TI DLP® IntelliBright™ Algorithms for the DLPC343x Controller

1 Scope

This document explains the function and use of the Texas Instruments DLP IntelliBright™ suite of image processing algorithms contained within the DLCP343x controller.

IntelliBright is comprised of two independent algorithms:

- Local Area Brightness Boost (LABB)
- Content Adaptive Illumination Control (CAIC)

This document also includes instructions on how to evaluate each algorithm using the DLP LightCrafter™ Display EVM GUI tool.

2 Applicable documents

The following TI Documents contain relevant information.

- DLPC343x ASIC Datasheet, latest revision
- DLPC343x Software Programmers Guide, latest revision
- DLPA200x Datasheet, latest revision
- DLPA300x Datasheet, latest revision

3 Terms and abbreviations

- ASIC – Application Specific Integrated Circuit
- CAIC – Content Adaptive Illumination Control
- EVM – Evaluation Module
- LABB – Local Area Brightness Boost
- GUI – Graphical User Interface
- LED – Light Emitting Diode

4 Local Area Brightness Boost (LABB)

4.1 Introduction

Local Area Brightness Boost, or LABB, is a TI image processing algorithm that adaptively enhances (gains up) dim regions of an image, on a frame-by-frame basis, resulting in brighter, more dynamic images.

The LABB algorithm evaluates each image frame in real time first identifying dark areas of the image which can benefit from a boost in brightness, and then applying a brightness gain based on the configured "boost strength" setting. A relatively higher gain is applied to darker regions of the image while little or no gain is applied to brighter regions of the image.

In practice, when many image frames have a net overall brightness gain applied, the overall perceived image brightness level is boosted, even if some parts of the each frame have little or no gain applied. Figure 1 shows a split screen example of the impact the LABB algorithm can have on an image.

Figure 1. LABB Boosts Local Areas of an Image (simulated image)

4.2 LABB Controls

The LABB algorithm is controlled via the following configuration parameters:

- Enable / Disable
- Brightness Boost Strength
- Sharpness

These configuration parameters are accessible through I2C software commands sent to the DLPC343x controller.

The DLP® LightCrafter Display EVM GUI also provides convenient access to these parameters (Figure 2) in real-time during operation of the EVM, thus facilitating easy and immediate evaluation of the algorithm's function and capability.
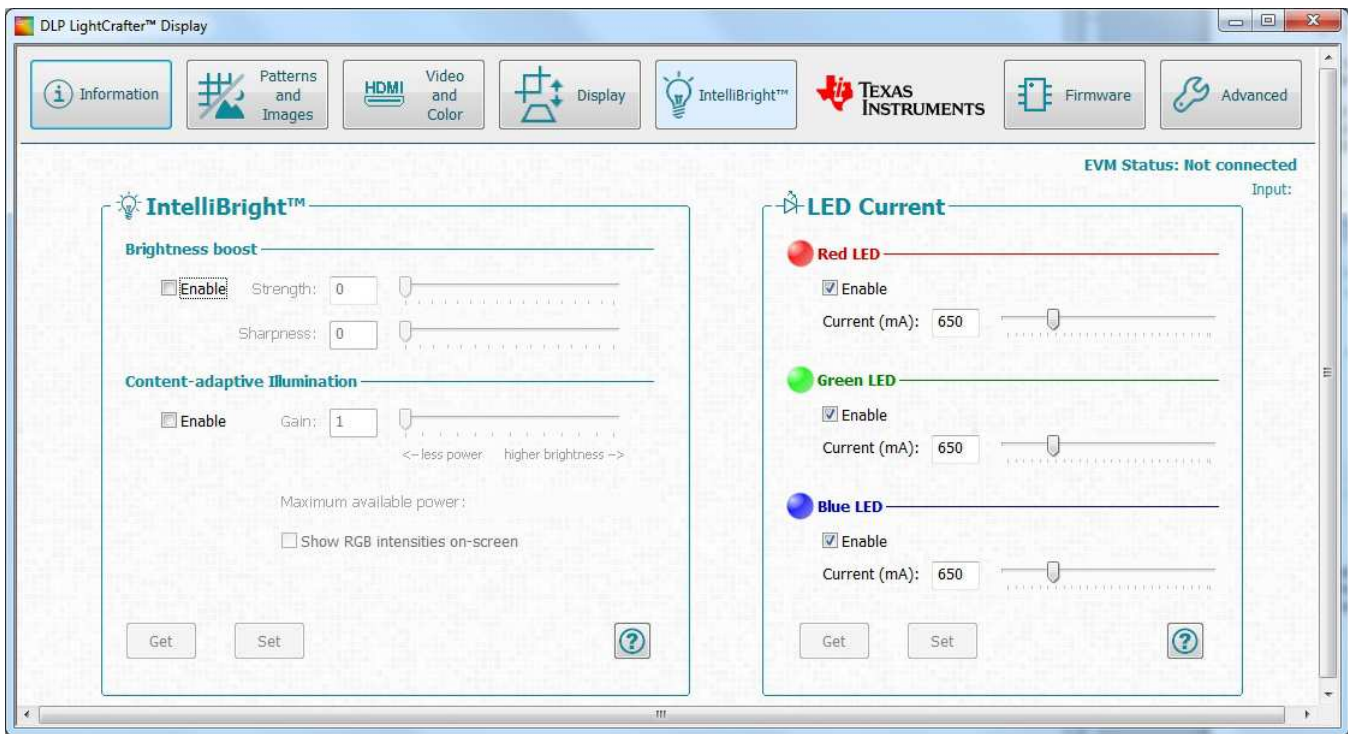
Figure 2. IntelliBright Algorithm Controls

Note that settings changed through the GUI are volatile and will be lost once the EVM is turned off. However, once the desired settings have been determined through experimentation, these settings can be set as the power-up default configuration within the DLPC343x controller. Refer to the Software Programmers Guide for details.

