
# CHROMOTION HD™ 2.0

## *for Chrome 400/500 Series Graphics Processors*

***A S3 Graphics White Paper***


*www.s3graphics.com*

*WP019-B.0*
*11/18/2008*

# Revision History

| | | | |
|---|---|---|---|
| B.0 | 11/18/2008 | Added Chrome 500 Series GPU Support | BT/KG |
| A.0 | 10/05/2007 | Initial Version | BT/KG |


## Introduction

This document describes the next generation ChromotionHD™ 2.0 video engine integrated into the S3 Graphics' Chrome™ 400/500 Series graphics processors to provide high quality high-definition (HD) 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™ 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, VC-1, and DTV Video-On-Demand (VOD) broadcast. With support for various HD formats and for digital ATSC (Advanced Television Systems Committee) and DVB (Digital Video Broadcasting) television configurations, the Chrome 400/500 Series GPUs are capable of playing back the latest in high resolution home movies and streamed DTV VOD 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.

To retain backwards compatibility with existing video formats, the ChromotionHD engine ensures the highest quality video playback of SD content using built-in hardware filters and scalers to detect incoming video quality and bitrates to dynamically adjust video processing for the best viewing experience. Low quality standard definition (SD) video or incoming MPEG-2 VOD streams can automatically be turned into full HD resolution with high-quality color and video fidelity. This unique technology brings older movie formats like DVD to life for a smooth, crisp, clear, and vivid movie experience.

Another benefit of the video engine includes its ability to work seamlessly with the GPU's internal display engines to provide HD display connectivity up to 1080p. A digital HD monitor or digital HDTV can be securely connected through the digital interface using an HDCP (High-bandwidth Digital Content Protection) enabled HDMI™, DVI, or DisplayPort connection for an immersive theatrical experience.

## ChromotionHD 2.0 Highlights

Features available with S3 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)
- **Dual-Stream Blu-ray Support**
  - A highly optimized decoding and post processing video and display pipeline allows simultaneous acceleration of multiple video streams.
  - Dual-stream Picture-in-Picture (PiP) to watch bonus footage and commentaries
- **HDMI / DVI / DisplayPort with HDCP Support**
  - An integrated HDCP ROM and decode logic supports HD digital content protection in CE and PC devices.
  - The GPU automatically synchronizes HD video and audio (A/V) signals internally, compliant with HDMI and DisplayPort specifications.
- **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 HD 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 and Expansion

- Provides a wide range of scaling and expansion capabilities for digital displays.

## ChromoVision Modes with Non-Linear Scaling (Enhanced Zoom)

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

## ChromoColor

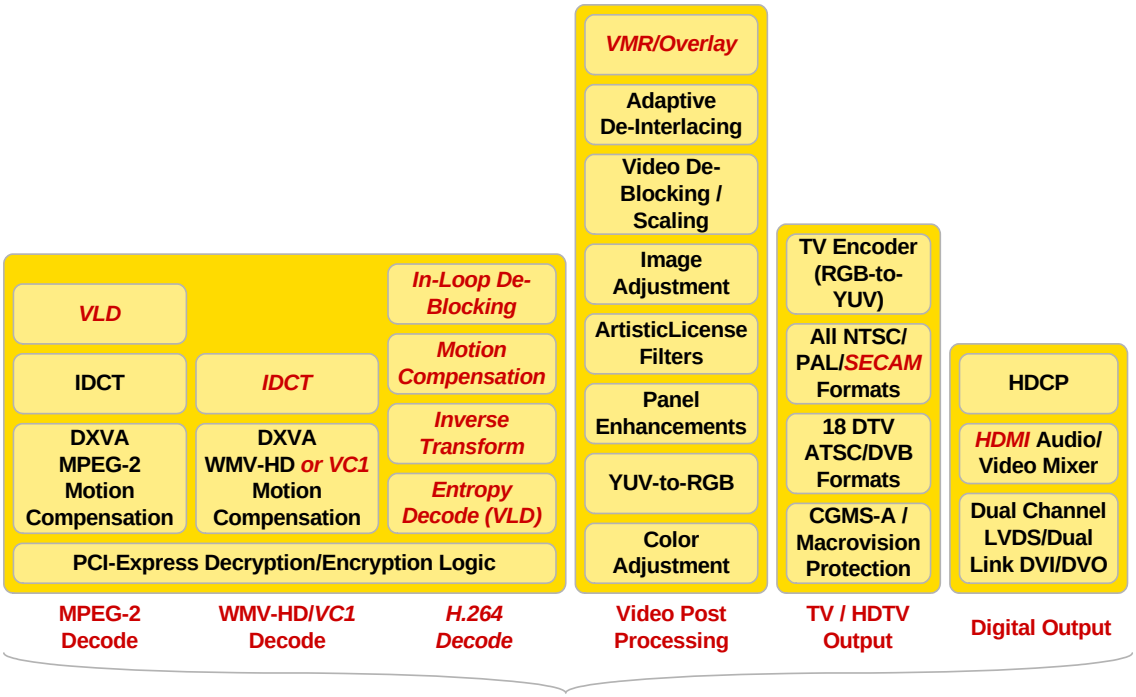
- Provides controls to adjust video image quality for brightness, contrast, hue, and saturation.

