MEGAPIXEL
VISUAL REALITY

GhostFrame

Megapixel Technology Overview

GhostFrame™ on the HELIOS® LED Processing Platform

February 2022

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What Is GhostFrame?

GhostFrame™ is a toolset for Megapixel VR's HELIOS® LED Processing Platform that allows users to accomplish real-time in-camera visual effects independent of the human observer experience. The set of features available includes:

- **GhostFrame Chroma** offers full chromakey backgrounds enabling real-time post-production workflows without burdening playback systems or reducing pixel capacity.

Chroma

- **GhostFrame Track** integrates camera tracking patterns without the need for physical markers by displaying still-store images that can be used for talent prompts or blocking paths, without reducing pixel capacity.

Track

- **GhostFrame MultiSource** allows you to display up to four different video feeds on the LED screen simultaneously, which can be captured by one or more cameras.

MultiSource

- **Patented Image Inversion** makes chromakey backgrounds, tracking patterns, and video streams invisible to in-person observers.

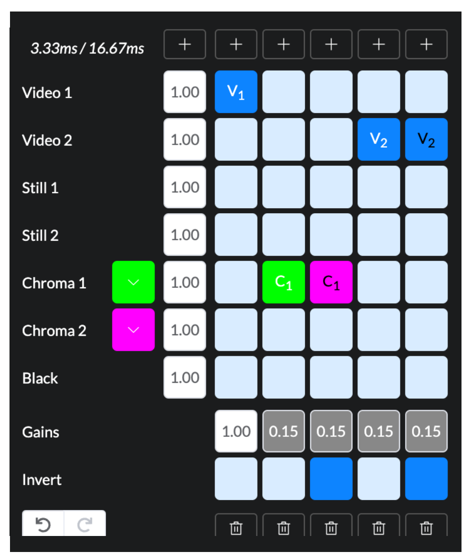
GhostFrame combines patented technologies from AGS and Megapixel VR and is available on select ROE Visual LED tiles.

Making Better Use of Time

Production time is precious. With GhostFrame, you can accomplish more by leveraging the inherent technology of LED panels and the limits of the human eye. Here are some basic use cases:

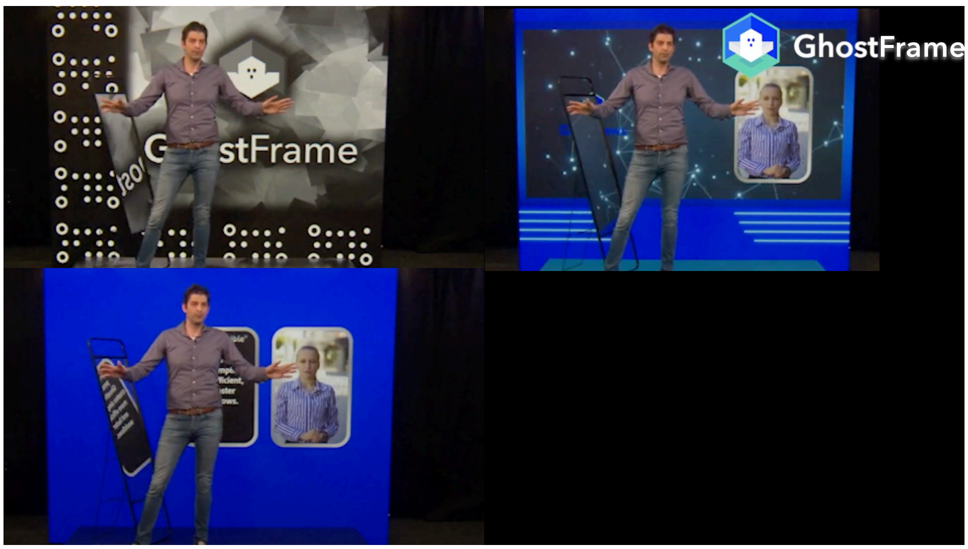
Capture Multiple In-Camera Images Simultaneously

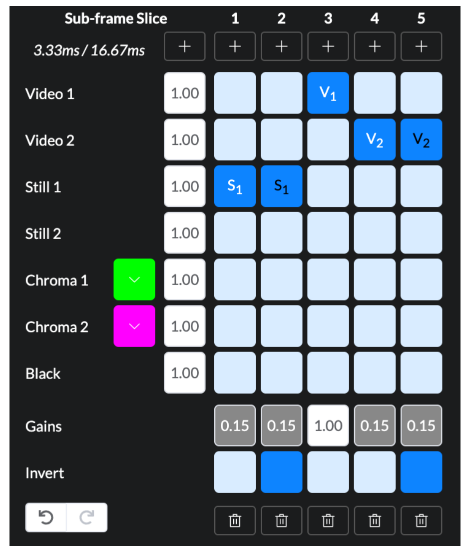
- Final pixel image and chromakey background
- Multiple video streams
- Overlapping frustums



Display Camera-Hidden Content

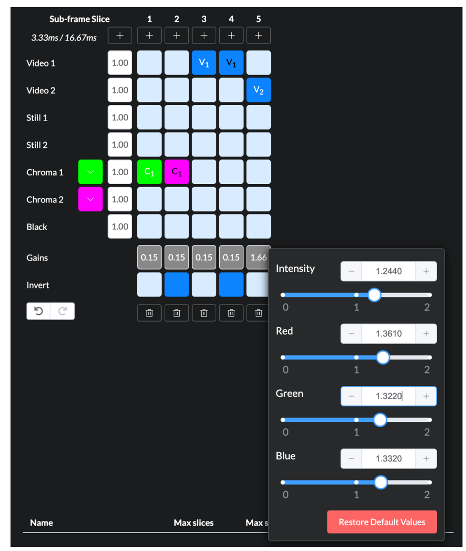
- Tracking markers visible only to the tracking system.
- Blocking markers or prompts visible only to the in-person talent.





Control the In-Person Experience

- Hide content using image inversion.
- Adjust the color and intensity gains of the in-person images independently of those in-camera images.



Balancing creative needs against technical requirements is critical when working with GhostFrame. Although GhostFrame has a simple interface, successful use requires detailed preparation. Additionally, adjustments within the GhostFrame toolset affect settings elsewhere in the system. This whitepaper explores concepts and strategies to optimize your workflow.

Core Concepts

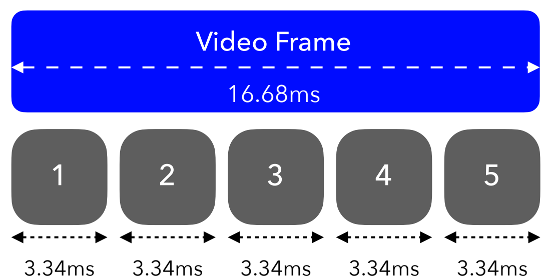
High Refresh Rate

An LED tiles' refresh rate may be dozens of times faster than required by the display media. GhostFrame uses these extra scan cycles to interleave additional images.

Sub-Frame Slices

Sub-frame slices are equal-length subdivisions of the video frame. Based on the tile's refresh rate and the frame rate of the display media, HELIOS calculates the maximum number of available sub-frame slices and the time duration of each slice.

