IMAGE SIGNAL PROCESSING PERFORMANCE ON 2ND GENERATION INTEL® CORE™ MICROARCHITECTURE

PRESENTATION

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Performance tests in this presentation were conducted by NA Software*, Ltd., and GE Intelligent Platforms* from 2009-2011. Please see details on the system configuration slides 9, 10, and 43 within this presentation. For more information please see http://www.nasoftware.co.uk/home/attachments/018_PPC_Intel_comparison_whitepaper.pdf and www.nasoftware.co.uk/home/attachments/avx_report3.pdf

Topics

Signal Processing on Intel® Processors

- Single Instruction Multiple Data (SIMD)
- Intel® Advanced Vector Extensions (AVX)
- Intel Microarchitecture formerly known as "Sandy Bridge"

Image Signal Processing Performance

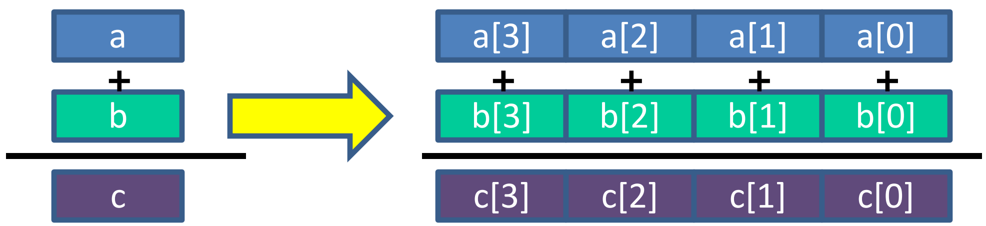
- Current Intel® Processor performance on representative VSIPL* functions compared with Freescale* and previous generation Intel processors

Synthetic Aperture Radar

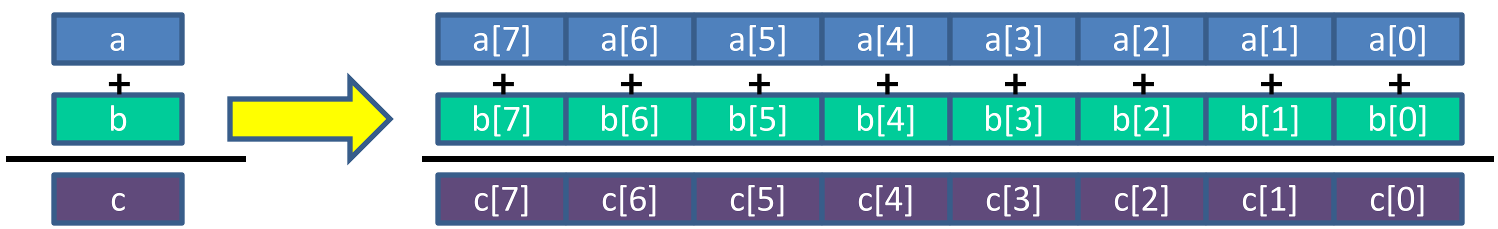
- Performance of current and previous generation Intel processors on two complete RADAR applications

Enhanced SIMD Features in 2nd Generation Intel® Core™ Microarchitecture

- High performance image signal processing on general purpose processors typically utilizes Single Instruction, Multiple Data (SIMD) instructions to process data in parallel
- Before Intel® microarchitecture formerly code named Sandy Bridge, SIMD vectorization was provided by Intel® Streaming SIMD Extensions (Intel® SSE)
  - Eight 128-bit registers where uniform type data can be packed – 4 floating point, single precision (32-bit) elements
  - Intel SSE instructions operate on all data items in parallel



- Intel® Advanced Vector Extensions (AVX) -- 2011
  - Increases floating point SIMD registers to 256-bits—8 32-bit elements per iteration



For more information on Intel® AVX, please see http://software.intel.com/en-us/articles/practical-intel-avx-optimization-on-2nd-generation-intel-core-processors/

2nd Generation Intel® Core™ Microarchitecture Highlights

Two Load/Store ports, greater instruction fetch bandwidth, and Intel® AVX all serve to increase performance on many image processing algorithms

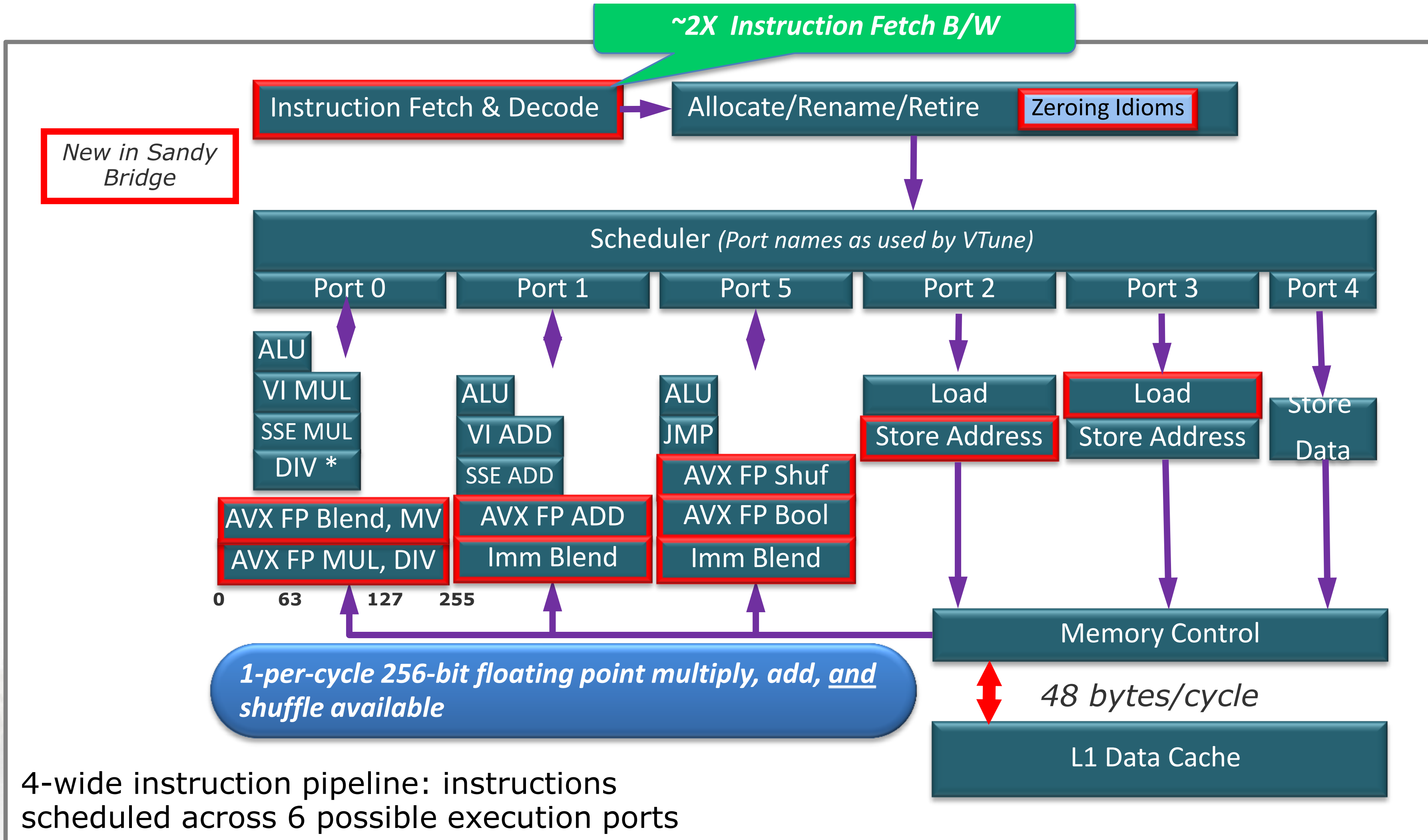


Image Signal Processing Performance

- This report
  - Gives results of tests conducted by independent third-party software vendors using Beta versions of their respective Vector Signal and Image Processing Library* (VSIPL) implementations for the Intel® Core™ i7-2710QE and the Intel® Core™ i7-2715QE processors
  - Compares these results with previous generations of Intel processors and the Freescale* MPC8641D processor, currently the latest released Freescale processor to support the AltiVec* SIMD instruction set architecture
  - Compares the performance of two complete RADAR applications on the first and second generations of the Intel® Core™ microarchitectures

Image Signal Processing Performance Measurements on VSIPL* Functions

Background: VSIPL*

Vector Signal Image Processing Library*

- Highly efficient computational middleware for
- signal and image processing applications
- Widely used in the US Defence Industry
- Application programming interface (API) defined by the VSIPL Forum*
- Abstracts hardware implementation details; applications are portable across processor types and generations

http://www.vsipl.org/

VSIPL* For Intel® Architecture

VSIPL performance libraries for Intel® Architecture are available from the following, among others

- Code Sourcery*
  - http://www.codesourcery.com/vsiplplusplus/benefits.html
- Curtiss Wright* Controls Embedded Computing
  - http://www.cwcembedded.com/
- GE Intelligent Platforms* AXISLib-AVX
  - http://defense.ge-ip.com/axisdemo
- N.A. Software, Ltd*
  - http://www.nasoftware.co.uk/
- RunTime Computing*
  - http://www.runtimecomputing.com

VSIPL* Benchmark Studies

- The following pages summarize results of tests conducted by NASoftware* Ltd. using a Beta version of their VSIPL* implementation for Intel® Advanced Vector Extensions (Intel® AVX)-enabled processors -- 2nd Generation Intel® Core™ microarchitecture**
- Results are shown for the same VSIPL functions from 2008 studies conducted by GE Fanuc* (now GE Intelligent Platforms*) showing the performance of GE's AXISLib* running on the Freescale* MPC8641D and from tests conducted by NA Software* of their beta VSIPL implementation for Intel® Architecture running on an Intel® Core™2 Duo SL9400 processor
- Results are also shown for the same VSIPL functions using GE IP AXISLib-AVX Beta performance library running under Linux* on their current DSP280 6U OpenVPX* multiprocessor board, which features 2x Intel® Core™ i7-2715QE processors, with four cores each. (Only one core used in these tests unless otherwise noted.)
- Timings for the GE-IP DSP280 are given here as an example of hardware and software solutions available from third party hardware and software solution providers

**Results are compared with those obtained from running the same tests on the 2010 Intel® Core™ i5-M430 processor which supports the previous generation Intel SSE 4.2 instruction set architecture

VSIPL* Benchmark Systems Configurations (1 of 2)

Processor	Freescale* MPC8641D	Intel® Core™ 2 Duo SL9400 (2008)	Intel® Core™ i5-430M (2010)
Max Thermal Design Power (TDP)	About 34W (no ancillary chipset)	About 31.5W including ancillary chipset	About 39W including ancillary chipset
Process Technology	90nm	45nm	32nm
Clock rate	1 GHz	1.86GHz	Fixed @ 2.0 GHz for these tests
Cores	2 (only 1 used)	2 (only 1 used)	2 (only 1 used in VSIPL tests)
L1 Data and Instruction caches	32KB (each per core)	32KB (each per core)	32KB (each, per core)
L2 cache	1MB (each)	6MB (shared)	256KB per core
L3 Cache	None	None	3MB (shared)
Front Side Bus	400MHz	1066MHz	None (Memory controller integrated in processor die)
SIMD	AltiVec* (per core)	Intel® SSE4.1 (per core)	Intel SSE 4.2 (per core)
Chipset	None	Intel® GS45E	Intel HM55 (Mobile Series 5)
Hardware details	GE Fanuc* DSP230	Hewlett Packard* 2530P laptop	Acer® Aspire® AS5741-6823 laptop with 4 GB DDR3-1066 Intel® Hyper-Threading technology turned off
Software Environment	VXWorks* 6.6; GE Fanuc* AXISLib* VSIPL rel 2.3.	Linux*; gcc; N.A. Software* VSIPL beta for Intel Architecture; gcc flags: O3 -mfpmath=sse -msse4 -m64 -Wall -Wno-unused	Linux* (Fedora* 12); gcc 4.6.6; icc version 12.0.1; Intel® IPP 7.0 build 205.23; N.A. Software VSIPL **Beta** for Intel AVX gcc AVX compiler flags: --O3 -mfpmath=sse -mavx -m64 -Wall -Wno-unused. gcc SSE flags: O3 -mfpmath=sse -msse4 -m64 -Wall -Wno-unused. icc flags: -O3 -xAVX -ip -fno-alias -fargument-noalias

All VSIPL measurements were done with data in warm caches; single core performance only. Freescale* CPU tests conducted by GE Fanuc* (now GE Intelligent Platforms*). Intel® CPU tests conducted by N.A. Software*, Ltd. All data is single-precision, floating point (32-bit), complex. Times are averages of 1000 (MPC8641D/SL9400) and 100 iterations (Core i5 and i7). NA Software* has both Linux* and VxWorks* 6.6 versions of their VSIPL libraries for Intel® architecture, and used the Linux* versions with the Intel® processor. There is no significant performance difference between the VxWorks and Linux versions in these applications. Software libraries, drivers, operating systems, and compilers used are not fully tuned for performance and additional performance gains may be possible. Data is at fixed CPU clock frequency and may change with Intel® Turbo Boost Technology enabled.

