White Paper | AMD UNIFIED VIDEO DECODER (UVD)

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INTRODUCTION

Thanks to a wide variety of sources, High Definition (HD) content is now a prevalent format among consumers, who are constantly looking for an immersive entertainment experience. From traditional media, like broadcast and discs (e.g. Blu-ray Disc™), to new sources such as streaming online videos and HD-capable smartphone cameras, HD is everywhere.

Another revolution has also unfolded over the last few years, as customers now own more media consumption devices than ever before: smartphones, tablets, laptops, game consoles, PCs, handheld consoles and PMPs are all HD video-ready. However, the personal computer (PC) remains for many users the central component to consume and manage their multimedia content, thanks to its flexibility in supporting multiple multimedia formats, high storage capacity and networking capabilities. All of this has allowed the PC to remain an authoritative hub for sharing with other companion devices.

This paper looks at the challenges of HD playback on the PC and the dedicated set of technologies implemented by AMD Radeon™ graphics processing units (GPUs) that provide efficient and flexible playback of this content.

SEAMLESS & EFFICIENT HD PLAYBACK

Unified Video Decoder (UVD)

To enable full HD video decode on a complete range of PC graphics solutions, AMD introduced the Unified Video Decoder (UVD) with AMD Radeon™ HD 2600 and HD 2400 family of products. UVD is a dedicated hardware video decoding block that facilitates the full, bit-accurate decoding of VC-1 or H.264/AVC-encoded video. Figure 1 illustrates a functional diagram of the decoding stages of the first-generation UVD block introduced on the aforementioned AMD Radeon™ HD 2000 Series products.

By utilizing dedicated hardware for decoding of VC-1 and H.264 via UVD, the central processing unit (CPU) is decoupled from the video decoding process, including the CPU-intensive entropy decoding stage. Through offloading the decode process from the CPU to the GPU, the system’s processor is freed to handle other tasks for the user.
In Figure 2, CPU utilization is measured during playback of a Hollywood movie, encoded in H.264 at 1080p. In our example case there is only 16% CPU utilization with UVD, representing a reduction in CPU workload of nearly 70%, which may now be reallocated to tasks of the user’s choosing. The remaining 16% CPU utilization is the operating system (OS) and application overhead required when playing back from an HD optical source. With UVD, VC-1 decoding also benefits from the same low CPU utilization.

One potential benefit of switching processing from a CPU-based software decoder to a dedicated, GPU-based solution is lower overall system power utilization. This decrease in power utilization is beneficial in a notebook PCs because HD playback processing places a greater burden on the battery. For desktop computers used as Home Theater PCs (HTPCs) low CPU utilization could lead to a cooler CPU and a quieter CPU fan, leading to a quieter environment during video playback.

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With the AMD Radeon™ HD 6000 family of GPUs, a 3rd generation of UVD was introduced to enable acceleration of wider range of video formats and media, both from hard disk-based and optical sources.

This 3rd generation, named UVD3, provides acceleration for MPEG-2 bitstream, MPEG-4 part 2 ASP (also known as DivX/Xvid) and Multi-View Codec (MVC/Blu-ray 3D) formats. Figure 3 illustrates the evolution of UVD architecture since its Introduction until its 3rd generation.

One key addition to UVD3 is MVC decode. This format is the only codec used in the new Blu-ray 3D™ movie specification. MVC combines, or “packs,” the left and right stereo views into a single stream and encodes it with H.264; these dual streams impose a tremendous compute workload. With UVD3, AMD brings Blu-ray 3D playback to mainstream PCs by offloading decode to AMD Radeon™ HD graphics. Figure 4 shows an example of Blu-ray 3D decode and the benefits of offloading MVC decode from the CPU.

Figure 3: AMD’s Unified Video Decoder Evolution

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Figure 4: Example of CPU utilization during Blu-ray 3D playback

[Blu-ray average CPU Usage (%) Lower is Better.]

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3 AMD HD3D is a technology designed to enable stereoscopic 3D support in games, movies and/or photos. Additional hardware (e.g. 3D enabled panels, 3D-enabled glasses/emitter, Blu-ray 3D drive) and/or software (e.g. Blu-ray 3D discs, 3D middleware, games) are required for the full enablement of stereoscopic 3D. Not all features may be supported on all components or systems – check with your component or system manufacturer for specific model capabilities and supported technologies.

