

"A SEMICONDUCTOR MEMORY".

This invention relates to a semiconductor memory, and to a technique which is effective when utilized for a dynamic RAM (random access memory) incorporating therein an address counter circuit for
5 automatic refresh, for example.

When a figure is displayed on a CRT (cathode ray tube), data in the form of logic "0" and logic "1" in accordance with dots constituting the figure is written in advance into memory. The figure is
10 displayed by sequentially reading out the data written into the memory in synchronism with the CRT raster scan timing. When a dynamic RAM is used as a refresh memory for displaying such a figure (or character), address signals must be sequentially
15 generated from an external control circuit such as a micro-processor or the like.

We have developed a semiconductor memory which can easily effect a read-out operation in a predetermined sequence such as that with the refresh
20 memory described above. As an example of the prior art references describing in detail the dynamic RAM, mention can be made of Japanese Patent Laid-Open No. 82282/1982.

It is an object of the present invention to provide a semiconductor memory capable of effecting easily the read-out operation in a predetermined sequence.

According to a first aspect of the present invention there is provided a semiconductor memory including:

- (a) a memory array having a plurality of memory cells;
- (b) first means for generating timing signals in a time series manner without the need of receiving external clock signals;
- (c) an address counter coupled to said first means, said address counter including means for generating address data designating memory cells from said memory array in response to the timing signal of said first means; and
- (d) second means coupled to said memory array and to an external terminal, said second means including means for serially transmitting data stored in memory cells designated by said address counter to said external terminal.

According to a second aspect of the present invention there is provided a semiconductor memory including:

- (a) a memory array including a plurality of memory cells arranged in rows and columns;

(b) first means for generating timing signals in a time series manner without the need of receiving external clock signals;

(c) an address counter coupled to said first means, said address counter including means for generating address signals designating a memory cell row from said memory array in response to the timing signal of said first means, so that said memory cell rows are sequentially designated by said address counter in accordance with the timing signal of said first means; and

(d) second means coupled to said memory array and to an external terminal, said second means including means for serially transmitting data stored in the memory cell row designated by said address counter to said external terminal.

According to a third aspect of the present invention there is provided a semiconductor memory including:

- (a) a memory array having a plurality of memory cells arranged in rows and columns;
- (b) first means for generating timing signals in a time series manner without the need of receiving external clock signals;
- (c) an address counter coupled to said first means, said address counter including means for generating address signals in response to the timing signal of said first means;
- (d) an address buffer circuit providing internal address signals in response to external address signals;
- (e) a multiplexor coupled between said memory array and said address buffer and between said memory array and said address counter;
- (f) control means including means for controlling said multiplexor to select either the internal address signals generated by said address buffer circuit or the address signals generated by said address counter;
- (g) an address decoder coupled between said memory array and said multiplexor, said address decoder including means for selecting a memory cell row from said memory array in response to the address signals selected by said multiplexor; and
- (h) second means coupled to said memory array and

to an external terminal, said second means including means for serially transmitting data stored in a memory cell row selected by the address signals which said address counter generates to said external terminal in series.

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The present invention will now be described in greater detail by way of example with reference to the accompanying drawings, wherein:-

Figure 1 is a block diagram showing a preferred embodiment of a semiconductor memory;

Figure 2 is a waveform diagram which explains the operation of the circuit shown in Figure 1;

Figure 3 is a circuit diagram of a sense amplifier and a memory array;

Figure 4 is a circuit diagram of a shift register and a column switch circuit;

Figure 5 is a circuit diagram of a CMOS inverter;

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Figure 6 is a circuit diagram of a CMOS clocked inverter;

Figure 7 is a circuit diagram of a data output buffer circuit;

5 Figure 8 is a block diagram of an automatic refresh circuit; and

Figure 9 is a circuit diagram of an alternative embodiment of an automatic refresh circuit.

10 Referring to Figure 1, each circuit block encircled by dotted lines is formed on one semiconductor substrate such as single crystal silicon, though not limited to this construction, by known MOS integrated circuit production
15 techniques. N-channel insulated gate field effect transistors (hereinafter referred to as "MOSFETs") constituting circuits which will be described later are formed on a P-type semiconductor substrate, and P-channel MOSFETs are formed
20 on an N-type well region that is in turn formed on the surface of

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the semiconductor substrate. Thus, the semiconductor substrate constitutes a common substrate gate of the N-channel MOSFETs, while the N-type well region forms the common substrate gate of the P-channel MOSFETs. Though not limited to this arrangement, the substrate gate of the N-channel MOSFETs is kept at a negative potential, and that of the P-channel MOSFETs, at a power source voltage V_{cc} level of the circuit.

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10 Terminals I/O, A0 - A17, $\overline{WE}$, $\overline{CS}$, $\overline{OE}$, $\overline{RESH}$, V_{cc} and V_{ss} are external terminals, and power is supplied from a suitable external power source, not shown, to the terminals V_{cc} and V_{ss} .

15 As will become apparent from the following description, the semiconductor memory of this embodiment constitutes a pseudo static memory, though the construction is not limited to this configuration. Each memory cell in this memory is formed by a dynamic type memory cell. The semiconductor memory includes address signal change
20 detection circuits for detecting change of address signals, and a timing generation circuit for generating various timing signals upon receiving the detection output of the detection circuits. Thus,
25 access can be made to the semiconductor memory

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also by changing the address signals alone.

In Figure 1, the symbol M-ARY represents a memory array; the familiar 1-MOS memory cells consisting of a memory capacitor and an address selection MOSFET are arranged in a matrix. Though not limited to this configuration, the memory cell has a folded bit line construction in which its input/output node is connected to either one of a pair of complementary data lines D and $\bar{D}$ that are disposed in parallel with each other.

The symbol PC represents a data line precharge circuit. Though not limited to this method, the precharge operation of the memory array of this embodiment is executed by merely short-circuiting the pair of complementary data lines by a MOSFET. This also holds true of the common complementary data lines which will be discussed later. In this instance, the precharge level of each complementary data line is equal to an intermediate level of about $V_{cc}/2$. This arrangement makes it possible to reduce the level change in comparison with the case where each complementary data line is charged up from 0 volt to the V_{cc} level. Since the transistor can be sufficiently turned on under the unsaturated state even by the use of an ordinary

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logic level (V_{cc}) as the gate voltage of the precharge MOSFET, the time required for the precharge operation can be reduced and moreover, with the lower power consumption.

