

Programming Matters

MLC NAND Reliability and Best Practices for Data Retention

Data I/O Corporation

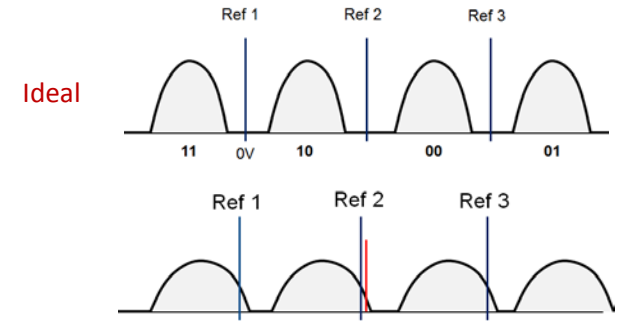
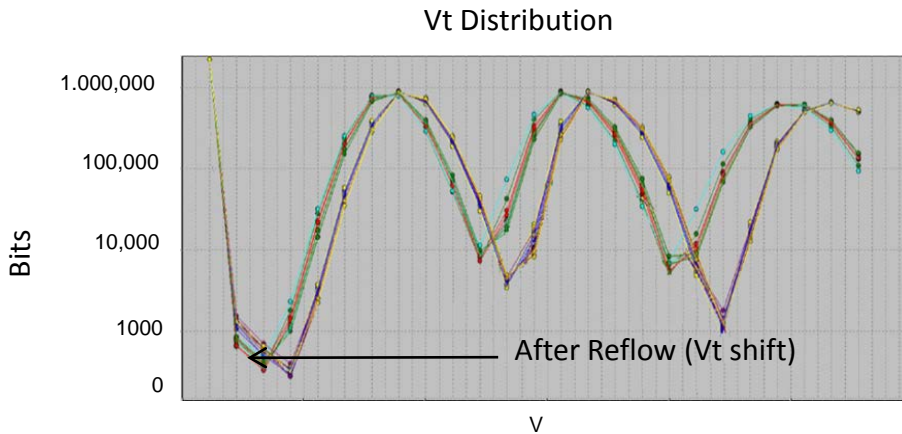
Anthony Ambrose

President & CEO

- *As Process Geometries Shrink down to 20nm and beyond, Data Retention through SMT reflow has become a topic of discussion among semiconductor vendors, programming vendors and end users using MLC NAND FLASH memories. (SLC NAND, NOR and Serial FLASH are not affected)*
- *Semiconductor vendors have developed methods to improve data retention through design and best practices.*
- *Data I/O, the leader in programming solutions for FLASH memory, has developed a set of programming best practices and product enhancements to improve reliability of programming MLC NAND FLASH.*
- *A leading Flash Memory supplier and Data I/O have conducted experiments to prove the reliability enhancements of many of these best practices, and demonstrated the reliability of 20nm devices using Data I/O programming solutions.*

What is the Problem?

- After high temperature processing, Multi-level cell NAND threshold voltages can shift beyond the reference voltage, causing read errors
- The problem gets worse as process geometries shrink



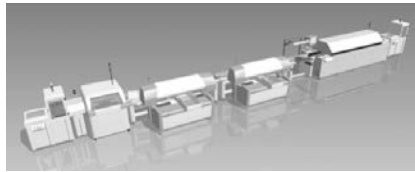
- Erase/Program cycles cause distribution to flatten and widen (shift-right)
- A cell reading "10" might now read "00". This is what causes bit-flips
- Reflow causes (shift-left)

Programming Methods

1



Offline Programming



SMT Line

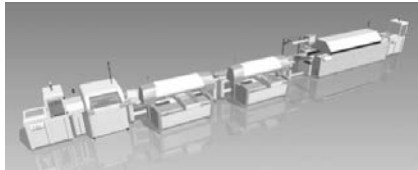


Test



Customization

2



SMT Line



ISP for Boot Code &
Test Code

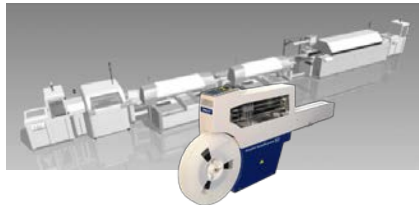


Test



USB Data
programming &
Customization

3



Program boot and test
code inline with
RoadRunner @ SMT Line



Test



USB Data
programming &
Customization

- Quality of Programming
 - Device algorithms
 - Hardware performance and longevity
 - Silicon Performance
- Total Cost
 - Per unit on an individual program
 - Flexibility for other products/programs within a factory
- Support and Service
- Ease of Integration into Manufacturing Flow
- Ability to Scale as production grows
 - Rapidly add /redeploy capacity

Why Not Just Program After Reflow?

