# Programming Guide: HDR Module in DPE

This programming guide contains necessary information for correctly configuring the HDR-related registers to perform color volume transform from SDR/HDR to SDR/HDR data. Currently the HDR standards supported are HDR10 and HLG10.

This guide will only give sample configurations for the various supported processing modes as the actual incoming metadata and the target parameters are not fixed.

In addition, it is assumed that the **correct** processing mode is detected before configuring the related registers. Otherwise the output of the HDR module will be erroneous.

## 1. Configurable Parameters/Registers

The configurable parameters or registers can be divided into 2 categories: the top-level application-wise parameters/registers and the low-level registers for the detailed LUT-related data.

### 1.1 Top-level Parameters/Registers

#### 1.1.1 Enable Signals

##### 1.1.1.1 dpe\_hdr\_en: Enable Signal for HDR Module

1-bit value. Set it to 0 if HDR module is bypassed, otherwise set to 1 to enable the module.

##### 1.1.1.2 dpe\_hdr\_tm\_sat\_en: Enable Signal for Saturation Enhancement

1-bit value. Set to 0 if saturation enhancement processing after tone mapping is bypassed, otherwise set to 1 and the processing will be performed.

#### 1.1.2 Processing Mode Related Parameters

All the parameters in this category can be of enumerated type.

##### 1.1.2.1 tf\_in & tf\_out: Input & Output Transfer Function Type

Possible types are as follows:

* SDR
  + TF\_ADOBERGB: transfer function of Adobe RGB signal
  + TF\_ITUOETF: transfer function defined in ITU’s BT.601/BT.709/BT.2020 standards
  + TF\_BT1886: transfer function defined in BT.1886 standard
  + TF\_SRGB: transfer function of sRGB signal
* HDR10
  + TF\_PQ: transfer function of PQ signal
* HLG10
  + TF\_HLG: transfer function of HLG signal

##### 1.1.2.2 tf\_in\_mode & tf\_out\_mode: Input & Output Transfer Function Mode

There are 4 possible modes:

* TF\_MODE\_EOTF
* TF\_MODE\_INVEOTF
* TF\_MODE\_OETF
* TF\_MODE\_INVOETF

The transfer function mode can be configured as shown below.

# tf\_in\_mode  
if tf\_in == TF\_ADOBERGB or tf\_in == TF\_BT1886 or tf\_in == TF\_SRGB or \  
 tf\_in == TF\_PQ:  
 tf\_in\_mode = TF\_MODE\_EOTF  
elif tf\_in == TF\_ITUOETF:  
 tf\_in\_mode = TF\_MODE\_INVOETF  
  
# tf\_out\_mode  
if tf\_in\_mode == TF\_MODE\_EOTF:  
 tf\_out\_mode = TF\_MODE\_INVEOTF  
elif tf\_in\_mode == TF\_MODE\_INVOETF  
 tf\_out\_mode = TF\_MODE\_OETF  
   
# overwrite mode if HLG format is involved  
if tf\_in == TF\_HLG or tf\_out == TF\_HLG:  
 tf\_in\_mode, tf\_out\_mode = TF\_MODE\_INVOETF, TF\_MODE\_OETF

##### 1.1.2.3 cs\_in & cs\_out: Input & Output Colorspace Type

Possible types are summarized below:

* CS\_ADOBERGB
* CS\_BT601\_525
* CS\_BT601\_625
* CS\_BT709
* CS\_BT2020

They should be configured according to the incoming metadata and the target colorspace of the destination.

#### 1.1.3 Tone Mapping Related Parameters

##### 1.1.3.1 minlin: Minimum Input Light Level

The parameter type is float. Normally, this parameter should be set to 0.

##### 1.1.3.2 minlout: Minimum Output Light Level

The parameter type is float. Normally, this parameter should be set to 0.

##### 1.1.3.3 maxfall: Maximum Frame-average Light Level (MaxFALL)

The parameter type is float. This parameter should be fetched from the MaxFALL HDR metadata. The range is [0, 10000] nit.

Default value can be set to 50 for SDR input, and 180 for HDR10/HLG10 input.

##### 1.1.3.4 maxcll: Maximum Content Light Level

The parameter type is float. It should be fetched from HDR metadata. Default values are: 100 for SDR inputs, 1000 for HLG10 input, and 10000 for HDR10 input.

