Technical Brief

Quadro FX 5600 SDI and Quadro FX 4600 SDI Graphics to SDI Video Output

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Quadro FX 5600 SDI and Quadro FX 4600 SDI Graphics to SDI Video

Introduction

This document describes the features and capabilities of the NVIDIA Quadro® FX 5600 SDI and Quadro® FX 4600 SDI and how to leverage the combination of the revolutionary processing power of the NVDIA graphics processing unit (GPU) with the graphics to SDI video out functionality to create high quality broadcast, video and film applications.

How this Paper is Organized

❑ Overview
❑ Desktop Device Control
❑ Application Programming
❑ Application Areas

Overview

The Quadro FX 5600 SDI and Quadro FX 4600 SDI combines the high performance and ultimate rendering quality of the Quadro FX 5600 SDI or Quadro FX 4600 SDI GPU with the ability to output industry standard Serial Digital (SDI) video. This is achieved through the use of a daughter board that converts the GPU-rendered data from the on-board graphics frame buffer directly into SDI video. The following sections highlight the important features of this product.

Quadro FX 4600 and Quadro FX 5600 GPU

The GPU found on the Quadro FX 5600 SDI and Quadro FX 4600 SDI features a unified architecture where processing units are dynamically allocated to perform all vertex, geometry and fragment shading. This unified architecture is designed to support the increased programmability of Shader Model 4.0. The features of Shader Model 4.0 include:

❑ Common set of vertex, geometry and pixel shader programming instructions

❑ Integer operations

❑ Virtually unlimited number of shader instructions

❑ Additional data load operations

❑ Bitwise operators

❑ Geometry programs

Other features of the Quadro FX 5600 SDI and Quadro FX 4600 SDI GPU useful for SDI-based broadcast, video and film applications include a 756 MB and 1.5 GB frame buffer and improved full-scene antialiasing over previous generation GPU architectures.

SMPTE Standard SD and HD SDI Video Output

The Quadro FX 5600 SDI and Quadro FX 4600 SDI supports standard-definition (SD), high-definition (HD) and 2K SMPTE standard serial digital video (SDI) output in the following popular formats.

- ❏ 720p 23.98 Hz (SMPTE296)
- ❏ 720p 24.00 Hz (SMPTE296)
- ❏ 720p 25.00 Hz (SMPTE296)
- ❏ 720p 29.97 Hz (SMPTE296)
- ❏ 720p 30.00 Hz (SMPTE296)
- ❏ 720p 50.00 Hz (SMPTE296)
- ❏ 720p 59.94 Hz (SMPTE296)
- ❏ 720p 60.00 Hz (SMPTE296)
- ❏ 1035i 59.94 Hz (SMPTE260)
- ❏ 1035i 60.00 Hz (SMPTE260)
- ❏ 1080i 47.96 Hz (SMPTE274)
- ❏ 1080i 48.00 Hz (SMPTE274)
- ❏ 1080i 50.00 Hz (SMPTE274)
- ❏ 1080i 59.94 Hz (SMPTE274)
- ❏ 1080i 60.00 Hz (SMPTE274)
- ❏ 1080PsF 23.976 Hz (SMPTE274)
- ❏ 1080PsF 24.00 Hz (SMPTE274)
- ❏ 1080PsF 25.00 Hz (SMPTE274)
- ❏ 1080PsF 29.97 Hz (SMPTE274)
- ❏ 1080PsF 30.00 Hz (SMPTE274)
- ❏ 1080p 23.976 Hz (SMPTE274)
- ❏ 1080p 24.00 Hz (SMPTE274)
- ❏ 1080p 25.00 Hz (SMPTE274)
- ❏ 1080p 29.97 Hz (SMPTE274)
- ❏ 1080p 30.00 Hz (SMPTE274)
- ❏ 2048 × 1080p 23.976 Hz (SMPTE372)
- ❏ 2048 × 1080p 24.00 Hz (SMPTE372)

- ❑ 2048 × 1080p 25.00 Hz (SMPTE372)

- ❑ 2048 × 1080p 29.97 Hz (SMPTE372)

- ❑ 2048 × 1080p 30.00 Hz (SMPTE372)

- ❑ 2048 × 1080i 47.96 Hz (SMPTE372)

- ❑ 2048 × 1080i 48.00 Hz (SMPTE372)

- ❑ 2048 × 1080i 50.00 Hz (SMPTE372)

