WHITEPAPER

Film-Look in live production — What are the specific requirements and what does an optimal camera look like

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Abstract

In live productions, there's a rising demand for a film look, at least for certain camera positions. Achieving this film look involves creating a shallower depth of field, which depends on the focal length of the lens and the size of the imager. However, many live productions face the challenge of overly shallow depth of field with the small 2/3" imagers typically used, complicating focus settings. Therefore, the solution isn't simply larger imagers for all positions but selecting cameras with appropriately sized imagers for each position.

A comprehensive live production setup requires various camera types, including standard system cameras, super slow-motion cameras, wireless cameras, and compact cameras. Uniform appearance in color reproduction, gradation, and image sharpness across all cameras is essential. This uniformity is achieved through consistent signal processing or compensatory solutions for different color separation systems.

The requirements for film and live production cameras differ. An optimal camera for live applications, aiming for a film look, would feature a larger imager, such as those used in digital cinematography cameras. A Super35 imager with PL mount lenses is likely the best compromise for live productions. However, many live applications also require a global shutter, which isn't always available in digital cinematography cameras. The specific needs of film and live applications vary, making the optimal imager for one unsuitable for the other.

The paper details the characteristics of an optimal camera solution for achieving a film look in live productions and suggests potential solutions based on the latest CMOS imager and signal processing developments.

Keywords: Film-look, 2/3-inch, S35, PL mount, global shutter, OLPF, CMOS imagers, LUT

Introduction

Live productions are increasingly aiming for a film-like aesthetic, especially for certain camera positions. But what exactly defines the 'film-look,' and how can it be replicated using existing or new camera technology?

The 'film look' is characterized by several key elements that distinguish it from typical video production. One of the most recognizable aspects is the 24p frame rate, usually combined with a shutter angle of less than 360°, which produces a distinctive motion blur that audiences instinctively associate with traditional cinema. Although this lower frame rate and reduced shutter angle can be achieved with most modern cameras used in live productions, it's often impractical for live broadcasts — particularly in fast-paced environments like sports. Instead, higher frame rates such as 50 or 59.94 fps are preferred to capture fast-moving action with greater clarity and smoother motion.

Figure 1 – Comparing large depth of field and shallow depth of field (simulated image)

In live production, one of the most sought-after aspects of the 'film look' is a shallow depth of field (Fig. 1). This technique allows for selective focus on a specific subject, effectively isolating it from the background and drawing the viewer's attention to the most important elements in the frame. Typically achieved with larger sensors and wider apertures, a shallow depth of field is particularly valued in live broadcasts for its ability to add visual sophistication and aesthetic appeal, ultimately enhancing the overall production quality.

At first glance, it might seem logical to use existing digital cinematography cameras to achieve this film look for specific shooting positions. These cameras offer exceptional image quality and are readily available, so why not simply utilize them?

However, upon closer examination, several factors suggest that digital cinematography cameras may be less suitable for live applications than initially expected. What are these factors, why do they matter, and what is the best solution?

Challenges of live productions

Depth of Field

In the context of live productions, the most coveted feature of the "film look" is often the shallow depth of field. The shallower depth of field, depends primarily on the focal length of the lens, which in turn depends on the size of the imager. In many live productions, however, the opposite problem exists with most camera positions, namely that even with the small 2/3" imagers commonly used there, the depth of field is already too shallow for a reliably optimal focus setting (Fig. 2).

Object conditions, 2.1m height, 100m distance		
Image Size	2/3" (d = 11 mm)	S35 (d = 27.5 mm)
Focal Length	260 mm	650 mm
Lens Aperture	Dof	
F.no		
2.8	5.8m	2.5m
4.0	8.3m	3.6m
5.6	11.6m	5.0m
8.0	16.6m	7.2m

Figure 2 – DoF comparison 2/3" versus S35 imagers

One might wonder why not simply close the lens iris to increase the depth of field, especially considering the excellent light sensitivity of the current generation of 2/3” UHD cameras [1]. While it’s true that narrowing the lens iris does increase the depth of field, allowing more of the scene to be in focus, this approach introduces a significant issue: diffraction (Fig. 3).

