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A-2-4 Threshold Difference Compensating Sense Amplifier for High Density Dynamic MOS RAM's

T.Furuyama, S.Saito and S.Fujii

Semiconductor Device Engineering Laboratory

Toshiba Corporation, Kawasaki, Japan

A dynamic flip-flop sense amplifier, which basically consists of two driver MOS transistors, is widely used in VLSI memories. However, a threshold difference ΔV_T between the two transistors has become one of the severest problems especially in high density dynamic MOS RAM's. Several sense amplifiers have been presented to obtain a large S/N ratio [1]-[2], or to compensate the threshold difference [3]-[4].

In this paper, a new threshold difference compensating sense amplifier technique for high density dynamic RAM's is described.

A typical 256K dynamic RAM will have 1024 sense amplifiers. The distance between two driver transistors of the sense amplifier is as long as 50μm. Typical ΔV_T distributions of paired transistors, which are about 50μm away from each other, are shown in Fig.1, for two different effective channel lengths. The distribution of 1.5μm transistors is broader than that of 2.0μm transistors because of size effects. The standard deviations σ are 12.6mV and 11.1mV for 1.5um and 2.0um transistors, respectively. Considering the number of sense amplifiers, the ΔV_T contribution to the sensitivity of conventional sense amplifiers can be roughly estimated as 3σ/(S/N ratio). So the sensitivity might easily exceed 500mV in the case of high density memories beyond 256K dynamic RAM.

To acquire higher sensitivity, a new ΔV_T compensating sense amplifier is introduced. An equivalent circuit and a timing diagram are shown in Fig.2 and Fig.3. Initially, paired bit lines of different levels are connected each other. Then, sense node N_1 and N_2 are precharged to Vcc level through T_3 and T_4, maintaining N_1 and N_2 to have the same potential. As a result, bit lines BL_1 and BL_2 are precharged to $V_{CC}-V_{T1}$ and $V_{CC}-V_{T2}$, through sense amplifier driver transiators T_1 and T_2, respectively, where V_{T1} and V_{T2} are the threshold voltages of T_1 and T_2. Subsequently T_5 and T_6 are turned on to connect each bit line and sense node, so a cross-coupled flip-flop organization is composed. The bit line potentials V_{N1}, V_{N2} are presented as follows, where C_B and C_N are the bit line and the sense node capacitance,

$$V_{Ni} = Vcc - \frac{C_B}{C_B+C_N} \cdot V_{Ti} \quad (\ i=1,2\ ).$$

Then, a certain word line is selected, and sensing operation starts as conventional amplifiers. The ΔV_T contribution to the sensitivity is described as follows, for a new sense amplifier and a conventional one, where C_S is a storage capacitance,

$$V_{\Delta V_T\text{-compensating}} = \left(\frac{C_N}{C_S}+1\right)\cdot \Delta V_T$$

$$V_{\text{conventional}} = \left(\frac{C_B+C_N}{C_S}+1\right)\cdot \Delta V_T\ .$$

Assuming that C_S, C_N and C_B are 40, 50 and 250fF respectively, $V_{\Delta V_T\text{-compensating}}$ and $V_{\text{conventional}}$ are calculated as $2.25\cdot\Delta V_T$ and $8.5\cdot\Delta V_T$.

To evaluate a new sense amplifier, a test device, shown in Fig.4, is designed and fabricated. This new amplifier can also operate as a conventional amplifier, when ϕ_T is always fixed to V_P level. This enables an accurate comparison between both types of amplifiers, using the same test sense amplifier. Fig.5 shows the measured and calculated data. Here, sensitivity is defined as a minimum cell signal, which can be sensed correctly. A good agreement between the measurement and the calculation is obtained, and the sensitivity of a new amplifier is four times higher than that of a coventional one.

In conclusion, the new ΔV_T compensating sense amplifier technique is introduced. Both of theoretical and experimental data show remarkable sensitivity improvement. This technique will become important for high density memories beyond a 256K dynamic RAM.

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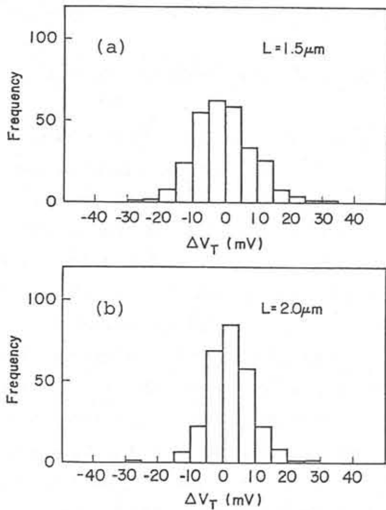

Fig.1 Typical ΔV_T distributions of two effective channel length transistors. Gate oxide thickness is about 300Å.

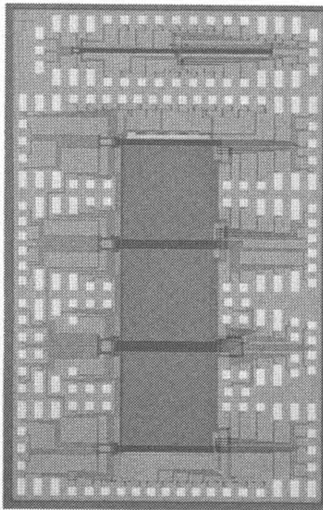

Fig.4 A microphotograph of the test dedice chip.

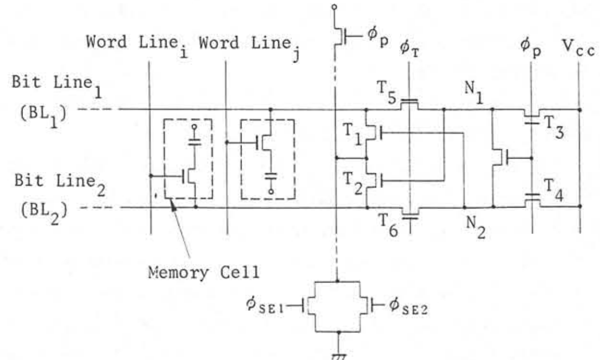

Fig.2 An equivalent circuit of the new ΔV_T compensatig sense amplifier.

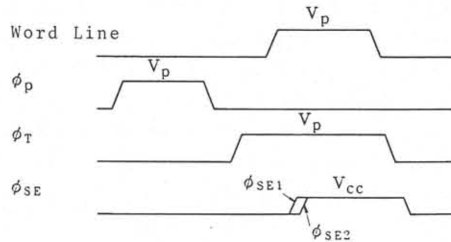

Fig.3 A timing diagram of the new sense amplifier. V_P satisfies $V_P > V_{CC} + V_T$.

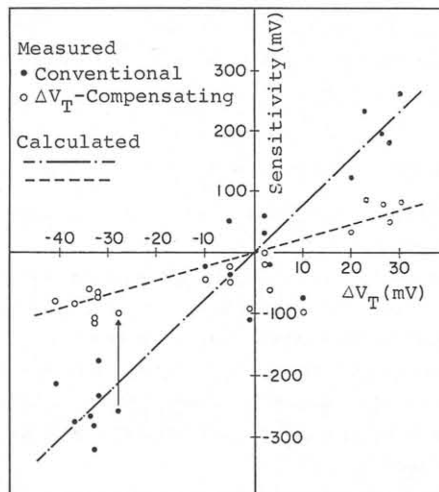

Fig.5 Measured and calculated sensitivity of the new sense amplifier and a conventional one.