##### 1.1.3.5 maxlin: Maximum Input Light Level

The parameter type is float. Set maxlin to 100 for SDR input.

For HDR input, fetch its value from MaxCLL (maximum content light level) HDR metadata. If MaxCLL value is unavailable or abnormal (such as less than 100), set a default value of 1000 for HLG10 input, or 10000 for HDR10 input.

##### 1.1.3.6 maxlout: Maximum Output Light Level

The parameter type is float. Set maxlout to 100 for SDR output.

For HDR output, the target display’s maximum light level data should be fetched. It it is unavailable or abnormal (such as less than 100), set a default value of 1000 for HLG10 output, or 10000 for HDR10 output.

#### 1.1.4 Saturation Enhancement Related Parameters

##### 1.1.4.1 satgain: Saturation Gain

The parameter type is float. Normally, this parameter can be set to 0.25 for a satisfied result.

### 1.2 Low-level Registers

#### 1.2.1 LUT Data for Electronic to Optical Conversion

The LUT-related registers can be divided into 2 groups:

* dpe\_hdr\_dg\_luty\_00, …, dpe\_hdr\_dg\_luty\_36: Y LUT data, 37 entries
* dpe\_hdr\_dg\_luts\_00, …, dpe\_hdr\_dg\_luts\_35: slope LUT data, 36 entries

They can be correctly configured as long as tf\_in, tf\_in\_mode and all 5 tone mapping related parameters are correctly configured.

#### 1.2.2 Registers for RGB-to-Y Coefficients

The 3 registers are:

* dpe\_hdr\_tm\_rgb2y\_kr
* dpe\_hdr\_tm\_rgb2y\_kg
* dpe\_hdr\_tm\_rgb2y\_kb

They can be correctly configured as long as cs\_in is correctly configured.

#### 1.2.3 LUT Data for Saturation Enhancement

The LUT-related registers can be divided into 2 groups:

* dpe\_hdr\_tm\_lutsy\_00, …, dpe\_hdr\_tm\_lutsy\_12: Y LUT data, 13 entries
* dpe\_hdr\_tm\_lutsy\_00, …, dpe\_hdr\_tm\_lutsy\_11: slope LUT data, 12 entries

They can be correctly configured as long as satgain is correctly configured.

#### 1.2.4 Linear Stretch Registers for Degamma Step

There are 2 such registers:

* dpe\_hdr\_dg\_stretch\_a: default value is 1
* dpe\_hdr\_dg\_stretch\_b: default value is 0

They should be set to default values unless specific processing modes are encountered. Specifically, in HDR10-to-HDR10 processing mode, dpe\_hdr\_dg\_stretch\_a = maxlout / maxlin.

#### 1.2.5 Registers for Color Space Conversion

There are 9 such registers:

* dpe\_hdr\_csc\_m\_00 ~ dpe\_hdr\_csc\_m\_22

They can be correctly configured as long as cs\_in and cs\_out are correctly configured.

#### 1.2.6 LUT Data for Gamma Step

The LUT-related registers can be divided into 2 groups:

* dpe\_hdr\_g\_luty\_00, …, dpe\_hdr\_g\_luty\_32: Y LUT data, 33 entries
* dpe\_hdr\_g\_luts\_00, …, dpe\_hdr\_g\_luts\_31: slope LUT data, 32 entries

They can be correctly configured as long as tf\_out, tf\_out\_mode are correctly configured.

#### 1.2.6 Linear Stretch Registers for Gamma Step

There are 2 such registers:

* dpe\_hdr\_g\_stretch\_a: default value is 1
* dpe\_hdr\_g\_stretch\_b: default value is 0

Normally they should be set to default values at all times.

## 2. Processing Modes

There are various processing modes for HDR module as the input and output are either in one of the SDR or one of the HDR formats. In the following sections, preset configurations are given for each mode.

All the configurable registers and parameters are set in the following sections. Other registers are computed based on the configured parameters/registers.

### 2.1 SDR-to-HDR Processing

#### 2.1.1 SDR-to-HLG10

In this processing mode, the configuration may need to be fixed to the following preset in order to get satisfied results regardless of the info fetched from the target display.

