DCP_LL Distortion Correction Processor (Low Latency Configuration)

Back View (connectors)

Front View

Per channel DVI I/O resolutions up to 1920 x 1200, including 1080P (1920x1080)

Up to (6) DVI video input channels and (6) DVI output channels

DCP API supports:

- √ **Definition of input/output resolutions and timing**
- √ **Access to output device EDID, and programmable EDID for each video source**
- √ **Source Image Plane definition and output area-of-interest within the Source Image Plane**
- √ **Downloading geometric and non-uniformity correction files**
- √ **Downloading test patterns and built-in filled rectangle test patterns for third-party projector calibration procedures**

2U rack-mount unit, latest settings and correction files applied at power up

Compatible with (2) DVI (2560x1600) and (4) DVI (4K) high resolution projectors, including 1024 x2400 striped sections for 4096 x 2400 projectors

The DCP_LL is a low latency, general purpose distortion correction processor. The DCP has numerous applications with a common requirement to "re-shape" incoming video prior to a subsequent display device. This re-shaping may be prior to a projector, or to "undo" the video shaping intended for a projector, prior to a flat panel display.

The DCP can be purchased with 1 to 6 I/O channels. Although some data sharing is possible across channels, typically an I/O channel processes and outputs pixels received on its input. Data may be required from neighboring I/O channels if the distortion correction requires video that is received on neighboring channels. Data sharing happens automatically, based on the concept of a source image plane and output area of interest within the source image plane.

Source Image Plane: The DCP places pixels from incoming video into a user defined source image plane. In the figure on the right, the 6 I/O channels receive video into a 3x2 array of images that form a larger source image plane. Output video is derived from the source image plane based on user-defined correction coefficients. These correction coefficients can be a "per pixel" correction map or a mesh that is converted to a "per pixel" correction map.
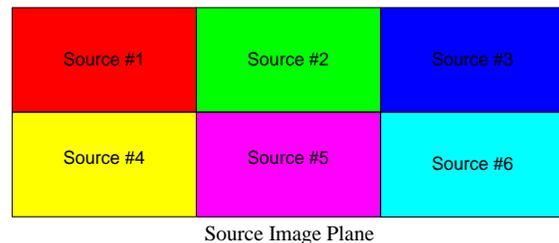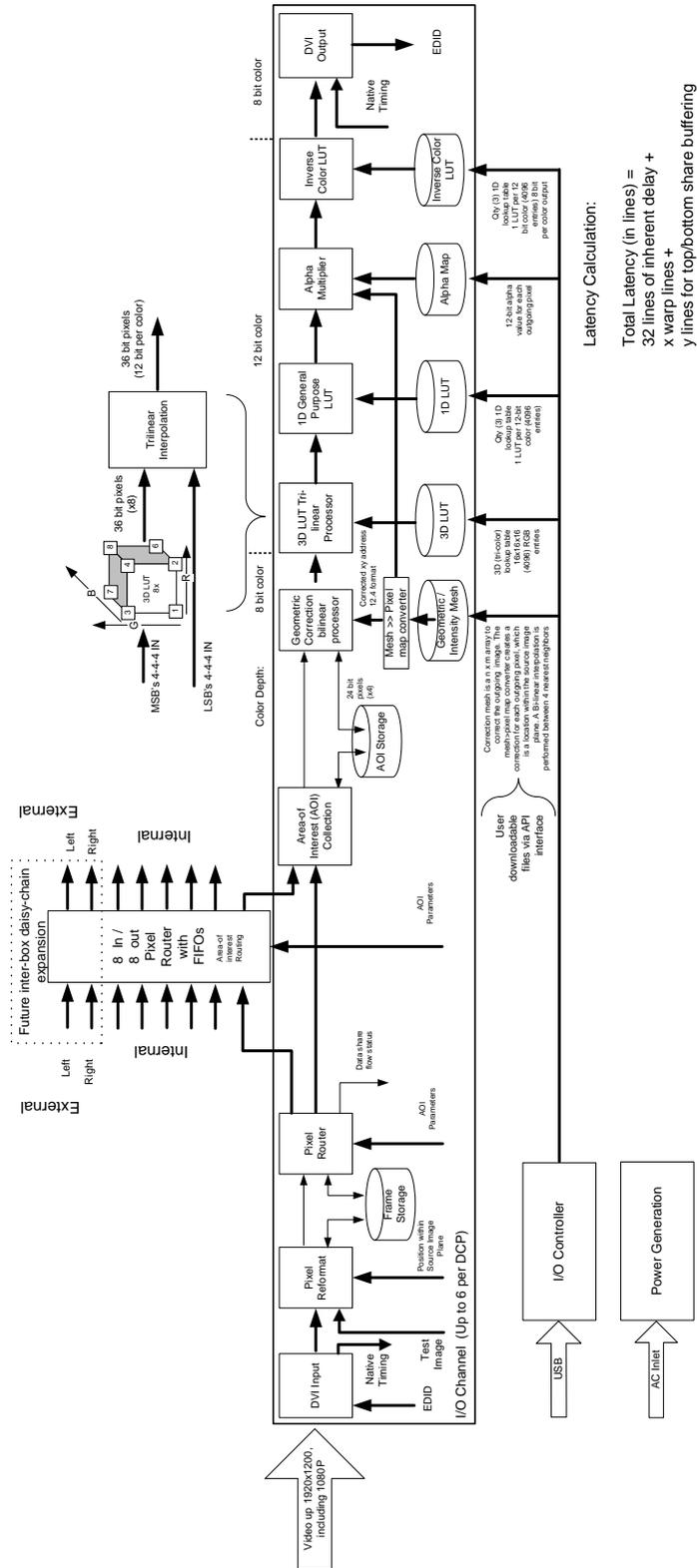
Source Image Plane

