Evaluation of Flash Memory Cells

Application Note 4156-4

Agilent 4155C/4156C Semiconductor Parameter Analyzer

Introduction

For next generation flash memory development, it is necessary to resolve two issues. For higher operation speed, it is necessary to shorten the time to write and erase memory cells. For higher reliability, it is necessary to make the life of memory cells longer. Therefore, evaluation of memory cell characteristics related to write/erase time and memory cell's life is very important.

This application note describes how to perform precise evaluation of flash memory cells by using the Agilent 4155C/4156C Semiconductor Parameter Analyzer.

Evaluating of Flash Memory Cells

There are several ways to evaluate flash memory cells. Typically, the following characteristics are measured:

Write/Erase pulse width (or pulse voltage) dependency. Pulse width (voltage) versus threshold voltage is evaluated.

Write/Erase times dependency. Number of write/erase cycles versus threshold voltages after write and erase (Vthw and Vthe) is evaluated. Figure 1 shows typical flowchart for this test. For this evaluation, Vth values are measured after alternately applying the "write" and "erase" pulses.

This application note mainly discusses the write/erase times dependency test.

Difficulties in Flash Memory Cell Evaluation

The tests are done by using a combination of pulse generators and dc measurement instrument. Pulse generators are used to write and erase a memory cell. Figure 2 shows typical pulse stress conditions for writing and erasing NOR type memory cell. A dc measurement instrument such as parameter analyzer is used to measure Vthw and Vthe. It is necessary to have switching instruments to change connections of those measurement instruments, which results in a complicated configuration. Moreover, you need to write complicated programs to synchronously control the instruments for automation of this long term test.

When applying erase pulses to a NOR type flash memory cell, it is necessary to open the drain terminal as shown in Figure 2. If you use conventional mechanical relays to open the drain terminal, the relays may be broken before completing the one million cycles test.