## 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.




*(Red italic text indicates additional features found in Chromotion HD 2.0)*

**Figure 1: Key Components of the ChromotionHD 2.0 Video Engine**

# ChromotionHD 2.0

ChromotionHD 2.0 includes H.264, MPEG-2 VLD, and VC1 decoding capabilities 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 400/500 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

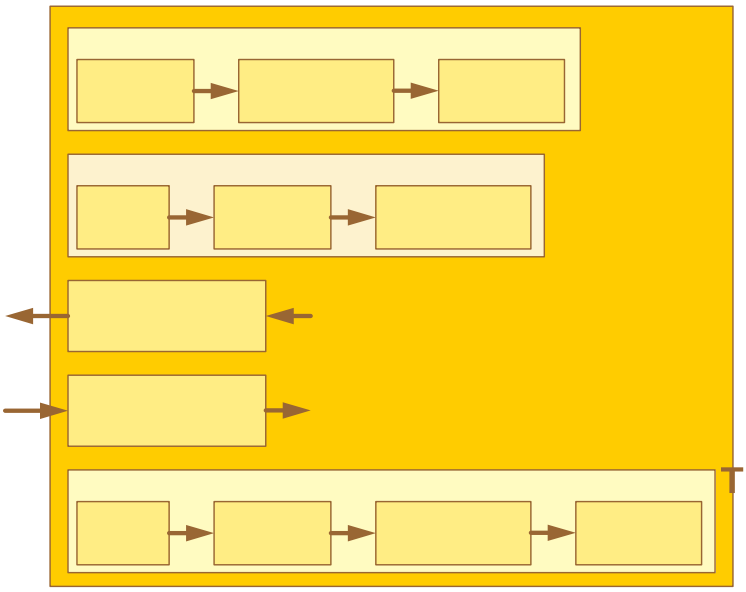



Figure 2: ChromotionHD 2.0 Decode Process Support

- **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 Advanced Video Decoding

H.264, also known as MPEG-4 AVC (Advanced Video Coding), is a video compression standard that offers significantly greater compression ratios (~2 - 3x improvement) than its predecessor MPEG-2, which is considered too inefficient and too bandwidth-limited to support multiple HD modes and video streams. 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. Many of the more powerful CPUs on the market today do not have enough computing power to perform all the necessary functions to decode high bitrate HD content in a timely manner. When used to decode, CPUs provide video playback that is jerky and has missing video frames, if the processing power required exceeds the functional CPU power available. S3 Graphics Chrome 400/500 Series high performance and cost effective GPUs have implemented the necessary hardware video blocks for HD playback, allowing a Chrome 400/500 Series equipped system to minimize CPU loading and provide the best picture quality for decoding and viewing HD content, while significantly saving total system power.

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 Blu-ray discs. Because of the benefits of and industry support for H.264, it has become 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 is possible on a wide range of PC systems running Microsoft® Windows Vista®. The system performance advantages, when incorporating a S3 Graphics Chrome 400/500 Series processor with a 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 SFF PCs. Table 1 shows a comparison between the capabilities of Blu-ray and DVD discs.

