



## White Paper | AMD HD3D Pro Technology: Stereoscopic 3D For Professionals

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## INTRODUCTION

### What is Stereoscopic 3D?

Stereoscopic 3D (referred to hereafter as 'Stereo 3D') is the term given to the visualization of pairs of images intended to give the human user an enhanced sense of depth in the content they are viewing or interacting with.

### About this document

This document seeks to inform the reader of the current state of Stereo 3D delivery from professional graphics accelerators and specifically of the capabilities of AMD HD3D Pro technology available with AMD FirePro™ graphics accelerators. Broadly, the document is broken down into three sections:

- An introduction to some Stereo 3D key terms and technologies. This includes a review of the different stages involved in Stereo 3D delivery that can help the reader better understand how AMD HD3D Pro technology ultimately helps to deliver a complete solution.
- A review of new Stereo 3D delivery approaches, including LCD technology and how it plays into Stereo 3D delivery. This will help explain some aspects of LCD-based Stereo 3D that are perhaps poorly understood today. In particular we contrast proprietary approaches with the emerging standards-based approaches that are preferable in many ways.
- Lastly, we will look specifically at how AMD FirePro graphics solutions enable Stereo 3D today, within the context of the previously discussed topics.

Please note that beyond a clarification of the terms used in this technology, a detailed review of stereo technology is not provided here. If the reader seeks an introduction to stereoscopy and its history, many resources (including <http://en.wikipedia.org/wiki/Stereoscopy> and <http://en.wikipedia.org/wiki/Stereopsis> at time of writing) exist to give details on the foundations of the concepts and applications.

### Professional Graphics applications of Stereo 3D

Stereo 3D is a technique highly valued in a number of professional use cases, where the additional information conveyed by stereo viewing enhances productivity and/or enables capabilities that are not possible otherwise. Some examples include:

- Computer Aided Design: many CAD workflows can benefit from enhanced depth perception afforded by Stereo 3D. In particular cable and/or pipe routing (in buildings, aircraft, etc.), object depth is a critical cue for the workflow.
- Digital Content Creation: clearly the highest profile area for Stereo 3D at the moment is the explosion of Stereo 3D content created for movie theaters and increasingly home consumption. This leads to a need for Stereo 3D capability throughout the production and post-production pipelines.
- Data visualization: the visualization of abstract or real-world data can often benefit from Stereo 3D. Examples span from visualization of financial data to geospatial data (oil and gas exploration, national intelligence analysis).
- Virtual reality: environments for providing immersive training programs gain a significant step up in realism by providing extra information via Stereo 3D.
- Molecular engineering: the visualization and comprehension by molecular scientists, particularly in the pharmaceutical industry, of complex molecules is critical to enhancing the productivity of workers in this field.

## STEREOGRAPHIC 3D TERMS AND TECHNOLOGIES

### Active and Passive Stereo 3D

These two terms have a history that is valuable to understand as we look at different stereo approaches. The term *active stereo* comes from the approach that was dominant for a number of years, and is still very much in use today. It comes from the fact that a pair of glasses (with a liquid crystal film in front of each eye) *actively* changes state to present the correct left and right images to the eye. This approach requires coordination between the source of Stereo 3D, the display of the stereo frames (done in a *frame-sequential* mode typically at 120Hz for a resulting 60Hz-per-eye Stereo 3D effect) and a pair of liquid crystal shutter glasses.

The synchronization of the glasses to the sequential left and right eye frames is typically accomplished using a VESA-standard 3-pin stereo connector on a GPU that connects either directly to the glasses or to an emitter that wirelessly communicates to the glasses.

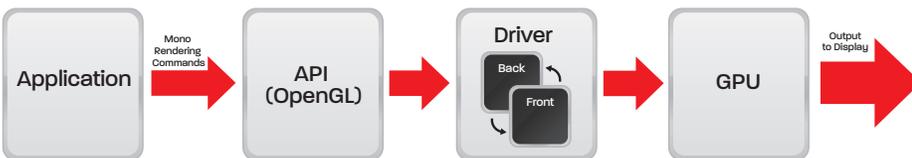
Passive Stereo 3D refers to the use of glasses that do not have any active components (i.e. they do not change state every frame). These filter light to ensure that the correct eye sees the correct left or right image. Filtering is typically done with light polarization, though color (light wavelength) filtering is sometimes employed.

