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SMPTE REGISTERED DISCLOSURE DOCUMENT

Acquisition Metadata Sets for Video Camera Parameters

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Proponent contact information:

Hiroshi Nakano
Sony Corporation
4-14-1 Asahi-cho, Atsugi
Kanagawa, 243-0014
Japan

Email: hiroshi.nakano@jp.sony.com

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Introduction

This document defines metadata that is intended to capture camera acquisition parameters associated with each individual frame of the captured video. Such camera metadata can be used to provide user accessible information that enables optimization of various parameters during acquisition. The metadata can also be stored or carried with the picture signal to form a record of the shooting parameters used in the shoot. The metadata values are created individually for the shoot to provide a dynamic record for each camera parameter.

The metadata in this document is composed of three distinct groups – Lens Unit metadata, Camera Unit metadata and User Defined Acquisition metadata. The Lens Unit metadata provides a set of metadata items that define the lens parameter values during a shoot. Likewise, the Camera Unit metadata is a set of metadata items that define the camera parameter values during a shoot. The User Defined Acquisition metadata may be defined by users.

These three groups are coded as KLV coded metadata sets with each set containing individual metadata items.

This document defines the KLV coded metadata sets and each KLV coded metadata item in full for the purpose of interoperability.

The final section provides guidance for the carriage of these KLV metadata sets through different transport mechanisms to allow the metadata sets to be successfully transported between applications using V-Anc packets on serial digital interfaces such as those complying with SMPTE ST 291 and in the essence containers of MXF files such as those complying with SMPTE ST 379-2.

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1 Scope

This document describes metadata sets for the grouping of professional video camera acquisition parameters with frame granularity. The metadata sets are coded using the SMPTE KLV coding protocol as defined by SMPTE ST 336. Coding the metadata sets as KLV packets is intended to ensure maximum acceptability across a wide range of application areas.

2 Normative References

Note: All references in this document to other SMPTE documents use the current numbering style (e.g. SMPTE ST 336:2007) although, during a transitional phase, the document as published (printed or PDF) may bear an older designation (such as SMPTE 336M-2007). Documents with the same root number (e.g. 336) and publication year (e.g. 2007) are functionally identical.

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

SMPTE ST 336:2007, Data Encoding Protocol Using Key-Length-Value

SMPTE ST 395:2003, Television — Metadata Groups Registry Structure

SMPTE ST 400:2004, Television — SMPTE Labels Structure

SMPTE RP 210, Metadata Dictionary Registry of Metadata Element Descriptions

SMPTE RP 224, SMPTE Labels Register

IETF RFC 4122, A Universally Unique Identifier (UUID) URN Namespace

3 Acronyms

Acronyms used in this document are listed below.

BER: Binary Encoding Rules

ID: Identifier

KLV: Key Length Value

MXF: Material Exchange Format

N/A: Not Applicable

UID: Unique Identifier

UL: Universal Label

UUID: Universally Unique Identifier

4 Definition of the Metadata Sets

The Acquisition Metadata sets are KLV coded according to SMPTE ST 336. All metadata item values in the sets described in this document are associated with a given frame of video and values may change on a frame-by-frame basis.

There are three metadata sets; a Lens Unit Metadata set, a Camera Unit Metadata set and a User Defined Acquisition Metadata set.

4.1 Set Keys

The set Key is as per Table 1.

Table 1 – The Acquisition Metadata Set Key Value

Byte No.	Description	Value (hex)	Meaning
1~4	SMPTE UL Identifier	06.0E.2B.34h	See SMPTE ST 336
5	Category Designator	02h	SMPTE Groups
6	Registry Designator	53h	Local set with 2-byte Length and 2-byte Local Tag values
7	Structure Designator	01h	Complies with register structure variant 1
8	Version Number	vv (01h)	Version of the register at set registration
9	Compound class	0Ch	Identifies the Compound class in SMPTE ST 395
10	Production Metadata	02h	Identifies metadata sets created at point of creation or capture.
11	Acquisition Metadata	01h	Identifies metadata sets associated with a video camera
12	Frame-based Acquisition Metadata	01h	01: Frame-based metadata set
13	Acquisition Set Kind	yyh	A non-zero value used to identify the specific camera acquisition set kind 01: Lens Unit Metadata set (Local set) 02: Camera Unit Metadata set (Local set) 03-7E: Reserved 7F: User Defined Acquisition Metadata [1]
14	Acquisition Metadata Version 1	01h	Backwards compatible version number of this Acquisition Metadata set
15	Null	00h	Zero value
16	Null	00h	Zero value

[1] The 'User Defined Acquisition Metadata' set kind may be used for private user defined ('dark') metadata. The local tags and values for this set are assigned with tag value ranges from E0.00h to FF.FFh. If this set is inside MXF header metadata, local tags are allocated dynamically. The mapping of the sets inside MXF header metadata is beyond the scope of this document.

4.2 Set Length

The set Length field is BER encoded using long-form encoding as specified by SMPTE ST 336. The Length field is 4-bytes in length.

4.3 Set Value

The contents of the Acquisition Metadata sets are as defined in Tables 2a and 2b.

All items in each set are encoded in the order shown in Tables 2a and 2b.

The local tag values used in the metadata sets below are considered unique only within the confines of this specification.

Any new items added to either of the sets described by Tables 2a and 2b should increment the local tag value within that set.

No new items should be added to these sets without a revision of this document.

4.3.1 Lens Unit Metadata Set

The Lens Unit Metadata set contents are as defined in Table 2a. Byte 13 of the set Key has the value of 01h.

Table 2a – Definition of the Lens Unit Metadata Set

Item Name	Type	Len	Local Tag [2]	Item UL	Req ?	Meaning
Lens Unit Metadata	Set Key (UL)	16		See Table 1	Req	Lens Unit Metadata Set Key 06.0E.2B.34.02.53.01.01. 0C.02.01.01.01.01.00.00
Length	BER Length	4			Req	Set length
Instance UID	UUID	16	3C.0A	06.0E.2B.34 01.01.01.01 01.01.15.02 00.00.00.00	Opt	Unique ID of the instance of this data set [defined in SMPTE RP 210]
Iris F-Number	UInt16	2	80.00	06.0E.2B.34 01.01.01.0D 04.20.02.02 01.00.00.00	Opt	Iris position value calculated from the “F-number” that is a measure of the amount of light transmitted through the lens.
Iris T-Number	UInt16	2	80.08	06.0E.2B.34 01.01.01.0E 04.20.02.02 08.00.00.00	Opt	Iris position value calculated from the “T-number” that is a measure of the amount of light transmitted through the lens in practice
Iris Ring Position	UInt16	2	80.09	06.0E.2B.34 01.01.01.0E 04.20.02.02 09.00.00.00	Opt	Iris ring rotation angle in unsigned integer. 0 is for full open, and FFFFh for close
Focus Position From Image Plane	Half Float (lens serial)	2	80.01	06.0E.2B.34 01.01.01.0D 04.20.02.02 02.00.00.00	Opt	Distance in meters between the image plane and the object in focus.
Focus Position From Front Lens Vertex	Half Float (lens serial)	2	80.02	06.0E.2B.34 01.01.01.0D 04.20.02.02 03.00.00.00	Opt	Distance in meters between the front of the lens and the object in focus.
Focus Ring Position	UInt16	2	80.0A	06.0E.2B.34 01.01.01.0E 04.20.02.02 0A.00.00.00	Opt	Focus ring rotation angle in unsigned integer. 0 is for near-end, FFFFh for infinity

