



CHR MOTION HD™

2.0

for
Chrome 400 Series
Graphics Processors

A
S3 Graphics
White Paper

CHROME

Introduction

This document describes the next generation ChromotionHD™ 2.0 video engine integrated into the S3 Graphics' Chrome™ 400 Series graphics processors to provide high quality high-definition (HD) and standard definition (SD) video processing and playback. The capabilities and benefits of ChromotionHD 2.0 build on the proven and award-winning Chrome 20 Series ChromotionHD video engine. Additions include support for H.264/MPEG-4 playback on PC (desktop and mobile) and consumer electronic (CE) platforms.

ChromotionHD 2.0

The introduction of HD media, such as Blu-ray Disc™, HD-DVD™ and digital TV (DTV) broadcasting, gives consumers a vast array of media delivery choices for the viewing of high quality video content. As the PC becomes a central console for the digital home, consumers need powerful graphics processors (GPUs) capable of delivering outstanding and stunning picture quality when displaying content generated from the latest HD media formats such as H.264/MPEG-4 and DTV broadcast. With support for various HD formats and for all eighteen ATSC (Advanced Television Systems Committee) and DVB (Digital Video Broadcasting) television configurations, the Chrome 400 Series GPUs are capable of playing back the latest in high resolution home movies and DTV broadcast content.

At the core of ChromotionHD 2.0 is a programmable video engine that supports a wide selection of decoding and video acceleration hardware to provide high quality processing for today's HD and streaming digital video content and codecs. The video engine incorporates full H.264 VLD bitstream decoding, VC-1/WMV™ HD (Windows Media Video-HD) iDCT with motion compensation (MC) decoding, and MPEG2-HD iDCT/MC hardware for HD decoding and playback. The specialized built-in hardware minimizes CPU utilization by offloading HD-compute-intensive tasks from the CPU to the GPU, which makes the decoding process more efficient and minimizes system power consumption. In addition,

CPU offloading prevents those annoying artifacts and imperfections that might appear onscreen when using CPU-decoding-based video processing. ChromotionHD 2.0 also includes professional video editing capabilities with features such as ArtisticLicense™, which can be used to create dramatic movie visuals and effects.

Other benefits of the video engine include its ability to work seamlessly with the GPU's internal display engines to provide HD or SD display connectivity up to 1080i/p using either digital or analog video outputs. An HD monitor or HDTV can be securely connected through the digital interface using an HDCP (High-bandwidth Digital Content Protection) enabled HDMI™/DVI or DisplayPort connection. Analog output includes Composite, S-Video, and Component video, with Macrovision® content protection included to support legacy and analog SD/HD displays.

The S3 Graphics' Chrome 400 Series with its integrated and powerful ChromotionHD 2.0 video technology raises the bar for entertainment PC based theatrical HD quality viewing.

ChromotionHD 2.0 Highlights

New features available with S3 Graphics' graphics processors incorporating a ChromotionHD 2.0 programmable video engine include:

➔ **H.264 Hardware Acceleration**

- ◆ Variable Length Decoding (VLD)
- ◆ Inverse Transform
- ◆ Motion Compensation (MC)
- ◆ In-loop Deblocking

➔ **VC-1 / WMV-HD Hardware Acceleration**

- ◆ Inverse DCT (iDCT)
- ◆ Motion Compensation (MC)

➔ **MPEG2-HD Hardware Acceleration**

- ◆ Variable Length Decoding (VLD)
- ◆ Inverse DCT (iDCT)
- ◆ Motion Compensation (MC)

➔ **Blu-ray and HD-DVD Support**

- ◆ A highly optimized decoding and post processing video and display pipeline allows simultaneous acceleration of multiple video streams.

➔ **HDMI / DVI / DisplayPort with HDCP Support**

- ◆ An Integrated HDCP ROM and decode logic support HD digital content protection in CE and PC devices.

- ◆ The GPU will automatically synchronize HD video and audio (A/V) signals internally, compliant with HDMI and DisplayPort specifications.

ChromotionHD 1.0 Compatibility

The powerful first generation ChromotionHD 1.0 engine implemented on the Chrome 20 Series GPUs is retained in version 2.0 for legacy support of standard definition video streams. To find out more details about ChromotionHD 1.0, please refer to S3 Graphics' white paper WP012.

➔ **Video Deblocking**

- ◆ Removes blocky artifacts inherent in low bit rate video images during processing and image reconstruction.