4.2.1 LABB Enable/Disable

With the DLP LightCrafter Display EVM GUI control highlighted in Figure 3, the LABB algorithm can be enabled or disabled.

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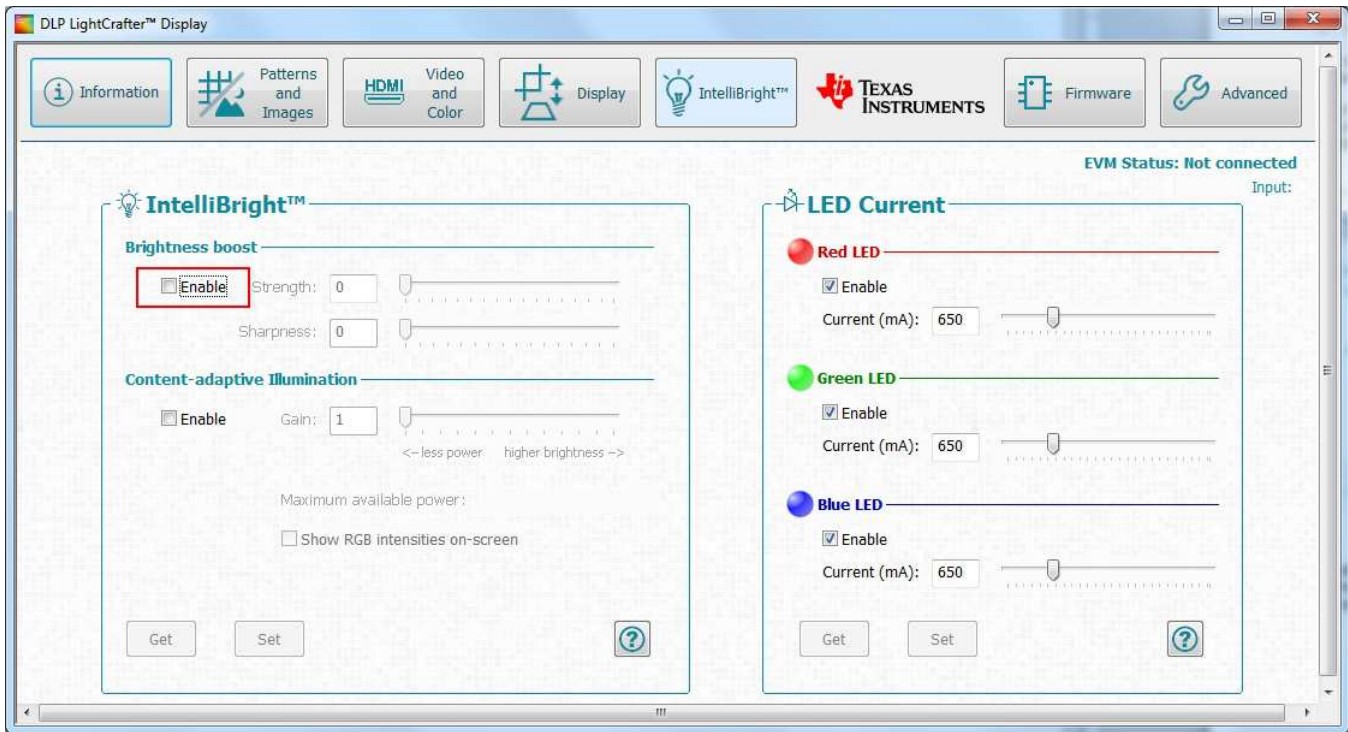
Figure 3. LABB Enable/Disable

When LABB is disabled, the LABB algorithm is inactive and LABB processing is not applied to image data.

When LABB is enabled, the LABB algorithm is active and functions according to the strength and sharpness controls as described in the following sections.

The I2C command to enable/disable LABB is: "**Write Local Area Brightness Boost Control (80h), byte #1**". Refer to the Software Programmers Guide for details on this command.

4.2.2   LABB Strength Setting

As previously described, the LABB algorithm evaluates images during runtime, on a frame-by-frame basis, and identifies dark areas of each image which can benefit from a boost in brightness. The relative amount of boost (gain) applied is controlled by the configurable strength setting, shown in Figure 4.
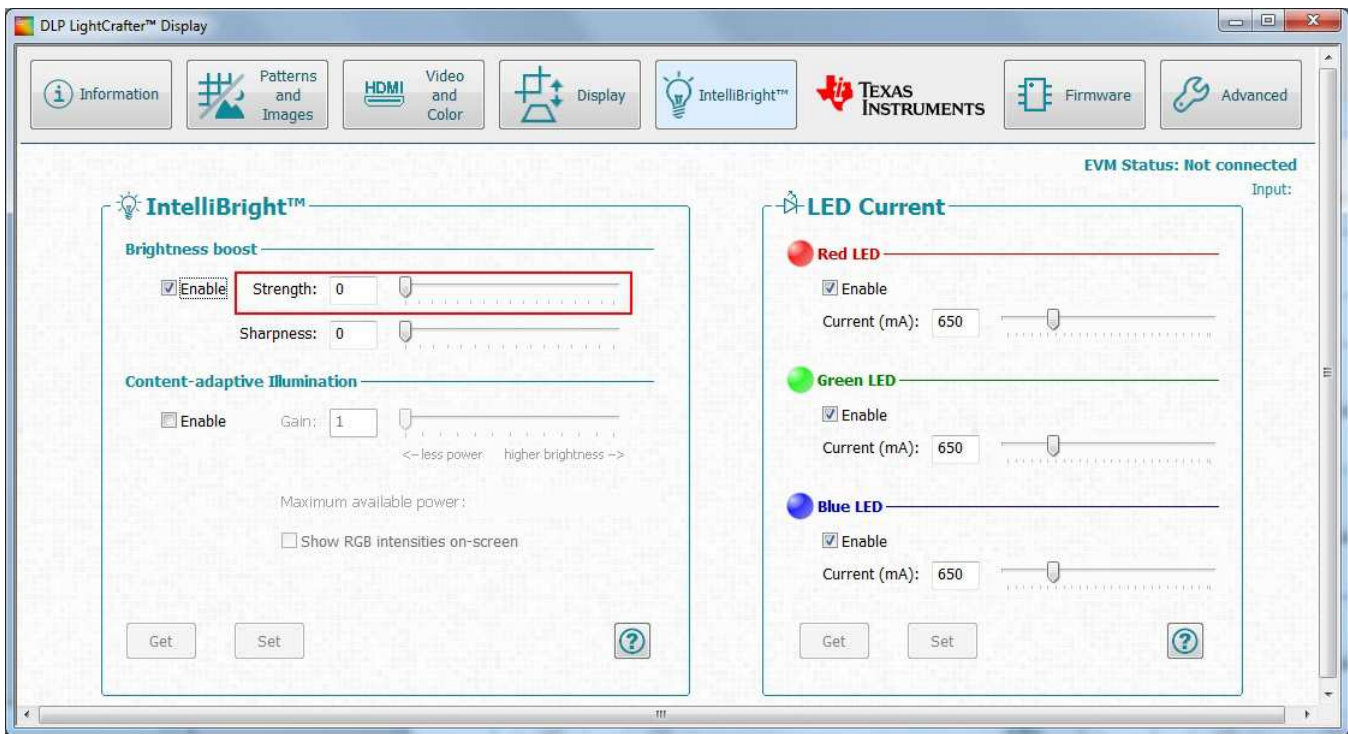
Figure 4. LABB Strength Setting

