



**The resilient, predictable software
flash controller for safety-critical
applications in embedded systems**

FlashFX® Tera is a resilient and stand-alone software controller for flash memory. It is designed for highly demanding environments, works with most standard types of NAND and NOR flash, and supports hundreds of different memory parts, interfaces, and controllers.

Flash memory is ideal for embedded applications due to its low power consumption, high density, and non-volatile nature. It can function as read-only memory for both the storage and execution of program code, as well as read-write storage for code and data files.

However, flash memory also has drawbacks, such as the need for data to be erased before it can be overwritten, limited write/erase cycles, and potential bad blocks that develop over time. Reliably integrating the many NAND and NOR flash memory devices, interfaces, and technologies available while maximizing their lifetime and performance also presents a significant design challenge.

Tuxera FlashFX Tera presents flash memory to the operating system or application as a standard block device, so any file system can run on it. This maximizes the positive benefits of flash memory while minimizing the factors that make it difficult to use. Our software flash controller goes beyond a simple flash translation layer – FTL – and includes advanced features that make flash memory management more effective.

With optimized read/write/erase operations, fault tolerance, and advanced features like wear leveling, bad block management, error correction, and deterministic execution times, FlashFX Tera provides a robust solution for the rapid integration and complete management of flash memory in any embedded system.

FEATURES OF TUXERA FLASHFX TERA

Flash translation layer

Fault tolerance

Bad block management

Enhanced wear leveling

Secure erase

Error correction and detection

Flash memory lifetime reporting

Deterministic operations

KEY APPLICATIONS

Zonal controllers, DMS, clusters, and telematics units

Engine diagnostics

Satellite on-board computers

Smart meters

Industrial IoT devices and motion controllers

Handsets and radios

Resiliency and maximum integrity for your embedded systems

Embedded systems often experience difficulties during power losses or when unexpected resets occur. FlashFX Tera is designed to handle power interruptions exceptionally well – guaranteeing that data will not be corrupted and the system will always recover. If writing to a page or sector is interrupted during a loss of power or unexpected reset, FlashFX Tera will always provide valid and consistent data. When used in conjunction with any Tuxera file system, the system will behave correctly and in a truly fail-safe manner.

Bad block management technology to protect flash from premature failure

Some flash memory technologies, such as NAND, may ship with bad blocks and develop more over time. During operation, data can be corrupted by charge leakage or disturbance from adjacent cells of the chip. The ability to dynamically correct errors and manage replacement blocks is crucial for successful NAND flash use. Tuxera FlashFX Tera provides an efficient mechanism to detect, correct, and manage the bad areas found in NAND flash technology. It maps unusable areas to make sure data is not corrupted, automatically detects bad blocks, and reserves replacement block regions on the flash array. If no good blocks are available, the device will become read-only. This approach extends the effective life of NAND memory, allowing for robust storage in case of memory region failures.

Enhanced wear leveling to maximize flash lifetime

Flash memory must be erased before data can be changed, but flash cells have a limited lifespan and can only be erased a certain number of times before becoming unreliable. Each flash part has an erase zone size, which varies from a few KB to 512 KB or more. Tuxera FlashFX Tera uses wear leveling algorithms to ensure that erase zones are evenly distributed across the entire flash array. Data is moved between physical blocks to ensure balanced usage, effectively maximizing the life of the chip.

Error detection and correction for added reliability

Flash manufacturers define the worst-case wear rate for flash memory. Error Correction Codes (ECCs) are additional information associated with flash data blocks that ensure data consistency within chip specifications. ECCs are used

to detect and correct bit flips, which could otherwise lead to significant data corruption or system malfunction.

Tuxera FlashFX Tera uses ECCs and other mechanisms to detect and correct errors, ensuring that data remains accurate and reliable at all times. Failing blocks are found and repaired early to avoid the read-disturb problems common in MLC flash devices.

In flash memory, errors can occur on pages that are actively read/accessed; errors can also pop up in unused areas of the flash. Tuxera Lazy Reader™ works silently in the background scrubbing and performing checks of seldom-used portions of the flash to maintain page and block reliability. This does not interfere with other tasks, and frees developers from having to build and implement this functionality at the application level.

Secure erase for safer data removal

Data written to flash memory is always written to a new page, which is then remapped. When data is overwritten it will not be accessible using a normal read operation, but it may persist for some time. Tuxera FlashFX Tera features Secure Data Erase technology that can be used to ensure overwritten data is immediately and permanently erased, providing complete data security.

Deterministic operations to meet safety-critical requirements

Predictable timing and behavior is essential for safety-critical applications. Tuxera FlashFX Tera(RT) guarantees deterministic execution time, preventing unexpected stalls when controlling the NAND flash. By managing the number of operations and expected erase/program cycles, completion times can be accurately calculated.

QuickMount for fast and predictable startup

Mounting a raw flash device normally means scanning every erase block to rebuild the map of where data is stored, so startup time grows with the size of the flash. Tuxera FlashFX Tera avoids this with QuickMount. At shutdown it saves the state information to reserved erase blocks, protected by a checksum. At the next start it validates and restores that state, instead of scanning, so mount time is constant and independent of partition size. If the saved state is missing or fails its check, after a power loss for example, FlashFX Tera falls back to a full scan and rebuilds it, so the device always mounts correctly.

Superior performance that gets the most from your flash hardware

Raw flash is only as fast as the software driving it. Tuxera FlashFX Tera is built to extract the full capability of the hardware, with optimized read, write and erase, background compaction and multithreaded I/O, for delivering its rated performance. Paired with a Tuxera file system it reaches up to 2.5 times the sequential write throughput of the standard Linux raw NAND stack while placing far less load on the host processor, leaving headroom for the application.

