Ultra MMI: an LDPC decoder that doubles throughput at end-of-life.

Dr. Shiuan-Hao Kuo
ECC team

Silicon Motion
LDPC for NAND flash

**2019 ultra MMI & Fast N4**

**2018 Expand enterprise level reliability**
Undetectable for 2K/4K TLC/QLC supports

**2017 Genuine 4KB LDPC**

- Encoder area: 2.7x
- Decoder area: 1.23x

**2018 Ultra MMI & Fast N4**

**2019 Expand enterprise level reliability**
Undetectable for 2K/4K TLC/QLC supports

**2017 Genuine 4KB LDPC**

- Encoder area: 2.7x
- Decoder area: 1.23x
LDPC decoder / decoding flow

Hard decoding
- Green mode decoder
- Regular decoder
- Auto Swap
- Regular decoder

Soft decoding
- Regular decoder

Hard read
- sign bit only

Soft read
- 1 sign
- 1 soft/2 soft bits

NAND

Green mode decoder

Regular decoder

Memory
Decoding spectrum

Product life-time

ECC margin

Bye Bye Data

UBER performance

Decoding latency

UBER

t\text{hard}

t\text{green (auto swap)}

t\text{hard (auto swap)}

t\text{soft}

t\text{soft}
User experience and Design effort

Flash Memory Summit 2019
Santa Clara, CA

2019 Green Mode
4th generation
MMI
ultraMMI

2017 Green Mode
3rd generation

2016 Green Mode
2nd generation
lite-engine

Begin of life
- Very fast

Middle of life
- Still very fast
- Occasionally a small lag for hard regular decode. Nearly cannot feel it.

End of life
- Throughput drop.
- Rarely an obvious lag for soft decode.

Host Throughput

Decoder under-clocking

Keep host throughput

Maintain throughput

RBER

Throughput (a.u.)
### 4th generation Green Mode Overview

#### 4th gen Green Mode: MMI

<table>
<thead>
<tr>
<th></th>
<th>Area</th>
<th>Peak Power</th>
<th>Correction rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nearly negligible</td>
<td>more accurate strategy</td>
<td>minor improvement</td>
</tr>
<tr>
<td></td>
<td>+0%</td>
<td>+2~5%</td>
<td>+0.06%</td>
</tr>
<tr>
<td>Throughput @ 0.6% RBER</td>
<td>0.466 bytes/cycle</td>
<td>1.362 bytes/cycle</td>
<td>+192%</td>
</tr>
</tbody>
</table>

#### 4th gen Green Mode: ultra MMI

<table>
<thead>
<tr>
<th></th>
<th>Area</th>
<th>Peak Power</th>
<th>Correction rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small increment</td>
<td>highly aggressive strategy</td>
<td>major improvement</td>
</tr>
<tr>
<td></td>
<td>+0.69%</td>
<td>+5~10%</td>
<td>+0.11%</td>
</tr>
<tr>
<td>Throughput @ 0.6% RBER</td>
<td>0.466 bytes/cycle</td>
<td>2.539 bytes/cycle</td>
<td>+445%</td>
</tr>
</tbody>
</table>

#### 4th gen Green Mode: Zero

<table>
<thead>
<tr>
<th></th>
<th>Area</th>
<th>Peak Power</th>
<th>Correction rate &amp; throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No change</td>
<td>Less memory access, lower toggle rate</td>
<td>No change</td>
</tr>
<tr>
<td></td>
<td>+0%</td>
<td>-15~20%</td>
<td>-</td>
</tr>
</tbody>
</table>
SMI Green mode

Green Mode Performance

Green Mode Throughput
SMI Green mode – QoS, power

Peak power

Average power

Energy efficiency

2nd Green mode

3rd Green mode

4th Green mode

Latency vs. RBER for different levels of QoS.

Peak power, average power, and energy efficiency comparisons between 2nd, 3rd, and 4th Green modes.
Mainstream algorithms

5th generation Green Mode

Hard decoding
- Hard read
  - sign bit only
- Auto Swap
- Green mode decoder
- Regular decoder

Fast N4
- Soft read
  - 1 sign 1 soft
- Green mode decoder

Soft decoding
- Soft read
  - 1 sign 1 soft/2 soft bits
- Regular decoder
Fast N4 decoding spectrum

UBER performance
Decoding latency

hard decode
green mode

Fast N4
1sgn 1soft
soft decode

1sgn 2soft
soft decode

Lost
Data integrity

auto swap

hard decode
regular mode

UBER

latency (a.u.)

0.002 0.004 0.006 0.008 0.01 0.012 0.014 0.016

0 4 8 12 16 20 24 28 32 36 40

5th green mode prototype

- Host Throughput
- NAND Throughput
- Gate count (a.u.)
- Power (a.u.)

FastN4

Hard decoding (auto swap)

4th peak Avg.
5th peak Avg.

4th green
5th green prototype

+9.7%

1408 (+11%)
Fast N4 scenarios

- A controller that never loses speed

Flash Memory Summit 2019
Santa Clara, CA
Fast N4 scenarios – programming time

Hard decode Fast N4

Raw error bits / 1KB

Codeword count

control 17

control 24

control 30

Program time

P/E

0 500 1000 1500 2000 2500 3000

0 0.5 1.5 2.5 3.5 4.5 5

control 10
control 17
control 24
control 30

Original $T_{\text{prog}}$

-40%

-20%
Fast N4 scenarios – burst write

- Other than run-time $T_{prog}$ adjustment, the same method can power a write throughput thruster.
- Burst write phase
  - Burst write quota.
  - Very short $T_{prog}$ (ex. Control 40~50).
- Recovery phase
  - Green mode ultraMMI fast N4.
  - Direct fastN4 mode
Thanks for your attention!
Visit our booth #413 for more information

www.siliconmotion.com