The valid range of strength values is from 0 to 255, where:
- 0 = No gain to be applied
- 255 = The maximum gain calculated by the LABB algorithm will be applied to the image.

Note: The actual gain applied by the LABB algorithm is not linear with the strength value. For example, a strength value of 128 does not mean that 50% of the maximum gain will be applied.

The I2C command to the set strength is "**Write Local Area Brightness Boost Control (80h), byte #2**". Refer to the Software Programmers Guide for details on this command.

Although system designers can choose to configure the LABB algorithm with a static strength setting as described above, the best user experience is achieved when the strength setting is determined based on ambient light conditions.

With an ambient light sensor connected to the host processor, the host processor can then dynamically change the strength setting based on changes in the ambient light conditions. Therefore, in high (bright) ambient light conditions, the LABB strength setting can be set to a relatively high value so as to prevent the image from looking "washed out". Conversely, in low (dark) ambient light conditions the LABB strength setting can be set relatively low to preserve contrast. Ultimately, the specific high and low settings will be based on the designer's judgment of the resulting image.

4.2.3   Sharpness Control

The LABB algorithm circuit inside the DLPC343x controller also includes an optional sharpness control that can be optionally used. LABB must be enabled for this sharpness filter to be available.

The valid range of sharpness values is from 0 to 15, where:
- 0 = Lowest sharpness (sharpness is turned off when set to 0)
- 15 = Highest sharpness

LABB sharpness has no correlation to LABB strength setting. A sharpness value of 7 is recommended.

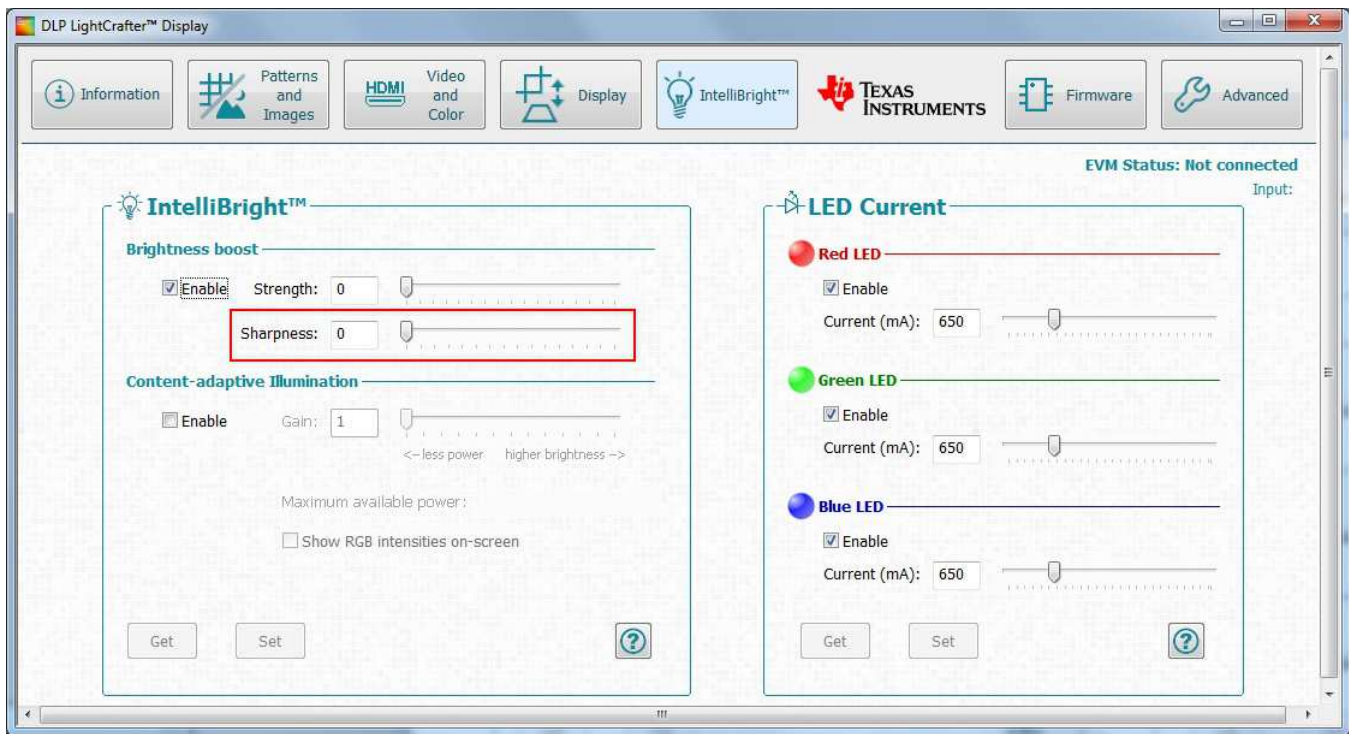The LABB sharpness value can be adjusted in the EVM GUI using as shown in Figure 5.

