

# Technical Note

## NAND Flash Performance Increase with PROGRAM PAGE CACHE MODE Command

### Overview

NAND Flash devices are designed for applications requiring nonvolatile, high-density, solid state storage memory. Although NAND Flash may meet the speed requirements of traditional applications, many newer applications require faster data processing capabilities. For these applications, Micron<sup>®</sup> NAND Flash can deliver higher data throughput using the PROGRAM PAGE CACHE MODE operation.

Cache programming works by pipelining data to the NAND Flash device. Pipelining involves sending a page (2KB) of data to the cache register and then transferring this data to the data register when the CACHE PROGRAMMING command is issued. When the transfer is complete, the cache register is available to receive new data while the data register simultaneously programs the NAND Flash array.

Typical page programming time (<sup>t</sup>PROG) for Micron NAND Flash devices is approximately 300 $\mu$ s for a 2KB page of data. PROGRAM PAGE CACHE MODE operation can improve data throughput by as much as 35% for x8 devices and 17% for x16 devices.

This technical note discusses the benefits of PROGRAM PAGE CACHE MODE operations over normal PROGRAM PAGE operations. It also provides specific timing examples and instructions for performing PROGRAM PAGE CACHE MODE operations.

### Functionality

#### Normal PROGRAM PAGE Operation

Micron NAND Flash devices have two command latch cycles and five address latch cycles, which are followed by up to 2112 bytes or 1056 words of data in a normal PROGRAM PAGE operation. Following the ADDRESS LATCH cycles, R/B# goes LOW for <sup>t</sup>PROG (a typical time of 300 $\mu$ s and a maximum time of 700 $\mu$ s). Timing details are provided in Tables 2 and 3 on page 5 for x8 devices and Tables 4 and 5 on page 6 for x16 devices.

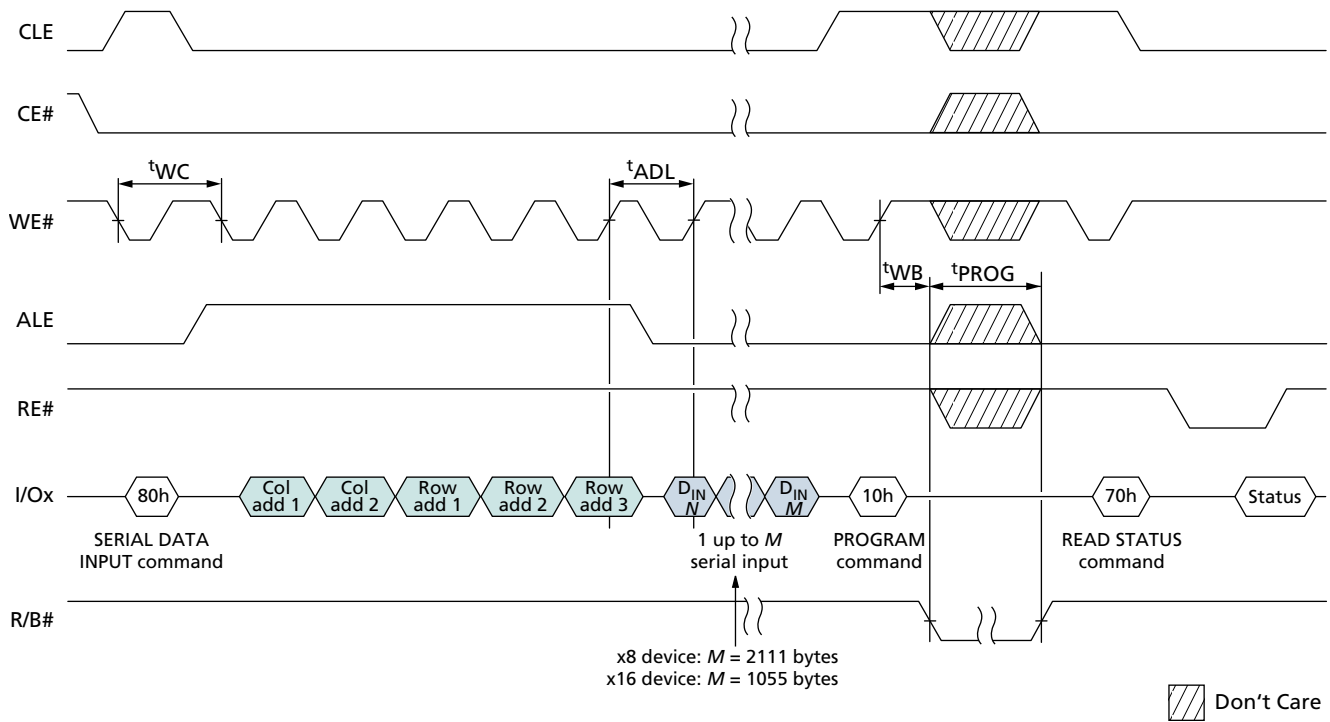
Data can be programmed sequentially, one byte or word per cycle, depending on the width configuration of the NAND Flash device. Assuming 50ns cycles, timing is shown in Figure 1 on page 2.