➔ **ChromoVision**

- ◆ Supports multiple display configurations that allow full screen HDTV output in addition to other display options.

➔ **Digital TV (DTV) and Video Support**

- ◆ Supports all 18 digital TV ATSC and DVB formats.
- ◆ Video-on-Demand (VOD) support
- ◆ IPTV (Internet TV) support
- ◆ Location-free DTV using notebook or portable CE devices
- ◆ Other forms of streaming video using MPEG-2/WMV-HD formats

➔ **Motion Adaptive Per-Pixel De-Interlacing**

- ◆ Produces superior video image quality for still and motion images using a proprietary de-interlacing process on a per-pixel basis.

➔ **Video Scaling, including PanelSharp™ Expansion**

- ◆ Provides a wide range of scaling and sharpening capabilities for flat panel displays.

➔ **ChromoVision Modes with Non-Linear Scaling (Enhanced Zoom)**

- ◆ Scales a standard 4:3 video image to a full 16:9 HDTV widescreen display with excellent image quality using enhanced algorithms, de-interlacing technologies, and interpolation filters.

➔ **ChromoColor**

- ◆ Provides controls to adjust video image quality for brightness, contrast, hue, and saturation.

➔ **Tonal Adjustment**

- ◆ Allows fine-tuning of luma values for the video display with controls for black and white point enhancement.

➔ **ArtisticLicense Effects**

- ◆ Allows high quality video image enhancements including Sharpening, Soft Focus, Embossing, and Neon Edge effects.

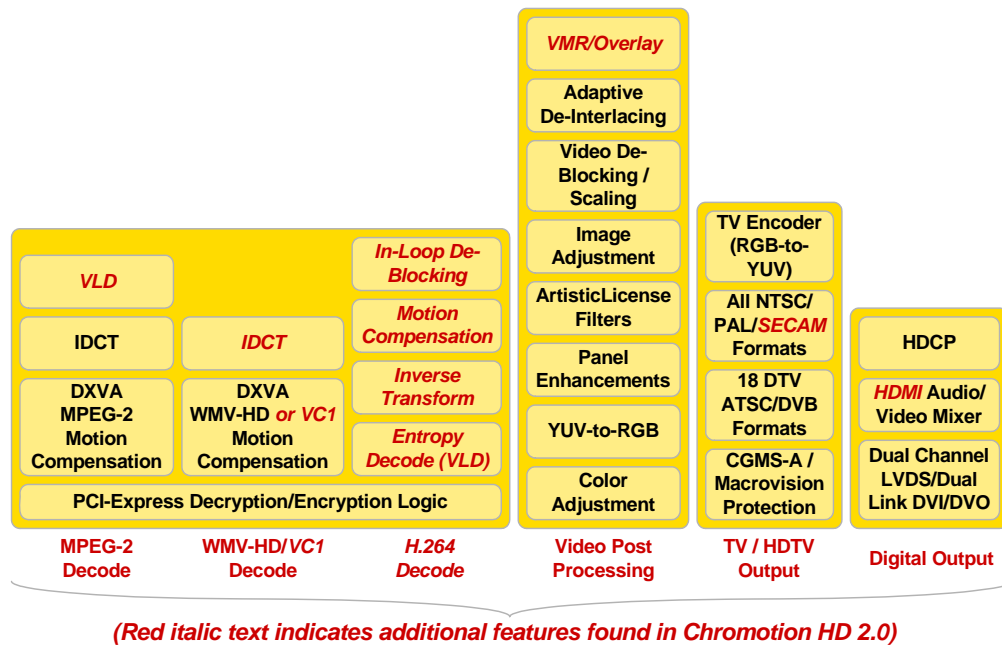


Figure 1: Key Components of the ChromotionHD 2.0 Video Engine

ChromotionHD 2.0

ChromotionHD 2.0 adds H.264, MPEG-2 VLD, and VC1 decoding capabilities to the existing ChromotionHD 1.0 video engine to offload intensive video processing from the CPU to the graphics processor. This section gives a brief overview of the components in the video stream encode / decode process. The first part describes the encoder function and the second part describes the decode capabilities native to S3 Graphics Chrome 400 Series graphics processors.