There also exist various approaches to glasses-less Stereo 3D presentation, known as auto-stereoscopy, and this will be discussed later in this document.

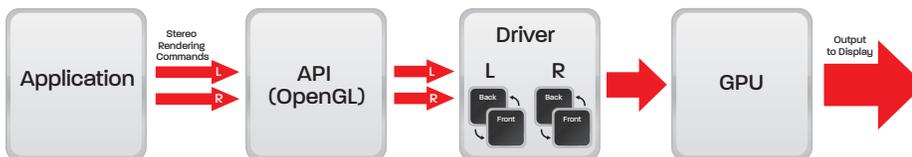
### Quad-buffer Stereo

Quad-buffer stereo is a term that applies to the generation of left/right pairs of images, and is most commonly associated with the OpenGL graphics API, though AMD now supports quad-buffer stereo capability with Microsoft® DirectX® as well.

In regular, monoscopic, rendering a typical approach taken is double-buffering. Here, the GPU renders content to one place in memory (called a buffer). During this time, a second buffer is feeding the actual display output of the GPU, driving the actual display. This is illustrated in the diagram below. When the rendering of one frame is complete the buffers are swapped and display proceeds of the rendered image (buffer).



Quad-buffering is simply the extension of this principle; the difference being that two images (one left, one right) are being rendered for every frame. This means that there are a total of four buffers involved. When it comes time to swap the buffers, both the left and the right are swapped to ensure that the stereo images represent the same frame (i.e. the same moment in rendered time), as illustrated below.



## Frame-Doubling and Frame-Multiplying

While typical Stereo 3D rendering involves rendering and displaying at 120Hz, some devices, notably projectors, are able to take an input of a lower frequency and then take care of repeatedly alternating the images for each eye in order to get to a 120Hz (or higher) refresh rate.

This approach is taken for example in the projection of Stereo 3D content in movie theaters. Here, movie content has been generated at 24Hz for each eye. The projection system actually displays each frame to each eye 3 times in a system known as *triple-flashing*. Thus we end up with 24Hz x 2 eyes x 3 flashes = 144Hz.

Other projectors used in visualization and cave environments also have this capacity to take 60Hz input (30Hz for each eye) and double-flash each eye. This makes it possible to allow for a lower rendering rate, or to accommodate transmission over slower interfaces (e.g. HDMI, single-link DVI).

## Stages of Stereo 3D presentation

A great deal of innovation in display technologies related to Stereo 3D has taken place in the last few years. The re-use of existing terms and the introduction of conversions for formats and approaches have led to some confusion of how terms in the different stages are used. Particularly with the variety of display types, the image pairs may be prepared in some format but the display may treat and present them differently, hence the need to separate a discussion of these stages:

- **Source:** Stereo 3D content creation or playback
- **Preparation and Transmission:** how left and right images are prepared for display and relayed to the display device
- **Presentation:** the actual display of left image and right image to the corresponding eyes, usually involving the use of stereo glasses



Options for each of the stages include:

### Source

The generation of left and right images ('image pairs') is the key first step in experiencing Stereo 3D. Broadly speaking, there are two approaches to generating the image pairs. *Native Stereo 3D* is the generation by an application (either 3D rendering, or video playback of Stereo 3D content), while *Stereo 3D conversion* is the creation, using additional software, of Stereo image pairs using a monoscopic source (again, 3D rendering or video).

Natively Stereo 3D-aware applications generate stereo pairs directly using programming hooks exposed by graphics application programming interfaces (APIs). This is the case for virtually all professional applications today (e.g. Autodesk® Maya®). The programming hooks include:

- Quad-Buffer Stereo natively exposed in OpenGL (as supported on AMD FirePro graphics accelerators detailed later)
- AMD's Quad-Buffer Stereo API/extension for Microsoft® DirectX®.

