For a Better HDR Gaming Experience

- Best Practice Recommendations for Game HDR Creation Version 1.1

HDR Gaming Interest Group

July 2019

Revision history

Version	Date	Updated slides	Revision
Version 1.0	August 15, 2018		Document created
Version 1.1	July 11, 2019	Slide#18 and #19	Apply default value proposal to Slide#18 and Slide#19

Background

- Game platforms support High Dynamic Range (HDR)
  - XBOX One S, XBOX One X
  - PlayStation® 4, PlayStation® 4 Pro
  - Windows 10

- Major game publishers have already released HDR games.
  - More than 100 HDR games were released so far on the above game platforms.

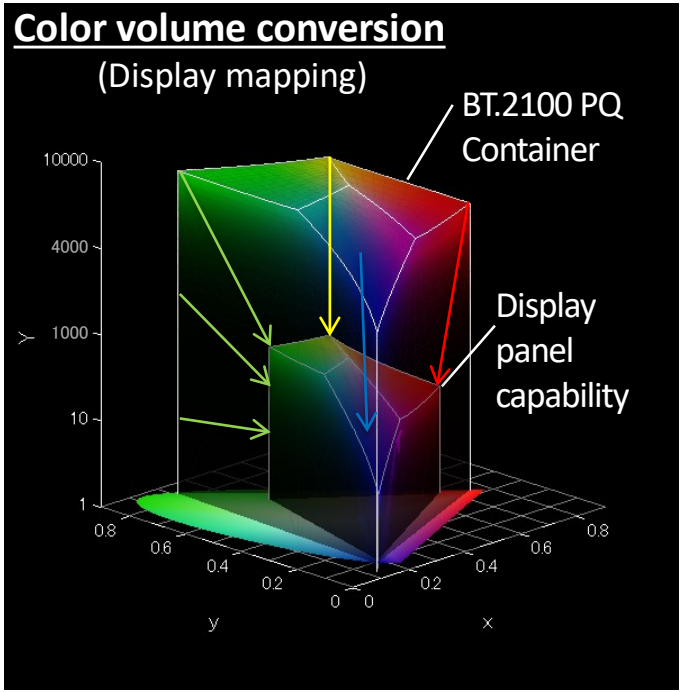
- HDR is a great technology, but consumer reactions are not always positive to HDR games. Games are different from other media content like movies, because they are interactive, immersive and competitive.

- HDR Gaming Interest Group, with participation of leading companies from the entertainment, game and TV industries, analyzed issues behind the negative reactions from consumers about HDR games and recommend the guidelines for HDR game production as outlined in the following pages. In sum, the core element of the recommendation is to produce an HDR game that parameterizes its tone mapper when given information about an HDR display's tone mapper. This will compensate for the variance in how displays handle HDR.

- As described in later pages, certain aspects of these recommendations may be further elaborated based on knowledge accumulated through experiences in HDR game production. HDR Gaming Interest Group also anticipates these recommendations will be implemented more easily with support from neighboring technological standards (e.g. some aspects of parameter exchange between game consoles and TVs/PC displays can be automated with CTA and HDMI Forum standards).

Challenges

- HDR displays cannot yet reproduce the full extent of luminance and color as specified in BT2100 PQ. Also, e.g. games using physical based rendering (PBR), render into an unconstrained linear space that exceeds BT2100 PQ. For example, a sun could be rendered much brighter than 10,000 nits.
- To make effective use of its display panel capabilities, an HDR display uses tone mappers to map the original color volume of source content to the color volume of its display panel (“Display mapping”)
- Different HDR displays handle display mapping in different ways, resulting in visual differences of the same source HDR content.
- TV manufacturers, based on their own research and development, design displays to bring the best picture quality in their own ways. Differences in their design philosophy may be a cause of the variance in HDR handling.
- Such variance unfortunately sometimes results in inconsistency in consumers’ game play.



Typical Undesirable User Experience – Details in bright areas, critical to gameplay, may be lost.

Some players can see the right turn after the tunnel, but other players can’t.

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Guiding Principles

The following are the guiding principles in identifying the best practice recommendations.

1. **Acknowledge difference**
   There is wide variance in how HDR content is processed in HDR displays, and the assumption that “displays perform exactly the same” cannot be taken. Each display’s HDR capability should be utilized to the full extent.

2. **Consistent and fair game play**
   Game design creative intent (e.g. a zombie appearing from the dark, an enemy shooter silhouetted in blinding light) needs to appear the same for consistent game playability, regardless of display performance difference.