Each video frame is composed of basic macroblocks that can range in size from 16x16 pixels to 4x4 pixels, depending on the codec. Block sizes are dependent on the level of detail required for a frame. Small 4x4 pixel blocks allow increased granularity by showing very fine detail, while the larger blocks can represent general areas such as an all blue sky in a background.

In general, there are three types of frames that are coded: I (intra coded), P (predictive), and B (bidirectional) frames. I frames are compressed versions of a single (key) frame and they do not reference any other frames. P frames are compressed and coded based on previous I or P frames. B frames are coded based on a previous and a subsequent frame. The make up of a sequence of video frames is usually I-B-B-P-B-B-P-I. The basic sequence of video frames transmitted from the encoder which the decoder receives usually follows the pattern I-P-B-B-P-B-B. The decoder will then reorder the video frames into the correct sequence for viewing.

Video Encoding Process

- **Motion Estimation / Predictive Compensation:**
 - To make more efficient use of bandwidth when transmitting video, a method using the spatial similarities between frames is used to minimize the amount of video data that needs to be transmitted. The basic idea is that consecutive frames have strong correlations between them so, instead of coding and transmitting all frames, a few key frames (I frames) can be sent, and the P and B frames will be able to provide the rest of the video frame information. The I frames will be compressed and will be decoded as-is, but P and B frame information is minimized (using motion estimation) to save bandwidth, since these frames can be reconstructed using information in adjacent frames.
 - The encoder will determine the P and B frame-to-frame changes on a macroblock level by comparing blocks to their reference(s). Any macroblocks that have changed position will cause the encoder to create a motion vector representing the horizontal and vertical displacement of the encoded macroblock to the macroblock of the reference frame. The motion vector is then transmitted (after passing through the steps below) so that the decoder motion compensation unit can use the motion vector information to reconstruct the original image.

- **Transform Coding:**
 - Transform coding relies on the principle that pixels in an image or video exhibit a high level of correlation between neighboring pixels and adjacent pixels in a sequence of video frames. Using this idea, it is possible to predict the value of a pixel based on its neighbor's value, so the total amount of encoded and transmitted data for each pixel can be reduced or removed. Transform coding maps the spatial data to transform coefficients based on the frequency of correlation.

- **Entropy Encode:**
 - During the entropy encoding process, frequently occurring values are represented with short binary codes and infrequent values with longer binary codes. For example, frequent values could be found in the image of a blue sky which does not change much from frame to frame. Since the encoding process is dependent on the data frequency, a sequence of variable length binary codes is output from the entropy encoder and synchronized with control information, such as motion vectors, to allow the decoder to recreate the motion compensated frame.