Geometric Correction: Each projector output channel processes an area-of-interest (AOI) within the source image plane. Each pixel within the I/O channel's output is derived from a "mapped" location within the I/O channel's area-of-interest, via a downloaded geometric correction mesh. Assume the following:

- 1080P I/O format. The incoming 1920 pixels per row are numbered 1 to 1920 and the rows are numbered 1 to 1080.
- the correction coefficients determine that output pixel (x, y) is mapped to (4.2, 2.7) in the projector's area of interest.

A bilinear interpolation between the four nearest neighbor pixels is used to determine the image value at (4.2, 2.7), as shown in the diagram above. This interpolation is performed on all outgoing pixels.
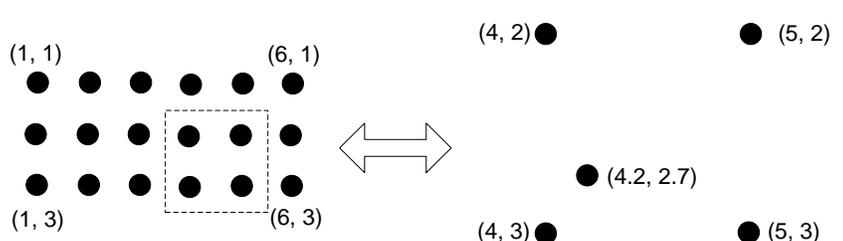
The DCP_LL block diagram is shown below. The following sections introduce several of the image processing functions. Westar application engineers can assist you in setting up the unit, using our DCP utility software. Please contact Westar for further details.

DVI Output — EDID

8 bit color

Native Timing

Inverse Color LUT

Inverse Color LUT
Qty (3) 1D lookup table 1 LUT per 12 bit color (4096 entries) 8 bit per color output

Alpha Multiplier

Alpha Map
12-bit alpha value for each outgoing pixel

1D General Purpose LUT

1D LUT
Qty (3) 1D lookup table 1 LUT per 12-bit color (4096 entries)

12 bit color

36 bit pixels (12 bit per color)

Trilinear Interpolation

3D LUT Trilinear Processor

3D LUT
3D (tri-color) lookup table 16x16x16 (4096) RGB entries

36 bit pixels (x8)

3D LUT 8x

B
R
G

8 bit color

Geometric Correction bilinear processor

Corrected x-y address 12.4 format

Mesh >> Pixel map converter

Geometric / Intensity Mesh

MSB's 4-4-4 IN
LSB's 4-4-4 IN

Color Depth:

AOI Storage
24 bit pixels (x4)

Area-of-Interest (AOI) Collection

AOI Parameters

Latency Calculation:

Total Latency (in lines) =
32 lines of inherent delay +
x warp lines +
y lines for top/bottom share buffering

Correction mesh is a n x m array to correct the outgoing image. The mesh>>pixel map converter creates a correction for each outgoing pixel, which is a location within the source image plane. A Bi-linear interpolation is performed between 4 nearest neighbors

