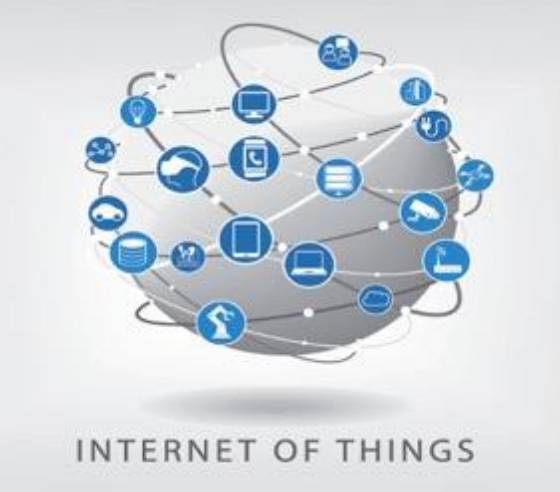
ReThink Internet of Things with Crossbar ReRAM Technology

A new world of connected devices is emerging. According to Gartner, there will be more than 20 billion connected devices worldwide by 2020. With the Internet of Things, we are entering an era where every device on the planet will be connected to other devices, sharing information and interacting with people across a broad range of industries and applications.

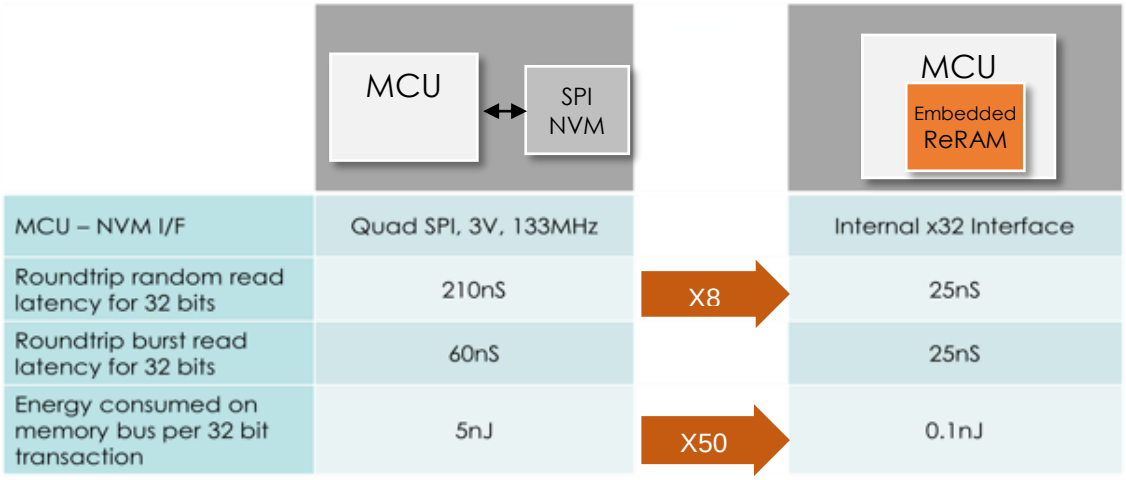


The network of sensor nodes used in wearables, smart homes, building automation, smart cities, smart metering, smart factories, smart agriculture and farming is changing the way we monitor and control our environment. These new generations of tiny devices, powered by small batteries or capable of harvesting energy from their own environments, are in ultralow power sleep mode most of time and awoken upon events to acquire data from sensors, process embedded algorithms, and store data in embedded memory before transmitting to the cloud. In most IoT applications, the available energy budget is the constraint. A 10 year lifetime on a single coin cell CR2032 would require it to operate with average system current of just 2.5 µA without a battery charge. This restricted energy budget determines how frequently data can be acquired, processed and transmitted. In order to meet these strict IoT energy requirements, the device needs a variety of energy-saving strategies. System architects have to define an architecture that complies with four simple rules: 1. put the system in deep sleep mode whenever possible, 2. wake-up the system as seldom as possible and as fast as

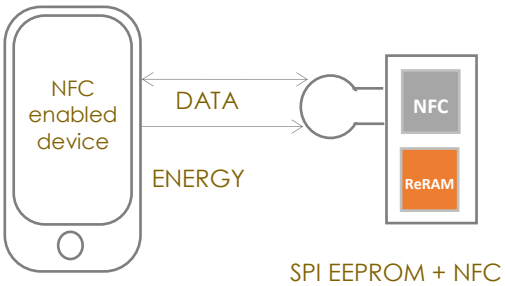
possible, 3. operate at maximum efficiency, and 4. terminate the job quickly and go back to sleep mode.

