Write Voltage and Read Reference Current Generator for MLC-PCM Considering with Temperature Characteristics

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I. Introduction

Phase change memory (PCM) is one of the candidates for the storage class memory (SCM) due to non-volatile, high speed and low energy characteristics [1], as an alternative for NAND flash memory or hard-disk drives (HDDs). Since PCM gives multi-level-cell (MLC) functionality [2] and simple $4F^2$ cell [3], the bit cost can be reduced. In addition, the access speed of PCM is about 500-times faster than NAND flash [1].

$Ge_2Sb_2Te_5$ (GST) is a mature material for PCM. As temperature rises, SET/RESET voltages (V_{SET}/V_{RESET}) become low/high because the device temperature is close to the crystallization temperature of GST. On the other hand, the resistance of PCM also has temperature dependence due to its semiconductor nature [4, 5]. Additionally, from our experimental results, these temperature coefficients can change not only by the temperature at read operation (T_{READ}), but also by the temperature at write operation (T_{WRITE}) [6, 7]. Especially in the MLC case, this dependency may lead to read errors if the fixed reference currents are used for each level. Therefore, the write voltage and reference currents (I_{ref}) should be calculated considering these problems.

II. Proposed write voltage and read reference current generator and experimental results

The variable temperature coefficient (TC) read reference generator has been presented in [6]. This generator can output both positive and negative linear TC currents. Thus, this generator is used for V_{SET} and V_{RESET} generation. Fig. 1 shows the fitting results. By using positive and negative coefficient, the proposed voltage generator achieves accurate reproduction of the temperature dependencies of V_{SET} and V_{RESET}.

On the other hand, the read current has non-linear but exponential TC. Hence, for the I_{ref} generation, only one configuration of the variable TC read reference generator cannot precisely reproduce the PCM's TC. Therefore, in the proposal, the temperature range is divided into three regions: -5ºC-25ºC, 25ºC-55ºC, 55ºC-85ºC as shown in Fig. 2. Using different setting for each temperature region, the optimum read reference can be generated. Fig. 3 shows the block diagram of the proposed reference current generation for a MLC-PCM. TWRITE data is updated and stored in SLC region of PCM when the corresponding user data is written in MLC-PCM. Fig. 4 demonstrates the read reference generation for various temperatures by SPICE simulation. Using the optimum configuration on the current temperature region, the reference current can accurately reproduce the PCM characteristics.

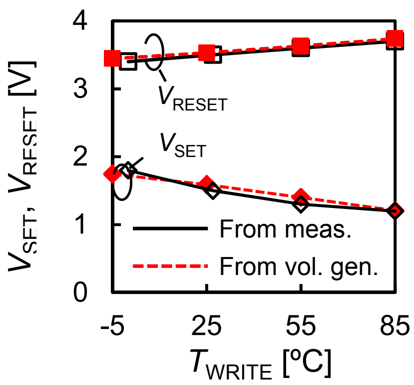


Fig. 1 Measured temperature dependence and fitting result of SET and RESET voltage

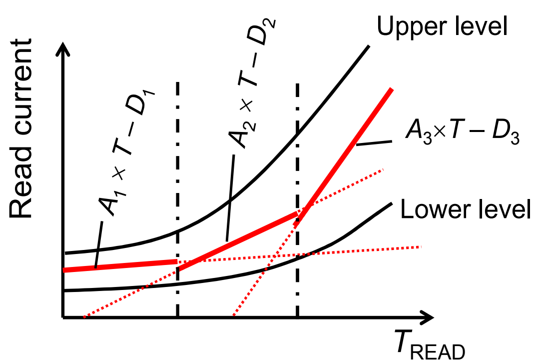


Fig. 2 Concept of the proposed exponential reference generator.

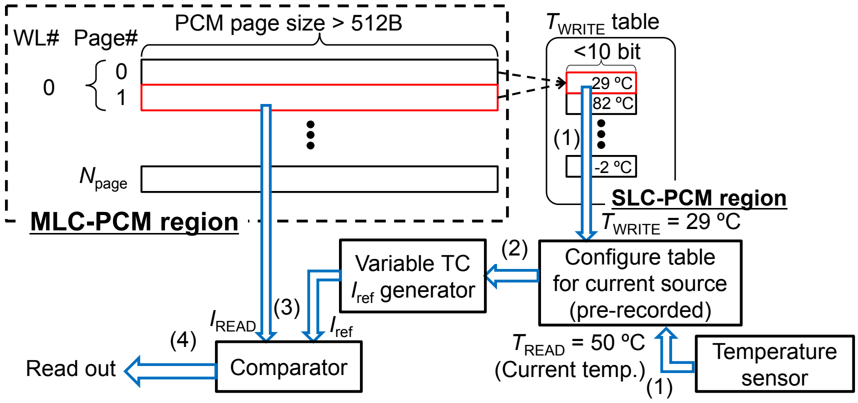
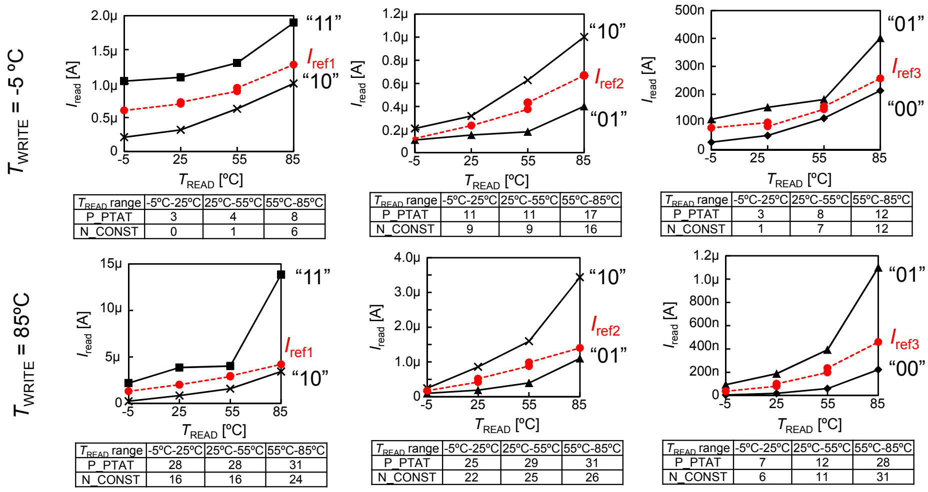


Fig. 3 Block diagram of the proposed read circuit for MLC-PCM.



(a) I_{ref1} (k = 1/20) (b) I_{ref2} (k = 1/60) (c) I_{ref2} (k = 1/100)

Fig. 4 Demonstration results of read reference current generation for 2 bit-MLC-PCM.

III. Conclusions

The temperature characteristics of PCM are presented with the experimental results. Since the optimum SET and RESET voltages changes by the temperature, the voltage supply circuit must track this characteristic. In addition, the measurement results show that the read current depends on not only the current but also the write temperatures. Dividing into three temperature regions and using the variable temperature coefficient current generator, the proposed generator can track both the linear write voltage and the exponential read current changes by the temperature.

Acknowledgement

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References

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