User downloadable files via API interface

External
Left
Right
Internal

8 In / 8 out Pixel Router with FIFOs
Area-of-interest Routing

Future inter-box daisy-chain expansion

Internal
Left
Right
External

AOI Parameters

Data share flow status

Pixel Router

AOI Parameters

Frame Storage

Position within Source Image Plane

Pixel Reformat

DVI Input

Native Timing
Test Image
EDID

I/O Channel (Up to 6 per DCP)

I/O Controller — USB

Power Generation — AC Inlet

Video up 1920x1200, including 1080P

DCP_LL Corrections:

In addition to the geometric correction already described, the DCP offers the following additional corrections:

3D Tri-Linear processor: Each pixel is color corrected from an ideal color space to the projector's color space, via a downloaded 3D lookup table. This table accounts for inter-color dependencies found in many projectors. The 4 most significant bits of each color define the vertex of the tri-color cube. The 4 least significant bits then are used to interpolate between the (8) 36-bit color vertices of the tri-color cube. *These LUTs may be bypassed*.

Alpha Multiplier: Each pixel of the projector's output resolution (typically 1920x1080) is multiplied by the appropriate 12-bit alpha value within the alpha map. These alpha adjustments account for non-uniformities as well as edge blending. The applied alpha map is derived from a downloaded "per pixel" alpha map and an intensity component of the downloaded correction mesh.

Inverse Color Lookup: (3) individual LUTs (R, G, B) convert the 12-bit color component in the projector color space back to an 8-bit color component in the ideal color space. *These LUTs may be bypassed*.

DVI Output Timing: The timing of a DCP_LL projector output channel is identical to the input timing of the channel. Corrected projector video lags the incoming video by an integer number of lines (see Latency Analysis).

Data Sharing:

The DCP_LL supports a limited amount of data sharing between I/O processors. Data sharing refers to image pixels that come into the DCP_LL on channel "x", but are contained in the area-of-interest in channel "y". Data sharing is crucial in at least (2) possible scenarios:

1. Correcting overlapping regions: Because multiple projectors illuminate an overlapped area of the screen, these projectors must share a limited amount of data to create a seamless image. Because the DCP_LL can share data internally, it is not required that the image generators send duplicate data across multiple image generator output channels.
2. Sharing data across video channels in a multi-input projector: A single projector may have multiple single link DVI (SL DVI) video inputs. For example, a 2560x1600 projector has 2x SL DVI inputs and a 4K projector has 4x SL DVI inputs. Applied distortion corrections may require video from input M to be applied to the portion of the projector imager normally driven by Input N. In this case, the pixel data is transported between video channels by the DCP.

DCP_LL Support:

DCP Driver API: The DCP API provides a programmer's interface to the DCP_LL. The API includes complete descriptions of all programming features and all correction file formats. The API uses a USB interface to the DCP_LL. Sample application code is available.

DCP Utility Software: All DCP customers get a copy of our DCP utility software. This software is useful for configuring the DCP and downloading correction coefficients.

EDID: Many image generators rely on display EDIDs to get critical data on the display's capability. The DCP_LL supports EDID functions in several ways. First, the DCP_LL can be commanded to read the EDID from a display connected to a DCP_LL output, and copy the EDID contents to a dedicated EDID on the corresponding DCP_LL input. Also, an EDID prom may be programmed from the DCP Utility Software.

Test Patterns: The DCP_LL supports many test pattern features. Test patterns of any rectangular size may be downloaded to the source image plane. The filled rectangle command loads a specific RGB color into a specific region of the source image plane.

I/O channel controls: Multiple channel controls exists, including the ability to "turn off" various correction processors.

Determining Correction Coefficients:

Westar does not provide software to determine correction coefficients. Our customers are generally savvy in the area of geometric corrections, and are capable of determining appropriate corrections for download to the DCP. Our support engineers are available to help customers

Latency Analysis:

The DCP_LL has 32 lines of built-in latency to account for pixel packaging and routing within the unit. In addition, a programmable register allows the user to program additional line delays for image warping (warp line delay) and up/down data sharing (up/down data share delay). The warp line delay accounts for the worst case vertical warping required for a particular installation. The up/down data share delay accounts for additional time needed to share data across a horizontal edge. This is relevant in situations where the vertical stack of projectors is 2 or more.

A typical total latency would be:
32 lines (built-in latency) +
10 lines (warp delay) +
16 lines (up / down data share delay) = 58 lines.

For a 1080P projector, this is ~ 5% of a frame, or 1 msec.