Item Name	Type	Len	Local Tag [2]	Item UL	Req ?	Meaning
Macro Setting	Boolean	1	80.03	06.0E.2B.34 01.01.01.0D 04.20.02.02 04.00.00.00	Opt	Specifies by a flag, whether the macro is activate. TRUE: on FALSE: off
Lens Zoom 35mm Still Camera Equivalent	Half Float (lens serial)	2	80.04	06.0E.2B.34 01.01.01.0D 04.20.02.02 05.00.00.00	Opt	Focal length in meters
Lens Zoom Actual Focal Length	Half Float (lens serial)	2	80.05	06.0E.2B.34 01.01.01.0D 04.20.02.02 06.00.00.00	Opt	Focal length in meters
Zoom Ring Position	UInt16	2	80.0B	06.0E.2B.34 01.01.01.0E 04.20.02.02 0B.00.00.00	Opt	Zooming ring rotation angle in unsigned integer. 0 is for wide-end, and FFFFh is for tele-end
Optical Extender Magnification	UInt16	2	80.06	06.0E.2B.34 01.01.01.0D 04.20.02.02 07.00.00.00	Opt	Magnification factor setup of an optical extender or conversion lens where present
Lens Attributes	UTF8 String	var	80.07	06.0E.2B.34 01.01.01.0D 03.02.03.02 02.10.01.00	Opt	Informative description of additional attributes about the lens in use (as a text string). The string length is less than 64 bytes.

[2] If this set is inside MXF header metadata, local tags are allocated dynamically.

4.3.2 Camera Unit Metadata Set

The Camera Unit Metadata set contents are as defined in Table 2b. Byte 13 of the set Key has the value of 02h.

Table 2b – Definition of the Camera Unit Metadata Set

Item Name	Type	Len	Local Tag [3]	Item UL	Req ?	Meaning
Camera Unit Metadata	Set Key (UL)	16		See Table 1	Req	Camera Unit Metadata Set Key 06.0E.2B.34.02.53.01.01. 0C.02.01.01.02.01.00.00
Length	BER Length	4			Req	Set length
Instance UID	UUID	16	3C.0A	06.0E.2B.34 01.01.01.01 01.01.15.02. 00.00.00.00	Opt	Unique ID of the instance of this data set [defined in SMPTERP 210]

Item Name	Type	Len	Local Tag [3]	Item UL	Req?	Meaning
Auto Exposure Mode	Label	16	81.00	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.01.00.00	Opt	Describes the setup mode the camera uses for automatic exposure. Each value is a SMPTE Label and registered in SMPTE RP 224
Exposure Index of Photo Meter	UInt16	2	81.15	06.0E.2B.34 01.01.01.0E 04.20.01.03 01.0C.00.00	Opt	Setting of the photo meter in ISO number
Auto Focus Sensing Area Setting	UInt8	1	81.01	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.02.00.00	Opt	Describes the selected areas used for the auto focus. Each value is a registered code.
Color Correction Filter Wheel Setting	UInt8	1	81.02	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.03.00.00	Opt	Specifies the setting of the attenuation ratio of the built-in optical density (ND) filter. Each value is a registered code.
Neutral Density Filter Wheel Setting	UInt16	2	81.03	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.04.00.00	Opt	Describes the reciprocal of the attenuation ratio of the built-in optical density (ND) filter as an integer value where the value 1 means a clear filter.
Image Sensor Dimension Effective Width	UInt16	2	81.04	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.05.00.00	Opt	Width of effective image area in micro meters
Image Sensor Dimension Effective Height	UInt16	2	81.05	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.06.00.00	Opt	Height of effective image area in micro meters
Capture Frame Rate	Rational	8	81.06	06.0E.2B.34 01.01.01.0D 04.01.03.01 03.01.00.00	Opt	Capture Frame Rate in fps (e.g. 50:1, 60000:1001). The rate at which the video is captured in frames per second.
Image Sensor Readout Mode	UInt8	1	81.07	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.07.00.00	Opt	Image sensor Readout mode defined as a registered code.
Shutter Speed (Angle)	UInt32	4	81.08	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.08.00.00	Opt	Shutter speed as an angle defining the shutter speed (angle) in minutes relative to a completely open shutter angle of 360 degrees.
Shutter Speed (Time)	Rational	8	81.09	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.08.01.00	Opt	Shutter speed as a time defining the shutter speed (time) in seconds.

Item Name	Type	Len	Local Tag [3]	Item UL	Req?	Meaning
Camera Master Gain Adjustment	Int16	2	81.0A	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.09.00.00	Opt	Master Gain Control setting in 0.01 decibel units
ISO Sensitivity	UInt16	2	81.0B	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.0A.00.00	Opt	Sensitivity to light in ISO exposure index
Color Matrix	Array of Rational	8 + 9x8	81.18	06.0E.2B.34 01.01.01.0E 04.20.01.03 01.0D.00.00	Opt	Specifies the setting of the color balance of the camera with the ordered elements (R to R, G to R, B to R, R to G, G to G, B to G, R to B, G to B, B to B)
Electrical Extender Magnification	UInt16	2	81.0C	06.0E.2B.34 01.01.01.0D 04.20.01.03 01.0B.00.00	Opt	Expresses the magnification setup of the picture size in percent where 100% (64h) represents the original picture size
Auto White Balance Mode	UInt8	1	81.0D	06.0E.2B.34 01.01.01.0D 04.20.01.03 02.01.00.00	Opt	Auto White Balance Mode defined as a registered code.
White Balance	UInt16	2	81.0E	06.0E.2B.34 01.01.01.0D 04.20.01.03 02.02.00.00	Opt	White Balance value defined by the temperature in Kelvin
Camera Master Black Level	Int16	2	81.0F	06.0E.2B.34 01.01.01.0D 04.20.01.03 02.03.00.00	Opt	Level of the master black level of the camera expressed as a percentage in relation to the white value. Defined in 0.1 % units.
Camera Knee Point	UInt16	2	81.10	06.0E.2B.34 01.01.01.0D 04.20.01.03 02.04.00.00	Opt	Level of the knee point in the camera transfer characteristic expressed as a percentage defined in 0.1 % units. Specifies the level in the white signal above which a nonlinear signal processing is active.
Camera Knee Slope	Rational	8	81.11	06.0E.2B.34 01.01.01.0D 04.20.01.03 02.05.00.00	Opt	Slope of the transfer characteristic above the knee point.
Camera Luminance Dynamic Range	UInt16	2	81.12	06.0E.2B.34 01.01.01.0D 04.20.01.03 02.06.00.00	Opt	Luminance Dynamic Range expressed as a percentage in reference to the nominal white level. Defined in 0.1 % units.

Item Name	Type	Len	Local Tag [3]	Item UL	Req ?	Meaning
Capture Gamma Equation	Label	16	32.10	06.0E.2B.34 01.01.01.02 04.01.02.01 01.01.02.00	Opt	Specifies the gamma of the camera transfer function as a SMPTE Label value registered in SMPTE RP 224. It describes the non-linear relationship between the linear scene light level and the amplitude-compressed video signal levels at signal origination.
Gamma for CDL	UInt8	1	81.16	06.0E.2B.34 01.01.01.0E 04.20.01.03 02.07.00.00	Opt	Enumerated code that represents the gamma characteristic applied at the input to the ASC CDL
ASC CDL V1.2	Array of Half Float	8 + 10x2	81.17	06.0E.2B.34 01.01.01.0E 04.20.01.03 02.08.00.00	Opt	10 parameters of ASC Color Decision List V1.2.
Camera Setting File URI	UTF8 String	var	81.13	06.0E.2B.34 01.01.01.0D 01.02.01.08 02.00.00.00	Opt	URI value of the file containing the camera setup parameters. The string length is less than 64 bytes.
Camera Attributes	UTF8 String	var	81.14	06.0E.2B.34 01.01.01.0D 03.02.03.02 02.10.02.00	Opt	Informative description of additional attributes about the camera in use (as a text string). The string length is less than 64 bytes.