Since the precharge level is set to the intermediate level of about $V_{cc}/2$ as described above, the switching MOSFET of the memory cell can be sufficiently changed in the unsaturated state even when its gate voltage (word line section voltage) is at the ordinary logic level (V_{cc}) at the time of read-out of the memory cell. Therefore, the whole charge of the data storage capacitor can be read out without using a bootstrap voltage. The precharge level of one of the data lines for which the memory cell is not selected is used as a read-out reference voltage. This eliminates the necessity of a dummy cell for generating a read-out reference voltage.

The symbol SA represents a sense amplifier, which consists of a CMOS (complementary MOS) latch circuit including a pair of power switch MOSFETs consisting of P- and N-channel MOSFETs located across the power source voltage V_{cc} and earth potential V_{ss} of the circuit, respectively. Its pair of input/output nodes are connected to the complementary data lines D and $\bar{D}$, respectively. A timing pulse

ϕ_{pa} controls the power switch MOSFETs. Here, both of non-inversion timing pulse ϕ_{pa} and inversion timing pulse $\bar{\phi}_{pa}$ are represented by ϕ_{pa} . The pair of power switch MOSFETs are turned on immediately before precharge, so that the complementary data lines D and $\bar{D}$ keep the Vcc and Vss levels in the floating state, respectively.

The symbol C-SW represents a column switch, which connects the complementary data line selected in accordance with a column selection signal to the common complementary data lines (represented by one line) CD, $\bar{CD}$.

The symbol R-ADB represents a row address buffer, which receives external address signals through the external terminals A0 - A8 and generates internal complementary address signals a_0 - a_8 and $\bar{a}_0$ - $\bar{a}_8$. In the following description and drawings, a pair of internal complementary address signals such as a_0 and $\bar{a}_0$ will be represented by the internal complementary address signal $\underline{a_0}$. Therefore, the internal complementary address signals a_0 - a_8 and $\bar{a}_0$ - $\bar{a}_8$ will be represented as the internal complementary address signals $\underline{a_0}$ - $\underline{a_8}$.

The symbol C-ADB represents a column address

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buffer, which receives external address signals through external terminals A9 - A14, and generates internal complementary address signals $a_9 - a_{14}$ and $\bar{a}_9 - \bar{a}_{14}$. In the following description and drawings, these internal complementary address signals $a_9 - a_{14}$ and $\bar{a}_9 - \bar{a}_{14}$ will be represented, as similar as the timing pulses, by internal complementary address signals $\underline{a}_9 - \underline{a}_{14}$.

The symbol R-DCR represents a row address decoder, which receives the internal complementary address signals $\underline{a}_0 - \underline{a}_8$ through the multiplexor MPX which will be discussed later, and generates word line selection signal for M-ARY. This word line selection signal is transmitted to M-ARY in synchronism with a word line selection timing signal ϕ_x .

The symbol MA represents a main amplifier, which has the same circuit construction as the sense amplifier SA described already. The timing pulse ϕ_{ma} controls its pair of power switch MOSFETs. The timing signal ϕ_{ma} consists of mutually complementary signals ϕ_{ma} and $\bar{\phi}_{ma}$. A precharge circuit (not shown) which is equivalent to the precharge circuit PC1 is located on the common complementary data lines on the input side of this main amplifier MA.

The symbol DOB represents a data output buffer, which delivers read-out data from the main amplifier MA to the external terminals I/O by means of the output timing pulse ϕ_{op} . Since the output timing pulse ϕ_{op} is at the low level during the write-in operation, this data output buffer is brought into the inoperative (output high impedance) state.

The symbol DIB represents a data input buffer, which delivers the write-in data from the external terminals I/O to the common complementary data lines by means of the input timing pulse ϕ_{in} . Since the input timing pulse ϕ_{in} is at the low level during the read-out operation, this buffer DIB is inoperative in the same way as the data output buffer DOB.

The various timing signals described above are generated by each of the following circuit blocks.

The symbol REG represents an address signal change detection circuit which receives the address signals $a_0 - a_8$ (or $\bar{a}_0 - \bar{a}_8$) and detects the change of the rise or fall of the signals, though the construction is not limited to this configuration.

Symbol CEG represents an address signal change

detection circuit, which receives address signals $a_9 - a_{14}$ (or $\bar{a}_9 - \bar{a}_{14}$), and detects the change of the rise or fall of the signals, though the circuit is not limited to this construction.

5 The address signal change detection circuit REG consists of exclusive-OR circuits receiving address signals $a_0 - a_8$ and their delay signals, respectively, and a logical sum circuit receiving the output signals of the exclusive-or circuits, 10 though the circuit is not limited to this construction. That is, an exclusive-OR circuit receiving the address signal and the delay signal of the address signal is provided for each address signal. In this embodiment, nine exclusive-OR circuits are 15 provided, and the output signals of these nine exclusive-OR circuits are applied to the logical sum circuit. Therefore, when any of the address signals $a_0 - a_8$ change, the address signal change detection circuit REG generates an address signal change detection pulse or which is synchronized 20 with its change timing.

 The address signal change detection circuit CEG has the same circuit construction as the address signal change detection circuit REG. It consists 25 of exclusive-OR circuits receiving the address

signals $a_9 - a_{17}$ and their delay signals, respectively, and a logical sum circuit receiving the output signals of these exclusive-OR circuits.

This address signal change detection circuit CEG

5 generates an address change detection pulse ϕ_c which is synchronized with the change timing when any of the address signals $a_9 - a_{17}$ changes, in the same way as the address signal change detection circuit REG described above.

10 The symbol TG represents a timing generation circuit, which generates principal timing signals described already as the typical examples. Besides the address signal change detection pulses ϕ_r and ϕ_c , the timing generation circuit TG receives a

15 write enable signal $\overline{WE}$, a chip selection signal $\overline{CS}$ and an output enable signal $\overline{OE}$ that are applied thereto, and generates a series of timing pulses.

The symbol MPX represents a multiplexor, which selectively transmits the internal complementary

20 address signals $a_0 - a_8$ generated by the address buffer R-ADB and the internal complementary address signals $a_0 - a_8$ generated by the automatic refresh circuit REF which will be described later, to the decoder R-DC, in accordance with a control signal

25 (not shown) from the automatic refresh signal REF

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which will be described later.

The symbol V_{BB} -G represents a substrate bias voltage generation circuit, which receives a positive power source voltage and generates a negative bias voltage to be supplied to the substrate gates of the N-channel MOSFETs.