**Figure 1: Normal PROGRAM PAGE Timing**

x8 Configurations  
 $(2 \times 50\text{ns}) \text{ commands} + (5 \times 50\text{ns}) \text{ address} + (2112 \times 50\text{ns}) \text{ data} + 300\mu\text{s } t_{\text{PROG}}$   
 $= 405.95\mu\text{s per page}$

x16 Configurations  
 $(2 \times 50\text{ns}) \text{ commands} + (5 \times 50\text{ns}) \text{ address} + (1056 \times 50\text{ns}) \text{ data} + 300\mu\text{s } t_{\text{PROG}}$   
 $= 353.15\mu\text{s per page}$

**Figure 2: NAND Flash Typical PROGRAM PAGE Operation Timing**



## PROGRAM PAGE CACHE MODE Operation

PROGRAM PAGE CACHE MODE operation begins with a PROGRAM PAGE CACHE MODE (80h-15h) command. Initially, data is copied into the cache register. When the 15h command completes, the data is transferred to the data register. Assuming that a page 0 address is issued in the PROGRAM PAGE CACHE MODE command, page 0 programming from the data register into the NAND Flash array begins when R/B# returns HIGH.

When R/B# returns HIGH, another PROGRAM PAGE CACHE MODE command sequence can be issued to write new data to the cache register. The time that R/B# stays LOW is determined by the actual programming time. On the first programming pass, R/B# stays LOW for the time it takes to transfer data from the cache register to the data register. On subsequent passes prior to the last page, the data in the data register must be programmed into the NAND Flash memory array before additional data can be transferred from the cache register.

When R/B# is used to determine programming status during PROGRAM PAGE CACHE MODE, a PROGRAM PAGE (80h-10h) command is used to program the last page of data. For the last cache programming sequence, R/B# stays LOW for  $t_{LPROG}$ . Table 1 and Figure 3 on page 4 provide signal and timing information required for PROGRAM PAGE CACHE MODE operations.

For programming a single page, the PROGRAM PAGE CACHE MODE operation takes the same time as a regular PROGRAM PAGE operation (see technical note TN-29-01); however, for two or more pages, there is a significant performance gain using PROGRAM PAGE CACHE MODE.