VSIPL* Benchmark Systems Configurations (2 of 2)

Processor	Intel® Core™ i7- 2710QE (2011) Intel Customer Reference Board (NAS)	Intel® Core™ i7- 2715QE (2011) GE Intelligent Platforms* DSP280 Open VPX* Board
Max Thermal Design Power (TDP) for Processor + Chipset	About 51W including Platform Controller Hub (PCH) chipset	
Process Technology	32nm	
Clock rate	Fixed @ 2.0 GHz for these tests	2.1 GHz; Intel® Turbo Boost technology enabled
Cores	4 (only 1 used in VSIPL tests)	4 (only 1 used unless noted)
L1 Data and Instruction caches	32KB (each, per core)	
L2 cache	256KB per core	
L3 Cache	6MB (shared)	
Front Side Bus	None (Memory controller integrated in processor die)	
SIMD	Intel AVX 1.0 (per core)	
Chipset	Intel BD82Q67	Intel QM67
Hardware details	Intel Emerald Lake Rev B. Customer Reference Board with 1 GB DDR3-1333. **Non-ECC**; PCH: Intel® Mobile AM67 chipset, B0 stepping. Intel® Hyper-Threading and Turbo Boost technologies turned off	GE IP DSP280 6u OpenVPX* board with dual Intel® Core™ i7-2715QE BGA processors , each with four cores. 8 GB DDR3-1333 **with ECC**. Turbo Boost technology enabled
Software Environment	Linux* (Fedora* 12); gcc 4.6.6; icc version 12.0.1; Intel® Integrated Performance Primitives (IPP) 7.0 build 205.23; N.A. Software VSIPL **Beta** for Intel AVX gcc AVX compiler flags: --O3 -mfpmath=sse -mavx -m64 -Wall -Wno-unused. gcc SSE flags: O3 -mfpmath=sse -msse4 -m64 -Wall -Wno-unused. icc flags: -O3 -xAVX -ip -fno-alias -fargument-noalias	Scientific* Linux* 6.0 x64, Kernel 2.6.32. gcc 4.5.1; AVX compiler flags: --O3 -mfpmath=sse -mavx -m64 -Wall -Wno-unused GE Intelligent Platforms* AXISLib-AVX Beta 1.0

All VSIPL measurements were done with data in warm caches when possible. Single core performance only. Freescale* CPU tests conducted by GE Fanuc* (now GE Intelligent Platforms*). Intel® CPU tests conducted by N.A. Software*, Ltd. and GE Intelligent Platforms* All data is single-precision, floating point (32-bit), complex. Times are averages of 1000 (MPC8641D/SL9400) and 100 iterations (Core i5 and i7.) Software libraries, drivers, operating systems, and compilers used are not fully tuned for performance and additional performance gains may be possible. Some test results are at fixed CPU clock frequency and may change with Intel® Turbo Boost Technology enabled.

1D Complex-Complex, In-Place FFT Timings (μ seconds)

1D Complex-Complex, In-Place FFT (μseconds) vsip_ccfftip_f (Lower is Better)						
N	***256***	***1K***	***4K***	***16K***	***256K***	***512K***
Freescale* MPC 8641D	2.4	10	71.4	414	***22,990***	***73,998***
Intel® Core™ 2 Duo SL9400	1.26	6.3	35.9	197	4,704	11,732
Intel® Core™ i5-430M IPP SSE	1.24	5.38	32.14	116.4	5,950	13,290
Intel® Core™ i7-2710QE NAS SSE	0.75	3.22	20.64	116.12	2,571	6,237
Intel® Core™ i7-2710QE NAS AVX	0.44	1.82	13.07	84.4	1,166	4,999
Intel® Core™ i7-2715QE DSP280 (ECC) **	0.51	1.4	8.21	49.59	1,272	5,908

- Times in ***italic bold*** indicate the data requires a significant portion or is too large to fit into the processor's L2 cache – so data must be fetched from slower main system memory
  - The Freescale* processor has 1MB of dedicated last level cache per core (not shared)
  - Both the Intel® Core™ 2 and Core i7 processors have 6MB of shared last level cache, all of which is available to the single core used in these tests
  - The Intel Core i5 processor has 3MB of shared last level cache

**Note the GE IP DSP280 is configured with ECC memory. ECC memory accesses are fractionally slower than non-ECC memory accesses

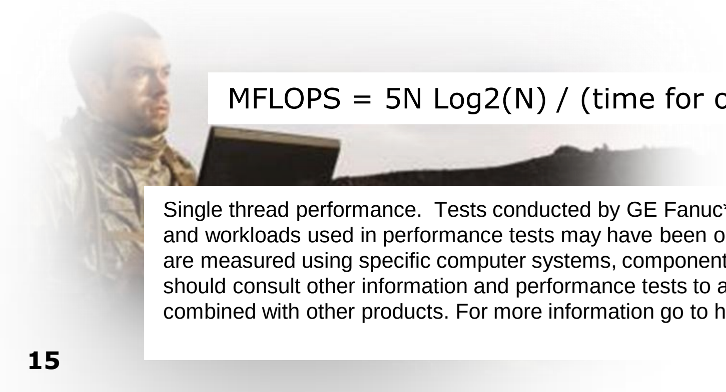
1D Complex-Complex, In-Place FFT - Relative Performance

Relative Performance ($Time_a/Time_b$)						
N	***256***	***512***	***4K***	***16K***	***256K***	***512K***
Intel® Core™ 2 Duo SL9400 vs Freescale* MPC8641D	1.90x	1.59x	1.99	2.10x	4.89x	6.31x
Intel® Core™ i5-430M IPP SSE vs Freescale* MPC8641D	1.94x	1.86x	2.22	3.56x	3.86x	5.57x
Intel® Core™ i7-2710QE NAS SSE vs Freescale* MPC8641D	3.20x	3.11x	3.46	3.57x	8.94x	11.86x
Intel® Core™ i7-2710QE AVX vs Freescale* MPC8641D	5.45x	5.49x	5.46	4.90x	13.88x	14.80x
Intel® Core™ i7-2710QE AVX vs Intel® Core™ 2 Duo SL9400	2.86x	3.46x	2.74	2.33x	2.84x	2.35x
Intel® Core™ i7-2710QE NAS SSE vs Intel® Core™ i5-M430 NAS SSE	1.92x	2.16x	2.16	1.99x	2.18x	2.89x
Intel® Core™ i7-2710QE AVX vs Intel® Core™ i5 M430 IPP SSE	2.82x	2.96x	2.46	1.38x	3.59x	2.66x
Intel® Core™ i7-2710QE AVX vs Intel® Core™ i7-2710QE SSE	1.70x	1.77x	1.58x	1.37x	1.55x	1.25x

- The performance advantage of the Intel® Core™ 2 Duo and Core i5 over the Freescale* processor for <256K points are mostly attributable to their clock speed being 2X that of the Freescale part. At ≥256K the larger caches in both Intel parts are a major factor in their performance advantage. (Rows 1 and 2)
- The performance advantage of the Intel Core i7 enhanced microarchitecture is evident even without the benefit of the wider Intel AVX vector registers is clearly evident in rows 3 (vs PPC) and 6 (vs the Intel Core i5)
- The bottom row shows the performance advantage when the same program is compiled on the Intel Core i7 platform with and without the –xAVX flag. Additional gains using AVX range from 70% to 25%, with the largest gains at the smaller data sizes

1D Complex-Complex, In-Place FFT (MFLOPS)

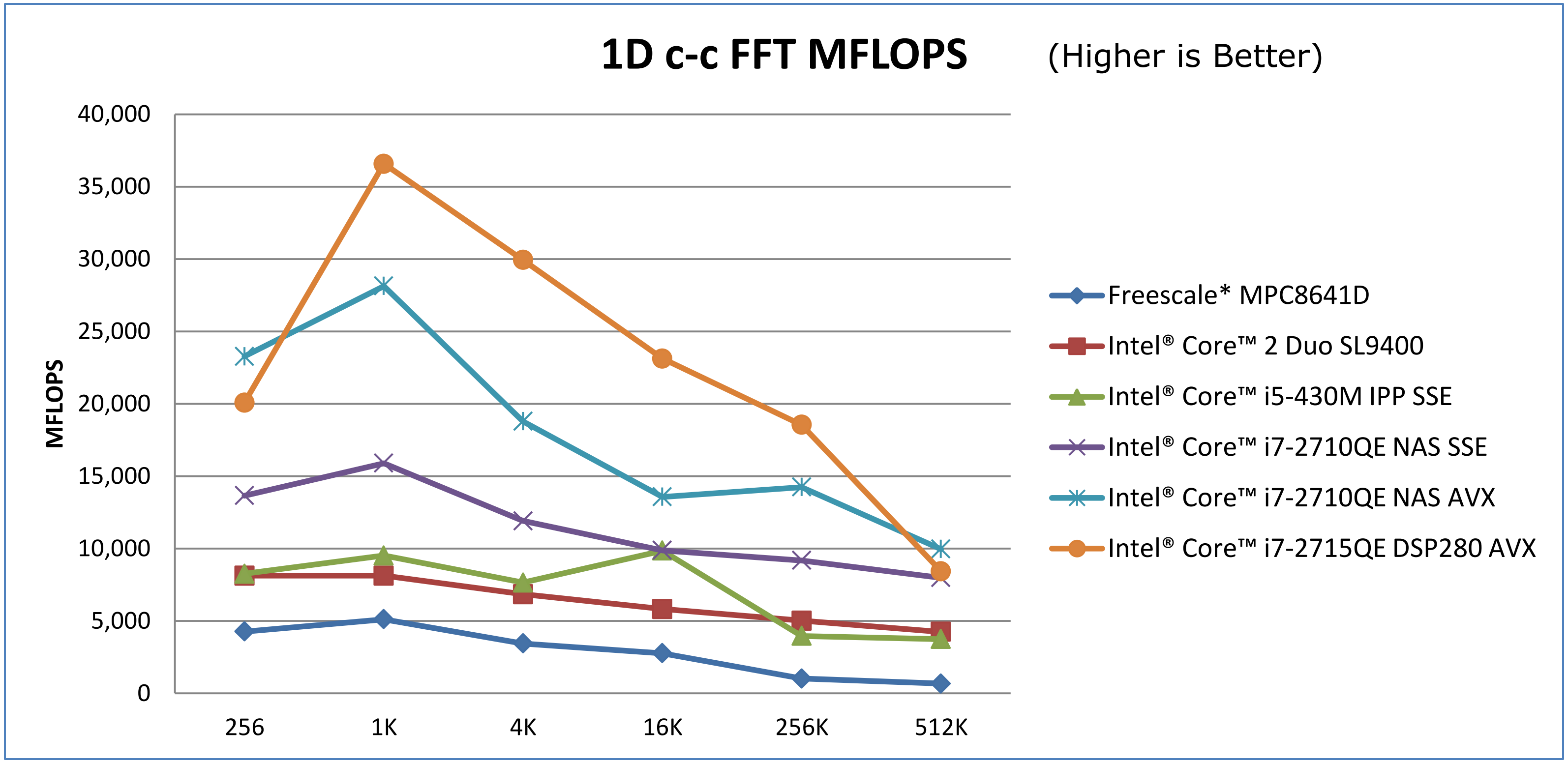
1D Complex-Complex, In-Place FFT (MFLOPS) vsip_ccfftip_f (Higher is Better)						
N	***256***	***1K***	***4K***	***16K***	***256K***	***512K***
Freescale* MPC8641D	4,267	5,120	3,442	2,770	1,026	673
Intel® Core™ 2 Duo SL9400	8,127	8,127	6,846	5,822	5,016	4,245
Intel® Core™ i5-430M SSE	8,258	9,517	7,647	9,853	3,965	3,748
Intel® Core™ i7-2715QE NAS SSE	13,653	15,901	11,907	9,878	9,177	7,986
Intel® Core™ i7-2715QE NAS AVX	23,273	28,132	18,789	13,573	14,247	9,963
Intel® Core™ i7-2715QE DSP280 (ECC)	20,078	36,571	29,934	23,127	18,548	8,430