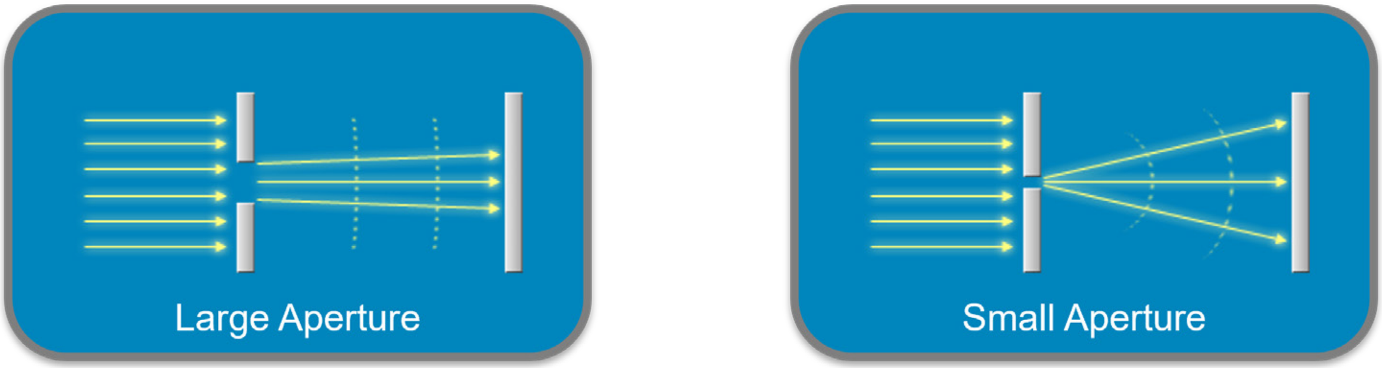


Figure 3 – Diffraction depending on lens aperture

Lenses are subject to two primary optical limitations. When the lens iris is wide open, aberrations — optical flaws such as chromatic aberration or spherical aberration — can degrade image quality. Conversely, when the iris is closed down too much, diffraction becomes the dominant issue. Diffraction occurs when light waves bend around the edges of the iris blades, leading to a loss of sharpness and detail in the image.

For high-definition (HD) resolution, the “sweet range” of the lens — the optimal aperture range that balances aberrations and diffraction — is typically around 3-4 f-stops wide (Fig. 4). However, in the case of UHD resolution, the situation becomes much more challenging. The increased pixel density of UHD sensors means that even slight optical imperfections are more noticeable. As a result, the sweet range shrinks dramatically, often to as narrow as half an f-stop. This means that for UHD applications, the iris must be kept at a nearly fixed position, typically around f/3.5, with very little flexibility to adjust up or down without sacrificing image quality.

