D-Cinema Distribution Master (DCDM) - Image Characteristics

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SMPTE 428-1-2006

SMPTE STANDARD

D-Cinema Distribution Master — Image Characteristics

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Foreword

SMPTE (the Society of Motion Picture and Television Engineers) is an internationally-recognized standards developing organization. Headquartered and incorporated in the United States of America, SMPTE has members in over 80 countries on six continents. SMPTE's Engineering Documents, including Standards, Recommended Practices and Engineering Guidelines, are prepared by SMPTE's Technology Committees. Participation in these Committees is open to all with a bona fide interest in their work. SMPTE cooperates closely with other standards-developing organizations, including ISO, IEC and ITU.

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SMPTE Standard 428-1 was prepared by SMPTE Technology Committee DC28.

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Introduction

This standard describes the image characteristics of the Digital Cinema Distribution Master (DCDM). The image characteristics and parameters are not subject to any further image processing prior to the compression process described elsewhere.

In order for content creators to convert a Digital Source Master (DSM) into a Digital Cinema Distribution Master (DCDM), this standard will define all of the metrics required for the image structure of the DCDM. This DCDM image structure may then be transported by being mapped into either real time interfaces or into file formats.

In the process of creating theatrical releases, a Digital Source Master, or DSM, is produced from which many distribution elements are created, (e.g., Film Distribution Masters, Digital Cinema Distribution Masters (DCDM), Home Video Masters, Airline Version Masters and Broadcast Masters). It is not the goal of this specification to define the DSM. It is recognized that the DSM may consist of any color space, pixel matrix (spatial), frame rate (temporal), bit depth and many other metrics.

This standard defines sets of operational levels, in terms of the maximum number of pixels, H pixel count and V pixel count. In combination with the frame rate this determines the operational level, 1-3 as defined in Table 1.

1 Scope

This standard defines the uncompressed image characteristics for DCDM by specifying a pixel array, frame rate, pixel bit depth, and colorimetry. The DCDM image operational levels are defined by the maximum number of pixels and frame rate.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

CIE Publication15:2004, Colorimetry

SMPTE 431-1-2006, D-Cinema Quality — Screen Luminance Level, Chromaticity and Uniformity

3 Image structures

The pixel array shall use equally sampled tristimulus code values to represent each pixel.[1] The maximum number of horizontal and vertical pixels shall be no greater than the limits of one of the operational levels as defined in Table 1[2]. The number of pixels shall extend to the maximum in either one or both of the horizontal and vertical directions of the defined operational level.

Table 1 – DCDM operational levels

Operational Level	Maximum Horizontal Pixels	Maximum Vertical Pixels	Frames per Second
1	4096	2160	24
2	2048	1080	48
3	2048	1080	24

The pixel shall have an aspect ratio of 1:1. No anamorphic or other geometric distortions of the image data shall be permitted

For operational level 1, the number of horizontal and vertical pixels shall be evenly divisible by four.

For operational levels 2 and 3, the number of horizontal and vertical pixels shall be evenly divisible by two.

3.1 Pixel orientation and numbering

The pixel orientation shall flow from left to right and top to bottom of the pixel array. The horizontal and vertical pixel count shall begin with 0. This is to mean that the top left pixel of the pixel array shall be notated as (0, 0).

[1] The pixel array is the set of pixels that are intended to be displayed on the cinema screen.

[2] Common film aspect ratios, unlike the native aspect ratio of the image boundaries shown in Table 1, shall be accommodated. Some examples of these are provided in the informative Annex A.

4 Colorimetry

The color encoding of the Digital Cinema Distribution Master (DCDM) embodies a device-independent, *X'Y'Z'* color space as described in CIE Publication 15:2004, Colorimetry, 3rd Edition. Because the DCDM incorporates all of the creative color decisions made in the mastering process, and these decisions are made on a calibrated projector in a controlled mastering room, it is by definition an output-referenced image state. The picture colorimetry is defined for its intended display on the cinema screen.

4.1 DCDM encoding primaries

The DCDM shall use the CIE Publication15:2004, (x,y coordinates) to describe the color primaries *X, Y,* and *Z* as a gamut container.

4.2 Pixel bit depth

The pixel bit depth for each code value for a color component shall be 12 bits.

4.3 Transfer function

The CIE *XYZ*[3] tristimulus values shall each be normalized with a constant that sets the *Y* tristimulus value equal to 1.0 for the reference luminance (L) where both *X* and *Z* values are multiplied by the same constant.[4] With this specification of the color, the following equations define the encoding transfer function[5], where *X, Y, Z* are the tristimulus values above black[6].

$$CV_{X'} = INT\left[4095 * \left(\frac{L * X}{52.37}\right)^{1/2.6}\right]$$

$$CV_{Y'} = INT\left[4095 * \left(\frac{L * Y}{52.37}\right)^{1/2.6}\right]$$

$$CV_{Z'} = INT\left[4095 * \left(\frac{L * Z}{52.37}\right)^{1/2.6}\right]$$

[3] *XYZ* are the linear tristimulus values and are linear with light. *X'Y'Z'* are the symbols used in place of $CV_{X'}$, $CV_{Y'}$, and $CV_{Z'}$.

