



ATI Theater™ 650 Pro: Bringing TV to the PC

Perfecting Analog and Digital TV Worldwide



Introduction: A Media PC Revolution

After years of build-up, the media PC revolution has begun. Driven by such trends as the worldwide migration to digital over-the-air television broadcasting and the imminent arrival of next-generation HD optical discs, consumers are demanding solutions which deliver the immersive experiences promised by these new technologies. The media PC in particular is seen as a key enabler and is well-placed to become the hub of the home entertainment network. Key to this vision is the delivery of high quality television on the PC. From using your computer as a television to recording TV shows, the idea of turning a personal computer into an intelligent TV watching/recording device is attracting millions of users worldwide.

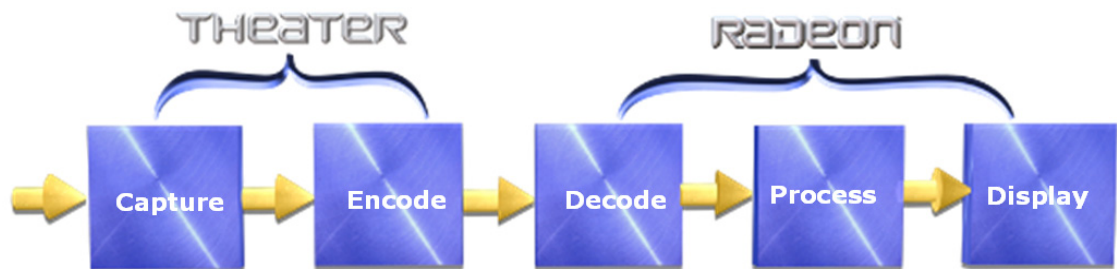


Fig.1 - The video pipeline and the role of the video capture card

Delivering broadcast television signals to the viewer, regardless of the platform, involves the steps outlined in the diagram above (the “video pipeline”), progressing from image capture through to eventual display. To achieve high quality video, the sequential nature of the video pipeline requires that high quality be maintained throughout every stage of the pipeline (for a comprehensive review of the entire video pipeline, refer to the whitepaper “Avivo and the Video Pipeline”). The purpose of the present whitepaper is to highlight some of the key requirements of a high quality video capture/encode solution.

Video Capture & Encode Challenges

A great video experience starts with high-quality video capture. The key processing steps involved in capturing and encoding video are as follows:

- TV tuning / video input
- Intermediate frequency (IF) demodulation
- Video decoding
- Video preprocessing / noise reduction
- MPEG encoding
- Bridge to system

Let's now examine each of these processing stages in turn and explore the key issues and challenges for producing high-quality video

TV Tuning / Video Input

Capturing analog and/or digital video signals (and in the case of analog signals, converting them to digital representations) is the first step required to view video on a PC. This is done through a video input device or a TV tuner. In the case of a TV tuner, the hardware must be tuned to a desired frequency to receive a desired television station.

Analog television is today the predominant broadcast method, for which there are three major transmission standards worldwide:

- NTSC (National Television System Committee)
 - used in North America, Japan, Korea, Taiwan, and parts of Latin America
- PAL (Phase Alternation Line)
 - used in most parts of Europe (France is the notable exception)
- SECAM (Sequential Color with Memory)
 - used in France, Russia, and parts of the Middle East

Increasingly, however, digital television is becoming more prevalent, driven in many cases by government-mandated deadlines for accommodation/switchover to high-definition digital broadcast. For instance, in the US all new TV devices are required to have the capability of receiving broadcast digital signals by March 1, 2007. Major television digital transmission standards worldwide are:

- ATSC (Advanced Television System Committee)
 - used in North America, Japan, Korea, Taiwan, and parts of Latin America
- DVB-T (Digital Video Broadcasting - Terrestrial)
 - used in Europe
- ISDB-T (Integrated Services Digital Broadcasting - Terrestrial)
 - used in Japan

To accommodate the many broadcast standards and variants thereof, TV manufacturers typically require multiple designs with different receivers for each standard, increasing the cost and complexity of multi-standard TV receivers. Increasingly, manufacturers are choosing so-called hybrid tuners (tuners which support both analog and digital formats in the same system) in an effort to reduce costs and improve system flexibility. The actual TV tuner, the 'can' or 'chip' used in a TV tuner card, can greatly affect the resultant video quality.