[3] If this set is inside MXF header metadata, local tags are allocated dynamically.

4.3.3 User Defined Acquisition Metadata Set

The User Defined Acquisition Metadata set contents are as defined in Table 2c. Byte 13 of the Set Key has the value 7Fh.

Table 2c – Definition of the User Defined Acquisition Metadata Set

Item Name	Type	Len	Local Tag	Item UL	Req ?	Meaning
User Defined Acquisition Metadata	Set Key (UL)	16		See Table 1	Req	User Defined Acquisition Metadata Set Key 06.0E.2B.34.02.53.01.01. 0C.02.01.01.7F.01.00.00
Length	BER Length	4			Req	Set length
Instance UID	UUID	16	3C.0A	06.0E.2B.34 01.01.01.01 01.01.15.02 00.00.00.00	Opt	Unique ID of the instance of this data set [defined in SMPTE RP 210]
UDAM Set Identifier	AUID	16	E0.00	06.0E.2B.34 01.01.01.0D 04.06.08.05 00.00.00.00	Req	The immutable ID of the instance of this user defined Acquisition Metadata set
All items can be defined by users						

The UDAM Set Identifier that may identify the manufacturer and the product may be formatted as a UUID as per IETF RFC 4122 or it may be a private universal label. This can be generated for any manufacturer or product that needs access to this data extension structure.

4.3.4 Guide to the Use of the Acquisition Metadata sets Definition Tables

Tables 2a, 2b and 2c use the following fields, which are defined as follows:

1. “Item Name” is a human readable name for easy reference.
2. “Type” identifies the data type of the item with the following type definitions:
   a. Set Key (UL) – a 16-byte Universal Label used a Set Key as defined in SMPTE ST 336.
   b. BER Length – the Set Length type as defined in SMPTE ST 336.
   c. UUID – a Universal Unique Identifier as defined by IETF RFC 4122.
   d. Label – a SMPTE Label as defined in SMPTE ST 400 and registered in SMPTE RP 224.
   e. AUID – a 16-byte UID that contains a Label or a UUID. If the value is a UUID, it is stored such that the top and bottom 8 bytes of the UUID are swapped. For UUIDs, this makes the most significant bit of the first byte a '1' and thus creates a UID value that is always distinct from a Label.
   f. Boolean – 1-byte value with the logical values: zero == FALSE, non-zero == TRUE. TRUE uses the value 01h.
   g. UInt8 – Unsigned 8-bit integer.
   h. Int16 – Signed 16-bit integer.
   i. UInt16 – Unsigned 16-bit integer.
   j. UInt32 – Unsigned 32-bit integer.

k. Rational – A pair of 32-bit integer values where the first is the numerator and the second is the denominator (e.g., for an aspect ratio of 4:3, the number would appear as 00.00.00.04.00.00.00.03 in hexadecimal format).

l. Half Float (lens serial) – a 16-bit floating point number as defined in Section 5.1.

m. Half Float – a 16-bit floating point number as defined in IEEE 754.

n. UTF8 String – a text string using variable length coding for each character according to the Unicode specification. UTF8 coding is backwards compatible with single-byte coding of ISO/IEC 646 (ASCII) characters.

3. "Len" is the length of the item. The length field is a 2-byte number.

4. "Local Tag" is the identifier for each item in the set. Local tag values are 2-bytes in length.

5. "Req?" is used to indicate whether the item in the set is 'required' [Req] or 'optional' [Opt].

6. "Meaning" is used to give a human-readable description of the item.

4.4 Extending the Acquisition Metadata Sets

The Acquisition Metadata sets may be extended with new sets that share the characteristics of acquisition processing.

Any addition of a new set (or new sets) to the Acquisition Metadata sets provides for an increment in the set version number described in byte 14 of the set UL of the additional set (or sets).

4.5 Basic Set Rules

The following statements describe the common aspects for each data item in both sets:

- The data is just a control function value corresponding to a setting or configuration in the acquisition device. For example, the Focus Position value is represented by the position of the focus ring and is not the measure of the actual focusing distance or the absolute distance to the object.
- Accuracy of the data value is not within the scope of this document.
- Synchronization with the video should be within a frame period.

5 Acquisition Metadata Definitions

This section defines the Acquisition Metadata items.

5.1 Common Distance Format

The common distance format is used to describe a spatial length (in meters) by a 16-bit floating point value.

distance(value) = $m \times 10^{e}$ [meters], where:

- "e" is the exponent in 2's complement form and is the upper 4 bits of the 16 bit value. "e" represents -8 to 7 with sign.
- "m" is the unsigned mantissa, and is the lower 12 bits of the 16 bit value. "m" represents 0 to 4095 unsigned.
- Using the above method of representation, multiple expressions could indicate a particular distance. The expression with the maximum value of mantissa should be used

Note: This format is compatible with the industry practice known as the "Lens Serial" format which is supported by several major camera manufacturers.

5.2 Instance UID

The instance UID value is a unique value that can be used to identify a given instance of the data set. All Instance UID of given instances of the sets on the signal interface are different.

5.3 Items of Lens Unit Metadata Set

5.3.1 Iris F-Number

This item represents the iris position of the lens as a value calculated from the “F-number” according to the following equation:

$$\text{Value} = 10000_{\text{h}} \times \left(1 - \frac{\log_2(F)}{8}\right)$$

The value is a 16-bit unsigned integer and is a dimensionless number.

The F-number is a measure of the amount of light transmitted through the lens. It is the focal length divided by the "effective" aperture diameter and is given by

$F = \frac{f}{D}$; where *f* is the focal length of a lens, and *D* is the effective lens diameter.

Notes:

1. The equation above implies that opening iris by one stop (+1EV [exposure value], e.g. 8 to 5.6) results in increasing 1000h (i.e. 4096) in value, such that, F000h represents F1.4, E000h represents F2, $A000_{\text{h}}$ represents F8 and 0000h~6000h actually represents “Closed”.

2. The iris position represents the setting of the iris ring on the lens without taking the optical limitation known as "F-drop" into consideration. This is commonly known as the "F-number".

3. This representation allows only F-numbers that are greater than (and not equal to) F1.0.

5.3.2 Iris T-Number

This item represents the iris position of the lens as a value calculated from the “T-number” according to the following equation:

$$\text{Value} = 10000_{\text{h}} \times \left(1 - \frac{\log_2(T)}{8}\right)$$

The value is a 16-bit unsigned integer and is a dimensionless number.

The T-number (T) is a measure of the amount of light transmitted through the lens in practice and is given by

$T = F / \sqrt{t}$; where *t* is the transmittance of the lens.

5.3.3 Iris Ring Position

This item represents the rotational position of the lens iris ring.

This value is set by a lens controller and forms the "Iris Ring Position" metadata item.

This value has no units and is expressed as a 16-bit unsigned integer. 0000h represents a fully open iris, FFFFh a closed (or narrowest possible) iris. Intermediate values are proportional to the angle of rotation between the minimum and maximum angles, scaled between 0000h and FFFFh.

5.3.4 Focus Position

This item represents the value of the focus position of the lens, in meters, using the common distance format (per Section 5.1). The value is a 16-bit floating point number.

There are two variants of the Focus Position item: Focus Position From Image Plane and Focus Position From Front Lens Vertex.