- ❑ 2048 × 1080i 59.94 Hz (SMPTE372)

- ❑ 2048 × 1080i 60.00 Hz (SMPTE372)

- ❑ 487i 59.94 Hz (SMPTE259) NTSC

- ❑ 576i 50.00 Hz (SMPTE259) PAL

Fill and Key Output

SDI video output can include both fill and key components. Fill data is sourced from the RGB frame buffer channels and output as either RGB or YCrCb. Key data originates as the graphics alpha (A) channel. Each channel can contain 8, 10 or 12-bits of data per component. This ability to output both fill and key from a single buffer makes the Quadro FX 5600 SDI and Quadro FX 4600 SDI ideal for chroma or luma key -based broadcast applications.

Genlock House Synchronization

The Quadro FX 5600 SDI and Quadro FX 4600 SDI supports synchronization of the outgoing SDI video signal with an external house synchronization source. The external reference source can be either an analog composite source or a digital (SDI) source. Termination of the composite video sync source at the Quadro FX 5600 SDI and Quadro FX 4600 SDI can be enabled and disabled. The following two synchronization modes are supported.

Genlock

Pixel accurate synchronization of the outgoing SDI video signal with the incoming house sync.

Frame lock

Line accurate synchronization of the outgoing SDI video signal with the incoming house sync. This mode permits video formats with timings that are a multiple of the incoming sync to be synchronized. This mode is useful for synchronizing 1080i5994 HD SDI output with an NTSC (487i5994) house sync commonly found in broadcast facilities. A complete summary of the available frame lock combinations can be found in Table 1.

Figure 1.   NVIDIA Quadro SDI II

Table 1.   Available Frame Lock Combinations

Reference \ Output	NTSC	PAL	720-23.98p	720-24.00p	720-25.00p	720-29.97p	720-30.00p	720-50.00p	720-59.94p	720-60.00p	1035-59.94i	1035-60.00i	1080-47.95i	1080-48.00i	1080-50.00i	1080-59.94i	1080-60.00i	1080-23.98p	1080-24.00p	1080-25.00p	1080-29.97p	1080-30.00p	2048-30.00p	2048-29.97p	2048-60.00i	2048-59.94i	2048-25.00p	2048-50.00i	2048-24.00p	2048-23.98p	2048-48.00i	2048-47.95i
NTSC	√		√			√			√		√		√			√		√			√			√		√				√		√
PAL		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
720-23.98p	√		√			√			√		√		√			√		√			√			√		√				√		√
720-24.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
720-25.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
720-29.97p	√		√			√			√		√		√			√		√			√			√		√				√		√
720-30.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
720-50.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
720-59.94p	√		√			√			√		√		√			√		√			√			√		√				√		√
720-60.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
1035-59.94i	√		√			√			√		√		√			√		√			√			√		√				√		√
1035-60.00i		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
1080-47.95i	√		√			√			√		√		√			√		√			√			√		√				√		√
1080-48.00i		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
1080-50.00i		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
1080-59.94i	√		√			√			√		√		√			√		√			√			√		√				√		√
1080-60.00i		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
1080-23.98p	√		√			√			√		√		√			√		√			√			√		√				√		√
1080-24.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
1080-25.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
1080-29.97p	√		√			√			√		√		√			√		√			√			√		√				√		√
1080-30.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
2048-30.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
2048-29.97p	√		√			√			√		√		√			√		√			√			√		√				√		√
2048-60.00i		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
2048-59.94i	√		√			√			√		√		√			√		√			√			√		√				√		√
2048-25.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
2048-50.00i		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
2048-24.00p		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
2048-23.98p	√		√			√			√		√		√			√		√			√			√		√				√		√
2048-48.00i		√		√	√		√	√		√		√		√	√		√		√	√		√	√		√		√	√	√		√	
2048-47.95i	√		√			√			√		√		√			√		√			√			√		√				√		√

Colorspace Conversion

The Quadro FX 5600 SDI and Quadro FX 4600 SDI supports 8, 10 and 12-bit output with full hardware accelerated colorspace conversion from RGB to YCrCb for standard ITU Rec. 601 and Rec.709 formats in both film (full range) and video (head room) ranges. A custom colorspace conversion matrix, offset and scale can also be specified via the API or control panel.

