Towards ML-KEM & ML-DSA on OpenTitan

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May 14, 2025

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A Paradigm Shift

[Res21; App20; Com22; Goo22; Cor19; Clo25; Gmb; FSS20]

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IACR Transactions on Cryptographic Hardware and Embedded Systems
ISSN 2569-2925, Vol. 2020, No. 4, pp. 239–280. DOI:10.13154/tches.v2020.i4.239-280

RISQ-V: Tightly Coupled RISC-V Accelerators for Post-Quantum Cryptography

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A Different Direction

*How efficient can we make **PQC***

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A Different Direction

*How efficient can we make **PQC***
*on an **existing pre-quantum platform***
with modest hardware changes?

Target: OpenTitan

- Open source silicon root of trust (RoT)
- Led by lowRISC, contributions from zeroRISC, Google, ETH Zurich, and many more
- Performs security critical operations
  - → Hardware support for many cryptographic operations
  - → Hardening against side-channel attacks
- Coming to, e.g., Google's 2025 Chromebooks [SO25]

Target: OpenTitan

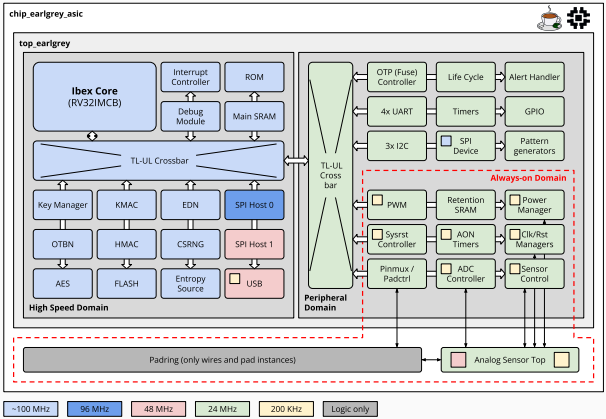
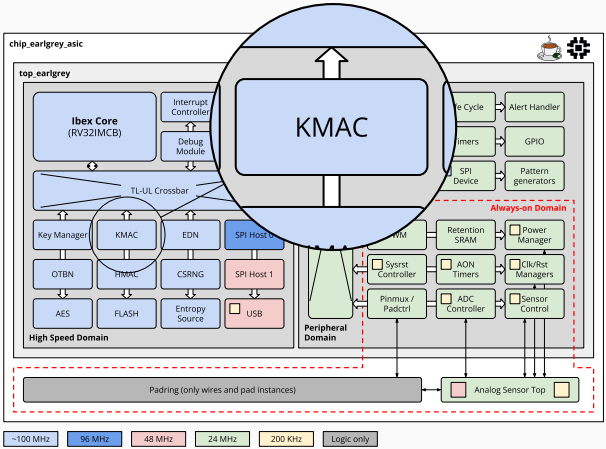


Figure 1: Overview OpenTitan Earl Grey [Ope23]

Target: OpenTitan

- Accelerator for SHA-3 and SHAKE



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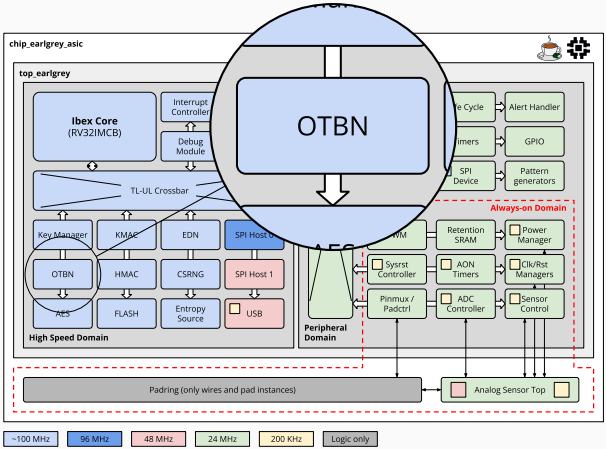

