
# eXecute-in-Place for Low-Power IoT and Instant-on Smart Devices (Preview)

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# Short history of NVM in embedded systems

- In the beginning…
  - Byte-wide ROM and EPROM were used as the Non-Volatile Memory in most embedded systems
  - Parallel NOR Flash devices were introduced in the late 80s and gradually replaced their predecessors
- Typical use case was eXecute-in-Place (XiP)
  - Though, that term did not exist at that time
  - Four byte-wide Flash devices typically created a 32-bit wide bus for the CPU
  - Latency and throughput delivered by the Flash array were sufficient for the fastest CPUs of that era




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# Faster PCs changed the picture

- The speed of CPUs ramped up beyond 1GHz
  - While NOR Flash devices could not keep up with these frequencies
  - XiP was abandoned and application code was now running from DRAM
  - NOR Flash was relegated to only support the system-boot operation


- In this new world, the speed of the Flash device was no longer important
  - Upon start-up, hardware would copy the contents of the Flash to DRAM and the Flash would not be needed until the next boot sequence
  - Atmel and later other suppliers came up with the Serial Flash
    - Smaller footprint and lower cost than parallel NORs
    - But, delivering much lower data throughput
    - Still, this was good enough for the new role of the Flash device



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# What's important in IoT and modern embedded systems

## Performance

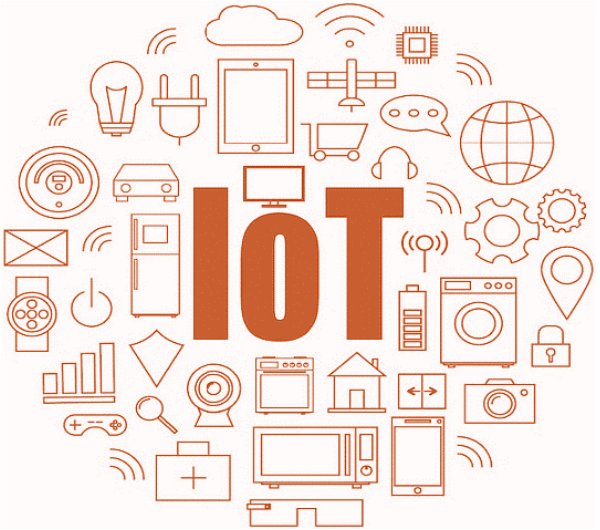
- Though small, these systems' complex communications protocols require significant processing horsepower

## Power

- When compared to IoT devices, phones which used to be the
poster child of low-power are considered power-hogs
- IoT devices typically are in deep-sleep most of the time, but when up, they need to deliver high performance

## And of-course, cost, cost, and cost

- Cost of design
- Cost of mask sets
- Cost of silicon







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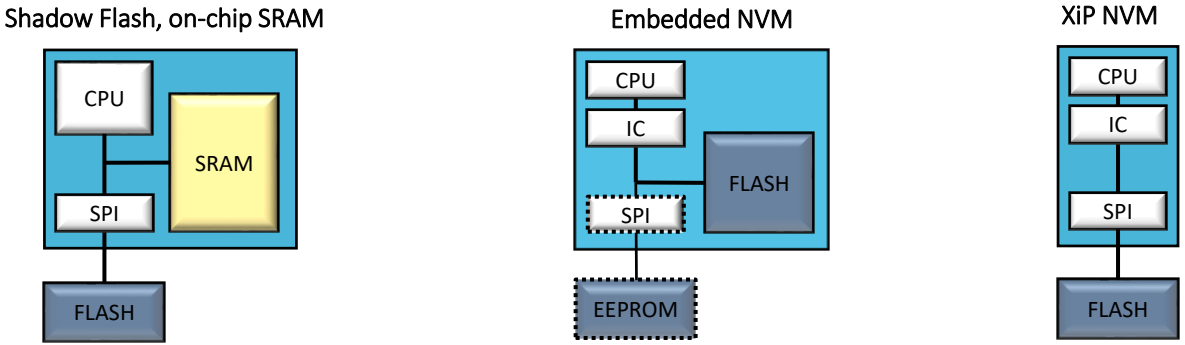
# Today's IoT systems: one of three architectures




- Shadow Flash: Upon boot, the code is copied to and executed from an internal SRAM (or external DRAM)
- Embedded NVM: Flash device is part of the IoT SOC, code is executed directly out of it
- XiP: Code executed directly from an external NOR Flash

**Combinations of these basic architectures are gaining momentum**

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# The problem

- Class of devices requiring intelligent local data processing capability
  - Relatively large program memory
  - Higher performance time critical applications
- Embedded flash only addresses low- to mid-range products
  - Limited scalability
  - Limited memory
  - Higher cost SoCs as a result of more expensive and “shrink-resistant” silicon process
- External DRAMs address only the highest-end products
- Existing solutions are power-hungry, performance-limiting and expensive



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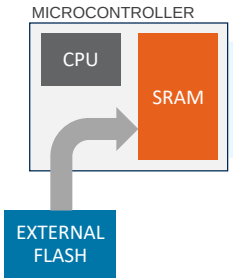
# The need for eXecute-in-Place

*microcontrollers removing / reducing embedded flash*

YESTERDAY

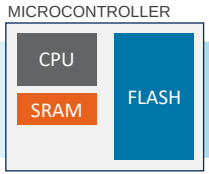
TODAY

## Code Shadow




Code downloaded from external flash to internal SRAM at boot up

## Embedded Flash



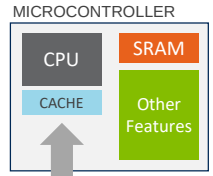

Code executes directly out of embedded Flash

*SMALLER SILICON GEOMETRIES*

Embedded flash more expensive or unavailable

SRAM leakage current becomes more significant

## eXecute-in-Place (XiP)




- Embedded flash removed or reduced
- SRAM optimized


Code executes directly from external flash

- Lower solution cost
- Higher processing speeds
- SRAM power impact reduced
- “Instant On” capabilities

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# The solution

- An NVM device designed specifically for eXecute-in-Place
  - High enough bandwidth on the interface between the Flash and the SoC
  - Optimized to deliver performance in cached-based CPUs
  - Easy handling of Over-The-Air (OTA) updates
  - Low power consumption in fetch (read) operations
  - Power down modes to support down-times of the IoT device
- The rest of this presentation will show:
  - How to handle each of the above design targets
  - Adesto's EcoXiP family of NVM devices for XiP applications
  - Performance and power characteristics of the EcoXiP when operating with NXP's i.MX RT1050

# Attend the session to learn more!