Video Decoding Process

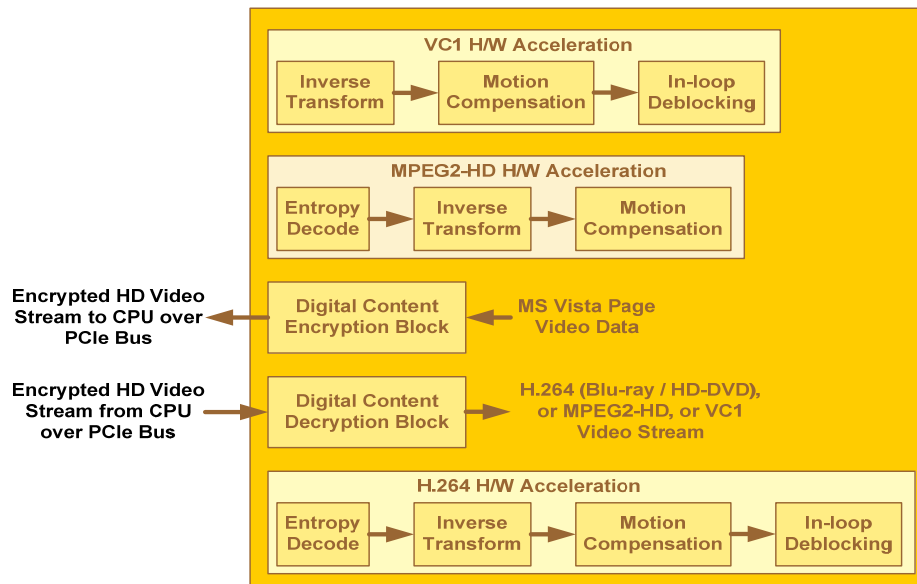


Figure 2: ChromotionHD 2.0 Decode Process Support

- **Entropy Decode:** The entropy decoder reverses the entropy process by extracting the variable length binary codes and motion vectors which the decoder then uses to reconstruct the final image.
- **Inverse Transform:** Inverse Transform reverses the encoder transform coding by converting frequency coefficients back to spatial data to recover the pixel values. Different formats, such as iDCT or integer inverse transforms, can be used varying with the codec.
- **Motion Compensation (MC):** Differences between the frames and motion vectors are used to reconstruct the current frame from the previous frame. The recovered motion vector from the encoder is used to place the macroblocks in the correct area of the current frame. The result of this stage is the reconstructed original frame, which is also placed in memory (frame store) and used to motion-compensate the next incoming frame.
- **In-loop Deblocking:** If the video stream bit rate is low, the data rate is not sufficient and edges between macroblocks can become visible, producing blocky artifacts during viewing. The ChromotionHD 2.0 engine's deblocking function prevents this blockiness from occurring at low bit rates, thereby allowing viewers to play streamed HD content regardless of the connection speed.

H.264 Decode – High Definition Video Decoding

H.264, also known as MPEG-4 AVC (Advanced Video Coding), is a new video compression standard that offers significantly greater compression ratios (~2 - 3x improvement) than its predecessor MPEG-2. As we progress towards the increasing popularity of HD content, MPEG-2 is considered too inefficient and too bandwidth limited to support multiple HD modes and video streams. A new codec needed to be introduced. H.264 is block-based, as is MPEG-2, but H.264 is more complex in terms of the processing and computing power required, incorporating a high level of integration between block prediction and variable block sizes. In the past, the CPU available with most basic systems was sufficient for decoding MPEG-2. H.264 decoding, on the other hand, is a very involved task. It requires powerful dedicated hardware to perform the decoding process with exceptional quality.

Since the CPU is a general purpose processor, it is not optimized to decode HD content effectively because the computing blocks cannot be configured in the most efficient manner. The most powerful CPUs on the market today do not have enough computing power to perform all the necessary functions to decode HD content in a timely manner. When used to decode, CPUs provide video playback that is jerky and has missing video frames. An incremental step, as we transition to HD content, is to offload the CPU and allow the GPU to perform the decoding function. S3 Graphics Chrome 400 Series high performance and cost effective GPUs have implemented the necessary hardware video blocks for HD playback, allowing a Chrome 400 Series equipped system to minimize CPU loading and provide the best picture quality for decoding and viewing HD content.

In addition, the highly efficient compression ratio of H.264 also allows true HD quality viewing across existing networks as more data can be transmitted at a given bit rate or throughput. This enables higher video quality and higher resolutions to be supported. H.264 also has lower storage requirements allowing more content to be stored on network servers for streaming HD video or next generation optical discs. Since the H.264 codec provides the best throughput and storage capacity, it has been chosen as a standard for next generation HD discs such as Blu-ray and HD-DVD. Because of the benefits of and industry support for H.264, it is rapidly becoming the worldwide digital video compression standard for HD video and games in the CE and PC market.

Since CPU utilization is reduced, the playback of H.264 HD premium movies on Blu-ray Disc or HD-DVD discs is possible on a wide range of PC systems running Microsoft® Windows Vista®. The system performance advantages, when incorporating a S3 Graphics Chrome 400 Series processor with its ChromotionHD 2.0 programmable video engine, provide users with a greatly improved experience while watching HD premium digital content displayed at full resolution from their desktop, notebook, or HDTV set. Table 1 shows a comparison between the capabilities of the new HD optical discs and current

DVD discs. The increase in capabilities is a large part of the reason H.264 is gaining in popularity.

Parameter	Blu-ray Disc	HD-DVD	DVD
Storage Capacity	25GB (single layer)	15GB (single layer)	4.7GB (single layer)
	50GB (dual layer)	30GB (dual layer)	8.5GB (dual layer)
Laser Wavelength	405nm (blue laser)	405nm (blue laser)	650nm (red laser)
Transfer Rate (Data)	36.0 Mbps (1x)	36.55 Mbps (1x)	11.08 Mbps (1x)
Transfer Rate (Video/Audio)	54.0 Mbps (1.5x)	36.55 Mbps (1x)	10.08 Mbps (<1x)
Video Resolution (Max)	1920x1080 (1080p)	1920x1080 (1080p)	720x480/576 (480i/576i)
Video Bit Rate (Max)	40.0 Mbps	29.4 Mbps	9.8 Mbps
Video Codecs	MPEG-2	MPEG-2	MPEG-2
	MPEG-4 AVC (H.264)	MPEG-4 AVC (H.264)	
	SMPTE VC-1	SMPTE VC-1	
Audio Codecs	Linear PCM	Linear PCM	Linear PCM
	Dolby Digital	Dolby Digital	Dolby Digital
	Dolby Digital Plus	Dolby Digital Plus	
	Dolby TrueHD	Dolby TrueHD	
	DTS Digital Surround	DTS Digital Surround	DTS Digital Surround
	DTS-HD	DTS-HD	