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Target: OpenTitan

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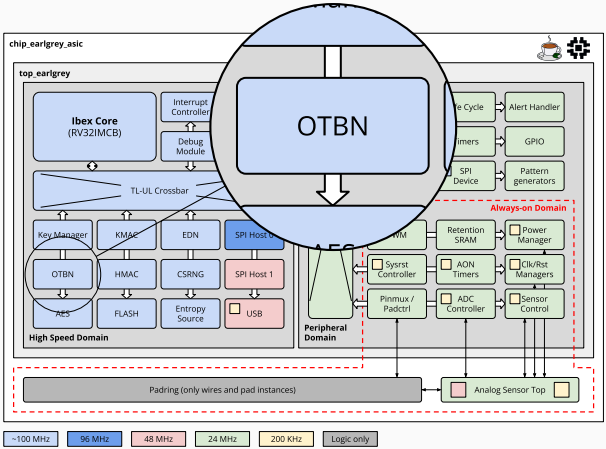
  - 32 256-bit registers



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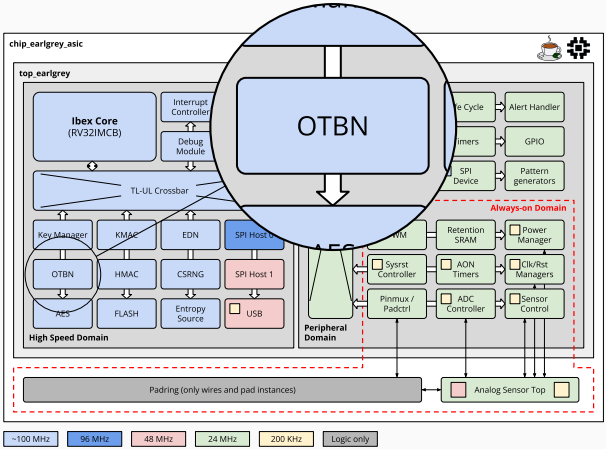

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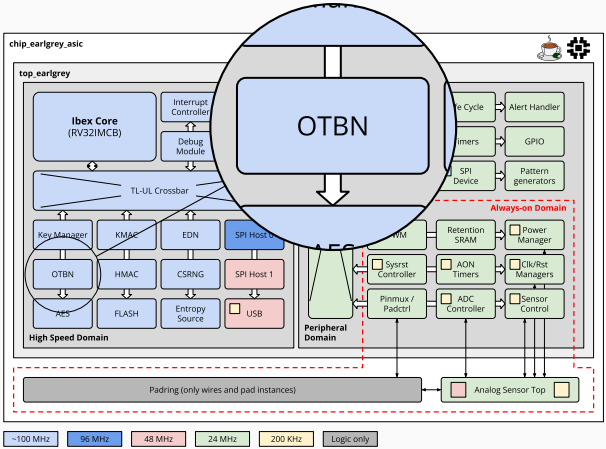
Target: OpenTitan

- Accelerator for SHA-3 and SHAKE
- OpenTitan Big Number
  - 32 256-bit registers
  - Reduced RV32I ISA
  - “Generic” big-number ISA for ECC & RSA



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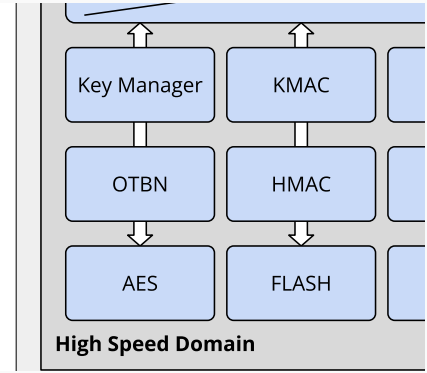

