CRAFFT: High Resolution FFT Accelerator in Spintronic Computational RAM

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Driven to Discover℠

Speaker Bio: Hüsrev Cılasun

- BSc from Istanbul Technical University, 2016
- Aselsan, Inc between 2016-2019
- PhD student at University of Minnesota since Fall 2019
- Adaptive, Technology-aware Architectures (ALTAI) Lab (PI: Ulya Karpuzcu)
  - Pushing traditional computing to its limits
  - Computing with post-CMOS devices and paradigms

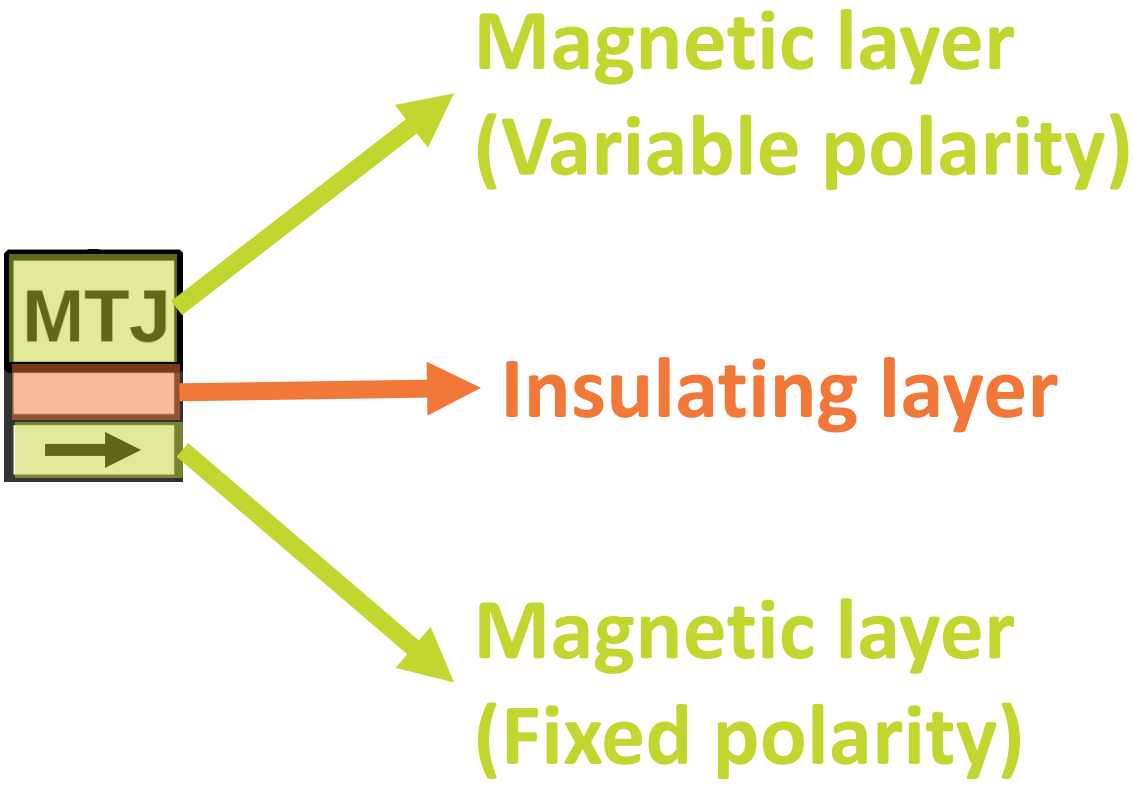
Motivation

- Ultra high resolution FFT (256K+ points)
  - Wireless communication, Wide-band spectrum analysis
  - Radar signal processing, sonar, echography
  - Frequency-hopping transmission detection
  - Telescope array imaging, High-res medical imaging
- Increased demand for
  - Memory access
  - Parallelism
  - Faster computation
  - Energy reduction
- **Conventional hardware can't address efficiently!**

