of circuit block. That is, the circuit can be designed with decoding logic to make only sub-blocks from the LABs observable. Similarly, the PLD can provide access to only selected memory blocks or selected logic elements at any given time. Thus the PLD can provide a variety of sampling options to the user.

Other embodiments of this invention may provide redundancy circuitry with built-in shadow latches for observability and controllability. For example, the PLD may include a redundant column of LABs that is identical in structure to the column of LABs shown in FIG. 1. Thus, in case of a defective LAB, a redundant column of LABs is switched in place of the column of LAB with the defective LAB, maintaining complete observability and controllability. Therefore, the scope of this invention should be determined not with reference to the above description, but should instead be determined by reference to the appended claims along with their full scope of equivalents.

What is claimed is:

1. In a programmable logic device (PLD), an input/output (I/O) architecture comprising:

a plurality of I/O cells disposed along a periphery of the PLD and coupled to respective I/O terminals, each I/O cell having an I/O register; and

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a plurality of shadow I/O storage units corresponding, and respectively coupled, to said plurality of I/O registers, wherein, in an observable mode, data is selectively sampled from an I/O register in an I/O cell into a respective shadow I/O storage unit, and made available on an I/O terminal.

2. The I/O architecture of claim 1 wherein said plurality of shadow I/O storage units form a serial chain between a PLD input terminal and a PLD output terminal when coupled together via a corresponding plurality of pass transistors, a control terminal of said plurality of pass transistors being coupled to a logic OR combination of a pre-load and observe control signals.

3. The I/O architecture of claim 2 wherein said plurality of shadow I/O storage units are a plurality of registers used for JTAG boundary scan testing.

4. A programmable logic device (PLD) with observable and controllable internal nodes, said PLD comprising:

a plurality of logic elements coupled by an interconnect network, each logic element comprising a primary register coupled to a shadow storage unit;

a memory array having a plurality of primary memory cells respectively coupled to a corresponding plurality of shadow storage units; and

a plurality of input/output (I/O) cells respectively coupled to a corresponding plurality of I/O terminals, each I/O cell comprising a primary I/O register coupled to a shadow storage unit,

wherein, in an observe mode of operation, data is selectively sampled from said primary register, primary memory cell and primary I/O register into their respective shadow storage units and made available on PLD I/O terminal, and

wherein, in a load mode of operation, data is selectively loaded from shadow storage units into respective primary register, memory cell and I/O register.

5. A method for observing and controlling the logic state of internal nodes of a [probable] programmable logic device (PLD), said method comprising the steps of:

A. providing a shadow storage unit for each internal node whose logic state is to be observed and controlled;

B. coupling said shadow storage unit to its respective internal node by a selective coupling circuit;

C. providing a data path from PLD input/output terminals to said shadow storage unit; and

D. observing a logic state of an internal node by:
i. transferring a logic state of said internal node into its respective shadow storage unit in a sample mode, and
ii. transferring said logic state from said shadow storage unit to a PLD I/O terminal via said data path in an observe mode.

6. The method of claim 5 further comprising the steps of:

[F] E. controlling a logic state of an internal node by:

i. pre-loading external data from a PLD I/O terminal into a shadow storage unit coupled to said internal node in a pre-load mode; and

ii. applying said external data to said internal node in a load mode.

7. A method of determining the contents of a memory block in a programmable logic device, the method comprising:

in the memory block, providing a plurality of memory storage cells and a corresponding plurality of shadow cells;

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writing data to at least one of the plurality of memory storage cells;
 storing data in the plurality of memory storage cells;
 transferring the data stored in the plurality of memory storage cells to the corresponding plurality of shadow cells;
 storing the transferred data in the plurality of shadow cells; and
 reading the data stored in the plurality of shadow cells, wherein the transferring of the data is done by a corresponding plurality of transfer circuits, and wherein each of the plurality of memory storage cells comprises a first inverter and a second inverter, an input of the first inverter coupled to an output of the second inverter, an output of the first inverter coupled to an input of the second inverter, and wherein each shadow cell comprises a third inverter and a fourth inverter, an input of the third inverter coupled to an output of the fourth inverter, an output of the third inverter coupled to an input of the fourth inverter.

