Intel® Quick Sync Video Technology on Intel® Iris™ Graphics and Intel® HD Graphics family—Flexible Transcode Performance and Quality

The 4th generation Intel® Core™ Processor introduces Intel® Iris™ Pro Graphics, Intel® Iris™ Graphics and Intel® HD Graphics (4200+ Series), featuring the newest iteration of Intel® Quick Sync Video technology. In addition, Intel Quick Sync technology is also available in the Intel Xeon® Processor E3-1200 v3 product family with Intel HD Graphics P4600/P4700. For the purposes of this whitepaper, we will refer simply to Intel Quick Sync technology. This advanced graphics solution sets a milestone in performance by delivering a blazingly fast transcode experience, and balances image quality and performance through a series of optimized user targets for easy adoption. This paper explains the changes in Intel Quick Sync Video transcode target usages, describes the new high-performance hardware acceleration engine, and sets performance and quality expectations for each target usage.

Introduction

Video transcoding involves converting one compressed video format to another. The process can apply changes to the format, such as moving from MPEG2 to H.264, or transcoding can change the properties of a given format, like bit rate or resolution. Conversions cannot generally happen in a single step; rather, a series of transitions is usually involved. At a high level, video transcoding requires these steps:

1. Read the source video from a file
2. Decode frames from the source codec format into raw pictures
3. Perform any desired video processing and image enhancement (e.g., picture size scaling, noise reduction, de-interlacing, etc.)
4. Encode the raw pictures into the target codec format
5. Write the resulting bit stream to a file.

In the past, transcoding has been a compute-intensive task that demanded a large amount of precious CPU resources. With multiple cores and more powerful processors driving today’s systems, transcoding happens faster, and is commonly used to support the format requirements of a whole range of video consumption devices. Intel Quick Sync Video can enable hardware-accelerated transcoding to deliver better performance than transcoding in the CPU without sacrificing quality.

Intel Quick Sync Video technology was first introduced with the 2nd generation Intel Core processor in 2011. Early generations of Intel Quick Sync Video technology enabled fast H.264 transcode speed with acceptable visual quality on mobile devices. The integrated hardware acceleration actually provided a faster than real-time H.264 transcode solution.
Intel Quick Sync Video on the Intel 3rd generation Core processor with Intel HD Graphics 4000 is capable of transcoding 1080p high quality to 1080p H.264 normal quality at up to eight times the speed of real-time (8x), depending on the contents. The performance of transcoding a 720p24 (AVC High Profile L4.1 at 3.6Mbps) video to the same format with normal quality reaches about 11x. The transcoding varies, based on the content selection and other factors such as system load memory. Practically speaking, at this speed, it is possible for a user to convert 40 minutes of video in less than 4 minutes and get the output ready to upload, for example to a social networking website for sharing with family and friends.

Market research has revealed a fast-growing consumer segment of media enthusiasts who record high-quality videos. These individuals, sometimes called “prosumers”, use high-end digital camcorders and DSLR cameras, and have a strong need to edit and create high quality content for large, high-resolution monitors and TVs. Although prosumers welcome faster transcoding speeds, quality is often a much higher priority. Quality versus transcoding speed is a trade-off prosumers have patiently accepted as long as sufficient disk space was available to handle the output. Now, with Intel Quick Sync Video, prosumers can get both speed and quality.

**New flexible Intel Quick Sync Video**

Intel Quick Sync Video on the 4th Generation Intel Core Processor includes these new H.264 encoding features:
1. Per-MB bit rate control
2. Trellis quantization
3. Multi-level hierarchical motion estimation
4. Multi-reference
5. Multi-predictor
6. B-pyramid
7. Lookahead

Figure 1 depicts the high-level design of the new Intel® Iris™ and Intel® Iris™ Pro Graphics (5100+ Series) and Intel HD Graphics (4200+ Series), which has seen a number of significant enhancements. Many new features and capabilities are included to improve performance, reduce power consumption, and boost image quality.

The key improvements are the following:
- Additional JPEG/MJPEG decode in the Multi-format codec engine. This support is on top of existing energy-efficient, high-performance AVC encode/decode that sustains multiple 4K and Ultra HD video streams
- A dedicated new video quality engine to provide extensive video processing at low power consumption
- Programmable and media-optimized EU (execution units)/Samplers for high quality
- A newly-designed media sampler capable of executing faster than previous generations
- A scalable architecture with the flexibility to enable acceleration based on application demand

![Figure 1. Intel HD Graphics 4200+ Block Diagram Overview](image-url)
There are different benefits to software and hardware approaches for encoding solutions. Typically, software encoders have the luxury of performing extremely complicated motion estimation and exhaustive rate-distortion optimization on the CPU, in order to obtain the best possible quality. The tradeoff comes in a very high computation cost. Hardware encoders, on the other hand, have commonly been regarded as less flexible and thought to be incapable of delivering the necessary quality. This is the reason many hardware encoders are assumed to be only good enough for simple video production and viewing. However, with the advances described in this whitepaper, Intel hardware encoders should improve video quality.