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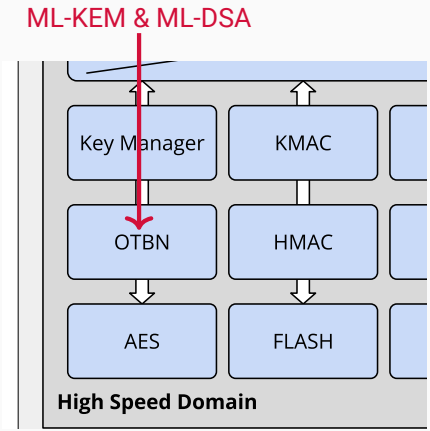
[a] Enlarged memories required



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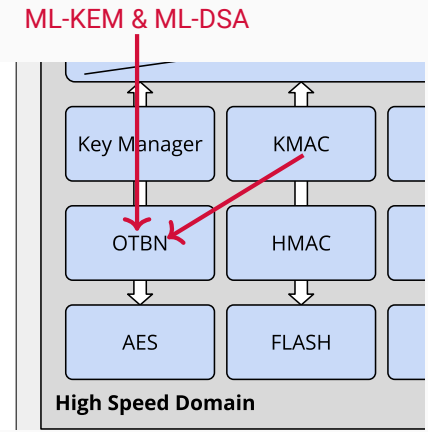

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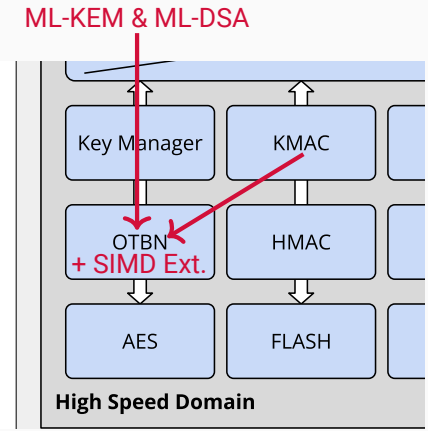

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2. Interface to **KMAC** accelerator
3. ISA extensions to utilize wide registers using **SIMD** on OTBN
   → Applicable to ML-KEM and ML-DSA but also beyond
4. Hardware implementation maximizing **resource-sharing** with pre-existing components

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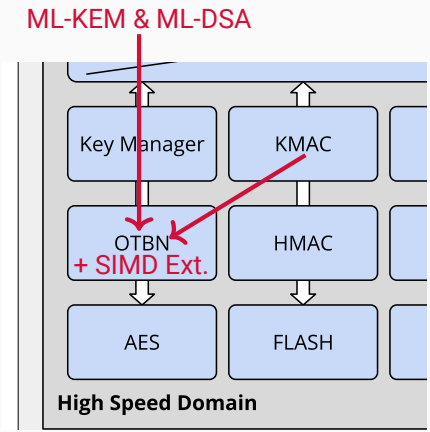

Implementation: High Level Overview

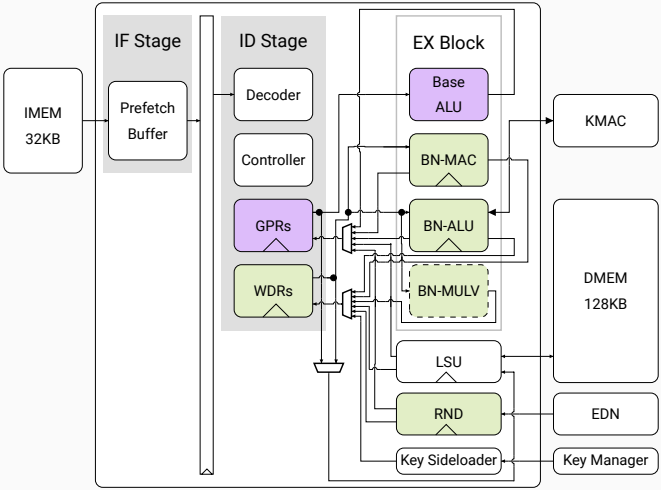

Figure 2: Simplified diagram of the modified OTBN pipeline.