8. The method of claim 7 wherein each of the plurality of transfer circuits comprises:

- a first device coupled between a first node and a first reference voltage, having a control node coupled to the input of the first inverter;
- a second device coupled between the first node and the input of the third inverter, having a control node coupled to a control line;
- a third device coupled between a second node and the first reference voltage, having a control node coupled to the input of the second inverter; and
- a fourth device coupled between the second node and the input of the fourth inverter, having a control node coupled to the control line.

9. The method of claim 8 wherein when the control line is asserted, the data is transferred from the plurality of memory storage cells to the corresponding plurality of shadow cells.

10. A method of initializing a memory block in a programmable logic device, the method comprising:

- in the memory block, providing a plurality of shadow cells and a corresponding plurality of memory storage cells;
- writing data to at least one of the plurality of shadow cells;
- storing data in the plurality of shadow cells;
- transferring the data stored in the plurality of shadow cells to the corresponding plurality of memory storage cells; and
- storing the transferred data in the plurality of memory storage cells, wherein the transferring of the data is done by a corresponding plurality of transfer circuits, and wherein each of the plurality of memory storage cells comprises a first inverter and a second inverter, an input of the first inverter coupled to an output of the second inverter, an output of the first inverter coupled to an input of the second inverter, and wherein each shadow cell comprises a third inverter and a fourth inverter, an input of the third inverter coupled to an output of the fourth inverter, an output of the third inverter coupled to an input of the fourth inverter.

11. The method of claim 10 wherein each of the plurality of transfer circuits comprises:

- a first device coupled between a first node and a first reference voltage, having a control node coupled to the input of the third inverter;

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- a second device coupled between the first node and the input of the first inverter, having a control node coupled to a control line;
- a third device coupled between a second node and the first reference voltage, having a control node coupled to the input of the fourth inverter; and
- a fourth device coupled between the second node and the input of the second inverter, having a control node coupled to the control line.

12. The method of claim 11 wherein when the control line is asserted, the data is transferred from the plurality of shadow cells to the corresponding plurality of memory storage cells.

13. A programmable logic device comprising:

- a logic element, programmably configurable to implement user-defined combinatorial or registered logic functions; and
- a memory block to store data, programmably coupled to the logic element, wherein the memory block comprises a plurality of memory cells, each memory cell comprising:
 - a memory storage cell to store a first data bit;
 - a shadow cell to store a second data bit; and
 - a transfer circuit, wherein when a first control line of the transfer circuit is asserted the second bit is transferred from the shadow cell to the memory storage cell, and when a second control line of the transfer circuit is asserted the first bit is transferred from the memory storage cell to the shadow cell.

14. The programmable logic device of claim 13 wherein the memory block further comprises:

- a first pass device to write to the memory storage cell;
- a first inverter to read from the memory storage cell;
- a second pass device to write to the shadow cell; and
- a second inverter to read from the shadow cell.

15. The programmable logic device of claim 14 wherein the memory storage cell comprises a first inverter and a second inverter, the first inverter to receive an output from the second inverter, the second inverter to receive an output from the first inverter, and wherein the shadow cell comprises a third inverter and a fourth inverter, the third inverter to receive an output from the fourth inverter, the fourth inverter to receive an output from the third inverter.

16. The programmable logic device of claim 15 wherein the content of the memory storage cell is initialized by writing to the shadow cell with the second pass device and asserting the first control line.

17. The programmable logic device of claim 15 wherein the content of the shadow cell is determined by asserting the second control line, and reading the shadow cell with the second inverter.