CLEAR & CRISP IMAGE QUALITY

AMD’s HD post-processing

The video frames decoded from a video stream can go through post-processing to improve the image quality and correct visual artifacts from the source video introduced during production or distribution of the content (e.g., broadcasting or internet streaming). Main causes for these visual artifacts are video interlacing, resolution reduction and high compression or scaling.

Each user can have a preference for a different set of visual controls, such as colors or sharpness. AMD’s post processing features different video quality enhancements and user controlled settings to provide a superior visual experience during playback, independently from the type (HD or SD) of the video source.

Below is a discussion of the main video quality processing featured in AMD Radeon™ HD graphics:

Advanced De-interlacing and inverse Telecine

HD content on optical discs is usually encoded as series of full progressive frames, mainly in 1080p resolution. However, interlaced video remains dominant today as most broadcast video (SD and HD) and video on standard DVD discs are interlaced. Playback of interlaced video on progressive displays requires the conversion of the content from interlaced – two fields representing half the vertical resolution each - to a full vertical resolution progressive frame. This process is called de-interlacing.

There are different algorithms to de-interlace video. The most basic ones are replication of lines of a field (“weave”) and averaging of lines of a field (“bob”). AMD Radeon™ graphics products include advanced de-interlacing algorithms that take into account the temporal element of the video to dramatically improve the visual quality of the picture (Figure 5).

Inverse telecine, also known as “pulldown detection”, is another sophisticated post-processing mechanism used to enable smooth playback of movie titles encoded in interlaced format. This processing is used to obtain the best image quality with titles created originally on film at 24 frames per second (fps) progressive, but encoded as interlaced video at 30 fps on optical discs, such as DVDs. At the time of encoding, six intermediate frames are duplicated to achieve 30fps from 24fps. This group of frames is called pulldown sequence. There are several types of pulldown sequences. The most common for film is 3:2 pulldown.
Playback of such interlaced video on progressive monitors requires detecting the nature of the pulldown sequence so it can be removed to play the original progressive content smoothly. This is achieved by “inverse telecine” post-processing, another advance post-processing feature in AMD Radeon™ GPUs.

Display Resolutions beyond 1080p

High resolution displays for PCs, such as dual-link monitors, are becoming more available and affordable. These monitors support resolutions higher than 1080p, at 2560x1600 (WQXGA) or 4096x2160 (Digital Cinema 4k). This represents a challenge for playback of high-definition, as well as standard-definition videos, because scaling the video to the higher display resolution will have an amplifying effect on any artifacts existing in the source content, and will likely introduce aliasing artifacts on the picture. The display engine in AMD Radeon™ graphics enables high quality scaling of video to resolutions higher than 1080p with for an immersive entertainment experience.4

Color Vibrancy and Adjustments

The AMD Radeon™ display engine processes data at 10-bits per color (30-bits RGB), enabling over 1 billion colors on 10-bit-capable displays.

For video playback, AMD Radeon™ GPUs expose advanced color controls, allowing users to adjust color saturation and vibrancy for vivid colors in the video, while preserving the natural look of human skin through an advanced “fleshtone” post-processing algorithm during video playback. Figure 6 provides a simulated illustration of this color vibrancy adjustment.

Figure 6: Color vibrancy adjustments

4 Supported resolutions may vary per product. For details on supported resolutions refer to the specific product page online at www.amd.com.
Noise Reduction and Edge Enhancement

Noise reduction is a post-processing operation performed on video to remove noise artifacts introduced by the camera during the shooting or during transfer and compression of the video.

Noise reduction introduces specific challenges: detecting true noise pixels from valid ones, preserving details in the picture, and avoiding common “ghosting” artifacts in sophisticated algorithms like Temporal Noise Reduction (TNR).

AMD's approach to noise reduction is both advanced--using TNR to lower risk of removing valid pixels--and balanced in noise reduction strength to reduce “ghosting” artifacts while preserving details of the picture. Figure 7 illustrates the original video with noise in the source, which is easily noticeable in the blue sky, and the video with AMD's HD noise reduction, which preserves details on the tower.