The symbol REF represents the automatic refresh circuit described above. As will be described later, this circuit includes a refresh address counter, a timer, and so forth, and is actuated when a refresh signal $\overline{RESH}$ from the external terminal falls to the low level. When the refresh signal $\overline{RESH}$ falls to the low level during the high level period of the chip selection signal $\overline{CS}$, the automatic refresh circuit REF supplies to the multiplexor MPX a control signal ϕ_{ref} for selecting the internal address signals from the refresh counter incorporated therein, in response to the fall of the refresh signal to the low level. Thus, the internal address signal produced from the refresh address counter is applied to the address signal change detection circuit REG and to the row decoder R-DCR through the multiplexor MPX. The address signal change detection circuit REG produces the detection pulse ϕ_r when the internal address signal

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applied thereto changes. Upon receiving the detection pulse ϕ_r , the timing generation circuit TG produces various timing signals. A plurality of memory cells connected to one word line that is designated by the refresh address counter are therefore refreshed.

When the refresh signal $\overline{\text{RESH}}$ is kept at the low level, the refresh address counter advances with a predetermined interval of time due to the timer operation. Therefore, the refresh operation (self-refresh) is carried out continuously.

This embodiment makes it possible to carry out a continuous read-out operation by utilizing the refresh operation (the word line selection operation) of this automatic refresh circuit REF. The memory array M-ARY is equipped with a shift register SR to which the read-out signals of the complementary data lines are applied in parallel. The automatic refresh circuit REF is equipped with an oscillation circuit which generates the shift clock ϕ_{sr} for the shift register SR described above.

Next, the continuous read-out operation of this embodiment will be described with reference to the waveform diagram of Figure 2.

When the chip selection signal $\overline{\text{CS}}$, the output

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enable signal $\overline{OE}$ and the refresh signal $\overline{RESH}$ are changed to the low levels as shown in Figure 2A to C

respectively, the address counter circuit provided in the automatic refresh circuit REF is once reset,

5 and the multiplexor MPX is set to the side of the automatic refresh circuit REF. In this instance, the word line selection operation is carried out by the address signal generated by the address counter circuit. The signal read out to each com-

10plementary data line is taken parallel into the shift register SR. Since the shift operation of the shift register SR is effected by the shift clock ϕ_{sr} generated by the oscillation circuit described above, 512-bit data, 0 to 511, is

15 serially delivered through the data output buffer DOB. When this operation is completed, the built-in timer circuit generates an advance pulse ϕ for the address counter circuit, and the address signal is changed to +1, thereby effecting the next word

20 line selection operation. Thereafter, the shift operation of the shift register SR and the advancing operation of the address counter circuit are repeated in the same way, thereby making it possible to read out continuously all the bits without supplying the
25 address signals from outside.

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When the chip selection signal $\overline{CS}$ and the refresh signal $\overline{RESH}$ are at the high level ($\overline{OE}$ is irrelevant), a chip non-selection state (or the stand-by situation) is established. The refresh operation is effected when the chip selection

signal $\overline{CS}$ is at the high level and when the refresh signal $\overline{RESH}$ is at the low level ($\overline{OE}$ is irrelevant), so that the continuous read-out operation can be distinguished from the other operation modes by the combination of the external control signals.

Figure 3 shows a circuit diagram of the sense amplifier SA, the precharge circuit PC1 and the memory array M-ARY.

The memory array M-ARY is constructed with a plurality of pairs of data lines, a plurality of word lines and a plurality of memory cells. In the drawing, however, only one pair of data lines D_0 , $\overline{D_0}$ and the memory cells MS1 to MS5 connected to these data lines are shown in order to simplify

illustration. Each of the memory cells MS1 - MS5 is constructed with a switching MOSFET Q_m and a data storage capacitor C_m . The gate of the switching MOSFET Q_m as the selection terminal of the memory cell is connected to one of the corresponding word lines $W_0 - W_4$, and its current carrying electrode as the

data input/output terminal of the memory cell is connected to one of the data lines D_0 and $\overline{D_0}$. One of the plates of each capacitor C_m is connected to the power source V_{CC} .

5 The sense amplifier SA comprises a CMOS latch circuit which in turn comprises P-channel MOSFETs Q_1 and Q_2 and N-channel MOSFETs Q_3 and Q_4 as shown in the drawing. A P-channel MOSFET Q_6 which is subjected to switching control by the timing signal ϕ_{pa} is interposed between the CMOS latch circuit and the power terminal V_{CC} , and an N-channel MOSFET Q_5 is interposed between the CMOS latch circuit and earth potential point (0 volt) of the circuit. This N-channel MOSFET Q_5 is subjected to switching control by the timing signal ϕ_{pa} .

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The precharge circuit PC1 consists of an N-channel MOSFET Q_7 that is interposed between a pair of data lines D_0 and $\overline{D_0}$.

Figure 4 is a circuit diagram of the shift register SR and the column switch C-SW.

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The shift register SR in this embodiment is constructed with first and second shift registers Sr_1 and Sr_2 in order to obtain complementary output signals $CD1$ and $\overline{CD1}$ which change at the same timing, though the embodiment is not limited to this construction.

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The first shift register Sr_1 is arranged in such a fashion as to receive the data from one side of data lines D_0, D_1, D_2 among a plurality of pairs of data lines $D_0, \overline{D_0}, D_1, \overline{D_1}, D_2$.

5 The second shift register Sr_2 is arranged in such a fashion as to receive the data from the other side of the data lines $\overline{D_0}, \overline{D_1}$ of the plurality of data line pairs.

10 The operations of the first and second shift registers are controlled by the presetting signal ϕps and the timing signals $\phi sr, \overline{\phi sr}$ and ϕsrl .

15 The presetting signal ϕps is raised to the high level for a predetermined period of time at the timing at which the data signal applied to the pair of data lines is amplified by the sense amplifier SA, though it is not limited to this arrangement.

20 The timing signal ϕsr is raised periodically to the high level after the operation of the sense amplifier SA if the refresh control signal $\overline{RESH}$ and the chip selection signal $\overline{CS}$ are at the low level. The timing signal ϕsr is a signal which has the opposite phase to the timing signal $\overline{\phi sr}$. The timing signal ϕsrl is a signal having substantially the same phase as the timing signal ϕsr .

25 The first and second shift registers have the

same construction. Therefore, the construction and operation of only the first shift register $Sr1$ will be described in detail but those of the second shift register $Sr2$ will be omitted.

5 The first shift register $Sr1$ comprises a plurality of unit shift stages each corresponding one by one to the data lines D_0 , D_1 , D_2 of the memory array, and an additional unit shift stage. Each unit shift stage cascades to the other stages.