Figure 5. LABB Sharpness Control

The I2C command to the set strength is "**Write Local Area Brightness Boost Control (80h), byte #1**". Refer to the Software Programmers Guide for details on this command.

5   Content Adaptive Illumination Control (CAIC)

5.1   Introduction

Content Adaptive Illumination Control, or CAIC, is a TI image processing algorithm which offers either power reduction, brightness enhancement, or a combination of the two. As such, the CAIC algorithm can be thought of as having the following operating modes:

- Brightness Enhancement Mode, which adaptively adjusts the illumination drive strength, on a frame-by-frame basis, resulting in optimal image brightness and contrast, while maintaining the original power settings
- Power Reduction Mode, which adaptively adjusts illumination drive strength, on a frame-by-frame basis, resulting in maximum power savings while maintaining the original brightness and improving contrast
- Hybrid Mode, which results in brightness enhancement (albeit, less than is achieved in the pure Brightness Enhancement Mode) and some power reduction (albeit, less than is achieve in the pure Power Reduction Mode)

Regardless of the operating mode, CAIC takes advantage of the fact that typical, real-world images (such as photographs and motion video) rarely utilize the full dynamic range of the imaging system. This fact can be viewed from two different perspectives:

- From the pixel-perspective, the R, G, B level of most pixels is typically well below the maximum (full scale) value.
- From the overall image-perspective, the average pixel level (APL) is also below the full scale value. Figure 6 provides an illustration of these two perspectives.

In operation, CAIC performs the following functions:

- CAIC first evaluates, on a frame-by-frame basis, both the available "pixel headroom" and the available "APL headroom".
- Based on this information, CAIC then calculates a red channel gain value (R-gain), a green channel gain value (G-gain), and a blue channel gain value (B-gain).
  - By considering both pixel headroom and APL headroom when computing these gain values, the CAIC algorithm ensures that minimal image quality degradation will occur when the gain values are applied to the image.
  - By computing (and adjusting) the gain independently for each R, G, B color channel, the CAIC algorithm can ensure that the target white point is maintained.
- CAIC then applies the R-gain, G-gain, and B-gain to each pixel in the entire image. This is done regardless of which mode CAIC has been configured for (Brightness Enhancement, Power Reduction, or Hybrid).

Figure 7 illustrates the application of gain to a single color channel.

- CAIC then adjusts the individual R, G, and B illumination drive strengths (currents), where the amount of adjustment depends on the CAIC operating mode:
  - When in the Brightness Enhancement Mode, the individual R, G, and B illumination drive strengths **are not adjusted**.
    In this mode, the objective of the CAIC algorithm is to maximize the brightness enhancement without regard for power consumption.
  - When in the Power Reduction Mode, the individual R, G, and B illumination drive strengths will be reduced by an amount proportional to the gain which was applied to each respective data color channel.
    In this mode, the objective of the CAIC algorithm is to maximize the power reduction while maintaining the same on-screen image brightness.
  - When in the Hybrid Mode, the individual R, G, and B illumination drive strengths **will also be reduced** by an amount proportional to the gain which was applied to each respective data color channel, but to a lesser degree than when CAIC is in the Power Reduction Mode.
    In this mode, the objective of the CAIC algorithm is to maximize the power reduction while also achieving the pre-programmed amount of brightness enhancement.

The performances achieved by the CAIC algorithm are measured relative to the following three baselines:

- Brightness Baseline
- Power Consumption Baseline
- White Point Baseline

All three baselines are defined by the same operating scenario: displaying an all-white image (R, G, B = 255, 255, 255) when the CAIC algorithm is disabled. The baseline performance can be controlled using the LED drive current values set using the I2C command "**Write RGB LED Current Control (54h)**".