The Focus Position From Image Plane item indicates the distance between the image plane (which is on the optical axis) and the object placed centrally in front of the lens when the center of the image is in focus.

The Focus Position From Front Lens Vertex item indicates the distance between the front of the lens and the object placed centrally in front of the lens when the center of the image is in focus.

Notes:

1. The focus position value can be, for example, derived from the setting of the focus ring on the lens.

2. If both of the Focus Position From Image Plane and the Focus Position From Front Lens Vertex items are recorded, priority is given to the Focus Position From Image Plane item.

5.3.5 Focus Ring Positions

This item represents the rotational position of the lens focus ring.

This value is set by a lens controller and forms the "Focus Ring Position" metadata item.

This value has no units and is expressed as a 16-bit unsigned integer. 0000h represents the minimum focus distance, FFFFh represents focusing at infinity. Intermediate values are proportional to the angle of rotation between the minimum and maximum angles, scaled between 0000h and FFFFh.

5.3.6 Macro Setting

This item is a Boolean item whose value is non-zero (TRUE) if the macro setting is ON, or zero (FALSE) if the macro setting is OFF.

This item indicates the capability of the lens macro function for close-up work with a limited focal range and can be generated by a macro on/off switch or by the zoom ring position. When the switch is ON, the value is true even if the focusing distance is long-range or infinity.

5.3.7 Lens Zoom

This item represents the focal length (zoom position) of the lens in meters, using the common distance format (see Section 5.1). The value is a 16-bit floating point number.

There are two variants of the Lens Zoom item: Lens Zoom Actual Focal Length and Lens Zoom 35mm Still Camera Equivalent.

The Lens Zoom Actual Focal Length implies the "effective focal length" considering the focal point on the image plane side). The value may be calculated by the angle of the zoom ring on the lens.

The Lens Zoom 35mm Still Camera Equivalent is normalized to the 35-mm still camera equivalent value. The actual focal length multiplied by the crop factor is the 35-mm equivalent value, where the crop factor is calculated as follows:

The crop factor = (effective diagonal of a 35-mm still camera film image area) / (effective diagonal of the image sensor).

The diagonal of the 24-mm by 36-mm image area of a standard 35-mm film still camera is 43.267 mm.

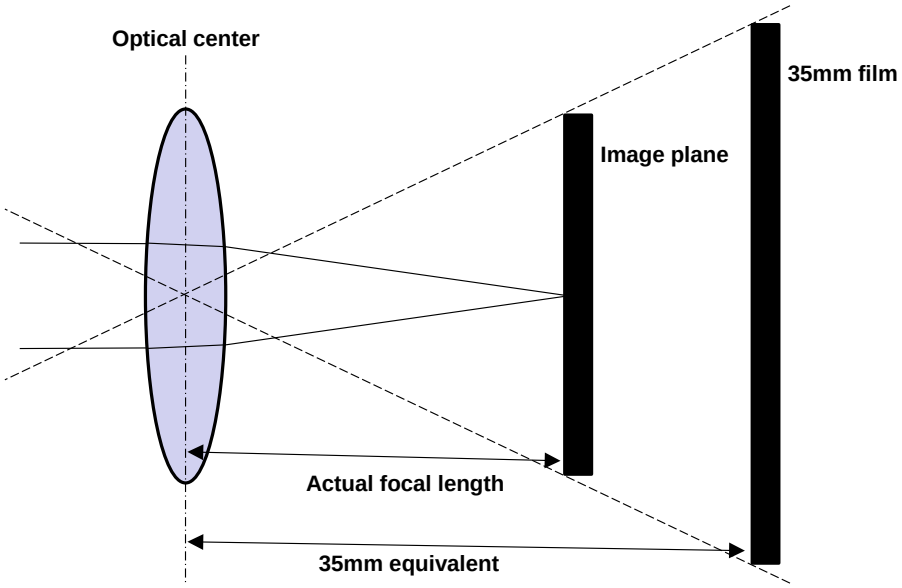

Figure 1 – Lens Zoom

The magnification ratio of any conversion lens or of any optical extender is ignored.

Notes:

1. This 35-mm still camera equivalent value is usually used to calculate the angle of view.

2. If both of the 35mm still camera equivalent and the actual value are recorded, priority is given to the Lens Zoom 35-mm Still Camera Equivalent item.

5.3.8 Zoom Ring Positions

This item represents the rotational position of the lens zoom ring.

This value is set by a lens controller and forms the "Zoom Ring Position" metadata item.

This value has no units and is expressed as a 16-bit unsigned integer. 0000h represents the wide end of the zoom, FFFFh represents the tele end. Intermediate values are proportional to the angle of rotation between the minimum and maximum angles, scaled between 0000h and FFFFh.

5.3.9 Optical Extender Magnification

This item represents the magnification ratio of the optical extender as a percentage value where 100% is a magnification ratio of 1.

The value is an unsigned 16-bit integer and the MSB is set to 0.
The item is expressed as a nominal value, which represents the magnification ratio at the central point of the image.

This function may be served by a lens built-in Extender, an optional Extender Lens unit, a Close-Up Lens unit or a Wide/Tele Conversion Lens unit. The data may be automatically or manually set. When two or more lenses are attached, the data should be the product of their magnification ratio. If all these functions are inactive or unavailable, the value is set to 100 (64h).

5.3.10 Lens Attributes

This item is a human-readable text description of the lens unit in use. The length of the text is less than 64 bytes.

5.4 Items of Camera Unit Metadata Set

5.4.1 Auto Exposure Mode

This item identifies the automatic exposure (AE) function by a SMPTE Label value.

The SMPTE Label values are defined in Table 3.

When the exposure is controlled by a camera specific method (so called "program AE"), other SMPTE label values may be used, including class 14 label values.

The evaluation area of the captured image, the response and transition to a change of brightness, and the controlling algorithm are not included in the scope of this function.

When the automatic control is inactive, the SMPTE Label value is set to the manual exposure mode.

Table 3 – AE Mode Label Values

Name	UL	Description
Manual Exposure mode	06.0E.2B.34.04.01.01.0B. 05.10.01.01.01.01.00.00	Fully manual exposure control
Full Auto Exposure mode	06.0E.2B.34.04.01.01.0B. 05.10.01.01.01.02.00.00	All available camera facilities used for exposure control
Gain Priority Auto Exposure mode	06.0E.2B.34.04.01.01.0B. 05.10.01.01.01.03.00.00	The gain control was set to manual exposure control.
Iris Priority Auto Exposure mode	06.0E.2B.34.04.01.01.0B. 05.10.01.01.01.04.00.00	The iris control was set to manual exposure control. This is widely known as ‘aperture priority’.
Shutter Priority Auto Exposure mode	06.0E.2B.34.04.01.01.0B. 05.10.01.01.01.05.00.00	The shutter speed was set to manual exposure control. This is widely known as ‘shutter priority’
Camera specific control mode	06.0E.2B.34.04.01.01.vv. 0E.xx.xx.xx.xx.xx.xx.xx	SMPTE class 14 Labels for manufacturer private

Notes:

1. Although several components (i.e. iris, shutter or gain of the amplifier) affect the exposure, the camera operator can manually fix each component in AE operation. For this reason, the AE mode label value identifies which component is manual.

2. SMPTE Label values are registered in SMPTE RP 224. The values of the second 8-byte group for each entry in Table 3 are structured as follows:

Byte 9: 05 (Process)
Byte 10: 10 (Settings)
Byte 11: 01 (Device Settings)
Byte 12: 01 (Camera Settings)
Byte 13: 01 (Exposure Settings)
Byte 14: 01~05 (per Table 3)

5.4.2 Exposure Index of Photo Meter

This item represents the applied index of the light meter in terms of an ISO number (refer to Section 5.4.12). The value is an unsigned 16-bit integer.