18. The programmable logic device of claim 15 wherein the transfer circuit comprises:

- a first device coupled between a first node and a first reference voltage, having a control node coupled to the input of the first inverter;
- a second device coupled between the first node and the input of the third inverter, having a control node coupled to the second control line;
- a third device coupled between a second node and the first reference voltage, having a control node coupled to the input of the second inverter;
- a fourth device coupled between the second node and the input of the fourth inverter, having a control node coupled to the second control line;

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a fifth device coupled between a third node and a first reference voltage, having a control node coupled to the input of the third inverter;

a sixth device coupled between the third node and the input of the first inverter, having a control node coupled to the first control line;

a seventh device coupled between a fourth node and the first reference voltage, having a control node coupled to the input of the fourth inverter; and

a eighth device coupled between the fourth node and the input of the second inverter, having a control node coupled to the first control line.

19. A programmable logic device comprising:

a logic element, programmably configurable to implement user-defined combinatorial or registered logic functions; and

a memory block to store data, programmably coupled to the logic element, wherein the memory block comprises:

a pass device;

a memory storage cell to store data coupled to the pass device;

a transfer circuit coupled to the memory storage cell;

a shadow cell to store data coupled to the transfer circuit; and

a inverter coupled to the shadow cell,

wherein the transfer circuit selectively transfers data from the memory storage cell to the shadow cell or from the shadow cell to the memory storage cell, and

wherein data is transferred from the shadow cell to the memory cell under control of a first control line, and data is transferred from the memory storage cell to the shadow cell under control of a second control line.

20. The programmable logic device of claim 19 wherein the content of the memory storage cell is initialized by writing to the shadow cell with the pass device and asserting the first control line, and wherein the content of the shadow cell is determined by asserting the second control line, and reading the shadow cell with the inverter.

21. The programmable logic device of claim 20 wherein the memory storage cell comprises a first inverter and a second inverter, an input of the first inverter coupled to an output of the second inverter, an output of the first inverter coupled to an input of the second inverter, and wherein the shadow cell comprises a third inverter and a fourth inverter, an input of the third inverter coupled to an output of the fourth inverter, an output of the third inverter coupled to an input of the fourth inverter.

22. The programmable logic device of claim 21 wherein the transfer circuit comprises:

a first device coupled between a first node and a first reference voltage, having a control node coupled to the input of the first inverter;

a second device coupled between the first node and the input of the third inverter, having a control node coupled to the second control line;

a third device coupled between a second node and the first reference voltage, having a control node coupled to the input of the second inverter;

a fourth device coupled between the second node and input of the fourth inverter, having a control node coupled to the second control line;

a fifth device coupled between a third node and a first reference voltage, having a control node coupled to the input of the third inverter;

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a sixth device coupled between the third node and the input of the first inverter, having a control node coupled to the first control line;

a seventh device coupled between a fourth node and the first reference voltage, having a control node coupled to the input of the fourth inverter; and

a eighth device coupled between the fourth node and the input of the second inverter, having a control node coupled to the first control line.

23. An integrated circuit comprising:

a memory storage cell;

a shadow cell;

a first transfer device coupled between a first write data port line and the memory storage cell;

a second transfer device coupled between a first read data port line and the memory storage cell;

a third transfer device coupled between a first shadow data line and the shadow cell;

a first device coupled between the shadow cell and a first node; and

a second device coupled between the first node and a fixed voltage potential, wherein a control electrode of the second device is coupled to the memory storage cell.

24. The integrated circuit of claim 23 further comprising: a fourth transfer device coupled between the first shadow data line and the shadow cell.

25. The integrated circuit of claim 24 wherein the memory storage cell comprises a first inverter and a second inverter, an input of the first inverter coupled to an output of the second inverter, an output of the first inverter coupled to an input of the second inverter, and wherein the shadow cell comprises a third inverter and a fourth inverter, an input of the third inverter coupled to an output of the fourth inverter, an output of the third inverter coupled to an input of the fourth inverter.

26. The integrated circuit of claim 24 wherein the first shadow data line, the first write data port line, and the first read data port line are different lines.

27. The integrated circuit of claim 23 wherein data may be written to the memory storage cell using the first write data port line, but data may not be directly written to the shadow cell using the first write data port line.

