

# SMPTE STANDARD

## Academy Density Exchange Encoding (ADX) — Encoding Academy Printing Density (APD) Values



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## Foreword

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SMPTE Engineering Documents are drafted in accordance with the rules given in its Standards Operations Manual. This SMPTE Engineering Document was prepared by Technology Committee TC 10E Essence.

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any section explicitly labeled as "Informative" or individual paragraphs that start with "Note:"

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword "reserved" indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword "forbidden" indicates "reserved" and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; then formal languages; then figures; and then any other language forms.

## Introduction

Academy Density Exchange Encoding (ADX) is an encoding of motion picture film color negative and internegative image data as Academy Printing Density (APD) values. ADX values encode image data as the APD printing density values of a color negative film designed to be printed on Kodak Vision® family, Fujifilm Eterna® family, and Fujifilm F-CP® color print films. It is expected that ADX will primarily be used to encode image data represented by the APD printing density values, or an approximation of the APD printing density values, from scanned film. The ADX equations specified in this document provide conversions from APD values to digital code values as 10-bit or 16-bit integer color components. This document also specifies the method for converting between the 16-bit and 10-bit component value encoding metrics.

Most color negative and internegative films require no transformation in order to be compatible with the ADX encoding method, because most color negative and internegative films can be printed onto contemporary motion picture color print films with reasonable results. Color interpositive films are also

compatible with the ADX encoding method, as they are part of the negative reproduction chain. Some film stocks, such as scan-only color negative film (e.g. Eastman Kodak® 5299) and color print films, were not designed to be printed onto color print films. Printing a scan-only negative or color print film onto a contemporary motion picture color print film is not likely to yield a result that would be considered “good-looking.” Scanned density values from these materials require additional transformation, not covered by this specification, in order to achieve compatibility with the ADX encoding method.

At the time of publication, no notice had been received by SMPTE claiming patent rights essential to the implementation of this Engineering Document. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

## **1 Scope**

This Standard defines the Academy Density Exchange Encoding (ADX) including the encoding method, the 16-bit and 10-bit component value encoding metrics, and the method for converting between the 16-bit and 10-bit component value encoding metrics.

## **2 Normative References**

The following documents 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.

SMPTE ST 2065-2:2020, Academy Printing Density (APD) — Spectral Responsivities, Reference Measurement Device and Spectral Calculation

## **3 Terms and Definitions**

For the purposes of this document, the terms and definitions given in SMPTE ST 2065-2 and the following apply:

### **3.1 Academy Density Exchange encoding**

#### **ADX**

encoding of motion picture film color negative and internegative image data as Academy Printing Density (APD)

Note 1 to entry: APD is defined in SMPTE ST 2065-2.

### **3.2 $D_{min}$**

optical density of an area of a chemically processed photographic medium that has received zero exposure

Note 1 to entry:  $D_{min}$  corresponds to the optical density of film base and non-image density due to factors other than exposure to light.

### **3.3 scan-only color negative film**

negative color photographic film primarily designed to be scanned by a motion picture film scanning device rather than printed on any photographic print medium

## 4 Academy Density Exchange encoding

### 4.1 General

The ADX equations specified in this section provide conversions from APD values, as defined in SMPTE ST 2065-2, to digital code values as 10-bit or 16-bit integer color components.

The following function definitions shall be used for Equations 1, 2, and 4:

- The function  $\text{ROUND}(x)$  returns the largest integer value less than or equal to  $x + 0.5$ .
- The function  $\text{MIN}(a, b)$  returns the value of  $a$  if  $a < b$ , and  $b$  if  $a \geq b$ .
- The function  $\text{MAX}(a, b)$  returns the value of  $a$  if  $a > b$ , and  $b$  if  $a \leq b$ .
- The function  $\text{FLOOR}(x)$  returns the value of the largest integer that is not greater than  $x$ .

### 4.2 Encoding method

ADX values shall encode image data as the APD values of a color negative film designed to be printed on contemporary motion picture color print films.