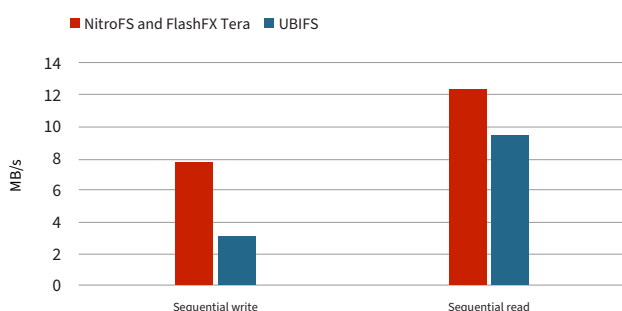


Figure 1. Sequential throughput on raw NAND, higher is better.

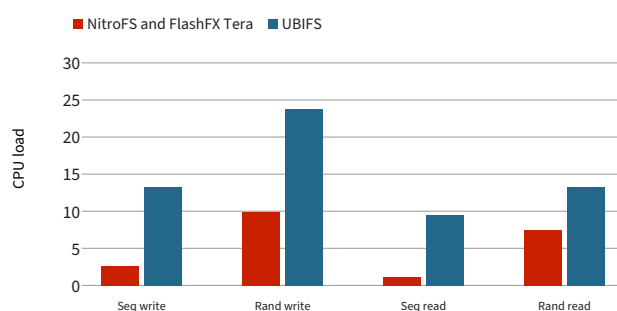


Figure 2. Host CPU load in percent at a matched 1 MB/s workload, lower is better.

Test platform: phyBOARD-Mira i.MX6 Quad, 1 GiB SLC raw NAND, Linux 6.6.

TECHNICAL FEATURES

	TUXERA FLASHFX TERA	TUXERA FLASHFX TERA ^{RT}
Best suited for	Systems with higher resources and high I/O performance requirements	Systems with low resources and memory constraints; projects with deterministic requirements
Flash translation layer	Yes	Yes
Management of raw NAND/NOR	Yes	Yes
Fault tolerance	Yes	Yes
Bad block management	Yes (patented)	Yes
Wear leveling	Static and dynamic	Static and dynamic
Error correction and detection	Yes	Yes
Read-disturb monitoring	Yes	Yes
Scrubbing	Yes	Yes
Background compaction	Yes	Yes
Ability to run from ROM	Yes	Yes
Discard of unused sectors	Yes	No
Zero copy block read/write	No (program in page size instead)	Yes
Support for program page cache	Yes	Yes
Secure erase	Yes	Yes
Memory allocation	Static and dynamic	Static
Flash lifetime monitoring and reporting	Yes	Yes
Other advanced features	Possibility to reserve sectors for private functions such as boot memory operations; incremental write-only used for pages in a block; automatic garbage collection; hardware cost savings (e.g. no need for a capacitor to guarantee program cycle completion in platforms using SLC memory)	

SYSTEM REQUIREMENTS

	TUXERA FLASHFX TERA	TUXERA FLASHFX TERA ^{RT}
Target configuration	32 or 64-bit architectures, virtually any CPU: Arm, x86, MIPS, RISC-V, PowerPC, ARC, SPARC	
RAM and ROM requirements	Minimum 100 KB RAM, 62 to 72 KB ROM	7 to 13 KB RAM, 15 KB ROM
Supported media	SLC and MLC NAND, EZNAND, NOR, NVRAM Supports parts from all major vendors: Micron, Winbond, Macronix, SK Hynix, Samsung, Infineon, Kioxia, and others	
Supported interface	Parallel and serial: SPI, QSPI, OctoSPI	
Supported standards	Open NAND Flash interface (ONFI 3.0) Common Flash Memory Interface (CFI)	
Compiler support	Eclipse/GCC, IAR Embedded Workbench, Keil ARM Compiler, Freescale CodeWarrior, Atmel AVR Studio, Green Hills Multi, Microchip MPLAB, Renesas HEW, TI Code Composer Studio, Mentor CodeSourcery, Atollic True Studio, any ANSI C compiler	
Microcontrollers	MCUs from the most popular manufacturers: Arm, Infineon i.MX, NXP, Microchip, Renesas, SiliconLabs, STMicro, Texas Instruments (TI OMAP), Toshiba, Marvell	
Best operating system fit	VxWorks, Linux, QNX, and Android	FreeRTOS, Integrity, ThreadX, Azure IoT, Nucleus, Keil RTX, CMX RTX, eCOS, emBOS, EUROS, Quadros RTXC, μ -velOSity, μ C/OS-II, and many other RTOSs through a 'No RTOS' abstraction, as well as custom schedulers and super loops

Readily available software and award-winning support

Tuxera FlashFX Tera includes preconfigured projects for the most popular reference platforms, allowing developers to get up and running quickly. FlashFX Tera has been designed to be easily ported to new architectures and support different target systems and configurations. Our proprietary abstraction layers and Flash Interface Module (FIM), NAND Technology Module (NTM), and Managed NAND host controller implementations make it possible to work with virtually any hardware and software – unlike competing alternatives that will work only with the part they are integrated with. Our award-winning support team is ready to offer comprehensive R&D support, including integration, testing, benchmarking, and platform-specific optimizations, ensuring your project's success.

**Make sure your embedded storage is resilient and secure.
Get in touch with us at sales@tuxera.com**