MFLOPS = 5N Log2(N) / (time for one FFT in microseconds)

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

Single Precision, Complex-Complex, 1D FFT (MFLOPS)



- The performance advantages of the 2nd Generation Intel® Core™ microarchitecture are strikingly illustrated on this graph
- Results for the Intel Core i7 processor use
  - NA Software's* VSIPL* libraries for Intel® AVX – Beta ("NAS AVX")
  - GE-Intelligent Platform* AXISLib-AVX Beta ("DSP280 AVX")
- Both companies plan higher-performing 'gold' releases during 2011

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Multiple 1D, Complex to Complex, In-place FFT Timings (µseconds)

Multiple 1D, Complex-Complex, In-Place FFTs (µseconds) vsip_ccfftmip_f (Lower is Better)						
N*M (M rows of length N)	***256 *256***	***1K *100***	***4K *50***	***16K *20***	***64K *20***	***128K *20***
Freescale* MPC8641D,	698	1,164	5,941	13,111	67,307	***231,970***
Intel® Core™ 2 Duo SL9400	361	661	2,004	4,552	26,577	61,178
Intel® Core™ i5-430M NAS SSE	382	738	2,271	4,945	25,343	59,462
Intel® Core™ i7-2710QE NAS SSE	189	325	1,037	2,390	12,105	27,078
Intel® Core™ i7-2710QE NAS AVX	130	201	755	1,814	9,416	22,361
Intel® Core™ i7-2715QE DSP280 (1 core)	141.98	229	861.8	1,888	9,775	22,732
Intel® Core™ i7-2715QE DSP280 (4 cores)	143.8	74.48	252.07	520.01	3,263.31	8,646.97

Times in *italic bold* indicate the data requires a significant portion or is too large to fit into the processor's last level cache

Multiple 1D, Complex to Complex, In-place FFTs

Multiple 1D FFT MFLOPS (Higher is Better)						
N	***256***	***1024***	***4096***	***16384***	***65536***	***131072***
M	***256***	***100***	***50***	***20***	***20***	***20***
Freescale* MPC8641D,	3,756	4,399	2,068	1,749	1,558	961
Intel® Core™ 2 Duo SL9400	7,262	7,746	6,132	5,039	3,945	3,642
Intel® Core™ i5-430M NAS SSE	6,862	6,938	5,411	4,639	4,138	3,747
Intel® Core™ i7-2710QE NAS SSE	13,870	15,754	11,850	9,597	8,662	7,936
Intel® Core™ i7-2710QE NAS AVX	20,165	25,473	16,275	12,645	11,136	9,965
Intel® Core™ i7-2715QE DSP280 (1 core)	18,463	22,355	14,259	12,147	10,727	9,802
Intel® Core™ i7-2715QE DSP280 (4 cores)	18,230	68,743	48,748	44,110	32,132	25,769

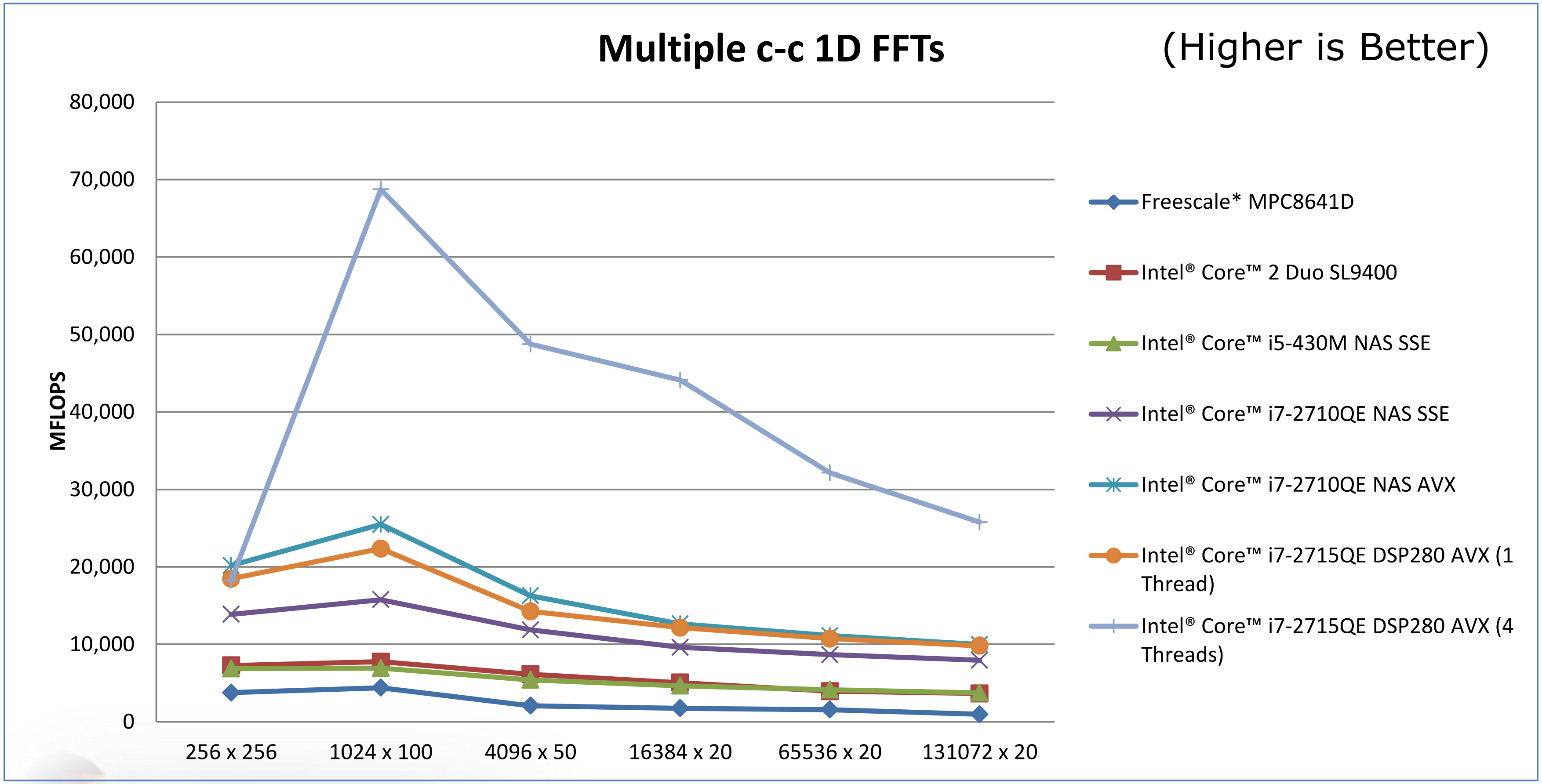
Relative Performance ($Time_a/Time_b$)						
N x M	***256 x 256***	***1K x 100***	***4K x 50***	***16K x 20***	***64K x 20***	***128K x 20***
Intel® Core™ i7-2710QE NAS AVX vs Freescale*MPC8641D	5.37x	5.82x	7.87x	7.23x	7.15x	10.37x
Intel® Core™ i7-2710QE NAS AVX vs Intel® Core™ 2 Duo SL9400	2.78x	3.31x	2.65x	2.51x	2.82x	2.74x
Intel® Core™ i7-2710QE NAS AVX vs Intel® Core™ i5-430M NAS SSE	2.94x	3.69x	3.01x	2.73x	2.69x	2.66x
Intel® Core™ i7-2710QE NAS AVX vs NAS SSE	1.45x	1.63x	1.37x	1.32x	1.29x	1.26x
Intel® Core™ i7-2715QE DSP280 4 cores vs 1 core	0.99x	3.08x	3.42x	3.63x	3.00x	2.63x

Make note of how well the performance scales from 1→4 cores on the GE-IP DSP280 blade

Complex to complex 1D in-place FFT; DATA: M rows of length N; FFT the rows

MFLOPS = M * (5N Log2(N)) / (Total time for multiple FFTs)

Multiple 1D, Complex to Complex, In-Place FFTs -- MFLOPS



- The top line shows the MFLOPS of the GE IP DSP280 when all four cores of one processor are utilized

MFLOPS = M * (5N Log2(N)) / (Total time for multiple FFTs)

Single thread performance except as noted. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on pp 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

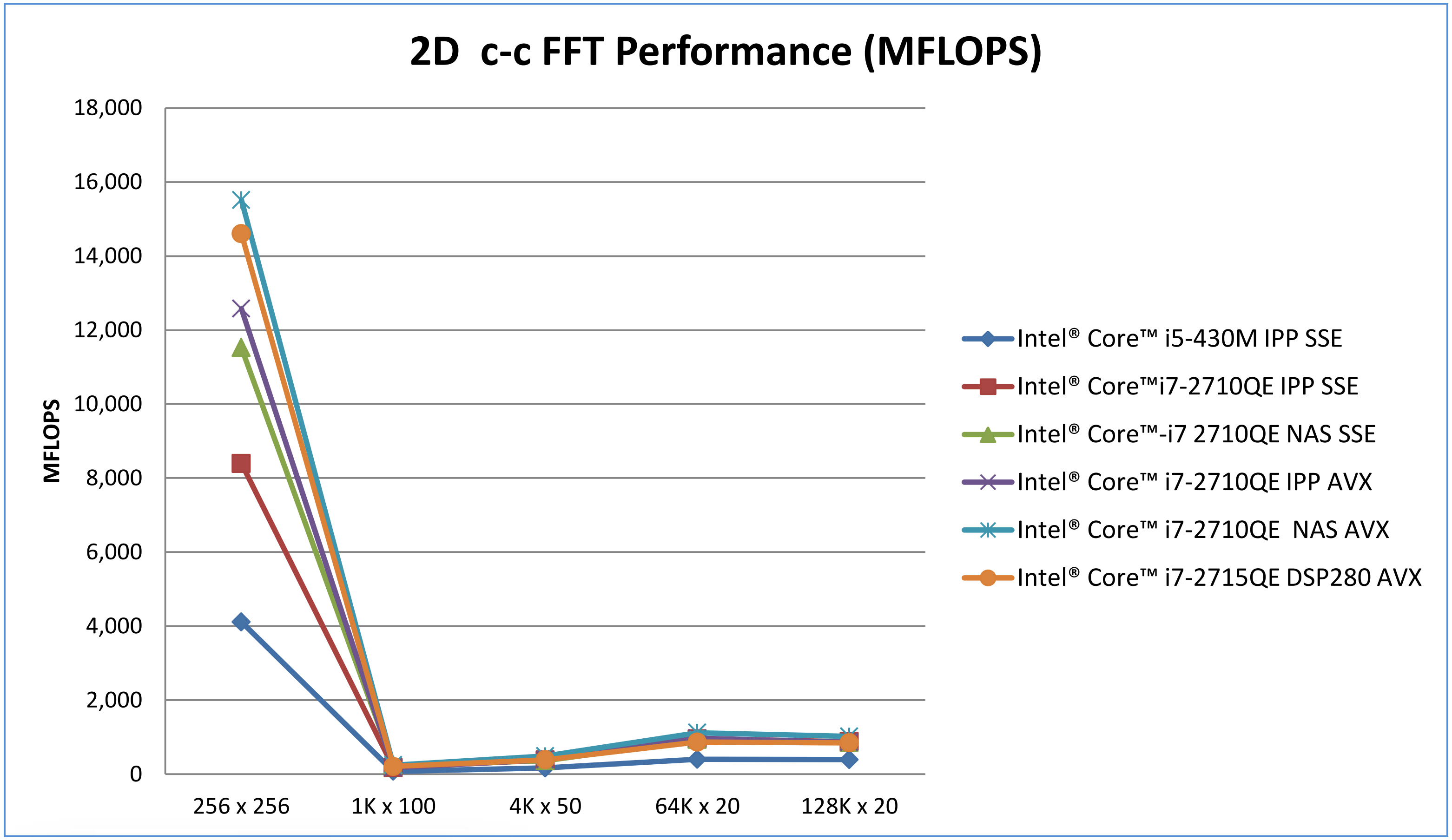
2D Complex-Complex, In-Place FFTs

	2D FFT Timings (µseconds) vsip_ccfft2dip_f (Lower is Better)					
N	***256***	***1024***	***4096***	***16384***	***65536***	***131072***
M	***256***	***100***	***50***	***20***	***20***	***20***
Intel® Core™ i5-430M IPP SSE	853	81891	84,964	63,805	292,110	586,851
Intel® Core™ i5-430M NAS SSE	956	83,331	85,307	64,404	303,901	614,801
Intel® Core™ i7-2710QE IPP SSE	418	35,534	37,284	26,721	131,128	267,319
Intel® Core™ i7-2710QE NAS SSE	455	25,578	39,748	27,143	133,968	280,492
Intel® Core™ i7-2710QE IPP AVX	279	35,956	36,928	26,323	133,607	269,949
Intel® Core™ i7-2710QE NAS AVX	338	34,655	37,018	26,824	130,293	267,780
Intel® Core™ i7-2715QE DSP280 (ECC)	359.1	40,666	46,211	34,568	157,063	308,624

