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Power and Energy Efficiency Analysis of HPC Workloads on Modern CPU Architectures

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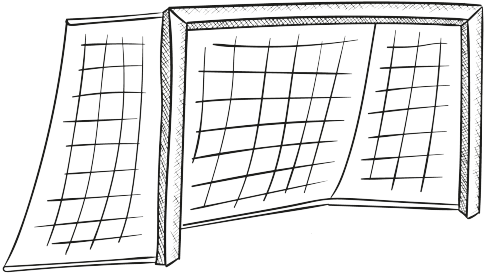
Goals

- find and write suitable benchmarks for different aspects of CPUs
- analyze under which circumstances CPUs work more energy efficiently
- comparison between different architectures and manufacturers



Benchmarks

- Heat Stencil & Monte Carlo Pi Approximation as compute intensive tasks
  - analyzing frequency, thread count and compiler optimization
- Stream benchmark as memory intensive task
  - analyzing behavior with cache and cache sizes
- Vector Multiply-Add to exploit vectorization
  - analyzing different SIMD instruction sets

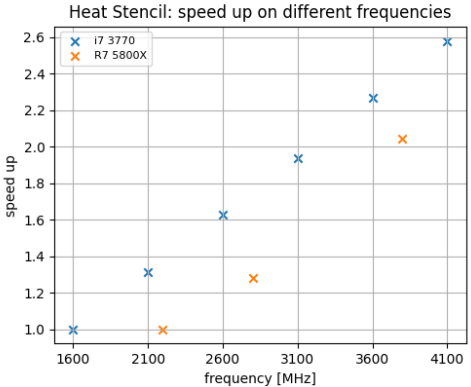
Tools

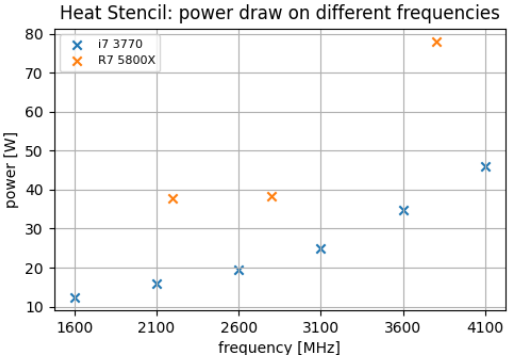
- benchmarks are written in C
  - OpenMP
  - intrinsics from different SIMD instruction sets
- parameterized benchmarks were executed automatically through a python script
- `cpupower`: to limit the frequency
- `powercap-set`: to limit the power draw

Measuring Energy

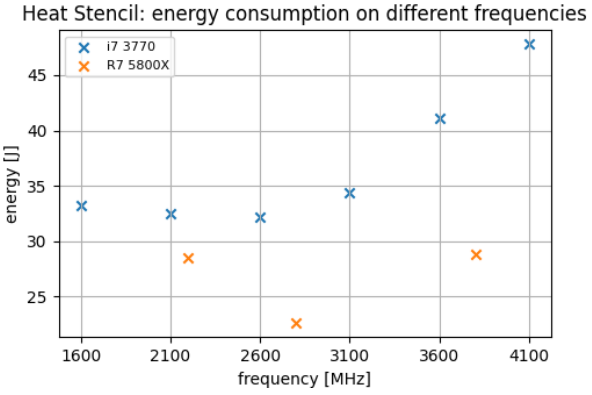
- energy was measured with the performance analysis tool `perf`
- `perf` exploits Intel RAPL interface (Running Average Power Limit)
- through RAPL model specific registers can be accessed
- MSR_RAPL_POWER_UNIT counts energy in fictional unit
- value in register is read out before and after each benchmark

Result Analysis - Heat Stencil





Result Analysis - Heat Stencil



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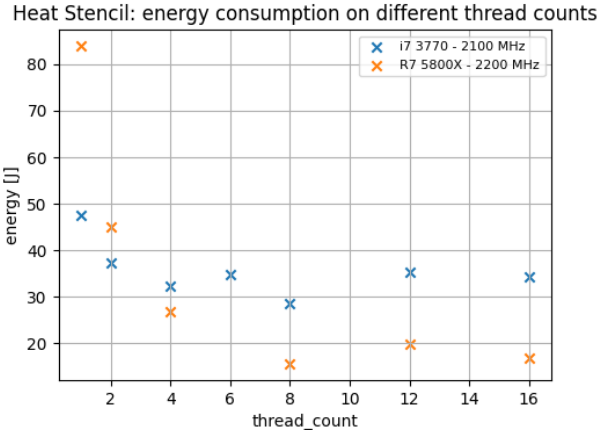