10 The final unit shift stage corresponding to the first data line D_0 comprises a CMOS inverter $IV1$, a CMOS clocked inverter $CIV1$, a transfer MOSFET Q_{14} interposed between the data line D_0 and the input node of the clocked inverter $CIV1$ and a
15 transfer MOSFET Q_{10} interposed between the input node of the clocked inverter $CIV1$ and the output node of the unit shift stage of a preceding stage. The unit shift stage of the preceding stage

corresponding to the second data line D_1 comprises
20 a half bit shift stage consisting, in turn, of a CMOS inverter $IV2$ and a CMOS clocked inverter $CIV2$ that are connected in series with each other, a half bit stage consisting of a transfer MOSFET Q_{11} and preset means consisting of a transfer MOSFET
25 Q_{15} . Similarly, the unit shift stage corresponding

to the third data line D_2 consists of two half bit shift stages and preset means.

5 In this embodiment, the additional unit shift stage is provided in order to detect completion of the shift operation. The additional unit shift stage has the same construction as the unit shift stage described above, and its output node is connected to the input node of the unit shift stage of the initial stage (not shown) that corresponds to the 512nd data line D_{511} (not shown). Though 10 not limited to this arrangement, the input node of the additional unit shift stage, that is, one current carry electrode of MOSFET Q13 shown in Figure 4, is kept at earth potential of the circuit. 15

Each inverter and each clocked inverter in the first shift register S_{r1} has the constructions such as shown in Figures 5 and 6, respectively.

Each inverter comprises a P-channel MOSFET Q30 and an N-channel MOSFET Q31 as shown in Figure 5. 20

The clocked inverter comprises P-channel MOSFETs Q32, Q33 and N-channel MOSFETs Q34, Q35. It is brought into the active state when the timing signals ϕ_{sr} and $\bar{\phi}_{sr}$ are at the low and high levels, 25

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respectively, in response thereto, and produces a signal having an inverted level to the level of the signal applied to its input node IN, from its output node OUT. When the timing signals ϕ_{sr} and $\bar{\phi}_{sr}$ are at the high and low levels, respectively, the clocked inverter is brought into the inactive state. In this case, the level of the output node OUT is kept at the previous level by the stray capacitance (not shown) that exists at the output node OUT.

The first shift register operates in the following manner.

First of all, when the data signal applied between each pair of data lines is amplified, the preset signal ϕ_{ps} is raised to the high level for a predetermined period of time. Therefore, the transfer MOSFETs Q14 to Q16 are turned on, and the data of the data lines D_0 , D_1 and D_2 are applied to the input nodes of the corresponding clocked inverters CIV1, CIV2 and CIV3, respectively. In this case, these inverters are in the active state. Therefore, the data of the data line D_0 is transferred to the output terminal of the inverter IV1 through the transfer MOSFET Q13, through the clocked inverter CIV1 and through the inverter IV1.

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Similarly, the data of the data lines D_1 and D_2 are transferred to the output terminals of the inverters IV2 and IV3.

Next, when the timing signals ϕ_{sr} and $\bar{\phi}_{sr}$ are at the high and low levels, respectively, the clocked inverters CIV1 through CIV3 are brought into the inactive state. Since the timing signal ϕ_{sr1} is raised to the high level in synchronism with the timing signal ϕ_{sr} , the transfer MOSFETs

Q10 to Q13 are kept ON. As a result, the data of the data line D_1 that has been transferred in advance to the output terminal of the inverter IV2 is transferred to the input node of the clocked inverter CIV1 through MOSFET Q10. Similarly, the data signal of the data line D_2 is transferred to the input node of the clocked inverter CIV2 through MOSFET Q11. The data signal of the data line D_3 , not shown, is transferred to the input node of the clocked inverter CIV3 through MOSFET Q12.

The signal level applied to the additional unit shift stage, not shown, that is, the 0 V low level, is transferred to the input node of the clocked inverter in the unit shift stage of the initial stage.

Next, when the timing signals ϕ_{sr} , $\bar{\phi}_{sr}$ and

φsr1 again change to the low, high and low levels, respectively, the clocked inverters CIV1 to CIV3 are brought into the active state, and the transfer MOSFETs Q10 to Q13 are turned OFF.

5 The data of the data line D₁ is transferred to the output node of the inverter IV1 in response thereto. Similarly, the data signals of the data lines D₂ and D₃ are transferred to the output nodes of the inverters IV2 and IV3, respectively.

10 The same operations are thereafter repeated. As a result, the data signals of the data lines are sequentially produced from the output of the final stage circuit of the first shift register S_{r1}, that is, from the output node of the inverter
15 IV1. The output of the final stage circuit drops to the low level in accordance with the input level (the low level) of the additional unit shift stage when the shift operation of the data signal is completed.

20 The second shift register S_{r2} has an additional unit shift stage connected to the unit shift stage of the initial stage, in the same way as the first shift register S_{r1}. The current carry electrode of MOSFET Q21 in this additional unit shift stage is kept at
25 earth potential of the circuit in the same way

as that of MOSFET Q13. The second shift register Sr2 is operated by the timing signals ϕ_{sr} , $\overline{\phi_{sr}}$ and ϕ_{sr1} that are the same as those supplied to the first shift register Srl.

5 The data signals applied to the data lines $\overline{D_0}$, $\overline{D_1}$, $\overline{D_2}$ when the sense amplifier SA is operated have the phases that are opposite to those of the data signals applied to the data lines D_0 , D_1 and D_2 .

10 Therefore, the first and second shift registers Srl and Sr2 produce the complementary signals CD1 and $\overline{CD1}$, respectively.

15 Since the first and second shift registers of this embodiment are equipped with the additional unit shift stages, respectively, the output signals CD1 and $\overline{CD1}$ after the data signals reset to these shift registers are shifted out are not at the complementary levels but are at the low level. Therefore, the completion of shift of the preset data
20 can be detected by detecting the point of time at which the output signals CD1 and $\overline{CD1}$ are no longer at the complementary levels.

25 In Figure 4, the column switch C-SW comprises MOSFETs Q20 to Q24 that are interposed between each data line and the common complementary data

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lines CD and $\overline{CD}$. MOSFETs Q20 and Q21 connected to the data lines Do and $\overline{Do}$ are subjected to switching control by the column selection signal Yo produced from the column decoder C-DCR shown in Figure 1. Similarly, MOSFETs Q22, Q23 and Q24 are subjected to switching control by the column selection signals Y1 and Y2, respectively.

Figure 7 is a circuit diagram of the data output buffer DOB.