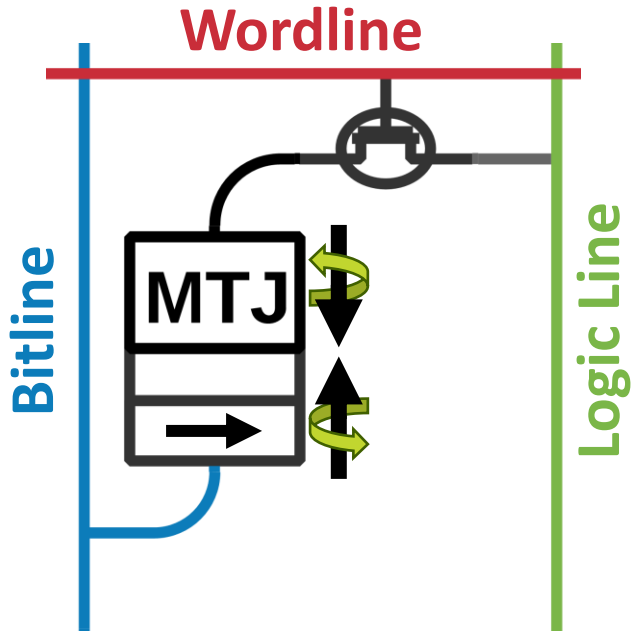
CRAFFT Solution

- Spintronic Computational RAM (CRAM)
  - Seamless memory access
  - Built-in massive parallelism
  - Energy-efficient logic
- Non-volatile memory
- True in memory computation
- Memory mode/logic mode