# top-level parameters/registers  
# 1) enable signals  
dpe\_hdr\_en = 1  
dpe\_hdr\_tm\_sat\_en = 1  
# 2) processing mode related parameters  
tf\_in = TF\_SRGB  
tf\_out = TF\_HLG  
tf\_in\_mode = TF\_MODE\_INVOETF  
tf\_out\_mode = TF\_MODE\_OETF  
cs\_in = CS\_BT709  
cs\_out = CS\_BT2020  
# 3) tone mapping related parameters  
maxcll = 100  
maxfall = 50  
minlin = 0  
maxlin = 100  
minlout = 0  
maxlout = 1000  
# 4) saturation enhancement related parameters  
satgain = 0.25  
  
# low-level registers  
# 1) linear stretch registers for degamma step  
dpe\_hdr\_dg\_stretch\_a = 1  
dpe\_hdr\_dg\_stretch\_b = 0  
# 2) linear stretch registers for gamma step  
dpe\_hdr\_g\_stretch\_a = 1  
dpe\_hdr\_g\_stretch\_b = 0

#### 2.1.2 SDR-to-HDR10

In this processing mode, the configuration may need to be fixed to the following preset regardless of info fetched from the target display in order to get satisfied results.

# top-level parameters/registers  
# 1) enable signals  
dpe\_hdr\_en = 1  
dpe\_hdr\_tm\_sat\_en = 1  
# 2) processing mode related parameters  
tf\_in = TF\_SRGB  
tf\_out = TF\_PQ  
tf\_in\_mode = TF\_MODE\_EOTF  
tf\_out\_mode = TF\_MODE\_INVEOTF  
cs\_in = CS\_BT709  
cs\_out = CS\_BT2020  
# 3) tone mapping related parameters  
maxcll = 100  
maxfall = 50  
minlin = 0  
maxlin = 100  
minlout = 0  
maxlout = 1000  
# 4) saturation enhancement related parameters  
satgain = 0.25  
  
# low-level registers  
# 1) linear stretch registers for degamma step  
dpe\_hdr\_dg\_stretch\_a = 1  
dpe\_hdr\_dg\_stretch\_b = 0  
# 2) linear stretch registers for gamma step  
dpe\_hdr\_g\_stretch\_a = 1  
dpe\_hdr\_g\_stretch\_b = 0

### 2.2 SDR-to-SDR Processing

Default preset for this mode is to configure a f(x)=x tone mapping curve. The following case is to convert the colorspace from BT.709 to BT.2020. Processed result may be more vibrant if saturation enhancement is enabled as the preset does.

# top-level parameters/registers  
# 1) enable signals  
dpe\_hdr\_en = 1  
dpe\_hdr\_tm\_sat\_en = 1  
# 2) processing mode related parameters  
tf\_in = TF\_ITUOETF  
tf\_out = TF\_ITUOETF  
tf\_in\_mode = TF\_MODE\_INVOETF  
tf\_out\_mode = TF\_MODE\_OETF  
cs\_in = CS\_BT709  
cs\_out = CS\_BT2020  
# 3) tone mapping related parameters  
maxcll = 100  
maxfall = 80 # make sure f(x)=x  
minlin = 0  
maxlin = 100  
minlout = 0  
maxlout = 100  
# 4) saturation enhancement related parameters  
satgain = 0.25  
  
# low-level registers  
# linear stretch registers for degamma step  
dpe\_hdr\_dg\_stretch\_a = 1  
dpe\_hdr\_dg\_stretch\_b = 0  
# linear stretch registers for gamma step  
dpe\_hdr\_g\_stretch\_a = 1  
dpe\_hdr\_g\_stretch\_b = 0

### 2.3 HDR-to-HDR Processing

#### 2.3.1 HDR10-to-HDR10

The following preset is to decrease maximum light level from 10000 nit to 400 nit for an inferior HDR display.

Notice the dpe\_hdr\_dg\_stretch\_a is set to 0.04 instead of the default value of 1. In this mode, it should be computed as maxlout / maxlin.