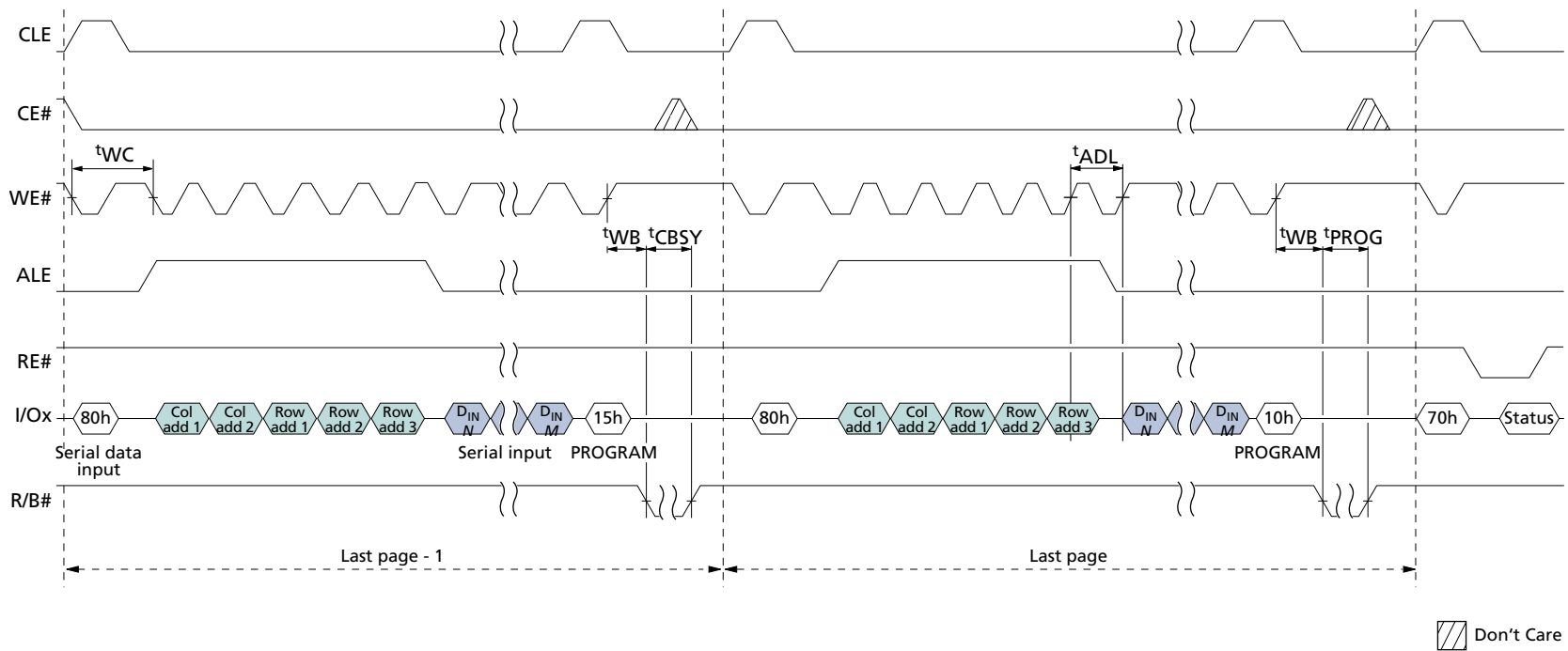
The following examples assume  $t_{CBSY}$  is equal to  $t_{PROG}$  (TYP) after the first  $t_{CBSY}$ .

**Table 1: Timing Delays**

| Parameter     | Description  | Typ | Max | Unit    |
|---------------|--|-----|-----|---------|
| $t_{PROG}$    | Data transfer from data register to NAND Flash array                                   | 300 | 700 | $\mu s$ |
| $t_{CBSY}$    | Busy time for PROGRAM PAGE CACHE MODE  | 3   | 700 | $\mu s$ |
| $t_{LPROG}^1$ | Last-page programming time for PROGRAM PAGE CACHE MODE (see 2Gb NAND Flash data sheet) | –   | –   | –       |

Notes: 1.  $t_{LPROG} = t_{PROG}$  (last page) +  $t_{PROG}$  ((last - 1) page) - command load time (last page) - address load time (last page) - data load time (last page).

**Figure 3: PROGRAM PAGE CACHE MODE Operation Timing**



**Table 2: Single-Block PROGRAM PAGE Operation Timing (x8)**

| Process  | Repetitions | 50ns Cycle Time |              | Unit |
|--|-------------|-----------------|--------------|------|
|  |             | Time            | Total Time   |      |
| Command latch (80h)                            | 1           | 50              | 50           | ns   |
| Address latch                                  | 5           | 50              | 250          | ns   |
| Program data cycles                            | 2112        | 50              |              | ns   |
| Program data cycles total page                 |             |                 | 105.6        | μs   |
| Command latch (10h)                            | 1           | 50              | 50           | ns   |
| R/B# LOW ( <sup>t</sup> PROG) typical          | 1           | 300             | 300          | μs   |
| Total time to program a page                   |             |                 | 405.95       | μs   |
| <b>Total time to program a block</b>           | 64          | 0.40595         | <b>25.98</b> | ms   |
| <b>Speed (programming 64 pages in a block)</b> |             |                 | <b>5.2</b>   | MB/s |