DCP Applications

Application #1: Distortion Correction for SL DVI, 2x SL DVI, and 4x SL DVI High Resolution projectors:

The DCP_LL can perform distortion correction for Single Link (SL) DVI, 2xSL DVI and 4xSL DVI projectors. These projectors present video in a striped approach, where a dedicated DVI channel provides video at up to 162 MPixels per second. The figure below shows typical high resolution projector video stripe implementations:

Typical 2560x1600 stripes
(2x SL DVI)

1280   1280

1600

SL DVI #1   SL DVI #2
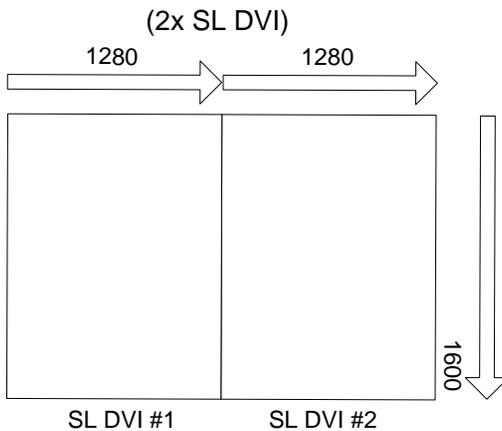
Typical 4096x2160 stripes
(4x SL DVI)

1024   1024   1024   1024

2160

SL DVI #1   SL DVI #2   SL DVI #3   SL DVI #4
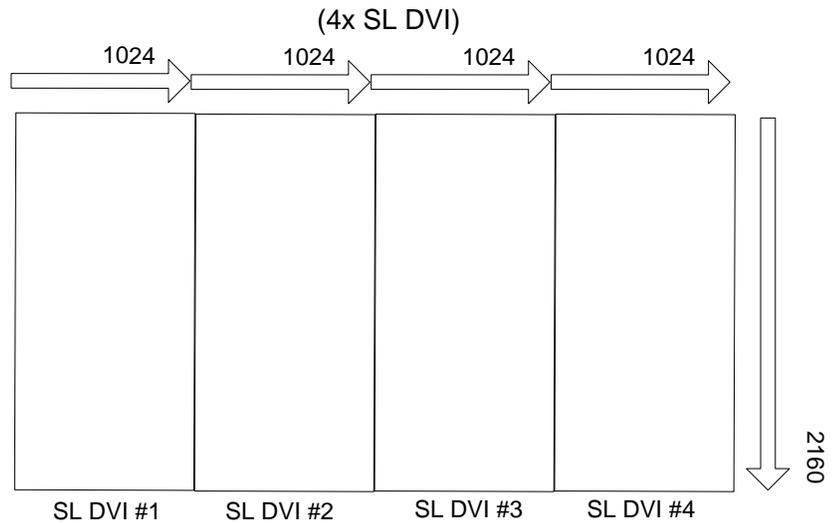
In this application, the DCP can render a corrected image by mapping the regular rectangular image coordinates of the incoming raster to rendered image display coordinates. The display imagery is received as DVI input video. Corrections are applied and new display coordinates are calculated to generate each outgoing pixel. A mesh correction map defines both position and intensity of the outgoing raster in terms of a normalized input raster. Output raster and input raster are always the same resolution.

A single mesh array is applied across the entire projector resolution. The outer (4) corners of the mesh define the locations of the (4) corners of the output raster, in terms of the normalized input raster. The unique data sharing ability of the DCP allows data sharing between Input Channel M and Output Channel N to account for distortions across video boundaries. The pictures below show an image before and after a 2x2 mesh map is applied on a 2560x1600 projector.