Note: This item is referred to by a push/pull process in post production. If the value is different from the ISO Sensitivity of the camera, pull or push processing will be needed during post production.

5.4.3 Auto Focus Sensing Area Setting

This item is an unsigned integer 8-bit code value to indicate the automatic focusing (AF) sensing area.

Available code values are assigned as defined in Table 4.

The AF Mode value is used to evaluate the area of the image for distance measurement.

The response and transition to a moving object, including any wobbling rate and depth, assistance from other measurement methods or any controlling algorithm is not included in the scope of this definition.

When any automatic control is inactive, the value is set to the code for the Manual Focus mode.

Table 4 – AF Mode Code List

Name	Code (hex)	Description
Manual Focus mode	00	The focus was manually set
Center Sensitive Auto Focus mode	01	The focus was at the center of the frame
Full Screen Sensing Auto Focus mode	02	The focus was set for the whole screen
Multi Spot Sensing Auto Focus mode	03	The focus was set using multiple spot sensing
Single Spot Sensing Auto Focus mode	04	The focus was set at a spot located adaptively or by the user
Reserved	05 – FE	Reserved
Undefined	FF	Undefined

5.4.4 Color Correction Filter Wheel Setting

This item represents the characteristics of the built-in optical color compensation (CC) filter. The value is an 8-bit unsigned integer.

Available code values are as listed in Table 5.

Table 5 – CC Filter Code List

Name	Code	Description
Cross effect filter	00	transparent filter with meshed groove for cross effect
CC filter 3200K	01	transparent filter for 3200K lighting
CC filter 4300K	02	light yellow filter for 4300K lighting
CC filter 6300K	03	pale orange filter for 6300K lighting
CC filter 5600K	04	pale orange filter for 5600K lighting
Reserved	05 – FE	Reserved
Undefined	FF	Undefined

Notes:

1. This item should be omitted from the metadata set if the camera is not equipped with a built-in CC filter wheel.

2 This item does not represent any pseudo-CC-filter code which is not an optical effect (i.e. an electrical color compensation function). In such cases, the White Balance item (Section 5.4.16) can be used.

5.4.5 Neutral Density Filter Wheel Setting

This item describes the attenuation ratio of the built-in optical neutral density (ND) filter (i.e. flat gray filter). It represents the reciprocal number of the attenuation ratio (i.e. the denominator of the attenuation ratio of the filter where the numerator is 1). The value is an unsigned 16-bit integer as follows.

Attenuation ratio = 1 / Value

Notes:

1. For example, the ND Filter Value of 32 is identified as "ND32" whose attenuation ratio is 1/32. In general, the value is expressed as a power of two. The data can be set automatically by any built-in ND filter.

2. This item is not intended for any "ND filter" which uses gradation or color tone for artistic effect.

5.4.6 Image Sensor Dimension

The Image Sensor Dimension is specified by the Image Sensor Dimension Effective Width and Image Sensor Dimension Effective Height values.

These values represent the width and height of the rectangular area of the image sensor in micrometers and are expressed as unsigned 16-bit integers.

Note: The rectangular area of the image sensor corresponds to the rectangular area of the video output image and can vary according to the selected aspect ratio. For example, when an image sensor has the effective area of 10 mm x 5.6 mm (16:9) and the output image is edge cropped to 4:3, the Image Sensor Dimension values are 7467 for width and 5600 for height.

5.4.7 Capture Frame Rate

This item represents the rate at which video images are captured, expressed in frames per second.

The Capture Frame Rate value is a 64-bit rational (ratio of two 32 bit signed integer, the first is the numerator and the second is the denominator).

The denominator value is a constant value throughout capture.

The numerator value should be less than 32768 and the value may vary during capture.

Both the denominator and numerator are positive.

Note: This item can be used to describe over/under-cranking to create slow/quick motion.

5.4.8 Image Sensor Readout mode

This item is an unsigned integer 8-bit code which identifies the method of reading the sensor signals from the image sensor pixels.

Available code values are assigned as defined in Table 6 (see also Figure 2).

Table 6 – Image Sensor Readout Mode

Name	Code	Description
Interlaced field	00	Interlaced scan (average of two lines)
Interlaced frame	01	Interlaced scan (line alternation)
Progressive frame	02	Progressive scan
Reserved	03-FE	Reserved
Undefined	FF	Undefined method

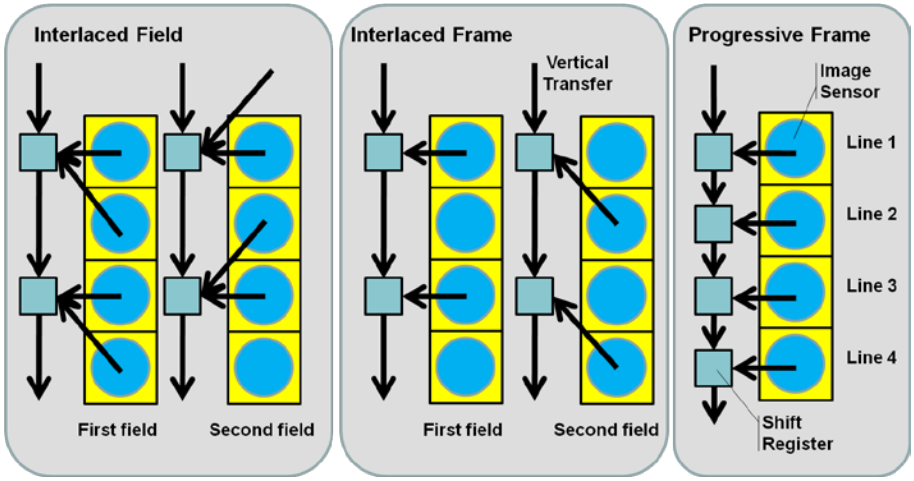

Figure 2 – Imager readout mode (e.g. CCD)

Note: This metadata identifies the effective exposure period of each line of pixels of the video signal output from the image sensor. If the video is scan-converted within the camera unit, the code value is determined according to the method of conversion.

5.4.9 Shutter Speed Angle

This item represents the exposure period, expressed as an angle [minutes] (i.e. 1/60 degree).

This value is a 32-bit unsigned integer where the value is the angle in minutes and is set to 21600 (360 x 60 = 5460h) where 21600 minutes represent a field/frame period.

Notes:

1. This function can also be used for slow shutter mode operation. For example, when the image sensor charges for 2 frame periods, the angle will be 43200 minutes, resulting in a value of 0000A8C0h.

2. When the shutter effect is not used, this is the equivalent to 360 degrees resulting in a value of 21600 minutes.

3. If both of the Shutter Speed Angle and the Shutter Speed Time items are recorded, priority is given to the Shutter Speed Angle item.

5.4.10 Shutter Speed Time

The Shutter Speed (Time) item represents the exposure period in seconds.

This value is a 64 bit rational (ratio of two 32 bit signed integer, the first is the numerator and the second is the denominator) that defines the Shutter Speed Time expressed in seconds.

Both the denominator and numerator are positive.

Notes:

1. For example, 1/1000 would define a shutter speed of 1 msec.

2. This function can also be used for slow shutter mode operation. For example, when the image sensor charges for 2 frame periods in a 24-frame system, i.e. 2/24 seconds, the result is a value of 0000000200000018h

5.4.11 Camera Master Gain Adjustment

This item represents the adjustment level of the master gain control, fed in increments of 0.01 decibel. The gain value implies a gain for each RGB signal.