Applications that are not written to natively support Stereo 3D can deliver stereo image pairs via the use of stereo conversion software. This approach is typically used for games and conversion of mono video to stereo, but is not typical for professional graphics applications; applications that benefit from Stereo 3D typically implement the native approach outlined above.

## Preparation and Transmission

Once Stereo 3D image pairs have been created by the source, they have to be prepared for the stereo display device that is being used by the user and transmitted to that display over a display interface in a format that the display can interpret and use. Where active shutter glasses are being used, a synchronization signal for these is also generated and transmitted.

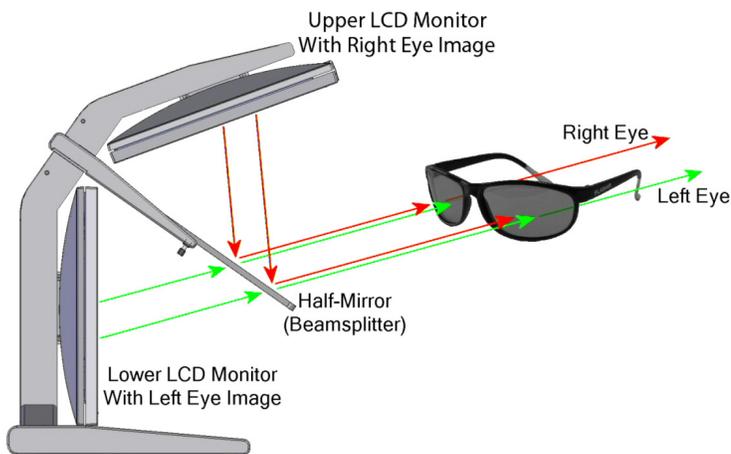
The main approaches for displays, and the consequent preparation required for them are as follows:

**Frame Sequential**, typically used with displays using active shutter glasses. This approach is sometimes referred to as 'page flipped'. Typical target display devices include:

- 120Hz (~96Hz-120Hz) projectors (i.e. 48-60Hz for each eye)
- 60Hz frame-doubling projectors (i.e. 30Hz for each eye, doubled to 60Hz by the projector)
- 120Hz CRT displays
- Certain 120Hz LCD displays

**Dual-Display**, typically with **passive** displays and **polarized glasses**. Typical Displays include:

- Any two projectors with filters (e.g. RealD LP Filter system)
- Dual LCD displays from Planar, RedRover
  - Redrover: [http://redroverinfo.com/html/col\\_01.html](http://redroverinfo.com/html/col_01.html)
  - Planar: <http://www.planar3d.com>



Operation of Planar StereoMirror displays (courtesy of Planar Systems Inc.)

**Interleaved** formats. A number of displays expect stereo image pairs to be combined into a single image that is then 'decoded' by the display and presented. This simplifies the transmission of the image pairs (there is no need for doubling of frame rate on the interface, nor for using two interfaces) but does result in a loss of spatial resolution of the image. The encoding of the image pairs is done by interleaving the left and right frames on a line-by-line or column-by-column basis. Alternately, it can be done using a checkerboard pattern.

There are a wide variety of displays that expect this interleaving, including auto-stereoscopic panels. The column interleaving mode is convenient as some auto-stereoscopic panels (such as those developed by Sharp and others) use a parallax barrier to ensure that alternating columns are viewed by the left and right eyes. Content that is column-interleaved can thus be presented without any decoding.

**Native interfaces:** HDMI 1.4a and DisplayPort display interfaces natively expose the ability to transmit stereo images using schemes described in their specifications. The schemes used include frame-sequential and packed (left/right in top/bottom or left/right of a frame) though importantly, this is hidden from the user as the interfaces allow for plug-and-play capability. It is then up to the display device to decode the image pairs and present them according to the presentation technology they implement (active, passive, auto-stereoscopic).

## Presentation

The presentation of the image pairs is the responsibility of the display device. Again, there has been a great deal of innovation in how this is achieved, but the main approaches are as follows:

**Active**, frame sequential, display with shutter glasses. As discussed earlier, the display presents left and right eyes in sequence and shutter glasses are synchronized with that display.