3. **Forward compatible**
   The existing HDR game experience should not be deteriorated, but stable or even enhanced with the improvement of future HDR display performance.

4. **Easy to use and practical for developers and consumers**
   Practical and easy-to-use means must be prepared for game developers and consumers. For example, any processing should not consume resources that may affect real-time processing, and complicated manual setup operations (e.g. in-game calibration) should be avoided.

Overview of the best practice recommendations

These best practice recommendations consist of the following elements. The best practice recommendations as a whole aim to achieve HDR rendering of game content as game creators intend and assure consistent user experiences with regards to objects critical to game play.

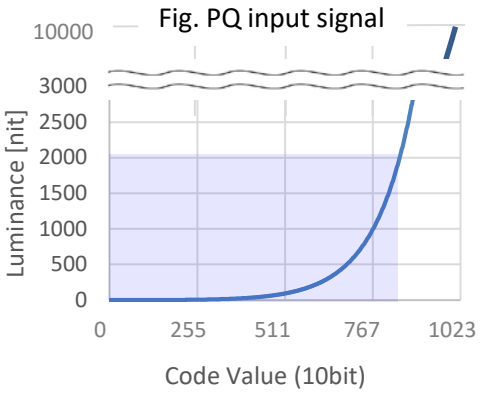
1. **HDR games** implement parameterized tone mappers that can render critical primary objects within a certain range of luminance to ensure consistent game play (“Primary HDR range”).

2. **HDR displays** preserve gradation within the Primary HDR range while in Game mode. Display manufacturers provide to game console manufacturers information relating to tone mapping to accommodate Games to leverage the full HDR capabilities of their HDR displays within the Primary HDR range. For PC monitors, recommendations based on standardization activities in the PC environment should still be incorporated.

3. **Game consoles** provide APIs to games in order to retrieve information relating to tone mapping to preserve gradation within the Primary HDR range. Game consoles also provide to consumers a system calibration which can override tone mapping information provided by display manufacturers, so that consumers can customize game play experience or optimize for different lighting environments.

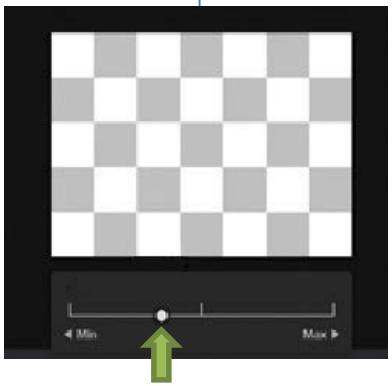
System Overview of the Best Practice Recommendations

- Preserve gradation for the Primary HDR range.
- Provide tone mapping information about its Primary HDR range to game console manufacturers.



Example: This display's Primary HDR range extends to 2000 nits and can preserve the gradation up to 2000 nits.

- Model names, tone map information are stored to database.
- Provide calibration screen to user.
- Provide final tone map information about Primary HDR range to Game.



Starting point of system calibration is display's Primary HDR range.

- Apply tone mapping information for the Primary HDR range to Game's parameterized HDR tone mapper.
- Critical objects are rendered within Primary HDR range.

Non-optimized image

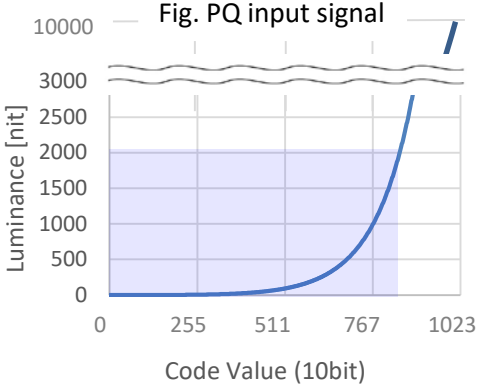
Optimized image

System Overview of the Best Practice Recommendations

Guideline to HDR Display Manufacturer

- Preserve gradation for the Primary HDR range.
- Provide tone mapping information about its Primary HDR range to game console manufacturers.

Fig. PQ input signal



Example: This display's Primary HDR range extends to 2000 nits and can preserve the gradation up to 2000 nits.