Sub-Frame Slices

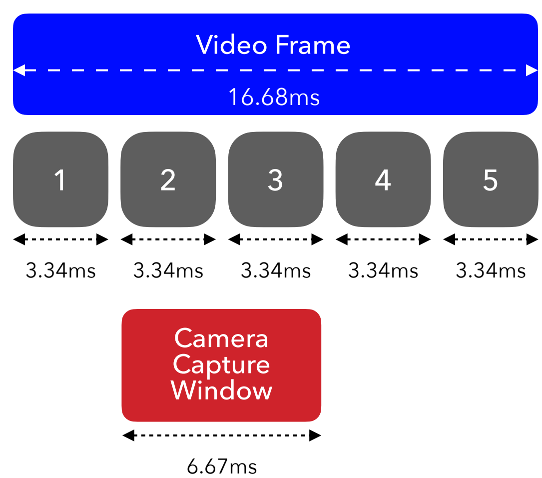


Camera Capture Window

A camera's capture window is the time required by a camera to capture a clean image, determined by the camera's sensor characteristics in conjunction with the exposure settings:

- Sensor Mode - Most cinematic cameras offer multiple sensor modes depending on the lens type, aspect ratio, and other creative demands. The more the sensor is employed, the more data must be read, resulting in a longer capture window - this can reduce the number of available GhostFrame features for use with particular camera models.

Camera Capture Window



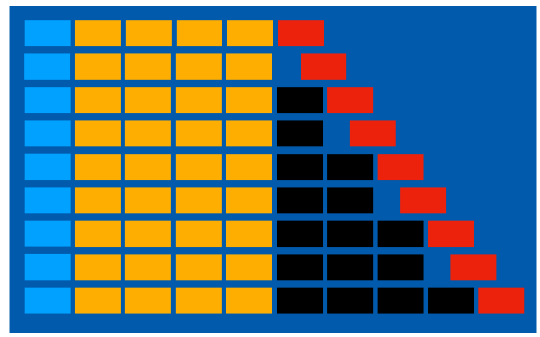
- Shutter Type - Three basic shutter types are used in today's camera technologies:
  - Global *(shortest capture window, highly recommended with GhostFrame)* - Exposes all rows of pixel sensors simultaneously, with all data fed through a single digital-to-analog converter (DAC), creating a bottleneck during read-out. Images will have less dynamic range, and larger sensors will have limited frame rates.
  - Rolling *(medium capture window)* - Exposes each row of pixel sensors in sequence, with a dedicated DAC per row allowing for images with a high-dynamic range. However, the sequential read-out can sometimes create undesirable artifacts with high-speed objects.
  - Pseudo-Global *(longest capture window)* - Offers high-dynamic range with no motion artifacts and utilizes an oversized sensor area but uses only the data captured at the same moment in time.
- Exposure Time - The amount of time a camera sensor is exposed to light, expressed as either shutter speed or shutter angle.

Shutter Types Legend

Charge Time *Exposure Time* *Read-out Time*

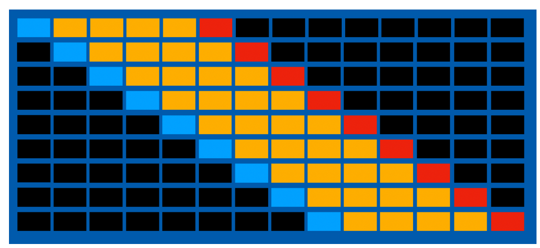
Global Shutter

Shortest capture window



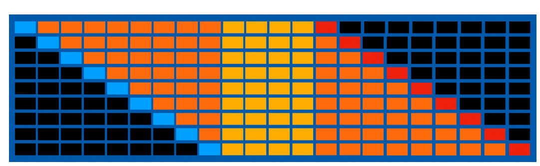
Rolling Shutter

Medium capture window



Pseudo-Global Shutter

Longest capture window



The camera capture window for a global shutter may closely approximate the exposure, while a pseudo-shutter may require 2-4x the exposure time.

The camera alignment process *(detailed on pages 14-21)* is required to determine the actual capture window for each specific camera setup.

Visual Perception

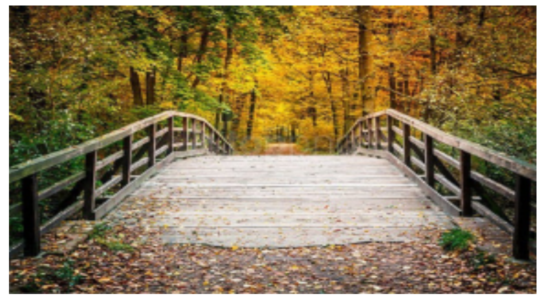
- **Image Inversion** - Quickly presenting the human retina with a positive and an inverted image *(in color, content, and intensity)* results in a solid, light gray after-image. When embedded with other images, this appears as a lifted image with lower contrast.

- **In-Camera vs. In-Person** - A camera may be tuned to capture select sub-frame slice(s). The human eye perceives an image based on the summation of all the sub-frame slices.

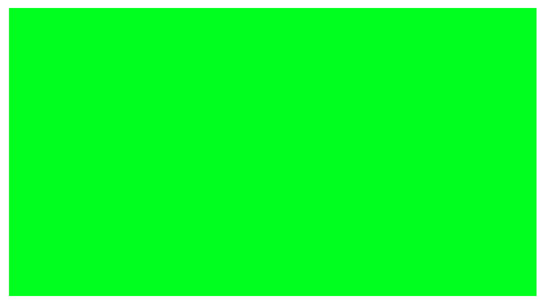
- **Visual Balance** - Certain playback frame rates/frequencies require the repetition of images in sequence and intensity for a stable in-person image.

Image Inversion

Camera Video

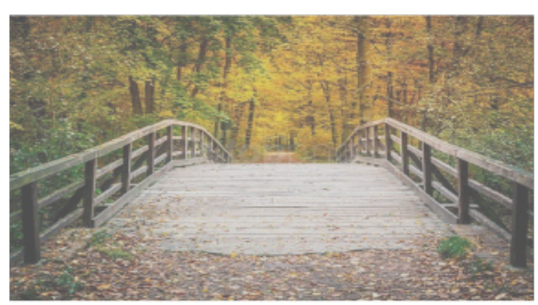


Camera Green Chroma



Inversion Magenta Chroma

In-Person View with Lifted Black Level



MultiSource Hardware Impact

GhostFrame's MultiSource feature increases the bandwidth required to drive each LED tile chain, reducing the max length of each. As a result, the available canvas size is reduced to either 4K (HDMI / SDI) or 6K (DisplayPort). Other GhostFrame features, including Chroma, still-store images, and image inversion functions, occur within the LED tile's PX1 Pixel eXchange Receiver and therefore do not impact bandwidth.

Integration

Configuring GhostFrame is an exercise in continuous optimization guided by the following questions:

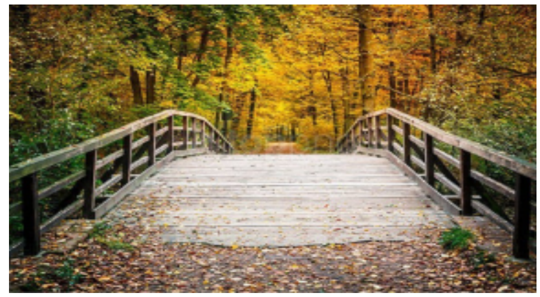
- *How many sub-frame slices can the tiles display?*
  A tile's performance and the media playback frame rate/ frequency determine the maximum available sub-frame slices.