**Table 3: Single-Block PROGRAM PAGE CACHE MODE Operation Timing (x8)**

| Process  | Repetitions | 50ns Cycle Time |               | Unit |
|--|-------------|-----------------|---------------|------|
|  |             | Time            | Total Time    |      |
| Command latch (80h)                            | 1           | 50              | 50            | ns   |
| Address latch                                  | 5           | 50              | 250           | ns   |
| Program data cycles                            | 2112        | 50              |               | ns   |
| Program data cycles total page                 |             |                 | 105.6         | μs   |
| Command latch (15h)                            | 1           | 50              | 50            | ns   |
| R/B# LOW (1st <sup>t</sup> CBSY)               | 1           | 3               | 3             | μs   |
| <b>Time to program page 0</b>                  |             |                 | <b>108.95</b> | μs   |
| R/B# LOW ( <sup>t</sup> CBSY) typical          | 1           | 300             | 300           | μs   |
| <b>Time to program page 1</b>                  |             |                 | <b>300</b>    | μs   |
| <b>Time to program pages 2:62</b>              | 61          | 0.300           | <b>18.3</b>   | ms   |
| R/B# LOW ( <sup>t</sup> LPROG)                 | 1           | 494.65          | 494.65        | μs   |
| <b>Time to program page 63</b>                 | 1           |                 | <b>494.65</b> | μs   |
| <b>Total time to program a block</b>           |             |                 | <b>19.20</b>  | ms   |
| <b>Speed (programming 64 pages in a block)</b> |             |                 | <b>7.04</b>   | MB/s |

**Table 4: Single-Block PROGRAM PAGE Operation Timing (x16)**

| Process  | Repetitions | 50ns Cycle Time |              | Unit |
|--|-------------|-----------------|--------------|------|
|  |             | Time            | Total Time   |      |
| Command latch (80h)                            | 1           | 50              | 50           | ns   |
| Address latch                                  | 5           | 50              | 250          | ns   |
| Program data cycles                            | 1056        | 50              |              | ns   |
| Program data cycles total page                 |             |                 | 52.50        | μs   |
| Command latch (10h)                            | 1           | 50              | 50           | ns   |
| R/B# LOW ( <sup>t</sup> PROG)                  | 1           | 300             | 300          | μs   |
| Total time to program a page                   |             |                 | 353.15       | μs   |
| <b>Total time to program a block</b>           | 64          | 0.35315         | <b>22.60</b> | ms   |
| <b>Speed (programming 64 pages in a block)</b> |             |                 | <b>5.98</b>  | MB/s |