Guideline to HDR Game Console Manufacturer

- Model names, tone map information are stored to database.
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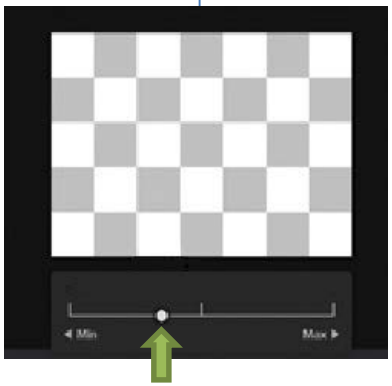


Starting point of system calibration is display's Primary HDR range.

Guideline to HDR Game Developer

- Apply tone mapping information for the Primary HDR range to Game's parameterized HDR tone mapper.
- Critical objects are rendered within Primary HDR range.

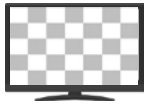
Non-optimized image

Optimized image

Terminology

(1) MaxFullFrameToneMapLuminance (MaxFFTML)

The value indicates max PQ Code Value which a display's tone mapper can preserve bright detail.
The value indicates the max value in 100% (full frame) area of display.



(2) MaxToneMapLuminance (MaxTML)

The value indicates max PQ Code Value which a display's tone mapper can preserve bright detail.
The value indicates the max value in 10% area of display.

(3) MinToneMapLuminance (MinTML)

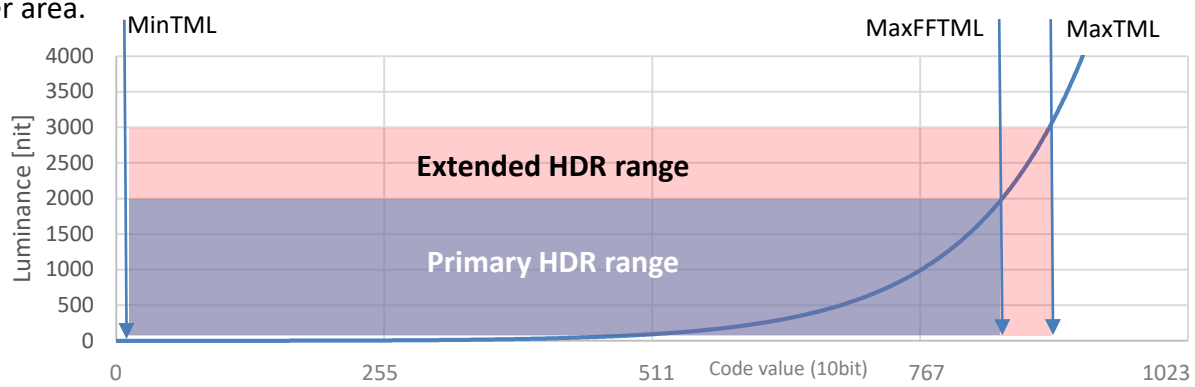
The value indicates minimum PQ Code Value which a display's tone mapper can preserve dark detail.
The value indicates the min value in 10% area of display.

(4) Primary HDR range

This range contains code values between MinTML and MaxFFTML. Displays should preserve gradations in this range where Games can render objects critical to game play.

(5) Extended HDR range

This range contains code values between MinTML and MaxTML. Displays should preserve gradations in this range for up to 10% of the display area. This range may be usable to games for critical game play objects within this smaller area.