Relative Performance ($Time_a/Time_b$)						
N x M	***256 x 256***	***1K x 100***	***4K x 50***	***16K x 20***	***64K x 20***	***128K x 20***
Intel® Core™ i7-2710QE IPP AVX vs Intel® Core i5-430M IPP SSE	2.04x	2.30x	2.28x	2.39x	2.23x	2.20x
Intel® Core™ i7-2710QE IPP SSE vs IPP AVX	1.5x	0.99x	1.01x	1.02x	0.98x	0.99x
Intel® Core™ i7-2710QE NAS SSE vs NAS AVX	1.35x	0.74x	1.07x	1.01x	1.03x	1.05x

- The 2nd Generation Intel® Core™ processor shows ~2X the performance of the previous generation processor
- Intel® Core™ i7 SSE vs Intel AVX™ performance improvement for 256*256 using the NAS code is about 35%. It's 50% for Intel IPP-based code. Other sizes do not benefit from Intel AVX, mostly because data is not aligned row to row – i.e. the data widths 100, 50 and 20 are not divisible by 8 and so do not fit well into the 256-bit vector registers. (All data is 32-bit single precision, so 8 operations can be performed per clock)

Complex-Complex 2D FFTs -- MFLOPS



MFLOPS = (5N Log2(N) • M + 5M Log2(M) •N) / (time for one FFT in microseconds)

- Large arrays do not fit into the processors' last level cache, so performance falls because of memory effects
- This graph also shows how performance falls when data lengths are not divisible by 8
  - Intel® AVX supports 8 single-precision floating point SIMD operations per cycle

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

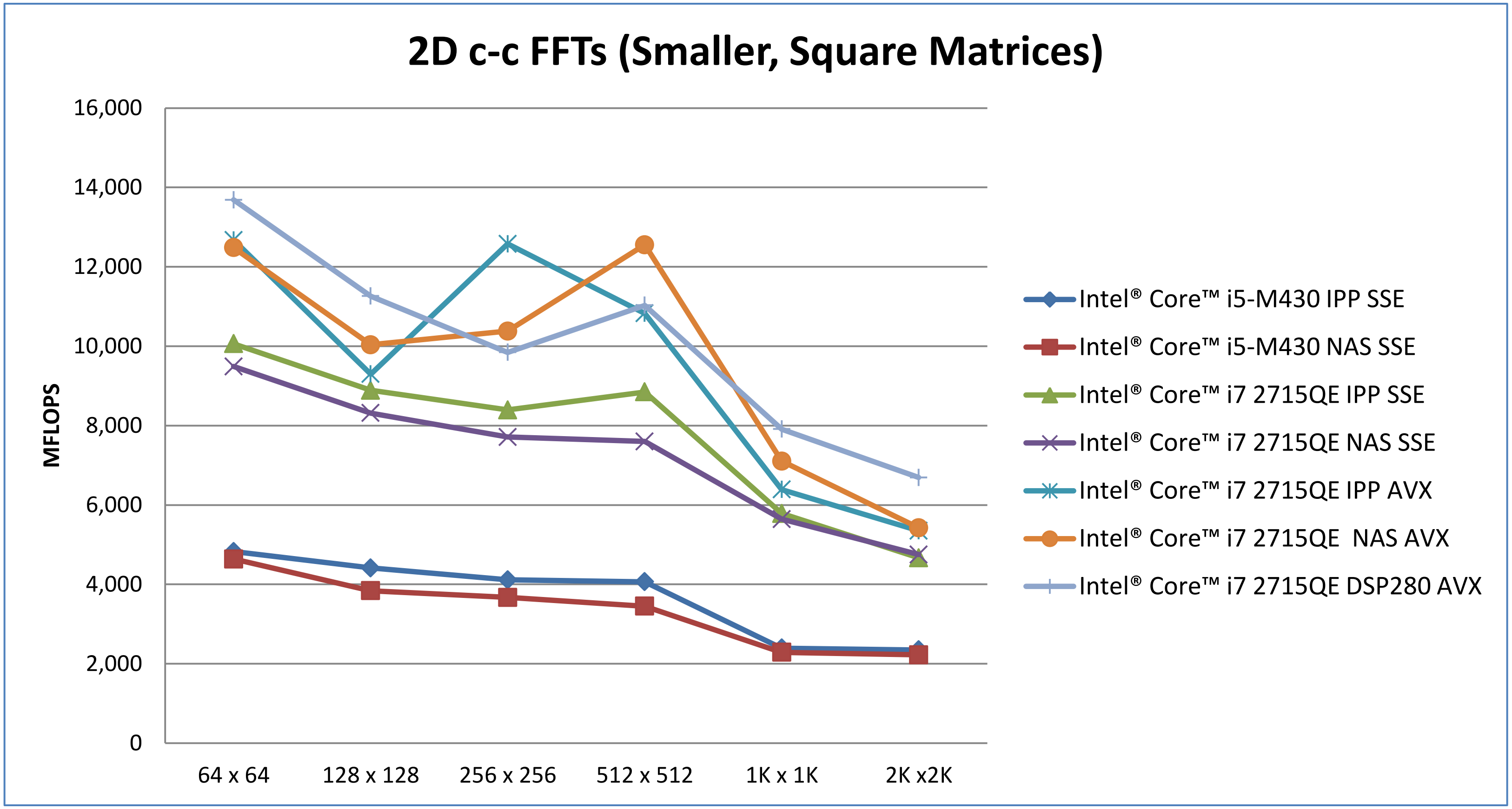
Complex-Complex 2D FFTs (Smaller, Square Matrices)

2D FFT Timings (µseconds) (Smaller, Square Matrices) vsip_ccfft2dip_f						
N	***64***	***128***	***256***	***512***	***1K***	***2K***
M	***64***	***128***	***256***	***512***	***1K***	***2K***
Intel® Core™ i5-M430 IPP SSE	34.4	174.6	853	3,872	29,183	130,519
Intel® Core™ i5-M430 NAS SSE	35.8	200.7	956	4,562	30,507	137,871
Intel® Core™ i7 2710QE IPP SSE	16.5	86.7	418.0	1,779.0	12,062.0	65,622.0
Intel® Core™ i7 2710QE NAS SSE	17.5	92.7	455.0	2,071.0	12,364.0	64,485.0
Intel® Core™ i7 2710QE IPP AVX	13.1	82.9	279.0	1,454.0	10,927.0	57,257.0
Intel® Core™ i7 2710QE NAS AVX	13.3	76.8	338.0	1,254.0	9,825.0	56,464.0
Intel® Core™ i7 2715QE DSP280 (ECC)	12.13	68.43	356.41	1,427.3	8,820.5	45,800.7

Relative Performance Intel® SSE vs Intel® AVX ($Time_a/Time_b$)						
N x M	***64x64***	***128 x 128***	***256 x 256***	***512 x 512***	***1K x 1K***	***2K x 2K***
Intel® Core™ i7 IPP AVX vs Intel® Core i5 IPP SSE	2.59x	2.27x	2.52x	3.09x	2.97x	2.31x
Intel® Core™ i7 IPP SSE vs AVX	1.26x	1.05x	1.50x	1.22x	1.10x	1.15x
Intel® Core™ i7 NAS SSE vs AVX	1.32x	1.21x	1.35x	1.65x	1.26x	1.14x

- Intel® AVX shows substantial improvement over Intel SSE for these smaller data sizes -- all divisible by 8
- The 2nd Generation Intel® Core™ processor shows ~2-3X the performance of the previous generation
- These results also suggest NA Software's 2D FFT beta algorithms can be improved for unaligned data and non-square matrices

Complex-Complex 2D FFTs – Smaller, Square Matrices



MFLOPS = (5N Log2(N) • M + 5M Log2(M) •N) / (time for one FFT in microseconds)

The performance improvement with Intel® AVX is much better for these data sizes

- All the data from row-to-row and column-to-column is aligned--the length and width are divisible by 8
- The algorithm is less memory dependent for smaller arrays so its throughput is better. As the data sizes increase they do not fit into cache and cache misses become a performance penalty.

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

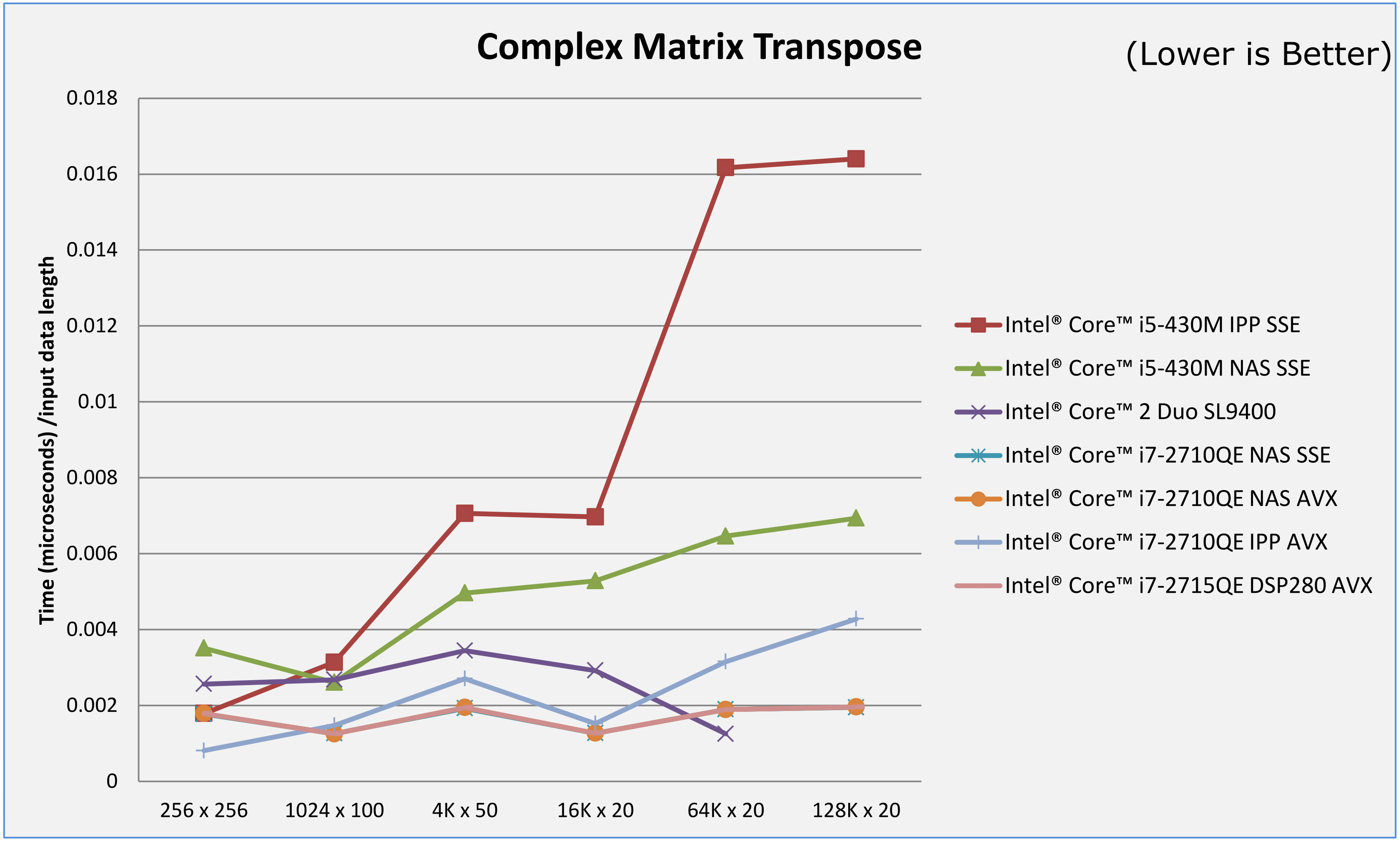
Complex Matrix Transpose Timings (µseconds)