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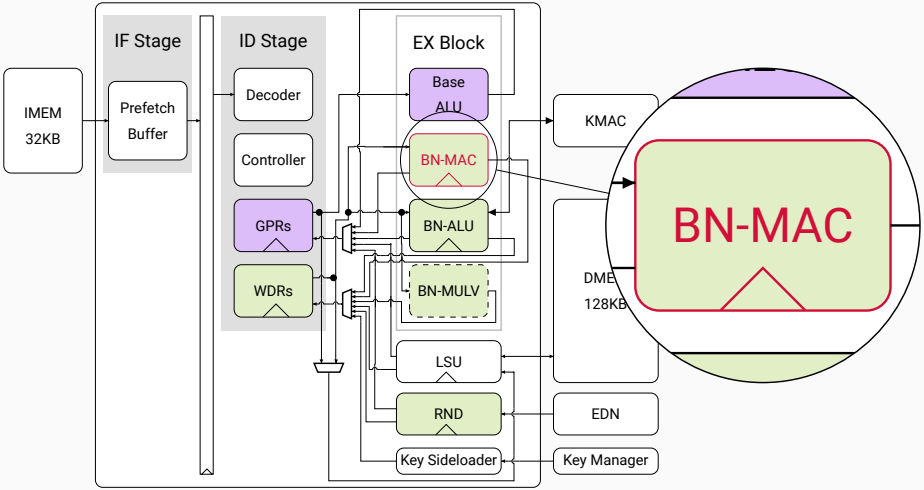

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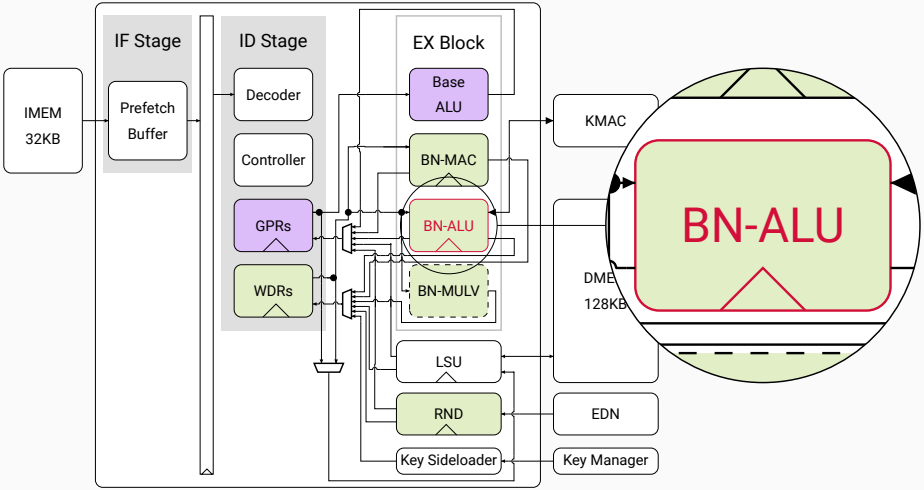

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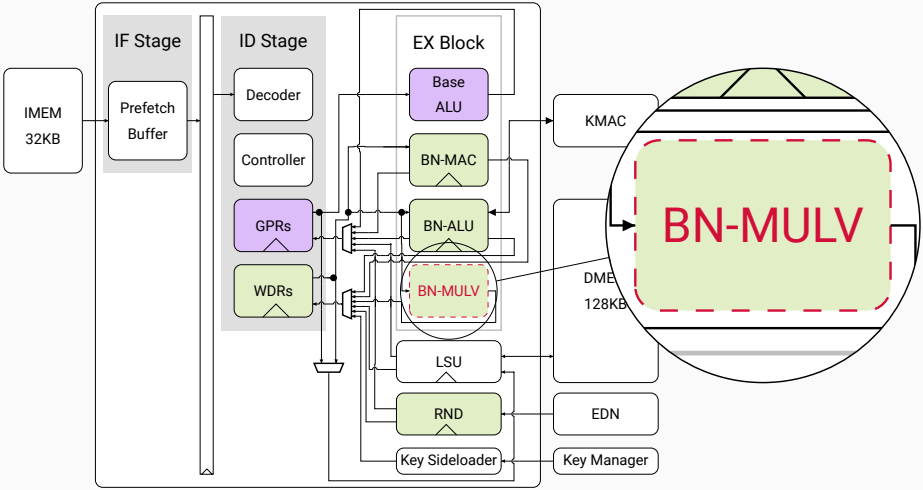