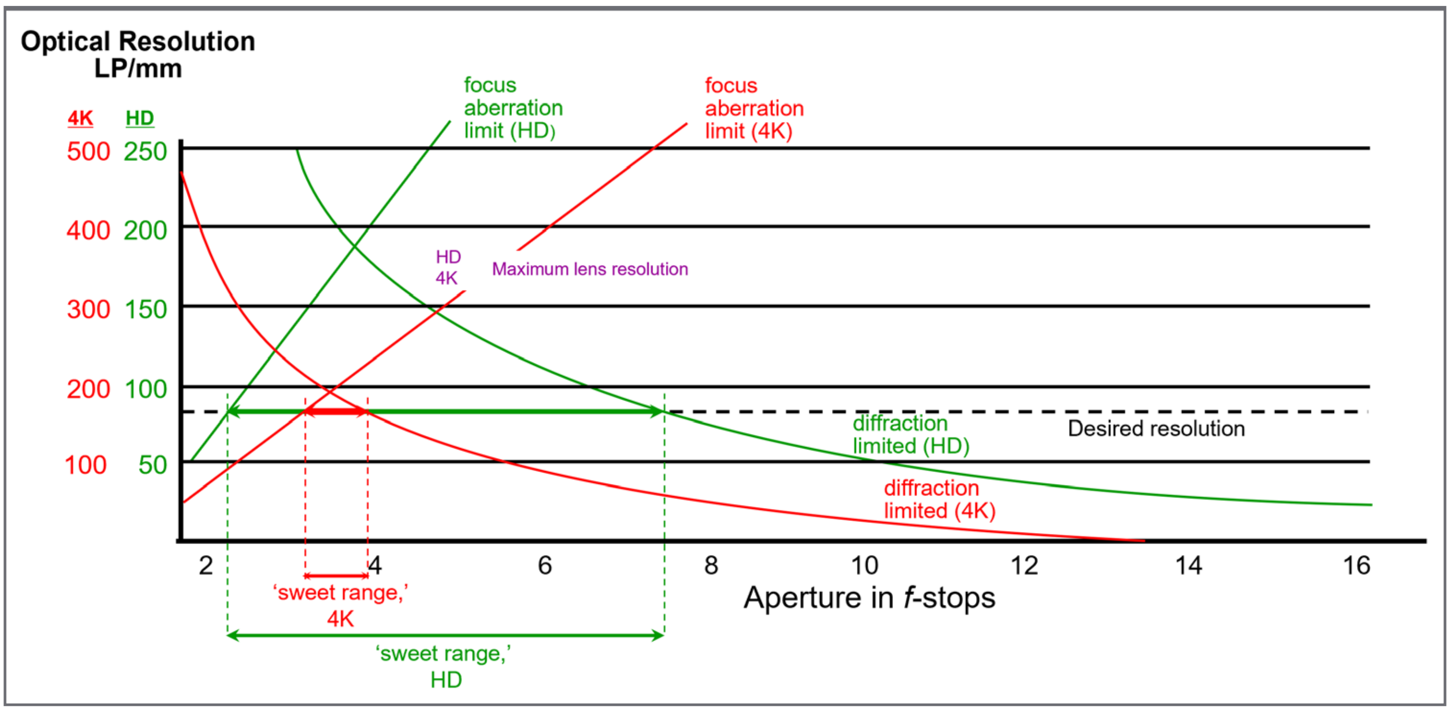
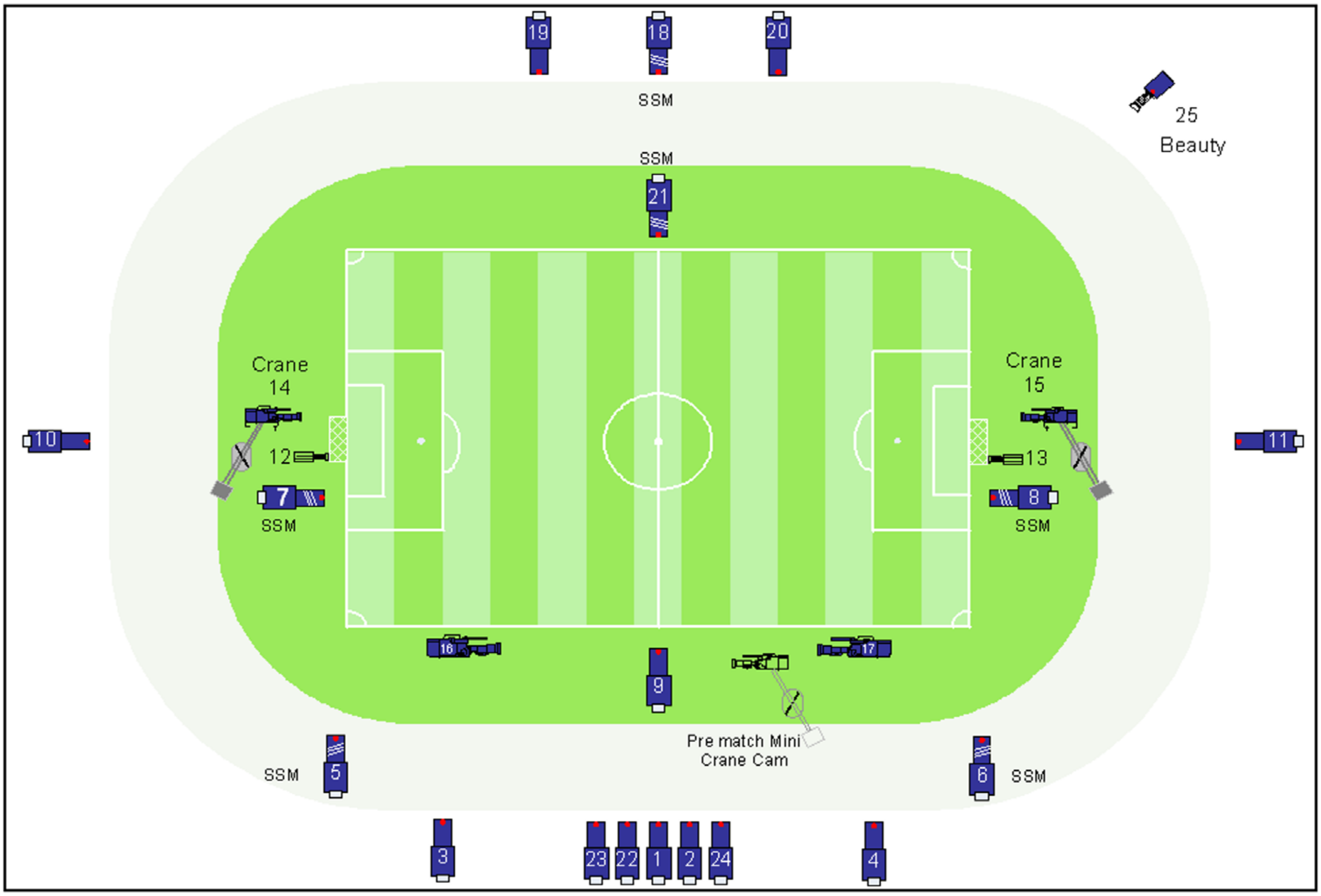


Figure 4 – Sweet range between aberration limits and diffraction limits depending on video format

This constraint makes it impossible to close the iris enough to achieve the extended depth of field needed for long-distance close-up shots in UHD production. As a result, camera operators face a significant challenge in managing focus, especially during fast-paced action. The delicate balance between capturing sufficient depth of field to keep subjects in focus and maintaining the high image quality demanded by UHD is much harder to achieve.

