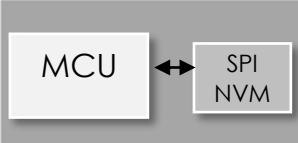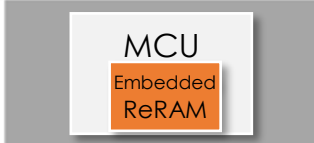# ReThink Automotive/Industrial/Medical with Crossbar ReRAM technology

As important as it is to have speed and reliability in enterprise and consumer electronics, it's most critical in automotive, industrial and medical applications, which demand high reliability, real-time responses, high security, and fast data read and write.

Crossbar's ReRAM memory technology offers faster read and write speeds, low latency, ultra-low energy and high-density capabilities to answer the challenges of real-time automotive, industrial and medical applications. It offers 20ns random read access and 12μs write in 32bit data access, 1M+ write cycles endurance, and 10 years data retention at 85°C (post 10K cycles). Excellent data integrity is also obtained across a wide temperature range from -40 up to 125°C. Crossbar's simple ReRAM cell structure makes it very easy and cost-efficient to integrate ReRAM arrays in back-end-of-line (BEOL) in-between metal layers on the same silicon die with real-time processing cores. The integration of ReRAM on-chip eliminates the need for external memory components, which reduces latencies, IO power consumption and potential security weakness of the external memory bus. Customer-base use-cases show results up to 50X energy savings and 8X performance improvement compared to external memory chips that introduce latencies and external memory bus throughput bottlenecks.

MCU – NVM I/F	Quad SPI, 3V, 133MHz		Internal x32 Interface
Roundtrip random read latency for 32 bits	210nS	X8	25nS
Roundtrip burst read latency for 32 bits	60nS		25nS
Energy consumed on memory bus per 32 bit transaction	5nJ	X50	0.1nJ

Compared with conventional embedded Flash which requires dedicated front-end

---

processes, the BEOL integration not only reduces manufacturing cost (estimated to be 32% lower per die), but also makes it much easier to port and customize with different chip companies to design and fabricate embedded solutions for a broad range of applications. Also, the on-chip ReRAM storage saves up to 20% BOM cost with smaller IC and fewer system footprints.

Unlike Flash memory, Crossbar ReRAM memory is bit/byte addressable and can be architected with small pages that can be independently re-programmed. It also doesn't need the slow Flash memory block erase operation, and drastically simplifies the memory management by removing a large portion of the background memory accesses required for garbage collection. On-chip storage also enables the use of wide memory buses that break the bandwidth bottleneck between computing cores and external data storage. ReRAM achieves visible benefits in terms of read and write latencies, lower energy consumption and increased life time of automotive, industrial, medical solutions.

	Embedded Flash	Crossbar Embedded ReRAM
Byte/Word Alterability	Not supported	Yes
Write Time/word	Write not possible (must erase first, then program) — 100x →	12µs
Program time/word	20us	Not required
Erase time per 4KB	2ms	Not required
Random Read Time	25ns	25ns

	3D NAND Flash	Crossbar 1TnR ReRAM
Page Read Time	25~100 µs — 100x →	1 µs
Page Program Time	600~1350 µs	NA
Block Erase Time	10 ms	NA
Page Write Time	Write not possible (must erase first) — 1000x →	2 µs

Automotive

Data from a car's on-board electronics must be processed and stored instantly and reliably in non-volatile memory, as any data loss at highway speeds could be catastrophic. The cars of the future will also seamlessly deliver entertainment, information and data as an extension of the home and office. Non-volatile memory technology lies at the heart of the car. Crossbar's ReRAM memory technology provides unparalleled reliability for fast random read access and byte accessibility across a wide temperature range (from -40 up to 125°C) to ensure safe and secure processing on the go.

With its high capacity storage, high reliability and very fast performance, Crossbar ReRAM solutions are well suited to replace embedded NOR, stand-alone NOR/SPI and NAND in a variety of automotive applications such as navigation, infotainment, critical active and passive safety, and advanced driver assistance systems.

Industrial

Industrial automation and measurement systems rely on rapid, reliable data to maximize their efficiency. Whether the goal is maximizing operational efficiency or getting real-time data from sensors and other systems, quick read/write access to data is a key success factor. Crossbar's ReRAM bit alterability provides very efficient data re-programmability at the smallest possible granularity. The design constraints of Flash-based solutions with slow page program and even slower block erase are totally removed with ReRAM-based

solutions. Fast small page program without block erase operations guarantees much more responsive systems.

Crossbar's ReRAM memory technologies enable the latest industrial automation and analytics by providing unrivaled performance, capacity and reliability while helping to minimize power consumption and footprint. Crossbar ReRAM is ideal for demanding applications requiring extreme durability, optimal data integrity and exceptionally fast data read and write. And it's tunable to the needs of different subsystems, significantly decreasing the complexity and physical footprint of next-generation systems.

Medical

Technology continues to revolutionize healthcare with diagnostic tools and treatment systems, pushing the limits of what was thought impossible only a few years ago. Medical imaging applications such as ultrasound, CT scanning and MRI, for example, all have demanding read/write performance and reliability needs. Compared with NOR and NAND Flash which is based on electrons movement, Crossbar ReRAM is based on nano-filaments ions movement. This guarantees higher reliability in wide temperature ranges or harsh environments. Crossbar's ReRAM memory technology helps manufacturers meet the ever-increasing needs for higher speed, higher precision, lower power and smaller equipment, while maintaining the high quality and reliability standards necessary for medical applications.

There's been a lot of discussion regarding the hacking of automotive, industrial and medical systems to obtain sensitive information and data. Correspondingly, system security is becoming big risk. Integrating Crossbar's ReRAM memory on the chip also enhances automotive, industrial and medical systems security.

Security Threats	Recommendations	Crossbar ReRAM Advantages on security
External memory bus snooping	Sensitive code and data should never be exposed outside of the SoC package	ReRAM integrated with logic CMOS scales to advanced process nodes.
Software attacks to unlock chain of trust	No backdoor. Implement cryptographic, hashing techniques to guaranty integrity and authenticity of boot code, OS and applications. Use true One-Time Programmable	Specific ReRAM program algorithms enable OTP capabilities in the same array
Physical attacks to read confidential data	Robust layout to prevent memory cell value extraction	ReRAM cell is vertical with very small cross-section making it very hard to measure resistance value

To summarize, Crossbar ReRAM memory technologies offer ultra-high reliability, lower energy, faster read and write performance, low manufacturing cost and BOM cost, on-chip security and capabilities, enabling the radical innovations for automotive, industrial and medical systems.

ReRAM Key Attributes for Industrial/Automotive/Medical Applications:

Higher Reliability
- 10 years @ 85ºC retention
- 1M+ write cycle endurance
- Temperature: -40º~125ºC

Ultra-Fast
- Low 20ns read latency
- Fast 12us write
- No block erase needed
- Bit/byte level alterability

Better Security
- On-chip code and data storage, prevent memory cell extraction
- Secure data access with embedded ReRAM

Lower Energy
- 5x lower energy than eflash
- 30x lower energy than SPI flash
- 40x lower write energy than Bluetooth Low Energy (BLE)