

AHG7: Consideration on the inverse transfer function

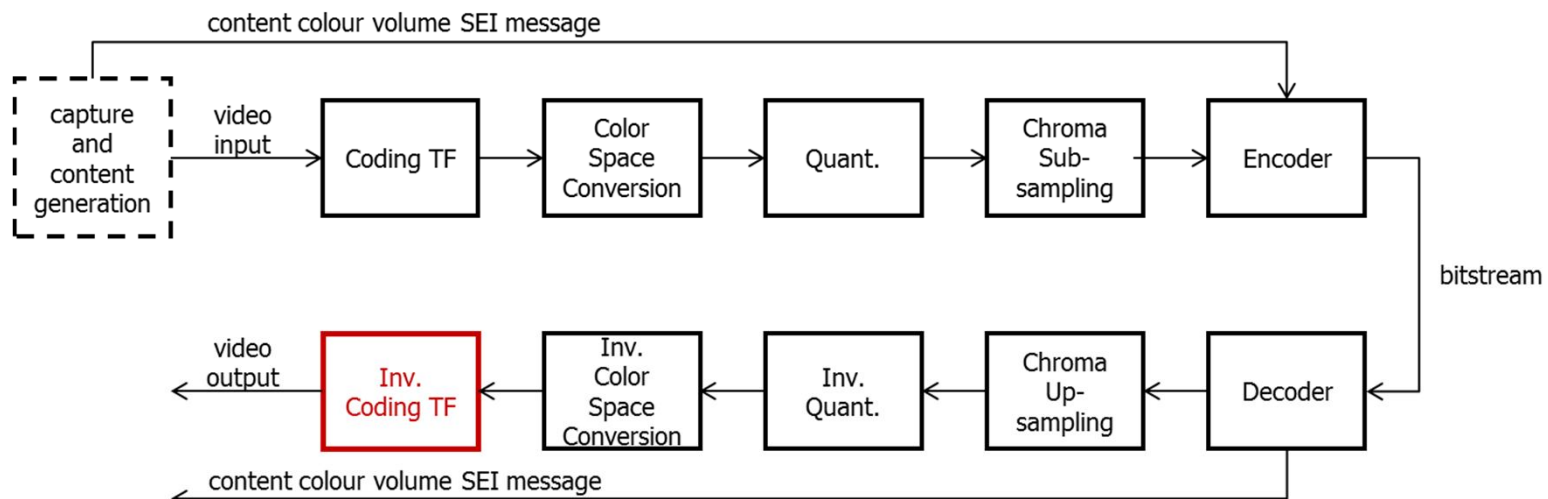
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Introduction

- A draft specification document for the content colour volume (CCV) SEI message was developed in 25th JCT-VC meeting.
 - JCTVC-Y1005 provides a description of content colour volume representation with three colour primaries and minimum and maximum luminance values.
- One issue is the choice of transfer function when converts the non-linear signal to a linear representation.
 - In JCTVC-Y1005 , two inverse transfer functions are defined depending on the OETF used in the encoding process.
 - For BT.709 and HLG transfer functions, corresponding EOTF is recommended.
 - For the other transfer functions, the exact inverse of the transfer function is recommended.