When using cameras with larger imagers, a key challenge is the longer focal lengths required to match the angle of view of 2/3" imagers. This change significantly reduces depth of field, which, while desirable for a cinematic look, can be problematic in live production. In long-distance telephoto shots, the shallow depth of field from these longer focal lengths can make it difficult to keep subjects in focus, especially in dynamic scenes. Additionally, lenses with the necessary zoom range for larger imagers are typically either not available or, if they are, they tend to be bulkier, heavier, and more expensive, making them impractical for many camera positions.



	High and large distance position		Low and short distance position	
	Wide angle	Tele	Wide angle	Tele
Example of camera positions	1, 3, 4	5, 6, 10, 18, 19, 20, 22, 24	14, 15	7, 8, 9, 21
Highest resolution	+	–	0	–
High sensitivity	0	+	0	+
Global shutter	–	+	+	+
High dynamic range	+	0	+	+
+ = very important / 0 = neutral / – = less important				

Figure 5 – Camera positions and their specific requirements on a typical sport production

Instead of using larger imagers across the board, it's more effective to match the imager size to the specific needs of each camera position (Fig. 5). Cameras with 2/3" imagers are ideal for positions requiring greater depth of field and consistent focus, such as long-distance shots. They also offer more manageable lenses for fast-paced environments. Conversely, cameras with larger imagers can be selectively used for close-ups, where a shallow depth of field enhances the cinematic effect. This strategic use of different imager sizes allows each camera position to be optimized, balancing the film look with the technical demands of live broadcasting, and improving overall production quality.

Multiple camera types

A significant challenge in achieving seamless live production is the need to integrate multiple camera types, each with a specific function — such as standard system cameras with portable or long zoom range box type lenses, super slow-motion cameras, wireless cameras, and compact cameras. Ensuring a consistent visual appearance across these diverse cameras is essential for maintaining uniformity in color reproduction, gradation, and image sharpness throughout the production.

To achieve this consistency, it is crucial that all camera types utilize the same signal processing technology. This uniform signal processing ensures that, despite differences in camera design and functionality, each one produces cohesive image quality that aligns with the overall aesthetic of the production.

Color separation methods

When using different camera systems with distinct color separation methods — such as three-imager RGB prism systems versus single-imager Bayer filters — variations in color response can become significant. Bayer pattern filters typically offer less selective color separation, resulting in greater overlap between color channels (Fig. 6 left). Conversely, the prism beam splitters in three-imager cameras provide more accurate color separation with minimal overlap (Fig. 6 right), leading to a different color reproduction.