[4] The peak luminance as shown in the transfer function equation is 52.37 cd/m^2. The extra headroom is reserved to accommodate a range of white points including D_{55}, D_{61} and D_{65}, while still supporting the reference luminance (L) of 48 cd/m^2 as specified in SMPTE 431-1,Table 5.2 for Digital Cinema-Screen Luminance Level, Chromaticity and Uniformity.

[5] The INT operator returns the value of 0 for fractional parts in the range of 0 to 0.4999… and +1 for fractional parts in the range 0.5 to 0.9999…, i.e. it rounds up fractions above 0.5.

[6] This equation specifies luminance relative to the screen black level of the mastering environment (the projector's response to a zero code value [0,0,0] input signal plus the operating ambient light of the room). Because tristimulus values are additive, the absolute luminance of the image seen can be found by adding the *XYZ* of the content to the *XYZ* of the black.

CV_X: Code Value of *X'*
CV_Y: Code Value of *Y'*
CV_Z: Code Value of *Z'*
L: *Reference Luminance*

INT: Integer operator

Annex A (informative)
Digital cinema image aspect ratios

Some examples of the accommodation of images of various aspect ratios are shown in Table A.1.

Where: **AR =** the aspect ratio of the image (ratio of width to height, expressed as a decimal.)

Ph = total number of horizontal pixels in image

Pv = total number of vertical pixels in image

Table A.1 – Example image aspect ratios

Level	Ph	Pv	AR
1	4096	1716	2.39:1
1	3996	2160	1.85:1
2&3	2048	858	2.39:1
2&3	1998	1080	1.85:1

NOTE – The Ph and Pv values must comply with the rules established in § 3.

Annex B (informative)
Dynamic range usage of the DCDM

The DCDM image characteristic specifies 12 bits resolution for each pixel and permits the range of values from 0 to 4095 (decimal). The 12-bit resolution is specified after a gamma transfer characteristic has been applied, thus the 12 bit digital samples represent the optical amplitude in a non-linear manner. This has a particular impact around low amplitude levels.

B.1 Black and white levels

SMPTE RP 431-2 defines the calibration white point of the Reference projector as having [x y Y] values of [0.314, 0.351, 48.00]. The *XYZ* tristimulus values that are associated with these [x y Y] values are:

$$X=42.94, \qquad Y=48.00, \qquad Z=45.82$$

Although the DCDM encoding is defined for *X'Y'Z'* above black, the white is so far above black that the black can be ignored for the white calculations. From the DCDM encoding equations, the code values for this white point are:

$$CV_{X'} = 3794,\ CV_{Y'} = 3960,\ CV_{Z'} = 3890.$$

None of these values exceed the maximum value of 4095 and the headroom for the value 3960 is 135 code values.

The minimum DCDM code value allowed is 0. Because the DCDM encoding is defined for *XYZ* above black, the set of DCDM code values CV*X'* = 0, CV*Y'*=0, and CV*Z'* = 0 defines a luminance above black of 0, which means theater black. Assume a projector and theater have a 2000:1 or a 4000:1 contrast ratio. For a 2000:1 contrast ratio the delta *XYZ* values above black that are one JND (Just Noticable Difference) above black are approximately:

delta *X* = 0.00043, delta *Y* = 0.00048, delta *Z* = 0.00046

and

$CV_{X'} = 45,\ CV_{Y'} = 47,\ CV_{Z'} = 46$

The headroom is 45 code values.

For a 4000:1 contrast ratio the delta *XYZ* values above black that are one JND (Just Noticeable Difference) above black are approximately:

delta *X* = 0.00021, delta *Y* = 0.00024, delta *Z* = 0.00023

and

$CV_{X'} = 35,\ CV_{Y'} = 36,\ CV_{Z'} = 36$

The headroom is 35 code values.

B.2 Impact on signal processing

All equipment should be able to handle any signal over the full range of 0 to 4095. However, certain signal processing operations may cause a signal that has been processed to overshoot these 12-bit integer minimum and maximum values. For example, a filtering operation may result in transient overshoots and undershoots.

Annex C (informative)
Bibliography

SMPTE RP 431-2, D-Cinema Quality — Reference Projector and Environment for the Display of DCDM in Review Rooms and Theaters

SMPTE EG 432-1, Digital Source Processing — Color Processing for D-Cinema