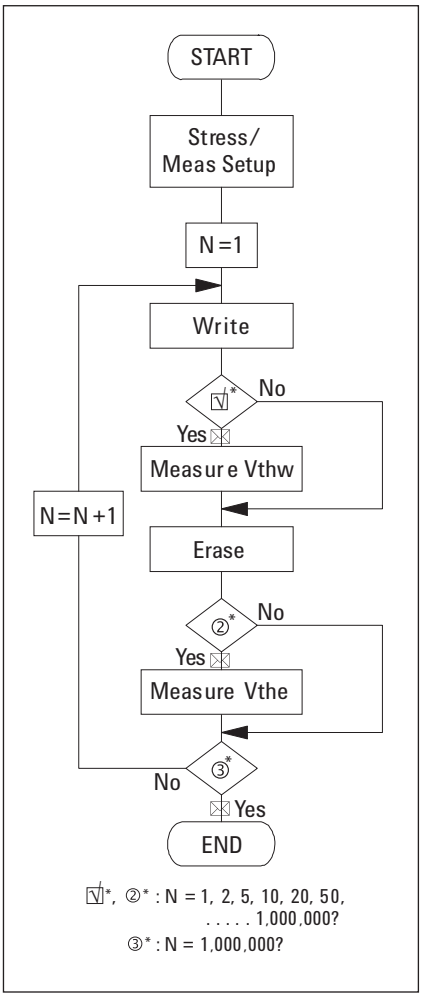

Figure 1. Write/Erase Times Dependency Test Flowchart

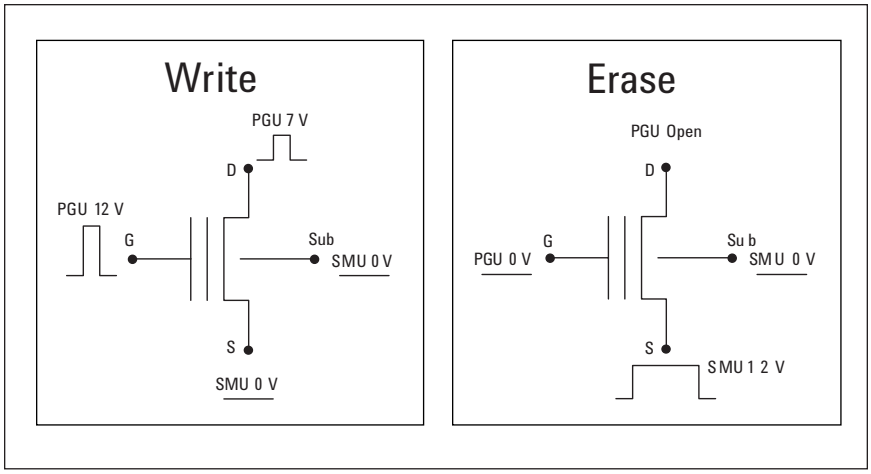

Figure 2. Typical Write and Erase Pulses for NOR Type Flash Memory Cell

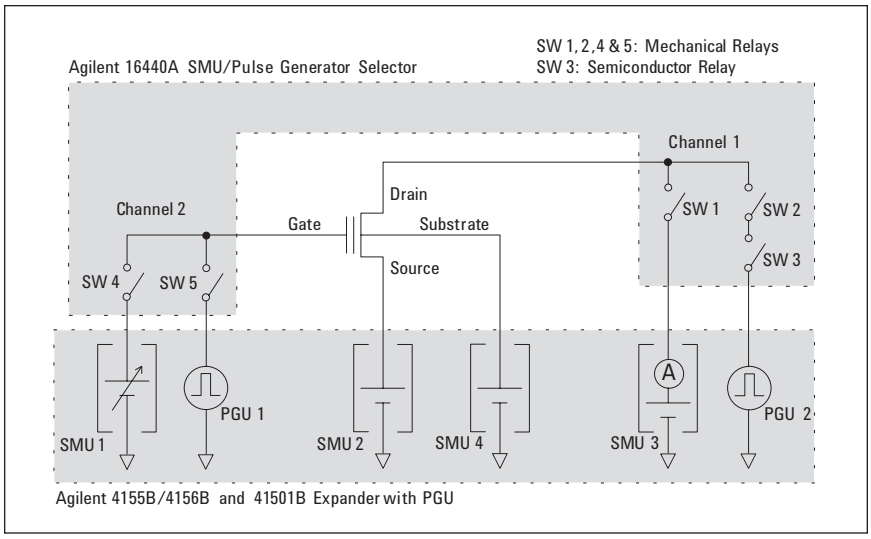

Figure 3. Connection Example for Write/Erase Cycles Test (NOR Type)

Solution Using the Agilent 4155C/4156C
The Agilent 4155C/4156C Semiconductor Parameter Analyzer has versatile functions and is a solution for flash memory cell evaluation. The analyzer has options to add 2-channel pulse generator unit (PGU) in the Agilent 41501B Expander. The PGUs can force up to 40 V pulses with minimum 1 µsec pulse width. You can control pulse transition times too.

As a switching tool, you can use the Agilent 16440A SMU/Pulse Generator Selector. It is synchronously controlled by the 4155C/4156C through the interface on PGU. Instrument configuration can be quite simple. You can easily operate PGU and selector in fill-in-the-blank manner, just like you operate SMUs.

The Agilent 16440A has two channels to switch SMUs and PGUs. Channel 1 has an additional semiconductor relay as shown in Figure 3. It can be used to open the drain terminal in a NOR type flash memory cell test because it is more durable than mechanical relays. Now you can perform real tests of memory cells.

Performing Write and Erase Cycles Test Using the Agilent 4155C/4156C
Entire test is controlled by using an IBASIC program. IBASIC runs on built-in controller of the 4155C/4156C.

First, the program copies previously saved write and erase stress setups and threshold voltage measurement setup into internal memory. Then the program repeats alternate write and erase stress forcings until predefined 1, 2, 5 step intervals. Then threshold voltage measurement is performed. This way allows you to make test programs simpler. Most test conditions can be set by filling in the stress and measurement setup pages, which can be saved to files. No complicated programming to control instrument is required.