- *How many sub-frame slices does the camera need?*
  The combination of a camera's sensor characteristics and exposure time determines the capture window.

- *What are the in-person versus in-camera requirements?*
  Hiding images and achieving visual balance consume sub-frame slices and may not be needed for certain workflows.

MultiSource Inversion

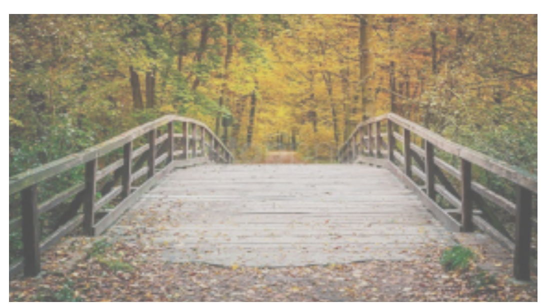
Camera Video 1



Camera Video 2

Inversion Camera Video 2

In-Person View with Lifted Black Level



Basic Requirements

1. HELIOS Processor(s) with GhostFrame License(s)

- Activation codes (browser must have internet access)
- GhostFrame Basic includes 2 chroma key + 2 still store images *(free - perpetual)*
- GhostFrame Track includes 2 chroma key + 2 still store images + inverse function *(paid - calendar time)*
- GhostFrame MultiSource includes 4 video streams + 2 chroma key + 2 still store images + inverse function *(paid - calendar time)*

2. GhostFrame Compatible LED Tile

- ROE Visual LED Tile with Megapixel PX1

3. Sync Pulse Generator (SPG) / Master Clock

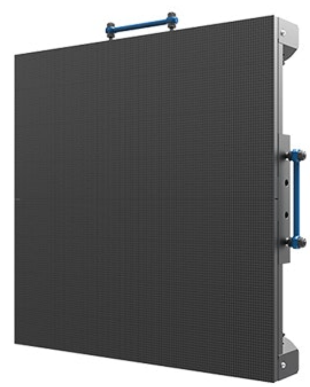
- All devices (media source, HELIOS, cameras) must be synchronized by a shared generator locking (tri-level genlock) signal.

HELIOS® LED Processing Platform

with GhostFrame License

GhostFrame Compatible LED Tile

ROE Visual LED tile with Megapixel PX1



Sync Pulse Generator/MasterClock

- Each camera must have a precise offset adjustment from the genlock signal. This may be accomplished in one of the following ways:

  - **SPG Vertical Phase Offset (required for multiple cameras)** - Sync pulse generators such as the Evertz 5601, Tektronix SPG8000A, or Brainstorm DXD-16 offer multiple independently adjustable outputs. Each camera and HELIOS require a unique output.

  - **NanoSync™ (for single camera only)** - HELIOS' NanoSync feature allows precise adjustment of the vertical phase of HELIOS in relation to the SPG's genlock signal. The camera remains locked to the base genlock signal.

  - **Camera Offset (not recommended)** - Some, but not all, cameras offer an internal genlock phase offset adjustment. This method is discouraged because the camera's timing device may lack the required accuracy.

Camera

with ability to sync to genlock signal

4. Camera

- Must be able to synchronize with a genlock signal.
- A confidence monitor to view the camera's output is highly recommended for calibration.

5. MultiSource Video Considerations

GhostFrame's MultiSource feature requires no alteration or preparation of the video signal.

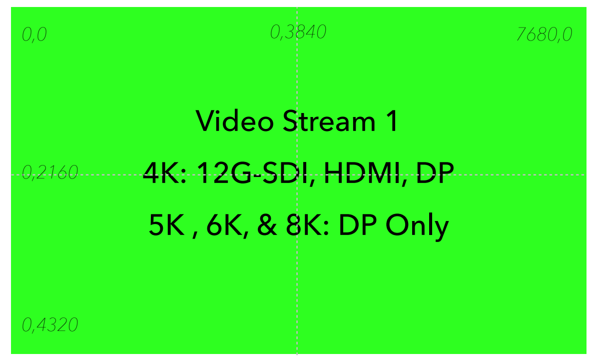
MultiSource input options include:

- 2 video streams (dual DisplayPort)
- 2 video streams (dual HDMI)
- 2 video streams (12G-SDI)
- 3 video streams (12G-SDI only)
- 4 video streams (12G-SDI only)

MultiSource works by vertically stitching the video inputs and displaying each successively in time. HELIOS's overall 8K canvas is then sequentially distributed between the smaller canvases. The input format dictates the size (usually 4K) and number (up to 4) of canvases. Any display of more than a single video stream engages the same canvas limitation. Alternatively, HELIOS supports ingestion of a single input with appropriately prepared content. Please contact support@megapixelvr.com for more details.

Available HELIOS Canvas

With Single Video Stream



with GhostFrame MultiSource

Additional video streams increase the system bandwidth proportionally. Table 1 shows the effective bandwidth for common frame rates when using MultiSource.

The LED tile chain lengths are determined by the combined bandwidth of the video streams, color bit depth, and tile connection speed. Table 2 uses the ROE Black Pearl 2v2 as an example. HELIOS supports 2.5G tile connection speeds, but few 2.5G-capable tiles are commercially available at this time.

MultiSource Effective Bandwidth

Table 1

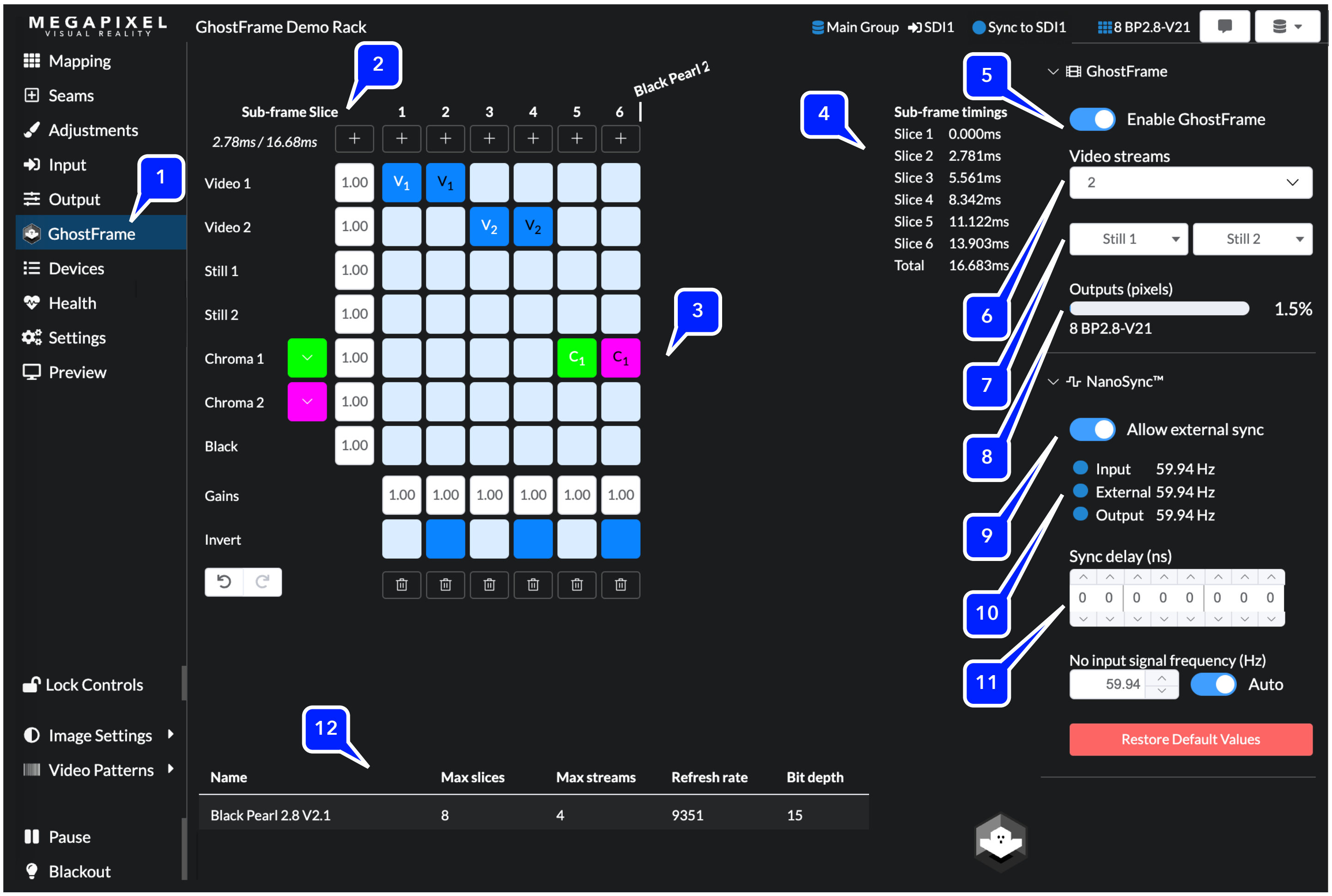
In Hz	1	2	3	4
24Hz	24	48	72	96
30Hz	30	60	90	120
50Hz	50	100	150	200
60Hz	60	120	180	240