IF Demodulation

Once a particular TV channel frequency is tuned, the signal must be converted from radio frequency to an intermediate frequency (IF) and then demodulated down to baseband frequency. A high quality TV reception device should pay special attention to the IF demodulation stage of the pipeline, as it will greatly affect the quality of the resultant video.

A high-quality IF demodulator should use digital processing rather than analog. Since PCs are inherently digital systems, the analog television signal must be converted into digital form. Doing this as early in the pipeline as possible reduces chances of signal degradation and allows greater control over the quality of the video. Performing IF demodulation digitally therefore has advantages over low-end solutions which utilize TV tuner modules that have built-in analog IF demodulation (mainly to save cost) and therefore delay the analog-to-digital (A/D) conversion process to the (downstream) video decoding stage. A good digital IF demodulator will ensure that the A/D conversion and demodulation operations are performed at high resolution to maintain a high level of accuracy and robustness of the video signal.

Video Decoding

After the IF demodulation stage, baseband video must be decoded from its broadcast format to a standard format that is recognized by an MPEG encoder. This is one of the most critical stages in the video pipeline – a low quality video decoder will irreparably destroy the video quality. Key requirements for a high quality video decoder include:


- Internal data paths should be sufficiently wide to maintain signal resolution and detail throughout
- High quality comb filtering for precise separation of video components from the composite video stream without artifacts

With respect to the last point, comb filtering is an integral part of the decoding process for composite analog video and is required for separation of the luminance (Y) and chrominance (C) components of the video signal. Note that video captured from an S-Video or Component Video source does not require comb filtering as the Y and C components are already separate.

High quality video decoders have the ability to apply either 2D (two-dimensional, e.g., within a single field/frame) or 3D (three-dimensional, e.g., across multiple fields/frames) filtering to the video stream depending on whether motion exists within the frame.

When there is significant motion in the frame, a multiple-line (3-5 lines are typical) 2D comb filter should be used. The filter in this case looks only at data within a single frame of video to determine the best representation of the content and ensure sharp images without motion artifacts.

If little or no motion is detected in the content, a 3D comb filter will provide much better results by utilizing data from adjacent frames as well as intra-frame data. Still or slow-moving scenes with details such as parallel lines will look much sharper and have far fewer flickering artifacts than if only a 2D comb filter were applied. Sometimes in a product feature specification a manufacturer will advertise a '3-line digital comb filter' - this should not be confused with a 3D filter, as it is in fact a 2D comb filter and will therefore not provide optimal quality for still images.



Given that quality 2D and 3D filters exist within the decoder, the key to ensuring high quality comb filtering is the ability of the processor to detect the presence of motion and therefore select in an intelligent way the appropriate filtering technique – 2D, 3D, or combinations thereof. Advanced chips employ per-pixel adaptive algorithms which will ensure that the best method is used for each and every pixel within a given frame. This will result in the sharpest possible video quality, with the best color representation.

Video Preprocessing / Noise Reduction

Most analog video available in the home contains a significant amount of noise. Even modern digital television that is received from a digital set-top box and imported to the PC over an S-Video connection will contain many visual imperfections. Thus, before video is compressed on the user's PC, noise reduction processing should be employed to clean up as much of this noise as possible. This is a delicate and often sophisticated process – applying too aggressive an algorithm can result in loss of detail and image smearing, whereas too mild an algorithm may yield little to no perceived quality improvements. Many algorithms can be adjusted from high (aggressive) to low (mild) noise reduction settings and can therefore be tuned to best match the requirements of the source content at hand.

A good de-noise algorithm not only provides better video quality but also improves video encoder compression efficiency. Video encoders seek to identify redundancies in an image or video stream and discard extraneous data so as to minimize the amount of data which must be encoded and stored. Since noise is a random artifact, its presence can trick the encoder into thinking that what it is seeing is unique and therefore important for preservation, resulting in reduced compression efficiency. Good noise reduction techniques prior to video encoding will result in more highly compressed bit streams, reducing data storage requirements and effectively increasing disk storage capacity.