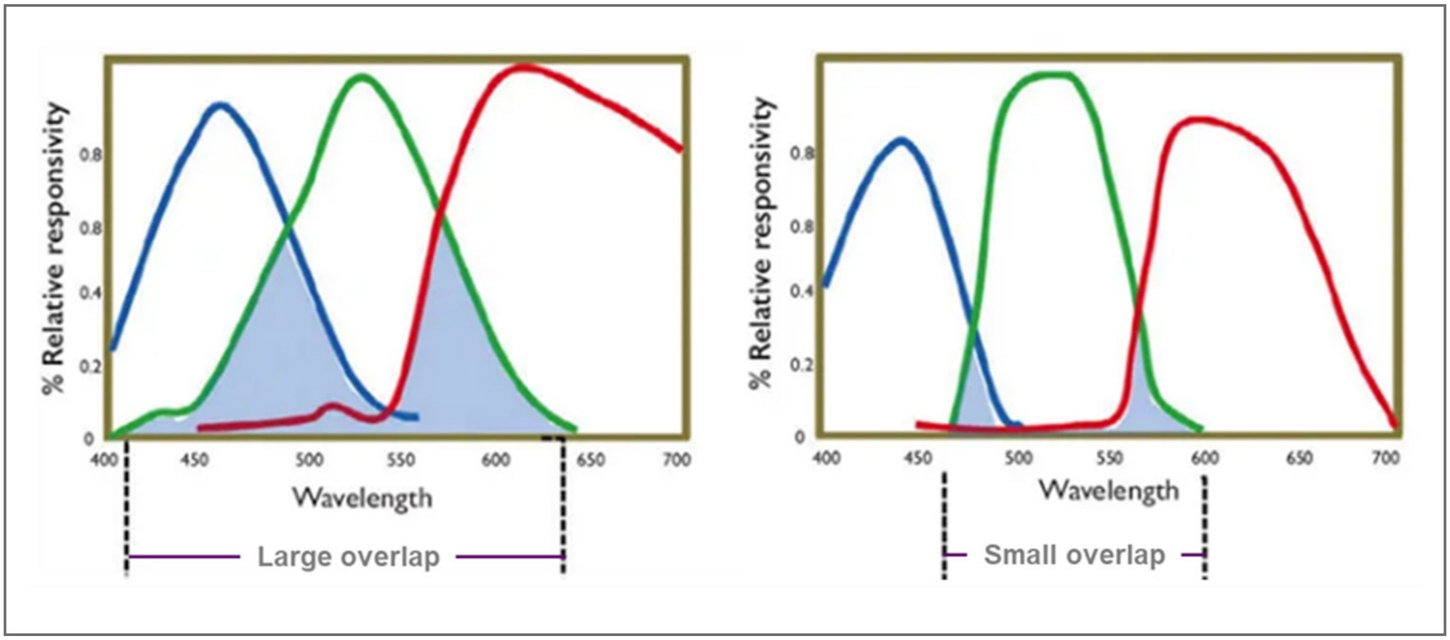


Figure 6 – Comparing different color separation filters

When both camera types are employed in the same production, these differences can lead to inconsistencies in color reproduction, complicating the task of achieving a uniform visual appearance across all camera feeds. To address this challenge, in-camera solutions are essential. Advanced color matching techniques, such as LUT-based color conversion integrated directly into the camera's signal processing, help harmonize the color output across different systems.

By implementing these corrections, the cameras can produce a unified visual standard, ensuring that the final broadcast or recording presents a consistent and cohesive look, regardless of the underlying color separation technology. This approach facilitates the seamless integration of diverse camera systems within a single production, enhancing the overall quality of the visual output.

Figure 7 – Camera shading solution with advance features for live applications

Signal processing

Beyond color consistency, maintaining uniform gradation and image sharpness is equally important. This may require additional measures like sharpness enhancement, gamma correction, and dynamic range optimization to harmonize the output across all camera types, ensuring a seamless production.

The primary distinction between a camera system optimized for live production and one designed for digital cinematography lies in the time available for image processing. In live applications, the interval between light hitting the imager and the signal going on-air is extremely limited — typically just one frame, or about 1/50th to 1/60th of a second, depending on the frame rate. This brief window necessitates highly efficient, real-time processing to produce the final image instantly, as there is no opportunity for post-production adjustments.

In contrast, digital cinematography cameras, used in cinema-style applications, are designed with a different priority. Their main purpose is to capture and preserve as much information as possible for post-production. These cameras are optimized to capture maximum dynamic range and latitude, often in the form of RAW data, allowing extensive manipulation of the image in post. This approach gives filmmakers the flexibility to fine-tune the image's look long after shooting but means that the in-camera processing requirements during capture are less demanding compared to live production.

The disparity in processing requirements highlights the substantial difference between live production cameras and digital cinematography cameras. In live production, cameras must perform complex operations such as real-time highlight compression, color correction, noise reduction, and detail enhancement—all within milliseconds. This immediate processing capability places significantly higher demands on the camera's internal systems compared to digital cinematography cameras, which focus on capturing high-quality, unprocessed footage for extensive post-production refinement.

Live camera control

A critical aspect of live production is live camera shading, a process performed by an operator to ensure consistent image quality across multiple cameras in real-time. Advanced tools have been developed to facilitate this [2], including dedicated, customizable live camera control panels and sophisticated software that provides an overview of all cameras and their settings (Fig. 7). These tools allow for precise adjustments on the fly, ensuring that the final broadcast maintains a cohesive look despite the varying conditions and camera types involved.

In contrast, digital cinematography cameras are typically not designed to handle the immediate demands of live production. When paired with third-party universal control panels, they often fall short of providing the necessary responsiveness and integration required for high-pressure live environments. The lack of seamless compatibility and the absence of dedicated live production features make these cameras less suitable for situations where multiple camera types must be synchronized into a single, cohesive production.

This difference underscores why live production environments require specialized camera systems that are purpose-built for the demands of real-time broadcasting. The ability to perform complex image processing tasks instantly, combined with advanced camera control systems, is essential for maintaining the high standards expected in live television and event coverage.

Multiple simultaneous outputs

Another critical area where cameras optimized for live production differ from those designed for cinema-style production is in handling and transmitting multiple versions of output signals [3].

Live production environments often require simultaneous outputs in various formats and dynamic ranges, tailored to different aspects of the production (Fig. 8). For example, the main production feed might need UHD resolution with HDR and Wide Color Gamut (WCG), while a separate 1080p HDR/WCG feed may be required for the Video Assistant Referee (VAR) system, and a 1080i SDR/Rec.709 feed is essential for camera shading and ISO recording.