NOTE Contemporary motion picture color print films include Kodak Vision<sup>®</sup> family, Fujifilm Eterna<sup>®</sup> family, and Fujifilm F-CP<sup>®</sup> color print films.

### 4.3 Encoding metric

#### 4.3.1 General (informative)

The encoding data metric for the ADX is based on  $D_{\min}$ -subtracted APD values, as specified in sections 4.3.2 and 4.3.3. Printing density values are always non-negative, as a value of 0 represents 100% transmission.

Two component value encodings are specified:  $\text{ADX}_{16}$  and  $\text{ADX}_{10}$ :

- In  $\text{ADX}_{16}$ , each of the R, G, and B printing density values is stored as 16-bit unsigned integers.
- In  $\text{ADX}_{10}$ , each of the R, G, and B printing density values is stored as 10-bit unsigned integers.

The 16-bit component value encoding metric (i.e.  $\text{ADX}_{16}$ ) allocates 2 bits of additional range and 4 bits of additional precision, as compared to the 10-bit component value encoding metric (i.e.  $\text{ADX}_{10}$ ). The 2 bits of additional range are allocated in the most significant bits. The 4 bits of additional precision are allocated in the least significant bits. Figure 1 illustrates the allocation of the additional bits in the 16-bit component value encoding metric, as compared to the 10-bit component value encoding metric.

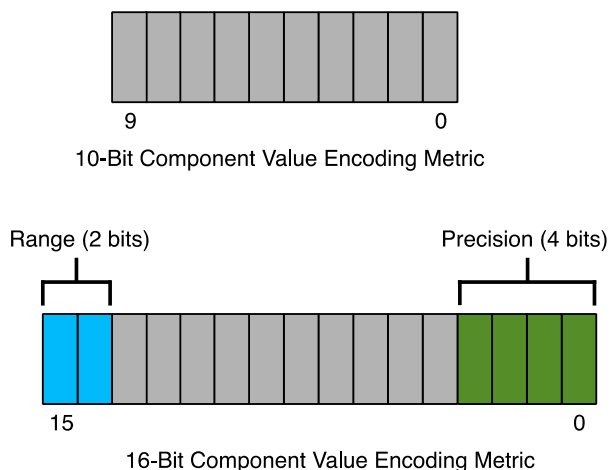


Figure 1 — Bit allocations of ADX<sub>10</sub> and ADX<sub>16</sub>

### 4.3.2 ADX<sub>16</sub> – The 16-bit component value encoding metric

The ADX 16-bit component value encoding metric shall be known as ADX<sub>16</sub> (or ADX16 where the use of subscripted text is not possible).

ADX<sub>16</sub> code values shall be 16-bit unsigned integer values. The value range for ADX<sub>16</sub> is [0, 65535].

ADX<sub>16</sub> code values shall be transformed from APD values using Equation 1.

$$\begin{aligned}
 ADX_{16_R} &= \text{MAX} \left[ 0, \text{MIN} \left[ 65535, \text{ROUND} \left[ 1.00 \times (APD_R - APD_{R\_Dmin}) \times 8000 + 1520 \right] \right] \right] \\
 ADX_{16_G} &= \text{MAX} \left[ 0, \text{MIN} \left[ 65535, \text{ROUND} \left[ 0.92 \times (APD_G - APD_{G\_Dmin}) \times 8000 + 1520 \right] \right] \right] \\
 ADX_{16_B} &= \text{MAX} \left[ 0, \text{MIN} \left[ 65535, \text{ROUND} \left[ 0.95 \times (APD_B - APD_{B\_Dmin}) \times 8000 + 1520 \right] \right] \right]
 \end{aligned} \tag{1}$$

Where

$APD_R$  are the red, green, and blue APD values, respectively

$APD_G$

$APD_B$

$APD_{R\_Dmin}$  are the red, green, and blue APD values, respectively, of the assumed or

measured  $D_{min}$  of the sample

$APD_{B\_Dmin}$

$ADX_{16_R}$  are the red, green, and blue ADX<sub>16</sub> values, respectively

$ADX_{16_G}$

$ADX_{16_B}$

NOTE The quantity  $(APD - APD_{Dmin})$  can produce negative values, as the  $D_{min}$  value of each color layer can vary throughout a scanned roll of film. The offset quantity, 1520, provides a target value for the scanned  $D_{min}$ , and allows “footroom,” so that densities lower than  $APD_{Dmin}$  will be encoded.