Example write and erase stress setups used in this test are shown in Figures 4 and 5, respectively. Stress conditions are defined in the STRESS: CHANNEL DEFINITION page and STRESS SETUP page. In the CHANNEL DEFINITION page, you can define units to be used in this test, stress mode for each unit, and connection setup of the selector. In the STRESS SETUP page, you can specify stress voltages for each SMU and pulse conditions for each PGU including voltages and pulse timing.

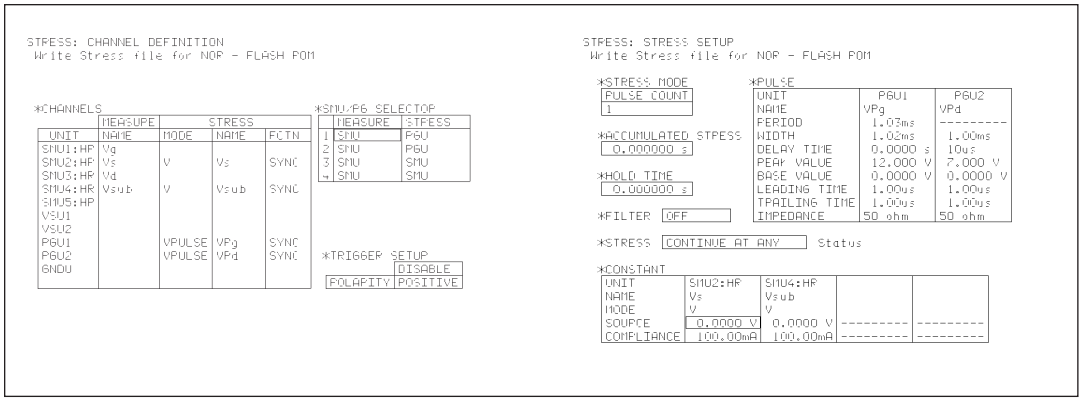

Figure 4. Write Stress Condition Example

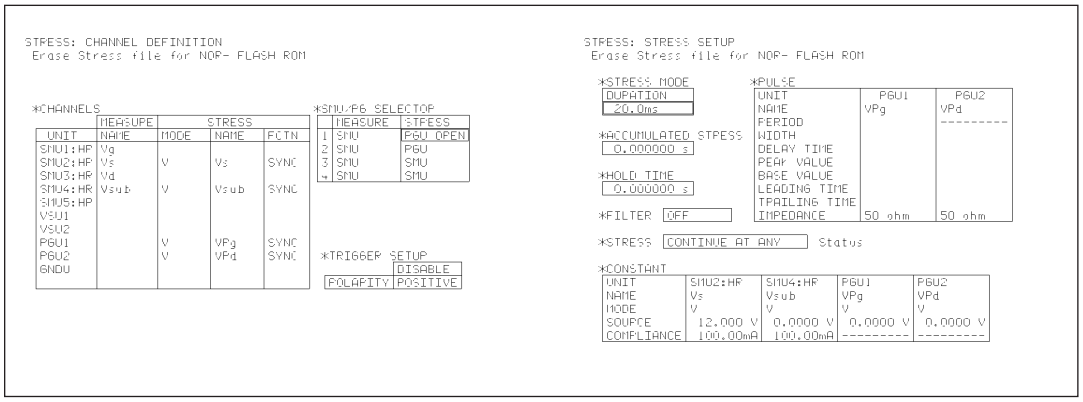

Figure 5. Erase Stress Condition Example

In the write stress example, PGU1 and PGU2 are used to force pulses to the gate and drain terminals. SMU2 and SMU4 force constant 0 V to source and substrate. For erase stress, PGU1 is used to force constant 0 V to gate. PGU2 is set to open by selecting PGU OPEN in SMU/PG SELECTOR field (Figure 5). An erase pulse is forced to source using SMU2. If you need narrower[1] pulse than SMU can force, you can use an external pulse generator with an additional Agilent 16440A selector instead of SMU2. The PGU has a trigger output function, so the external pulse generator can be synchronized with parameter analyzer's output.

Figure 6 shows the timing chart of this test including output sequence for each measurement units and connections for write/erase stresses and Vth measurements.