# top-level parameters/registers  
# 1) enable signals  
dpe\_hdr\_en = 1  
dpe\_hdr\_tm\_sat\_en = 1  
# 2) processing mode related parameters  
tf\_in = TF\_PQ  
tf\_out = TF\_PQ  
tf\_in\_mode = TF\_MODE\_EOTF  
tf\_out\_mode = TF\_MODE\_INVEOTF  
cs\_in = CS\_BT2020  
cs\_out = CS\_BT2020  
# 3) tone mapping related parameters  
maxcll = 10000  
maxfall = 640  
minlin = 0.005  
maxlin = 10000  
minlout = 0.01  
maxlout = 400  
# 4) saturation enhancement related parameters  
satgain = 0.25  
  
# low-level registers  
# linear stretch registers for degamma step  
dpe\_hdr\_dg\_stretch\_a = 0.04  
dpe\_hdr\_dg\_stretch\_b = 0  
# linear stretch registers for gamma step  
dpe\_hdr\_g\_stretch\_a = 1  
dpe\_hdr\_g\_stretch\_b = 0

#### 2.3.2 HLG10-to-HLG10

The default preset is a f(x)=x tone mapping curve as HLG signal typically has a maximum content level of 1000 nit. Assume the colorspace is not changed throughout.

# top-level parameters/registers  
# 1) enable signals  
dpe\_hdr\_en = 1  
dpe\_hdr\_tm\_sat\_en = 0  
# 2) processing mode related parameters  
tf\_in = TF\_HLG  
tf\_out = TF\_HLG  
tf\_in\_mode = TF\_MODE\_INVOETF  
tf\_out\_mode = TF\_MODE\_OETF  
cs\_in = CS\_BT2020  
cs\_out = CS\_BT2020  
# 3) tone mapping related parameters  
maxcll = 1000  
maxfall = 800 # make sure f(x)=x tone mapping curve is set  
minlin = 0  
maxlin = 1000  
minlout = 0  
maxlout = 1000  
# 4) saturation enhancement related parameters  
satgain = 0  
  
# low-level registers  
# linear stretch registers for degamma step  
dpe\_hdr\_dg\_stretch\_a = 1  
dpe\_hdr\_dg\_stretch\_b = 0  
# linear stretch registers for gamma step  
dpe\_hdr\_g\_stretch\_a = 1  
dpe\_hdr\_g\_stretch\_b = 0

### 2.4 HDR-to-SDR Processing

#### 2.4.1 HDR10-to-SDR

The default preset in this mode cap the maximum output light level to 300 nit instead of the default 100 nit for a more satisfied result.

# top-level parameters/registers  
# 1) enable signals  
dpe\_hdr\_en = 1  
dpe\_hdr\_tm\_sat\_en = 1  
# 2) processing mode related parameters  
tf\_in = TF\_PQ  
tf\_out = TF\_SRGB  
tf\_in\_mode = TF\_MODE\_EOTF  
tf\_out\_mode = TF\_MODE\_INVEOTF  
cs\_in = CS\_BT2020  
cs\_out = CS\_BT709  
# 3) tone mapping related parameters  
maxcll = 10000  
maxfall = 180  
minlin = 0  
maxlin = 10000  
minlout = 0  
maxlout = 300  
# 4) saturation enhancement related parameters  
satgain = 0.25  
  
# low-level registers  
# linear stretch registers for degamma step  
dpe\_hdr\_dg\_stretch\_a = 1  
dpe\_hdr\_dg\_stretch\_b = 0  
# linear stretch registers for gamma step  
dpe\_hdr\_g\_stretch\_a = 1  
dpe\_hdr\_g\_stretch\_b = 0

#### 2.4.2 HLG10-to-SDR

In this mode, in order to get a satisfied result, the maxlout parameter must be equal to maxlin.

# top-level parameters/registers  
# 1) enable signals  
dpe\_hdr\_en = 1  
dpe\_hdr\_tm\_sat\_en = 1  
# 2) processing mode related parameters  
tf\_in = TF\_HLG  
tf\_out = TF\_BT1886  
tf\_in\_mode = TF\_MODE\_INVOETF  
tf\_out\_mode = TF\_MODE\_OETF  
cs\_in = CS\_BT2020  
cs\_out = CS\_BT709  
# 3) tone mapping related parameters  
maxcll = 1000  
minlin = 0  
maxlin = 1000  
maxfall = 180  
minlout = 0  
maxlout = 1000  
# 4) saturation enhancement related parameters  
satgain = 0.25  
  
# low-level registers  
# linear stretch registers for degamma step  
dpe\_hdr\_dg\_stretch\_a = 1  
dpe\_hdr\_dg\_stretch\_b = 0  
# linear stretch registers for gamma step  
dpe\_hdr\_g\_stretch\_a = 1  
dpe\_hdr\_g\_stretch\_b = 0