This value is a 16-bit integer. When this function is inactive, the value is set to 0.

Note: For example, when a head-amplifier boosts the camera signal by +12dB, the value is set to 1200 (4B0h).

5.4.12 ISO Sensitivity

This item represents the sensitivity of the camera unit to light in terms of an ISO number.

The value is an unsigned 16-bit integer.

The value (i.e. the ISO number) is calibrated in accordance with the exposure index defined in ISO 12232:2006 and is measured under the test conditions described in ISO 12232 except for "photosite integration time" which depends on the video rate. The range of possible values is continuous, unlike the discrete values (e.g., 100, 125, 160, 200 etc) defined for still cameras in ISO 12232.

Note: This item does not specify the performance of the image sensor device, but is a parameter to determine the exposure during acquisition. Therefore, although the ISO number is initially adjusted to an appropriate setting as made available by the camera manufacturer, the actual value will in practice fluctuate depending on the Master Gain or other settings.

5.4.13 Color Matrix

This item represents the matrix applied between the R, G, B channels.

Compensation of a color filter of an image sensor according to the color matrix should be applied prior to gamma encoding.

The Color Matrix item is a 9 elements ordered array of 64-bit rational (ratio of two 32-bit signed integer, the first is the numerator and the second is the denominator) containing the following values (see Table 7):

Table 7 – Structure of Color Matrix Array

Name	Type	Len	Description
Number of elements	UInt32	4	9
Length of each element.	UInt32	4	8
R to R	Rational	8	Amount of Red channel into Red Channel
G to R	Rational	8	Amount of Green channel into Red Channel
B to R	Rational	8	Amount of Blue channel into Red Channel
R to G	Rational	8	Amount of Red channel into Green Channel
G to G	Rational	8	Amount of Green channel into Green Channel
B to G	Rational	8	Amount of Blue channel into Green Channel
R to B	Rational	8	Amount of Red channel into Blue Channel
G to B	Rational	8	Amount of Green channel into Blue Channel
B to B	Rational	8	Amount of Blue channel into Blue Channel

5.4.14 Electrical Extender Magnification

This item represents the ratio of the Electrical Extender Magnification, expressed as a percentage value where 100% is a magnification ratio of 1.

The percentage value is an unsigned 16-bit integer and the MSB is set to 0.

Since this item is for simple picture magnification, it does not separately specify the position of the close up. The center of the resized picture should be considered the same as the captured picture. This item is not intended for any special effects such as partial screen zooming, i.e. distorting picture or superimposing sub screen, but for full screen zooming.

When this function is inactive, the value is set to 100 (64h).

5.4.15 Auto White Balance Mode

This item represents the mode of the automatically adjusted white balance as an 8-bit code value.

Available code values are as enumerated in Table 8.

Table 8 – White Balance (WB) Setup Code List

Name	Code	Description
Preset White Balance Setup	00	The WB is set to a fixed value.
Automatic White Balance Setup	01	The WB value is continuously adjusted automatically.
Hold White Balance Setup	02	The current WB value is held. This mode is usually triggered manually during the automatic WB mode.
One Push White Balance Setup	03	Rapid adjustment to an automatically determined WB value. This mode is usually triggered manually during the preset WB mode or the automatic WB mode.
Reserved	04 - FE	Reserved values.
Undefined	FF	Undefined

Notes:

1. This function is not used to define a target color tone. The evaluation area of the image, the response and transition against the change of light and the controlling algorithm are considered out of scope for this definition.

2. When the automatic white balance mode control is inactive, the value is set to the ‘Preset White Balance’ code.

5.4.16 White Balance

This item represents the white balance, expressed as a color temperature [Kelvin].

The value is an unsigned 16-bit integer and the MSB is set to 0.

This item is implemented by electrical and optical filters inside the camera.

Notes:

1. This value does not imply the actual color temperature of the light source.

2. The WB color temperature has a spectral power distribution curve that is a close approximation to that of black body radiation calculated by Planck's law.

5.4.17 Camera Master Black Level

This item represents the master black level setting of the camera.

The value is a signed 16-bit integer

The value is the difference between the camera output black level and the input black level in units of 0.1 percent where 100 percent means white.

When this function is inactive, the value is set to 0.

Note: A positive value means that the black level is shifted upwards to brighten the picture. The contrast of picture will be modified by this control in order to maintain a stable white level.

5.4.18 Knee Function

Video cameras typically ameliorate their sensor's harsh clipping with a knee function which allows compression of the upper portion of the dynamic range. The compression charactereristic of the knee function is described with two parameters: Knee Point and Knee Slope. When this function is inactive, the Knee Slope value is set to 1/1.

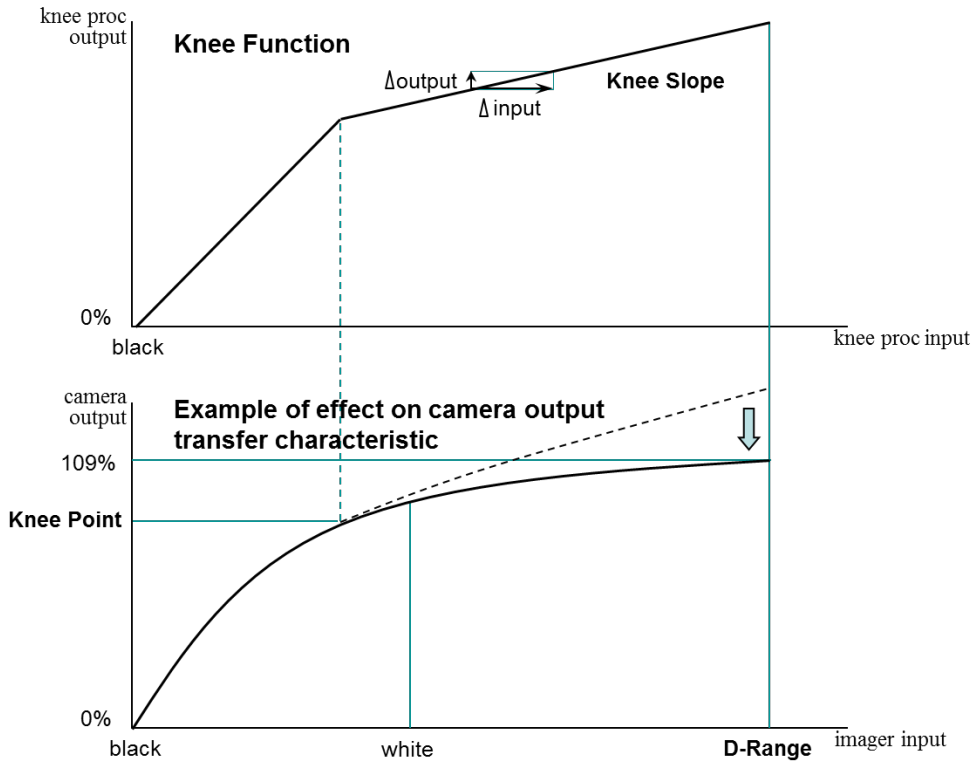

Figure 3 – Knee and Dynamic Range

5.4.18.1 Camera Knee Point

This item represents the knee point of the camera knee characteristic (see Figure 3) expressed as the luminance level at which dynamic range compression starts to flatten the contrast curve.

The Knee Point value increment is in units of 0.1 percent and the value is an unsigned 16-bit integer.