For Vthw and Vthe measurements, Id-Vg characteristics are measured using four SMUs, then constant current Vth values (gate voltage at drain current of typically 1 μA) are automatically obtained by using the auto analysis function of the 4155C/4156C. Figure 7 is an example Vth measurement result.

Finally, a graph of Vthw and Vthe versus write/erase times is drawn on the graphics screen of the 4155C/4156C. An example test result is shown in Figure 8. Write and erase cycles were repeated to one million times in this example. Upper curve is Vthw and lower curve is Vthe. At the end of this test, the difference between Vthw and Vthe became very small, which means the memory cell was not functional in the end.

1. The Agilent 16440A's bandwidth (–3dB) is typically less than 10 MHz though it is not specified.

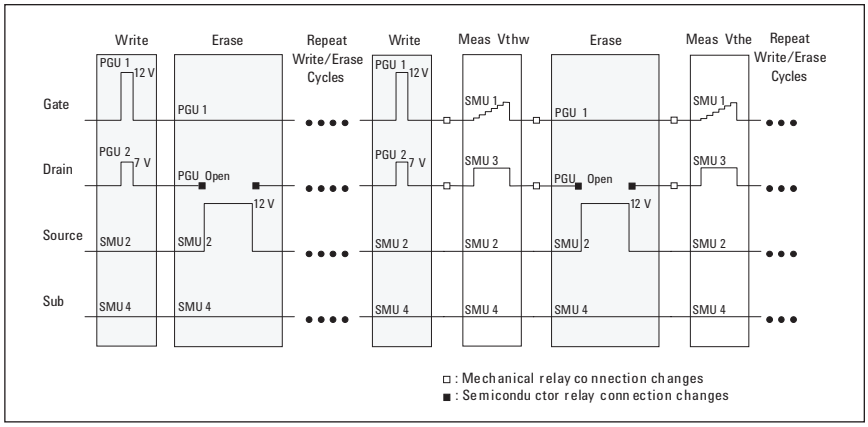

Figure 6. NOR Type Flash Memory Write/Erase Cycles Test Timing Chart

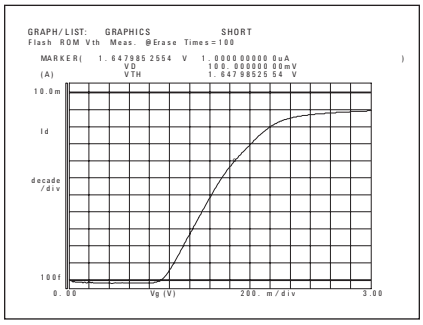

Figure 7. Vth Measurement Example

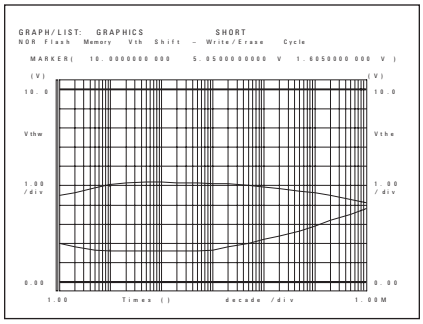

Figure 8. Write/Erase Times Dependency Test Result Example

Note: The information contained in this application note is also applicable to the Agilent 4155A/4156A and Agilent 4155B/4156B.

Conclusion

By using the Agilent 4155C/4156C with its PGU options and Agilent 16440A, you can easily configure a small and inexpensive system to perform flash memory cell evaluation. The control of this system can be easily done by using previously saved stress and measurement setup files.

The 16440A has a special relay for opening the measurement circuit. You can perform memory cell evaluation without worrying about the life of relay.

By using the same system configuration, you can perform pulse width dependency test and pulse voltage dependency test too. The system can also be used for NAND type flash memory evaluation. The Agilent 4155C/4156C's PGU can force high enough voltage pulses for NAND type flash memory cells.

If you want much higher speed test capability or much narrower and faster pulse stresses, Agilent has the Agilent 4072A and 4073A Parametric Test Systems, which can be used for process monitoring in production lines as well.

For more information about Agilent Technologies semiconductor test products, applications, and services, visit our website: **www.agilent.com/go/semiconductor** or you can call one of the centers listed and ask to speak with a semiconductor test sales representative.

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