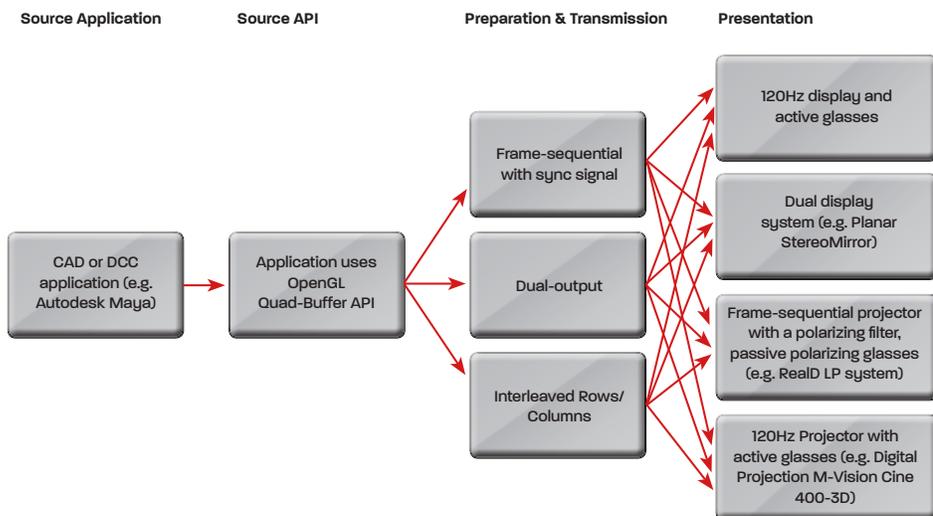
**Passive** (polarizing) display and polarized glasses. As discussed earlier, the use of polarizing or wavelength-filtering glasses exist. Passive displays come in a few forms:

- **Dual display**: two displays present images with different polarization, and they are typically aligned with a half-mirror that permits the light from both displays to be presented together to the user's eyes. This approach allows for full brightness and full resolution stereo to be presented to the user.
- **Single display**: typically, a polarizing filter is added to the front glass of a display, carefully aligned to rows or columns of pixels (or some checkerboard pattern). Left and right images of a stereo pair are aligned to the corresponding pixels. This approach is attractive because of the lower cost of the display (than dual display), but it does result in lower resolution and brightness.
- **Projected**: polarized images are presented from one or two projectors and cast onto a screen that preserves the polarization. This approach is taken in most new Stereo 3D movie theatres.

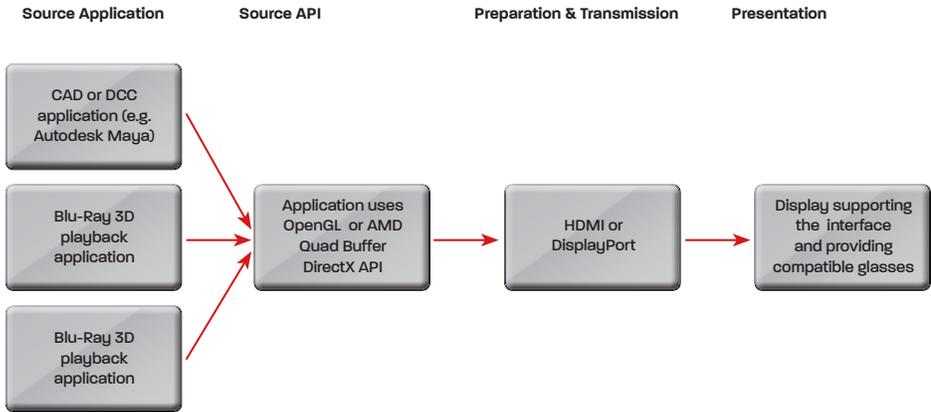
**Auto-stereoscopic** displays: these displays do not require glasses and typically depend on 'parallax barriers' that ensure that each eye only receives the image destined for it. This requires that the user positions their head (and thus their eyes) in a 'sweet spot' where the effect is available.