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

**Table 1: Blu-ray Disc and DVD 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.

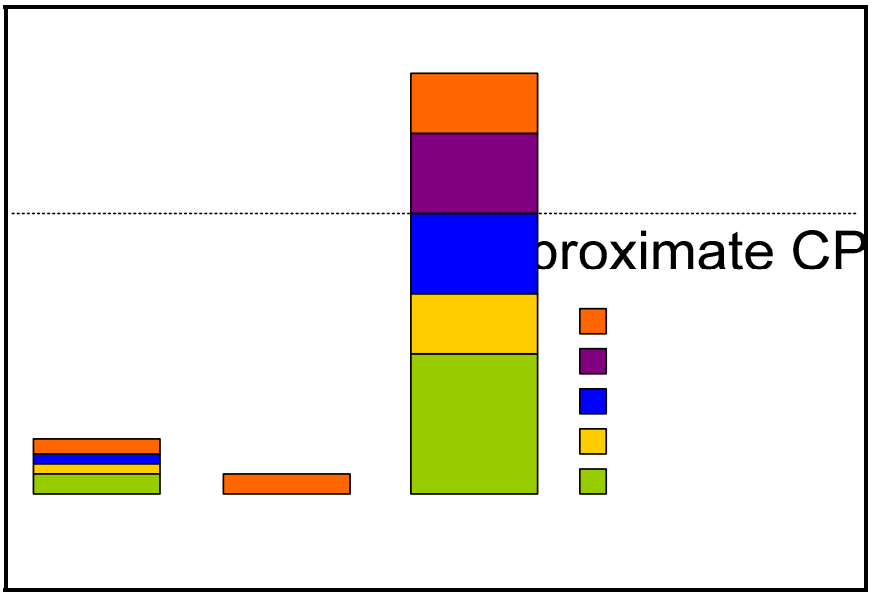



**Figure 3: H.264 Decode by Entry-Level CPU**

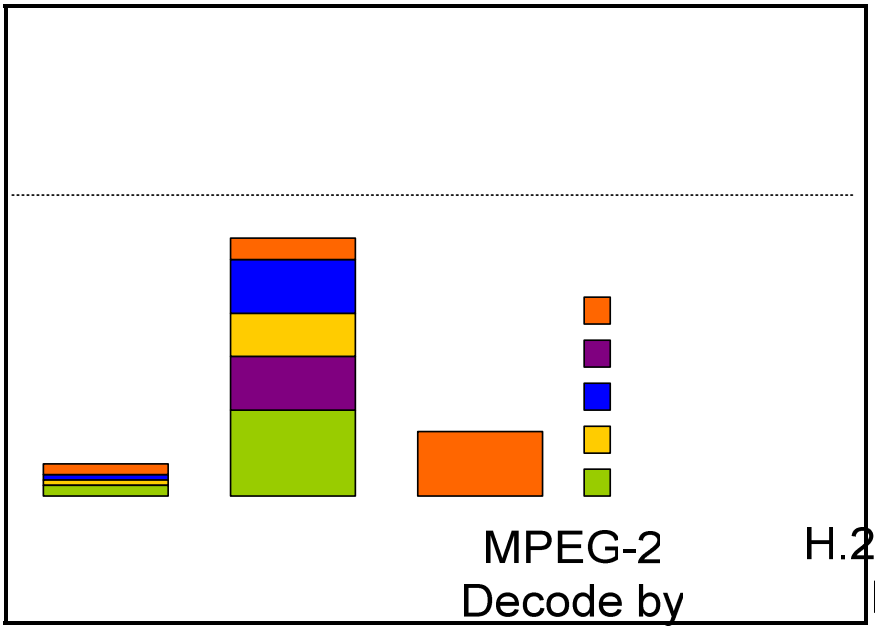



**Figure 4: H.264 Decode by Video Processor in GPU**

When the H.264 decoding is executed by the CPU, the process will exceed the maximum processing power and capability of today's entry-level CPUs (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 on PCs.

Approximate CPU Utilization for
and some

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

- Enhanced motion predictability (MC) support which uses 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 the 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.

## 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 entry-level CPUs 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 dramatically reduced but also greater quality video playback is provided at high resolutions. The ChromotionHD 2.0 video engine 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 starting with 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, the Blu-ray Disc Association has 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 400/500 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<br>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)<br>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)<br>720 x 576 @ 25 Hz (PAL-SD) |
| | **L2** | 20 Mbps | 720 x 480 @ 60 Hz (480p)<br>1280 x 720 @ 30 Hz (720p) |
| | **L3** | 45 Mbps | 1920 x 1080 @ 24 Hz (1080p)<br>1920 x 1080 @ 30 Hz (1080i)<br>1280 x 720 @ 60 Hz (720p) |
| | **L4** | 135 Mbps | 1920 x 1080 @ 60 Hz (1080p)<br>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 interfame 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.

# Conclusion

The market transition to high quality HD entertainment has created large performance and computational constraints on previous generation hardware platforms that can be mitigated by GPU products from S3 Graphics. In the past, software video processing based on CPU power was sufficient to provide smooth and vivid SD-only video playback. Today's HD codecs for Blu-ray movies or HD games has brought a new level of complexity. Today's graphics hardware must support increasing amounts of data processing and computational power, and must provide IP/content protection needs. S3 Graphics hardware helps create a secure delivery ecosystem from HD content providers to end users.

In addition, S3 Graphics Chrome 400/500 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. The GPUs also have 8 channels of high fidelity Dolby® 7.1 digital surround sound and HD audio and video synchronization logic to provide a complete, seamless HD A/V stream.

The feature rich ChromotionHD 2.0 video technology raises the home entertainment bar and enables cinematic, high quality video playback over network broadcasts, Blu-ray Disc, streaming videos, and other forms of multimedia content delivery. With Hi-Def™ 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.