ROE BP2v2 Tile Chain Lengths

Table 2

# of tiles	1G		2.5G	
	12 bit	10 bit	12 bit	10 bit
24Hz	34	41	85	102
30Hz	27	32	68	82
48Hz	17	20	42	51
50Hz	16	19	41	49
60Hz	13	15	34	41
100Hz	7	9	19	23
120Hz	6	7	16	19
200Hz	3	4	8	10
240Hz	2	3	7	8

GhostFrame Interface



1	GhostFrame Page Selection
2	Sub-frame Slice Display
3	Sub-frame Slice Controls
4	Sub-frame Timings Display
5	Enable GhostFrame Toggle
6	Video Streams Selection Menu Drop-down
7	Still 1 and Still 2 Menu Drop-down
8	Output Pixel Status
9	Allow External Sync Toggle
10	Sync Source Display
11	Sync Delay (ns) Dial
12	Tile Data Pane

1	GhostFrame Page Selection	Only visible when *Advanced Mode* is selected. GhostFrame controls will only appear when connected to ROE LED tiles and with an active GhostFrame license.
2	Sub-frame Slice Display	Shows duration of each active sub-frame slice and overall frame time.
3	Sub-frame Slice Controls	A. The + (plus sign) buttons add sub-frame slice templates. Templates do not become active sub-frame slices until assigned a video source or color. Active slices are numbered at the top with moving flags to indicate sub-frame slice capacity per tile. B. The trash can buttons delete sub-frame slices. C. The grid tiles assign content sub-frame slices. Select once to assign a positive image/color, a second time to invert the image/color, and a third time to unassign. i. The *Video 1-4* buttons assign respective video feeds to sub-frame slices. ii. The *Still 1-2* buttons assign respective still-store images to sub-frame slices. iii. The *Chroma 1-2* buttons assign chroma key background color to sub-frame slices. The color button to the left opens a color picker with optional hex input. iv. The *Black* button assigns a black background color to sub-frame slices. D. The *Gains* buttons display current intensity (0.00-2.00) and open a menu to adjust RGB and intensity gains. Horizontal buttons apply across a source, vertical buttons apply to single sub-frame slices. Sub-frame slices are impacted by both buttons. E. The *Invert* buttons invert an active sub-frame slice image. They have no function on sub-frame templates.
4	Sub-Frame Timings Display	Shows number of active sub-frame slices and start time of each slice.
5	Enable GhostFrame Toggle	Enables GhostFrame functions.
6	Video Streams Drop-down	Selects number of active video streams.
7	Still 1 and Still 2 Drop-down	Allows still-store capture of current video image.
8	Output Pixel Status	Displays percentage of overall bandwidth currently in use.
9	Allow External Sync Toggle	Selects which genlock signal is followed. ‣ *Input* for video source ‣ *External* for sync pulse generator
10	Sync Source Display	Displays the status and frequency of video source, sync pulse generator, and HELIOS output sync signals.
11	Sync Delay (ns) Dial	NanoSync adjustment allows offset from genlock signal.
12	Tile Data Pane	Displays each tile type's maximum number of sub-frames slices, maximum number of video streams, and color bit depth.

Camera Alignment

This process identifies the camera capture period, the number of sub-frame slices required for a clean image, and time-aligns the LED refresh within the video frame to best align with the capture period. This alignment process is required for every change in camera settings or media playback frame/rate frequency.

Being methodical in the following process pays significant dividends, especially in multi-camera setups. Missing a step or forgetting to reset an offset value will require repeating the process. A simple checklist (included as an appendix) can be an excellent tool.

STEP 1: Configure the Sync Pulse Generator (SPG)

1. Camera(s) and HELIOS must be connected to the same genlock source.
2. Set SPG to proper tri-level frame rate/frequency.
3. If applicable, reset any vertical phase offsets.

STEP 2: Configure the Camera

1. Set the sensor mode.
2. Set the frame rate/frequency and shutter angle.
3. Confirm the camera is locked to the SPG at the proper frame rate/frequency. If applicable, confirm the camera has no vertical phase offset.

   NOTE: *Most cameras do not track changes in the genlock signal and require a synchronization reset. This is most easily accomplished by unplugging and replugging the sync cable.*

4. Position the camera (and adjust zoom if appropriate) to ensure the full height of the LED wall is visible in frame. A confidence monitor is recommended to observe camera output.

STEP 3: Determine the camera sensor exposure time.

Table 3 provides the minimum exposure times based on common frame rates and shutter angles using the following formula:

Exposure Time (ms) = 1000 * 1 / ((Frame Rate * 360) / Shutter Angle)

1. Record the exposure time for use in Step 5.

Common Exposure Times (in milliseconds)
Table 3

	8.6°	12.4°	22.5°	45°	72°	90°	144°	172.8°	180°	270°	360°
23.98 fps	0.996	1.436	2.606	5.213	8.340	10.425	16.681	20.017	20.851	31.276	41.701
24 fps	0.995	1.435	2.604	5.208	8.333	10.417	16.667	20.000	20.833	31.250	41.667
25 fps	0.956	1.378	2.500	5.000	8.000	10.000	16.000	19.200	20.000	30.000	40.000
29.97 fps	0.797	1.149	2.085	4.171	6.673	8.342	13.347	16.016	16.683	25.025	33.367
30 fps	0.796	1.148	2.083	4.167	6.667	8.333	13.333	16.000	16.667	25.000	33.333
48 fps	0.498	0.718	1.302	2.604	4.167	5.208	8.333	10.000	10.417	15.625	20.833
50 fps	0.478	0.689	1.250	2.500	4.000	5.000	8.000	9.600	10.000	15.000	20.000
59.94 fps	0.399	0.575	1.043	2.085	3.337	4.171	6.673	8.008	8.342	12.513	16.683
60 fps	0.398	0.574	1.042	2.083	3.333	4.167	6.667	8.000	8.333	12.500	16.667
120 fps	0.199	0.287	0.521	1.042	1.667	2.083	3.333	4.000	4.167	6.250	8.333

NOTE *A camera's capture window can never be smaller than the exposure time.*
These numbers are theoretical and do not account for an individual sensor's characteristics or a camera's other processing requirements.