All colorspace conversions are performed with full 12-bit precision using the following formulas:

$$Y = offset_Y + scale_Y * (r_y*R + g_y*G + b_y*B)$$

$$Cb = offset_{cb} + scale_{cb} * (r_{cb}*R + g_{cb}*G + b_{cb} *B)$$

$$Cr = offset_{cr} + scale_{cr} * (r_{cr}*R + g_{cr}*G + b_{cr}*B)$$

where **scale** controls the magnitude of the result and **offset** controls the position of the result within that range. The input RGB data from the GPU can range from 8 to 16-bits per component.

Ancillary Data

The Quadro FX 5600 SDI and Quadro FX 4600 SDI supports insertion of ancillary data packets into the vertical and horizontal blanking regions as specified by SMPTE 291M. Currently support ancillary data packets include timecode (SMPTE RP188) and 24-bit embedded audio (SMPTE 299M). Ancillary data packets are specified via an API. This API is also flexible enough to support the sending of custom packets or any specified packet type.

2D Compositing

2D compositing combines the image data from the incoming video stream with GPU-rendered images based upon the values in a third image known as a matte or key channel. 2D compositing requires that the signal format of the incoming video matches that of the outgoing signal format and that the outgoing SDI video signal is genlocked to the input signal. The compositing operation applies to the full frame; scaling or retiming of the video input to match the video output signal format is not supported. The Quadro FX 5600 SDI and Quadro FX 4600 SDI supports the following compositing methods.

Alpha Compositing

The application provides the key / matte channel per field / frame in the alpha channel of the OpenGL graphics stream. When the application enables alpha compositing via the API, the Quadro FX 5600 SDI and Quadro FX 4600 SDI simply executes the function below to compute the final pixel color.

*output color = input video color * (1 - alpha) + input graphics color * (alpha)*

When the value of the key or matte is strictly 1 or 0, the compositing is complete replacement. When the key value is between 0 and 1, the two images (video and graphics) are blended. The above formula would be executed for each and every pixel in the SDI output stream.

Figure 2.   Virtual Set Background

Figure 3.   Alpha Matte

Figure 4.   Alpha Composite Result

Images Courtesy of Accuweather using Cineam Live HD Sysstem

Chroma-Keying

The application specifies up to two (Cr,Cb) pairs that represent the starting and ending chroma values for replacement. These ranges are specified using the control API. When the application enables chroma keying, the Quadro FX 5600 SDI and Quadro FX 4600 SDI examines the chroma (Cr and Cb) for each incoming video pixel. If the (Cr, Cb) value for that pixel is within one of the specified ranges, the color of that pixel is replaced with the pixel color from the GPU.

Figure 5.   Green Screen Shot Prior to Keying

Figure 6.   Final Shot After Application After Chroma Key

Luma-Keying

The application specifies up to two pairs of luma (Y) values via the API. These values represent the starting and ending luma values for replacement. When luma compositing is enabled, the Quadro FX 5600 SDI and Quadro FX 4600 SDI compares the luma (Y) for each incoming video pixel to the specified ranges. If the value for that pixel is within a specified range, the color of that pixel is replaced with the pixel color from the GPU. Luma keying is useful when the feature to be composited into a scene is significantly brighter or darker than the background.

Figure 7.   Source Image

Figure 8.   Luma Matte

Figure 9.   Final Composite

Device Control

SDI video output from the Quadro FX 5600 SDI and Quadro FX 4600 SDI can be controlled either through the use of the NVIDIA control panel or through an application-level programmable interface. The NVIDIA control panel permits the SDI video output of the Quadro FX 5600 SDI and Quadro FX 4600 SDI to be setup either in Dualview/Twinview or Clone modes. For more information on each, please refer to the *Quadro FX 4600 and Quadro FX 5600 User Guide*.

Dualview/Twinview

In Dualview/Twinview mode, the Windows or Linux desktop is expanded to span the SDI video output. In this mode, the resolution and refresh rate of the SDI display must be one of the supported SDI formats but otherwise, the SDI display is treated as simply another display device. This mode permits application windows to be dragged between the graphics display and the SDI display, or span the two displays. This mode can be useful in a broadcast environment to constrain UI elements to the graphics display while graphic elements destined for broadcast to air are displayed on the SDI device.

Clone

In Clone mode, the Windows or Linux desktop from the primary graphics display is simply replicated on the SDI display device at a set SDI supported resolution and refresh rate. This mode is analogous to the use a scan converter. This mode is useful for broadcast or training applications where the desire is to display the complete Windows or Linux desktop.