Image prior to application of 2x2 distortion map

Image after application of 2x2 distortion map
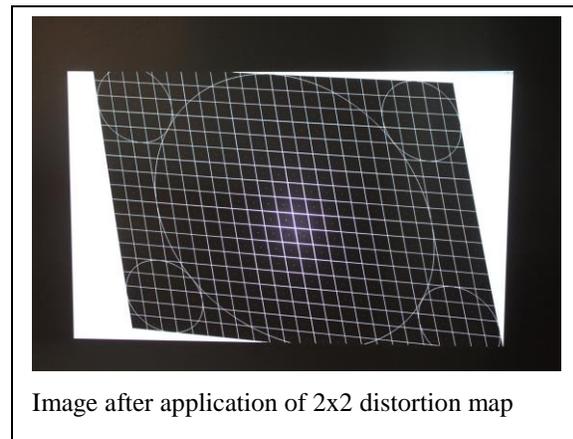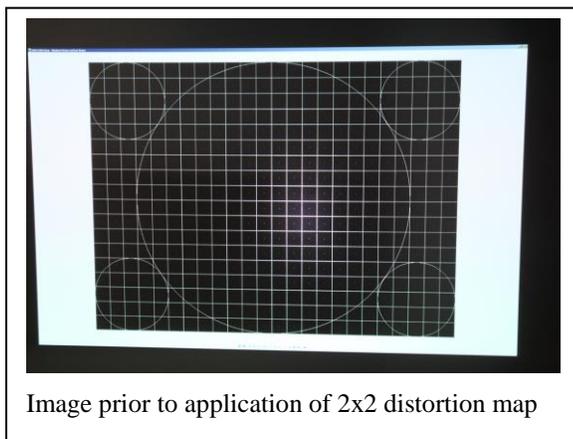
By placing mesh points at various locations of the input raster, the output raster can be re-shaped as required to correct distortions caused by curved surfaces, tilted screens, etc.

Example setup for Application #1: The DCP operates on pixels that reside within a defined source image plane. In the figure below, assume that (2) 2560x1600 projectors are to be used to create a 5120 x 1600 image. Each projector uses 2x SL DVI channels, so a DCP-4 will be used to geometrically correct the image as required on a display surface. Assume no edge blending is required at the intersection of Projector #1 and #2.

Note: The area of interest is increased to allow overlap between projector images 1 and 2. This overlap may be required for either distortion across the projectors, or for blending. Blending coefficients must be developed by the customer.

The DCP would be programmed as follows:

Source Image Plane definition:
1. Incoming video on DCP Channel 1 is defined as a 1280x1600 rectangle located at (0,0) in the Source Image Plane.
2. Incoming video on DCP Channel 2 is defined as a 1280x1600 rectangle located at (1280,0) in the Source Image Plane.
3. Incoming video on DCP Channel 3 is defined as a 1280x1600 rectangle located at (2560,0) in the Source Image Plane.
4. Incoming video on DCP Channel 4 is defined as a 1280x1600 rectangle located at (3840,0) in the Source Image Plane.

We assume some minimal data sharing (an additional 80 pixels per shared channel) is required across video channels for distortion correction. The resulting Output Area-of-Interest definition:
1. DCP Channel 1 Output Area-of-Interest is a rectangular area located at (0,0) and 1360W x 1600H
2. DCP Channel 2 Output Area-of-Interest is a rectangular area located at (1200,0) and 1440W x 1600H
3. DCP Channel 3 Output Area-of-Interest is a rectangular area located at (2480,0) and 1440W x 1600H
4. DCP Channel 4 Output Area-of-Interest is a rectangular area located at (3760,0) and 1360W x 1600H
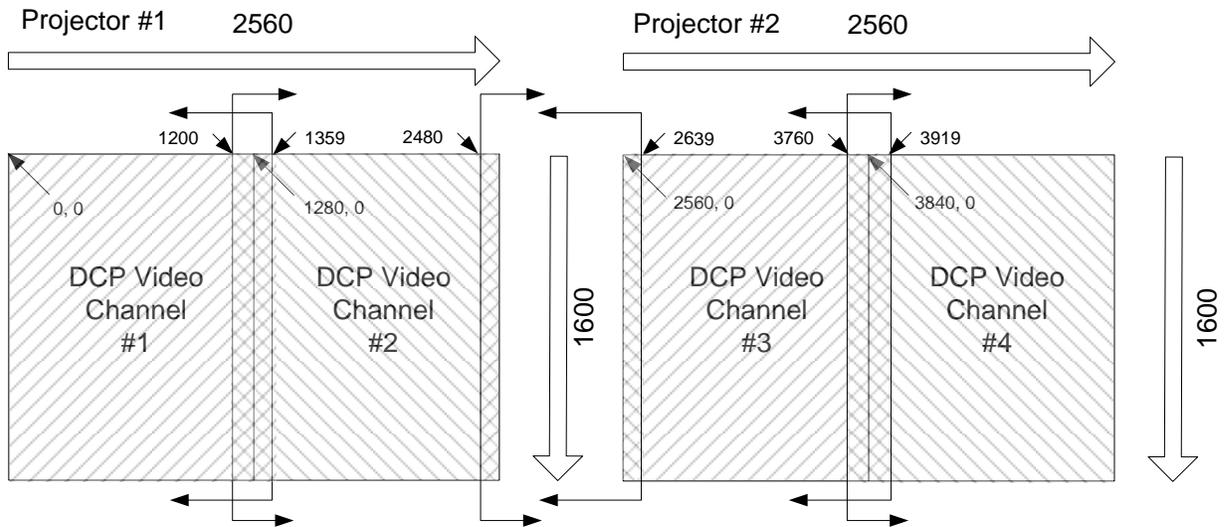
Projector #1 uses Video Channels 1 and 2.
- A mesh definition is required per projector, so an identical mesh is downloaded to each Video Channel 1 and 2.
- The mesh is an n x m array of normalized correction coefficients.
- It includes an output resolution parameter (2560x1600) and a source image plane offset parameter (0,0).