Video Encoding

MPEG-2 is the video compression standard that is used on DVD discs and home personal video recorder devices. This standardization makes it the compression algorithm of choice for video capture and playback on the PC. Video recorded directly into MPEG-2 can be immediately exported to a DVD or shared across networks.

MPEG-2 encoding is very computationally intensive and requires advanced motion prediction algorithms in order to compress raw video coming in at 160Mbps (megabits per second) bit-rates down to 4-8Mbps, while maintaining the same resolution and minimizing visible artifacts. Although it is possible to achieve MPEG-2 compression purely in software, the complexity of the task consumes significant CPU resources. This can be a problem when the CPU is simultaneously required to perform other (perhaps higher priority) tasks, and the result can be dropped frames or other undesirable video quality artifacts. High system power consumption is another effect of having the CPU heavily and continuously occupied with video encoding.

Bridge to System - Moving Video to Host Storage (Hard Disk/RAM)

Once video is compressed to MPEG-2 format it must be written to disk, either a local hard disk, a local optical disk or a network disk. Current PC architecture requires that video data



from add-in TV tuner boards be sent across either internal buses such as PCI or PCI Express, or over USB to be written to disk or host buffer. PCI Express is the bus of choice due to its lower cost and much higher bandwidth relative to PCI or USB. It is extremely important that the bus and disk/buffer have sufficient bandwidth to keep up with the streaming video, otherwise frame drops may occur and degrade the perceived video quality.

It is clear from the above that there are a number of challenges to implementing high quality video capture on a PC platform. In the following section, we shall introduce the new Theater 650 Pro integrated circuit and explore how this product addresses the challenges.

Theater 650 Pro and the ATI Avivo™ advantage for video capture

The Theater 650 Pro is ATI's next generation solution for unprecedented home-theater quality TV on your PC. As a successor to the highly successful Theater 550 Pro and the latest addition to ATI's exclusive Avivo™ platform, the Theater 650 Pro delivers superior features and performance for video capture and digital encoding, at unparalleled levels of integration.



As a leading supplier of video processing components to both PC and consumer electronics markets, ATI offers a unique combination of capabilities and expertise unmatched in the industry. For the Theater 650 Pro this translates into a comprehensive and tightly-integrated feature set encompassing the entire front end of the video pipeline:

- IF demodulation
- Analog and digital video capture and encode
- Complete worldwide TV standards support
- Sophisticated video preprocessing
- MPEG encoding
- Advanced bus interfaces

We'll now examine in more detail some of the key features and benefits of the Theater 650 Pro and see how they contribute to a superior video experience for media PC applications.

Worldwide support for both analog and digital broadcast formats

The Theater 650 Pro supports all major analog television standards (NTSC/PAL/SECAM) and both ATSC and DVB-T digital HD broadcast standards, and is thus optimized to support the creation of hybrid tuner solutions using both an analog and a digital tuner on a single board.

Intermediate-Frequency (IF) Demodulation

Digital IF demodulation of standard-definition (NTSC/PAL/SECAM) analog signals is carried out within the Theater 650 Pro chip, which as described earlier provides advantages over alternative solutions which implement IF demodulation within the tuner. The Theater 650 Pro is able to separate audio and video (A/V) signals in the digital domain with near-perfect precision with only a single analog-to-digital converter (ADC), virtually eliminating any cross-talk (undesirable interference) between A/V carriers.

For capture of digital HD (ATSC and DVB-T) signal formats, the Theater 650 Pro can be seamlessly paired with external tuner/demodulator solutions such as the ATI Theater 314, recently tapped as the best performing ATSC demodulator in FCC testing.

High-Resolution Video Decoder with 12-bit ADC

Translating the demodulated analog broadcast signal into the digital realm is the job of the video decoder. Theater 650 Pro integrates high performance analog-to-digital converters (ADCs) with 12-bit per channel resolution, which offers precise video capture with more realistic color and without the visible banding or color artifacts associated with the lower-resolution 8- or 10-bit ADCs employed in competing solutions.