STEP 4: Configure HELIOS

1. Set *Enable GhostFrame* to the active position.
2. Set *Allow external sync* to the active position.
3. Confirm HELIOS is locked to the SPG at the proper frame rate/frequency.
4. Confirm *Sync delay (ns)* is set to 00000000.
5. Create the maximum number of sub-frame slices for the tiles at the desired frame rate.
    a. Press the Plus (+) button above each column to add new sub-frame slice templates.
    b. Assign each slice a black background to activate it. Each column is assigned a number and a flag which will move to the right as slices are added, stopping when the tile's maximum slice capacity is reached (also displayed in HELIOS' tile data pane at the bottom of the screen.)

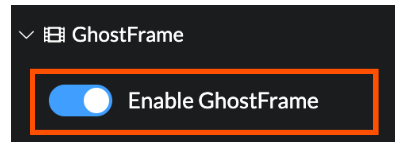
WARNING: *Photosensitive viewers should exercise caution as the screen will pulse during configuration.*

NOTE: *Do not create more sub-frame slice templates than the tiles can display. This will produce inaccurate sub-frame slice times.*

    c. Record the final sub-frame slice time for use in Step 5 and ensure all slices have content assigned or the time values will be incorrect.

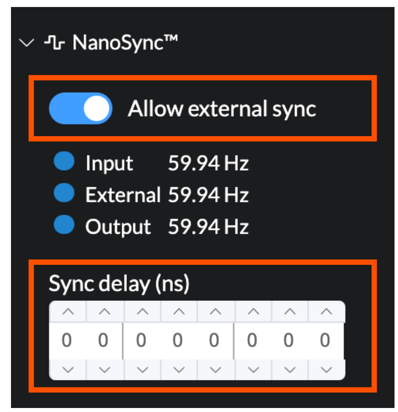
Configure HELIOS

4.1.

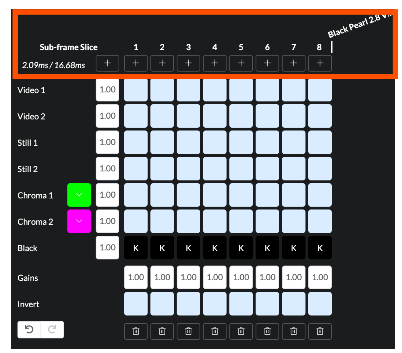


4.2.

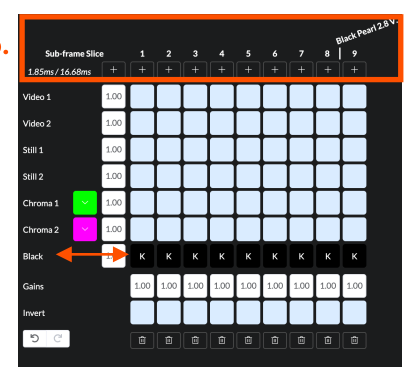
4.4.



4.5.a.



4.5.b.



4.5.b.

Name	Max slices	Max streams	Refresh rate	Bit depth
Black Pearl 2.8 V2.1	8	4	7792	15

STEP 5: Determine the Camera Capture Window

> ***WARNING:*** *Running screens at low frame rates (eg 24 or 30) may cause flashing/strobing that can be uncomfortable or triggering for photosensitive or epileptic viewers.*

NOTE: *Identifying and aligning the camera capture window is similar to tuning an analog radio. The goal is to center on the strongest portion of the broadcast signal (the desired sub-frame slices) and eliminate interference from adjacent stations (the adjacent sub-frame slices). Using black and primary chromakey is the most efficient way to distinguish individual slices. Global and roller shutters are visually distinctive and react differently to genlock vertical phase offset changes.*

1. Divide the duration of the camera capture window from Step 3.2 by the sub-frame slice duration from Step 4.5.c to predict the minimum number of sub-frame slices required.
   - This number is most useful for global shutters.
   - Rolling shutters cameras will span multiples of the predicted value.
2. Start with the first sub-frame slice, sequentially assign a chromakey, then return each slice to black. Tilt the camera up and down to ensure that the entire camera sensor is being exposed. Watch the camera's output video feed (not the screen itself), and record the sub-frame slices where chroma appears to show the slices visible to the camera.

Camera Capture Window Example

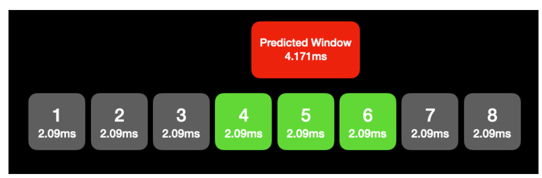
BP2V2 tile @ 60Hz = max. 8 sub-frame slices
Sub-frame slice time = 2.09ms

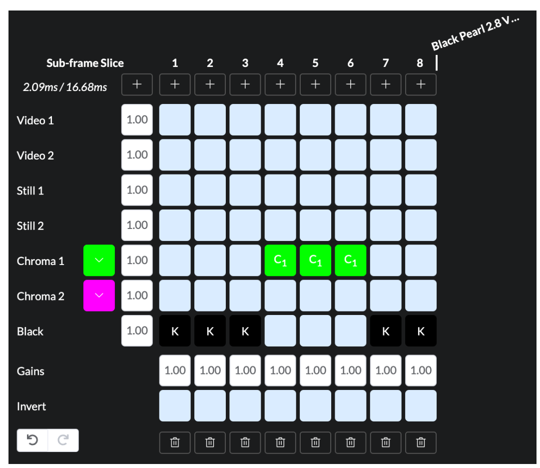
Global Shutter Camera
with 90° shutter angle @ 59.94 fps
Exposure time = 4.171ms

Minimum number of sub-frame slices = 2
(4.171 / 2.09 = 1.996)

Determine Camera Capture Window

Sequential color assignment to slices reveals initial window position observed in slices 4, 5 and 6. This is one more slice than predicted.