5.4.18.2 Camera Knee Slope

This item represents the degree of dynamic range compression applied to the signal from the camera imager, expressed as the slope of the line shown in Figure 3 (a) starting at the Knee Point.

$$\text{Knee Slope} = \frac{\Delta \text{output}}{\Delta \text{input}}$$

The value is a 64-bit rational (ratio of two 32-bit signed integer, the first is the numerator and the second is the denominator).

Both the denominator and numerator are positive.

The slope of the bottom line (between black level and the Knee Point) is one (e.g. no transformation).

5.4.19 Camera Luminance Dynamic Range

This item represents the peak signal level that the camera image sensor would deliver in the absence of any signal compression that may be applied through the knee characteristics described above. The value is expressed in units of 0.1 percent and is represented as a UInt16 to allow a large headroom for peak signal levels at the camera sensor (see Figure 3).

5.4.20 Capture Gamma Equation

This item represents the camera capture gamma value as a 16-byte SMPTE Label.

The Label values are as enumerated in Table 9.

When a camera-specific gamma curve is required, an organizationally registered as private label (i.e. Class 14) may be used.

Note: The signal processor compensates for the distortion of the image sensor. Since this item indicates the basic gamma curve, the value is not affected by the other non-linear level conversion functions (i.e. knee control, black gamma, solarization reduction, etc.).

Table 9 – Gamma Type Label list

Name	UL	Description
ITU-R BT.709 Transfer Characteristic	06.0E.2B.34.04.01.01.01. 04.01.01.01.01.02.00.00	
SMPTE ST 240 Transfer Characteristic	06.0E.2B.34.04.01.01.01. 04.01.01.01.01.03.00.00	
preset specific gamma curve	06.0E.2B.34.04.01.01.vv. 0E.xx.xx.xx.xx.xx.xx.xx	Class 14 labels for manufacturer private use

5.4.21 Gamma for CDL

This item represents the gamma characteristics at the input of the CDL, i.e. called ICT (Input Conversion Transform).The value is described in an 8-bit code. Available code values are as enumerated in Table 10.

Table 10 – ASC CDL ICT Code List

Name	Code	Description
Content Video	00	gamma not defined below, specified as Capture Gamma
Scene Linear	01	propotional to the light level
S-Log	02	The formula representing the S-Log curve is as follows $y = (0.432699 \times \log_{10}(t + 0.037584) + 0.616596) + 0.03$ where *t* ranges from 0 to 10.0, representing 0% to 1000% input light level to the camera. Multiply y by 100 to obtain the percentage value.
Cine-Log	03	generic logarithm gamma in cinema system
Reserved	04 - FE	Reserved
Undefined	FF	Undefined

5.4.22 ASC CDL V1.2

This item represents ASC CDL V1.2. The V1.2 includes 10 items: Slope R, Slope G, Slope B, Offset R, Offset G, Offset B, Power R, Power G, Power B and Saturation. Each item is described in “ASC Color Decision List (ASC CDL) Transfer Functions and Interchange Syntax” instituted by American Society of Cinematographers.

Item type is array of Half Float that is defined in IEEE 754 as the half precision binary floating-point format.

Table 11 – Structure of ASC CDL V1.2

Name	Type	Len	Description
Number of elements	UInt32	4	10
Length of each element.	UInt32	4	2
Slope R	Half Float	2	ASC Slope Red Value
Slope G	Half Float	2	ASC Slope Green Value
Slope B	Half Float	2	ASC Slope Blue Value
Offset R	Half Float	2	ASC Offset Red Value
Offset G	Half Float	2	ASC Offset Green Value
Offset B	Half Float	2	ASC Offset Blue Value
Power R	Half Float	2	ASC Power Red Value
Power G	Half Float	2	ASC Power Green Value
Power B	Half Float	2	ASC Power Blue Value
Saturation	Half Float	2	ASC Saturation Value

5.4.23 Camera Setting File URI

This item is used to identify the URI (Uniform Resource Identifier) of a file that defines the camera setting values as human-readable UTF8 text. The URI complies with IETF RFC 3986.

Note: UTF8 may be used within a URI to represent characters outside the range of the US-ASCII coded character set. IETF RFC 3987 defines this method as a complement to the URI.

5.4.24 Camera Attributes

This item is a human-readable text description of the camera unit in use. The length of the text is less than 64 bytes.

6 Carriage of the Acquisition Metadata Sets

Since each metadata set can be considered simply as a KLV coded set, there are several methods available to transport and store the data. Since the metadata sets carry time-sensitive metadata, the Acquisition Metadata sets should be carried in frame synchronism with the associated video essence data. Unless otherwise specified, it is assumed that all Acquisition Metadata sets are carried.

This section explains how the Acquisition Metadata sets can be used in two different application areas — the MXF Generic Container and V-Anc packets on serial digital interfaces. Other methods of transport and storage can also be used where there is a provision for carrying KLV coded data.

6.1 Carriage in the MXF Generic Container

The MXF Constrained Generic Container (GC) is defined by SMPTE ST 379-2.

SMPTE ST 385 defines how the SDTI-CP System Item can be mapped to the MXF GC (CP-System Item). SMPTE ST 394 defines a superset of the System Item defined in SMPTE ST 385 (GC-System Item).

The KLV Acquisition Metadata sets defined in this document can be carried in the MXF-GC by application of the mapping specifications that allow the CP-System Item or GC-System Item to be mapped into the MXF-GC (see Figure 4). The reverse mapping of the Acquisition Metadata sets onto CP or GC-System Item can also be made using reversed mapping rules.

SMPTE ST 331 defines metadata packets that are intended for use in the System Item including a packet for the carriage of KLV metadata (SMPTE ST 331, Section 8.9, KLV metadata). The Lens Unit Metadata set, the Camera Unit Metadata set and the User Defined Acquisition Metadata set can be carried as Metadata Blocks in the Picture Metadata set of the CP-System Item or the Picture Item Descriptor of the GC-System Item. Figure 4 shows how to convey two Acquisition Metadata sets in the CP-System Item or the GC-System Item. The mapping of the metadata sets to an associated picture element is beyond the scope of this document.

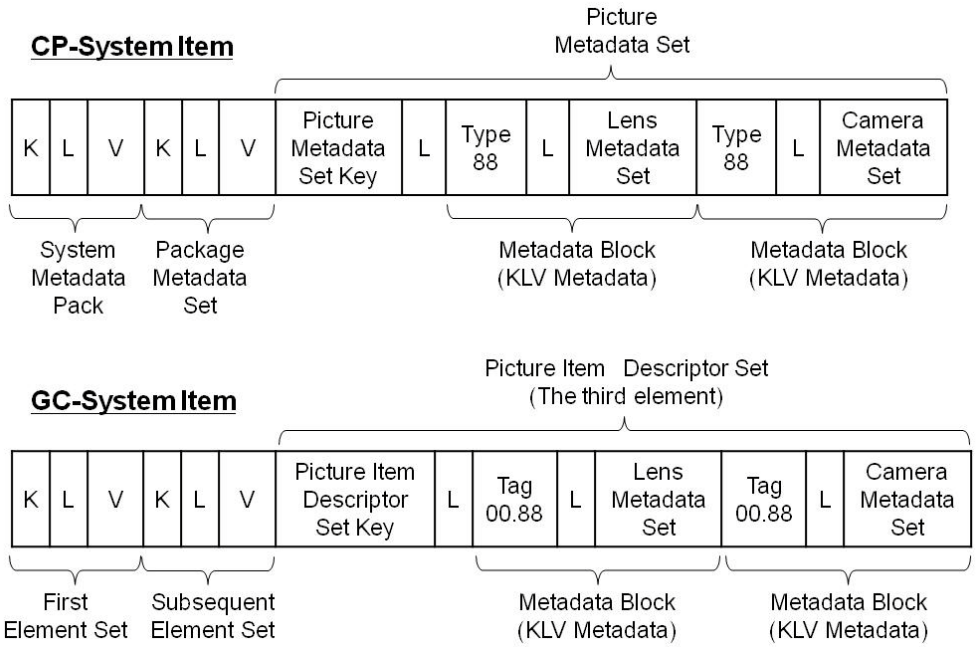

Figure 4 – System Item

CP-System Item Picture Metadata set key; 06.0E.2B.34.02.43.01.01.0D.01.03.01.04.01.03.xx

The 16th byte of the Picture Metadata set key represents the number of metadata blocks in this set.