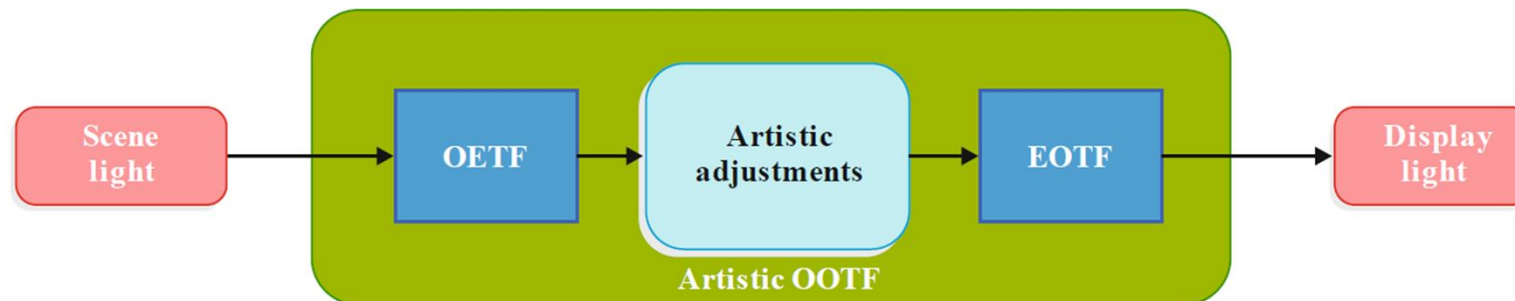
Definitions of transfer functions

- In ITU-R Rec. BT.2100, different transfer functions are defined.
 - OETF (opto-electronic transfer function)
 - converts linear scene light into the video signal, typically within a camera.
 - EOTF (electro-optical transfer function)
 - converts the video signal into the linear light output of the display.
 - OOTF (opto-optical transfer function)
 - has the role of applying the “rendering intent”.
- The relationship between the transfer functions are given as follows.

$$\text{OOTF} = \text{OETF} \otimes \text{EOTF}$$

$$\text{EOTF} = \text{OETF}^{-1} \otimes \text{OOTF}$$

$$\text{OETF} = \text{OOTF} \otimes \text{EOTF}^{-1}$$



Problems caused by OOTF

- The outputs are different
 - OETF coding followed by EOTF produces OOTF modified signal, which contains rendering intent.
 - This signal is not same with the input signal to TF encoding.
- The problems are
 - The decoded output is different from the signal described by the SEI message. So the colour volume boundary described by the CCV SEI message will not match with the actual boundary of the output signal.

$$\text{e.g. } E \neq \text{EOTF}_{1886} [\text{OETF}_{709}[E]] = \text{OOTF}_{\text{SDR}}[E]$$

- The output signals from HLG system might not be consistent between display devices since the OOTF changes depending on the viewing environment.

$$\text{e.g. } \text{OOTF}[E] = \alpha Y_S^{\gamma-1} E + \beta$$

Problems caused by OETF - 1) BT.709 and BT.1886

- The decoder output is different from the signal described by the SEI message. So the colour volume boundary described by the CCV SEI message will not match with the actual boundary of the output signal.

- OETF in ITU-R Rec. BT.709

$$V = 1.099 L^{0.45} + 0.099 \quad \text{for} \quad 1 \geq L \geq 0.018$$

$$V = 4.500 L \quad \text{for} \quad 0.018 > L \geq 0$$

where:

L : luminance of the image $0 \leq L \leq 1$

V : corresponding electrical signal

- OETF in ITU-R Rec. BT.1886

$$L = a(\max[(V + b), 0])^\gamma$$

where:

L : Screen luminance in cd/m^2

L_W : Screen luminance for white

L_B : Screen luminance for black

V : Input video signal level (normalized, black at $V = 0$, to white at $V = 1$. For content mastered per Recommendation ITU-R BT.709³, 10-bit digital code values “D” map into values of V per the following equation: $V = (D - 64)/876$

γ : Exponent of power function, $\gamma = 2.404$

a : Variable for user gain (legacy “contrast” control)

$$a = (L_W^{1/\gamma} - L_B^{1/\gamma})^\gamma$$

b : Variable for user black level lift (legacy “brightness” control)

$$b = \frac{L_B^{1/\gamma}}{L_W^{1/\gamma} - L_B^{1/\gamma}}$$

Problems caused by OOTF - 2) HLG system

- The output signals from HLG system might not be consistent depending of the change of viewing environment.

	Application 1 Perceptual Quantization (PQ) System	Application 2 Hybrid Log-Gamma (HLG) system
OETF	$OETF[E] = EOTF^{-1}[OOTF[E]]$	HLG ref. OETF^{5a} $OETF[E] = \begin{cases} \sqrt{E}/2 & 0 \leq E \leq 1 \\ a \cdot \ln(E - b) + c & 1 < E \end{cases}$
EOTF	PQ ref. EOTF $EOTF[E'] = 10000 \cdot \left(\frac{\max\left[\left(E'^{1/m_2} - c_1\right), 0\right]}{c_2 - c_3 E'^{1/m_2}} \right)^{1/m_1}$	$OOTF[E] = OOTF[OETF^{-1}[E']]$
OOTF	$OOTF[E] = G_{1886} [G_{709}[E]]$	$OOTF[E] = \alpha Y_s^{\gamma-1} E + \beta$

NOTE 5a – The inverse of this non-linearity should be used when it is necessary to convert between the non-linear representation and the linear representation of scene light.