Display Category Definitions

Category 1 Display

Category1
- MinTML = 0.1nits
- MaxTML= 600nits

Category 2 Display

Category2
- MinTML = 0.1nits
- MaxTML = 1000nits

Category 3 Display

Category3
- MinTML = 0.1nits
- MaxTML = 4000nits

Category 4 Display

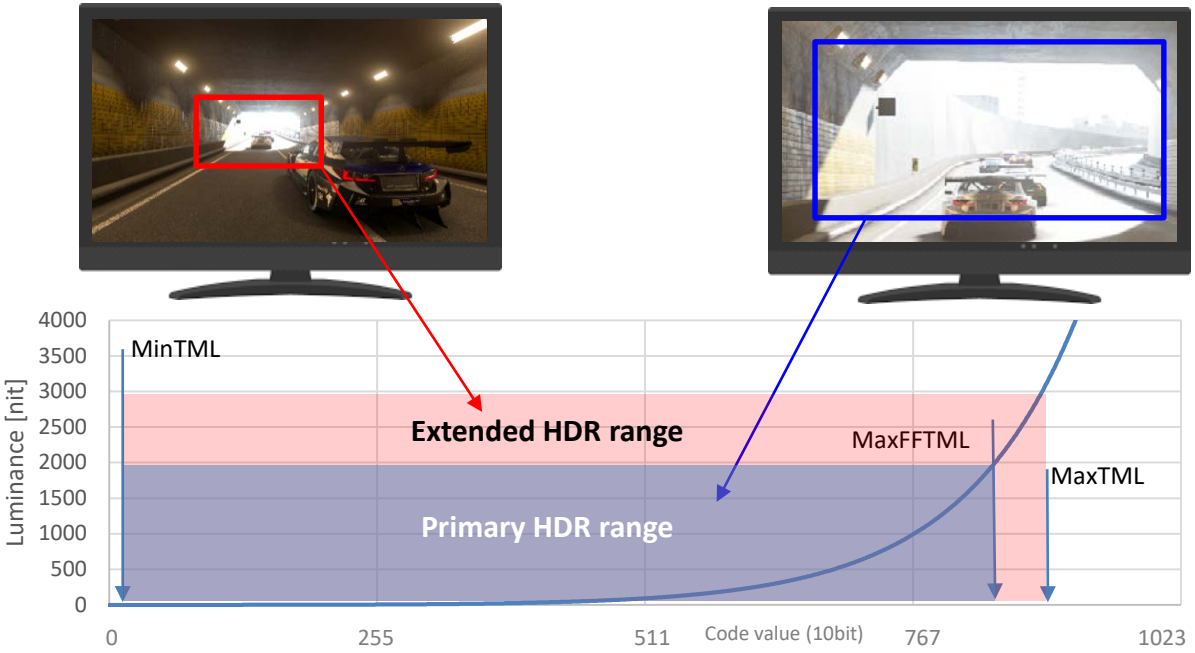
Category4
- MinTML = 0nits
- MaxTML = 10000nits

- Display Categories are used when full luminance values are not available.
- The Categories define default luminance values.
- In all Categories, MaxFFTML=600 nits.

Guideline to HDR Game Developer

Leverage full capability of HDR displays and ensure consistent game play

1. Game retrieves MaxFFTML, MaxTML and MinTML about attached HDR display
2. Game renders objects critical to gameplay in either the Primary or Extended HDR Range
3. Game uses Primary HDR range when critical objects cover very large area of screen, and the Extended HDR range when covering a smaller area of the screen



Examples of using Primary HDR Range and Extended HDR Range

Example 1

- Game knows it will never render very bright objects critical to game play over the full area of the screen
- Game adjust its tone mapper to make use of the Extended HDR range

Example 2

- Game knows it will very rarely render very bright objects critical to game play over the full area of the screen, e.g. only 1 or 2 seconds in total during an hour of game play
- Developer opts for simplicity and accepts the possibility that some HDR displays might clip in very rare occasions, and adjusts game's tone mapper to make use of the Extended HDR range

Example 3

- Game knows it will often render very bright objects critical to game play over the full area of the screen
- Game interpolates between the Primary HDR range and the Extended HDR range, based on histogram information about luminance values, which is already determined at runtime for calculating bloom effects

Guideline to HDR Display Manufacturer

1. Provided MaxFFTML, MaxTML and MinTML values are determined by running the development version of the HDR game console system calibration screen described in this document with HDR display set to game mode. Slider values for this version are shown, whereas in the consumer version, they are not. Using this tool also helps the manufacturer to determine the most-accurate Category to indicate instead of the actual values if they prefer.

2. HDR display manufacturer communicates with HDR game console manufacturer to provide the following information about the HDR display.
    a. Display identification scheme to differentiate models with different parameters
    b. Display Parameters
        - MaxFFTML, MaxTML, and MinTML; or
        - Category Designation (which provides default parameters)

3. In operation, the HDR display should preserve details and gradation of objects within the Primary HDR and Extended HDR ranges as defined in this document.

Guideline to HDR Game Console Manufacturer

1. HDR game console manufacturer communicates with display manufacturer to create database

2. Identify the connected HDR display

3. Query database for HDR display’s tone mapper luminance values

4. Optionally present calibration screen to consumer to customize or optimize tone mapper luminance values

5. Provide tone map luminance values to game through API

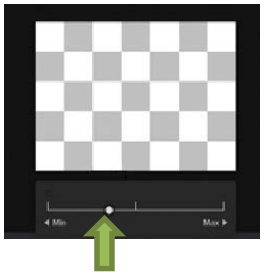
Guideline to HDR Game Console Manufacturer

1. Communicate with HDR display manufacturers to obtain
   (a) Display identification
      i. How HDR game console can identify the display (e.g. EDID model ID etc.).
      ii. Alternate identification scheme when repeaters are used.
   (b) Display parameters
      i. MaxTML, MinTML and MaxFFTML; or
      ii. Category Designation.
2. Game console should have database of Display IDs and display parameters.

