White Paper on D-Log and D-Gamut of DJI Cinema Color System

DJI Zenmuse X9 6K & 8K

2022.02

Revision history

Revision	Date	Edition
Rev.1.0	2022.02	First Edition

Contents

Abstract

This document provides technical information on DJI's gamma curve (D-Log) and gamut (D-Gamut) for DJI Zenmuse X9 6K & 8K.

D-Log curve for DJI Zenmuse X9 6K & 8K requires a slightly different implementation of D-Log that was released with DJI Zenmuse X7 in 2017, while D-Gamut remains the same.

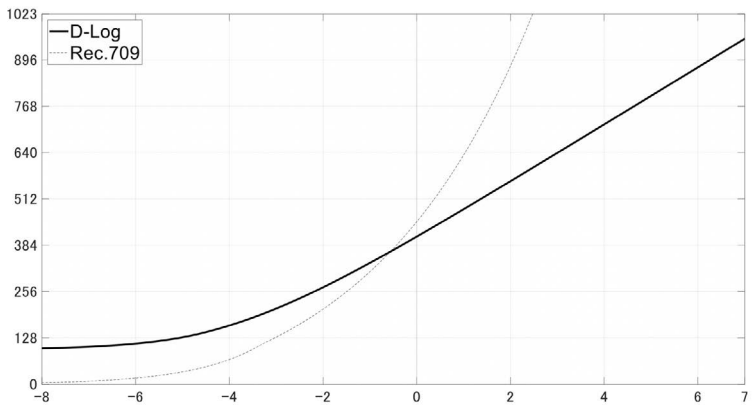
Introduction

D-Log is designed based on opto-electric conversion function characteristics of negative film scans to be compatible with conventional film workflows.

The D-Log curve for DJI Zenmuse X9 6K & 8K is based on an original D-Log curve and tuned for new 6K & 8K sensors. It is intended to balance the camera's performance for highlights, mid-tones, and shadow and cover 14 stops of dynamic range while keeping visual noise at a minimal level.

D-Log Curve Characteristics and Formula

D-Log curves for DJI Zenmuse X9 6K & 8K differ across different EI. The curve for Native EI (6K: EI 800/5000; 8K 800/4000) is shown in the graph below:



Exposure (f-stops)
0 stands for 18% mid gray

The conversion function from linear signal to D-Log data is:

```
in <= 0.0078
        out = 6.025 * in + 0.0929;
in > 0.0078
        out = (log10(in * 0.9892 + 0.0108)) * 0.256663 + 0.584555;
```


The reverse conversion (from D-Log data to linear signal) is:

```
in <= 0.14
        out = (x - 0.0929) / 6.025;
in > 0.14
        out = (10^(3.89616 * x - 2.27752) - 0.0108)/0.9892;
```

The following table shows characteristics of D-Log curve at native EI:

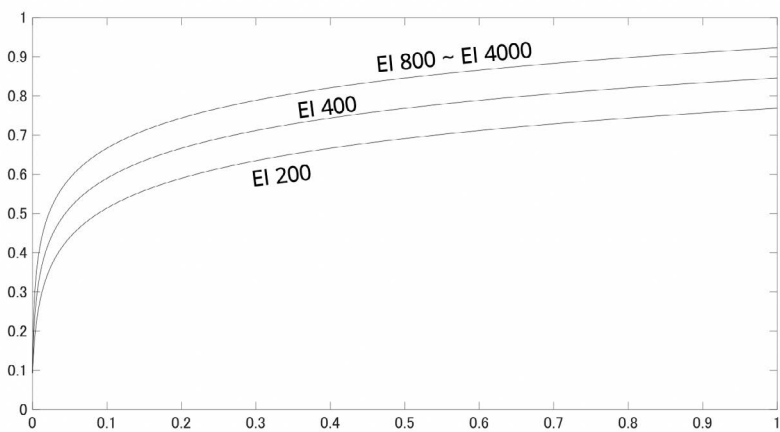
Input reflection (%)	10bit code value
0	95
18	408
90	586

D-Log curves for EI above native EI, e.g., EI 5000 – EI 12800 on DJI Zenmuse X9 6K, are the same as the curve for native EI. High EI on DJI Zenmuse X9 6K & 8K is realized with analog gain on the image sensor in order to achieve better noise performance in dark shooting environments.

