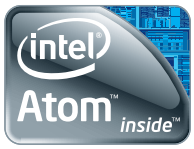
White Paper

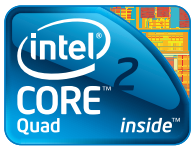
Intel® Atom™ Processor

Intel® Core™2 Processor

Intel® Digital Security Surveillance Applications

Optimizing H.264 Software Codec on Intel® Atom™ and Intel® Core™2 Processors Targeting Intel® Digital Security Surveillance (Intel® DSS) Applications





Abstract

H.264/AVC is the latest video coding standard from ISO/IEC Moving Picture Experts Group (MPEG). Due to its high compression efficiency and superior video quality, H.264/AVC is becoming the most preferred and common video codec in DSS applications despite increasing encoding complexity.

Intel® Atom™ processors are low-power CPUs with Intel® SSSE3 instruction sets and Intel® Hyper-Threading Technology,† making the product line ideal for cost-effective, embedded DSS applications.

Intel® Core™2 Quad processors feature four complete execution cores with the latest Intel® SSE4 instruction support, delivering exceptional performance in multi-threaded, multi-channel DSS applications.

This paper proves H.264 encoding performance boost when utilizing processor-specific Intel® SSSE3 and SSSE4 instructions.

Introduction

ITU-T Video Coding Experts Group's (VCEG) and ISO/IEC Moving Picture Experts Group's (MPEG) latest video encoding standard, H.264/AVC is becoming the most preferred and common video codec in DSS applications today. For the same video quality, H.264/AVC achieves more than a 50 percent bit-rate saving over MPEG-2, delivering high compression efficiency and superior video quality. However, its encoding complexity is significantly higher compared to previous video coding standards, such as MPEG-2 and MPEG-4.

Figure 1 and Table 1 show the CPU usage profile of a software-based H.264 encoder running on a PC based on Intel® Architecture.

In order to achieve maximum performance, instruction-level optimization using single-instruction-multiple-data (SIMD) is a must for an H.264 encoder in DSS applications. Intel introduced MMX, SSE, SSE2 and SSE3 instructions in 1997 for multimedia application. More recent SIMD instruction sets from Intel include SSSE3 and SSE4. We will show the performance gain with these more recent SIMD instructions.

Since most DSS units have multiple video inputs, it is highly desirable to make DSS applications multi-threaded to fully utilize the logical and physical CPUs of Intel Hyper-Threading Technology and multi-core technology. We will also show the performance boot by running a multi-threaded encoder to fully utilize the available CPUs.

Test Methodology

Most video coding research literature uses well-known benchmark video sequences in their experiments available on public domain. Table 2 shows the test sequences used in this study. Sequence "Hall," "News," "Akiyo" and "Foreman" are public-domain benchmark sequences (Source: http://trace.eas.asu.edu/yuv/); the last sequence, "car," is captured by generic CCTV camera by Huperlab.

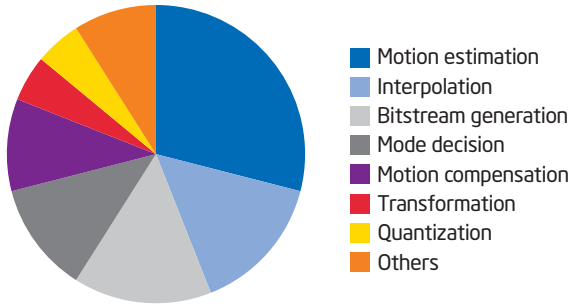


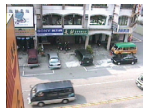
Figure 1. H.264 CPU usage distribution

Table 1. H.264 CPU usage profile. Encoder options: QP=26, search range=16, CAVLC (Context-adaptive variable-length coding).

H.264 modules	CPU clock ticks %
Motion estimation	29
Interpolation	15
Bitstream generation	15
Mode decision	12
Motion compensation	10
Transformation	5
Quantization	5
Others	9

(Source: Huper Laboratories Co., Ltd.)

Table 2. H.264 test sequences

Sequence Name	Resolution	Sample image
Hall	352x288	
News	352x288	
Akiyo	352x288	
Foreman	352x288	
Car	320x240	

H.264 encoding based on Intel® Atom™ processor 330Δ

Intel Atom processors 330 support Intel SSSE3 instructions. This dual-core processor also has Intel® Hyper-Threading Technology translating up to 4 logical CPUs.

Table 3 shows the encoding fps (frame per second) of a single-thread H.264 encoder with and without using Intel SSSE3 instructions. Performance gain with Intel SSSE3 optimization is 3-5 percent.

Table 3. Single-threaded H.264 encoder based on Intel® Atom™ processor 330 with and without Intel® SSSE3 instructions.