Preprogramming is the preferred method for a large percentage of manufacturers and changing processes presents big challenges and investment:

- Offline automated benefits (Preprogramming)
 - Lowest cost per part – one solution can support several SMT lines
 - Supports volatile demand with a capacity of hundreds of thousand of devices per month
 - Offers Opportunity for outsourced programming (cost effective for low volumes)
- Just-in-time programming at placement (Preprogramming)
 - Low cost – integrates programming with placement process step (Lean Process)
 - No inventory float
- Programming-at-test or on-board presents increased challenges
 - Large data files may take hours to program at test
 - Consumes a substantial amount of test capacity
 - May become a bottleneck on the production line
 - Requires internal resources for device support (its not turn-key)
 - Printed circuit boards need to support on-board programming

At the Programmer:

- ✓ Bad Block Management
- ✓ FlashCORE III with SuperBoost
- ✓ Full Block Programming
- ✓ Low Noise Intelligent Adapters
- ✓ *Optional (Program MLC in SLC mode)*

On the Production Line:

- ✓ Thermal Management

After Solder Reflow:

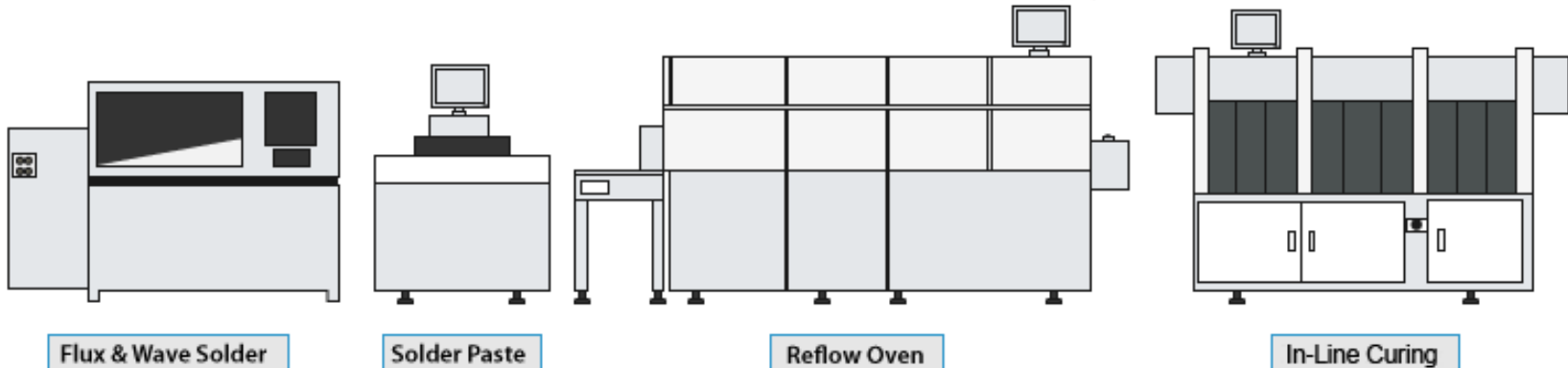
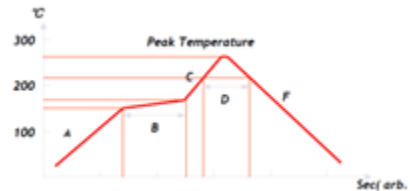
- ✓ Read-Retry-Mode
- ✓ Data Refresh
 - Build Product
 - Boot Device
 - Perform a “Block Refresh” (DEVICE IS AS GOOD AS NEW)

Manage Thermal profiles (Time and Temperature) in accordance with memory supplier guidelines