Note: White Point correction is outside the scope of this paper. Please contact TI representative for more information.
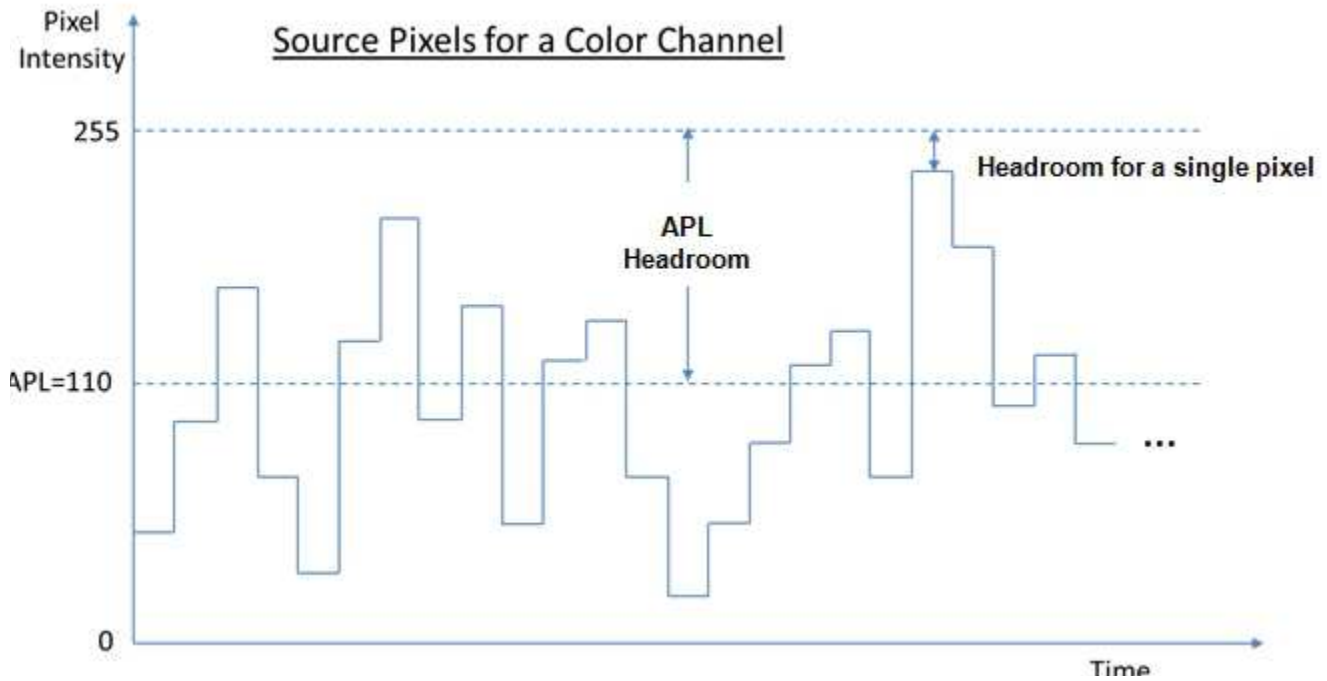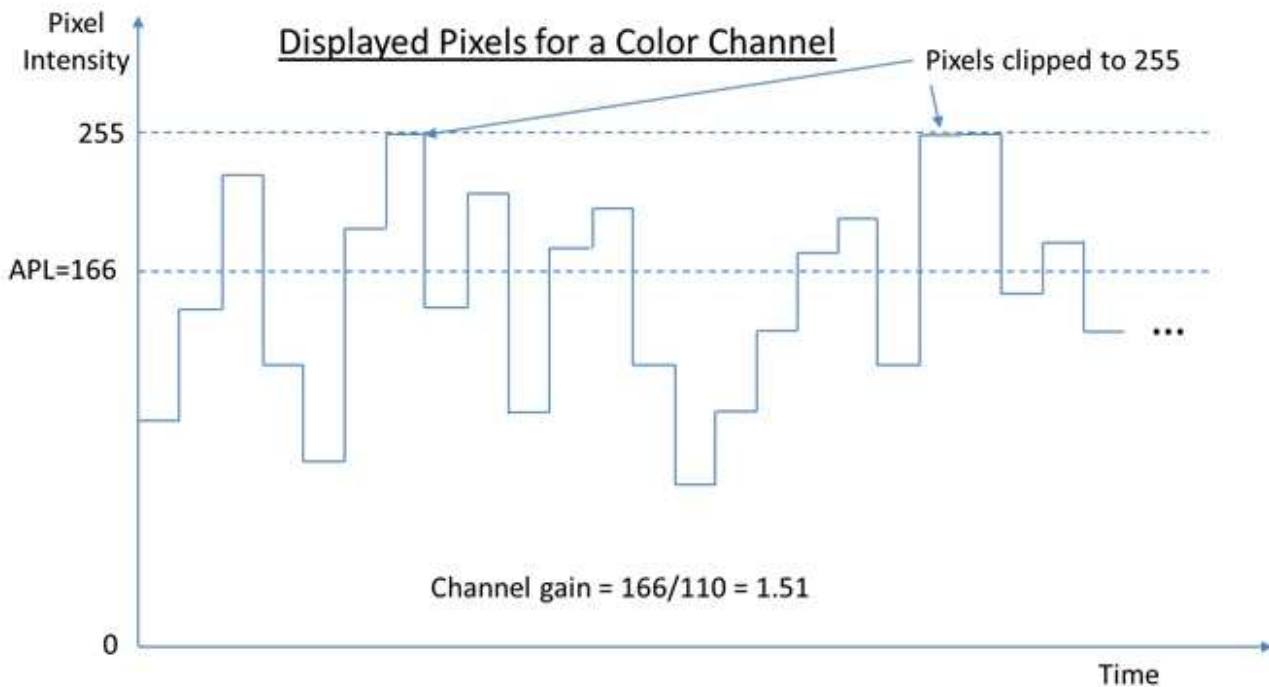
Figure 6. Input Pixels Example

Figure 7. Displayed Pixels after CAIC Processing

5.2 CAIC Controls

The CAIC algorithm is controlled via the following configuration parameters:

- Enable / Disable
- Gain

- Enable / Disable Red LED Current Control
- Maximum Red LED Current

- Enable / Disable Green LED Current Control
- Maximum Green LED Current

- Enable / Disable Blue LED Current Control
- Maximum Blue LED Current

These configuration parameters are accessible through I2C software commands sent to the DLPC343x.