In each of these modes, the SDI video output is limited to a single fill channel with 8-bit per-component RGB or YCrCb color values. A key channel cannot be provided in either of these modes. In order to have a key channel, the programmable mode must be utilized as described in the next section, *Applications Programming*.

Applications Programming

An application may also control the SDI video output directly. In this mode, an application first allocates the video device and then sets the initial device settings (resolution, refresh rate, gunlock, color space conversion, etc.) prior to commencing video transfers. Once video transfers are started, the SDI video device scans out rendered data directly from the GPU with less than a single frame of latency. A ring buffer can be utilized for preroll and the handling of system glitches inherent in the non-realtime nature of the Windows and Linux operating systems.

In the programmable mode, the Quadro FX 5600 SDI and Quadro FX 4600 SDI can output 8, 10 or 12-bit per-component RGB or YCrCb color values as well as a key channel where the contents of the key channel are sourced from the GPU alpha channel. The programmable mode also supports standard ITU Rec. 601 and Rec.709 colorspace conversion into both film (full range) and video (head room) ranges as well as fully programmable colorspace conversion that can be utilized for example for conversion from RGB into the XYZ colorspace used in digital cinema applications.

More details on programming the Quadro FX 5600 SDI and Quadro FX 4600 SDI can be found in the *Quadro FX SDI Programmer's Guide.* An SDK is also available to application developers.

Figure 10.   Graphics Solution Brainstorm Using API with
                    Quadro FX 5600 SDI

Image Courtesy of Accuweather Inc.

Integrated Design Yields Workflow Improvement

The advantage of using the Quadro FX 5600 SDI and Quadro FX 4600 SDI versus other video input/output solutions is that high-quality rendered images from the Quadro FX 5600 SDI and Quadro FX 4600 SDI GPU can be sent directly to the SDI video output as both fill and key without reading back the data from video memory on the graphics board to system memory and then passing the data to the video input/output card. The Quadro FX 5600 SDI and Quadro FX 4600 SDI provides an integrated graphics to SDI video out solution.

Image courtesy of New England Sports Network NESN

NVIDIA Quadro SDI

Workflow improvement through Integrated Design

Classic PCI SDI boards workflow:
1 – retrieve data from sys mem
And create graphics   (MEM → GFX)
2 – read back graphics to cpu (GFX → CPU)
3- write frame to system memory (CPU → MEM)
4 – read frame and color convert (MEM → CPU)
5- write from CPU to PCI card (CPU → PCI)
6- PCI card formats and transmits (PCI → SDI)

NVIDIA Quadro FX SDI:
1 – Retrieve Data from sys mem
and create graphics (MEM → GFX)
2- NVSDI formats and transmits (GFX → SDI)

PCIe

2   **1**

FSB

CPU   **Memory Controller**   **CH 1**

3   **4**   **CH 2**

5

I/O   **PCI**   **6**

Ntwrk
Audio
Video
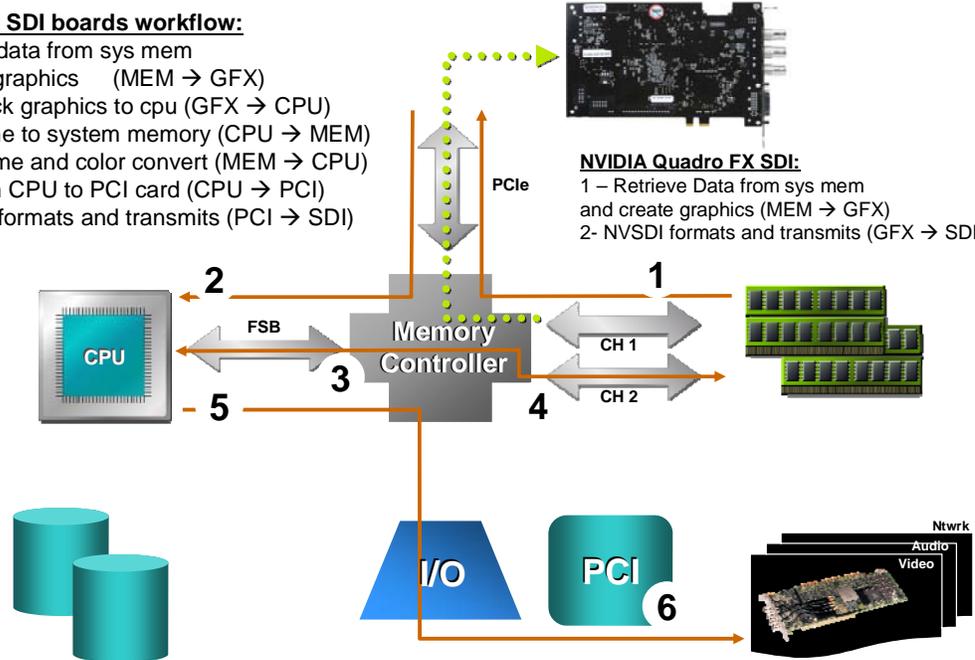
Figure 11.   Workflow Improvement through Integrated
            Design