CRAM MTJ Device

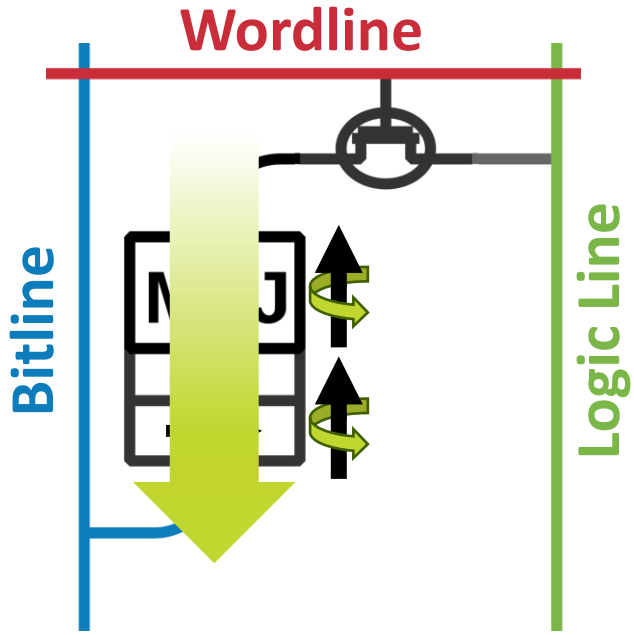


CRAM MTJ Cell



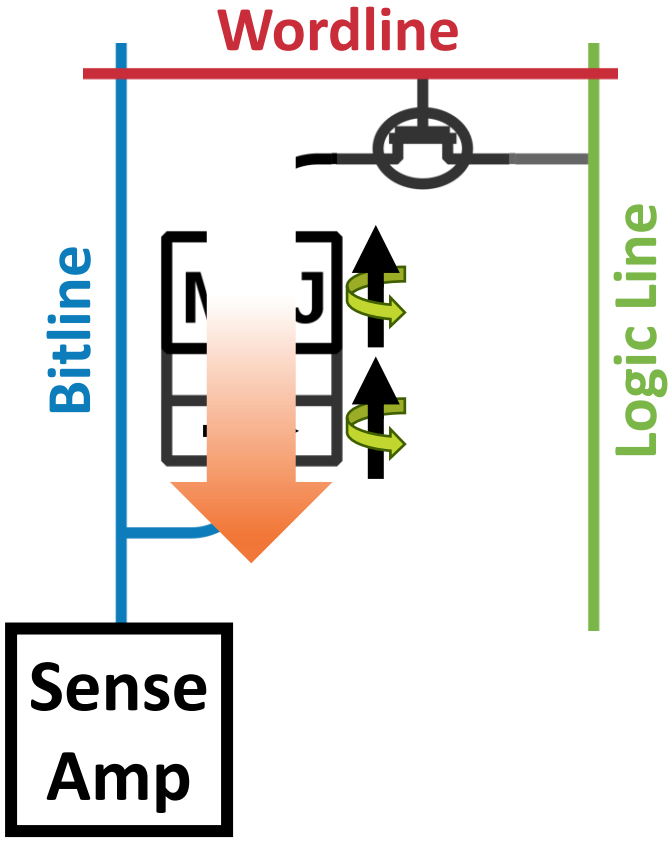
Anti-Parallel (AP)
High Resistance

CRAM MTJ Cell Write