The DLP LightCrafter Display EVM GUI provides convenient access to these parameters (Figure 8), in real-time during operation of the EVM, thus facilitating easy and immediate evaluation of the algorithm's function and capability.
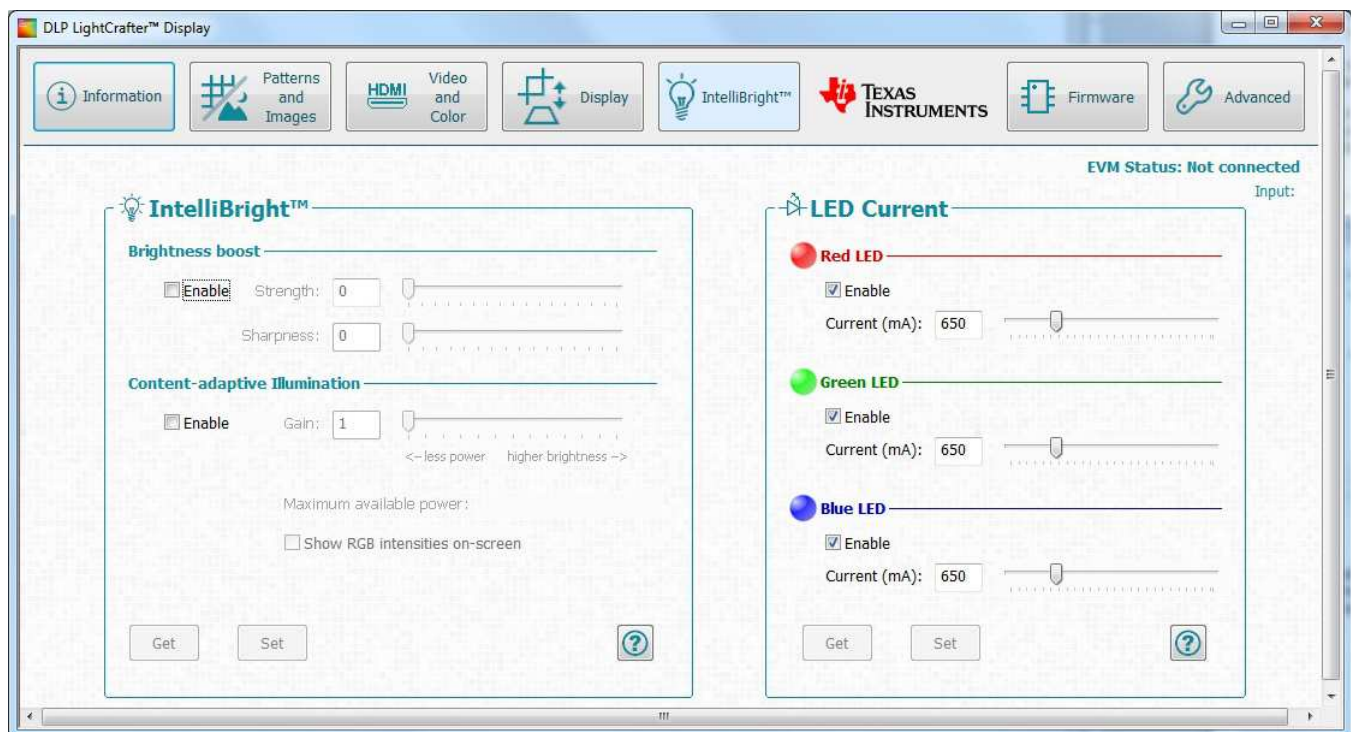
Figure 8. CAIC Controls

Note that settings changed through the GUI are volatile and will be lost once the EVM is turned off. However, once the desired settings have been determined through experimentation, these settings can be set as the power-up default configuration within the DLPC343x. Refer to the Software Programmers Guide for details.

5.2.1 CAIC Enable/Disable

With the DLP LightCrafter Display EVM GUI control highlighted in Figure 9, the CAIC algorithm can be enabled and disabled.
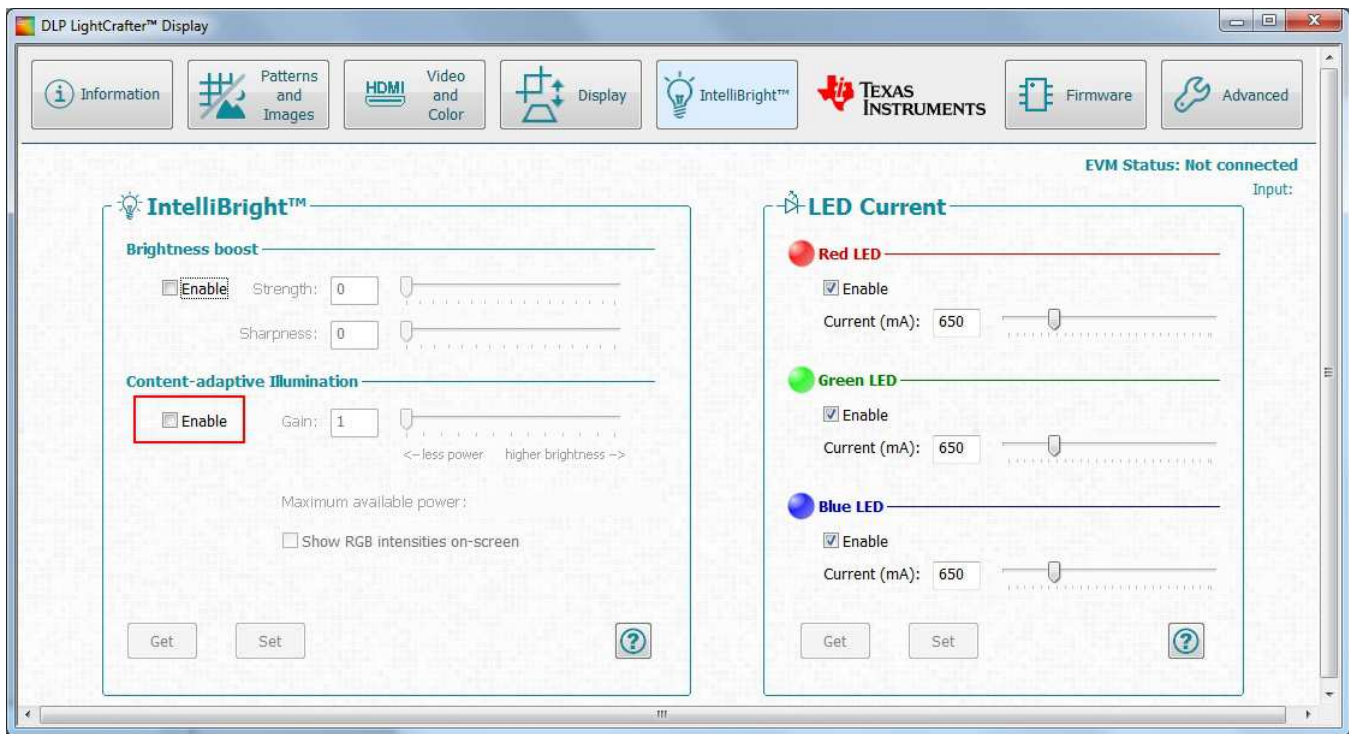
Figure 9. CAIC Enable/Disable

When CAIC is disabled, the CAIC algorithm is inactive; no CAIC processing is applied to the image data, and no modifications are made to the LED current. In this case, the LED currents are set manually via I2C command "Write RGB LED Current Control (54h)". Refer to the Software Programmers Guide for details.