## Fitting the stages together

With a wide and varied history of Stereo 3D, the terms used in the different stages have changed, and been confused by the various technologies involved. Notably, it is possible that a display expects stereo pairs to be presented using a method historically associated with a different display interface. The table below shows some examples of how the various schemes fit together. The table is not exhaustive, but illustrates some of the complexities that exist today:



As we can see, there is a wide variety of modes for interoperation of different source applications, the APIs (or conversion software) they use, the transmission approach they use and the final device that presents the Stereo 3D experience. Fortunately, the arrival of HDMI and DisplayPort standards for Stereo 3D makes this plug-and-play, essentially as follows:



We will review how this simplification is achieved in the following section.

## NEW STANDARDS FOR STEREO 3D

As previously discussed, a great deal of innovation has been taking place in Stereo 3D display technologies, leading to a fairly complex set of options for driving these displays, and a need for the user to understand the display type and select the corresponding preparation and transmission method.

With the increasing popularity of Stereo 3D content for consumers (e.g. Blu-ray 3D, transmission to the home from various cable and satellite providers), display interfaces have been evolving. This is particularly important as we understand the question of how now-dominant Liquid Crystal Displays (LCD) can work with Stereo 3D.

### LCD panels and Stereo 3D

Historically, active Stereo 3D evolved in a world dominated by Cathode Ray Tube (CRT) displays. A typical refresh rate of 120Hz was chosen, corresponding to 60Hz of images to each eye. This stems from a need to ensure that with CRT displays, flicker caused by the fading of pixels (inherent in CRT technology) was not noticeable.

LCD panels differ in a fundamental way from CRT displays in the way that the pixels are updated on the display (notably, the pixels do not fade after being refreshed, as is the case with CRTs). This means that the usual approach of using active shutter glasses does not work with LCD displays without some modification to the approach used by the LCD panels, the glasses, or both.

While some LCD panel displays have been introduced that support 120Hz stereo, it is important to note that these implement proprietary approaches to this capability and that no industry standard has yet been implemented established to support the same approach as exists for CRTs.

These proprietary approaches have been implemented by vendors of 3D glasses for use with a small set of displays that support their approach. This limits the purchaser of the glasses to use only the supported displays, and ultimately limits the use of these glasses across multiple displays.

Proprietary approaches have also been adopted by vendors of Stereo 3D-enabled television sets. These displays are typically sold with Stereo 3D glasses that work only with the television sets they are intended for.

While standardization is underway, it is important to bear this in mind when considering the purchase of a Stereo 3D solution that uses LCD panels (LCD projectors are not affected).

### **Standards-based Stereo 3D**

HDMI 1.4a and DisplayPort now support transmission of Stereo 3D frames and offer 'plug and play' support for Stereo3D via communication of device capabilities and standard Stereo 3D transmission formats.

A key point about these transmission approaches is that the matching-up of appropriate glasses (including synchronization of active shutter glasses, where appropriate) is driven by the displays supporting the standards, rather than directly by the GPU or system generating Stereo 3D content. This will further simplify Stereo 3D solutions by taking out the requirement of an understanding (by the user) of exactly which glasses to use with a given display type. We already see this with the availability of stereo glasses (active and passive) from the vendors of consumer TV sets (all of which support the HDMI 1.4a standard).

A description of the actual formats used by these standards was touched on earlier, but the most important aspect is that they are plug-and-play and don't dictate any understanding or purchase decisions by the user. Thanks to these factors, it is very probable that these approaches will become the dominant standards.

One point of note, however, is that the current HDMI infrastructure, including the cables in use and most devices today, supports limited bandwidth. This means that 120Hz Stereo 3D can be achieved only up to 720p resolution. In order to support 1080p resolutions, the frame rate is limited to 48Hz, or 24Hz Stereo 3D. This refresh rate is suitable for film content playback (e.g. Blu-Ray 3D), the bandwidth required for 120Hz stereo (devices today support 48Hz stereo – corresponding to 24Hz Stereo for standard movie playback).

DisplayPort (particularly v1.2), with its significantly higher bandwidth does support 120Hz Stereo 3D, and it is anticipated that displays supporting Stereo 3D over DisplayPort will be available soon.