As shown in this drawing, the data output buffer DOB comprises transfer MOSFETs Q36 to Q39, CMOS inverters IV20 to IV22, CMOS NAND circuits G1 and G2, and N-channel output MOSFETs Q40 and Q41.

The timing signal $\phi s1$ applied to this circuit drops to the low level only when both the chip selection signal $\overline{Cs}$ and the refresh control signal $\overline{RESH}$ are at the low level, that is, when the continuous serial output of the memory data is designated to memory, and it rises to the high level at the other times.

Therefore, the complementary signals CD1 and $\overline{CD1}$ produced from the shift register shown in Figures 1 and 4 are applied to the NAND circuits G1 and G2 through the transfer MOSFETs Q36 and Q37

if the timing signal ϕ_{sl} is at the low level.

When an ordinary memory operation is requested by the external control signals ($\overline{Cs}$: low level, $\overline{RESH}$: high level), MOSFETs Q38 and Q39 are turned
 5 OK by the timing signal ϕ_{sl} , and the complementary signals of the common complementary data lines CD and $\overline{CD}$ are supplied to the NAND circuits G1 and G2.

The operation of the data output buffer DOB is controlled by the timing signal ϕ_{op} . It becomes
 10 inoperative when the timing signal ϕ_{op} is at the low level. In this case, the output MOSFETs Q40 and Q41 are turned OFF, and the data output buffer DOB is in the high output impedance state.

When the timing signal ϕ_{op} is raised to the
 15 high level, the data output buffer DOB becomes operative, and produces a high or low level output signal.

Figure 8 is a schematic circuit diagram of the automatic refresh circuit REF.

The automatic refresh circuit comprises an
 20 address counter ACNT, a timer circuit TM, an oscillation circuit OSC, a waveform shaping circuit WFS, a gate circuit GC, a control circuit CNC and a coincidence detection circuit COD, though this
 25 circuit is not limited to this construction.

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The address counter ACNT comprises nine binary counters (not shown) for generating 9-bit internal address signals a0 to a8, that are connected in series, and count advance pulses ϕ supplied from the timer circuit TM. The address counter ACNT is reset by a reset signal ϕ_{rs1} supplied from the control circuit CNC.

The oscillation circuit OSC generates a pulse signal of a reference period. Though not shown in detail, the oscillation circuit OSC comprises a ring oscillation circuit consisting of a plurality of inverters that are connected in the ring form, for example.

The operation of the timer circuit TM is controlled by the control signal ϕ_{rs2} supplied from the control circuit CNC, and the timer circuit TM produces the advance pulse ϕ during operation.

The waveform shaping circuit WFS receives the output of the oscillation circuit OSC, and generates pulse signals having a phase which is substantially the same as the control signals ϕ_{sr} , $\overline{\phi_{sr}}$ to be produced from the gate circuit GC.

The operation of this gate circuit GC is controlled by the control signal ϕ_{gc} supplied from the control circuit CNC. The gate circuit GC transfers

the pulse signals of the waveform shaping circuit WFS to its output terminals during its operation.

The coincidence detection circuit COD receives the output signals $CD1$ and $\overline{CD1}$ of the shift register SR shown in Figure 4, and produces a detection pulse $\overline{\phi_{CC}}$ when the signal levels of these output signals coincide with each other. The coincidence detection circuit can be composed of a two-input CMOS NAND circuit, for example.

The control circuit CNC receives the output enable signal, the chip selection signal and the refresh control signal through the external terminals $\overline{OE}$, $\overline{CS}$ and $\overline{RFSH}$, and receives also the detection pulse $\overline{\phi_{CC}}$ described above and the word line selection timing signal ϕ_x generated from the timing generation circuit TG shown in Figure 1 to produce various control signals.

The control signal ϕ_{ref} is formed on the basis of the refresh control signal $\overline{RFSH}$, and has the opposite phase to the refresh control signal $\overline{RFSH}$, though it is not limited to this arrangement.

The multiplexor MPX shown in Figure 1 selects the output of the address counter ACNT when the refresh control signal $\overline{RFSH}$ is at the low level in order to execute the auto refresh operation and

32

the continuous read-out operation of the data signal.

When all of the external control signals $\overline{OE}$, $\overline{CS}$ and $\overline{RFSH}$ are at the low level, that is, when

5 the continuous read-out operation of the data is requested to the memory, the control signal ϕ_{rs1} is raised to the high level for a predetermined period of time. In this instance, the address counter ACNT is reset to the state of the count

10 value 0.

The control signal ϕ_{rs2} is set to the low level when the external control signals $\overline{CS}$ and $\overline{RFSH}$ are at the high and low levels, respectively. It is raised to the high level when the external

15 control signal $\overline{RFSH}$ is at the high level. When the control signal ϕ_{rs2} is at the low level, the timer circuit TM is brought into the active state and produces the advance pulse ϕ of a predetermined period.

20 The control signal ϕ_{rs2} is raised to the high level when all of the external control signals $\overline{CS}$, $\overline{OE}$ and $\overline{RFSH}$ are at the low level, and is set to the low level for a predetermined period after the passage of a predetermined period of time from the

25 point of time when the coincidence detection pulse

$\overline{\phi_{cc}}$ is produced while the external control signals $\overline{CS}$, $\overline{OE}$ and $\overline{RFSH}$ are at the low level. Thus, one advance pulse ϕ is produced from the timer circuit TM. As will become more apparent from further description, the delay time from the generation of the coincidence detection pulse $\overline{\phi_{cc}}$ till the generation of the control signal ϕ_{rs2} is substantially equal to the retrace time necessary for driving a CRT display.

10 The presetting signal ϕ_{ps} is raised to the high level for a predetermined period after the sense amplifier SA is operated, though it is not limited to this arrangement. In this embodiment, the preset signal ϕ_{ps} is raised to the high level after
15 the passage of a predetermined delay time from the point of time when the word line selection timing signal ϕ_x is raised to the high level. The preset signal ϕ_{ps} may be set to the high level after the sense amplifier control signal ϕ_{pa} has been produced.

20 The gate control signal ϕ_{gc} is also raised to the high level in synchronism with the generation of the word line selection timing signal ϕ_x after all of the external control signals $\overline{CS}$, $\overline{OE}$ and $\overline{RFSH}$ have dropped to the low level, though not limited.
25 This arrangement, the gate control signal ϕ_{gc} is

set to the low level in order to inhibit the generation of the shift control signals ϕ_{sr} , $\overline{\phi_{sr}}$ and ϕ_{sr1} when the control signal ϕ_{sr2} is at the high level.