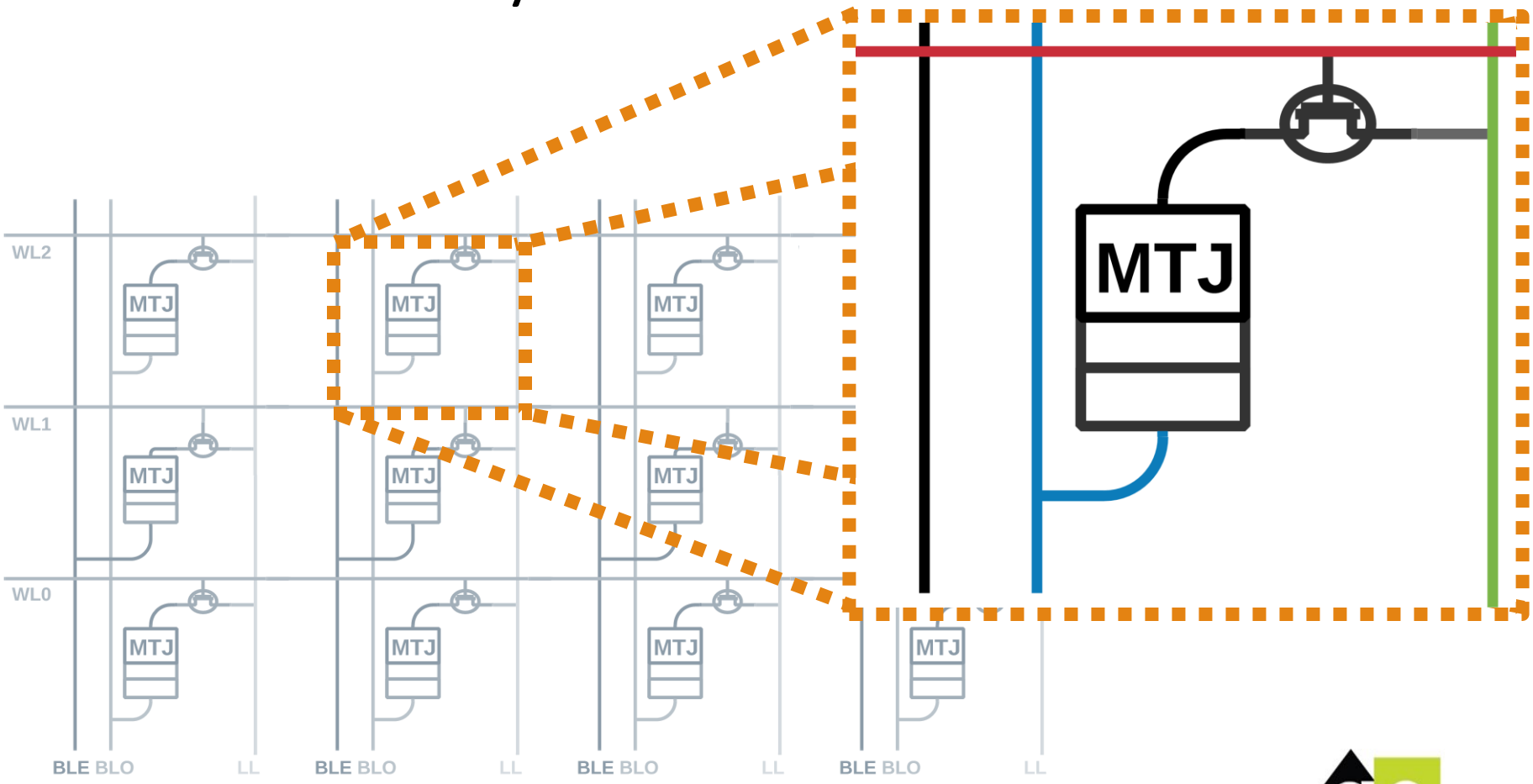


Parallel (P)
Low resistance

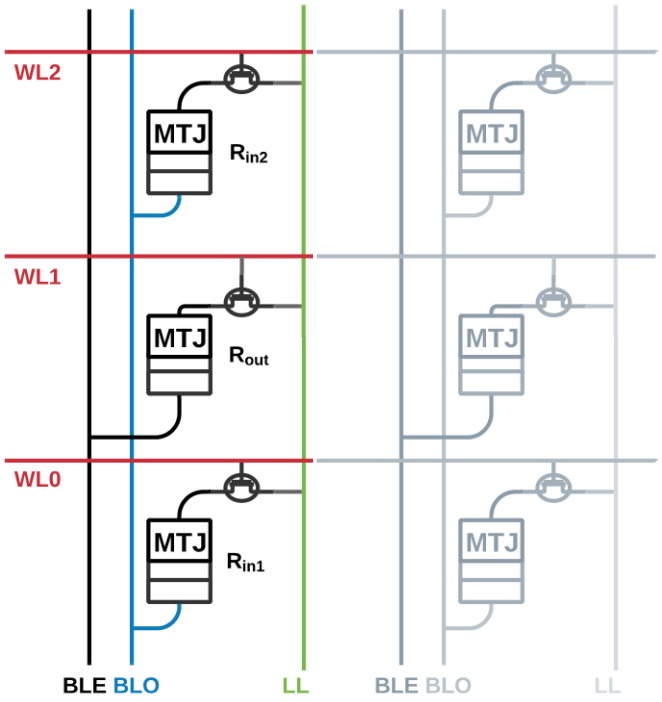
CRAM MTJ Cell Read

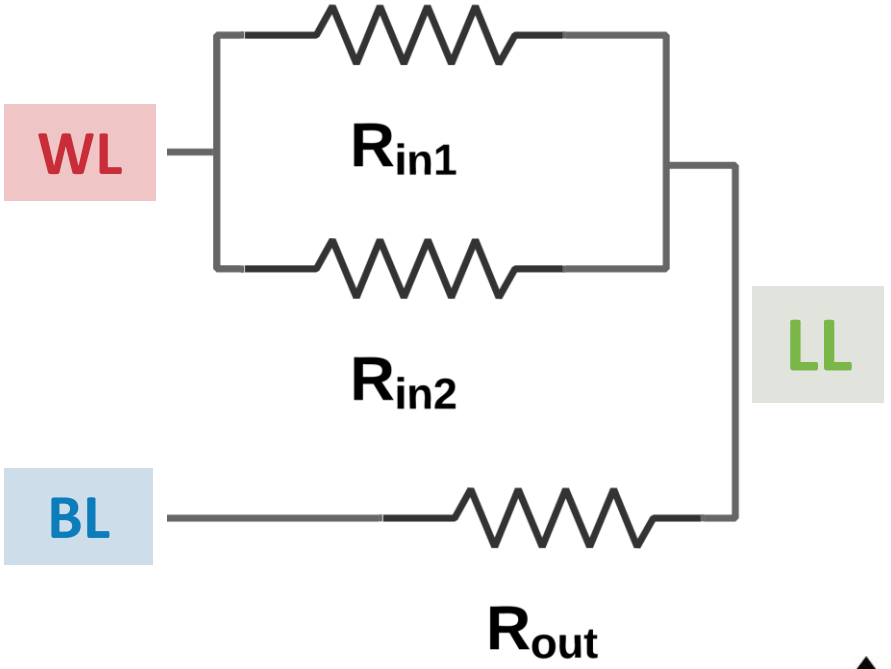