Guideline to HDR Game Console Manufacturer

A display cannot be identified by game console

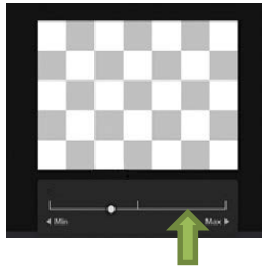
No information



Default values are used.
MaxFFTML : 600nits
MaxTML : 1000nits
MinTML: 0.1nits

Can be identified by game console
With full information

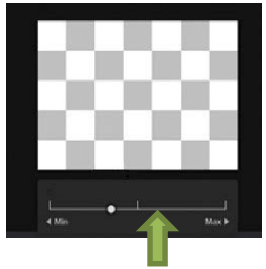
Example:
MaxFFTML : 1200
MaxTML : 1500
MinTML : 0.08



Example:
Start point of calibration is
MaxFFTML : 1200
MaxTML : 1500
MinTML : 0.08

Can be identified by game console
Category information only available

Example:
Category 2 display



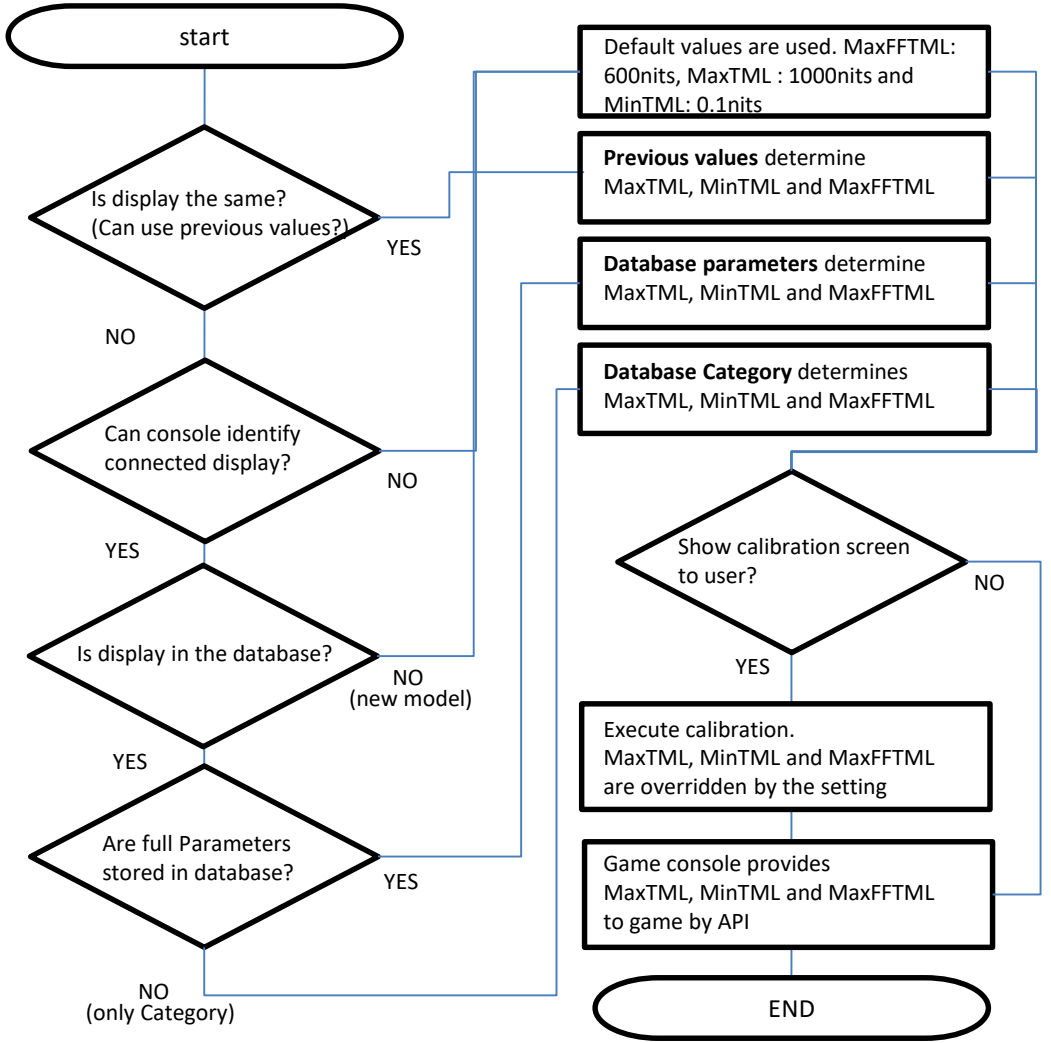
Example:
Start point of calibration is Category 2
MaxFFTML : 600
MaxTML : 1000
MinTML : 0.1

Guideline to HDR Game Console Manufacturer

Game console sets the fields as determined by the flowchart.