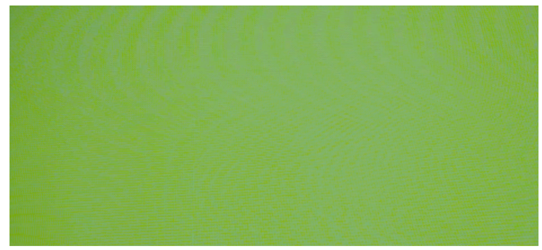




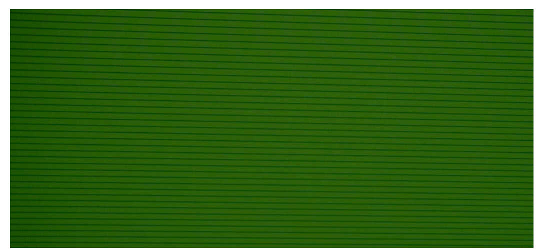
- Global Shutter - Camera-visible slices create scan lines that fill the entire screen area. The thickness and density of the scan lines increase with sub-frame slice alignment. A fully-aligned slice presents as a solid, unbroken background, while a partially-aligned slice presents as thinly spaced scan lines distributed over the screen area. If the adjacent slice is black, the lines will continue to become thinner and less dense, eventually disappearing as the phase offset is adjusted. If the adjacent slice is another color or image, the image will eventually crossfade as the offset is adjusted.
- Rolling Shutter - Each camera-visible slice creates a solid horizontal color band that fills a portion of the screen area. Additional slices increase the thickness of the band. The band moves vertically as the phase offset is adjusted - decreasing the offset moves the bands upward on the screen (earlier in the video frame), whereas increasing the offset value moves them downward (later in the video frame). Center the capture window in the fewest sub-frame slices by adjusting the vertical phase offset from the genlock signal. Assign chromakey to the first clear slice before the first identified slice in the previous step. Adjust the vertical phase offset until the color lines/band first appear, then reverse direction until they disappear.

Global Shutter Color Scan Lines

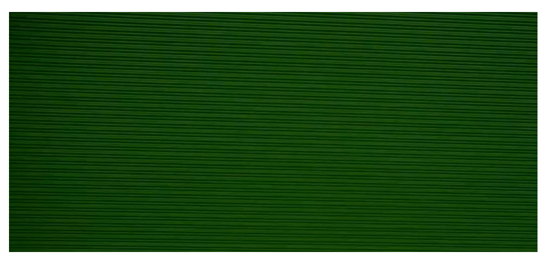
Example of fully aligned sub-frame slice



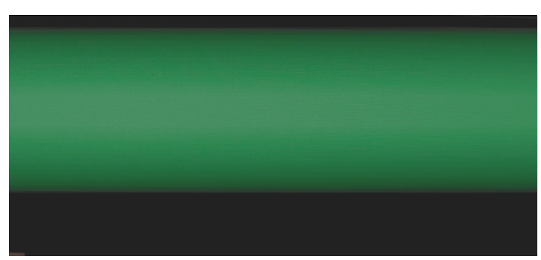
Example of partially aligned sub-frame slice



Example of barely aligned sub-frame slice (about to disappear)



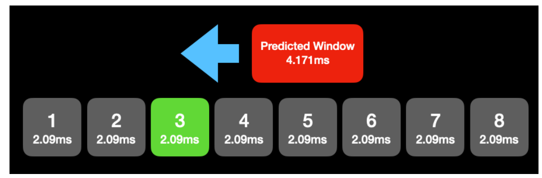
Rolling Shutter Color Scan Lines

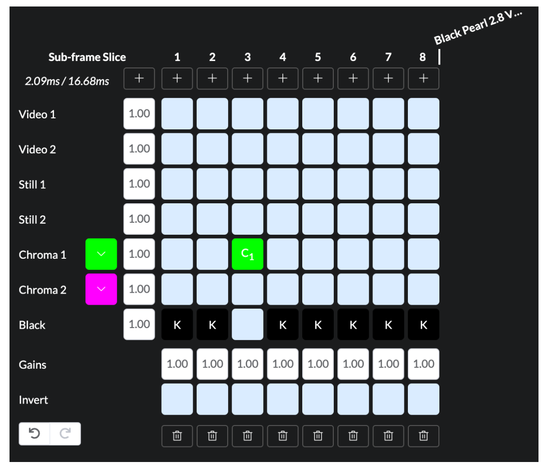


3. Center the capture window in the fewest sub-frame slices by adjusting the vertical phase offset from the genlock signal. Assign chromakey to the first clear slice before the first identified slice in the previous step. Adjust the vertical phase offset until the color lines/band first appear, then reverse direction until they disappear.
    - For single-camera setup, use HELIOS' NanoSync feature to easily and accurately adjust vertical phase offset (in nanoseconds).
    - For multi-camera setup, the vertical phase offset must be adjusted using the individual outputs of the SPG. It is most efficient to adjust the HELIOS sync output rather than the camera. Most cameras require a reset and/or blank their display output when the genlock signal changes. Units of adjustments are in lines of resolution.
        - For tri-level sync (recommended for greater accuracy), there are 1125 lines of resolution, of which 1080 are visible in each frame.
4. Referring to the results from Step 5b, set all sub-frame slices to black except for the one *preceding* the start of the observed capture window. If Slice 1 was the start, use the last slice. When the capture window is bounded by either end of the video frame, be sure that the image does not wrap into the adjacent frame.
5. Identify the left boundary. Slowly increase the vertical phase offset value (either in seconds or lines of resolution) to move the capture window to the left (into lower-

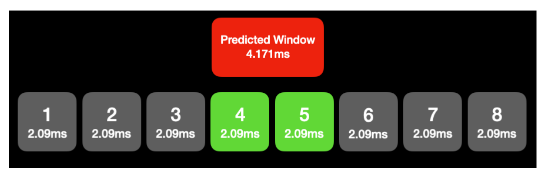
Identify Left Boundary Setting

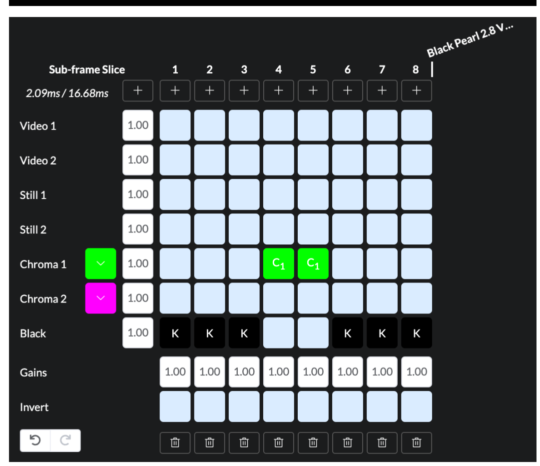
Set slice 3 to color and decrease the vertical phase offset value to move the capture window to the left in the video frame. Once color is just visible, shift back and record value.





Start at slice 4 to confirm the capture window within slices 4 and 5.





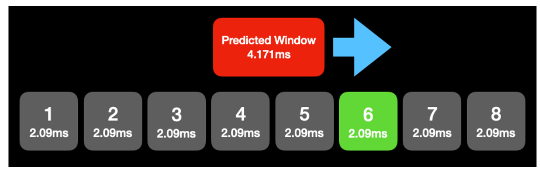
numbered slices) until color banding just begins to appear. Decrease the vertical phase offset (moving the window to right) until the frame is fully black again. Record this value (in seconds or lines of resolution).

- Global shutter: chroma color scan lines will remain static in position but will increase or decrease in thickness and density.
- Rolling shutter: chroma color bands will move up or down.

6. Identify the right boundary. Cycle back through the sub-frame slices to identify the last sub-frame slice showing chroma color. Set the slice after this to chroma color. Decrease the vertical phase offset value until the color banding just begins to appear. Increase the vertical phase offset until the frame is fully black. Record this value (in seconds or lines of resolution).
7. Center the capture window. Split the difference between the values and set the offset to that value, centering the capture window in the sub-frame slices. This confirms the number of sub-frame slices required. Centering the window helps to prevent image bleed from adjacent sub-frame slices.