The screenshots in Figure 2 demonstrate the different quality levels observed in popular hardware encoders, as compared to the previous-generation Intel HD Graphics 4000. Clearly, Intel HD Graphics 4000 provides superior visual quality for wider usages, as compared with these other hardware encoders. With the new acceleration power and flexibility provided by the latest Intel Quick Sync Video technology, even better hardware-based encoding is possible. Developers should quickly learn to facilitate state of the art algorithms that should improve the quality.

**Evolution of Target Usage**

Intel Quick Sync Video technology pre-defines various target usages (TU), based on a range of different performance and quality tradeoffs. The baseline configurations are defined for a low-level driver interface. Table 1 summarizes the low-level target usage evolution for each Intel Quick Sync Video generation. Target usages highlighted with the same color share the same configuration, quality, and performance. Note that at the Intel® Media SDK API level, there are additional options available for developers to further fine-tune their targets. Full details are available in the SDK documentation.

Prior generations of Intel Quick Sync Video focused on three pre-defined configurations or usages, but now application developers have more options. Intel Quick Sync Video now defines seven distinct target usages (TUs), each with a particular balance of quality and performance. Many software vendors only use two or three of the defined target usages in their application, saving development time.

Speed goes up in this numbering scheme, so in general, TU7 gives the best performance, while TU1 gives the best video quality.

<table>
<thead>
<tr>
<th>Target Usage</th>
<th>Best Quality</th>
<th>Best Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD Graphics 2500/4000</td>
<td>TU1</td>
<td>TU2</td>
</tr>
<tr>
<td>Iris/Iris Pro (5100+) and HD Graphics (4200+)</td>
<td>TU3</td>
<td>TU4</td>
</tr>
<tr>
<td></td>
<td>TU5</td>
<td>TU6</td>
</tr>
<tr>
<td></td>
<td>TU7</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Evolution of Low-level Target Usage Definition.
The benefit of the approach illustrated in Table 1 is better usage experience coverage across the wide range of performance and quality requirements. In the next section of this paper, we will focus on balancing performance and quality.

**Performance and Quality Differentiation Across Target Usages**

To examine the performance and quality differentiation across all target usages, we will compare the Intel Iris™ Pro Graphics 5200 capabilities with the Intel HD Graphics 4000. The image quality will be the same across all versions of the 4th Generation Intel Core Processor with Intel® Iris™ and Intel® Iris™ Pro and Intel HD Graphics and Xeon. The actual performance, measured as the time to complete a task at a given TU, will vary across these products. The comparison is based on two different Intel-created demo video clips, and summarizes the performance differentiation in each target usage (See chart in Figure 3).

Both clips are in 1080p AVC/H.264 High Profile format, at a 25Mbps bit rate. We transcode them to the same resolution and same profile, using Constant QP and 2 B-frame encode settings. In order to make it easier to observe the performance difference across all target usages, we normalized all performance to Intel Demo Clip1 TU1 transcoding speed.

As we can observe in Figure 3 below, performance is monotonically increased in each target usage for the Intel Iris™ Pro Graphics 5200. Performance for TU7 is ~3.5x faster than for TU1. In addition, TU1 also provides an average of ~0.6 dB quality improvement (See Figure 4). Note the encode/transcode speed is highly dependent on content selection.

Understanding video encode quality is not trivial, and it becomes more complicated when combining performance and power ratings. Figure 4 shows a BD-PSNR comparison across more than 160 different video clips, in order to summarize the overall encode quality expectation from two internal studies. BD-PSNR is one of the popular objective metrics to mathematically evaluate encoding quality; for more information, download a reference from ITU-T at [http://www-ee.uta.edu/dip/courses/ee5356/BDPSNR.doc](http://www-ee.uta.edu/dip/courses/ee5356/BDPSNR.doc). However, keep in mind that the objective metric does not necessarily correlate to subjective visual perception for the human eye. It is possible to have one content sample look better visually than the other content when the two are mathematically close in an objective metric. Therefore, always observe image quality subjectively in addition to using objective metrics to form a complete quality evaluation.