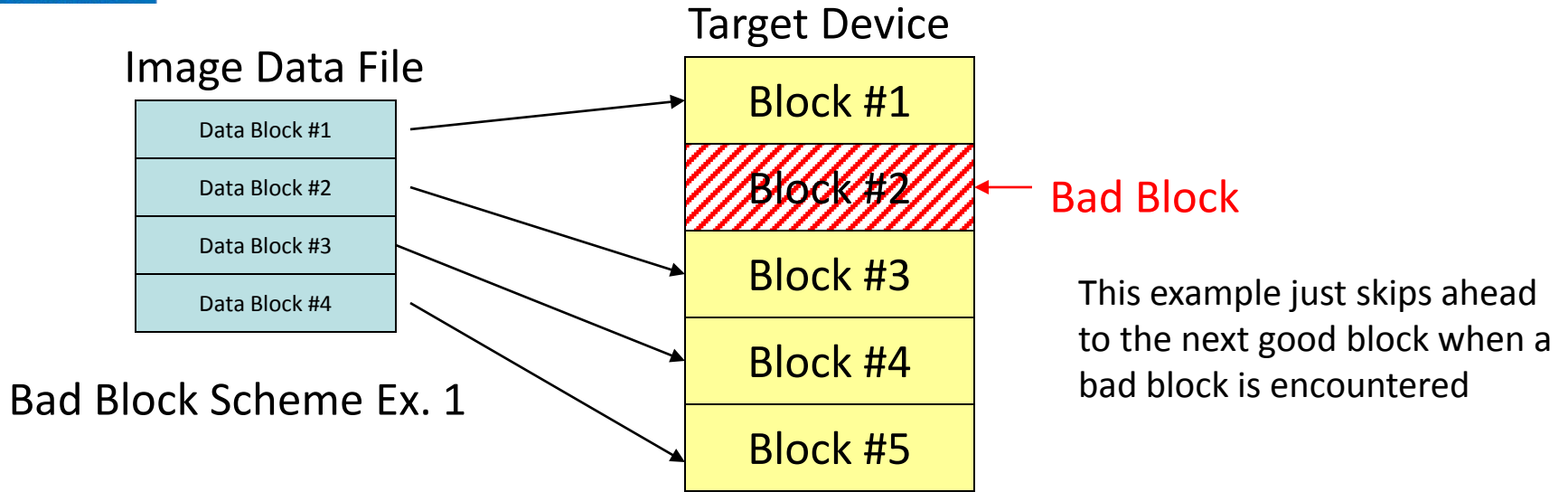
- PCB profiling tools are used to create a repeatable thermal process that meets the specifications required by the solder paste and/or component manufacturers
- Only by profiling do you have any idea of what the actual temperatures are on the components and solder in a reflow soldering process

Profiling has two primary objectives:

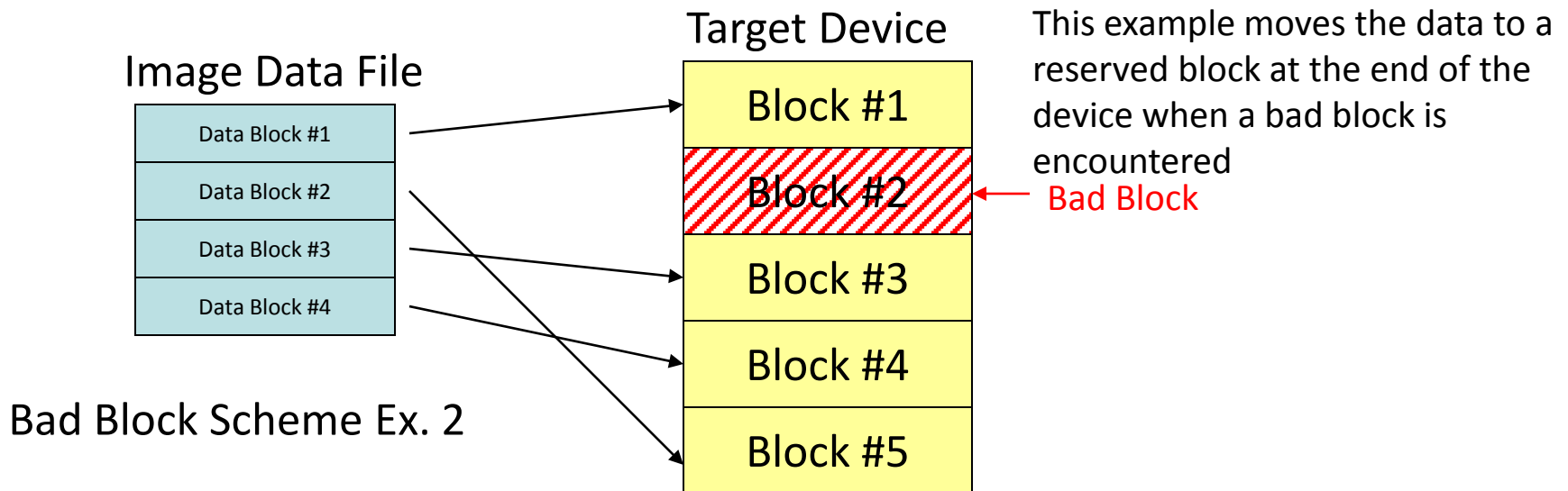
- Determining the correct process settings (oven recipe) needed to meet the requirements of the components and solder for a given assembly
- Verifying a process consistency for repeatable results