5 The circuit operation of the memory brought forth by the automatic refresh circuit RFE shown in Figure 8 is as described above.

10 Thus, when the chip selection signal $\overline{CS}$ is at the chip non-selection level (the high level) and the refresh control signal $\overline{RFSH}$ are at the low level, the control signal ϕ_{ref} is raised to the high level in response to the former, and the address signals a0 to a8 of the row system of the address counter ACNT are selected by the multiplexor MPX
15 (shown in Figure 1). The address signal change detection circuit REG (see Figure 1) detects the change of the internal address signal produced from the multiplexor MPX. Upon receiving the detection pulse ϕ_r , the timing generation circuit TG (see
20 Figure 1) produces various control signals in order to operate the row system circuit.

25 The word line selection timing signal ϕ_x is temporarily changed to the non-selection level (the low level), so that one word line, that has been selected in advance in the previous operation cycle,

is temporarily changed to the non-selection level together with the other non-selected word lines.

5 The sense amplifier control signal ϕ_{pa} is set to the level that renders the sense amplifier SA (Figures 1 and 3) inoperative, in synchronism with the timing at which the timing signal ϕ_x is changed to the low level.

10 The control signal ϕ_{pc} is raised to the high level for a predetermined period of time after the word line is set to the non-selection level, so that the precharge circuit PC1 (Figures 1 and 3) is operated and each data line in the memory array M-ARY is precharged to a precharge level of about $V_{cc}/2$.

15 The word line selection timing signal ϕ_x is raised to the high level after the control signal ϕ_{pc} is set to the low level. Then, the row decoder R-DCR sets the word line corresponding to the internal address signal a0 - a8 to the selection level.

20 The sense amplifier control signal ϕ_{pa} is set to the level for operating the sense amplifier SA after the word line selection timing signal ϕ_x is set to the high level. Therefore, the data signals applied from the memory cells to the data lines are amplified by
25 the sense amplifier SA. The amplified data signals

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are re-written into the memory cells. In other words,
a refresh operation is conducted.

When the chip selection signal $\overline{CS}$ and the
refresh control signal $\overline{RFSH}$ are at the high and
5 low levels, respectively, the control signals ϕ_{rs1}
and ϕ_{rs2} are kept at the low level. In this case,
the address counter ACNT and the timer circuit TM
are kept in the active state.

Therefore, the advance pulse ϕ is produced
10 from the timer circuit TM, and the address counter
CNT is incremented by 1. The word line having the
updated address is then selected, and the refresh
operation of the memory cells belonging to that
word line is executed.

15 When the chip selection signal $\overline{CS}$ is at the
non-selection level, the timing generation circuit
TG does not produce the control signals that
operate the column system circuit.

Next, the circuit operation when the conti-
20 nuous read-out operation is instructed will be
explained.

When all the external control signals $\overline{CS}$, $\overline{OE}$ and
 $\overline{RFSH}$ are changed to the low level, the control signal
 ϕ_{rs1} is set to the high level for a predetermined
25 period in response to the former. Therefore, the

The preset signal ϕ_{ps} and the gate control signal ϕ_{gc} are again produced in response to the word line selection timing signal ϕ_x . Therefore, the data signals read out from the memory cells belonging to the second word line are continuously read out, repeating thereafter the same operation.

Figure 9 is a block diagram of an automatic refresh circuit in accordance with another embodiment of the present invention.

In this embodiment, a refresh operation is carried out in a relatively short period during the continuous data read-out operation. Therefore, the refresh operation becomes possible in this embodiment even when the speed of continuous data read-out operation is low.

The automatic refresh circuit REF comprises an address counter ACNT, a timer circuit TM, an oscillation circuit OSC, a waveform shaping circuit WFS, a gate circuit GC, a control circuit CNC and a coincidence detection circuit COD, though this circuit is not limited to this construction.

The address counter ACNT, the oscillation circuit OSC, the waveform shaping circuit WFS, the gate circuit GC and the coincidence detection circuit COD have the same constructions as those shown

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in Figure 8, respectively.

The timer circuit TM receives the output of the oscillation circuit OSC, and its operation is controlled by the control signal ϕ_{rs2} applied from the control circuit CNC.

The timer circuit TM generates the advance pulse ϕ having the same period as the period of the pulse signals that are generated from the waveform shaping circuit WFS when the control signal ϕ_{rs2} is in the active low level state. If the control signal ϕ_{rs2} is at the high level, the timer does not generate the advance pulse ϕ .

Upon receiving the external control signals $\overline{CS}$, $\overline{OE}$, $\overline{RFSH}$, the detection pulse $\overline{\phi_{cc}}$ and the word line selection timing signal ϕ_x , the control circuit CNC produces various control signals.

The control signal ϕ_{ref} is generated on the basis of the refresh control signal $\overline{RFSH}$ in the same way as the control signal shown in Figure 8.

When all of the control signals $\overline{CS}$, $\overline{OE}$ and $\overline{RFSH}$ are changed to the low level, the control signal ϕ_{rs1} is raised to the high level for a predetermined period in the same way as the control signal shown in Figure 8. Therefore, the address counter ACNT is reset to the count value 0.

address counter ACNT is set to the count value 0. In other words, the count in the address counter ACNT is changed to a value which causes instructions to be sent to the first word line.

5 The output of the address counter ACNT is applied to the address signal change detection circuit REG through the multiplexor MPX; hence, the detection pulse ϕ_r is produced. The timing generation circuit TG produces the control signals
10 in response to the detection pulse ϕ_r , and the row address decoder R-DCR, the sense amplifier SA and the precharge circuit PC1 are operated at the same timing as described above.

15 When the data signal applied to each data line of the memory array M-ARY is amplified by the sense amplifier SA, the preset signal ϕ_{ps} is raised to the high level for a predetermined period. Therefore, each of the data signals applied to each data line is preset to the shift register SR (see Figures 1 and
20 2).

 The gate control signal ϕ_{gc} is raised to the high level in synchronism with the timing at which the preset signal ϕ_{ps} is set to the low level. Therefore, the gate circuit GC is opened, and
25 produces the shift control signals ϕ_{sr} , $\overline{\phi_{sr}}$ and

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$\phi sr1$. Since these control signals ϕsr , $\overline{\phi sr}$ and $\phi sr1$ are produced, the data signals that have been preset to the shift register SR are continuously produced therefrom.

5 When all the data signals read out from the memory cells belonging to the first word line are produced, the two outputs $CD1$ and $\overline{CD1}$ of the shift register SR are set to the low level. When these outputs $CD1$ and $\overline{CD1}$ are set to the same level, the coincidence

10 detection circuit COD produces the coincidence detection pulse $\overline{\phi cc}$.