Category	MinTML (nits)	MaxTML (nits)
1	0.1	600
2	0.1	1000
3	0.1	4000
4	0.0	10000

MaxFFTML is 600nits throughout the Categories

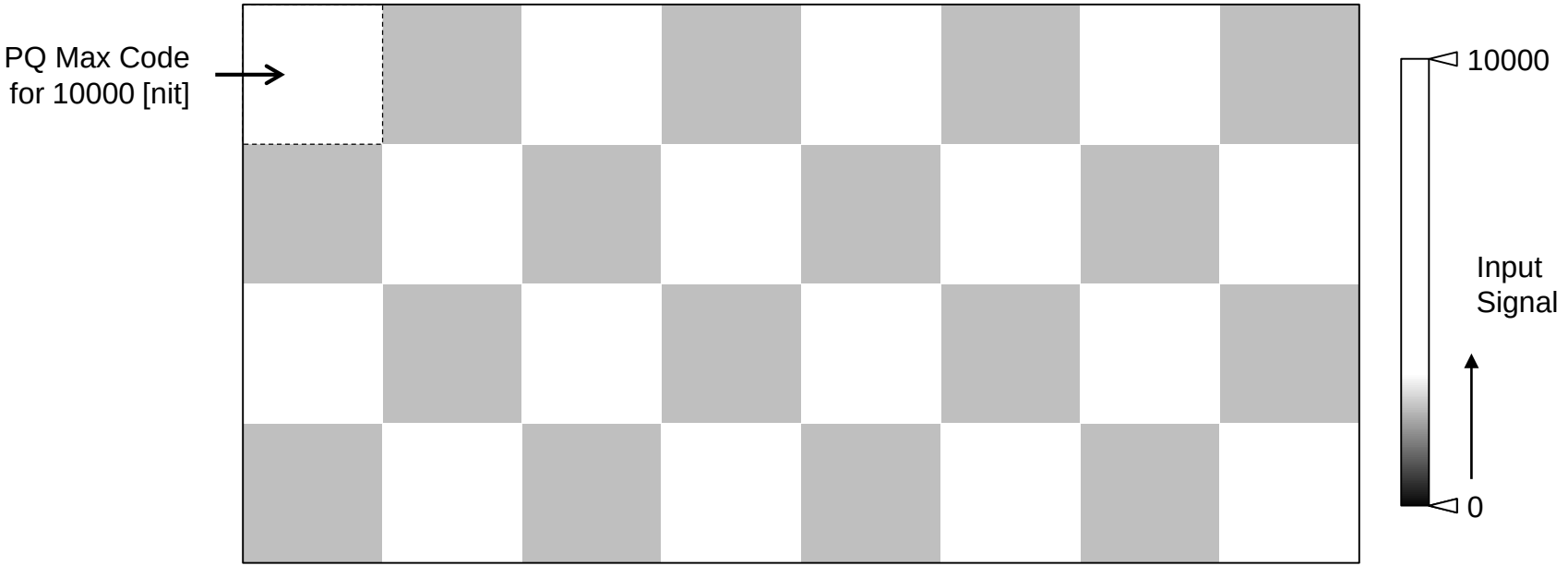


Guideline to HDR Game Console Manufacturer

Provide 3 types of calibration screens to user.

