

Ambient Light Compensation for Filmmaker Mode

Introduction

The collaboration of UHDA with the creative community and display manufacturers resulted in the introduction of Filmmaker Mode in 2019. Filmmaker Mode is now available on a large number of TV sets from different manufacturers. The goal of the Filmmaker Mode is to preserve the visual experience the creative community sees when approving content viewed in a reference viewing environment. Filmmaker Mode has worked great when the viewing conditions of the consumer match the reference viewing environment (a dim-surround color grading suite at 5 cd/m²). In non-reference viewing environments, with elevated ambient illuminance, the human visual system adapts to the surround luminance. This adaptation results in a change in the observer's sensitivity to contrast, causing shadow detail that is visible in a reference dim surround to fall below the threshold of visibility. This results in a perceived loss of image detail and a darker overall picture, which has been the primary source of negative feedback on Filmmaker Mode from consumers and manufacturers. The UHDA has addressed this feedback by developing an ambient light compensation algorithm for Filmmaker Mode.

Ambient Light Compensation

Guiding Principles

The Technical Workgroup (TWG) of UHDA established several guiding principles and assumptions prior to the development of the Ambient Light Compensation (ALC) algorithm. The overall formula and further development steps of the algorithm stem back to these principles:

1. The processing should ideally be computationally inexpensive to allow the algorithm to be deployed on displays spanning a wide price range and processing power.
2. To allow ALC to work with the widest range of content, it should not rely on dynamic metadata or any information about the content that might not be available during playback.
3. The algorithm must be suitable for HDR content playback, however, SDR content playback should be supported as well if at all feasible.
4. Screen reflections are considered as a separate problem because of their high dependence on the anti-reflective coating used in each display. They might be addressed in the future if the UHDA considers such research relevant.
5. The algorithm should apply no processing at surround luminance below 5 cd/m².

6. The algorithm should ideally not raise the black level of the screen. This is a direct result of the black level treatment as a sensation (the appearance of the screen emitting no light) and not as a signal (each display's black level can appear differently) in the problem definition. The values above the black level can and should be raised to preserve the visibility of details in the content.
7. ALC should be applied as the last processing step, after all tone-mapping and processing has been applied. If the input image fits within the dynamic range of the display, then after applying the ALC the output image should also fit within the dynamic range of the display, i.e. the algorithm should not cause additional clipping or crushing of content.

In an early meeting of the TWG, the group approved a general solution that the algorithm should follow. It was composed of three steps: (a) normalization of the input PQ-encoded image to [0,1] range, where 0 represents the black level of the display and 1 represents the peak luminance of the display, (b) applying a power function (gamma) and (c) rescaling the image back to the PQ range of the display luminance. By anchoring the display black and white levels at 0 and 1, respectively, during the application of the gamma function, guiding principles 6 and 7 were observed. The choice of the specific gamma values used at each surround luminance level was determined experimentally.

Experiment

The experiment was conducted in a controlled environment with overhead lights switched off and lighting provided by adjustable stage lamps, allowing to control the surround luminance from 0 to 500 cd/m². The lights were positioned behind the display to reduce the screen reflections to a minimum, with white background provided behind the reference display to maximize the achievable surround luminance. The ALC algorithm has the following three main steps: normalization, application of the compensating gamma, and re-normalization. The only controllable parameter is the adjustable gamma value. A playback solution was developed, implementing the proposed compensation algorithm as a DCTL plugin for Blackmagic DaVinci Resolve with the gamma value controlled with a single knob on a colorist panel.

Multiple colorists working for the Hollywood studios participated in a visual matching experiment in which they adjusted the compensating gamma parameter using the provided setup. Their main goal was to achieve a perceptual match in shadow detail visibility and mid-tone contrast, compared to their memory of the same content in the reference environment. The primary task was to adjust the compensating gamma parameter until the detail in the shadows was equally discernible in both the test and reference conditions.