 The gate control signal ϕgc is set to the low level in response to the output of the coincidence detection pulse $\overline{\phi cc}$, and the gate circuit GC is

15 closed.

 After a predetermined period has passed from the generation of the coincidence detection pulse $\overline{\phi cc}$, the control signal $\phi rs2$ is set to the low level, so that the timer circuit TM becomes opera-

20 tive and produces the advance pulse ϕ . Since this advance pulse ϕ is produced, the address counter ACNT is incremented by one. Thus, the count changes from 0 to 1.

 The row system circuit starts again operating

25 when the output of the address counter ACNT changes.

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41

When the external control signals $\overline{CS}$ and $\overline{RFSH}$ are kept at the high and low levels, respectively, the control signal ϕ_{rs2} is kept at the low level in the same way as the control signal in the foregoing embodiment. Unlike the control signal ϕ_{rs2} in the foregoing embodiment, however, this control signal ϕ_{rs2} is raised to the high level for a predetermined period from the point of time when the coincidence detection pulse ϕ_{cc} is produced in response to the low level state of all the external control signals $\overline{CS}$, $\overline{OS}$ and $\overline{RFSH}$.

In response to the high level state of the control signal ϕ_{rs2} , the timer circuit TM is brought into the inoperative state for a predetermined period from the generation of the coincidence detection pulse $\overline{\phi_{cc}}$, in the opposite way to the foregoing embodiment. The period of the inoperative state of the timer circuit TM when the external control signals $\overline{CS}$, $\overline{OE}$ and $\overline{RFSH}$ are at the low level corresponds with the retrace period necessary for a CRT display.

The presetting signal ϕ_{ps} is raised to the high level for a predetermined period when all the external control signals $\overline{CS}$, $\overline{OE}$ and $\overline{RFSH}$ are at the low level. When the detection pulse $\overline{\phi_{cc}}$ is

produced, the preset signal ϕ_{ps} is raised also to the high level for a predetermined period after the control signal ϕ_{rs2} falls to the low level. The timing at which the preset signal ϕ_{ps} is raised to the high level is controlled by the word line selection timing signal ϕ_x in the same way as in the foregoing embodiment.

The gate control signal ϕ_{gc} is raised to the high level in synchronism with the timing at which the preset signal ϕ_{ps} is set to the low level. The gate signal ϕ_{gc} is kept at the high level until the coincidence pulse $\overline{\phi_{cc}}$ is generated.

The automatic refresh operation ($\overline{CS}$: high level, $\overline{RFSH}$: low level) when the circuit of this embodiment is used is the same as in the foregoing embodiment.

The circuit operation when a data continuous read-out operation is requested is as follows.

Thus, when all the external control signals $\overline{CS}$, $\overline{OE}$ and $\overline{RFSH}$ are changed to the low level, the control signal ϕ_{rs1} is raised to the high level for a predetermined period, and the count number of the address counter ACNT is reset to 0.

The timing generation circuit TG shown in Figure 1 generates various control signals in

response to the change of the output of the address counter ACNT. Therefore, the row address decoder R-DCR, the sense amplifier SA and the precharge circuit PC1 are operated at the same timing as in the foregoing embodiment.

The presetting signal ϕ_{ps} is raised to the high level for a predetermined period after the sense amplifier SA is operated, so that the data signals of the memory cells connected to the first word line are preset to the shift register SR shown in Figure 4.

The gate control signal ϕ_{gc} is raised to the high level in synchronism with the change timing of the preset signal ϕ_{pc} to the low level, so that the gate circuit GC is opened.

The data signals of the first data lines D_0 , $\overline{D_0}$ are generated from the shift register SR in response to the first shift control signals ϕ_{sr} and $\overline{\phi_{sr}}$. The output signals from the shift register SR are applied to the external terminal I/O through the data output buffer DOB.

Similarly, the data signals of the second and third data lines D_1 , $\overline{D_1}$ and D_2 , $\overline{D_2}$ are sequentially generated at the external terminal I/O through the shift register SR and the data output buffer DOB

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in response to the second and third shift control signals, respectively.

5 The timer circuit TM generates the advance pulse ϕ in synchronism with the output of the shift control signal. Therefore, the address counter ACNT is repeatedly incremented by one in synchronism with the shift operation of the shift register SR. The row system circuits are sequentially operated in response to the change of the count in the

10 address counter ACNT. As a result, a plurality of word lines are sequentially selected, and the refresh operation of the memory cells connected to the respective word lines is executed.

15 In this case, the coincidence detection pulse $\overline{\phi_{cc}}$ is not produced unless all the data signals preset to the shift register SR are shifted out. Therefore, the preset signal ϕ_{ps} is kept at the low level.

20 After the preset data signal corresponding to the 512nd data line is produced from the shift register SR, the shift control signals ϕ_{sr} , $\overline{\phi_{sr}}$ and $\overline{\phi_{srl}}$ are generated, and both of the outputs CD1 and $\overline{CD1}$ of the shift register SR are set to the low level.

25 The coincidence detection pulse $\overline{\phi_{cc}}$ is

generated when these output signals $CD1$ and $\overline{CD1}$ are at the low level.

When this detection pulse $\overline{\phi cc}$ is generated, the control signal $\phi sr2$ is raised to the high level for a predetermined period. Therefore, the generation of the advance pulse ϕ from the timer circuit TM is inhibited.

The address counter ACNT comprises nine binary counters and hence has the count number of 0 to 511. Therefore, when the first detection pulse $\overline{\phi cc}$ is generated, the count in the address counter ACNT is returned from 511 to 0.

The shift operation of the shift register SR is not executed during the period in which the control signal $\phi sr2$ is at the high level.

When the control signal $\phi sr2$ is returned to the low level after a predetermined period, the timer circuit TM is operated in response thereto. As a result, the advance pulse ϕ is generated by the timer circuit TM.

The address counter ACNT is incremented by 1. In this case, the count number when the first detection pulse $\overline{\phi cc}$ is generated is 0 as described above, the increased count number is 1. That is, it becomes a value designating the second word line.

The row system circuits are again operated in response to the change of the output of the address counter ACNT.

5 The preset signal ϕ_{ps} is again set to the high level for a predetermined period in response to the first word line selection signal ϕ_x after the control signal ϕ_{sr2} is returned to the low level. As a result, the data signals read out from the memory cells connected to the second word line
10 are set to the shift register SR.