Result Analysis - Monte Carlo

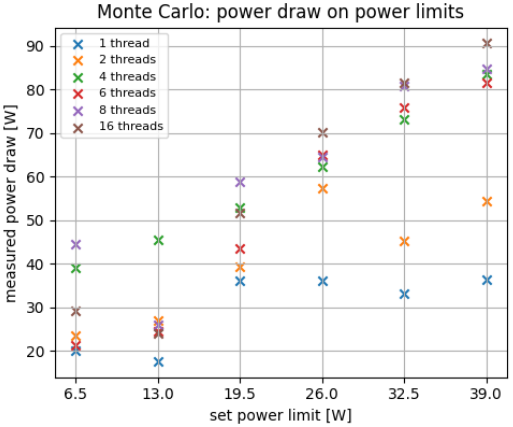

Figure: data from Xeon E5-4650

Result Analysis - Stream

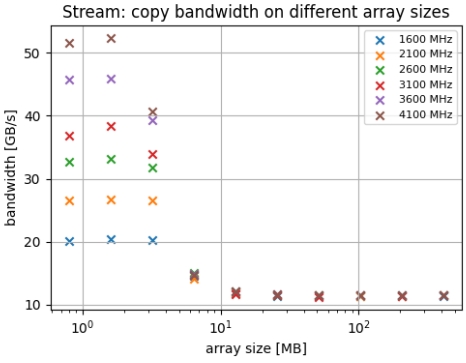

Figure: Core i7 3770

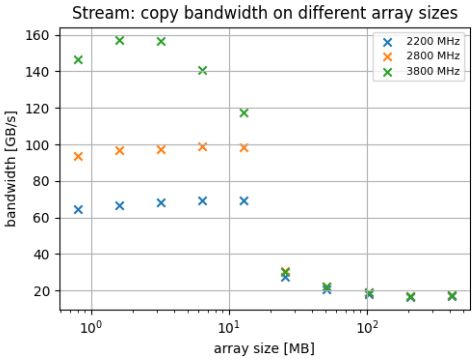

Figure: Ryzen 7 5800X

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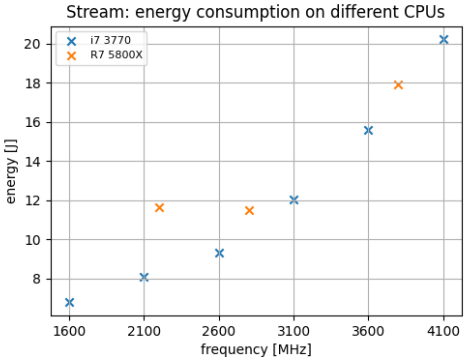
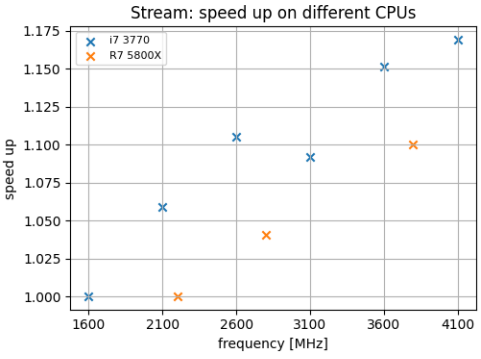
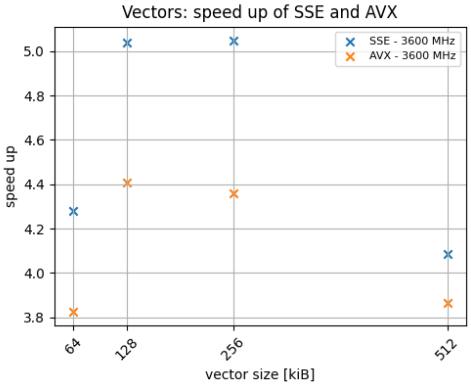




Result Analysis - Vectorization



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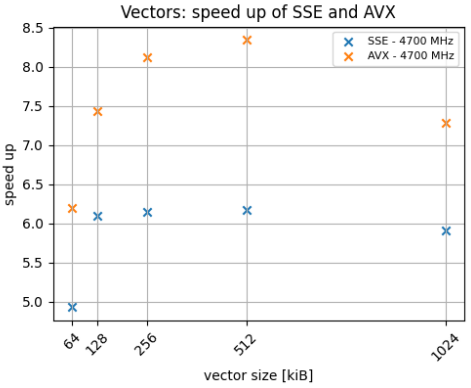

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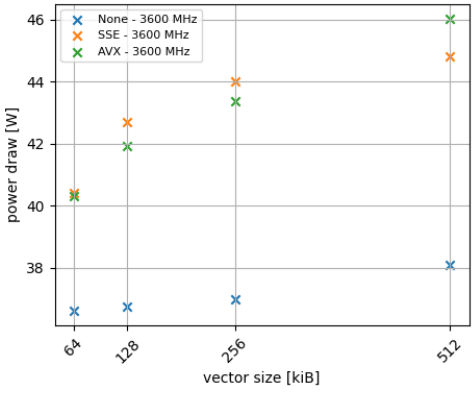