CRAM Array

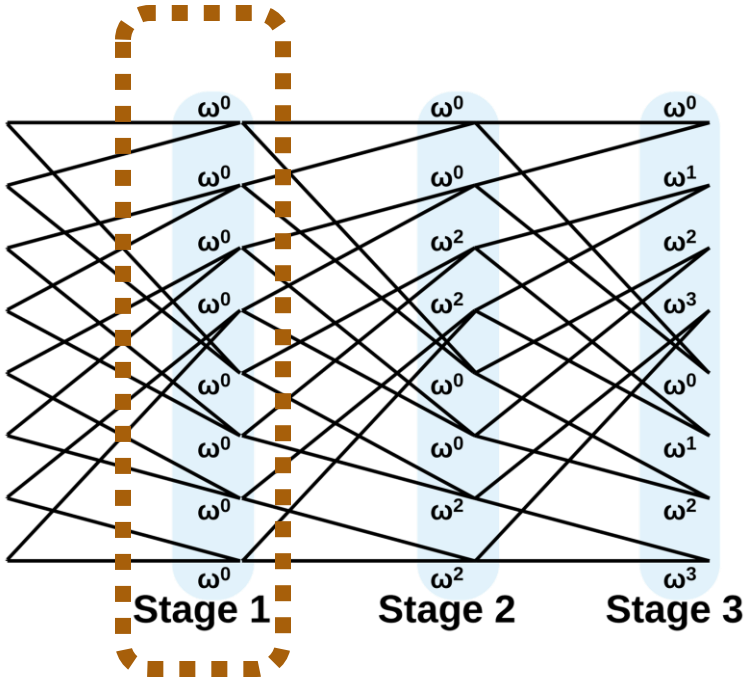


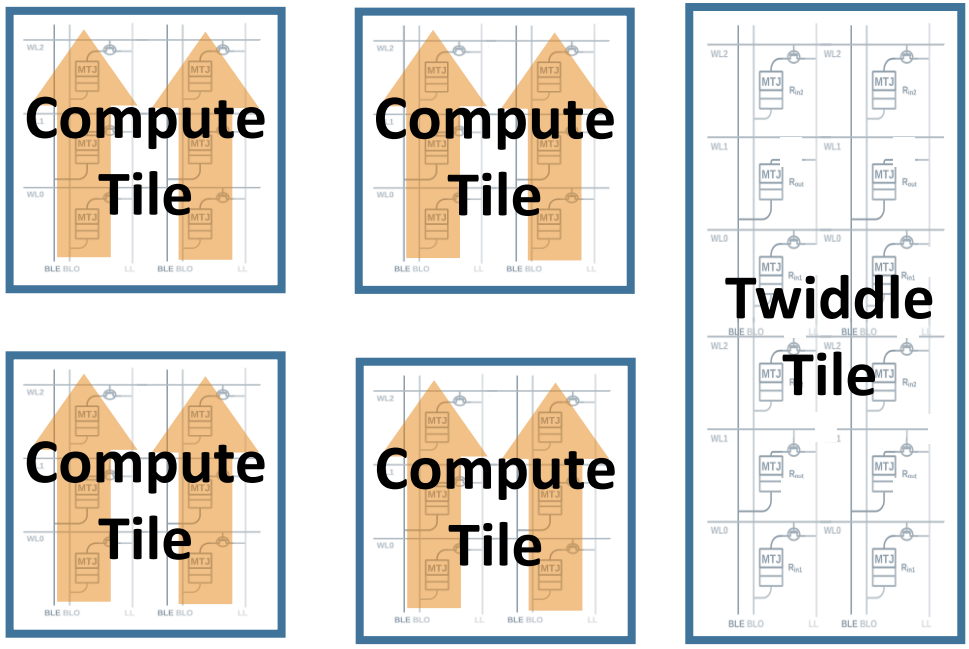
CRAM Gate Implementation





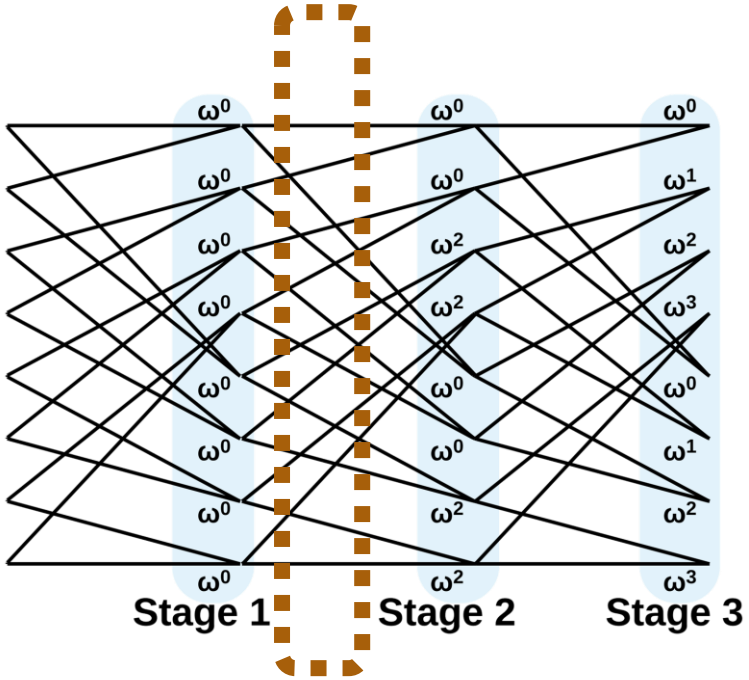