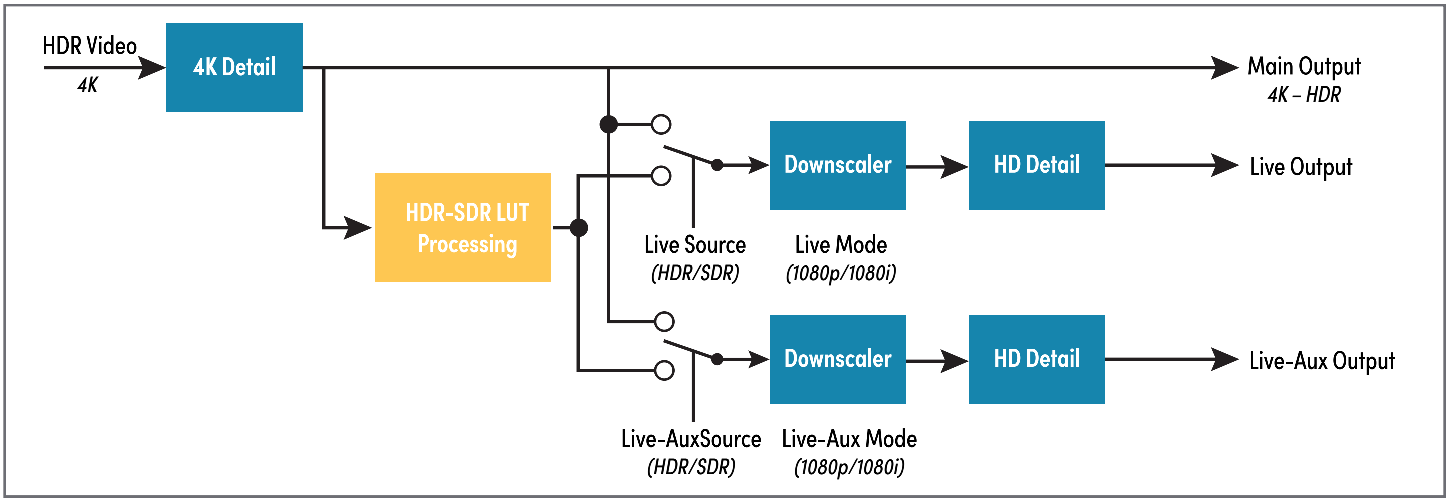


Figure 8 – Choice of output signal selection

If a camera cannot natively deliver all the required signals, external converters must be used, which not only increases costs but also introduces additional points of potential failure. This is particularly critical in HDR productions, where a simultaneous SDR signal is often mandatory. A well-established workflow known as “closed-loop camera shading” (Fig. 9) relies on the camera shader viewing down-mapped SDR signals. It is essential that the down-mapping characteristics of the camera’s output match those of the downstream production chain to maintain consistency and accuracy in image representation.

To minimize reliance on external converters and maintain a streamlined workflow, modern live production cameras must integrate sophisticated LUT (Look-Up Table) processing capabilities. This allows the camera to output multiple signal versions simultaneously, each tailored to specific needs within the production environment. For example, integrated LUT processing enables the selection between industry-standard 3D-LUTs — such as those provided by the BBC or NBC — or custom LUTs developed for large-scale international sports productions. These features ensure that the camera can deliver the precise signal characteristics required by different parts of the production chain without the need for additional hardware.

In contrast, cinema-style cameras are generally not designed to output multiple simultaneous signal versions, as the focus in film production is primarily on capturing the highest quality image in a single format for later manipulation in post-production. The need for diverse, real-time outputs simply isn’t as pressing in a cinematic context, where post-production workflows can accommodate extensive adjustments and format conversions after the fact.