Complex Matrix Transpose (µseconds) vsip_cmtrans_f (Lower is Better)						
N*M	***256 *256***	***1024 *100***	***4K *50***	***16K *20***	***64K *20***	***128K *20***
Freescale* MPC 8641D	877	902	6,744	11,859	65,511	*No Data*
Intel® Core™ 2 Duo SL9400	168	274	705	957	1,608	
Intel® Core™ i5-430M IPP SSE	117	321	1,446	2,283	20,837	42,994
Intel® Core™ i5-430M NAS SSE	230	267	1,016	1,731	8,325	18,178
Intel® Core™ i7-2710QE IPP AVX	53	151	554	498	4,063	11,217
Intel® Core™ i7-2710QE NAS SSE	116	129	394	415	2439	5,100
Intel® Core™ i7-2710QE NAS AVX	117	128	398	415	2,435	5,137
Intel® Core™ i7-2715QE DSP280 (ECC)	51.2	120.9	296.9	386	2,294.6	4,628.4

Relative Performance ($Time_a/Time_b$)						
N*M	***256 x256***	***1K x100***	***4K x50***	***16K x20***	***64K x20***	***128K x20***
Intel® Core™ i7-2710QE AVX vs Freescale*MPC8641D	7.5X	7.05x	16.94x	28.58x	26.89x	*No Data*
Intel® Core™ i7-2710QE NAS AVX vs Intel® Core™ 2 Duo SL9400	1.44x	2.14x	1.77x	2.31x	0.66x	
Intel® Core™ i7-2710QE NAS SSE vs Intel® Core™ i5-430M NAS SSE	1.97x	2.09x	2.55x	4.17x	3.38x	3.54x
Intel® Core™ i7-2710QE NAS AVX vs SSE	No improvement					

- Intel® AVX gives no performance improvement for non-square matrixes vs SSE -- the operation is mainly memory dependent and is not computationally expensive
- However, the 2nd Generation Intel® Core™ i7 processor shows ~2-4X the performance of the previous generation processor because of other microarchitecture enhancements and it's larger last level cache

Complex Matrix Transpose Performance



- Results for the Freescale* processor are not shown so the performance differences among the other processors are more apparent

Complex Split Vector Multiply Timings (µseconds)

v1(n) := v2(n)*v3(n)

Complex Vector Multiply (µseconds) vsip_cvmul_f (Lower is Better)							
N	***256***	***1K***	***4K***	***16K***	***32K***	***64K***	***128K***
Freescale* MPC 8641D	0.78	2.5	18.7	74	145	***3,391***	***9,384***
Intel® Core™ 2 Duo SL9400	0.44	2	8.8	35	75	151	300
Intel® Core™ i5-430M NAS SSE	0.3	1.09	5.4	31.52	75.55	135.7	383.3
Intel® Core™ i7-2710QE SSE	0.2	0.45	2.76	15.39	41.98	66.9	134.6
Intel® Core™ i7-2710QE AVX	0.07	0.24	2.34	13.82	31.69	63.2	130
Intel® Core™ i7-2715QE DSP280 (ECC)	0.1	0.25	2.9	16.0	35.8	71.4	143.4

Times in *italic bold* indicate the data requires a significant portion or is too large to fit into the processor's L2 cache

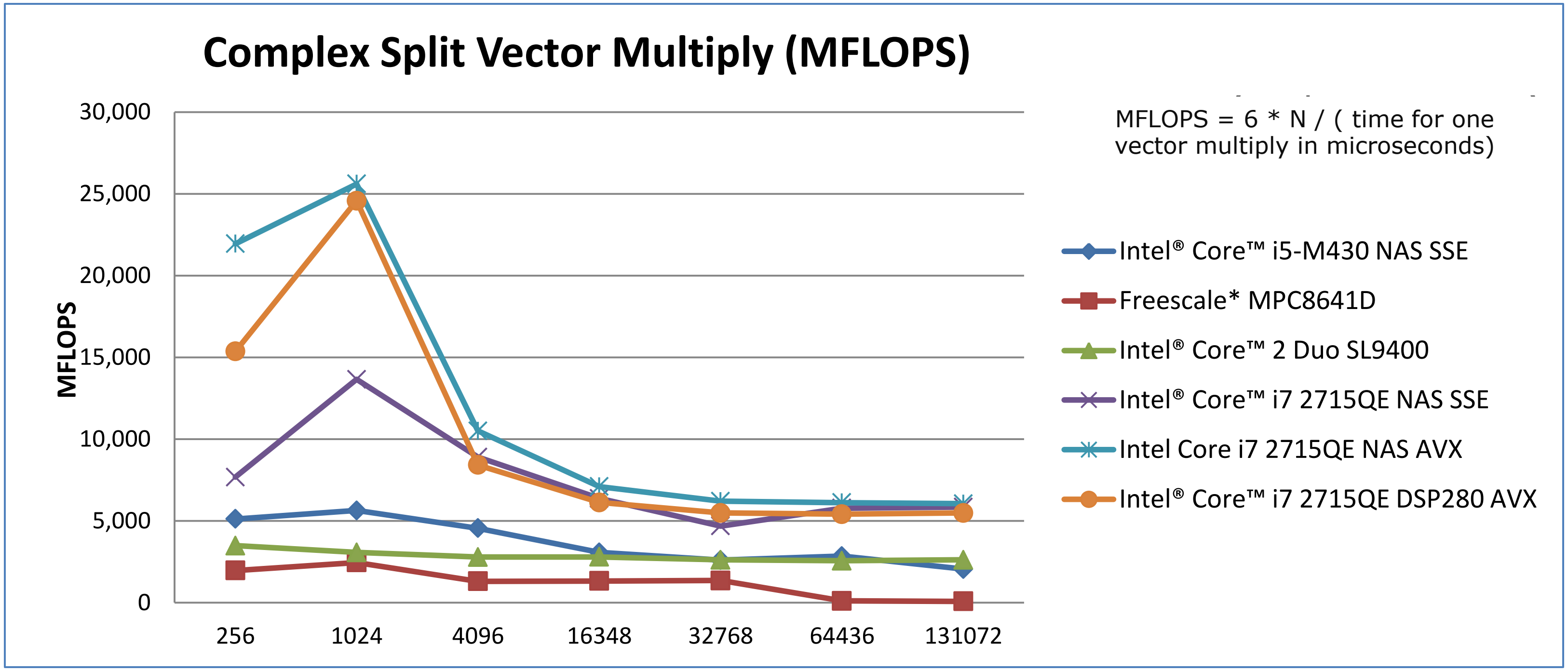
Freescale* MPC8641D: 1 MB L2 cache per core; Intel® processors in this study have 3 or 6 MB of shared last level cache--all of which is available when only one core is used (as here).

The complex vector multiply calculation repeatedly works on the same area of memory.

- 3MB of memory is required for N = 128K (128K × sizeof(complex) × 3 vectors)
- The algorithm requires only half of the Intel® Core™ 2 and i7 processors' last level cache – hence a very low % of cache misses
- The algorithm requires 3X the size of the MPC 8641D's L2 Cache -- very high % of cache misses requires much slower external memory accesses

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

Complex Vector Multiply Graphed



Relative Performance (Time$_a$/Time$_b$)							
N	***256***	***1024***	***4096***	***16K***	***32K***	***64K***	***128K***
Intel® Core™ i7 AVX vs Freescale*MPC8641D	11.14x	10.42x	7.99x	5.35x	4.58x	53.66x	72.18x
Intel® Core™ i7 AVX vs Intel® Core™ 2 Duo SL9400	6.29x	8.33x	3.76x	2.53x	2.37x	2.39x	2.31x
Intel® Core™ i7 AVX vs Intel® Core™ i5-430M NAS SSE	4.29x	4.54x	2.31x	2.31x	2.38x	2.15x	2.95x
Intel® Core™ i7-2710QE AVX vs SSE	2.86x	1.88x	1.18x	1.11x	1.32x	1.06x	1.04x

Vector Sine Timings (µseconds)

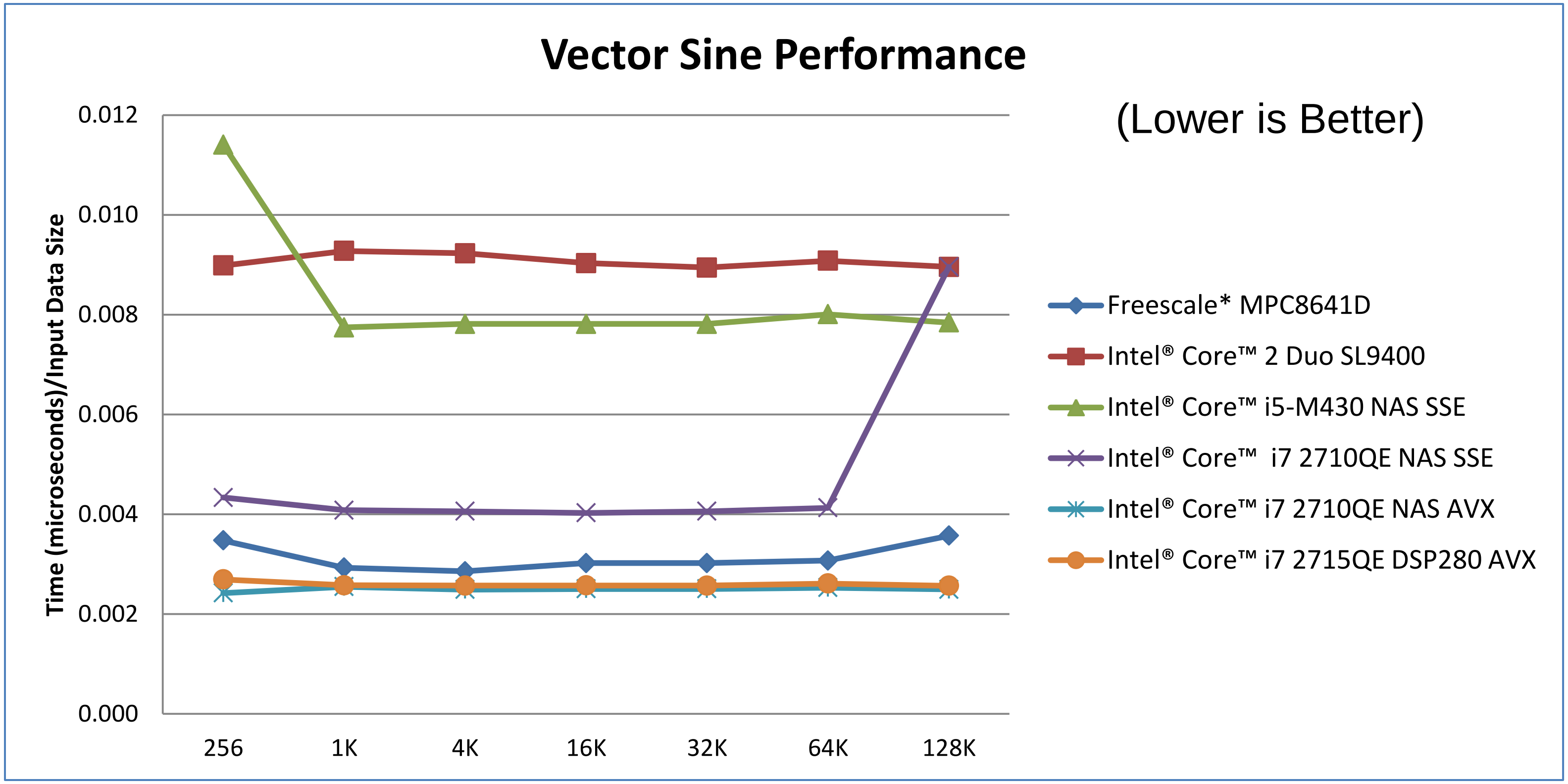
v1(i):= sin(v2(i))

Vector Sine (µseconds) vsip_vsin_f (Lower is Better)							
N	***256***	***1K***	***4K***	***16K***	***32K***	***64K***	***128K***
Freescale* MPC 8641D	0.89	3	11.7	49.5	99	198	468
Intel® Core™ 2 Duo SL9400	2.3	9.5	37.8	148	293	585	1,174
Intel® Core™ i5-M430 NAS SSE	2.92	7.93	32	128	256	516	1,028
Intel® Core™ i7 2710QE SSE NAS	1.11	4.18	16.63	66	133	266	531
Intel® Core™ i7 2710QE AVX NAS	0.62	2.61	10.2	41	82	163	327
Intel® Core™ i7 2715QE DSP280 (ECC)	0.69	2.64	10.53	42.16	84.2	168.3	336.7

Relative Performance ($Time_a/Time_b$)							
N	***256***	***1K***	***4K***	***16K***	***32K***	***64K***	***128K***
Intel® Core™ i7 NAS AVX vs Freescale* MPC8641D	1.44x	1.15x	1.15x	1.21x	1.21x	1.21x	1.43x
Intel® Core™ i7 NAS AVX vs Intel® Core™ 2 Duo SL9400	3.71x	3.64x	3.71x	3.61x	3.57x	3.59x	3.59x
Intel® Core™ i7 NAS AVX vs Intel® Core™ i5-M430 NAS SSE	4.71x	3.04x	3.14x	3.12x	3.12x	3.17x	3.14x
Intel® Core™ i7 NAS AVX vs SSE	1.79x	1.60x	1.63x	1.61x	1.62x	1.63x	1.62x

The sine is taken of each element within a floating point input vector and the result placed into an output vector. NA Software*'s routine utilizes 24-bit accuracy.