D-Log curves for EI below native EI, e.g., EI 200 – EI 640 on DJI Zenmuse X9 6K, are generated from the same linear to D-Log conversion function with scaled input. The scale factor is linear with the EI value. Since the normalized sensor signal is always clipped at 1.0, the clip level of the D-Log curve is also lower as EI goes down.

Technically, D-Log curves for EI between two native EI's can be implemented in either of the above two ways. For the specific case of DJI Zenmuse X9 6K & 8K, the decision is made with real-world shooting tests. Part 3. Dual Native EI gives the gain and curve configuration of DJI Zenmuse X9 6K & 8K.

D-Log curves for several different EI of DJI Zenmuse X9 6K are shown in the following figure as an example.



D-Log curves for several different exposure indices on DJI Zenmuse X9 6K.
X-axis is the normalized signal of the image sensor.

The clipping level of each EI of DJI Zenmuse X9 6K & 8K are given in the tables below:

EI Value	Clipping Level 10bit code	EI Value	Clipping Level 10bit code
200	789	1600	948
250	816	2000	948
320	842	2500	948
400	868	3200	948
500	895	4000	921
640	921	5000 (native)	948
800 (native)	948	6400	948
1000	948	8000	948
1250	948	10000	948
12800	948		

Clipping level of EI's of DJI Zenmuse X9 6K

EI Value	Clipping Level 10bit code	EI Value	Clipping Level 10bit code
200	789	1600	948
250	816	2000	948
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500	895	4000 (native)	948
640	921	5000	948
800 (native)	948	6400	948
1000	948	8000	948
1250	948	10000	948
12800	948	12800	948

Clipping level of EI's of DJI Zenmuse X9 8K

Dual Native EI

DJI Zenmuse X9 6K & 8K support dual native EI. DJI Zenmuse X9 6K has dual EI of EI 800 and EI 5000; DJI Zenmuse X9 8K has dual EI of EI 800 and EI 4000.

It is recommended to always use native EI when possible. Changing aperture or using ND filters could be helpful to correct exposure in order to use native EI.

Low native EI and high native EI use the same curve as described in Part 2. D-Log Curve Characteristics and Formula. The difference is that the image sensor is working at a low sensitivity mode and high sensitivity mode, respectively.

EI above high native EI uses the same curve as native EI but applies an analog gain on the image sensor. Using analog gain on the sensor instead of a higher curve to gain sensitivity is on purpose in order to achieve better noise performance in dark shooting environments. However, the dynamic range on highlights will be compromised proportionally.

EI below low native EI uses a lower curve than that of native EI. As a result, the maximum output level, namely the clip level of lower EI, is also lower, which leads to reduced dynamic range on the highlights side.

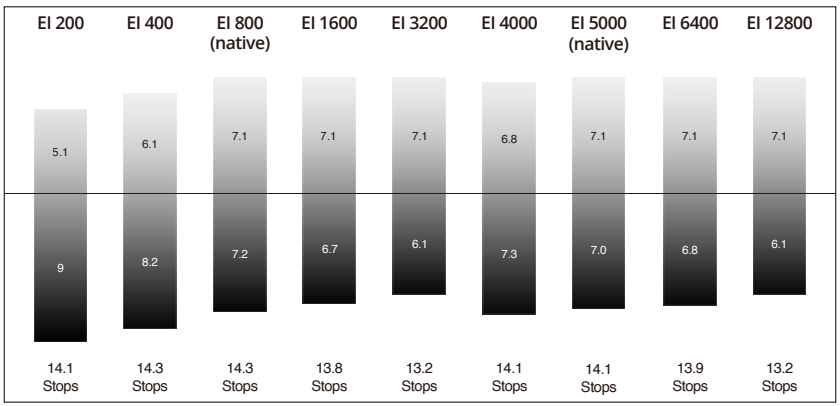
EI between two native EI are case-by-case decided with real-world shooting tests.

For DJI Zenmuse X9-6K, EI 1000 to EI 3200 are realized with the image sensor working at low sensitivity mode, native EI curve, and sensor analog gain, while EI 4000 is realized with the image sensor working at high sensitivity mode in combination with a 1/3 stop lower curve.