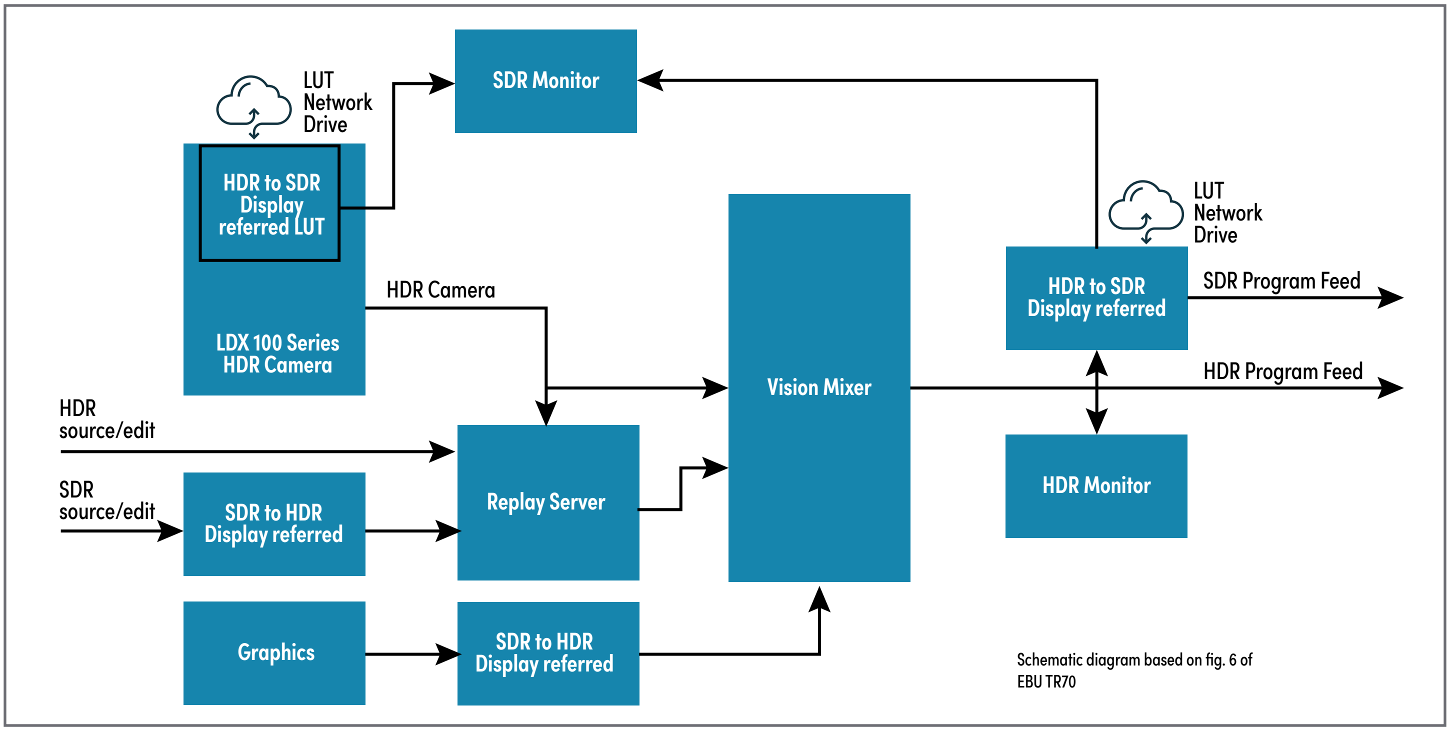


Figure 9 – Overview HDR/SDR workflow with "closed-loop shading"

The integration of these advanced signal processing features in live production cameras is therefore not just a convenience but a necessity. It ensures that all elements of the live broadcast — whether it's the main production feed, VAR system, or camera shading — can operate seamlessly and efficiently, with minimal risk of error and without the burden of additional external equipment. This capability is essential in high-stakes environments like live sports or large-scale events, where maintaining a flawless broadcast across multiple platforms and standards is paramount.

In summary, the ability to deliver multiple versions of output signals directly from the camera, tailored to the specific needs of the production, is a fundamental difference between cameras optimized for live production and those designed for cinema-style applications. This capability reduces complexity, enhances reliability, and ensures that live broadcasts meet the diverse technical demands of modern production environments.

LED walls

In recent years, LED walls have become a staple in various live production environments, revolutionizing how visual content is presented [4]. In news studios, they have become the *de facto* standard for displaying virtual backgrounds, interview partners, weather forecasts, and other dynamic content. In music productions, LED walls are integral for showcasing performers and creating immersive show effects, often displayed on massive screens for the audience. Similarly, in sports productions, virtual ad replacement on LED banners has become standard practice, providing valuable advertising space.

A common requirement across these diverse applications is the need for camera imagers equipped with a global shutter for optimal performance. Global shutter technology ensures that every pixel on the camera sensor is exposed simultaneously, eliminating the rolling shutter artifacts that can occur with fast-moving content or when filming LED screens. Without a global shutter, issues like image distortion, flickering, or tearing can arise, particularly when capturing LED walls, making global shutters not just advantageous but sometimes essential for achieving high-quality results.

Additionally, in scenarios where LED walls operate at higher frame rates — such as for virtual ad replacement in sports or in studios where different content is shown to multiple cameras simultaneously — additional processing features like v-shift become critical. V-shift technology helps synchronize the timing of the LED display with the camera's capture process (Fig. 10), ensuring that the content displayed on the LED wall integrates seamlessly into the broadcast feed.

This is particularly important in complex productions where content needs to be synchronized across multiple displays and cameras, or where the LED wall content must appear natural to both the camera and the live audience in the studio or stadium.

In summary, the widespread adoption of LED walls in live production has driven the need for specialized camera technologies that can handle the unique challenges these displays present. Global shutter sensors, V-shift processing, and high frame rate capabilities are now essential features in live production cameras, enabling seamless integration with LED walls and ensuring the highest quality output in real-time environments. These advancements underscore the distinct requirements of live production compared to cinema-style filmmaking, further emphasizing the need for dedicated camera systems tailored to each type of production.