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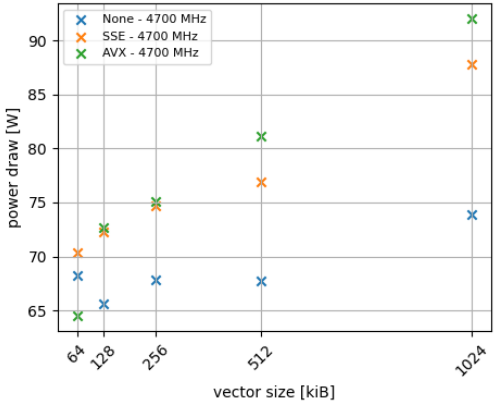

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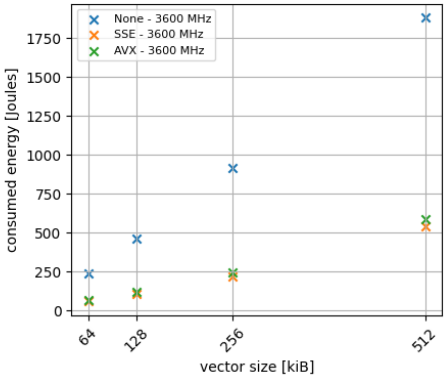

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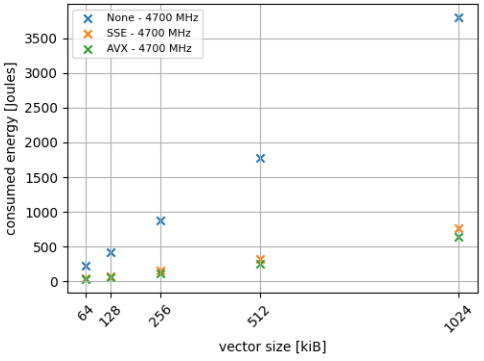


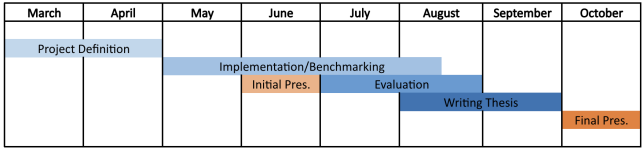
Figure: Ryzen 7 5800X

Conclusion

- higher frequencies increase the energy consumption
- higher thread counts decrease the energy consumption
- being memory bound is not beneficial
  - larger caches can be beneficial
- vectorization can reduce the energy consumption to a fraction (if utilized correctly)

Timeline

anticipated timeline (as of June 2022):



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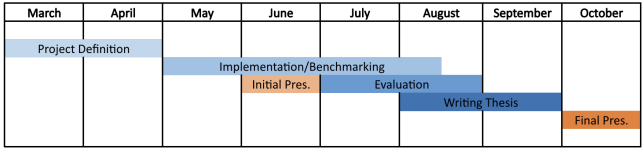
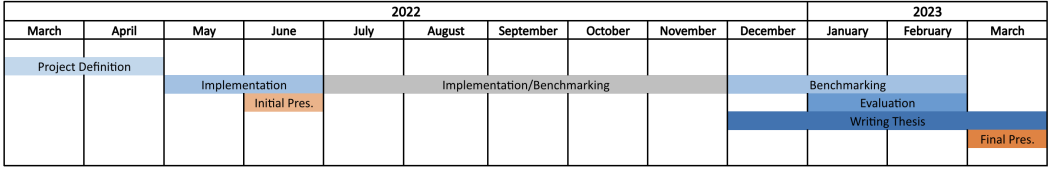
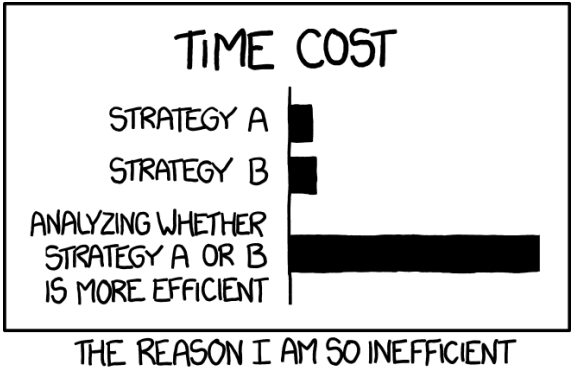


actual timeline:



Thanks for your attention



Credit: `https://xkcd.com/1445/`

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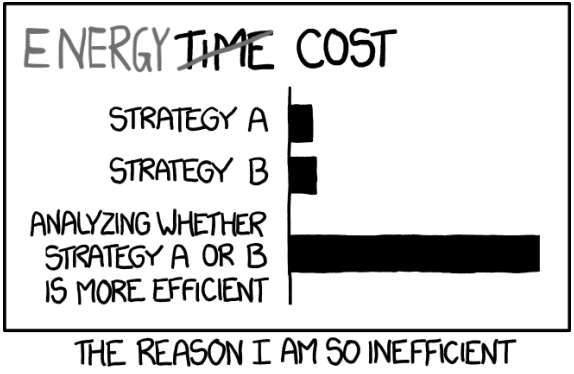

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