Figure 7: Noise reduction example
[Simulated images]
AMD Steady Video 2.0*

The availability of video recording capabilities on a wide range of affordable mobile devices, combined with the success of social Internet video streaming, has created a new and enormous category of user-created content.

While professional content (e.g. movies, broadcast) is visually polished with a high standard for the equipment and production, user-created content is typically raw and contains many visual artifacts, the most common of which is random image movement introduced by camera shake due to manual handling of the camera or phone.

AMD introduced in early 2011 a new technology named Steady Video, which helps to correct camera shake. With the AMD Radeon™ HD 7000 Series, Steady Video 2.0 was introduced to deliver enhanced correction by leveraging Quad Sum of Absolute Differences (QSAD) hardware instruction available on this family of GPUs.

This technology starts by applying statistics to derive models of the camera’s motion (Figure 8), which requires very complex mathematical calculations and is a very intensive computational stage. For example, in order to detect random shifts of 32 pixels in any possible direction in HD video (1920x1088 @60Hz), the number of required SAD instructions is over 513 billion calculations per second.

Once the type of motion is detected, AMD Steady Video defines a smoother motion path for the video. Each picture is then warped (translated, rotated, scaled) from its original position to a position on the smoother motion path. All processing must happen in few milliseconds to keep real-time playback; this is possible thanks to the processing power of the GCN Architecture present in all 28nm AMD Radeon™ HD 7000 Series products.6

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6The GCN Architecture and its associated features are exclusive to the AMD Radeon™ HD 7900, HD 7800 and HD 7700 Series Graphics.
ACCELERATED VIDEO TRANSCODING

With the increasing number of media sources and playback devices, users are constantly looking for a fast and seamless way to move and manage video content.

In 2009, AMD introduced the Accelerated Video Transcoding (AVT) architecture to help speed up video conversion. AVT is a combination of hardware and low level software employed to convert H.264 and MPEG-2 video sources, up to 1080p resolution, to another H.264 video suitable for a target device, e.g., portable media players.

AVT leverages all resources in the system, including UVD and compute processors, to accelerate the overall process, while keeping CPU usage and low levels for a balanced and responsive PC as illustrated in Figure 9.1

Figure 9: AMD’s Accelerated Video Transcoding architecture

Figure 10: AVT transcoding speed and CPU usage

System configuration: AMD Athlon™ II X2 215 (2.7GHz), 4GB DDR3-1600, AMD Radeon™ HD 6870, and Microsoft® Windows® 7 Ultimate. Software configuration: AMD Catalyst™ 8.78_RC2 and CyberLink MediaEspresso 6 (6.0.0722_28792). Transcode Target: 1080p H.264 video @ 20Mbps to Apple iPhone® 640x480 video.
Video Codec Engine (VCE)

As the PC has become the central hub for multimedia content in the house, there is a growing need for end-users to access and transfer video content to other devices like tablets, or streaming to other PCs in real-time, requiring video encode, which is a very complex and long processing, especially for HD video encoding. For years, HD video encoding has been limited to PCs with quad-core CPUs and was slower than real-time, creating frustration for end-users.

To solve this challenge, new and dedicated hardware named the Video Codec Engine (VCE) was introduced with AMD Radeon™ HD 7900 Series to accelerate HD video encoding. This technology is also present in the AMD Radeon™ HD 7700 and HD 7800 Series GPUs.

At the heart of VCE is a multi-stream hardware H.264/AVC encoder (Figure 11). It is power-efficient and faster than real-time, enabling 60 FPS encoding of content with a resolution up to 1920x1080 (1080p).

VCE supports 4:2:0 color sampling encode, the most commonly used color space of consumer video formats. VCE also includes optimizations for scene changes and variable compression bitrate for an enhanced visual quality of the encoded video.

![Figure 11: Block diagram of AMD Video Codec Engine (VCE)](image)
SUMMARY

The challenges of multimedia consumption go beyond the simple decode to include video quality challenges, especially on high resolution displays, and acceleration of content management operations, such as transcoding.

AMD delivers a comprehensive set of video and display technologies designed to enable a seamless video playback and use power efficiently with high visual quality on AMD Radeon™ HD graphics, to truly provide users with The Ultimate Visual Experience™.

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