The experiment used short clips from the ASC StEM2 test content exhibiting a wide-range of image statistics, including high-key, low-key and high contrast scenes. After completing the task, the colorists reported being overall satisfied with the end result and the quality of the match achieved. The data from the experiment, including the surround luminance and the selected

compensating gamma value, was analyzed to determine an average gamma compensation value that corresponded to each of the different ambient lighting environments.

Evaluation

After determining the average gamma compensation value for each different ambient lighting environment, the ALC was tested with additional content and demonstrated to Hollywood Studio executives and UHDA members. After receiving positive feedback, the UHDA organized a demonstration event at the ASC Clubhouse in Hollywood, CA where 31 members of the ASC and Colorist Society evaluated the proposed algorithm. After the demonstration of multiple video clips, including content provided by the demo participants themselves, each participant filled out a questionnaire asking about potential improvements and overall impressions. The feedback from the demonstration participants was overwhelmingly positive, concluding that this solution would significantly improve the user experience in non-reference viewing environments.

Additionally, the compensation algorithm was tested on several displays using both LCD-based and OLED-based display technologies with different screen surface characteristics, and it was confirmed that the compensation algorithm resulted in a visual match in the non-reference viewing environment to how each display looked when operating in Filmmaker Mode mode in a reference viewing environment.

Finalized Compensation Algorithm

While the full details of the compensation algorithm are included in the Filmmaker Mode v1.1 specification, the algorithm's input and output characteristics and algorithm steps can be summarized as follows.

Algorithm input and output characteristics:

- 1) nonlinear luminance Y' input signal $[Yn_input]$ corresponds to ITU-R BT.2100 PQ Full-Range and has signal values in the range $[0,1]$.
- 2) nonlinear luminance Y' Output Signal $[Yn_output]$ corresponds to ITU-R BT.2100 PQ Full-Range and has signal values in the range $[0,1]$.
- 3) Input Signal content is assumed to have already been tone-mapped to the equivalent of the display min and max luminance $[min_nits, max_nits]$,
- 4) $min_PQ = pq_inverse_EOTF(min_nits)$ and $max_PQ = pq_inverse_EOTF(max_nits)$ where $pq_inverse_EOTF(x)$ is the Reference Inverse-EOTF defined in Section 5 of SMPTE ST2084:2014.

Algorithm steps:

- 1) Normalize: $Yn_norm = (Yn_input - min_PQ) / (max_PQ - min_PQ)$
- 2) Apply compensating gamma: $Yn_gamma = pow(Yn_norm, gamma)$, where $pow(x,a)$ is the power function equivalent to $f(x,a) = x^a$

3) Re-Normalize: $Yn_output = Yn_gamma * (max_PQ - min_PQ) + min_PQ$

The gamma exponent value used by the compensation algorithm depends on the estimated average surround luminance in close proximity of the display showing the content. The table below defines the relationship between the average surround luminance and the compensating gamma value.

Surround Luminance (cd/m ²)	gamma
5	1.0
10	0.980
20	0.954
40	0.913
80	0.859
160	0.794
320	0.715
500	0.668

The efficacy of this algorithm is dependent on an accurate estimation of the surround luminance by the display's integrated ambient light sensor. The large number of sensors available on the market along with the changes caused by the positioning of the sensor on the display make it unfeasible for the UHDA to provide general guidance on how to achieve accurate readings from the sensor. It is the manufacturer's responsibility to calibrate a sensor so that it accurately measures the average illuminance of the visual field surrounding the display and convert from illuminance to luminance, as this value is the direct input for selecting the appropriate gamma from the table. The UHDA recommends a measurement methodology that emphasizes diffuse, average surround conditions rather than direct, specular light sources.

Conclusion

The Ambient Light Compensation algorithm for Filmmaker Mode is the first correction algorithm that was developed in collaboration with Hollywood professionals and has been approved for use by the creatives. It has been implemented in some displays that shipped in 2025.