(1) MaxFullFrameToneMapLuminance

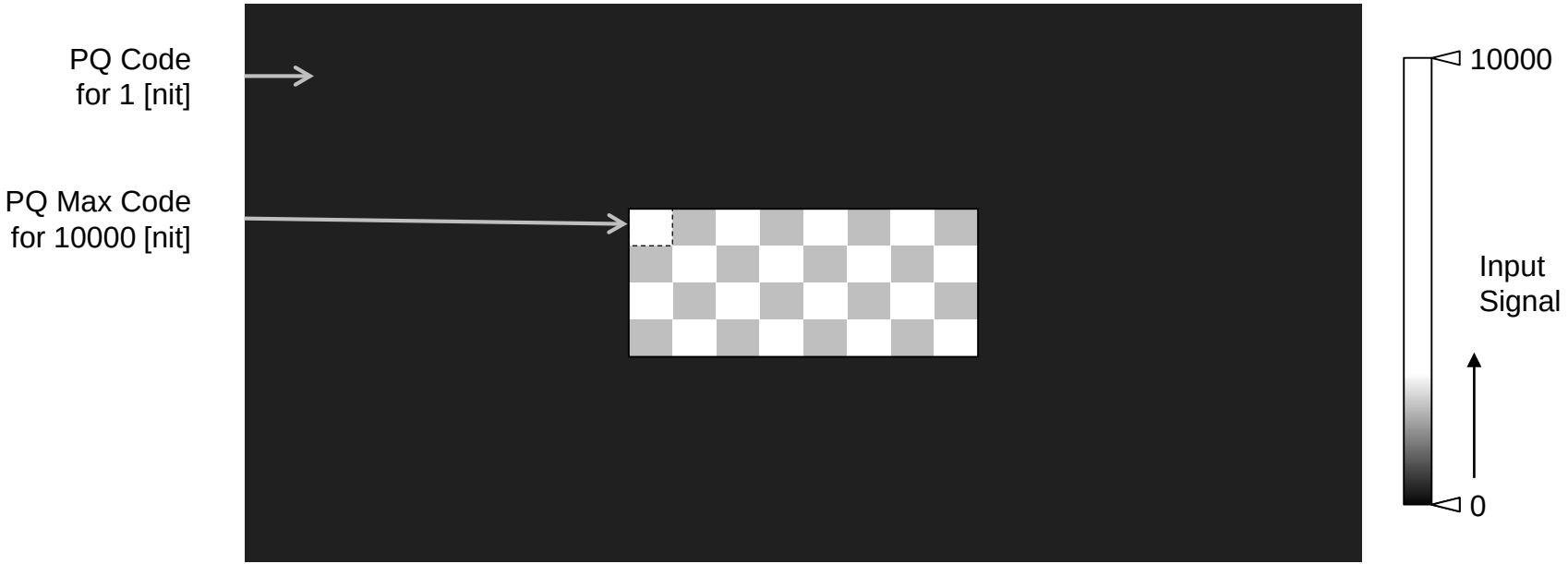
- The value indicates max luminance in 100% area of display.
- Max 12 bit BT.2100 PQ Code Value at which display perceptually preserves the checker box.
- Adjust slider until gray squares just disappear.



Provide 3 types of calibration screens to user.

(2) MaxToneMapLuminance

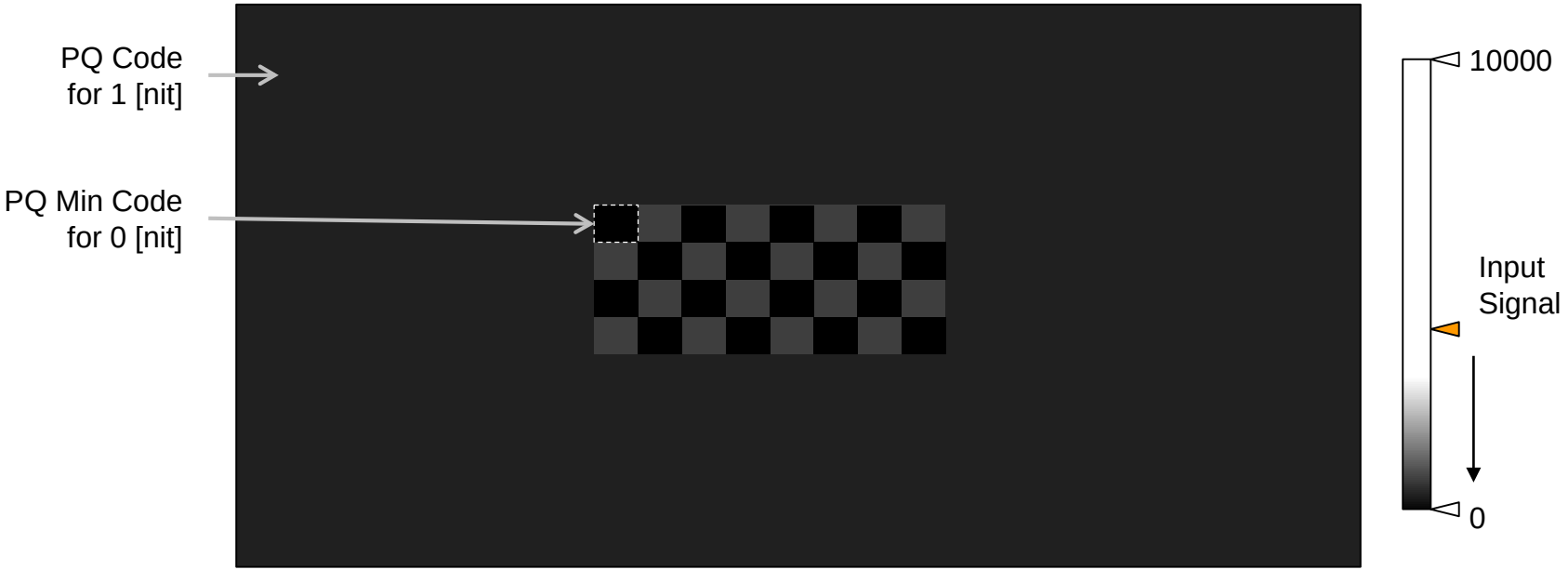
- The value indicates max luminance in 10% area of display.
- Max 12 bit BT.2100 PQ code value at which display perceptually preserves the checker box.
- Same operation as for MaxFFTML. Expect MaxTLM≠MaxFFTML.