Projector #2 uses Video Channels 3 and 4.
- A mesh definition is required per projector, so an identical mesh is downloaded to each Video Channel 3 and 4.
- The mesh is an n x m array of normalized correction coefficients.
- It includes an output resolution parameter (2560x1600) and a source image plane offset parameter (2560,0).

Application #2: Processing video intended for projector into video for IOS monitor:

Images may be rendered in the image generators for the intended projectors. This video may not be suitable for display on a regular desktop monitor or IOS monitor. The DCP_LL can perform geometric correction to converted projector video into video more suited for desktop monitor display.

In the figure below, (3) 1920x1080 images are rendered by IG's and sent to projectors. The images are rendered sideways, so that 1080P projectors can be mounted sideways. The images include overlapped data for edge blending, and a trapezoidal look based on the projector and screen geometries. While these images help create an outstanding multi-projector out-the-window view, the images are not suitable for display on an IOS (trainer) monitor.

The DCP can take each of the feeds, trim out the duplicate data, and "undo" the trapezoidal shape for each of the (3) projector feeds. A Westar SP2 is then used to combine the 3 slices into (1) 1080P feed that can be displayed on any monitor.
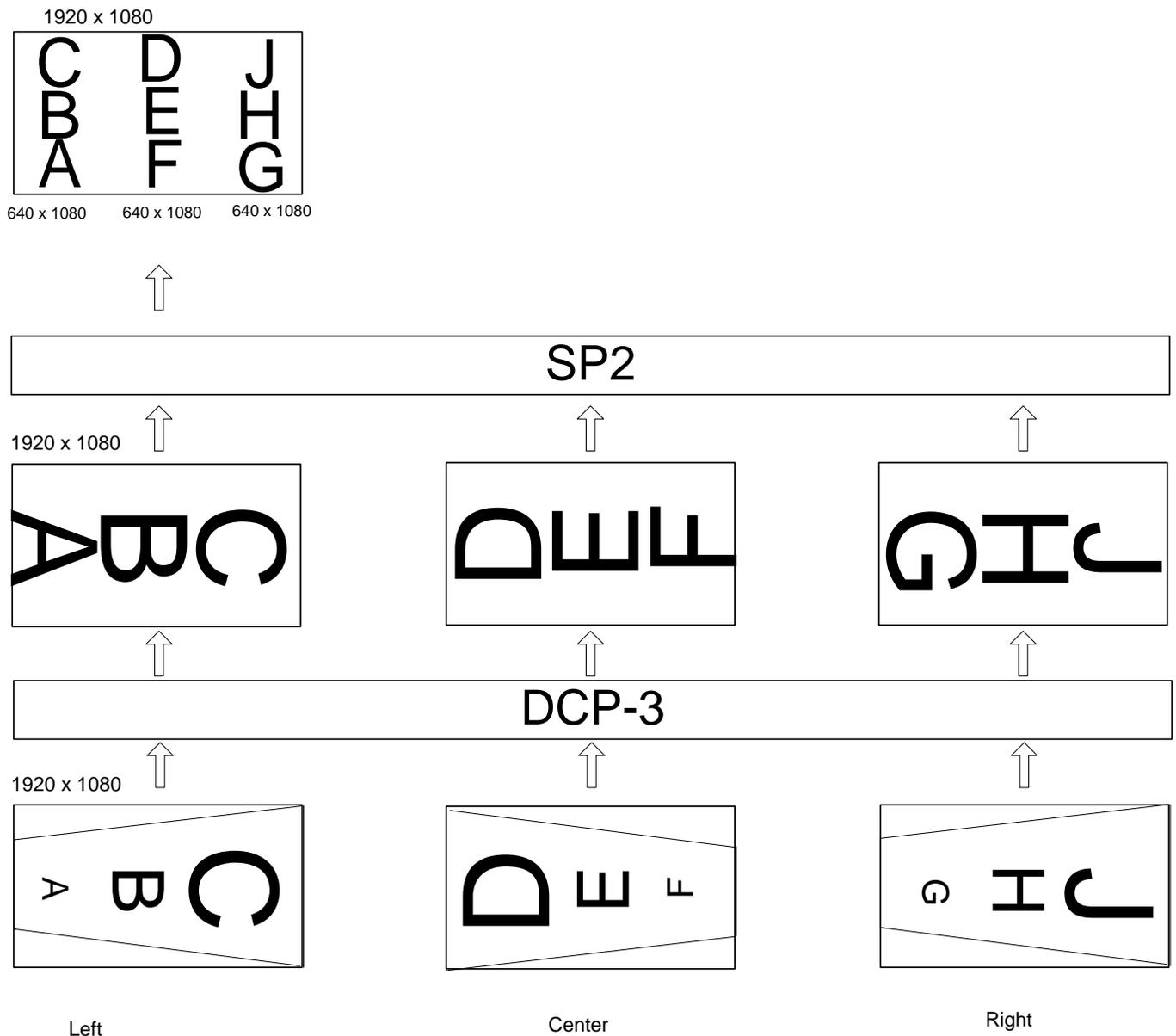