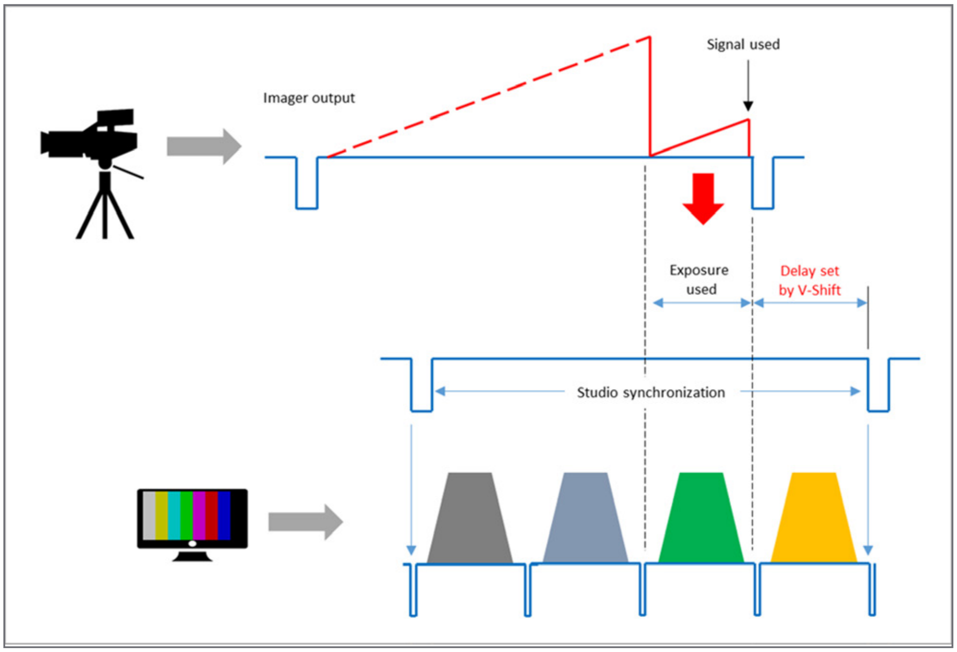


Figure 10 – Overview V-shift function

Optimized camera for Film-look in live applications

Imager and optical filtering

An ideal camera for film-look in live applications should be built around a single S35 CMOS imager with a PL lens mount, as this combination offers a wide selection of lenses suitable for live production. As previously mentioned, a global shutter is not just optional but essential for the imager, given the demands of most live applications.

The S35 image sensor should have a significantly higher pixel count than the standard UHD resolution (3840x2160), enabling oversampling. This process involves capturing more detail than necessary and then downsampling to UHD, which enhances the modulation transfer function (MTF) and the camera's ability to reproduce fine details. A higher MTF results in greater image sharpness without relying on digital sharpening or detail correction, leading to smoother, more natural images.

However, this increased pixel count introduces new challenges for the signal bandwidth that the sensor must process and deliver. To meet these demands, some of the advanced technologies developed for the latest 2/3" UHD CMOS sensors [1+5] are now being leveraged to handle these even more extensive requirements.

To achieve an optimal balance between image sharpness and the suppression of aliasing artifacts when working with LED walls, the camera must include an additional optical low-pass filter (OLPF) specifically optimized for this purpose.

Finally, the sensor and signal processing should support a dynamic range of at least 15 f-stops, ensuring that the camera can capture the full dynamic range expected from the best live cameras on the market without any limitations.

Processing and workflow

The requirements in this area are relatively straightforward: the camera should match the capabilities of current top-tier live cameras equipped with 2/3" image sensors. This includes all essential processing features necessary for simultaneous HDR and SDR output across different video formats, as well as the ability to select from the same color matrices and utilize V-shift functionality for optimized integration in VR/AR applications.

Any differences resulting from variations in image sensors and color separation systems must be internally compensated within the camera, ensuring that both types can operate seamlessly side by side in production without users noticing any discrepancies or limitations.

Connectivity, signal flow, and the flexibility and number of output signals should remain consistent across both camera types, with any differences ideally limited to the image sensors, lenses, and resulting optical characteristics. This approach suggests that both cameras were developed on a shared platform.

Conclusion

In summary, the key difference between live production cameras and digital cinematography cameras lies not only in the size and number of imagers but also in their fundamentally different approaches to image processing. Live production cameras are designed to deliver a polished, broadcast-ready image in real-time, while digital cinematography cameras focus on capturing the highest possible quality for later enhancement, reflecting the distinct demands of their respective applications.

Achieving a film look in live production is a complex task that requires a careful balance of various technical elements. The optimal camera for this purpose should feature a larger image sensor, preferably a Super35, paired with PL mount lenses, a global shutter, and advanced real-time processing capabilities. Consistent color science across different camera models within the same production is crucial for maintaining a uniform visual appearance.

Leveraging the latest advancements in CMOS imaging technology and signal processing, it is possible to develop camera systems that deliver the cinematic quality demanded in live environments. These advancements enable the creation of tools that meet the high standards of both live and film production, providing a seamless integration of cinematic visuals into live broadcasts.

In summary, while achieving a film-like look in live production presents significant challenges, ongoing innovations in camera technology offer promising solutions. By addressing the specific demands of both live and film production, it is possible to achieve a harmonious blend that meets the rigorous expectations of both fields.

Acknowledgements

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