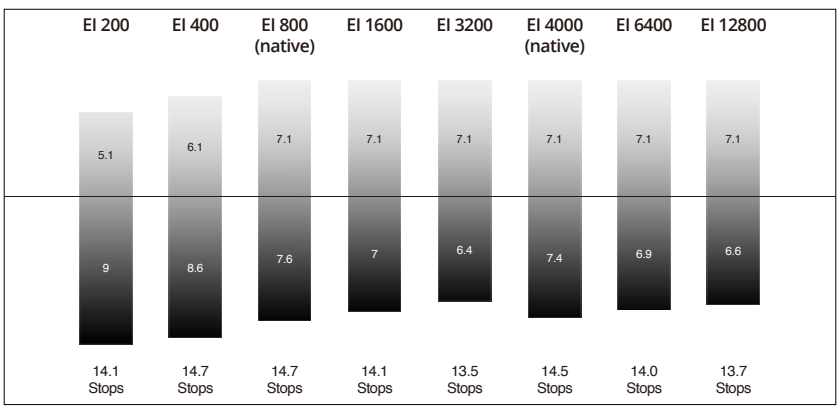
For DJI Zenmuse X9-8K, EI between two native EI's are all realized with the image sensor working at a low sensitivity mode, native EI curve, and sensor analog gain.

Different EI have different dynamic range maximums. Moreover, the dynamic range below and above neutral gray changes substantially with EI.

The figures below show the overall dynamic range, dynamic range above 18% gray, and dynamic range below 18% gray of each EI on DJI Zenmuse X9 6K & 8K.



Dynamic range of different EI on DJI Zenmuse X9-6K



Dynamic range of different EI on DJI Zenmuse X9-8K

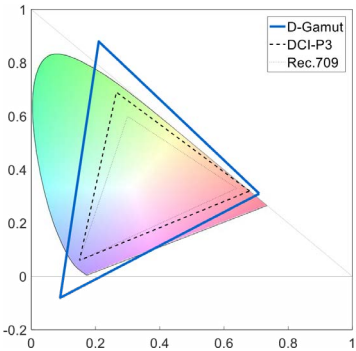
Colorimetric Information

D-Gamut is designed to fully utilize the capability of the DJI Zenmuse camera's image sensor and, at the same time, provide an optimal starting point for grading.

D-Gamut fully covers ITU-R Rec. 709 and DCI-P3. It has a margin over DCI-P3, so it is capable of grading and archiving for use in cinema. The RGB primaries of D-Gamut are designed the way that red, green, blue primaries of D-Gamut are respectively aligned with red, green, blue primaries of DCI-P3 and white point (D65) in alignment as much as possible. The benefit is that the hue remains mostly unchanged during color space conversion when gamut mapping occurs. For users, there are two important advantages: Firstly, manual grading is much easier because contrast and saturation are relatively easier to tune than hue.

Secondly, footage before grading has the right color, so log preview is more meaningful.

The following graph and table show D-Gamut and its RGB primaries. The white point is defined as D65.



	x	y
R	0.71	0.31
G	0.21	0.88
B	0.09	-0.08
White (D65)	0.3127	0.3290

The D-Gamut RGB to CIE 1931 XYZ conversion matrix is shown below.

0.6482	0.1940	0.1082
0.2830	0.8132	-0.0962
-0.0183	-0.0832	1.1903

The CIE 1931 XYZ to D-Gamut RGB conversion matrix is shown below.

1.7257	-0.4314	-0.1917
-0.6025	1.3906	0.1671
-0.0156	0.0905	0.8489

The D-Gamut RGB to ITU Rec. 709 RGB conversion matrix is shown below.

1.6746	-0.5797	-0.0949
-0.0981	1.3340	-0.2359
-0.0410	-0.2430	1.2840

The ITU Rec. 709 RGB to D-Gamut RGB conversion matrix is shown below.

0.6163	0.2857	0.0980
0.0505	0.7990	0.1505
0.0292	0.1604	0.8104

Changes from D-Log for DJI Zenmuse X7

The D-Log curve for DJI Zenmuse X9 6K & 8K is a slightly different implementation of D-Log that was released with DJI Zenmuse X7 in 2017.

The conversion function from a linear signal to D-Log remains the same. The only thing that changes is the maximum output level, namely clipping level, which is given in Part 2. D-Log Curve Characteristics and Formula.

The dynamic range on the highlight side changes with the clipping level; detailed information is given in Part 3. Dual Native EI.

D-Gamut remains unchanged.

This content is subject to change.

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