$\gamma = 1.2$ at the nominal display peak luminance of 1000 cd/m². ^{5e, 5f}

NOTE 5e – For displays with nominal peak luminance (L_W) greater than 1000 cd/m², or where the effective nominal peak luminance is reduced through the use of a contrast control, the system gamma value should be adjusted according to the formula below, and may be rounded to three significant digits:

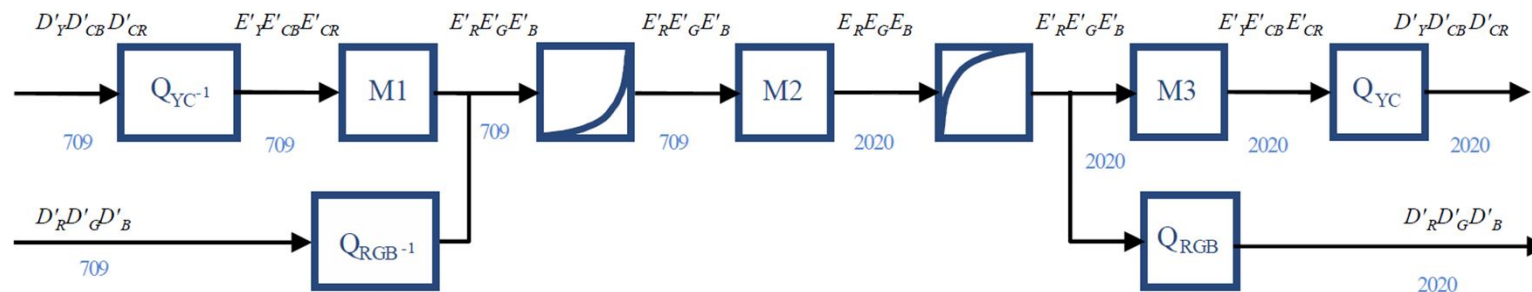
$$\gamma = 1.2 + 0.42 \log_{10}(L_W/1000)$$

NOTE 5f – The system gamma value may be decreased for brighter background and surround conditions.

Recommendation in ITU-R Rec. BT.2087

- The choice of transfer function in BT.709 to BT.2020 colour conversion is addressed.
 - Case 1 - To preserve colours seen on BT.709 display
 - Recommends to use EOTF
 - Example use case is a pre-produced content conversion
 - Case 2 – To preserve colour characteristics of a signal regardless of signal representation
 - Recommends to use inverse OETF
 - Example use case is a camera output exchange or mixing
- The Case 2 is suitable for CCV SEI message
 - It describes the colour characteristics of a signal, not the displayed colour

Block diagram of colour conversion from Rec. 709 $Y'C'_BC'_R$ or $R'G'B'$ to Rec. 2020 $Y'C'_BC'_R$ or $R'G'B'$ for the non-constant luminance signal format in Recommendation ITU-R BT.2020



Proposed alternative text for JCT-VC Y1005

- Propose the alternative text for the introductory part of the semantics to recommend the use of the exact inverse of OETF for all cases.

The content colour volume SEI message provides information about the colour volume characteristics of the associated picture. This SEI message describes the colour volume characteristics of the associated picture in terms of a nominal range and deviations from this range may occur. This SEI message requires knowledge of the colour description information of the signal, such as the colour_primaries, transfer_characteristics, and matrix_coeffs in the VUI parameters syntax. This SEI message shall not be present when any of these parameters is unspecified or reserved. When alternative transfer characteristics SEI message is present, the transfer_characteristics in the SEI message is precedent to the corresponding parameter in VUI. In all values of transfer_characteristics, the exact inverse of the transfer function specified in Table E.4 (Transfer Characteristics) shall be used to convert the non-linear signal to a linear representation.

Conclusion

- Two different types of inverse transfer function are defined in JCTVC-Y1005.
 - EOTF for BT.709 and HLG
 - Inverse of the encoding transfer function for others
- EOTF cause problems by introducing OOTF in the output signal.
 - Mismatch between the output signal and the information described by CCV SEI message.
 - Variation of HLG reference OOTF parameter depending on the viewing condition.
- Propose to use identical approach to all encoding transfer functions.
 - propose to use inverse of the encoding transfer function when a decoder uses CCV SEI message.

Thank you