### 4.3.3 ADX<sub>10</sub> – The 10-bit component value encoding metric

The 10-bit component value encoding metric is specified to provide compatibility with existing hardware. Whenever possible, the 16-bit component value encoding metric should be used.

The ADX 10-bit component value encoding metric shall be known as ADX<sub>10</sub> (or ADX10 where the use of subscripted text is not possible).

ADX<sub>10</sub> code values shall be 10-bit unsigned integer values. The value range for ADX<sub>10</sub> is [0, 1023].

ADX<sub>10</sub> code values shall be transformed from APD values using Equation 2.

$$\begin{aligned}
 ADX_{10,R} &= \text{MAX} \left[ 0, \text{MIN} \left[ 1023, \text{ROUND} \left[ 1.00 \times (APD_R - APD_{R,Dmin}) \times 500 + 95 \right] \right] \right] \\
 ADX_{10,G} &= \text{MAX} \left[ 0, \text{MIN} \left[ 1023, \text{ROUND} \left[ 0.92 \times (APD_G - APD_{G,Dmin}) \times 500 + 95 \right] \right] \right] \\
 ADX_{10,B} &= \text{MAX} \left[ 0, \text{MIN} \left[ 1023, \text{ROUND} \left[ 0.95 \times (APD_B - APD_{B,Dmin}) \times 500 + 95 \right] \right] \right]
 \end{aligned} \tag{2}$$

Where

$APD_R$  are the red, green, and blue APD values, respectively

$APD_G$

$APD_B$

$APD_{R,Dmin}$  are the red, green, and blue APD values, respectively, of the assumed or measured  $D_{min}$  of the sample

$APD_{G,Dmin}$

$APD_{B,Dmin}$

$ADX_{10,R}$  are the red, green, and blue ADX<sub>10</sub> values, respectively

$ADX_{10,G}$

$ADX_{10,B}$

NOTE 1 The quantity  $(APD - APD_{Dmin})$  can produce negative values, as the  $D_{min}$  value of each color layer can vary throughout a scanned roll of film. The offset quantity, 95, provides a target value for the scanned  $D_{min}$ , and allows “footroom,” so that densities lower than  $APD_{Dmin}$  will be encoded.

NOTE 2 Some motion picture color negative and internegative film products are capable of producing density ranges that exceed the density range capable of being encoded by the 10-bit component value encoding metric.

## 4.4 Conversions between component-value encoding metrics

This section specifies the conversions between the 10-bit and 16-bit encoding metrics.

Equation 3 shall be used to convert ADX<sub>10</sub> values to ADX<sub>16</sub> values.

$$ADX_{16} = ADX_{10} \times 16 \tag{3}$$

Equation 4 shall be used to convert  $ADX_{16}$  values to  $ADX_{10}$  values.

$$\begin{aligned} &\text{if FLOOR}[ADX_{16}/16] \text{ is even} \\ &\quad ADX_{10} = \text{MIN}[1023, \text{FLOOR}[(ADX_{16} + 7)/16]] \\ &\text{if FLOOR}[ADX_{16}/16] \text{ is odd} \\ &\quad ADX_{10} = \text{MIN}[1023, \text{FLOOR}[(ADX_{16} + 8)/16]] \end{aligned} \tag{4}$$

## **Bibliography (informative)**

Academy of Motion Picture Arts and Sciences (A.M.P.A.S.) Specification S-2008-002, Academy Density Exchange Encoding (ADX) and the Spectral Responsivities Defining Academy Printing Density (APD)