Advanced Motion-Adaptive 3D Comb Filter

The Theater 650 Pro employs a high-performance 3D motion-adaptive comb filter for separating the luma (Y) and chroma (C) components from a composite video stream, delivering quality levels typically found only in high-end television receivers. The filter combines a 5-line 2D comb filter, a temporal (3D) frame comb filter, a comb filter blender, and a pixel-based motion detection engine for exceptional image sharpness and detail for both still and moving images.

The key to the exceptional performance of the Theater 650 filter is a sophisticated algorithm for detecting, on a per-pixel basis, the presence of motion within the scene and adjusting the filtering technique accordingly. When no motion is detected between two adjacent frames, the filter will engage both the 2D and frame comb filters, utilizing the resultant inter- and intra-frame data to provide sharp images with minimal flicker artifacts. When motion is detected, the 2D filter alone is used to avoid motion artifacts such as blurring. In cases where motion detection is less reliable (such as when noise is present in the video) both the 2D and frame comb filters will be engaged and their outputs blended, resulting in an output image that is more pleasing than if either 2D or 3D filtering were applied alone.

Fig.2 below illustrates the performance advantage of the Theater 650 Pro 3D filtering relative to competing solutions. Note that with Theater 650 Pro fine detail is preserved resulting in a clearer, sharper image.

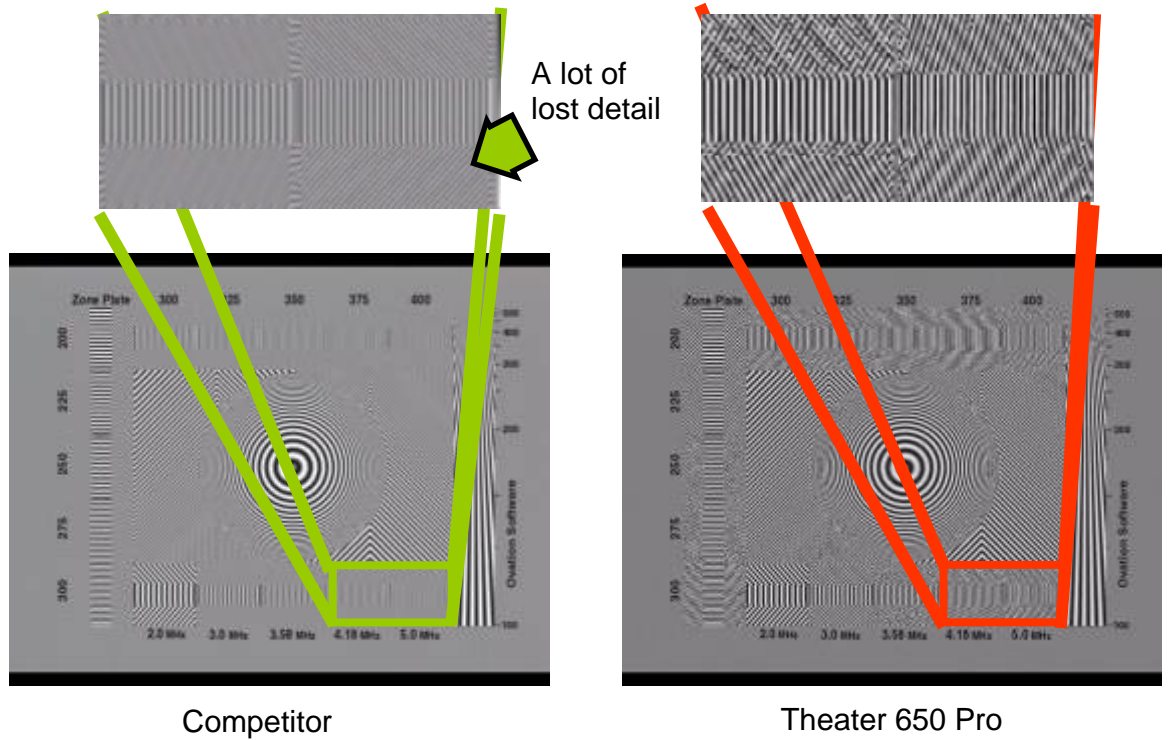


Fig.2 – Comparative 3D comb filter performance on reference test pattern

Automatic Gain Control (AGC)

The purpose of AGC is to smooth out the incoming video in case there are fluctuations in signal strength, brightness, or intensity of an image. When an AGC is implemented properly, the user should not notice any major changes in brightness when changing channels or when there is a sudden change in the color on the screen. The Theater 650 Pro employs an advanced AGC algorithm which provides superior signal control relative to competitive solutions resulting in clearer more vibrant images, as illustrated in Fig.3 below.

