



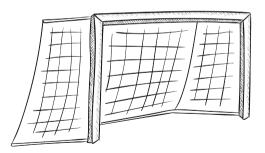
Power and Energy Efficiency Analysis of HPC Workloads on Modern CPU Architectures

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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

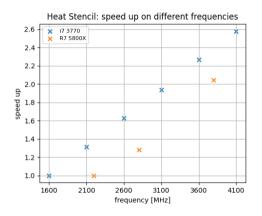


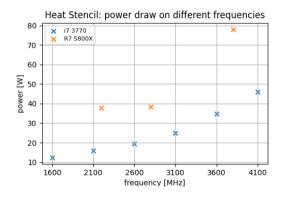
Measuring Energy

- 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



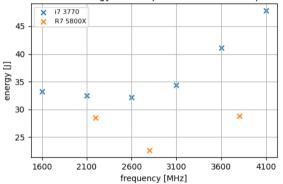
Result Analysis - Heat Stencil





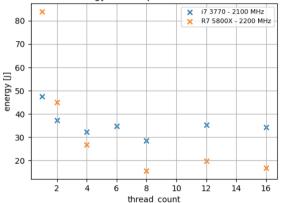
Result Analysis - Heat Stencil

Heat Stencil: energy consumption on different frequencies



Result Analysis - Heat Stencil





Result Analysis - Monte Carlo

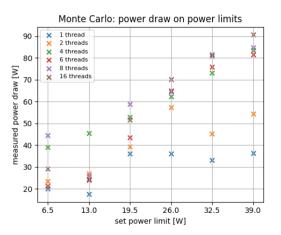


Figure: data from Xeon E5-4650

Result Analysis - Stream

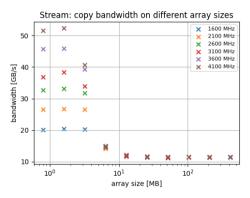


Figure: Core i7 3770

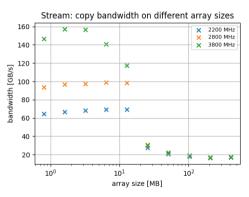
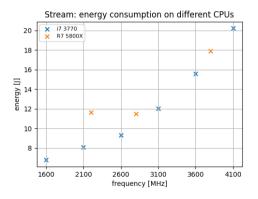
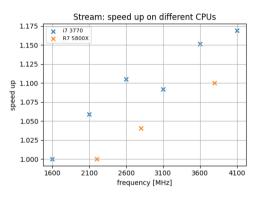


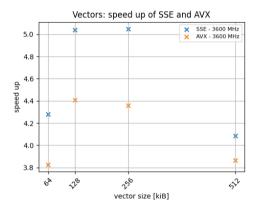
Figure: Ryzen 7 5800X

Result Analysis - Stream





Result Analysis - Vectorization

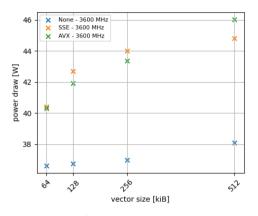


Vectors: speed up of SSE and AVX 8.5 SSE - 4700 MHz AVX - 4700 MHz 8.0 7.5 7.0 6.5 6.0 5.5 5.0 64 28 vector size [kiB]

Figure: Core i7 3770

Figure: Ryzen 7 5800X

Result Analysis - Vectorization



None - 4700 MHz SSF - 4700 MHz AVX - 4700 MHz 85 power draw [W] 70 65 vector size [kiB]

Figure: Core i7 3770

Figure: Ryzen 7 5800X

Result Analysis - Vectorization

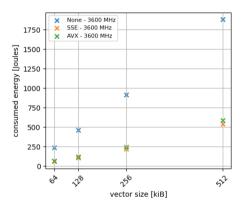


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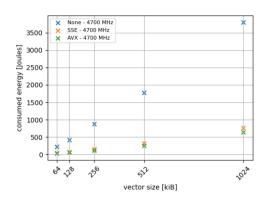


Figure: Ryzen 7 5800X

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):

March	April	May	June	July	August	September	October	
Project Definition								
		Imp	Implementation/Benchmarking					
			Initial Pres.	Evalu	uation			
					Writing	Thesis		
							Final Pres.	
				1				

Timeline

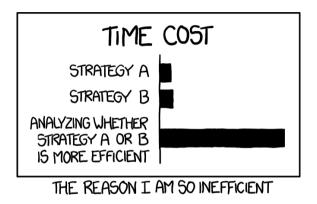
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actual timeline:

2022								2023				
March	April	May	June	July	August	September	October	November	December	January	February	March
Project [Definition											
		Implementation		Implementation/Benchmarking					Benchmarking			
			Initial Pres.							Evalu	ation	
									Writing Thesis			
1												Final Pres.

Thanks for your attention



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

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