It is also worth noting that Constant QP (Constant Quantization Parameter) and VBR (Variable Bit Rate Control) are two different types of usages in video transcoding. VBR is used when the predictable file size is important to users. The encoder needs to meet the user’s target bit rate request and encode the video frames within the bit rate limitations. Constant QP uses a fixed QP value for each type of frame, and is often used when the primary objective is to maintain consistent quality across all frames, regardless of the bit rate and file size.
In the CQP (Constant Quantization Parameter) BD-PSNR figure 4, we can observe two plateaus in the quality curve on the Intel HD Graphics 4000. The quality from TU1 through TU4 remains fairly even, while in contrast, the Intel Iris™ Pro Graphics 5200 series differentiates quality in each target usage. In this study, we normalized all data to Intel HD Graphics 4000 TU7 quality for easier comparison purposes. Looking across generations, the Intel HD Graphics 4600 TU7 value is about 0.2 dB better than for the Intel HD Graphics 4000 TU7 level. The new TU1 level in the Intel Iris™ Pro Graphics 5200 is nearly 0.9 dB better than the value for the Intel HD Graphics 4000 TU7, and is about 0.7 dB better than for TU7 in the Intel Iris™ Pro Graphics 5200 series. The quality delta looks small from TU1 to TU4 because this is the average across 160+ test contents.

Similarly, the VBR BD-PSNR comparison shows the same trend in Figure 5. In addition to the default configuration comparison, an optional Lookahead feature is enabled in each TU in order to show performance and quality flexibility. Lookahead is an advanced feature available at the SDK level that can provide further quality improvements, especially when the contents have many scene changes. There is a performance overhead for enabling this feature, but developers will be able to trade off performance and quality differently. The overall quality delta can be up to 1dB with Lookahead enabled, which is a large improvement.

To better understand the actual quality improvement and different performance implications in each TU, we provide screenshots with more detailed explanations for selected TUs. All screenshots in the following discussions were encoded with AVC/H.264 High Profile at a 2Mbps target bit rate.
**Target Usage 7 (TU7) - Speed**

Target Usage 7 (TU7) is the fastest encode mode provided on Intel Quick Sync Video. TU7 is meant to provide the fastest mode and quality improvements, but they are only provided in this mode when doing so does not hinder the targeted performance. The TU7 setting in the new Intel Quick Sync Video technology improves both energy efficiency and visual quality while still meeting a 12x real-time speed target.

As a result, applications using TU7 mode are generally expected to be equal to or faster in performance, with better visual quality, and with lower power consumption resulting in better battery life. Note that in some cases, users may not get all three improvements together. Some system configurations and video transcode combinations may run slightly slower than in previous generations, due to a new emphasis on energy efficiency.

The overall quality delta in this TU7 comparison is about 0.2 dB, although the interpretation of this difference depends on the content and the absolute quality level in the encode settings. If the absolute quality is low (for example, the user chooses to encode at a very low bit rate), a 0.2 dB difference could effectively reduce some of the visual artifacts and make the picture look better. If the absolute quality is high, the visual difference would become less perceivable, and only with carefully examination of the picture will the improvement be spotted.

Next are two sample screenshots encoded in TU7 with Intel HD Graphics 4000 (Figure 6) and HD Graphics 4600 (Figure 7). Both images generally look similar and are reasonably good. But if we zoom in on certain regions, we can visually observe that the Bally’s building is blurrier and the night sky looks blockier on the Intel HD Graphics 4000, but thanks to the Lookahead feature, the images look much better on the Intel Iris™ Pro Graphics 5200 (see Figure 8 and Figure 9).
**Target Usage 6 (TU6) – Better Performance, Better Quality**

In most cases, the new TU6 achieves both better performance and better quality than previous generations. This is the most balanced mode in terms of performance and quality for general purpose encoding, and is the recommended setting. Using the same transcode settings and the same contents, users can expect the visual quality to be generally better than seen in the Intel HD Graphics 4000, and the speed is faster.

Better performance and quality of successive generations of Intel Quick Sync Video depends on advances in hardware design and encoding algorithms. The performance advantage from newer and faster media accelerators is seen when we execute a more complicated encode algorithm to improve quality. In Intel Iris Pro Graphics 5200+, an improved media accelerator design creates up to 50% faster transcode speeds. If we execute a less complicated algorithm, the performance difference between the two generations becomes smaller.

The screenshots in Figures 10 to 13 were generated with the same transcode configurations and contents and provide a TU6 comparison that gives users an apparent visual difference even without zooming. Then, when zooming in, the difference in the details of the windows and the buildings easily stands out, and the sky is also smoother and not as blocky.
Target Usage 1 (TU1) through Target Usage 5 (TU5) - Quality

The design goal of target usage levels TU1-TU5 is to deliver increasing quality output, with TU1 being the highest quality. Therefore, depending on the encode configuration and algorithm tuning, these five target usages are designed to provide better visual quality at the cost of speed. Transcode speed is a secondary consideration for this design point, and in fact, these TUs will generally run slower than prior generations. As we have explained previously, the balance point where better performance and high quality are maximized could change. As the performance of media accelerators continues to improve, it is possible that the balance point between speed and quality will continue to shift.