Bad Block Management



Bad Block Scheme Ex. 1



Bad Block Scheme Ex. 2



FlashCORE III with SuperBoost Technology



Data I/O FlashCORE III with SuperBoost

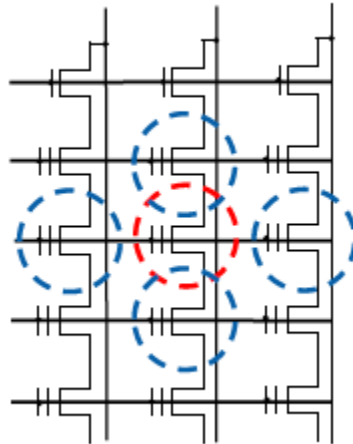


- SuperBoost is technology giving customers the ability to achieve the highest programming speeds available on the market today for eMMC devices
- SuperBoost is a field-upgradeable enhancement for FlashCORE III programmers that re-architects and optimizes the programming engine without making any hardware changes
- Designed to optimize programming speed for high density devices such as eMMC and embedded SD device, SuperBoost allows customers to program many devices at theoretical maximum speed
- Experimental results conducted by Data I/O and a leading Flash Memory supplier show improved data retention when using FlashCORE III with SuperBoost

***Data I/O's SuperBoost technology- enabled from both hardware and software
Assures low noise and high programming yields, and best data retention***

Full Block Programming

- Program full blocks, rather than partial blocks
 - Reduces 'leakage' across cells within the same block
 - Programming erased blocks to higher threshold voltage levels, improves data retention for blocks which are preprogrammed with content prior to reflow



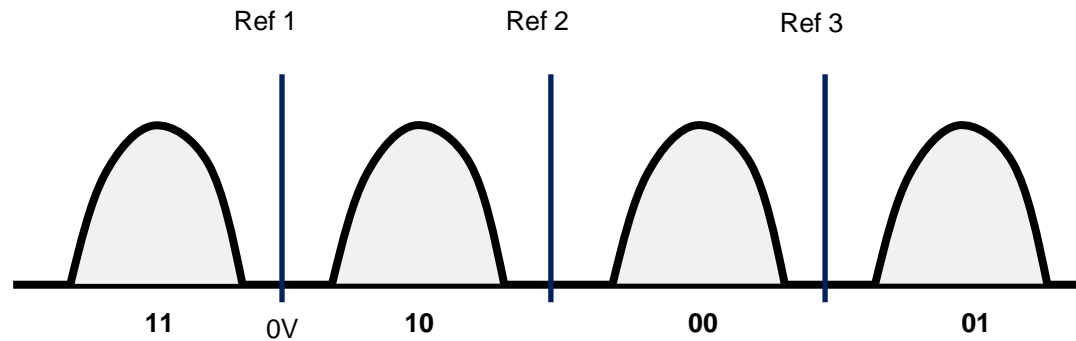
Programming Solution should enable Full Block Programming

- Semiconductor manufacturers are constantly trying to improve efficiency (die shrinkage, wafer size), and new applications require greater access speeds and higher densities
- Data I/O handles the demands of new device families through new programmer platforms, new algorithms, and through new adapter designs as needed. Adapter designs will periodically change to meet the changes and improvements put forward by Semiconductor Vendors.
- Data I/O's Low Noise Adapters
 - Provide supply-side filtering for the device
 - Eliminates low frequency coupling
 - Filters noise transients
- Low noise adapters ensure clean programming signals for the highest yields and reliability

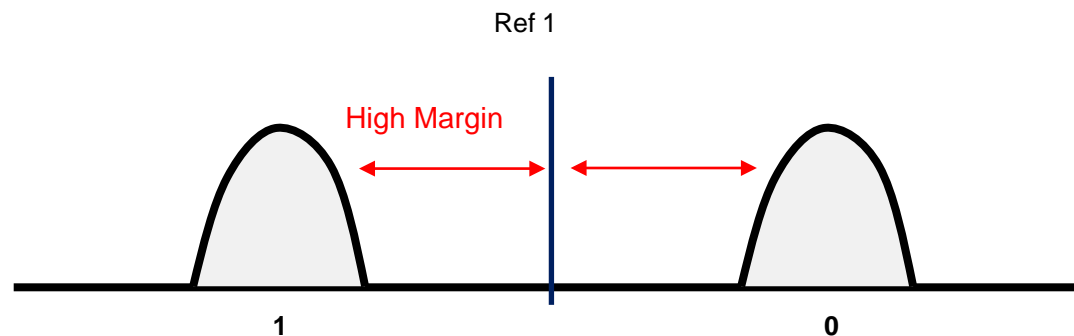
Low Noise Adapters should be used

- Critical sections of the device can be programmed in SLC mode
- Total bit capacity is reduced, but reliability and data retention is greatly improved for those designated critical sections