Identify Right Boundary Setting

Set slice 6 to color and increase the vertical phase offset value to move the capture window to the right in the video frame. Once color is just visible, shift back and record value.



STEP 6: Position Camera Capture Window in Video Frame

1. Align the camera capture window with the desired sub-frame slice(s) using the same methods in Step 5.
   a. Set all sub-frame slices to black.
   b. Choose the sub-frame slice where the capture window should begin.
   c. Set the preceding slice (or final slice if aligning to Slice 1) to a chromakey. Increase the vertical phase offset to identify the left boundary and record the value.
   d. Set the first sub-frame slice after the Camera Capture Window (known from 6.a.) to a chromakey. Decrease the vertical phase offset to identify the right boundary and record the value.
   e. Split the difference between the values to center the Capture Window in the sub-frame slices.
2. For single camera setup, all of the above may be accomplished using HELIOS' Sync Delay (ns). Once the camera is aligned, you are ready to shoot.
3. For multi-camera setup, for each camera in turn:
   a. Use the SPG's output for HELIOS to make the vertical phase offset adjustments to avoid issues with the camera's response to sync changes. When complete, write down the phase line number.

   b. Transfer the vertical phase offset value to the camera.

      a. Reset the SPG's HELIOS output vertical phase to line

      b. Calculate the inverse value of HELIOS offset by subtracting the phase offset value from 3a above from the number of lines in the video frame (1125 for tri-level).

      c. Set the SPG's camera output to this new value.

      d. Reset camera or sync cable re-stab to accept the altered sync signal *(required for most cameras)*.

4. Repeat this process with any additional cameras.

Note: *Adjusting one offset without properly resetting the others will lead to repeated efforts.*

Optimizing

The previous steps illustrated how to:

- Determine the maximum number of sub-frame slices the tiles can display.
- Determine the minimum number of sub-frame slices for the camera capture window.
- Align the camera capture window to a specific sub-frame slice or range of slices.

The relationship of these numbers determines the number of GhostFrame features available for use. A unique configuration may be developed for each setup/shot and only needs to last until the word "cut".

For each shot/setup, consider the following:

1. *What in-camera content is essential at this moment?*
    - Multiple video images?
    - Chromakey backgrounds?
    - Still-store images for camera tracking?

2. *How important is in-person experience?*
    - Are there still-store images that need to be visible to talent but not the camera?
    - Is the in-person image as important as the in-camera capture? If so, effectively hiding images in-person requires image inversion (which uses sub-frame slices) and lower intensities (which impacts camera exposure).

- Can the in-person image be sacrificed for additional in-camera features? Layering chromakey over video or even multiple videos over one another may be acceptable for short periods.

3. *What is the display media frame rate?*
    - Certain frame rates require visual balancing to eliminate in-person flicker. See "Flicker, Frequency, and Visual Balance" item in "Notes and Strategies."
    - If a single camera is being used to capture multiple images (by running at a higher multiple frame rate), visual balancing may negate this strategy.

4. *Is the director and/or cinematographer willing to make creative compromises on the technical camera settings to get more functions?*
    - These include choosing smaller shutter angles and sensor modes to reduce the size of the capture window.

Based on those decisions, align the camera(s) and set the content (and gains) for each sub-frame slice. Record each setup as a Saved Configuration, which can be recalled with a single button push. See "Saved Configurations" in "Notes and Strategies."

Notes and Strategies

Saved Configurations

HELIOS' Saved Configurations feature (via Settings) allows for the storage and recall of unique GhostFrame settings.

To record each Saved Configuration:

1. Navigate to the Settings page.
2. Select the Saved Configurations tab.
3. Select the New button.
4. In the pop-up window, name the configuration, select the desired settings, then select "Create Configuration".

Recall Saved Configurations via the HELIOS interface or an external interface that supports the HTTP REST web service or the HTTP WebSocket JSON-RPC protocols. Email support@megapixelvr.com to request the HELIOS Public API documentation.

Examples include:

- Stream Deck with Bitfocus Companion Generic HTTP Request instance (Mac or PC)
- Stream Deck using the API Ninja plug-in (PC only)
- iPhone or iPad using the Actions app
- REST protocol:
  HTTP POST: http://xxx.xxx.xxx.xxx/api/v1/presets/apply
  Body: { "presetName": "saved configuration name" }
  (xxx.xxx.xxx.xxx = IP address of the HELIOS)

Stream Deck

With Bitfocus Companion Generic HTTP POST

Flicker, Frequency, and Visual Balance

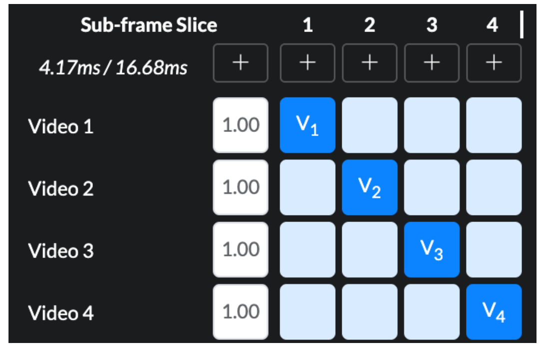
When using GhostFrame, unbalanced video frames exhibit noticeable in-person flicker at slower frequencies such as 24Hz and 30Hz, while none are observed at 60Hz. Simple balancing strategies to improve the in-person experience are explained below. It is crucial to balance both the temporal display and intensity of sub-frame slices.

As seen, these mitigations have a significant cost in terms of sub-frame slice capacity. While a tile operating at 30Hz usually has twice as many available slices as one at 60Hz, any advantage is negated by the visual balancing requirements.

Repetition is also significant when planning to capture multiple images in the same camera operating at a frame rate multiple. It may become mathematically impossible for the camera to capture different images.

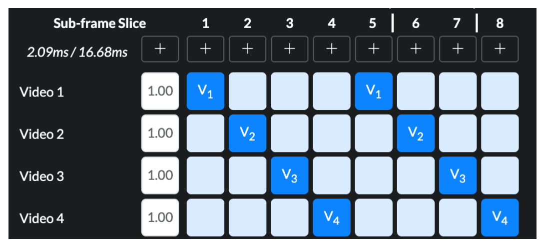
60Hz (1:1)

Requires no visual balance



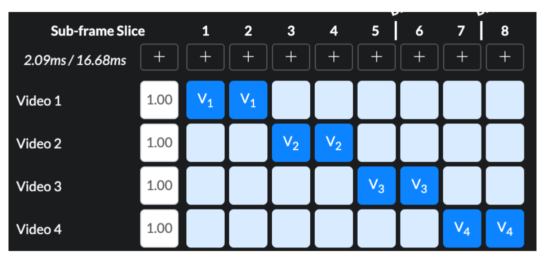
30Hz (2:1)

Eliminates in-person flicker by repeating an identical sequence of sub-frame slices.



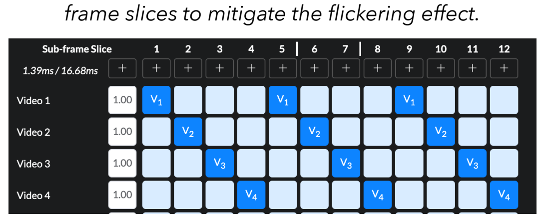
30Hz

Exhibits significant flicker, as the frame does not repeat the same sequence.



24Hz

A reduction from 30Hz to 24Hz requires extra sub-frame slices to mitigate the flickering effect.