Vector Sine Performance Graphed



- Anomalous behavior at 256 and 128K points is under investigation
- The sine is taken of each element within a floating point input vector and the result placed into an output vector. 24-bit accuracy is maintained
- The vector sine algorithms carry out full range reduction on input values to ensure they are in the correct quadrant, so the routine is more computationally expensive than, for example, the vector multiply operation
  - Most of the range reduction operations use 4-way SIMD integer operations since Intel processors do not yet support 8-way SIMD for integer operations

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

Vector Cosine Timings (µseconds)

v1(i):=cos(v2(i))

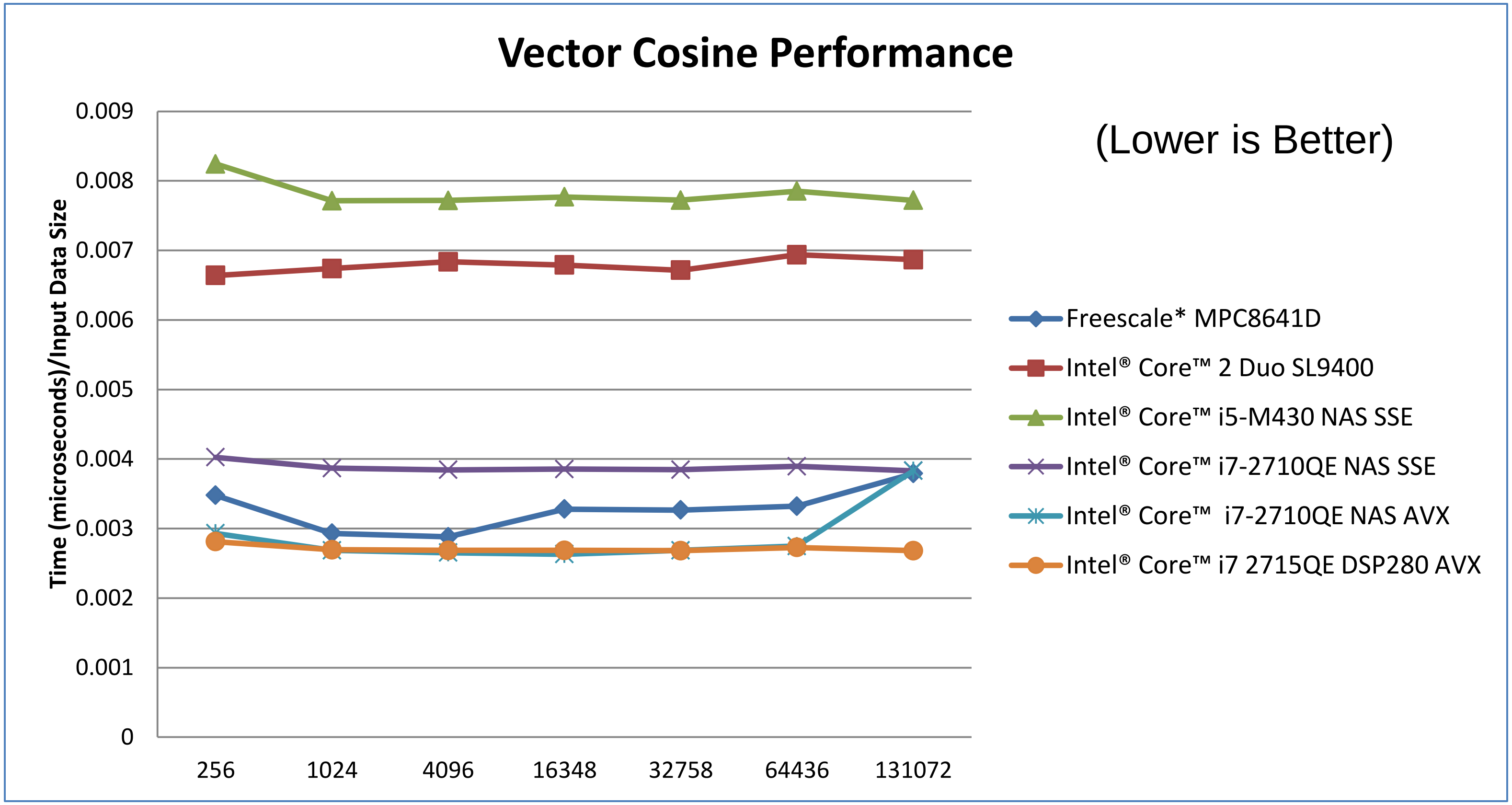
Vector Cosine (µseconds) vsip_vcos_f (Lower is Better)							
N	***256***	***1K***	***4K***	***16K***	***32K***	***64K***	***128K***
Freescale* MPC 8641D	0.89	3	11.8	53.6	107	214	497
Intel® Core™ 2 Duo SL9400	1.7	6.9	28	111	220	447	900
Intel® Core™ i5-430M NAS SSE	2.11	7.9	31.61	127	253	506	1,012
Intel® Core™ i7-2710QE NAS SSE	1.03	3.96	15.74	63	126	251	502
Intel® Core™ i7-2710QE NAS AVX	0.75	2.75	10.87	43	88	177	355
Intel® Core™ i7-2715QE DSP280 (ECC)	0.72	2.76	11	43.91	87.86	175.75	351.5

Relative Performance ($Time_a/Time_b$)							
N	***256***	***1024***	***4048***	***16348***	***32758***	***64436***	***131072***
Intel® Core™ i7-2710QE AVX vs Freescale*MPC8641D	1.19x	1.09x	1.09x	1.25x	1.22x	1.21x	1.40x
Intel® Core™ i7-2710QE AVX vs Intel® Core™ 2 Duo SL9400	2.27x	2.51x	2.58x	2.58x	2.50x	2.53x	2.54x
Intel® Core™ i7-2710QE NAS AVX vs Intel® Core™ i5-430M NAS SSE	2.81x	2.87x	2.91x	2.95x	2.88x	2.86x	2.85x
Intel® Core™ i7-2710QE AVX vs SSE	1.37x	1.44x	1.45x	1.47x	1.43x	1.42x	1.41x

The cosine is taken of each element within a floating point input vector and the result placed into an output vector.   24-bit accuracy

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

Vector Cosine Performance Graphed



- As with the Vector Cosine performance graph, the performance differences among the platforms has been highlighted by dividing the time to complete the operation on the entire input data set (in microseconds) by the size of the input data

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

Vector Square Root Timings: (µseconds)

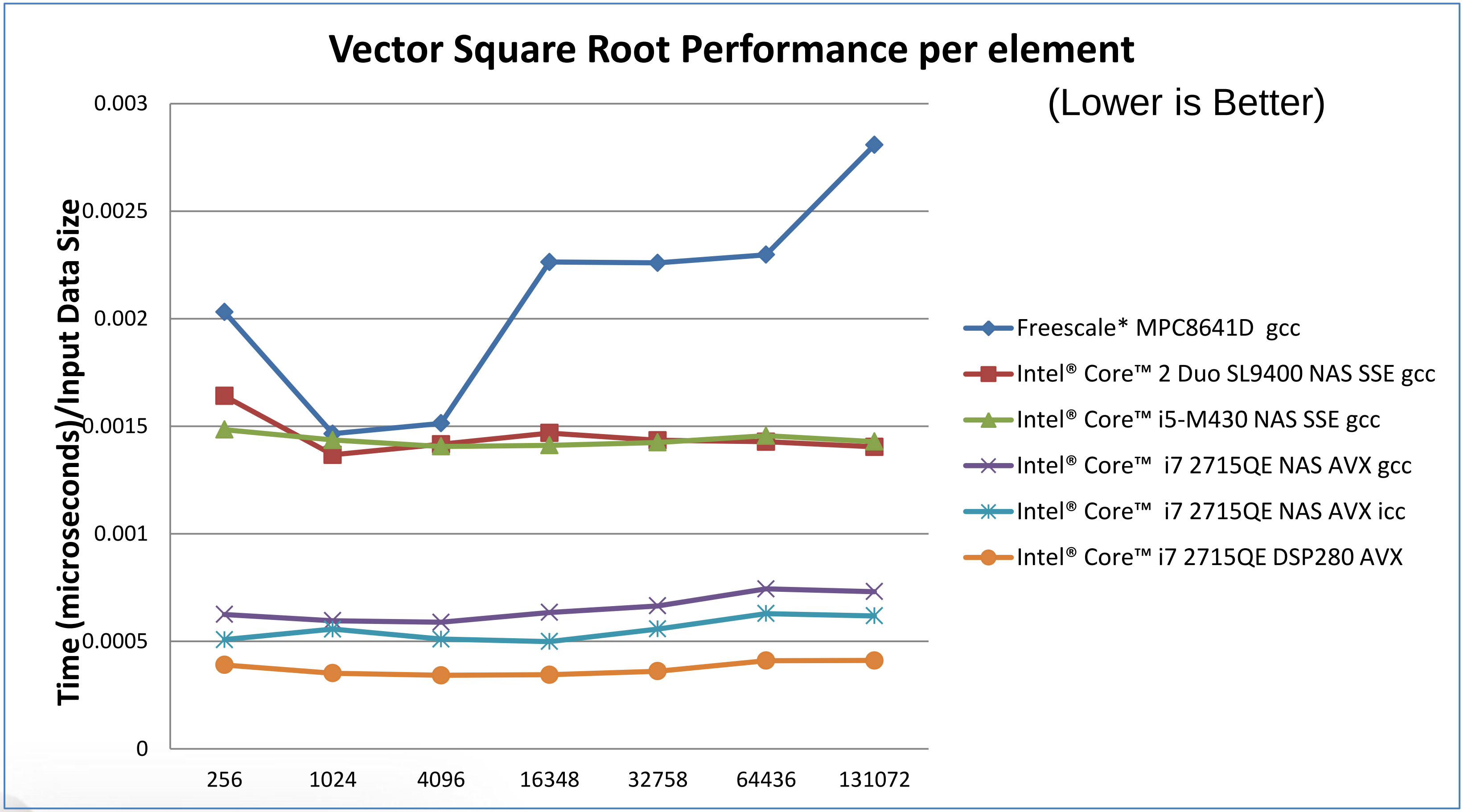
v1(i):= sqrt(v2(i))

Vector Square Root (µseconds) vsip_vsqrt_f (Lower is Better)							
N	***256***	***1K***	***4K***	***16K***	***32K***	***64K***	***128K***
Freescale* MPC 8641D	0.52	1.5	6.2	37	74	148	368
Intel® Core™ 2 Duo SL9400	0.42	1.4	5.8	24	47	92	184
Intel® Core™ i5-430M NAS SSE	0.38	1.47	5.76	23.07	46.67	93.80	187.25
Intel® Core™ i7-2710QE NAS gcc	0.16	0.61	2.41	10.37	21.78	47.91	95.84
Intel® Core™ i7-2710QE NAS icc	0.13	0.57	2.09	8.16	18.25	40.51	81.07
Intel® Core™ i7-2715QE DSP280 (ECC)	0.1	0.36	1.4	5.63	11.82	26.45	53.89