Singleton's FFT in CRAM

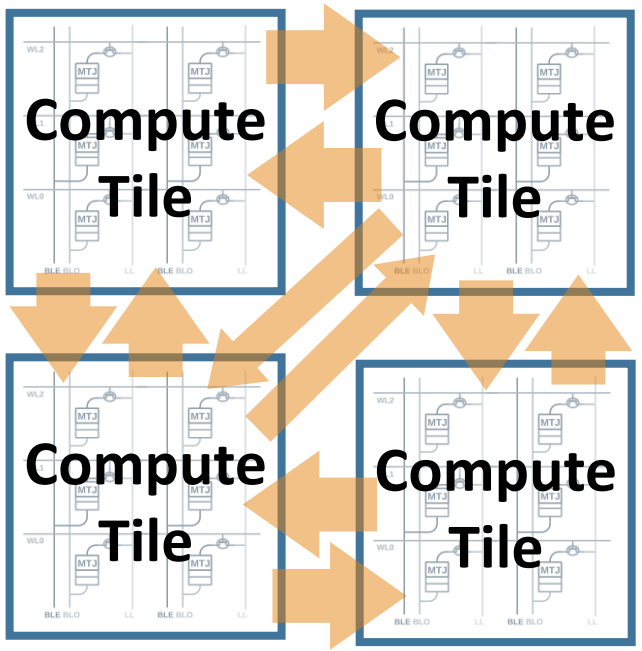


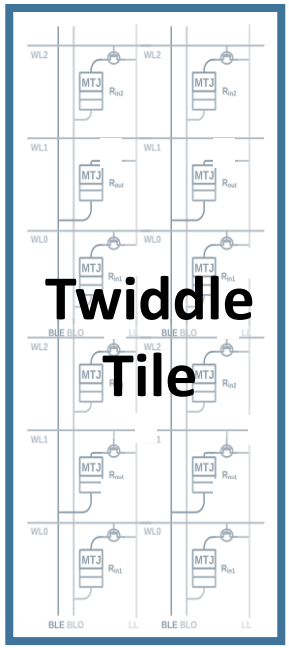


Computation: Complex mult. by ω, add.