Provide 3 types of calibration screens to user.

(3) MinToneMapLuminance

- The value indicates min luminance in 10% area of display.
- Max 12 bit BT.2100 PQ code value at which display perceptually preserves the checker box.
- Adjust slider until gray squares just disappear.



Example 1 – The ideal scenario

TV Manufacturer “ABC”

1. Develop new TV, model “XYZ-123”
2. Attach TV to Game console
3. Run game console’s system calibration and determine MaxFFTML = 1500 nits, MaxTML = 1500 nits, MinTML = 0.01 nits
4. Communicate to game console manufacturer: EDID ID “ABC-XYZ-123”, 1500, 1500, 0.01

Game Console Manufacturer

1. Update database with: “ABC-XYZ-123”, 1500, 1500, 0.01

Consumer

1. Buy new TV “ABC” model “XYZ-123”
2. Install and run Game

Game

1. Call game console API
2. Game console determines “ABC-XYZ-123” from TV’s EDID
3. Game console queries database and returns from its API: MaxFFTML = 1500, MaxTML = 1500, MinTML = 0.01
4. Adjust parameters of tone mapper between 0.01 and 1500 nits

Example 2

TV Manufacturer “DEF”
1. Develop new TV, model “TUV-456”
2. Attach TV to game console
3. Run game console’s system calibration and determine MaxFFTML = 2000 nits, MaxTML = 2000 nits, MinTML = 0.05 nits
4. Uncomfortable to communicate 2000, 2000, 0.05 to game console manufacturer, decides to use Category 3 instead
5. Communicate to game console manufacturer: EDID ID “DEF-TUV-456”, Category 3

Game console manufacturer
1. Update database with: “DEF-TUV-456”, Category 3

Consumer
1. Buy new TV “DEF” model “TUV-456”
2. Install and run game

Game
1. Call game console API
2. Game console determines “DEF-TUV-456” from TV’s EDID
3. Game console API returns default tone map information for Category 3: MaxFFTML = 600, MaxTML = 4000, MinTML = 0.1
4. Adjust parameters of tone mapper between 0.1 and 4000 nits

TV
1. Receive PQ values between 0.1 and 4000 nits
2. TV’s tone mapper only maps to 2000 nits, so clips information above 2000 nits

Example 2 - continued

Consumer

1. Not satisfied with HDR game
2. Run game console's system calibration

Game console

1. Determine "DEF-TUV-456" from TV's EDID
2. Query database and determine TV is Category 3
3. System calibration use default start values for Category 3: MaxFFTML = 600 nits, MaxTML = 4000 nits, MinTML = 0.1 nits
4. Consumer adjust values to: MaxFFTML = 2000 nits, MaxTML = 2000 nits, MinTML = 0.05 nits
5. Store new values for TV locally

Consumer

1. Run game again

Game

1. Call game console API
2. Game console determines "DEF-TUV-456" from TV's EDID
3. Game console returns locally stored calibrated values from its API: MaxFFTML = 2000, MaxTML = 2000, MinTML = 0.05
4. Adjust parameters of tone mapper between 0.05 and 2000 nits