### **Further Standardization**

One point of note is that while today TV set vendors offer differing approaches to driving active stereo with their glasses, there is a wide recognition that a standards-based approach would be ideal to ensure portability of active stereo glasses between vendors. This should ultimately further lower the complexity and cost of setting up Stereo 3D.

Of note here is that the Consumer Electronics Association (CEA) has announced an initiative to achieve this standardization. As of writing, this standard draft is expected shortly and it is hoped that standard glasses would start to appear in 2011.

This standardization will help complete an open standards approach to Stereo 3D that will likely render proprietary solutions all but obsolete and ultimately lead to the best choices for the user.

## AMD HD3D PRO - PROFESSIONAL SOLUTIONS FOR STEREO 3D

With an understanding of the parts of the Stereo 3D pipeline we can review how AMD FirePro™ graphics solutions support the pertinent capabilities to help deliver a stereo experience to the user.

AMD has supported Stereo 3D functionality in the AMD FirePro™ and AMD FireGL™ product line for a number of years. AMD HD3D Pro technology encompasses this existing support and is adding the support for the new HDMI and DisplayPort Stereo 3D standards, as well as the capability to drive multiple Stereo 3D displays synchronized across multiple GPUs or even across multiple computer systems.

Referring back to the three stages of Stereo 3D delivery we covered earlier, we can see that the graphics accelerator and its driver are involved in the two first stages (the Stereo 3D content source and preparation and transmission to a display). We will review the capabilities that AMD FirePro graphics accelerators and AMD HD3D Pro technology expose for these two stages.

### Sources Supported

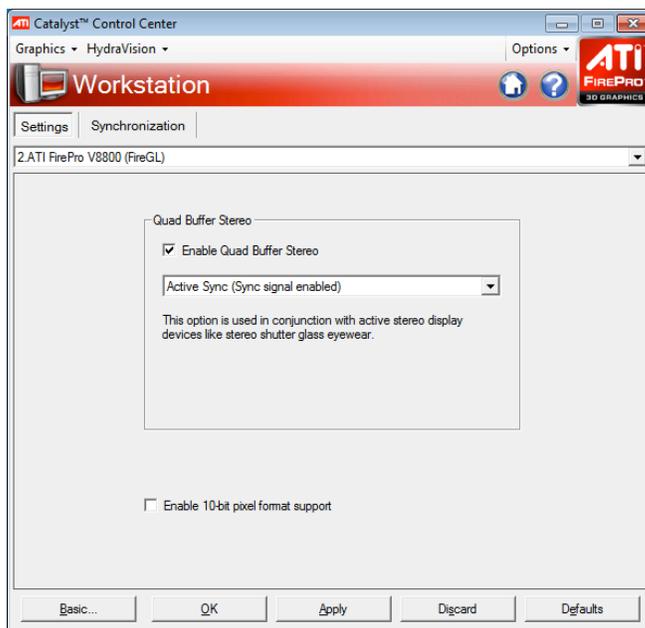
The following AMD FirePro graphics accelerators expose support for the OpenGL quad-buffer stereo feature:

- AMD FirePro V9800, V8800, V7800, V5800, V4800, V3800
- AMD FirePro V8750, V8700, V7700
- AMD FireGL V8600, V8650, V7600

In addition to a supported graphics accelerator, an application that uses OpenGL quad-buffer support is needed. Provided that the application's implementation of stereo is standard, support is assured. This includes essentially all professional stereo-supporting applications today. Some examples include:

- Autodesk Maya
- The Foundry Nuke
- Eyeon Fusion
- Mercury/Pfizer MoVIT

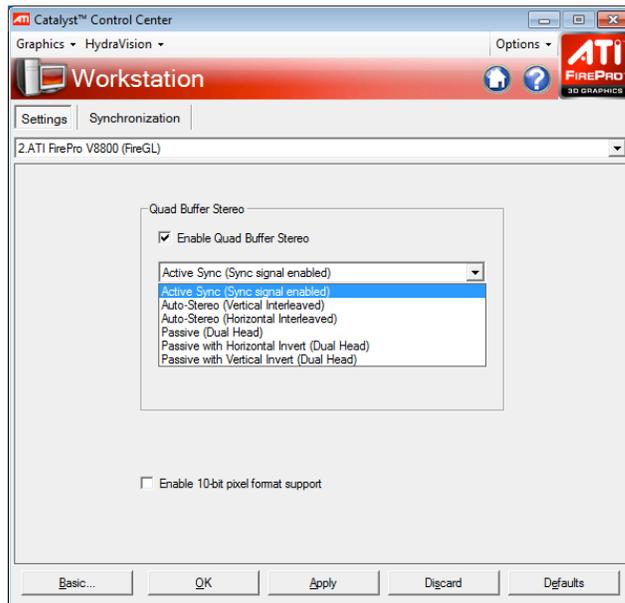
As of writing, AMD's quad-buffer extension for enabling stereo with Microsoft DirectX is available for developers interested in using this functionality; full support in AMD's line of professional graphics accelerators is planned for upcoming drivers.



AMD Catalyst™ Control Center User Interface showing AMD FirePro™ Stereo 3D option for enabling Quad Buffer Stereo

## Preparation and Transmission Capabilities

AMD FirePro graphics accelerators have support for a wide variety of display types; the GPU and drivers support the following modes:



AMD Catalyst™ Control Center User Interface showing AMD FirePro™ options stereo preparation and transmission

**Active Sync (Sync signal enabled)**, for driving frame-sequential devices (usually driving a 120Hz display or projector and active glasses); this includes providing an Active Sync signal for 3D glasses via:

- The VESA 3-pin stereo connector available on the following boards: AMD FirePro V9800, V8800, V8750, V8700, V7700 and AMD FireGL V8600, V8650, V7600
- An external sync signal generator that can create 3-pin signal from sources without the connector. In this case, the GPU inserts a 'blue-line' signal into the video frames to communicate the sync order to the external device. This type of device is typically used on laptops, as they do not feature the 3-pin connector natively. This mode is also enabled by default on AMD FirePro graphics accelerators that do support Stereo 3D, but do not have a 3-pin connector: AMD FirePro V3800, V4800, V5800, V7800

**Auto-Stereo (Interleaved)** modes. While these modes are originally intended to drive auto-stereoscopic displays, they can be used to drive a variety of different display types that expect incoming stereo pairs on alternating lines or columns or pixels. Support for checkerboard interleave is also provided.

**Passive (Dual Head)** modes. These modes are intended for driving Stereo 3D presentation technologies that use two images streams: one for left eye, the other for right eye. AMD drivers support the following capabilities:

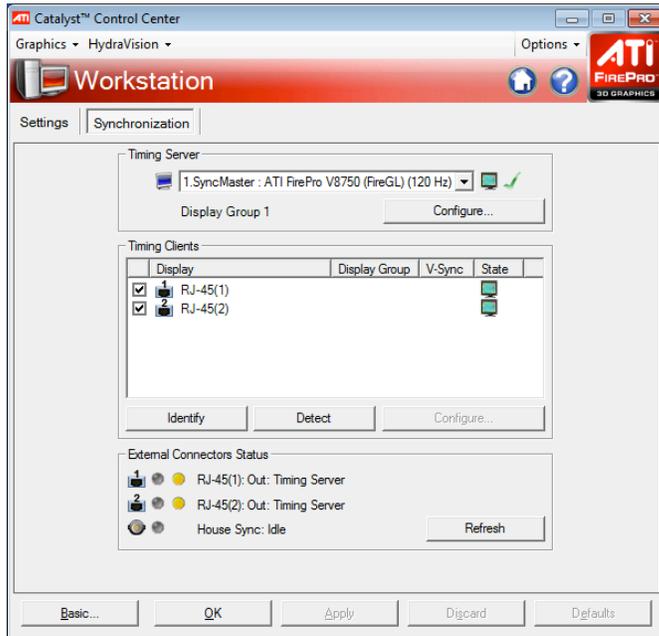
- 'Inverted' modes: The driver can flip on horizontal or vertical axis, for support of displays such as Planar StereoMirror displays
- Unmodified mode for use with:
  - Dual projectors that project superimposed polarized images
  - Single projectors that expect incoming stereo pairs on separate interfaces
  - Dual display systems that use an inverter (an option for Planar StereoMirror systems)