The quality improvement in the new TU1 over prior generations should be very easily observed in most cases, as most compute cycles are spent in achieving better quality. Nevertheless, TU1 encode performance in the new Intel Quick Sync Video still offers faster than real-time transcode speed, at much lower power consumption. TU1 delivers comparable encode quality to state of the art software encoders, and consumers should no longer face long overnight transcoding sessions to create high quality home videos.

Preserving image detail is challenging when encoding 1080p video at a low bit rate. Observing some artifacts is inevitable, and Intel HD Graphics 4000 is not an exception with this particular scenario. While TU1 quality in Intel HD Graphics 4000 is good for general usage, the TU1 quality in Intel Iris™ Pro Graphics 5200 really enables wider usages when a high quality level is desired.

Figures 14 to 17 show the major quality differences between Intel HD Graphics 4000 and Intel Iris™ Pro Graphics 5200 when encoded with AVC High Profile at 2Mbps settings. If we examine the zoomed in
Intel Quick Sync Video

screenshot closely, the small font text on the mobile phone and the skin texture are both better in the Intel HD Graphics 4600 image.

Summary
The latest version of Intel Quick Sync Video is a significant improvement over the previous generations, in terms of performance and quality. The new high-performance hardware acceleration engine improves speed and quality targets for a full range of uses. New target usage design optimizations provide significant performance headroom and enable a wider variety of applications, including prosumer quality video processing solutions. Developers can take advantage of greater flexibility in performance and quality to meet any kind of application requirement, from HD video conferencing to high quality video editing.

Tests conducted with Intel internal test application on standard hardware platforms.

Intel’s compilers may or may not optimize to the same degree as non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. These optimizations include SSE2, SSE3, and SSE3 instruction sets and other optimizations. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel. Microprocessor-dependent optimizations in this product are intended for use with Intel microprocessors. Certain optimizations are specific to Intel microarchitecture and are reserved for Intel microprocessors. Please refer to the applicable product User and Reference Guides for more information regarding the specific instruction sets covered by this notice.

Notice revision 8.20110804

Intel does not control or audit the design or implementation of third-party benchmark data or web sites referenced in this document. Intel encourages all of its customers to visit the referenced web sites or others where similar performance benchmark data are reported and confirm whether the referenced benchmark data are accurate and reflect performance of systems available for purchase.

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.

Configuration:
CPU: Intel Core(TM) i7-4770R; GPU: Intel Iris Pro Graphics 5200; BIOS: 10B; PCH: Lynxpoint; Mem Freq: 1600MHz; Stepping C2; Processor Speed: 2500MhZ Turbo up to 3700GHz; OS: Win7, 64bit; RAM: 8GB; Graphics Drive: 15.31.3055
CPU: Intel Core(TM) i7-4940MQ; GPU: Intel HD Graphics 4600; BIOS: 10B; PCH: Lynxpoint; Mem Freq: 1600MHz; Stepping C3; Processor Speed: 2800MHz Turbo up to 3800GHz; OS: Win7, 64bit. RAM: 8GB; Graphics Drive: 15.31.3055
CPU: Intel Core(TM) i7-3820QM mobile part, GPU: Intel HD Graphics 4000; BIOS: 006B; PCH: PantherPoint; Mem Freq: 1333MHz; Stepping E2; Processor Speed: 2700MHz Turbo up to 3700GHz OS: Win7, 64bit; RAM: 8GB; Graphics:Driver: 15.31.3055

Other Details:
The software used in comparisons is non-commercial Intel test application MFX transcoder.

Clips/Videos:
Figure 2: Cyberlink Media show express software tool v5.2.2.119 to compare Intel with Hardware A & Hardware B.
Figure 3: shows two lines with regard to two clips. Demo 1 clip - Mammoth 1080p 25Mbs 30fps, Demo 2 clip - 1080p Final Master (24fps, 20Mbs). Encode parameters used are all driver/MSDK defaults but run under CQP mode only (QP) 24.
Figure 6 to 17 - Screen shots taken from transcoded of Demo Clip 1 - Mammoth 1080p 25Mbs 30fps. Output is an H264 MP4 1080p 10Mbs video file using described features.

For more information go to http://www.intel.com/performance

*Other names and brands may be claimed as the property of others. Printed in USA Please Recycle