GC-System Item Picture Item Descriptor key; 06.0E.2B.34.02.53.01.01.0D.01.03.01.14.02.03.yy

The 16th byte of the Picture Item Descriptor key represents the element number (e.g. '02' represents the number of the third element).

6.2 Carriage in Vertical Ancillary Data Packets

SMPTE ST 291 defines an ancillary data packet. The Acquisition Metadata sets can be carried in vertical ancillary space as type 2 data packets.

The type 2 data packet consists of the ancillary data flag (ADF), the data ID (DID), the secondary data ID (SDID), the data count (DC), the user data words (UDW), and the checksum (CS). The DID is set to the value 43h. The SDID is set to the value 05h. The ADF and CS are defined in SMPTE ST 291.

The first user word of the ancillary packet payload that follows the DC field defines a packet sequence count (PSC). This word forms a 8-bit PSC number that defines the number of ancillary packets with the same DID/SDID value necessary to carry the KLV encoded message (bit 7 of the word represents the MSB and bit 0 of the word represents the LSB of the PSC value).The PSC number is incremented with the value 1 assigned to a first ancillary packet containing the first part of a set.

The ancillary space packet UDW is a sequence of 10-bit words. The Acquisition Metadata sets are transmitted in bits b7 through b0 of the 10-bit data word. Bit b8 is even parity for bits b7 through b0 of the 10-bit data word, and bit b9 equals not bit b8 (see Figure 5).

The Acquisition Metadata sets carried in the vertical ancillary space are encoded in the order described in this document. For example, the Lens Unit Metadata set is encoded first in the data packet, followed by the Camera Unit Metadata set and any User Defined Acquisition Metadata set. If the total length of the Metadata sets encoded in the data packet is more than or equal to 255 bytes, the remaining data from the 255th byte are encoded in the subsequent packets using the same DID/SDID (see Figure 6).

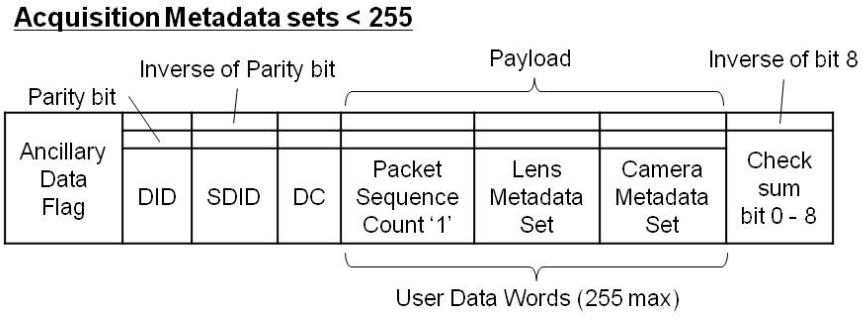

Figure 5 – Structure of an ANC Packet carrying the Acquisition Metadata sets

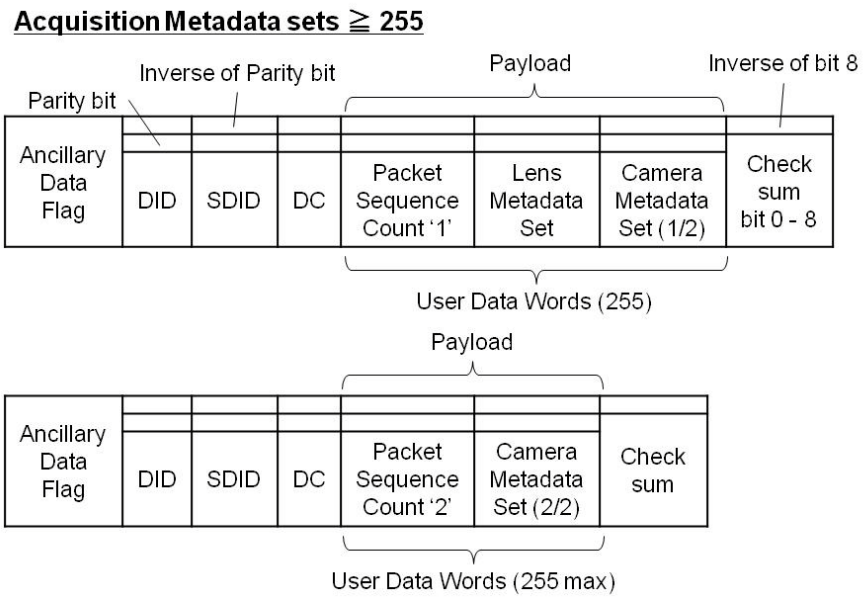

Figure 6 – Structure of multiple ANC Packets carrying the Acquisition Metadata sets

Annex A Bibliography (Informative)

Note: All references in this document to other SMPTE documents use the current numbering style (e.g. SMPTE ST 240:1999) although, during a transitional phase, the document as published (printed or PDF) may bear an older designation (such as SMPTE 240M-1999). Documents with the same root number (e.g. 240) and publication year (e.g. 1999) are functionally identical.

SMPTE ST 240:1999, Television — 1125-Line High-Definition Production Systems — Signal Parameters

SMPTE ST 291:2011, Ancillary Data Packet and Space Formatting

SMPTE ST 326:2000, Television — SDTI Content Package Format (SDTI-CP)

SMPTE ST 331:2011, Element and Metadata Definitions for the SDTI-CP

SMPTE ST 379-2-2010, Television — Material Exchange Format (MXF) — MXF Constrained Generic Container

SMPTE ST 385:2004, Television — Material Exchange Format (MXF) — Mapping SDTI-CP Essence and Metadata into the MXF Generic Container

SMPTE ST 394:2006, Television — Material Exchange Format (MXF) —System Scheme 1 for the MXF Generic Container

SMPTE ST 405:2006, Television — Material Exchange Format (MXF) —Elements and Individual Data Items for the MXF Generic Container System Scheme 1

IETF RFC 3986, Uniform Resource Identifier (URI): Generic Syntax

IETF RFC 3987, Internationalized Resource Identifiers (IRIs)

ISO/IEC 646:1991, Information Technology — ISO 7-Bit Coded Character Set for Information Interchange

ISO 12232:2006, Photography -- Digital still cameras -- Determination of exposure index, ISO speed ratings, standard output sensitivity, and recommended exposure index

ITU-R BT.709-5 (04/02), Parameter values for the HDTV standards for Production and International Programme Exchange

The Unicode Consortium. The Unicode Standard, Version 5.1.0, defined by: The Unicode Standard, Version 5.0 (Boston, MA, Addison-Wesley, 2007. ISBN 0-321-48091-0), as amended by Unicode 5.1.0 (http://www.unicode.org/versions/Unicode5.1.0/).

IEEE Std 754-2008, IEEE Standard for Floating-Point Arithmetic