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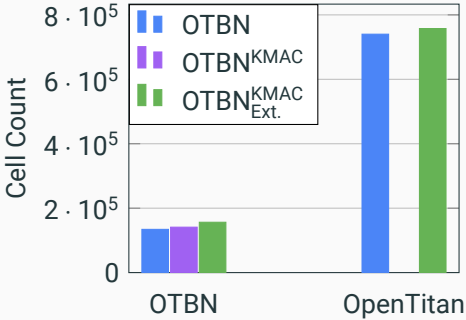

- Cell count-increase of $<$**17%** for OTBN
- Cell count-increase of $<$**3%** for OpenTitan

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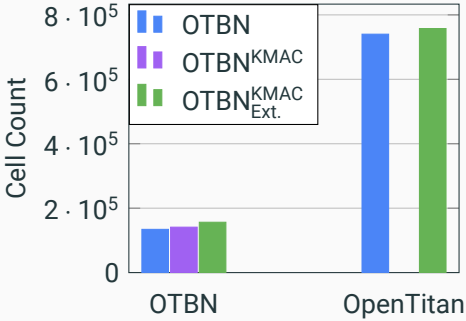

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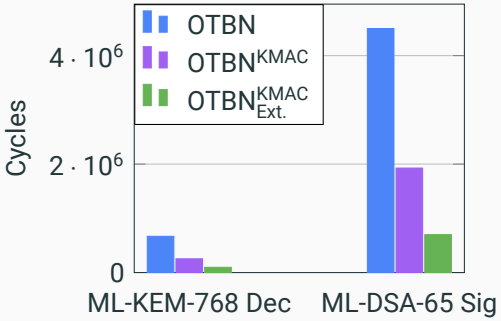

- Target Freq.: **6–9**$\times$ speedup for ML-{KEM,DSA}
- Max. Freq: **4–6**$\times$ net-speedup for ML-{KEM,DSA}

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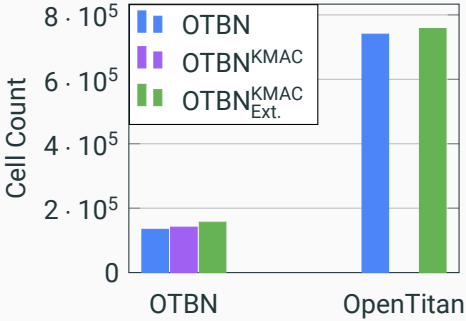

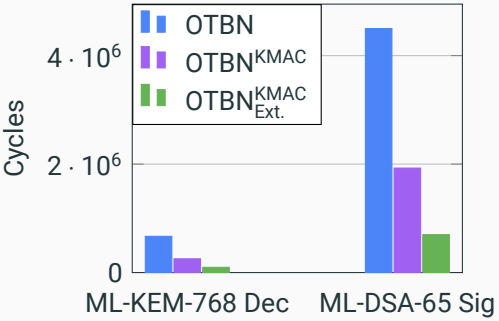

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$\rightarrow$ ML-KEM-768 Dec in 0.8 ms, ML-DSA-65 Sig in 7 ms @ Target Freq.

OpenTitan is Going PQC

ia.cr/2024/1192

github.com/PQC-OpenTitan/towards-ml-kem-and-ml-dsa-on-opentitan

opentitan.org

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