Application using DCP-3 and SP2 to render projector video suitable for IOS Monitor

Application #3: High Resolution, edge-blended displays: One application of the DCP_LL is to translate a PC's source image plane to a high resolution display composed of multiple, loosely aligned projectors. The source image plane typically originates in graphics memory distributed across multiple video cards. The video cards output the imagery via multiple 1080P DVI video streams. In the case shown on the right, a source image plane is composed of a 3x2 array of 1080P sub-images that are piped to (6) 1080P DVI outputs.

This video is captured by the DCP_LL on (6) 1080P inputs. Each of (6) DCP_LL projector outputs is programmed to a specific area-of-interest within the source image plane. The area-of-interest includes appropriate overlap regions, allowing the projectors overlapping beams to be corrected and smoothed into a continuous image plane.

At 1080P HD resolutions, the overlap region may typically be 160 lines on top or bottom, and 160 pixels on the left and/or right. The picture to the right shows a typical area-of-interest definition for projector output "N". **Typical latency through the DCP_LL is 1 msec.**

Projector Area-of-Interest Definition

The figure below shows a typical configuration with (3) projectors mounted with their 1080P output images overlapped on the screen. The video source, typically a PC, requires no internal corrections or data overlap. From the PC's perspective, the display is a single, high resolution, uniform, rectangular display. A typical calibration process (not offered by Westar) uses a camera and test images to determine appropriate distortion, color, and uniformity corrections. These corrections are downloaded to the DCP_LL and stored in non-volatile memory. Upon power-up, the DCP_LL auto-configures based on its latest calibration data. The corrections translate the source image plane of the PC to the screen, while correcting distortions due to projector warping, overlap and color and brightness differences.
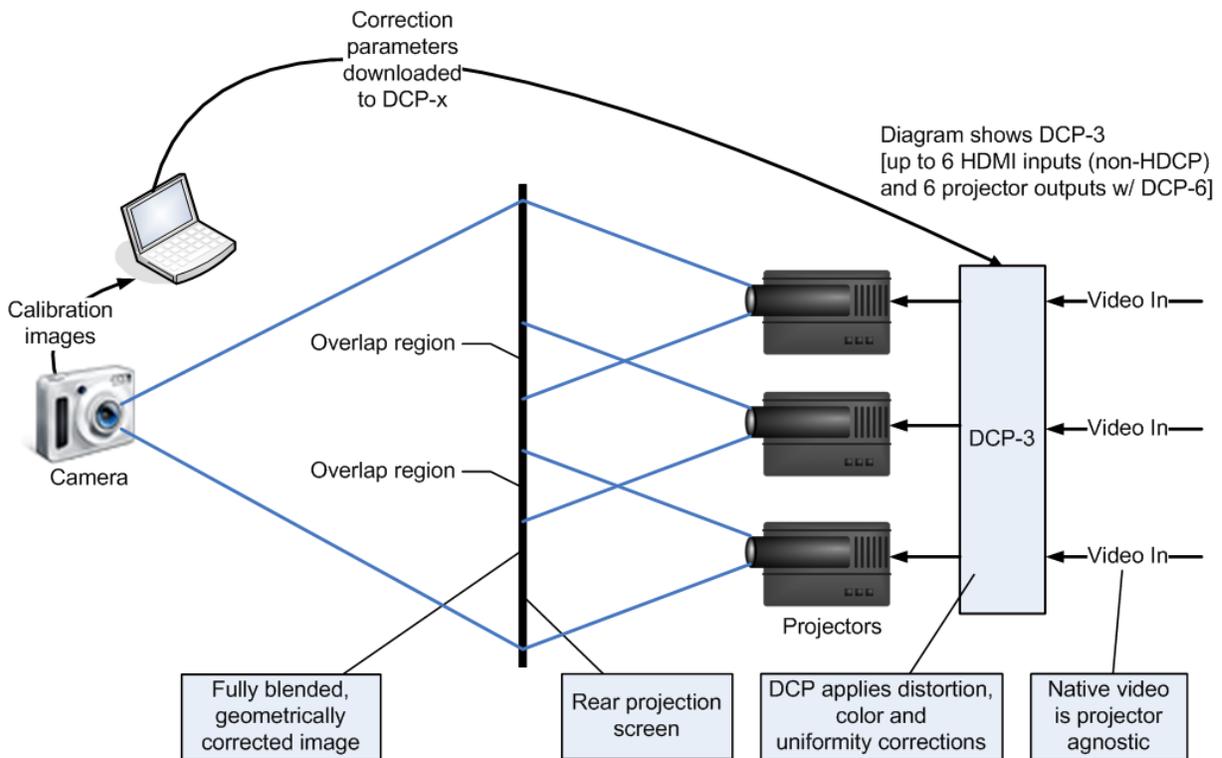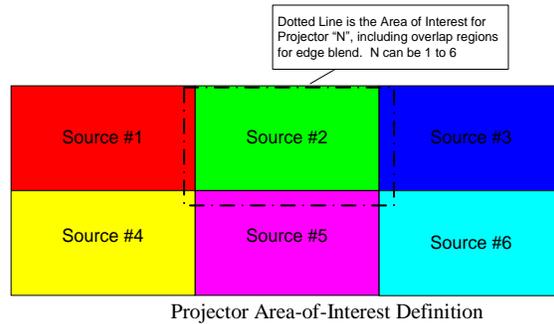