Application Areas

The integrated graphics to SDI video output Quadro FX 5600 SDI and Quadro FX 4600 SDI solution is applicable to many application areas. Each of these areas is outlined in this section.

On-Air Broadcast Graphics

For on-air broadcast graphics for weather, sports, news and entertainment content, the Quadro FX 5600 SDI and Quadro FX 4600 SDI provides an ultimate quality direct-to-air solution. High quality images rendered using the latest vertex and pixel shader technology on the Quadro FX 5600 SDI and Quadro FX 4600 SDI GPU can be sent directly to air to add increased detail and polish to broadcast content.

NVIDIA Powered Broadcast Graphics
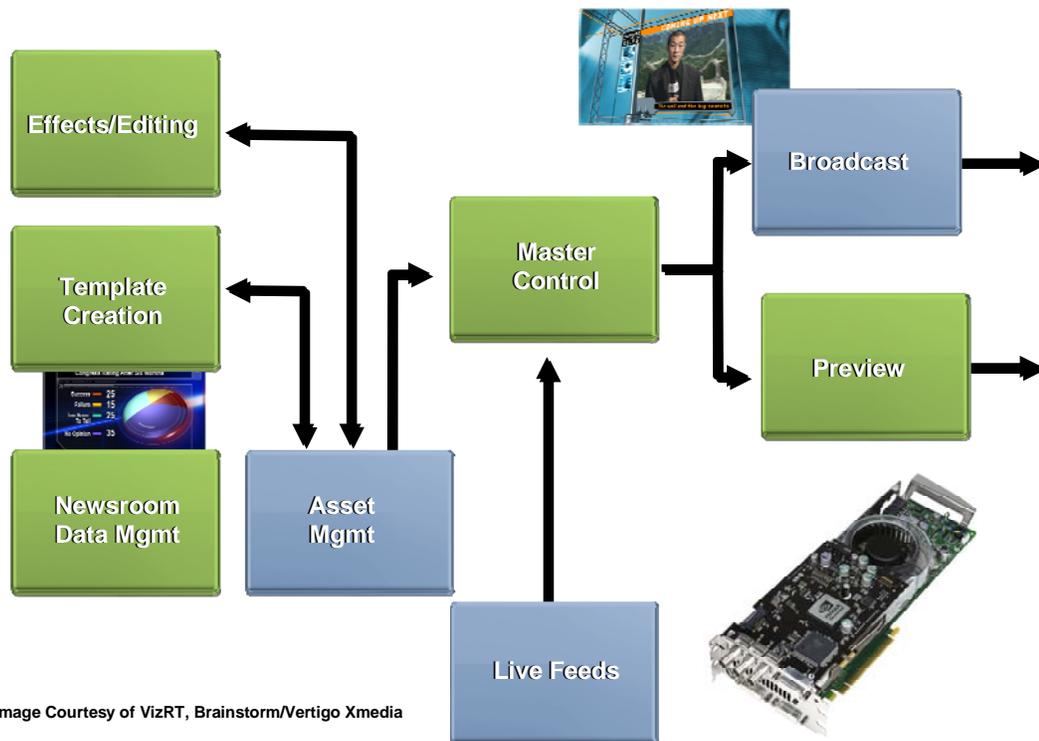
Image Courtesy of VizRT, Brainstorm/Vertigo Xmedia

Film and Video Post Production

For film and video post production, the user programmable SDI colorspace conversion hardware combined with the vertex and pixel shader power of the Quadro FX 5600 SDI and Quadro FX 4600 SDI GPU make the Quadro FX 5600 SDI and Quadro FX 4600 SDI the ultimate solution for color grading and real-time effect preview as well as digital daily review.