The gate control signal ϕ_{gc} is raised again to the high level in synchronism with the change of the preset signal ϕ_{ps} to the low level. Thus, the same operations as those described already are
15 carried out.

Since the additional unit shift stage described above is provided in this embodiment, the shift register SR has the number of unit shift stages which is greater by one than the number of data
20 line pairs. Therefore, the preset signal ϕ_{ps} is generated at a timing such that a plurality of word lines can be sequentially selected.

The above described semiconductor memory has the following advantages.

25 (a) Since the memory cells are selected by the

47

built-in address counter, continuous read-out can be made without supplying external address signals.

(b) Due to the effect described in paragraph (a), a semiconductor memory suitable for a refresh memory
5 for displaying characters or figures on CRT can be obtained. In other words, an external address signal generation circuit consisting of a micro-processor or the like is unnecessary, and the system can be simplified.

10 (c) The address counter of the automatic refresh circuit is used as the address counter described above to select the word line direction, and the shift register is used to select the data line direction. Therefore, the circuit can be simplified
15 and high speed data read-out can be made. For, when the shift register is used, a column change-over operation involving the resetting of the common data line is not necessary.

A number of modifications of the above
20 described semiconductor memory may be made. For example, the shift clock of the shift register may be supplied from an external terminal. A column selection address counter circuit may be provided in place of the shift register. Furthermore, various
25 combinations of external control signals for executing continuous read-out may be employed, or

62

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new control signals may be disposed.

Though the invention has thus been described primarily with reference to a dynamic RAM which is the background and field of utilization of the
5 invention, the present invention is not particularly limited thereto, but can also be applied to a static type RAM by adding an address generation circuit so as to add the similar operation functions.

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CLAIMS:

1. A semiconductor memory including:
 - (a) a memory array having a plurality of memory cells;
 - (b) first means for generating timing signals in a time series manner without the need of receiving external clock signals;
 - (c) an address counter coupled to said first means, said address counter including means for generating address data designating memory cells from said memory array in response to the timing signal of said first means; and
 - (d) second means coupled to said memory array and to an external terminal, said second means including means for serially transmitting data stored in memory cells designated by said address counter to said external terminal.
2. A semiconductor memory according to claim 1, wherein each of said memory cells comprises a dynamic type memory cell.
3. A semiconductor memory according to claim 2, further including:
 - (e) an address buffer circuit providing internal address signals for said memory array in response to external address signals;
 - (f) a multiplexor coupled between said memory



array and said address buffer and between said memory array and said address counter; and

(g) control means including means for controlling said multiplexor to select either internal address signals generated by said address buffer circuit or address data generated by said address counter to apply to said memory array.

4. A semiconductor memory including:

(a) a memory array including a plurality of memory cells arranged in rows and columns;

(b) first means for generating timing signals in a time series manner without the need of receiving external clock signals;

(c) an address counter coupled to said first means, said address counter including means for generating address signals designating a memory cell row from said memory array in response to the timing signal of said first means, so that said memory cell rows are sequentially designated by said address counter in accordance with the timing signal of said first means; and

(d) second means coupled to said memory array and to an external terminal, said second means including means for serially transmitting data stored in the memory cell row designated by said address counter to said external terminal.

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(65)

5. A semiconductor memory according to claim 4, wherein said second means comprises converting means coupled to said external terminal and which converts parallel data into serial data, and transmitting means coupled between said memory array and said converting means and which transmits data stored in memory cells designated by said address counter to said converting means in parallel, and wherein said control means further includes means for controlling said converting means so that said converting means serially provides data applied to said converting means by said transmitting means to said external terminal.

6. A semiconductor memory according to claim 5, wherein said converting means includes a shift register.

7. A semiconductor memory according to claim 4, wherein each of said memory cells comprises a dynamic type memory cell.

8. A semiconductor memory according to claim 7, further including an address decoder coupled between said memory array and said address counter.

9. A semiconductor memory according to claim 8, further including a control circuit, wherein said second means comprises converting means which are coupled to said external terminal and which convert parallel data into serial data, and transmitting

52



means which are coupled between said memory array and said converting means and which transmit data stored in the memory cell row designated by said address counter to said converting means in parallel, and wherein said control circuit includes means for controlling said converting means so that said converting means serially provide data applied to said converting means by said transmitting means to said external terminal.

10. A semiconductor memory according to claim 9, wherein said first means includes means for controlling said address counter so that said address counter designates a different memory cell row when said converting means transmits all of the data stored in a previously designated memory cell row to said external terminal.

11. A semiconductor memory according to claim 10, wherein said converting means includes a shift register.

12. A semiconductor memory according to claim 10, wherein said first means comprises a timer circuit for generating said timing signals.

13. A semiconductor memory including:
(a) a memory array having a plurality of memory

53



(62)

cells arranged in rows and columns;

(b) first means for generating timing signals in a time series manner without the need of receiving external clock signals;

(c) an address counter coupled to said first means, said address counter including means for generating address signals in response to the timing signal of said first means;

(d) an address buffer circuit providing internal address signals in response to external address signals;

(e) a multiplexor coupled between said memory array and said address buffer and between said memory array and said address counter;

(f) control means including means for controlling said multiplexor to select either the internal address signals generated by said address buffer circuit or the address signals generated by said address counter;

(g) an address decoder coupled between said memory array and said multiplexor, said address decoder including means for selecting a memory cell row from said memory array in response to the address signals selected by said multiplexor; and

(h) second means coupled to said memory array and to an external terminal, said second means including means for serially transmitting data stored in a memory cell row selected by the address signals which

68

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said address counter generates to said external terminal in series.

14. A semiconductor memory according to claim 13, wherein each of said memory cells comprises a dynamic type memory cell.

15. A semiconductor memory according to claim 14, wherein said second means comprises converting means coupled to said external terminal and which converts parallel data into serial data, and transmitting means coupled between said memory array and said converting means and which transmits data stored in the memory cell row selected by the address signals of said address counter to said converting means in parallel, and wherein said control means further include means for controlling said converting means so that said converting means serially provides data applied to said converting means by said transmitting means to said external terminal.

16. A semiconductor memory according to claim 15, wherein said first means include means for controlling said address counter so that said address counter designates a different memory cell row when said converting means transmits all of the data stored in a previously designated memory cell row to said external terminal.

17. A semiconductor memory according to claim

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(9)

16, wherein said converting means include a shift resistor.

18. A semiconductor memory according to any one of the preceding claims 13 to 17, wherein said means for generating address signals within said address counter does so in response to the timing signals of said first means without the need of receiving external address signals.

19. A semiconductor memory constructed and arranged to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.