Table 1: DVD, HD-DVD and Blu-ray Disc Capability Comparison

Figures 2 and 3 show the approximate CPU and GPU utilization when decoding H.264 content, compared to MPEG-2. In both cases, MPEG-2 decoding can be performed by the CPU or a combination of CPU and GPU. Since H.264 is a leap above MPEG-2 in resolution, picture quality and compression, the computational resources required are even more demanding, which translates into the need for a GPU with complex and specialized hardware.

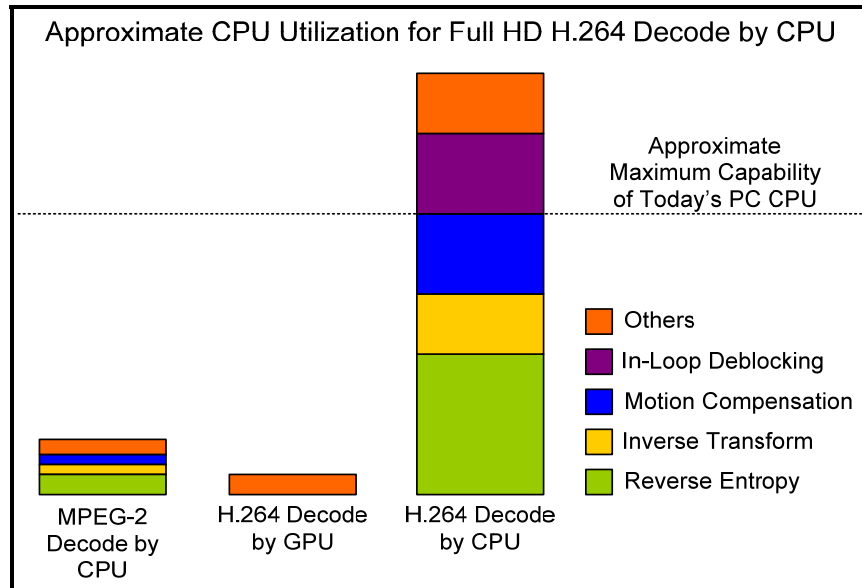


Figure 3: H.264 Decode by CPU

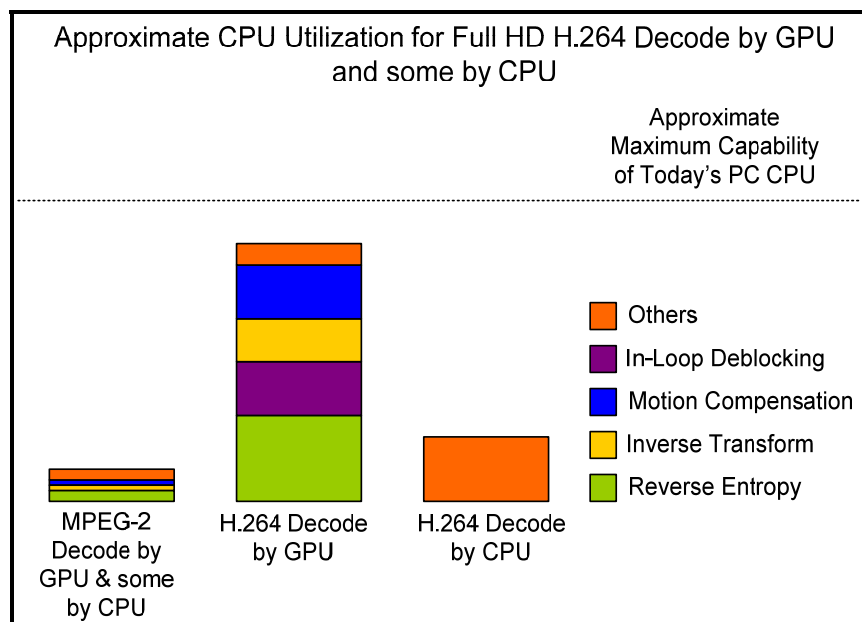


Figure 4: H.264 Decode by Video Processor in GPU

When the H.264 decoding is executed by the CPU, the process will exceed the maximum processing power and capability of the CPU (Figure 3) preventing smooth HD content playback. In Figure 4, the GPU offloads the demanding decoding process by incorporating entropy decoding, inverse transformation, motion compensation, and in-loop deblocking. The benefits of offloading to the GPU include a significant reduction in CPU overhead as well as enabling full resolution quality playback of HD content via Blu-ray Discs or HD-DVD on PCs.

A few major highlights of the H.264 codec include:

- Enhanced motion predictability (MC) support using variable block sizes as small as 4x4, multiple reference pictures/frames, and quarter sample motion vector support for finer details and granularity.
- Multiple video frames can be stored in memory for a higher level of frame decoding. In the past, only one frame could be stored at any given time.
- iDCT is replaced by integer based transforms to reduce complexity and inverse transform mismatches that existed with “real” number representations in previous codecs.
- Enhanced context-adaptive entropy encoding using CABAC (context-adaptive binary arithmetic coding) and CAVLC (context-adaptive variable-length coding).
- Adaptive in-loop deblocking filter has become standard to smooth edges between blocks for high quality video playback.
- H.264 separates the Video Coding Layer (VCL) and Network Abstraction Layer (NAL) to allow video processing regardless of the type of medium.

For more detailed information about H.264, please refer to the H.264 standards, the ITU-T H.264 standard and the ISO/IEC MPEG-4 Part 10 standard (formally, ISO/IEC 14496-10).

Windows Media® Video – WMV-HD / VC-1 HD Decoding

The Windows Media Video – High Definition (WMV-HD) encoding process is based on the VC-1 codec and allows higher compression ratios than MPEG-2. This efficient compression algorithm enables streaming video playback of consumer-quality HD video over the internet in Microsoft Windows-based applications and devices.