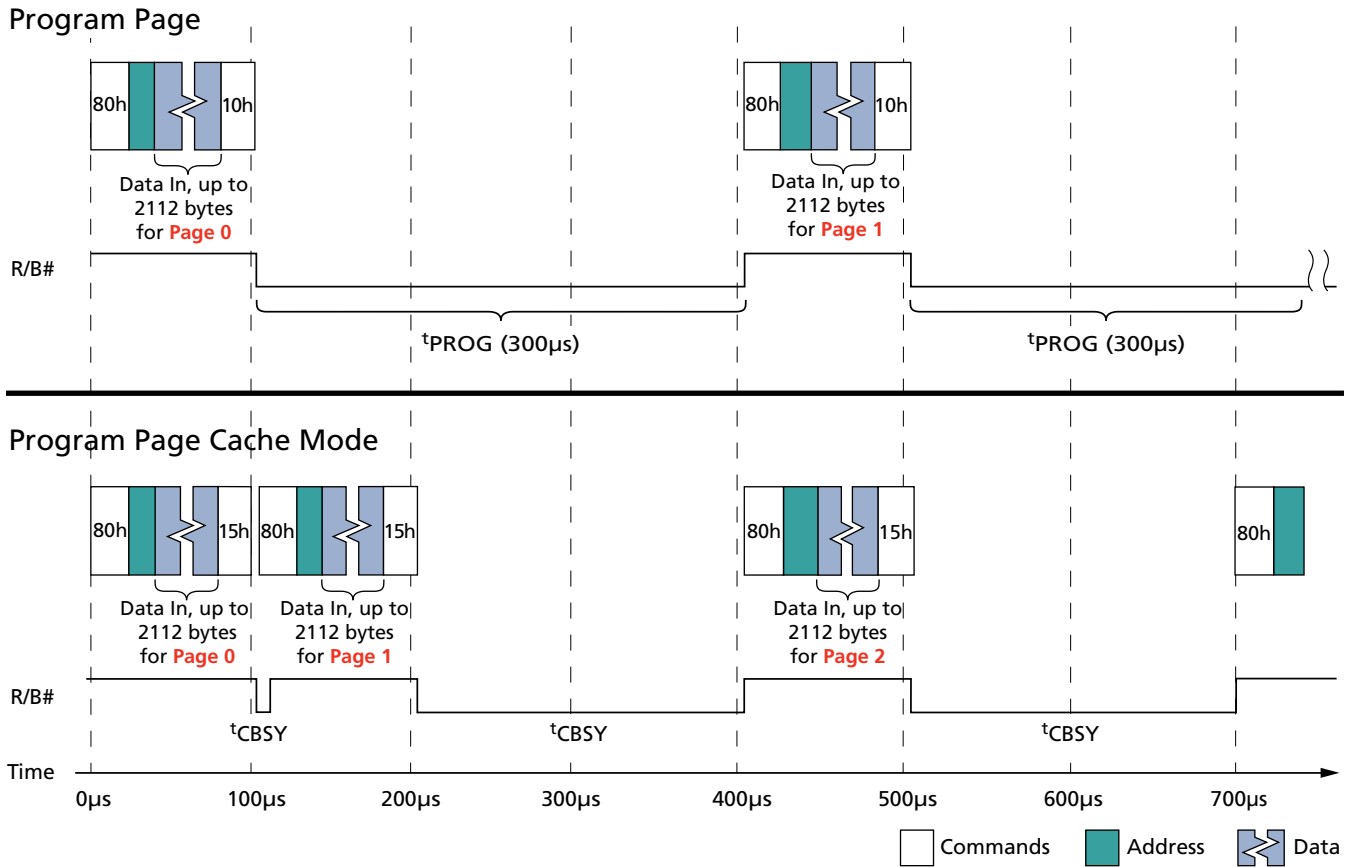
Table 5 shows timing calculations for 50ns PROGRAM CLOCK cycles with PROGRAM PAGE CACHE MODE.

**Table 5: Single-Block PROGRAM PAGE CACHE MODE Operation Timing (x16)**

| Process  | Number of Cycles | 50ns Cycle Time |               | Units |
|--|------------------|-----------------|---------------|-------|
|  |                  | Time/Cycle      | Total Time    |       |
| <b>Timing for page 0 programming</b>           |                  |                 |               |       |
| Command latch (80h)                            | 1                | 50              | 50            | ns    |
| Address latch                                  | 5                | 50              | 250           | ns    |
| Program data cycles                            | 1056             | 50              |               | ns    |
| Program data cycles total page                 |                  |                 | 52.50         | μs    |
| Command latch (15h)                            | 1                | 50              | 50            | ns    |
| R/B# LOW (1st <sup>t</sup> CBSY)               | 1                | 3               | 3             | μs    |
| <b>Time to program page 0</b>                  |                  |                 | <b>56.15</b>  | μs    |
| R/B# LOW ( <sup>t</sup> CBSY)                  | 1                | 300             | 300           | μs    |
| <b>Time to program page 1</b>                  |                  |                 | <b>300</b>    | μs    |
| <b>Time to program pages 2:62</b>              | 61               | 0.300           | <b>18.3</b>   | ms    |
| R/B# LOW ( <sup>t</sup> LPROG)                 | 1                | 543.85          | 543.85        | μs    |
| <b>Time to program page 63</b>                 |                  |                 | <b>543.85</b> | μs    |
| <b>Total time to program a block</b>           |                  |                 | <b>19.2</b>   | ms    |
| <b>Speed (programming 64 pages in a block)</b> |                  |                 | <b>7.04</b>   | MB/s  |

Figure 4 shows the time savings associated with using PROGRAM PAGE CACHE MODE.

**Figure 4: PROGRAM PAGE CACHE MODE Time Savings**



## Conclusion

By using the PROGRAM PAGE CACHE MODE operation available in Micron NAND Flash devices, customers can experience programming performance gains and increased data throughput in their systems.

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