Turn This

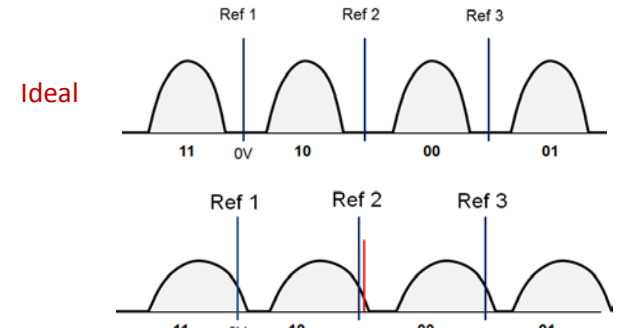
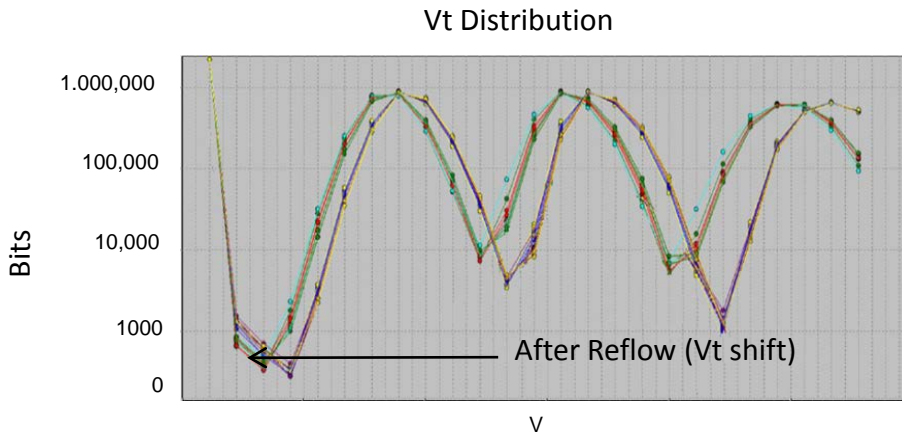


Into This



NAND's Read Retry Feature

- Multi-level cell placements can shift beyond the reference voltage, causing read errors. As long as the distributions are not overlapping, the data should be recoverable
- Read Retry can shift the reference until a passing read point is found
- Block Refresh combined with read retry further enhances reliability



- Erase/Program cycles cause distribution to flatten and widen (shift-right)
- A cell reading "10" might now read "00". This is what causes bit-flips
- Reflow causes (shift-left)
- Read-Retry can adjust the reference voltage to determine where there are bit flips.

Read Retry enhances accuracy and should be used

- Data I/O and a leading semiconductor vendor tested devices under multiple conditions of noise and programming methods
- The key success factor to programming is that the noise of system must be extremely low. This must be controlled with the programmer, adapters and algorithms.
- Data I/O SuperBoost technology enabled from both hardware and software assures low noise through programming, therefore contributing to high yield of high volume programming production.
- It is acceptable to use pre-programming for NAND devices based on 20nm process node if read-retry is enabled and using Data I/O SuperBoost technology.

Pre Programming

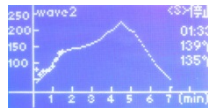
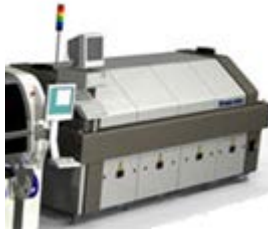


Offline Automated Programming

Data I/O Recommended Best Practices

- ✓ Bad Block Management
- ✓ FlashCORE III with SuperBoost
- ✓ Full Block Programming
- ✓ Low Noise Intelligent Adapters
- ✓ Annual Programmer Support (APS)
- ✓ Optional (Program MLC in SLC mode)

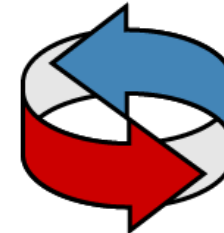
Solder Reflow



Thermal Profiles

- ✓ MLC guidelines

Read Retry



End Product

- ✓ Boot
- ✓ Bit Error Recovery with Read-Retry
- ✓ Auto block refresh

Data Refresh



Want to Know More?



- Talk with a Data I/O NAND expert. We can recommend best programming practices to help maximize your MLC NAND flash data retention
- Learn how Superboost technology and our algorithms, adapters and process control can maximize your production yields and reliability

Contact your local Data I/O NAND programming experts

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