Embedded non-volatile memory can play an important role in meeting energy requirements. Lower energy and lower operation voltage, monolithic integration, faster read and write times, nonvolatility and higher capacity are ways that non-volatile memory technology can help IoT devices achieve greater energy efficiency. Also, non-volatile memory technology does not require power to retain its state, and is very convenient for instant power up / power down cycles.

Crossbar's ReRAM embedded memory technology offers ultra-low energy, scalable capacity, high performance and low latency characteristics with non-volatile memory. It eliminates the need for expensive controllers, simplifies the complex memory management and can be easily integrated on a single MCU, SoC chip or FPGA. Being on-chip reduces the gap between processing logic and data and results up to 50X read energy savings and 8X read performance improvement compared to an external memory chip.



The connected devices, such as IoT tags, smart cards, or pairing devices need to transfer code and data each other. With the ReRAM memory technology, the write energy between the IoT system is dramatically saving as well. The EEPROM with Crossbar ReRAM technology is up to 100x less write energy and 400x shorter write time than traditional SPI EEPROM.



	Existing EEPROM		EEPROM with Crossbar RRAM	
Write size	Write Time	Energy	Write Time	Energy
1B	5ms	17uJ	12us	0.18uJ
4B	5ms	17uJ	12us	0.18uJ
128B	5ms	17uJ	384us	5.76uJ

Example of IoT tags, smart cards, pairing devices or over-the-air code and data transfer

Once data is sampled by the sensors, it is crucial to determine what to do with it from an energy stand-point. It is more energy-efficient to log data locally in the IoT device than to transmit data out to the cloud even using the lowest form of wireless communication such as Bluetooth Low Energy(BLE). Transmitting 32bits of data to the cloud with BLE consumes 7.2 µJ; the consuming energy which ReRAM writes 32bits data is only 180nJ, 40x lower than BLE.

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 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 storage. ReRAM achieves visible benefits in terms of read and write latencies, lower energy consumption and increased lifetime of the IoT solutions.

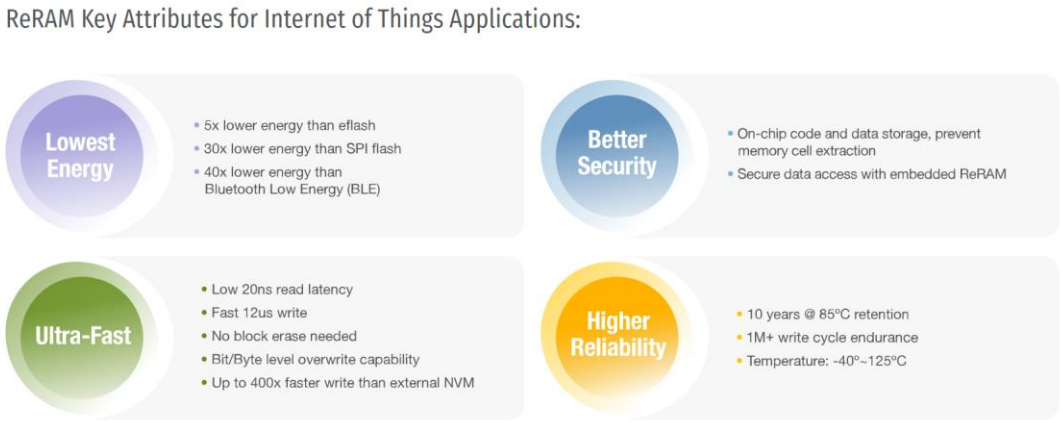
Crossbar's embedded ReRAM solutions offer 20ns random read access and 12µs write in 32bit data access, 1M+ write cycles endurance, and 10 year data retention at 85°C (post 10K cycles). Excellent data integrity is also obtained across a wide temperature range up to 125°C.

Additionally, Crossbar's simple ReRAM cell structure, requiring only 2 masks, makes it very easy and cost-efficient to integrate ReRAM arrays in back-end-of-line (BEOL) in between metal layers. This allows the embedded ReRAM to be fabricated with the underlying logic circuits in the same logic foundry, compared to 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 more flexible to work 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. The low energy saves up to 23% battery cost with small capacity battery.

There's been a lot of discussion regarding the hacking of IoT devices and systems to obtain sensitive information and data. The security of IoT systems are at risk. Integrating the ReRAM memory on the chip enhances the IoT 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 enabling 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 low energy, fast read and write performance, low manufacturing cost and BOM cost, on-chip security and ultra-reliability capabilities.



Crossbar's ReRAM memory technologies are enabling new applications where the data can now be stored locally to reduce the frequency of data transmission to the cloud with massive energy savings for the connected IoT world.