As with most encoding processes, WMV-HD/VC-1 produces some inherent visual artifacts if performed by the CPU without any computational offloading to a video decoder. When implemented in software with the decoding process executed completely by the CPU, system resource and CPU utilization increase dramatically and overall performance decreases, resulting in video output of marginal quality. When WMV-HD/VC-1 is decoded using hardware acceleration provided by the ChromotionHD 2.0 video engine, not only is CPU utilization is dramatically reduced but also greater quality video playback is provided at high resolutions. The ChromotionHD 2.0 video engine’s blocks that perform WMV-HD/VC-1 acceleration are the inverse transform, motion compensation, and in-loop deblocking engines.

The VC-1 video codec was initially standardized by SMPTE (SMPTE 421M) and implemented by Microsoft in Windows Media Video 9. VC-1 is based on the conventional DCT-based video codec specification of other video compression standards and offers high video quality video and compression efficiency. The standard supports a wide range of content formats and variable bit rates (low to

high), so multiple video formats can be viewed on Microsoft applications and devices regardless of connection speed and quality. VC-1, like H.264, has a compression ratio that is two to three times better than MPEG-2, allowing it to support both HD progressive and interlaced formats. Since VC-1 is an alternative to H.264, HD-DVD and Blu-ray Disc have adopted VC-1 as one of three video encoding formats that can support HD premium content.

The following table lists the different VC-1 profiles and levels that can be supported by S3 Graphics Chrome 400 Series GPUs.

VC-1 Profile	Level	Maximum Bit Rate	Representative Resolutions by Frame Rate (Format)
Simple	Low	96 kilobits per second (Kbps)	176 x 144 @ 15 Hz (QCIF)
	Medium	384 Kbps	240 x 176 @ 30 Hz 352 x 288 @ 15 Hz (CIF)
Main	Low	2 megabits per second (Mbps)	320 x 240 @ 24 Hz (QVGA)
	Medium	10 Mbps	720 x 480 @ 30 Hz (480p) 720 x 576 @ 25 Hz (576p)
	High	20 Mbps	1920 x 1080 @ 30 Hz (1080p)
Advanced	L0	2 Mbps	352 x 288 @ 30 Hz (CIF)
	L1	10 Mbps	720 x 480 @ 30 Hz (NTSC-SD) 720 x 576 @ 25 Hz (PAL-SD)
	L2	20 Mbps	720 x 480 @ 60 Hz (480p) 1280 x 720 @ 30 Hz (720p)
	L3	45 Mbps	1920 x 1080 @ 24 Hz (1080p) 1920 x 1080 @ 30 Hz (1080i) 1280 x 720 @ 60 Hz (720p)
	L4	135 Mbps	1920 x 1080 @ 60 Hz (1080p) 2048 x 1536 @ 24 Hz