The picture below shows a 4 projector (2 top, 2 bottom) display before DCP_LL corrections (left) and after corrections are applied (right). Note that the top projectors are mounted upside down. The top projectors are placed in a mode to flip the image.

Although Westar does not offer the automated camera-based calibration solution, there are companies that can create appropriate calibration files either in an automated, camera-based approach, or with a man-in-the-loop and appropriate display calibration/registration features.

DCP_LL Specifications

Input Specifications (Subject to change without notice)

	Video Type	DVI; HDMI connector
	Pixel Rate	Up to 154 MHz
	Standard Computer resolutions	Up to 1920x1200 (Programmable EDID included for each input channel)
Output Specifications		
	Video Type	DVI; HDMI connector
	Pixel Rate	Up to 154 MHz
	Standard Computer resolutions	Up to 1920x1200 (EDID Read function for each output channel)
Electro Mechanical		
	Input Power	IEC Connector, 100-240 VAC, 47-63 Hz, 150 Watts Maximum Input Power
	Control	USB 2.0
	Size	Rackmount config: 19"W x 13.75"D x 3.5"H (2U), Benchtop config: 17.4"W x 13.75"D x 3 7/8"H
	Weight	Less than 10 lbs.
Processing Bandwidth		Each incoming frame is processed with no frame dropping.
Latency		32 lines built-in delay, plus additional lines of delay based on warping and top/bottom data sharing
Warranty		One year
Functional	Specialty Features	Geometric, color, and alpha corrections per pixel
		Each projector output has access to area-of-interest within the Source Image Plane
		Includes data sharing to handle video overlap regions outside of the image generator.
	Color processing depth	8 bits per color I/O, 12 bit per color internal processing
Each DCP_LL delivery includes:		DCP_LL unit configured w/ input cards as ordered, rack-mount ears, benchtop feet, IEC power cable with US plug, USB cable, and a CD containing:
		DCP API (Linux and Windows)
		DCP Utility Software
		DCP Documentation (API Guide, Instruction Sheet)

Ordering Info / Notes:

1. DCP_LL is ordered with 1 to 6 I/O processors, and is identified as DCP_LL-x, where x is the # of I/O channels.