Single-threaded H.264 encoder based on Intel® Atom™ processor 330	Video frame rate without Intel® SSSE3 (fps)	Video frame rate with Intel® SSSE3 (fps)	Performance gain with Intel® SSSE3 (%)
Hall	108.0	110.6	2.4%
News	159.4	166.6	4.5%
Akiyo	201.5	211.9	5.1%
Foreman	89.1	91.8	3.0%
Car	156.8	162.3	3.5%

(Source: Huper Laboratories Co., Ltd.)

Meanwhile, Table 4 compares single-thread and four-thread H.264 encoder encoding fps. Note that the four-thread encoder has an average of 2.7x fps as compared to single-thread encoder.

Table 4. Performance comparison between single-thread and multi-thread encoder on Intel® Atom™ processor 330.

H.264 encoding based on Intel® Atom™ processor 330 optimized with Intel® SSSE3	Single-threaded H.264 encoder (fps)	Four-threaded H.264 encoder (fps)	Performance gain with four threads (ratio)
Hall	110.6	319.0	2.88
News	166.6	427.3	2.56
Akiyo	211.9	502.0	2.37
Foreman	91.8	268.3	2.92
Car	162.3	447.4	2.76

(Source: Huper Laboratories Co., Ltd.)

H.264 encoding based on Intel® Core™2 Quad Processor Q9400Δ

Intel Core 2 Quad processor Q9400 is the first quad-core processor within the Intel® Core™2 processor product line with an embedded 7-year life cycle support. It features four complete execution cores within a single processor and offers Intel SSSE3 and SSE4 instructions.

Table 5 shows the encoding fps of a single-thread H.264 encoder with and without using Intel® SSSE3 and SSE4 instructions. The performance gain is about 7-10 percent.

Table 5. Single-threaded H.264 encoder based on Intel® Core™2 Quad processor Q9400 with and without Intel® SSSE3/SSE4 instructions.

Single-threaded H.264 encoding based on Intel® Core™2 Quad processor Q9400	Video frame rate without Intel® SSSE3 and SSE4 (fps)	Video frame rate with Intel® SSSE3 and SSE4 (fps)	Performance gain with Intel® SSSE3 and SSE4 (%)
Hall	507.3	543.5	7.14%
News	704.4	765.9	8.73%
Akiyo	911.5	1,004.2	10.17%
Foreman	396.4	425.7	7.39%
Car	704.5	762.6	8.25%

(Source: Huper Laboratories Co., Ltd.)

Table 6 shows the encoding fps of a single-threaded and four-threaded H.264 encoder. The four-thread encoder yields an average of 3.5x fps compared to the single-thread encoder.

Table 6. Performance difference between single-thread and multi-thread encoder run in Intel® Core™2 Quad processor Q9400.

H.264 encoding based on Intel® Core™2 Quad processor Q9400 optimized with Intel® SSSE3/SSE4	Single-threaded H.264 encoder (fps)	Four-threaded H.264 encoder (fps)	Multi-thread performance gain (ratio)
Hall	543.5	1,923.5	3.54
News	765.9	2,511.9	3.28
Akiyo	1,004.2	2,934.4	2.92
Foreman	425.7	1,592.0	3.74
Car	762.6	2,888.2	3.79

(Source: Huper Laboratories Co., Ltd.)

Conclusion

To maximize performance of DSS applications, the latest Intel® SSSE3 and SSE4 instructions which enhance video encoding should be used. It will boost the performance up to 10 percent for the H.264 encoder.

In addition, the multi-threaded H.264 encoder outperforms single-threaded encoders with a ratio of 2.7x and 3.5x on Intel Atom processor 330 and Intel Core 2 Quad processor Q9400, respectively.

Below is a list of Embedded Intel® Architecture processors with Intel® SSSE3 and SSE4 options.

Embedded Intel® Architecture processors with Intel® SSSE3 and SSE4 options

SSE4.2	Intel® Core™ i7 processors
SSE4.1	Intel® Core™2 Quad processor 9XXX series Intel® Core™2 Duo processor 8XXX series
SSSE3	Intel® Core™2 Extreme processor7XXX, 6XXX series Intel® Core™2 Quad processor 6XXX series Intel® Core™2 Duo processor (except E7200), 6XXX, 5XXX, 4XXX series Intel® Core™2 Solo processor 2XXX series Intel® Pentium® dual-core processor E2XXX, T23XX series

† Hyper-Threading Technology requires a computer system with an Intel processor supporting Hyper-Threading Technology and an HT Technology enabled chipset, BIOS and operating system. Performance will vary depending on the specific hardware and software you use. See http://www.intel.com/info/hyperthreading/ for more information including details on which processors support HT Technology.

Δ Intel processor numbers are not a measure of performance. Processor numbers differentiate features within each processor family, not across different processor families. See www.intel.com/products/processor_number for details.

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