NVIDIA Powered Post Production
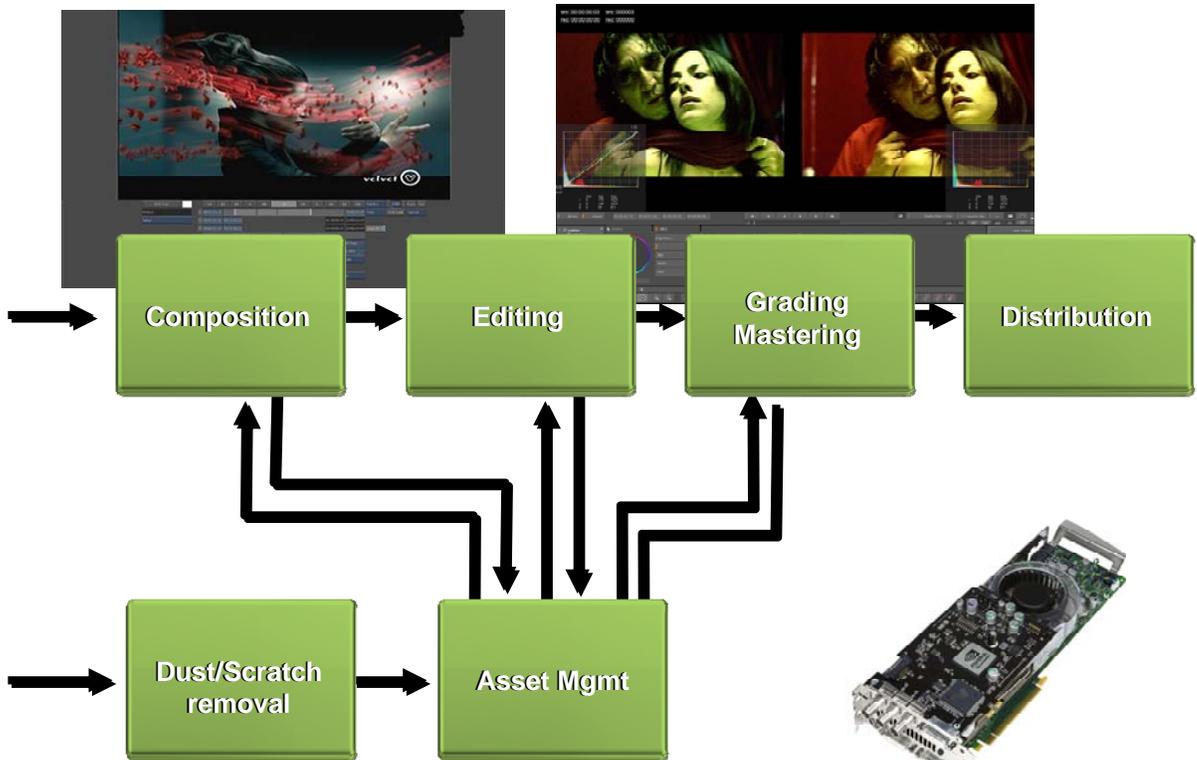
Image Courtesy of Autodesk Media Entertainment, Nucoda

Large-Venue Projection

For large venue projection, the Quadro FX 5600 SDI and Quadro FX 4600 SDI can connect directly to all the available projectors that support SDI input. This provides the direct display of ultimate quality rendered images for a variety of application areas. For large venues, where projectors are typically a significant distance from computer systems, the use of SDI overcomes the signal integrity issues inherent in DVI signals while at the same time providing the capabilities for standard 10 and 12-bit signals.

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Conclusion

The NVIDIA Quadro FX 5600 SDI and Quadro FX 4600 SDI combine the awesome power of the NVIDIA GPU with standard SDI video output to provide a best-of-class graphics-to-video solution for professional broadcast, film and video applications. Studio and production ready, the NVIDIA Quadro FX 5600 SDI and Quadro FX 4600 SDI can output up to two 8, 10 or 12-bit uncompressed RGB or YCrCb channels in 2K, HD or SD formats complete with ancillary data synchronized to an external sync source as well as perform alpha compositing or luma or chroma keying operations to composite an incoming video stream with ultimate quality GPU rendered assets.