28. The integrated circuit of claim 23 wherein data may be written to the shadow cell using the first shadow data line, but data may not be directly written to the memory storage cell using the first shadow data line.

29. The integrated circuit of claim 23 further comprising: a third device coupled between the memory storage cell and a second node; and

a fourth device coupled between the second node and the fixed voltage potential, wherein a control electrode of the fourth device is coupled to the shadow cell.

30. The integrated circuit of claim 23 wherein the fixed voltage potential is ground.

31. The integrated circuit of claim 23 wherein the first transfer device, second transfer device, and third transfer devices are NMOS transistors.

32. The integrated circuit of claim 23 wherein data stored in the memory storage cell cannot be transferred directly to the first shadow data line without first passing through the shadow cell.

33. An integrated circuit comprising:

a memory storage cell;

a shadow cell;

a first transfer device coupled between a first write data port line and the memory storage cell;

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- a second transfer device coupled between a first read data port line and the memory storage cell;
- a third transfer device coupled between a first shadow data line and the shadow cell;
- a first device coupled between the memory storage cell and a first node; and
- a second device coupled between the first node and a fixed voltage potential, wherein a control electrode of the second device is coupled to the shadow cell.
34. The integrated circuit of claim 33 further comprising:
a fourth transfer device coupled between the first shadow data line and the shadow cell.
35. The integrated circuit of claim 34 wherein the memory storage cell comprises a first inverter and a second inverter, an input of the first inverter coupled to an output of the second inverter, an output of the first inverter coupled to an input of the second inverter, and wherein the shadow cell comprises a third inverter and a fourth inverter, an input of the third inverter coupled to an output of the fourth inverter, an output of the third inverter coupled to an input of the fourth inverter.
36. The integrated circuit of claim 34 wherein the first shadow data line, the first write data port line, and the first read data port line are different lines.
37. The integrated circuit of claim 33 wherein data may be written to the memory storage cell using the first write data port line, but data may not be directly written to the shadow cell using the first write data port line.
38. The integrated circuit of claim 33 wherein data may be written to the shadow cell using the first shadow data line, but data may not be directly written to the memory storage cell using the first shadow data line.
39. The integrated circuit of claim 33 further comprising:
a third device coupled between the shadow cell and a second node; and
a fourth device coupled between the second node and the fixed voltage potential, wherein a control electrode of the fourth transistor is coupled to the memory storage cell.
40. The integrated circuit of claim 33 wherein the fixed voltage potential is ground.
41. The integrated circuit of claim 33 wherein the first transfer device, second transfer device, and third transfer devices are NMOS transistors.

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42. The integrated circuit of claim 33 wherein data placed at the first shadow data line cannot be transferred directly to the memory storage cell without passing through the shadow cell.
43. The memory cell of claim 44 wherein the first data line and the second data line are different lines.
44. A memory cell comprising:
a first storage cell;
a first transfer device coupled between a first data line and the first storage cell;
a second storage cell;
a second transfer device coupled between a second data line and the second storage cell; and
a plurality of devices coupled in series between the first storage cell and a fixed voltage potential, the plurality of devices comprising:
a first device; and
a second device coupled to the first device, wherein a control electrode of the second device is coupled to the second storage cell,
wherein data placed at the second data line cannot be transferred directly to the first storage cell without passing through the second storage cell.
45. The memory cell of claim 44 wherein the fixed voltage is ground.
46. The memory cell of claim 44 wherein the first storage cell is a shadow cell.
47. The memory cell of claim 44 wherein the second storage cell is a shadow cell.
48. The memory cell of claim 44 wherein the first, and second transfer devices are NMOS devices.
49. The memory cell of claim 44 wherein the first device is coupled to the first storage cell.
50. The memory cell of claim 44 wherein the second device is coupled to the fixed voltage potential.
51. The memory cell of claim 44 wherein the first and second devices are NMOS transistors.
52. The memory cell of claim 44 wherein the first storage device comprises cross-coupled inverters.

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