Relative Performance (Time$_a$/Time$_b$)							
N	***256***	***1K***	***4K***	***16K***	***32K***	***64K***	***128K***
Intel® Core™ i7-2710QE AVX icc vs Freescale*MPC8641D	4x	2.63x	2.97x	4.53x	4.05x	3.65x	4.54x
Intel® Core™ i7-2710QE AVX icc vs Intel® Core™ 2 Duo SL9400	3.23x	2.46x	2.78x	2.94x	2.58	2.27x	2.27x
Intel® Core™ i7-2710QE NAS AVX vs Intel® Core™ i5-430M NAS SSE	2.92x	2.58x	2.76x	2.83x	2.56x	2.32x	2.31x
Intel® Core™ i7-2715QE DSP280 (ECC) vs Intel® Core™ i5-430M NAS SSE	3.8x	4.08x	4.11x	4.1x	3.95x	3.55x	3.47x

- GE-IP's AXISLib-AVX running on their Intel® Core™ i7-2715QE processor showed ~4x the performance compared the previous generation Intel® Core™ i5 processor.
- The square root is taken of each element within a floating point input vector and the result placed into an output vector. 24-bit accuracy

Vector Square Root Performance



The best results were obtained with the GE-IP AXISLib-AVX beta compiled with gcc

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 11-12. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

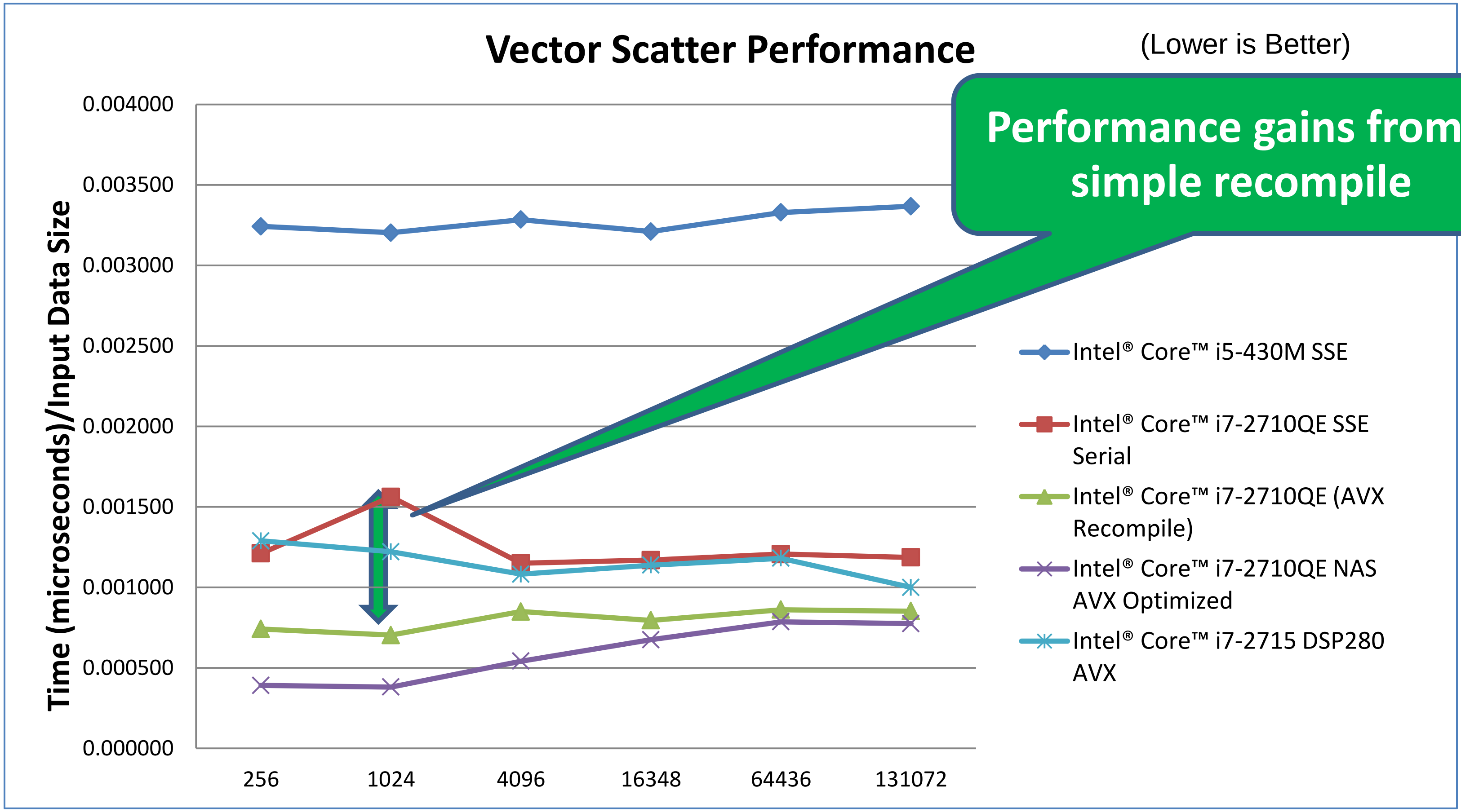
Vector Scatter Timings (µseconds)

Vector Scatter (µseconds) vsip_vscatter_f (Lower is Better)						
N (Input Vector)	*256*	*1K*	*4K*	*16K*	*64K*	*128K*
Intel® Core™ i5-M430 SSE Serial	0.83	3.28	13.45	52.47	214.47	441.32
Intel® Core™ i7-2710QE SSE Serial	0.31	1.60	4.71	19.11	77.79	155.51
Intel® Core™ i7-2710QE SSE Serial (Recompiled with -xAVX)	0.19	0.72	3.48	13.00	55.50	111.75
Intel® Core™ i7-2710QE NAS AVX Optimized	0.16	0.61	2.41	10.37	47.91	95.84
Intel® Core™ i7-2715QE DSP280 (ECC)	0.330	1.25	4.43	18.6	76.1	152.53

Relative Performance Vector Scatter ($Time_a/Time_b$)						
N (Input Vector)	*256*	*1K*	*4K*	*16K*	*64K*	*128K*
Intel® Core™ i7 2710QE SSE Serial vs Intel® Core™ i5-M430 SSE Serial	2.68x	2.05x	2.86x	2.75x	2.76x	2.84x
Intel® Core™ i7 2710QE AVX optimized vs Intel® Core™ i5-430M SSE Serial	8.3x	8.41x	6.06x	4.76x	4.23x	4.35x
Intel® Core™ i7 2710QE AVX Optimized vs Intel® Core™ i7 SSE Serial	3.1x	4.1x	2.12x	1.73x	1.53x	1.53x
Intel® Core™ i7 2710QE AVX recompile vs Intel® Core™ i7 SSE	1.63x	2.22x	1.35x	1.47x	1.4x	1.39x
Intel® Core™ i7 2710QE AVX optimized vs Intel® Core™ i7 recompile	1.90x	1.85x	1.57x	1.18x	1.09x	1.1x

Input vector of size N. Elements in N are scattered into every other element of a larger output vector (N*2). "AVX recompile" is the SSE code recompiled with the -xAVX option. "AVX Optimized" is hand optimized code to take advantage of Intel® AVX 8-way FP SIMD

Vector Scatter Performance



- The red line shows the performance of the Intel® Core™ i7-2710QE running 128-bit SIMD code (SSE 4.2)
- The green line shows the performance gains achieved simply by recompiling the same SSE code with the -xAVX compile flag. The compiler itself has autovectorized the code to take advantage of the new 256-bit Intel® AVX floating point vector registers
- Hand optimizing the NAS routine for Intel® AVX produces significant additional gains <16K elements
- No data available for processors <2010

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 9-10. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

Vector Gather Timings (μseconds)

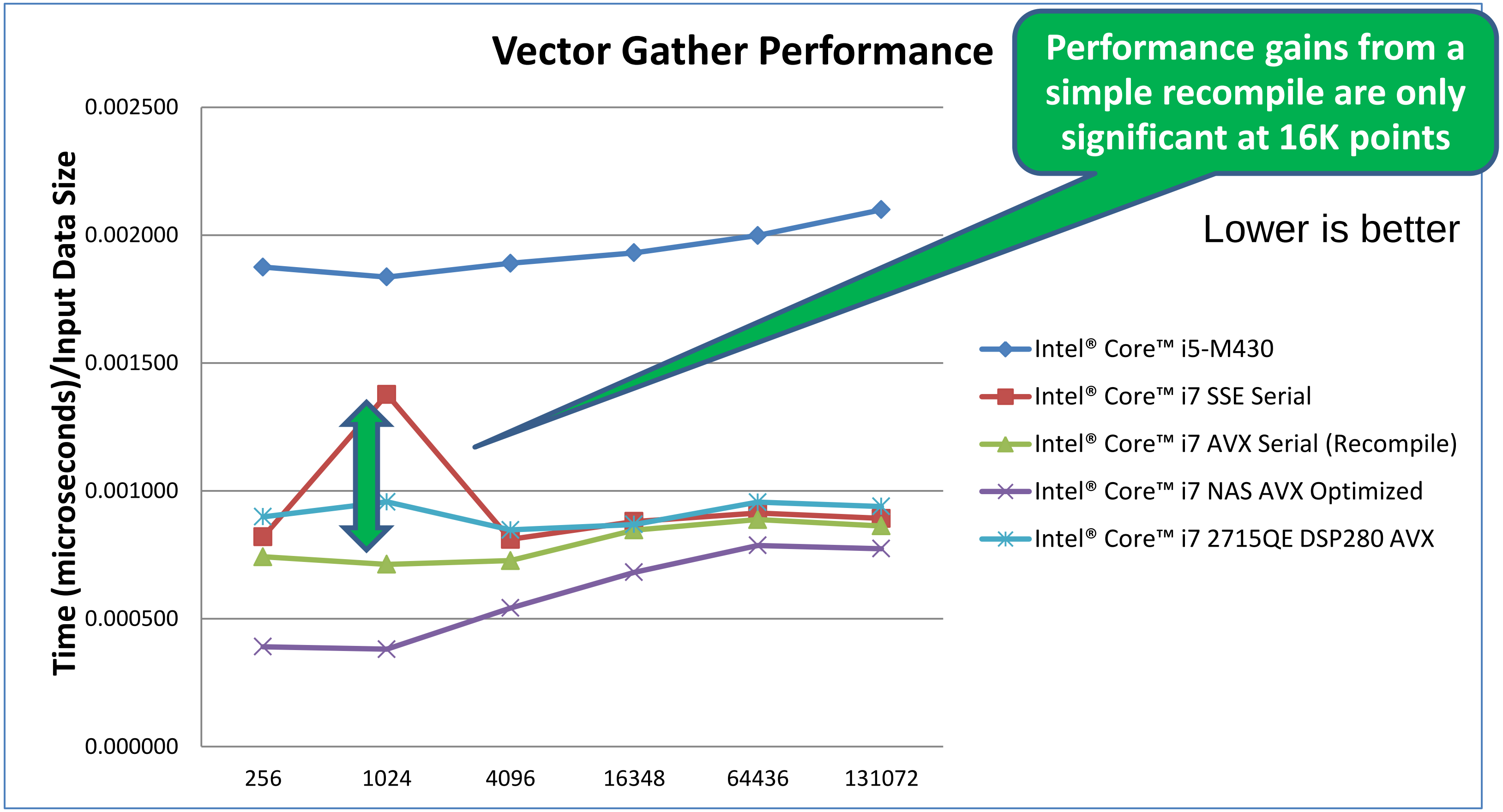
Vector Gather (μseconds) vsip_vgather_f (Lower is Better)						
N (Output Vector)	***256***	***1K***	***4K***	***16K***	***64K***	***128K***
Intel® Core™ i5-M430 SSE Serial	0.48	1.88	7.74	31.56	128.77	275.15
Intel® Core™ i7 SSE Serial	0.21	1.41	3.32	14.39	58.88	116.96
Intel® Core™ i7 AVX Serial (Recompile)	0.19	0.73	2.98	13.84	57.21	113.13
Intel® Core™ i7 NAS AVX Optimized	0.1	0.39	2.22	11.14	50.7	101.49
Intel® Core™ i7 2715QE DSP280 (ECC)	0.23	0.98	3.47	14.2	61.6	123.1

Relative Performance Vector Gather ($Time_a/Time_b$)						
N (Output Vector)	***256***	***1K***	***4K***	***16K***	***64K***	***128K***
Intel® Core™ i7 2710QE SSE Serial vs Intel® Core™ i5-M430 SSE Serial	2.29	1.33	2.33	2.19	2.19	2.35
Intel® Core™ i7 NAS AVX Optimized vs Intel® Core™ i5-M430 SSE Serial	4.80	4.82	3.49	2.83	2.54	2.71
Intel® Core™ I7 Optimized AVX vs Intel® Core™ i7 SSE Serial	2.10	3.62	1.50	1.29	1.16	1.15
Intel® Core™ i7 SSE Serial (Recompile with -xAVX) vs Intel® Core i7 SSE Serial	1.11	1.93	1.11	1.04	1.03	1.03
Intel® Core™ i7 NAS AVX Optimized vs Intel® Core™ i7 AVX Recompile	1.90	1.87	1.34	1.24	1.13	1.11

Output vector of size N. Elements from a larger input vector are gathered into a smaller output vector according to a vector of indexes stating the position of the elements in the larger vector. "AVX Serial" is the SSE code recompiled with the AVX option flag. "AVX Optimized" is hand optimized code to take advantage of AVX 8-way FP SIMD.