When CAIC is enabled, the CAIC algorithm is active and functions according to the gain and Current Control settings, as described in the following sections.

The I2C command to Enable/Disable CAIC is: "**LED Output Control Method (50h)**". Refer to the Software Programmers Guide for details on this command.

5.2.2   CAIC Gain

The CAIC gain parameter sets the maximum brightness gain that will be applied to the displayed image, through the combination of digital gain applied to the image data as well as adjustments made to the LED drive strength (drive currents).

The valid range of gain values is from 1 to 4, where:

- 1 = No gain applied
- 4 = Maximum gain applied

The CAIC gain parameter effectively controls which mode the CAIC algorithm will operate in.

- When the gain parameter is set to 1, the CAIC algorithm will operate purely in Power Reduction Mode.
- When the gain parameter is set to 4, the CAIC algorithm will operate purely in Brightness Enhancement Mode.
- For values between 1 and 4, the CAIC algorithm will operate in a "hybrid mode", resulting in varying amounts of power consumption reduction and brightness enhancement, depending on the specific gain value.

The I2C command to adjust the CAIC gain is: "**Write CAIC Image Processing Control (84h), byte #2**". Refer to the Software Programmers Guide for details on this command.

The CAIC gain value can be adjusted in the EVM GUI using as shown in Figure 10
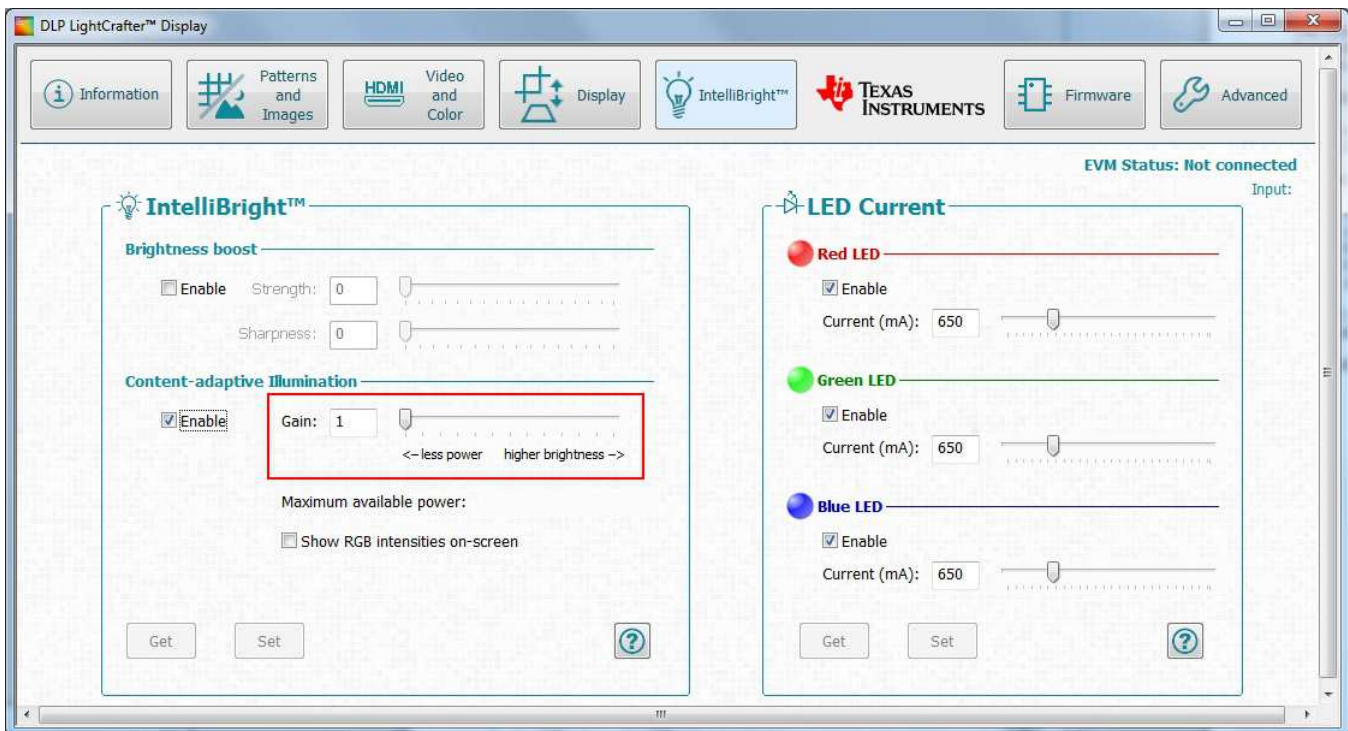
Figure 10. CAIC Gain

5.2.3   Max LED Currents for CAIC

In order for the CAIC algorithm to operate properly, the maximum allowable LED currents must be defined and set in the DLPC343x ASIC.

The following ratings should be considered when defining the CAIC Maximum LED Currents:

*   The CAIC Maximum LED Currents should not exceed the maximum rated LED current as defined by the LED manufacture.
*   The CAIC Maximum LED Currents should not exceed the maximum output rating of the LED drive circuit.

The I2C command to set the Maximum LED Currents is: "**Write RGB LED Max Current (5Ch)**". Refer to the Software Programmers Guide for details on this command.