Camera Notes

- A global shutter has a smaller capture window than a rolling shutter, which is smaller than a pseudo-global shutter. Limited sensor size has a smaller capture window than an open sensor. The smaller the capture window, the fewer the sub-frame slices needed resulting in more available GhostFrame features.

- A rolling shutter camera may have a wider capture window than is visible using the alignment methods detailed earlier. The camera sensor has reset and readout times that extend beyond the visible window. Image changes in these areas may result in a degraded image. Bookending the visible window with additional frames may be necessary. Image comparisons should be performed during camera testing to verify.

- A high-speed broadcast camera can utilize more GhostFrame features than a cinematic camera.

- Custom shutter angles may be selected on advanced cinema cameras with granularity down to 1/10 of a degree. Precise adjustment of the capture window duration is possible by making fractional adjustments to the shutter angle rather than jumping to the next common preset.

- A single camera may capture multiple images if set to a higher multiple frame rate/frequency. Multiple sub-frame slices within the video are captured, requiring the signal to be de-interleaved with either software or hardware. If you are visually balancing frames, this may not be possible.

- Improper camera alignment will result in scan lines.

General Strategies

- The GhostFrame feature set requires pre-planning and balancing for the best outcome - solving one part may have implications for others.

- An acceptable in-person (but not in-camera) image may be created with fewer sub-frame slices than the in-camera image. The intensity and color balance for the non-camera image can be independently adjusted using the sub-frame slice gains controls.

Slice Gain Controls

- One inverted sub-frame slice can balance multiple positive slices. For inversion, intensity is more important than duration.

- Image inversion increases the light output of the panels. The in-person image will exhibit greater lift and reduced contrast as you invert more images.

- It is easier to hide/disregard images at lower intensities. Remember that the camera's exposure is calibrated to specific sub-frame slices, not the overall in-person image.

- Improve in-person image contrast by adding black sub-frame slices.

- More sub-frame slices do not always translate into more features. Reducing the number of slices increases the duration of each slice, which may allow a camera's capture window to fit in fewer slices.

About Megapixel VR

Megapixel is an innovative technology partner dedicated to delivering fast-tracked, customized, state-of-the-art LED displays and processing to the world's leading entertainment, film & TV, and architectural applications.

Our unrivaled team of engineers and designers consistently delivers the most unique and breakthrough LED solutions to market, helping our visionary clients bring their ideas to life in ways that inspire a sense of wonder and make the seemingly impossible possible. With over 200 patents and award wins from Live Design, the Emmys, and the Oscars, we endeavor to always be at the forefront of digital displays and technology for which we set the bar as the industry standard.

We provide superior product design development, manufacturing expertise, and successful deployment to deliver unsurpassed visual performance for any project and look forward making the world's next iconic projects a reality.

Visit www.megapixelvr.com for more information on HELIOS and GhostFrame.

Megapixel Visual Reality
28316 Constellation Rd
Valencia, CA 91355

Jeremy Hochman
CEO & Innovator
20 years experience
LED Video Design & Manufacturing

Previous

- Executive Director R&D, VER
- Director of Product Management, Barco
- Founder, Element Labs *(acquired by Barco)*

Major Product Accomplishments

- All VER / Revolution Display LED systems
- Barco C-Series
- Element Labs COBRA tile
- World's first creative mapping software (RasterMAPPER)

Keith Harrison
COO
30+ years experience
LED Video Operations

Previous

- Executive Director LED, VER
- Managing Director, PSL Los Angeles
- Managing Director, Gearhouse Los Angeles

Major Project Accomplishments

- MGM Macau – Spectacular, Theater, Exterior
- Radio City Music Hall, NYC
- Coldplay "A Head Full of Dreams" Tour

Camera Alignment Worksheet

1. Configure the sync pulse generator
   - ☐ Set the proper frame rate/frequency for all devices.
   - ☐ Reset any vertical phase offsets.

2. Configure the camera.
   - ☐ Set the sensor mode.
   - ☐ Set the frame rate/frequency and shutter angle.
   - ☐ Confirm the camera is locked to the sync pulse generator at the proper frame rate/frequency.
   - ☐ Focus the camera to capture the full height of the tile wall.

3. Refer to Table 3 (page 15) to determine & record camera sensor exposure time: ______________ *(in milliseconds)*

4. Configure HELIOS
   - ☐ Set *Enable GhostFrame* to active position.
   - ☐ Set *Allow external sync* to the active position.
   - ☐ Confirm HELIOS is locked to the sync pulse generator at the proper frame rate/frequency.
   - ☐ Confirm *Sync delay (ns)* is set to 00000000.
   - ☐ Create sub-frame slices by pressing the Plus (+) button above each column.
   - ☐ Assign each template a black background.
   - ☐ Record final sub-frame slice time for use in Step 5: ______________________
   - ☐ Ensure all slices have content assigned.

5. Determine the Camera Capture Window
   - ☐ Estimate minimum number of sub-frame slices: ______________ ÷ ______________ = ________________

Camera Sensor Exposure Time (from Step 3)	Sub-frame slice duration (from Step 4)	Min # of sub-frame slices required.

   - ☐ Sequentially assign a chromakey to each slice and return slice to black.
   - ☐ Record the sub-frame slices where chroma appears in camera's output video feed.

     Slices: ____

- [ ] Adjust the vertical phase offset from the genlock signal to center the capture window.
- [ ] Assign a chromakey to the first clear slice before the first identified slice in the previous step.
- [ ] Adjust vertical phase offset until color lines/band first appear, then reverse direction until they disappear.
- [ ] Set all sub-frame slices to black except the *preceding* slice from the observed capture window, or final slice if aligning to Slice 1.
- [ ] Identify & record the left boundary: ______________________ (nanoseconds or lines of resolution)
- [ ] Identify & record the right boundary: ____________________ (nanoseconds or lines of resolution)
- [ ] Center the Capture Window: ______________________ – ______________________ = ____________________

Left Boundary	Right Boundary	Offset Value

6. Position the Camera Capture Window in the Video Frame

   For Single Camera setup: Align via Sync delay(ns) on HELIOS

   For Multi Camera setup:

- [ ] Set all sub-frame slices to black.
- [ ] Choose the sub-frame slice where the capture window should begin.
- [ ] Set the preceding slice (or final slice if aligning to Slice 1) to a chromakey.
- [ ] Increase the vertical phase offset to identify the left boundary and record the value.
- [ ] Set the first sub-frame slice after the Camera Capture Window to a chromakey.
- [ ] Decrease the vertical phase offset to identify the right boundary and record the value.
- [ ] Split the difference between the values to center the Capture Window in the sub-frame slices.

______________________ – ______________________ = ______________________

HELIOS phases line value	# of lines in video frame	Inverse Value

- [ ] Make the vertical phase offset adjustments via the SPG's output for HELIOS.
- [ ] Record phase line number: ______________________
- [ ] Transfer the vertical phase offset value to the camera.
  - [ ] Reset the SPG's HELIOS output vertical phase to line 1.
  - [ ] Set camera to the inverse value of HELIOS (in the opposite direction in the video frame).

______________________ – ______________________ = ______________________

Left Boundary	Right Boundary	Offset Value

- [ ] Set the SPG's camera output from the sync pulse generator to this new value.
- [ ] Reset or sync cable re-stab to accept the altered sync signal.
- [ ] Repeat process with any additional cameras.