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 9-10. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

Vector Gather Performance Graphed



- The blue line shows the performance of the Intel® Core™ i5-M430 running 128-bit SSE4.2 SIMD code
- The red line shows the performance of the Intel® Core™ i7 2710QE running 128-bit SIMD code without Intel® AVX
- The red line shows the performance gains achieved simply by recompiling the SSE code with the 'AVX' compile flag. The compiler itself has autovectorized the code to take advantage of the new 256-bit AVX FP vector registers. The improvement is significant for lengths under 16K but not for longer vectors
- Hand optimizing the routine for AVX produced additional gains of 10-90% , as shown by the purple line
- No data available for processors <2010

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 9-10. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

VSIPL Benchmark Summary Performance Gains

VSIPL* Function	Intel® Core™ i7-2710QE AVX vs Freescale* MPC-8641D	Intel® Core™ i7-2710QE AVX vs Intel® Core™ 2 Duo SL9400 (2008)	Intel® Core™ i5-430M vs Intel® Core™ 2 Duo SL9400	Intel® Core™ i7-2710QE AVX vs Intel® Core™ i5-M430 SSE (2010)	Intel® Core™ i7- 2710QE AVX vs SSE (2011)
1D FFT	5 – 14 X	2.4 - 3.5 X	< 1.1x	2.3 – 3.5 X	1.2 - 1.8 X
Multiple 1D FFT	5.4 – 10.4 X	2.5 – 3.3 X		2.6 – 3.7 X	1.3 – 1.6X
2D FFT, non-square matrices	No Data			2 – 2.3 X	0.7 – 1.3X
2D FFT, smaller square matrices				2.3 – 3.1 X	1.1 – 1.6 X
Complex Matrix Transpose	7 – 26 X	0.6 – 2.14 X	< 1.1x	2 – 4.1 X	None
Vector Multiply	4.6 – 72 X	2.3 – 8.3 X		2.1 – 4.5 X	1 – 2.9 X
Vector Sine	1.1 – 1.4 X	3.6 – 3.7 X		3.1 – 4.7 X	0.4 – 1.8 X
Vector Cosine	1.1 – 1.4 X	2.2 – 2.6 X		2.8 – 2.9 X	1.4 X
Vector Square Root	2.6 – 4.5 X	2.3 – 3.2 X		2.3 – 2.9 X	1.2 -2.1 X
Vector Scatter	No Data			4.2 – 8.2x	1.5 – 4.1 X
Vector Gather				2.5 – 4.8x	1.5 – 4.1 X

Single thread performance. Tests conducted by GE Fanuc* /GE Intelligent Platforms*, and N.A. Software*, Ltd. See test configuration information on slides 9-10. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more information go to http://www.intel.com/performance

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VSIPL* Performance Summary

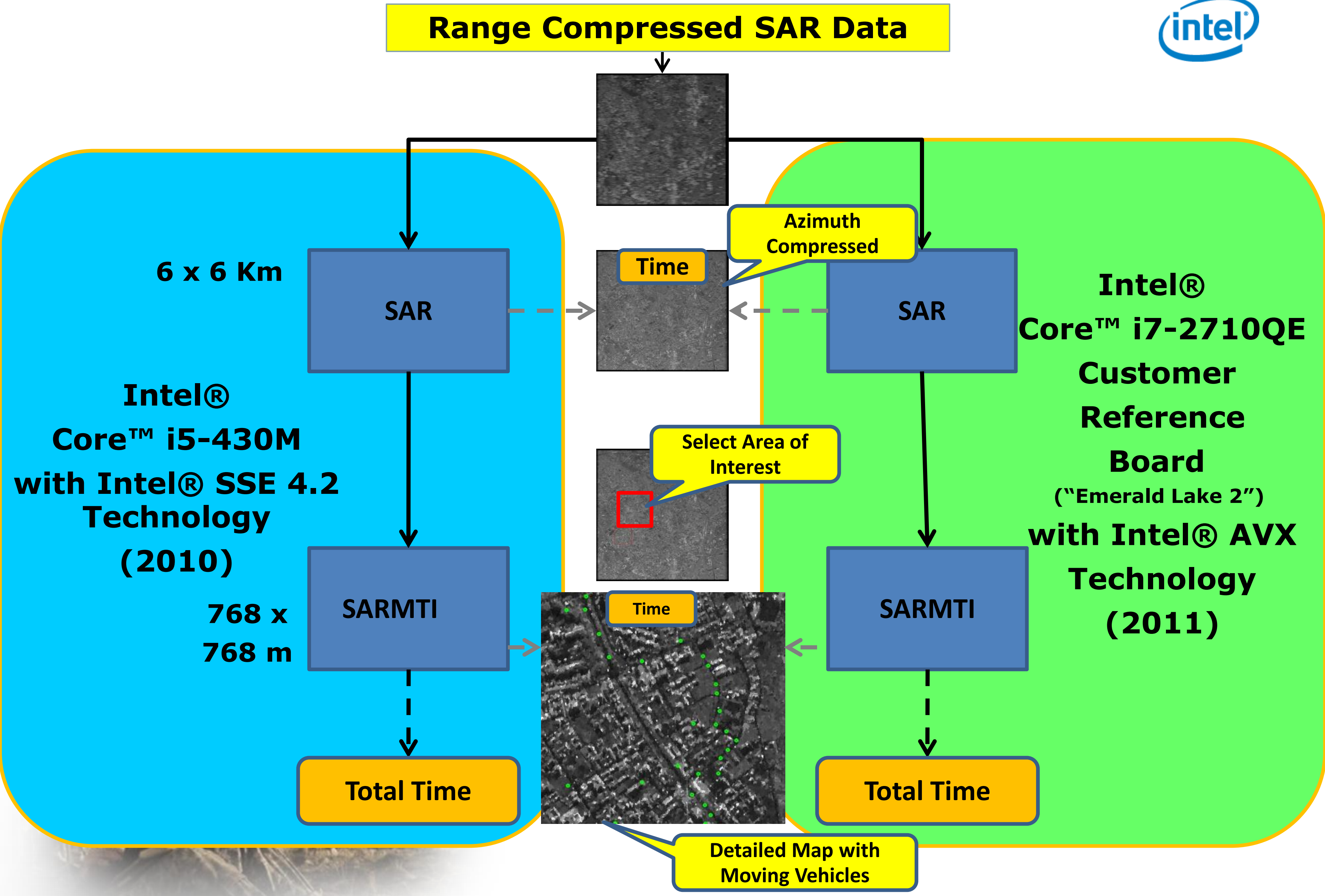
- Intel® processors' improvement from 2008-2011 primarily reflect the effects of the 2nd Generation Intel® Core™ microarchitecture, formerly codenamed 'Sandy Bridge'
- The highest percentage increases are generally seen with short vector lengths.
  - As the length of the vector(s) increases the complete data set can no longer fit within the last level cache. The data must therefore be fetched from (slower) main memory, and the algorithm thus becomes more memory-dependent than processor-dependent.
  - This factor is especially noticeable with the Freescale* MPC8641D since it has a fixed 1MB last level cache per core. The Intel® Core™ 2 Duo and Core™ i7 processors all have 6 MB of shared LLC (which is all available to a single core) so their performance does not fall off as rapidly with larger vector lengths.

Image Signal Processing Performance on Synthetic Aperture Radar Applications

Performance on Synthetic Aperture Radar (SAR) Algorithms

- Synthetic Aperture Radar (SAR) and SARMTI (Moving Target Indication) algorithms from NA Software*, Ltd.
  - Multi-threaded and optimized separately for Intel® SSE4.2 and Intel® AVX
  - SAR : Azimuth processing clarifies ground features
    - Range compressed data used as input to shorten processing time of live demos
  - SARMTI: Extracts high resolution data with positions of slow and fast moving vehicles directly from SAR data
    - New algorithm from NA Software—no need for two separate types of radar (SAR and MTI)
    - Resolution to the size of 1 pixel (1.5 meters with this input data)
- Performance comparisons between 2010 and 2011 Intel 2/4C processors
  - 2011 2nd Generation Intel® Core™ processor: ~2X faster (core/core) than 2010 Intel processor

Test Scenario



Results

N.A. Software*, Ltd. Algorithm	System	2 Threads (cores)	4 Threads (cores)
		Seconds	
SAR	Intel® Core™ i7-2710QE with Intel® AVX 1.0	0.059	0.027
	Intel® Core™ i5-430M with Intel SSE 4.2	0.135	0.121*
	Intel® Core™ i7-2710QE Speed Up	2.3X	4.4X*
SARMTI	Intel® Core™ i7-2710QE with Intel® AVX 1.0	6.03	3.841
	Intel® Core™ i5-430M with Intel SSE 4.2	15.197	13.667*
	Intel® Core™ i7-2710QE Speed Up	2.5X	3.5X*

The Intel® Core™ i5-430M processor (formerly code named "Arrandale") was released in Q1 2010; the Intel Core i7-2710QE (formerly code named "Sandy Bridge") was released in Q1, 2011. Sandy Bridge utilizes Intel's 2nd Generation "Core™" Microarchitecture, including Intel AVX.

Timings with graphics rendering turned off; Relative speedup with graphics on is equivalent.

* Note: Arrandale 4 thread timings utilize hyperthreading since only a 2-core version is available. SNB 4-thread timings use all 4 cores. 4C Sandy Bridge's maximum Thermal Design Power is roughly 12W more than a 2-core Arrandale processor. Please see next slide for system configuration information.

SAR/SARMTI Test Configurations

- System1: Gateway* NV59 laptop with Intel® Core™ i5-430M processor, formerly codenamed "Arrandale" (Nehalem uA, SSE 4.2); 2 Cores @ 2.26 GHz + Hyper Threading. 3 GB DDR3-1066
- System 2: Intel® "Emerald Lake FAB B" Customer Reference Board with Low Voltage Intel® Core™ i7-2710QE processor, 'D0' Stepping; 4 Cores @ 2.16 GHz. Intel Hyper Threading and TurboBoost™ technology OFF. 2 GB DDR3-1066; Intel® Mobile AM67 chipset, B0 stepping
- Both systems: Processor frequency set @ 2.0 GHz; Fedora* 13 Linux*; Intel Integrated Performance Primitives 7.0.3 Beta; Intel C++ compiler version 11.1.073; Frequency Scaling (Intel® Turbo Boost technology) stopped.
- Source (raw) SAR image data: Japanese airborne PiSAR X-Band image of Tsukuba, Japan. Moving objects inserted manually. Test input has previously been range compressed to shorten the time of the live demo.
  - Image size: 6 km x 6 km (4096 x 4096 pixels) – 1 pixel = 1.5m
  - Blocked road detail area: 768m x768m (512 x 512 pixels)

Data is at fixed CPU clock frequency and may change with Intel® Turbo Boost Technology enabled.

Tools for Converting AltiVec* SIMD Applications to Intel® SSE/AVX SIMD Instruction Set Architecture

Tools for Converting AltiVec* DSP Code to Intel® SSE/AVX

Intel® has worked with NA Software, Ltd* to develop tools that automatically convert PPC AltiVec* DSP code to Intel® SSE/AVX Instructions

- **Tool 1:** VSIPL* performance library optimized for Intel Architecture

AVX Beta Available Now For Evaluation From NASoftware

AVX versions are also be available from RunTime Computing and others

- **Tool 2:** AltiVec.h header file for Intel Architecture

Gold Available Now from edc.intel.com **Free**

- **Tool 3:** PPC AltiVec* to Intel SSE assembly source converter

Alpha , August 2011

All dates, product descriptions, availability and plans are forecasts and subject to change without notice.

Converting AltiVec* DSP Code to Intel® SSE/AVX