In production, the defined Maximum LED Currents should be a part of the DLPC343x power-up default (refer to the Software Programmers Guide for details).

For testing during development, the Maximum LED Current settings can be manually adjusted in the EVM GUI as shown in Figure 11. Note however that CAIC should always be disabled before changes are made to the Maximum LED Current settings to prevent overdriving and potentially damaging the LEDs.
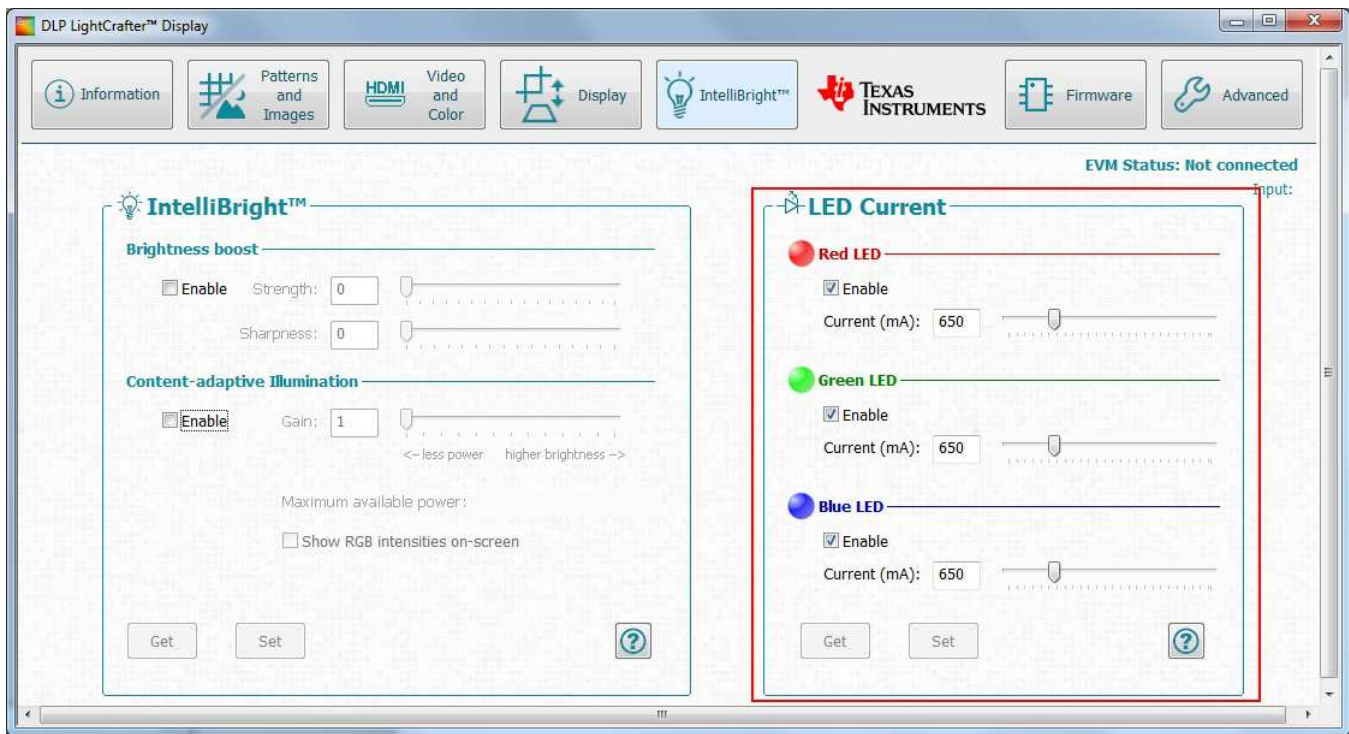
Figure 11. LED Currents for CAIC

The individual LED Enables shown in Figure 11 can be used to evaluate the impact that CAIC has on the drive strength of each LED. It is safe to operate the system with any combination of LED Enabled and/or Disabled.

5.3 *Examples of CAIC Power Reduction Mode*

Figure 12 and Table 1 show examples of CAIC running in Power Reduction Mode. Note that the power numbers shown in these figures **are not actual power measurements**. They are approximations intended only for illustrative purposes.
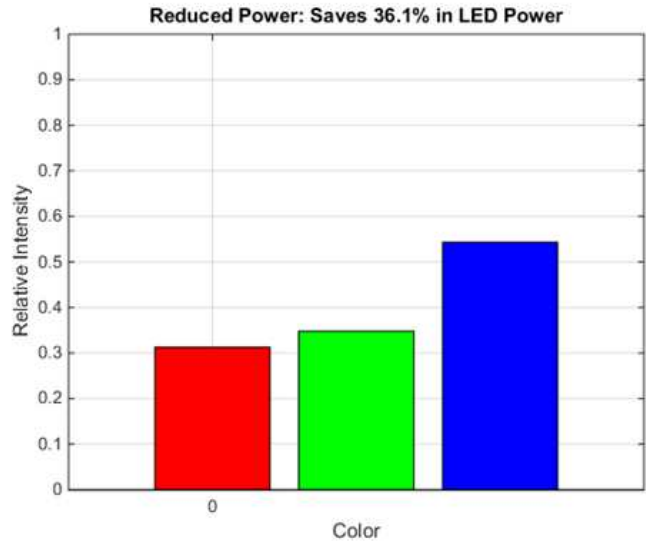
Figure 12. Simulated Example of CAIC Power Reduction Mode (Constant Brightness)

Table 1. CAIC Power Reduction Mode (Constant Brightness)

	CAIC Disabled	CAIC Enabled (Power Reduction Mode)
Screen Lumens	28 L	28 lm
LEDs	1.0 W	0.7 W
LED Driver	0.11 W	0.073 W
Total reduction in Power		= (1-.7) + (0.11-0.073) = 0.337 W

IMPORTANT NOTICE

Products		Applications	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		