Singleton's FFT in CRAM

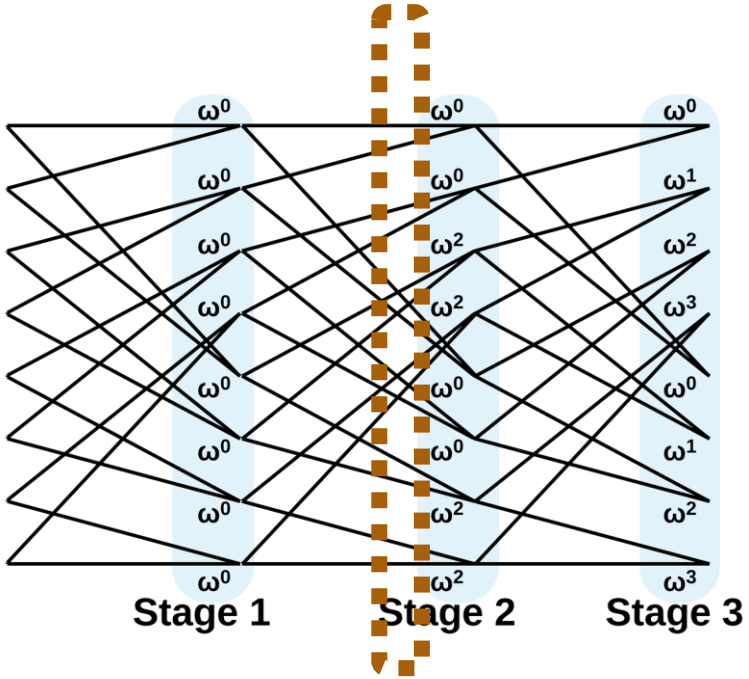


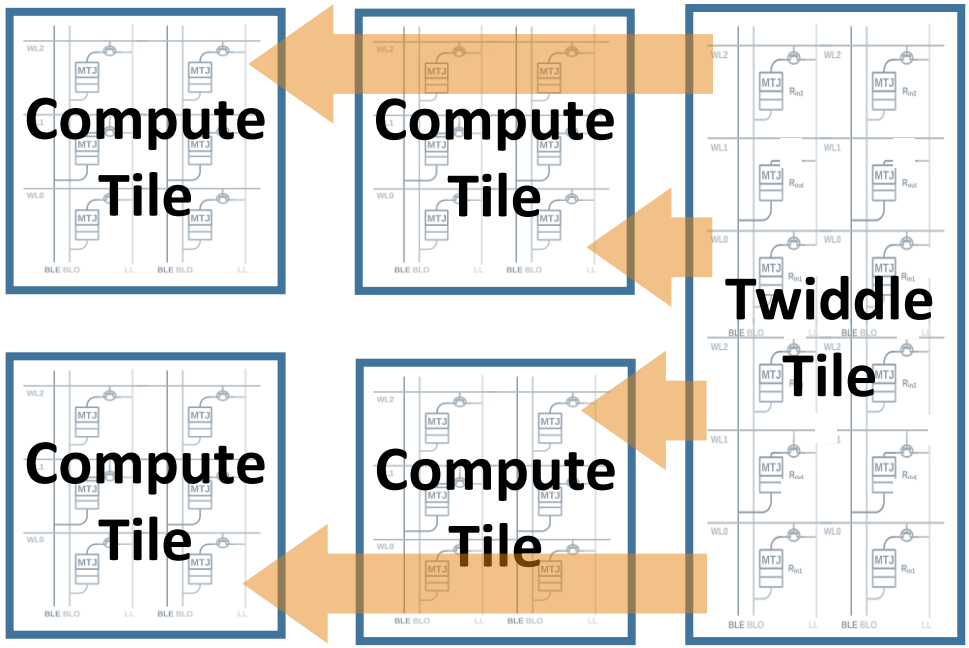




Data Transfer: Inter-subarray communication

Singleton's FFT in CRAM



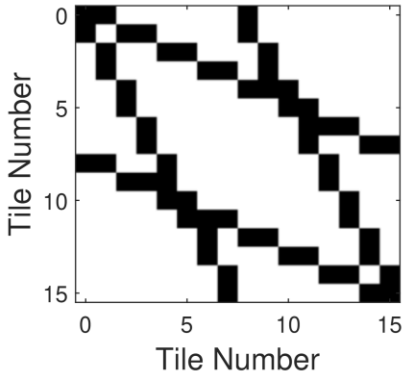


Twiddle Distribution: Factor Broadcast

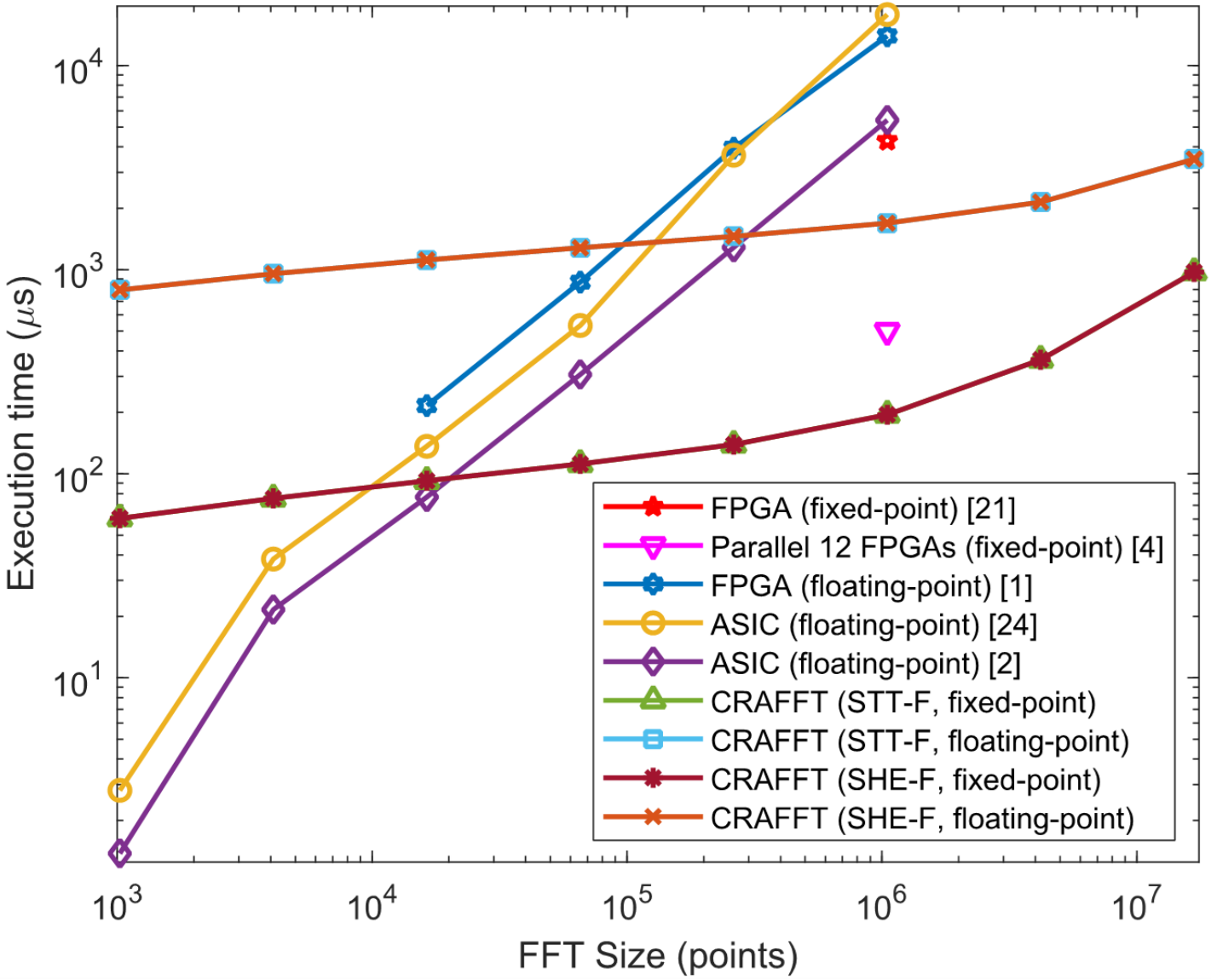
Evaluation Setup

- In-house simulator
  - Functional verification
  - Energy and time extraction
- NVSim for peripherals
- Fixed-point and proof-of-concept floating-point

Parameter	Value
Total memory	17MB – 66MB (1M FFT)
MTJ Resistances	3.15kΩ – 76.39kΩ
Switching Time	3ns – 1ns
Switching Current	40μA – 3μA



Evaluation Results



Conclusion

- Fixed-point
  - Up to 2.73× speedup
  - Significantly lower Energy and EDP
- Proof-of-concept floating point
  - Up to 3.2× speedup
  - 1.93× more energy but 1.66× lower EDP
- Acceleration for ultra-high res FFT
- Efficient addressing of scalability demands

Questions?