Table 2: Different VC-1 Profiles and Levels of Support provided by ChromotionHD 2.0

MPEG2-HD Decoding

MPEG2-HD is the next iteration of MPEG-2. It provides support for both HD and legacy SD formats and uses a number of techniques to achieve higher compression ratios than its predecessor. The algorithm first utilizes a block-based motion estimation algorithm to reduce the temporal redundancy between adjacent frames using interframe or intraframe coding. Interframe coding assumes translational motion of objects in a scene and high frame to frame correlation with previous and/or future frames. If there are view or scene changes in the frame, then interframe coding is not relevant, since there is almost no connection between frames, and another method called intraframe coding is used. Motion vectors are defined for each 16-sample by 16-line region of the picture to be used for motion estimation. Motion vectors define the direction and distance a particular block has moved between frames. The blocks are further compressed using discrete cosine transfer (DCT) to remove spatial redundancies before it is quantized in an irreversible process that discards unneeded information. The last stage combines the motion vectors with the quantized DCT information, and then encodes and compresses into variable length codes (VLC).

ChromotionHD 2.0 has a high performance MPEG-2 decoding engine that reverses the encoding process, changing the compressed MPEG2-HD data bit-stream back to its original format. Decoding starts with parsing the bit-stream to detect the proper code words and translating them into relevant data in a process called variable length decoding (VLD). The next steps are de-quantization (iDCT) to reverse the DCT process, and motion compensation (MC) which is the most time consuming stage. Motion compensation uses predictive coding and motion vectors (based on the VLD and iDCT block outputs) to construct the final decoded video image for display.

The underlying architecture of the MPEG2-HD engine is based on the Microsoft DirectX® Video Acceleration (DXVA) standard, allowing it to work seamlessly with third party MPEG-2 software decoders supporting the interface. This design allows the GPU to handle video acceleration for the most common software video applications available for the Microsoft Windows environment.

ChromotionHD 2.0 for SDTV and HDTV

SDTV/HDTV Formats

ChromotionHD 2.0 supports all 18 DTV ATSC and DVB formats up to 1080p resolution.

Vertical Lines	Pixels	Aspect Ratio	Picture Rate
1080	1920	16:9	60i, 30p, 24p
720	1280	16:9	60i, 30p, 24p
480	704	16:9 and 4:3	60p, 60i, 30p, 24p
480	640	4:3	60p, 60i, 30p, 24p

Table 3: ChromotionHD 2.0 SD and HD TV support

Conclusion

As the transition from standard definition to high definition video content follows consumer trends towards high quality HD entertainment, the need to support this incremental shift has placed large constraints on previous generation hardware platforms. In the past, software video processing based on CPU power was sufficient to provide smooth and vivid SD video playback. The introduction of new HD codecs, such as VC-1 and H.264, has brought a new level of complexity to graphics hardware which now needs to provide an increased amount of data processing and computational capabilities, as well as to support the content protection needs of HD content providers.

S3 Graphics Chrome 400 Series graphics processors have built-in hardware that offloads the CPU and provides system efficiency and low power consumption for HD support in notebook, desktop, and CE devices. Content protection through HDCP (High-bandwidth Digital Content Protection) is also supported inside the GPU for HD digital displays using HDMI or DisplayPort interfaces. In addition, the GPU has built-in HD audio and video synchronization logic to provide a complete HD A/V stream.

The feature rich ChromotionHD 2.0 video technology enables cinematic, high quality video playback over network broadcasts, Blu-ray Disc, HD-DVD discs, streaming videos, and other forms of multimedia content delivery. With HD and SD support in all current and future GPUs, S3 Graphics has truly enabled a broad spectrum of support for playback of consumer video content, adding value to the HD experience with an enhanced and proprietary video processing engine and supporting software.