**Competitor****Theater 650 Pro****Fig.3 – AGC performance for Theater 650 Pro vs. competition**

Hardware-based MPEG-2 Encoding

The Theater 650 Pro performs full on-chip MPEG-2 encoding of both video and audio in dedicated hardware, significantly reducing the impact of this computationally-intensive operation on the system CPU. Also, by combining the audio encoding process on the same hardware as the video, perfect synchronization is achieved on every recording.

Noise Reduction

Noise in the video signal, aside from impacting image quality, has the effect of reducing the coding efficiency of the MPEG encoder. The Theater 650 Pro contains dedicated hardware to identify and minimize noise prior to encode, and as a result will effectively increase disk storage density by up to 20% or more. In practical terms this means that, with noise reduction enabled, 2 hours of MPEG-2 content (i.e., DVD movie) can be stored as opposed to approximately 1 hr 40 minutes of content if no noise reduction is applied prior to encoding (see Fig.4 below).

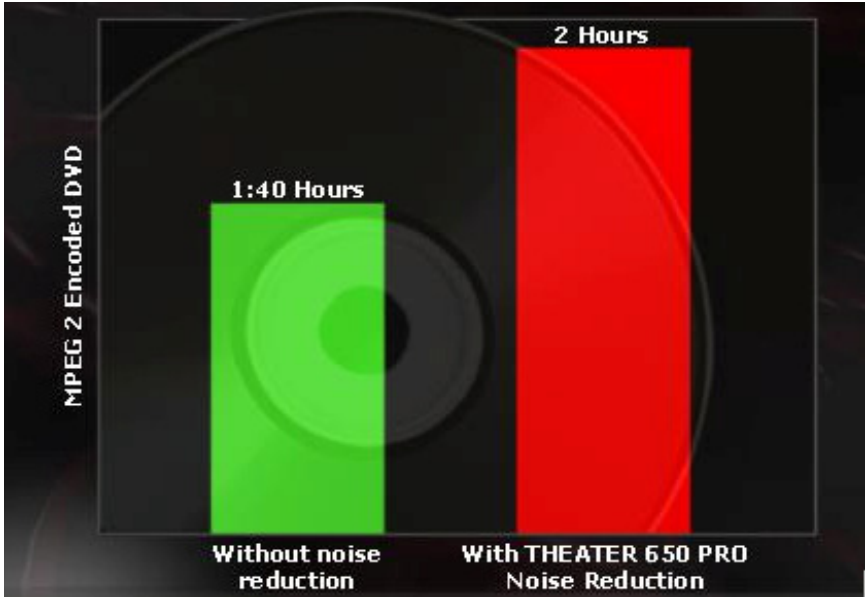


Fig.4 – MPEG-2 Storage Density with and without noise reduction

Conclusion

The growing popularity of media PCs as a platform for TV viewing is creating a demand for better video processing and a more satisfying TV experience overall. As we have shown, PC manufacturers confront numerous problems due to a multitude of TV standards worldwide (both analog and digital), stiff technical challenges in signal tuning, demodulation, and decoding, and the often conflicting requirements for maintaining high signal quality throughout the pipeline at reasonable cost.

Leveraging the extensive experience gained by ATI in both the PC and consumer electronics industries, the Theater 650 Pro provides the solutions manufacturers need for bringing high quality TV to the PC. Industry-leading video quality is achieved with innovations in motion-adaptive 3D comb filtering, digital IF demodulation, noise reduction, and high-resolution video decoding. Comprehensive support for hybrid tuners and worldwide TV standards provides manufacturers and users maximum flexibility and cost savings. Additional value is provided with features such as PCI Express bus and Microsoft Windows Vista Premium logo support.

As video becomes an ever more important part of the PC experience, high-quality processing throughout the video pipeline becomes critical. The Theater 650 Pro from ATI is engineered to meet this challenge and ensures a high-fidelity TV experience on the PC.

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