## Stereo 3D and Multi-GPU synchronization

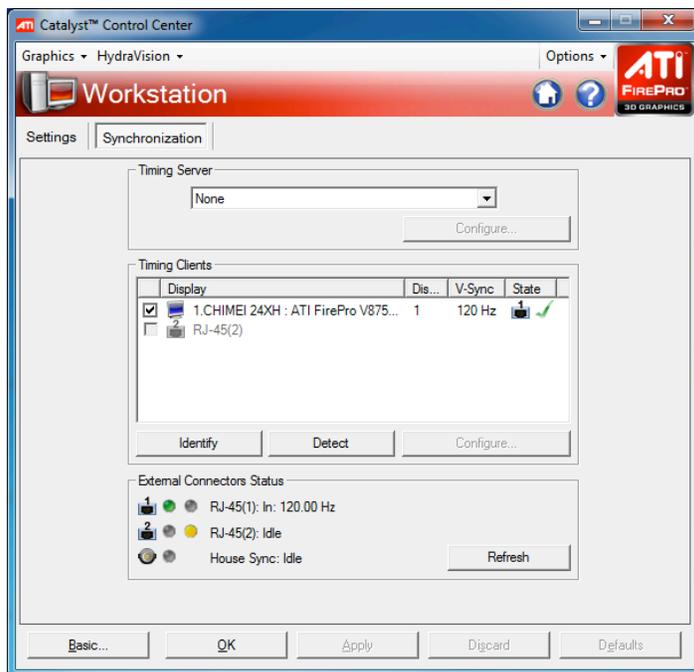
Data visualization and virtual reality are key use cases for Stereo 3D in professional markets. Typical scenarios involve the use of multiple displays (usually projectors), and often these are driven by multiple GPUs, sometimes in multiple computers. In cases where the presentation method is frame-sequential display with active glasses, it is critical that all of the displays being driven are synchronized

to one common refresh rate (in order to ensure that the sync signal is driving the correct left/right image at each frame).

This synchronization capability is possible with the AMD FirePro line of graphics accelerators by using the AMD FirePro S400 Synchronization Module. A detailed review of this product and its configuration is outside the scope of this document; however the sync module permits synchronization of up to four graphics accelerators in a single system, and supports synchronization across multiple computers via a connection between AMD FirePro S400 modules in those computers.



AMD Catalyst™ Control Center User Interface showing the AMD FirePro™ S400 Synchronization Module configuration page showing one machine configured as a timing server (source of the synchronization signal for all systems connected). Note that the timing signal is set at 120Hz.



AMD Catalyst™ Control Center User Interface showing the AMD FirePro™ S400 Synchronization Module configuration page showing a machine configured as a timing client. It is using the synchronization signal from the timing server coming in on one of the AMD FirePro S400's RJ-45 connectors. Note that in this example, a timing signal of 120Hz is being received.

## Summary

Over the course of this document, we've explored a number of topics relating to Stereo 3D technology in the professional space and how AMD HD3D Pro technology enables the use cases.

In particular, we have looked at the complexities involved in getting Stereo 3D to work given the innovation that has taken place over the last few years (leading the large number of possibilities of source, preparation and transmission, and actual presentation technologies).

With an overview of those complexities, we have also explored the pitfalls associated with newer 120Hz LCD panels, and the proprietary approaches employed to enable Stereo 3D with them.

The emergence of standards-based approaches to Stereo 3D via HDMI, DisplayPort (and the CEA's standardization of glasses) has two major impacts:

- A substantial simplification, via plug-and-play, in the configuration of Stereo 3D systems.
- Enablement of a Stereo 3D ecosystem where vendors of different components (sources, displays, glasses) can provide the best solutions to customers instead of having a single approach dictated by proprietary solutions.

Lastly, we reviewed how AMD FirePro graphics accelerators and AMD HD3D Pro technology comprehensively support stereo today (and have done so for a number of years), and are planned to continue to do so as the new standards take hold in the market, making AMD FirePro graphics accelerators an excellent choice for Stereo 3D workflows today and tomorrow.

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